CITY OF FORT SASKATCHEWAN

2024 Cemetery Flood Risk Study

Final Report

September 2024 – 24-8102

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Final Report for 2024 Cemetery Flood Risk Study

Dear Mr. Waite,

Dillon Consulting Limited (Dillon) is pleased to present the City of Fort Saskatchewan with this technical report detailing the flood inundation mapping efforts conducted for the 2024 Cemetery Flood Risk Study. The key deliverables of this project include a hydrologic and hydraulic assessment, along with flood extent and hazard maps that show the estimated inundation area during 25-year, 100-year, and 200-year flood events.

Sincerely,

DILLON CONSULTING LIMITED

PROFESSIONAL ENGINEER ALBERTA
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RM SIGNATURE:
RM APEGA ID #: 100600
DATE: 2024-10-02
PERMIT NUMBER: P002528
The Association of Professional Engineers and Geoscientists of Alberta (APEGA)

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Our file: 24-8102

Dillon Consulting Limited

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Executive Summary

Dillon Consulting Ltd. (Dillon) was commissioned by the City of Fort Saskatchewan to conduct a flood inundation analysis for the proposed expansion of the existing Fort Saskatchewan Cemetery along the banks of Ross Creek. The primary objective is to evaluate the feasibility of expanding the cemetery by estimating flood inundation areas across three designated zones – Area 1, Area 2, and Area 3 – outlined in the Fort Saskatchewan Cemetery Master Plan published by Hilton Landmarks Inc. in July 2017. This evaluation was conducted under different return periods (25-year, 100-year, and 200-year) and both existing climate normal and projected climate change scenarios.

Dillon completed hydrologic and hydraulic analyses to create flood inundation maps for Areas 1, 2, and 3, illustrating the extent of flooding for the specified return periods under both existing and projected climate change scenarios, resulting in a total of six scenarios. Based on communication with the City it is understood that they wish to move forward with recommendations using the projected future climate change results. Therefore, the following recommendations are based on the more conservative climate change projections depicted in **Maps 9 to 11**, which illustrate the 1 in 25-year, 1 in 100-year, and 1 in 200-year inundation zones.

Area 1:

- Development is not recommended in the vegetated areas around Ross Creek, as all three return periods show inundation with minimal discrepancy.
- Most of Area 1, excluding Ross Creek's treed valley, is suitable for further development.

Area 2:

- The majority of Area 2 is unsuitable for development due to significant inundation risks.
- Floodproofing measures could be considered but would require additional studies/investigation to confirm feasibility.

Area 3:

- Most of Area 3 is suitable for development, except for the low-lying northern portion and a small section in the southern part along the treed valley, which are prone to inundation.

These recommendations aim to align with the City's risk tolerance and aim to ensure safe and sustainable cemetery expansion.

1.0 Introduction

The City of Fort Saskatchewan (the City) has commissioned Dillon Consulting Ltd. (Dillon) to execute a flood inundation analysis for the proposed expansion of the existing Fort Saskatchewan Cemetery along the banks of Ross Creek. The primary objective of this analysis is to evaluate the feasibility of expanding the cemetery, in accordance with the Fort Saskatchewan Cemetery Master Plan published by Hilton Landmarks Inc. in July 2017. The "Study Area," encompassing the cemetery's current and potential expansion boundaries, is divided into three zones: Area 1, Area 2, and Area 3, as illustrated in **Map 1.**

The primary focus of this report is to estimate the flood inundation areas across the three expansion zones under different return periods to support the creation of setback limits. Dillon retained Challenger Geomatics (Challenger) to complete a field visit to collect topographic details within Ross Creek and assess the existing structures within the study area.

Hydrologic and hydraulic analyses were completed by Dillon to support the creation of flood inundation maps for Ross Creek between 89th Avenue and 109th Street. In hydrology, return periods describe the statistical likelihood of a flood occurring based on historical records, expressed in years, indicating the average interval at which a certain flood magnitude is equalled or exceeded. For instance, a 100-year return period represents a 1% chance (annual exceedance probability, AEP) of occurring or being exceeded in any given year, while a flood with a 25-year return period has a 4% AEP, and a 200-year event has a 0.5% AEP. Statistically, this does not mean that such a flood will occur once every 100 years, but rather that the likelihood of a flood of this magnitude occurring in any given year is 1 in 100 (1%). For this study, hydrologic and hydraulic modelling was performed for the 25-year, 100-year, and 200-year return periods, each analyzed under existing climate normal and a projected climate change scenario.

The resulting flood inundation maps illustrate the extent of flooding in each of the three areas (Area 1, Area 2, and Area 3) under the different return periods and climate change scenarios. These maps will provide the City of Fort Saskatchewan with information regarding the feasibility of the proposed cemetery expansion.

2.0 Background

2.1 Background Documents Review

The first document reviewed was the Fort Saskatchewan Cemetery Master Plan, authored by Hilton Landmarks Inc. and submitted to the City in July 2017. This document indicates that the Fort Saskatchewan Cemetery covers 3.9 ha, of which 3.0 ha are currently developed and 0.2 ha are undevelopable. Approximately 0.7 ha of developable land remains in five discrete areas within the existing cemetery. Additionally, approximately 2.3 ha remain of potential expansion land to the south of the existing cemetery.

The existing cemetery (Area 1) is projected to provide sufficient interment options until around 2043. The development of the southern expansion areas (Areas 2 and 3) is contingent upon the results of an upcoming basin study expected within 10 years of the report's submission, which could extend the cemetery's sales lifespan by an additional 75 years.

Various drawings and reports were reviewed to gather information related to the Study Area, including reported flow rates, high-water levels, channel geometry, bridge/culvert structure opening sizes, inverts, soffit elevations, and catchment areas. The resources reviewed are summarized in **Table 2-1**.

Table 2-1: Background Documents Summary

Title	Author(s)	Client	Year Published	Relevance
East of 101st Street – East of DOW Chemical Access	Alberta Transportation	Alberta Transportation	1981	Provided a plan view and associated profile sketch of Highway 15.
Ross Creek Culverts 1984 Construction	Stanley Associates Engineering Ltd.	City of Fort Saskatchewan	1981 - 1984	Provided information about the culvert constructions, enhancing understanding of historical infrastructure over Ross Creek within the City of Fort Saskatchewan.
New Correctional Centre Fort Saskatchewan – Off-Site Services Ross Creek Culvert	Stanley Associates Engineering Ltd.	Alberta Public Works Supply and Services	1986 - 1987	Provided information regarding the culvert that runs beneath Highway 15.
86 Avenue Extension	Stantec Consulting Ltd.	City of Fort Saskatchewan	2010	Provided information on the bridge structure crossing 86 Avenue.

Title	Author(s)	Client	Year Published	Relevance
Clover Park Secondary Access Bridge Condition Assessment	WSP	City of Fort Saskatchewan	2018	Provided information about the Clover Park Secondary Access bridge, crossing 109th Street over Ross Creek within the City of Fort Saskatchewan.
Preliminary Engineering Report Clover Park Secondary Access	WSP	City of Fort Saskatchewan	2018	Provided information regarding the Clover Park Secondary Access bridge, crossing 109th Street over Ross Creek within the City of Fort Saskatchewan.
City of Fort Saskatchewan Servicing Design Brief – Annexed Land	ISL Engineering	City of Fort Saskatchewan	2023	Provided information about the watersheds contributing to the flow of Ross Creek.

2.2 Study Area

The Study Area, shown in **Map 1,** is situated along the banks of Ross Creek. This creek flows through the central and northern parts of the City before draining into the North Saskatchewan River, approximately 5 km downstream from the Study Area.

According to the Annexation Servicing Design Briefs by ISL Engineering, four primary watersheds contribute to the flow of Ross Creek. These watersheds are illustrated in **Figure A 1**, which is titled as Figure 5.2 in ISL's report and is included in **Appendix A**.

1. **City Limits Watershed**: This is the catchment area within the city limits that drains directly into Ross Creek. Most of this drainage area is located downstream of the Study Area.
2. **East Drainage Course Watershed**: This watershed comprises an unnamed drainage course located east of Ross Creek, merging with it at the downstream end. The watershed for this drainage course extends both inside and outside city limits.
3. **Ross Creek to City Boundary Watershed**: This watershed encompasses a specific area that drains into Ross Creek up to the City boundary.
4. **Yorkville Ditch Watershed**: Situated at the south border of the City, this watershed channels water to Ross Creek, with portions located both within and outside the City. This portion of the watershed outlets downstream of the Study Area.

The land use for all four watersheds primarily consists of farmlands, interspersed with several natural areas and wetlands. The catchment areas that contribute to the total drainage into Ross Creek upstream of the Study Area, as listed in ISL's report, are shown in **Table 2-2.**

The "Preliminary Engineering Report Clover Park Secondary Access" published by WSP in 2018 indicates that the drainage basin for the Clover Park Access bridge, which spans 109th Street over Ross Creek in the City of Fort Saskatchewan, has been modified. This bridge is located within 100 m south of the Study Area. A portion of the natural drainage is now being diverted from the site using a ditch. The basin features a mix of low valleys, flat treed areas, and willow-covered marshlands upstream of the crossing. Beyond the valley walls, the floodplain primarily consists of flat, cultivated land. The crossing itself appears to be situated on a characteristic section of the watercourse. The estimated drainage area for the basin is approximately 160 km^2, as listed in **Table 2-2.**

Table 2-2: Ross Creek Watershed Catchment Areas

Watershed	WSP Catchment Area (km^2)	ISL Catchment Area (km^2)
East Drainage Course	-	96
Ross Creek to City Boundary	-	146
Ross Creek Drainage Area at Study Boundary	160	242

The catchment areas for the Ross Creek Drainage Area at the study boundary, obtained from two sources and listed in **Table 2-2**, serve as reference points for comparing the manually delineated catchment area for the Study Area to the estimated catchment areas from other sources. The procedure for manually delineating the catchment area for the Study Area is outlined in **Section 4.1**.

2.3 Historical Flooding within the Study Area

A review of historical flooding within Fort Saskatchewan was conducted. Based on the Historical Flood Events information available through Natural Resources Canada (NRCan), most of the recorded flooding in the area is due to the North Saskatchewan River, which flows from Edmonton through the northern portion of Fort Saskatchewan. Additionally, local newspapers were reviewed, and no instances of flooding related to Ross Creek were identified.

The Government of Alberta recently completed floodplain mapping of the North Saskatchewan River through Fort Saskatchewan and neighbouring municipalities. An initial review of the flood inundation maps indicates that the flow is primarily contained within the river valley near Fort Saskatchewan and does not extend up Ross Creek to the Study Area. Therefore, any tailwater influences on the Study Area are negligible.

3.0 Data Collection

To support the creation of the hydraulic model, a site visit and topographic survey of the Study Area was conducted. The data collected on-site was used to compare with or supplement the information gathered from the review of background documents. The primary focus of the site survey was to collect the following information:

- Cross sections along the study reach were spaced 100 metres apart, from 89th Avenue to 109th Street, with additional sections before and after each roadway. These cross sections, as shown in **Map 2** provide detailed measurements of the topography and elevations at regular intervals. This data was used to create a surface to support the hydraulic model development;
- Measured inverts and geometry of the culverts located at major roadways within the study reach including Cemetery Road, 89th Avenue, and 86th Avenue; and
- Geometry and soffit elevation of the bridge at 109th Street.

In addition to these data, the team obtained a CAD drawing file containing surveyed linework, a CSV file of the surveyed points, and site photos. A PDF version of the CAD file, **Map 3**, is appended in the Maps tab, and the site photos are included in **Appendix A**. The spatial data uses the North American Datum 1983 (NAD83), with Canadian Spatial Reference System (CSRS) refinements up to the year 2002 for high positional accuracy. The location is specified within Universal Transverse Mercator (UTM) Zone 12 North, covering a longitudinal section that includes parts of western Canada and the western United States. Elevations are expressed as orthometric heights based on the Canadian Geodetic Vertical Datum of 1928 (CGVD28), using the HT v2.0 transformation model to achieve accurate conversion from ellipsoidal heights to mean sea level-relative elevations.

In November 2013, Natural Resources Canada (NRCan) released the Canadian Geodetic Vertical Datum of 2013 (CGVD2013), the new reference standard for heights across Canada, replacing CGVD28. To maintain consistency in modelling, Dillon converted survey data to CGVD2013 using the 1646D control station (Station Report – 61A157). All elevations presented in this report are in CGVD2013 unless otherwise stated.

A summary of the data for the hydraulic structures used as input into the hydraulic model is presented in **Table 3-1**; more details about the hydraulic model are discussed in **Section 5.0.** The data was largely compiled through the field survey.

Table 3-1: Hydraulic Structure Summary

Location	Type	Hydraulic Opening	Elevation (m)
86th Avenue	Culvert	Circular opening	Upstream invert: 617.45 Downstream invert: 617.39
88th Avenue	Parallel culverts with differing diameters: Two culverts installed side by side, each with a different diameter.	West opening: 3.2 m in diameter.	Upstream invert: 616.66 Downstream invert: 616.86
		East opening: 2.5 m in diameter.	Upstream invert: 617.52 Downstream invert: 617.367
89th Avenue	Triple parallel culverts: The west culvert has a circular opening, while the middle and east culverts consist of double box culverts.	West opening: 3 m in diameter.	Upstream invert: 617.21 Downstream invert: 616.90
		Middle opening: span of 1.8 m and a rise of approximately 2.43 m.	Upstream invert: 617.35 Downstream invert: 616.90
		East opening: span of 1.8 m and a rise of approximately 2.43 m.	Upstream invert: 617.37 Downstream invert: 616.92
109th Street	Girder bridge (1 span)	Standard girder bridge allowing for unrestricted flow underneath. The bridge deck is 0.81 m thick.	Upstream elevation of the top of the bridge opening: 620.86 Downstream elevation of the top of the bridge opening: 620.79

In addition to the hydraulic structures noted above, the surveyors discovered a beaver dam in Ross Creek, with photos included in **Appendix A**.

4.0 Hydrologic Assessment

The primary objective of the hydrologic assessment is to estimate peak flow rates for Ross Creek, which will serve as essential inputs for the hydraulic model. The subsequent sections detail the methodology for estimating the peak flow values to be used in the hydraulic model.

4.1 Drainage Area Delineation

The drainage area for the study was manually delineated using ArcMap, with the aid of available LiDAR data for the surrounding area. A 25-m Digital Elevation Model (DEM) for Alberta was used to generate 5 m elevation contours within ArcMap, facilitating the delineation of the Ross Creek watershed. The 25 m DEM consists of cells or pixels measuring 25 m by 25 m, each representing the average elevation of the land surface within that cell.

To support the delineation process, the National Hydro Network (NHN) data was employed in ArcMap to identify the locations of watercourses. The NHN provides high-quality geometric descriptions and a set of basic attributes related to Canada's inland surface waters, including lakes, rivers, streams, and other watercourses. These data, produced collaboratively by federal and interested provincial and territorial partners, adheres to the NHN Standard, and offers significant potential for analysis, cartographic representation, and display. The NHN Work Unit Limits, derived from the Water Survey of Canada Sub-Sub-Drainage Area, were particularly useful for pinpointing the locations of watercourses.

The delineated drainage area is calculated to be 191 km^2, which is in between the drainage area values reported by WSP and ISL, as shown in **Table 2-2.** The manually delineated catchment area is depicted in **Map 4.**

4.2 Hydrometric Data

An initial screening of Water Survey of Canada (WSC) hydrometric gauges was conducted within a 100 km radius of the Study. Key characteristics of the watershed, including drainage area, location, land use, and development attributes linked to each gauge, were subsequently reviewed. These characteristics were compared against those of the Study Area's watershed to identify the flows most representative of the local conditions. Additionally, the historical 100-year unit runoff rates were estimated for each station based on the 100-year instantaneous peak flow rates and the associated tributary drainage areas.

Based on drainage area, location, land use, and development attributes, three hydrometric stations—Waskatenau Creek near Waskatenau (05EC002), Wabash Creek near Pibroch (07BC007), and Stony Creek near Tawatinaw (07BE004)—were found to be most representative of the watershed in the study. Details of these WSC hydrometric gauges are provided in **Table 4-1.**

Table 4-1: Relevant Regional Hydrometric Station Summary

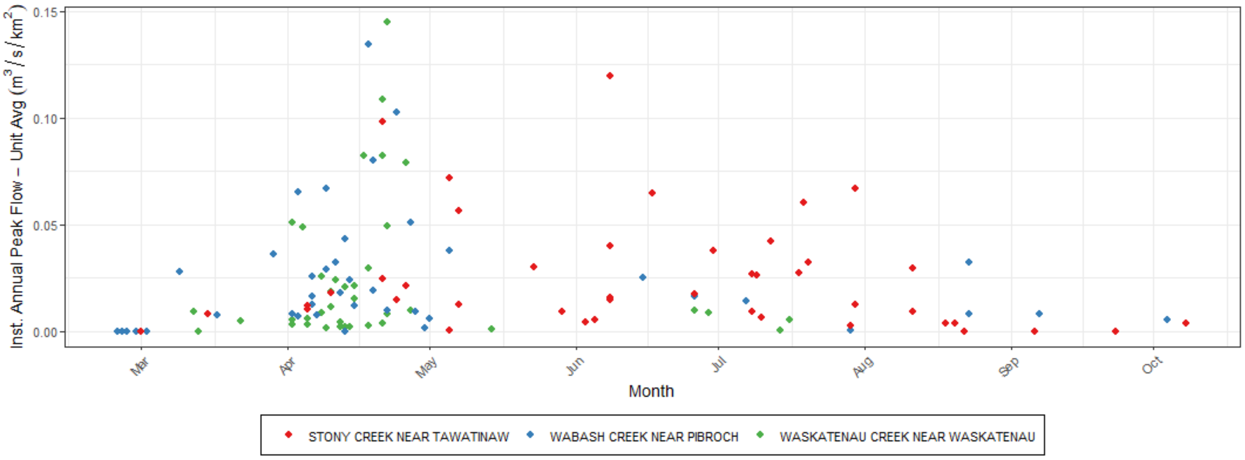
Station Name	Station Number	Distance from Site (km)	Years of Usable Data	Drainage Area (km^2)	Watershed Land Use	100-Year Unit Runoff Rate ($m^3/s/km^2$)
Stony Creek Near Taxational	07BE004	45.8	26	128	Agriculture and Development, along with some forested areas.	0.15
Waskatenau Creek Near Waskatenau	05EC002	73.9	38	313	Agriculture and Development, along with some forested areas.	0.19
Wabash Creek Near Pibroch	07BC007	66.3	27	344	Agriculture and Development, along with some forested areas.	0.17

Data for the three hydrometric gauges were obtained from the HYDAT database for instantaneous peak flows using the R software package “tidyhydat” (Albers, 2017), and the annual instantaneous peak flow data for the gauges are provided in **Appendix B**. The period of record for each of the gauges was initially assessed for any gaps in the data. The span of available records varied among the gauges. The period of available records for Waskatenau Creek near Waskatenau (05EC002) spans from 1966 to 2022, with 14 years of missing data. For Wabash Creek near Pibroch (07BC007), the records range from 1979 to 2022, also with 14 years of missing annual instantaneous peak flow data. Finally, for Stony Creek near Tawatinaw (07BE004), the records range from 1982 to 2022, with 12 years of missing annual instantaneous peak flow data. Typically to complete a regional flood frequency analysis (RFFA) a minimum of 20 years of data is required.

The 2018 article “Snow Does Not Equal Flood: Alberta’s Snowmelt and Its Impact on Alberta Rivers,” published by the Government of Alberta, highlights that the province experiences two distinct snowmelt seasons due to its proximity to the Rocky Mountains. The plains and boreal regions accumulate snow from November to March, melting quickly in April, while the Rocky Mountains accumulate snow from October to early April, melting from mid-April to early June.

The Study Area and the three selected hydrometric gauges are all located within the prairies. As previously mentioned, the snowmelt in this region occurs in early April, coinciding with longer days and rising air temperatures, leading to potential overland flooding and high river levels. The instantaneous peak flow data for the selected hydrometric gauges generally align with the information presented in the Government of Alberta's article. Most of the annual instantaneous peak flows for two of the stations (05EC002 and 07BE004) occur in April. All three stations show annual instantaneous peaks mostly recorded in the spring (beginning in March and April) and summer months, with rare instances of peak flows recorded in months extending into October. This is illustrated in **Figure 4-1,** and tables showing the instantaneous annual peak flows for each station are found in **Appendix B**.

Figure 4-1: Peak Annual Instantaneous Discharge for Selected Hydrometric Stations



4.3 Regional Flood Frequency Analysis

Regional Flood Frequency Analysis (RFFA) is a method used in hydrology to estimate flood risks and characteristics across a specific geographic region. Unlike approaches that rely solely on local data, RFFA leverages historical flood data from multiple monitoring sites within a region. This technique describes regional watershed characteristics, especially in areas with limited local data, by drawing on extensive datasets from nearby stations.

The RFFA process begins with the collection of historical flood data from various hydrometric monitoring gauges. These gauges provide valuable long-term records of flood events, which are essential for a robust analysis. The Federal Hydrologic and Hydraulic Procedures for Flood Hazard Delineation (NRCan, 2019) identified several key assumptions that must be checked before a flood frequency analysis can be undertaken. That is, the data must be independent, homogeneous, and stationary. To do this Dillon used three different probability tests to assess the applicability of the data series:

- Wald-Wolfowitz Test of Independence: non-parametric statistical test that checks a randomness hypothesis for a two-valued data sequence. In other words, it can evaluate whether the elements of a sequence are occurring randomly and independently of each other;
- Kendall Stationarity Test: non-parametric statistical test is used to detect any prominent trends in time-series data. The main objective of Kendall's stationarity test is to evaluate whether the variability of the time-series data remains constant over time; and
- Wilcoxon Homogeneity Test (at annual scale): non-parametric statistical test that compares two related samples to assess whether their population mean ranks differ. It is a paired difference test and an alternative to the paired student's t-test when the population cannot be assumed to be normally distributed.

For ease of interpretation, p-values (or probability values) can range from 0 to 1, values close to 0 would indicate a significant result whereas, values close to 1 would signify a result that is very unlikely to be significant. The current analysis uses the 5% threshold to assess statistically significant; therefore, if a p-value falls below 0.05 it would be identified as significant, whereas values greater than 0.05 would not be statistically significant. The result of the probability tests for the instantaneous annual data is presented in **Table 4-2.**

Table 4-2: Probability Test Results of Chosen Gauge Stations

Dataset	Wald-Wolfowitz p-value	Kendall p-value	Wilcoxon p-value
Stony Creek Near Taxational	0.537	0.113	0.161
Waskatenau Creek Near Waskatenau	0.105	*0.015*	0.440
Wabash Creek Near Pibroch	0.930	0.950	0.435

Based on the probability tests, the gauge data located at Waskatenau Creek Near Waskatenau was flagged during the Kendall test, indicating that this data set does not meet the stationarity criteria. This likely means that there are changes in either the climate or watershed that are resulting in a shift in flow characteristics over the 54 years of data (38 of those years are usable). The test was re-assessed using the 30 most recent years of flow data and the resulting p-value is 0.432. For the remainder of the RFFA, only these years of data will be considered for this station.

The following extreme value statistical probability distributions were assessed for goodness-of-fit using the HYFRAN-Plus software package at each of the selected hydrometric gauges:

- Weibull;
- Log-Pearson Type III;
- Pearson Type III;
- Lognormal; and
- Normal.

Distributional parameter estimates were derived using the method of maximum likelihood (ML) where possible, and the method of moments where ML estimates could not be attained. Comparative goodness-of-fit was initially assessed using probability paper plots of the statistical distributions. Those displaying an adequate fit, particularly in the upper tail (where the fit of extreme value distribution is most critical when considering low frequency, high magnitude events), were further assessed using the minimum Akaike Information Criterion (AIC). The AIC is a measure of model fit that also addresses the potential overfitting of a prospective statistical model.

Based on tail behaviour and minimum AIC:

- Pearson Type III distribution was identified as the best fitting for the Waskatenau Creek Near Waskatenau (05EC002) gauge; and
- Weibull distribution was selected as the best fitting for the Wabash Creek Near Pibroch (07BC007) and Stony Creek Near Tawatinaw (07BE004) gauges.

The best fit distribution plots are included in **Appendix B**. The results of the frequency analysis of the peak annual instantaneous data for each station, covering a range of return period events, are provided in **Table 4-3**. These include the 25-year, 100-year, and 200-year peak flood estimates.

Table 4-3: Peak Annual Instantaneous Discharge by Return Period for the Selected Hydrometric Gauges

Station Name	Station ID	Drainage Area (km^2)	Probability Distribution	Return Period (Year)	Peak Annual Instantaneous Discharge (m^3/s)	Standard Deviation (m^3/s)
Stony Creek Near Taxational	07BE004	128	Weibull	200	18.8	4.06
				100	16.9	3.44
				25	12.7	2.27
Waskatenau Creek Near Waskatenau	05EC002	313	Weibull	200	40.2	6.89
				100	33.6	5.82
				25	21.2	3.97
Wabash Creek Near Pibroch	07BC007	344	Pearson Type III	200	56.8	14.10
				100	49.8	11.80
				25	35.7	7.39

An RFFA was conducted to assess flows for the three selected hydrometric gauges. The aim was to develop peak flows for the 25-year, 100-year, and 200-year return periods, corresponding to the drainage area associated with the Study Area. The analysis employed a logarithmic regression model to estimate peak flow values based on drainage area. This model involved:

1. Applying a natural logarithm transformation to both the historical peak flow values and their corresponding drainage areas.
2. Calculating the slope and intercept of the best-fit line through the transformed data points for each return period.

The resulting R^2 values for each station are shown in **Figure 4-2.** The regression analysis results and the calculated peak flows for the Study Area, with a new drainage area input of 191 km² as discussed in **Section 4.2**, are presented in **Table 4-4.** This method provided peak flow estimates for the 25-year, 100-year, and 200-year return periods tailored to the Study Area.

Figure 4-2: Lines of Best Fit for Peak Flow vs. Drainage Area across 25-year, 100-year, and 200-year Return Periods

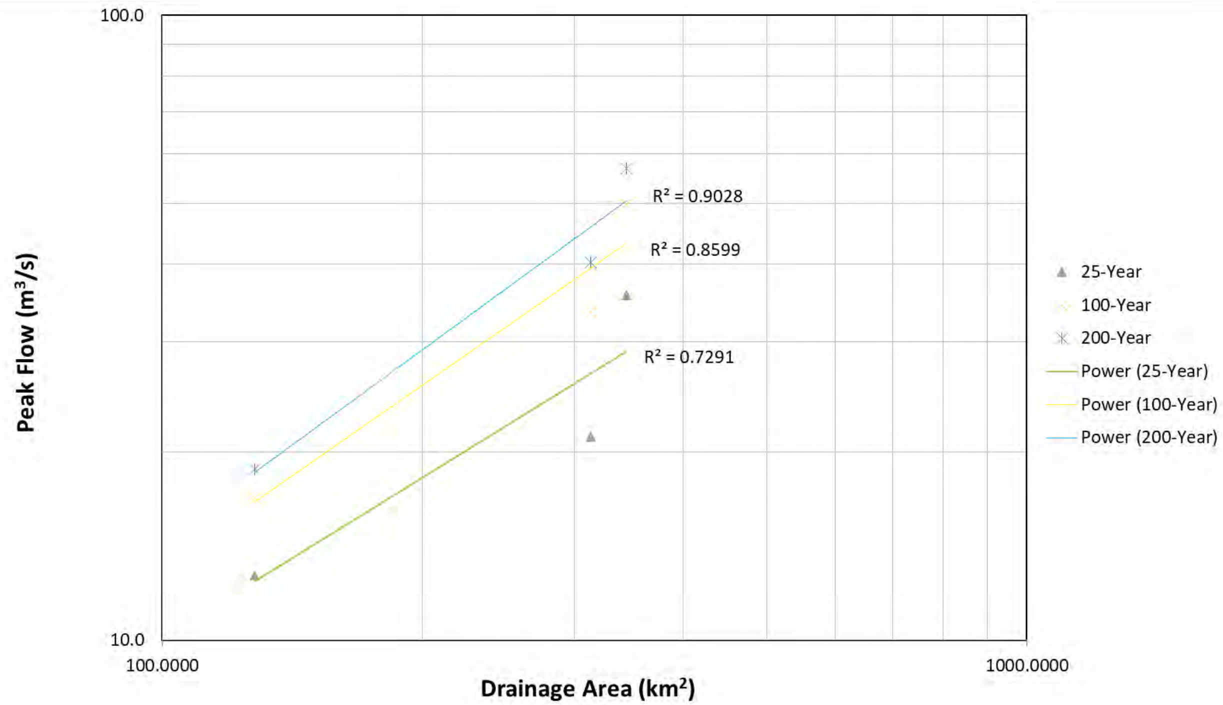


Table 4-4: Estimated Peak Flows for the 25-year, 100-year, and 200-year Return Periods for the Study Area (191 km2)

Return Period (year)	Peak Flow from RFFA (m^3/s)
25	17.50
100	24.47
200	27.82

4.4 Climate Change Considerations

Various sources were reviewed to gather information on climate change impacts in Alberta, including the article "The History of Climate in Alberta and Effects of Climate Change on Alberta's Watersheds" by the Alberta WaterPortal Society. The article notes significant climatic events over the last three decades, including massive floods and devastating droughts. For example, ten counties declared a state of emergency during the 2009-2010 drought, and floods occurred in 2005 and 2013. The June 2013 flood resulted from a combination of melted snowpack and several days of torrential rain, which led to extremely high river levels across Southern Alberta. Data from the selected hydrometric gauges introduced in **Section 4.2** and the annual instantaneous peak flow data for these gauges provided in **Appendix B** show low flows during drought years and higher flows during flood years.

For more localized impacts, the Climate Data Viewer by the Government of Canada was reviewed to examine climate change-induced increases in peak flow for the City of Fort Saskatchewan. **Table 4-5** illustrates the projected changes in total precipitation under the SSP5-8.5 emissions scenario, with detailed climate projections provided by the CMIP6 High-Resolution Future Climate Simulations Dataset (CanDCS-U6). This dataset features downscaled projections at a high resolution of 0.1 x 0.1 degrees (~6 x 10 km) for three Shared Socioeconomic Pathways (SSPs), representing different greenhouse gas emission scenarios:

- SSP1-2.6: Low emissions, with peak radiative forcing of 2.6 watts per square metre by 2100;
- SSP2-4.5: Moderate emissions, with peak radiative forcing of 4.5 W/m^2 by 2100; and
- SSP5-8.5: High emissions, with peak radiative forcing of 8.5 W/m^2 by 2100.

For this study, the project team adopted the SSP high emission scenario (SSP5-8.5) which represents the highest emissions condition, providing a conservative estimate of future climate impacts.

Table 4-5: Projected Year-Round Percentage Change in Total Precipitation for SSP5-8.5 Emissions Scenario by 2071-2100 with a Reference Period of 1971-2000

Season	Months	Projected Percentage Change in Precipitation (%)	Range (%)
Winter	December to February	+15.5	+5.2 to +24.3
Spring	March to May	+26.9	+13.7 to +45.9
Summer	June to August	-16.7	-65.2 to +27.5
Autumn	September to November	+9.7	+1.3 to +23.8

The effect of climate change on smaller-duration events was assessed using the IDF CC Tool developed and maintained by the University of Western Ontario. This tool was used to estimate future Intensity-Duration-Frequency (IDF) statistics and leverages the "Bias Corrected Ensemble" to generate robust future IDF relationships. A regional climate gauge at Elk Island Nat Park (ID: 3012275) was specifically assessed using the IDF CC Tool. Utilizing the SSP5-8.5 high emission scenario, the tool generated IDF curves to estimate the percent increase in rainfall for the 25-year and 100-year return periods. Calculations showed the percentage changes in total precipitation between historical IDF data and climate adjusted IDF data for the periods spanning from 2070 to 2100. The calculated rainfall increases for the 25-year and 100-year return periods are 12.25% and 13.81%, respectively, as shown in **Table 4-6**.

Table 4-6: IDF Data for 25-year and 100-year Return Periods at Elk Island National Park

Design Storm Length	25-year Rainfall Depth (mm)			100-year Rainfall Depth (mm)		
	Existing	Climate Change	Percent Increase	Existing	Climate Change	Percent Increase
6 hours	44.05	50.06	13.64 %	49.4	57.86	17.13 %
12 hours	57.5	64.46	12.10 %	68.95	78.1	13.27 %
24 hours	71.95	79.88	11.02 %	89.26	99.1	11.02 %
Average Increase	-	-	12.25 %	-	-	13.81 %

Given that most peak flows occur in April during the snow melt window, potentially exacerbated by rain events such as the 2013 event described above, the project team believes it is more appropriate to use the percent increase obtained from Climate Data Viewer. Over the winter period, an estimated increase in precipitation of 15.5 % is anticipated, rising to 26.9% in the spring. This increase in precipitation, both as winter snow buildup and spring storm events, will affect peak instantaneous flows within the study area. Therefore, an average peak increase in precipitation of 21.2 % can be expected. For conservatism, it has been assumed that most of the additional precipitation will convert proportionally to runoff, the peak flow rates are also anticipated to increase by 21.2%. The existing and climate-change-adjusted peak flow rates are presented in **Table 4-7.**

Table 4-7: Historical and Peak Flows Under Climate Change Considerations

Return Period	RFFA Peak Flow (m^3/s)	Estimated Climate Change Peak Flow (m^3/s) for 2070 to 2100
25-year	17.50	21.21
100-year	24.47	29.66
200-year	27.82	33.72

5.0 Hydraulic Assessment

The appropriate selection of hydraulic modelling tools for the study area is a key aspect of building a robust mathematical model. A primary consideration for the Study Area was the selection of a one- or two-dimensional (1-D or 2-D) simulation approach. Concerning the watershed associated with the drainage area, the size of the river network, the number of crossings, and limited bathymetric data, a 1-D hydraulic model was selected as the appropriate choice for this study.

HEC-RAS is a computer program designed to simulate steady and unsteady flow for a network of natural and constructed channels. The steady flow component uses the 1-D energy equation to calculate water surface profiles for steady gradually varied flow using subcritical, supercritical, and mixed flow regimes. The steady flow component calculates flow stages maintaining a constant peak discharge through the model. Energy losses are calculated using friction (Manning's equation) and contraction and expansion coefficients.

A total of 24 cross-sections were created along the study reach within the HEC-RAS model to capture the extent of flooding. These included sections added upstream and downstream of bridges and culverts. The cross-sectional data was primarily derived from LIDAR data, supplemented by field surveys, obtaining details such as inverts, channel geometry, and bridge/culvert opening sizes. Manning's n values were assumed based on ortho-imagery for the overbank values and based on Manning's n for natural watercourses.

Modelled structures including the three culverts and one bridge were configured in HEC-RAS based on details collected during the field survey. Expansion and contraction coefficients were assumed to be 0.1 and 0.3 in the open channel, and the bounding and upstream cross-sections near structures were assumed to be 0.3 and 0.5 unless the flow obstruction was abrupt.

As discussed in **Section 2.3**, the Government of Alberta's recent floodplain mapping of the North Saskatchewan River through Fort Saskatchewan and neighbouring municipalities indicates that the flow remains primarily within the river valley and does not extend upstream along Ross Creek to the Study Area. Therefore, any tailwater influences on the Study Area are negligible, and no boundary conditions representing tailwater effects were included in the model.

During the field visit, the team noted the presence of a beaver dam within the river, approximately 135 m downstream of the 109th Street crossing. A sensitivity analysis was completed to characterize the effect of the beaver dam on water levels surrounding the expansion areas. Obstructions were introduced at the cross-section closest to the beaver dam to estimate the potential impact, which resulted in a decrease in flow area within the low-flow channel. Given that the beaver dam is located near the upper portion of the Study Area, it had no notable effects on the model results. In the final models, the beaver dam was removed from the simulation as it is not a permanent structure within the watercourse.

Map 5 displays the Hydraulic Model Layout used in this study and HEC-RAS outputs, including water surface elevations at each cross section are presented in **Appendix C**. Outputs from the hydraulic model were imported into GIS software to create the flood inundation maps presented in **Section 6.0**.

6.0 Flood Inundation Mapping

Flood inundation maps are essential tools in flood risk management and planning. These maps delineate the calculated inundation areas during various flood scenarios, often based on statistical return periods (e.g., 25-year, 100-year, or 200-year events). These delineations provide visual insights into the spatial extent of floodwaters under different conditions, helping communities, planners, and policymakers understand the potential effect of flooding on infrastructure, properties, and lives. The flood inundation maps for this study are presented in **Map 6 to Map 11.**

The recommendations for cemetery expansion in each area, based on more conservative climate change projections (**Maps 9 to 11**), are summarized below. According to the legend, red areas indicate the 1 in 25-year inundation zone (4% annual chance) and are not suitable for development. Yellow and green areas represent the 1 in 100-year (1% annual chance) and 1 in 200-year (0.5% annual chance) inundation zones, respectively, and may be considered for development based on the City's risk tolerance.

Area 1:

- The areas surrounding Ross Creek that are currently covered by vegetation (trees) are not recommended for development, as per **Map 9**. All three return periods show inundation in these areas, with minimal discrepancy between the scenarios.
- Based on the inundation maps there is room for further development in most of Area 1, outside of Ross Creek's treed valley.

Area 2:

- As per **Map 10**, the majority of Area 2 is inundated by a 1 in 200-year event, with more than 50% of the area inundated by the 1 in 100-year event. Additionally, the western portion of Area 2 is inundated by a 1 in 25-year event.
- Based on the inundations maps the majority of Area 2 is not recommended for development. Additional work can be completed to floodproof this area (requiring additional studies and engineering design work) but under existing conditions, the majority of the site is undevelopable based on the project team's understanding of the City's risk tolerance.

Area 3:

- The inundation results for Area 3 are presented in **Map 11**. The majority of Area 3 remains outside of the inundation area, except for a low-lying portion of the northern half. In this northern area, floodwater overtop the banks of Ross Creek and inundate the northern portion of the proposed development area.
- Based on the project team's understanding of the City's risk tolerance the majority of Area 3 is suitable for development, except for the northern portion of the area and a small section in the southern portion of Area 3 along the treed valley.

6.1 Mapping Limitations

When developing flood inundation maps, it is important to note the application of the final mapping documents. For this project, it was identified that Regulatory Level floodplain maps were not required for the planning purposes of the cemetery expansion. Regulatory floodplain map preparation often includes detailed bathymetric/topographic data collection as well as a more thorough and rigorous hydrologic and hydraulic modelling exercise which includes flow/level data collection to support hydrologic and hydraulic model calibration and validation.

The maps within this document were produced to be used as a tool for planning and risk assessment of the proposed cemetery expansion areas. They should not be relied upon for official land-use planning or development of regulations or the design of infrastructure.

7.0 Conclusions

This report provides a flood inundation analysis for the proposed expansion of the Fort Saskatchewan Cemetery along Ross Creek, in line with the Fort Saskatchewan Cemetery Master Plan.

The project involved several key steps:

- A field visit to collect topographic data within Ross Creek;
- Reviews of relevant background documents; and
- Hydrologic and hydraulic analyses.

The Study Area, divided into three zones (Area 1, Area 2, and Area 3), was assessed under different return periods (25-year, 100-year, and 200-year) and climate change scenarios to generate peak flow estimates and flood inundation maps.

Based on conservative climate change projections, the recommendations for cemetery expansion in each area are as follows:

- **Area 1**: Development is not recommended in the vegetated areas around Ross Creek, as all climate change scenarios indicate inundation. Most of Area 1, excluding Ross Creek's treed valley, is suitable for development.
- **Area 2**: The majority of Area 2 is unsuitable for development due to significant inundation risks, with over 50% affected by a 1 in 100-year event and the western portion by a 1 in 25-year event. Floodproofing measures could be considered for this area but would require additional studies to confirm the feasibility.
- **Area 3**: Most of Area 3 is suitable for development, except for the low-lying northern portion and a small section in the southern part along the treed valley, which are prone to inundation.

These recommendations align with the City's risk tolerance and aim to ensure safe and sustainable cemetery expansion.

Maps

FORT SASKATCHEWAN 2024 CEMETERY EXPANSION

FLOOD RISK ASSESSMENT

STUDY AREAS

MAP 1

Study Areas
Watercourse (NHN)
Road

SCALE 1:3,500

0 40 80 160 m

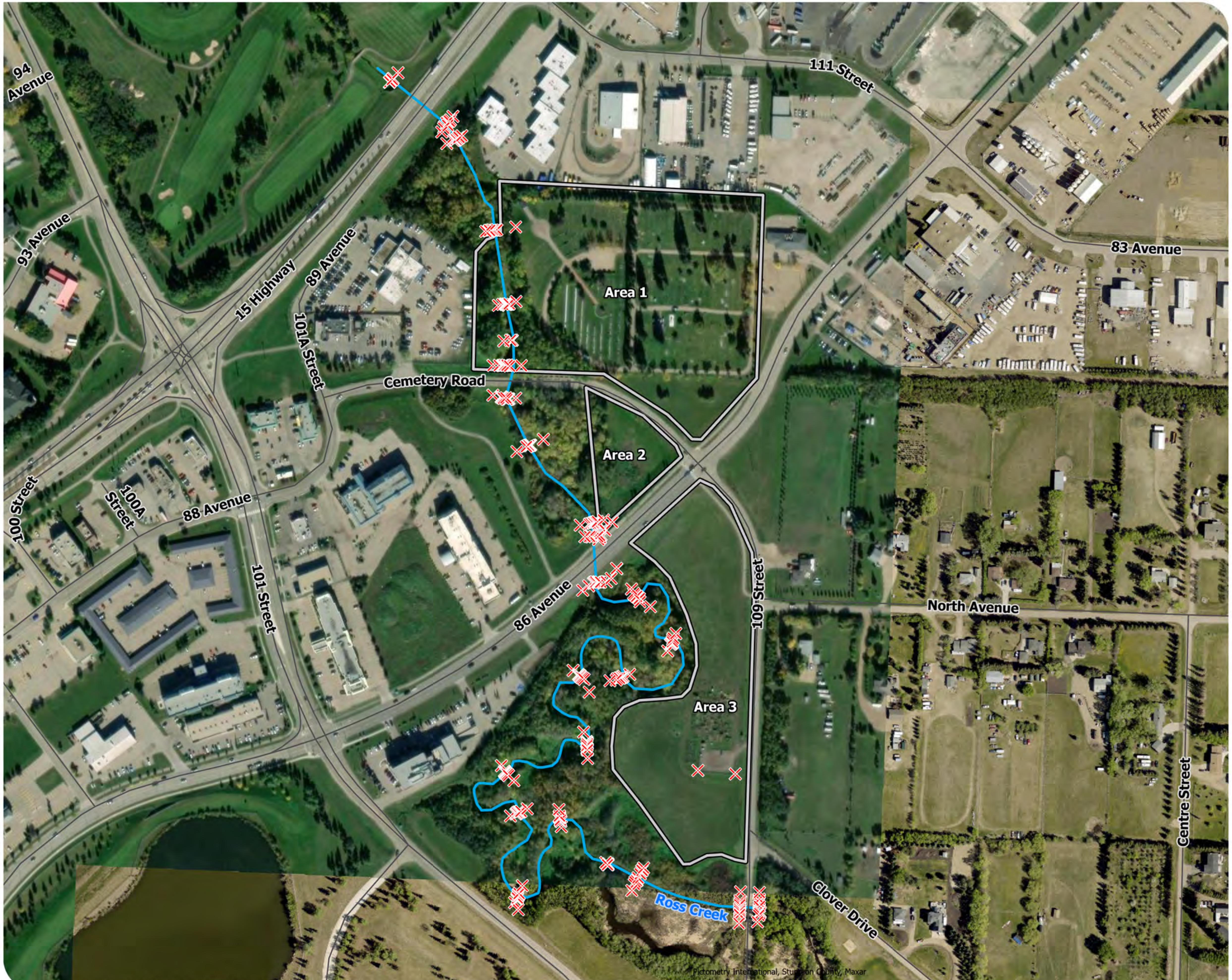
MAP DRAWING INFORMATION:
DATA PROVIDED BY NHN

MAP CREATED BY: LMM
MAP CHECKED BY: ATC
MAP PROJECTION: NAD 1983 UTM Zone 12N

DILLON CONSULTING

PROJECT: 24-8102
STATUS: FINAL
DATE: 2024-09-25

FILE LOCATION: K:\2024\248102\Product\Client\FloodRiskAssessment\FloodRiskAssessmentMapping.aprx; LAYOUT: 248102_F1-1_StudyArea



FORT SASKATCHEWAN 2024 CEMETERY EXPANSION

FLOOD RISK ASSESSMENT

DATA COLLECTION

MAP 2

- Survey Point
- Study Areas
- Ross Creek Centerline
- Road

SCALE 1:3,500

0 40 80 160 m

N E S W

MAP DRAWING INFORMATION:
DATA PROVIDED BY NHN

MAP CREATED BY: LMM
MAP CHECKED BY: ATC
MAP PROJECTION: NAD 1983 UTM Zone 12N

DILLON CONSULTING

PROJECT: 24-8102
STATUS: FINAL
DATE: 2024-09-25

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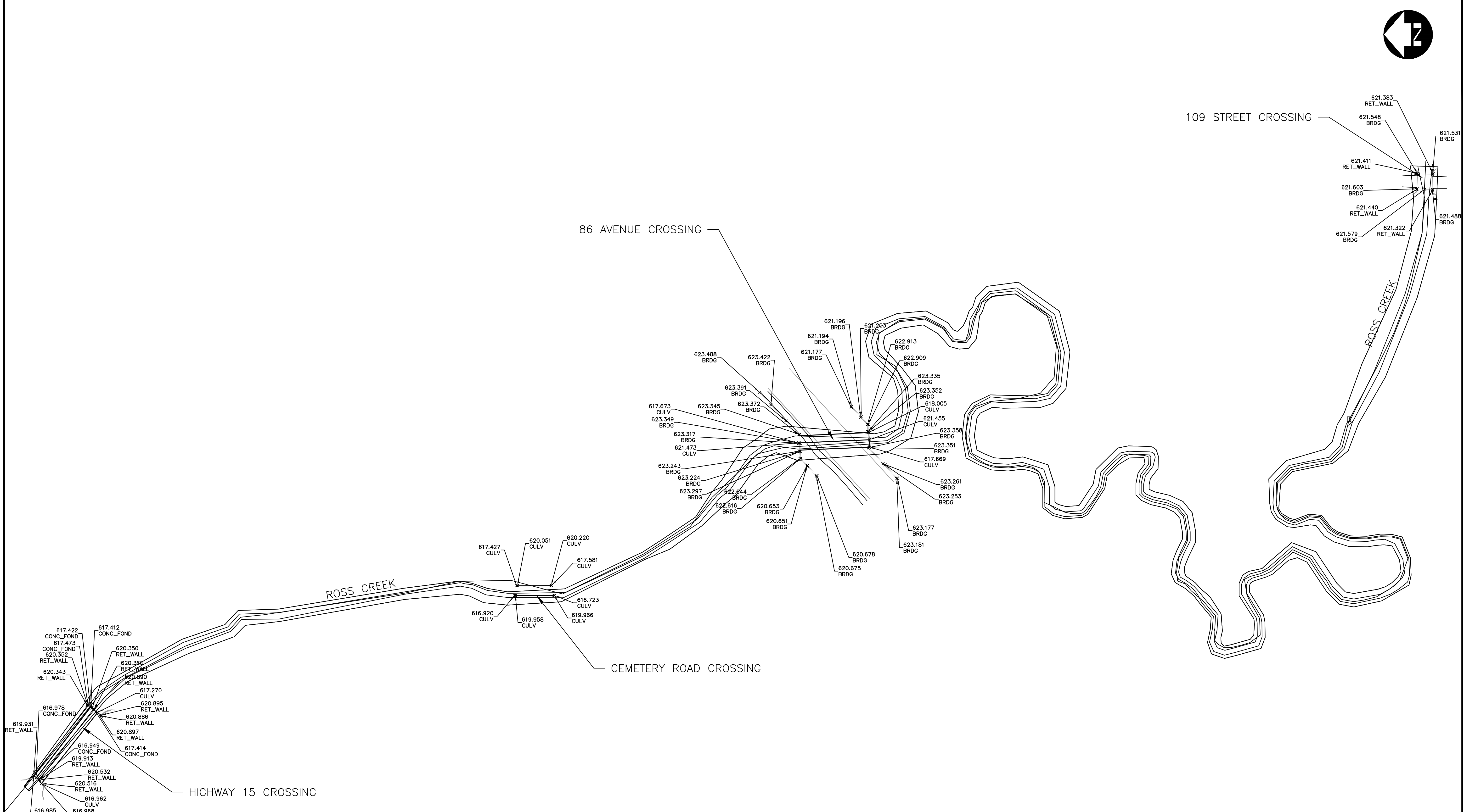
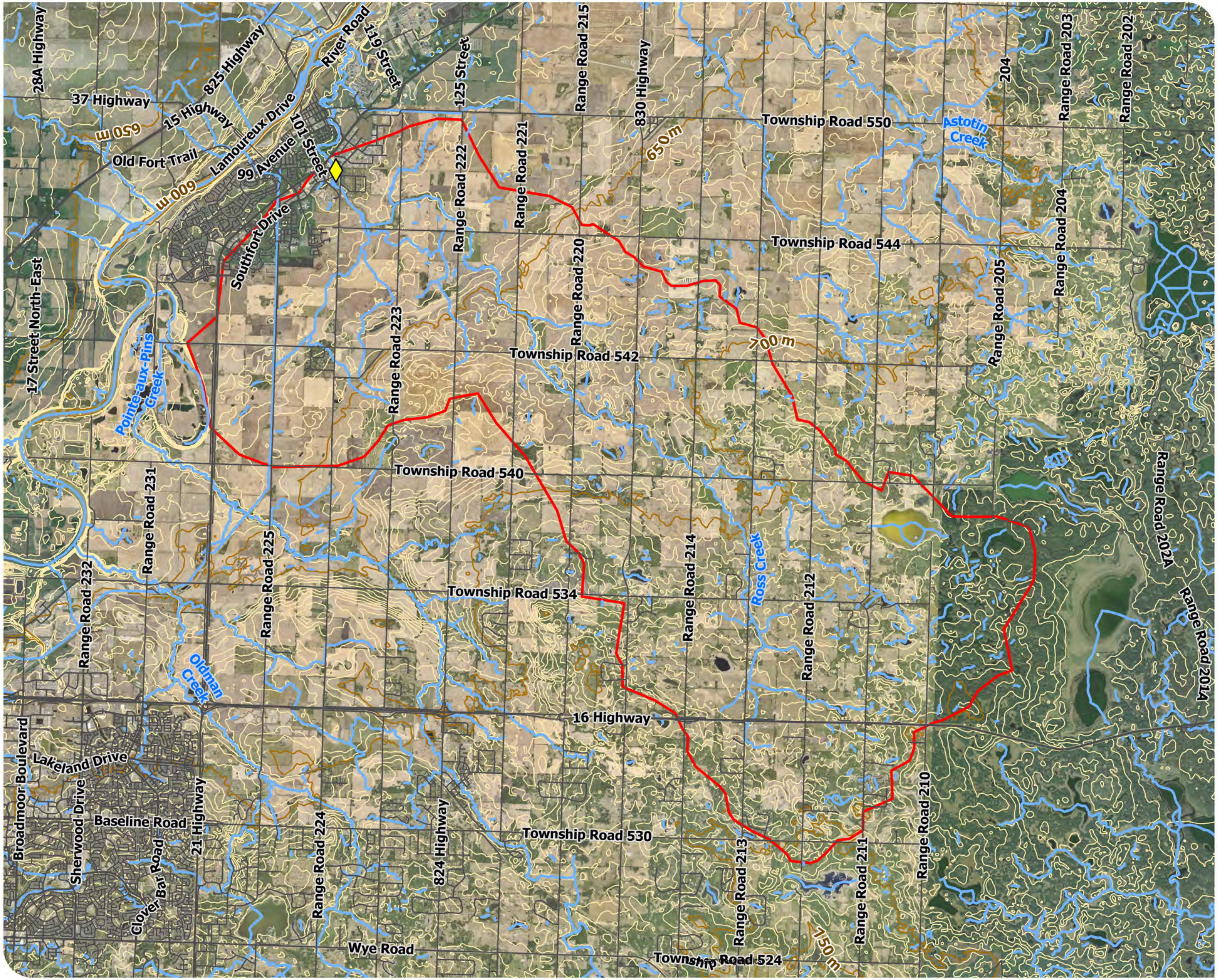


DILLON CONSULTING

PROJECT	FORT SASKATCHEWAN 2024 CEMETERY FLOOD RISK STUDY	PROJECT NO. 248102
DATE August 2024	TITLE SURVEY DETAILS OF ROSS CREEK AND HYDRAULIC STRUCTURES	FIGURE NO. MAP 3

FileName: c:\pw working directory\projects 2024\dillon_34\wdms34652\248102-03-drn-fig.dwg



FORT SASKATCHEWAN 2024 CEMETERY EXPANSION

FLOOD RISK ASSESSMENT

ROSS CREEK WATERSHED AREA

MAP 4

- Study Areas Location
- Ross Creek Watershed
- Road
- Watercourse (NHN)
- Major Contour (50 m)
- Minor Contour (10 m)

SCALE 1:100,000

0 1 2 4 km

MAP DRAWING INFORMATION:
DATA PROVIDED BY NHN

MAP CREATED BY: LMM
MAP CHECKED BY: -
MAP PROJECTION: NAD 1983 UTM Zone 12N

DILLON CONSULTING

PROJECT: 24-8102
STATUS: FINAL
DATE: 2024-09-25

FILE LOCATION: K:\2024\248102\Product\Client\FloodRiskAssessment\FloodRiskAssessmentMapping.aprx; LAYOUT: 248102_F4-1_RossCreekWatershedArea

FORT SASKATCHEWAN 2024 CEMETERY EXPANSION

FLOOD RISK ASSESSMENT

ROSS CREEK HEC-RAS MODEL LAYOUT

MAP 5

- Cross Section
- Study Areas
- Ross Creek Centerline
- Road

SCALE 1:6,500

0 80 160 320 m

MAP DRAWING INFORMATION:
DATA PROVIDED BY NHN

MAP CREATED BY: LMM
MAP CHECKED BY: ATC
MAP PROJECTION: NAD 1983 UTM Zone 12N

DILLON CONSULTING

PROJECT: 24-8102
STATUS: FINAL
DATE: 2024-09-25

FILE LOCATION: K:\2024\248102\Product\Client\FloodRiskAssessment\FloodRiskAssessmentMapping.aprx; LAYOUT: 248102_F5-1_RossCreekHECRAS

FORT SASKATCHEWAN 2024 CEMETERY EXPANSION

FLOOD RISK ASSESSMENT

AREA 1 YEAR INUNDATION AREAS

MAP 6

- Cross Section
- 1 in 200 Year Inundation Area
- 1 in 100 Year Inundation Area
- 1 in 25 Year Inundation Area
- Study Areas
- Ross Creek Centerline
- Road

SCALE 1:1,000

0 12.5 25 50 m

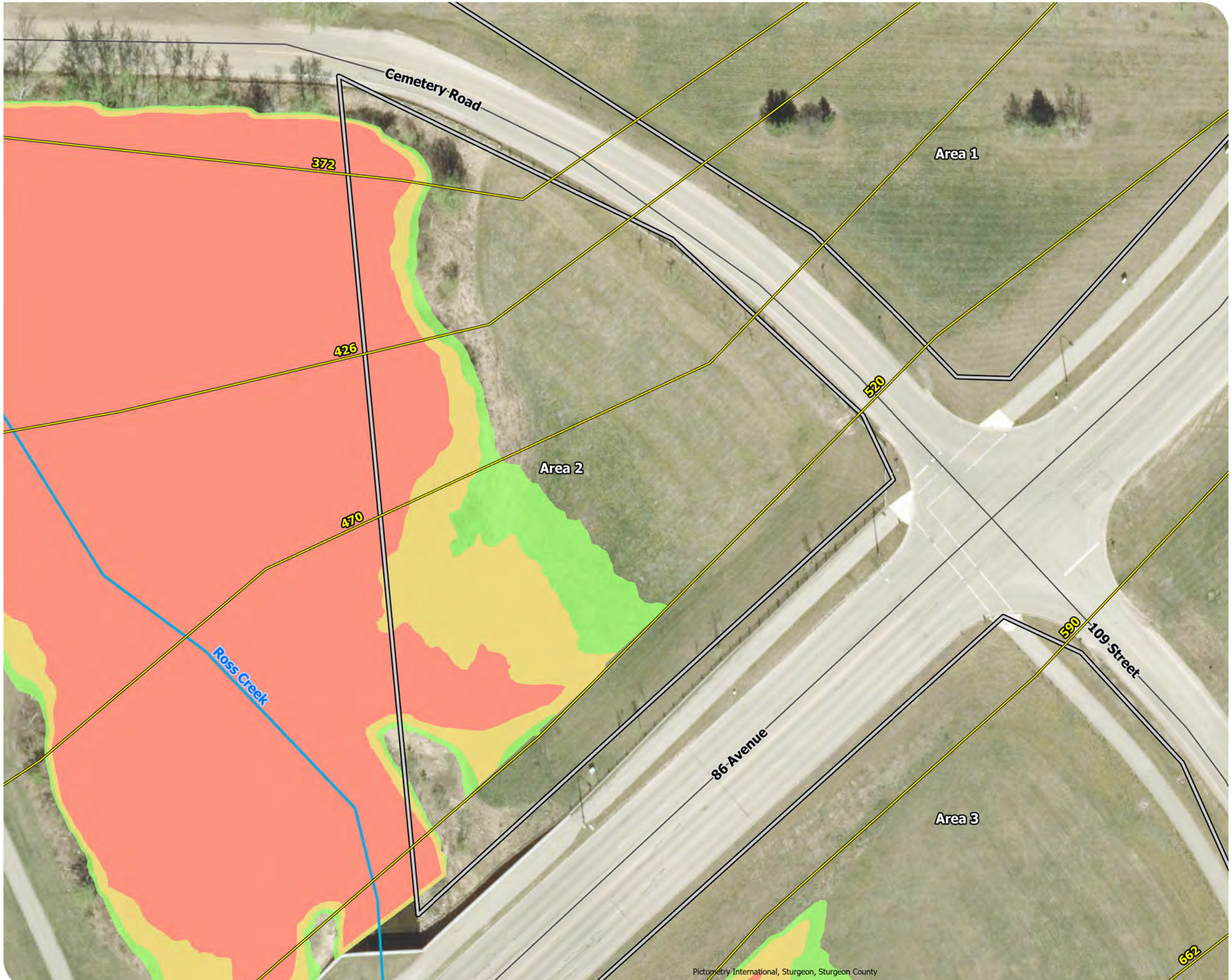
MAP DRAWING INFORMATION:
DATA PROVIDED BY NHN

MAP CREATED BY: LMM
MAP CHECKED BY: ATC
MAP PROJECTION: NAD 1983 UTM Zone 12N

DILLON CONSULTING

PROJECT: 24-8102
STATUS: FINAL
DATE: 2024-09-25

FILE LOCATION: K:\2024\248102\Product\Client\FloodRiskAssessment\FloodRiskAssessmentMapping.aprx; LAYOUT: 248102_F6-1_A1YearInundationArea



FORT SASKATCHEWAN 2024 CEMETERY EXPANSION

FLOOD RISK ASSESSMENT

AREA 2 YEAR INUNDATION AREAS

MAP 7

- Cross Section
- 1 in 25 Year Inundation Area
- 1 in 100 Year Inundation Area
- 1 in 200 Year Inundation Area
- Study Areas
- Ross Creek Centerline
- Road

SCALE 1:600

0 5 10 20 m

N
W E
S

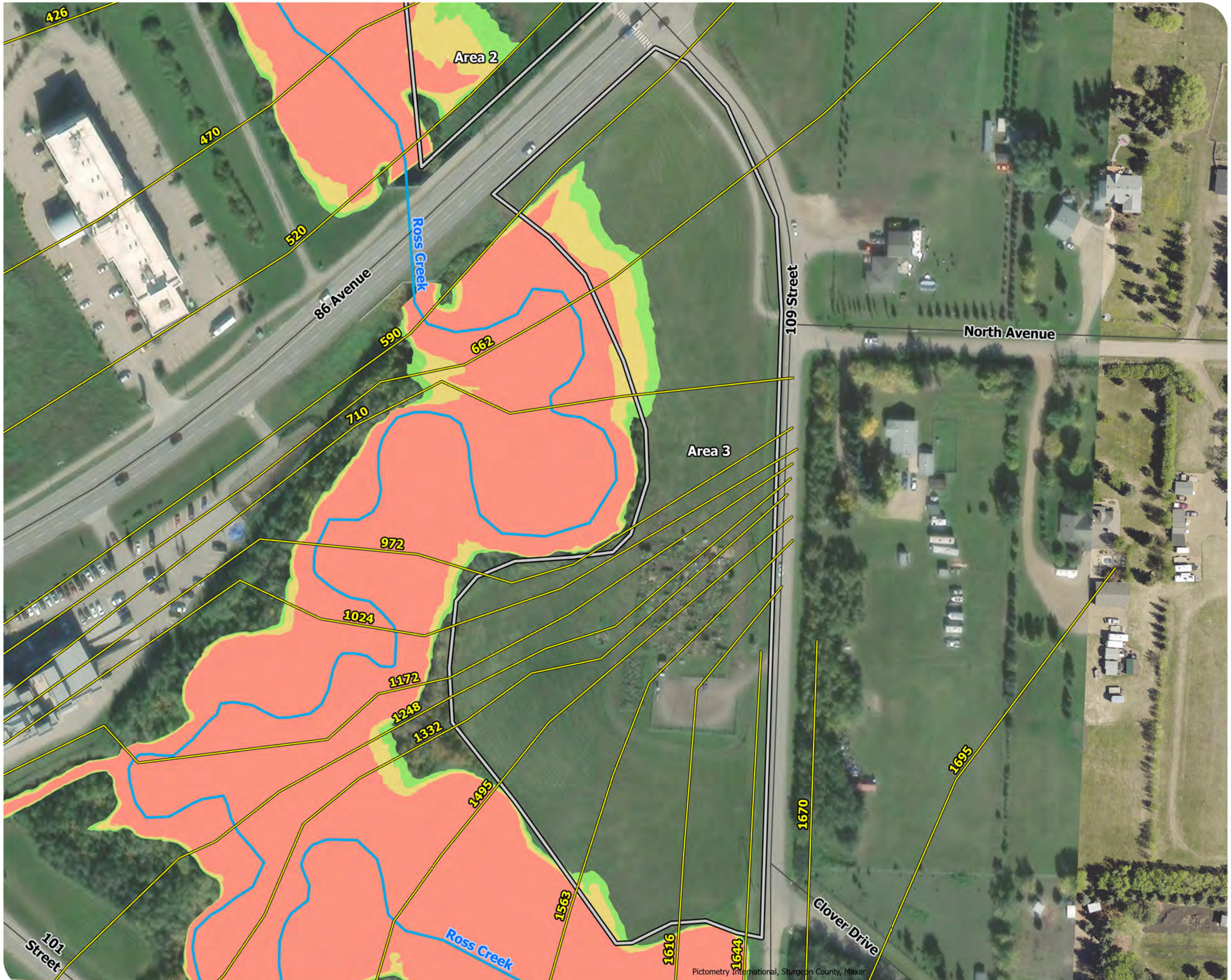
MAP DRAWING INFORMATION:
DATA PROVIDED BY NHN

MAP CREATED BY: LMM
MAP CHECKED BY: ATC
MAP PROJECTION: NAD 1983 UTM Zone 12N

DILLON CONSULTING

PROJECT: 24-8102
STATUS: FINAL
DATE: 2024-09-25

FILE LOCATION: K:\2024\248102\Product\Client\FloodRiskAssessment\FloodRiskAssessmentMapping.aprx; LAYOUT: 248102_F6-2_A2YearInundationArea



FORT SASKATCHEWAN 2024 CEMETERY EXPANSION

FLOOD RISK ASSESSMENT

AREA 3 YEAR INUNDATION AREAS

MAP 8

Cross Section
1 in 200 Year Inundation Area
1 in 100 Year Inundation Area
1 in 25 Year Inundation Area
Study Areas
Ross Creek Centerline
Road

SCALE 1:1,500

0 15 30 60 m

N W E S

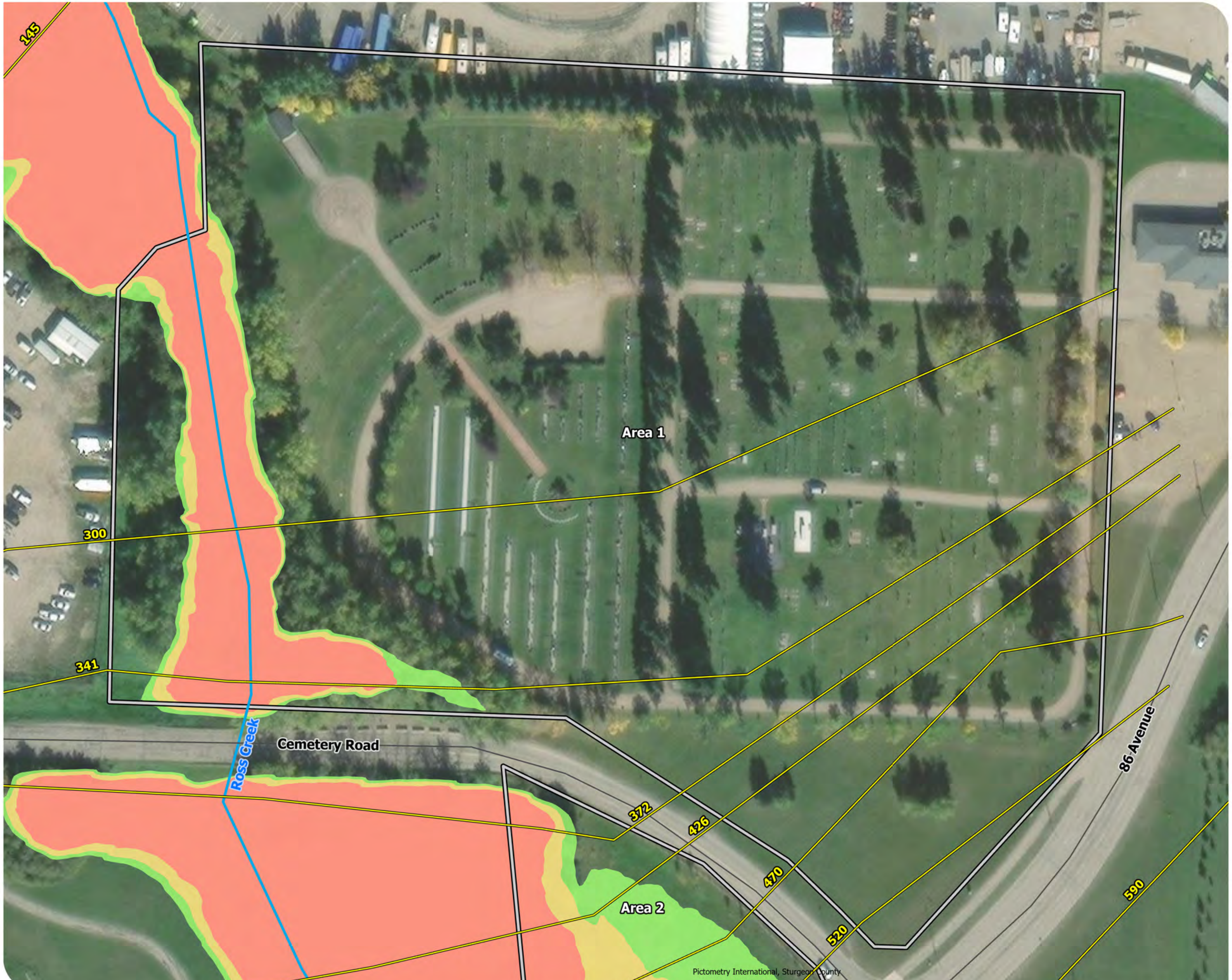
MAP DRAWING INFORMATION:
DATA PROVIDED BY NHN

MAP CREATED BY: LMM
MAP CHECKED BY: ATC
MAP PROJECTION: NAD 1983 UTM Zone 12N

DILLON CONSULTING

PROJECT: 24-8102
STATUS: FINAL
DATE: 2024-09-25

FILE LOCATION: K:\2024\248102\Product\Client\FloodRiskAssessment\FloodRiskAssessmentMapping.aprx; LAYOUT: 248102_F6-3_A3YearInundationArea



FORT SASKATCHEWAN 2024 CEMETERY EXPANSION

FLOOD RISK ASSESSMENT

AREA 1 YEAR INUNDATION AREAS CLIMATE CHANGE

MAP 9

- Cross Section
- 1 in 100 Year Inundation Area Climate Change
- 1 in 25 Year Inundation Area Climate Change
- 1 in 200 Year Inundation Area Climate Change
- Study Areas
- Road
- Ross Creek Centerline

SCALE 1:1,000

0 12.5 25 50 m

N E S W

MAP DRAWING INFORMATION:
DATA PROVIDED BY NHN

MAP CREATED BY: LMM
MAP CHECKED BY: ATC
MAP PROJECTION: NAD 1983 UTM Zone 12N

DILLON CONSULTING

PROJECT: 24-8102
STATUS: FINAL
DATE: 2024-09-25

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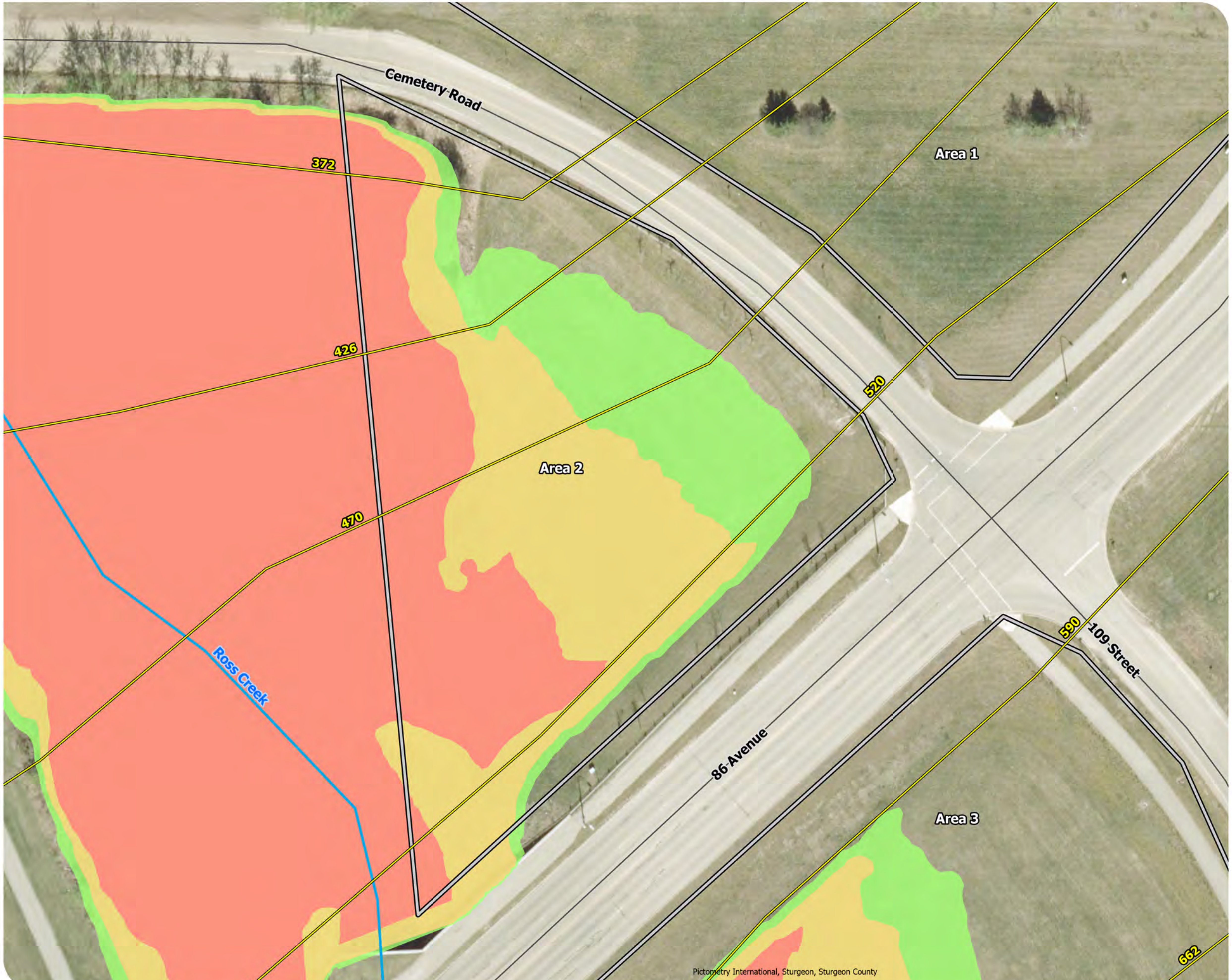


FORT SASKATCHEWAN 2024 CEMETERY EXPANSION

FLOOD RISK ASSESSMENT

AREA 2 YEAR INUNDATION AREAS CLIMATE CHANGE

MAP 10

- Cross Section
- 1 in 200 Year Inundation Area Climate Change
- 1 in 100 Year Inundation Area Climate Change
- 1 in 25 Year Inundation Area Climate Change
- Study Areas
- Road
- Ross Creek Centerline

SCALE 1:600

0 5 10 20 m

MAP DRAWING INFORMATION:
DATA PROVIDED BY NHN

MAP CREATED BY: LMM
MAP CHECKED BY: ATC
MAP PROJECTION: NAD 1983 UTM Zone 12N

DILLON CONSULTING

PROJECT: 24-8102
STATUS: FINAL
DATE: 2024-09-25

FILE LOCATION: K:\2024\248102\Product\Client\FloodRiskAssessment\FloodRiskAssessmentMapping.aprx; LAYOUT: 248102_F6-5_A2YearInundationAreaCC

FORT SASKATCHEWAN 2024 CEMETERY EXPANSION

FLOOD RISK ASSESSMENT

AREA 3 YEAR INUNDATION AREAS CLIMATE CHANGE

MAP 11

- Cross Section
- 1 in 200 Year Inundation Area Climate Change
- 1 in 25 Year Inundation Area Climate Change
- 1 in 100 Year Inundation Area Climate Change
- Study Areas
- Road
- Ross Creek Centerline

SCALE 1:1,500

0 15 30 60 m

N W E S

MAP DRAWING INFORMATION:
DATA PROVIDED BY NHN

MAP CREATED BY: LMM
MAP CHECKED BY: ATC
MAP PROJECTION: NAD 1983 UTM Zone 12N

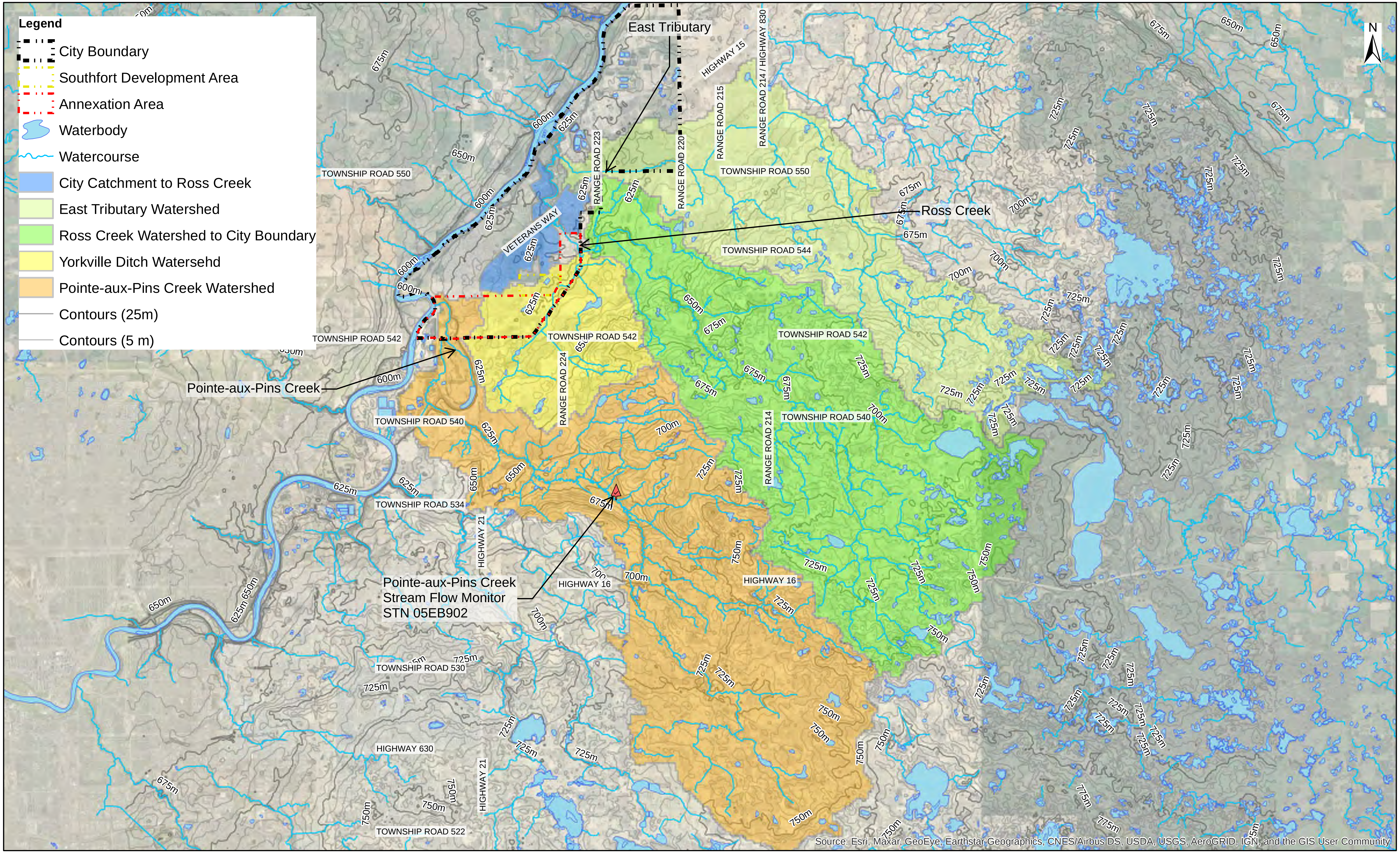
DILLON CONSULTING

PROJECT: 24-8102
STATUS: FINAL
DATE: 2024-09-25

FILE LOCATION: K:\2024\248102\Product\Client\FloodRiskAssessment\FloodRiskAssessmentMapping.aprx; LAYOUT: 248102_F6-6_A3YearInundationAreaCC

Appendix A

Background Documents



ISL Engineering and Land Services

City of Fort Saskatchewan Alberta

FORT SASKATCHEWAN ANNEXATION AREA SERVICING DESIGN BRIEF

Watershed Plan of Local Creek Systems

FIGURE 5.2

1:135,000

0 750 1,500 3,000 4,500 6,000 Meters

Coordinate System: NAD 1983 CSRS 3TM 114
Projection: Transverse Mercator
Datum: North American 1983 CSRS

86 Avenue Culvert

88 Avenue Culvert

89 Avenue Culvert

109 Street Bridge

Beaver Dam


Jun 7, 2024 9:30:29 a.m.
53.69716639N 113.19904067W
66° NE
109 Street
Fort Saskatchewan
Alberta
Job Nr.42705
Ross Creek


Jun 7, 2024 9:30:15 a.m.
53.69718915N 113.19896W
63° NE
109 Street
Fort Saskatchewan
Alberta
Job Nr.42705
Ross Creek

Appendix B

Annual Instantaneous Peak Flow Data & Probability Distributions

Table B 1: Annual Instantaneous Peak Flow for Station 05EC002

Year	Annual Instantaneous Peak Flow (m^3/s) for Station 05EC002
1969	6.740
1970	4.760
1971	45.300
1972	25.800
1973	3.140
1974	34.000
1975	3.060
1976	3.540
1977	5.830
1978	8.010
1979	24.800
1981	16.000
1982	2.580
1983	1.690
1984	1.700
1985	2.740
1991	0.335
1994	6.480
1995	1.510
1996	7.510
1997	25.800
1998	0.940
1999	0.698
2000	1.070
2001	0.198
2002	1.110
2003	0.704
2004	1.860
2005	2.820
2006	0.512
2007	9.320
2008	0.804
2009	1.380
2011	0.683
2013	3.110
2017	2.690
2018	15.200
2020	15.400
1969	6.740

Table B 2: Annual Instantaneous Peak Flow for Station 07BC007

Year	Annual Instantaneous Peak Flow (m^3/s) for Station 07BC007
1980	4.370
1981	12.500
1982	35.300
1983	5.630
1985	22.400
1987	9.960
1988	4.900
1994	11.100
1995	1.800
1996	23.100
1997	46.300
2000	0.484
2001	0.168
2002	3.460
2003	14.900
2004	8.940
2005	9.550
2007	13.000
2008	2.080
2009	6.190
2010	2.780
2011	8.330
2012	4.180
2013	17.600
2016	11.100
2017	8.730
2020	27.500

Table B 3: Annual Instantaneous Peak Flow for Station 07BE004

Year	Annual Instantaneous Peak Flow (m^3/s) for Station 07BE004
1982	3.130
1983	1.210
1984	1.860
1985	2.730
1986	7.730
1987	2.300

Year	Annual Instantaneous Peak Flow (m^3/s) for Station 07BE004
1989	5.420
1990	4.860
1991	2.250
1992	0.531
1995	8.310
1996	5.140
1997	12.600
1998	0.676
2000	0.454
2001	0.367
2004	3.490
2005	4.150
2007	9.220
2008	3.870
2010	0.093
2011	3.350
2013	7.250
2014	3.420
2017	3.770
2019	8.590
2020	15.300

Figure B 1: Best Fit Probability Distribution Plot for Station 05EC002 (Pearson Type III)

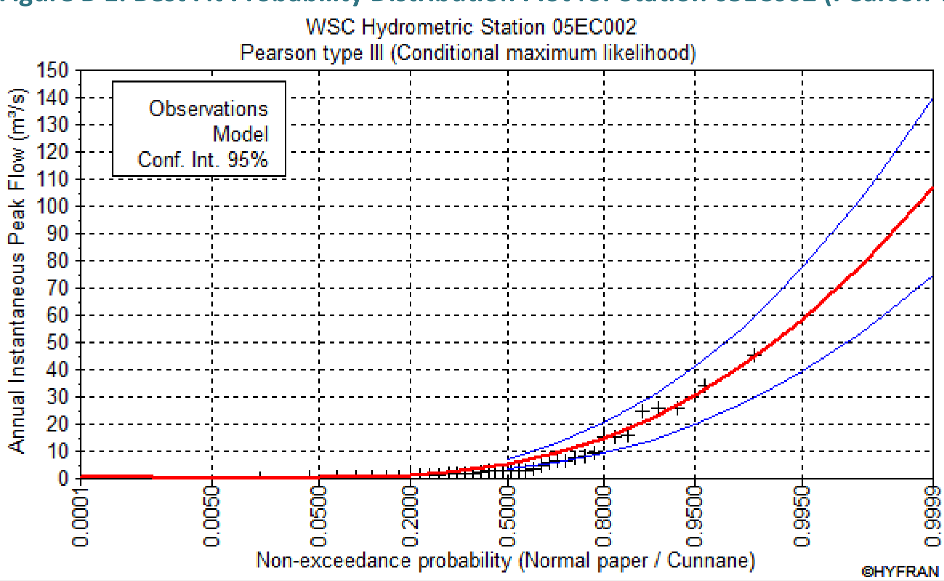


Figure B 2: Best Fit Probability Distribution Plot for Station 07BC007 (Weibull)

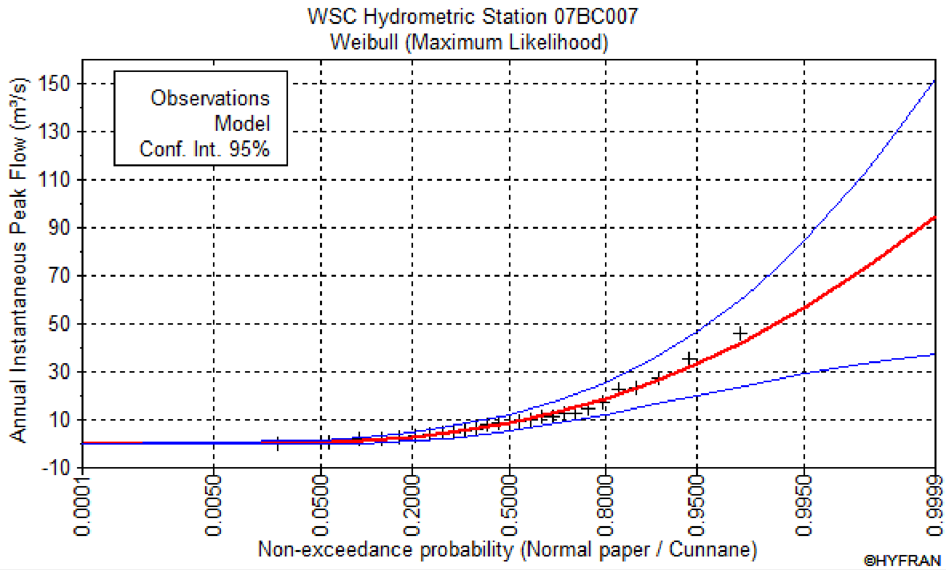
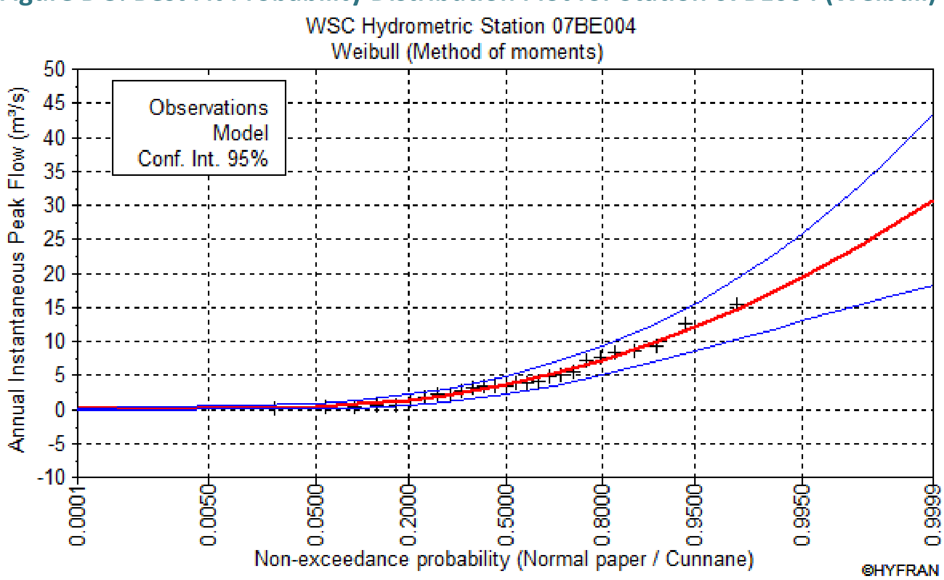


Figure B 3: Best Fit Probability Distribution Plot for Station 07BE004 (Weibull)



Appendix C

HEC RAS Outputs

HEC-RAS Plan: Existing River: RossCreek Reach: Reach 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Reach 1	1695	25YR	17.50	618.91	620.66	620.13	620.69	0.001055	0.80	46.21	78.79	0.28
Reach 1	1695	100YR	24.47	618.91	621.07	620.26	621.09	0.000491	0.70	78.70	83.16	0.21
Reach 1	1695	200YR	27.82	618.91	621.15	620.30	621.17	0.000507	0.75	85.27	84.21	0.21
Reach 1	1695	25YR - CC	21.21	618.91	620.82	620.18	620.85	0.000833	0.79	58.77	80.04	0.26
Reach 1	1695	100YR - CC	29.66	618.91	621.28	620.31	621.29	0.000331	0.64	137.96	142.71	0.17
Reach 1	1695	200YR - CC	33.72	618.91	621.59	620.40	621.60	0.000197	0.57	183.07	144.15	0.14
Reach 1	1670	25YR	17.50	618.75	620.60	619.81	620.66	0.001203	1.01	17.32	123.14	0.31
Reach 1	1670	100YR	24.47	618.75	621.01	620.01	621.06	0.000810	1.03	24.13	141.09	0.27
Reach 1	1670	200YR	27.82	618.75	621.08	620.15	621.14	0.000901	1.12	25.32	143.90	0.29
Reach 1	1670	25YR - CC	21.21	618.75	620.75	619.92	620.81	0.001140	1.07	19.81	128.19	0.31
Reach 1	1670	100YR - CC	29.66	618.75	621.20	620.20	621.27	0.000785	1.10	27.61	148.48	0.27
Reach 1	1670	200YR - CC	33.72	618.75	621.53	620.28	621.58	0.000565	1.05	37.05	171.22	0.24
Reach 1	1650		Bridge									
Reach 1	1644	25YR	17.50	618.64	620.51	619.81	620.58	0.001477	1.11	15.91	97.23	0.38
Reach 1	1644	100YR	24.47	618.64	620.73	620.00	620.81	0.001583	1.24	20.27	154.37	0.39
Reach 1	1644	200YR	27.82	618.64	620.86	620.08	620.94	0.001467	1.25	23.03	155.98	0.37
Reach 1	1644	25YR - CC	21.21	618.64	620.64	619.92	620.71	0.001489	1.17	18.55	151.11	0.38
Reach 1	1644	100YR - CC	29.66	618.64	620.95	620.13	621.03	0.001365	1.24	24.82	156.89	0.35
Reach 1	1644	200YR - CC	33.72	618.64	621.17	620.24	621.25	0.001110	1.19	29.39	159.33	0.31
Reach 1	1616	25YR	17.50	618.50	620.50	619.66	620.53	0.000712	0.87	54.61	95.92	0.25
Reach 1	1616	100YR	24.47	618.50	620.72	619.87	620.76	0.000706	0.96	75.75	97.33	0.25
Reach 1	1616	200YR	27.82	618.50	620.86	619.96	620.89	0.000626	0.96	89.34	98.06	0.24
Reach 1	1616	25YR - CC	21.21	618.50	620.63	619.78	620.67	0.000682	0.91	67.43	96.87	0.25
Reach 1	1616	100YR - CC	29.66	618.50	620.95	620.00	620.98	0.000568	0.95	98.21	98.50	0.23
Reach 1	1616	200YR - CC	33.72	618.50	621.18	620.10	621.21	0.000439	0.90	120.84	99.67	0.21
Reach 1	1563	25YR	17.50	618.16	620.48	619.38	620.49	0.000723	0.55	75.18	102.99	0.15
Reach 1	1563	100YR	24.47	618.16	620.70	619.58	620.71	0.000734	0.61	98.40	107.81	0.15
Reach 1	1563	200YR	27.82	618.16	620.84	619.67	620.85	0.000647	0.61	114.16	111.85	0.15
Reach 1	1563	25YR - CC	21.21	618.16	620.61	619.49	620.62	0.000704	0.58	89.28	105.57	0.15
Reach 1	1563	100YR - CC	29.66	618.16	620.93	619.71	620.94	0.000581	0.60	124.64	113.61	0.14
Reach 1	1563	200YR - CC	33.72	618.16	621.17	619.83	621.18	0.000434	0.56	151.84	118.62	0.12
Reach 1	1495	25YR	17.50	618.15	620.37	619.50	620.42	0.001067	1.02	27.37	46.94	0.31
Reach 1	1495	100YR	24.47	618.15	620.62	619.76	620.66	0.000825	0.96	69.73	91.08	0.26
Reach 1	1495	200YR	27.82	618.15	620.77	619.88	620.80	0.000722	0.93	83.76	92.36	0.24
Reach 1	1495	25YR - CC	21.21	618.15	620.50	619.64	620.56	0.001128	1.09	33.53	48.77	0.31
Reach 1	1495	100YR - CC	29.66	618.15	620.87	619.95	620.90	0.000649	0.91	93.03	93.39	0.23
Reach 1	1495	200YR - CC	33.72	618.15	621.12	620.07	621.15	0.000491	0.84	116.61	95.95	0.20
Reach 1	1332	25YR	17.50	618.01	620.22	619.54	620.26	0.001062	0.91	47.88	119.94	0.29
Reach 1	1332	100YR	24.47	618.01	620.52	619.72	620.55	0.000689	0.87	84.78	126.87	0.24
Reach 1	1332	200YR	27.82	618.01	620.69	619.84	620.72	0.000525	0.82	107.38	130.50	0.21
Reach 1	1332	25YR - CC	21.21	618.01	620.37	619.64	620.40	0.000859	0.90	66.35	123.83	0.26
Reach 1	1332	100YR - CC	29.66	618.01	620.81	619.91	620.83	0.000443	0.79	122.13	133.89	0.20
Reach 1	1332	200YR - CC	33.72	618.01	621.08	620.00	621.09	0.000303	0.73	159.36	142.14	0.17
Reach 1	1248	25YR	17.50	617.94	620.10	619.50	620.15	0.001595	1.04	30.71	82.88	0.35
Reach 1	1248	100YR	24.47	617.94	620.46	619.70	620.49	0.000787	0.91	61.55	89.68	0.26
Reach 1	1248	200YR	27.82	617.94	620.65	619.79	620.68	0.000570	0.85	79.19	95.41	0.22
Reach 1	1248	25YR - CC	21.21	617.94	620.29	619.60	620.33	0.001071	0.97	46.70	86.43	0.29
Reach 1	1248	100YR - CC	29.66	617.94	620.77	619.83	620.79	0.000470	0.81	90.88	98.46	0.21
Reach 1	1248	200YR - CC	33.72	617.94	621.05	619.92	621.07	0.000311	0.74	119.17	102.34	0.17
Reach 1	1172	25YR	17.50	617.89	620.11	618.75	620.12	0.000115	0.41	62.47	72.02	0.10
Reach 1	1172	100YR	24.47	617.89	620.46	618.88	620.47	0.000095	0.43	126.93	130.80	0.10
Reach 1	1172	200YR	27.82	617.89	620.65	618.93	620.66	0.000085	0.43	151.94	131.45	0.09
Reach 1	1172	25YR - CC	21.21	617.89	620.29	618.82	620.30	0.000113	0.44	75.79	73.18	0.10
Reach 1	1172	100YR - CC	29.66	617.89	620.77	618.95	620.78	0.000077	0.42	167.62	131.91	0.09
Reach 1	1172	200YR - CC	33.72	617.89	621.05	619.01	621.06	0.000063	0.41	204.95	133.26	0.08
Reach 1	1024	25YR	17.50	617.69	620.06	619.03	620.09	0.000473	0.74	41.01	55.66	0.20
Reach 1	1024	100YR	24.47	617.69	620.42	619.24	620.44	0.000415	0.79	61.66	61.27	0.19
Reach 1	1024	200YR	27.82	617.69	620.61	619.31	620.64	0.000367	0.78	73.91	64.84	0.18
Reach 1	1024	25YR - CC	21.21	617.69	620.25	619.16	620.27	0.000449	0.77	51.46	58.35	0.19
Reach 1	1024	100YR - CC	29.66	617.69	620.73	619.34	620.76	0.000334	0.77	81.91	66.54	0.17
Reach 1	1024	200YR - CC	33.72	617.69	621.02	619.42	621.04	0.000268	0.75	101.81	71.78	0.15
Reach 1	972	25YR	17.50	617.68	620.01	619.14	620.06	0.000814	0.99	30.74	60.97	0.26
Reach 1	972	100YR	24.47	617.68	620.38	619.37	620.42	0.000595	0.98	54.39	66.46	0.23
Reach 1	972	200YR	27.82	617.68	620.58	619.49	620.62	0.000489	0.95	67.97	68.57	0.21
Reach 1	972	25YR - CC	21.21	617.68	620.20	619.26	620.25	0.000701	0.99	42.72	64.76	0.24

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Reach 1	972	100YR - CC	29.66	617.68	620.71	619.54	620.74	0.000430	0.93	76.69	70.67	0.20
Reach 1	972	200YR - CC	33.72	617.68	621.00	619.63	621.03	0.000323	0.87	98.12	74.58	0.18
Reach 1	710	25YR	17.50	617.48	619.86	618.74	619.88	0.000569	0.69	29.29	60.15	0.22
Reach 1	710	100YR	24.47	617.48	620.29	618.94	620.31	0.000317	0.65	62.20	88.35	0.17
Reach 1	710	200YR	27.82	617.48	620.52	619.03	620.53	0.000238	0.62	83.14	97.04	0.15
Reach 1	710	25YR - CC	21.21	617.48	620.09	618.84	620.11	0.000410	0.67	45.67	76.25	0.19
Reach 1	710	100YR - CC	29.66	617.48	620.65	619.07	620.67	0.000201	0.60	96.90	105.62	0.14
Reach 1	710	200YR - CC	33.72	617.48	620.97	619.17	620.98	0.000136	0.55	131.58	114.77	0.12
Reach 1	662	25YR	17.50	617.54	619.82	618.71	619.85	0.000614	0.83	36.83	68.98	0.23
Reach 1	662	100YR	24.47	617.54	620.27	618.93	620.30	0.000329	0.74	73.79	95.10	0.18
Reach 1	662	200YR	27.82	617.54	620.51	619.02	620.52	0.000240	0.69	96.83	105.74	0.15
Reach 1	662	25YR - CC	21.21	617.54	620.06	618.83	620.09	0.000436	0.79	54.98	80.54	0.20
Reach 1	662	100YR - CC	29.66	617.54	620.64	619.07	620.66	0.000198	0.65	111.98	111.84	0.14
Reach 1	662	200YR - CC	33.72	617.54	620.96	619.18	620.97	0.000129	0.58	149.41	123.07	0.12
Reach 1	590	25YR	17.50	617.45	619.76	618.58	619.80	0.000816	0.91	19.14	14.99	0.26
Reach 1	590	100YR	24.47	617.45	620.22	618.80	620.26	0.000658	0.92	26.55	17.48	0.24
Reach 1	590	200YR	27.82	617.45	620.45	618.90	620.49	0.000572	0.90	30.93	20.76	0.23
Reach 1	590	25YR - CC	21.21	617.45	620.00	618.71	620.05	0.000723	0.92	22.96	16.15	0.25
Reach 1	590	100YR - CC	29.66	617.45	620.59	618.95	620.63	0.000493	0.88	33.98	66.67	0.22
Reach 1	590	200YR - CC	33.72	617.45	620.92	619.05	620.95	0.000359	0.83	41.12	84.88	0.19
Reach 1	550		Culvert									
Reach 1	520	25YR	17.50	617.35	619.69	618.32	619.72	0.000303	0.64	27.27	30.12	0.17
Reach 1	520	100YR	24.47	617.35	620.11	618.49	620.13	0.000302	0.70	35.05	39.81	0.17
Reach 1	520	200YR	27.82	617.35	620.32	618.57	620.35	0.000291	0.71	39.46	45.52	0.17
Reach 1	520	25YR - CC	21.21	617.35	619.92	618.41	619.94	0.000304	0.68	31.34	35.57	0.17
Reach 1	520	100YR - CC	29.66	617.35	620.45	618.61	620.47	0.000283	0.70	42.30	51.50	0.16
Reach 1	520	200YR - CC	33.72	617.35	620.74	618.68	620.77	0.000225	0.68	49.82	127.10	0.15
Reach 1	470	25YR	17.50	617.25	619.68	618.49	619.70	0.000259	0.62	72.03	70.18	0.15
Reach 1	470	100YR	24.47	617.25	620.10	618.66	620.12	0.000219	0.66	103.96	83.25	0.15
Reach 1	470	200YR	27.82	617.25	620.31	618.72	620.33	0.000195	0.67	122.11	88.25	0.14
Reach 1	470	25YR - CC	21.21	617.25	619.91	618.60	619.92	0.000238	0.65	88.46	77.39	0.15
Reach 1	470	100YR - CC	29.66	617.25	620.44	618.76	620.46	0.000178	0.66	134.07	96.58	0.14
Reach 1	470	200YR - CC	33.72	617.25	620.74	618.83	620.75	0.000141	0.64	164.51	110.12	0.12
Reach 1	426	25YR	17.50	617.14	619.67	618.62	619.69	0.000318	0.62	66.97	82.33	0.17
Reach 1	426	100YR	24.47	617.14	620.09	618.87	620.11	0.000203	0.59	102.50	86.34	0.14
Reach 1	426	200YR	27.82	617.14	620.31	618.94	620.32	0.000165	0.57	121.39	89.76	0.13
Reach 1	426	25YR - CC	21.21	617.14	619.90	618.78	619.91	0.000247	0.60	85.84	84.22	0.15
Reach 1	426	100YR - CC	29.66	617.14	620.44	618.98	620.45	0.000146	0.56	133.13	91.61	0.12
Reach 1	426	200YR - CC	33.72	617.14	620.74	619.06	620.75	0.000113	0.54	161.48	102.39	0.11
Reach 1	372	25YR	17.50	617.03	619.65	618.21	619.67	0.000293	0.64	27.74	140.32	0.16
Reach 1	372	100YR	24.47	617.03	620.07	618.38	620.09	0.000263	0.70	35.25	143.72	0.16
Reach 1	372	200YR	27.82	617.03	620.28	618.45	620.31	0.000242	0.72	39.09	145.20	0.15
Reach 1	372	25YR - CC	21.21	617.03	619.87	618.30	619.90	0.000277	0.68	31.77	142.26	0.16
Reach 1	372	100YR - CC	29.66	617.03	620.41	618.49	620.43	0.000227	0.73	41.41	146.12	0.15
Reach 1	372	200YR - CC	33.72	617.03	620.71	618.58	620.73	0.000196	0.73	46.81	148.70	0.14
Reach 1	355		Culvert									
Reach 1	341	25YR	17.50	617.28	619.43	618.40	619.45	0.000457	0.66	27.56	37.80	0.19
Reach 1	341	100YR	24.47	617.28	619.70	618.57	619.73	0.000442	0.75	35.13	58.22	0.20
Reach 1	341	200YR	27.82	617.28	619.82	618.63	619.85	0.000438	0.78	38.40	60.07	0.20
Reach 1	341	25YR - CC	21.21	617.28	619.58	618.50	619.61	0.000444	0.71	31.81	52.97	0.19
Reach 1	341	100YR - CC	29.66	617.28	619.88	618.66	619.91	0.000434	0.80	40.22	61.08	0.20
Reach 1	341	200YR - CC	33.72	617.28	620.03	618.74	620.06	0.000420	0.83	44.25	63.96	0.20
Reach 1	300	25YR	17.50	617.45	619.34	618.78	619.40	0.001864	1.12	15.65	17.58	0.38
Reach 1	300	100YR	24.47	617.45	619.61	618.95	619.68	0.001757	1.18	20.79	20.70	0.38
Reach 1	300	200YR	27.82	617.45	619.73	619.01	619.80	0.001669	1.19	23.32	21.90	0.37
Reach 1	300	25YR - CC	21.21	617.45	619.49	618.87	619.56	0.001761	1.15	18.44	19.02	0.37
Reach 1	300	100YR - CC	29.66	617.45	619.80	619.05	619.87	0.001598	1.20	24.80	22.46	0.36
Reach 1	300	200YR - CC	33.72	617.45	619.95	619.13	620.02	0.001426	1.19	28.24	23.53	0.35
Reach 1	145	25YR	17.50	617.18	618.96		618.98	0.005327	0.80	41.82	63.99	0.24
Reach 1	145	100YR	24.47	617.18	619.32		619.33	0.003724	0.65	65.75	68.48	0.18
Reach 1	145	200YR	27.82	617.18	619.48		619.49	0.002984	0.63	76.89	69.51	0.16
Reach 1	145	25YR - CC	21.21	617.18	619.16		619.17	0.004853	0.68	54.84	67.56	0.20
Reach 1	145	100YR - CC	29.66	617.18	619.57		619.58	0.002686	0.62	82.99	70.13	0.16
Reach 1	145	200YR - CC	33.72	617.18	619.75		619.76	0.002206	0.60	96.37	71.68	0.15

HEC-RAS Plan: Existing River: RossCreek Reach: Reach 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Reach 1	111	25YR	17.50	617.20	618.88	618.07	618.91	0.001037	0.77	22.83	29.64	0.28
Reach 1	111	100YR	24.47	617.20	619.26	618.24	619.29	0.000546	0.70	34.82	51.57	0.21
Reach 1	111	200YR	27.82	617.20	619.43	618.31	619.46	0.000439	0.69	40.35	97.47	0.20
Reach 1	111	25YR - CC	21.21	617.20	619.09	618.16	619.12	0.000722	0.72	29.29	46.74	0.24
Reach 1	111	100YR - CC	29.66	617.20	619.52	618.35	619.55	0.000396	0.69	43.36	98.05	0.19
Reach 1	111	200YR - CC	33.72	617.20	619.71	618.43	619.74	0.000329	0.69	49.88	99.31	0.18
Reach 1	75		Culvert									
Reach 1	34	25YR	17.50	616.90	618.17	617.62	618.23	0.001682	1.10	15.84	16.93	0.36
Reach 1	34	100YR	24.47	616.90	618.38	617.77	618.46	0.001822	1.26	19.48	18.20	0.39
Reach 1	34	200YR	27.82	616.90	618.47	617.84	618.56	0.001876	1.32	21.11	18.74	0.40
Reach 1	34	25YR - CC	21.21	616.90	618.29	617.70	618.36	0.001765	1.19	17.82	17.63	0.38
Reach 1	34	100YR - CC	29.66	616.90	618.51	617.87	618.61	0.001905	1.35	21.97	19.03	0.40
Reach 1	34	200YR - CC	33.72	616.90	618.62	617.95	618.71	0.001771	1.35	27.36	61.44	0.39
Reach 1	7	25YR	17.50	616.77	617.97	617.77	618.13	0.006003	1.74	10.04	14.14	0.66
Reach 1	7	100YR	24.47	616.77	618.16	617.93	618.35	0.006001	1.91	12.83	15.76	0.68
Reach 1	7	200YR	27.82	616.77	618.24	618.00	618.44	0.006010	1.96	14.18	16.72	0.68
Reach 1	7	25YR - CC	21.21	616.77	618.07	617.86	618.25	0.006009	1.84	11.52	14.95	0.67
Reach 1	7	100YR - CC	29.66	616.77	618.29	618.04	618.49	0.006000	1.99	14.92	17.23	0.68
Reach 1	7	200YR - CC	33.72	616.77	618.38	618.11	618.59	0.006009	2.04	16.54	18.43	0.69

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