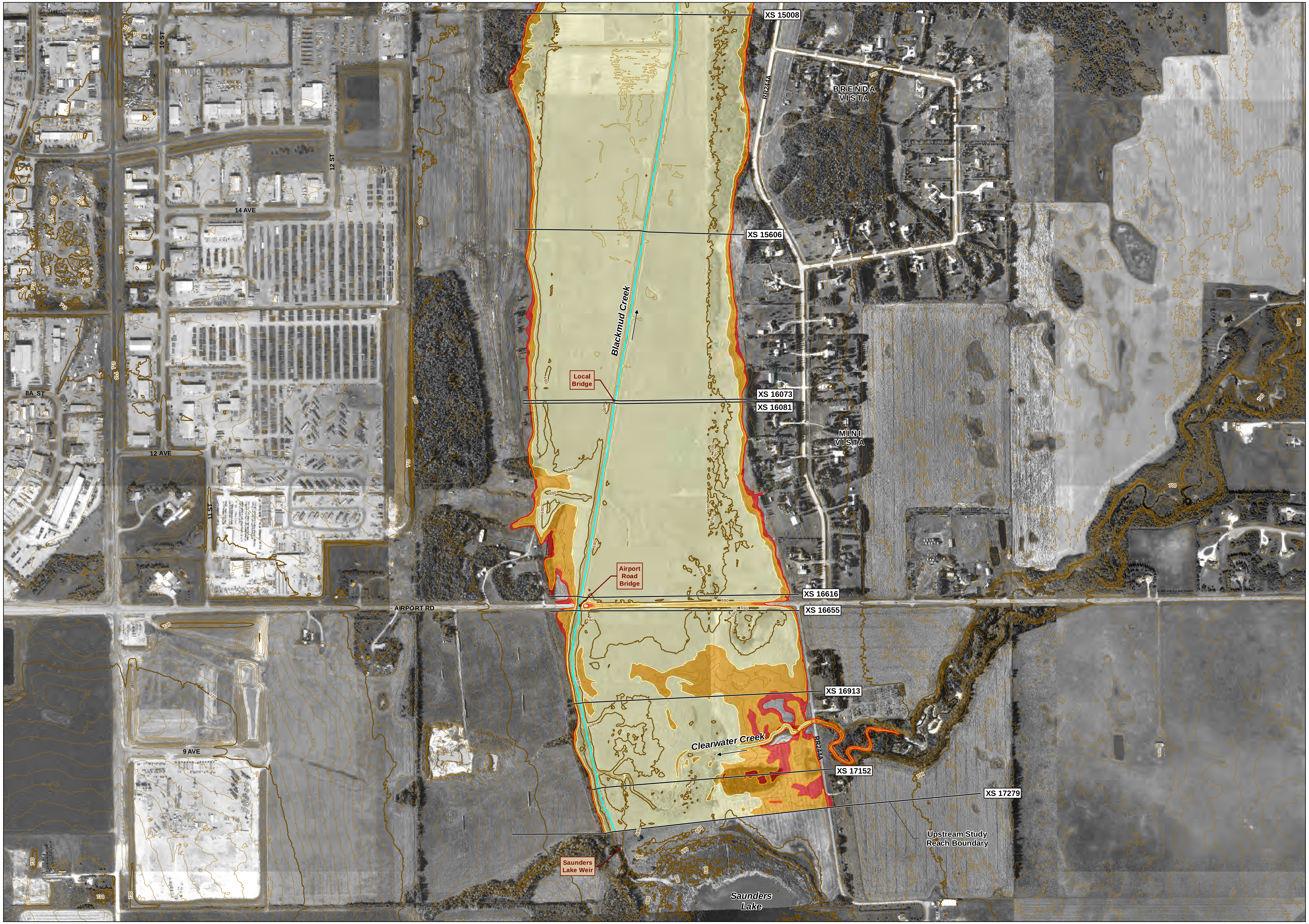
APPENDIX C

FLOOD FREQUENCY MAPS



NISKU FLOOD HAZARD STUDY

FLOOD FREQUENCY MAP

MAPSHEET 1 OF 5

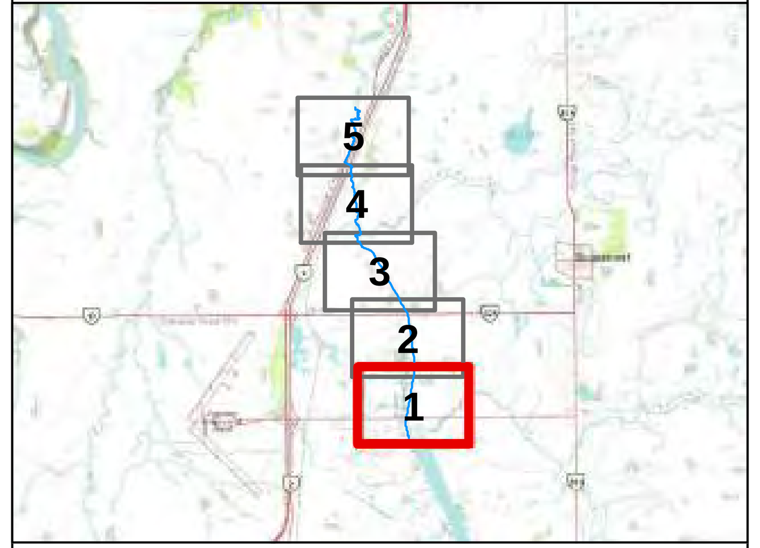
Job: 100132	Date: FEBRUARY 2014

SCALE - 1:5,000

0 100 200 300 400 M

N

Coordinate System: 3TM 114˚, NAD 1983
Units: METRES



- 10-Year Flood Extent
- 50-Year Flood Extent
- 100-Year Flood Extent
- Creek Centreline
- Cross Section
- XS 8991 Cross Section Number
- Contour (10 m interval)
- Contour (1 m interval)

Notes to Users:

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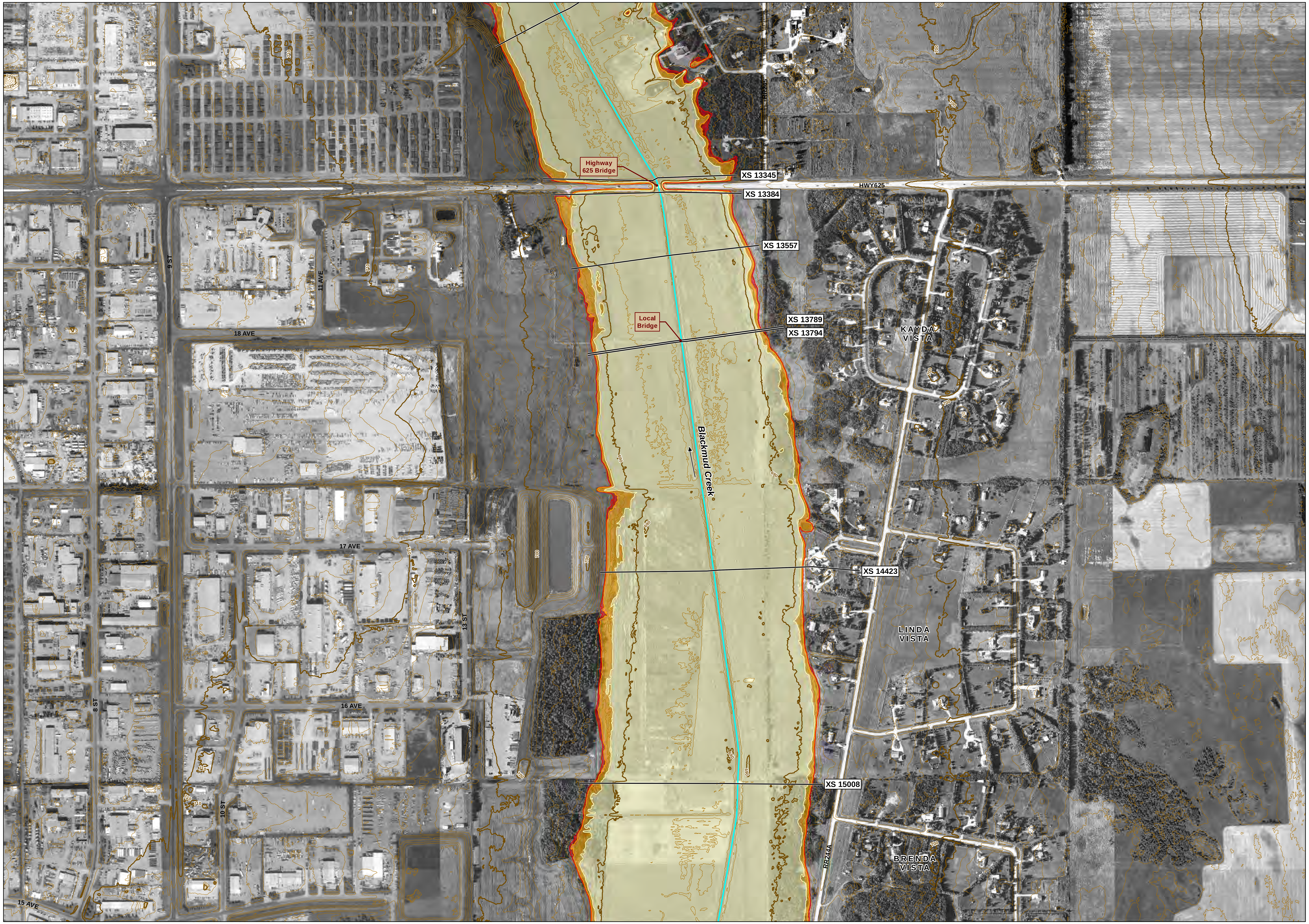


NISKU FLOOD HAZARD STUDY

FLOOD FREQUENCY MAP

MAPSHEET 2 OF 5

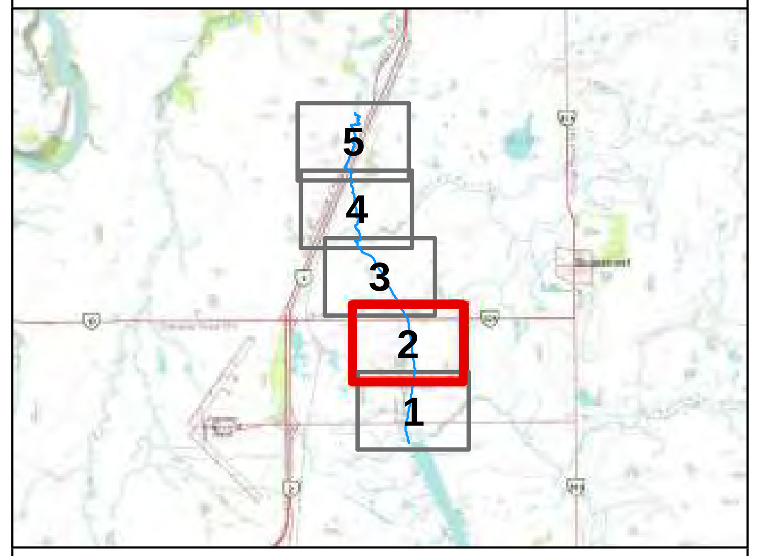
Job: 100132 | Date: FEBRUARY 2014

SCALE - 1:5,000

0 100 200 300 400 M

N

Coordinate System: 3TM 114˚, NAD 1983
Units: METRES



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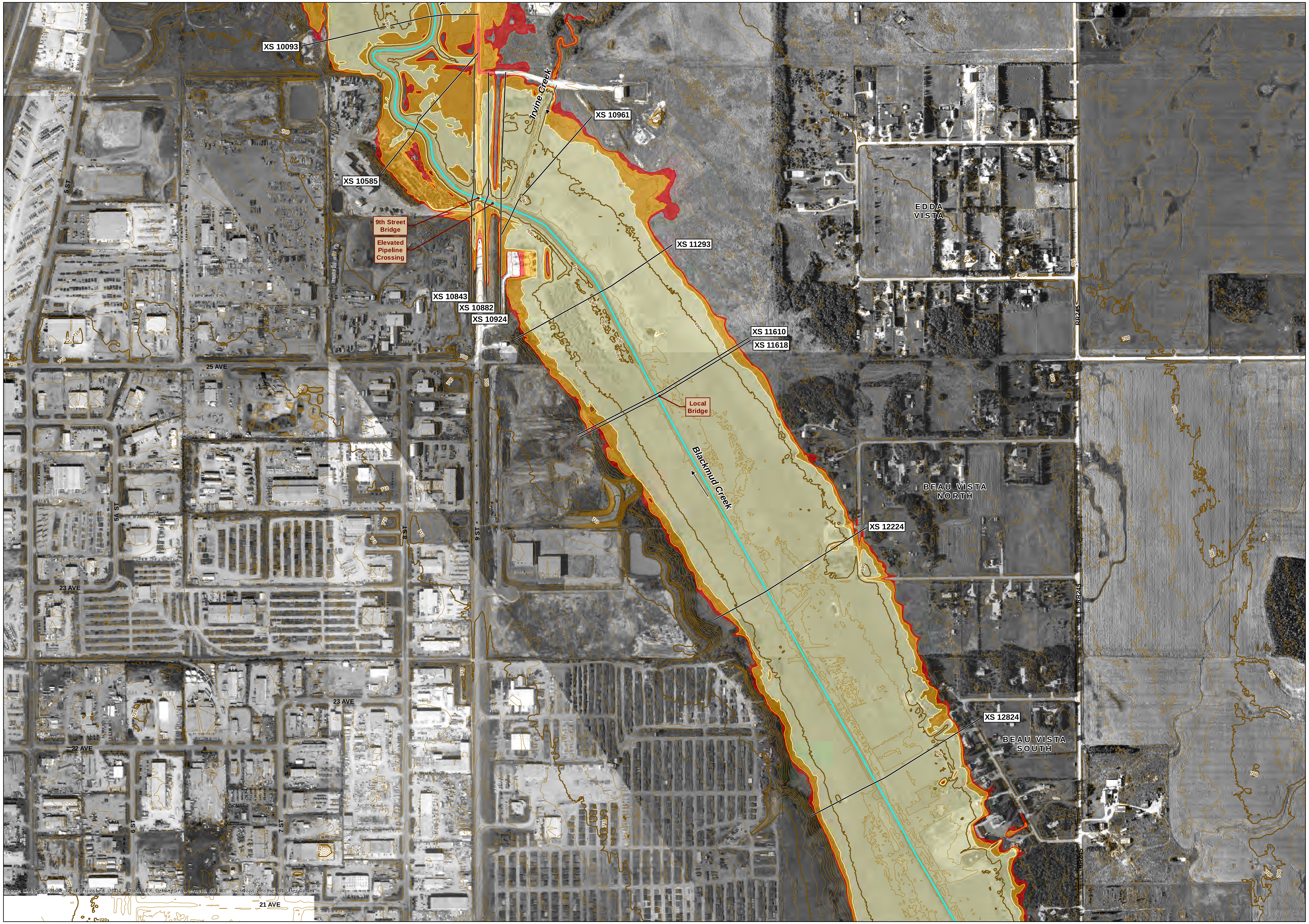


NISKU FLOOD HAZARD STUDY

FLOOD FREQUENCY MAP

MAPSHEET 3 OF 5

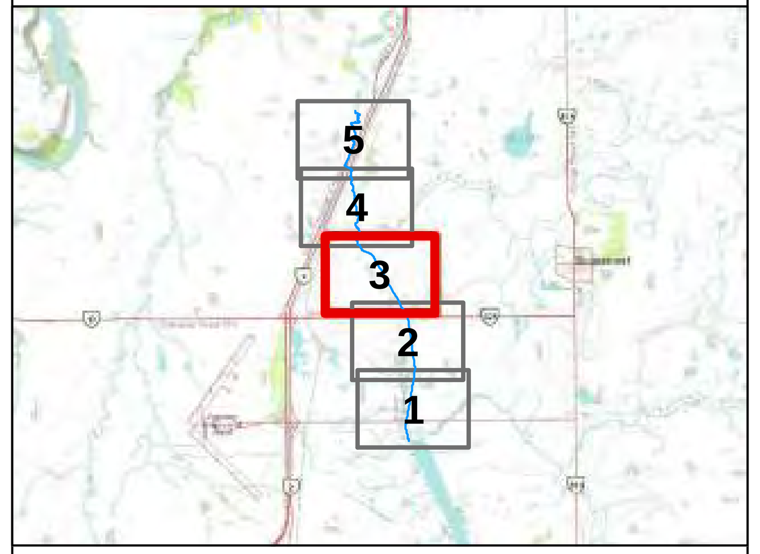
Job: 100132 | Date: FEBRUARY 2014

SCALE - 1:5,000

0 100 200 300 400 M

N

Coordinate System: 3TM 114˚, NAD 1983
Units: METRES



10-Year Flood Extent

50-Year Flood Extent

100-Year Flood Extent

Creek Centreline

Cross Section

XS 8991 Cross Section Number

Contour (10 m interval)

Contour (1 m interval)

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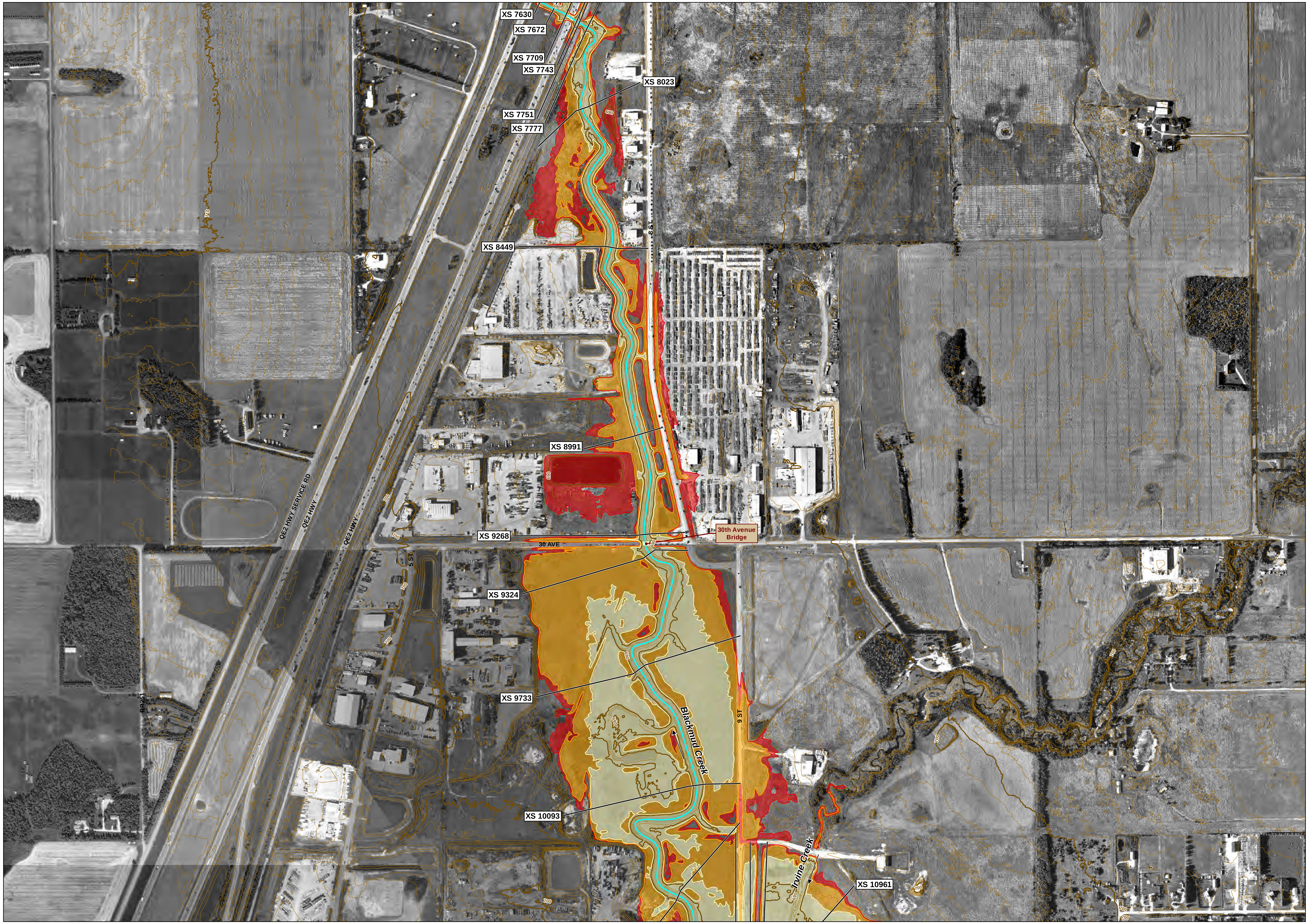


NISKU FLOOD HAZARD STUDY

FLOOD FREQUENCY MAP

MAPSHEET 4 OF 5

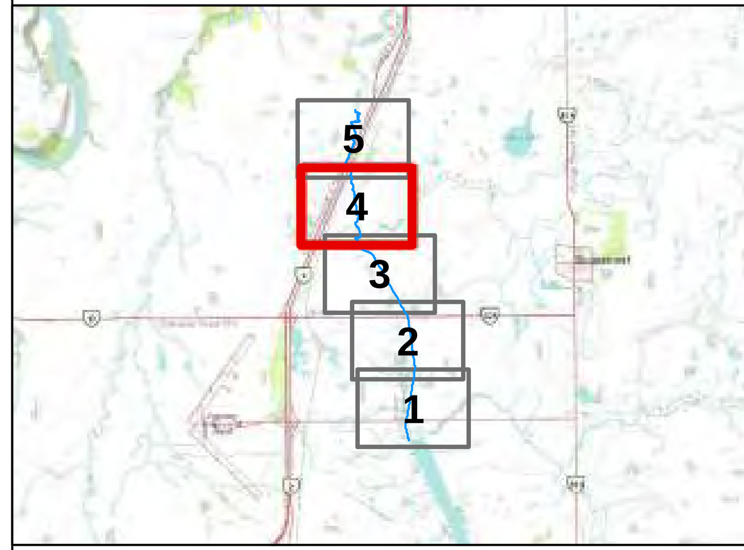
Job: 100132	*Date: FEBRUARY 2014*

SCALE - 1:5,000

0 100 200 300 400 M

N

Coordinate System: 3TM 114˚, NAD 1983
Units: METRES



10-Year Flood Extent

50-Year Flood Extent

100-Year Flood Extent

Creek Centreline

Cross Section

XS 8991 Cross Section Number

Contour (10 m interval)

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NISKU FLOOD HAZARD STUDY

FLOOD FREQUENCY MAP

MAPSHEET 5 OF 5

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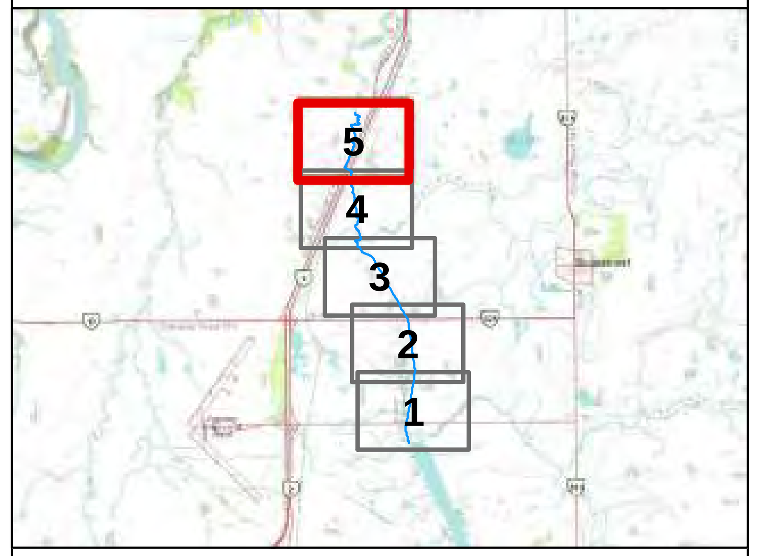

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Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

TECHNICAL MEMORANDUM NO. 3

Blackmud/Whitemud Creek Surface Water Management Group

Blackmud/Whitemud Creek Surface Water Management Study
Hydrology Assessment

October 2016

CANADA'S BEST MANAGED COMPANIES Platinum member

Executive Summary

Associated Engineering (AE) was retained by the Blackmud/Whitemud Surface Water Management Group to complete a Surface Water Management (SWM) Study. The study involves hydrologic, hydraulic, hydrogeologic and environmental analyses of the Blackmud and Whitemud Creek basins.

Large portions of the Blackmud/Whitemud Creek watershed are expected to be intensively developed in the foreseeable future by the surrounding municipalities. This development will place additional stresses on Blackmud and Whitemud Creeks, which have already been impacted by previous development.

The objective of this technical memorandum was to provide a preliminary hydrology assessment for Whitemud and Blackmud Creeks. The information obtained from this assessment will be used to analyse flooding and erosion potential along the creeks and the impact of future development in the basins. This hydrology assessment included the following:

- Review of previous hydrology reports.
- Understanding the existing topography and hydrologic characteristics of the basins.
- Analyzing available hydrometric information to characterize the existing flow regime in the study area, including annual runoff and seasonal runoff patterns.
- Flood frequency analysis to estimate peak flows at different return periods.
- Assessment of peak runoff rates for the study area.

Below is a summary of the key conclusions from the study:

- Portions of the Blackmud and Whitemud basins are flat and poorly drained, and there are numerous wetlands especially in the upper basin. The upper basin creek channels are poorly defined and have limited capacities.
- The Blackmud Creek channel is relatively flat in its upper reaches (longitudinal slope = 0.05 m/km upstream of Highway 2) and steeper in the lower reaches, downstream of Highway 2.
- Whitemud Creek is relatively steep in the upstream and downstream reaches and flat in the middle. This profile suggests that the creek is still downcutting to its base level at the North Saskatchewan River which could partly explain the channel erosion that is occurring.
- Approximately 90-95% of the annual precipitation within the basin is lost to evaporation and evapotranspiration. The remaining 5-10% runs off. Runoff percentages are considerably higher in urban areas (typically 40-50% on an annual basis). This means that runoff volumes will increase by a factor of five even if peak flows are controlled, unless source controls (low impact development practices) are adopted.
- Groundwater recharge generally begins in March and peaks in early May; therefore, rainfall events in this period tend to produce relatively more surface runoff than the summer period due to the increased soil saturation in the active layer.

- Peak flows within the watercourses in the study area generally occur during the spring runoff period due to snowmelt or rain-on-snow events.
- The flood frequency analysis provides the most reliable estimates of peak discharges as it is based on actual creek discharge records from over 45 years.
- The table below provides the flood frequency estimates for key locations within the study area.

Table E-1: Flood Frequency Estimates for Key Study Area Locations

Return Period (Years)	Clearwater Creek at the mouth (m^3/s)	Irvine Creek at the Mouth (m^3/s)	Blackmud Creek at the Mouth (m^3/s)	Whitemud Creek above Blackmud Creek (m^3/s)
2	5.7	4.8	5.0	10.7
5	13.7	11.4	17.8	26.3
10	20.3	17.0	29.6	40.1
25	30.0	25.0	47.0	61.1
50	38.0	31.7	61.3	79.5
100	46.8	39.1	76.5	100.6

They indicate that the 1:100 year pre-development (existing conditions) runoff rate within the study area ranges from 1.8 to 3.0 L/s/ha based on the effective drainage area. These flood estimates are preliminary and are intended for basin planning and for comparison with modelling results, not for floodplain delineation. They will be reviewed when the modelling is completed.

- The various municipalities and the Edmonton International Airport (EIA) have different forms of SWM designed to provide varying levels of control and service level.
- The unit area runoff rates used for design of these facilities are somewhat higher than the pre-development runoff rates estimated herein and in previous studies; that is to say they are not conservative with respect to flooding and erosion potential.
- Creek channels in the project area are generally not expected to have capacity for the pre-development peak flows.

Table of Contents

SECTION **PAGE NO.**

1 Introduction

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- Flood frequency analysis to estimate peak flows at different return periods.
- Assessment of peak runoff rates for the study area.

2 Study area

The study area is the Whitemud Creek watershed, which includes the Blackmud sub-basin as shown in **Figure 2.1**.

Blackmud Creek starts at the outlet of Saunders Lake, east of Nisku. It drains northwest through Nisku into the City of Edmonton before discharging into Whitemud Creek. Whitemud Creek originates in the farmland south of the Edmonton International Airport (EIA) and continues northwards to the North Saskatchewan River.

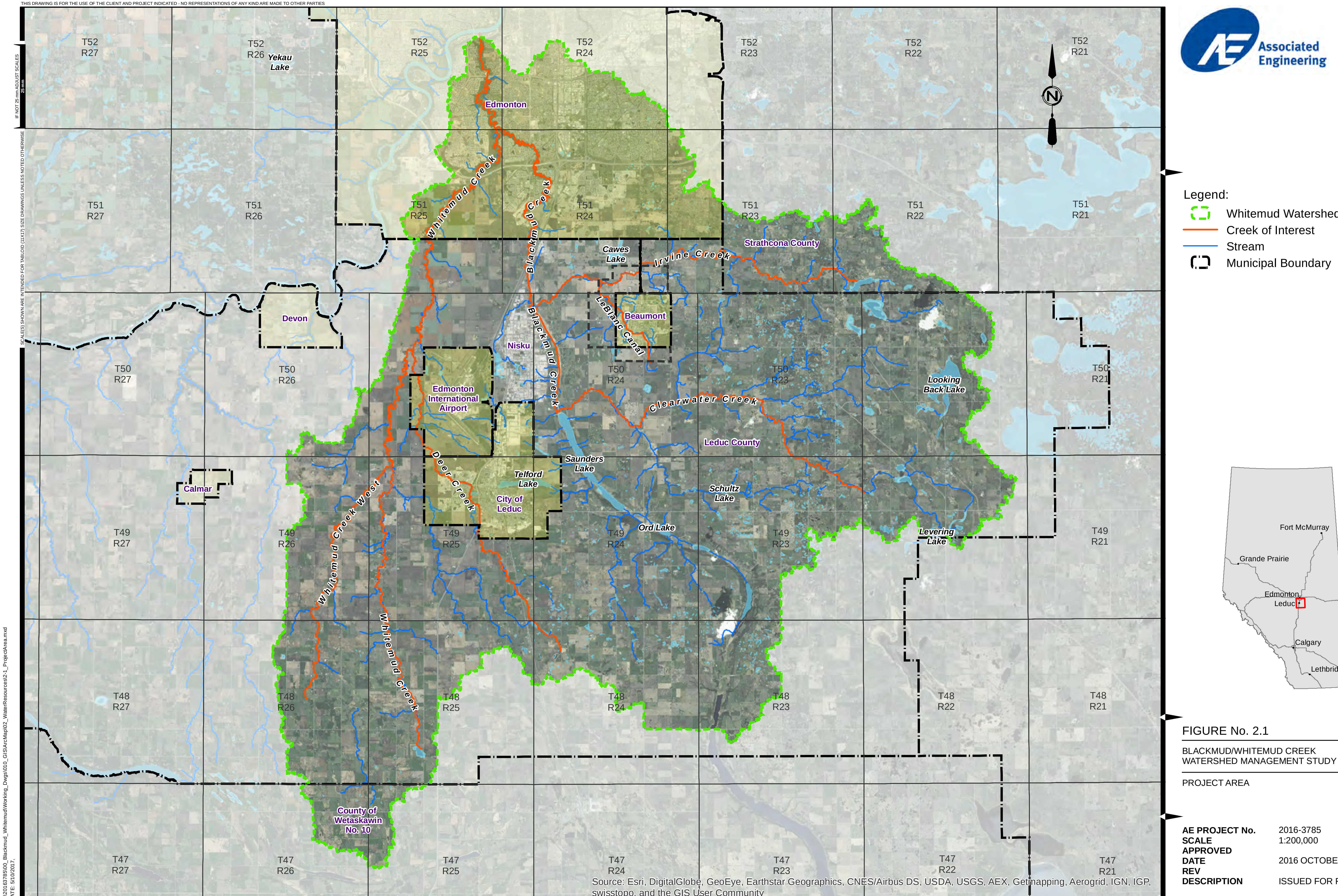
The study area includes a number of tributaries and creeks. Major watercourses within the study area are: Irvine Creek, Clearwater Creek, Deer Creek and the LeBlanc Canal. **Figure 2.2** presents the Whitemud/Blackmud Creek catchment boundaries and the major watercourses.

Irvine Creek is a tributary of Blackmud Creek located in the northeastern of Leduc County. The Irvine Creek basin includes lands within the Town of Beaumont, the City of Edmonton, City of Leduc, Leduc County, and Strathcona County. This area is mostly undeveloped with the exception of the Town of Beaumont. The Creek flows in a westerly direction from its upstream point at an unnamed lake east of Highway 21 into the Blackmud Creek just south of the intersection of 9th Street and 30th Avenue in Nisku.

Cawes Lake drains into Irvine Creek watershed in the Leduc County but does not have a defined outlet. The LeBlanc Canal drains into the Irvine Creek. It was originally constructed in 1910 to facilitate agricultural development in the lands south and west of the early Beaumont Village. The Canal flows in a northwesterly direction from a low area south of Beaumont into Irvine Creek. According to previous reports that we have reviewed, significant drainage modifications have been made to the Canal and its tributaries over time. This includes the addition of storm sewer outfalls, inline stormwater management ponds, and channel crossings. The Canal drains most of the Town of Beaumont, but runoff is controlled with a system of stormwater management ponds.

Clearwater Creek drains into Blackmud Creek north of Saunders Lake. The Clearwater Creek basin is mainly undeveloped with the exception of two small communities, New Sarepta and Rolly View.

Deer Creek runs in a westerly direction towards the Whitemud Creek. The Creek receives flow from the west half of the City of Leduc, the EIA, and stormwater management facilities in several developments (Deer Valley, Lakeside Estates, Bridgeport and West Haven). The eastern portion of the City of Leduc drains to Telford Lake and Blackmud Creek. The eastern portion of the EIA drains to the Blackmud Creek.



Associated Engineering

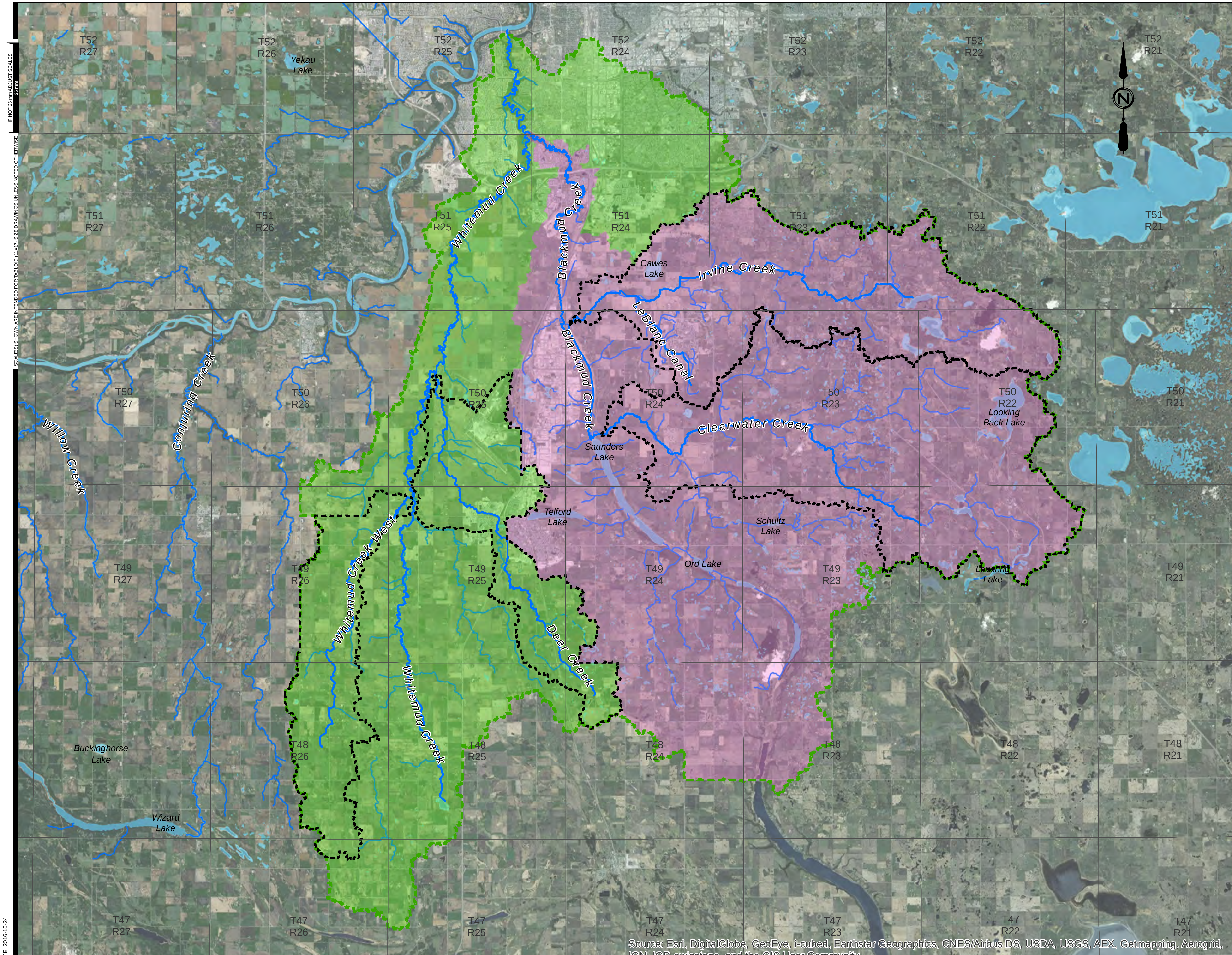
FIGURE No. 2.1

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

PROJECT AREA

AE PROJECT No.	2016-3785
SCALE	1:200,000
APPROVED	
DATE	2016 OCTOBER
REV	
DESCRIPTION	ISSUED FOR REPORT

THIS DRAWING IS FOR THE USE OF THE CLIENT AND PROJECT INDICATED - NO REPRESENTATIONS OF ANY KIND ARE MADE TO OTHER PARTIES



IF NOT 25 mm ADJUST SCALES 25 mm

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

\\s-edm-fs-01\projects\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\2-2_CatchmentBoundaries.mxd
DATE: 2016-10-24.

Associated Engineering

Legend:

- Whitemud Creek Watershed
- Blackmud Creek Watershed
- Subcatchment
- Creek Centreline

FIGURE No. 2.2

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

CATCHMENT BOUNDARIES

AE PROJECT No.	2016-3785
SCALE	1:200,000
APPROVED	
DATE	2016 OCTOBER
REV	
DESCRIPTION	ISSUED FOR REPORT

2.1 EXISTING TOPOGRAPHY AND NATURAL FEATURES

AE used the bare-earth LIDAR data to generate a digital elevation model (DEM) and detailed ground elevation contours for the study area.

Figure 2.3 provides a view of the topography within the study area derived from the LIDAR data. The map is colour-coded to represent the relative elevations and the locations of the stream channels. The elevation contours have a resolution of 15 m. The DEM defines the stream channels and their physical dimensions. The LIDAR data was used to delineate boundaries for the study area as previously shown in **Figure 2.2**.

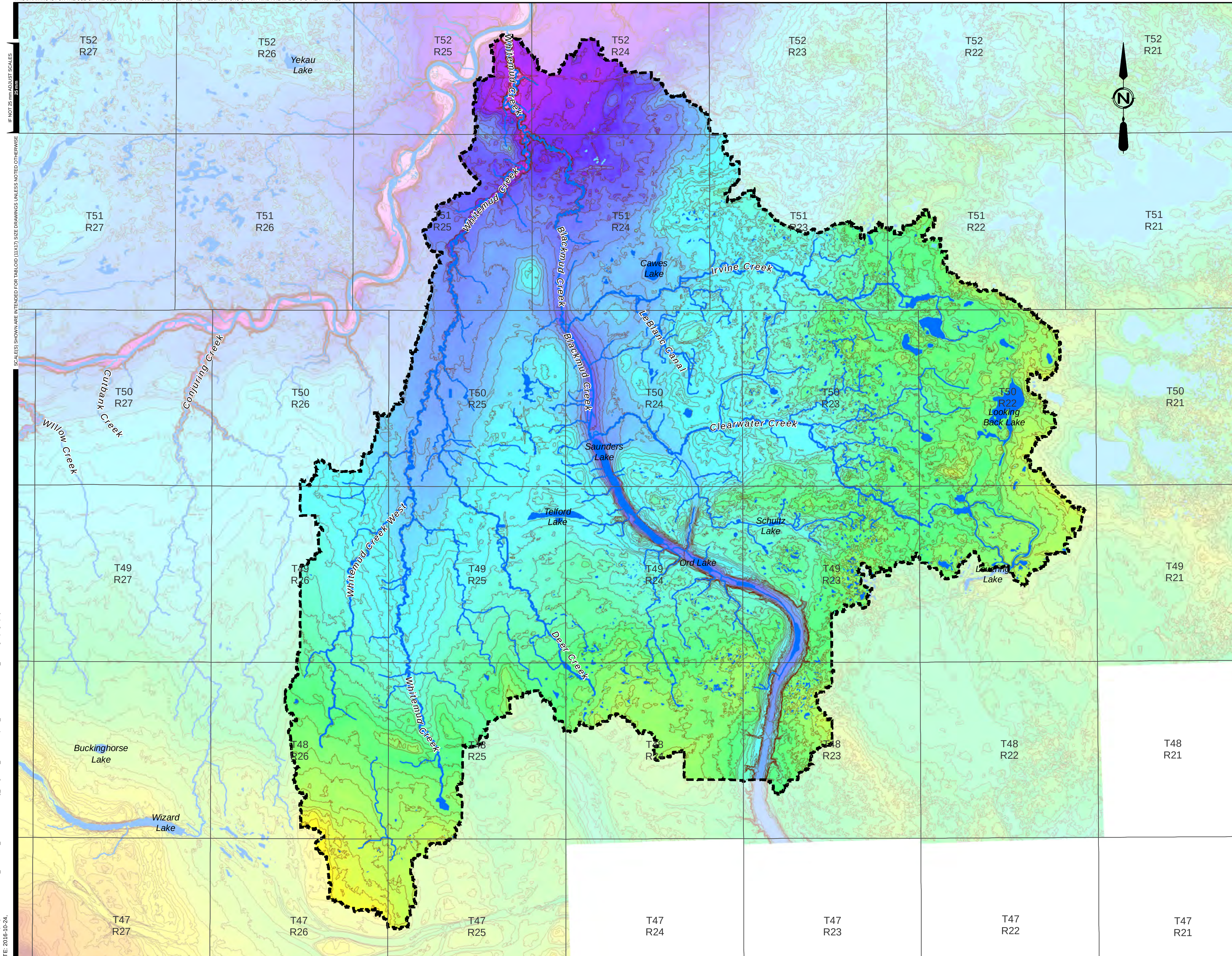
Based on the derived elevation contours, in general the Blackmud and Whitemud catchments both have gently sloping topography with average basin slopes of 1.7% for Blackmud and 1.5% for the Whitemud (at the mouth). Clearwater and Irvine Creek sub-basins have average slopes of 1.6%.

Portions of the Blackmud and Whitemud basins are flat and poorly drained. There are numerous wetlands especially in the upper basins.

Table 2.1 provides a summary of the Blackmud and Whitemud Creek watershed characteristics.

Table 2.1
Blackmud Creek and Whitemud Creek Watershed Characteristics

Basin	Drainage Area (km^2)	Average Basin Slope (%)	Sub-Basins
Clearwater Creek	208	1.6	-
Irvine Creek	158	1.6	-
Telford, Saunders and Ord Lake	237	2.1	-
Blackmud Creek	683	1.7	Clearwater Creek Irvine Creek
Deer Creek	74.5	0.8	-
West Whitemud Creek	64.8	0.7	-
Whitemud Creek at the mouth	1,168	1.5	Blackmud Creek West Whitemud Creek Deer Creek



Associated Engineering

Legend:

- Whitemud Watershed
- Creek Centreline
- 5 m Contour

Elevation

- 880 m
- 840 m
- 800 m
- 760 m
- 720 m
- 680 m
- 640 m

FIGURE No. 2.3

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

EXISTING TOPOGRAPHY

AE PROJECT No.	2016-3785
SCALE	1:200,000
APPROVED	
DATE	2016 OCTOBER
REV	
DESCRIPTION	ISSUED FOR REPORT

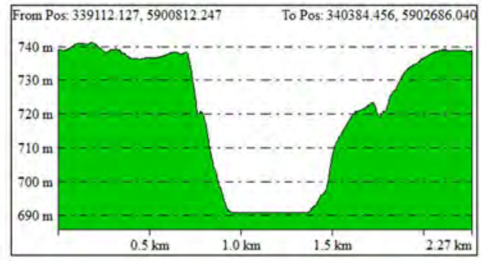
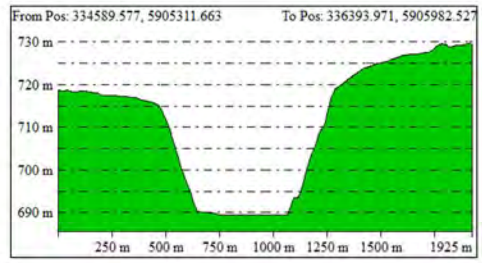
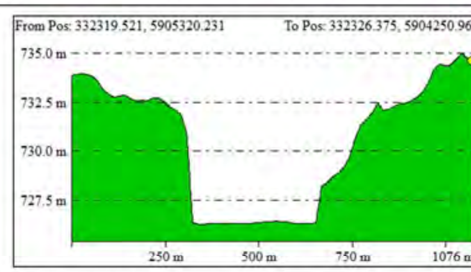
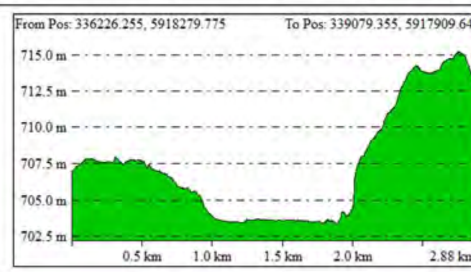
The upper catchment of Blackmud Creek contains several large lakes, namely: Saunders, Ord, Telford, Looking Back, and Cawes Lakes. It also contains vast areas of knob-and-kettle terrain that store runoff and reduce peak flows. The contributing drainage areas into these lakes is approximately 249 km^2.

Analysis of the topography of the study area indicates the following:

- The Blackmud/Whitemud Basin covers an area of approximately 1,168 km^2.
- Approximately 60% of the study area (683 km^2) is drained by Blackmud Creek and its tributaries.
- The major lakes in the Blackmud Basin cover an area of approximately 4.2 km^2 and drain an area of 249 km^2, thus providing significant streamflow routing potential and reducing peak flows.

Table 2.2 summarizes the lake characteristics based on the 15 m LIDAR data.

Table 2.2
Lake Characteristics within the Study Area

Lakes	Catchment Area (km2)	Water Level Elevation* (m)	Top of Bank Elevation (m)	Surface Area** (km2)	Typical Cross-section
Ord Lake	**99.9**	690.1	740	0.6	
Saunders Lake***	**237**	689.4	715	2.4	
Telford Lake	**11.9**	726.3	732.5	0.9	
Cawes Lake	**12**	703.6	707.5	0.5	

*Water level corresponds to the surface water elevation at the time of obtaining the 15 m LIDAR.

**Surface Area refers to the area at the surface of a lake. This is based on LIDAR data.

***Catchment area to Saunders Lake includes catchments of Ord Lake and Telford Lake.

Cross sections are taken from coordinates indicated.

2.2 CREEK CHARACTERISTICS

Blackmud and Whitemud Creeks are tributaries to the North Saskatchewan River.

Figure 2.4 and Figure 2.5 illustrate the channel profiles for Blackmud and Whitemud Creeks, respectively. These profiles are based on the 15 m LIDAR data for the study area. The upper reaches of Blackmud Creek are relatively flat with the channel steepening down in the lower basin. In contrast, the upper and lower reaches of the Whitemud Creek are relatively steep. The channel flattens out as the creek drains through the central part of the basin. Table 2.3 summarizes the estimated average slopes within the different sections of the creeks.

Table 2.3
Average Slopes for different Creek Reaches

Creek	Section	Slope (m/km)
Blackmud Creek	Upper Reach	0.05
	Middle Reach	1.3
	Lower Reach	3.4
Whitemud Creek	Upper Reach	2.8
	Middle Reach	0.7
	Lower Reach	2.4

AE conducted a bathymetric survey on both creeks in September 2016. The survey included approximately 6 channel cross-sections along the Blackmud and 65 along the Whitemud Creek. Typical channel cross-sections and channel dimensions are presented in Table 2.4.

The bathymetric survey shows that the upper basin creek channels are poorly defined and have limited hydraulic capacities. Flooding and erosion have been experienced in various areas of the basin, specifically along Irvine Creek, Blackmud Creek and Whitemud Creek. In some locations these channels are too shallow to drain run off from urban development.

Portions of the LeBlanc Canal, Irvine Creek, and the Blackmud Creek (upstream of 41st Avenue) have been extensively channelized in the past. Our assumption is that, this was undertaken to improve drainage and reduce flooding. Other channelized stream courses exist in some parts of the basin. These are likely a result of farming drainage practices. These practices tend to increase peak flow rates, erosion, and sedimentation downstream.

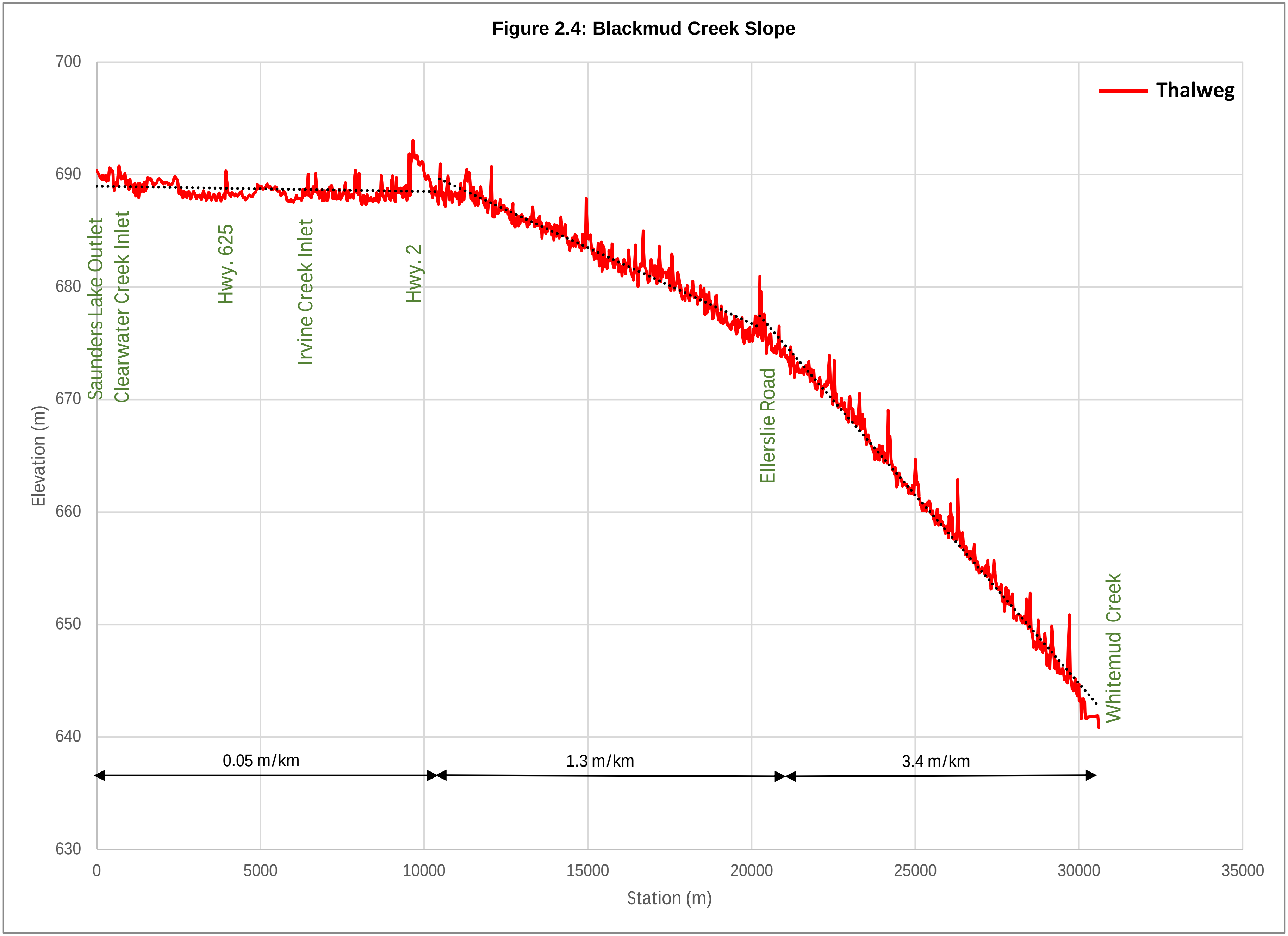


Figure 2.4: Blackmud Creek Slope
Thalweg
Elevation (m)
Station (m)
700
690
680
670
660
650
640
630
0
5000
10000
15000
20000
25000
30000
35000
Saunders Lake Outlet
Clearwater Creek Inlet
Hwy. 625
Irvine Creek Inlet
Hwy. 2
Ellerslie Road
Whitemud Creek
0.05 m/km
1.3 m/km
3.4 m/km

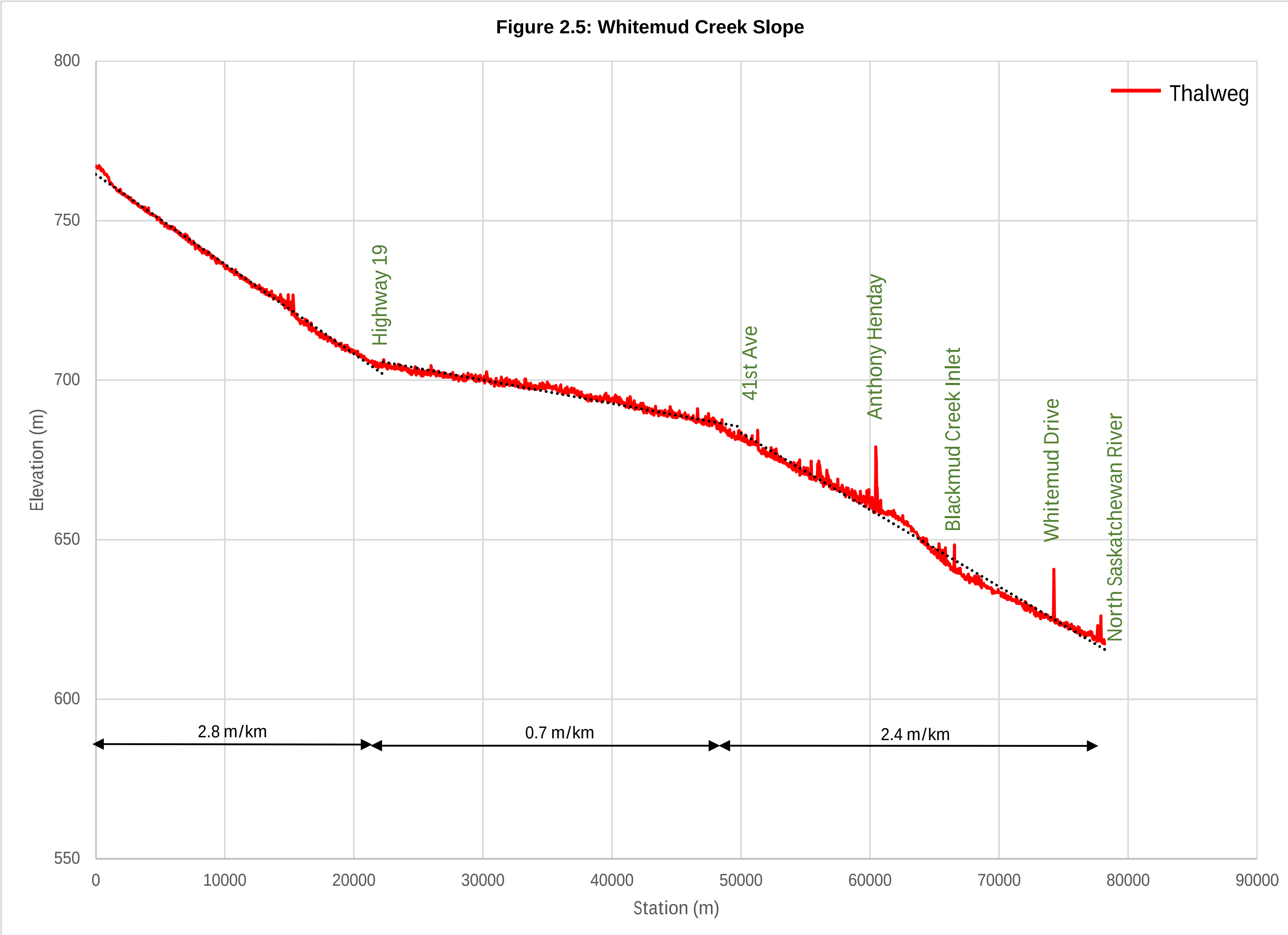
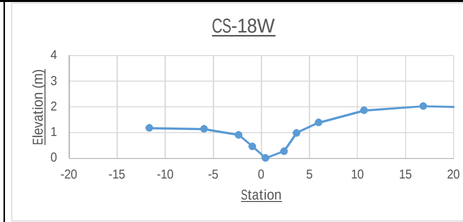
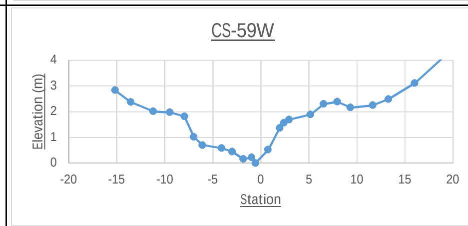
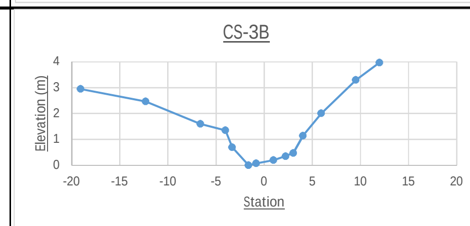
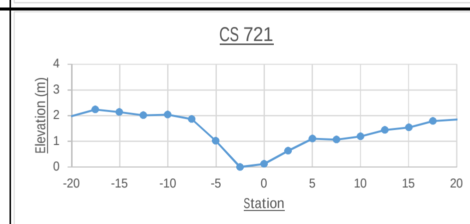
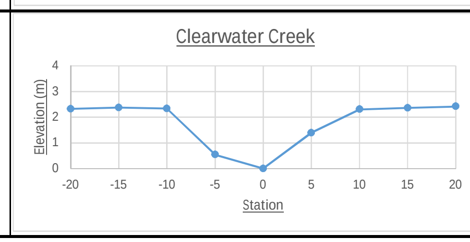


Figure 2.5: Whitemud Creek Slope
Thalweg
Elevation (m)
Station (m)
800
750
700
650
600
550
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
Highway 19
41st Ave
Anthony Henday
Blackmud Creek Inlet
Whitemud Drive
North Saskatchewan River
2.8 m/km
0.7 m/km
2.4 m/km

Table 2.4: Typical Creek Cross-sections

Creek	Reach	Top Width (m)	Depth (m)	Bottom Width (m)	Typical Cross-section
WHITEMUD CREEK	**Within Leduc County (Upstream of 41 ave)**	7.4	0.9	3.0	
	Within the City of Edmonton Limits	10.4	1.4	3.9	
BLACKMUD CREEK	**Within the City of Edmonton Limits**	8.0	1.1	6.1	
IRVINE CREEK*	Upstream of the mouth	10.0	1.0	1.0	
CLEARWATER CREEK**	Upstream of the mouth	20.0	2.3	5.0	

*Cross Section obtained from Irvine Creek Stantec MIKE 11 model
**Cross Section obtained from 1 m resolution LiDAR surface
CS-3B represents survey x-sec location

2.3 EXISTING DEVELOPMENT

The Blackmud and Whitemud basins are being developed and this trend is envisioned to continue in the future. The following are developed areas that are currently discharging into the Whitemud and Blackmud Creeks:

- City of Edmonton extending south to 41st Avenue SW;
- City of Leduc;
- Leduc County's Nisku Industrial Park;
- Town of Beaumont; and
- Edmonton International Airport.

Our review of the available data shows that existing subdivisions within the study area have been developed following different standards and criteria. Based on the background review (TM1), **Table 2.5** presents the discharge release rates that have been adopted or proposed for development by each municipality. Older areas within the City of Leduc currently drain without stormwater management (SWM) or controls. These areas drain to the east towards the Telford Lake and to the northwest towards a tributary of the Whitemud Creek.

Table 2.5
Summary of SWM Discharge Release Rate

Municipality	SWM Discharge Release Rate (l/s/ha)
City of Edmonton	5
City of Leduc	2 – 8.8**
Leduc County	3.1 - 3.8*
Town of Beaumont	1.8 – 6.7

* Obtained from Planning studies

** Estimated based on outlet pipe and drainage catchment

It should be noted that the contributing drainage areas within Strathcona County are not developed.

Older developments within the City of Edmonton drain directly to Whitemud Creek without SWM or controls. The newer developments drain into Whitemud Creek and Blackmud Creek with SWM, in accordance with the Whitemud Creek Watershed Plan (1982 and 1999 Update). SWM facilities within the newer development areas of the City of Edmonton are currently designed for a release rate of 5 l/s/ha.

The Town of Beaumont, City of Leduc, Leduc County's Nisku Industrial Park, and the Edmonton International Airport all have various forms of SWM facilities designed to provide different levels of control and service levels.

The majority of runoff from the Town of Beaumont discharges into the Leblanc Canal which drains into Irvine Creek. The Town has approximately 20 SWM facilities with discharge release rates ranging from 1.8 to 6.7 l/s/ha as identified in the Irvine Creek and Cawes Lake Watershed Study (STANTEC 2014). The higher release rates correspond to areas that were built before standards were developed and adopted in the Town. However, new developments are currently being designed for a 1.8 l/s/ha release rate, as noted in the Town's design standards.

The City of Leduc also has over 25 SWM facilities for runoff control and water treatment. The release rates from these facilities range from 2 l/s/ha to 8.8 l/s/ha. The City of Leduc's design standards indicate an allowable release rate of 7.5 l/s/ha.

In general, runoff from most developments is being controlled with SWM facilities, but not always to the same standard. Drainage standards have also become more restrictive over time. In addition, significant drainage changes and channelization have occurred due to agricultural drainage practices throughout much of the basin.

These changes, plus historic land clearing to create farmland, have undoubtedly increased the flows in the study area streams in the past. As development continues in the Blackmud and Whitemud basins, the runoff rates and volumes will increase. As a result, flooding and erosion issues will likely increase unless stormwater releases are mitigated in the future.

3 Previous Hydrology Studies Summary

A number of background reports were provided by the Group during the background review stage. The most recent reports that were relevant to the hydrology of Blackmud and Whitemud Creeks are summarized in the following sections.

3.1 NISKU FLOOD HAZARD STUDY - BLACKMUD CREEK

Northwest Hydraulic Consultants (NHC) (2014) conducted a flood hazard study for Blackmud Creek within Leduc County. The study was part of the continuing flood hazard mapping efforts by the Government of Alberta to identify, map, and document flood hazard areas in communities throughout Alberta. The study area included 12 km of Blackmud Creek, from Saunders Lake to the north boundary of Leduc County.

The following is a summary of the results of the Nisku Flood Hazard Study:

- Two main tributaries discharge to Blackmud Creek.
- Upper Blackmud Creek catchment contains several large lakes, including Saunders Lake, Ord Lake, and Telford Lake and drains an area of 237 km^2.
- A Water Survey of Canada (WSC) hydrometric station, reflecting an effective drainage area of 643 km^2 (current study estimate is 683 km^2) is located on Blackmud Creek at 111th Street SW (WSC 05DF003, Blackmud Creek near Ellerslie).
- Alberta Environment (1981) provided an estimate of the Blackmud Creek 1974 hydrograph from April 11 to May 1, with a peak occurring on April 24. Maximum daily discharge was estimated by Alberta Environment to be 87.8 m^3/s. The corresponding instantaneous peak of 97.5 m^3/s was estimated by applying the Blackmud Creek peak to mean discharge ratio of 1.110 to the maximum daily discharge.
- The 1974 peak (greater than the 100-year flood event) is estimated to have an instantaneous peak of 97.35 m^3/s at the Blackmud Creek near Ellerslie WSC station.
- The next highest flood on record occurred in 1983, with a maximum instantaneous discharge of 19.4 m^3/s being recorded on July 7 at the Blackmud Creek near Ellerslie WSC station. This flood is estimated to be less than a 5-year event.
- The majority of the Blackmud Creek flood peaks have occurred in spring with the earliest peak recorded on March.
- Based on the report, the distributed runoff on a unit basis is the same everywhere in the basin – both upstream and downstream of Saunders Lake. Based on the analysis, there is a little difference in runoff depth between the catchment downstream of Saunders Lake and the entire Blackmud catchment. The storage in the Saunders Lake does not play a significant role over and above the distributed storage elsewhere in the catchment, in reducing runoff volumes, however, this will be reviewed in further project stages.

- Flow frequency analysis was completed by including the 1974 flood event. Pearson III distributions were selected for the flood peaks. The peaks at the outlet of Saunders Lake were assumed to scale with the peak for the entire catchment area downstream of Saunders Lake.
- Flood discharges on Blackmud Creek for 2-year to 1000-year return periods were estimated using peak discharge recorded by WSC at the following gauges: Blackmud Creek near Ellerslie (1974 - 2011), Whitemud Creek near Ellerslie (1969 – 2011), West Whitemud Creek near Ireton (1976 – 2000), Whitemud Creek near Nisku (1960 – 1968) and Pipestone Creek near Wetaskiwin (1972 – 2011).
- Flood frequencies for each of the salient reaches along Blackmud Creek are summarized in **Table 3.1**.

Table 3.1
Flow Frequency Estimates for Blackmud Creek

Return Period (years)	Probability of Exceedance (%)	Peak Instantaneous Discharge (m^3/s)		
		Saunders Lake to Clearwater Creek	Clearwater Creek to Irvine Creek	Irvine Creek to WSC Gauge at Ellerslie
1000	0.1	25.7	76.8	124
500	0.2	22.7	68.02	110
200	0.5	18.9	56.6	91.5
100	1	16.1	48.2	78.0
50	2	13.4	40.0	64.8
20	5	9.89	29.6	47.9
10	10	7.37	22.1	35.7
5	20	4.94	14.8	23.9

Source: Nisku Flood Hazard Study – Blackmud Creek 2014

3.2 IRVINE CREEK AND CAWES LAKE WATERSHED STUDY

The Irvine Creek and Cawes Lake Watershed Study delineated the Irvine Creek floodplain and provided options to reduce flooding and erosional impacts.

The following is a summary of the Irvine Creek and Cawes Lake watershed study (STANTEC, 2014):

- A water balance was completed based on data from nearby basins:
  - Blackmud Creek (gross area 643 km^2, effective area 374.2 km^2, flow recorded 1977-2011),
  - West Whitemud Creek (gross area 65.4 km^2, effective area 53.2 km^2, flow record 1969-2011),
  - Whitemud Creek (gross area 330.4 km^2, effective area 300.5 km^2, flow record 1969-2011).
- According to the study, a simplified water balance equation (P = Q + L) was used in the analysis, where P represents precipitation, Q represents flow, and L represents losses (combining evapotranspiration and groundwater infiltration). Calculations were performed on three different time scales: on a daily, monthly, and yearly basis. Water balance results indicated a runoff range from 6-10% of total precipitation (losses to evaporation of 90-94% on an annual basis). This contrasts with annual runoff of 40-50% of precipitation from an urban area.
- The 1:100-year peak flow for Irvine Creek at the mouth was calculated as 17.5 m^3/s. This peak flow is equivalent to a unit discharge rate of 1.1 L/s/ha (based on effective area).
- The study provided a summary of an erosion study completed by Golder (2006). Golder completed a brief hydrological assessment and flood frequency analysis of three hydrometric stations on Blackmud and Whitemud Creeks. Golder (2006) reported that high flows in Blackmud and Whitemud Creeks typically occur during the snowmelt period (mid-March and mid-April).
- The maximum recorded flow for the Whitemud Creek occurred on 23 April 1974, with a maximum instantaneous discharge of 114 m^3/s and a maximum daily discharge of 95.1 m^3/s.
- Various methods were used to generate flood flow estimates (Single-Station transfer, Regional Flood Frequency Analysis, Alberta Transportation method, Hydrological Modeling). The HEC-SSP software package was used to compute flood frequencies and to fit a 3-parameter log Pearson statistical distribution to the data. Using computed flows for the 2, 5, and 100 year return periods for each station, a power function line-of-best-fit was applied to the data to determine regression equations.
- Irving Creek Peak flows estimates are shown in **Table 3.2**.
- Expressed on a unit area basis, the 100-year return period unit discharge peak flows estimated in the report range from 0.9 l/s/ha – 2.7 l/s/ha, with the median estimate being 1.3 l/s/ha. The median value is lower than the unit release rate adopted by any of the municipalities in the basin.

Table 3.2
Irvine Creek Maximum Instantaneous Flows Estimates

Peak Flow Calculation Method	2 Year		5 Year		100 Year	
	Flow (cms)	L/s per Ha	Flow (cms)	L/s per Ha	Flow (cms)	L/s per Ha
Single Station Transfer (Blackmud)	1.7	0.1	3.5	0.2	15.6	0.9
Single Station Transfer (Whitemud)	6.2	0.4	13.5	0.8	44.6	2.7
Single Station Transfer (West Whitemud)	5.8	0.4	11.2	0.7	23.1	1.4
Regional Flood Frequency Analysis (Gross)	3.0	0.2	6.9	0.4	22.2	1.3
Regional Flood Frequency Analysis (Effective)	2.4	0.1	5.3	0.3	15.5	0.9
Alberta Transportation Method	-	-	-	-	18.1	1.1
Hydrological Modelling	-	-	-	-	17.5	1.1

Source: Irvine Creek and Cawes Lake Watershed Study 2014

4 Hydrometeorological Review

The following sections provide an overview of the hydrometeorological conditions in the study area and the general runoff mechanisms.

4.1 CLIMATE

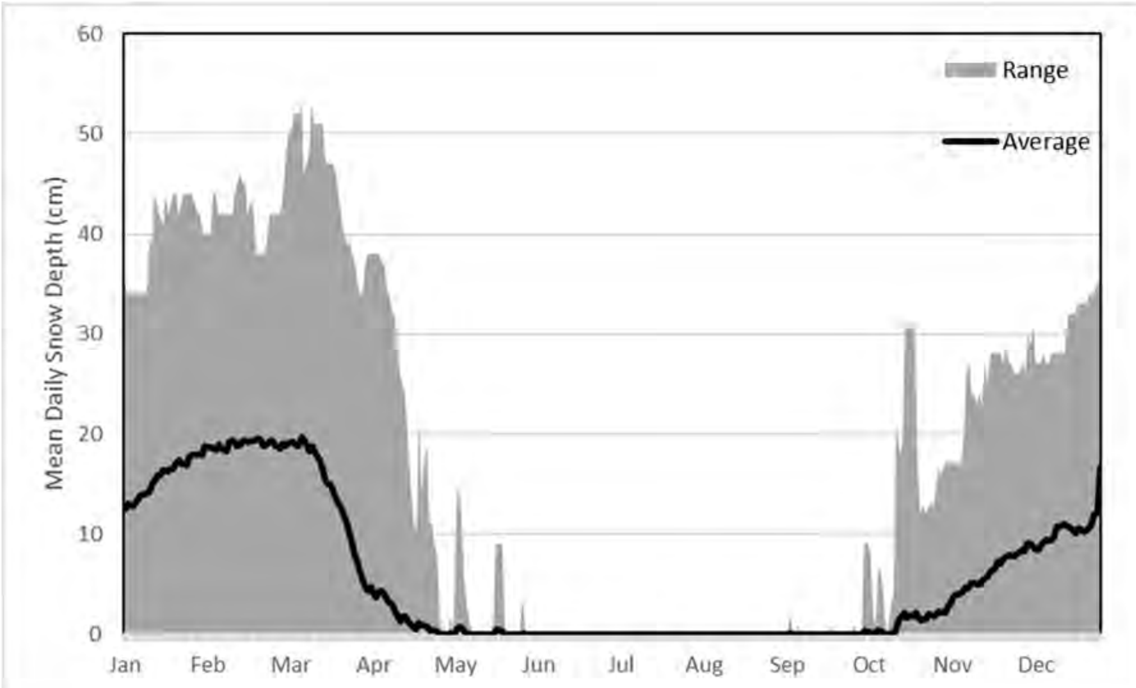
The climate of the study area is characterized by warm summers and cold winters, with a relatively even distribution of precipitation throughout the year. Based on 1981-2010 averages (i.e., climate "normal") from Edmonton International Airport (Meteorological Service of Canada Station No. 3012205; Elevation = 703.1 m), the mean monthly air temperatures of the study area ranges from -12.1°C in January to 16.2°C in July. Air temperatures are, on average, below zero from November to March. Approximately 25% of the total annual precipitation of 446 mm falls as snow. Rainfall in June and July (combined) provides almost 40% of the total annual precipitation. **Table 4.1** presents a summary of climate information for the Edmonton International Airport.

Table 4.1
Climate Summary for Edmonton International Airport (Station No. 3012250), 1981-2010

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Air Temp (°C)	-12.1	-9.9	-4.4	4.2	10.2	14.1	16.2	15.2	10.2	3.8	-5.4	-11	2.6
Rain (mm)	1.4	0.5	0.9	14.9	42.9	72.7	95.6	54.9	40.3	12.6	1.6	0.8	339
Snow (cm)	21.7	13.4	17.5	14.4	6.5	0	0	0.1	1.1	10.4	17.3	15.9	118.1
Total Precip. (mm)	20.8	11.9	16.5	28.7	49.4	72.7	95.6	54.9	41.3	22.6	17.3	14.5	446.1

Based on snow depth records collected at the Edmonton International Airport, the snowpack in the study area begins to develop in October and generally persists until April. Maximum snowpacks occur in mid-February / early March and melting occurs from mid-March to April. The trend of snowpack development and melt is illustrated in **Figure 4.1**.

Figure 4.1: Summary of Snowpack Development and Melt at the Edmonton International Airport (Station No. 3012250), 1981-2010



4.2 GROUNDWATER

The study area is located in the Eastern Alberta Plains physiographic region, within the Lake Edmonton Plain district (Agriculture Canada 1986). The Lake Edmonton Plain district is an undulating area of low relief, with soils comprised of glaciolacustrine and glaciofluvial deposits.

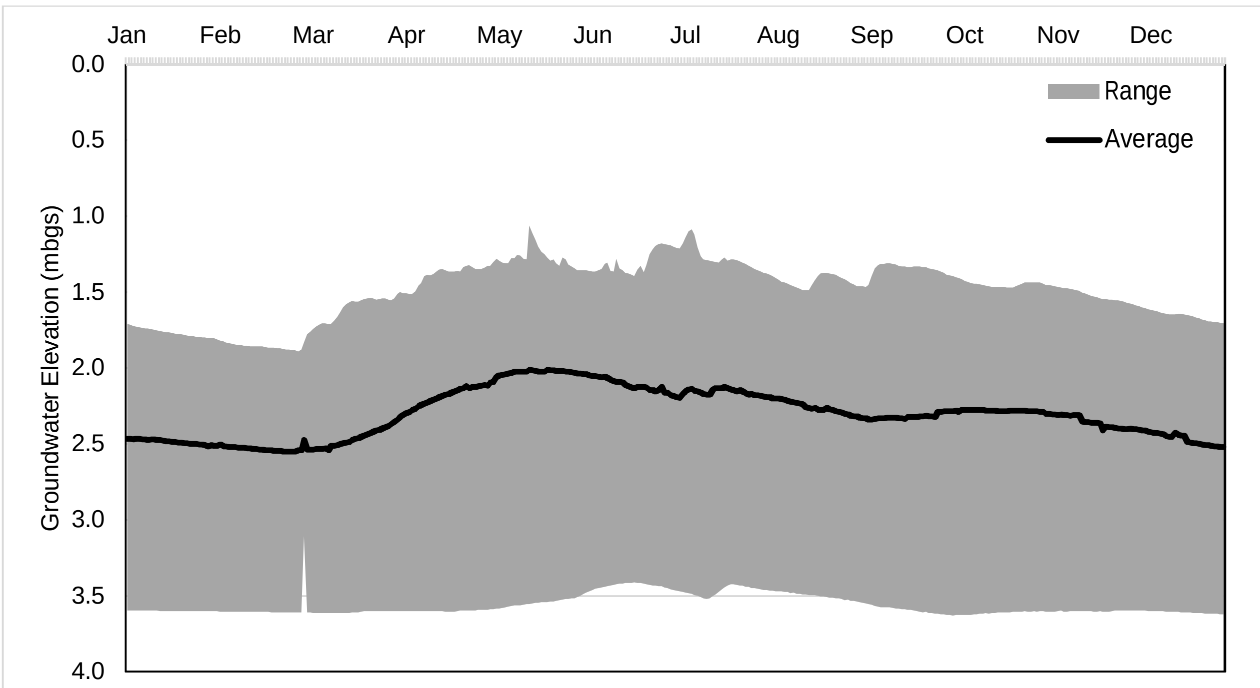
p

Research Council of Alberta (1979) reported that groundwater movement for the study area was from the southwest to the north towards the North Saskatchewan River. No specific surficial aquifer mapping is available for the study area, but the Research Council of Alberta (1979) noted that the surficial aquifer materials consisted of sands and clayey tills. Recharge of the surficial aquifer within the study area is dependent on the surficial materials present and is generally low in clayey materials (Research Council of Alberta 1979). ECOS Engineering Services Ltd. (1982) also reported that the surficial aquifer materials are directly connected to the creeks within the study area and impact baseflows.

There are numerous water wells within the study area, but no groundwater level monitoring is available. An Alberta Environment and Parks observation well (No. 05DFG007) is located approximately 8 km southwest of the study area north of the North Saskatchewan River opposite the Town of Devon. Figure 4.2 presents a summary of groundwater levels recorded at this well site. The seasonal trend is one of peak levels occurring in late April or early May and lowest levels generally occurring in February.

Well No. 05DFG007 is located within an unconfined aquifer and is comprised of sands. Although the well is located on the opposite side of the North Saskatchewan River to the study area, the recorded seasonal variability of groundwater levels is likely consistent with groundwater levels within the study area.

Figure 4.2: Summary of groundwater levels measured by Well No. 05DF007 (Devon), 1981-2010



4.3 HYDROLOGIC REGIME

According to NHC (2014), high flows in the study area are generally the result of spring snowmelt runoff. Figure 4.3 shows a summary of the flow data recorded by Water Survey of Canada (WSC) in Whitemud Creek near Ellerslie (WSC Gauge 05DF006). The graph shows the minimum and maximum flow recorded for each day of the calendar year along with the daily flow measurements for 2014, the most recent year of published data. As noted by NHC, the creek flow is generally highest in the spring and early summer due to snowmelt and spring rains. Peak events are relatively isolated and typically lower during the summer months June to October.

Figure 4.3: Historic Flow Data for Whitemud Creek near Ellerslie (WSC 05DF006)

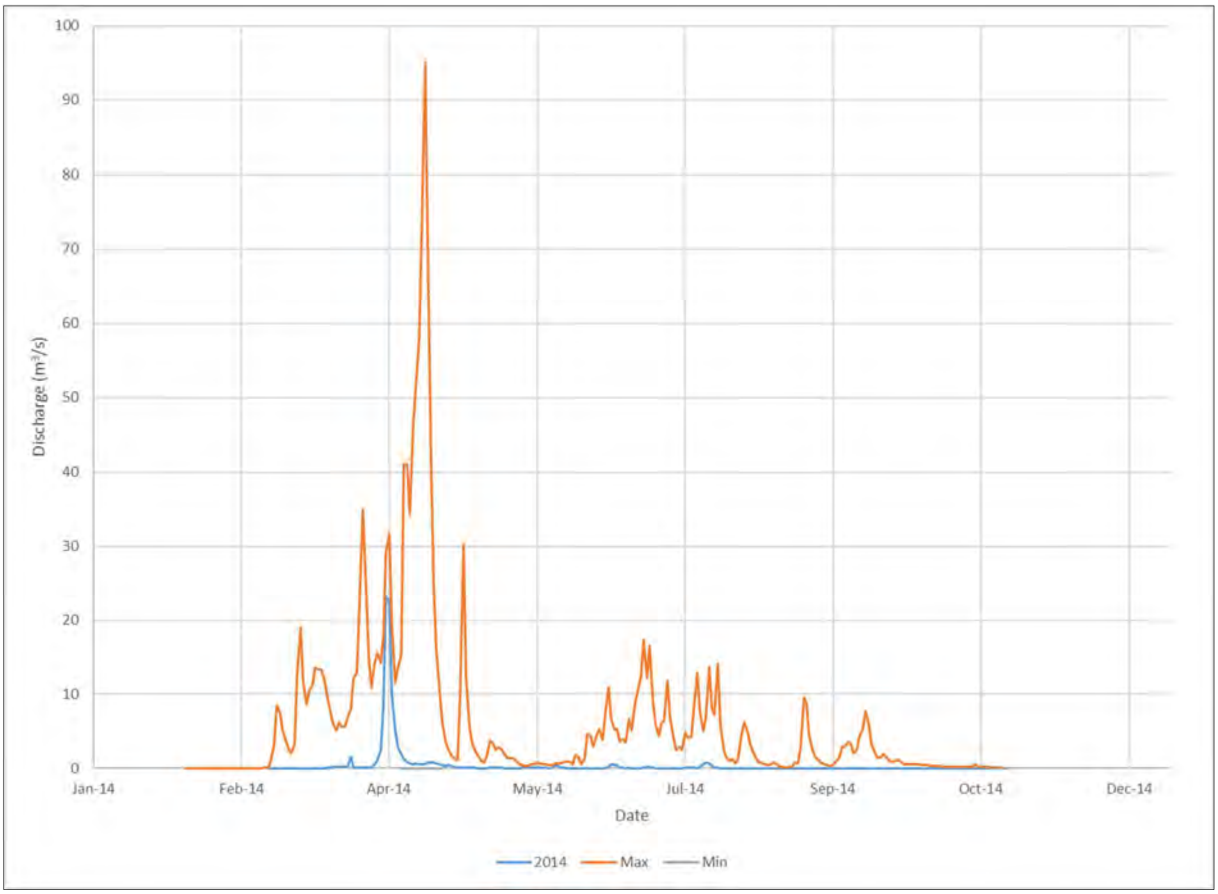


Figure 4.4 shows the historic (since 1977) and 2014 flow data for Blackmud Creek. A comparison of **Figure 4.3** to **4.4** show that summer runoff events are more significant in the Blackmud Creek than in the Whitemud Creek. The record for Blackmud Creek does not include the high snowmelt year of 1974 which dominates the flood hydrology of the region.

Figure 4.4: Historic Flow Data for Blackmud Creek near Ellerslie (WSC 05DF003)

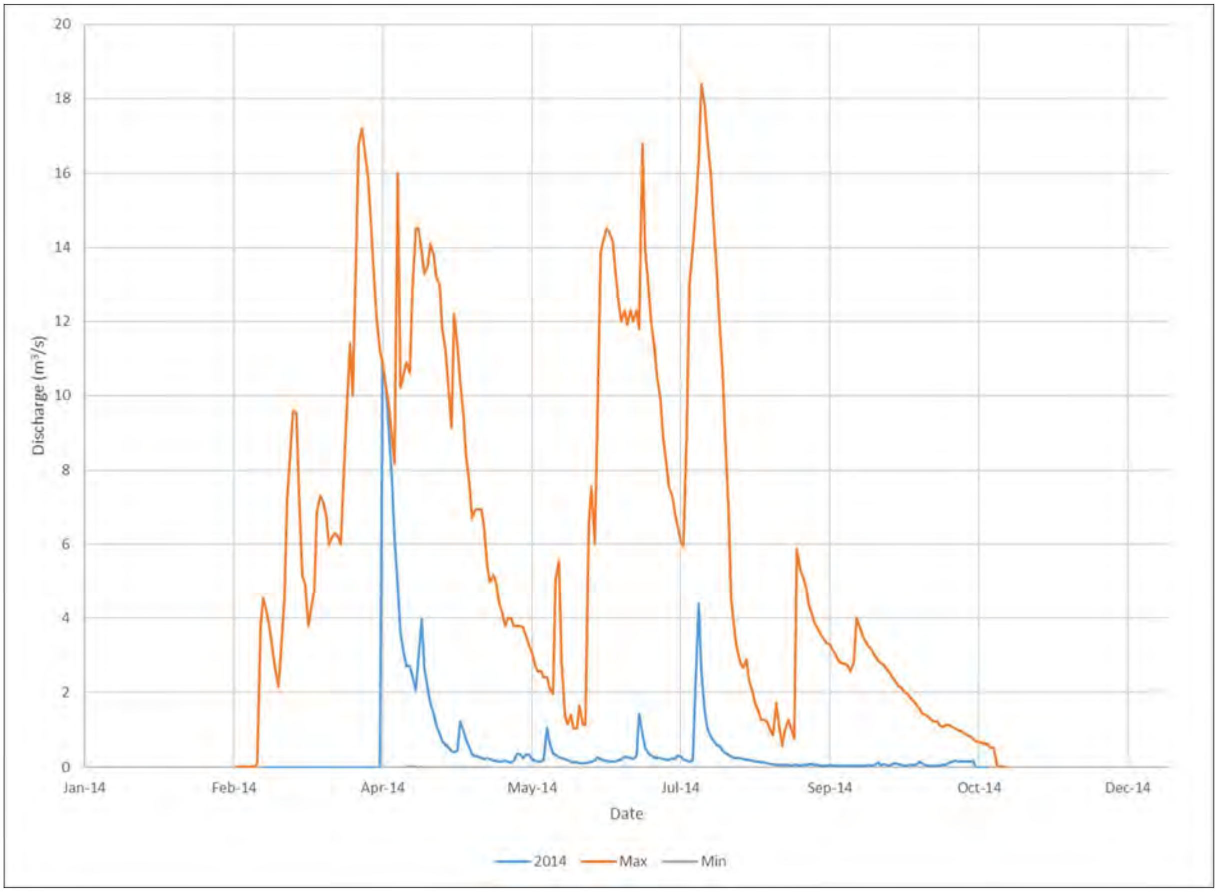


Figure 4.5 shows a direct comparison between the Whitemud and Blackmud Creks at the same scale.

Figure 4.5: Historic Flow Data for Whtiemud and Blackmud Creeks near Ellerslie

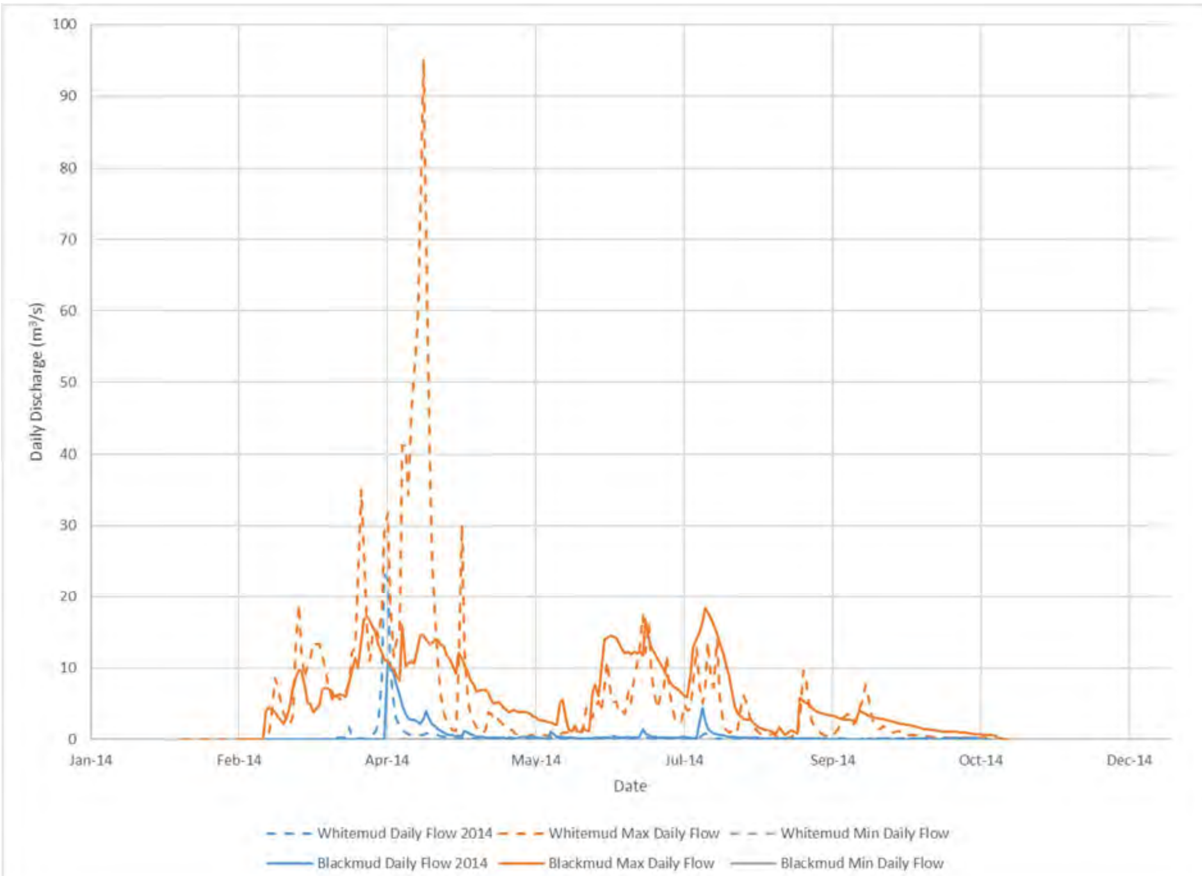


Figure 4.6 presents an overview of the annual peak flows recorded in Whitemud Creek near Ellerslie based on WSC flow records since 1969. As shown on this graph, the highest flow occurred in 1974. This was due to heavy snowpack during the previous winter months and rapid melt in April. Generally, flood peaks have been somewhat lower since 1985.

Figure 4.6: Annual Peak Flows in Whitemud Creek near Ellerslie (WSC 05DF006)

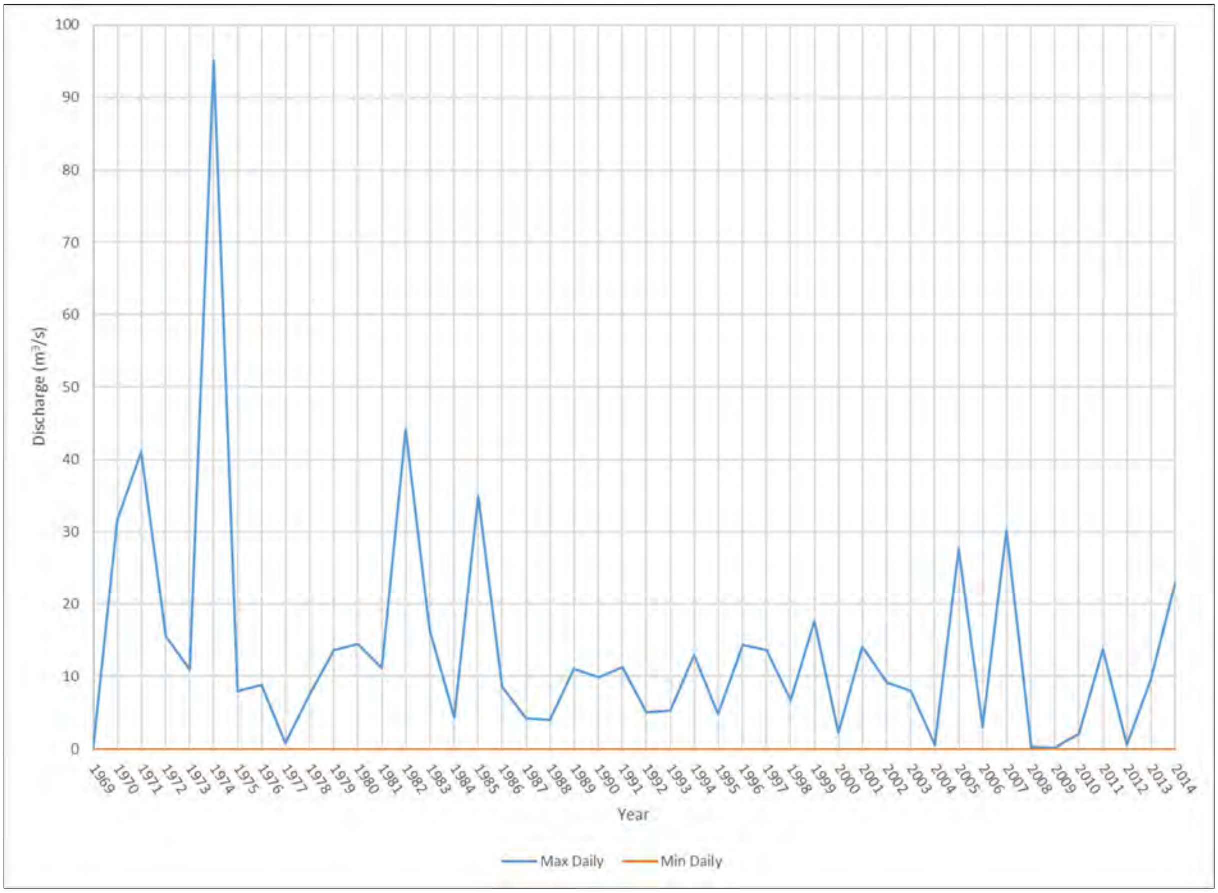
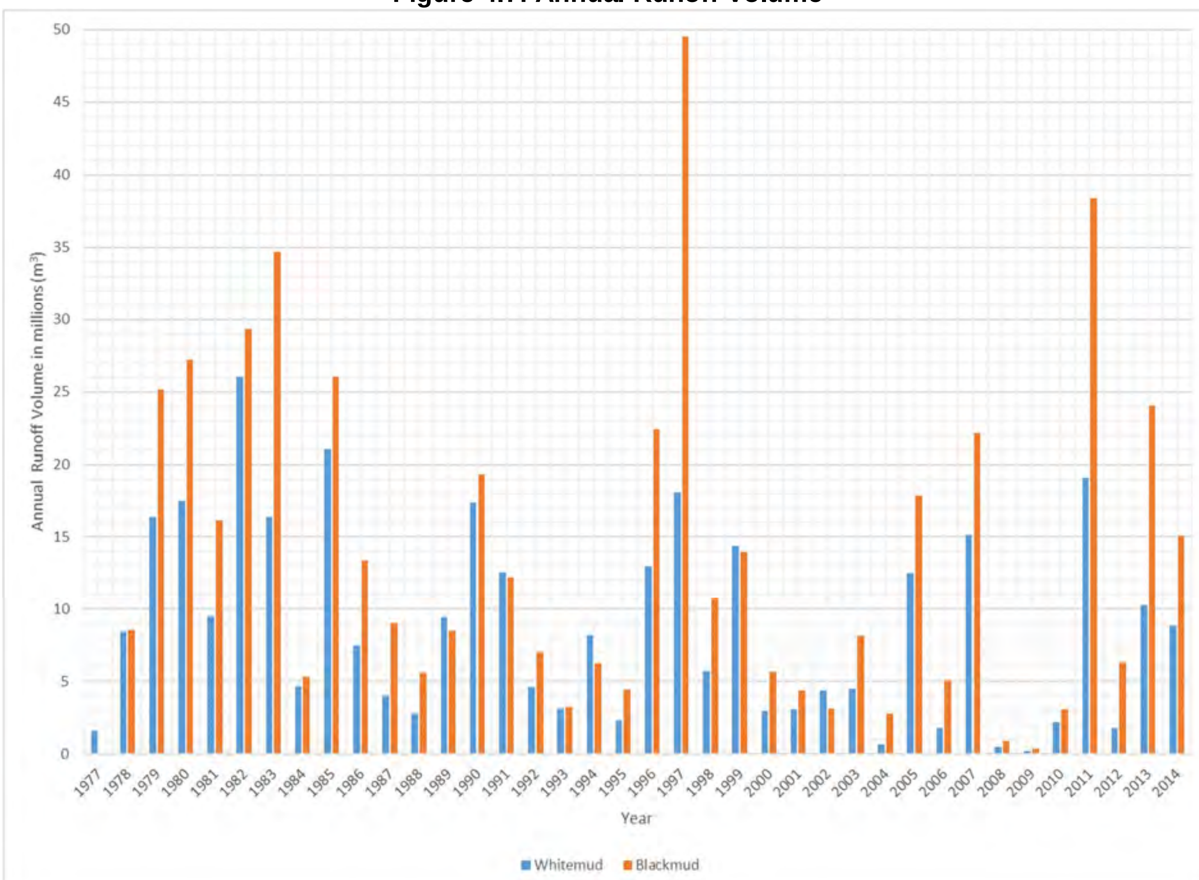


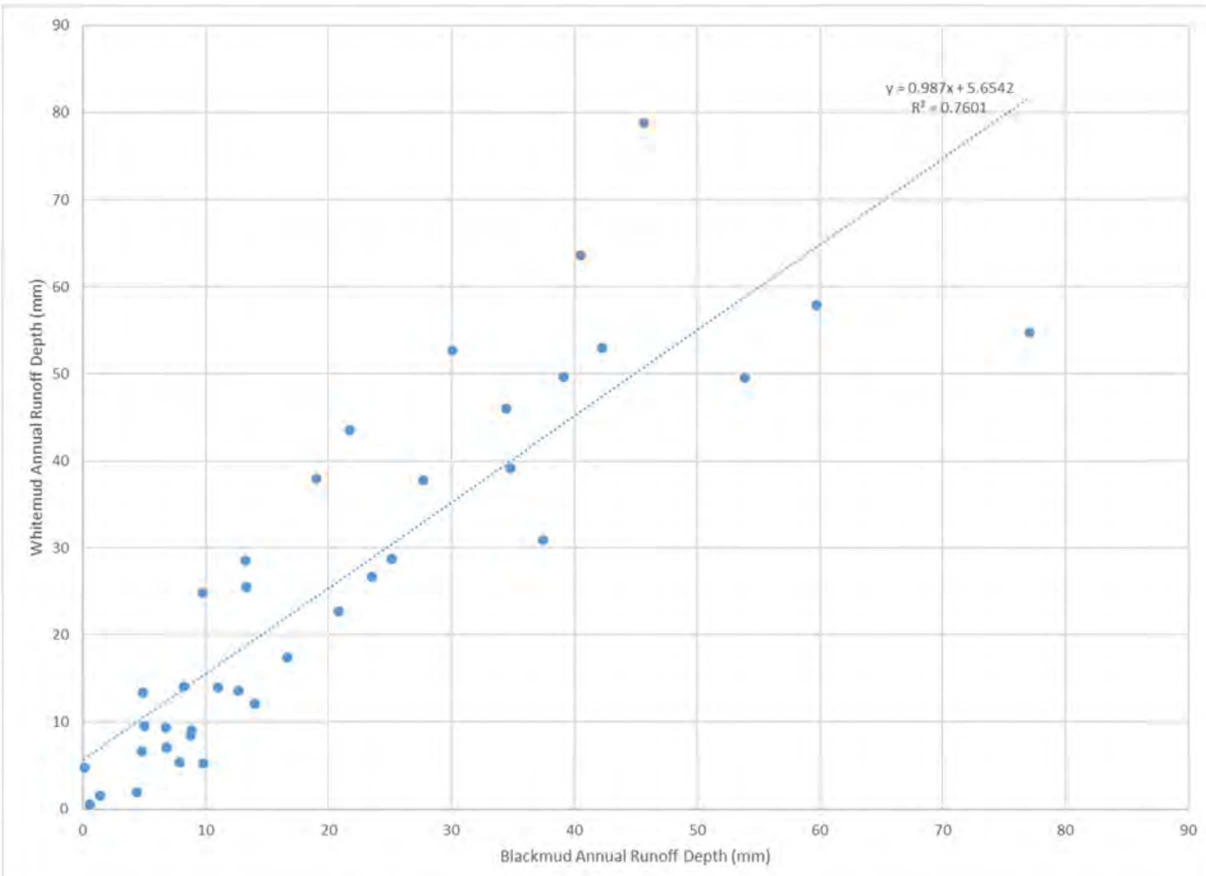
Figure 4.7 shows the annual runoff volume inBlackmud and Whitemud Creeks for the period of record. On an average annual basis the runoff volume (average flow) in Blackmud creek near Ellerslie is 50% higher than that of the Whitemud Creek near Ellerslie.

Figure 4.7: Annual Runoff Volume



A relationship was established between the annual runoff depth (volume/gross drainage area) for the Blackmud and Whitemud Creeks near Ellerslie. The analysis showed an R^2 value 0.76 which indicates a relatively good data correlation. **Figure 4.8** presents the annual run off depth correlation. This Figure shows that on a unit area basis the Blackmud and Whitemud basins generate relatively similar runoff depths although the temporal variation of this runoff, as reflected in peak flow, is affected by lake and upland storage routing which is somewhat more significant in the Blackmud basin.

Figure 4.8: Annual Runoff Depth Correlation



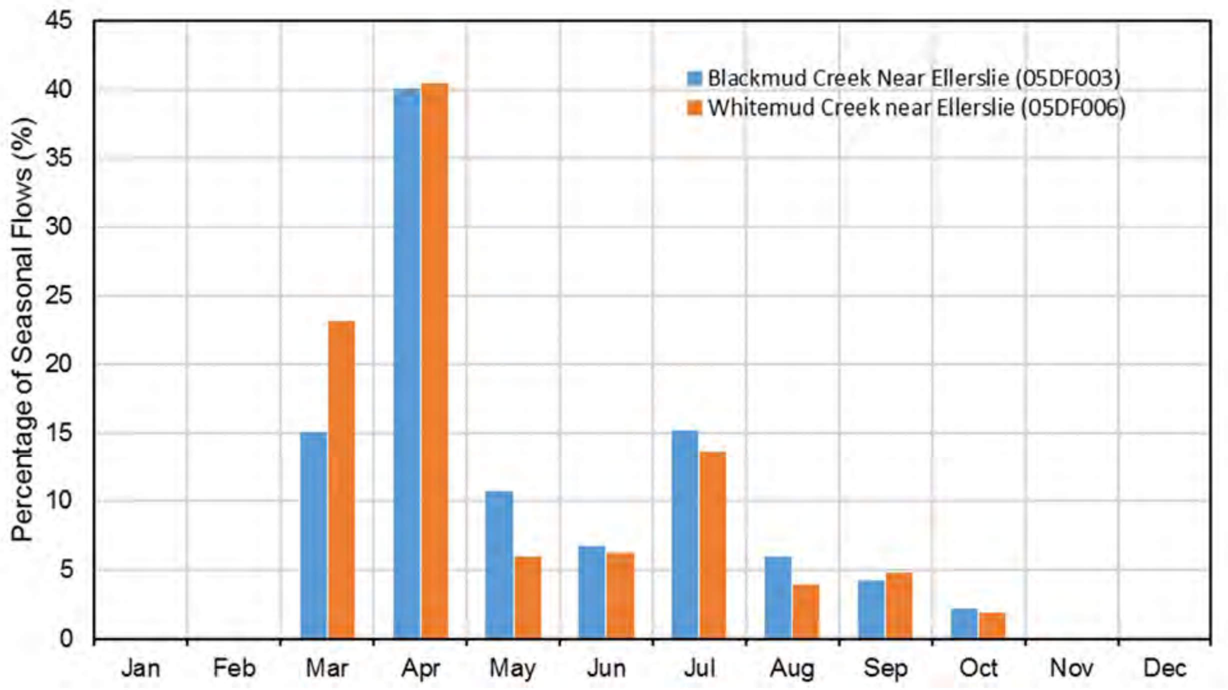
The general hydrologic regime of the study area, based on streamflow records from WSC 05DF003 and WSC 05DF006, is as follows:

- During the late summer, fall, and winter, discharge is very low or zero.
- Mid-summer and late fall rainstorms are common, recharging soil moisture and producing short-duration peak flows.

- The majority of peak flows occur in March to April (10 out of 24 years of record for WSC 05DF003 and 17 out of 26 years of record for WSC 05DF006) and are associated with snowmelt runoff events. The WSC also reports that some of the peak flows in March to April are backwater influenced, indicating the presence and influence of ice within creek channels during flood peaks.
- Other maximum instantaneous peak flows occur in June to July (10 out of 24 years of record for WSC 05DF003 and 7 out of 26 years of record for WSC 05DF006) and are associated to convectional rainfall or regional storm events.

Due to the low monthly streamflows recorded in October it is assumed that there is very low or zero flow within most watercourses within the study area from November to February when stream flows are not measured. However, during the open water season, monthly streamflows are highly variable. The highest monthly streamflows occur during March and April, with a secondary streamflow increase in July. **Figure 4.9** shows the study area monthly streamflow distribution.

Figure 4.9: Study area Monthly Streamflow Distribution based on Available Seasonal Records



The mean monthly streamflow distribution for the study area recorded by WSC 05DF003 and WSC 05DF006 was averaged. The mean monthly distribution is assumed to be representative of the natural distribution within the study area. **Table 4.2** presents the estimated natural monthly stream flow distribution, however, there can be natural variability within each month (as observed in **Figure 4.3**). As stated earlier, it is assumed that there is very low or zero streamflow within the watercourses in the study area from November to February.

Table 4.2
Estimated Monthly Streamflow Distribution within the Study area

Month	Monthly Flow Distribution (%)	Month	Monthly Flow Distribution (%)
January	0.0	July	14.4
February	0.0	August	4.9
March	19.1	September	4.5
April	40.2	October	2.0
May	8.3	November	0.0
June	6.5	December	0.0

Table 4.2 indicates that most of the natural streamflow in the study area is typically generated by snowmelt, which accounts for about 60% of the annual streamflow runoff. However, the monthly distribution is highly variable and can be significantly different from year to year.

5 Peak Flow Analysis

AE updated the flood frequency analysis using the most recent flow data (up to 2014) to estimate the peak streamflows at various locations in the study area. The following sections summarizes the analysis completed for both Blackmud and Whitemud Creeks.

5.1 FLOW FREQUENCY ANALYSIS

The available Water Survey of Canada (WSC) gauge data showed that there is one (1) gauge located on Blackmud Creek and three (3) gauges located on Whitemud Creek. **Figure 5.1** shows the gauge locations and the outlines of their catchment areas. **Table 5.1** presents key information about the gauges located within the study area.

Table 5.1
WSC Gauges

Gauge	Description	Gross Drainage Area (km^2)	Effective Drainage Area (km^2) *	Years of Available Data
05DF003	Blackmud Creek near Ellerslie	643	375	1935 + 1977 - 2016
05DF006	Whitemud Creek near Ellerslie	330.4	300	1969 - 2016
05DF007	West Whitemud Creek near Ireton	65.4	53	1976 - 2016
05DF009	Whitemud Creek at Edmonton	1107.8	800	2013 - 2016

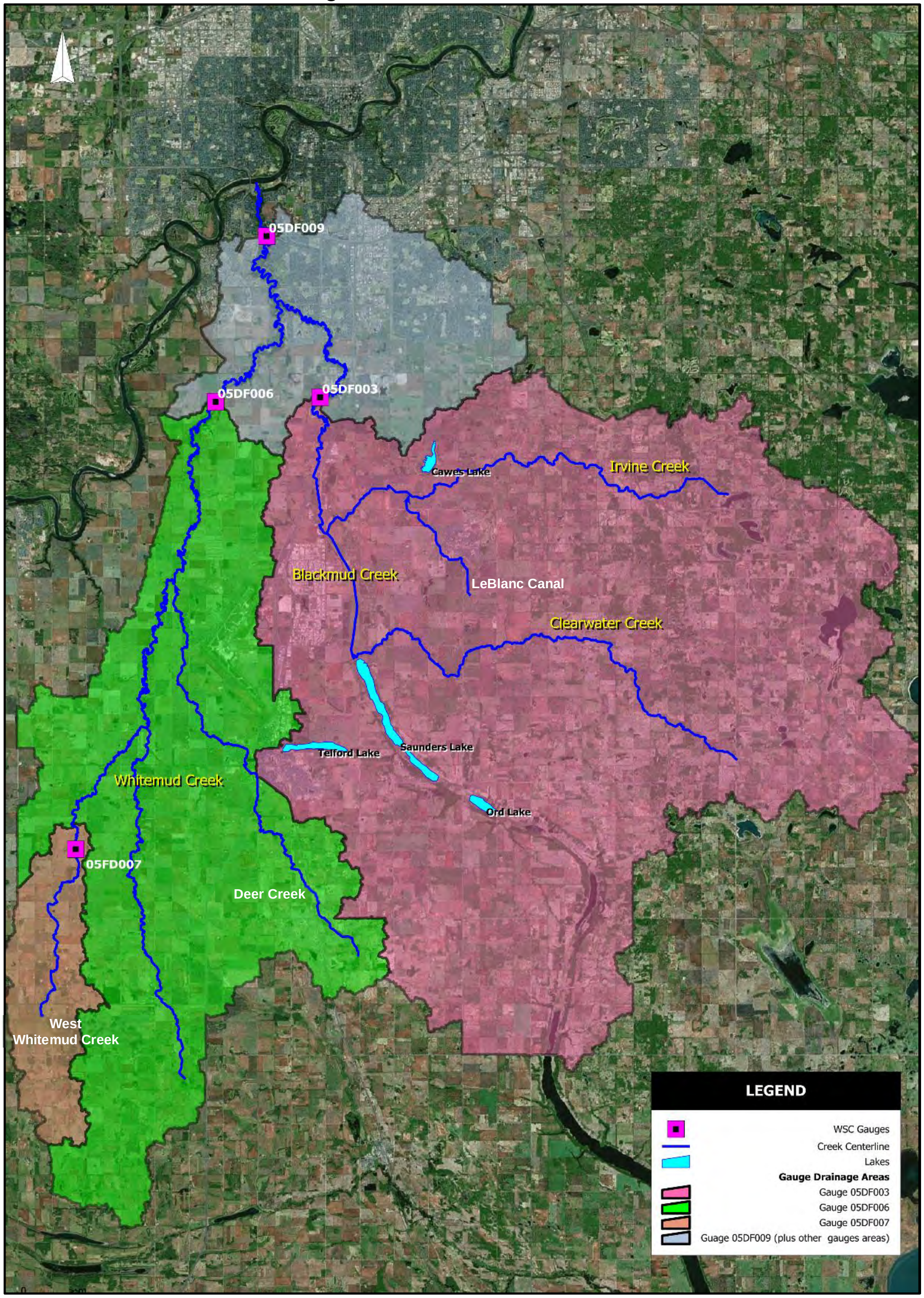
*To be modified if necessary

Table 5.2 presents below the available data for annual peak flows provided by Water Survey of Canada for the study area flow gauges.

Alberta Environment estimated the maximum daily discharge for the 1974 event to be 87.8 m^3/s for Blackmud Creek. The corresponding instantaneous peak was estimated to be 97.5 m^3/s. This value was included in the flood frequency analysis for the Blackmud Creek.

Flood frequency analysis was conducted using the available data for maximum instantaneous values up to 2014. Where maximum instantaneous values were not available, they were estimated based on a linear relationship between maximum daily values and maximum instantaneous values, as shown in **Figure 5.2** and **Figure 5.3**. The average ratio of instantaneous to daily maximum flow is 1.10 for Blackmud Creek and 1.18 for Whitemud Creek. Missing years (1969-1976 for Blackmud Creek and West Whitemud Creek) were estimated by correlating annual maximum daily peak flows for Blackmud and Whitemud Creeks. The 1974 flood peak was estimated previously by Alberta Environment.

Figure 5.1
WSC Gauge Locations and Catchment Areas



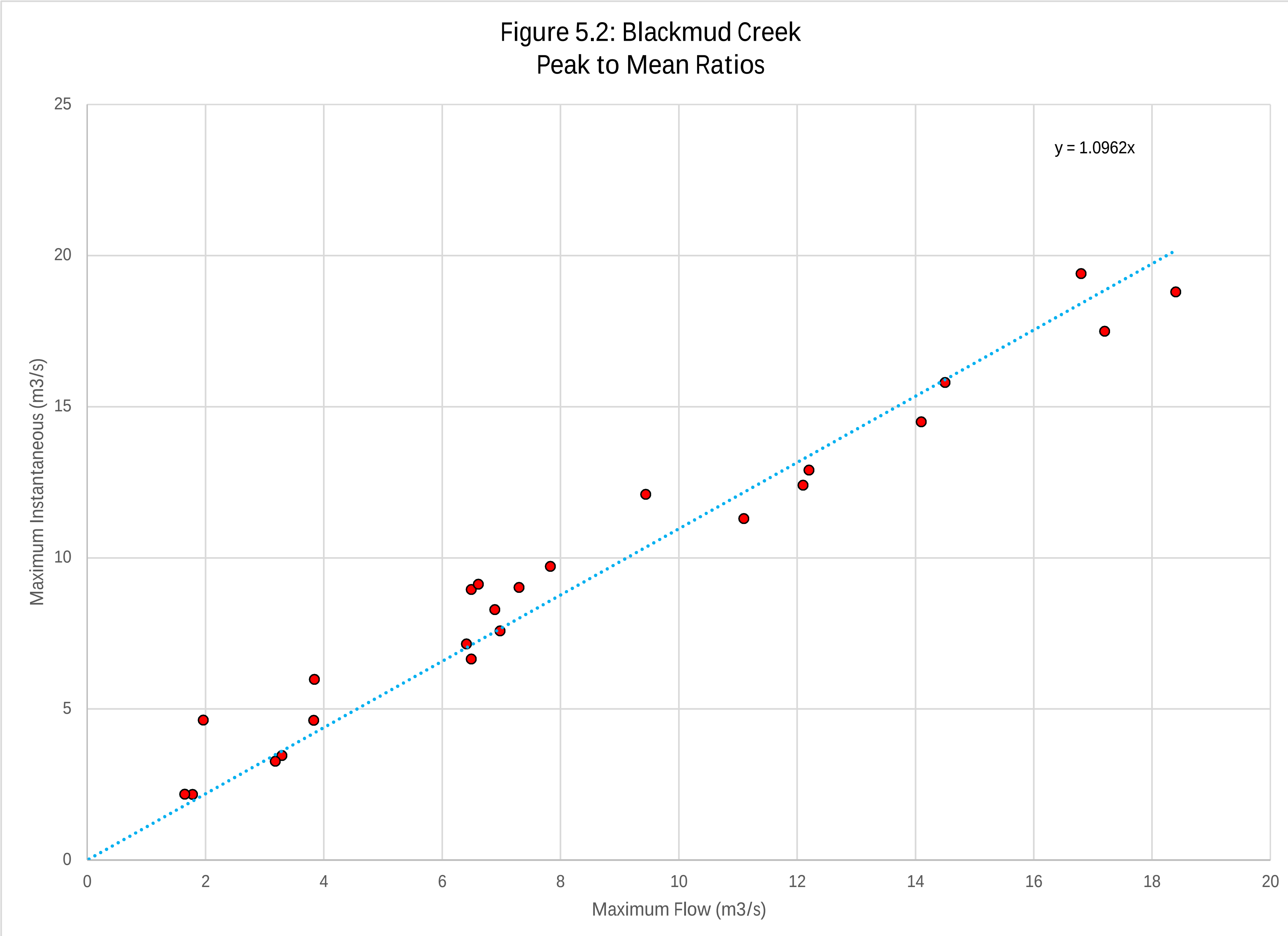


Figure 5.2: Blackmud Creek
Peak to Mean Ratios
y = 1.0962x
Maximum Instantaneous (m3/s)
Maximum Flow (m3/s)
0
5
10
15
20
25
0
2
4
6
8
10
12
14
16
18
20

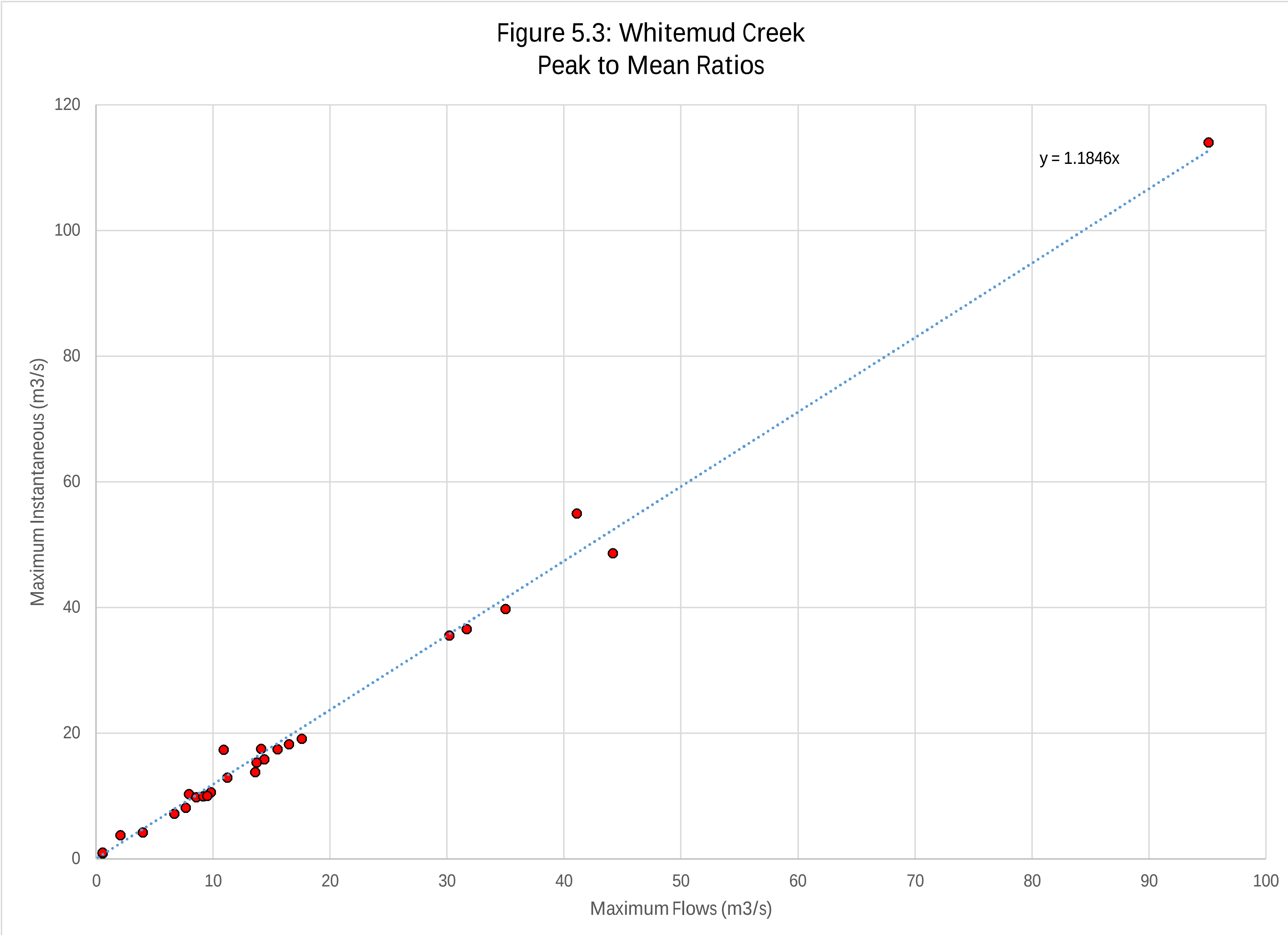


Figure 5.3: Whitemud Creek
Peak to Mean Ratios
y = 1.1846x
Maximum Instantaneous (m3/s)
Maximum Flows (m3/s)
0
20
40
60
80
100
120
0
10
20
30
40
50
60
70
80
90
100

Table 5-2
Maximum Instantaneous and Mean Discharges

Year	Blackmud Creek		Whitemud Creek		West Whitemud Creek		Whitemud Creek COE	
	Maximum Instantaneous Values (m^3/s)	Maximum Mean Values (m^3/s)	Maximum Instantaneous Values (m^3/s)	Maximum Mean Values (m^3/s)	Maximum Instantaneous Values (m^3/s)	Maximum Mean Values(m^3/s)	Maximum Instantaneous Values (m^3/s)	Maximum Mean Values (m^3/s)
1969	0.17	0.15	0.4	0.303	0.06	0.05	-	-
1970	17.48	15.95	36.5	31.7	6.63	5.28	-	-
1971	22.66	20.67	54.9	41.1	8.59	6.85	-	-
1972	8.55	7.80	17.4	15.5	3.24	2.58	-	-
1973	6.01	5.48	17.3	10.9	2.28	1.82	-	-
1974	97.5**	87.8**	114	95.1	19.88	15.85	-	-
1975	4.37	3.99	10.3	7.93	1.66	1.32	-	-
1976	4.84	4.42	10.4	8.78	1.84	1.46	-	-
1977	0.034	0.031	0.9	0.776	3.14	1.59	-	-
1978	2.17	1.78	8.07	7.65	3.77	3.23	-	-
1979	9.02	7.3	13.8	13.6	3.6	2.9	-	-
1980	7.58	6.98	15.8	14.4	3.3	2.35	-	-
1981	6.906	6.3	12.9	11.2	1.72	1	-	-
1982	14.5	14.1	48.6	44.2	6.21	5.52	-	-
1983	19.4	16.8	18.2	16.5	3.64	2.72	-	-
1984	4.056	3.7	5.1	4.27	0.871	0.818	-	-
1985	17.5	17.2	39.7	35	5.75	5.2	-	-
1986	8.29	6.89	9.75	8.56	1.13	1.1	-	-
1987	5.98	3.84	4.9	4.14	3.48	1.76	-	-
1988	12.1	9.44	4.15	3.98	0.49	0.337	-	-
1989	4.62	3.83	13.0	11	6.16	3.14	-	-
1990	12.497	11.4	10.6	9.82	4.05	3.81	-	-
1991	8.95	6.49	13.4	11.3	4.02	2.82	-	-
1992	3.881	3.54	5.9	5	0.78	0.62	-	-
1993	2.751	2.51	6.2	5.21	1.59	1.27	-	-
1994	4.472	4.08	15.3	12.9	1.63	1.3	-	-
1995	3.201	2.92	5.6	4.75	0.71	0.565	-	-
1996	8.846	8.07	16.9	14.3	3.45	2.75	-	-
1997	15.8	14.5	16.1	13.6	5.02	4	-	-
1998	9.72	7.83	7.14	6.68	4.18	2.95	-	-
1999	6.65	6.49	19.1	17.6	4.01	2.63	-	-
2000	3.46	3.29	2.6	2.19	0.28	0.227	-	-
2001	9.13	6.61	17.5	14.1	1.99	1.41	-	-
2002	3.047	2.78	9.91	9.16	1.12	0.972	-	-
2003	10.140	9.25	9.5	8	3.18	2.54	-	-
2004	1.206	1.1	0.789	0.564	0.013	0.01	-	-
2005	10.513	9.59	32.8	27.7	3.67	2.93	-	-
2006	3.27	3.18	3.5	2.98	1.05	0.955	-	-
2007	12.9	12.2	35.5	30.2	7.1	6.11	-	-
2008	2.18	1.65	0.3	0.293	0.061	0.049	-	-
2009	0.409	0.373	0.2	0.168	0.035	0.028	-	-
2010	4.63	1.96	3.73	2.07	2.02	1.44	-	-
2011	18.8	18.4	15.3	13.7	5.4	4.63	-	-
2012	7.15	6.41	0.982	0.549	0.208	0.075	-	-
2013	12.4	12.1	10	9.52	1.01	0.796	21.1	31.8
2014	11.3	11.1	27.4	23.1	5.46	4.45	41.1	48.3

Estimated Values Highlighted in red

**Estimated by AEP

Calculations were based on the analysis and comparison of Pearson Type III, Log Pearson Type III, Log Normal and Gumbel frequency distribution systems. **Figure 5.4a-c** shows the adopted flood frequency curves. **Table 5.3** provides a summary of the flood frequency estimates for the three gauge sites along with the gross and effective drainage area and the unit discharge rates per hectare calculated from the peak flow estimate and the gross drainage area.

Based on the above data, the estimated 1:100 year return period discharge is 71.5 m^3/s for Blackmud Creek and 95 m^3/s for Whitemud Creek at the WSC gauge sites. The unit discharge rates range from 1.1 to 2.9 L/s/ha for the 1:100 year return period when calculated using the gross drainage area. Note that this analysis includes the 2013 and 2014 peak flows from the WSC gauge stations and therefore yields slightly different values than the previous analyses.

Figure 5.4a: Blackmud Creek near Ellerslie Flow Frequency Curve

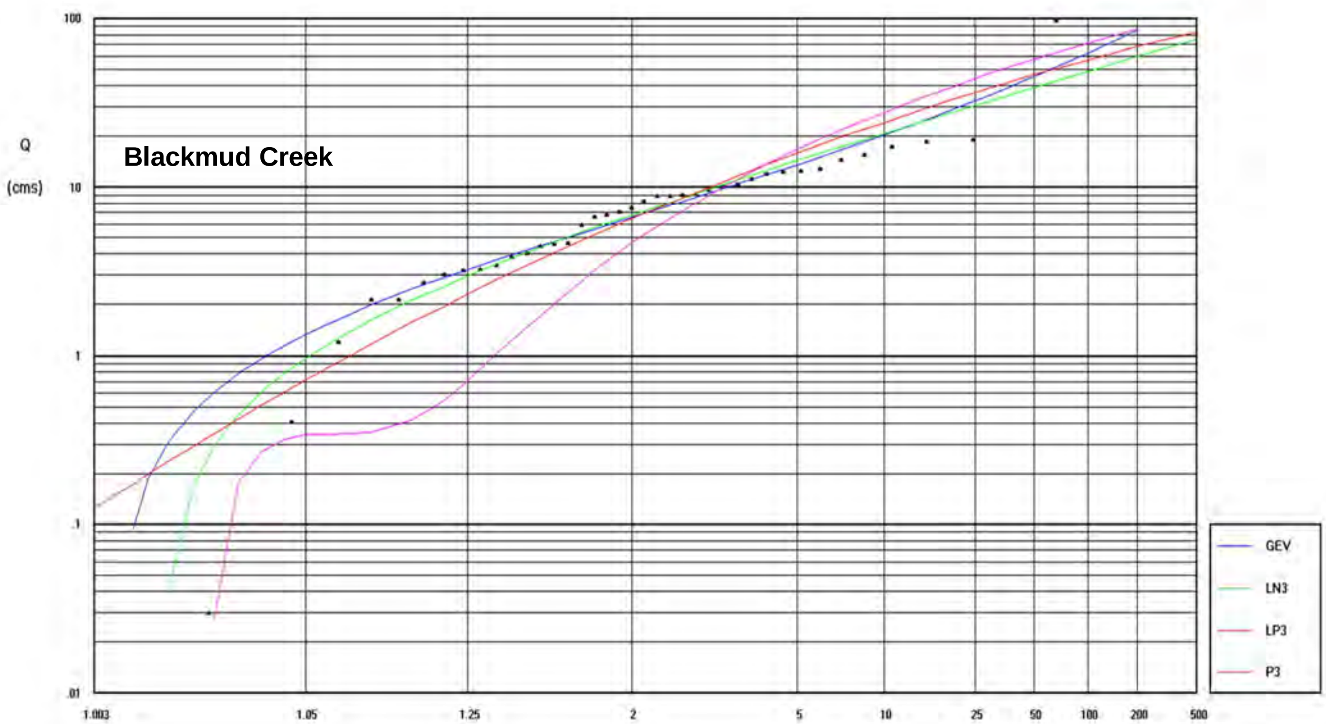


Figure 5.4b: Whitemud Creek near Ellerslie Flow Frequency Curve

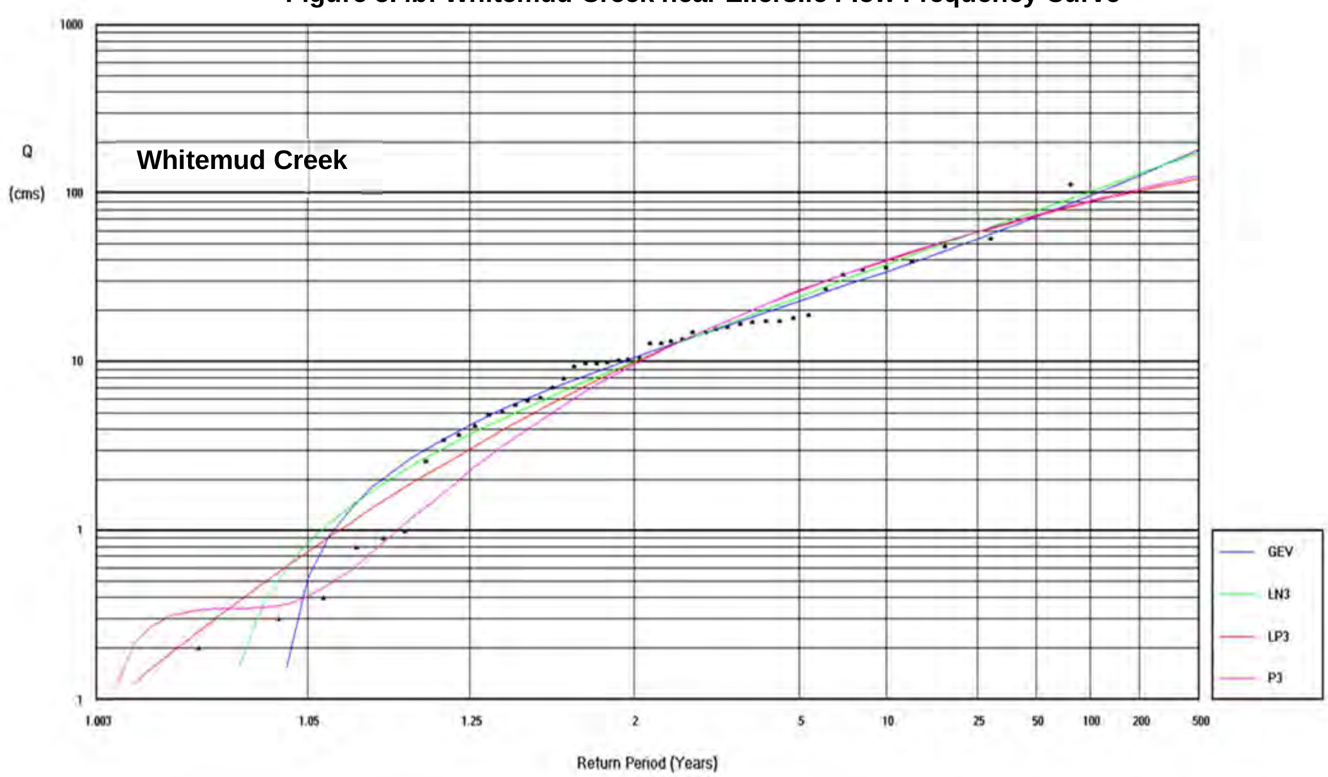


Figure 5.4c: West Whitemud Creek near Ireton Flow Frequency Curve

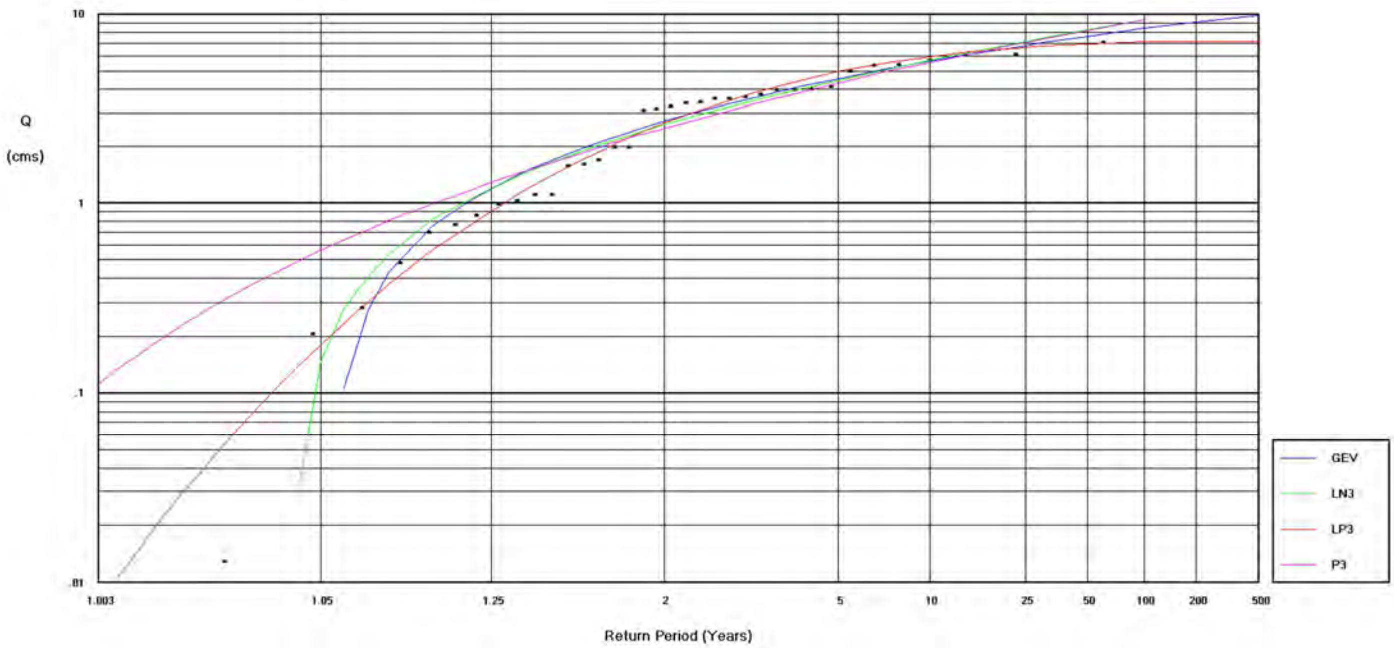


Table 5.3
Flood Frequency Estimates at WSC Gauge Sites

	Blackmud Creek WSC 05DF003	Whitemud Creek WSC 05DF006	West Whitemud Creek WSC 05DF007
Gross Drainage Area (km^2)	643	330.4	65.4
Effective Drainage Area (km^2)	375	300	53
Return Period (years)	**Maximum Instantaneous Flood Estimates (m^3 /s)**		
2	4.6	10.1	2.6
5	16.6	24.9	4.6
10	27.6	37.9	5.7
25	43.9	57.7	6.9
50	57.3	75.1	7.8
100	71.5	95	8.5
Return Period (years)	**Unit Discharge Rates (L/s/ha) Based on Gross Drainage Area**		
2	0.1	0.3	0.4
5	0.3	0.8	0.7
10	0.4	1.1	0.9
25	0.7	1.7	1.1
50	0.9	2.3	1.2
100	1.1	2.9	1.3

5.2 REGIONAL ANALYSIS

AE conducted a regional analysis using Water Survey of Canada (WSC) gauge data for nearby streams such as Sturgeon River, Battle River, Beaverhill Creek, Amisk Creek, Vermillion River, Redwater River, Pipestone Creek, Pointe-Aux-Pins Creek, Atim Creek, Maskwa Creek, and Muskeg Creek based on flow data up to 1997. The advantage of the regional analysis method is that it is based on flow data for a number of streams within the area of interest. Therefore, it is less sensitive to limitations of data and statistical analysis for any individual stream. Although the data on which it is based is somewhat dated the form of the regional relationship is still valid.

Figure 5.5 shows the regional results. The analysis showed an R^2 value of 0.73 which indicates a relatively good data correlation between the effective drainage area and the flood discharge. The scatter around the best-fit regional line may be due to differences in record length and differences in topography between the individual basins.

The correlation equation indicates that the peak flow can be estimated as a function of effective drainage area raised to the power of 0.67. Using this regional exponent and the results of the updated flood frequency analysis, peak flows can be estimated for the various catchments in the Whitemud/Blackmud Basin as indicated in **Table 5.4**. Estimates are based on The Irvine Creek and Cawes Lake Watershed Study (2014) estimate of effective drainage area for each of the sub-basins.

Figure 5.5: Blackmud and Whitemud Creek Regional Analysis

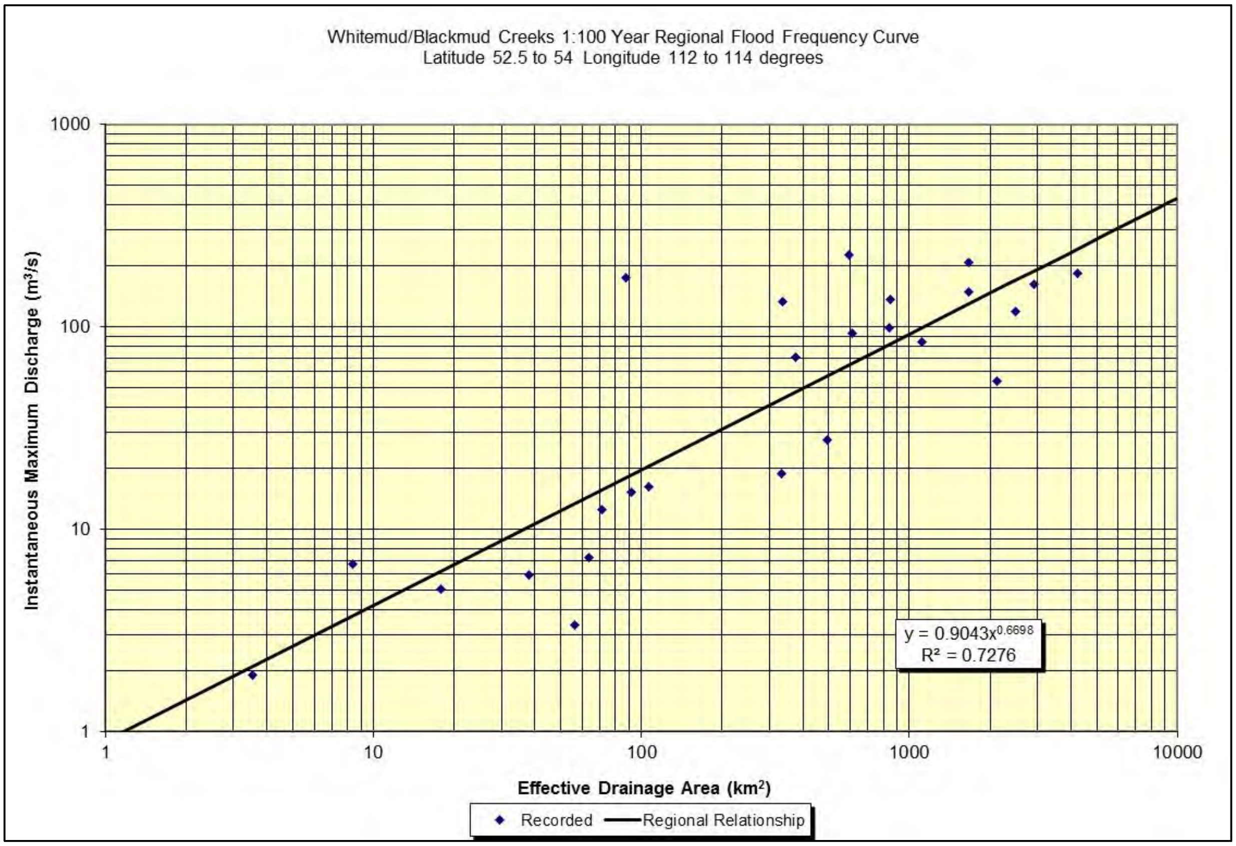


Table 5.4:
Flood Frequency Estimates for Key Study Area Locations

Return Period (Years)	Clearwater Creek at the mouth	Irvine Creek at the Mouth	Blackmud Creek at the Mouth	Whitemud Creek above Blackmud Creek
Gross Drainage Area (km^2)	208	158	683	385.9
Effective Drainage Area (km^2)	200.92	153.28	415	326.67
Return Period (years)	**Maximum Instantaneous Flood Estimates (m^3/s)**			
2	5.7	4.8	5.0	10.7
5	13.7	11.4	17.8	26.3
10	20.3	17.0	29.6	40.1
25	30.0	25.0	47.0	61.1
50	38.0	31.7	61.3	79.5
100	46.8	39.1	76.5	100.6

Note that these flood estimates are preliminary and are intended for basin planning and for comparison with modelling results, not for floodplain delineation. They will be reviewed when the modelling is completed.

5.3 CHANNEL CAPACITY

As noted in Section 2.2, AE completed channel survey for the Blackmud and Whitemud Creeks in September 2016. Based on the average channel cross-sections and a Manning's n of 0.03, the estimated channel capacity at bankfull stage for Whitemud Creek, upstream of the City of Edmonton was estimated to be 4.4 m^3/s upstream, and 16.1 m^3/s within the City limits. The Blackmud Creek channel capacity was estimated to be 12 m^3/s at bankfull stage and 26 m^3/s at floodplain level.

The channel capacity in an alluvial stream typically corresponds to the median (1:2 year) annual peak discharge. For the study area, the Blackmud Creek channel capacity corresponds to the 1:5 year storm. The Whitemud Creek channel capacity corresponds to the 1:2 year (upstream of the City limits) and 1:5 year storm (downstream of the City limits). These results also show that the 1:100 year peak flow is approximately 3-5 times larger than the channel capacity in the study area. This suggests that the study area channels generally do not have capacity for the pre-development peak flows.

6 Conclusions

Based on the hydrologic assessment of the Blackmud Creek and Whitemud Creek, the following conclusions are made:

- Development will place additional stresses on Blackmud and Whitemud Creeks, which have already been impacted by both agricultural and urban development. Potential impacts include increased peak flows, runoff volumes and increased channel erosion.

- Portions of the Blackmud and Whitemud basins are flat and poorly drained. There are numerous wetlands especially in the upper basin. The upper basin creek channels are poorly defined and have limited capacities.

- The Blackmud Creek channel is relatively flat in its upper reaches (longitudinal slope = 0.05 m/km upstream of Highway 2) and steeper in the lower reaches downstream of Highway 2. The flatter headwater slope is the result of the creek's glacial origin as an outflow channel from glacial Lake Edmonton, which originally flowed to the southeast.

- Whitemud Creek is relatively steep in the upstream and downstream reaches and flat in the middle. This profile suggests that the creek is still downcutting to its base level at the North Saskatchewan River, which could partly explain the channel erosion that is occurring.

- On an annual basis about 90-95% of the precipitation is lost to evaporation and evapotranspiration in the basin. Five to ten percent of the annual precipitation runs off. Runoff percentages are considerably higher in urban areas (typically 40-50% on an annual basis) which means that runoff volumes will increase by a factor of five (5) even if peak flows are controlled, unless source controls (low impact development practices) are adopted.

- Groundwater recharge generally begins in March and peaks in early May. Therefore, rainfall events in this period tend to produce relatively more surface runoff than the summer period due to the increased soil saturation in the active layer.

- Peak flows within the study area watercourses generally occur during the spring runoff period due to snowmelt or rain-on-snow events.

- Early summer peak events do occur due to convectional rainfall or regional storm events, but are typically smaller than the early-season snowmelt events.

- Different methods (regional analysis, channel capacity and flood frequency analysis) have been used to estimate peak flows for different return periods within the creeks. The flood frequency analysis provides the most reliable estimates of peak discharges as it is based on actual creek discharge records from over 45 years. It does not account for the possible impacts of climate change that are likely to be relatively small compared to other sources of uncertainty in the flood discharge estimates.

- As noted in the NHC report, 1974 was the year of greatest flow recorded in the Edmonton region. For this reason, the estimated 1974 peak flow was included in the flood frequency analysis where actual measurements were not available.

- Including the more recent 2013 and 2014 peak flows from the WSC gauge stations results in the following estimates: 1:100 year return period discharge of 71.5 m^3/s and 95 m^3/s for Blackmud and Whitemud Creeks.

- The 1:100 year pre-development (existing conditions) runoff rate is in the range of 1.8 to 3 L/s/ha in the study area. This is based on the effective drainage area. Pre-development runoff rates are somewhat lower if they are based on gross drainage area which includes some areas that drain at a reduced rate.

- The various municipalities and the Edmonton International Airport have different forms of SWM designed to provide varying levels of control and service level. The unit area runoff rates used for design of these facilities are somewhat higher than the pre-development runoff rates estimated herein and in previous studies; that is to say they are not conservative with respect to flooding and erosion potential.

- Creek channels in the project area are generally not expected to have capacity for the pre-development peak flows.

Closure

This report was prepared for the Blackmud/Whitemud Creek Surface Water Management Group to summarize the hydrology assessment results for the Blackmud and Whitemud Creeks.

The services provided by Associated Engineering Alberta Ltd. in the preparation of this report were conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No other warranty expressed or implied is made.

Respectfully submitted,
Associated Engineering Alberta Ltd.

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APEGA Permit to Practice P 3979

References

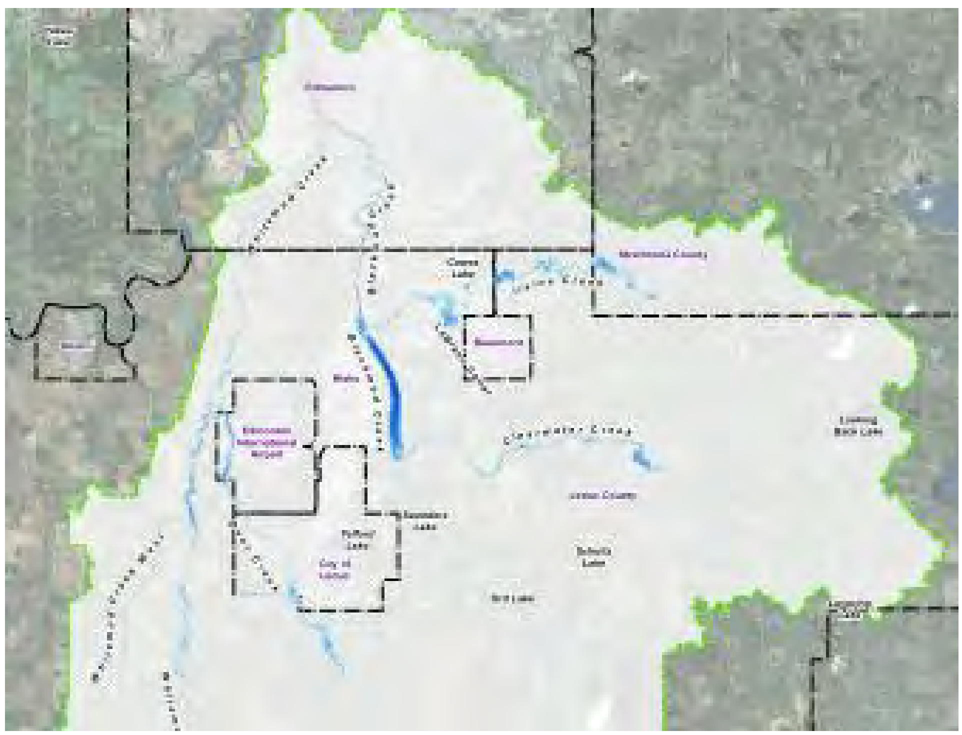
1. Stantec, 2014. Irvine Creek and Cawes Lake Watershed Study.

2. Northwest Hydraulic Consultants, 2014. Nisku Flood Hazard Study – Blackmud Creek.

TECHNICAL MEMORANDUM NO. 4

Blackmud/Whitemud Creek
Surface Water Management Group

Blackmud/Whitemud Creek
Surface Water Management Study
Hydrologic and Hydraulic Modelling



January 2017

Executive Summary

The Blackmud/Whitemud Surface Water Management Group retained Associated Engineering (AE) to complete a Surface Water Management Study. This study involves hydrologic, hydraulic, hydrogeologic and environmental analyses of the Blackmud and Whitemud Creek basins.

This technical memo summarizes the development of the Blackmud/Whitemud basin model and the evaluation of existing hydraulic conditions and constraints. The purpose of the basin model was to estimate flows, water levels, and velocities at various locations throughout the basin for the existing conditions of development. The results of the model developed will form a basis to be used in simulating the potential impacts of further development in the basin. These will also be used to develop a surface water management strategy to minimize and mitigate those impacts.

The model development involved the following steps:

1. Cross sections of the creeks were obtained from surveyed data, 1m LiDAR resolution, Northwest Hydraulic Consultant's (NHC's) HEC-RAS model of Blackmud Creek, and Stantec's MIKE 11 model of Irvine Creek (TM 3). These were used to build the model.
2. A 1D model was developed to simulate water levels and flows in all the creeks.
3. A 2D model was developed for the lower reaches of the Whitemud and Blackmud Creeks. This was to simulate local hydraulic conditions in more detail and to give a qualitative assessment of erosion potential.
4. Each sub-catchment was divided into one of three categories, namely: developed-controlled, developed-uncontrolled, and undeveloped areas.
5. Boundary conditions (model inflows) were based on the hydrologic analysis provided in TM 3 which accounted for peak flows generated by snowmelt and rainfall events used for the statistical analysis.
6. The model was simulated in a steady state (constant) condition for the design events.

The accuracy of the models developed in this task is affected limited by several assumptions and limitations, principally the following:

- Design flows were estimated from a statistical analysis of limited hydrometric data at three locations (and more recently a fourth location) in the basin having approximately 45 years of data, which was significantly skewed by one single runoff event (1974) and had to be extrapolated to a 1:100 year return period. Furthermore, the historic discharge data have already been impacted by development in the basin and this development impact has increased over the time frame of the monitor data. The design flows presented herein are AE's best estimates based on engineering judgement and the available data.

- Channel cross-sections were developed from LiDAR data, previous studies, and limited channel surveys and may not accurately represent the actual cross-section or the capacity of the smaller channels at low to intermediate flows. This effect of this approximation diminishes at higher flows where a larger portion of the total flow is carried by the floodplain.

- The models are essentially un-calibrated, for lack of data required to do so. Some calibration was previously completed in the Flood Hazard Study which provided guidance for the model parameters adopted herein.

Notwithstanding these limitations, the models are deemed to be adequate for planning purposes and for development of an overall water management strategy for the basin. They are no substitute for more detailed site-specific analyses that will be required during implementation of the strategy. They do provide an assessment of baseline hydraulic conditions against which the potential impacts of future development can be measured.

The models are steady-state based on AE's best estimate of a peak design flow rate for current conditions. The software is capable of fully-dynamic simulation which could be used to simulate flows and water levels using precipitation and weather data from the Edmonton International Airport, to extend the period of recorded flow data, and to better define the interactions between the runoff from urban and rural areas. Ultimately this option is limited by the availability of the required weather data at only one location within a basin of approximately 1,000 km^2 and by the uncertainties involved in rainfall-runoff modelling. In particular, the runoff from snowmelt events in a cold climate, with frozen ground conditions during snowmelt such as occur in Edmonton, is poorly understood and not well simulated with currently available software although some progress has been made in recent years and a practical snowmelt model may soon be available. These limitations provide a severe impediment to improving the estimates that are possible with a steady-state model.

Generally, the project area creeks have capacity for peak flows that will occur in a 1:2 to 1:5 year return period flood. Localized flooding occurs in the 1:100 year event but is mostly confined to the natural creek floodplains except in portions of Irvine Creek, Leblanc Canal, Deer Creek, and the glacial spillway valley of Blackmud Creek in the vicinity of Leduc where extensive overbank flooding will occur. Previous attempts to improve the drainage in these areas has provided capacity for at best the 1:5 year flood.

The majority of the creeks within the basin have complex geometry, are small, lack well defined channels, and have limited channel capacity to convey runoff flows from the existing development. These conditions will constrain future development in the following ways:

- The extent of flooding will constrain development. In some locations along the Blackmud Creek, Irvine Creek, Deer Creek, and Leblanc Canal the flood-risk areas are extensive. The Municipal Government Act empowers municipalities to preserve floodplain areas as Environmental Reserve (land subject to flooding) at the time of development but these powers are not always applied consistently or uniformly. Where extensive overland flooding occurs it is not always practical to sterilize large areas from development, and these locations should be considered as possible sites for stormwater management ponds or wetlands. A policy for protecting floodplains that recognizes the flood risk and the environment values they create should be developed.

- Along with the extensive flooding, some of the creek channels, in the same locations as above, are too shallow to permit drainage of adjacent development using a conventional underground pipe system. Typically, a depth of 4 m from adjacent land areas to channel bottom is required and in many places this does not exist. Alternatives need to be considered such as:

    - a surface drainage system
    - channel deepening and widening to provide the required capacity (a drainage parkway)
    - a trunk storm sewer system to carry outflows from stormwater management facilities to a safe and reliable discharge point
    - Low-Impact Development standards to reduce the volume and peak runoff rates to pre-development levels

- Erosion issues in Whitemud and Blackmud Creek are understood in only a general way and could be aggravated by increasing runoff volumes and flood peak discharges resulting from further development in the basin. There are no reliable models of the erosion process to give quantitative estimates of the erosion rates and the impacts of the changing flow regime that will occur with development, but a qualitative estimate is possible from the model-simulated velocities and shear stresses and morphological principles that relate these hydraulic parameters to the rate of sediment transport.

Existing development in the basin has undoubtedly increased the runoff volume and may have increased peak flows, flood risk, and erosion rates. Some of the older areas were developed before these impacts and the importance of managing stormwater were understood and these older areas discharge directly into the receiving streams without any control. More recent developments have been completed with differing discharge rates in different municipalities and have changed over time for lack of an overall basin water management plan. We have not attempted to quantify these historic impacts but the possibility of further impacts due to anticipated development should be recognized going forward.

Channel velocities in Blackmud and Whitemud Creeks generally increase from upstream to downstream, reflecting the increase in discharge and longitudinal slope, and generally correlate with the bank erosion processes that have been observed. These erosion processes are the results of natural and human influences including previous historic development in the basin since the land was first cleared for agriculture and urban development.

The City of Edmonton has developed and has begun to implement a strategy for erosion control in Whitemud and Blackmud Creek but much work remains to be done. There is significant potential for the existing conditions to worsen if runoff from future development is not adequately managed. Streambank erosion is very sensitive to increases in velocity and flow and could potentially be impacted by development upstream. These potential impacts will be further evaluated in the next phase of this project.

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1 Introduction

The Blackmud/Whitemud Surface Water Management Group (Group) retained Associated Engineering (AE) to complete a Surface Water Management Study. This study involves hydrologic, hydraulic, hydrogeologic and environmental analyses of the Blackmud and Whitemud Creek basins.

A series of Technical Memoranda (TM) was planned to be issued at key stages of the study to document the interim findings. These memoranda were also meant to form the basis for discussions and deliberations with the Group. AE completed development of the Blackmud/Whitemud basin model.

The purpose of the basin model was to estimate flows, water levels, and velocities at various locations throughout the basin for the existing conditions of development. The results of the model developed will form a basis to be used in simulating the potential impacts of further development in the basin. These will also be used to develop a surface water management strategy to minimize and mitigate those impacts.

This technical memo summarizes the development of the Blackmud/Whitemud basin model and the evaluation of existing hydraulic conditions and constraints.

Figure 1-1 provides an outline of the Blackmud/Whitemud basin, the sub-catchments and the major creeks within it, which were all included in the model. The basin encompasses five municipalities, the City of Edmonton, the City of Leduc, Leduc County, the Town of Beaumont and Strathcona County.

Based on the project scope and objectives, a lumped[1] model was adopted with an intermediate level of detail to simulate the key hydraulic processes in sections within the basin. The model included:

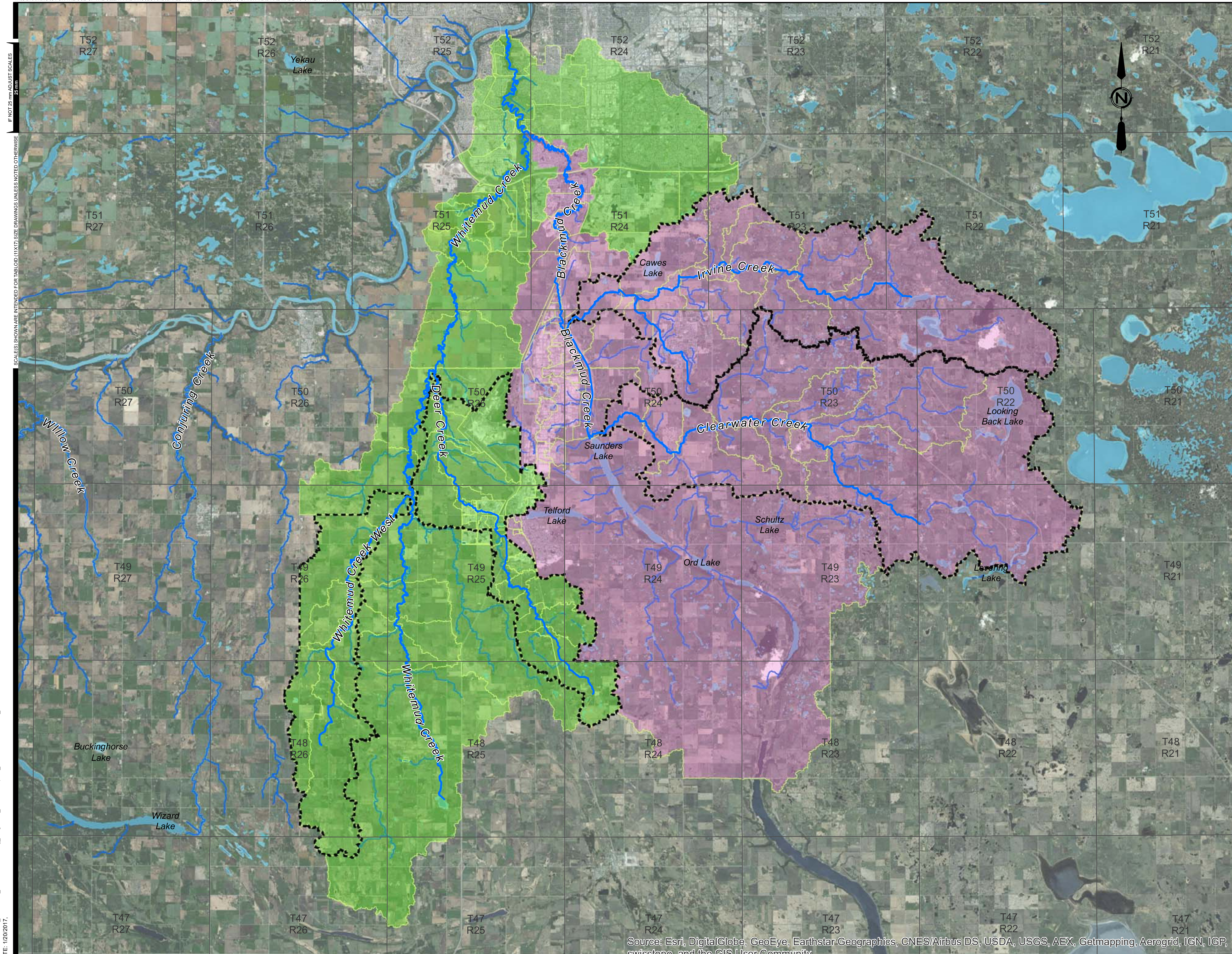
- West Whitemud Creek to Whitemud Creek.
- Whitemud Creek to the North Saskatchewan River.
- Deer Creek to Whitemud Creek.
- Blackmud Creek from the Sauders Lake outlet to Whitemud Creek.
- Clearwater Creek to Blackmud Creek.
- LeBlanc Canal from the Town of Beaumont to Irvine Creek.
- Irvine Creek to Blackmud Creek.
- The developed and undeveloped areas or sub-catchments within the basin that drain into the modelled creeks

Figure 1-2 provides a schematic plan of the basin model and its principal components.

Note that for simplicity not all sub-catchments are shown in **Figure 1-2**.

[1] Lumped model - Parameters not Spatially dependent.

THIS DRAWING IS FOR THE USE OF THE CLIENT AND PROJECT INDICATED - NO REPRESENTATIONS OF ANY KIND ARE MADE TO OTHER PARTIES



Associated Engineering

Legend:
- Whitemud Creek Watershed
- Blackmud Creek Watershed
- Catchment
- Subcatchment
- Creek Centreline

FIGURE No. 1-1

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

CATCHMENT BOUNDARIES

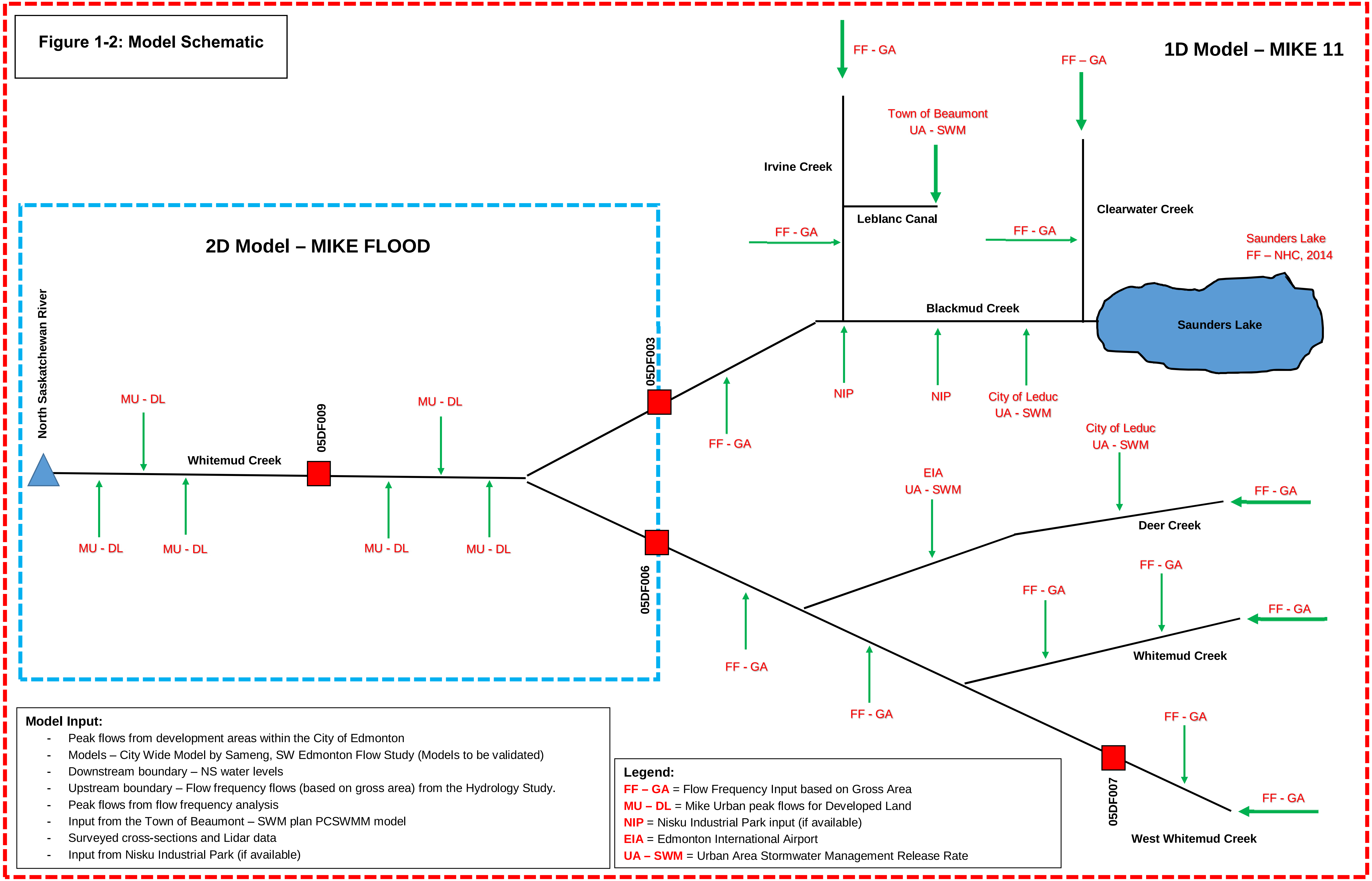
AE PROJECT No.	2016-3785
SCALE	1:200,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

IF NOT 25 mm ADJUST SCALES 25 mm

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

P:\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\xxx_CatchmentSubcatchmentBoundaries.mxd
DATE: 1/20/2017,

Figure 1-2: Model Schematic



Model Input:

- Peak flows from development areas within the City of Edmonton
- Models – City Wide Model by Sameng, SW Edmonton Flow Study (Models to be validated)
- Downstream boundary – NS water levels
- Upstream boundary – Flow frequency flows (based on gross area) from the Hydrology Study.
- Peak flows from flow frequency analysis
- Input from the Town of Beaumont – SWM plan PCSWMM model
- Surveyed cross-sections and Lidar data
- Input from Nisku Industrial Park (if available)

Legend:

FF – GA = Flow Frequency Input based on Gross Area
MU – DL = Mike Urban peak flows for Developed Land
NIP = Nisku Industrial Park input (if available)
EIA = Edmonton International Airport
UA – SWM = Urban Area Stormwater Management Release Rate

2 Model Development

2.1 METHODOLOGY FOR MODEL DEVELOPMENT

The following summarizes the methodology used in model development, setting of the boundary conditions, and the assumptions made:

1. Cross sections of the creeks were obtained from surveyed data, 1m LiDAR resolution, Northwest Hydraulic Consultant's (NHC's) HEC-RAS model of Blackmud Creek, and Stantec's MIKE 11 model of Irvine Creek (TM 3). These were used to build the model.
2. A 1D model was developed to simulate water levels and flows in all the creeks.
3. A 2D model was developed for the lower reaches of the Whitemud and Blackmud Creeks as shown in **Figure 1-2**. This was to simulate local hydraulic conditions in more detail and to give a qualitative assessment of erosion potential.
4. Each sub-catchment was divided into one of three categories, namely: developed-controlled, developed-uncontrolled, and undeveloped areas. Sub-catchments are discussed in detail in **Section 2.3.3**.
5. Boundary conditions (model inflows) were based on the hydrologic analysis provided in TM 3 which accounted for peak flows generated by snowmelt and rainfall events used for the statistical analysis. Boundary conditions are discussed in detail in **Section 2.3.3**.
6. The model was simulated in a steady state[2] (constant) condition for the design events.

As described above a lumped and steady state approach was adopted for the hydrologic and hydraulic modelling phase of the study. This approach required a number of simplifying assumptions compared to a long-term simulation based on a fully dynamic modelling approach. As part of the hydrologic and hydraulic model development, AE developed a pilot model to define the key hydrologic processes, to explore the feasibility of a fully dynamic model, and to try to estimate how conservative the steady-state model would be. **Appendix A** summarizes the pilot model development and simulation results.

2.2 MODEL SOFTWARE

Flood depths, flood extents, velocities, and shear stresses were estimated using the commercially available MIKE software-modeling package developed and marketed by Danish Hydraulic Institute (DHI). This software is widely used and contains one dimensional (1D), two dimensional (2D) and three dimensional (3D) modules for urban and rural environments. The MIKE11 – 1D and MIKE21 FM – 2D modules were used for this study as shown in **Figure 1-2**.

MIKE11 is a 1D model developed with a variety of basic modules each simulating a particular phenomenon in a river system. The hydrodynamic module uses an implicit finite difference scheme to solve the non-linear equations of open channel flow. It can be run in a fully dynamic mode that accounts for backwater effects, or in a kinematic mode that simulates the principal routing processes but cannot simulate backwater

[2] Steady State - Depth of flow does not change with time.

effects or highly dynamic conditions. This study used the fully dynamic mode to simulate steady-state flows and water levels.

Similar to MIKE11, MIKE21FM is a 2D model with a variety of basic modules each simulating a particular phenomenon in a river system. However, the hydrodynamic module in MIIKE21FM is based on solving the 2D shallow water equations, the depth-integrated incompressible Reynolds averaged Navier-Stokes equations. Thus, the model consists of continuity, momentum, temperature, salinity and density equations. The creek and floodplain are represented by a flexible and quadrangular mesh and the equations are solved from cell to cell to simulate flow, water level, velocity, and other optional parameters in each cell. It provides more detailed output than the 1D MIKE11 model but is considerably more detailed and requires much longer run times.

2.3 1D - MODEL

2.3.1 Model Network

Figure 2-1 illustrates the 1D model network developed for this study. The model network and extent consist of the following:

- Whitemud Creek - 83 km.
- West Whitemud Creek - 22 km.
- Deer Creek - 27 km.
- Blackmud Creek - 34 km.
- Clearwater Creek - 29 km.
- Irvine Creek - 20 km.
- LeBlanc Canal - 2 km.

2.3.2 Cross-sections

The model required cross-sections of the creeks in order to simulate the flood depths, flood extents, and velocities. A total of 478 cross-sections were used in the 1D model averaging approximately one cross-section for every 500 m. **Figure 2-1** and **2-2** show the approximate locations from which cross sections were taken.

In generating the cross-sections for the model, a combination of surveyed data, 1m resolution LiDAR, and existing cross-section data from previous studies was used as follows:

- Cross-sections for Blackmud Creek and Irvine Creek downstream of Beaumont were extracted from previous studies. The Nisku Flood Hazard Study (NHC, 2014) provided cross-sections for Blackmud Creek, which were originally derived from channel surveys extended across the floodplains using LiDAR data. The Irvine Creek cross-sections were obtained from the Irvine Creek and Cawes Lake Watershed Study (Stantec, 2014) which was based on LiDAR data.

- AE used 1m resolution LiDAR data to generate cross-sections along Whitemud Creek, West Whitemud Creek, Deer Creek, LeBlanc Canal, and Irvine Creek upstream of Beaumont.

- Seventy-two cross-sections were surveyed for this study: 29 along Whitemud Creek, 36 along West Whitemud Creek, and 7 along Blackmud Creek. **Figure 2-2** shows the approximate locations and sources of the cross-sections. The surveyed channel cross-sections were extended using LiDAR data across the floodplains. The surveyed channel inverts were used to estimate the channel bottom elevations for the intervening LiDAR cross-sections, where the LiDAR data represents the water surface which obscures the channel bottom. LiDAR cross-sections along Whitemud Creek within the City of Edmonton were modified based on channel bottom elevations taken from the Blackmud and Whitemud Creek Erosion Study (AMEC, 2006).

Table 2-1 shows typical cross-sections that were used in developing the model. In addition, **Photos 2-1** to **2-17** provide typical views of the creeks and floodplains within the basin during low and high flows.

The Whitemud Creek and Blackmud Creek cross-sections were divided into three zones as follows:

- the channel
- the right floodplain
- the left floodplain

A roughness coefficient (Manning's n) of 0.035 was used for the two creek channels. A roughness coefficient of 0.10 was used for the floodplain in the lower reach of Blackmud Creek and 0.050 in the upper reaches of Blackmud Creek and in Whitemud Creek per NHC's floodplain study.

The channel topography for all creeks, except in the Whitemud and Blackmud Creeks, is poorly-defined and therefore a single-zone definition with an n-value of 0.050 was used.

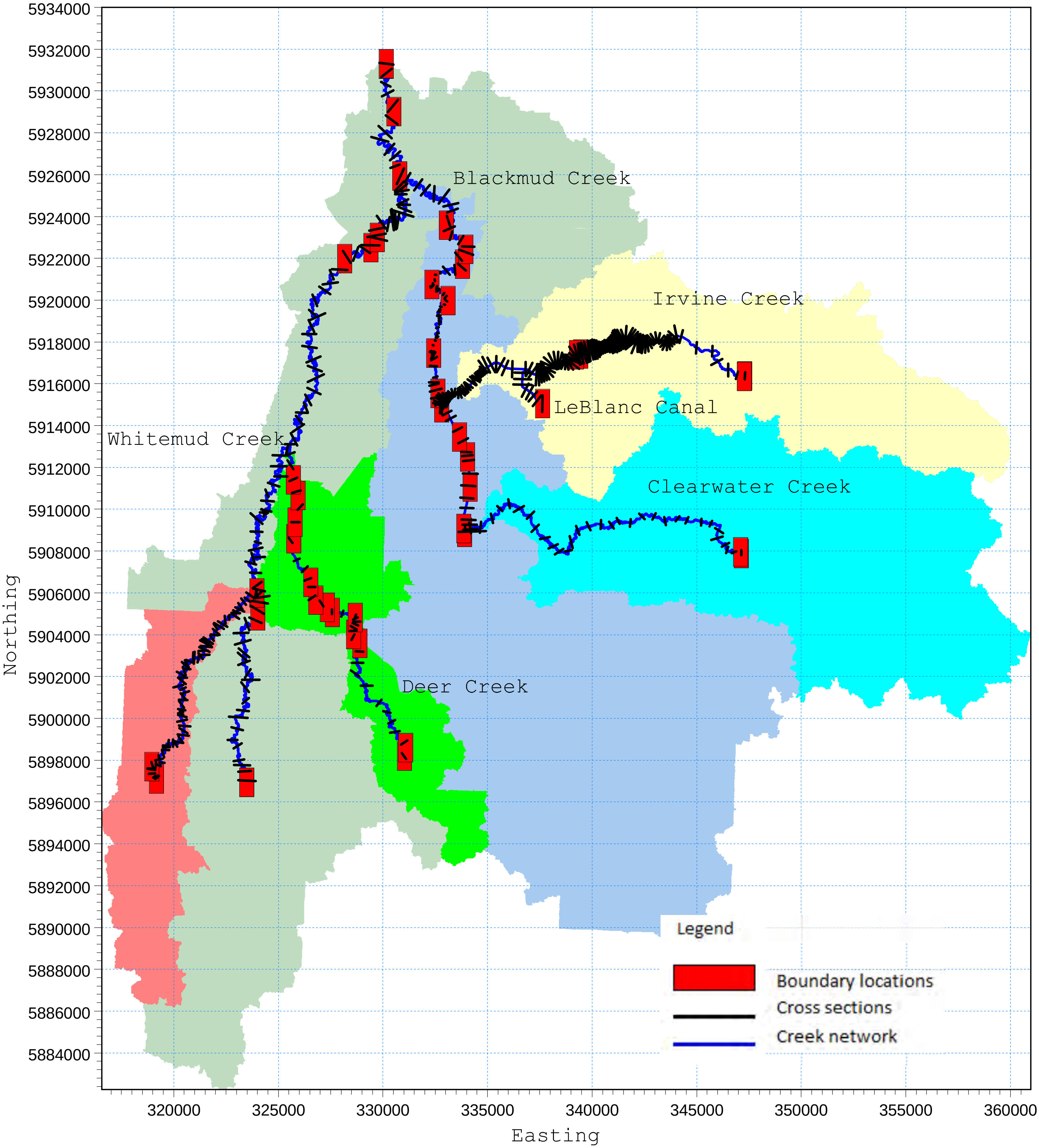
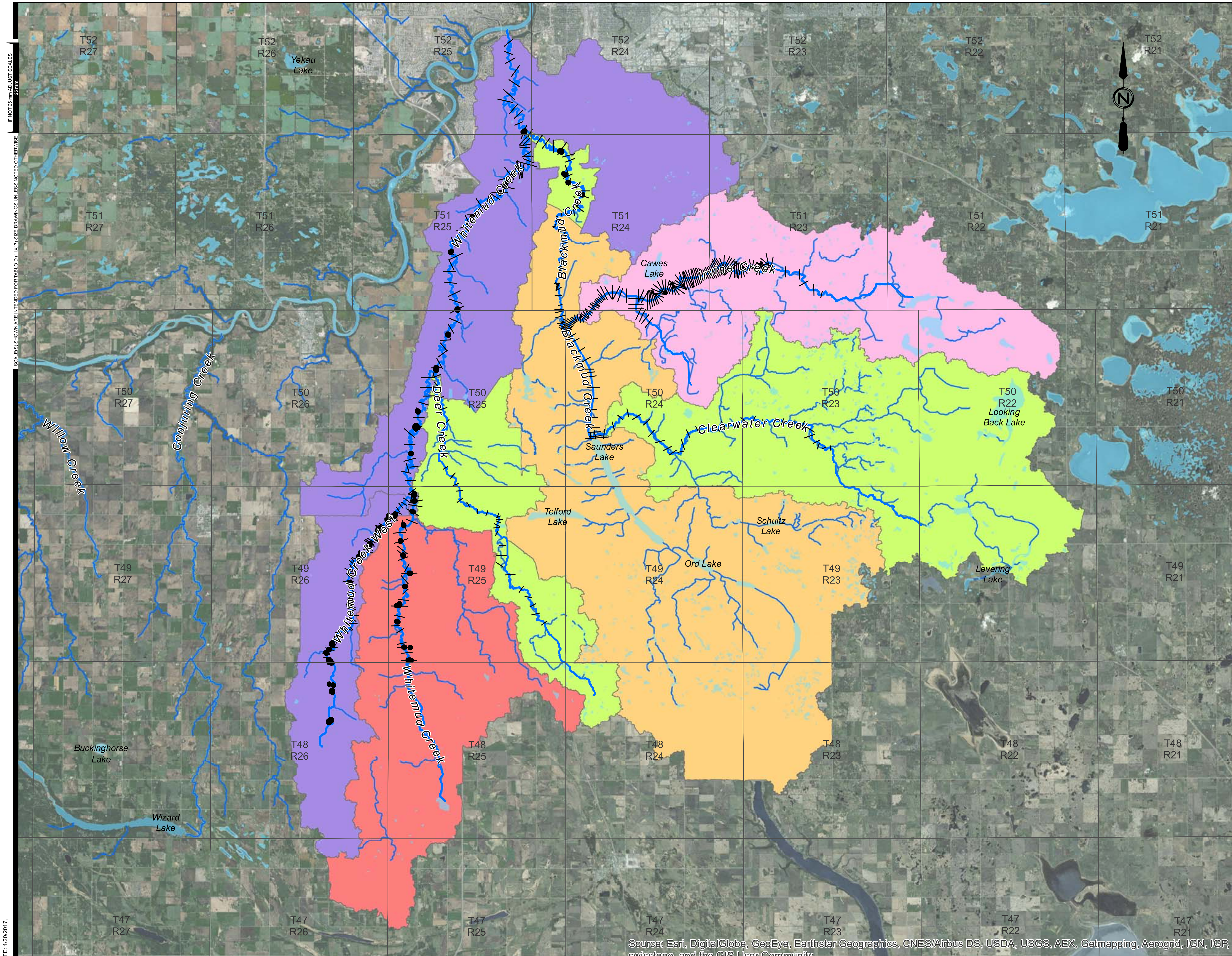


Figure 2-1: 1D Model Network



Associated Engineering

Legend:
- Survey Points

Watershed Data Source
- LiDAR & Surveyed
- Surveyed
- LiDAR
- NHC
- STANTEC
- Cross Section
- Creek Centreline

FIGURE No. 2-2

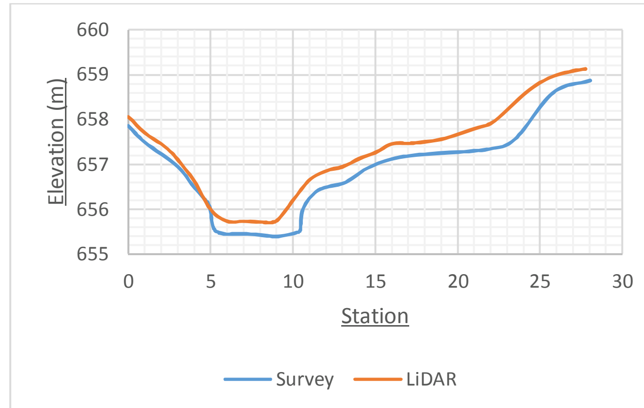
BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

DATA SOURCES

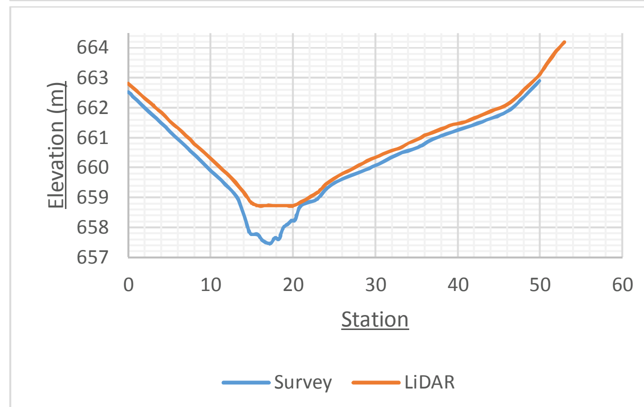
AE PROJECT No.	2016-3785
SCALE	1:200,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

Table 2-1: Typical Cross Sections

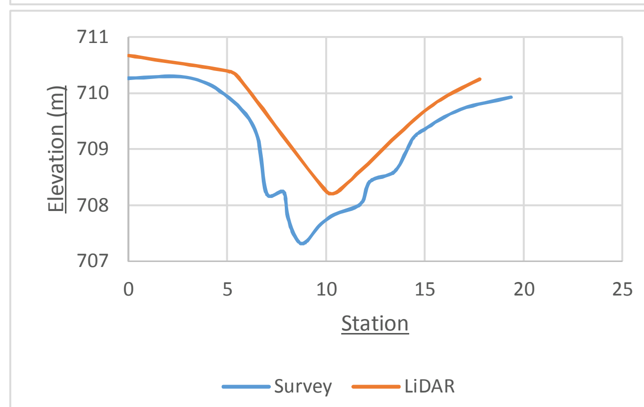
Blackmud Creek



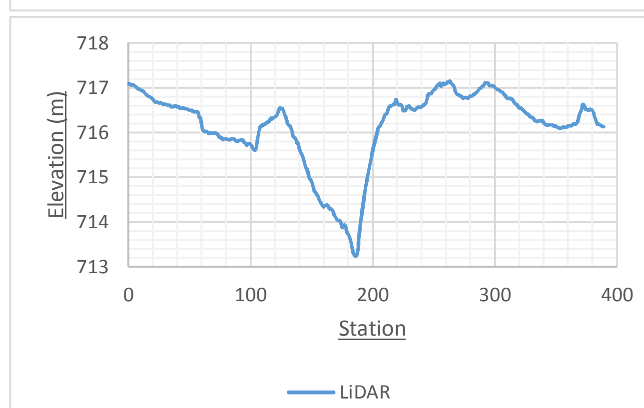
Whitemud Creek



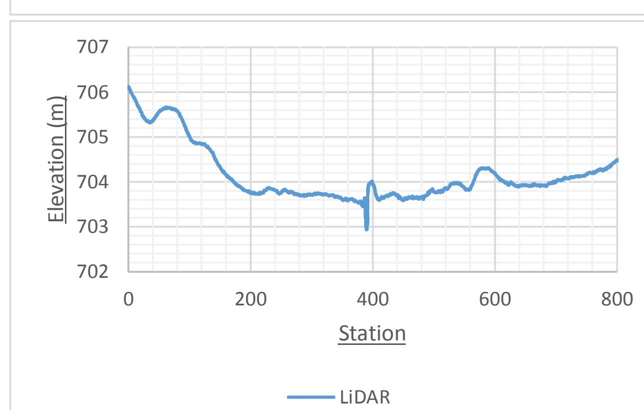
West Whitemud Creek



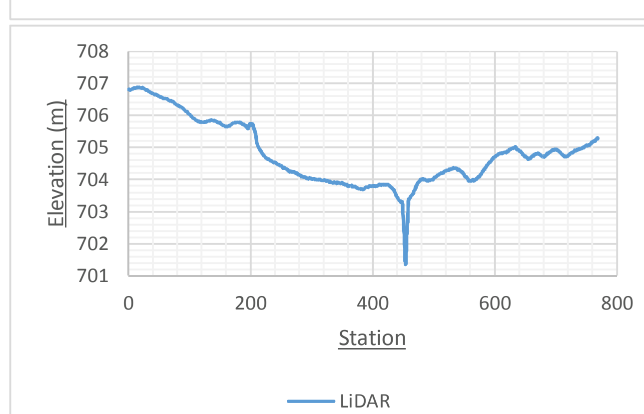
Deer Creek



LeBlanc Canal



Irvine Creek



Clearwater Creek

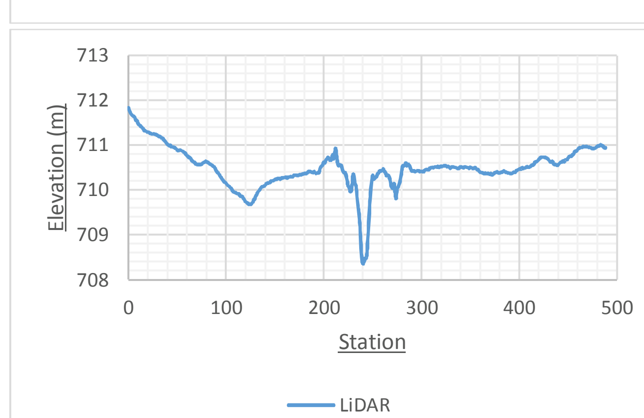


Photo 2-1. Saunders Lake Outlet South of Township Road 502 (2016)

Photo 2-2. Whitemud Creek at Township Road 510 (2016)

Photo 2-3. Blackmud Creek North of Township Road 510 (2016)

Photo 2-4. Deer Creek West of Range Road 254 (2016)

Photo 2-5. Irvine Creek West of Range Road 243 (2016)

Photo 2-6. Clearwater Creek North of Township Road 502 (2016)

Photo 2-7. LeBlanc at Township Road 505 (2016)

Photo 2-8. 300 yd East of Clearwater Creek (2013)

Photo 2-9. Floodplain at Highway 625 (2013)

Photo 2-10. At Highway 625 Looking South (2013)

Photo 2-11. Floodplain at Highway 625 (2013)

Photo 2-12. Blackmud Creek at Airport Road Bridge (2013)

Photo 2-13. At Highway 625 Looking South (2005)

Photo 2-14. At Highway 625 Looking South (2005)

Photo 2-15. At Highway 625 Looking North (2005)

Photo 2-16. At Highway 625 Looking North (2005)

Photo 2-17. At Highway 625 Looking North (2005)

2.3.3 Boundary Conditions

The hydrodynamic module in MIKE11-1D model requires that boundary conditions be specified upstream and downstream of the model extent. In developing this model the upstream boundary represented inflow into the creek system from rural areas. The downstream boundary represented the water level at the North Saskatchewan River. In addition, inflow boundaries were applied along the creeks to represent runoff from different sub-catchments and were specified as point inflows or distributed along some sections of the channels.

A total of 70 inflow boundaries were defined and applied within the 1D model. Design flow rates for the 1:2, 1:5, and 1:100 year return periods were estimated at the various inflow boundaries, based on the results of the hydrology study presented in TM 3 Basin Hydrology. **Table 2-2** summarizes the existing design flows at key locations within the basin.

Table 2-2
Existing Design Flows at Key Locations

*UD – Undeveloped, Duc – Developed Uncontrolled, DC – Developed Controlled

			Unit Flow (L/s/ha)			Design Flow (m^3/s)		
Basin	Type	Area (km2)	2 year	5 year	100 year	2 year	5 year	100 year
Beaumont (to Irvine Creek)	Urban controlled + U/S rural	18	0.38	0.57	3.00	0.68	1.03	5.40
Irvine	Rural	140	0.07	0.26	1.11	0.98	3.64	15.54
Saunders	Rural lake controlled	153	0.13	0.32	1.05	1.93	4.94	16.10
Clearwater	Rural	207	0.07	0.26	1.11	1.45	5.38	22.98
Leduc + Nisku	Urban direct	18.5	2.85	3.75	7.92	5.27	6.94	14.65
	Urban controlled	15.4	0.61	0.91	4.80	0.94	1.40	7.39
Blackmud Local excl Beaumont and Saunders)	Rural	91.1	0.07	0.26	1.11	0.64	2.37	10.11
Total		643				11.9	25.7	92.2
Blackmud WSC Gauge		643				4.6	16.6	71.5
NHC estimate		643				9.4	23.4	78.0
West Whitemud	Rural (UD)	65.4	0.31	0.75	2.88	2.03	4.91	18.84
West Leduc (to Deer Creek)	Urban direct (Duc)	2.75	3.65	4.84	10.10	1.00	1.33	2.78
	Urban controlled (DC)	3.84	0.95	1.43	7.50	0.36	0.55	2.88
	Leduc Reservoir	2.59	0.31	0.75	2.88	0.08	0.19	0.75
EIA (to Deer Creek)	Semi-urban controlled	10.23	0.31	0.75	2.88	0.32	0.77	2.95
Deer Creek	Rural (UD)	55.09	0.31	0.75	2.88	1.71	4.13	15.87
Whitemud	Rural (UD)	190.5	0.31	0.75	2.88	5.91	14.29	54.86
Total at WSC gauge		330.4				11.4	26.2	98.9
Whitemud WSC Gauge		330.4	0.31	0.75	2.88	10.1	24.9	95.0
Lower Basin (WSC gauges to NSR)	Rural	15.18	0.31	0.75	2.88	0.47	1.14	4.37
	Urban Direct D/S of 23 Ave	16.2	2.14	2.81	5.94	3.46	4.56	9.62
	Urban controlled (U/S of 23 Ave)	48.5	0.63	0.95	5.00	3.07	4.61	24.25
Whitemud at NSR		1053.3				30.3	62.2	229.3

2.3.3.1 Sub-catchment Areas

Detailed Geographical Information System (GIS) analysis was conducted to determine drainage patterns and catchment areas towards the boundary points. Catchment areas and detailed contours were generated from the available LIDAR data using Manifold and Global Mapper GIS software. Developed areas were lumped into large sub-catchments based on details of their internal drainage systems (storm sewers, culverts, and stormwater ponds).

Sub-catchments were classified according to their existing land use and stormwater management (SWM) practices as shown in **Figure 2-3** and summarized as follows:

- Urban Controlled - defined as developed areas where runoff is controlled by SWM facilities before discharging into the creek.
- Urban Direct - defined as developed areas where runoff drains directly into the creek without any control with SWM.
- Rural includes all currently undeveloped areas.

2.3.3.2 Urban Direct Runoff

Peak flow rates from developed areas were estimated using a combination of the following:

- Existing PCSWMM and MIKE URBAN modelling results.
- Rational Method.
- SWM release rates specified in existing standards.

A detailed PCSWMM model, provided by the Town of Beaumont and completed as part of the Town's Master Plan, was used to determine inflow rates into the LeBlanc Canal and Irvine Creek. The model setup included the entire length of the LeBlanc Canal up to its confluence with Irvine Creek. This comprised of approximately 28 SWM facilities, the Town of Beaumont storm sewer system and 5 outfalls, as shown in **Figure 2-4** (Model Schematic). The PCSWMM model was run for the 1:2, 1:5 and 1:100-year, 24 hour duration storm events, and flows were extracted immediately upstream of the confluence with Blackmud Creek (Range Road 243).

Flows from undeveloped areas downstream of Beaumont were excluded as they were computed separately using the flood frequency analysis and the unit rate flows as noted below.

The City of Edmonton provided a detailed MIKE-URBAN storm drainage model for the entire City of Edmonton which included those portions which lie within the Blackmud/Whitemud basin. This model is too detailed and cumbersome to use for planning purposes and therefore AE estimated the unit flow rates from direct-draining sub-catchments using the Rational Method. The 24-hour duration storm intensities were used to generate daily flows consistent with rest of the basin model.

For developed urban areas where previous models were not available, urban direct flows were estimated for the 1:2, 1:5 and 1:100 year return period 24 hour storms using the Rational Method. These areas include portion of Leduc and Nisku Industrial areas. Land use maps were reviewed and runoff coefficients were assigned to each sub-catchment using the runoff coefficients provided in **Table 2-3**. The Edmonton International Airport (EIA) IDF parameters and a time of concentration equal to 1440 minutes, corresponding to a 24 hour storm duration, were used in the calculation of peak daily flows. For the 1:100 year storm, runoff coefficients were increased by 25% to a maximum of 1.0.

Table 2-3
Urban Area Runoff Coefficients

Land Use	Runoff Coefficient	
	1:2 – 1:5 Year Storm	1:100 Year Storm
Industrial	0.6	0.75
Commercial	0.8	1
Park/Golf Course	0.1	0.125
Residential	0.55	0.6875

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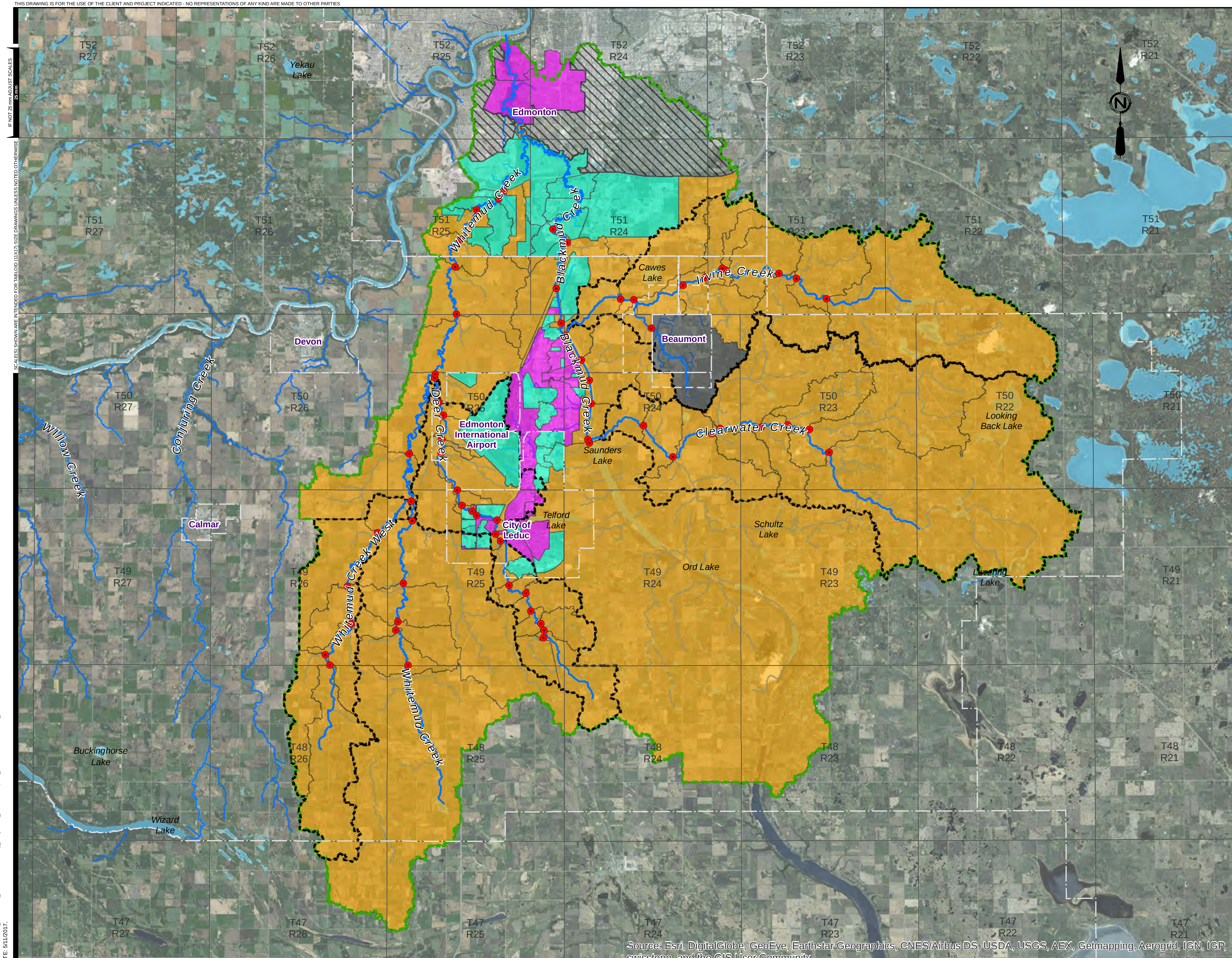


IF NOT 25 mm ADJUST SCALES 25 mm

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

P:\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\xxx_CatchmentSubcatchmentBoundaries.mxd
DATE: 5/11/2017,

Associated Engineering

Legend:
- Mike11 Inflow Boundary Location
- Catchment

Subcatchment Classification
- Urban Controlled
- Urban Direct
- Rural
- Town of Beaumont
- Draining to Trunk
- Creek Centreline
- Municipal Boundary

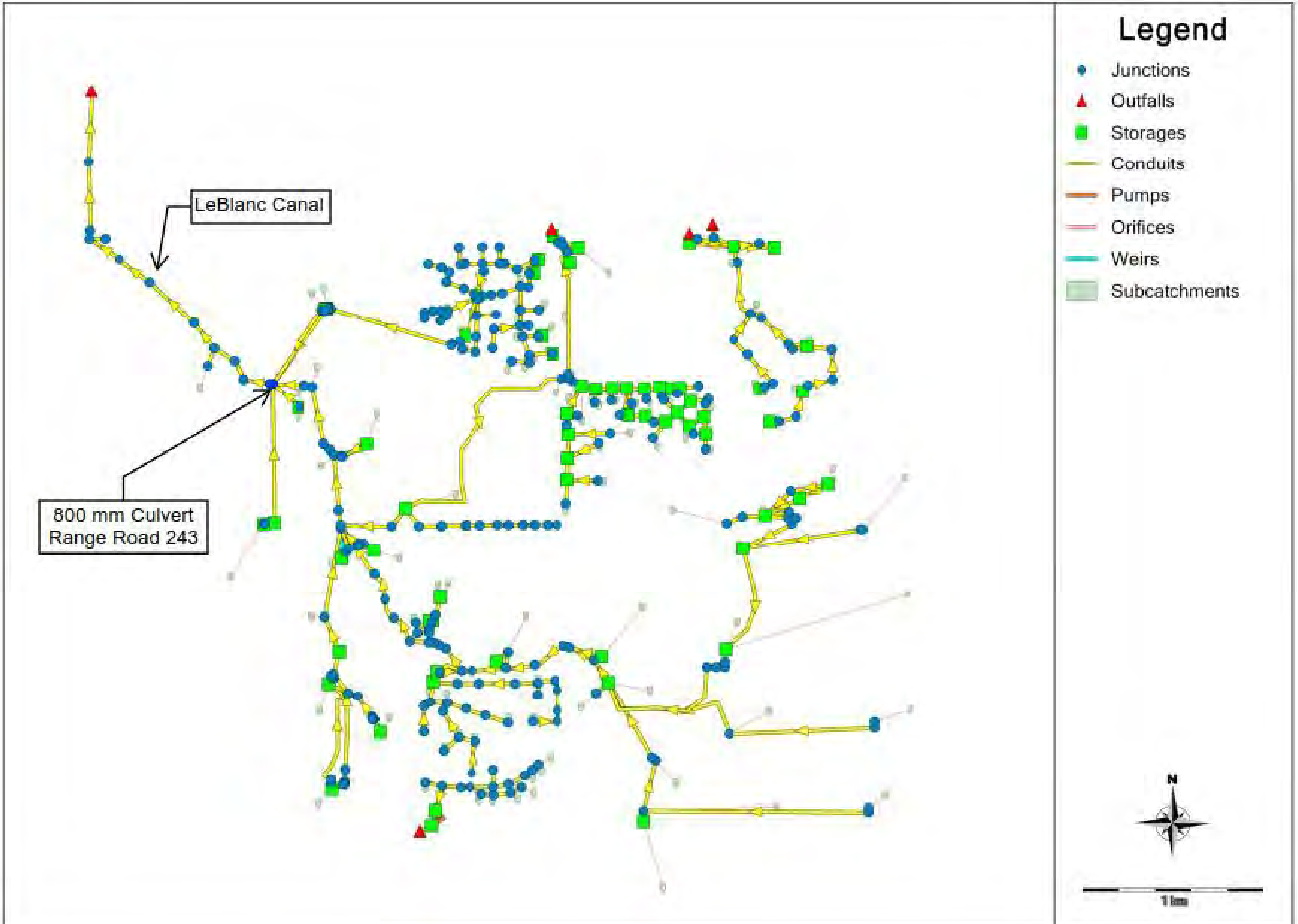
FIGURE No. 2-3

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

CATCHMENT AREA CLASSIFICATIONS

AE PROJECT No.	2016-3785
SCALE	1:200,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

Figure 2-4: Town of Beaumont – PCSWMM Model Schematic



2.3.3.3 Urban Controlled Runoff

Flows from urban controlled areas were estimated using the allowable release rate of the existing SWM facilities for the 1:100 year storm. A release rate of 7 L/s/ha was used for controlled areas within the City of Leduc based on the design standards. A release rate of 5 L/s/ha was used for urban controlled areas within the City of Edmonton (upstream of 23rd Avenue) based on the City's current design standards. Peak flows for the 1:2 year and 1:5 year storm event were estimated for the study extent based on the Town of Beaumont PCSWMM model results.

Runoff from the EIA was assumed to be controlled to pre-development rates similar to the Whitemud Creek unit peak flows for the basin. It is understood that the EIA has a defined stormwater management plan which includes a series of SWM facilities that collect and treat runoff before releasing to the creek at pre-development rates. Details of this operation were not available at the time of this analysis.

2.3.3.4 Rural Areas

Peak flows from undeveloped areas were based on the flood frequency analysis of the available data at the Water Survey of Canada (WSC) gauge stations (05DF003, 05DF006). Unit peak flows were calculated from the peak flow estimates and gross drainage areas outlined in the TM 3 Basin Hydrology, after subtracting the contribution from developed urban areas.

Flows from undeveloped areas within the Blackmud Creek, Irvine Creek, and Clearwater Creek were computed using the unit rate estimated from gauge 05DF003 (Blackmud Creek near Ellerslie). Flows from undeveloped areas within Whitemud Creek, Deer Creek, and West Whitemud Creek were calculated based on the unit rate estimated from gauge 05DF006 (Whitemud Creek near Ellerslie).

A major input boundary within the 1D model was located at the upstream of the Blackmud reach to represent the outflow from Saunders Lake. Peak outflows from Saunders Lake for the various return periods were adopted from the 2014 Nisku Flood Hazard Study.

2.3.3.5 Downstream Boundary

The downstream boundary in the model was set as the North Saskatchewan River. The boundary water level was fixed at the water surface elevation in the LiDAR data (617.5 m) and was assumed to represent typical river water levels. This approximation only affects a short reach of Whitemud Creek immediately upstream of the confluence with the river.

2.3.3.6 Design Flows for Existing Conditions

Table 2-4 presents the boundary inflow rates from each of the model sub-catchments. Upstream rural inflows and flows from urban areas were applied as point inflows while other rural sub-catchments were applied as a distributed flow to a reach of channel.

Table 2-4: Existing Design Flows - Model Inputs

	INFLOW POINT	AREA (HA)	AREA TYPE	RATE (L/S/HA) 2 YEAR	RATE (L/S/HA) 5 YEAR	RATE (L/S/HA) 100 YEAR	COMPONENT FLOW (L/s) 2 YEAR	COMPONENT FLOW (L/s) 5 YEAR	COMPONENT FLOW (L/s) 100 YEAR	TOTAL FLOWS FOR MODEL (m3/s) 2 YEAR	TOTAL FLOWS FOR MODEL (m3/s) 5 YEAR	TOTAL FLOWS FOR MODEL (m3/s) 100 YEAR	BOUNDARY INFLOW (m3/s) 2 YEAR	BOUNDARY INFLOW (m3/s) 5 YEAR	BOUNDARY INFLOW (m3/s) 100 YEAR
WEST WHITEMUD CREEK	P1_WW	2394.57	UD	0.31	0.75	2.88	742.32	1795.93	6896.36	0.74	1.80	6.90	0.74	1.80	6.90
	P2_WW	996.92	UD	0.31	0.75	2.88	309.05	747.69	2871.13	0.31	0.75	2.87	0.31	0.75	2.87
	P3_WW	629.36	UD	0.31	0.75	2.88	195.10	472.02	1812.56	0.20	0.47	1.81	0.20	0.47	1.81
	P4_WW	682.97	UD	0.31	0.75	2.88	211.72	512.23	1966.95	0.21	0.51	1.97	0.21	0.51	1.97
	P5_WW	1476.01	UD	0.31	0.75	2.88	457.56	1107.01	4250.91	0.46	1.11	4.25	0.46	1.11	4.25
DEER CREEK	P1_DC	407.09	UD	0.31	0.75	2.88	126.20	305.32	1172.42	0.13	0.31	1.17	0.13	0.31	1.17
	P2_DC	1037.41	UD	0.31	0.75	2.88	321.60	778.06	2987.74	0.32	0.78	2.99	0.32	0.78	2.99
	P3_DC	476.28	UD	0.31	0.75	2.88	147.65	357.21	1371.69	0.15	0.36	1.37	0.15	0.36	1.37
	P4_DC	156.69	UD	0.31	0.75	2.88	48.57	117.52	451.27	0.05	0.12	0.45	0.05	0.12	0.45
	P5_DC	511	UD	0.31	0.75	2.88	158.41	383.25	1471.68	0.16	0.38	1.47	0.16	0.38	1.47
	P6_DC	209.05	UD	0.31	0.75	2.88	64.81	156.79	602.06	0.06	0.16	0.60	0.06	0.16	0.60
	P7_DC	129.35	DC to Reservoir	0.31	0.75	2.88	40.10	97.01	372.53	0.04	0.10	0.37	0.13	0.32	1.24
		300.23	UD	0.31	0.75	2.88	93.07	225.17	864.66	0.09	0.23	0.86			
	P8_DC	52.54	UD	0.31	0.75	2.88	16.29	39.41	151.32	0.02	0.04	0.15	0.02	0.04	0.15
	P9_DC	130.3	DC_Duc to Reservoir	0.31	0.75	2.88	40.39	97.73	375.26	0.04	0.10	0.38	0.05	0.12	0.46
		28.75	UD	0.31	0.75	2.88	8.91	21.56	82.80	0.01	0.02	0.08			
	P10_DC	127.4	DC	0.95	1.43	7.50	121.03	182.18	955.50	0.12	0.18	0.96	0.38	0.54	1.71
		10.84	UD	0.31	0.75	2.88	3.36	8.13	31.22	0.00	0.01	0.03			
		71.26	Duc	3.65	4.84	10.10	260.10	344.90	719.73	0.26	0.34	0.72			
	P11_DC	63.1	DC	0.95	1.43	7.50	59.95	90.23	473.25	0.06	0.09	0.47	0.08	0.12	0.54
		4.14	Duc	3.65	4.84	10.10	15.11	20.04	41.81	0.02	0.02	0.04			
		8.37	UD	0.31	0.75	2.88	2.59	6.28	24.11	0.00	0.01	0.02			
	P12_DC	35.79	DC	0.95	1.43	7.50	34.00	51.18	268.43	0.03	0.05	0.27	0.04	0.06	0.31
		13.74	UD	0.31	0.75	2.88	4.26	10.31	39.57	0.00	0.01	0.04			
	P13_DC	128.79	UD	0.31	0.75	2.88	39.92	96.59	370.92	0.04	0.10	0.37	0.04	0.10	0.37
	P14_DC	823.7	UD	0.31	0.75	2.88	255.35	617.78	2372.26	0.26	0.62	2.37	0.97	1.58	4.57
		186.01	Duc	3.65	4.84	10.10	678.94	900.29	1878.70	0.68	0.90	1.88			
		42.47	DC	0.95	1.43	7.50	40.35	60.73	318.53	0.04	0.06	0.32			
	P15_DC	924.42	UD	0.31	0.75	2.88	286.57	693.32	2662.33	0.29	0.69	2.66	0.29	0.69	2.66
	P16_DC	198.2	UD	0.31	0.75	2.88	61.44	148.65	570.82	0.06	0.15	0.57	0.38	0.92	3.52
		1022.95	AIRPORT	0.31	0.75	2.88	317.11	767.21	2946.10	0.32	0.77	2.95			
	P17_DC	281.99	UD	0.31	0.75	2.88	87.42	211.49	812.13	0.09	0.21	0.81	0.09	0.21	0.81
WHITEMUD CREEK	P1_WC	7904.07	UD	0.31	0.75	2.88	2450.26	5928.05	22763.72	2.450	5.93	22.76	2.45	5.93	22.76
	P2_WC	730.55	UD	0.31	0.75	2.88	226.47	547.91	2103.98	0.226	0.55	2.10	0.23	0.55	2.10
	P3_WC	757.71	UD	0.31	0.75	2.88	234.89	568.28	2182.20	0.235	0.57	2.18	0.23	0.57	2.18
	P4_WC	965.66	UD	0.31	0.75	2.88	299.35	724.25	2781.10	0.299	0.72	2.78	0.30	0.72	2.78
	P5_WC	4479.79	UD	0.31	0.75	2.88	1388.73	3359.84	12901.80	1.389	3.360	12.902	1.55	3.59	13.91
		115.95	DC	0.95	1.43	7.50	110.15	165.81	869.63	0.110	0.166	0.870			
		13.34	Duc	3.65	4.84	10.10	48.69	64.57	134.73	0.049	0.065	0.135			
	P6_WC	41.4	UD	0.31	0.75	2.88	12.83	31.05	119.23	0.013	0.03	0.12	0.13	0.30	1.16
		362.7	UD	0.31	0.75	2.88	112.44	272.03	1044.58	0.112	0.27	1.04			
	P7_WC	1644.35	UD	0.31	0.75	2.88	509.75	1233.26	4735.73	0.510	1.23	4.74	0.51	1.23	4.74
	P8_WC	927.81	UD	0.31	0.75	2.88	287.62	695.86	2672.09	0.288	0.696	2.672	0.31	0.74	2.84
		58.57	UD	0.31	0.75	2.88	18.16	43.93	168.68	0.018	0.044	0.169			
	P9_WC	575.3	UD	0.31	0.75	2.88	178.34	431.48	1656.86	0.178	0.43	1.66	0.18	0.43	1.66
	P10_WC	1510.47	UD	0.31	0.75	2.88	468.25	1132.85	4350.15	0.468	1.13	4.35	0.47	1.13	4.35
	P11_WC	1674.47	UD	0.31	0.75	2.88	519.09	1255.85	4822.47	0.519	1.26	4.82	0.52	1.26	4.82
	P12_WC	503.73	UD	0.31	0.75	2.88	156.16	377.80	1450.74	0.156	0.38	1.45	0.16	0.38	1.45
	P13_WC	351.57	UD	0.31	0.75	2.88	108.99	263.68	1012.52	0.109	0.26	1.01	0.22	0.43	1.87
		172.41	DC	0.63	0.95	5.00	108.62	163.79	862.05	0.109	0.16	0.86			
	P14_WC	461.16	DC	0.63	0.95	5.00	290.53	438.10	2305.80	0.291	0.44	2.31	0.29	0.44	2.31
	P15_WC	313.29	DC	0.63	0.95	5.00	197.37	297.63	1566.45	0.20	0.30	1.57	0.29	0.52	2.44
		302.64	UD	0.31	0.75	2.88	93.82	226.98	871.60	0.09	0.23	0.87			
	P16_WC	1505.65	DC	0.63	0.95	5.00	948.56	1430.37	7528.25	0.95	1.43	7.53	0.96	1.46	7.63
		34.78	UD	0.31	0.75	2.88	10.78	26.09	100.17	0.01	0.03	0.10			
	P17_WC	37.96	UD	0.31	0.75	2.88	11.77	28.47	109.32	0.01	0.03	0.11	2.76	3.63	7.73
		1283.04	Duc	2.14	2.81	5.94	2745.71	3605.34	7621.26	2.75	3.61	7.62			
	P18_WC	335.15	Duc	2.14	2.81	5.94	717.22	941.77	1990.79	0.72	0.94	1.99	0.72	0.94	1.99
CLEARWATER CREEK	P1_CW	9600.08	UD	0.07	0.26	1.11	672.01	2496.02	10656.09	0.67	2.50	10.66	0.67	2.50	10.66
	P2_CW	3327.89	UD	0.07	0.26	1.11	232.95	865.25	3693.96	0.23	0.87	3.69	0.23	0.87	3.69
	P3_CW	997.4	UD	0.07	0.26	1.11	69.82	259.32	1107.11	0.07	0.26	1.11	0.07	0.26	1.11
	P4_CW	707.24	UD	0.07	0.26	1.11	49.51	183.88	785.04	0.05	0.18	0.79	0.05	0.18	0.79
	P5_CW	2624.42	UD	0.07	0.26	1.11	183.71	682.35	2913.11	0.18	0.68	2.91	0.18	0.68	2.91
	P6_CW	489.4	UD	0.07	0.26	1.11	34.26	127.24	543.23	0.03	0.13	0.54	0.03	0.13	0.54
	P7_CW	1806.77	UD	0.07	0.26	1.11	126.47	469.76	2005.51	0.13	0.47	2.01	0.13	0.47	2.01
	P8_CW	654.48	UD	0.07	0.26	1.11	45.81	170.16	726.47	0.05	0.17	0.73	0.05	0.17	0.73
LEBLANC CANAL	P1_LC	213.62	UD	0.07	0.26	1.11	0.40	55.54	237.12	0.00	0.06	0.24	0.40	0.64	3.82
		N/A	Town of Beaumont	0.38	0.57	3.00	402.00	580.00	3580.00	0.40	0.58	3.58			
IRVINE CREEK	P1_IC	6060.83	UD	0.07	0.26	1.11	424.26	1575.82	6727.52	0.42	1.58	6.73	0.42	1.58	6.73
	P2_IC	1361.4	UD	0.07	0.26	1.11	95.30	353.96	1511.15	0.10	0.35	1.51	0.10	0.35	1.51
	P3_IC	1019.34	UD	0.07	0.26	1.11	71.35	265.03	1131.47	0.07	0.27	1.13	0.07	0.27	1.13
	P4_IC	1078.97	UD	0.07	0.26	1.11	75.53	280.53	1197.66	0.08	0.28	1.20	0.08	0.28	1.20
	P5_IC	378.92	UD	0.07	0.26	1.11	26.52	98.52	420.60	0.03	0.10	0.42	0.03	0.10	0.42
	P6_IC	647.39	UD	0.07	0.26	1.11	45.32	168.32	718.60	0.05	0.17	0.72	0.05	0.17	0.72
	P7_IC	1053.63	UD	0.07	0.26	1.11	73.75	273.94	1169.53	0.0738	0.2739	1.1695	0.35	0.72	2.99
		N/A	Town of Beaumont	0.38	0.57	3.00	280.00	450.00	1820.00	0.2800	0.4500	1.8200			
	P8_IC	348.97	UD	0.07	0.26	1.11	24.43	90.73	387.36	0.0244	0.0907	0.3874	0.02	0.09	0.39
	P9_IC	1354.37	UD	0.07	0.26	1.11	94.81	352.14	1503.35	0.0948	0.3521	1.5034	0.09	0.35	1.50
BLACKMUD CREEK	P1_BC	15300	UD	0.13	0.32	1.05	1930.00	4940.00	16100.00	1.93	4.94	16.1	2.00	5.05	16.66
		116.21	DC	0.61	0.91	4.8	70.89	105.75	557.81	0.07	0.11	0.56			
	P2_BC	539.75	UD	0.07	0.26	1.11	37.78	140.34	599.12	0.04	0.14	0.60	0.04	0.14	0.60
	P3_BC	327.04	UD	0.07	0.26	1.11	22.89	85.03	363.01	0.02	0.09	0.36	1.39	1.91	4.88
		432.58	Duc	2.85	3.75	7.92	1232.85	1622.18	3426.03	1.23	1.62	3.43			
		107.68	DC	0.61	0.91	4.8	65.68	97.99	516.86	0.07	0.10	0.52			
		120.21	DC	0.61	0.91	4.8	73.33	109.39	577.01	0.07	0.11	0.58			
	P4_BC	446.04	UD	0.07	0.26	1.11	31.22	115.97	495.10	0.03	0.12	0.50	0.17	0.30	0.98
		39.17	Duc	2.85	3.75	7.92	111.63	146.89	310.23	0.11	0.15	0.31			
		36.38	DC	0.61	0.91	4.8	22.19	33.11	174.62	0.02	0.03	0.17			
	P5_BC	1218.17	UD	0.07	0.26	1.11	85.27	316.72	1352.17	0.09	0.32	1.35	0.43	0.77	2.32
		121.57	Duc	2.85	3.75	7.92	346.47	455.89	962.83	0.35	0.46	0.96			
	P6_BC	485.23	UD	0.07	0.26	1.11	33.97	126.16	538.61	0.03	0.13	0.54	0.57	0.87	2.29
		214.11	UD	0.07	0.26	1.11	14.99	55.67	237.66	0.01	0.06	0.24			
		178.78	Duc	2.85	3.75	7.92	509.52	670.43	1415.94	0.51	0.67	1.42			
		21.2	DC	0.61	0.91	4.8	12.93	19.29	101.76	0.01	0.02	0.10			
	P7_BC	59.48	UD	0.07	0.26	1.11	4.16	15.46	66.02	0.00	0.02	0.07	3.27	4.36	10.53
		1048.61	Duc	2.85	3.75	7.92	2988.54	3932.29	8304.99	2.99	3.93	8.30			
		450.33	DC	0.61	0.91	4.8	274.70	409.80	2161.58	0.27	0.41	2.16			
	P8_BC	143.32	UD	0.07	0.26	1.11	10.03	37.26	159.09	0.01	0.04	0.16	0.36	0.55	2.56
		25.82	Duc	2.85	3.75	7.92	73.59	96.83	204.49	0.07	0.10	0.20			
		456.8	DC	0.61	0.91	4.8	278.65	415.69	2192.64	0.28	0.42	2.19			
	P9_BC	1304.27	UD	0.07	0.26	1.11	91.30	339.11	1447.74	0.09	0.34	1.45	0.12	0.38	1.68
		48.24	DC	0.61	0.91	4.8	29.43	43.90	231.55	0.03	0.04	0.23			
	P10_BC	71.58	UD	0.07	0.26	1.11	5.01	18.61	79.45	0.01	0.02	0.08	0.12	0.19	0.97
		185.67	DC	0.61	0.91	4.8	113.26	168.96	891.22	0.11	0.17	0.89			
	P11_BC	216.03	DC	0.63	0.95	5.00	136.82	205.23	1080.17	0.14	0.21	1.08	0.14	0.21	1.08
	P12_BC	1885.39	DC	0.63	0.95	5.00	1194.10	1791.16	9427.14	1.19	1.79	9.43	1.35	2.17	10.86
		498.83	UD	0.31	0.75	2.88	154.64	374.12	1436.63	0.15	0.37	1.44			
	P13_BC	293.64	DC	0.63	0.95	5.00	185.98	278.96	1468.23	0.19	0.28	1.47	0.19	0.28	1.47

3 1D Model Results

The maximum flows, water depths, and velocities for existing conditions were simulated for the 1:2, 1:5, and 1:100 year design events. Inflows were applied to the 1D model from developed and undeveloped portions of the basin as described above. Flood maps depicting the maximum extent of flooding were developed by overlaying the simulated water surface on the 1m ground LiDAR surface within the MIKE 11 software.

3.1 FLOOD DEPTHS AND EXTENT

Figure 3-1 provides the flood map and the water depths for the entire basin for the simulated 1:100 year design event. The results of the model simulation show significant flooding along Irvine Creek, Leblanc Canal, Blackmud Creek upstream of Highway 2, and more localized flooding along Whitemud and Clearwater Creeks.

Figures 3-2 to **3-5** show the flood extent and water depths for the simulated 1:100 year design event at critical locations along Blackmud Creek, Irvine Creek, Deer Creek, and Whitemud Creek, respectively. In addition, **Appendix A** provides maps showing flood extents and water depths during the 1:2, 1:5 and 1:100 year design events. The following observations were made from the modelling results:

- Generally, flows generated by the existing conditions were confined within the channel banks during the 1:2 year design event. Localized flooding occurred along the creeks during the 1:5 year design event. Overland flooding occurred during the 1:100 year design event.

- The majority of the creeks within the basin had limited hydraulic capacity to convey runoff generated from existing and any future development. However, in the lower reaches of Blackmud and Whitemud Creeks erosion is a significant concern.

- The upper reaches of the Blackmud Creek experienced flooding over a wide floodplain that geologically formed the outlet from glacial Lake Edmonton. Flooding was mostly confined to the valley. Flows were mostly confined to the Blackmud Creek channel as they approached the City of Edmonton.

- The upper reaches of the Whitemud Creek experienced flooding within the valley. Flows in the lower reaches were mostly confined to the creek channel.

- Portions of the Irvine Creek and LeBlanc Canal near Beaumont experienced significant overland flooding due to limited channel capacity. These areas had been channelized in the past to provide drainage but do not have the capacity to prevent flooding in a major runoff event. The lower reaches of the LeBlanc Canal also experienced backwater effects from Irvine Creek.

- Deer Creek had limited channel capacity to convey runoff and this resulted in overland flooding along the creek.

Figure 3-6 provides the longitudinal profile of Blackmud Creek showing the creek bed and 1:100 year water surface. **Figures 3-7A** and **B** provide typical cross-sections upstream and downstream of Nisku. From the profile, it can be observed that the longitudinal slope of the Blackmud Creek steepens downstream of Nisku, as the valley becomes deeper and flows increase. Extensive flooding occurred in the glacial valley upstream of Nisku (**Figure 3-7A**) and became confined to the creek channel at Highway 2 (**Figure 3-7B**) and downstream.

Figure 3-8 shows the longitudinal profile of Irvine Creek and **Figures 3-9C** and **D** provide typical cross-sections between Beaumont and Nisku. The channel is flat and shallow near Beaumont, which is a factor in the extensive flooding that occurs there (**Figure 3-9C**). The natural (un-modified) reaches were somewhat steeper and the channel is larger and better defined (**Figure 3-9D**).

Figure 3-10 presents the longitudinal profile of Deer Creek and **Figures 3-11E** and **F** show typical cross-sections between Leduc and the Edmonton International Airport. The longitudinal channel slope is relatively uniform, other than the backwater from the Leduc Reservoir outlet. The channel changes substantially from a fairly confined and well-defined channel upstream (**Figure 3-11E**) to a shallow and poorly-defined channel downstream (**Figure 3-11F**). Portions of this creek downstream of Range Road 254 have been channelized in the past. The results of the model showed that the channel had capacity for the 1:5 year return period peak flow which is typically used for channel design.

Figure 3-12 shows the longitudinal profile of the Whitemud Creek and **Figures 3-13G** and **H** provide typical cross-sections near Highway 19 and Anthony Henday Drive. The channel becomes steeper and the valley deeper near the WSC gauge and downstream of Anthony Henday Drive (**Figure 3-13H**). Flood flows are mostly confined to the valley of Whitemud Creek and to the vegetated floodplain in the upper reaches.

Appendix B presents longitudinal profiles showing the channel bottom and the maximum water surface for the 1:2, 1:5 and 1:100 year design events. **Appendix C** presents typical cross sections within the various reaches along with the simulated maximum water surface for the 1:2, 1:5 and 1:100 year design events. **Appendix D** presents longitudinal profiles showing the maximum velocity for the 1:2, 1:5 and 1:100 year design events.

3.2 CHANNEL VELOCITY ALONG THE BLACKMUD AND WHITEMUD CREEKS

The channel morphology is a function of the hydrologic regime, bed and bank materials, and longitudinal channel slope. Bed and bank erosion are, in turn, an expression of the channel morphology.

Bank erosion was found to be common throughout the lower reaches of Whitemud and Blackmud Creeks. It is the result of various natural and human influences. The City of Edmonton has conducted several studies to understand the nature and cause of the bank erosion and to develop a mitigation plan. This City of Edmonton currently collects levies from area developers which is used to fund channel upgrade and protection projects.

Figures 3-14 and **3-15** present the simulated channel average velocities along the Blackmud and Whitemud Creeks, respectively, for the 1:2, 1:5, and 1:100 peak design flows. These velocities represent the averages taken across the channel cross section at intervals along the creek.

The average velocities for both creeks was found to increase from upstream to the downstream, corresponding to the overall increase in flow and longitudinal channel slope. In general, velocities higher than 1.0 m/s occur in channels that are geologically more active such as the lower reaches of Whitemud and Blackmud Creeks. Upper reaches where the velocities are generally lower than 1 m/s are typically stable and show little sign of active channel erosion.

Streambank erosion is very sensitive to increases in velocity and flow and could potentially be impacted by development upstream. These potential impacts will be further evaluated in the next phase of this project.

3.3 DEVELOPMENT ISSUES AND CONSTRAINTS

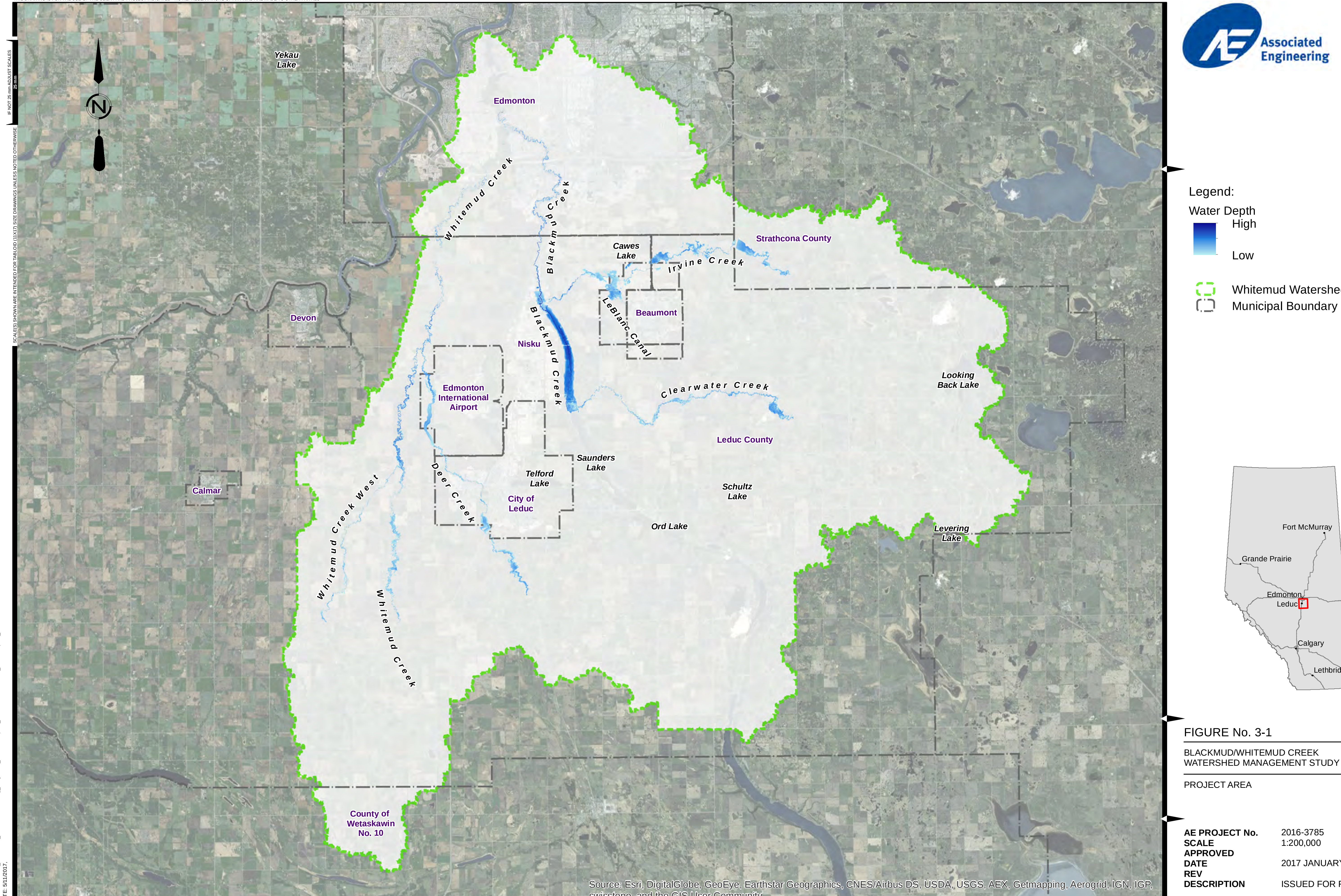
The analysis of existing conditions has identified several issues and constraints that will need to be addressed in subsequent tasks of the Surface Water Management Study. The following issues will need to be addressed:

- The extent of flooding will constrain development. In some locations along the Blackmud Creek, Irvine Creek, Deer Creek and Leblanc Canal, the flood-risk areas are extensive. The Municipal Government Act empowers municipalities to preserve floodplain areas as Environmental Reserve (land subject to flooding) at the time of development, however, these powers are not always applied consistently. Where extensive overland flooding is found to occur, it is not always practical to sterilize large areas from development, and these locations should be considered as possible sites for stormwater management ponds or wetlands. A policy for protecting floodplains that recognizes the flood risk and the environmental value that floodplains create should be developed.

- Along with the extensive flooding, some of the creek channels, in the same locations as above, are too shallow to permit drainage of adjacent development using a conventional underground pipe system. Typically, a depth of 4 m from adjacent land areas to channel bottom is required and in many places this does not exist. Alternatives need to be considered such as:

    - a surface drainage system
    - channel deepening and widening to provide the required capacity (a drainage parkway)
    - a trunk storm sewer system to carry outflows from stormwater management facilities to a safe and reliable discharge point
    - Low-Impact Development standards to reduce the volume and peak runoff rates to pre-development levels

- Erosion issues in Whitemud and Blackmud Creek are understood in only a general way and could be aggravated by increasing runoff volumes and flood peak discharges resulting from further development in the basin. There are no reliable models of the erosion process to give ***quantitative*** estimates of the erosion rates and the impacts of the changing flow regime that will occur with development, but a ***qualitative*** estimate is possible from the model-simulated velocities and shear stresses and morphological principles that relate these hydraulic parameters to the rate of sediment transport.



Associated Engineering

FIGURE No. 3-1

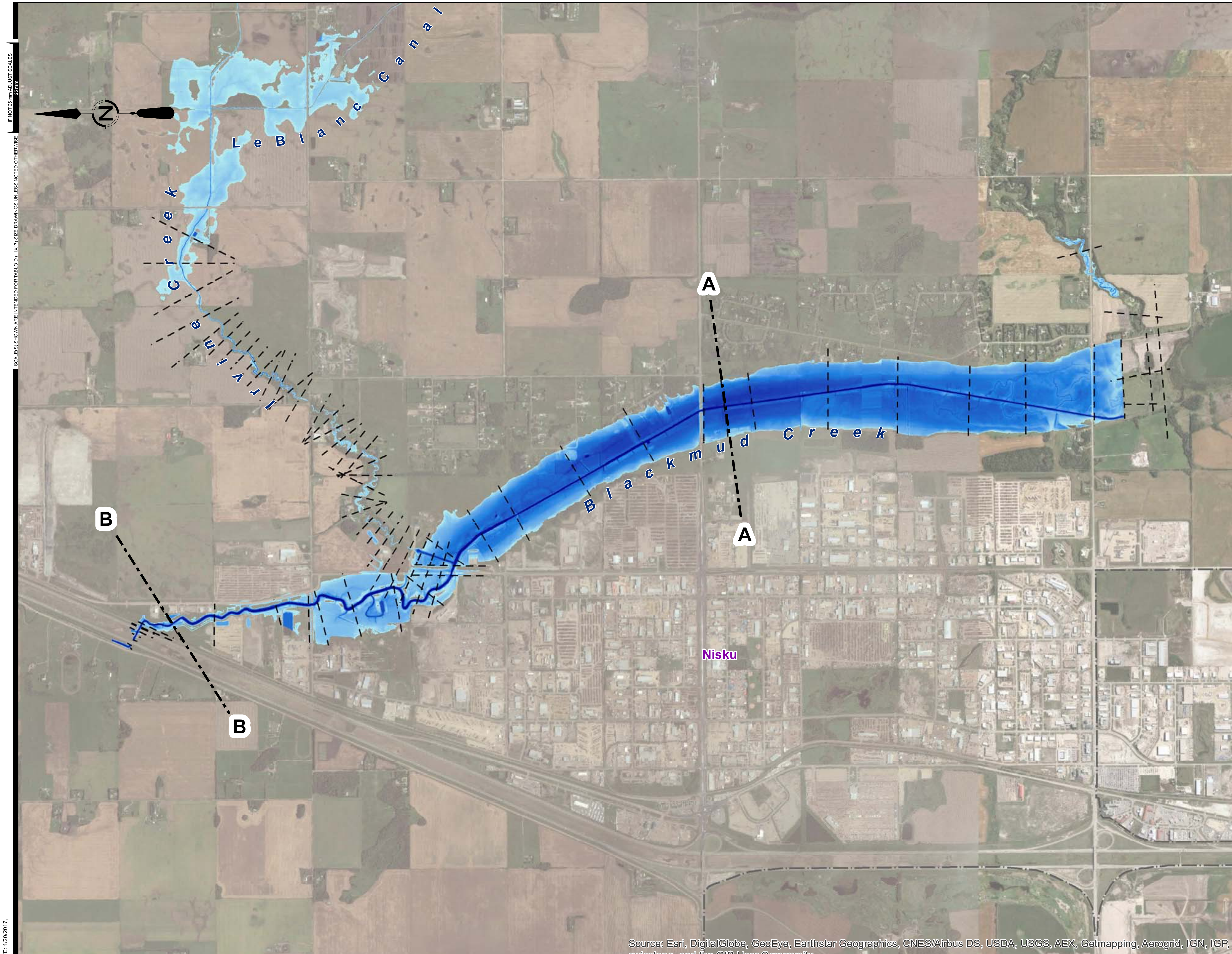
BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

PROJECT AREA

AE PROJECT No.	2016-3785
SCALE	1:200,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE IF NOT 25 mm ADJUST SCALES 25 mm

P:\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\xxx_CreekDepths_v2.mxd DATE: 5/11/2017,



Associated Engineering

Legend:

Water Depth (100 Year)

High (4.1 m)

Low (0 m)

Cross Section

Municipal Boundary

FIGURE No. 3-2

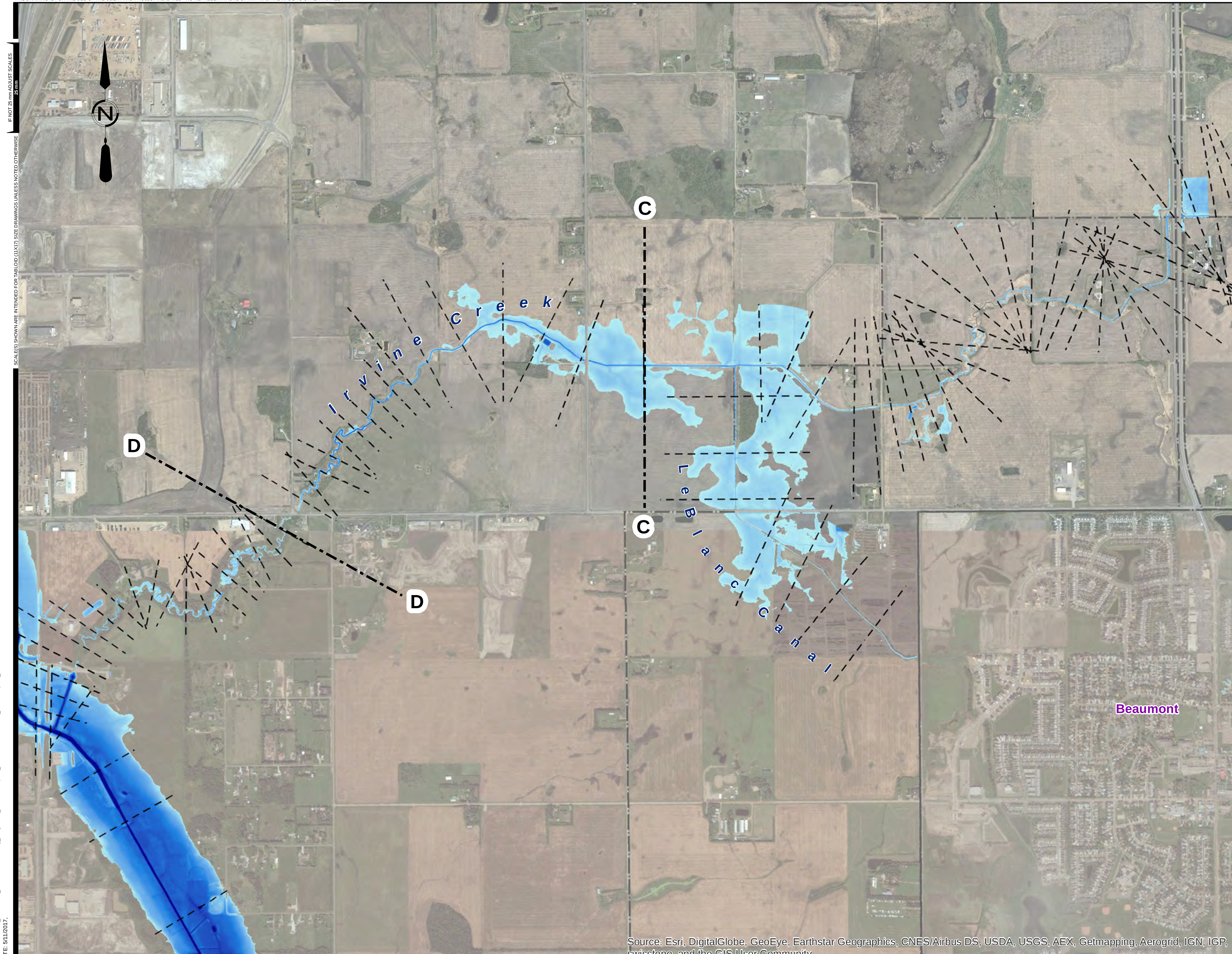
BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

Blackmud Creek 1:100 Year

AE PROJECT No.	2016-3785
SCALE	1:30,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

P:\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\xxx_CreekDepths_v2.mxd
DATE: 1/20/2017,

IF NOT 25 mm ADJUST SCALES
SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE



Associated Engineering

Legend:

Water Depth (100 Year)

High (3.7 m)

Low (0 m)

Cross Section

Municipal Boundary

FIGURE No. 3-3

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

IRVINE CREEK 1:100 YEAR

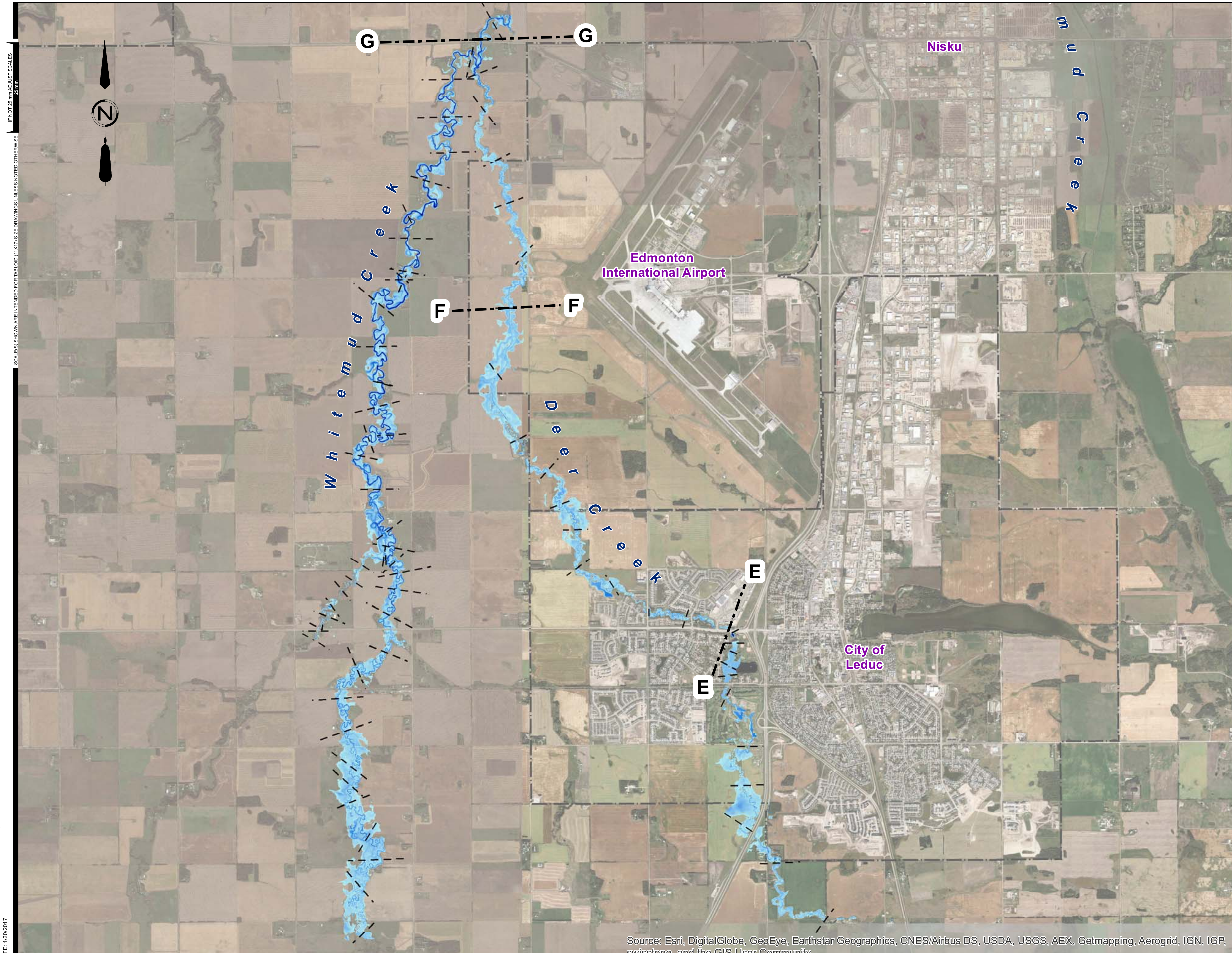
AE PROJECT No.	2016-3785
SCALE	1:20,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

IF NOT 25 mm ADJUST SCALES

25 mm

P:\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\xxx_CreekDepths_v2.mxd
DATE: 5/11/2017,



Associated Engineering

Legend:

Water Depth (100 Year)

High (4.1 m)

Low (0 m)

Cross Section

Municipal Boundary

FIGURE No. 3-4

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

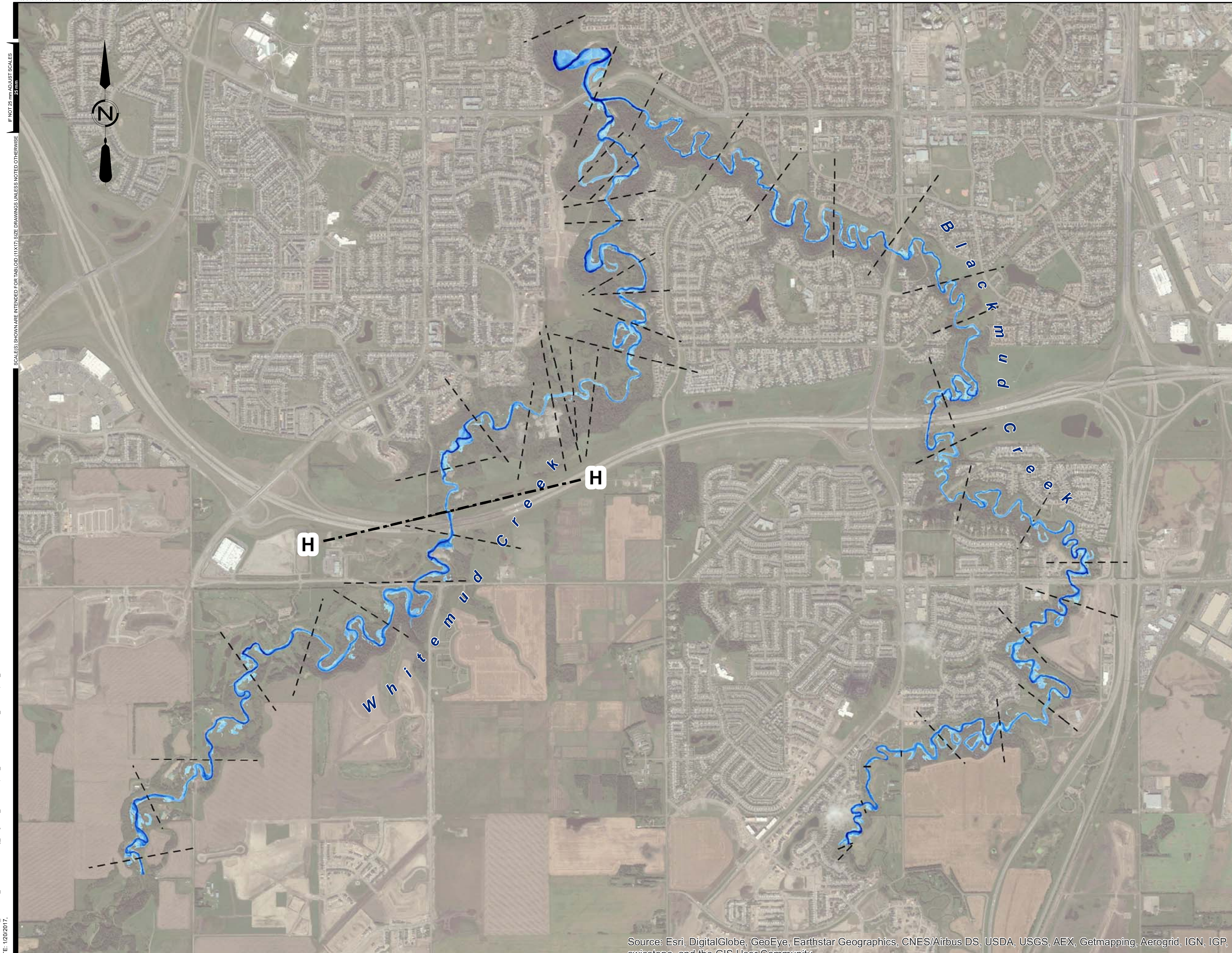
Deer Creek 1:100 Year

AE PROJECT No.	2016-3785
SCALE	1:50,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

IF NOT 25 mm ADJUST SCALES 25 mm

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

P:\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\xxx_CreekDepths_v2.mxd
DATE: 1/20/2017,



IF NOT 25 mm ADJUST SCALES
25 mm
SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

Associated Engineering

Legend:

Water Depth (100 Year)
High (4.1 m)
Low (0 m)

Cross Section
Municipal Boundary

FIGURE No. 3-5

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

Whitemud Creek 1:100 Year

AE PROJECT No.	2016-3785
SCALE	1:25,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

P:\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\xxx_CreekDepths_v2.mxd
DATE: 1/20/2017,

Figure 3-6: Blackmud Creek Longitudinal Profile

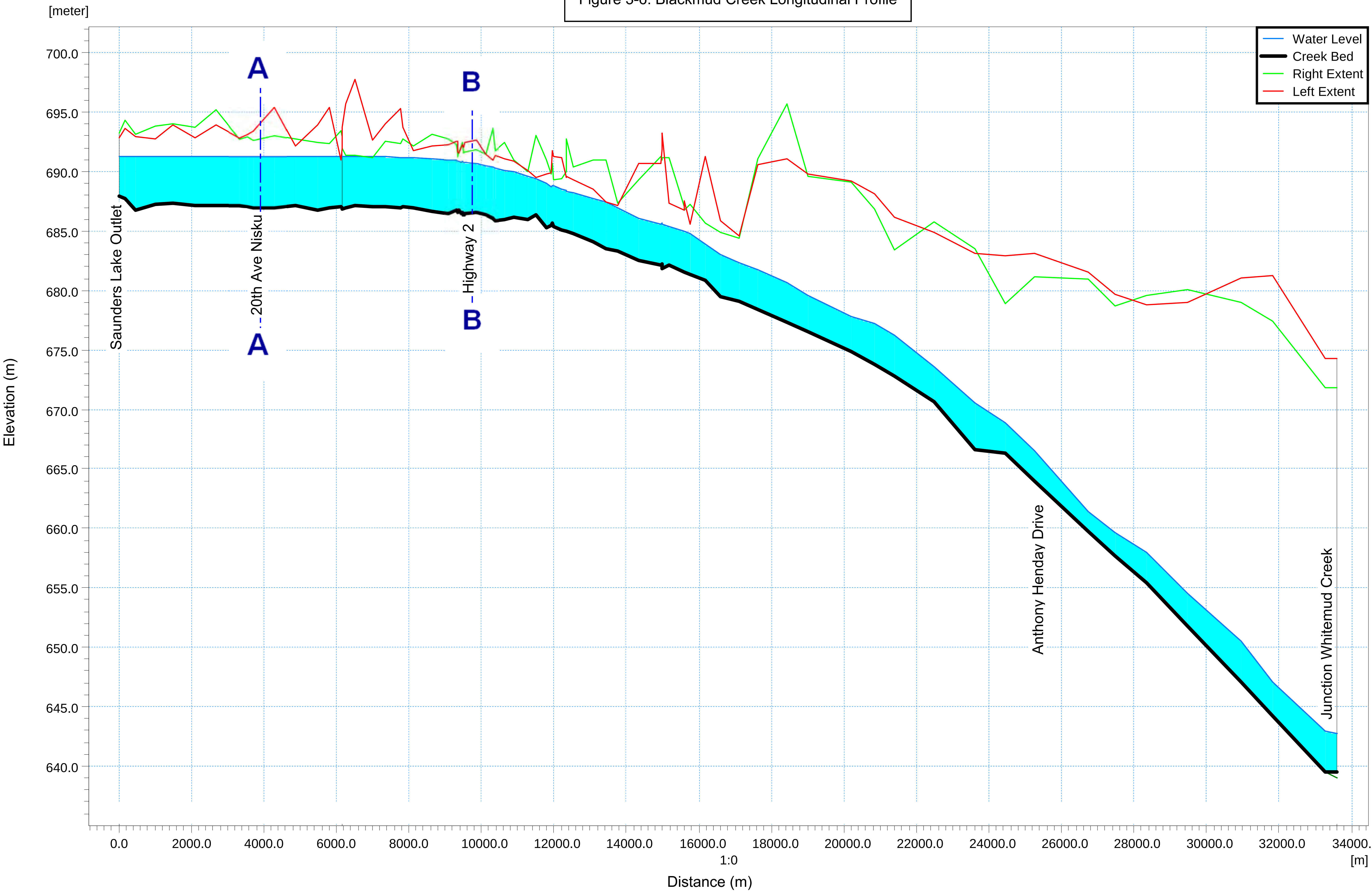


Figure 3-7 A: Blackmud Creek Section A-A

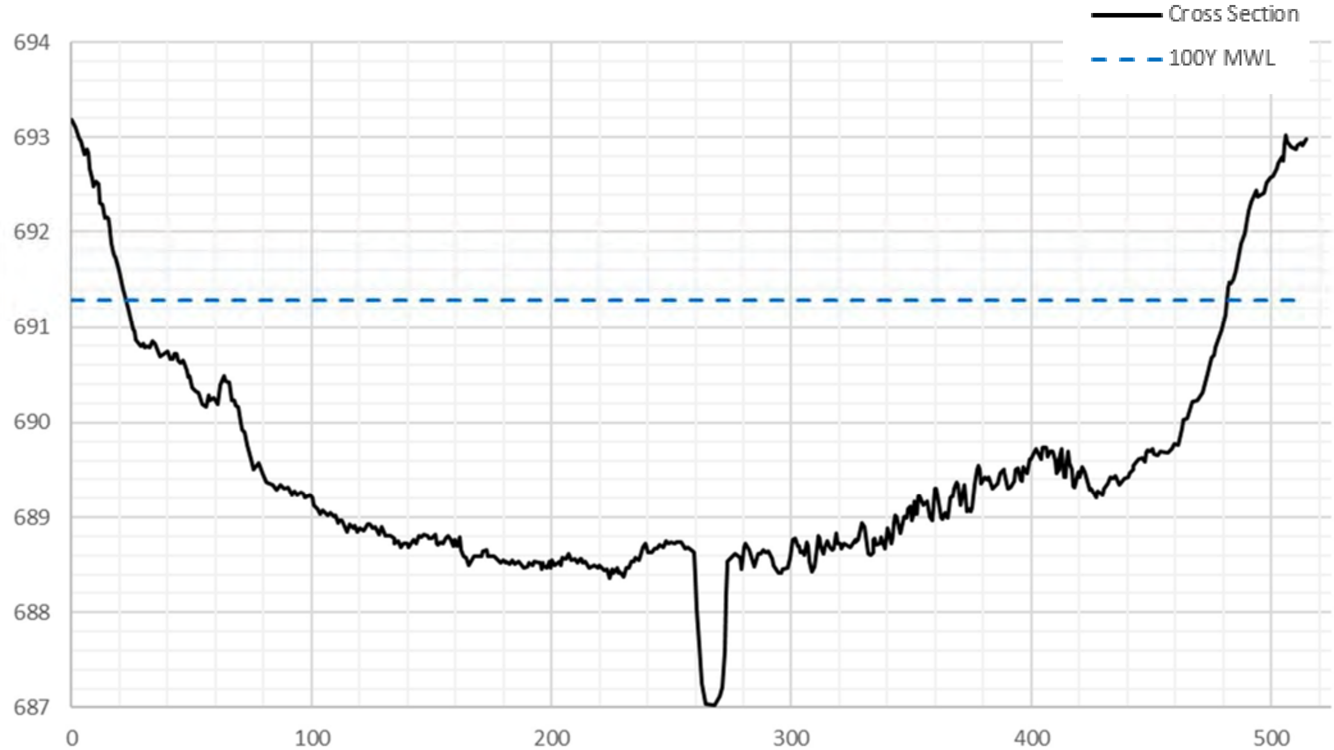


Figure 3-7 B: Blackmud Creek Section B-B

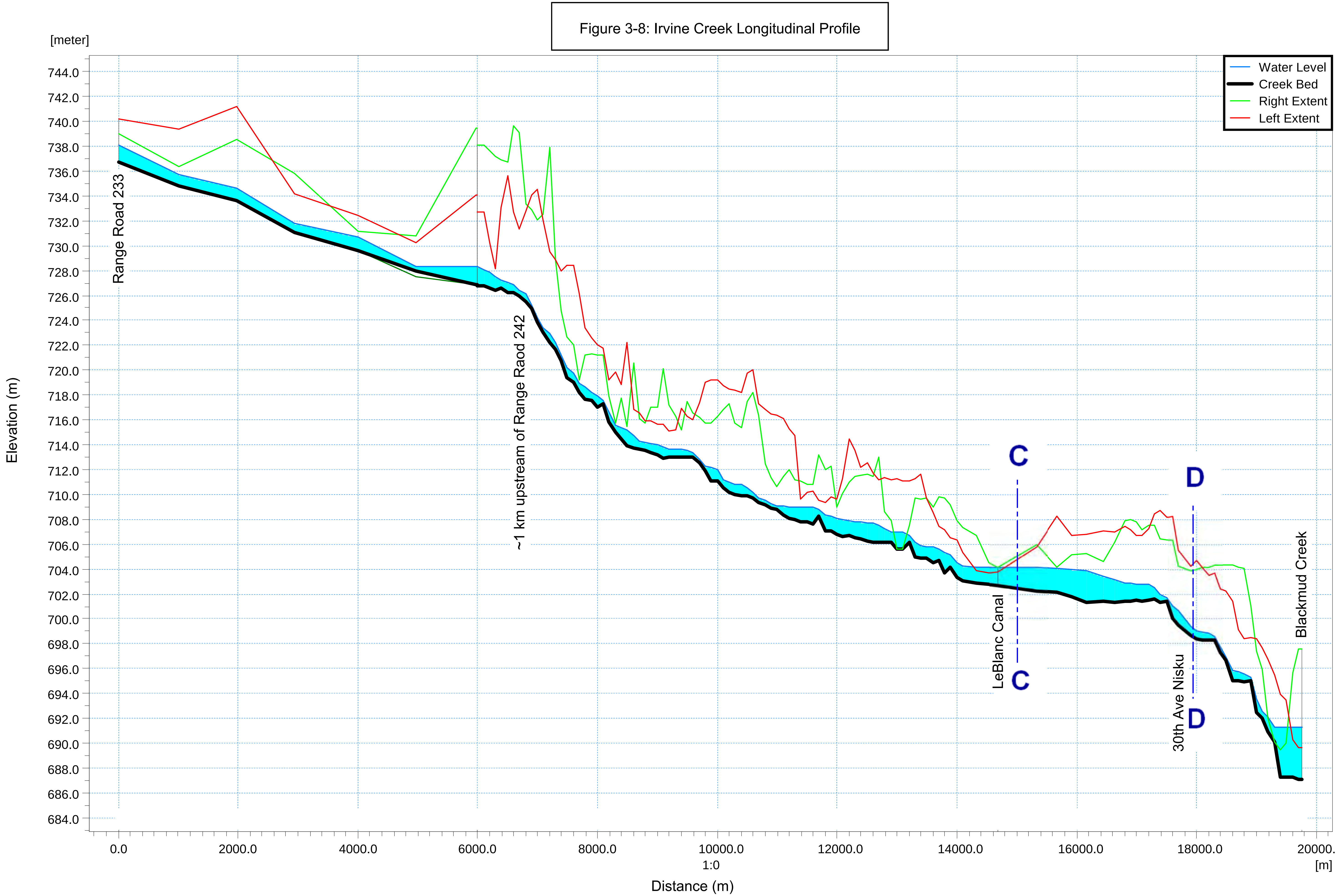


Figure 3-8: Irvine Creek Longitudinal Profile
[meter]
Elevation (m)
744.0
742.0
740.0
738.0
736.0
734.0
732.0
730.0
728.0
726.0
724.0
722.0
720.0
718.0
716.0
714.0
712.0
710.0
708.0
706.0
704.0
702.0
700.0
698.0
696.0
694.0
692.0
690.0
688.0
686.0
684.0
Water Level
Creek Bed
Right Extent
Left Extent
Range Road 233
~1 km upstream of Range Raod 242
C
C
LeBlanc Canal
D
D
30th Ave Nisku
Blackmud Creek
0.0
2000.0
4000.0
6000.0
8000.0
10000.0
12000.0
14000.0
16000.0
18000.0
20000.0
1:0
[m]
Distance (m)

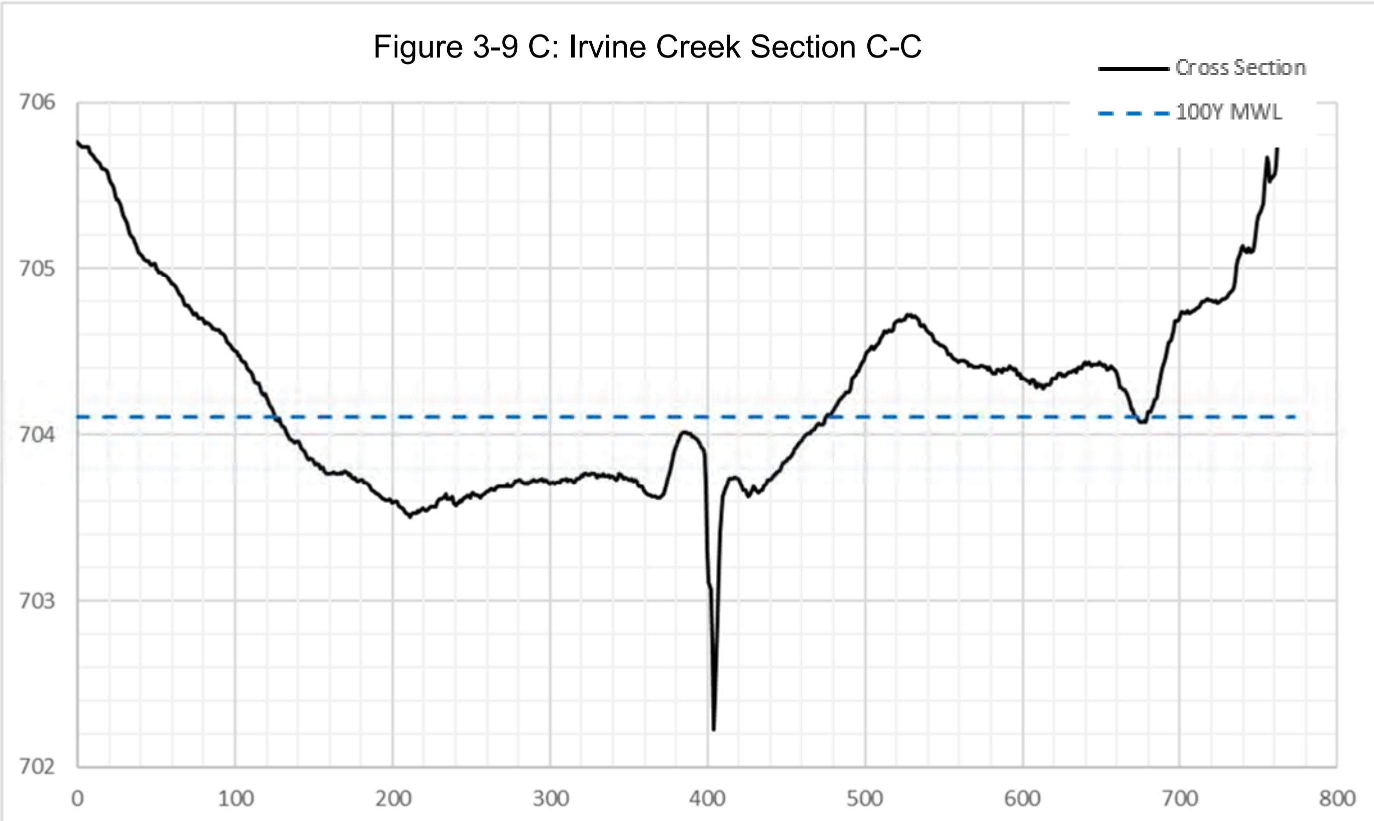


Figure 3-9 C: Irvine Creek Section C-C
Cross Section
100Y MWL
706
705
704
703
702
0
100
200
300
400
500
600
700
800

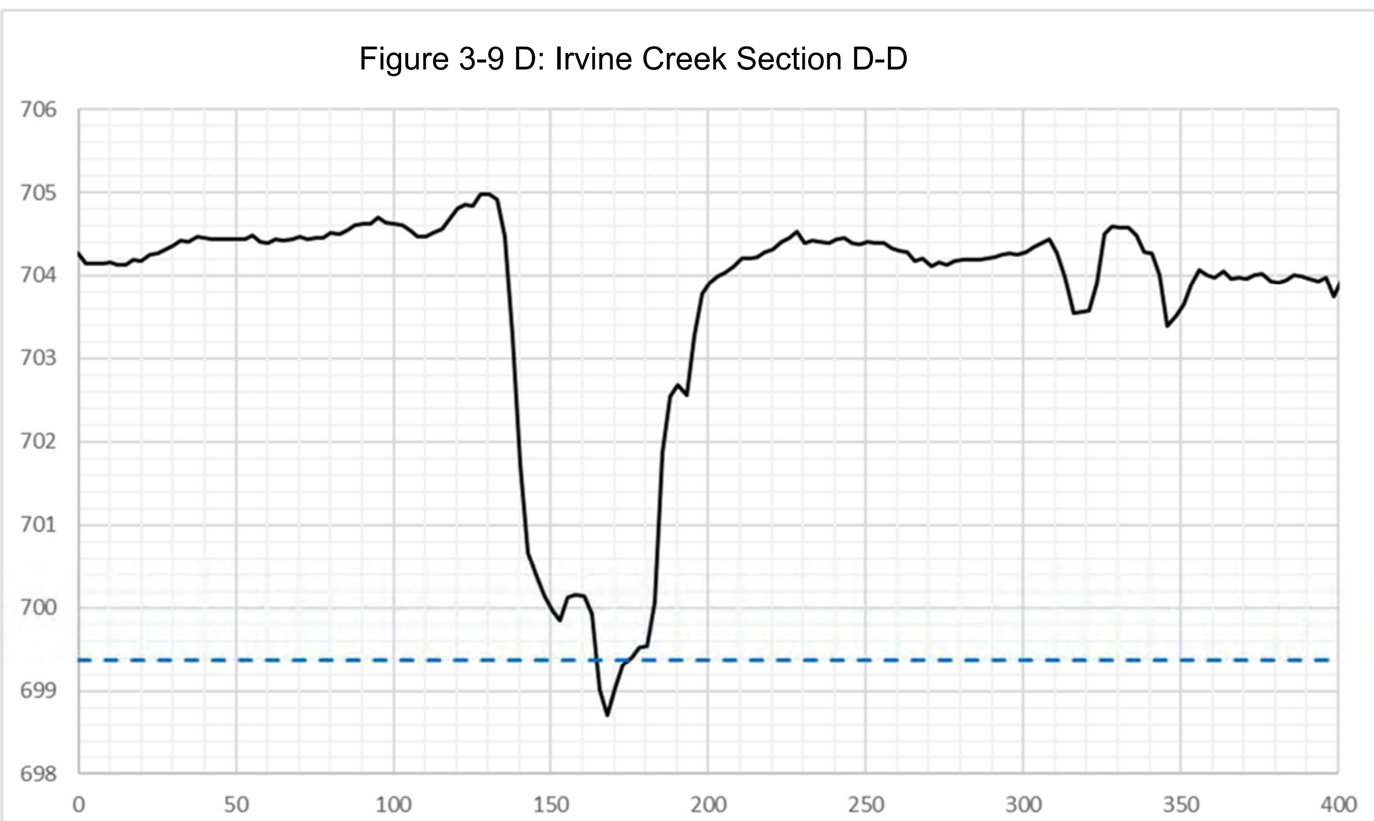


Figure 3-9 D: Irvine Creek Section D-D
706
705
704
703
702
701
700
699
698
0
50
100
150
200
250
300
350
400

Figure 3-10: Deer Creek Longitudinal Profile

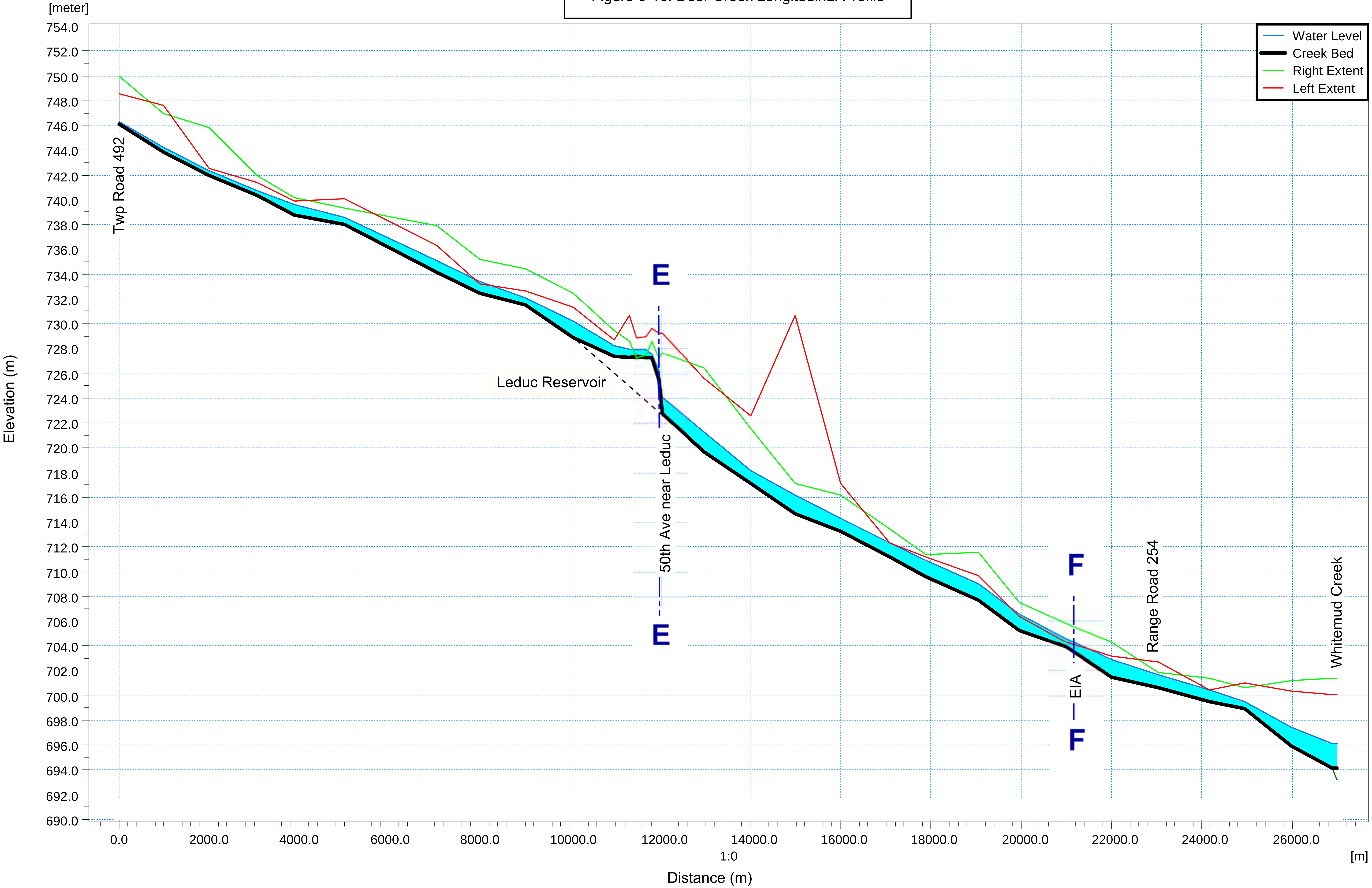


Figure 3-11 E: Deer Creek Section E-E

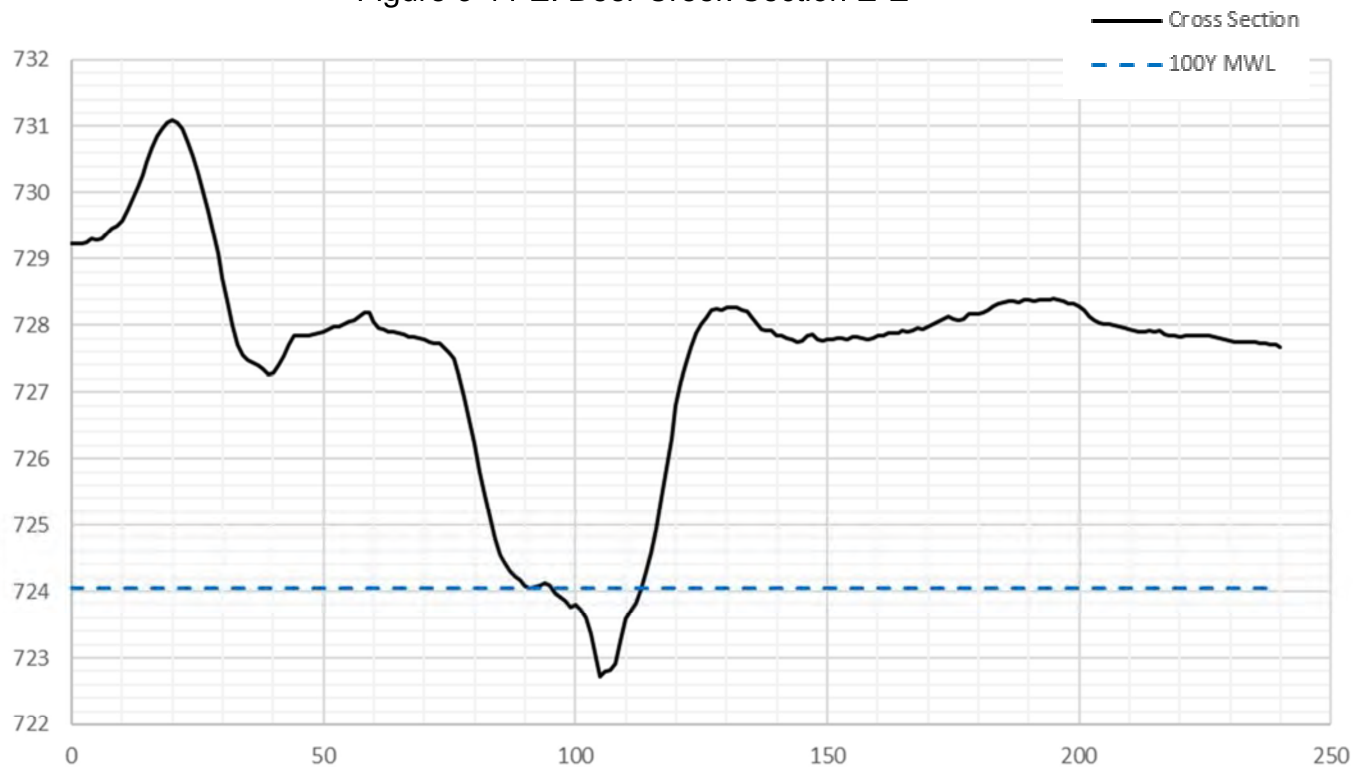


Figure 3-11 F: Deer Creek Section F-F

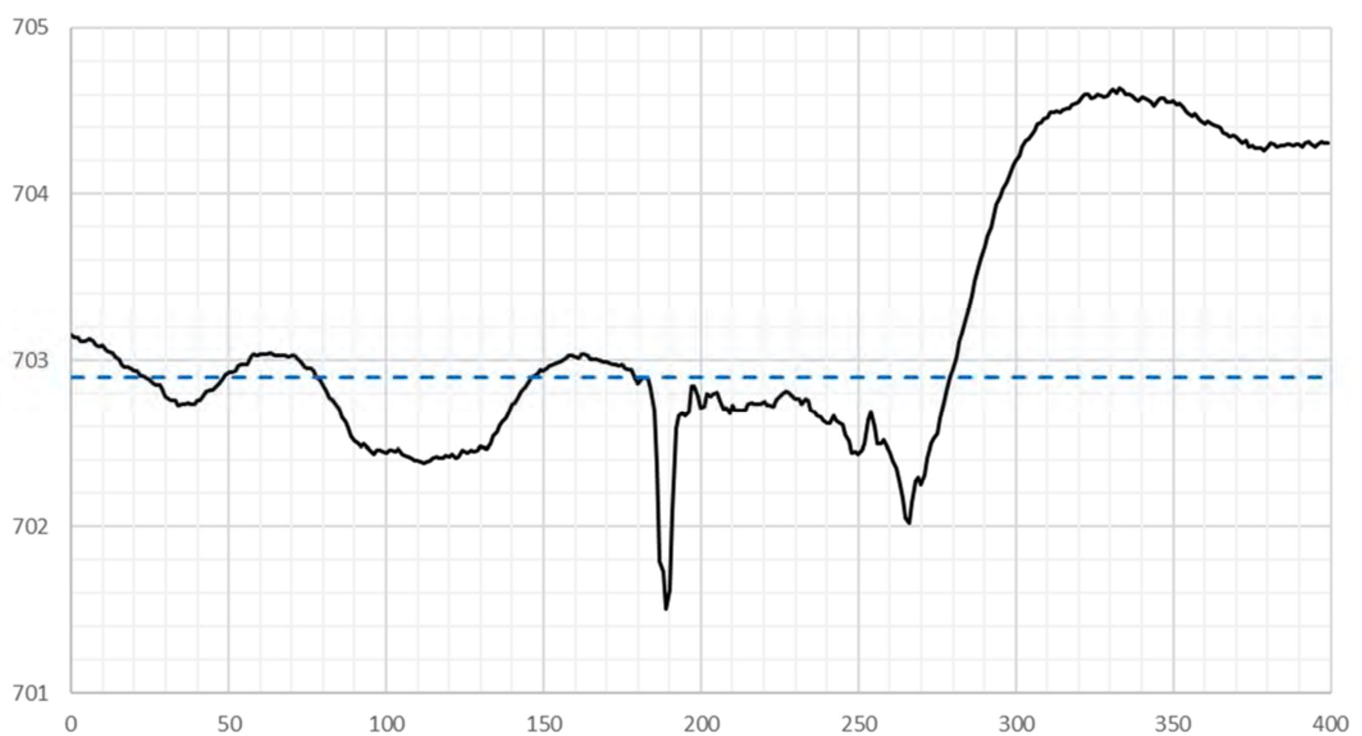
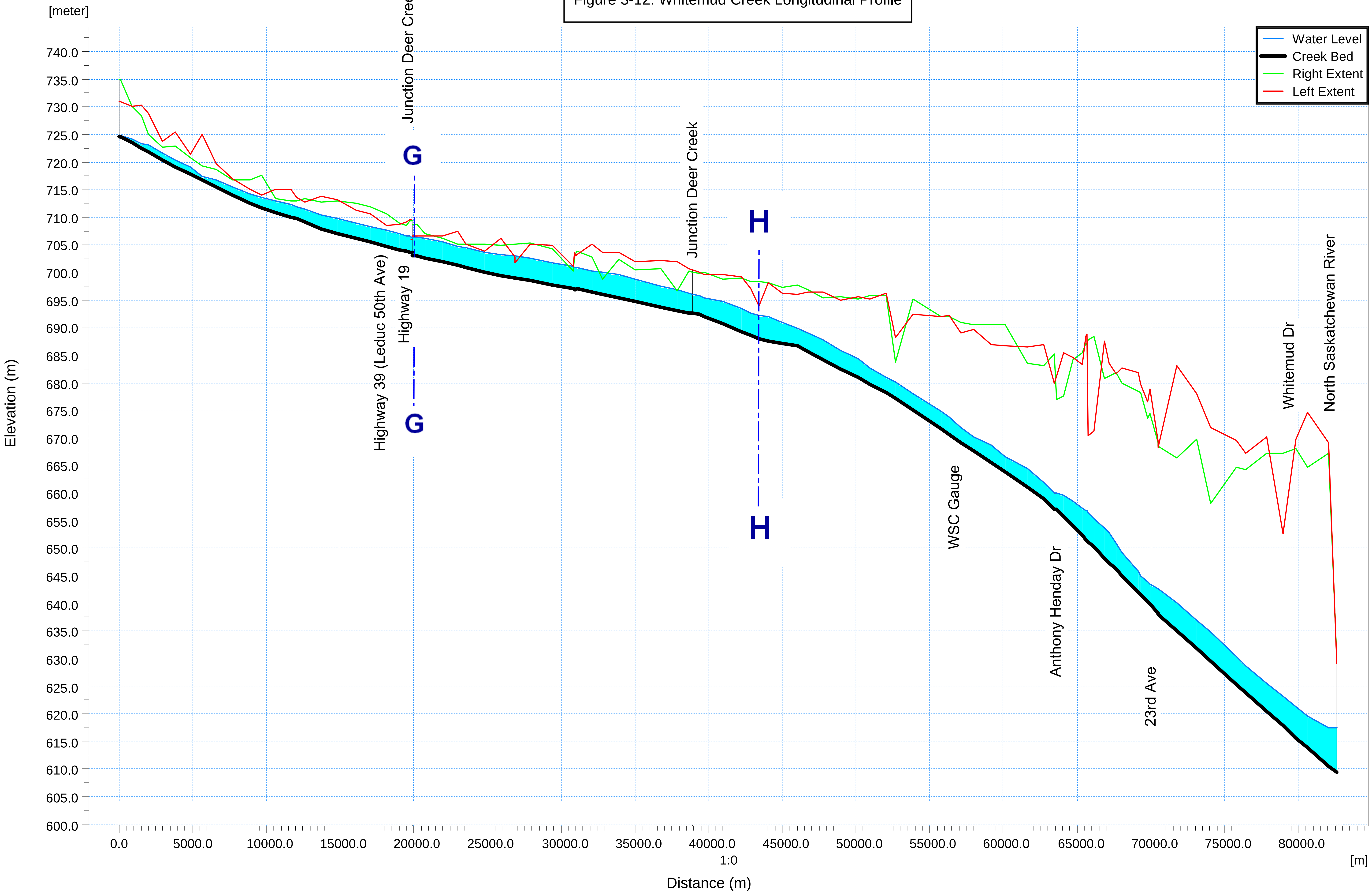


Figure 3-12: Whitemud Creek Longitudinal Profile



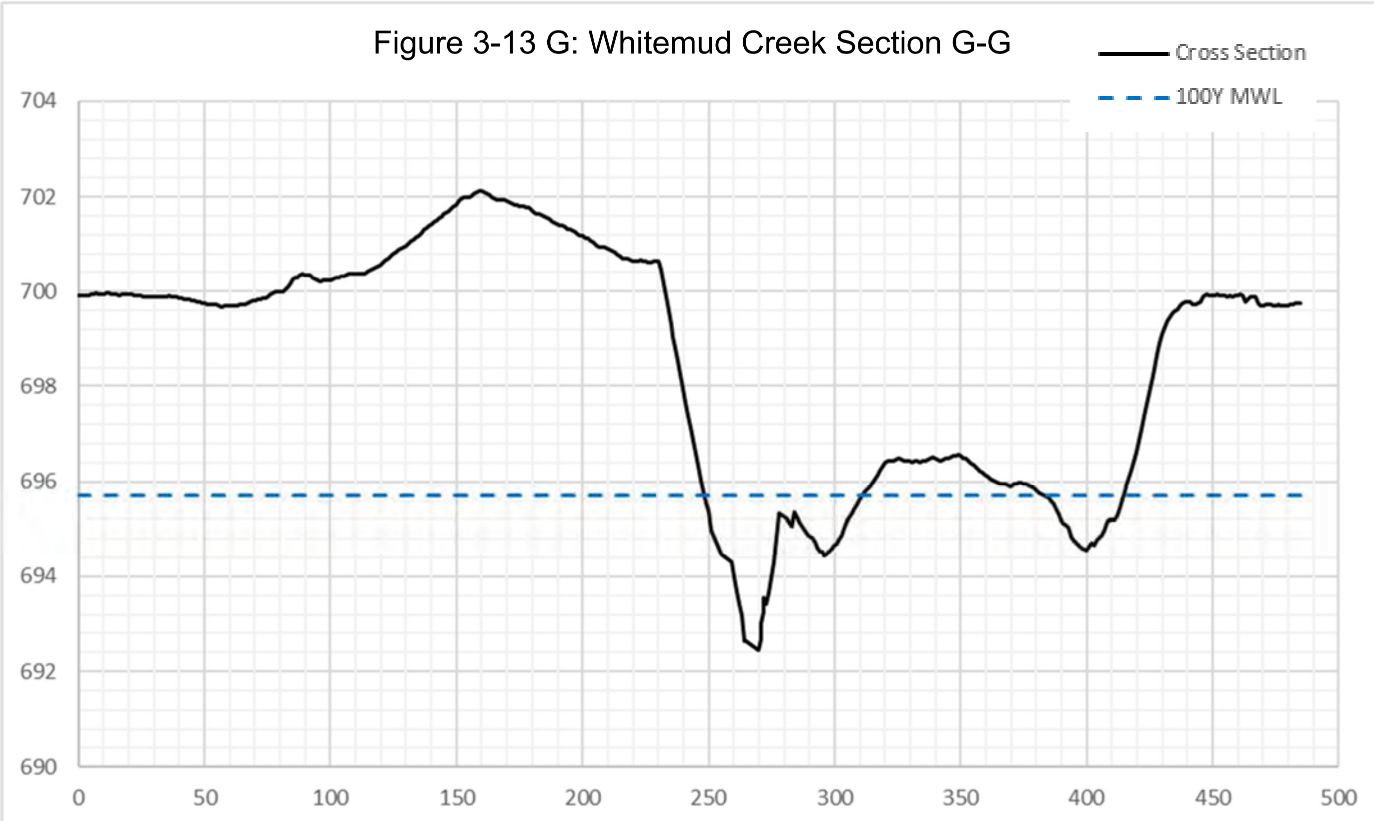


Figure 3-13 G: Whitemud Creek Section G-G
Cross Section
100Y MWL
704
702
700
698
696
694
692
690
0
50
100
150
200
250
300
350
400
450
500

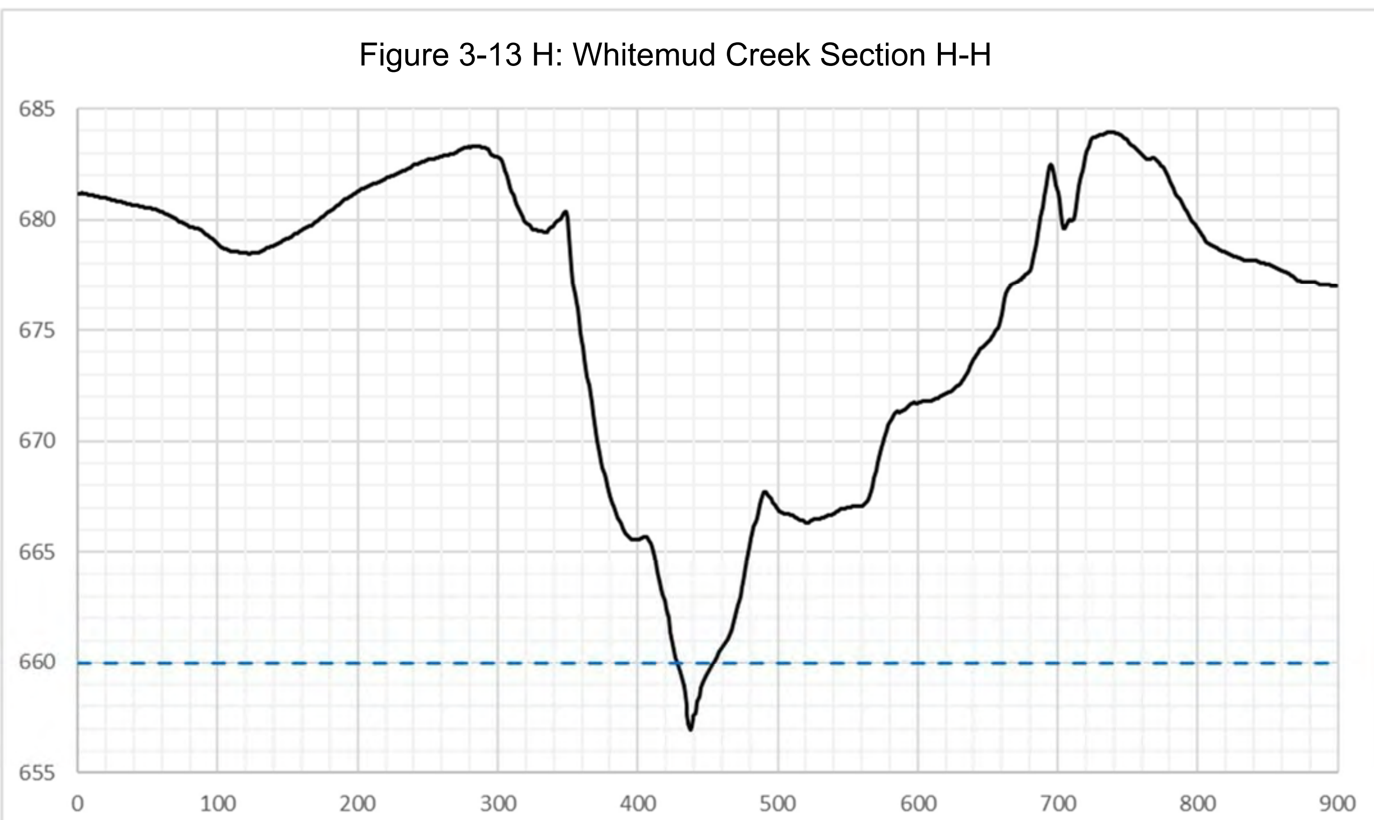


Figure 3-13 H: Whitemud Creek Section H-H
685
680
675
670
665
660
655
0
100
200
300
400
500
600
700
800
900

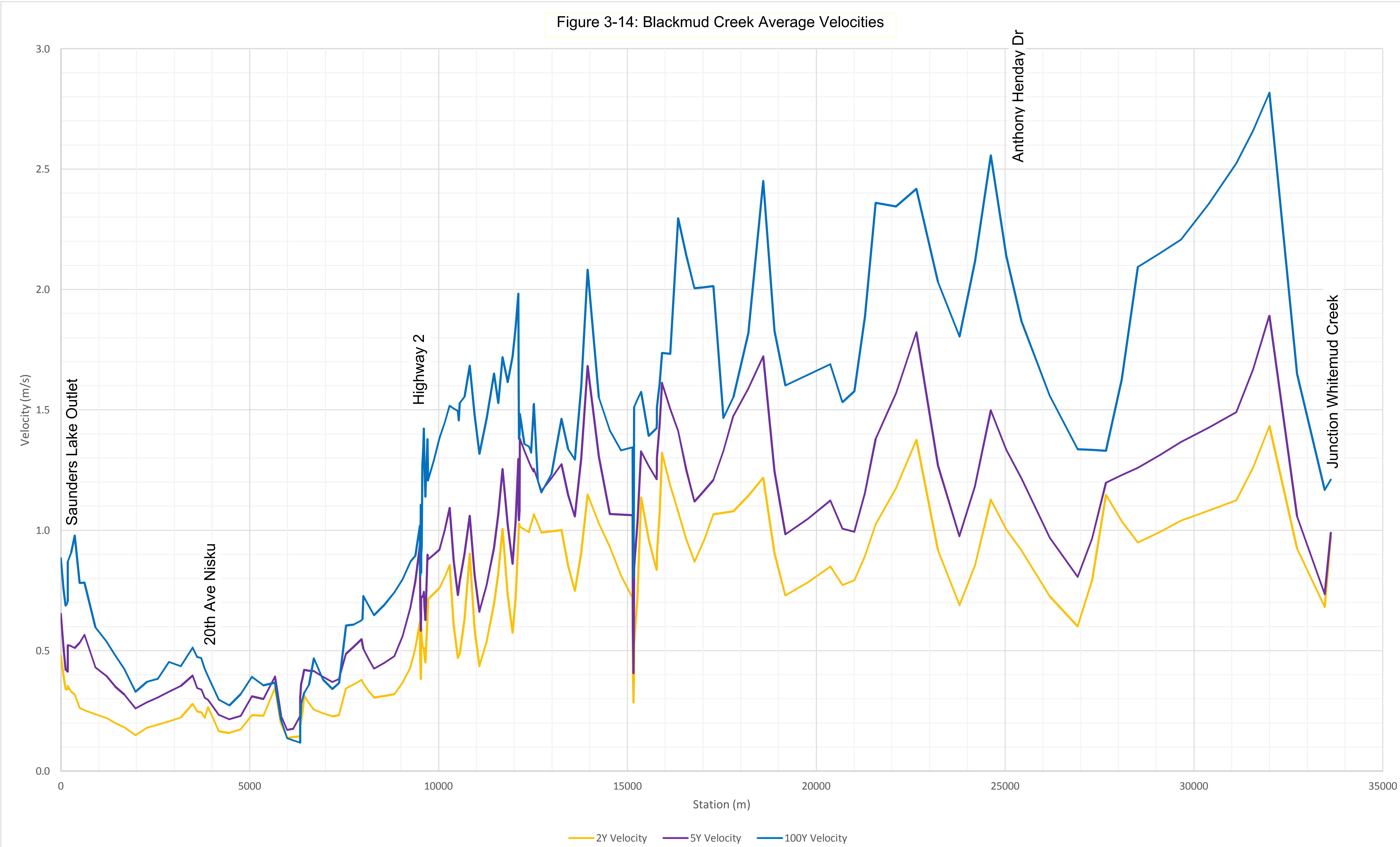


Figure 3-14: Blackmud Creek Average Velocities
Velocity (m/s)
Station (m)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
5000
10000
15000
20000
25000
30000
35000
Saunders Lake Outlet
20th Ave Nisku
Highway 2
Anthony Henday Dr
Junction Whitemud Creek
2Y Velocity
5Y Velocity
100Y Velocity

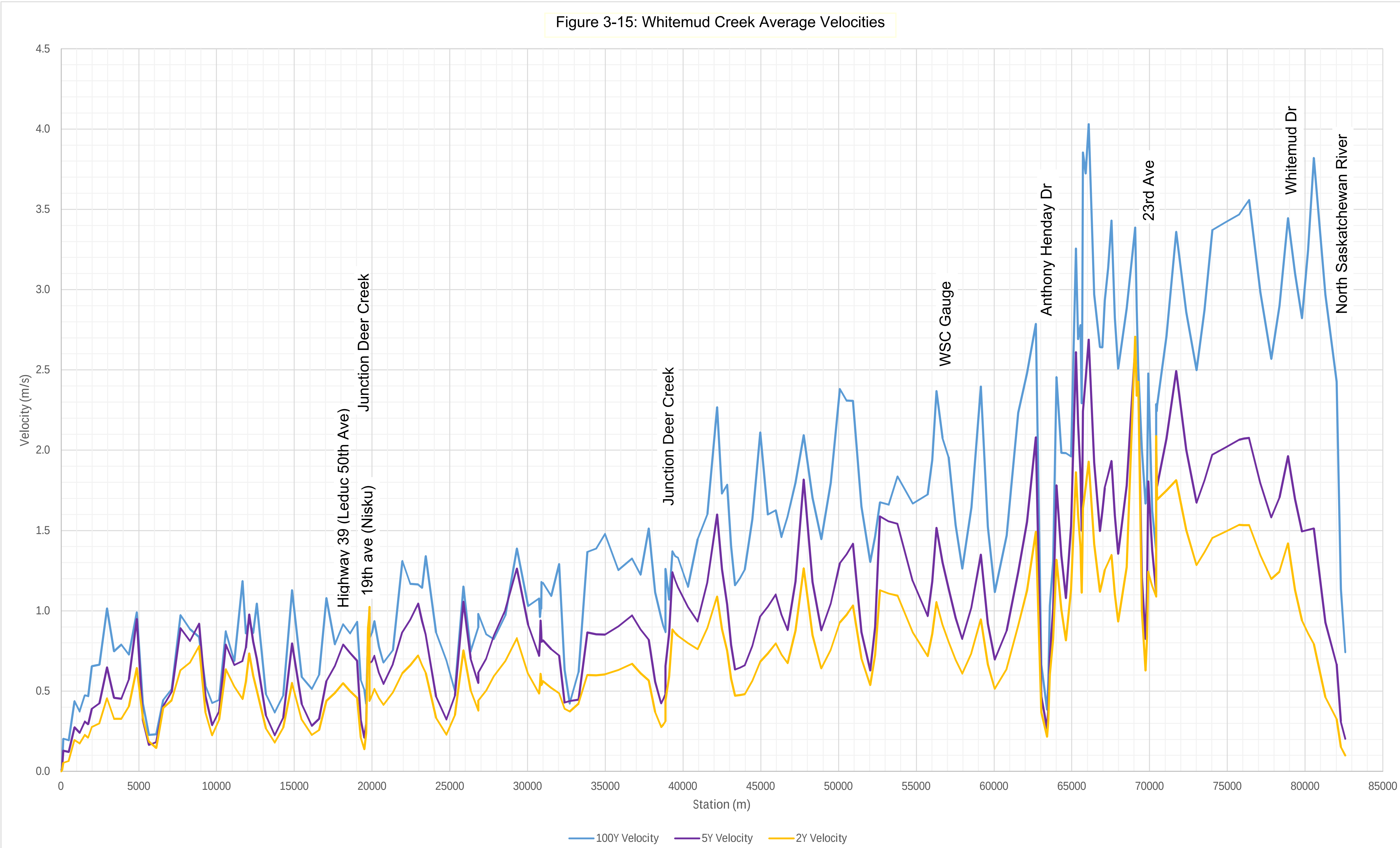


Figure 3-15: Whitemud Creek Average Velocities
Velocity (m/s)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
55000
60000
65000
70000
75000
80000
85000
Station (m)
Highway 39 (Leduc 50th Ave)
Junction Deer Creek
19th ave (Nisku)
Junction Deer Creek
WSC Gauge
Anthony Henday Dr
23rd Ave
Whitemud Dr
North Saskatchewan River
100Y Velocity
5Y Velocity
2Y Velocity

4 2D Model

To better understand the rate and extent of erosion in Whitemud and Blackmud Creeks, a detailed 2D model was developed. This model was used to determine velocity distribution and bed shear stresses along the Blackmud and Whitemud Creeks within the City of Edmonton and will form the baseline against which to measure changes due to development in subsequent phases of this project.

4.1 MODEL DEVELOPMENT

The 2D model extends from the gauge stations on Whitemud and Blackmud Creeks (05DF006 and 05DF003) to the North Saskatchewan River (**Figure 1-2**). The creek topography and floodplain were represented by using LIDAR data and a flexible mesh routine. The flexible mesh routine in MIKE21-FM develops a triangular mesh configuration in which the individual cell spacing is varied to better represent key elements of the topography such as the channel alignment than does a rectangular grid. The mesh sizes and arrangement affect the resolution of the final results and require a compromise between mesh resolution and run times. A 5 m mesh size was used within the creek and a range between 10 m and 100 m sizes were used for the floodplain.

Inflow boundary conditions were consistent with those adopted in the 1D model. However, the downstream boundary was represented as a negative discharge to avoid instabilities in the model. Roughness coefficients (Manning's n) of 0.035 within the creeks and 0.1 along the floodplain were used, consistent with the values used in the 1D model.

4.2 2D MODEL RESULTS

The maximum flows, water depths and velocities for existing conditions were simulated for the 1:2, 1:5, and 1:100 year design events. **Appendix E** presents the maximum velocity distribution along the creeks for the 1:2, 1:5 and 1:100 year design events. These results will be summarized below.

4.2.1 Channel Velocity and Bed Shear Stress

Figures 4-1 to **4-3** show a sample of the simulated velocities for the 1:2, 1:5 and 1:100 year design flow conditions, respectively, for a representative site located at the junction of Whitemud and Blackmud Creeks upstream of 23 Avenue. These maps show that the flow is mostly confined to the channel in the 1:2 year flood and some overbank flow occurs in the 1:5 year and 1:100 year floods as would be expected. These maps clearly show that the velocities are higher in the channel than in the floodplain, as would be expected, and that they increase with increasing flow. Typically, the highest velocities occur at the outside of the meander bends, as expected.

As stated in the previous section, bank erosion is common throughout the lower reaches of Blackmud and Whitemud Creeks. In general, the rate of bed and bank erosion is related to the velocity of water flowing in the channel. Vertical changes in these velocities produce shear forces that are parallel to the bed. These shear forces acting on the bed of a channel generate shear stress, which causes bedload transport or erosion, and the rate of erosion is generally higher where the velocities are higher.

Instream erosion is actively occurring at many meander bends throughout the lower reaches of Blackmud and Whitemud Creeks. In part measure this is due to the higher velocities at these locations and in part due to other processes that govern the lateral migration that occurs naturally at bends.

The erosion process is complicated and depends on a number of factors such as bed and bank materials and local hydraulic effects. Hydraulic theory indicates that the rate of sediment transport is proportional to the 3rd power of velocity or, alternatively, the shear stress raised to a power of 1.5, which means that erosion rates are very sensitive to changes in velocity. It is clear that increasing the creek flow would increase the local velocities and therefore the rate of erosion and sediment transport. These issues will be explored in the next phase of this project, for which the simulated velocities will form a baseline against which those changes resulting from future development can be measured.

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

IF NOT 25 mm ADJUST SCALES 25 mm

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DATE: 1/23/2017,

Associated Engineering

Note: Maps are preliminary and subject to change.

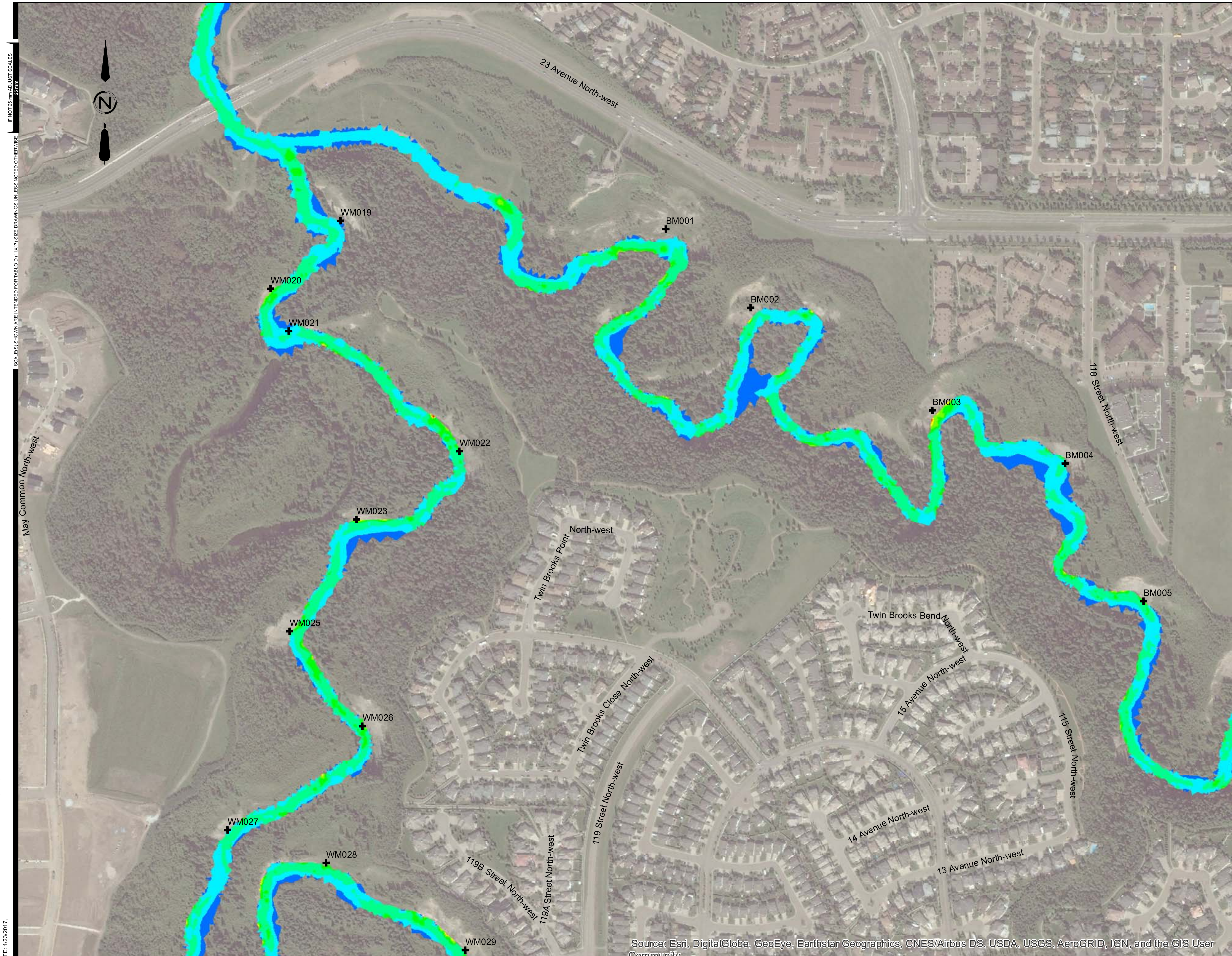
FIGURE No. 4-1

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

2 YEAR
VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

THIS DRAWING IS FOR THE USE OF THE CLIENT AND PROJECT INDICATED - NO REPRESENTATIONS OF ANY KIND ARE MADE TO OTHER PARTIES



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DATE: 1/23/2017,

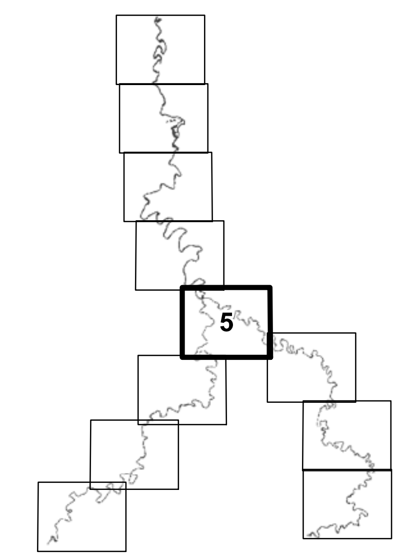
Associated Engineering

Legend:

✚ Erosion Site

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



Note: Maps are preliminary and subject to change.

FIGURE No. 4-2

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

5 YEAR VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

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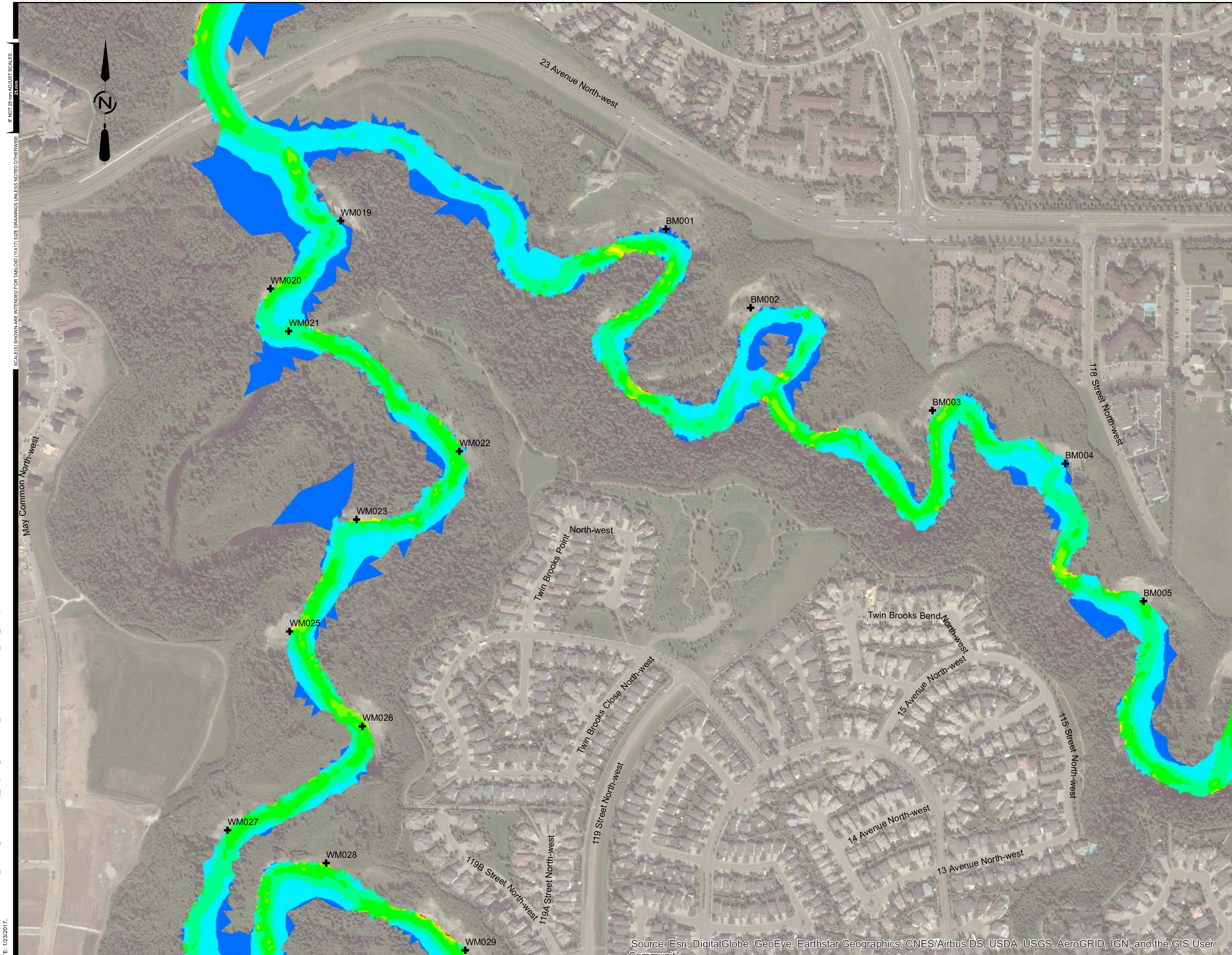

Associated Engineering

Legend:

- ✚ Erosion Site

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5

5

Note: Maps are preliminary and subject to change.

FIGURE No. 4-3

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

100 YEAR VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

IF NOT 25 mm ADJUST SCALES 25 mm

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

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DATE: 1/23/2017.

5 Limitations

The accuracy of the models developed in this task is limited by several assumptions and limitations, principally the following:

- Design flows were estimated from a statistical analysis of limited hydrometric data at three locations (and more recently a fourth location) in the basin having approximately 45 years of data. This was significantly skewed by one single runoff event (1974) and had to be extrapolated to a 1:100 year return period. Furthermore, the historic discharge data have already been impacted by development in the basin. This development impact has increased over the time frame of the monitor data. The design flows presented herein are AE's best estimates based on engineering judgement and the available data.

- Channel cross-sections were developed from LiDAR data, previous studies, and limited topographic survey and may not accurately represent the actual cross-section or the capacity of the channel at low to intermediate flows. The effect of this approximation diminishes at higher flows where a larger portion of the total flow is carried by the floodplain.

- The models are essentially un-calibrated, due to the lack of data required to do so. Some calibration was previously completed in the Flood Hazard Study which provided guidance for the model parameters adopted herein.

Notwithstanding these limitations, the models are deemed to be adequate for planning purposes and for development of an overall water management strategy for the basin. They are no substitute for more detailed site-specific analyses that will be required during implementation of the strategy. They do provide an assessment of baseline hydraulic conditions against which the potential impacts of future development can be measured.

The models are steady-state, based on AE's best estimate of a peak design flow rate for current conditions. The software is capable of fully-dynamic simulation which could be used to simulate flows and water levels using precipitation and weather data from the Edmonton International Airport, to extend the period of recorded flow data, and to better define the interactions between the runoff from urban and rural areas. Ultimately this option is limited by the availability of the required weather data at only one location within a basin of approximately 1,000 km^2 and by the uncertainties involved in rainfall-runoff modelling. In particular, the runoff from snowmelt events in a cold climate, with frozen ground conditions during snowmelt such as occur in Edmonton, is poorly understood and not well simulated with currently available software although some progress has been made in recent years and a practical snowmelt model may soon be available. These limitations provide a severe impediment to improving the estimates that are possible with a steady-state model.

6 Conclusions

The project area creeks were found to have capacity for peak flows that will occur in a 1:2 to 1:5 year return period flood. Localized flooding occurred in the 1:100 year event but was mostly confined to the natural creek floodplains, except in portions of Irvine Creek, Leblanc Canal, Deer Creek, and the glacial spillway valley of Blackmud Creek in the vicinity of Leduc County where extensive overbank flooding occurred. Previous attempts to improve the drainage in these areas had provided capacity for at best the 1:5 year flood.

The majority of the creeks within the basin have complex geometry, are small, lack well defined channels, and have limited channel capacity to convey runoff flows from the existing development. These conditions will constrain future development in the following ways:

- The extent of flooding will constrain development. In some locations along the Blackmud Creek, Irvine Creek, Deer Creek, and Leblanc Canal the flood-risk areas are extensive. The Municipal Government Act empowers municipalities to preserve floodplain areas as Environmental Reserve (land subject to flooding) at the time of development but these powers are not always applied consistently or uniformly. Where extensive overland flooding occurs, it is not always practical to sterilize large areas from development, and these locations should be considered as possible sites for stormwater management ponds or wetlands. A policy for protecting floodplains that recognizes the flood risk and the environment values they create should be developed.

- Along with the extensive flooding, some of the creek channels, in the same locations as above, are too shallow to permit drainage of adjacent development using a conventional underground pipe system. Typically, a depth of 4 m from adjacent land areas to channel bottom is required and in many places this does not exist. Alternatives need to be considered such as:

    - a surface drainage system
    - channel deepening and widening to provide the required capacity (a drainage parkway)
    - a trunk storm sewer system to carry outflows from stormwater management facilities to a safe and reliable discharge point
    - Low-Impact Development standards to reduce the volume and peak runoff rates to pre-development levels

- Erosion issues in Whitemud and Blackmud Creek are understood in only a general way and could be aggravated by increasing runoff volumes and flood peak discharges resulting from further development in the basin. There are no reliable models of the erosion process to give ***quantitative*** estimates of the erosion rates and the impacts of the changing flow regime that will occur with development, but a ***qualitative*** estimate is possible from the model-simulated velocities and shear stresses and morphological principles that relate these hydraulic parameters to the rate of sediment transport.

Existing development in the basin has undoubtedly increased the runoff volume and may have increased peak flows, flood risk, and erosion rates. Some of the older areas were developed before these impacts and the importance of managing stormwater were understood and these older areas discharge directly into the receiving streams without any control. More recent developments have been completed with differing discharge rates in different municipalities and have changed over time for lack of an overall basin water management plan. We have not attempted to quantify these historic impacts but the possibility of further impacts due to anticipated development should be recognized going forward.

Channel velocities in Blackmud and Whitemud Creeks generally increase from upstream to downstream, reflecting the increase in discharge and longitudinal slope, and generally correlate with the bank erosion processes that have been observed. These erosion processes are the results of natural and human influences including previous historic development in the basin since the land was first cleared for agriculture and urban development.

The City of Edmonton has developed and has begun to implement a strategy for erosion control in Whitemud and Blackmud Creek but much work remains to be done. There is significant potential for the existing conditions to worsen if runoff from future development is not adequately managed. Streambank erosion is very sensitive to increases in velocity and flow and could potentially be impacted by development upstream. These potential impacts will be further evaluated in the next phase of this project.

TECHNICAL MEMORANDUM NO. 4

Closure

This report was prepared for the Blackmud/Whitemud Creek Surface Water Management Group to summarize the hydrology and hydraulic modelling results for the Blackmud and Whitemud Creeks.

The services provided by Associated Engineering Alberta Ltd. in the preparation of this report were conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No other warranty expressed or implied is made.

Respectfully submitted,
Associated Engineering Alberta Ltd.

PROFESSIONAL ENGINEER AKINBOLA GEORGE ALBERTA

May 30, 2017

Akinbola George, M.A.Sc., P.Eng., PMP
Project Technical Lead

PROFESSIONAL ENGINEER TONDERAI CHAKANYUKA ALBERTA

May 30, 2017

Tonderai Chakanyuka, MBA, P.Eng., PMP, C.Eng
Project Manager

PROFESSIONAL ENGINEER LARRY E. BODNARUK ALBERTA

May 30, 2017

Technical Review:
Larry Bodnaruk, P.Eng.

ASSOCIATED ENGINEERING QUALITY MANAGEMENT SIGN-OFF	
Signature:	
Date:	MAY 30, 2017

APEGA Permit to Practice P 3979

Appendix A - Pilot Model Memo

Associated Engineering — GLOBAL PERSPECTIVE. LOCAL FOCUS.

Date:	April 27, 2017	**File:**	2016-3785.00.E.03.00
To:	Rae-Lynne Spila, P.Eng.		
From:	Tonderai Chakanyuka, MBA, P.Eng, PMP, C.Eng		
Project:	Blackmud/Whitemud Surface Water Management Study		
Subject:	Pilot Model		

MEMO

1 INTRODUCTION

The Blackmud/Whitemud Surface Water Management Group (Group) retained Associated Engineering (AE) to complete a Surface Water Management Study. This study involved hydrologic, hydraulic, hydrogeologic and environmental analyses of the Blackmud and Whitemud Creek basins.

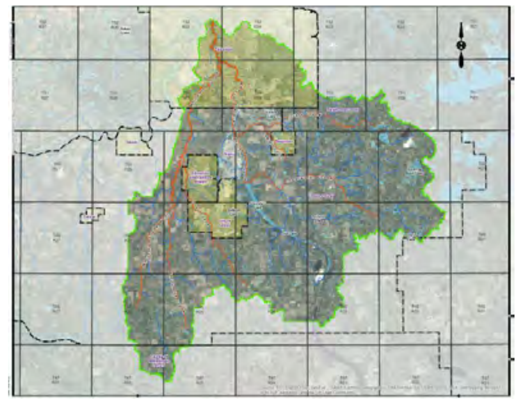


Figure 1-1: Blackmud/Whitemud Creek Basin

A lumped and steady state approach was adopted for the hydrologic and hydraulic modelling phase of the study. This approach required a number of simplifying assumptions compared to a long-term simulation based on a fully dynamic modelling approach. As part of the hydrologic and hydraulic model development, AE developed a pilot model to define the key hydrologic processes, to explore the feasibility of a fully dynamic model, and to try to estimate how conservative the steady-state model would be.

This memo summarizes the pilot model development and simulation results.

2 PILOT MODEL DEVELOPMENT

The extent of the pilot model was the Irvine Creek sub-basin (**Figure 2-1**) which included Irvine Creek and LeBlanc Canal. This sub-basin has a drainage area of approximately 158 km^2 which is about 15% of the entire study basin area. This sub-basin is representative of the hydrology/hydraulic conditions experienced within the basin and was chosen because it experiences the most significant flooding and peak flow attenuation due to routing effects.

Irvine Creek is a tributary of Blackmud Creek located in northeast Leduc County. The Irvine Creek basin includes lands within the Town of Beaumont, the City of Edmonton, Leduc County, and Strathcona County. This area is mostly undeveloped except for the Town of Beaumont. The creek flows in a westerly direction from its upstream point at an unnamed lake east of Highway 21 into Blackmud Creek just south of the intersection of 9th Street and 30th Avenue in Nisku.

Cawes Lake drains into the Irvine Creek watershed in Leduc County but does not have a defined outlet.
LeBlanc Canal also drains into Irvine Creek. The canal drains most of the Town of Beaumont, and Town runoff is controlled with a system of stormwater management ponds.

2.1 MODEL SET-UP

Figure 2-2 provides the schematic of the pilot MIKE 11 model. The model consisted of 45 cross-sections on LeBlanc Canal and Irvine Creek over approximately a 7 km reach from the Town of Beaumont to Blackmud Creek. Boundary inflows were generated using PCSWMM for two locations, representing runoff from the Town of Beaumont and from the upper Irvine Creek basin, upstream of the LeBlanc Canal. The Mike11 model then simulated the routing of this flow through the LeBlanc Canal and Irvine Creek to determine the resulting outflow to Blackmud Creek. It also calculated the water level at each time step at every cross-section in the model.

Cross-sections used within the MIKE 11 model were extracted from the existing Irvine Creek model (Stantec, 2014 Irvine Creek and Cawes Lake Watershed Study) and the 1 m LIDAR data.

Figure 2-3 shows the schematic of the PCSWMM model that was used to generate the boundary inflows. The existing Town of Beaumont PCSWMM model was used to generate an inflow hydrograph to LeBlanc Canal for the 1:100 year, 24 hour design storm event (Huff distribution). The PCSWMM model was expanded to include the Irvine Creek catchment upstream of the Town which was modelled using the following parameters:

Parameter	Value
Ground Slope	Average catchment slope calculated based on LIDAR
Catchment Width	15,000 m
Impervious Area Manning's n	0.015
Pervious Area Manning's n	0.25
Impervious Depression Storage	2 mm
Pervious Depression Storage	5 mm
Percent of Area with Zero Detention	25 %
Maximum Infiltration Rate	75 mm/hr
Minimum Infiltration Rate	5 mm/hr
Decay Constant	4 (1/hr)

Validation of the model for the undeveloped area was completed based on the hydrology assessment carried out for the Blackmud/Whitemud Surface Water Management Study. For this task, basin width was used as a calibration parameter.

For the dynamic model the PCSWMM model was run for the 1:100 year, 24 hour storm duration design storm event (Huff distribution) and the discharge hydrographs were extracted and applied to the Mike 11 pilot model as a time series inflow. For the steady-state model the peak inflows were applied as a steady state boundary inflow at the two inflow nodes.

2.2 MODEL RESULTS

The model results compared a dynamic single-event model to a steady state model for a 1:100 year design storm. This was to determine the impact of flood routing and storage on peak flow and water level within Irvine Creek.

Figure 2-4 compares the routed flow with the dynamic model with those of the steady state model. The results indicated that:

- The peak flow from the urban area coincided with those from the rural area in Irvine Creek. This implies that the peak flows can be added, at least for rainfall events in Irvine Creek.
- The storage and routing effects in Irvine Creek reduce the peak flow by about 5% between the Town of Beaumont and the confluence with Blackmud Creek.

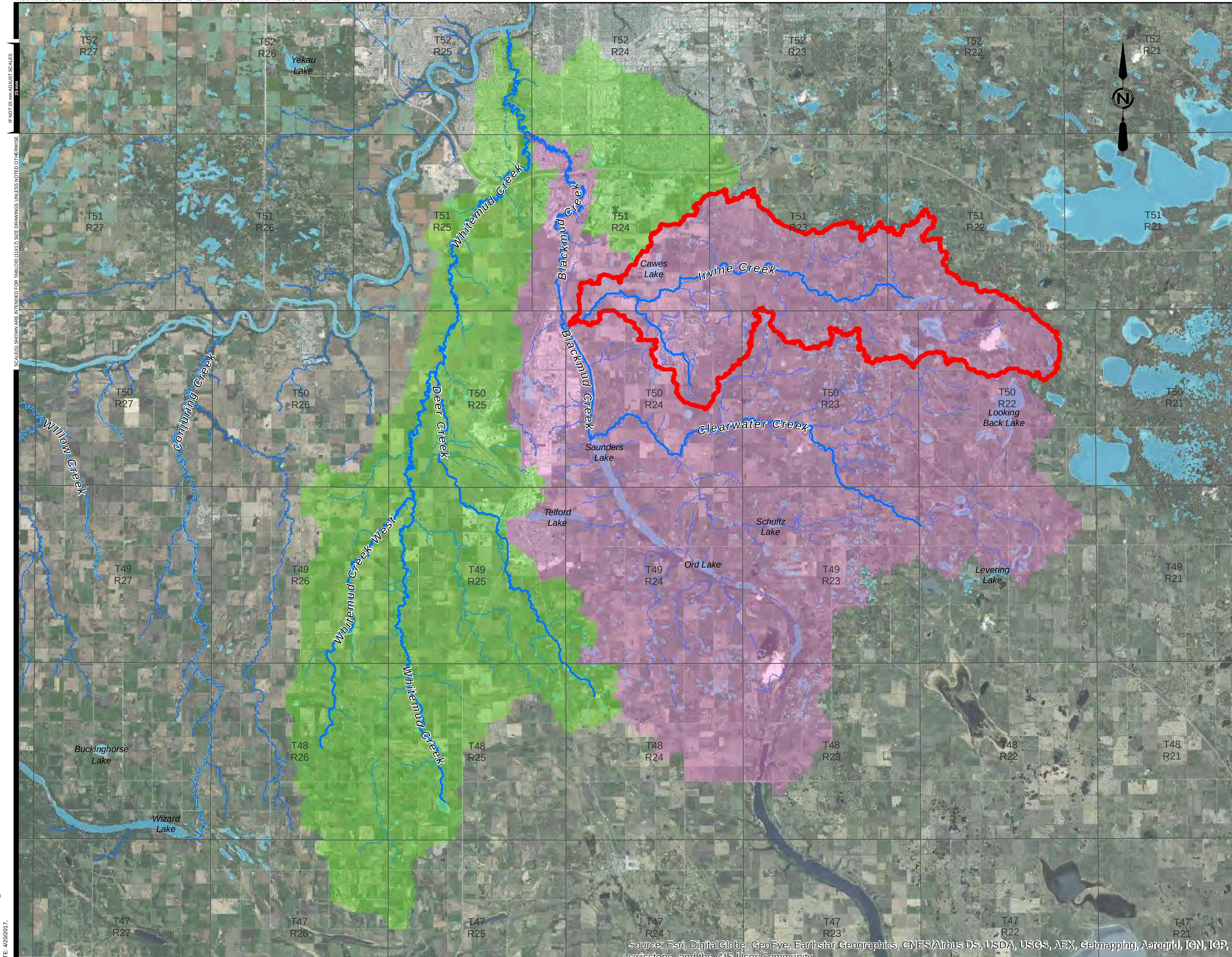
The MIKE11 model required approximately 1 minute to run a 5-day simulation period. Based on this result it is estimated that a dynamic model simulation of the full basin for a 45-year period of recorded flows would require a run time of the order of 30 days. The model run time is affected by the number and spacing of cross-sections, which govern the simulation time step required for stability. The model run time could be reduced by deleting a number of cross-sections, but this would reduce the accuracy of the flood mapping which is a key deliverable of the project and a key consideration in the basin water management plan.

2.3 CONCLUSIONS

The pilot model demonstrated that the urban and rural runoff peaks can be reasonably assumed to coincide, at least for long-duration rainfall events in the Irvine Creek catchment and for urban runoff controlled with stormwater management. Flood storage and routing effects reduced the peak flows by about 5% compared with a steady-state model.

The pilot model also demonstrated that a steady-state model can be made to produce realistic results if appropriate inputs are selected. Also, calibration of the runoff model is required for rural areas and such calibration is hampered by the available flow data at 4 locations and the available precipitation data at only one location. Rainfall varies over relatively short distances and this variability affects our ability to reproduce historic flows.

Finally, the pilot model demonstrated that model run times for a dynamic model would be excessive which limits the practicability of a dynamic model to predict flood levels and extent.



Associated Engineering

Legend:
- Whitemud Creek Watershed
- Blackmud Creek Watershed
- Creek Centreline
- Irvine Creek Sub-basin

FIGURE No. 2-1

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

PILOT MODEL EXTENT

AE PROJECT No.	2016-3785
SCALE	1:200,000
APPROVED	
DATE	2017 APRIL
REV	
DESCRIPTION	ISSUED FOR REPORT

E:\Blackmud\Whitemud\2-2_CatchmentBoundaries.mxd
DATE: 4/20/2017.

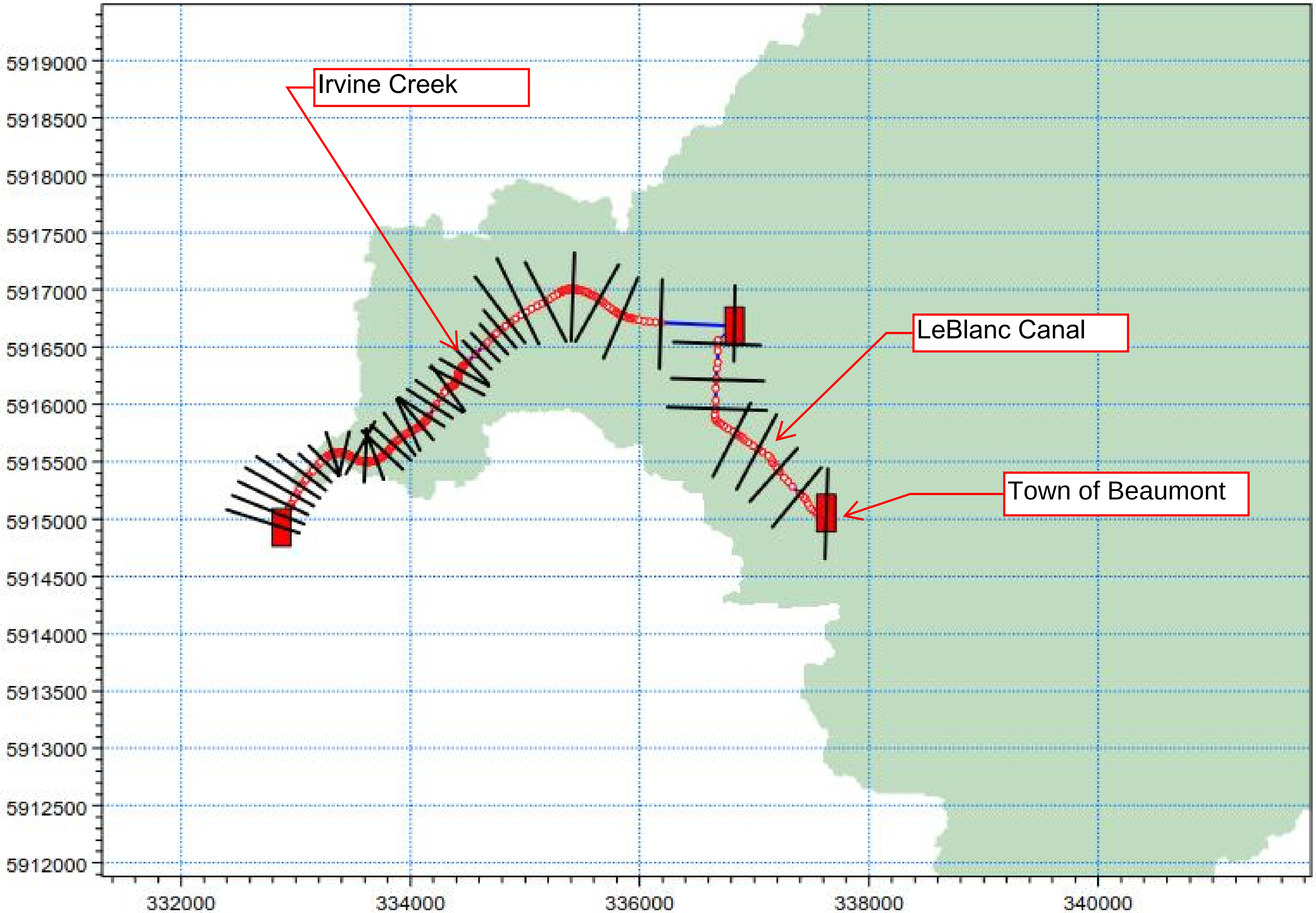


FIGURE No. 2-2

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

MIKE 11 MODEL SCHEMATIC

AE PROJECT No. 2016-3785
SCALE
APPROVED
DATE 2017 APRIL
REV
DESCRIPTION ISSUED FOR REPORT

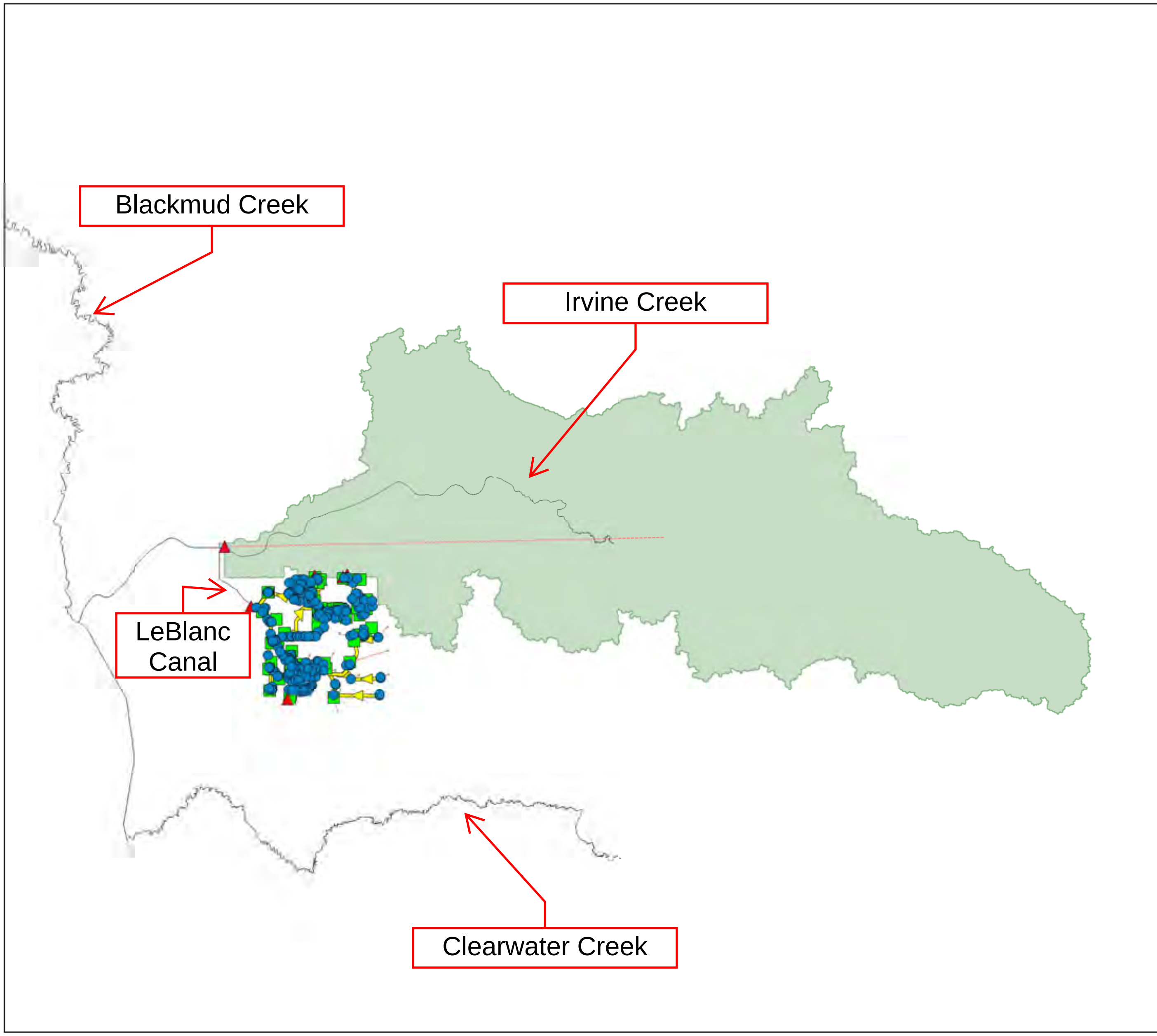


FIGURE No. 2-3

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

PILOT MODEL SCHEMATIC

AE PROJECT No. 2016-3785
SCALE
APPROVED
DATE 2017 APRIL
REV
DESCRIPTION

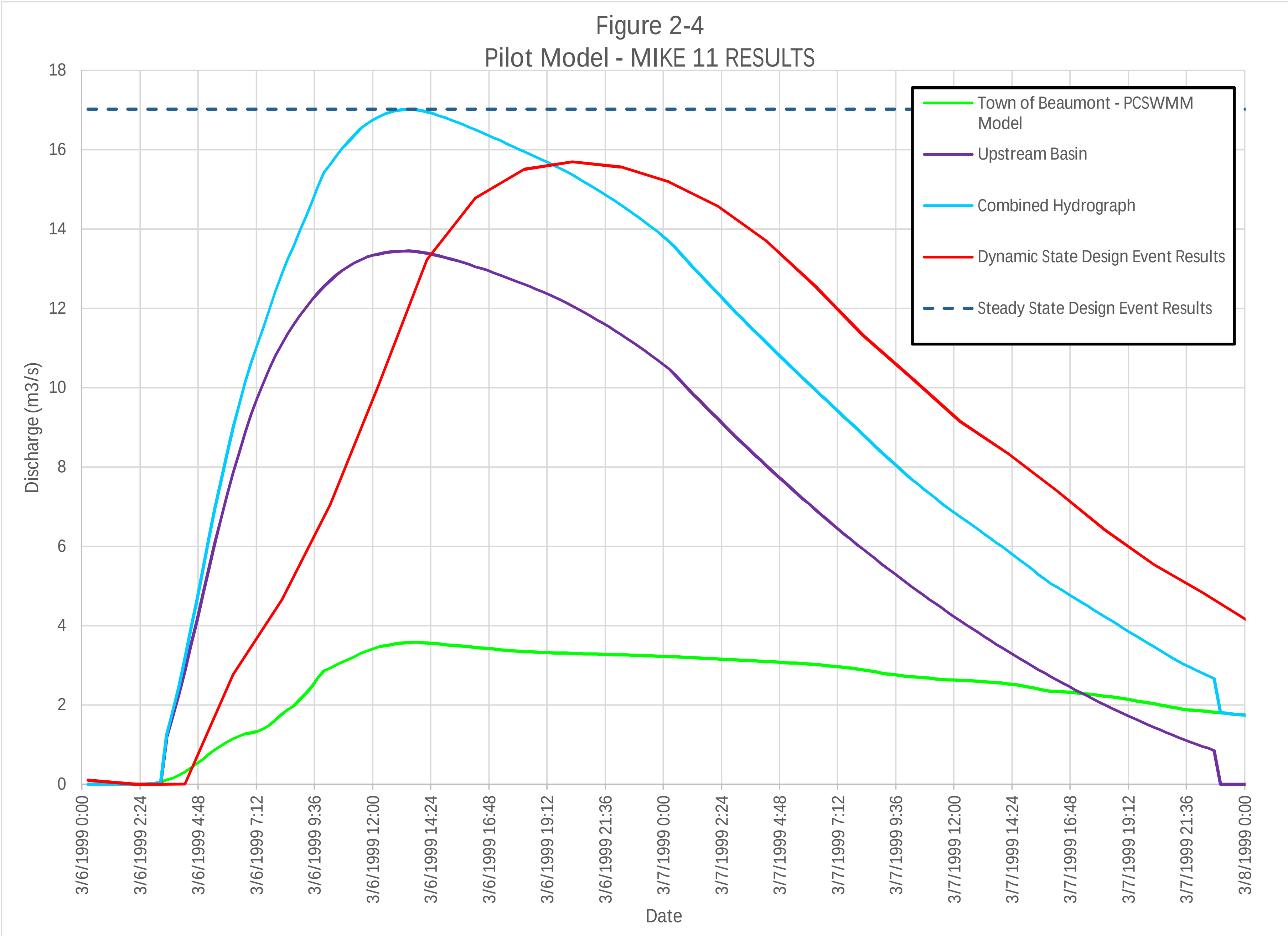
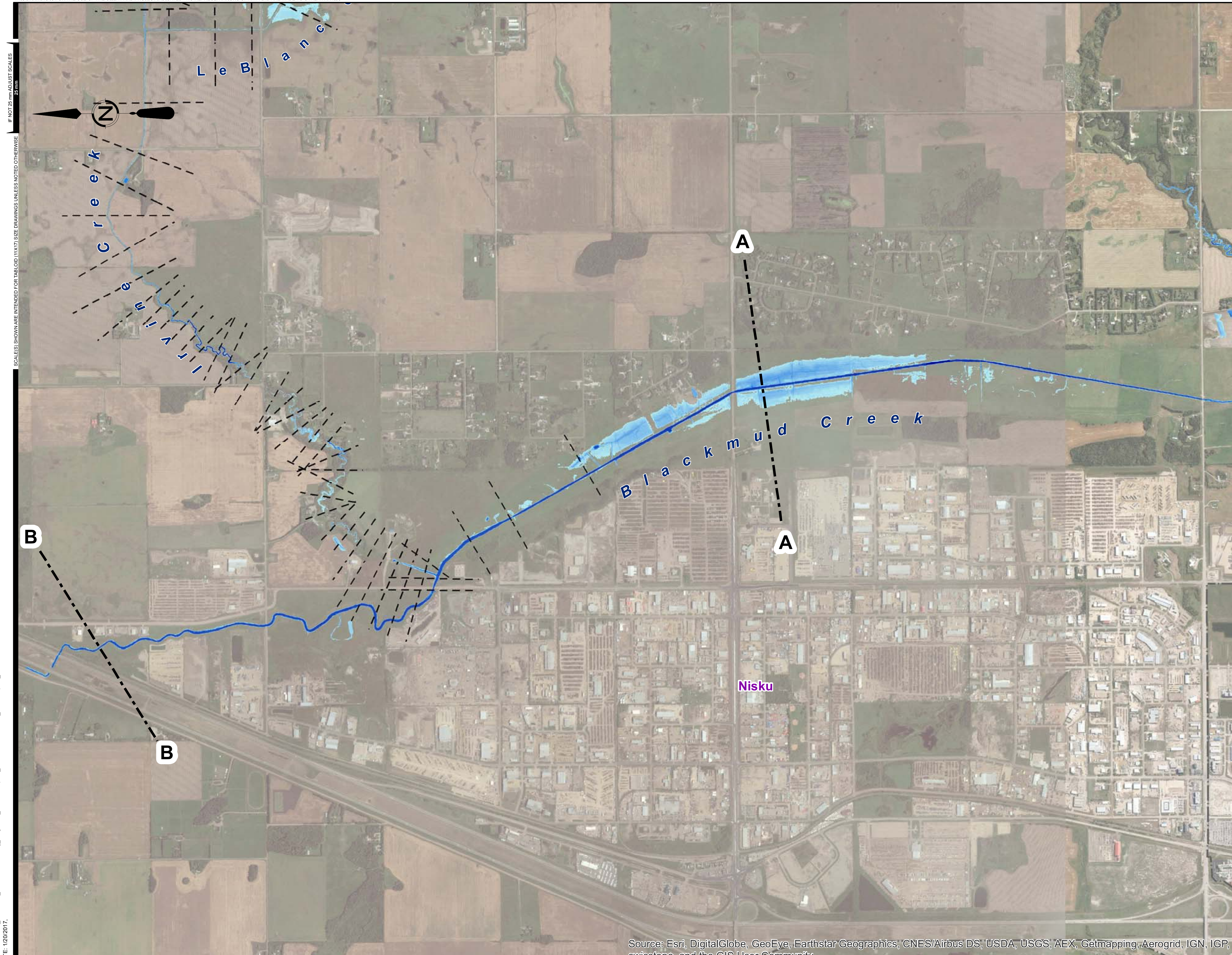


Figure 2-4
Pilot Model - MIKE 11 RESULTS
Discharge (m3/s)
Date
18
16
14
12
10
8
6
4
2
0
3/6/1999 0:00
3/6/1999 2:24
3/6/1999 4:48
3/6/1999 7:12
3/6/1999 9:36
3/6/1999 12:00
3/6/1999 14:24
3/6/1999 16:48
3/6/1999 19:12
3/6/1999 21:36
3/7/1999 0:00
3/7/1999 2:24
3/7/1999 4:48
3/7/1999 7:12
3/7/1999 9:36
3/7/1999 12:00
3/7/1999 14:24
3/7/1999 16:48
3/7/1999 19:12
3/7/1999 21:36
3/8/1999 0:00
Town of Beaumont - PCSWMM Model
Upstream Basin
Combined Hydrograph
Dynamic State Design Event Results
Steady State Design Event Results

Appendix B - Flood Maps



Legend:

Water Depth (2 Year)

High (1.8 m)

Low (0 m)

Cross Section

Municipal Boundary

FIGURE No. A-1

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

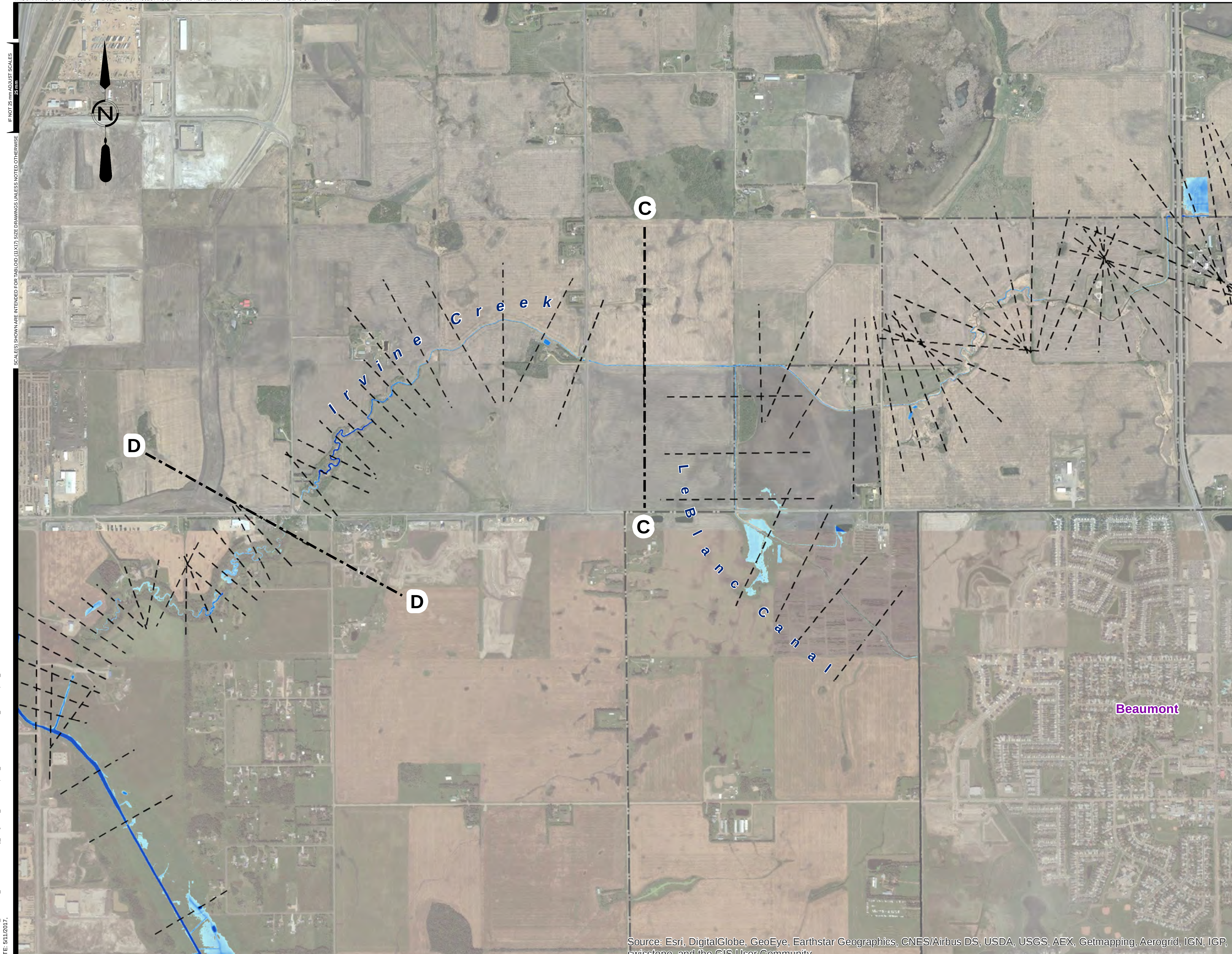
Blackmud Creek 1:2 Year

AE PROJECT No.	2016-3785
SCALE	1:25,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

IF NOT 25 mm ADJUST SCALES 25 mm

P:\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\xxx_CreekDepths_v2.mxd DATE: 1/20/2017,



Associated Engineering

Legend:

Water Depth (2 Year)

High (1.8 m)

Low (0 m)

Cross Section

Municipal Boundary

FIGURE No. A-2

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

Irvine Creek 1:2 Year

AE PROJECT No.	2016-3785
SCALE	1:20,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE
IF NOT 25 mm ADJUST SCALES 25 mm

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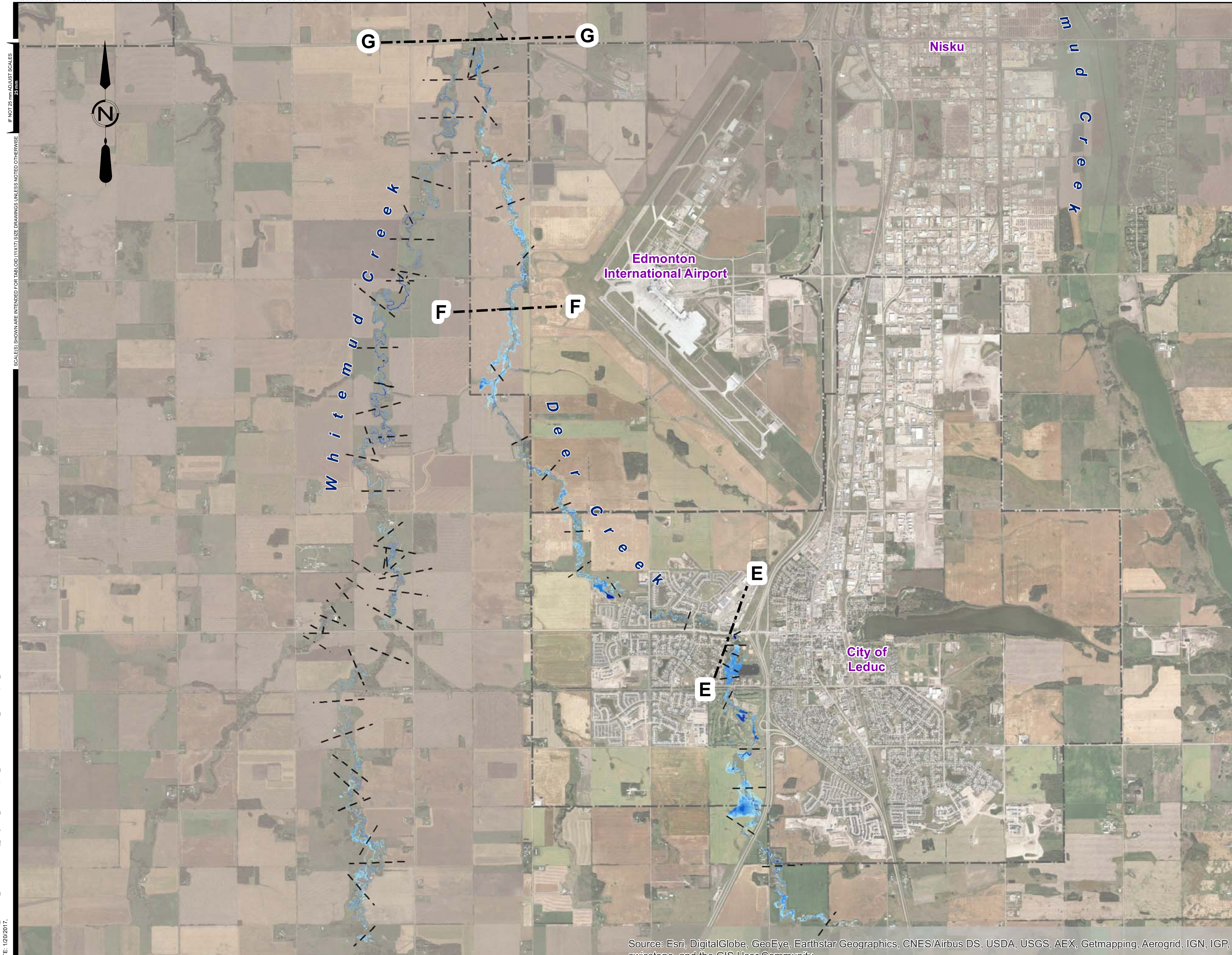
DATE: 5/11/2017,



Associated Engineering

Legend:

Water Depth (2 Year)

High (3.1 m)

Low (0 m)

Cross Section

Municipal Boundary

FIGURE No. A-3

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

Deer Creek 1:2 Year

AE PROJECT No.	2016-3785
SCALE	1:50,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

IF NOT 25 mm ADJUST SCALES 25 mm

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

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DATE: 1/20/2017,

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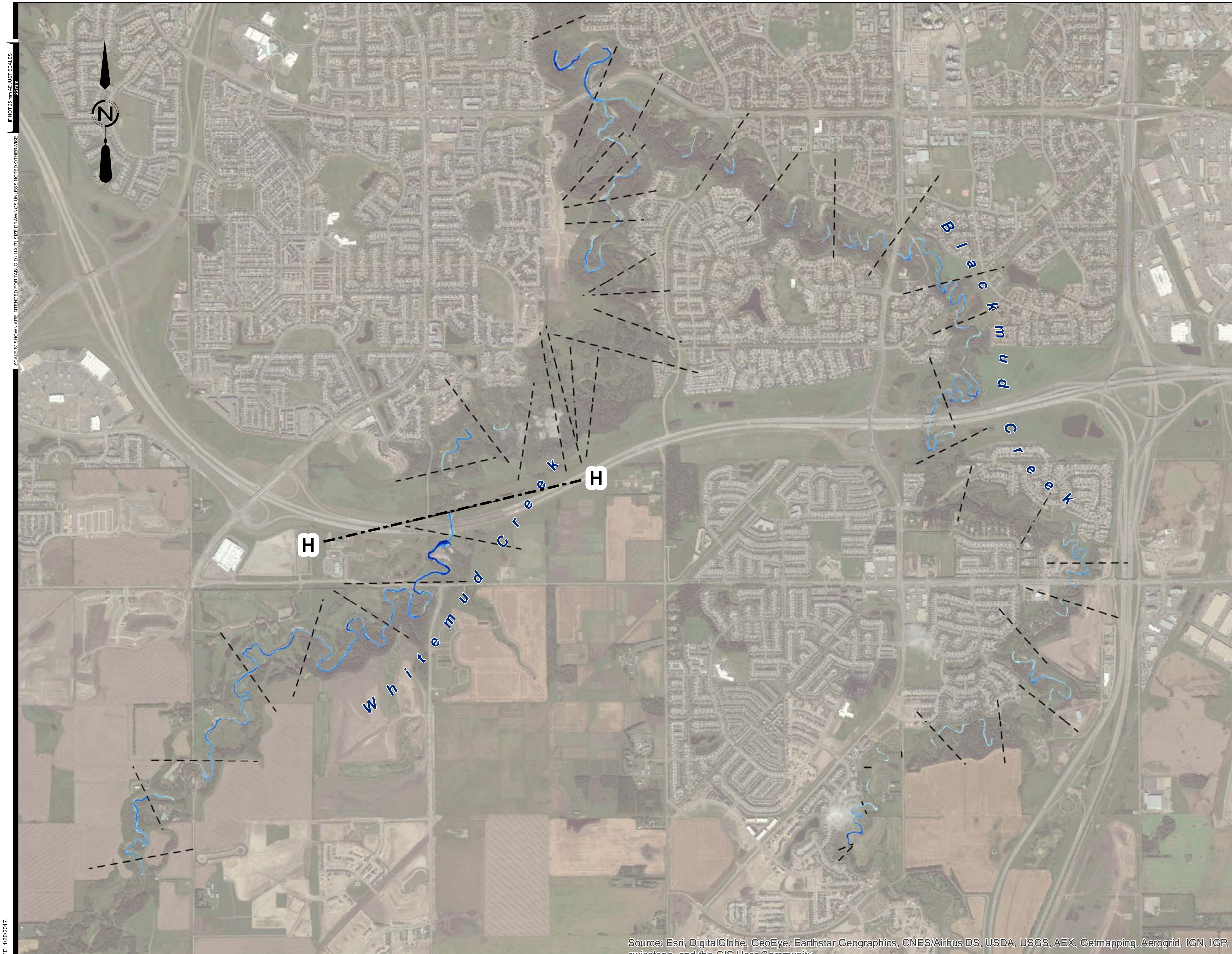

Associated Engineering

Legend:

Water Depth (2 Year)

High (1.9 m)

Low (0 m)

Cross Section

Municipal Boundary

FIGURE No. A-4

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

Whitemud Creek 1:2 Year

AE PROJECT No.	2016-3785
SCALE	1:25,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

IF NOT 25 mm ADJUST SCALES 25 mm

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

P:\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\xxx_CreekDepths_v2.mxd
DATE: 1/20/2017,

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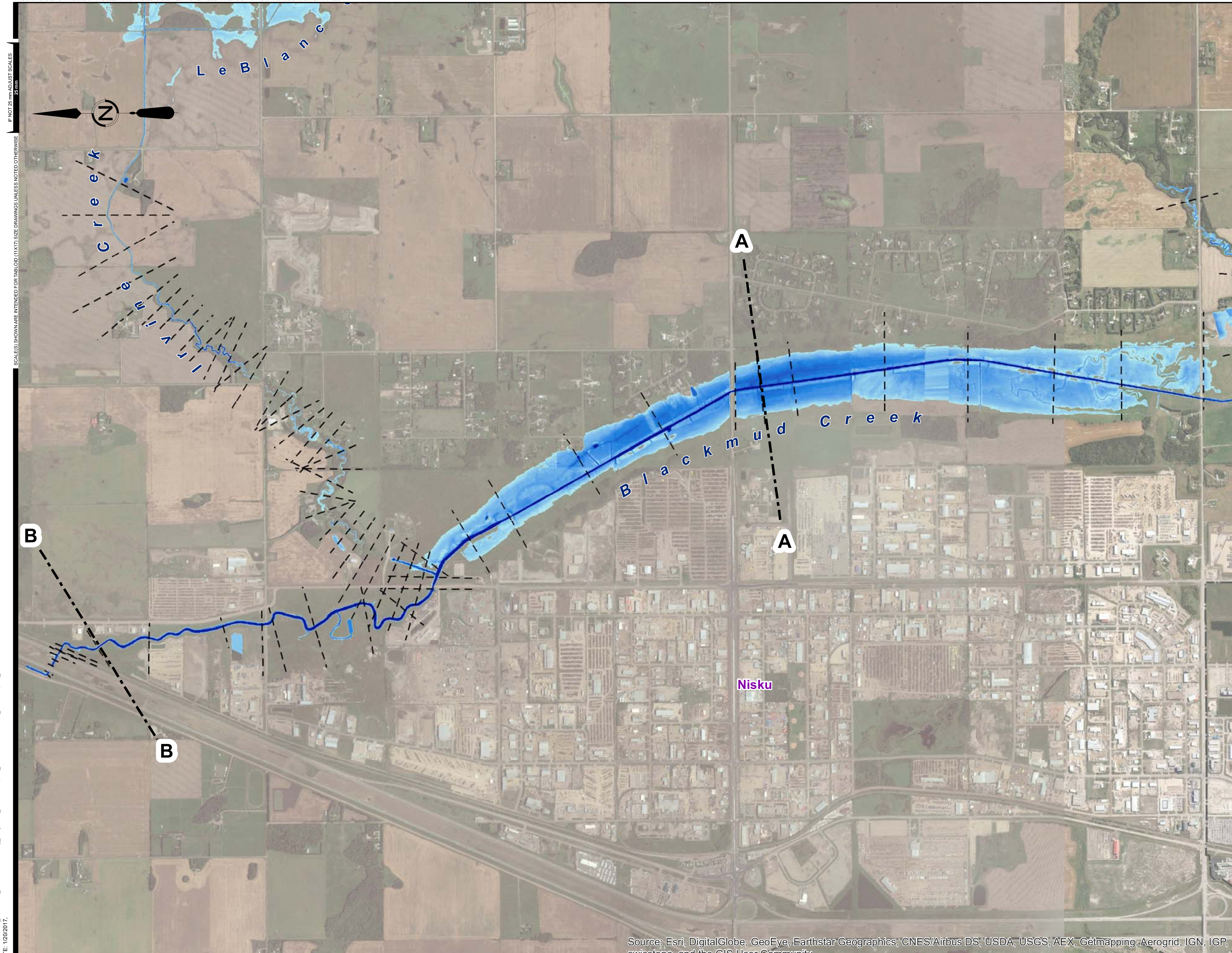

Associated Engineering

Legend:

Water Depth (5 Year)

High (2.4 m)

Low (0 m)

Cross Section

Municipal Boundary

FIGURE No. A-5

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

Blackmud Creek 1:5 Year

AE PROJECT No.	2016-3785
SCALE	1:25,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

IF NOT 25 mm ADJUST SCALES 25 mm

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

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DATE: 1/20/2017,

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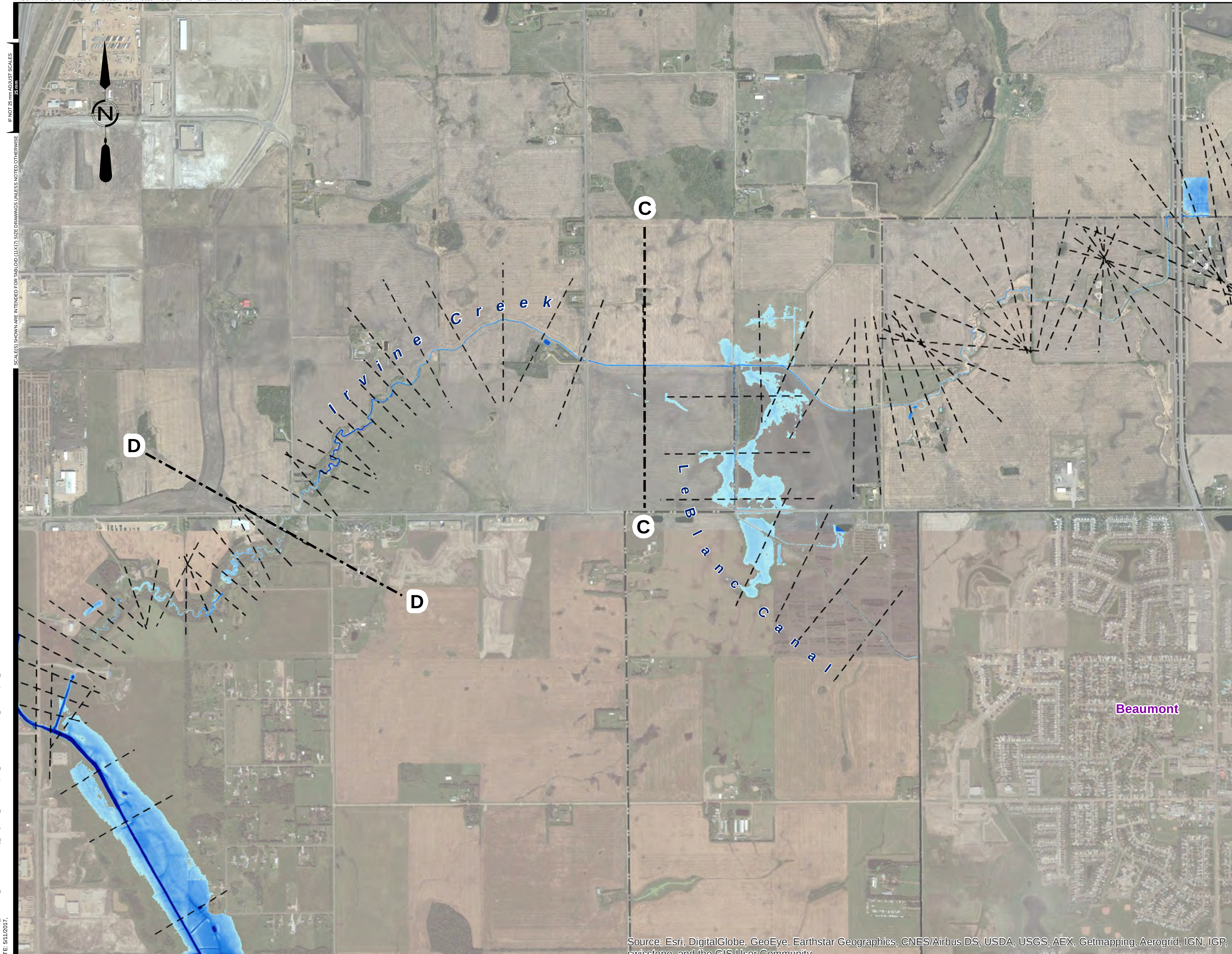

Associated Engineering

Legend:

Water Depth (5 Year)
High (2.0 m)
Low (0 m)

Cross Section
Municipal Boundary

FIGURE No. A-6

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

Irvine Creek 1:5 Year

AE PROJECT No.	2016-3785
SCALE	1:20,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

IF NOT 25 mm ADJUST SCALES 25 mm
SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

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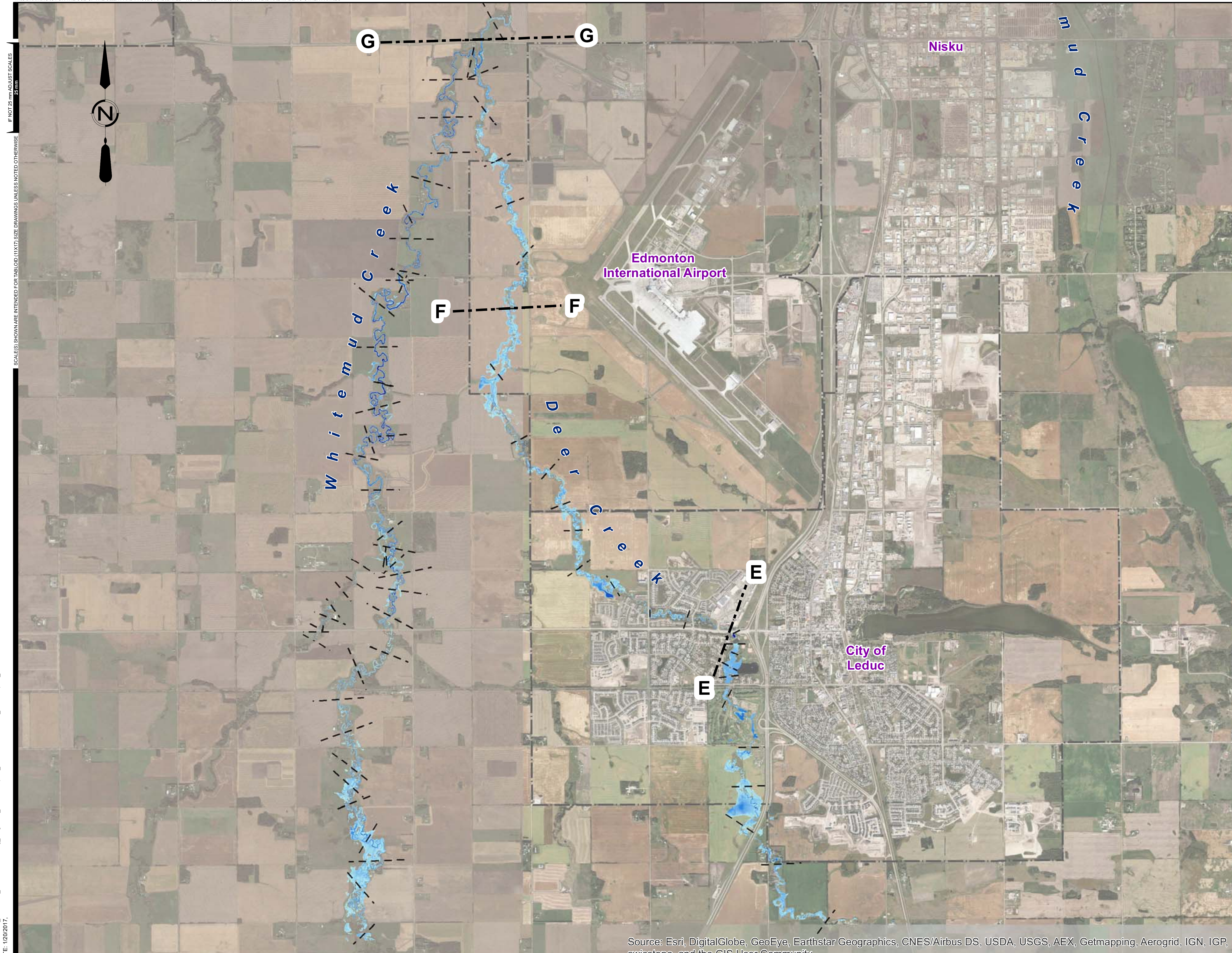
DATE: 5/11/2017

THIS DRAWING IS FOR THE USE OF THE CLIENT AND PROJECT INDICATED - NO REPRESENTATIONS OF ANY KIND ARE MADE TO OTHER PARTIES



Associated Engineering

Legend:

Water Depth (5 Year)

High (3.2 m)

Low (0 m)

Cross Section

Municipal Boundary

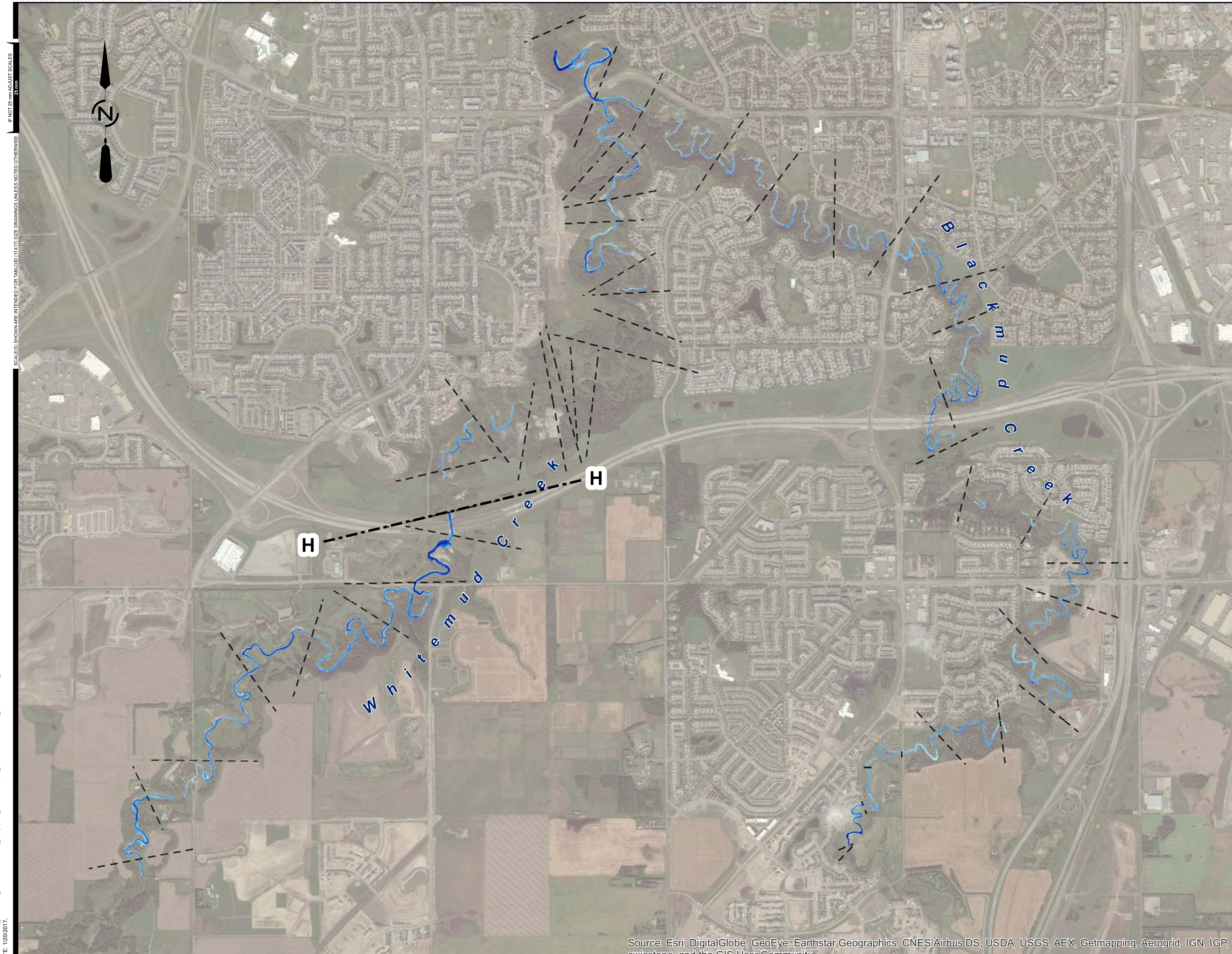
FIGURE No. A-7

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

Deer Creek 1:5 Year

AE PROJECT No.	2016-3785
SCALE	1:50,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

THIS DRAWING IS FOR THE USE OF THE CLIENT AND PROJECT INDICATED - NO REPRESENTATIONS OF ANY KIND ARE MADE TO OTHER PARTIES



Associated Engineering

Legend:

Water Depth (5 Year)
High (2.0 m)
Low (0 m)

Cross Section
Municipal Boundary

FIGURE No. A-8

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

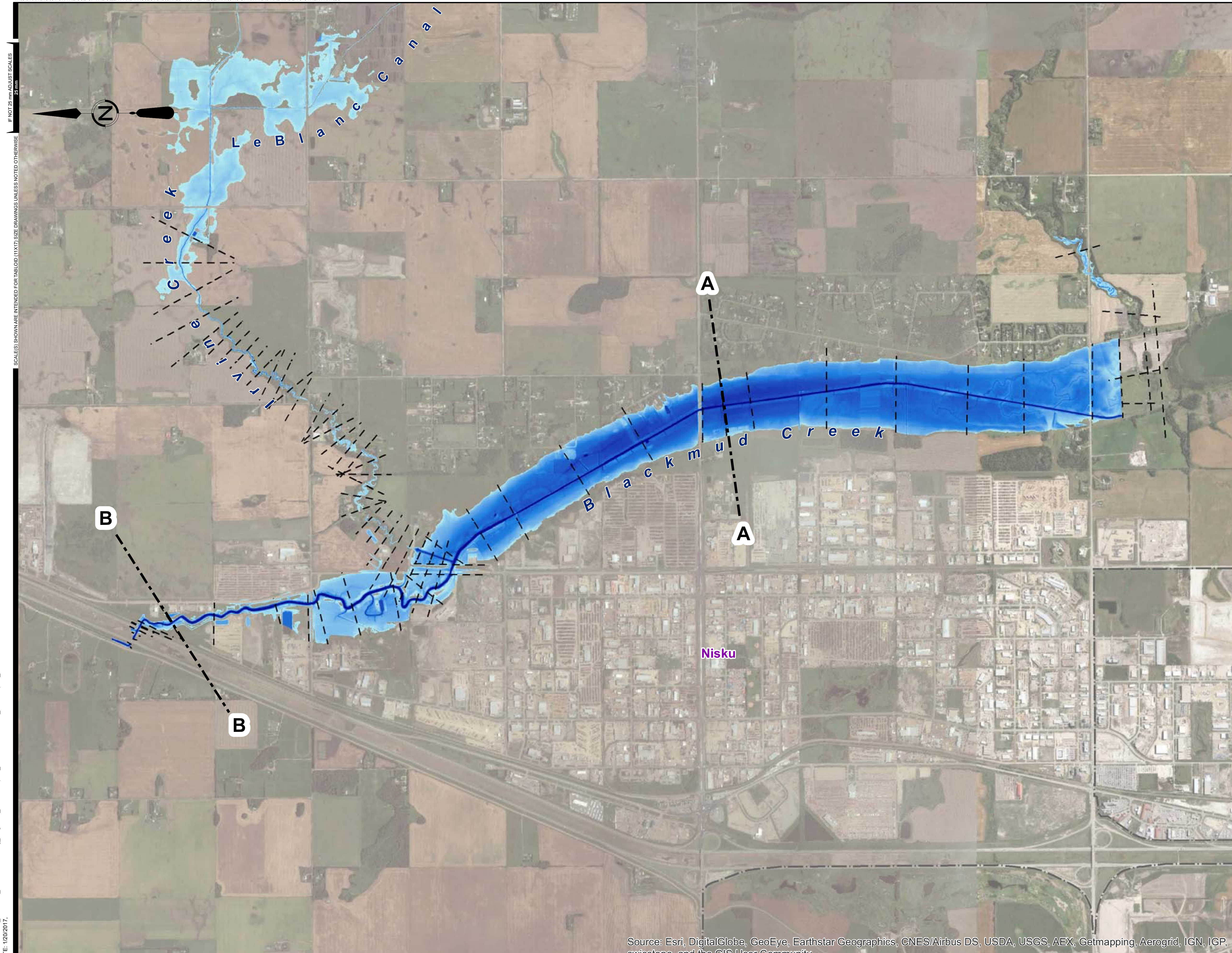
Whitemud Creek 1:5 Year

AE PROJECT No.	2016-3785
SCALE	1:25,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

IF NOT 25 mm ADJUST SCALES 25 mm

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

P:\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\xxx_CreekDepths_v2.mxd
DATE: 1/20/2017,



Associated Engineering

Legend:

Water Depth (100 Year)

High (4.1 m)

Low (0 m)

Cross Section

Municipal Boundary

FIGURE No. A-9

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

Blackmud Creek 1:100 Year

AE PROJECT No.	2016-3785
SCALE	1:30,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

P:\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\xxx_CreekDepths_v2.mxd
DATE: 1/20/2017.

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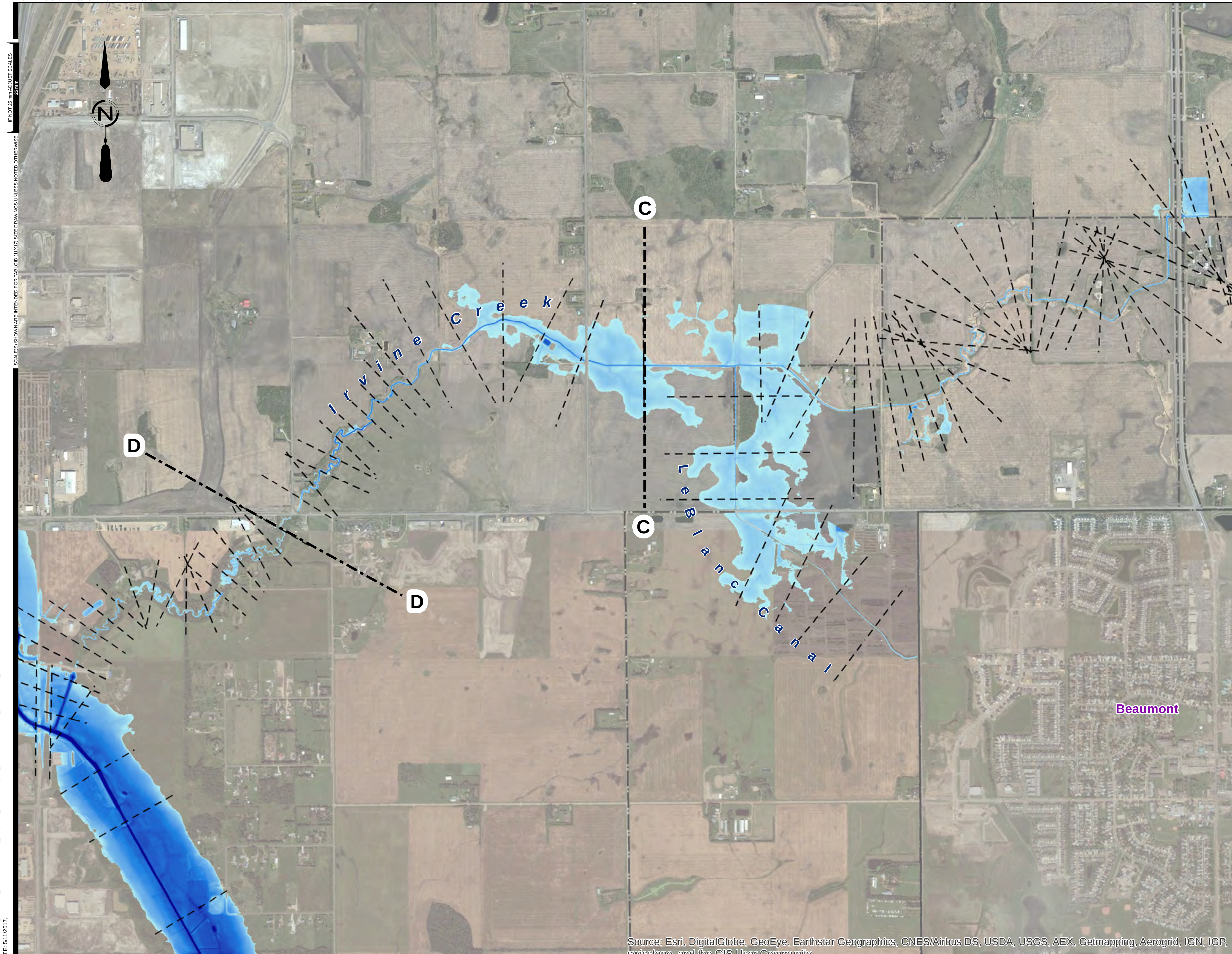


IF NOT 25 mm ADJUST SCALES 25 mm

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

Associated Engineering

Legend:

Water Depth (100 Year)
High (3.7 m)
Low (0 m)

Cross Section
Municipal Boundary

FIGURE No. A-10

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

Irvine Creek 1:100 Year

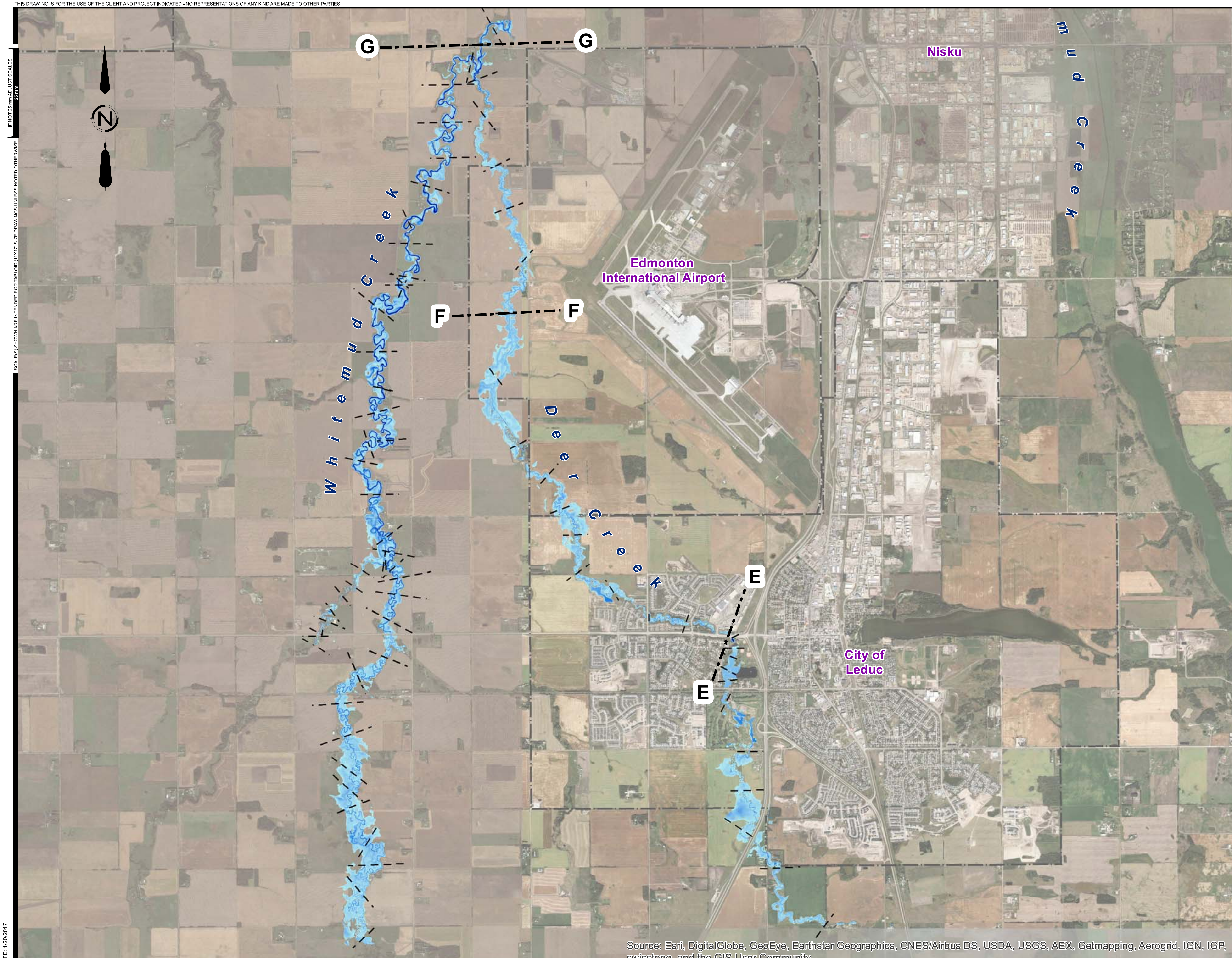
AE PROJECT No.	2016-3785
SCALE	1:20,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

P:\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\xxx_CreekDepths_v2.mxd
DATE: 5/11/2017,

THIS DRAWING IS FOR THE USE OF THE CLIENT AND PROJECT INDICATED - NO REPRESENTATIONS OF ANY KIND ARE MADE TO OTHER PARTIES

IF NOT 25 mm ADJUST SCALES

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE



Associated Engineering

Legend:

Water Depth (100 Year)

High (4.1 m)

Low (0 m)

Cross Section

Municipal Boundary

FIGURE No. A-11

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

Deer Creek 1:100 Year

AE PROJECT No.	2016-3785
SCALE	1:50,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

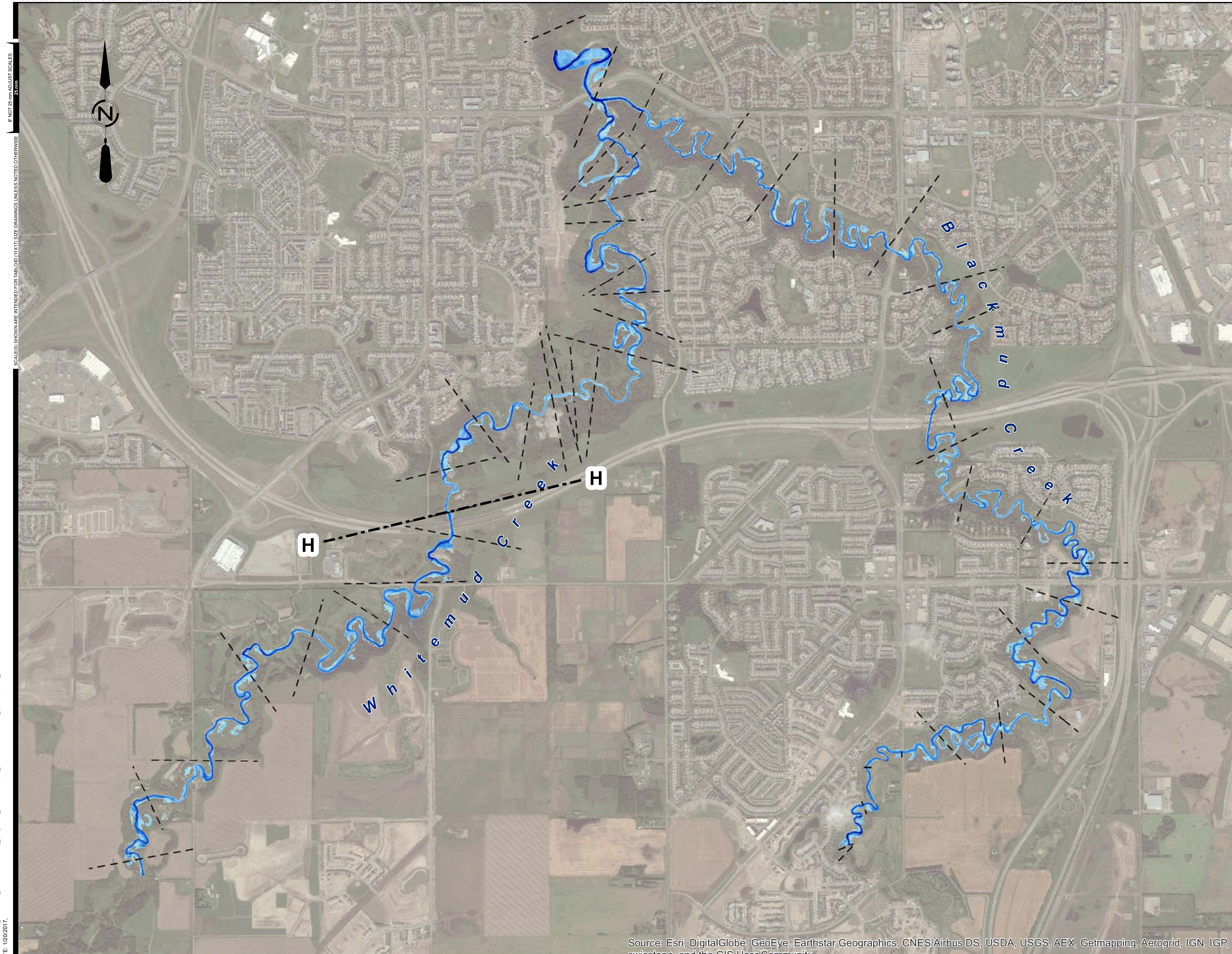
P:\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\xxx_CreekDepths_v2.mxd

DATE: 1/20/2017,

THIS DRAWING IS FOR THE USE OF THE CLIENT AND PROJECT INDICATED - NO REPRESENTATIONS OF ANY KIND ARE MADE TO OTHER PARTIES

IF NOT 25 mm ADJUST SCALES 25 mm

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE



Associated Engineering

Legend:

Water Depth (100 Year)

High (4.1 m)

Low (0 m)

Cross Section

Municipal Boundary

FIGURE No. A-12

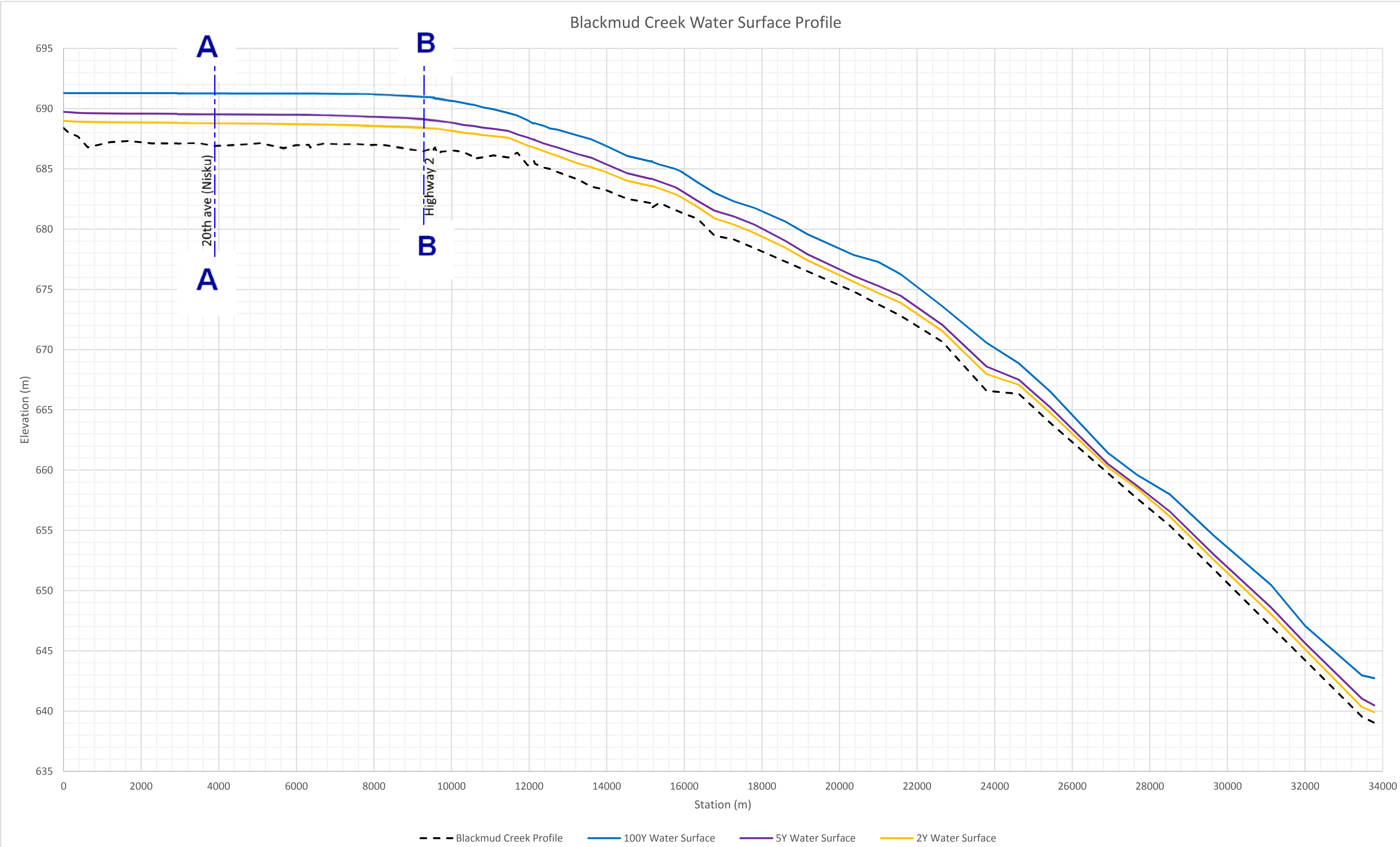
BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

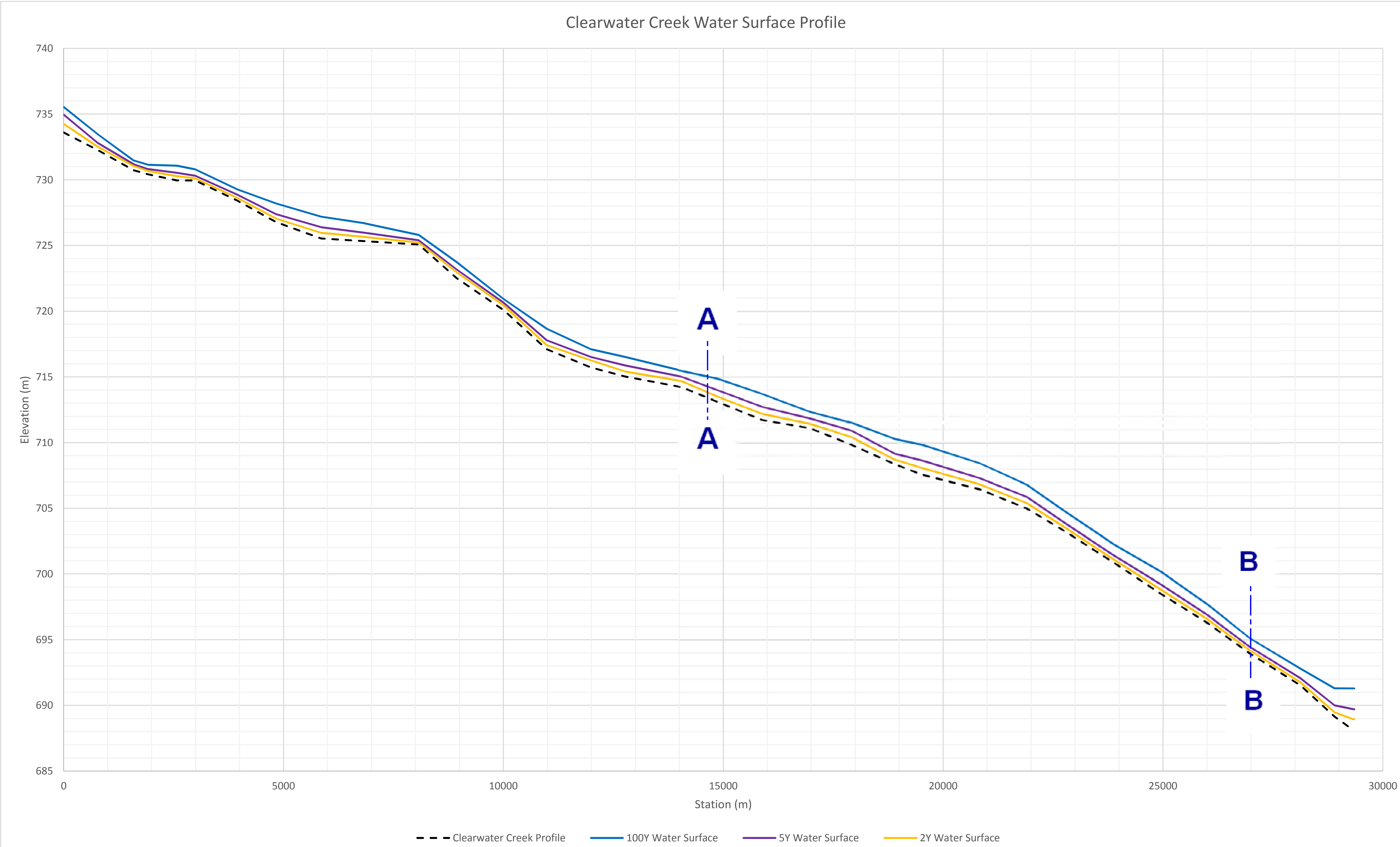
Whitemud Creek 1:100 Year

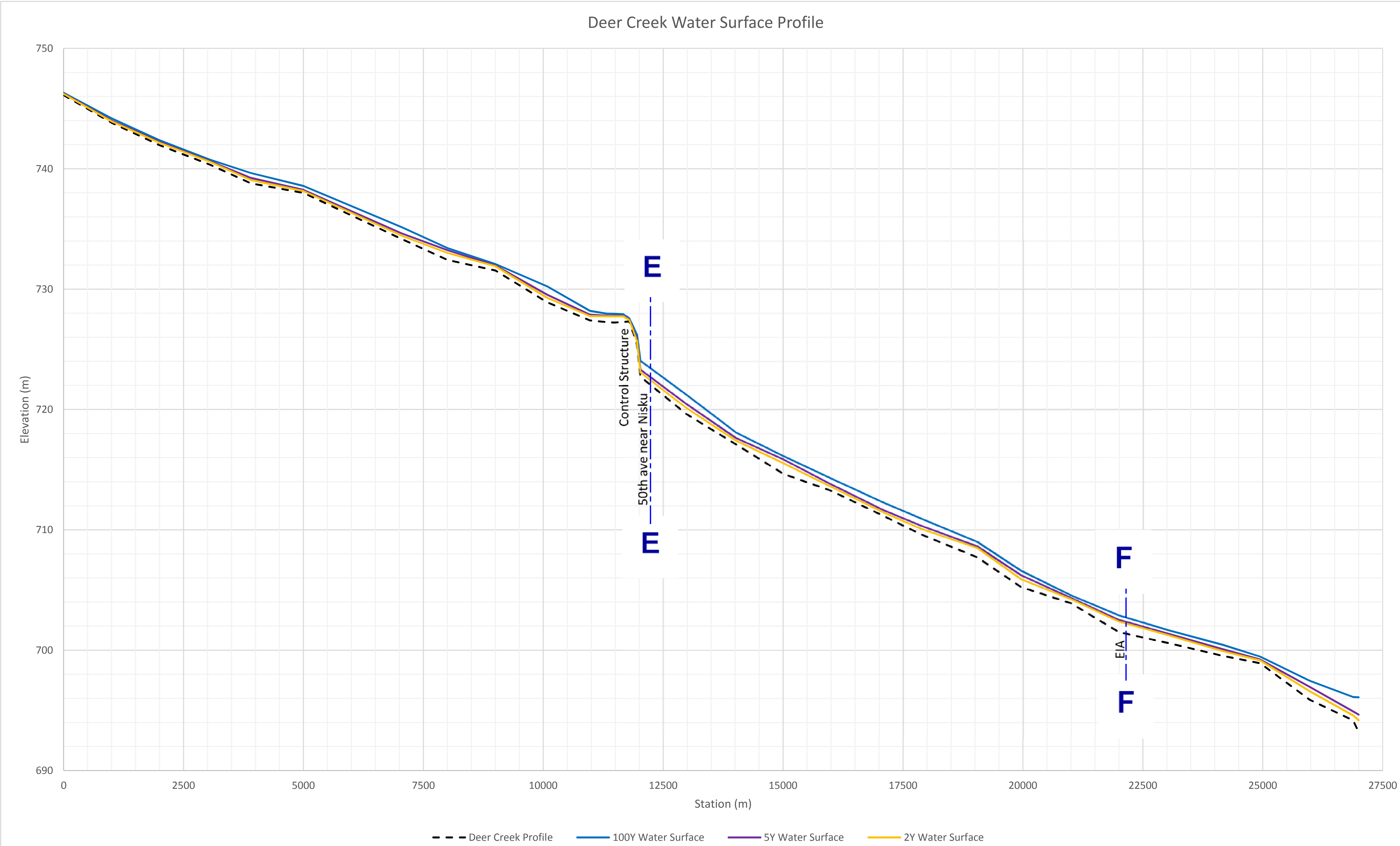
AE PROJECT No.	2016-3785
SCALE	1:25,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

P:\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\xxx_CreekDepths_v2.mxd
DATE: 1/20/2017,

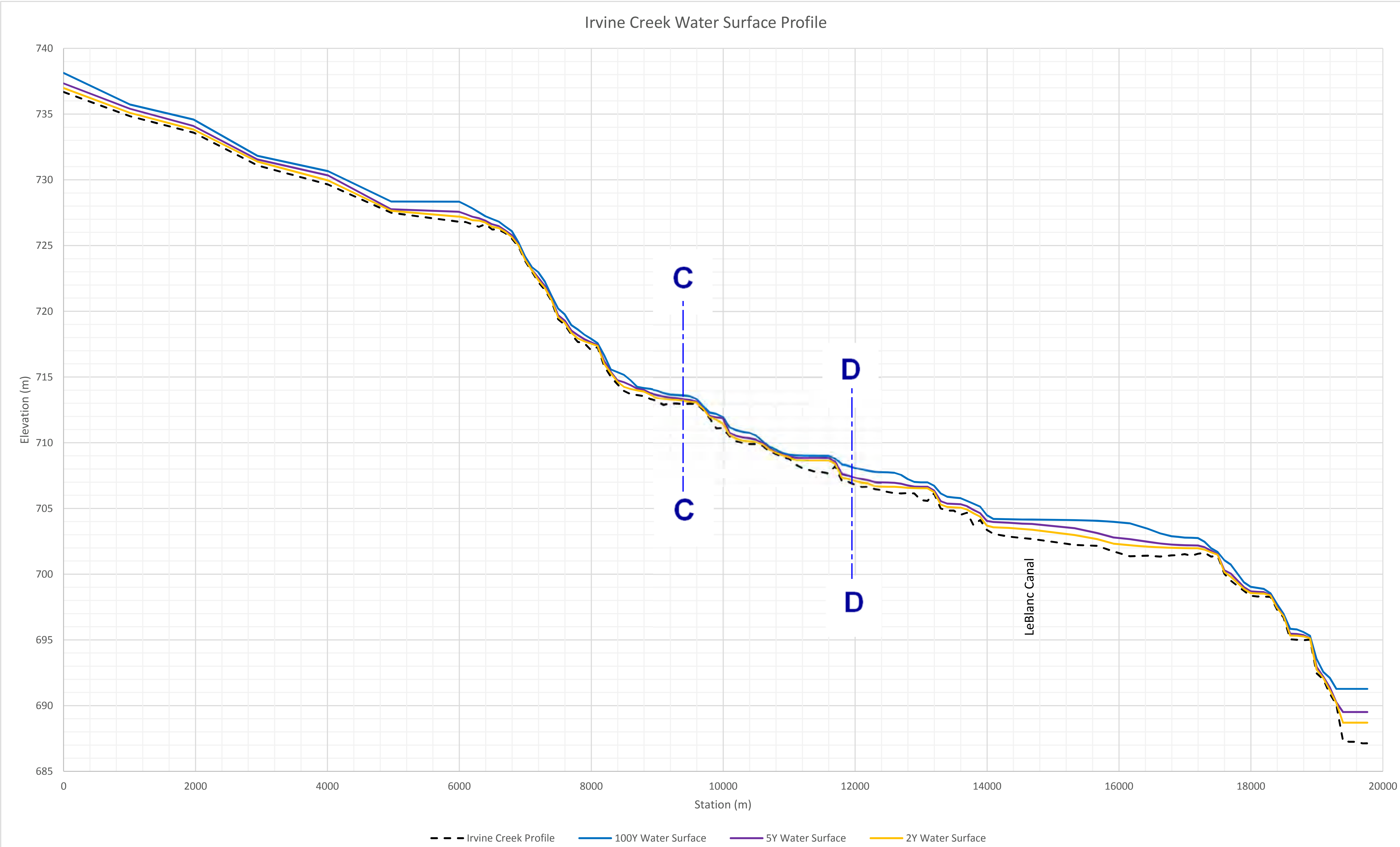
Appendix C - Longitudinal Profiles


Blackmud Creek Water Surface Profile
A
B
20th ave (Nisku)
Highway 2
A
B
695
690
685
680
675
670
665
660
655
650
645
640
635
Elevation (m)
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
24000
26000
28000
30000
32000
34000
Station (m)
Blackmud Creek Profile
100Y Water Surface
5Y Water Surface
2Y Water Surface

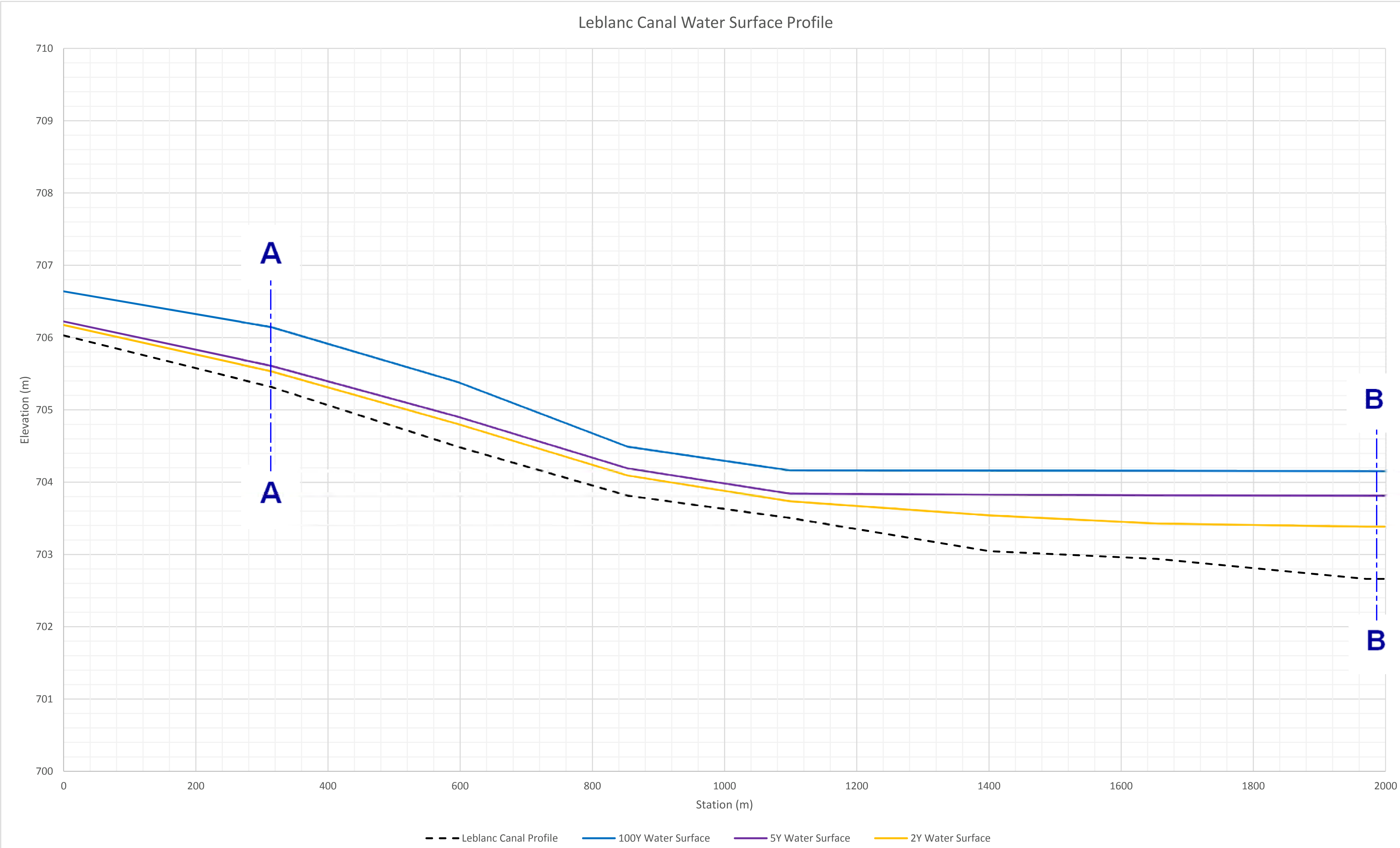

Clearwater Creek Water Surface Profile
740
735
730
725
720
715
710
705
700
695
690
685
Elevation (m)
0
5000
10000
15000
20000
25000
30000
Station (m)
A
A
B
B
Clearwater Creek Profile
100Y Water Surface
5Y Water Surface
2Y Water Surface



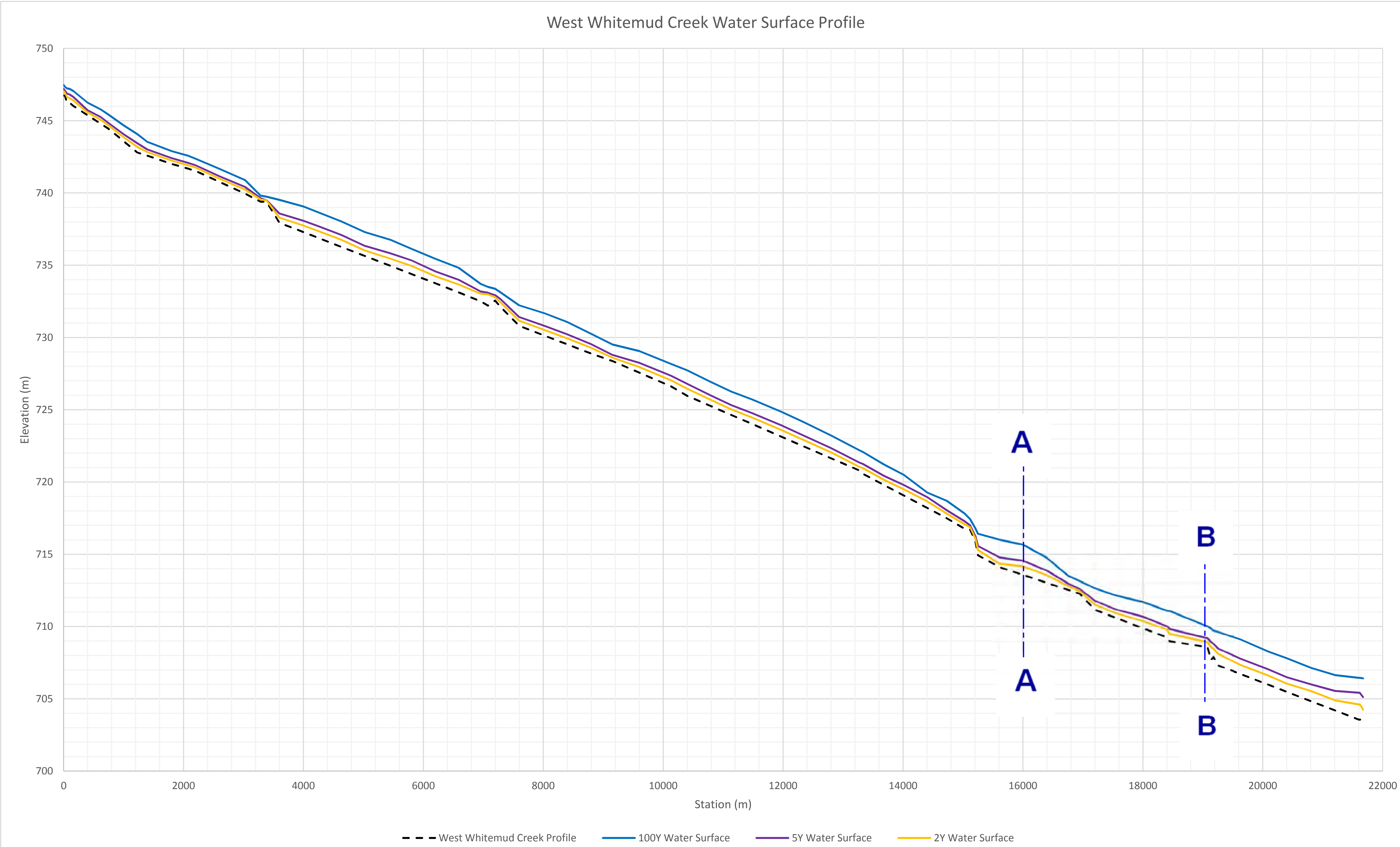
Deer Creek Water Surface Profile
750
740
730
720
710
700
690
Elevation (m)
0
2500
5000
7500
10000
12500
15000
17500
20000
22500
25000
27500
Station (m)
E
E
F
F
Control Structure
50th ave near Nisku
EIA
Deer Creek Profile
100Y Water Surface
5Y Water Surface
2Y Water Surface

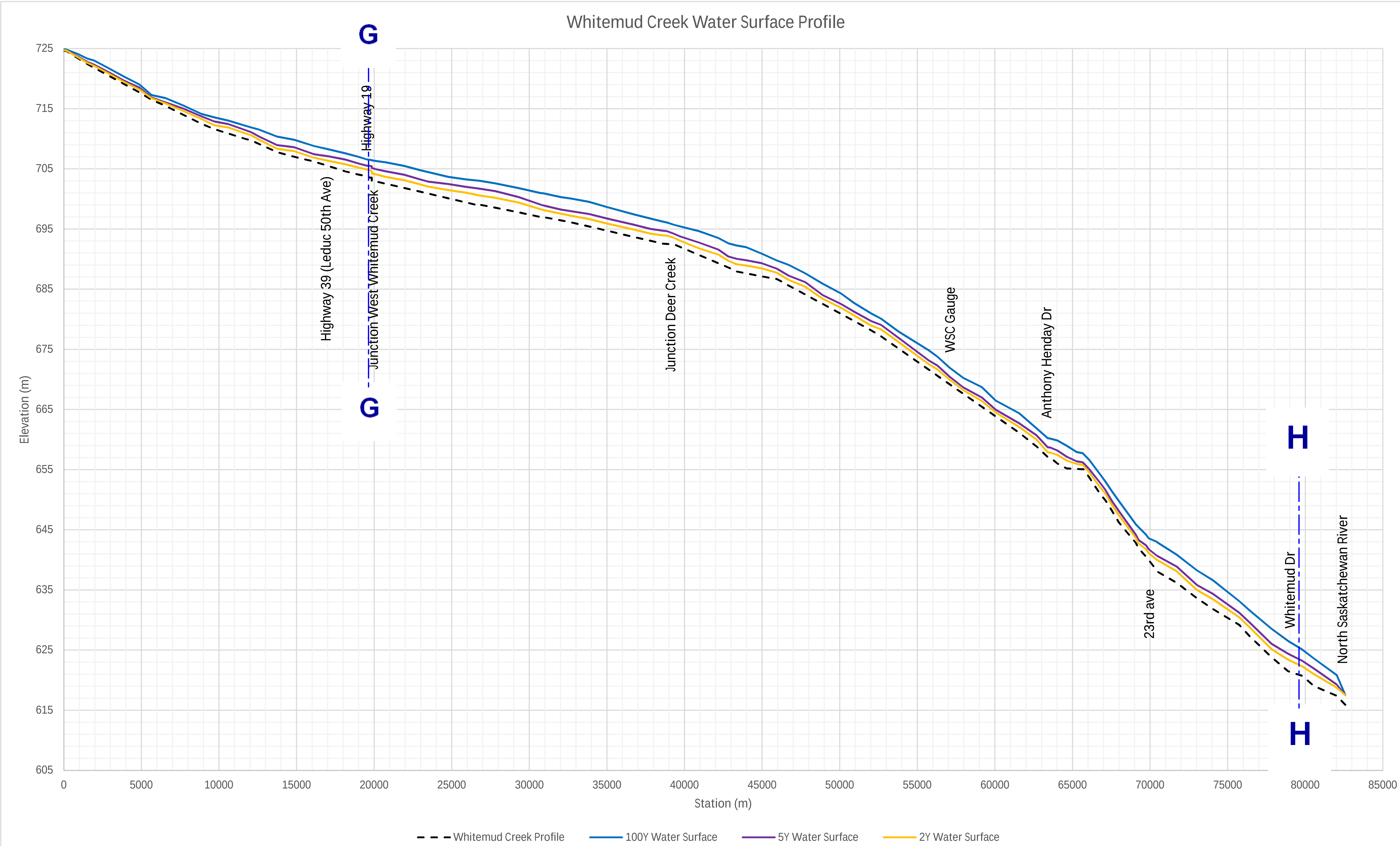


Irvine Creek Water Surface Profile
Elevation (m)
740
735
730
725
720
715
710
705
700
695
690
685
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Station (m)
C
C
D
D
LeBlanc Canal
Irvine Creek Profile
100Y Water Surface
5Y Water Surface
2Y Water Surface



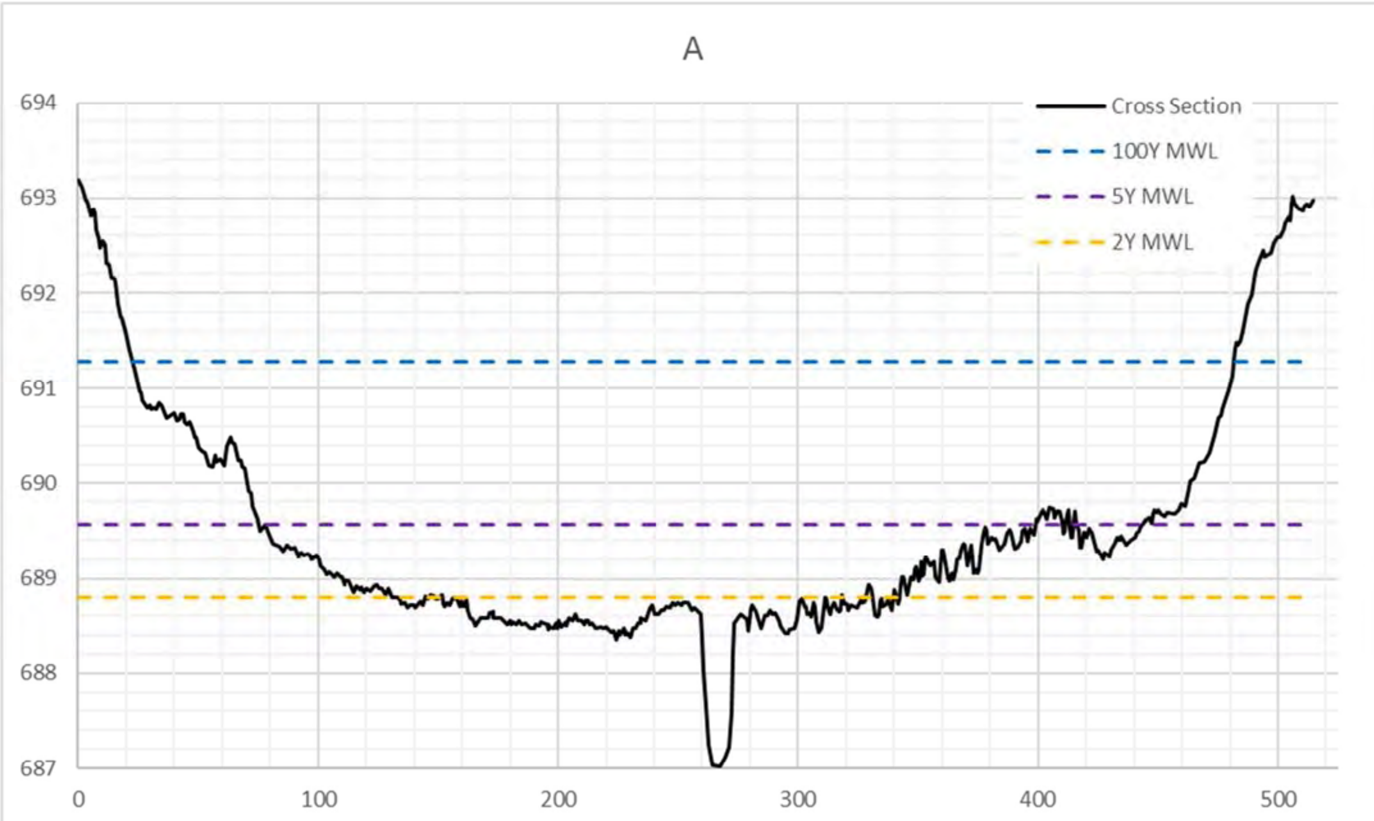
Leblanc Canal Water Surface Profile
Elevation (m)
710
709
708
707
706
705
704
703
702
701
700
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Station (m)
A
A
B
B
Leblanc Canal Profile
100Y Water Surface
5Y Water Surface
2Y Water Surface

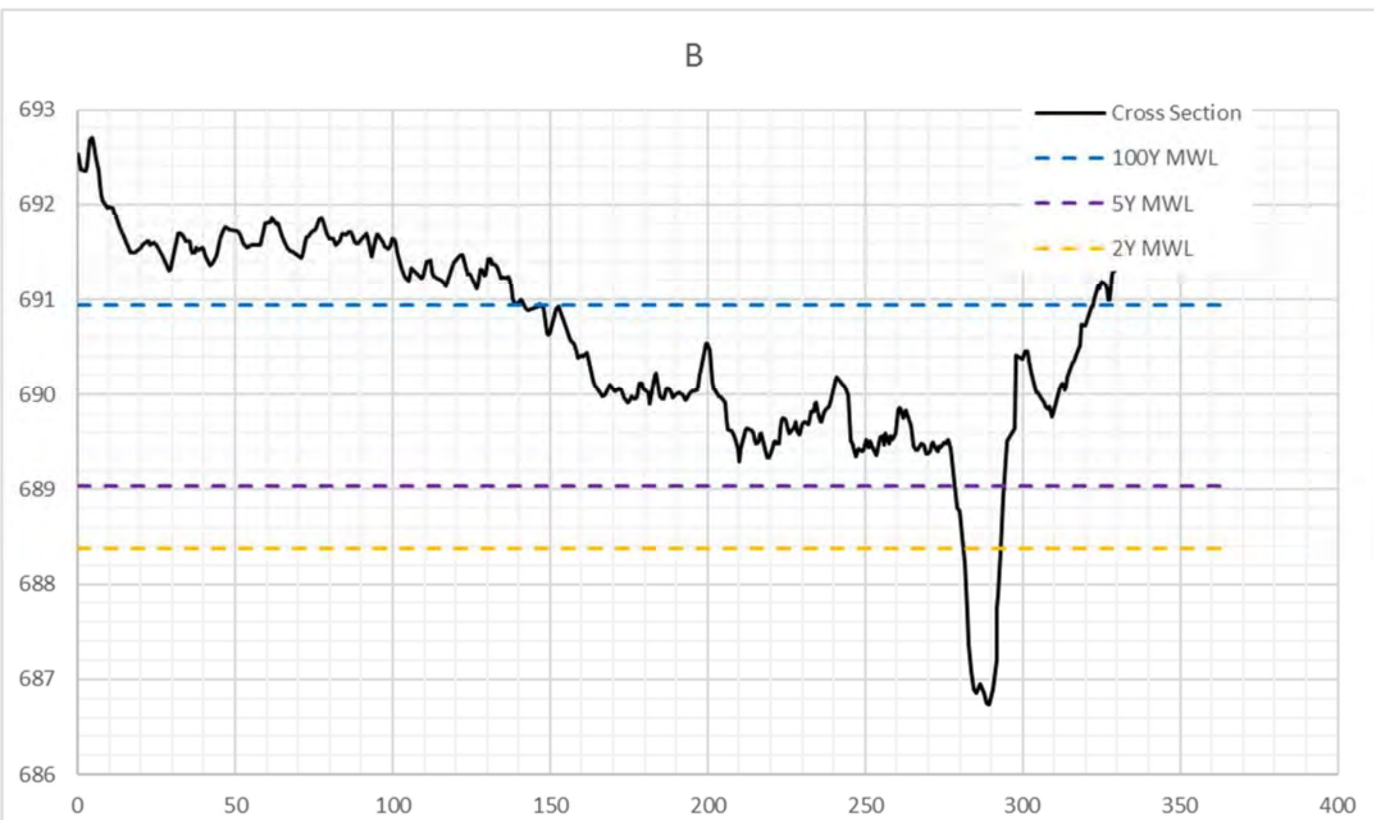

West Whitemud Creek Water Surface Profile
Elevation (m)
750
745
740
735
730
725
720
715
710
705
700
Station (m)
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
A
A
B
B
West Whitemud Creek Profile
100Y Water Surface
5Y Water Surface
2Y Water Surface


Whitemud Creek Water Surface Profile
G
Highway 19
Highway 39 (Leduc 50th Ave)
Junction West Whitemud Creek
G
Junction Deer Creek
WSC Gauge
Anthony Henday Dr
H
23rd ave
Whitemud Dr
North Saskatchewan River
H
Elevation (m)
725
715
705
695
685
675
665
655
645
635
625
615
605
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
55000
60000
65000
70000
75000
80000
85000
Station (m)
Whitemud Creek Profile
100Y Water Surface
5Y Water Surface
2Y Water Surface

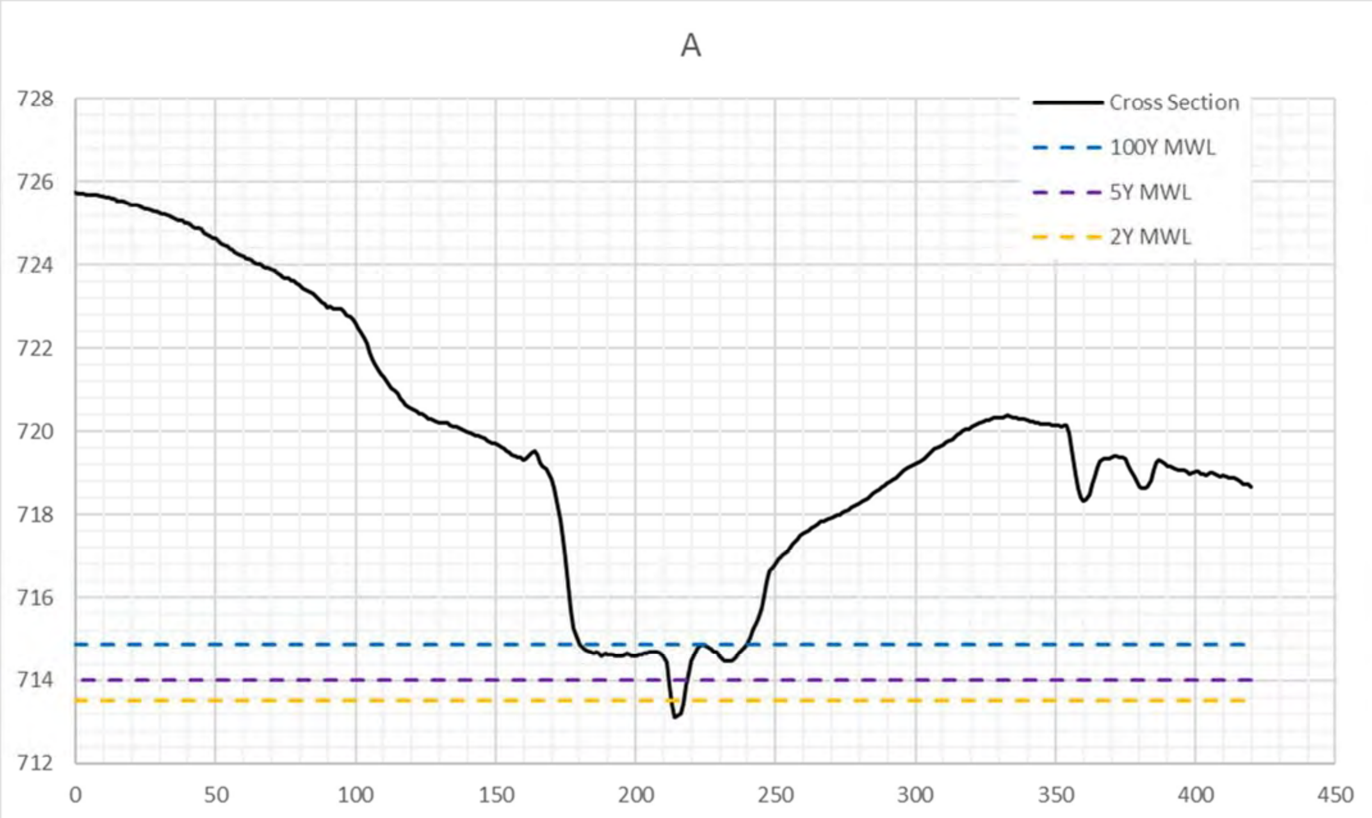
Appendix D - Typical Cross Sections

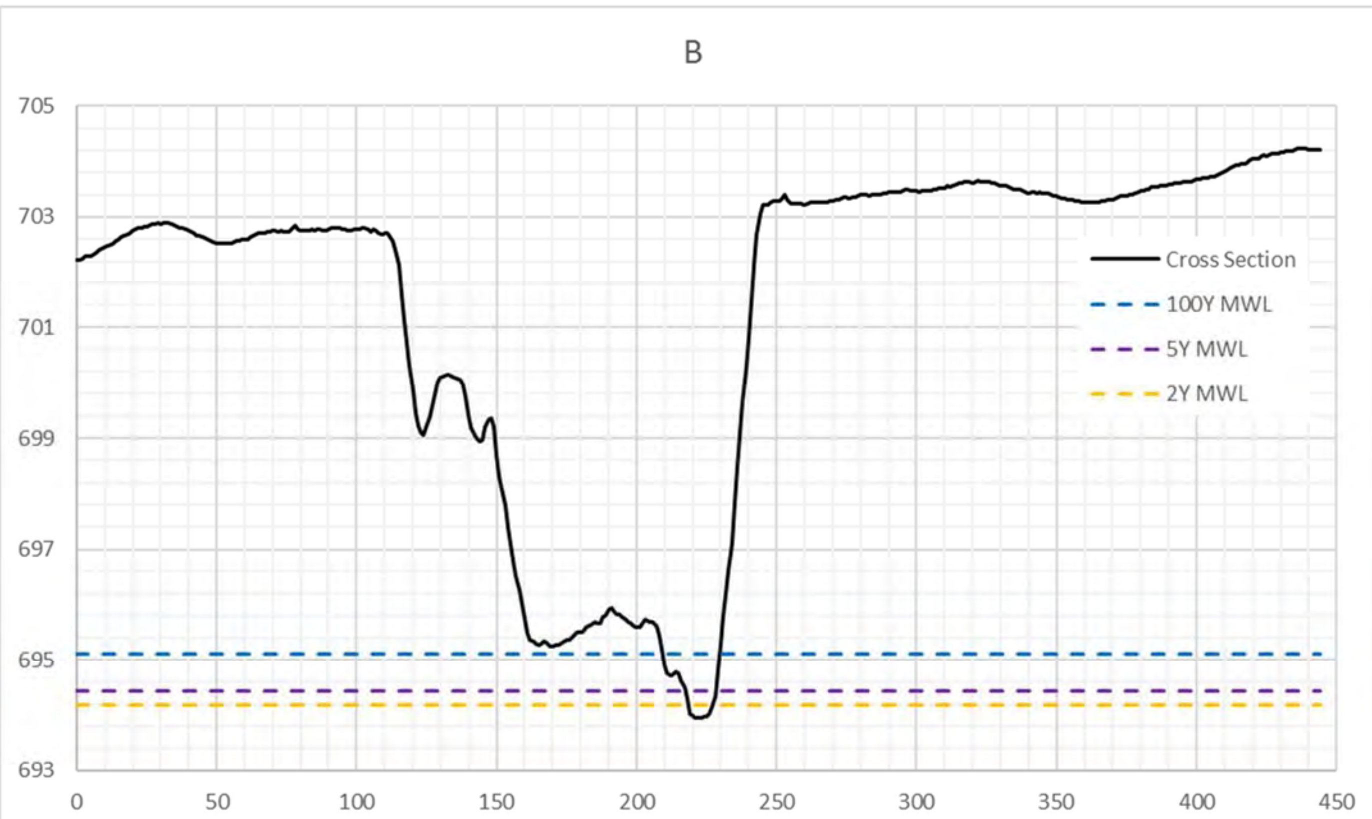
Blackmud Creek Cross Sections



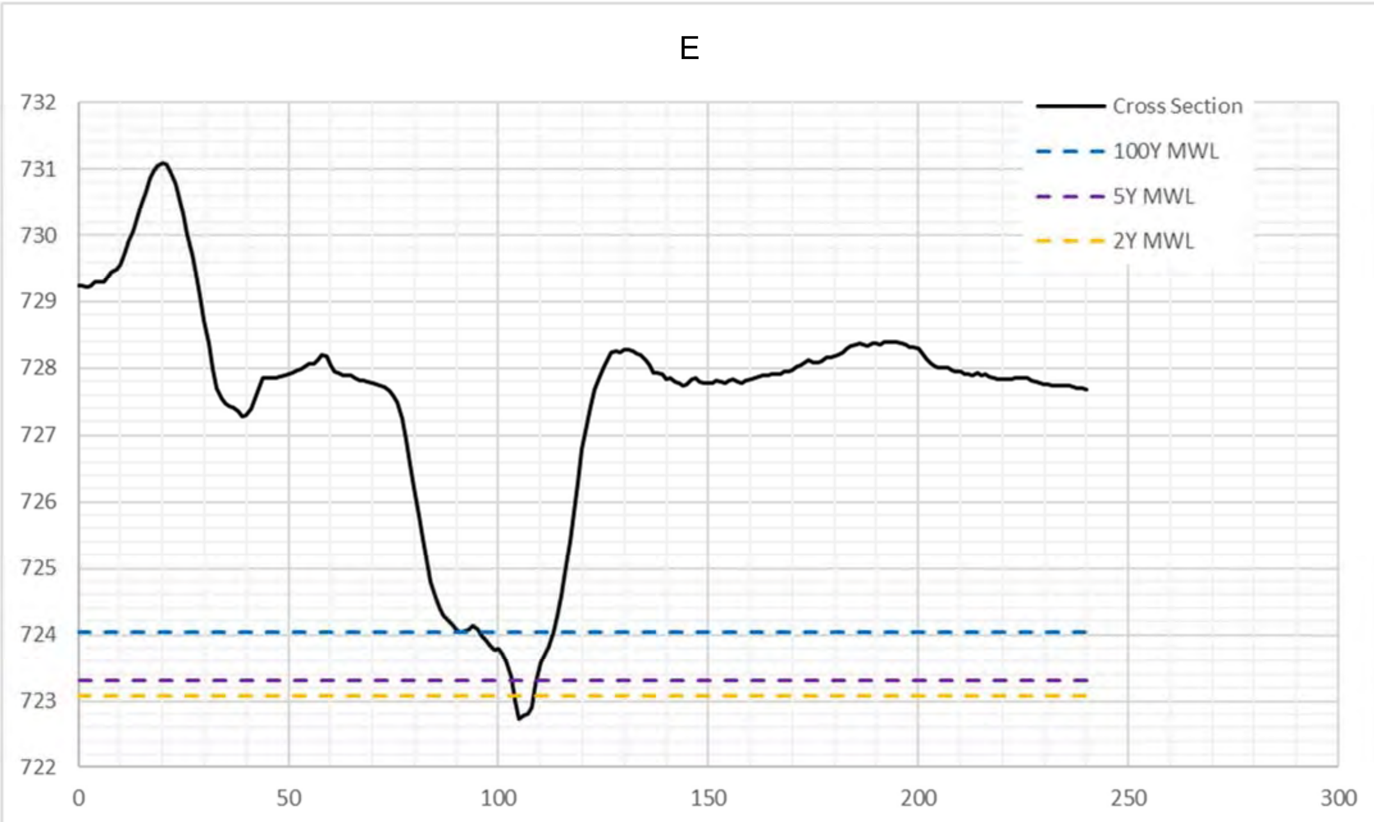


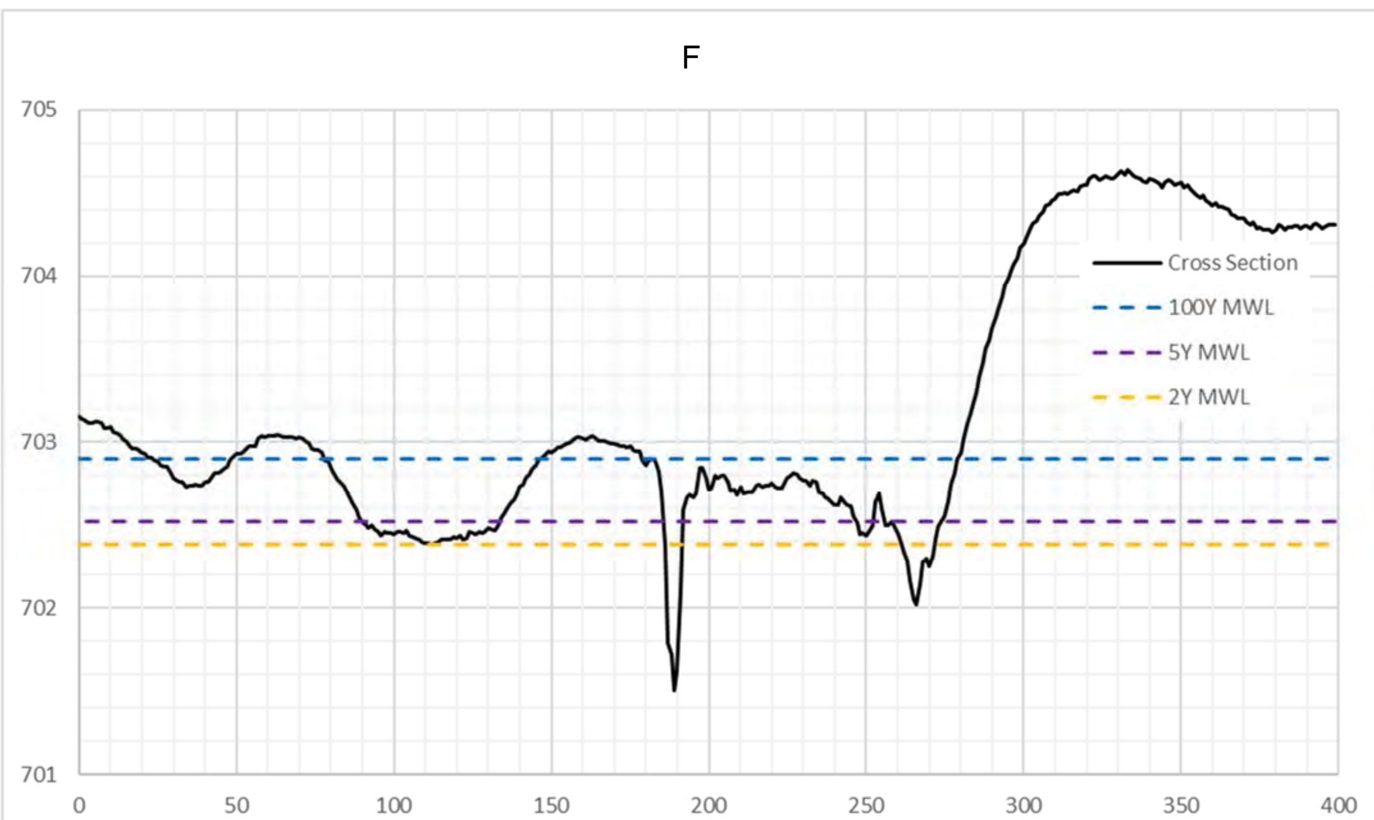
Clearwater Creek Cross Sections



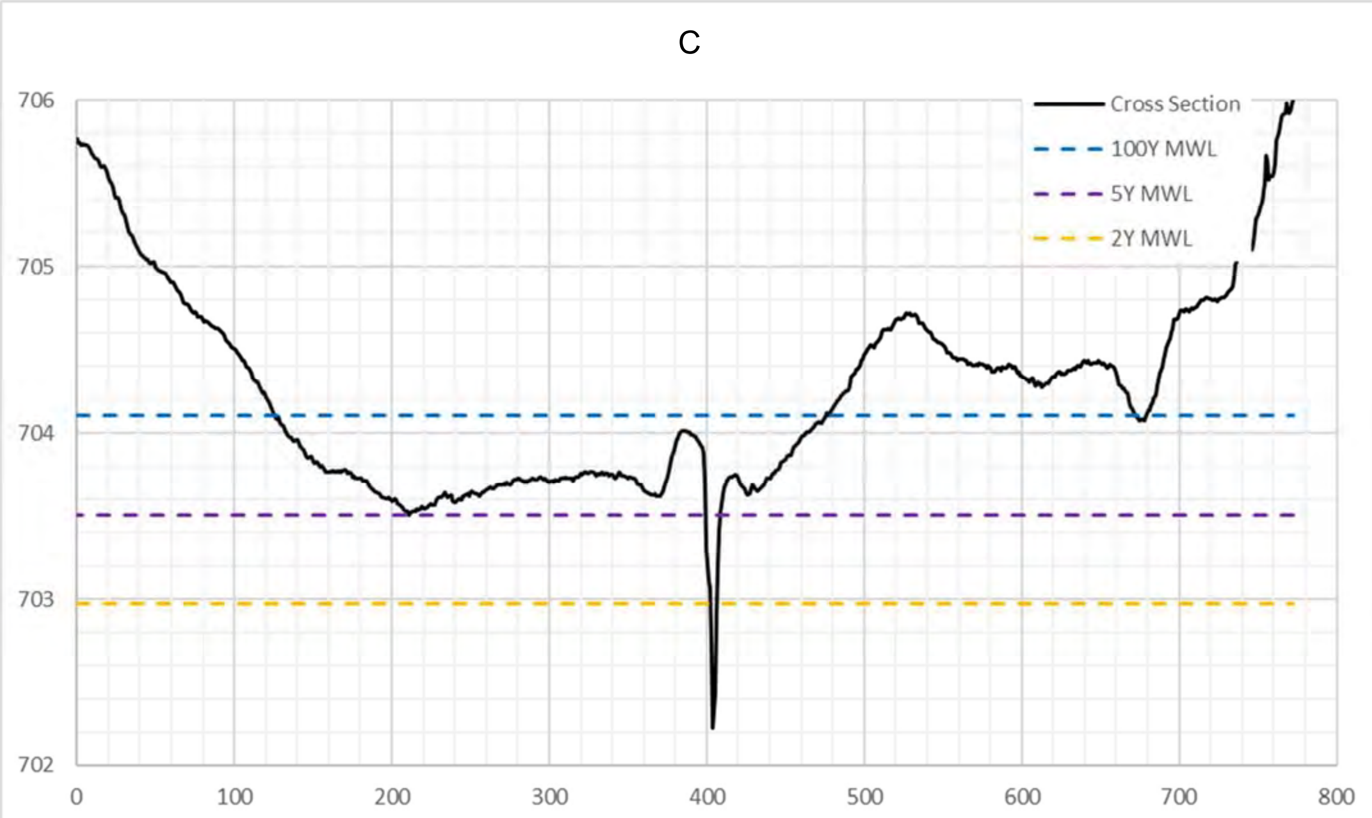


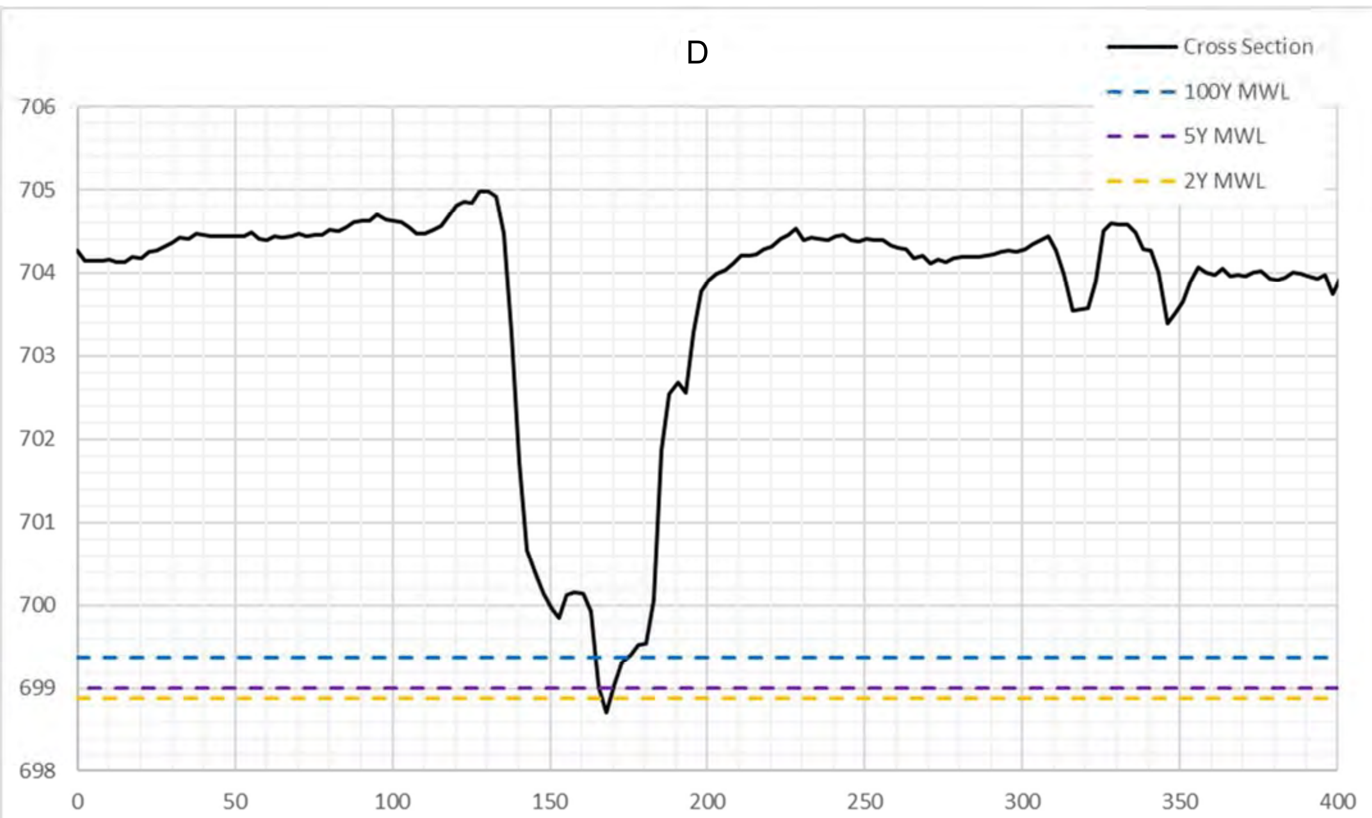
Deer Creek Cross Sections



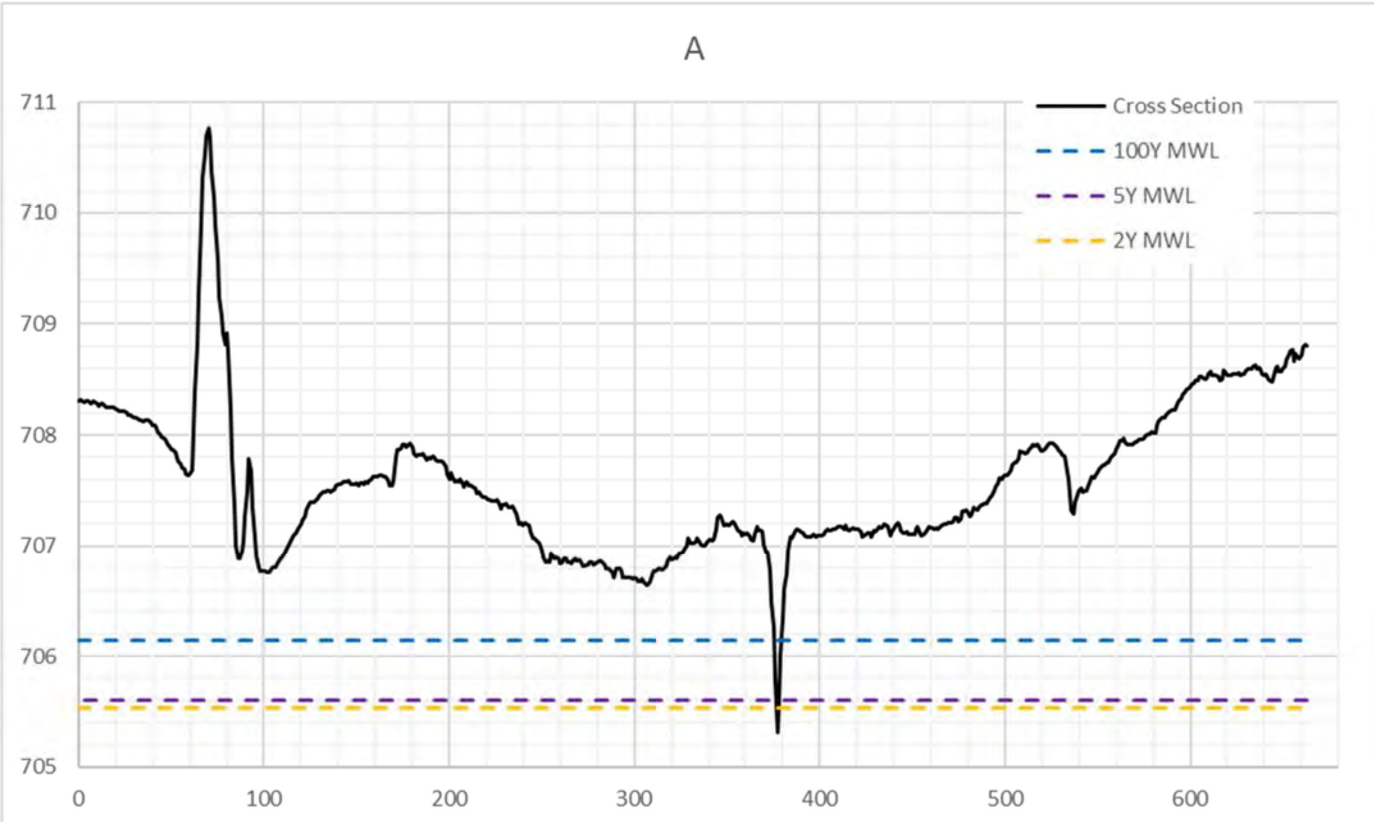


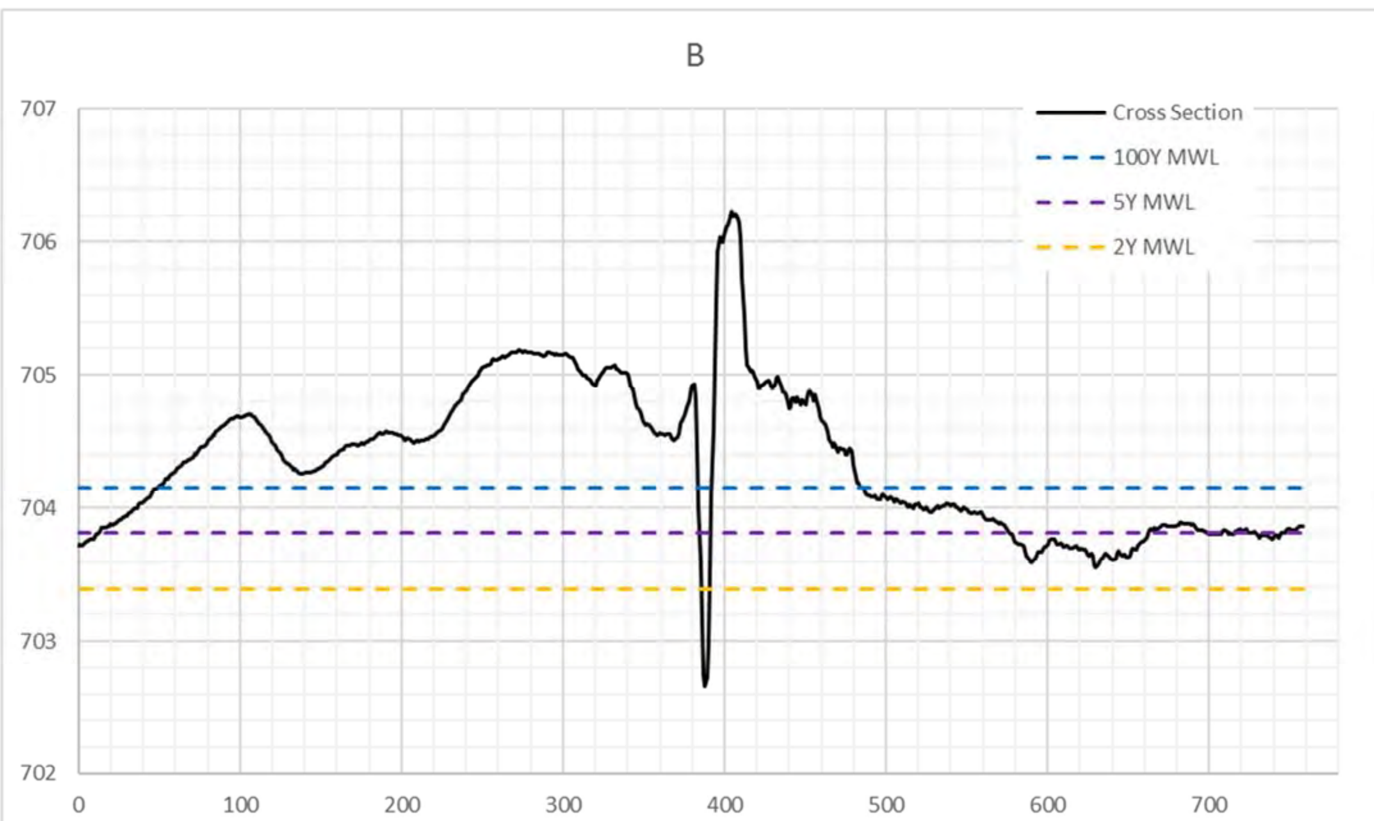
Irvine Creek Cross Sections



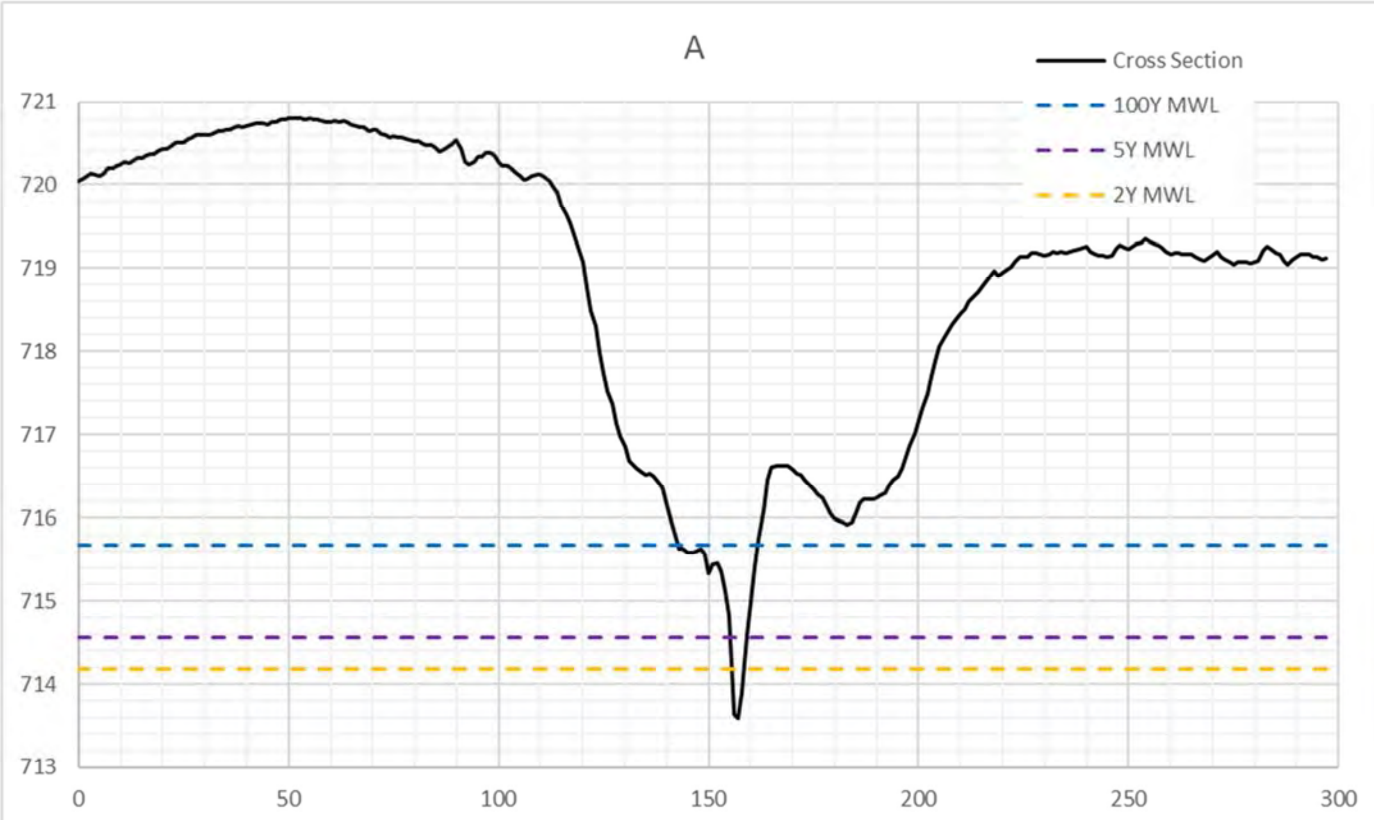


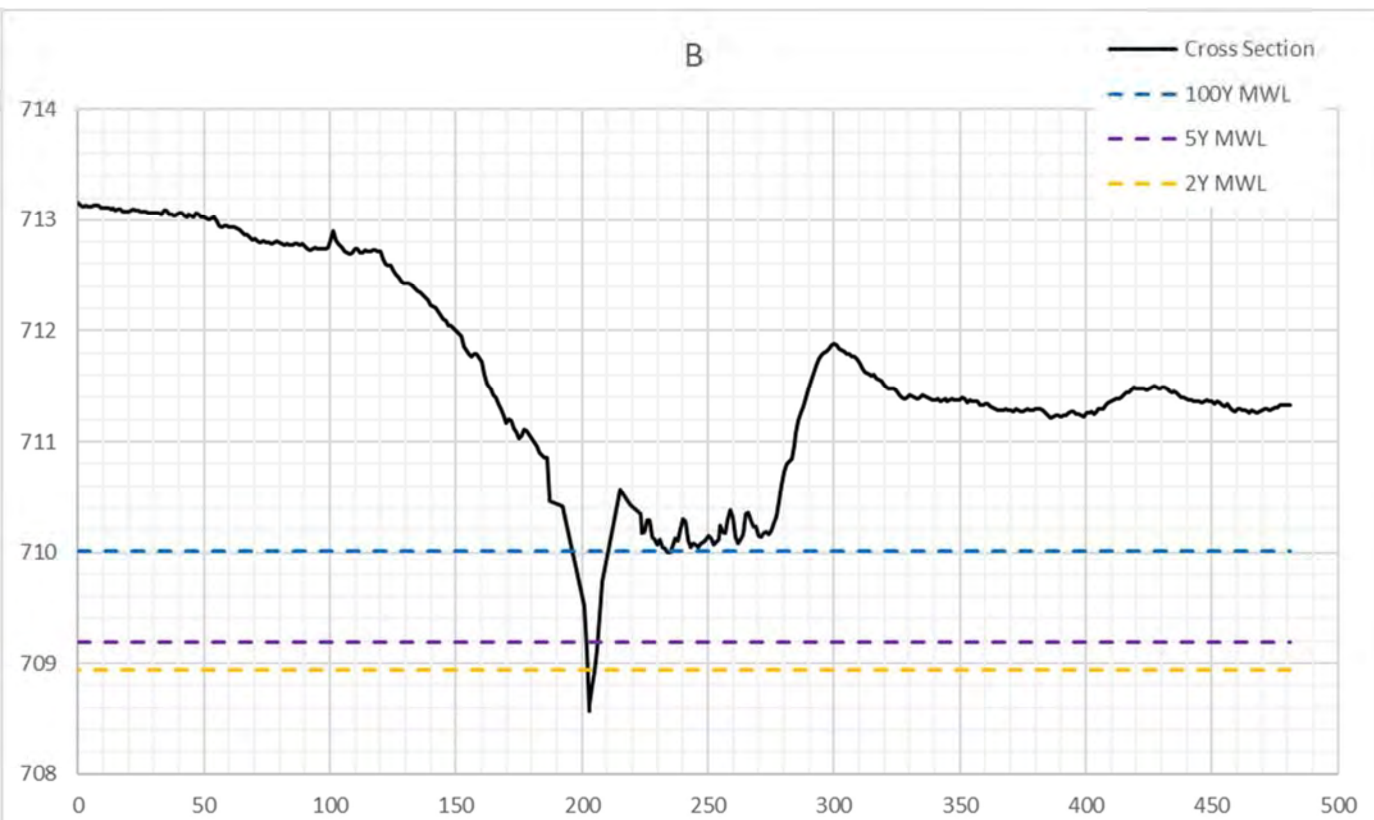
LeBlanc Canal Cross Sections



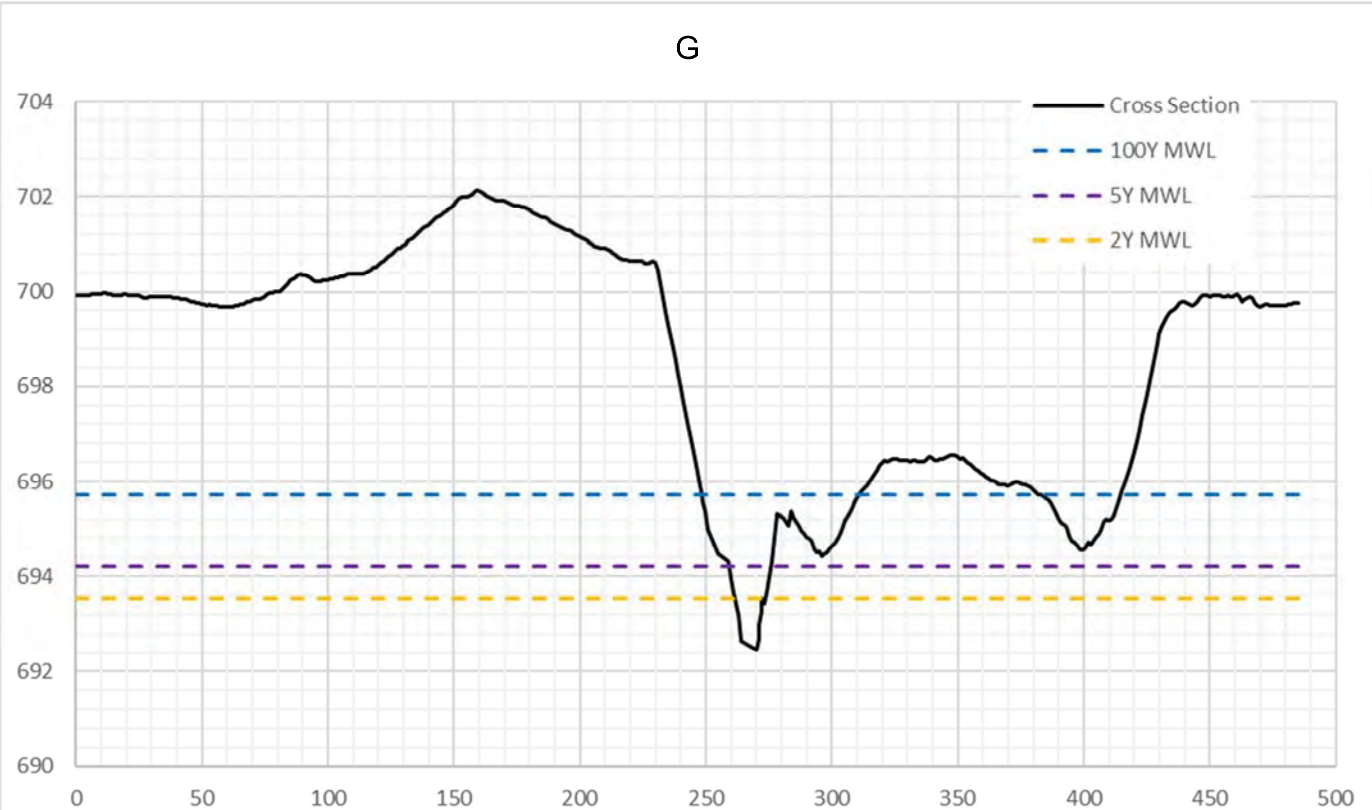


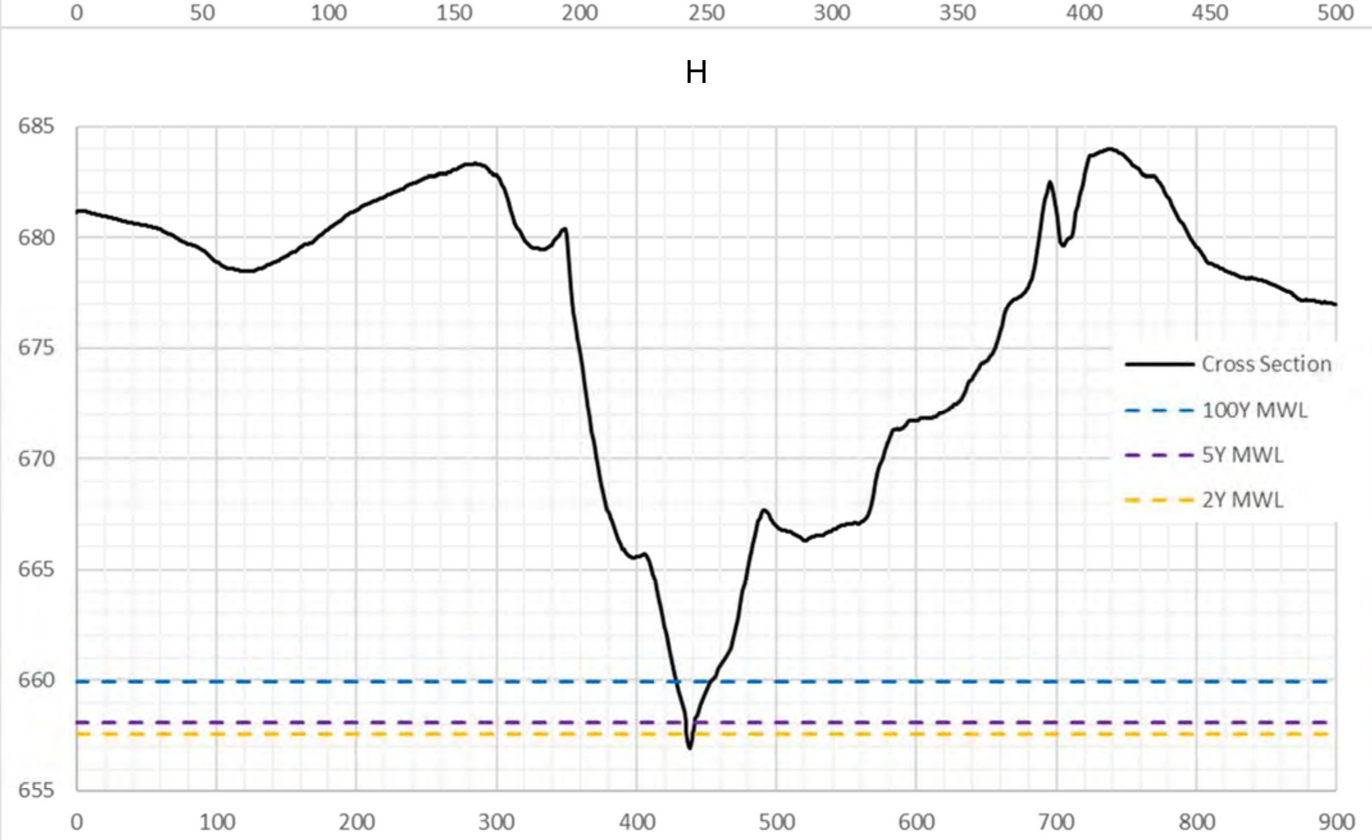
West Whitemud Creek Cross Sections



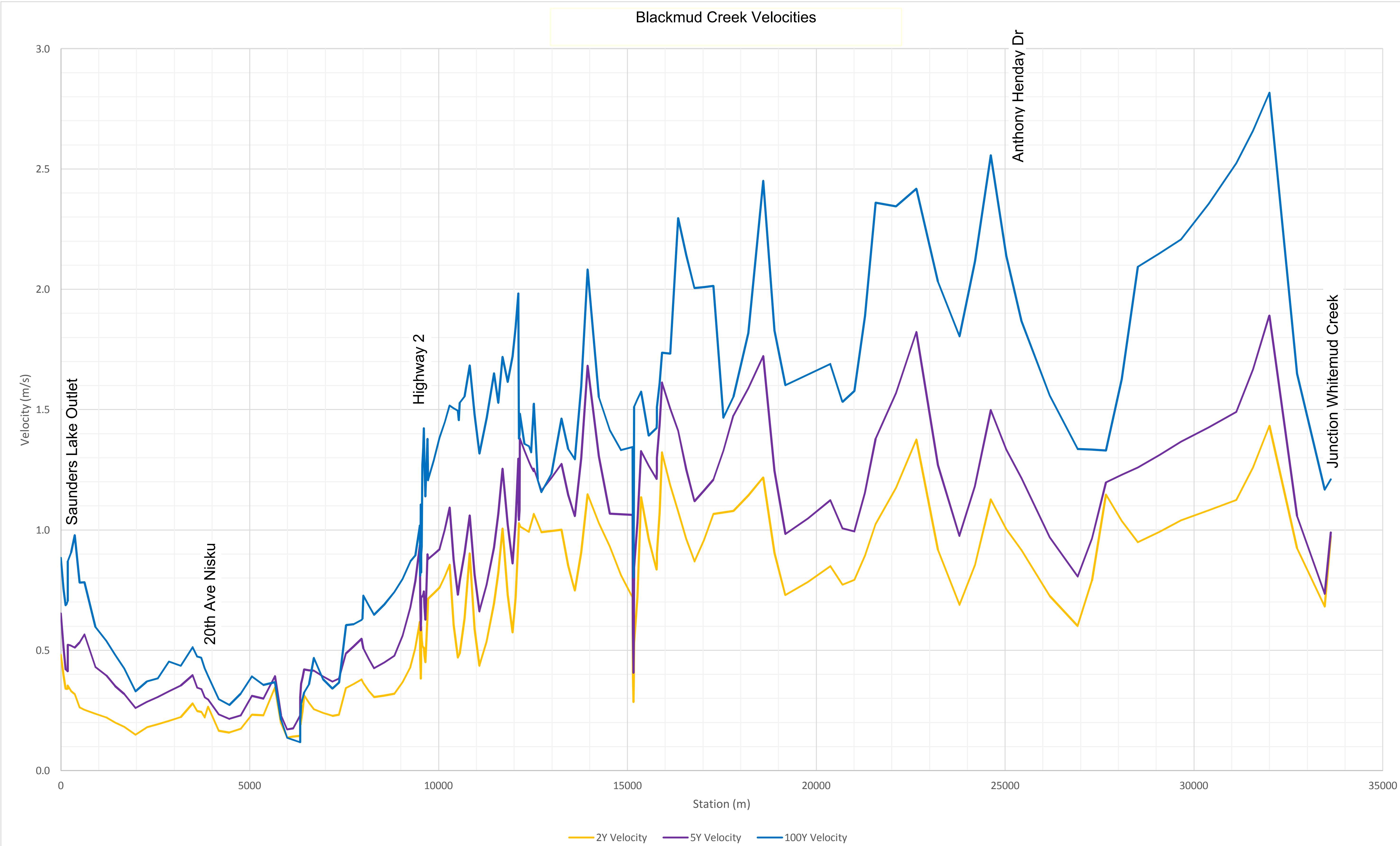


Whitemud Creek Cross Sections

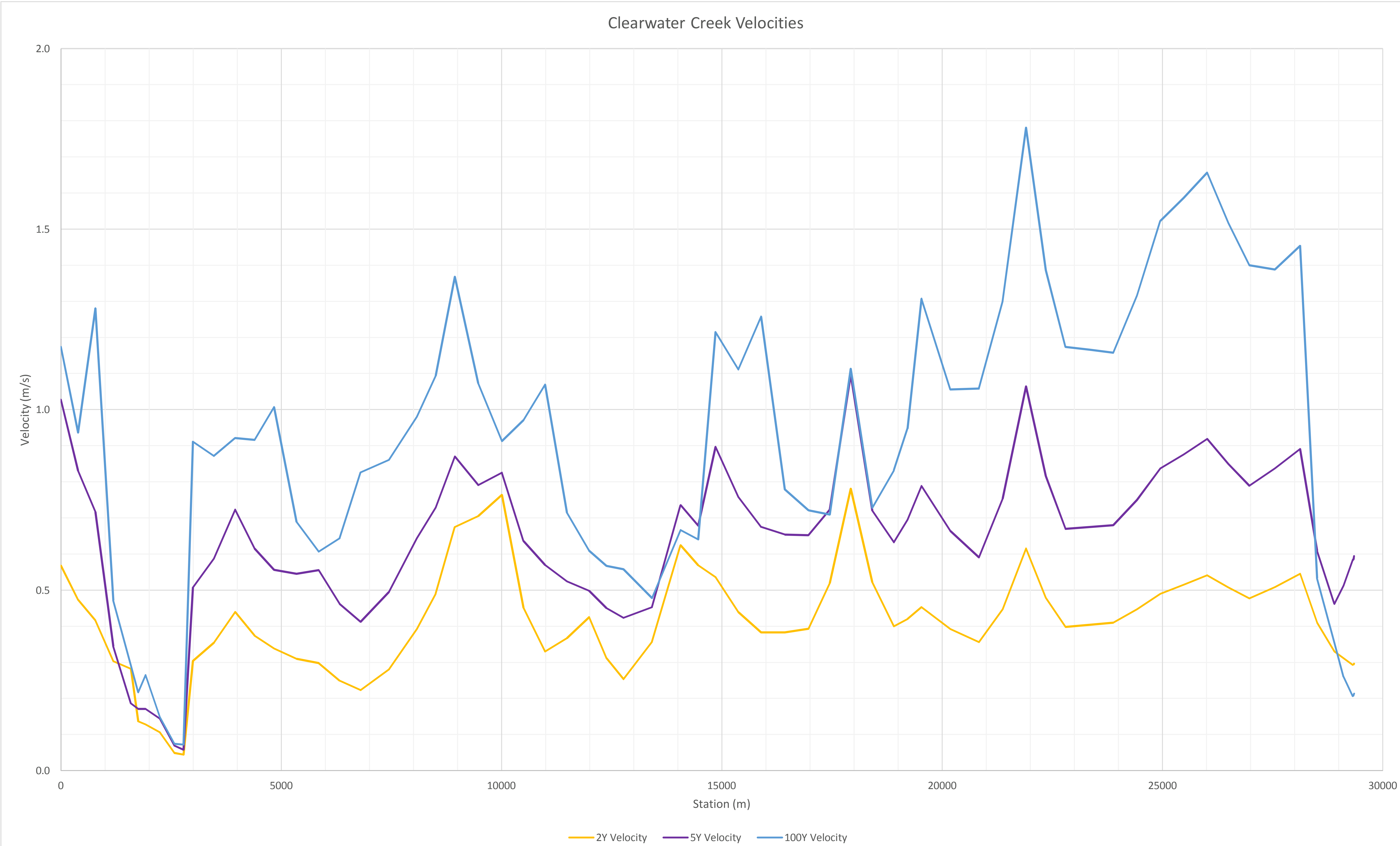




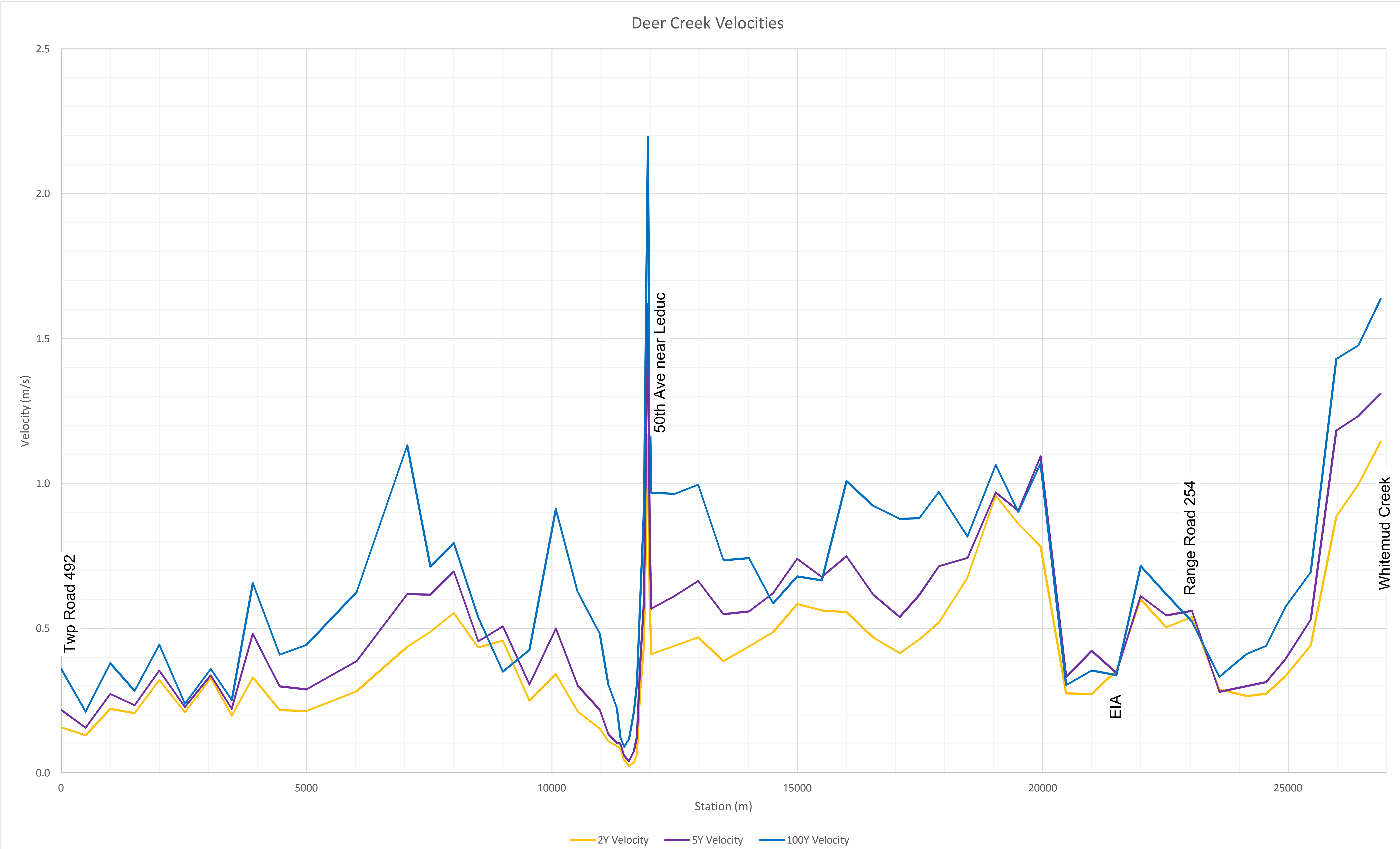
Appendix E - Velocity Profiles



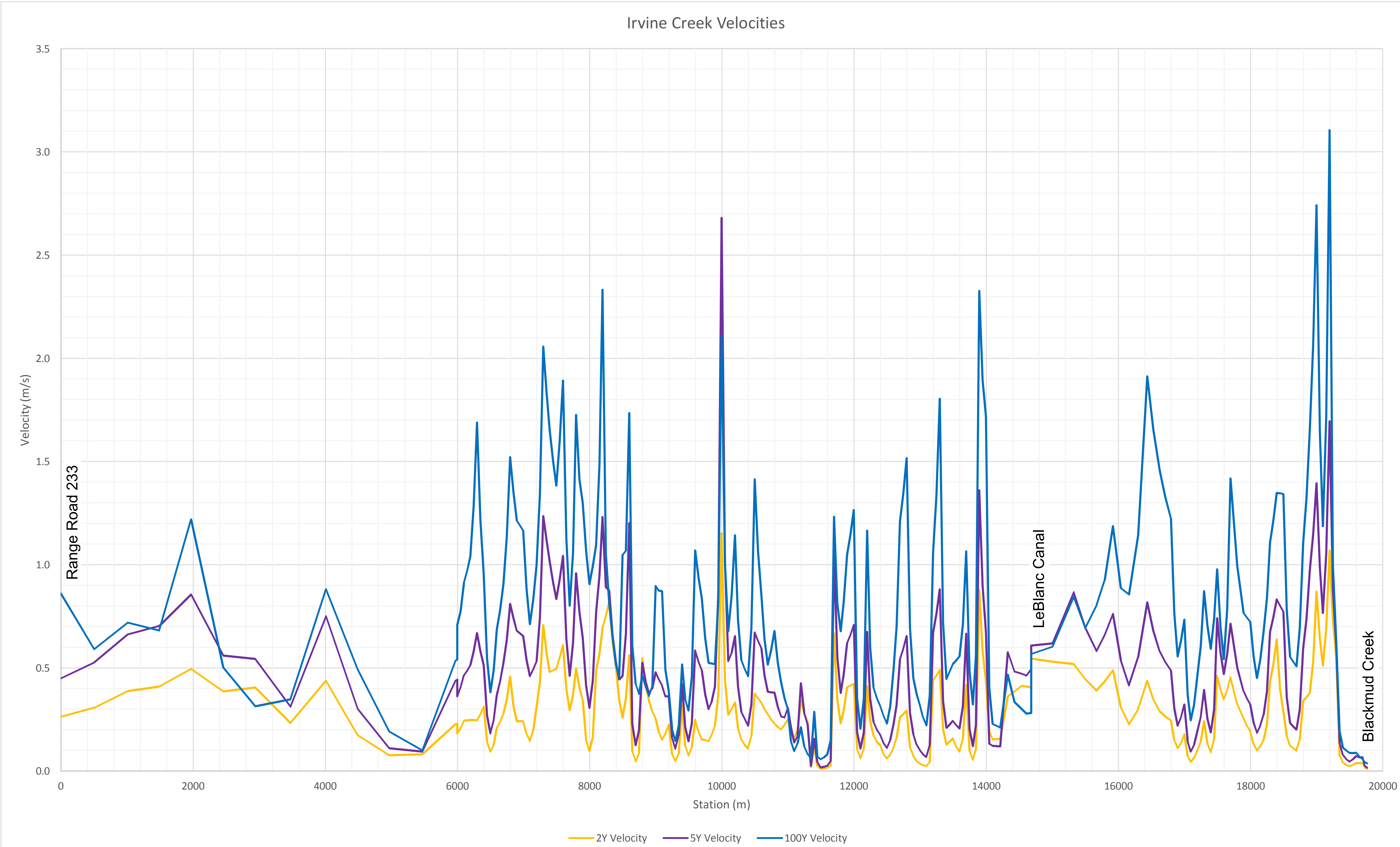
Blackmud Creek Velocities
Velocity (m/s)
Station (m)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
5000
10000
15000
20000
25000
30000
35000
Saunders Lake Outlet
20th Ave Nisku
Highway 2
Anthony Henday Dr
Junction Whitemud Creek
2Y Velocity
5Y Velocity
100Y Velocity



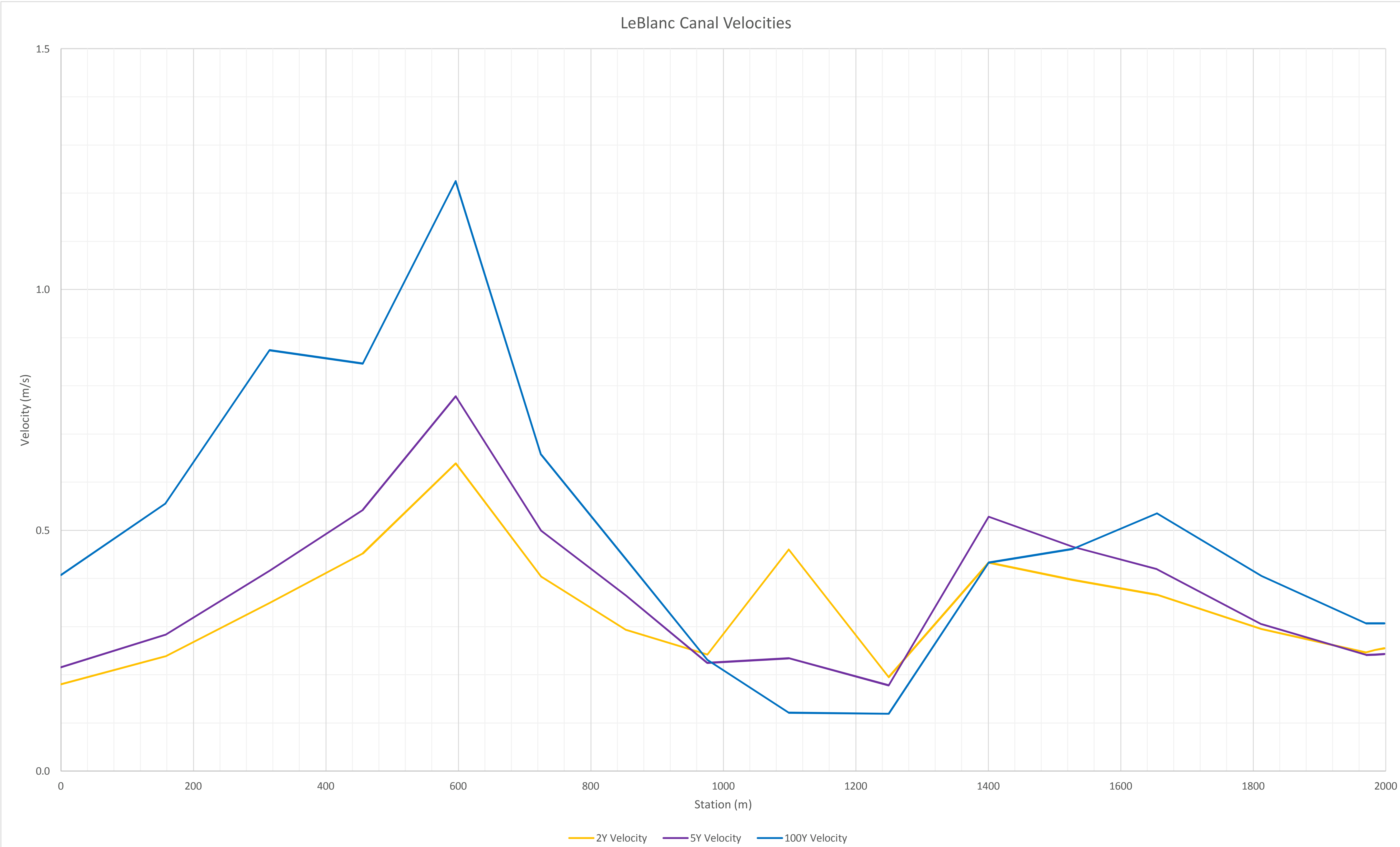
Clearwater Creek Velocities
Velocity (m/s)
2.0
1.5
1.0
0.5
0.0
0
5000
10000
15000
20000
25000
30000
Station (m)
2Y Velocity
5Y Velocity
100Y Velocity

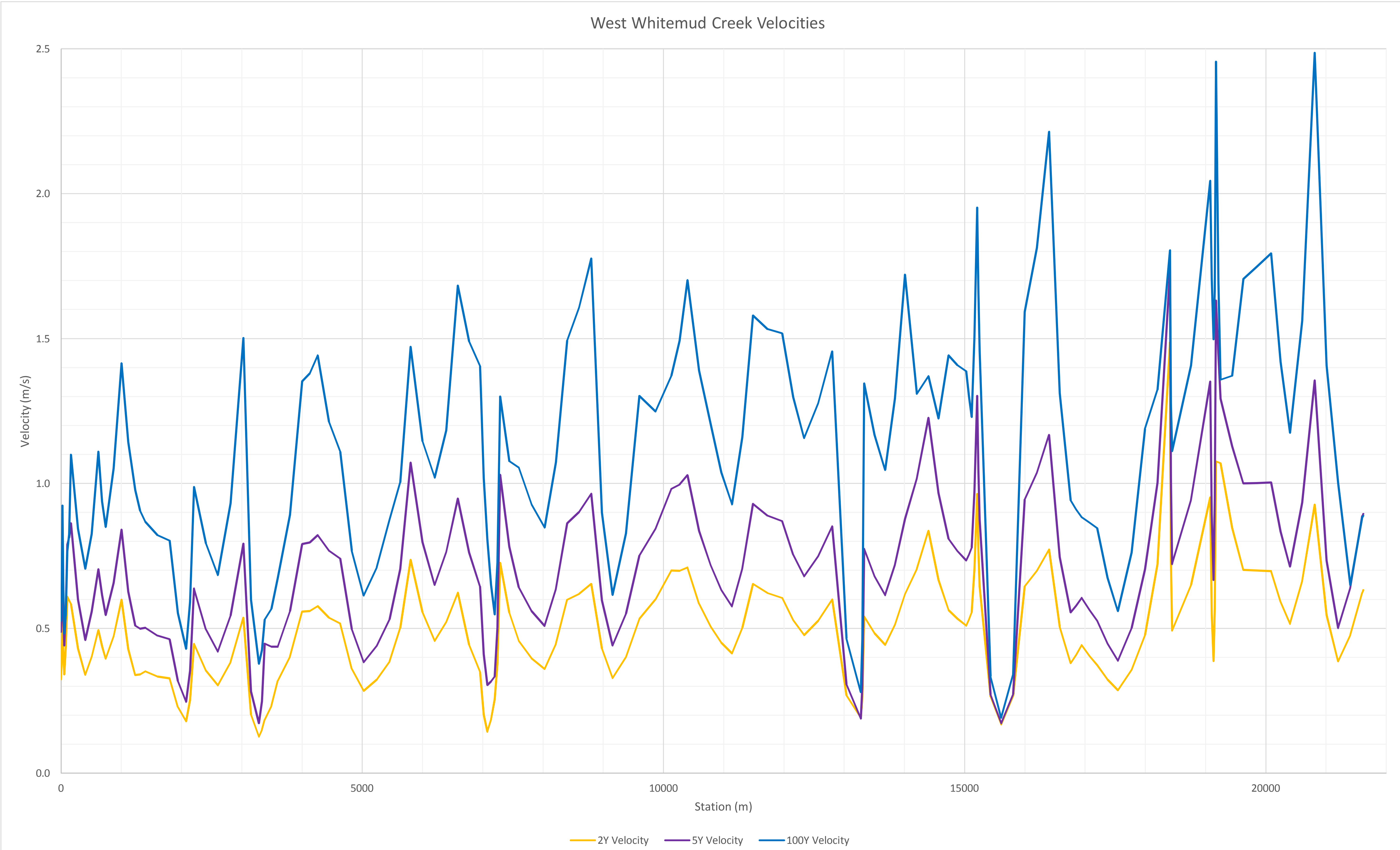


Deer Creek Velocities
Velocity (m/s)
2.5
2.0
1.5
1.0
0.5
0.0
0
5000
10000
15000
20000
25000
Station (m)
Twp Road 492
50th Ave near Leduc
EIA
Range Road 254
Whitemud Creek
2Y Velocity
5Y Velocity
100Y Velocity

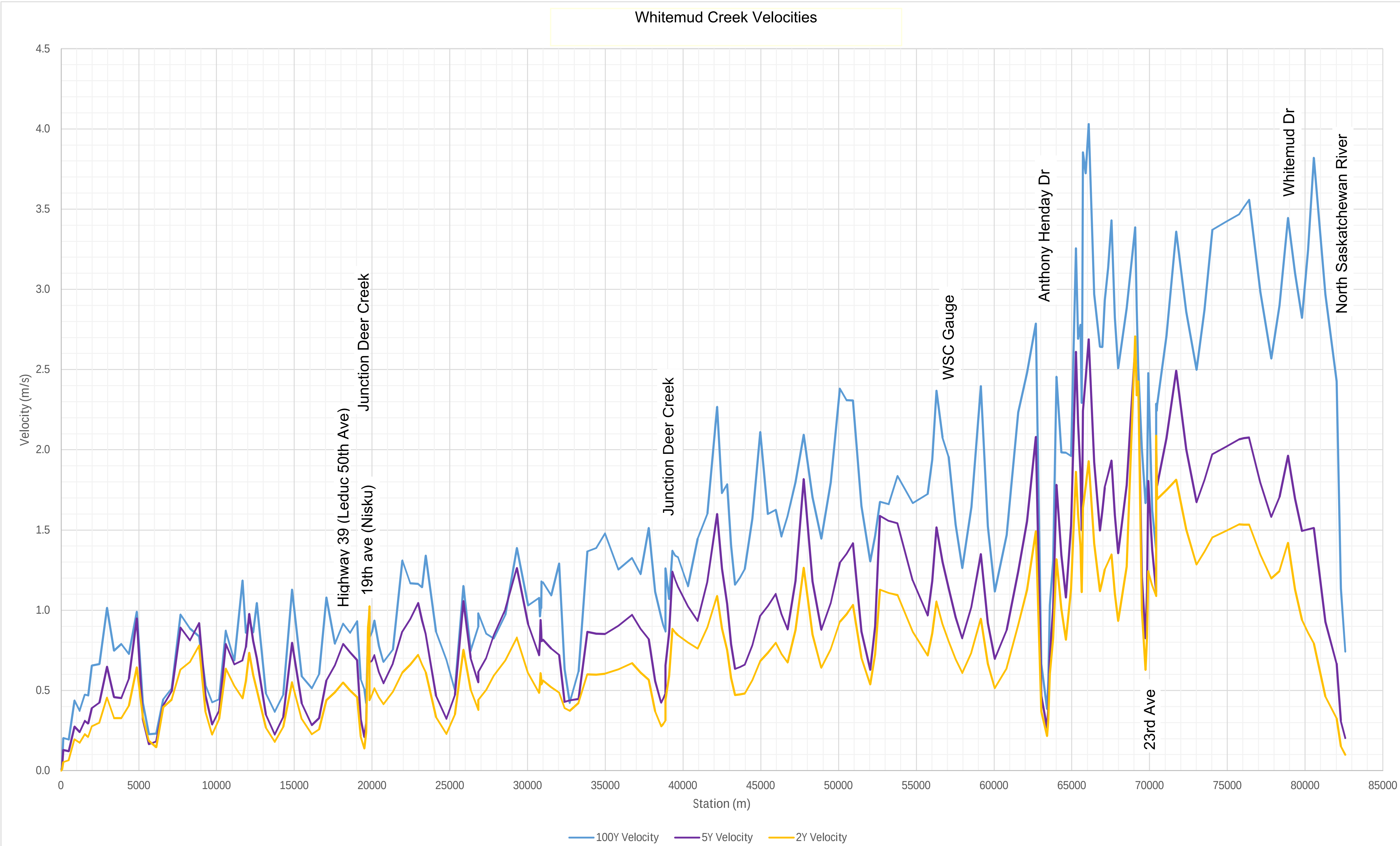


Irvine Creek Velocities
Velocity (m/s)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Station (m)
Range Road 233
LeBlanc Canal
Blackmud Creek
2Y Velocity
5Y Velocity
100Y Velocity


LeBlanc Canal Velocities
1.5
1.0
0.5
0.0
Velocity (m/s)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Station (m)
2Y Velocity
5Y Velocity
100Y Velocity

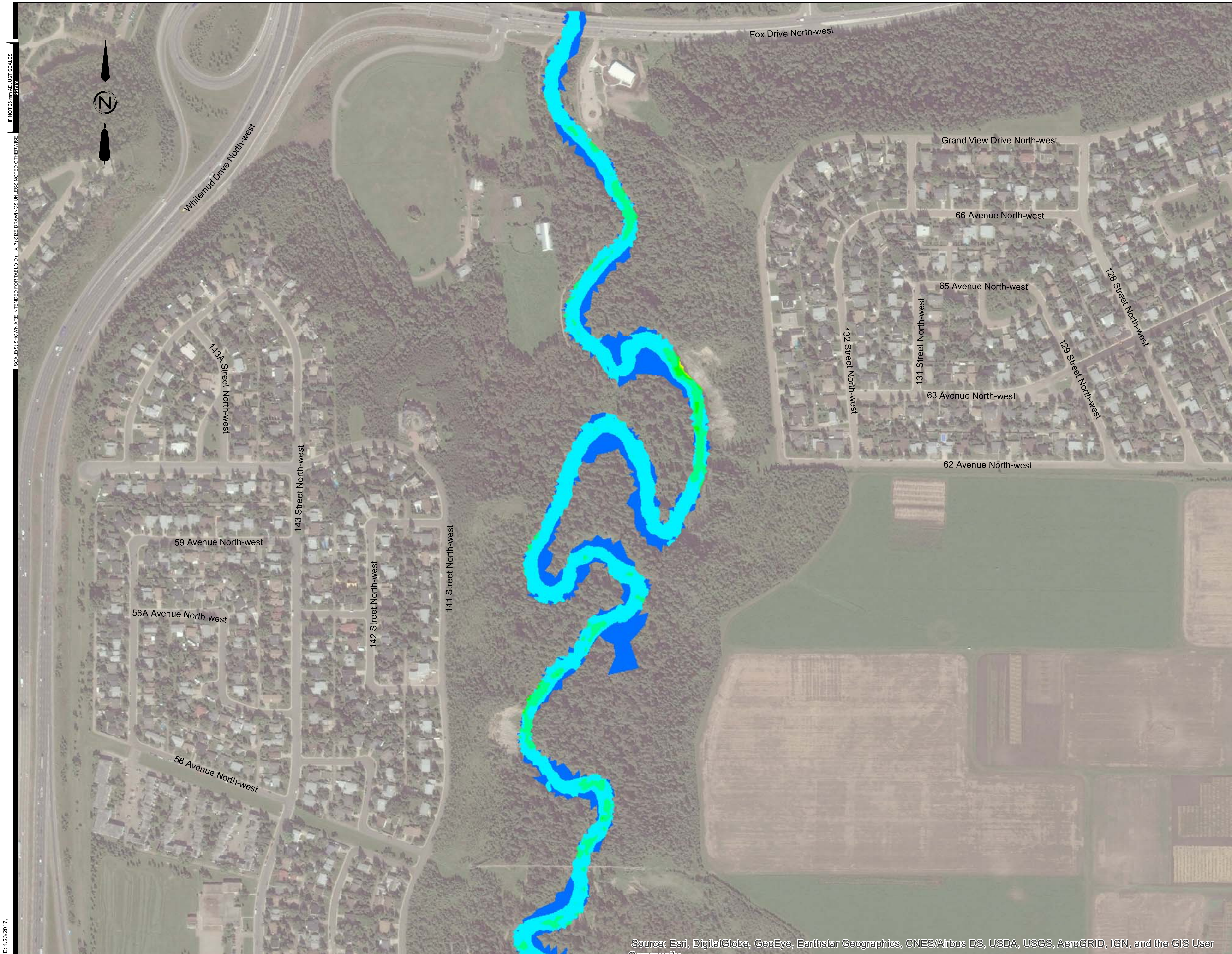


West Whitemud Creek Velocities
Velocity (m/s)
2.5
2.0
1.5
1.0
0.5
0.0
0
5000
10000
15000
20000
Station (m)
2Y Velocity
5Y Velocity
100Y Velocity



Whitemud Creek Velocities
Velocity (m/s)
Station (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
55000
60000
65000
70000
75000
80000
85000
Highway 39 (Leduc 50th Ave)
Junction Deer Creek
19th ave (Nisku)
Junction Deer Creek
WSC Gauge
Anthony Henday Dr
23rd Ave
Whitemud Dr
North Saskatchewan River
100Y Velocity
5Y Velocity
2Y Velocity

Appendix F - 2D Velocities

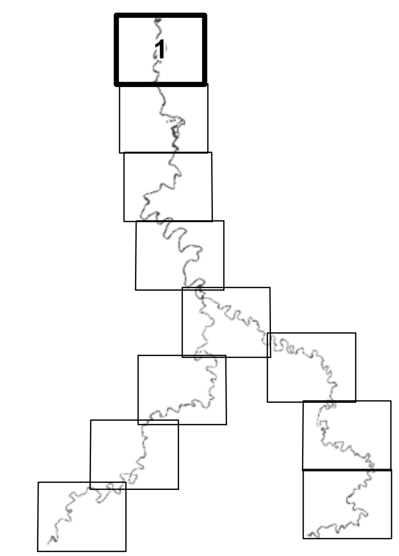


Associated Engineering

Legend:

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



Note: Maps are preliminary and subject to change.

FIGURE No. F-2

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

2 YEAR VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

IF NOT 25 mm ADJUST SCALES

25 mm

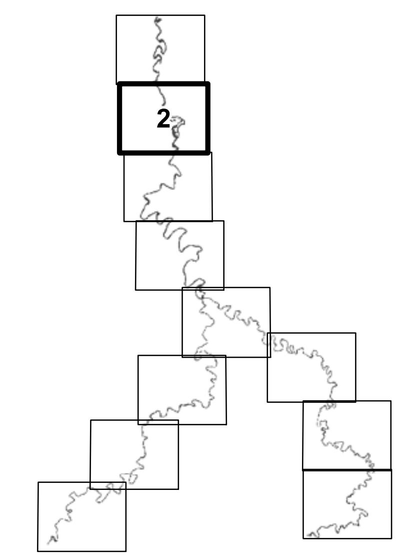
DATE: 1/23/2017.

Associated Engineering

Legend:

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



Note: Maps are preliminary and subject to change.

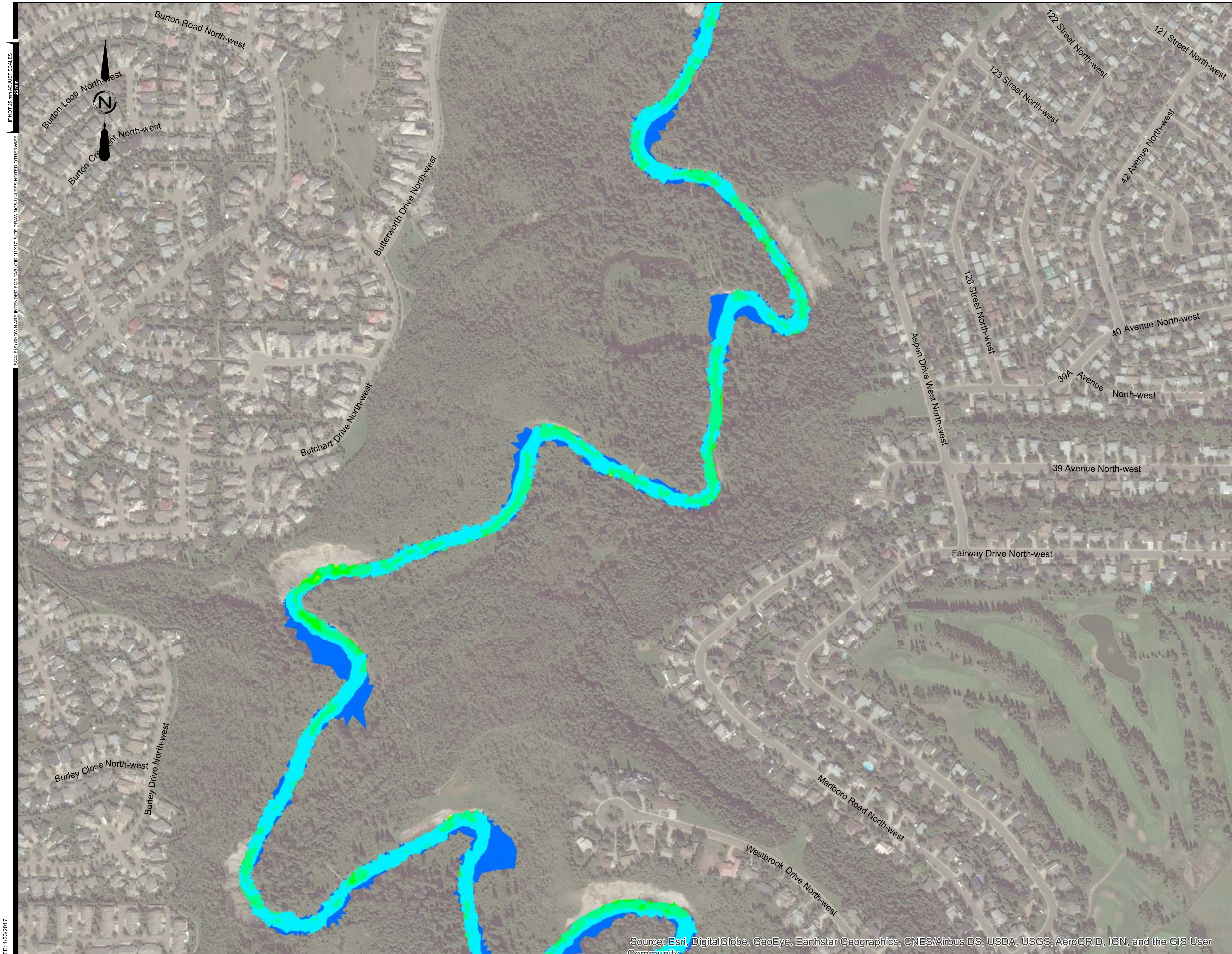
FIGURE No. F-3

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

2 YEAR VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

THIS DRAWING IS FOR THE USE OF THE CLIENT AND PROJECT INDICATED - NO REPRESENTATIONS OF ANY KIND ARE MADE TO OTHER PARTIES

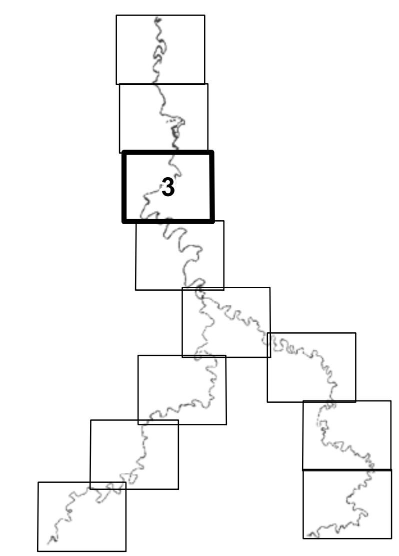


Associated Engineering

Legend:

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



Note: Maps are preliminary and subject to change.

FIGURE No. F-4

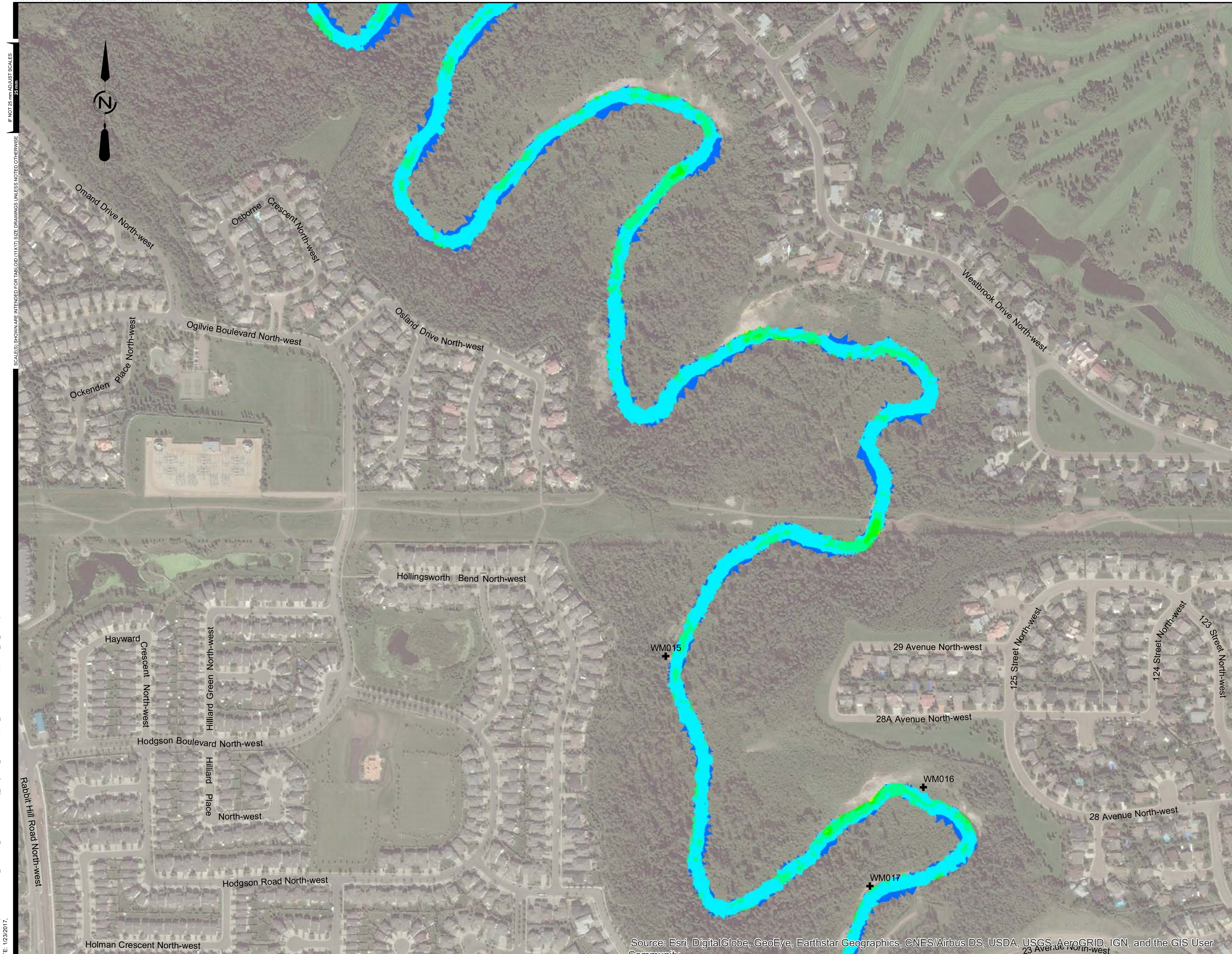
BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

2 YEAR VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE IF NOT 25 mm ADJUST SCALES 25 mm

\\s-edm-fs-01\projects\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\Appendix_2Y_Velocity.mxd DATE: 1/23/2017,



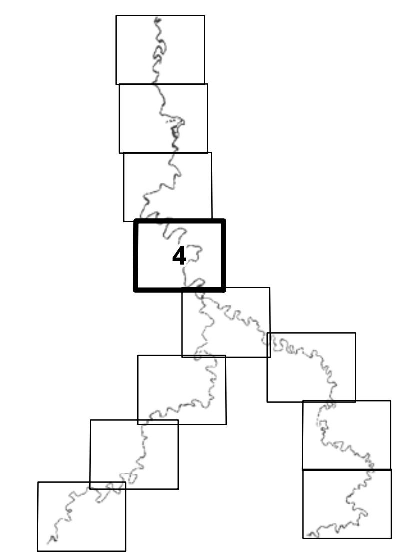
Associated Engineering

Legend:

✚ Erosion Site

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



Note: Maps are preliminary and subject to change.

FIGURE No. F-5

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

2 YEAR VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

IF NOT 25 mm ADJUST SCALES 25 mm

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

\\s-edm-fs-01\projects\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\Appendix_2Y_Velocity.mxd
DATE: 1/23/2017,

Associated Engineering

Legend:

✚ Erosion Site

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5

5

Note: Maps are preliminary and subject to change.

FIGURE No. F-6

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

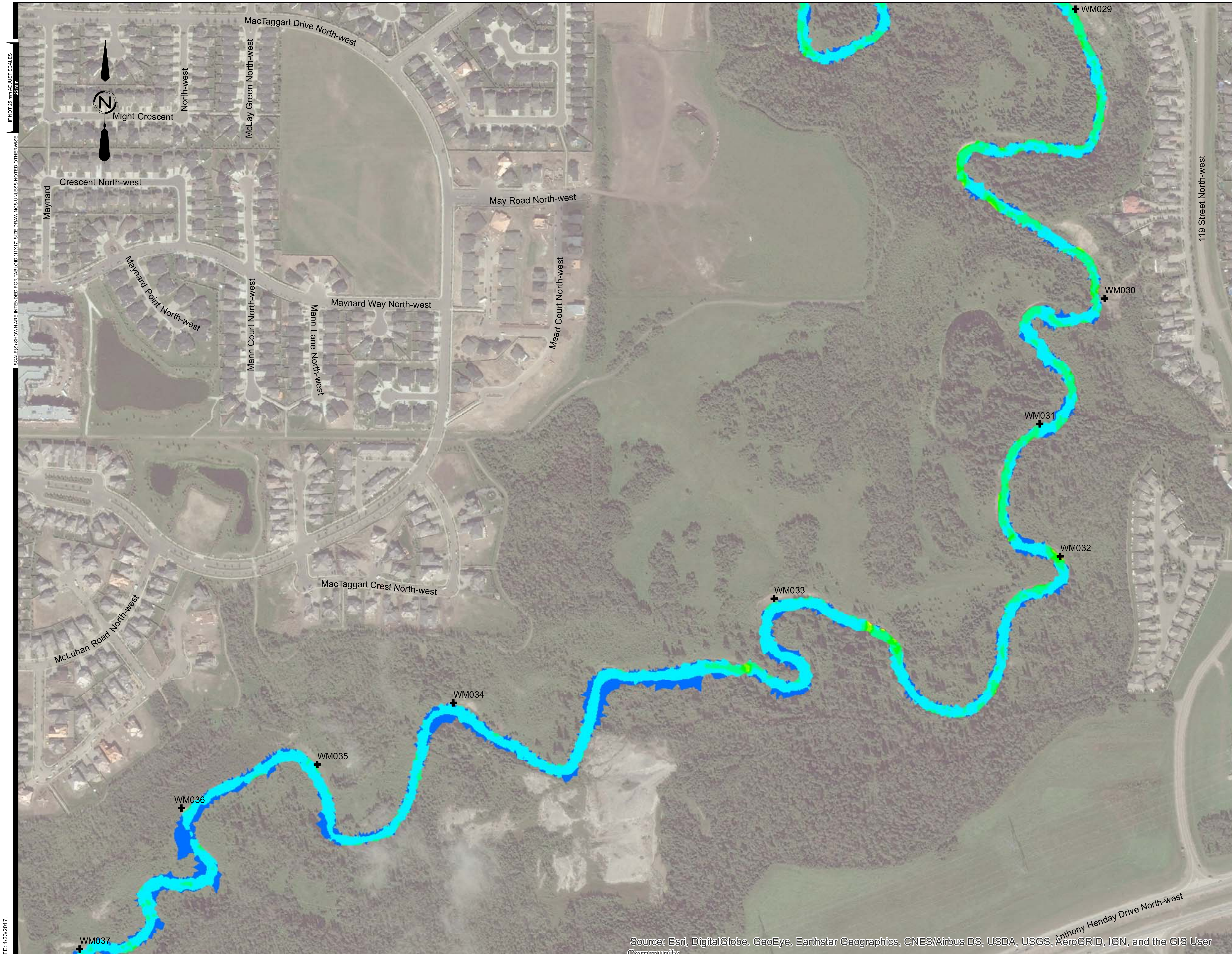
2 YEAR VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

IF NOT 25 mm ADJUST SCALES 25 mm

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

\\s-edm-fs-01\projects\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\Appendix_2Y_Velocity.mxd
DATE: 1/23/2017,



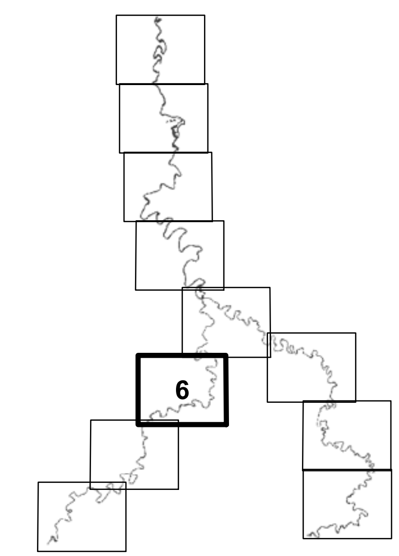
Associated Engineering

Legend:

✚ Erosion Site

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



Note: Maps are preliminary and subject to change.

FIGURE No. F-7

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

2 YEAR VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

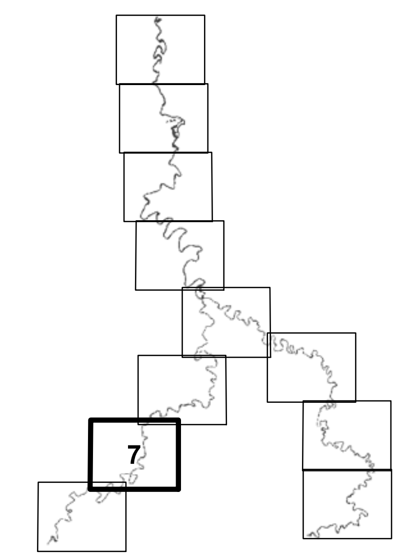
Associated Engineering

Legend:

- Erosion Site

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



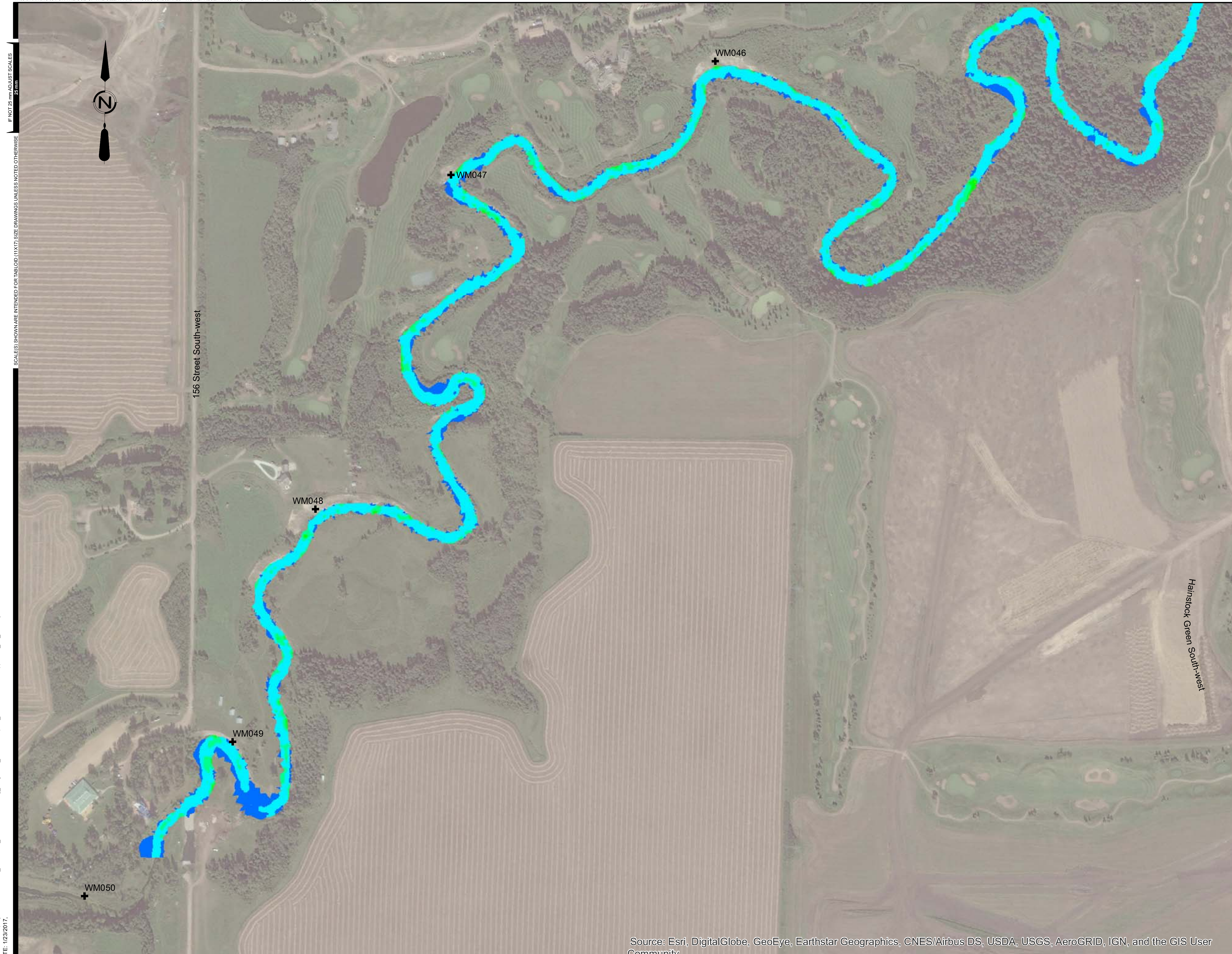
Note: Maps are preliminary and subject to change.

FIGURE No. F-8

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

2 YEAR
VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT



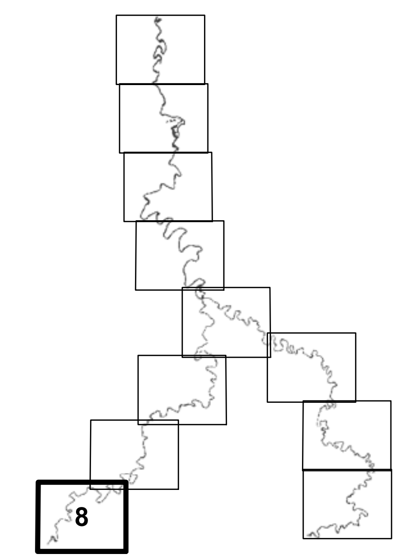
Associated Engineering

Legend:

✚ Erosion Site

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



Note: Maps are preliminary and subject to change.

FIGURE No. F-9

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

2 YEAR
VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

THIS DRAWING IS FOR THE USE OF THE CLIENT AND PROJECT INDICATED - NO REPRESENTATIONS OF ANY KIND ARE MADE TO OTHER PARTIES

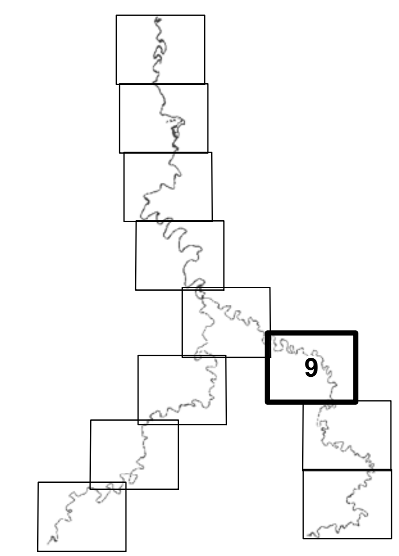
Associated Engineering

Legend:

- ✚ Erosion Site

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



Note: Maps are preliminary and subject to change.

FIGURE No. F-10

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

2 YEAR VELOCITY

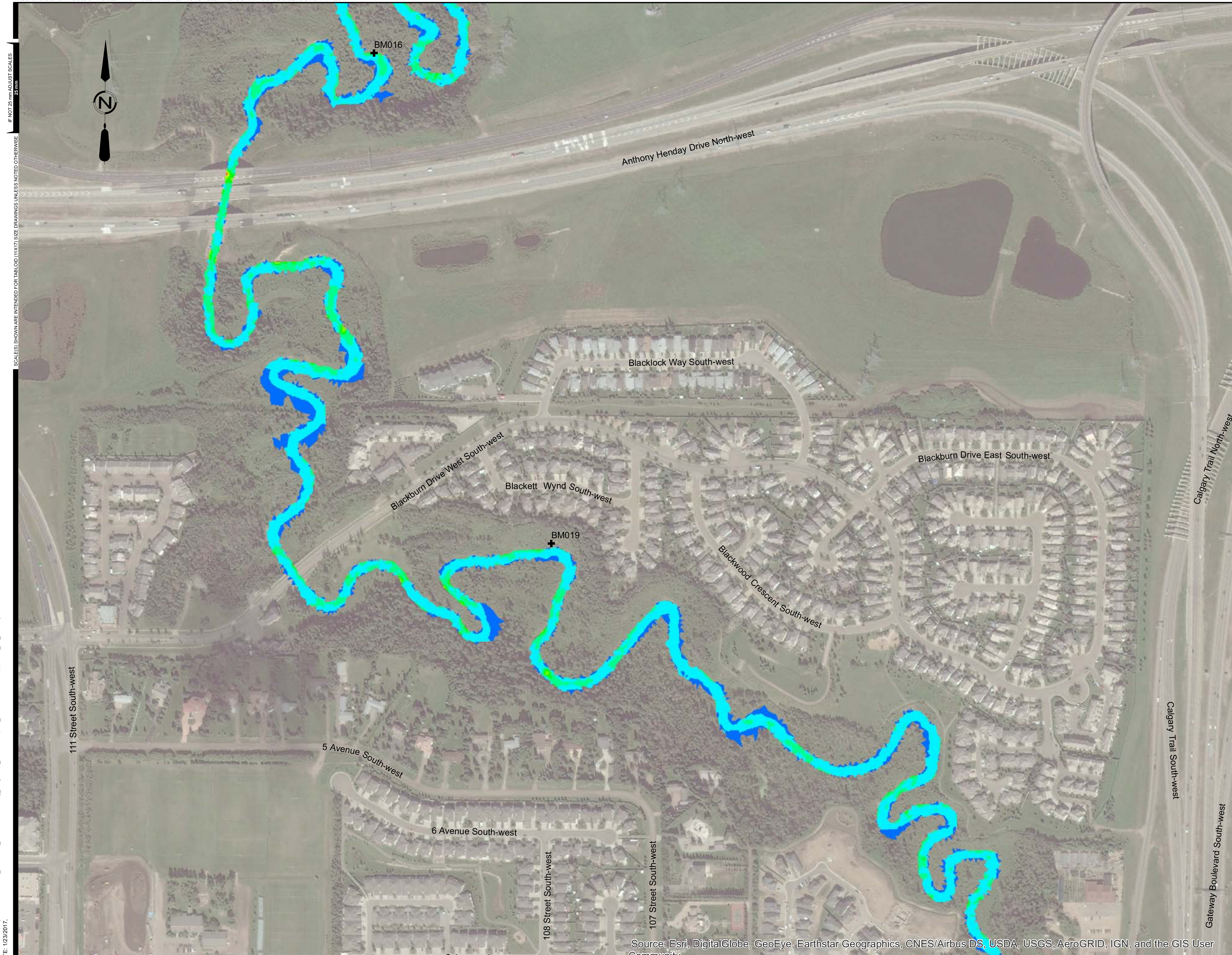
AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

IF NOT 25 mm ADJUST SCALES 25 mm

\\s-edm-fs-01\projects\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\Appendix_2Y_Velocity.mxd
DATE: 1/23/2017

THIS DRAWING IS FOR THE USE OF THE CLIENT AND PROJECT INDICATED - NO REPRESENTATIONS OF ANY KIND ARE MADE TO OTHER PARTIES



IF NOT 25 mm ADJUST SCALES 25 mm

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

\\s-edm-fs-01\projects\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\Appendix_2Y_Velocity.mxd
DATE: 1/23/2017,

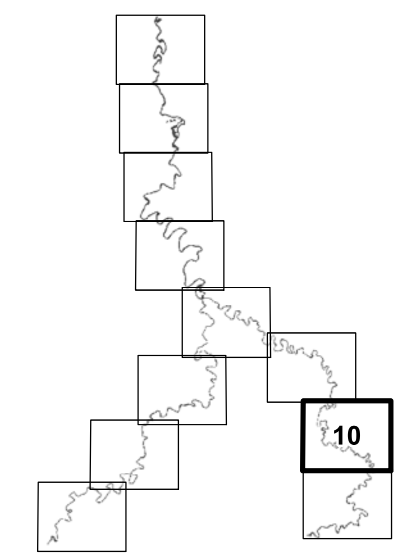
Associated Engineering

Legend:

✚ Erosion Site

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



Note: Maps are preliminary and subject to change.

FIGURE No. F-11

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

2 YEAR
VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

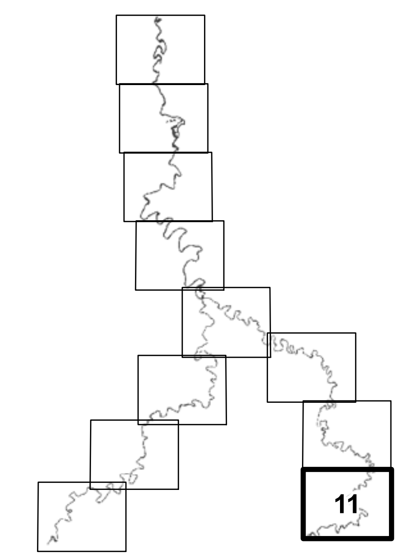
Associated Engineering

Legend:

- ✚ Erosion Site

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



Note: Maps are preliminary and subject to change.

FIGURE No. F-12

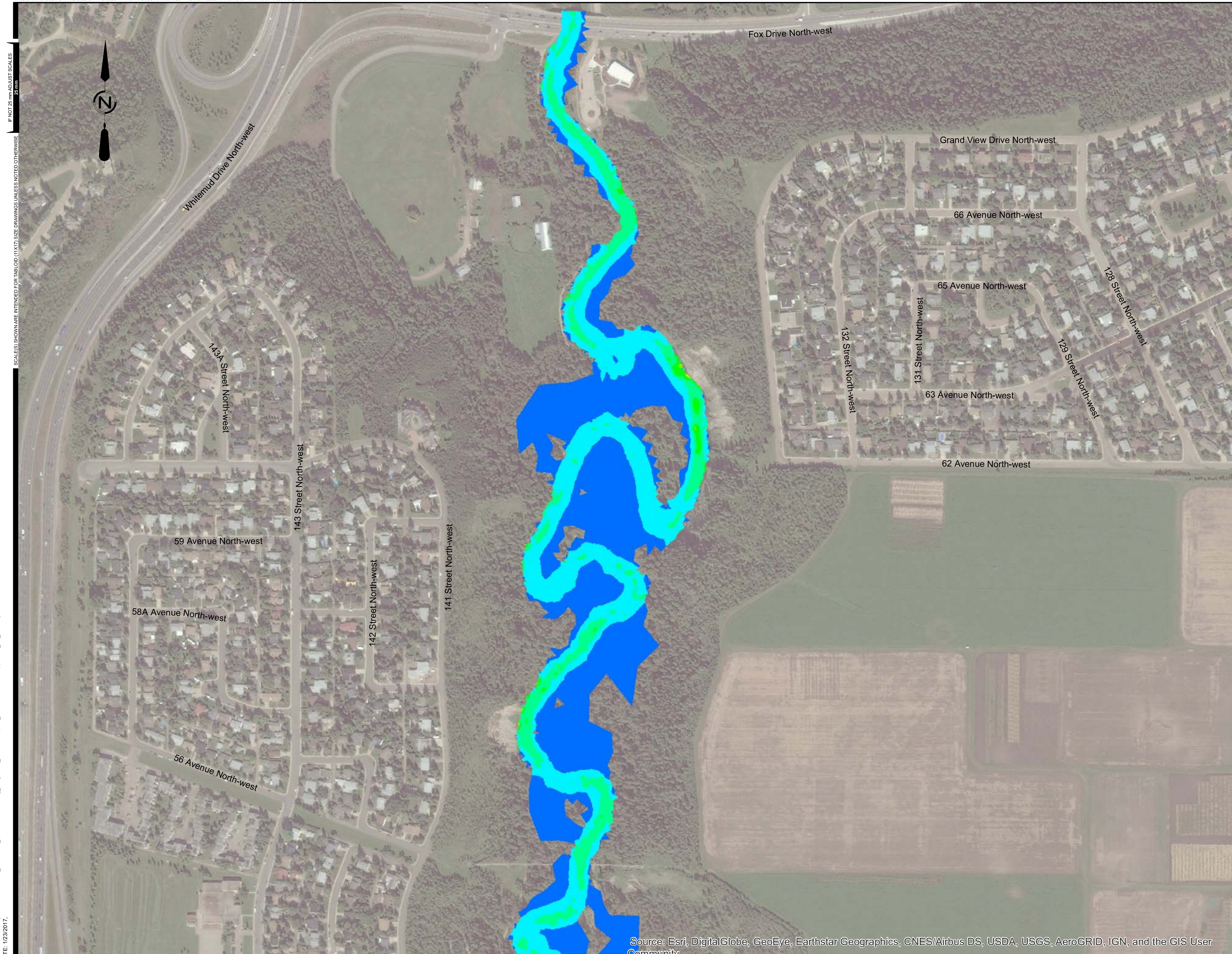
BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

2 YEAR VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

DATE: 1/23/2017.

THIS DRAWING IS FOR THE USE OF THE CLIENT AND PROJECT INDICATED - NO REPRESENTATIONS OF ANY KIND ARE MADE TO OTHER PARTIES



IF NOT 25 mm ADJUST SCALES

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

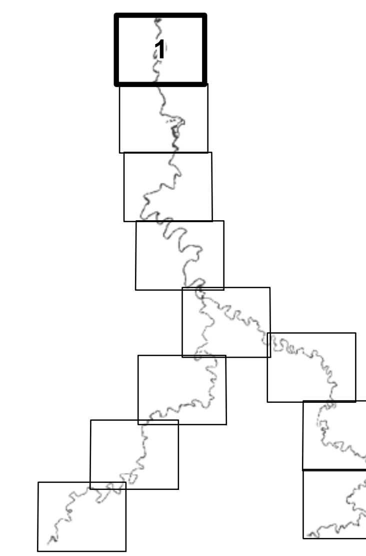
DATE: 1/23/2017.

Associated Engineering

Legend:

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



Note: Maps are preliminary and subject to change.

FIGURE No. F-13

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

5 YEAR VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

THIS DRAWING IS FOR THE USE OF THE CLIENT AND PROJECT INDICATED - NO REPRESENTATIONS OF ANY KIND ARE MADE TO OTHER PARTIES

IF NOT 25 mm ADJUST SCALES 25 mm

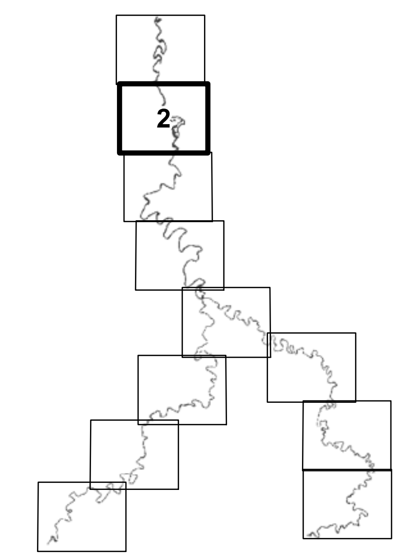
SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

Associated Engineering

Legend:

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



Note: Maps are preliminary and subject to change.

FIGURE No. F-14

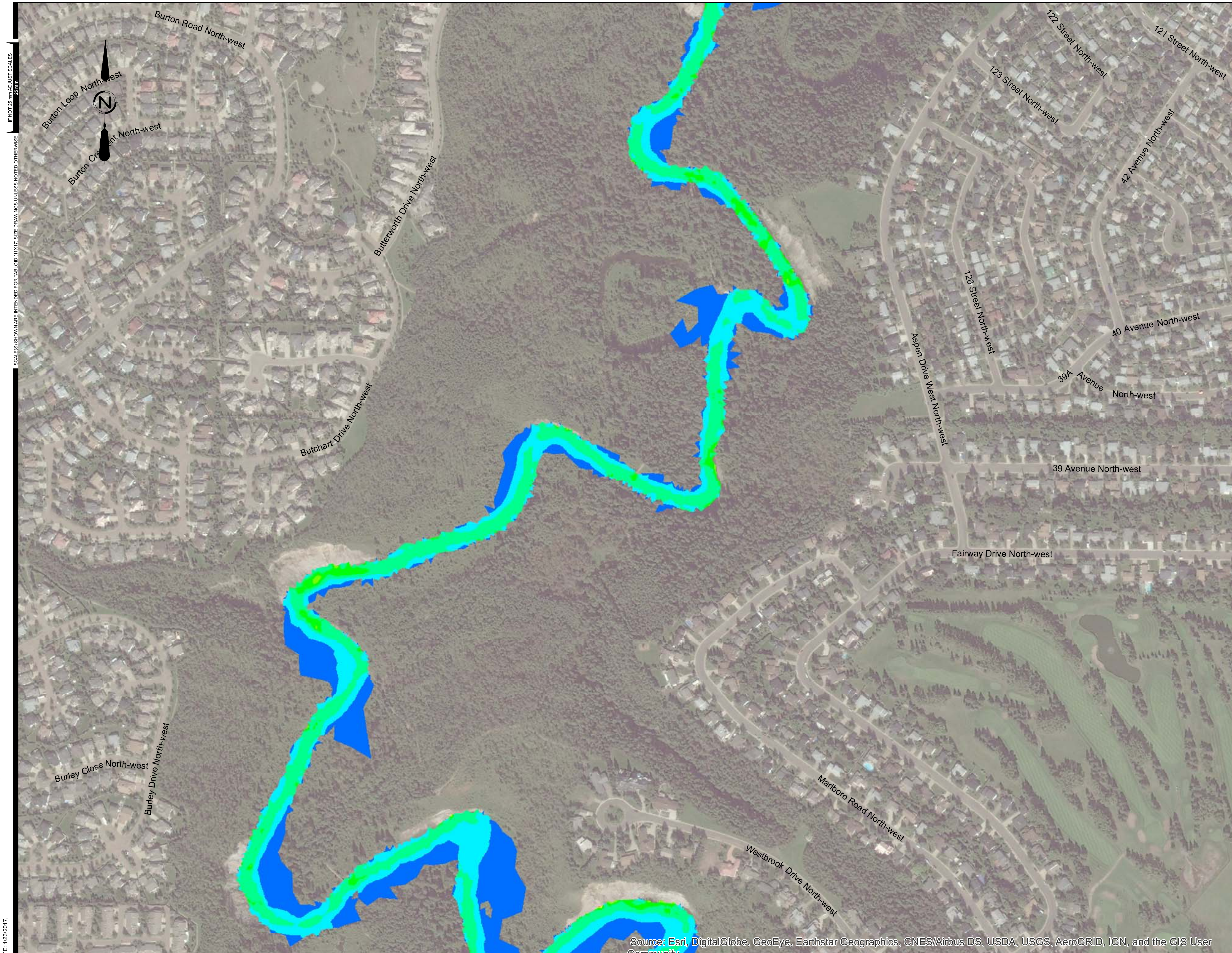
BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

5 YEAR VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

\\s-edm-fs-01\projects\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\Appendix_5Y_Velocity.mxd
DATE: 1/23/2017,

THIS DRAWING IS FOR THE USE OF THE CLIENT AND PROJECT INDICATED - NO REPRESENTATIONS OF ANY KIND ARE MADE TO OTHER PARTIES

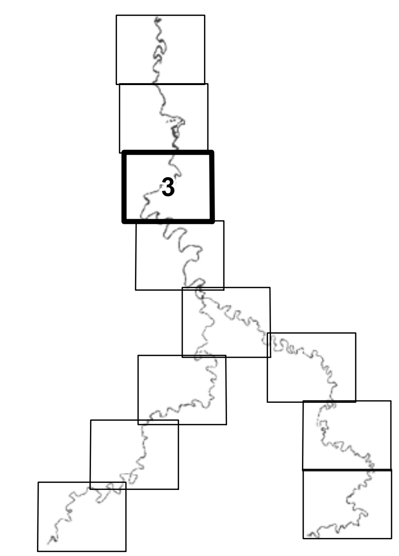


Associated Engineering

Legend:

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



Note: Maps are preliminary and subject to change.

FIGURE No. F-15

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

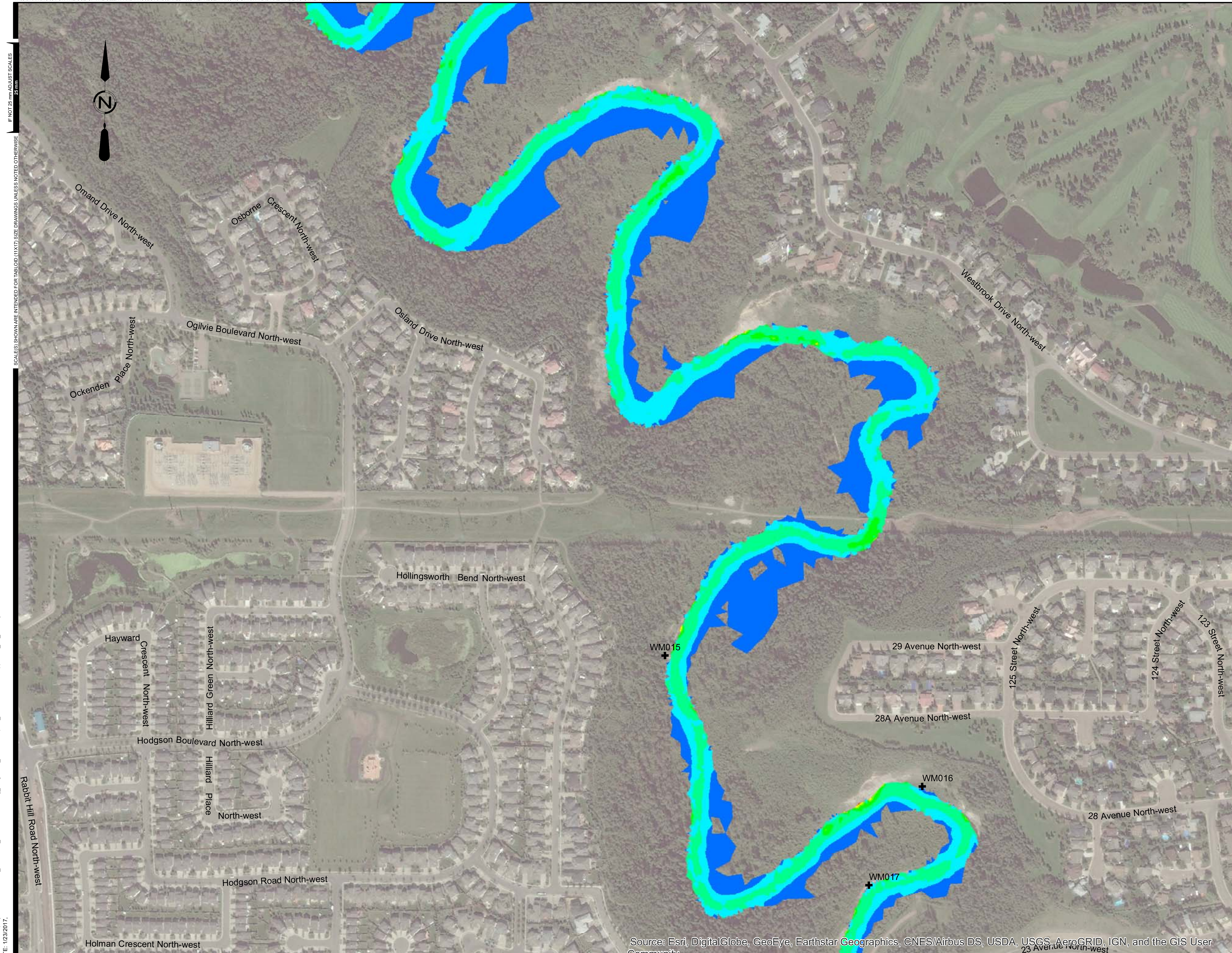
5 YEAR VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE IF NOT 25 mm ADJUST SCALES 25 mm

\\s-edm-fs-01\projects\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\Appendix_5Y_Velocity.mxd DATE: 1/23/2017,

THIS DRAWING IS FOR THE USE OF THE CLIENT AND PROJECT INDICATED - NO REPRESENTATIONS OF ANY KIND ARE MADE TO OTHER PARTIES



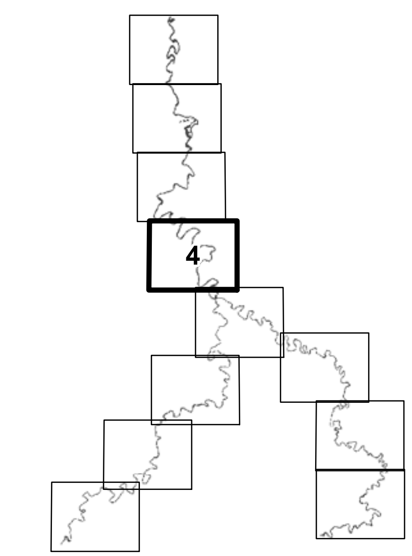
Associated Engineering

Legend:

✚ Erosion Site

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



Note: Maps are preliminary and subject to change.

FIGURE No. F-16

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

5 YEAR VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

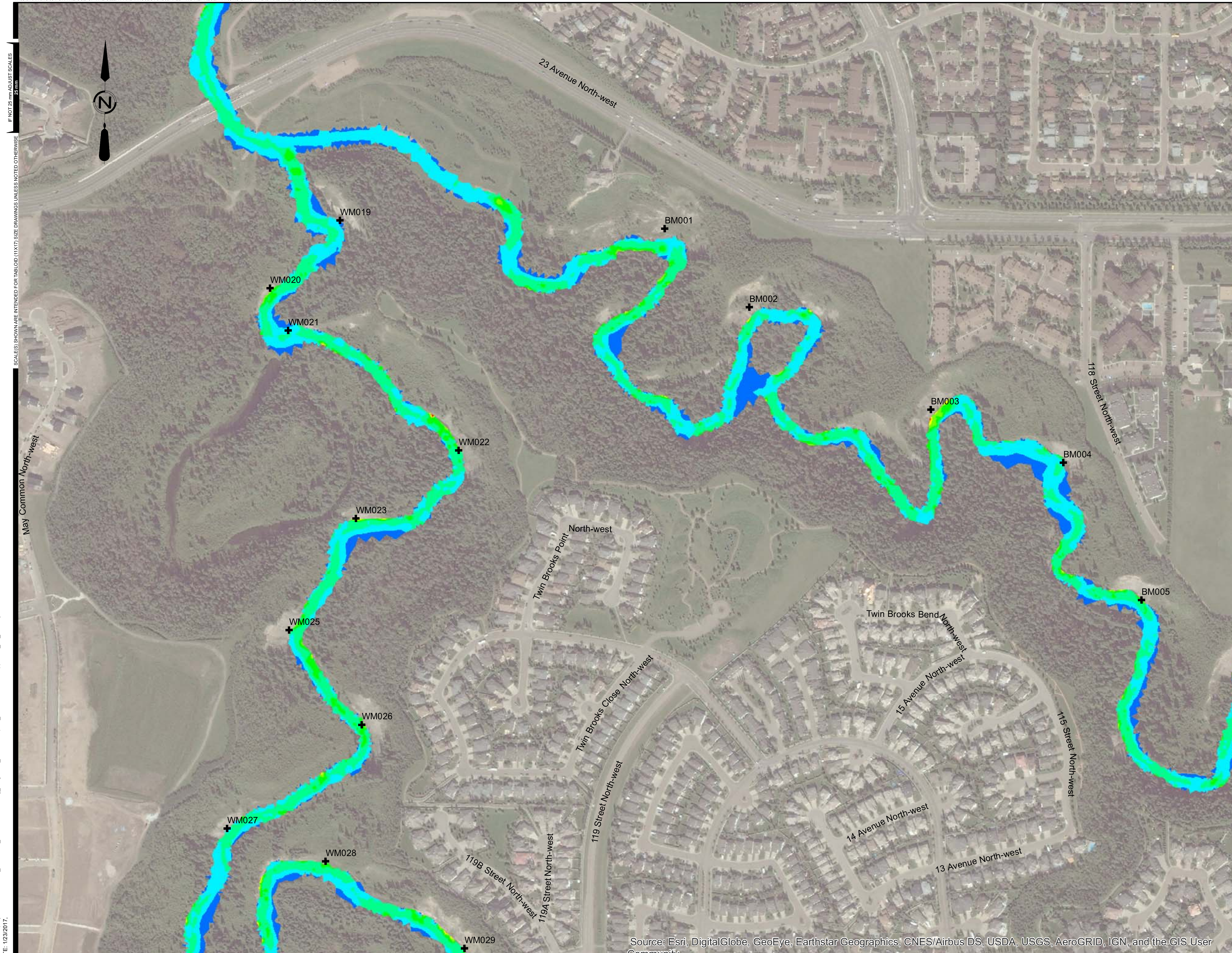
IF NOT 25 mm ADJUST SCALES 25 mm

\\s-edm-fs-01\projects\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\Appendix_5Y_Velocity.mxd
DATE: 1/23/2017,

THIS DRAWING IS FOR THE USE OF THE CLIENT AND PROJECT INDICATED - NO REPRESENTATIONS OF ANY KIND ARE MADE TO OTHER PARTIES

IF NOT 25 mm ADJUST SCALES

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE



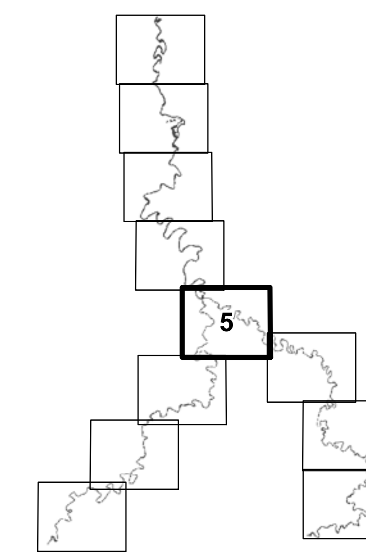
Associated Engineering

Legend:

✚ Erosion Site

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



Note: Maps are preliminary and subject to change.

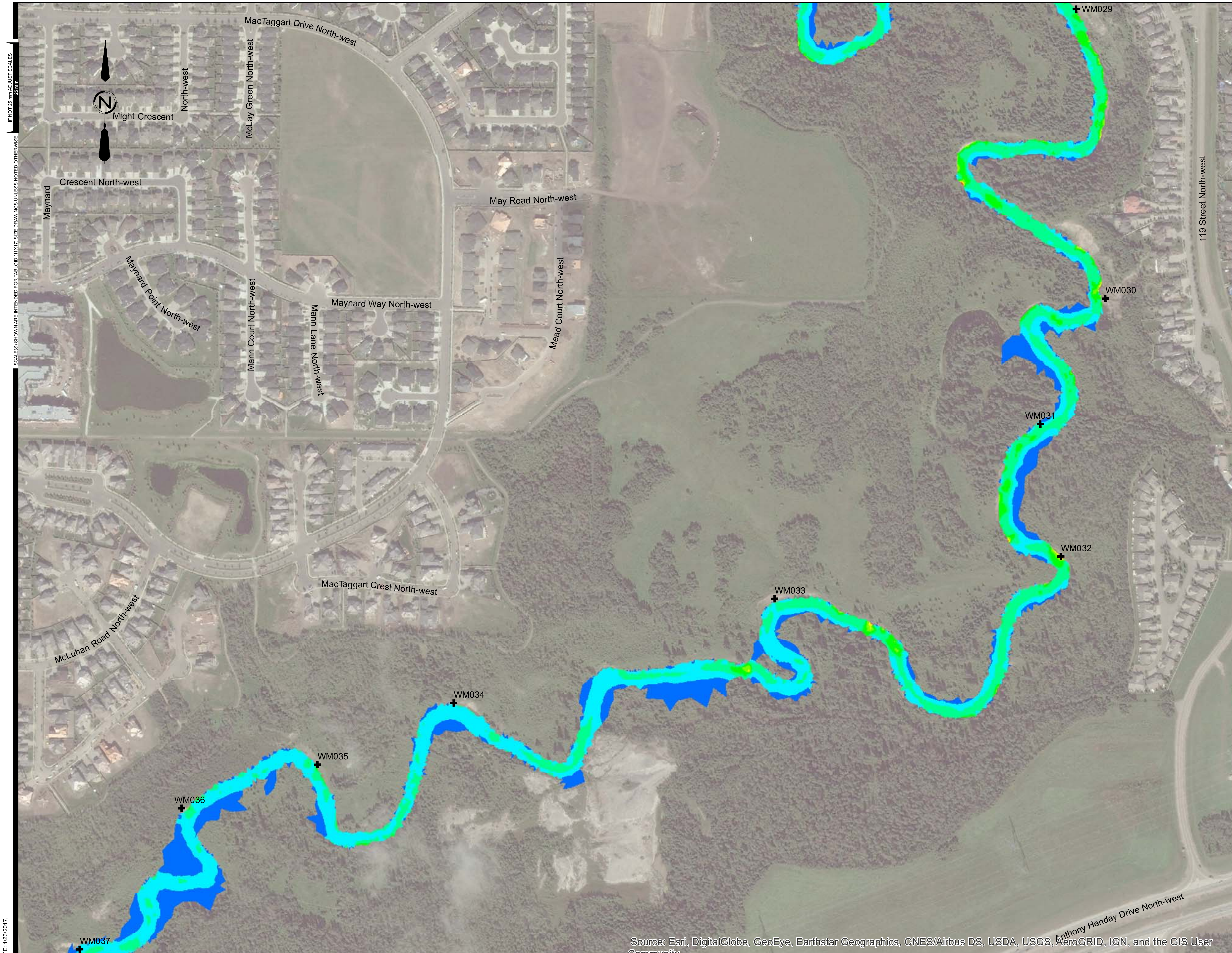
FIGURE No. F-17

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

5 YEAR VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

\\s-edm-fs-01\projects\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\Appendix_5Y_Velocity.mxd
DATE: 1/23/2017,



Associated Engineering

Legend:
- ✚ Erosion Site

Velocity (m/s)
- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5

Note: Maps are preliminary and subject to change.

FIGURE No. F-18

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

5 YEAR VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

IF NOT 25 mm ADJUST SCALES 25 mm
SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

\\s-edm-fs-01\projects\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\Appendix_5Y_Velocity.mxd
DATE: 1/23/2017,

Associated Engineering

Legend:

✚ Erosion Site

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5

7

Note: Maps are preliminary and subject to change.

FIGURE No. F-19

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

5 YEAR VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

THIS DRAWING IS FOR THE USE OF THE CLIENT AND PROJECT INDICATED - NO REPRESENTATIONS OF ANY KIND ARE MADE TO OTHER PARTIES

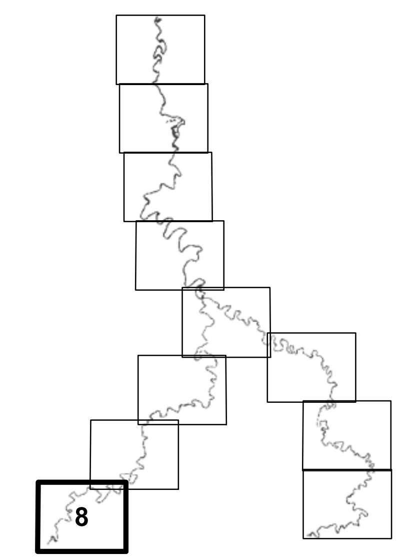
Associated Engineering

Legend:

✚ Erosion Site

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



Note: Maps are preliminary and subject to change.

FIGURE No. F-20

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

5 YEAR
VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

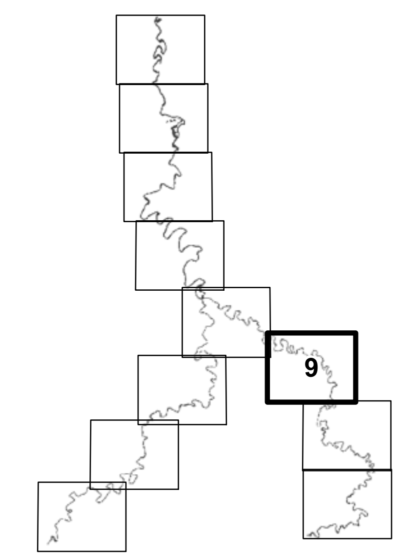
Associated Engineering

Legend:

- ✚ Erosion Site

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



Note: Maps are preliminary and subject to change.

FIGURE No. F-21

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

5 YEAR VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

THIS DRAWING IS FOR THE USE OF THE CLIENT AND PROJECT INDICATED - NO REPRESENTATIONS OF ANY KIND ARE MADE TO OTHER PARTIES

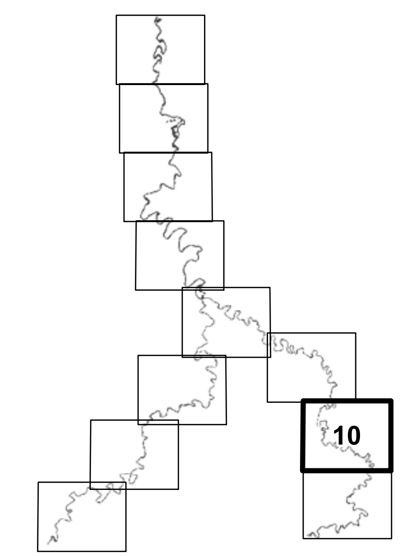
Associated Engineering

Legend:

✚ Erosion Site

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



Note: Maps are preliminary and subject to change.

FIGURE No. F-22

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

5 YEAR
VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

THIS DRAWING IS FOR THE USE OF THE CLIENT AND PROJECT INDICATED - NO REPRESENTATIONS OF ANY KIND ARE MADE TO OTHER PARTIES

IF NOT 25 mm ADJUST SCALES

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

DATE: 1/23/2017.

Associated Engineering

Legend:

- ✚ Erosion Site

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5

11

Note: Maps are preliminary and subject to change.

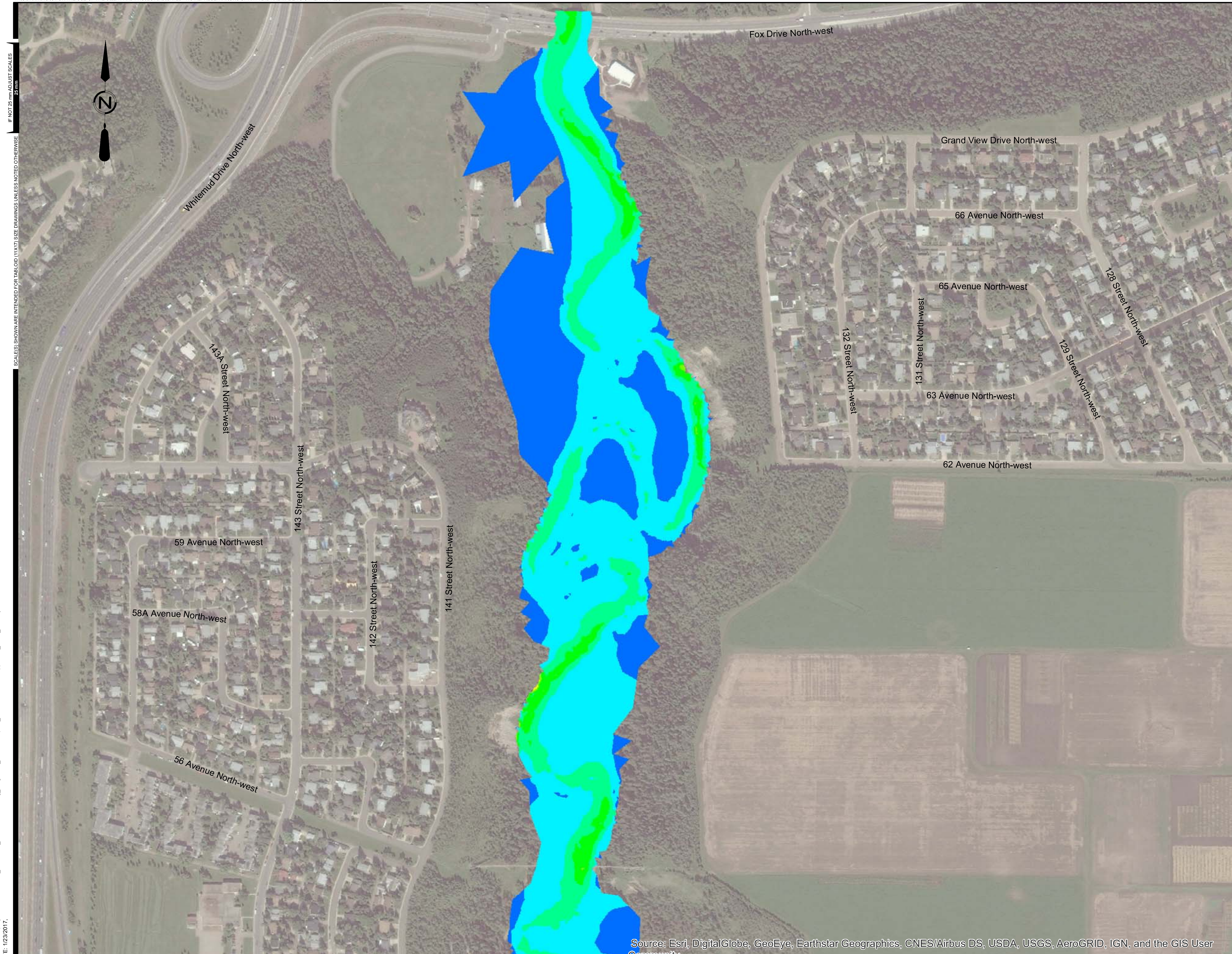
FIGURE No. F-23

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

5 YEAR VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

THIS DRAWING IS FOR THE USE OF THE CLIENT AND PROJECT INDICATED - NO REPRESENTATIONS OF ANY KIND ARE MADE TO OTHER PARTIES

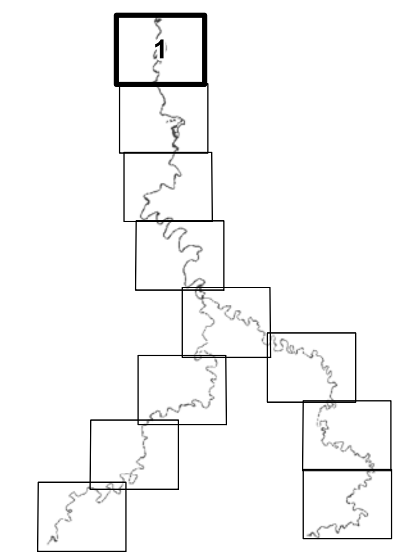


Associated Engineering

Legend:

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



Note: Maps are preliminary and subject to change.

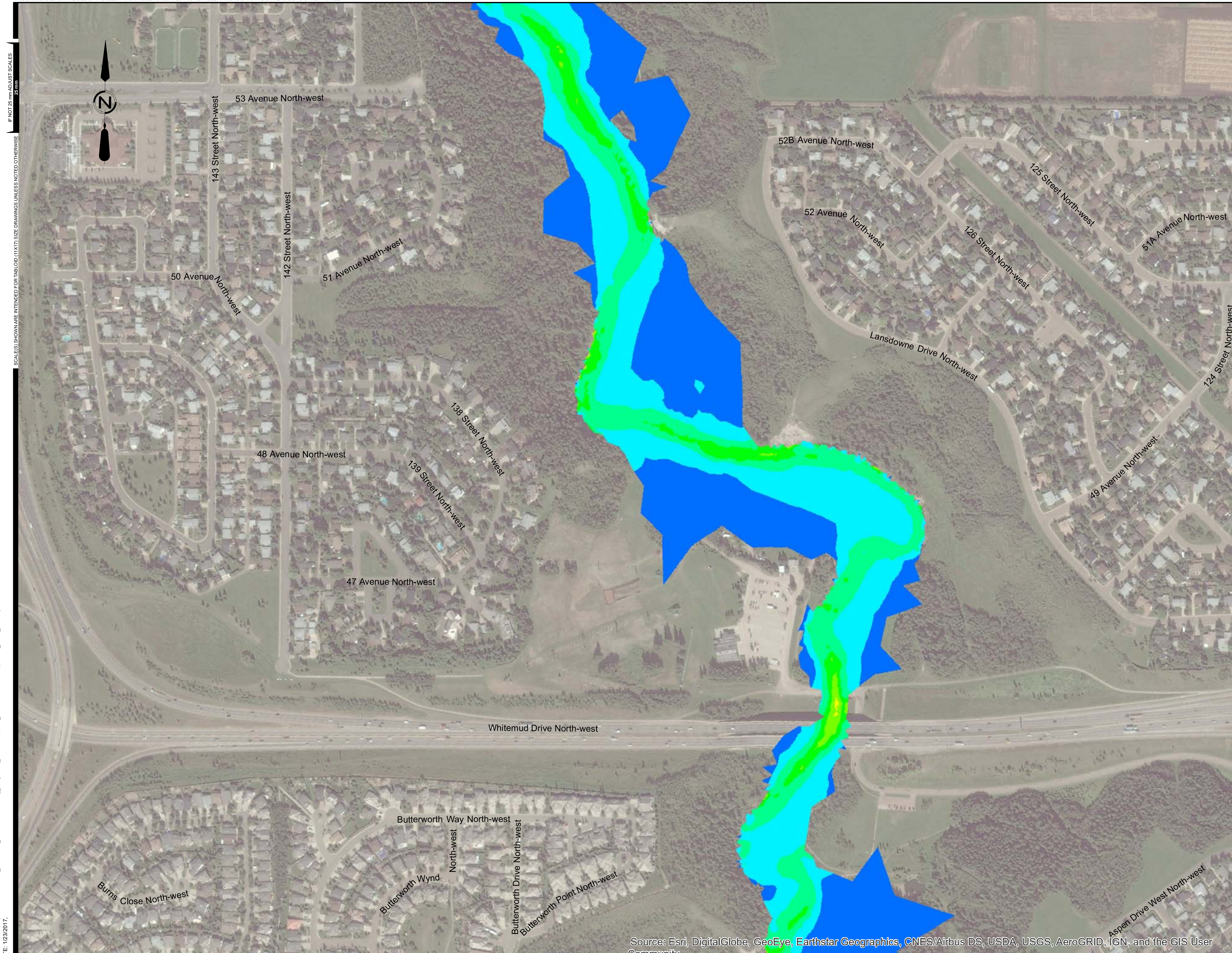
FIGURE No. F-24

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

100 YEAR VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

THIS DRAWING IS FOR THE USE OF THE CLIENT AND PROJECT INDICATED - NO REPRESENTATIONS OF ANY KIND ARE MADE TO OTHER PARTIES

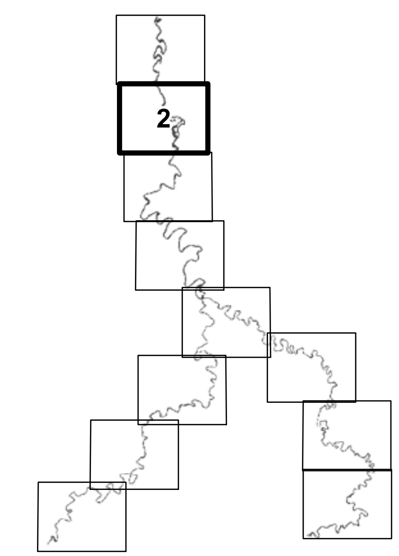


Associated Engineering

Legend:

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



Note: Maps are preliminary and subject to change.

FIGURE No. F-25

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

100 YEAR VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

IF NOT 25 mm ADJUST SCALES

DATE: 1/23/2017,

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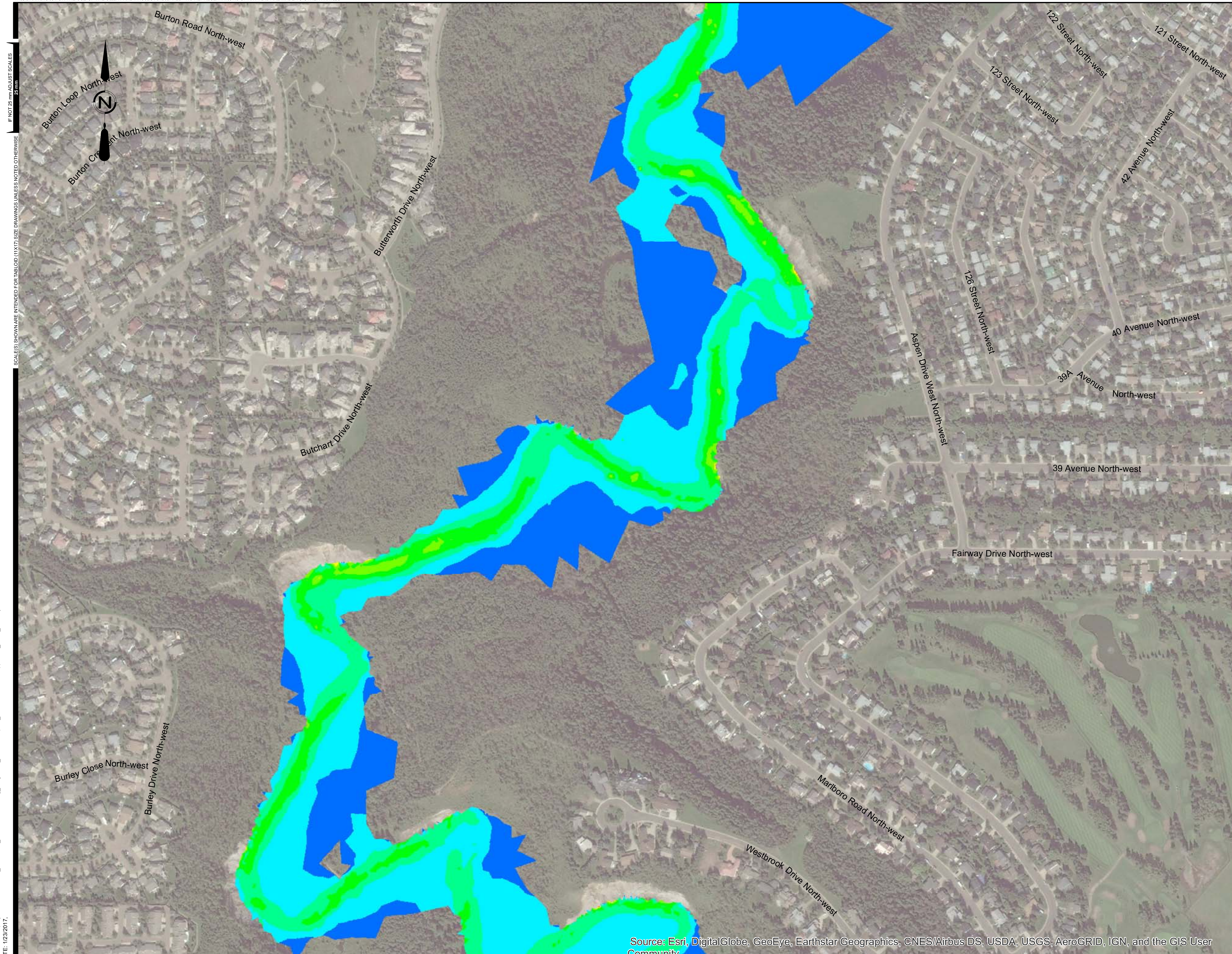
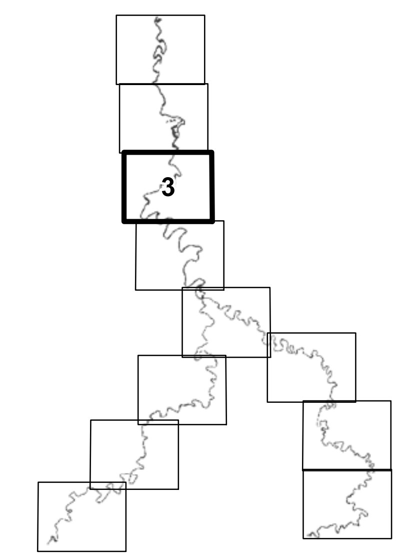


Associated Engineering

Legend:

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



Note: Maps are preliminary and subject to change.

FIGURE No. F-26

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

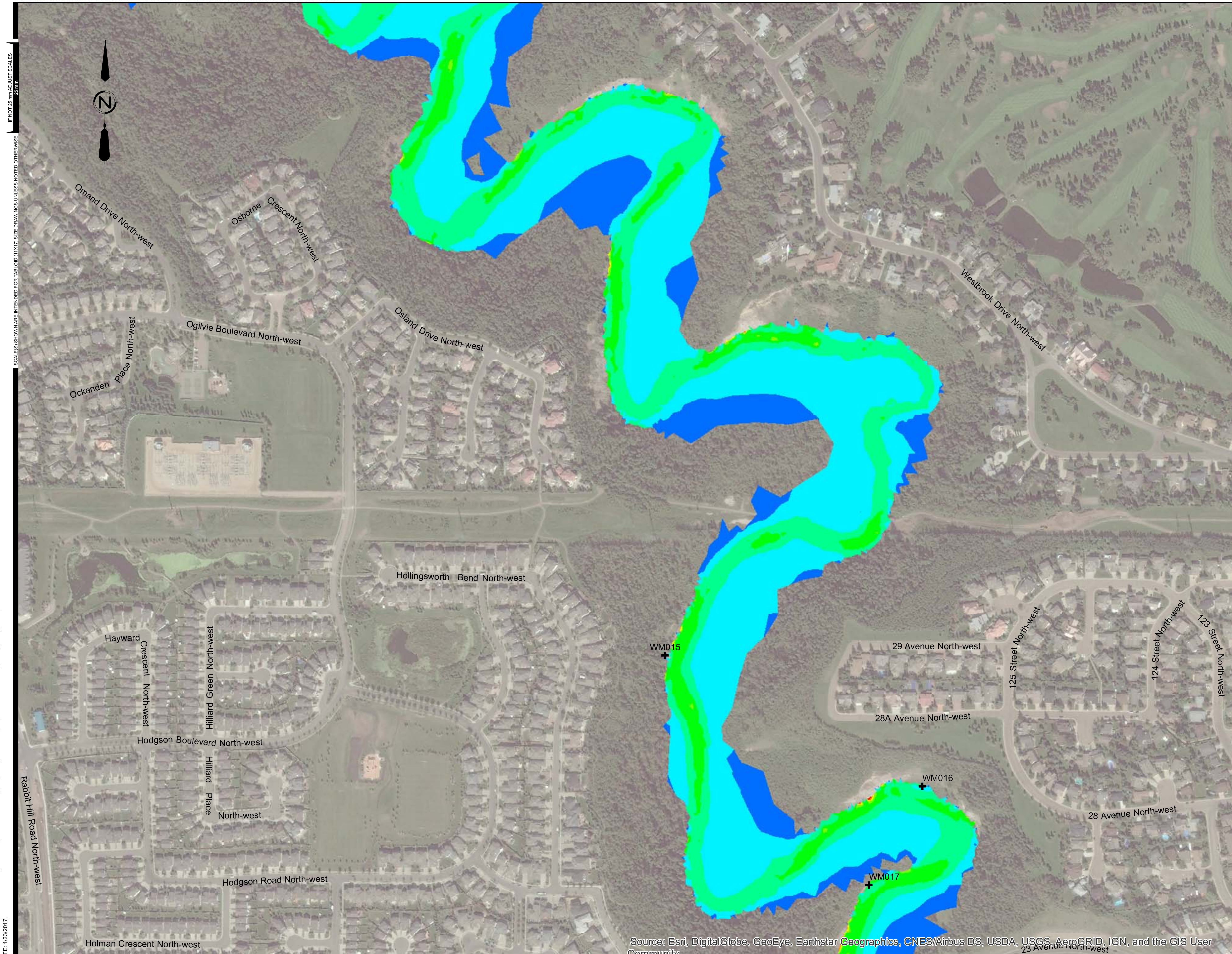
100 YEAR VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

IF NOT 25 mm ADJUST SCALES 25 mm

\\s-edm-fs-01\projects\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\Appendix_100Y_Velocity.mxd
DATE: 1/23/2017,



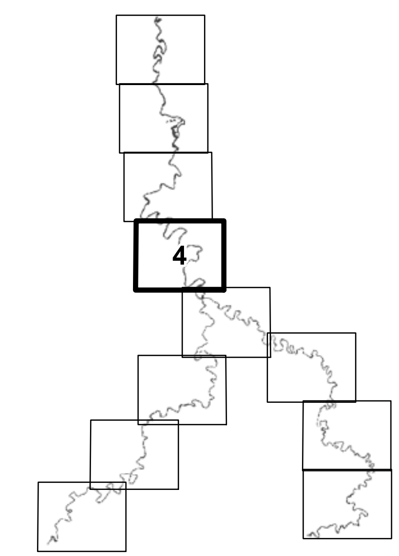
Associated Engineering

Legend:

✚ Erosion Site

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



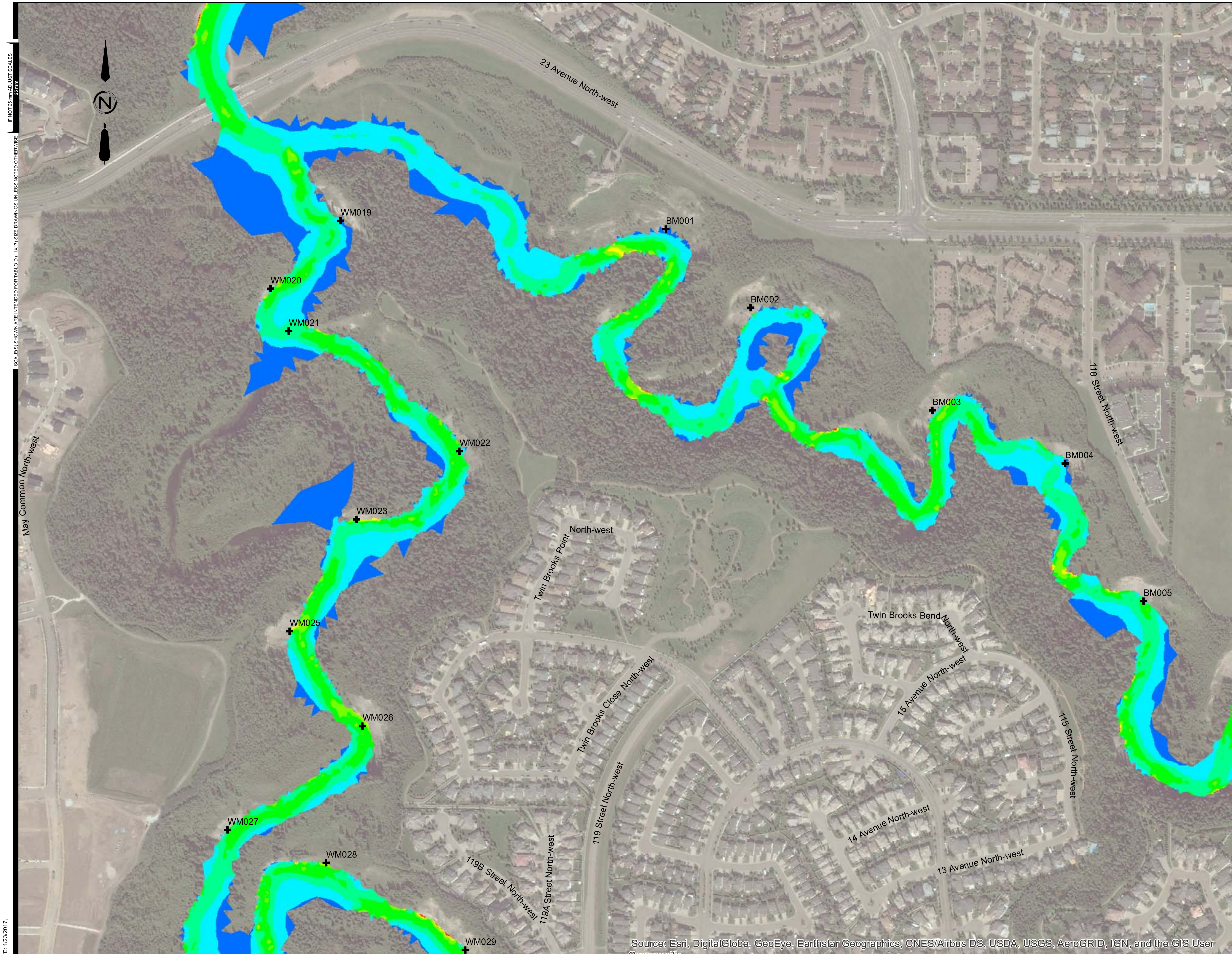
Note: Maps are preliminary and subject to change.

FIGURE No. F-27

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

100 YEAR VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT



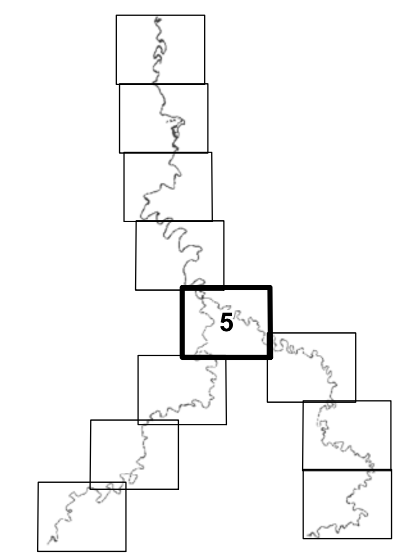
Associated Engineering

Legend:

- ✚ Erosion Site

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



Note: Maps are preliminary and subject to change.

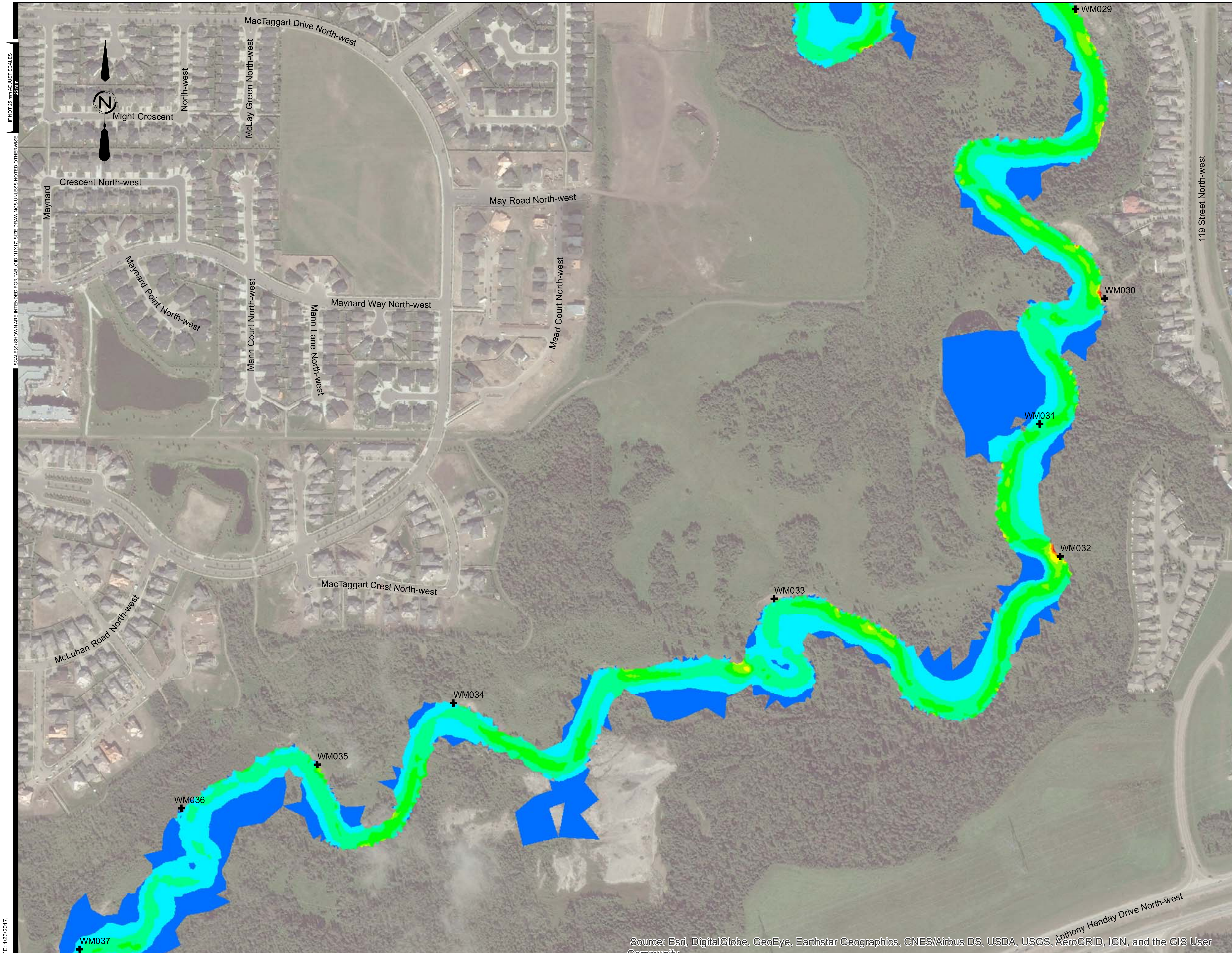
FIGURE No. F-28

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

100 YEAR VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

THIS DRAWING IS FOR THE USE OF THE CLIENT AND PROJECT INDICATED - NO REPRESENTATIONS OF ANY KIND ARE MADE TO OTHER PARTIES



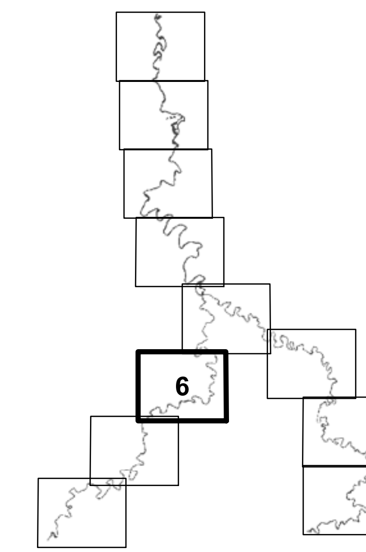
Associated Engineering

Legend:

- Erosion Site

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



Note: Maps are preliminary and subject to change.

FIGURE No. F-29

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

100 YEAR VELOCITY

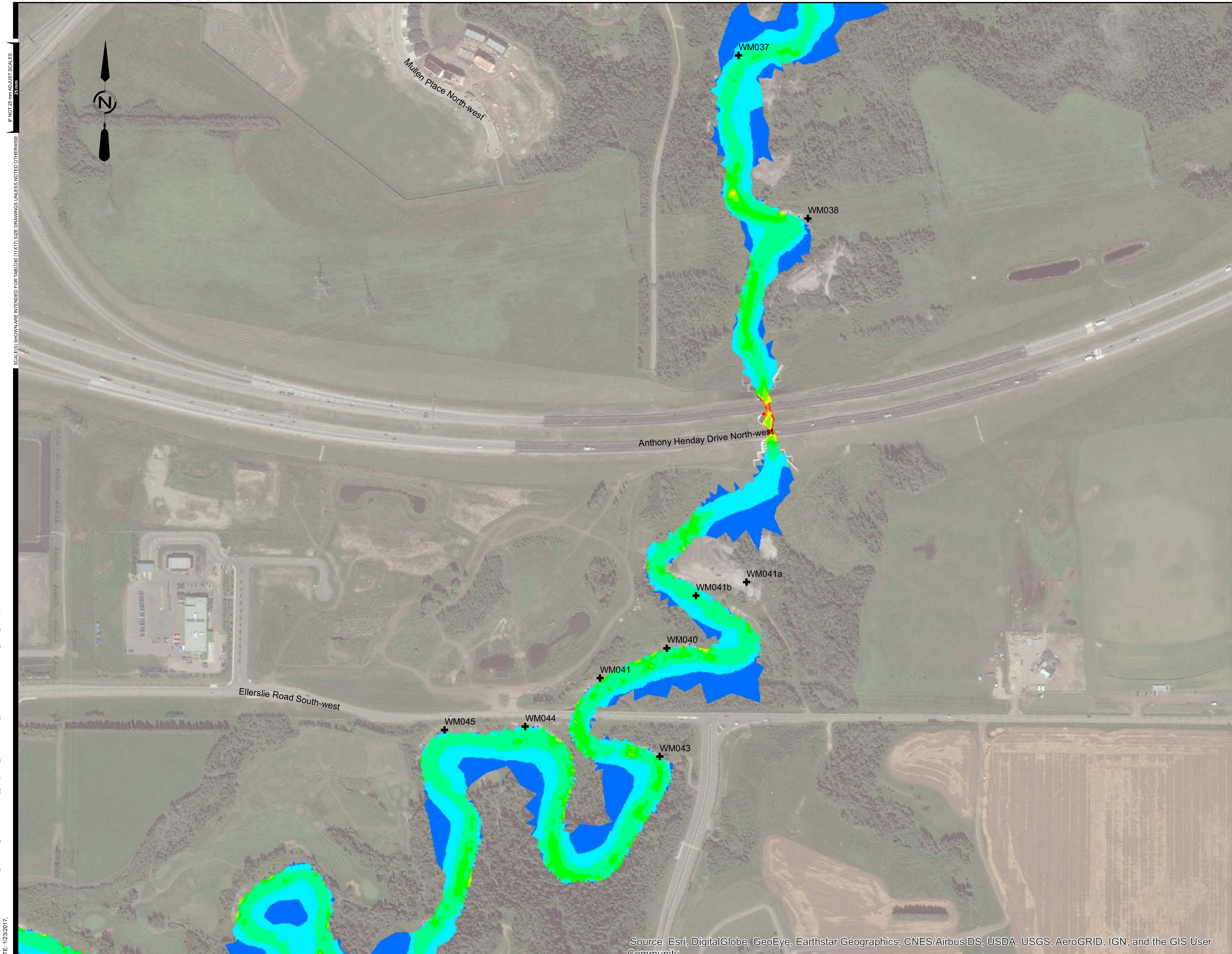
AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

IF NOT 25 mm ADJUST SCALES 25 mm

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

\\s-edm-fs-01\projects\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\Appendix_100Y_Velocity.mxd
DATE: 1/23/2017,

THIS DRAWING IS FOR THE USE OF THE CLIENT AND PROJECT INDICATED - NO REPRESENTATIONS OF ANY KIND ARE MADE TO OTHER PARTIES



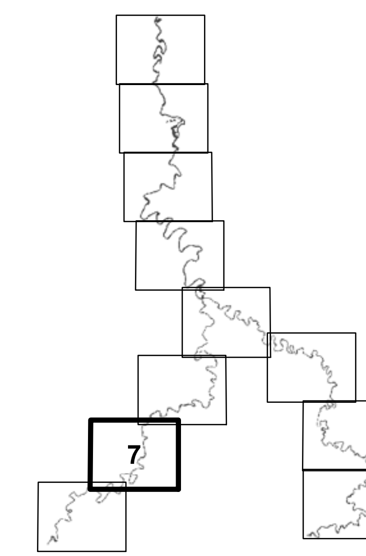
Associated Engineering

Legend:

✚ Erosion Site

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



Note: Maps are preliminary and subject to change.

FIGURE No. F-30

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

100 YEAR VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

IF NOT 25 mm ADJUST SCALES 25 mm

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

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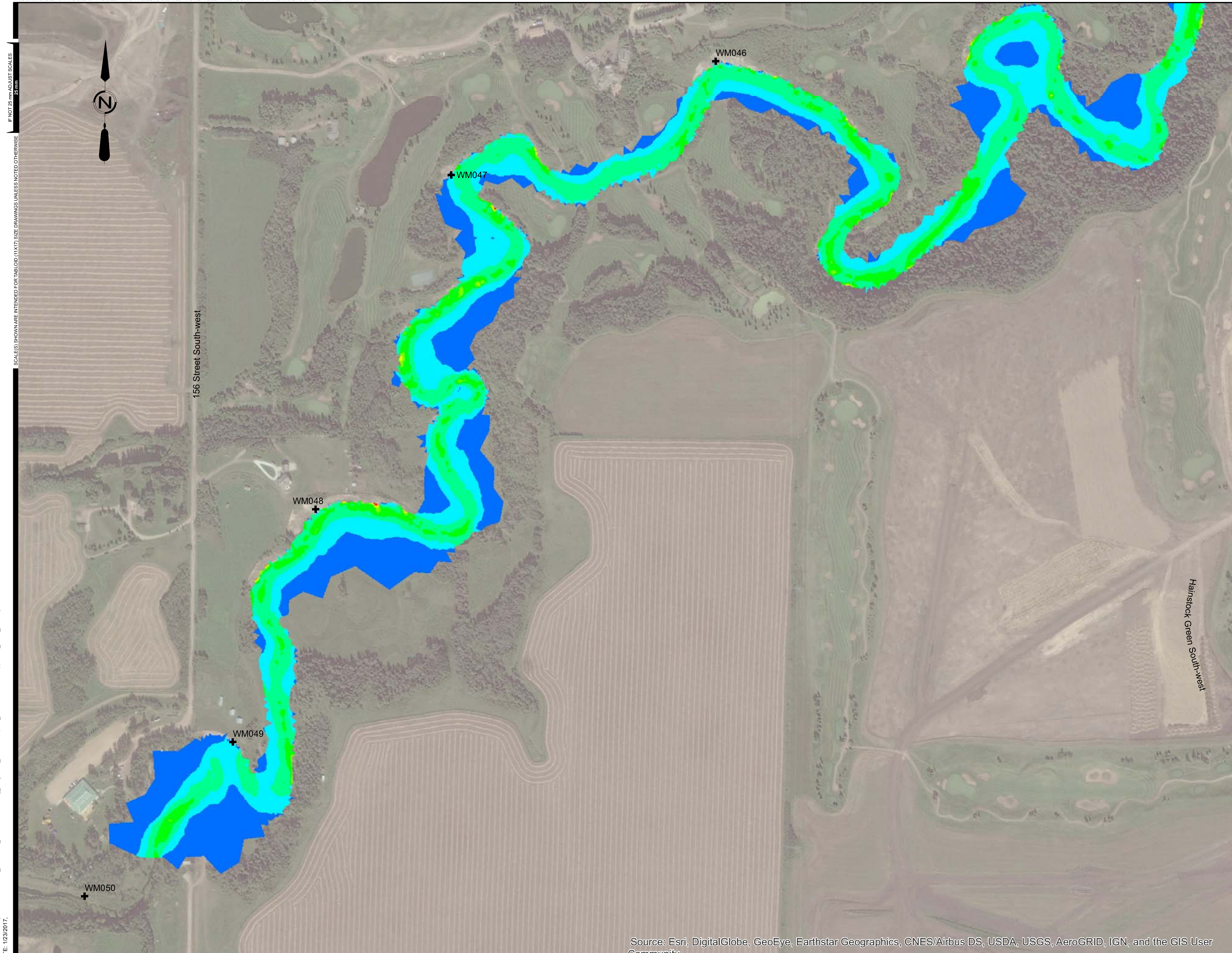
THIS DRAWING IS FOR THE USE OF THE CLIENT AND PROJECT INDICATED - NO REPRESENTATIONS OF ANY KIND ARE MADE TO OTHER PARTIES

IF NOT 25 mm ADJUST SCALES

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE



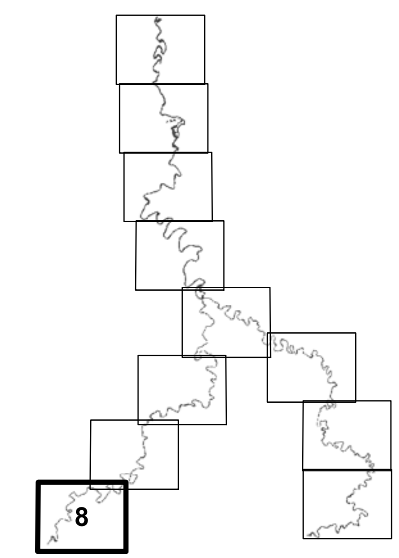
Associated Engineering

Legend:

✚ Erosion Site

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



Note: Maps are preliminary and subject to change.

FIGURE No. F-31

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

100 YEAR VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

Associated Engineering

Legend:

- ✚ Erosion Site

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5

9

Note: Maps are preliminary and subject to change.

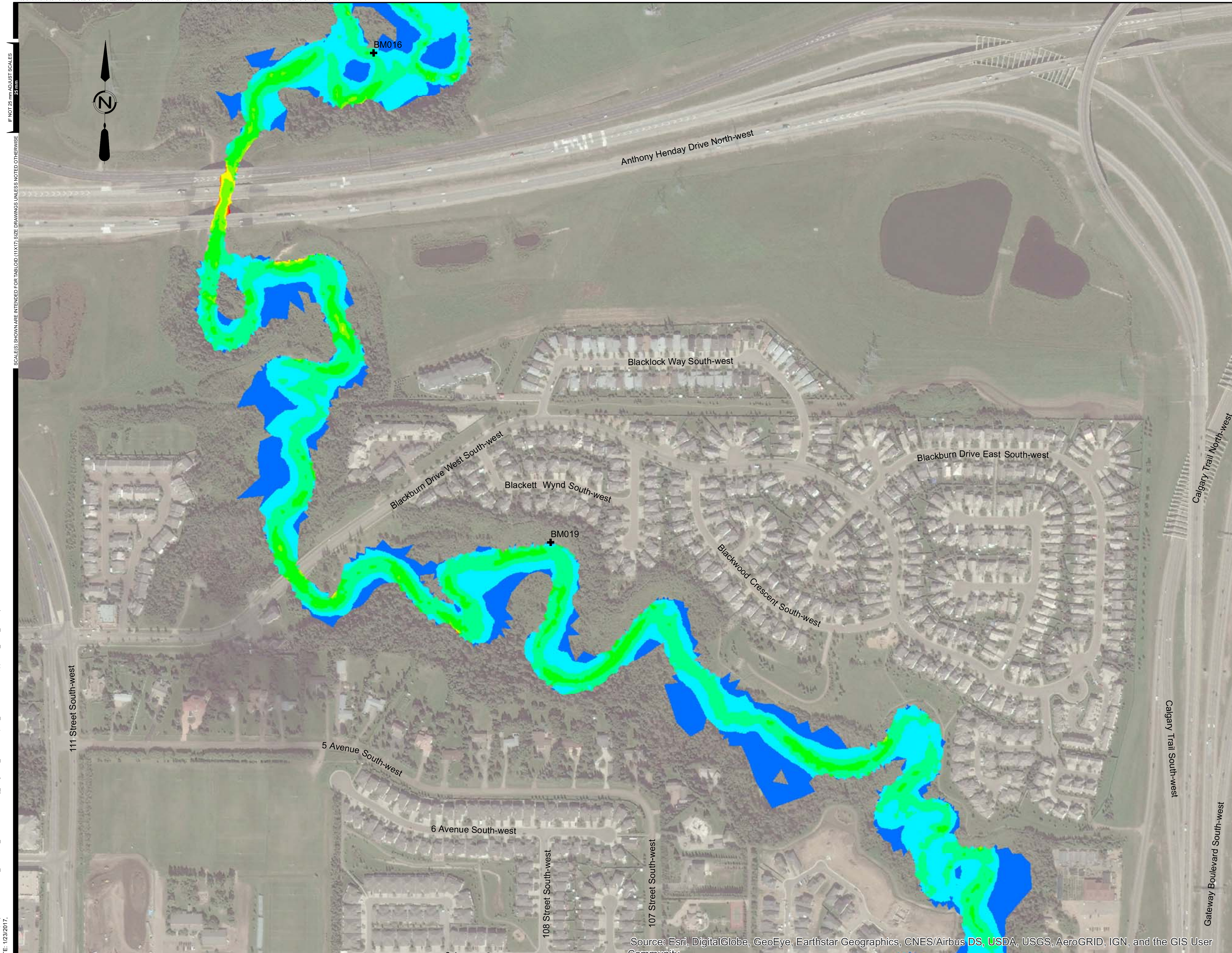
FIGURE No. F-32

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

100 YEAR VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

DATE: 1/23/2017



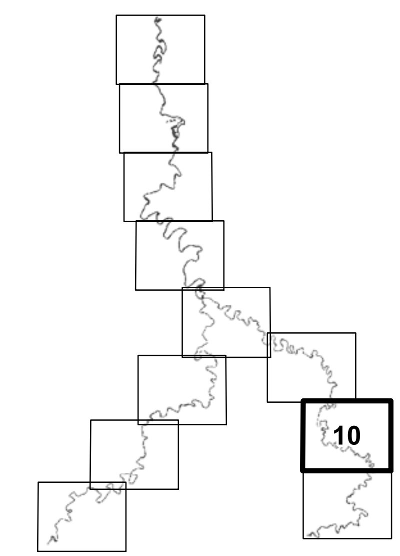
Associated Engineering

Legend:

✚ Erosion Site

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



Note: Maps are preliminary and subject to change.

FIGURE No. F-33

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

100 YEAR VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

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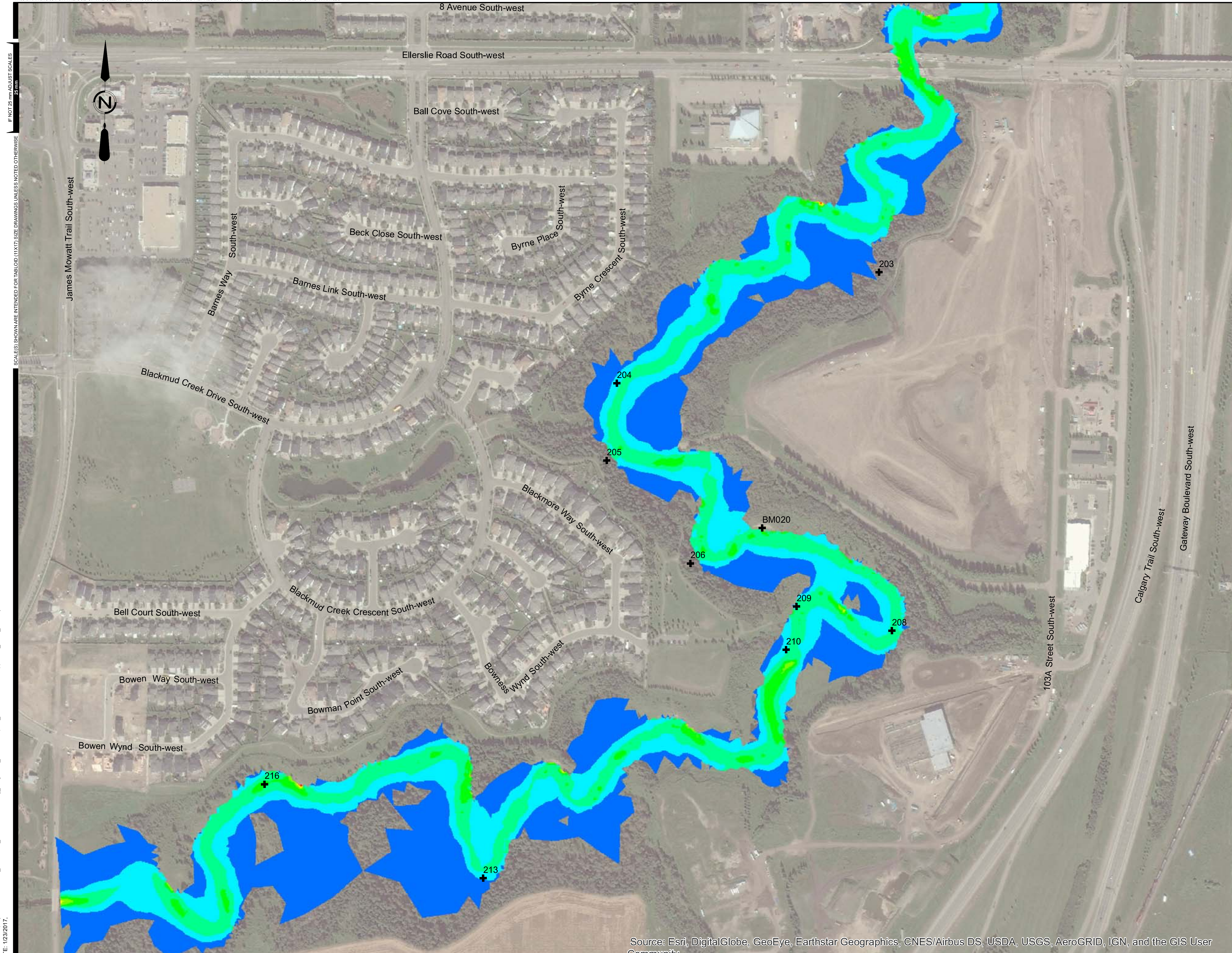


IF NOT 25 mm ADJUST SCALES 25 mm

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

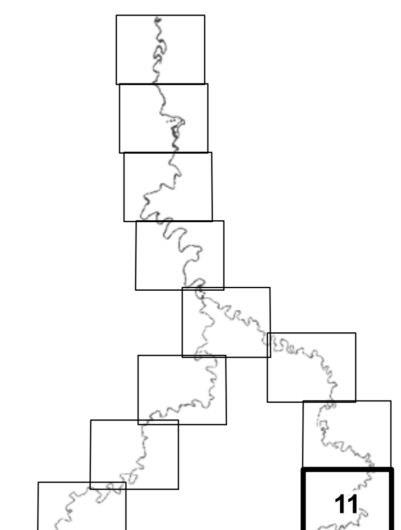
Associated Engineering

Legend:

- ✚ Erosion Site

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5



Note: Maps are preliminary and subject to change.

FIGURE No. F-34

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

100 YEAR VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JANUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

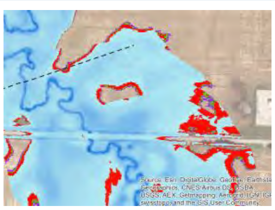
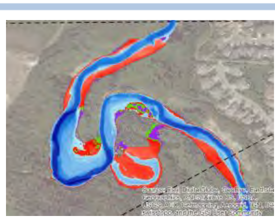
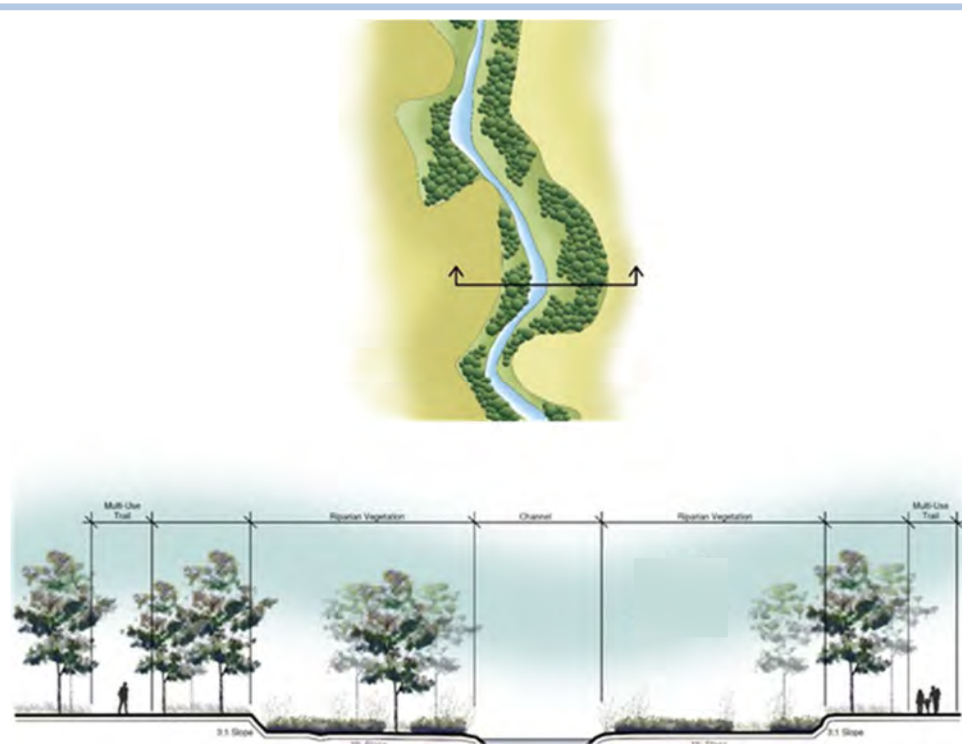
DATE: 1/23/2017,

Associated Engineering | GLOBAL PERSPECTIVE. LOCAL FOCUS.

TECHNICAL MEMORANDUM NO. 5

Blackmud/Whitemud Creek
Surface Water Management Group

Blackmud/Whitemud Creek
Surface Water Management Study
Concept Development

June 2017

Executive Summary

This technical memo summarizes the concept development and stormwater management options developed by AE based on discussion and review of Technical Memorandum No. 4 with the Blackmud/Whitemud Surface Water Management Group. The basin model was used to simulate future flooding and hydraulic conditions related to erosion in Blackmud and Whitemud Creek with various stormwater release rates from the future development areas. These results were reviewed with the Group in a progress meeting on February 24, 2017. AE then developed a surface water management strategy to minimize and mitigate potential impacts of future development.

Localized flooding is expected to occur along the existing creeks during the design storm event with the three stormwater management release rates considered for future development (1.5, 3.0, and 5.0 L/s/ha).

Velocities and runoff volumes in the creeks will increase with development and will aggravate the on-going erosion issues in the Blackmud and Whitemud Creeks. The magnitude of this impact will depend somewhat on the release rate adopted for new development and can be minimized by adopting the lowest release rate that is reasonably practical. Continuing the existing standard for the City of Edmonton, 5.0 L/s/ha, could cause erosion rates to increase by double or more compared with the existing condition. Otherwise there is little difference in flood level or extent or the cost of stormwater management facilities (SWMFs) among the different release rates. However, adopting a release rate of 3.0 L/s/ha produces flows that are similar to the existing flows within most of the creeks except Irvine creek and LeBlanc Canal.

The City of Edmonton's design criteria have the effect of increasing the required storage volume in SWMFs by about 40%. AE recommends that the differences in design criteria be rationalized and that a uniform design criteria be adopted for the basin.

Based on the best information currently available it is concluded that climate change is unlikely to have a significant impact on storage volumes, release rates, and the basin drainage strategy.

Two alternative drainage concepts were developed for the 1:100 year design event with a release rate of 3.0 L/s/ha as agreed upon during discussions with the Group as follows:

- Constructing drainage parkways along Irvine Creek and Deer Creek to provide capacity and facilitate drainage of the adjacent lands which are otherwise too low to be drained with an underground drainage system (**Figure 3-2**).
- Constructing a network of outfall trunk sewers adjacent to the same stream channels to carry the releases from the connected stormwater management facilities to a downstream location where adequate channel capacity and depth are available (**Figure 3-7**).

The final concept plan might include a combination of the above concepts.

All proposed drainage works must be constructed in an environmentally sensitive manner. Further detailed analyses will be required to integrate existing wetlands into the urban fabric and to establish the appropriate water management strategy and water levels for existing and proposed wetlands. Cawes Lake should be preserved and provided with a defined outlet to manage lake levels for habitat enhancement and to prevent flooding of the adjacent lands. A regional wetland is proposed to replace the flood storage that would otherwise be lost with channelization of Irvine Creek. Existing floodplain areas should be preserved as Environmental Reserve and protected from further development.

More detailed floodplain modelling will be required during subsequent planning stages to define the extent of the floodplains and the design requirements for any channel improvements (drainage parkways) that might be adopted.

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List of Figures

1 Introduction

The Blackmud/Whitemud Surface Water Management Group (Group) retained Associated Engineering (AE) to complete a Surface Water Management Study. This study involved hydrologic, hydraulic, hydrogeologic and environmental analyses of the Blackmud and Whitemud Creek basins and assessment of stormwater management options to accommodate future development in the basin.

A series of Technical Memoranda (TM) was planned to be issued at key stages of the study to document the interim findings. These memoranda also meant form the basis for discussions and deliberations with the Group.

A Blackmud/Whitemud basin model was developed and simulated for existing conditions. The model development and results were previously discussed in TM No. 4 Hydrologic and Hydraulic Modelling.

This technical memo summarizes the concept development and stormwater management options developed by AE based on discussion and review of TM No. 4 with the Group. The basin model was used to simulate future flooding and hydraulic conditions related to erosion in Blackmud and Whitemud Creek with various stormwater release rates from the future development areas. These results were reviewed with the Group in a progress meeting on February 24, 2017. AE then developed a surface water management strategy to minimize and mitigate potential impacts of future development.

In Workshop #3 on December 16, 2016 the Group agreed that the Capital Region Board (CRB) Edmonton Metropolitan Region Growth Plan (2016) would be used as the future development boundary. **Figure 1-1** presents the existing and planned development areas, overlaid on a map of the basin.

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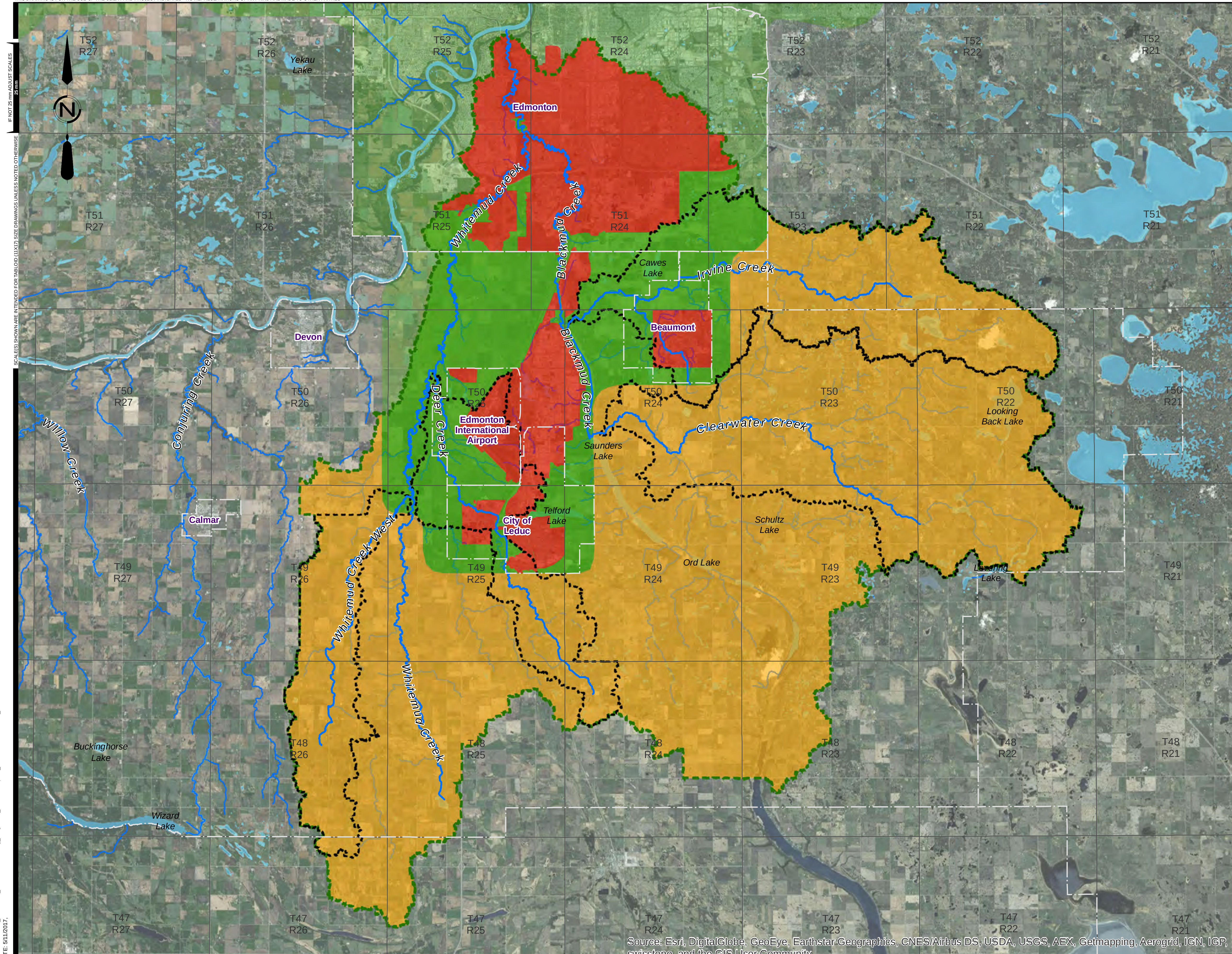


Associated Engineering

Legend:
Catchment
Classification
Existing Development
Future Development
Rural
Creek Centreline
Municipal Boundary

FIGURE No. 1-1

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

FUTURE DEVELOPMENT AREAS

AE PROJECT No.	2016-3785
SCALE	1:200,000
APPROVED	
DATE	2017 FEBRUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

P:\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\xxx_LandClassifications.mxd
DATE: 5/11/2017,

2 Stormwater Management Release Rates

AE evaluated three possible stormwater management release rates to be simulated for future developments during a 1:100 year design event. These release rates were based on findings in TM No. 3.

- 1.5 L/s/ha
- 3.0 L/s/ha
- 5.0 L/s/ha

These release rates were applied uniformly to all future development areas, assuming each will be controlled to the same rate of discharge. The model update and model results are discussed below.

2.1 MODEL UPDATE

Boundary flows used in the existing model (TM No. 4) were updated based on the future developments and potential range of release rates. **Table 2-1** summarizes creek flows at key locations within the basin for existing conditions and with future development releasing at 1.5, 3.0, or 5.0 L/s/ha. For comparison, the existing or "pre-development" discharges rates are also provided in **Table 2-1**.

Overall it was observed that a release rate of 5.0 L/s/ha would significantly increase peak flows in the basin. Results indicate that flows would increase by 20-25% in Whitemud Creek, by about 40% in Blackmud Creek, and as much as 100% in Irvine Creek. With a release rate of 3.0 L/s/ha, the impacts would be much more modest, with peak flows increasing slightly in Whitemud and Deer Creeks and as much as 50% in Irvine Creek. A release rate of 1.5 L/s/ha would result in decreased flows or similar flows compared to existing conditions and would minimize the potential impacts to the creek system.

The potential impacts of the different release rates, in terms of costs, flood depth and extent, and erosion potential are discussed below.

Appendix A provides details of the boundary inflows applied within the model.

Table 2-1
Creek Flows at Various Locations

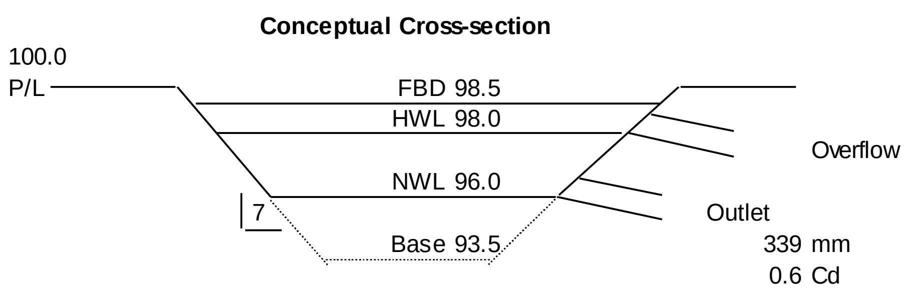
Location	Basin Condition				
	Pre-development Flows (L/s/ha)	Existing Flow (m^3/s)	Future Development Flow (m^3/s)		
			1.5 L/s/ha	3.0 L/s/ha	5.0 L/s/ha
Clearwater Creek at the mouth	1.1	23	23	23	23
Irvine Creek at the mouth	1.1	16	17 (+6%)	24 (+50%)	32 (+100%)
Blackmud Creek WSC Gauge	1.1	92	95 (+3%)	110 (+20%)	131 (+42%)
Whitemud Creek WSC Gauge	2.9	99	86 (-13%)	100 (+1%)	119 (+20%)
Deer Creek at the mouth	2.9	25	22 (-12%)	26 (+4%)	31 (+24%)
Whitemud Creek at NSR		229	215 (-6%)	244 (+7%)	284 (+24%)

2.2 STORMWATER MANAGEMENT COSTS

AE estimated the stormwater management costs that would accrue to typical development assuming the release rates of 1.5, 3.0, and 5.0 L/s/ha. These estimates were based on the following:

- A typical service area draining to a stormwater management facility (SWMF) of 65 ha.
- Storage volumes and draining times were estimated using the Modified Rational Method and storm durations of 1 to 24 hours.
- City of Edmonton design standards were used in developing the conceptual design of a typical SWMF resulting in a conceptual pond cross-section shown in **Figure 2-1**.
- To be conservative all SWMFs were assumed to be wet ponds in which a permanent pool of water is provided. Dry ponds or constructed wetlands could also be used and would yield a reduced cost.
- Construction costs were based on typical unit rates in the Edmonton area.
- Lot yield of 35 lots per net hectare as proposed by the Capital region Board (approximately 27 dwelling units per gross hectare). It is noted that all the municipalities aspire to achieve greater densities in the future which would reduce the SWM costs per hectare.
- Residential development was assumed for the typical SWMF service area. Note that multi-family development is likely to occur on some parcels and commercial/industrial development is likely to occur along the Highway 2 corridor, which would also reduce the cost per dwelling unit or equivalent.

Figure 2-1
Typical Pond Cross-Section



Design Parameters						
Item	**Elevation**	**Area**	**Total Volume**	**Storage Volume**	**Discharge**	**Depth**
	m	**ha**	**ha.m.**	**m3**	**m^3/s**	**m**
Minimum property line	100.0	4.0	16.3	121345	0.470	6.5
Freeboard	98.5	3.2	10.8	66658	0.366	5.0
HWL	98.0	3.0	9.3	**51050**	**0.325**	4.5
Normal water level	96.0	2.1	4.2	0	0.000	2.5
Base of pond	93.5	1.2	0.0		0.000	0.0
Storage capacity				**51050**		
Average existing ground	100.0	4.0	16.3			
Side slope	7.0	H:V				

Table 2-2 provides the estimated SWMF costs, expressed in dollars per net hectare and per lot. Results indicate the typical SWMF cost will vary between approximately $4,000 per lot if a design release rate of 5.0 L/s/ha is adopted, to $6,000 per lot with 3.0 L/s/ha and $8,000 per lot at 1.5 L/s/ha. These results show that the SWMF costs are relatively small in the range of release rates considered.

Table 2-2
Estimated SWMF Costs

			Pond - 1.5 L/s/ha		Pond - 3.0 L/s/ha		Pond - 5.0 L/s/ha	
Description	**Units**	**Unit Cost**	**Quantity**	**Cost**	**Quantity**	**Cost**	**Quantity**	**Cost**
Clearing and grubbing	**ha**	$50,000	8.2	$410,000	6.7	$335,000	4.7	$235,000
Stripping	**ha**	$50,000	8.2	$410,000	6.7	$335,000	4.7	$235,000
Excavation and grading	**m^3**	$15	383000	$5,745,000	303000	$4,545,000	197700	$2,965,500
Topsoil Replacement	**ha**	$50,000	8.2	$410,000	6.7	$335,000	4.7	$235,000
Landscaping	**ha**	$100,000	2.9	$290,000	2.6	$260,000	2.1	$210,000
Shoreline Treatment	**m**	$200	920	$184,000	810	$162,000	650	$130,000
Control Structure c/w inlet and outlet pipes	**LS**	$200,000	1	$200,000	1	$200,000	1	$200,000
Sub-Total				$7,649,000		$6,172,000		$4,210,500
Overhead, Administration, Engineering and Contingency		50%		$3,824,500		$3,086,000		$2,105,250
GST		5%		$573,675		$462,900		$315,788
Total Cost				**$12,047,175**		**$9,720,900**		**$6,631,538**
Cost/Unit (net)				**$7,859**		**$6,180**		**$4,076**

It was noted that the drawdown time (the time required to drain the SWMF) is considerably more sensitive to release rate than is cost, varying in direct proportion to the release rate. The pond drawdown time is an important consideration as it affects the time required to empty the pond after a storm event. An extended drawdown time increases the risk that the pond will be partly full when the next storm event occurs. This could potentially increase the required storage volume and pond size required to contain the 1:100 year design event. This could also lead to citizen concerns that the pond is not emptying quickly enough.

In light of this concern, the City of Edmonton has adopted a practice of requiring 90% of the pond storage capacity to be emptied within 96 hours (4 days) of the design 1:100 year storm. This typically requires a design release rate of 5.0 L/s/ha. This provision essentially assumes two 1:100 year design events occurring within 4 days, which is a conservative assumption.

One option to meet this design standard is to increase the pond size to provide sufficient storage volume so that the available capacity, after 96 hours of drawdown, is 90% of the volume required for the 1:100 year design event. This approach has been adopted by the City of Edmonton in a recent development. Table 2-3 provides a summary of required pond storage volumes, pond size, and construction cost to meet this criterion, as has been assumed in Table 2-2.

Table 2-3
Typical SWMF Parameters for Various Release Rates with 96 Hour Drawdown Time*

	1.5 L/s/ha	3.0 L/s/ha	5 L/s/ha
Storage Volume Provided (m^3)	120,000 m^3	95,000 m^3	62,000 m^3
Storage Volume Provided (m^3/ha)	1,846 m^3/ha	1,462 m^3/ha	954 m^3/ha
Surface Area (ha)	8.2 ha	6.7 ha	4.7 ha
Construction Cost	$12.0 million	$9.7 million	$6.6 million
Construction Cost per Unit	$7,859 /Unit	$6,180 /Unit	$4,076 /Unit
Time to Drain to 90% of Required Storage	4 days	4 days	4 days

*65 ha development area at 35 units/ha net (27 units/ha gross)

Previous modelling in the Big Lake Basin Drainage Study demonstrated that the release rate could be reduced to as low as 1.5 L/s/ha without excessively affecting the storage volume. This implies that the City of Edmonton design standard for pond drawdown could be modified to adopt a longer duration. **Table 2-4** provides a summary of drawdown time for the various (peak) release rates as well as the storage volume and construction cost (per lot), without the 96 hour drawdown time constraint. A design release rate of 3.0 L/s/ha would increase the drawdown time to 8 days after the 1:100 year storm event.

Table 2-4
Typical SWMF Parameters with Extended Drawdown*

	1.5 L/s/ha	3.0 L/s/ha	5 L/s/ha
Storage Volume Required (m^3)	72,000 m^3	68,000 m^3	62,000 m^3
Storage Volume Required (m^3/ha)	1,1108 m^3/ha	1,046 m^3/ha	954 m^3/ha
Surface Area (ha)	5.3 ha	5.1 ha	4.7 ha
Construction Cost	$7.6 million	$7.2 million	$6.6 million
Construction Cost per Unit	$4,719 /Unit	$4,452 /Unit	$4,065 /Unit
Time to Drain	17 days	8 days	4 days

*65 ha development area at 35 units/ha net (27 units/ha gross)

Comparing **Table 2-3** and **Table 2-4** demonstrates that the stormwater management costs could potentially be reduced by about $2,000 per lot or $50,000 per gross hectare if a release rate of 3.0 L/s/ha is adopted. AE recommends that further study be undertaken to refine the design standard for pond drawdown, to include continuous long-term simulation of pond performance, with a goal of reducing the servicing cost.

It was also noted that design criteria for SWMFs are similar for the various municipalities except for the design storm which is somewhat greater in the City of Edmonton's design standards than in the other municipalities. **Table 2-5** compares the various design standards.

Table 2-5
SWMF Design Standards in the Edmonton Region

Parameter	City of Edmonton	City of Leduc	Town of Beaumont	Strathcona County	Leduc County	Proposed for Planning
Design storm	most critical: 100 year 24 hour Huff, July 1937, July 1978, July 2004, July 2012	100 years 4 hr or 24 hr	most critical: 100 year 24 hour huff, July 1937, July 1978	100 years	100 years	100 year 24 hour storm
IDF Curve	COE 2014 based on upper bound of 13 rain gauges from 1984-2010	EIA 1914-1995	EIA 1914-1995	EIA 1914-1995	EIA IDF curves	COE 2014 IDF curve
Maximum release rate		7.5 L/s/ha	1.8 L/s/ha			
Maximum drawdown time	5yr event within 24 hours		5yr event within 24 hours	2 yr event >=24 hours	5yr event within 24 hours	
	25 yr event within 48 hours		25 yr event within 48 hours	5 yr event within 48 hours	25 yr event within 48 hours	
	90% of full storage volume within 96 hours	90% of full storage volume within 96 hours	90% of full storage volume within 96 hours	90% total storage volume within 96 hours	95% of 100 yr event within 96 hours	
Minimum depth at WML	2.5m	2.5 m	2.5m	2.5m	2m	2.5m
Maximum storage depth		2.0m				2.0 m
Minimum size			2ha	2ha		
side slopes	3:1 to 1.0m below nwl, 7:1 above	7:1 from 1.5 m below the nwl to 0.5 m above 1:100 water level	3:1 to 1.0m below nwl, 7:1 above	3:1 to 1.0m below nwl, 5:1 up to nwl, 7:1 to hwl, 4:1 above hwl	3:1 to 1.0m below nwl, 7:1 to 0.6m above hwl	7:1
freeboard	0.3m to lowest landscape grade or building openings	0.5 m freeboard above the 1978 event hwl in absence of overflow	0.5m to footing elevation swmf backing lots	0.3m to lowest basement weeping tile	0.6m to lowest ground surface for adjacent property	0.5 m above overflow elevation
	0.5m in absence of overflow	0.3m to floor elevation of pond backing lot	0.3m to lowest landscaped level of adjacent buildings/building opening			
		0.5m to building opening pond backing lot	0.6m in absence of overflow			

The City of Edmonton's design criteria have the effect of increasing the required storage volume in SWMFs by about 40%. AE recommends that the differences in design criteria be rationalized and that a uniform design criteria be adopted for the basin. The final column in **Table 2-5** provides the parameters that were adopted for this study.

The potential impact of climate change should also be considered in the adoption of a basin water management strategy. Review of recent research indicates that rainfall rates are expected to increase in the coming century but that the impact is most likely to be felt in short-duration high-intensity thunderstorms. Recent research by the City of Edmonton and the University of Alberta suggest that summers are likely to become wetter in north-central Alberta, but that the volume of rainfall in a major 24-hour storm event of the magnitude used for SWMF design is projected to decline slightly. Based on these estimates it is concluded that climate change is unlikely to have a significant impact on the basin drainage strategy, at least compared with other sources of uncertainty.

2.3 FLOOD EXTENT AND DEPTH

Figures 2-2 to 2-5 show the simulated flood extent for existing conditions and for future development with the different release rates during the 1:100 year design event. These maps correspond to different locations along Blackmud Creek, Irvine Creek, Deer Creek, and Whitemud Creek, respectively. In general, the model results in minor differences in the flood extent based on the different release rates.

Figures 2-6 to 2-9 show the difference in flood depth between the existing flows and future flows for each release rate, at various chainages along Blackmud Creek, Whitemud Creek, Deer Creek, and Irvine Creek, respectively. The results show a maximum rise of about 0.5 m in flood levels with a release rate of 5.0 L/s/ha and lesser impacts with the lower release rates. In general the rise in water level is not deemed to be significant.

2.4 CHANNEL VELOCITIES AND EROSION RATES

As stated in TM No. 4, bank erosion is common throughout the lower reaches of Blackmud and Whitemud Creeks. In general, the rate of bed and bank erosion is related to the velocity of water flowing in the channel. Vertical changes in these velocities produce shear forces that are parallel to the bed. These shear forces act on the bed of a channel and cause bedload transport or erosion. The rate of erosion is generally higher where the velocity is higher, and the velocity generally increases with depth, flow, and slope of the channel which, in Whitemud Creek, occurs in the downstream direction.

In-stream erosion is actively occurring at many meander bends throughout the lower reaches of Blackmud and Whitemud Creeks. In part measure this is due to the higher velocities at these locations and in part due to other processes that govern the lateral migration that occurs naturally at bends. Increasing flows with development will tend to increase velocities which in turn will increase erosion rates.

To estimate the magnitude of these impacts the 1D and 2D models were used to simulate in-channel velocities for release rates of 1.5, 3.0, and 5.0 L/s/ha. The future velocities were then compared with existing velocities at the same location. Maps were then prepared which depict the relative velocity which represents the change from existing conditions to the three scenarios with different release rates for future drainage.

Appendix B provides the mean in-channel velocity computed with the 1D model for the different scenarios (Existing Conditions and Development at 1.5, 3.0, and 5.0 L/s/ha).

Appendix C presents the velocities along Blackmud and Whitemud Creeks computed with the 2D model for the 1.5, 3.0, and 5.0 L/s/ha release rates during the 1:100 design event.

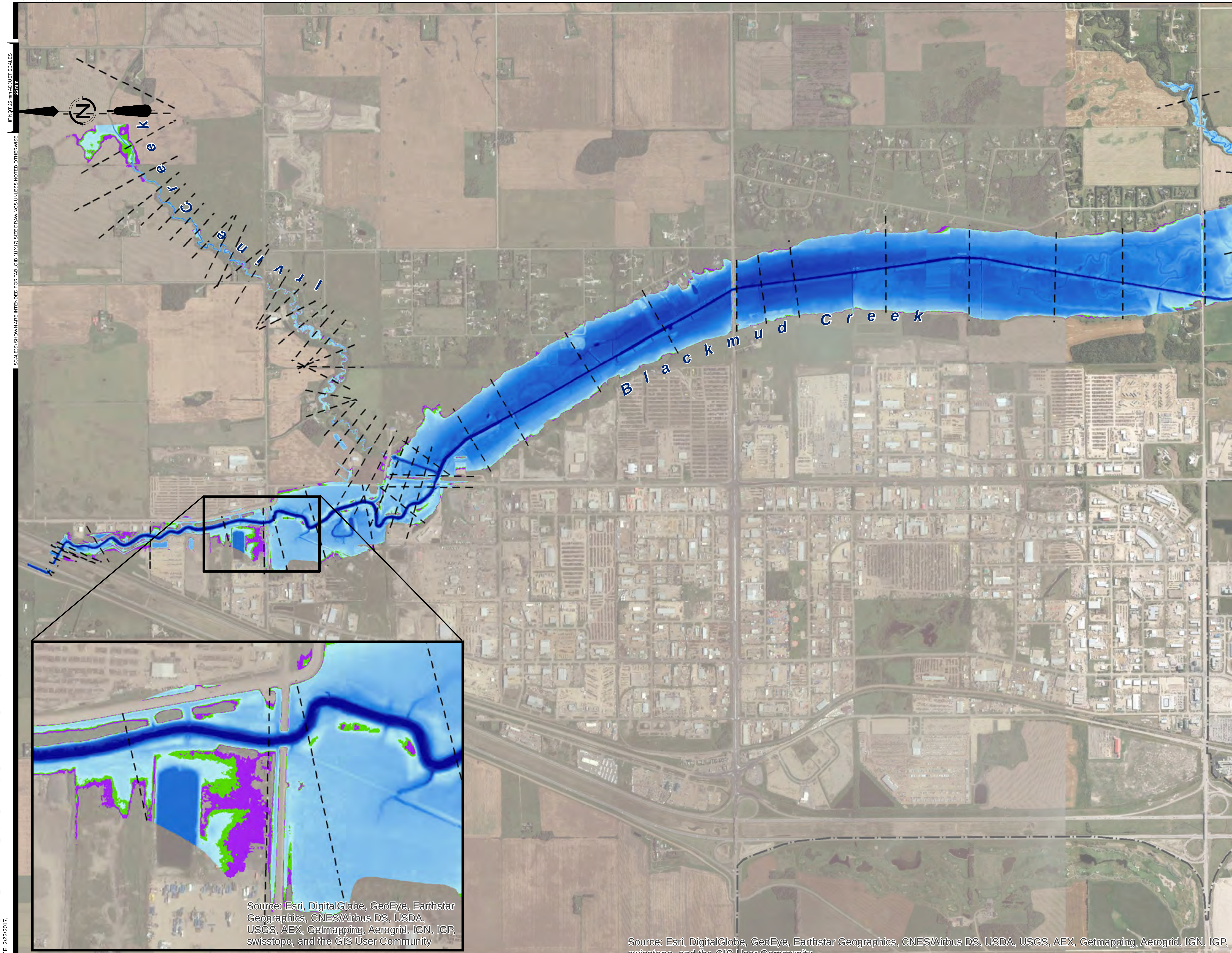
Appendix D presents the velocity ratio maps which compare the in-channel velocity for the future scenarios as a ratio to the velocities for existing conditions for Blackmud and Whitemud Creeks within the City of Edmonton boundary during the 1:100 design event.

Figures 2-10 to **2-12** present the most relevant results at the critical reach of Whitemud and Blackmud Creeks upstream of their confluence at 23 Avenue, where erosion is actively occurring at present. These maps show that the main-channel velocity will increase up to 50% throughout most of this reach if a release rate of 5.0 L/s/ha is adopted. This impact will be less, but still significant, if a release rate of 3.0 L/s/ha is adopted. To limit erosion rates to the existing condition will require release rates to be reduced to 1.5 L/s/ha or less.

It is noted that the City of Edmonton has previously used a release rate of 5.0 L/s/ha for existing development upstream of 23 Avenue. It is likely that the existing development has contributed to the erosion occurring in the creeks.

Hydraulic theory indicates that the rate of sediment transport is proportional to the 3rd power of velocity or, alternatively, the shear stress raised to a power of 1.5, other factors such as bed and bank materials remaining the same. This implies that erosion rates are very sensitive to changes in velocity. Based on this, the rate of erosion or sediment transport within the Blackmud and Whitemud Creeks is expected to remain the same or increase by about 50% if a release rate of 3.0 L/s/ha is adopted. This rate of erosion could increase by double or more if a release rate of 5.0 L/s/ha is adopted.

As discussed earlier, instream erosion is actively occurring at many meandering bends throughout the lower reaches of Blackmud and Whitemud Creeks. Peak flows will increase and velocities will also increase during flood conditions, resulting in increased erosion rates. The magnitude of this impact depends on the release rates adopted which implies that the release rates should be as low as possible.



Associated Engineering

Legend:

- Cross Section
- Existing
- 1.5 l/s /ha
- 3.0 l/s /ha
- 5.0 l/s ha

FIGURE No. 2-2

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

Flood Extent - Blackmud Creek

AE PROJECT No.	2016-3785
SCALE	1:25,000
APPROVED	
DATE	2017 FEBRUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE IF NOT 25 mm ADJUST SCALES 25 mm

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DATE: 2/23/2017,

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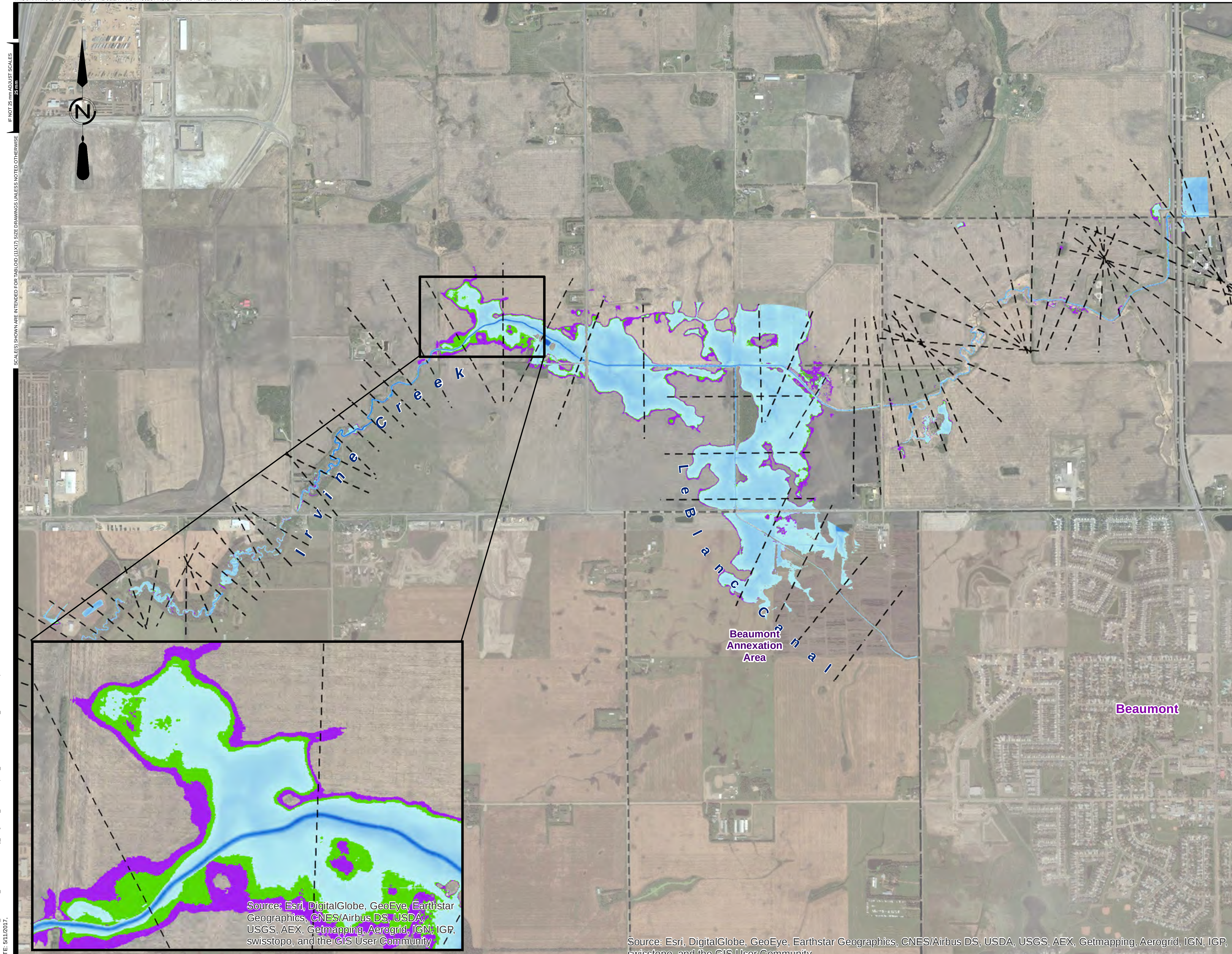
SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE



Associated Engineering

Legend:

- Cross Section
- Water Depth (100 Year)
- 1.5 l/s /ha
- 3.0 l/s /ha
- 5.0 l/s ha

FIGURE No. 2-3

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

FLOOD EXTENT - IRVINE CREEK

AE PROJECT No.	2016-3785
SCALE	1:20,000
APPROVED	
DATE	2017 FEBRUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

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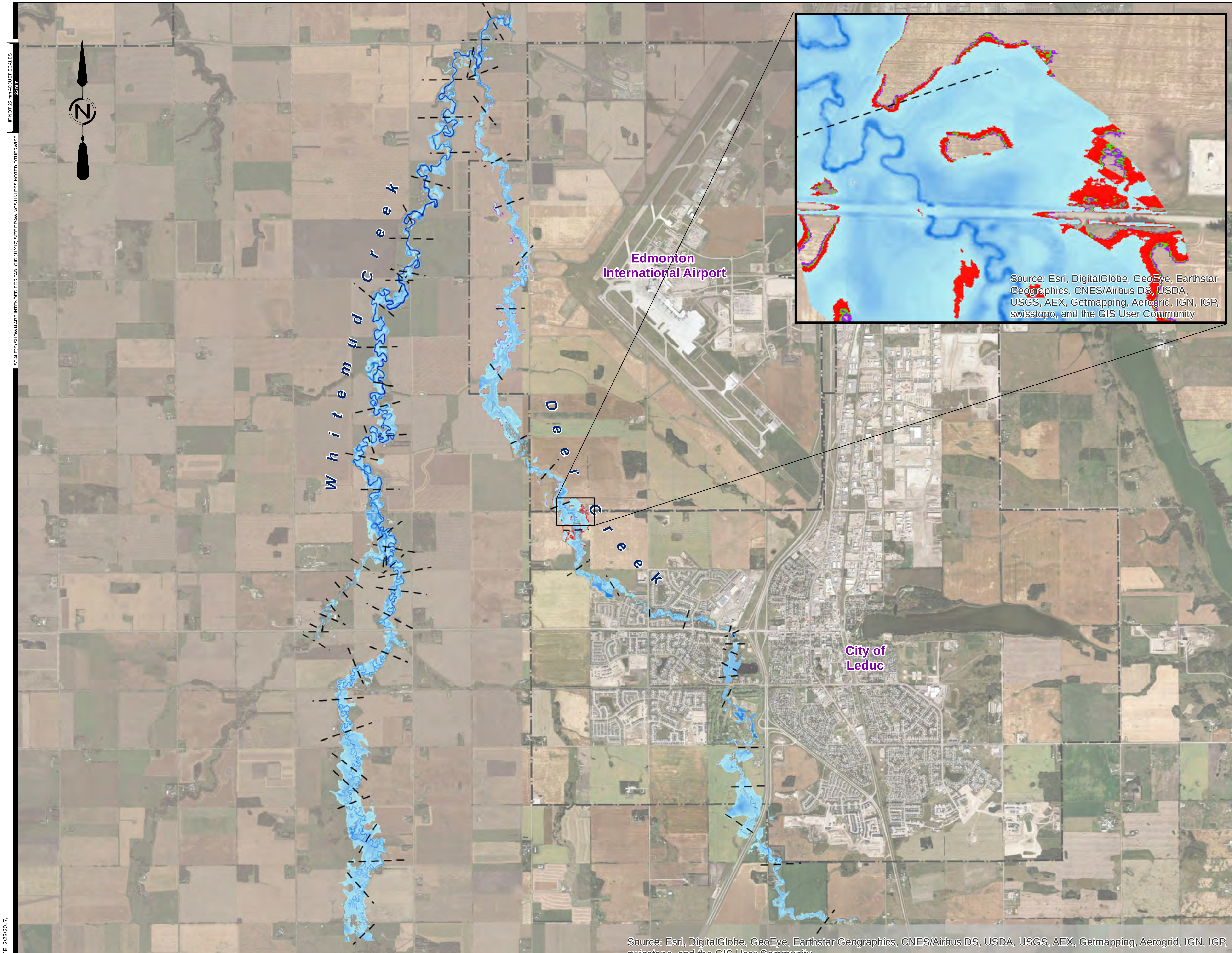

Associated Engineering

Legend:

- - - Cross Section
Existing
1.5 l/s /ha
3.0 l/s /ha
5.0 l/s ha

FIGURE No. 2-4

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

Flood Extent - Upper Whitemud and Deer Creeks

AE PROJECT No.	2016-3785
SCALE	1:50,000
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DATE	2017 FEBRUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

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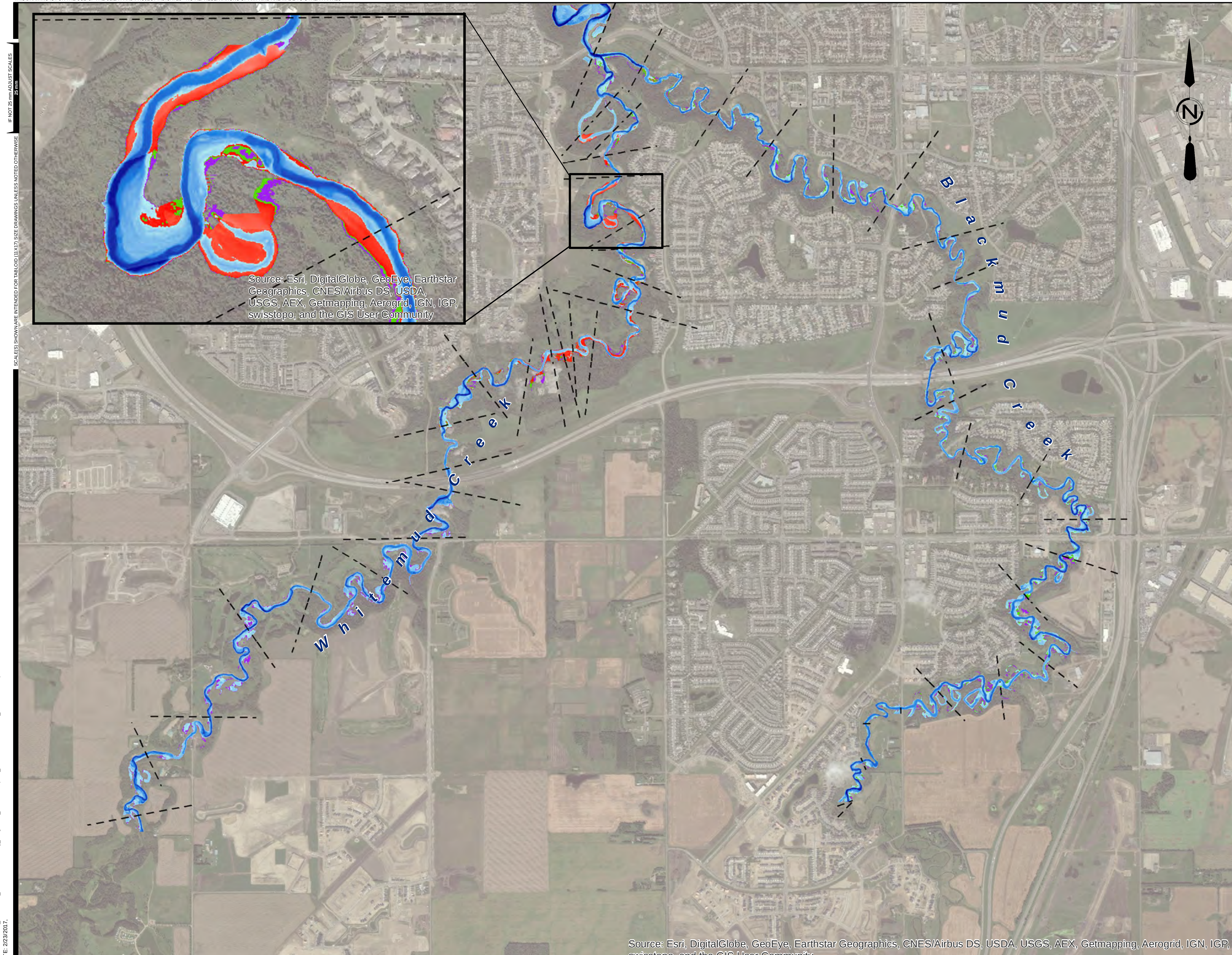

Associated Engineering

Legend:

- Cross Section
- Existing
- 1.5 l/s /ha
- 3.0 l/s /ha
- 5.0 l/s ha

FIGURE No. 2-5

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

Flood Extent - Lower Whitemud and Blackmud Creeks

AE PROJECT No.	2016-3785
SCALE	1:25,000
APPROVED	
DATE	2017 FEBRUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

IF NOT 25 mm ADJUST SCALES 25 mm

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

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DATE: 2/23/2017,

Figure 2-6: Blackmud Creek
Depth Variation from Existing Flows

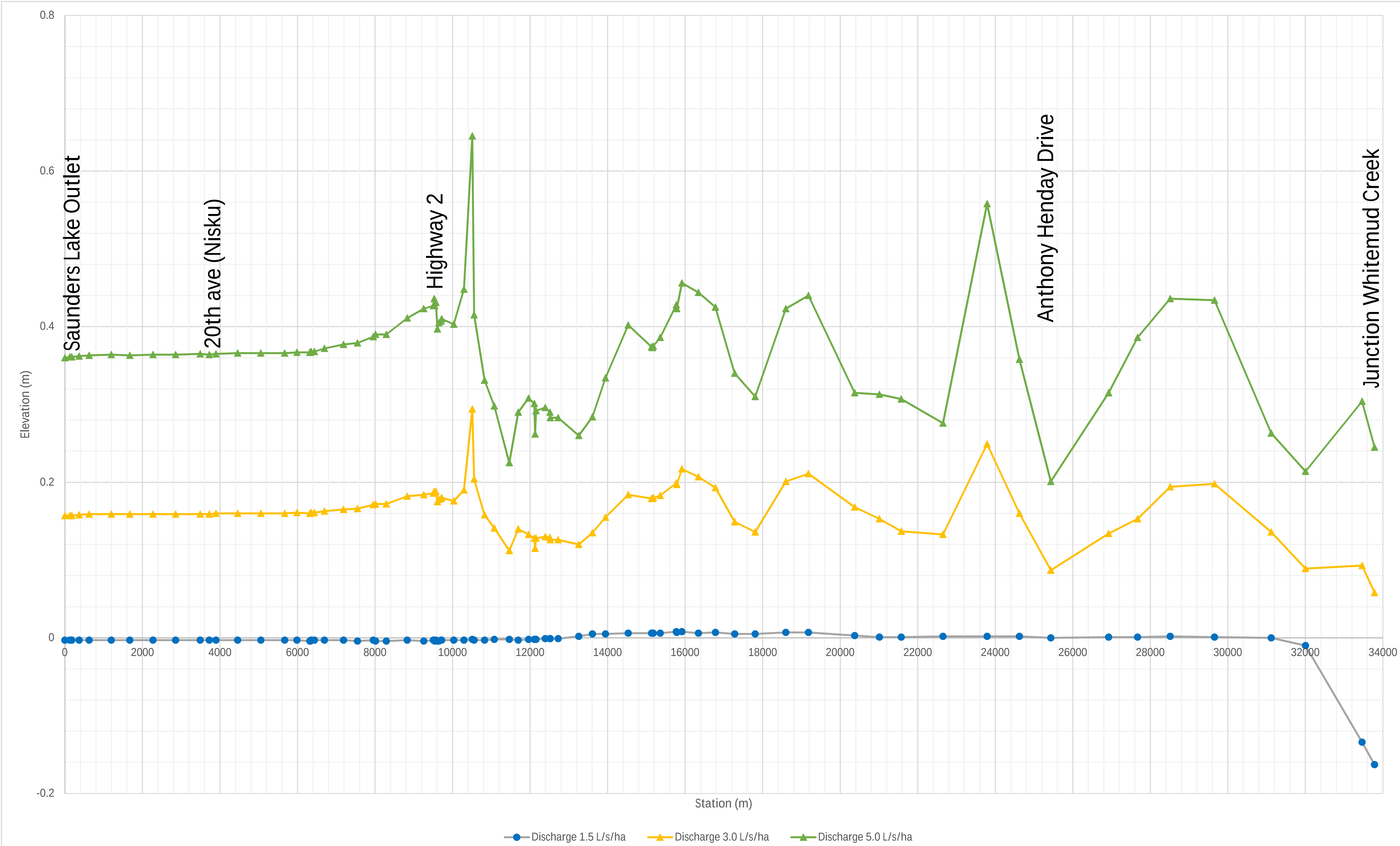


Figure 2-7: Whitemud Creek
Depth Variation from Existing Flows

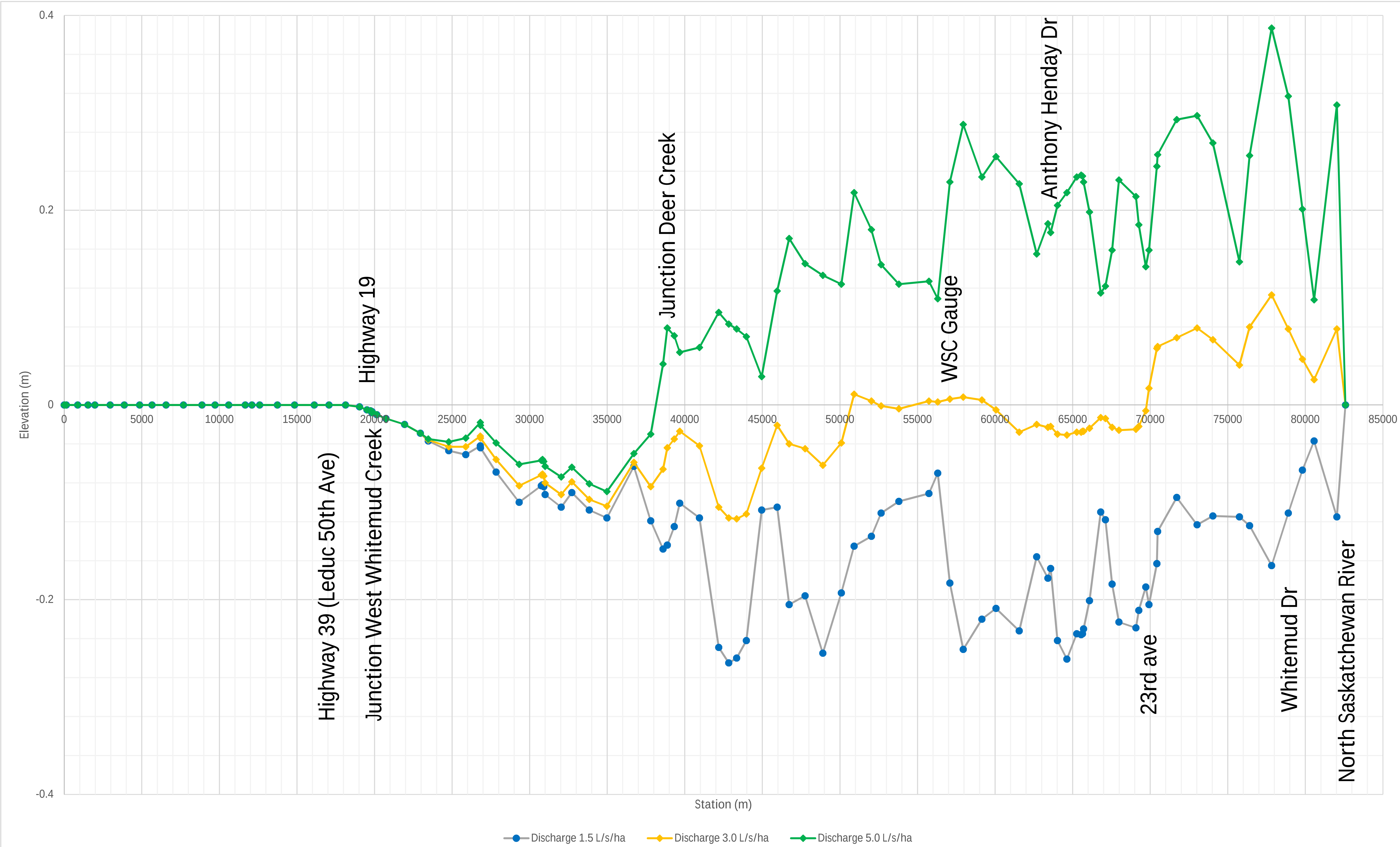


Figure 2-8: Deer Creek
Depth Variation from Existing Flows

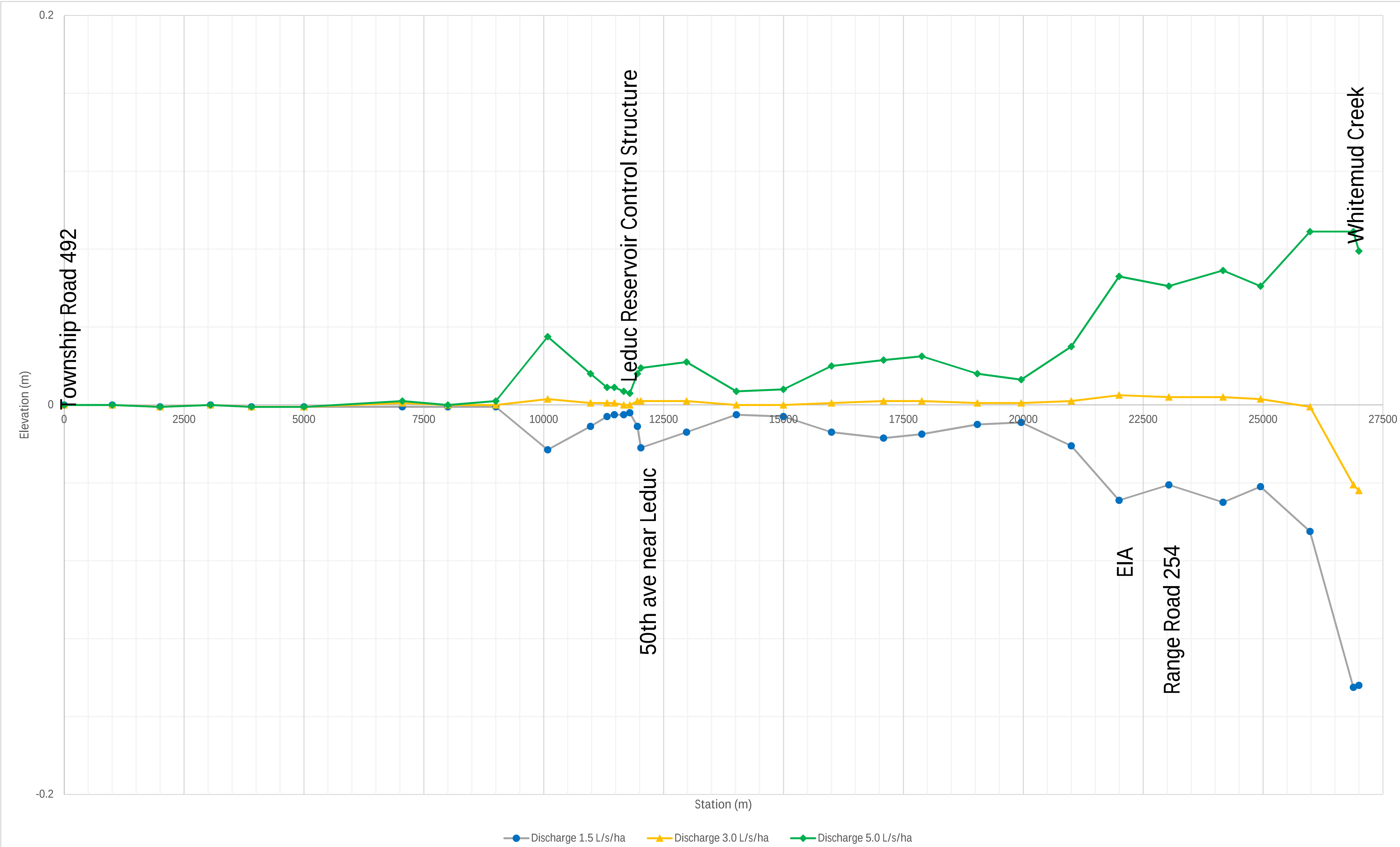
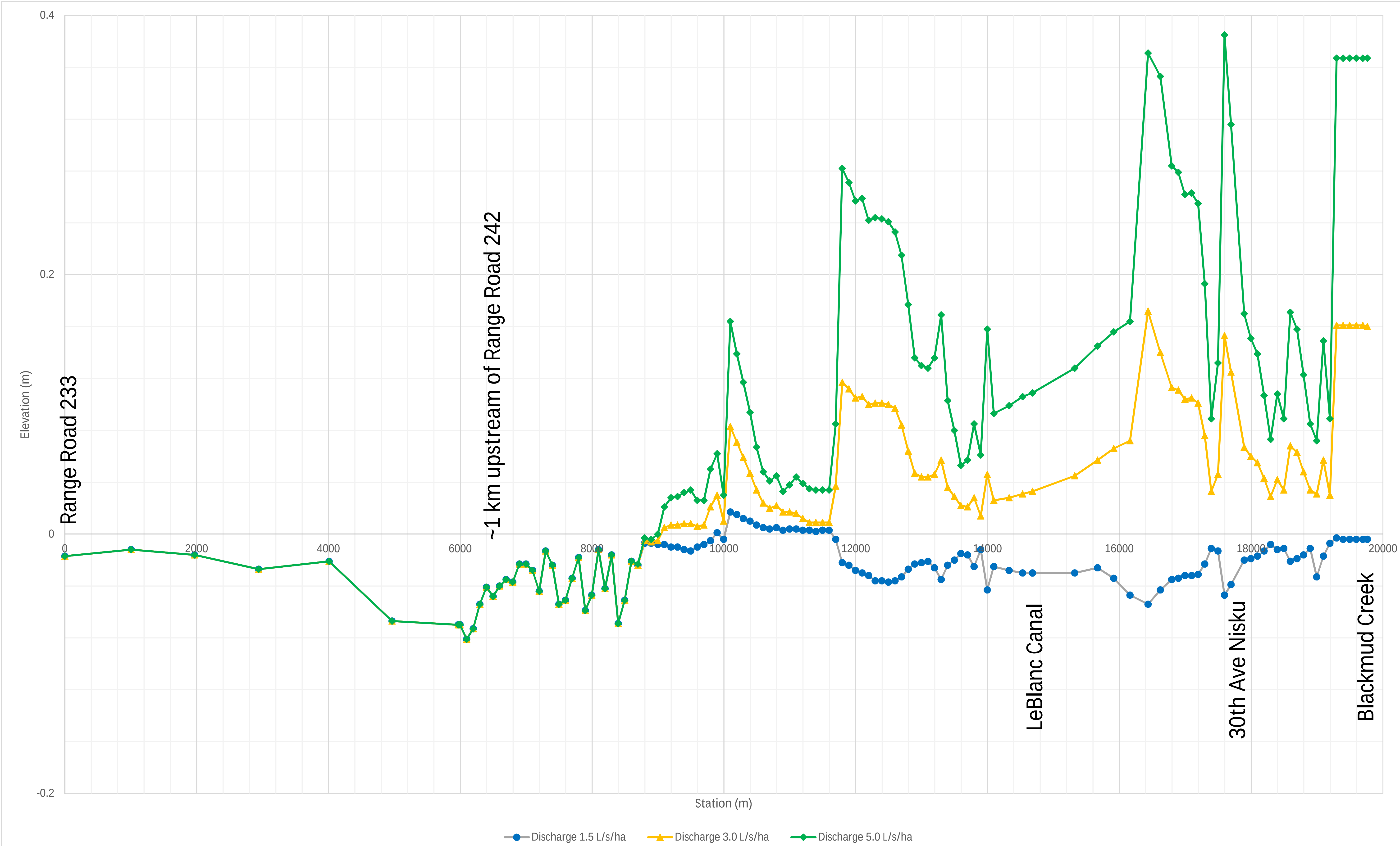


Figure 2-9: Irvine Creek
Depth Variation from Existing Flows



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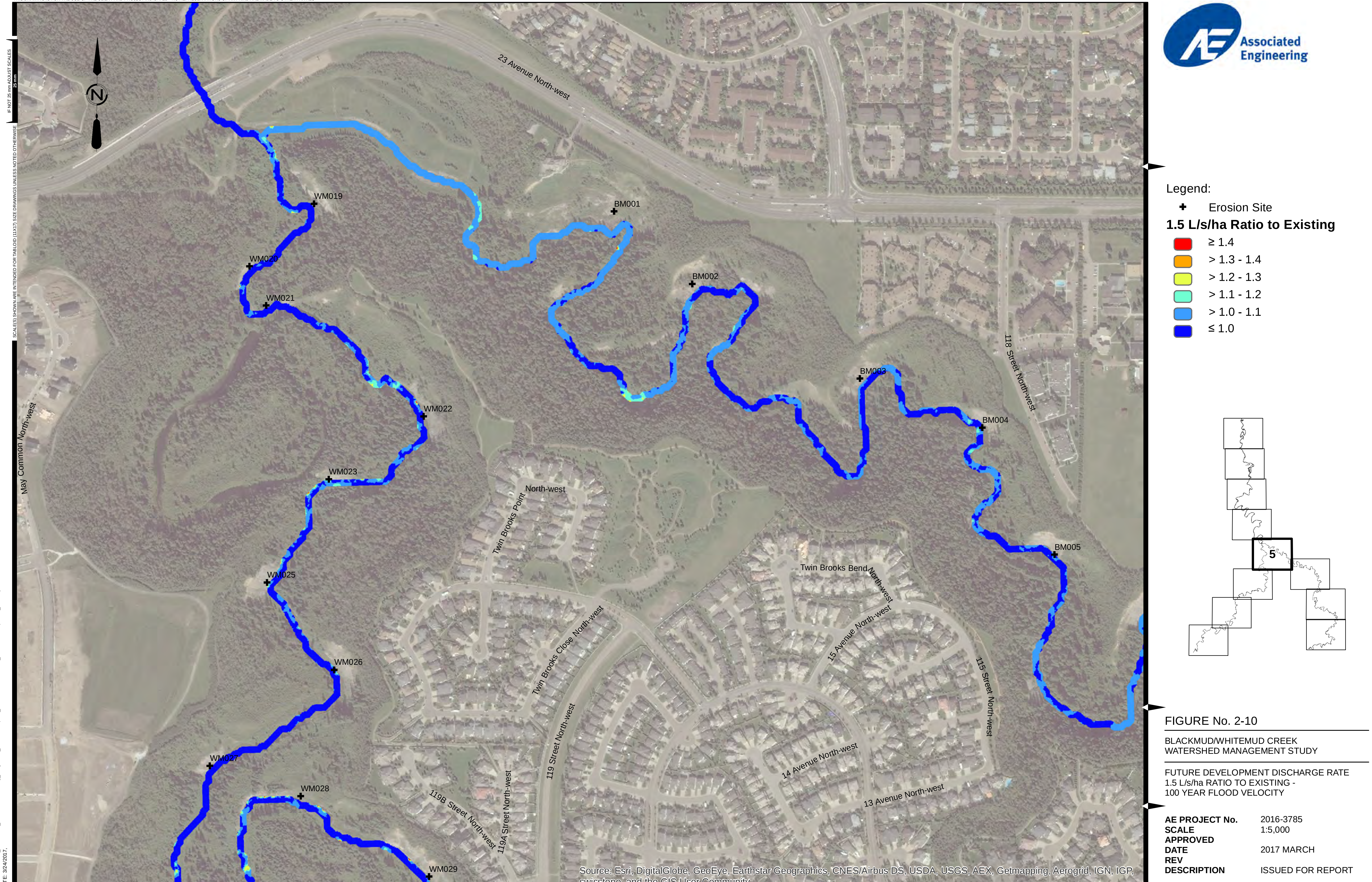

Associated Engineering

FIGURE No. 2-10

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

FUTURE DEVELOPMENT DISCHARGE RATE
1.5 L/s/ha RATIO TO EXISTING -
100 YEAR FLOOD VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 MARCH
REV	
DESCRIPTION	ISSUED FOR REPORT

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE
IF NOT 25 mm ADJUST SCALES
25 mm

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DATE: 3/24/2017,

Associated Engineering

Legend:

- ✚ Erosion Site

3.0 L/s/ha Ratio to Existing

- ≥ 1.4
- > 1.3 - 1.4
- > 1.2 - 1.3
- > 1.1 - 1.2
- > 1.0 - 1.1
- ≤ 1.0

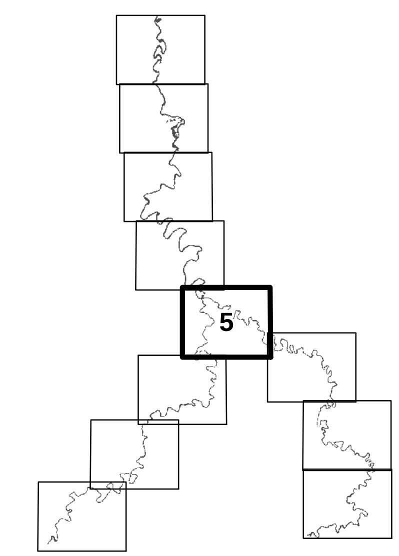

FIGURE No. 2-11

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

FUTURE DEVELOPMENT DISCHARGE RATE 3.0 L/s/ha RATIO TO EXISTING - 100 YEAR FLOOD VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 MARCH
REV	
DESCRIPTION	ISSUED FOR REPORT

IF NOT 25 mm ADJUST SCALES 25 mm

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

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IF NOT 25 mm ADJUST SCALES 25 mm

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

Associated Engineering

Legend:

✚ Erosion Site

5.0 L/s/ha Ratio to Existing

- ≥ 1.4
- > 1.3 - 1.4
- > 1.2 - 1.3
- > 1.1 - 1.2
- > 1.0 - 1.1
- ≤ 1.0

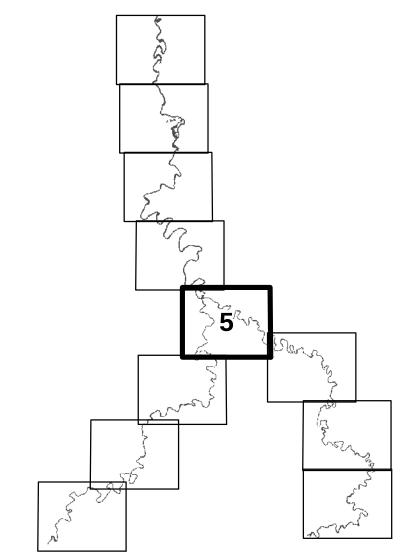

FIGURE No. 2-12

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

FUTURE DEVELOPMENT DISCHARGE RATE
5.0 L/s/ha RATIO TO EXISTING -
100 YEAR FLOOD VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 MARCH
REV	
DESCRIPTION	ISSUED FOR REPORT

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DATE: 3/24/2017,

2.5 EFFECTS OF INCREASED RUNOFF VOLUME

Regardless of the release rate adopted for future stormwater management, the volume of runoff will also increase with development due to conversion of pervious agricultural surfaces to impervious paved roads and rooftops, unless the runoff volume is controlled at the source through low-impact development practices. The available streamflow data indicate that the average runoff in the basin is about 5-10% of annual precipitation at present. Those areas that will be developed are estimated to generate runoff of about 50-60% of precipitation in the future.

Table 2-5 compares the annual runoff volumes (annual average streamflow) at various locations in the basin, estimated for the proposed development in the adopted growth area. These data indicate that the annual runoff volume will increase by about 50% in Blackmud and Whitemud Creeks. Other factors being equal, the amount of sediment transport, or rate of erosion, is directly proportional to runoff volume, which means that the amount of erosion in Whitemud and Blackmud Creeks will increase by about 50% due to the increase in runoff volume alone. Adding the increase due to increasing flood peaks as noted above, the rate of erosion is expected to double in the currently-eroding areas, and the extent of erosion will similarly increase.

Table 2-6
Estimated Runoff Volumes

Location	Existing (1,000 m^3)	Future (1,000 m^3)	Ratio
Clearwater Creek at the mouth	2,200	2,200	1.0
Irvine Creek at the mouth	3,400	11,300	3.4
Blackmud Creek WSC Gauge	14,200	25,500	1.8
Whitemud Creek WSC Gauge	9,000	12,100	1.3
Deer Creek at the mouth	1,100	5,300	4.7
Whitemud Creek at NSR	35,000	51,700	1.5

2.6 ISSUES AND CONSTRAINTS

Table 2-6 provides a summary of the projected impacts of development on peak flow, flood extent, runoff volume, and erosion rate in the basin. As noted above, the erosion problems in Whitemud and Blackmud Creek will increase over time, with the main concerns being the increase in runoff volume due to conversion of agricultural lands to paved surfaces and the potential increase in discharge rates. All future development will have stormwater management to control peak flows, and the magnitude of the impact will depend on the release rate adopted

In the progress meeting on February 24, 2017 the Group agreed on a maximum allowable release rate of 3.0 L/s/ha for planning of all future development in the basin, with a provision that individual municipalities could adopt a lower release rate to minimize the downstream impacts.

Floodplain lands are at risk of flooding and provide valuable environmental spaces. They should be preserved as Environmental Reserve and no development of these lands should be permitted.

In addition, stream channels are relatively small, shallow, and poorly defined, especially in Irvine Creek and Deer Creek and in the upper reaches of West Whitemud Creek. This constraint will potentially impact development of adjacent lands that drain to the creeks in that these stream channels are too shallow to provide an outfall from a piped drainage system. This issue will be explored in the following section of this report.

Table 2-7
Projected Impacts of Development in the Basin

Peak Flow	Significant -13% to 100% depending on release rate and location
Flood Extent **Flood Depth**	Relatively minor (localized) <0.4M
Runoff Volume	Significant 1-5x depending on location
Erosion Rate and Extent	Significant 0-2x depending on release rate and location

3 Drainage Concepts

Two alternative drainage concepts were developed to address the constraints identified above. These concepts involve the following

- Channel improvement (lowering) to facilitate drainage of the worst flood-impacted areas and development of the adjacent lands.
- A trunk storm sewer system that would parallel the existing stream channels, connecting the various SWMFs and draining to a defined stream channel that has sufficient depth and capacity. In this scenario, the existing stream courses would convey the runoff from un-developed portions of the basin.

3.1 CHANNEL IMPROVEMENT

The main goal of channel improvements would be to lower the creek channel in places to facilitate drainage of the adjacent, tributary lands. The existing channels of Irvine Creek and Deer Creek would be lowered to provide an outlet of sufficient capacity for an underground piped system. Lowering the channels would also lower the flood levels and reduce the extent of flooding which would facilitate development of the benefitting lands.

Figure 3-1 illustrates the drainage parkway concept in plan view and cross-section. It involves deepening the existing channel or constructing a new channel within the floodplain to provide the required conveyance. The channel would be aligned to preserve existing treed areas wherever possible and would meander to mimic a natural channel. The existing floodplain would be preserved to provide wildlife habitat and migration corridors.

Figure 3-2 shows the extent of the proposed channel improvements. Drainage parkways would extend along Irvine Creek and Deer Creek from the CRB boundary to their confluences with Blackmud and Whitemud Creek, respectively. LeBlanc Canal would also be deepened to provide more capacity. Drainage parkways would also be constructed along two existing channels carrying runoff into Whitemud Creek southwest of the Edmonton International Airport and west of the City of Leduc.

Several local trunk mains are required to facilitate drainage from connected SWMFs into the proposed parkways (not all are shown).

Cawes Lake would be provided with an outlet channel to Irvine Creek to control the lake levels and convey the outflow from developing areas to the north. Current development plans call for the Decoteau Neighborhood to the north and east to drain to Cawes Lake through an inter-connected system of stormwater management facilities. Further study of Cawes Lake will be required to determine the optimum water level for wildlife habitat and to prevent flooding of adjacent lands.

A large regional wetland is also proposed at the junction of the LeBlanc Canal and Irvine Creek. Its main purpose will be to replace the flood storage that would otherwise be lost if the Irvine Creek channel is deepened and thus to prevent increasing peak flows downstream.

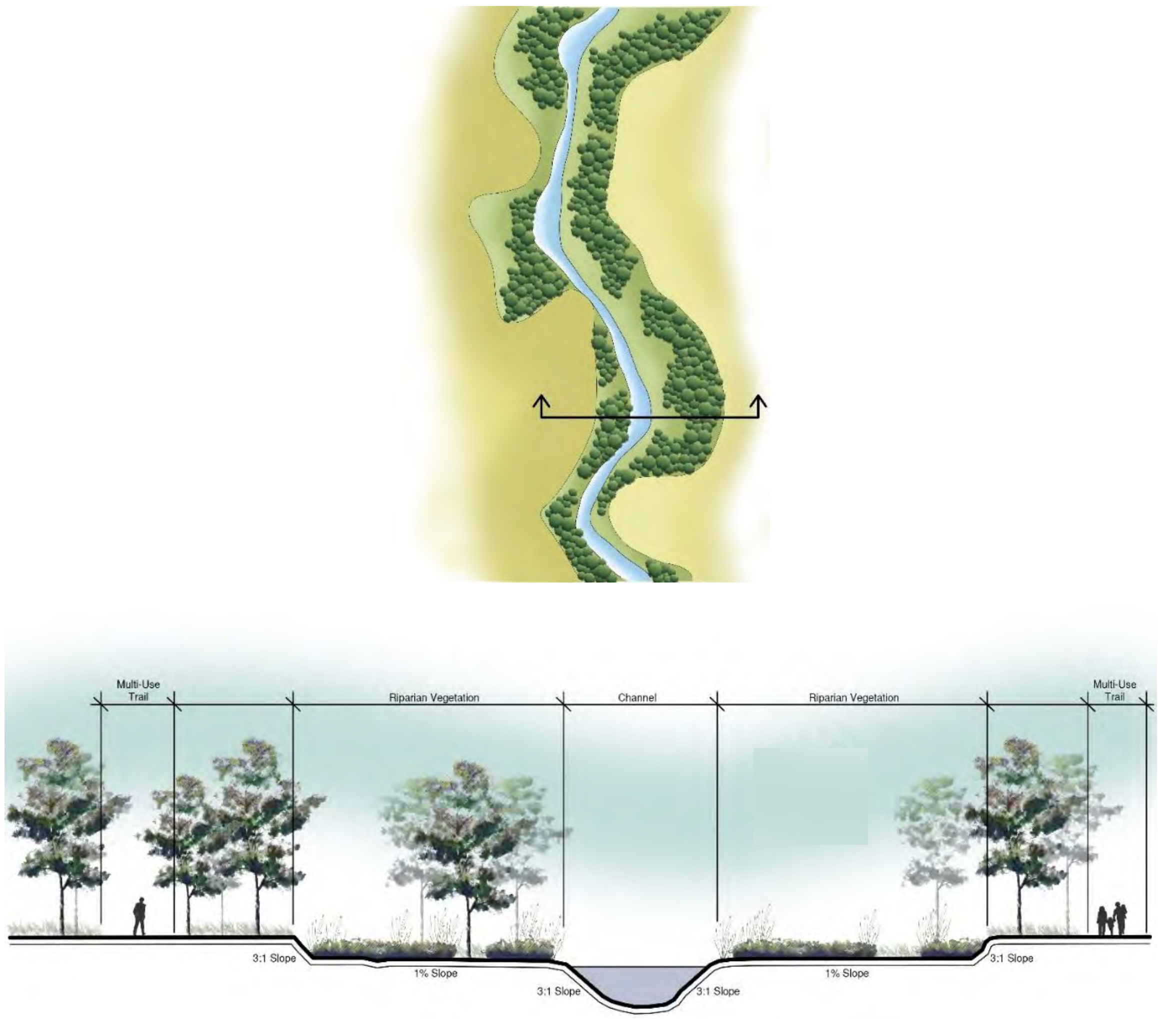
Figure 3-3 and **3-4** show longitudinal profiles of Deer Creek and Irvine Creek, respectively, with channel improvement locations noted.

Preliminary modeling was adopted to better understand the impacts of the proposed channel improvements along Deer and Irvine Creeks. Sections of Deer Creek were modified in the MIKE 11 model by dropping the channel bottom by 1.5 m. The Irvine Creek channel was modified to a rectangular channel to accommodate the peak flow. Simulation was carried out for the 3.0 L/s/ha release rate during a 1:100 year design event.

Preliminary flood maps are presented in **Figure 3-5** for Deer Creek and **Figure 3-6** for Irvine Creek. They indicate that the flood extent would not be significantly reduced along Deer Creek and that some reduction in flooding would occur along Irvine Creek near Beaumont. Note that some flooding is still observed along LeBlanc Canal that could be mitigated with the proposed improvements to this reach and with the proposed regional wetland at the junction with Deer Creek. Also note that the channel improvements are intended to facilitate drainage, not necessarily to reduce flooding.

Channel improvements must be done in an environmentally sensitive manner. Detailed environmental impact studies will be required to establish the appropriate environmental design measures to minimize the environmental impacts and provide a valuable amenity to the development.

Figure 3-1
Proposed Drainage Parkway Concept



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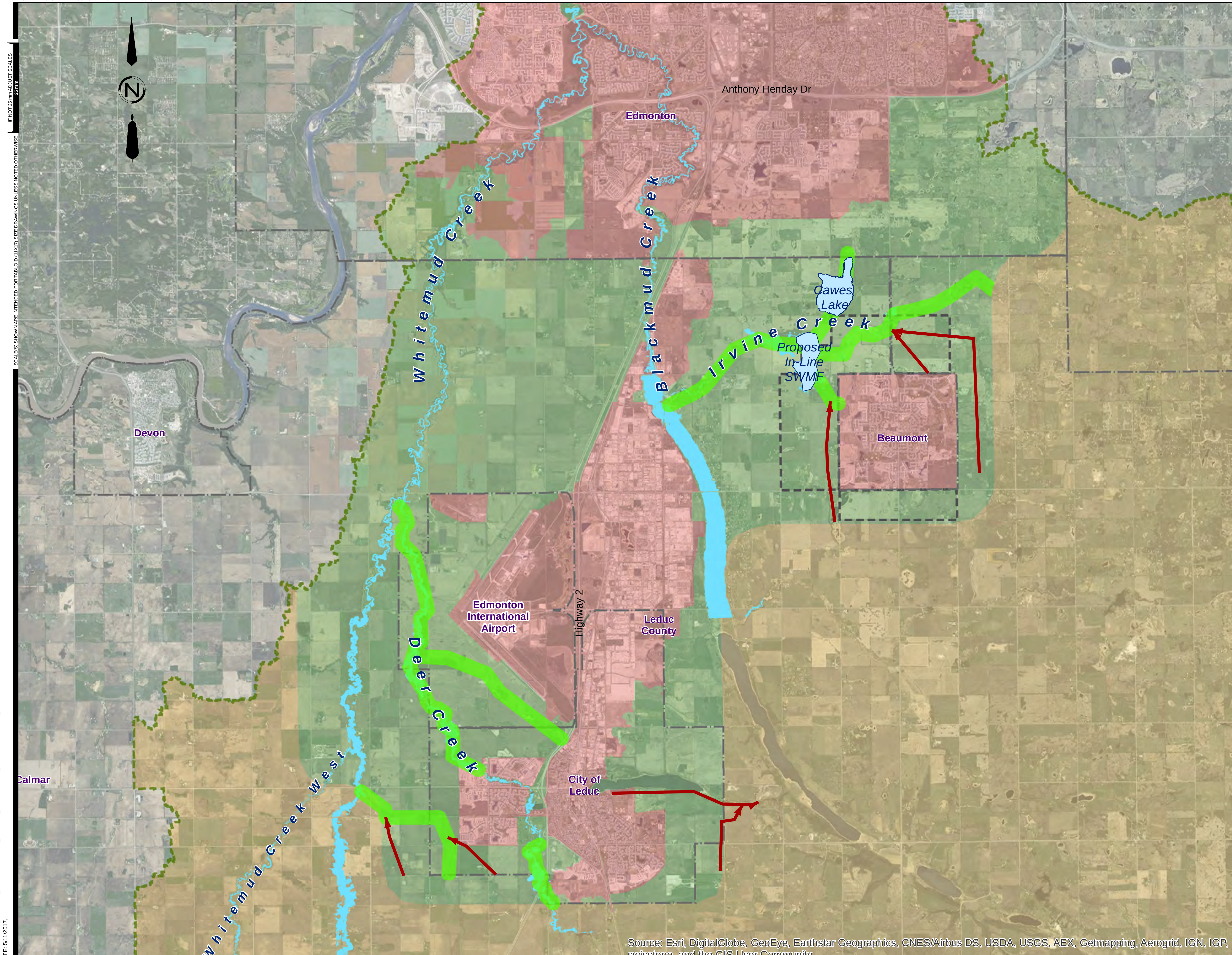

Associated Engineering

FIGURE No. 3-2

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

PARKWAY CONCEPT

AE PROJECT No.	2016-3785
SCALE	1:100,000
APPROVED	
DATE	2017 MARCH
REV	
DESCRIPTION	ISSUED FOR REPORT

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

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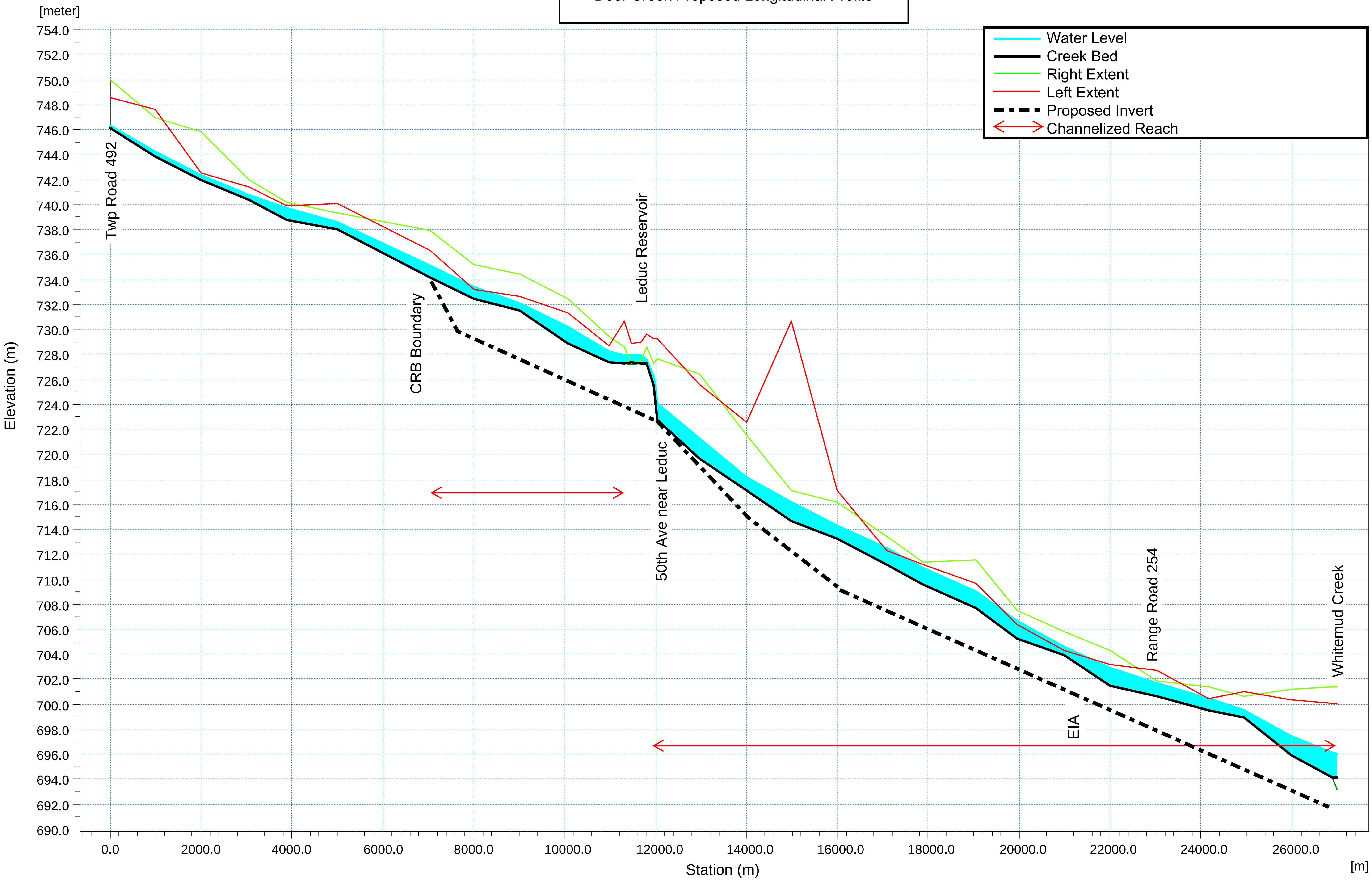
DATE: 5/11/2017,

Figure 3-3:
Deer Creek Proposed Longitudinal Profile



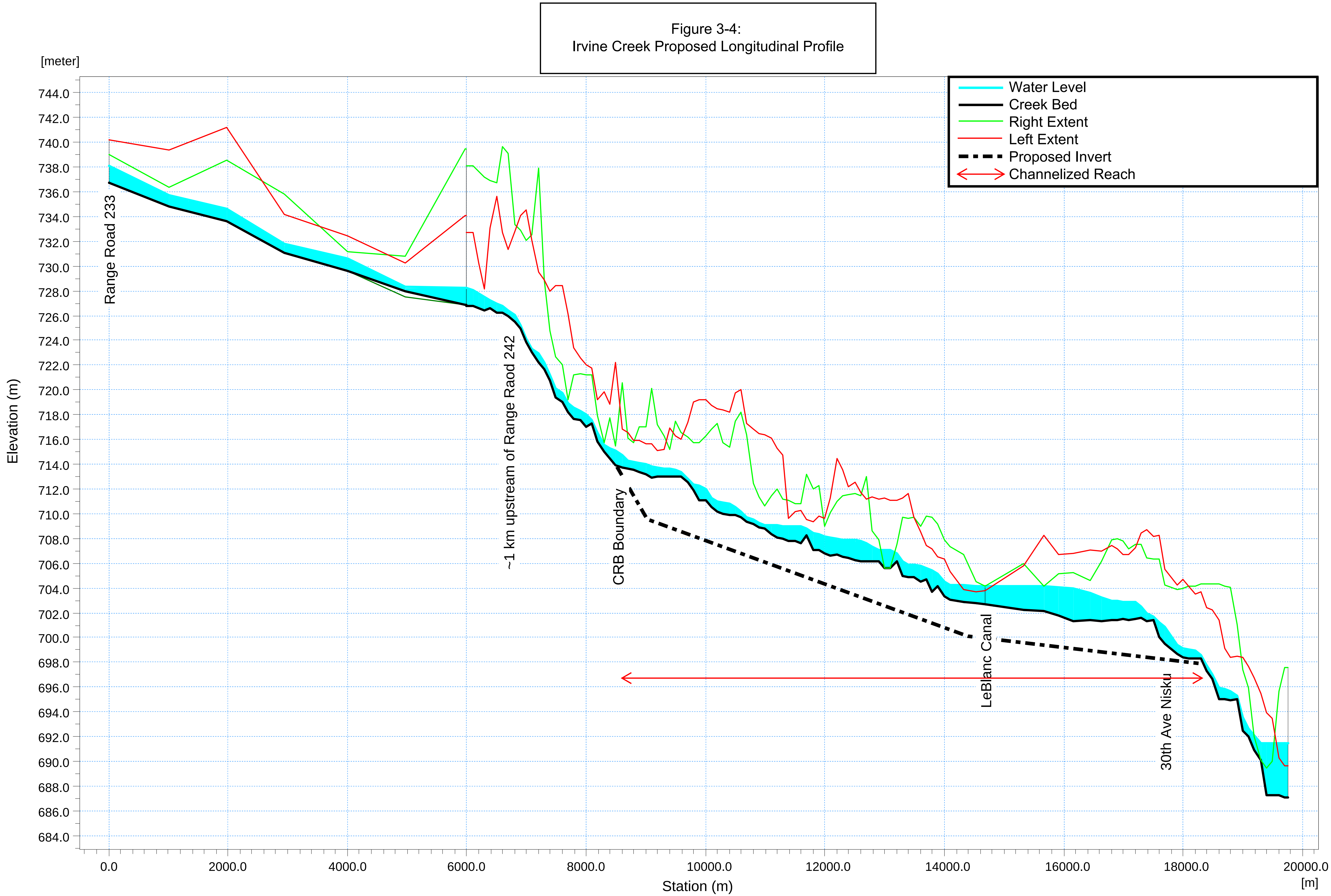


Figure 3-4:
Irvine Creek Proposed Longitudinal Profile
[meter]
Water Level
Creek Bed
Right Extent
Left Extent
Proposed Invert
Channelized Reach
Range Road 233
~1 km upstream of Range Raod 242
CRB Boundary
LeBlanc Canal
30th Ave Nisku
Elevation (m)
Station (m)
[m]
744.0
742.0
740.0
738.0
736.0
734.0
732.0
730.0
728.0
726.0
724.0
722.0
720.0
718.0
716.0
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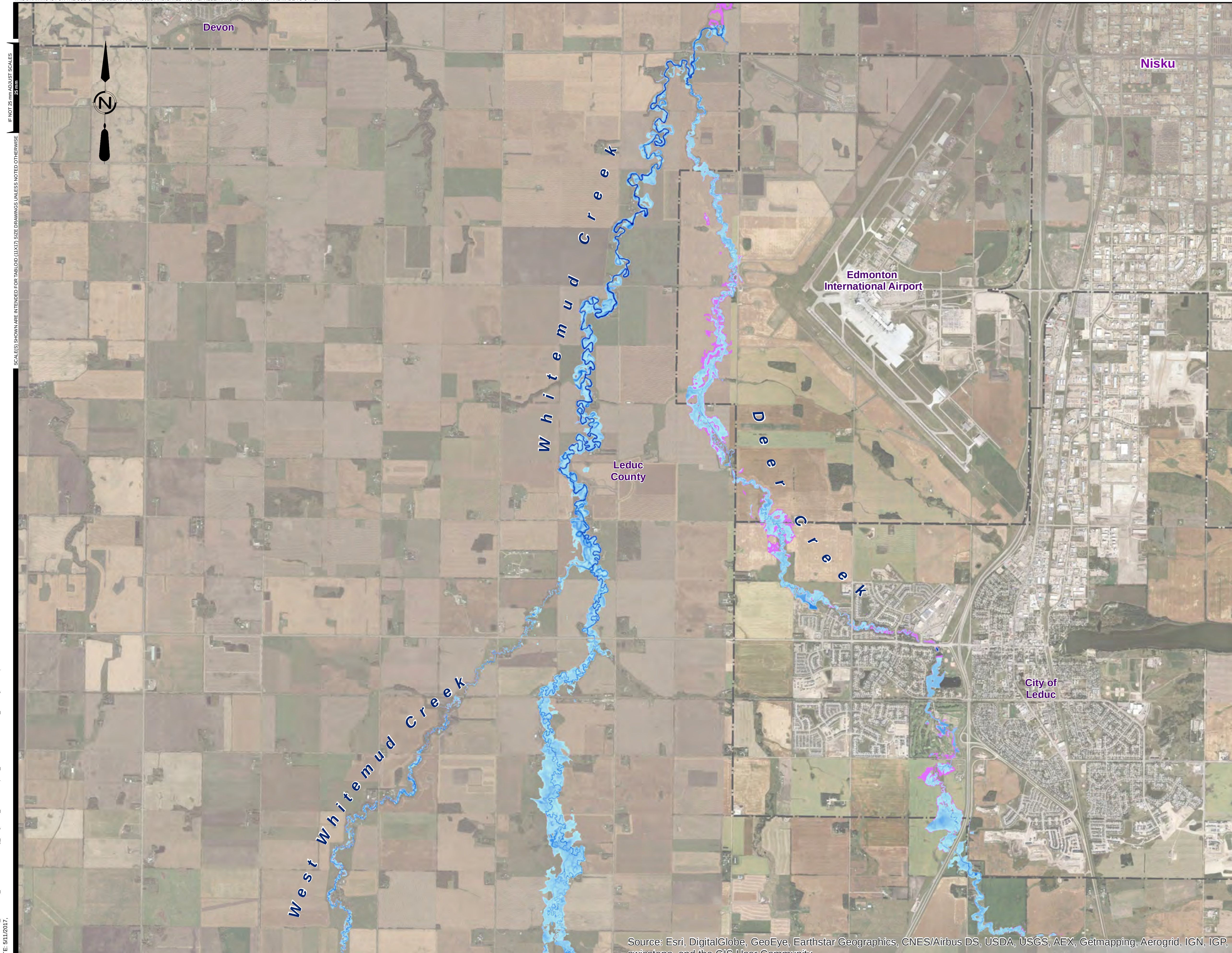


IF NOT 25 mm ADJUST SCALES 25 mm

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

P:\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\xxx_DrainageConcepts.mxd
DATE: 5/11/2017

Associated Engineering

Legend:

Creek Depth (m)

High : 4.0333

Low : 0

3.0 L/s /ha Extent

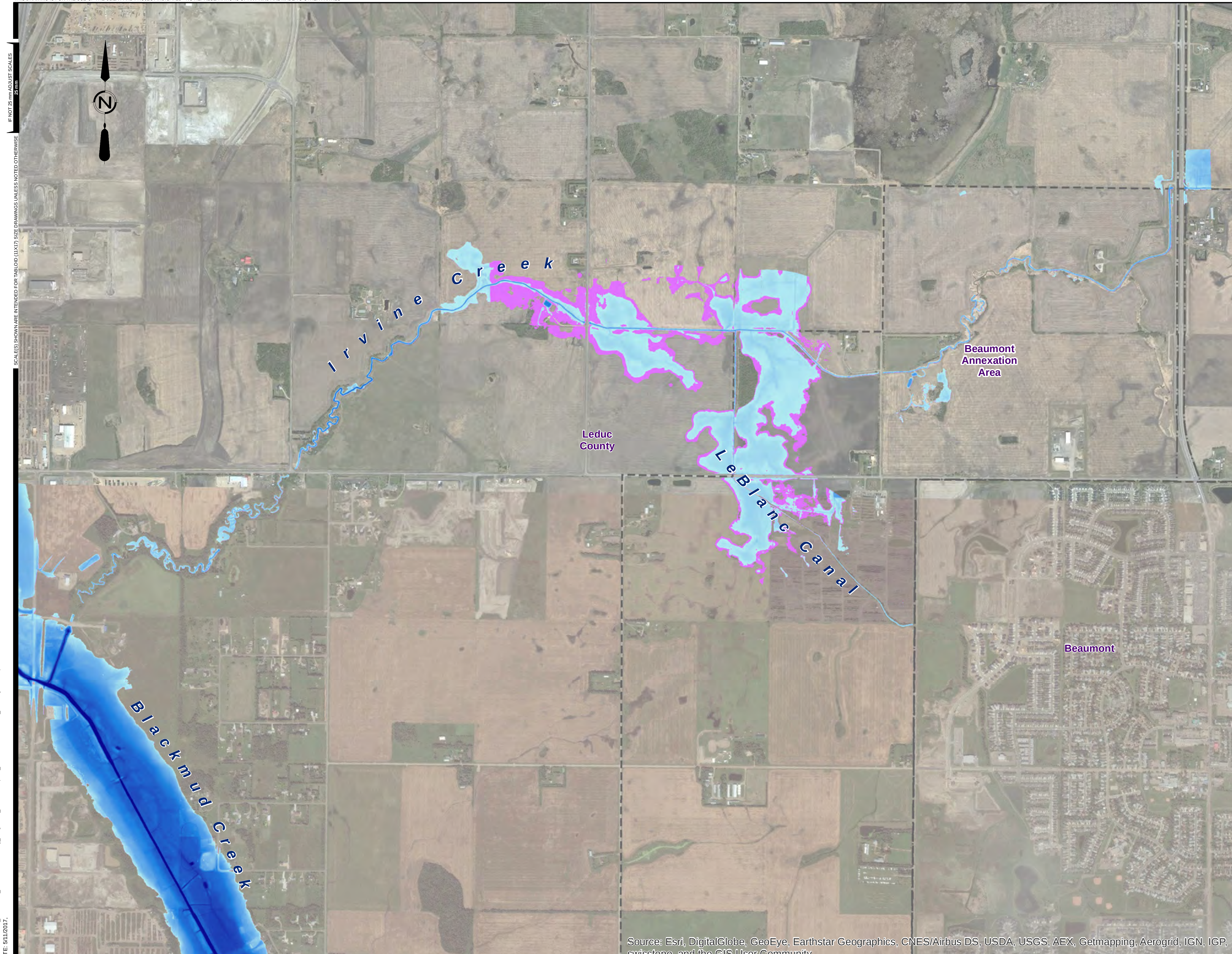
Note: Maps are preliminary and subject to change.

FIGURE No. 3-5

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

DEER CREEK DRAINAGE PARKWAY CONCEPT

AE PROJECT No.	2016-3785
SCALE	1:50,000
APPROVED	
DATE	2017 MARCH
REV	
DESCRIPTION	ISSUED FOR REPORT



Associated Engineering

Legend:

Creek Depth (m)

High : 3.9203

Low : 0

3.0 L/s /ha Extent

Note: Maps are preliminary and subject to change.

FIGURE No. 3-6

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

IRVINE CREEK DRAINAGE PARKWAY CONCEPT

AE PROJECT No.	2016-3785
SCALE	1:20,000
APPROVED	
DATE	2017 MARCH
REV	
DESCRIPTION	ISSUED FOR REPORT

IF NOT 25 mm ADJUST SCALES

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

P:\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\xxx_DrainageConcepts.mxd

DATE: 5/11/2017.

3.2 TRUNK SEWER OUTFALLS

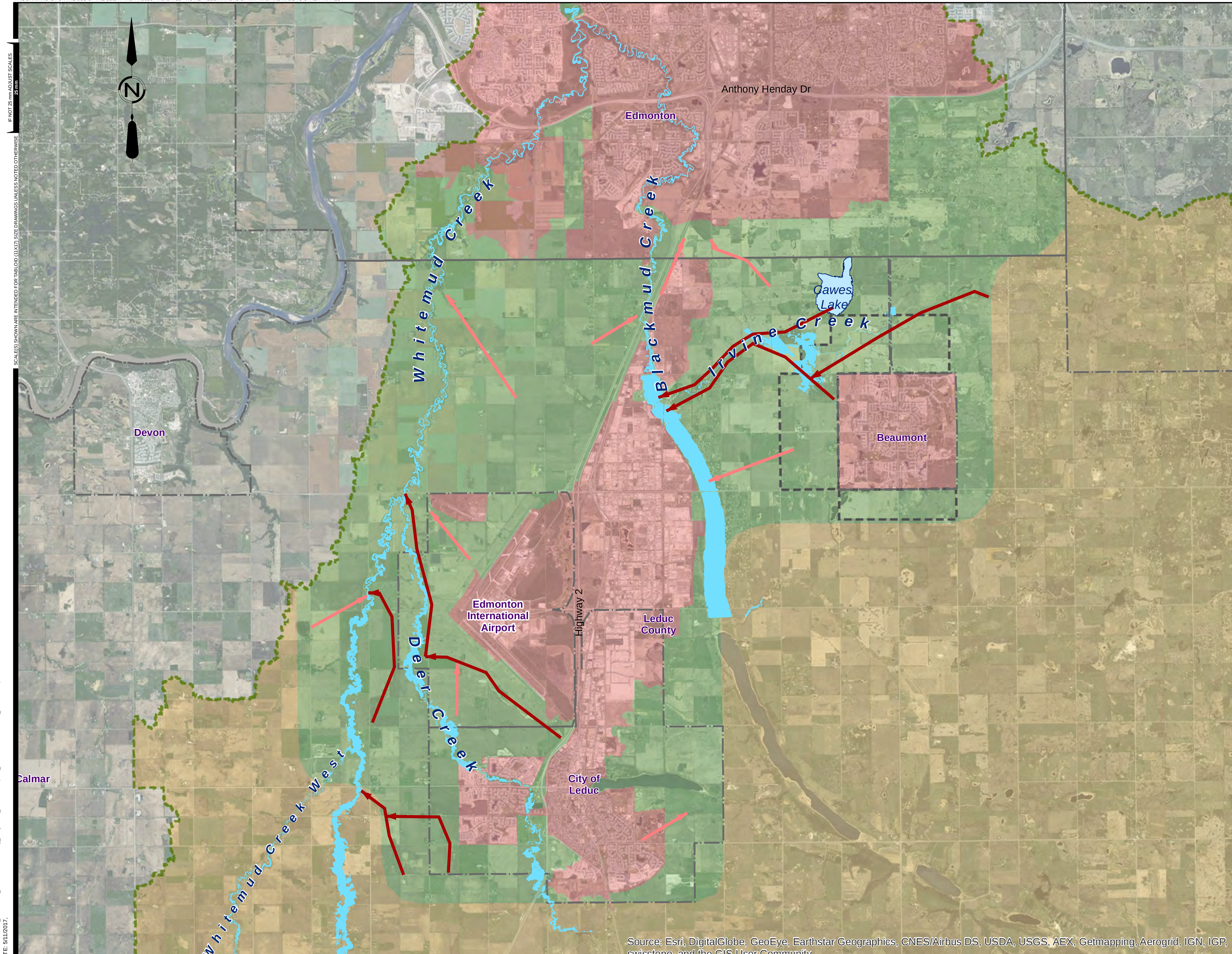
Figure 3-7 illustrates the trunk outfall concept for the Blackmud/Whitemud basin.

This concept provides drainage and discharge at downstream creek locations where there is more capacity for increased flow. In the cases of Deer Creek and Irvine Creek where existing capacity is limited, trunks will be required to bypass drainage.

This concept also provided for a defined outlet from Cawes Lake to maintain a controlled water level and an outlet to Irvine Creek. Further study of the Cawes Lake will be required to define the appropriate managed water levels for waterfowl and to prevent flooding of the adjacent lands. Cawes Lake will receive runoff from southeast Edmonton (Decoteau Neighborhood) and discharge into the proposed trunk.

Preliminary modeling was conducted to better understand the effects of the proposed trunks on the adjacent reaches of stream channels. Simulations were carried out for the 3.0 L/s/ha release rate during a 1:100 year design event. Figures 3-8 and 3-9 show the simulated flood depth and extents for Deer Creek and Irvine Creek, respectively. Results indicate that flood levels and extent would not be significantly reduced. Again, note that this scheme is intended primarily to provide drainage and not necessarily to reduce flooding. Flood areas will need to be protected from development as Environmental Reserve.

The main advantage of this option would be to avoid disturbing the channels of Irvine and Deer Creeks and to avoid the associated environmental impacts.



Associated Engineering

Legend:
- Proposed Trunk
- Drainage Direction
- 3.0 l/s /ha Extent
- Beaumont Annexation

Classification
- Existing Development
- Future Development
- Rural

FIGURE No. 3-7

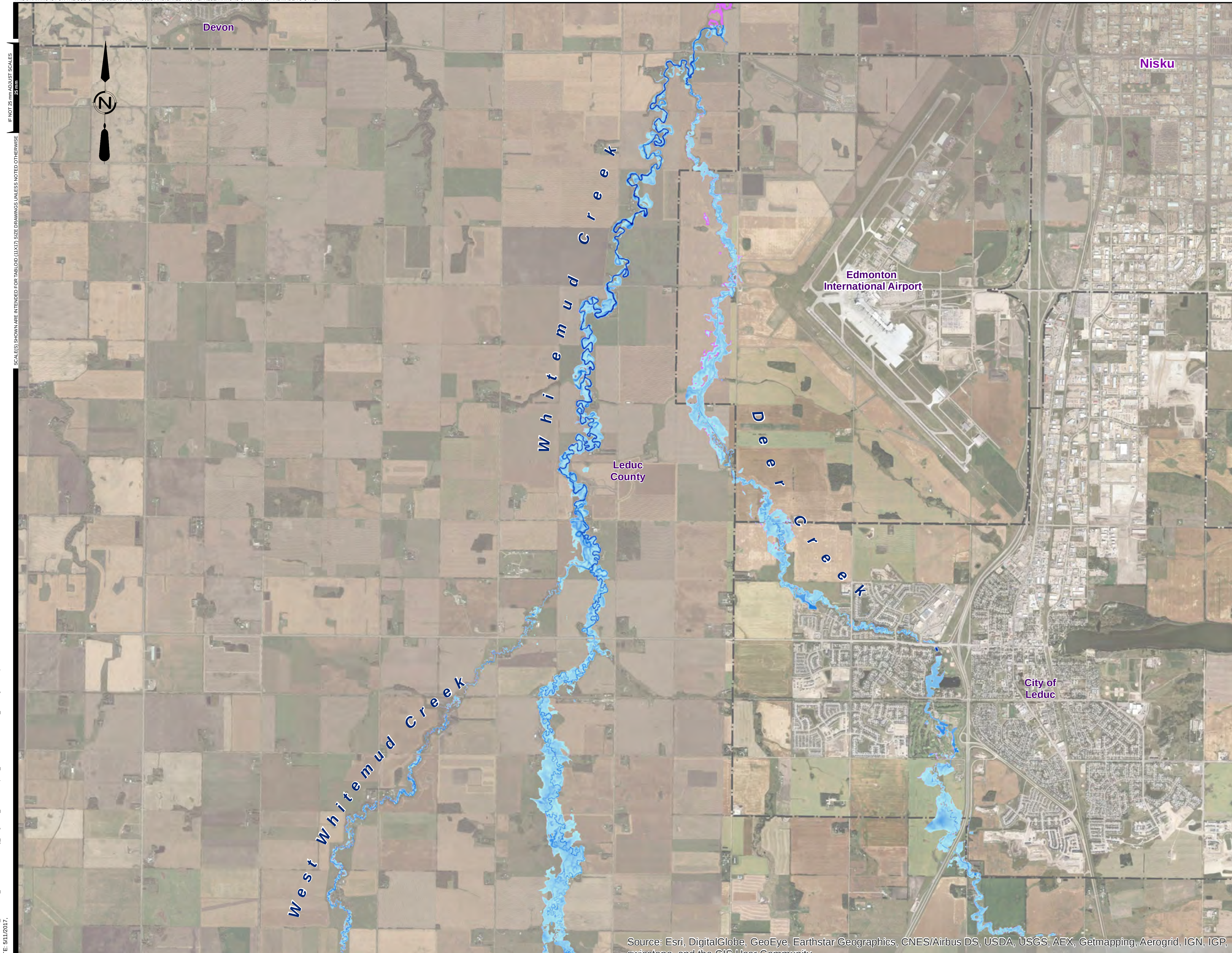
BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

TRUNK CONCEPT

AE PROJECT No.	2016-3785
SCALE	1:100,000
APPROVED	
DATE	2017 MARCH
REV	
DESCRIPTION	ISSUED FOR REPORT

P:\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\xxx_ChannelImprovements.mxd
DATE: 5/11/2017,

THIS DRAWING IS FOR THE USE OF THE CLIENT AND PROJECT INDICATED - NO REPRESENTATIONS OF ANY KIND ARE MADE TO OTHER PARTIES



IF NOT 25 mm ADJUST SCALES
25 mm
SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

P:\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\xxx_DrainageConcepts.mxd
DATE: 5/11/2017,

Associated Engineering

Legend:

Creek Depth (m)

High : 4.0362

Low : 0

3.0 L/s /ha Extent

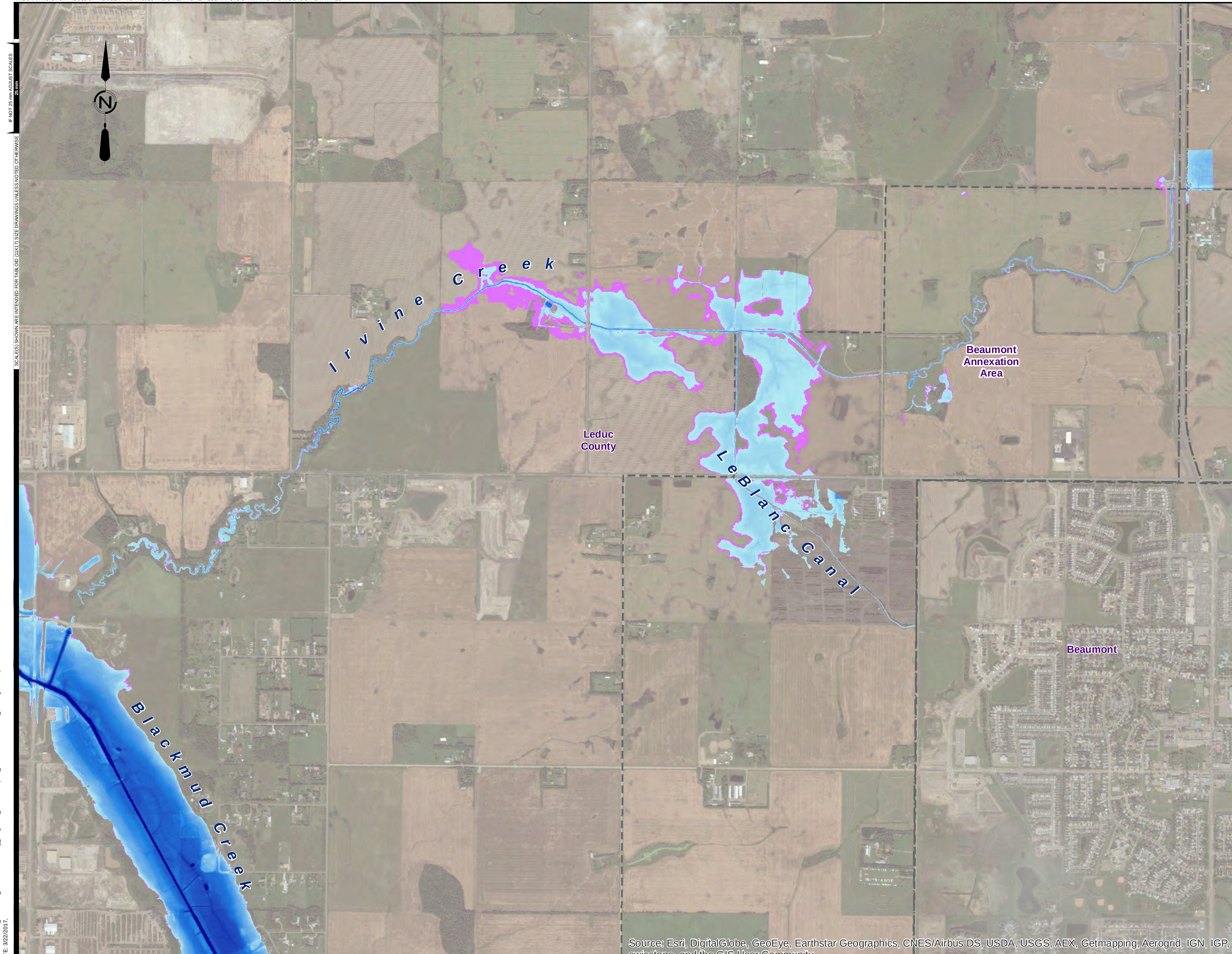
Note: Maps are preliminary and subject to change.

FIGURE No. 3-8

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

DEER CREEK DRAINAGE TRUNK CONCEPT

AE PROJECT No.	2016-3785
SCALE	1:50,000
APPROVED	
DATE	2017 MARCH
REV	
DESCRIPTION	ISSUED FOR REPORT



Associated Engineering

Legend:

Creek Depth (m)

High : 3.798

Low : 0

3.0 L/s /ha Extent

Note: Maps are preliminary and subject to change.

FIGURE No. 3-9

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

IRVINE CREEK TRUNK CONCEPT

AE PROJECT No.	2016-3785
SCALE	1:20,000
APPROVED	
DATE	2017 MARCH
REV	
DESCRIPTION	ISSUED FOR REPORT

P:\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\xxx_DrainageConcepts.mxd
DATE: 3/22/2017,

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE
IF NOT 25 mm ADJUST SCALES 25 mm

4 Conclusions

Localized flooding is expected to occur along the existing creeks during the design storm event with the three stormwater management release rates considered for future development (1.5, 3.0, and 5.0 L/s/ha).

Velocities and runoff volumes in the creeks will increase with development and will aggravate the on-going erosion issues in Whitemud and Blackmud Creeks. The magnitude of this impact will depend somewhat on the release rate adopted for new development and can be minimized by adopting the lowest release rate that is reasonably practical. Continuing the existing standard for the City of Edmonton, 5.0 L/s/ha, could cause erosion rates to increase by double or more compared with the existing condition. Otherwise there is little difference in flood level or extent or the cost of stormwater management facilities among the different release rates. However, adopting a release rate of 3.0 L/s/ha produces flows that are similar to the existing flows within most of the creeks except Irvine creek and LeBlanc Canal.

The City of Edmonton's design criteria have the effect of increasing the required storage volume in SWMFs by about 40%. AE recommends that the differences in design criteria be rationalized and that a uniform design criteria be adopted for the basin.

Based on the best information currently available it is concluded that climate change is unlikely to have a significant impact on storage volumes, release rates, and the basin drainage strategy.

Two alternative drainage concepts were developed for the 1:100 year design event with a release rate of 3.0 L/s/ha as agreed upon during discussions with the Group as follows:

- Constructing drainage parkways along Irvine Creek and Deer Creek to provide capacity and facilitate drainage of the adjacent lands which are otherwise too low to be drained with an underground drainage system.
- Constructing a network of outfall trunk sewers adjacent to the same stream channels to carry the releases from the connected stormwater management facilities to a downstream location where adequate channel capacity and depth are available.

The final concept plan might include a combination of the above concepts.

All proposed drainage works must be constructed in an environmentally sensitive manner. Further detailed analyses will be required to integrate existing wetlands into the urban fabric and to establish the appropriate water management strategy and water levels for existing and proposed wetlands. Cawes Lake should be preserved and provided with a defined outlet to manage lake levels for habitat enhancement and to prevent flooding of the adjacent lands. A regional wetland is proposed to replace the flood storage that would otherwise be lost with channelization of Irvine Creek. Existing floodplain areas should be preserved as Environmental Reserve and protected from further development.

More detailed floodplain modelling will be required during subsequent planning stages to define the extent of the floodplains and the design requirements for any channel improvements (drainage parkways) that might be adopted.

Closure

This report was prepared for the Blackmud/Whitemud Creek Surface Water Management Group to summarize the surface water management options and their modelling results for the Blackmud and Whitemud Creeks.

The services provided by Associated Engineering Alberta Ltd. in the preparation of this report were conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No other warranty expressed or implied is made.

Respectfully submitted,
Associated Engineering Alberta Ltd.

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QUALITY MANAGEMENT SIGN-OFF

Signature:

Date: June 29, 2017

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