BEAR CREEK CORRIDOR ASSESSMENT

CITY OF GRANDE PRAIRIE

Report Prepared for:
CITY OF GRANDE PRAIRIE

Prepared by:
MATRIX SOLUTIONS INC.

Version 1.0
September 2018
Grande Prairie, Alberta

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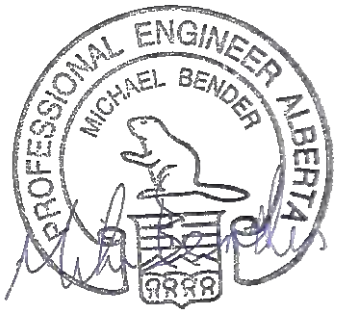
CITY OF GRANDE PRAIRIE

Report prepared for City of Grande Prairie, September 2018



September 26, 2018

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Permit No. P5540

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1 INTRODUCTION

Matrix Solutions Inc. (Matrix), in association with Westhoff Engineering Resources, Inc. (Westhoff), was retained by the City of Grande Prairie (The City) to complete the Bear Creek Corridor Assessment. The Bear Creek Corridor Assessment will help establish setback limits for development along Bear Creek upstream of the old city limits (to the 2016 city limit) and to provide related services, such as an assessment of outfalls along the entire Bear Creek corridor. This study also included the development of flood hazard maps for an upstream area along Bear Creek that expanded upon existing flood hazard mapping. The overall study area is shown on Figure 1.

The main components of the project included the following:

- **Geohazard assessment** along Bear Creek, with a focus on the new areas in the northwest expansion of The City limits. The local geohazards through the city generally consist of slope stability and local erosion issues along the deep valley walls. The geohazard assessment for the northwest expansion is dominated by the potential channel migration where there is no defined valley. The geomorphological interpretation of potential channel migration was based on historical aerial photographs and channel meander pattern analysis. The geohazard assessment through the city relied on a geotechnical interpretation of available reports to recommend important next steps for geotechnical investigations.

- **Outfall assessment** along the length of Bear Creek within the city to document existing outfall conditions, identify erosion issues, and to recommend next steps (if any) to rehabilitate erosion issues that are expected to worsen over time.

- **Floodplain hazard mapping** along the creek for the new city area north of the existing floodplain hazard mapping, documenting flood hazards for the 1:100 year return period flood, and tying into the existing downstream floodplain hazard map. The hazard mapping was based on available LiDAR data without the benefit of additional river bathymetry surveys (note that LiDAR only reports the instream water surface). This decision to forego the standard practice of conducting river bathymetry surveys was based on the character of the river upstream of the city where the river is controlled by beaver dams with relatively ineffective flow (i.e., stagnant water) along the channel. With this assumption to rely on LiDAR data, the resulting flood hazard maps are expected to be relatively conservative from the perspective of predicting the extent of flooding. The LiDAR data was supplemented with information from the downstream HEC-RAS model and Alberta Transportation (AT) structure data.

- **Setback limits** for development along Bear Creek to provide a protective buffer adjacent to Bear Creek that provides for natural migration of the channel plus potential geotechnical failure of the banks. In this way, the recommended setback limits northwest of current developments extend to the expected flood inundation limit for a 1:200 year flood event, and considers the geotechnical

setbacks recommended previously through the city where there is a greater risk of slope failure. The recommended setback limits also account for undeveloped park areas that dominate other portions of the Bear Creek valley through the city (at the direction of The City).

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Easting (m)

250000 252000 254000 256000 258000 260000

Northing (m)

1128000 1126000 1124000 1122000 1120000 1118000 1116000 1114000 1112000

Twp. 72

Twp. 71

Rg. 7 Rg. 6 Rg. 5

W6M

Bear Lake
Grande Prairie Creek
Ferguson Lake
Clairmont Lake
Hughes Lake
Township Road 720
Crystal Lake
Grande Prairie
Bear River
Hermit Lake
Canon Smith Lake
Flyingshot Lake
Wood Lake
Spring Creek
Wapiti River
68 Avenue

2 43X 670 43 40 668

72-7-W6 72-6-W6 72-5-W6 71-7-W6 71-6-W6 71-5-W6

Main Map Extent

Bear Creek Corridor Study Area
City of Grande Prairie Corporate Limits
Water Body
Watercourse
Highway
Road

1:50,000 metres
500 0 500 1,000
North American 1983 CSRS 10TM

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City of Grande Prairie
Bear Creek Corridor Assessment

Study Area

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Bender	A. Chan

Figure 1

2 AVAILABLE INFORMATION

The following documents were reviewed as a part of the study.

- City of Grande Prairie Mapping of Environmental Reserve (ER) and Science Based Setback for ER (O2 Planning + Design Inc. 2012)
- Grande Prairie Storm Drainage Master Plan (Focus 2013)
- LiDAR data (County of Grande Prairie 2014)
- 2016 City of Grande Prairie Boundary map
- Recreation Master Plan (ISL 2006)
- Design Manual (City of Grande Prairie 2017)
- Grande Prairie Flood Risk Mapping Study (NHC 2007), prepared by Northwest Hydraulics Consultants for Alberta Environment and Parks
- 2009 Bear Creek Corridor Outfall Inspection Report (Parkland Geotechnical Ltd. 2010)
- Bear Creek Corridor Geohazard Slope Stability and Erosion Assessment (Parkland Geotechnical Ltd. 2011)
- Grande Prairie Reservoir Feasibility Study (Golder 2012)
- Geotechnical Investigation and Remedial Design to Mitigate a Slope Failure near Grande Prairie Museum (2016)
- Hydrotechnical Information System (AT 2017)

A site reconnaissance was completed in October 2017, and again on May 23, 2018, to identify erosion sites along the Beer Creek Corridor and at the outfall locations. Photographs of the outfalls are provided in Appendix A. Photographs taken on May 23, 2018, followed a spring flood event that occurred at the end of April 2018 and are provided in Appendix B.

Subsequent to the draft report submission, The City provided revised bridge information on July 4, 2018, for the following bridges:

- The previous Township Road 722 bridge was replaced by a new bridge corresponding with the realigned roadway

- Addition of two new bridges at the new Highway 43X crossing (eastbound and westbound lanes).

3 OUTFALL ASSESSMENT

3.1 Overview

The outfall assessment was based on available City information, plus an inspection of each outfall. The assessment was based on standard practice and included the condition of the structure, the impact of the structure on the valley wall, and potential erosion near the outfall. Figure 2 shows the locations of the outfalls. An outfall assessment report has been prepared by Westhoff and is included in Appendix A (Westhoff 2018). The summary of the findings of the assessment is provided herein.

The purpose of the field inspection was to document existing outfall conditions, assess outfall damage, identify causes of such damage, and recommend next steps to rehabilitate erosion issues that are expected to worsen over time.

A total of 66 outfall sites on the Bear Creek were visited in October 2017. Fifty-eight outfalls were found and inspected. Eight outfalls were reported as decommissioned or not found. As part of the inspections, the conditions of the outfall components (storm sewer pipe, pre-cast flared ends, cast-in-place structures, gabions, riprap, handrails, grates, etc.) were documented. In addition, the instability factors on the surrounding slopes, the erosion caused by sewer or creek flows, and other relevant information to assess the level of damage were documented.

3.2 Assessment Classifications

The outfalls were classified based on the level of damage according to the following categories:

- Major Damage – Outfalls under this classification are either not functioning according to the original design or are partially functioning. They are likely to fail or cease to function if repair works are not conducted soon. Major works or complete reconstruction is usually required at this level of damage.
- Moderate Damage – Outfalls are currently functioning or partially functioning but there is some level of damage to the outfall or adjacent river bank or bed. It is possible that the outfall condition will worsen if no action is taken over a 1 to 5 year period.
- Minor Damage – Outfalls have minor deficiencies which are relatively easy to repair; e.g., minor scouring around the structure or poor vegetated coverage along the channel near the outfalls.
- No Damage – Outfalls under this classification are currently functioning with no observable deficiencies. Routine monitoring as a part of outfall maintenance schedule is required.

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Easting (m)

256000 257000 258000 259000 260000

Northing (m)

1119000 1118000 1117000 1116000 1115000 1114000

Crystal Lake

N

1 2 3 4 5 6 60 59 9 63 7 8 10 11 12 13 62 61 14 15 16 17 18 19 20 21 22 23 25 26 24 27 30 29 28 31 33 32 34 35 37 36 64 38 39 57 56 40 43 65 41 42 44 46 47 45 48 52 51 50 49 54 53 58 55 66

43 40 68 Avenue

Bear River

Grande Prairie City Limit

Twp. 71

Rg. 6 Rg. 5

W6M

Water Body
Watercourse
Community Boundary
Highway
Road
Outfall Location

1:20,000 metres
200 0 200 400
North American 1983 CSRS 10TM

Reference: Data obtained from AltaLIS © Government of Alberta used under license. GDM transportation infrastructure data provided by IHS © 2018 used under license. Imagery (2017) obtained from Valtus © (2018) used under license.

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City of Grande Prairie
Bear Creek Corridor Assessment

Outfall Locations

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Shome	A. Chan

Figure 2

3.3 Assessment Results

A total of 14 outfalls were classified as having Major damage. Table 1 lists the outfalls within each category. A priority ranking was developed based on the level of damage, risk of affecting nearby infrastructure, size of the outfall catchment area, potential safety hazards for public, maintenance, and environmental issues. Storm sewer pipe erosion (erosion caused by flows exiting through the outfall sewer pipe) has been identified as the major type of failure influencing outfall damages, followed by erosion damage caused by Bear Creek flows. Other noted types of failure are slope stability, storm sewer pipe damage, structural damage of the outfall structure, and possible damage along the storm sewer line. Table 2 lists the prioritization for the outfall repairs by Outfall ID (see also Figure 2).

TABLE 1 Level of Damage Statistics for Existing Outfalls

Level of Damage	No. of Outfalls
Major	14
Moderate	13
Minor	22
No damage	9
Missing/decommissioned	8
Total Inspected sites	66

TABLE 2 Priority Ranking of Outfalls

Outfall ID	Initial Damage	Priority
50	Major	1
5	Major	2
39	Major	3
1	Major	3
52	Major	5
44	Major	6
24	Major	7
19	Major	8
8	Major	9
53	Major	10
59	Moderate	11
40	Moderate	12
41	Major	13
14	Major	14
30	Moderate	14
56	Moderate	16
28	Major	17
48	Moderate	18
7	Minor	19
43	Minor	20
37	Moderate	21
46	Moderate	22
33	Major	23
18	Minor	23
25	Moderate	25
2	Minor	26
17	Moderate	27
13	Moderate	27
10	Moderate	29
34	Moderate	30
3	No damage	30
20	Moderate	32
51	Minor	32
54	Minor	34
23	Minor	35
21	Minor	36
42	Minor	36
6	Minor	38
16	Minor	39
26	Minor	40

Outfall ID	Initial Damage	Priority
55	Minor	40
58	Minor	40
12	Minor	43
15	Minor	43
57	Minor	43
61	Minor	43
66	No damage	47
9	Minor	48
45	Minor	49
65	Minor	50
63	No damage	50
27	Minor	52
62	No damage	53
11	No damage	54
60	No damage	55
35	No damage	56
64	No damage	56
22	No damage	58

Detailed information for each outfall can be found in the report included in Appendix A.

4 FLOOD HAZARD MAPPING

4.1 Map Extents

In 2016, the City limits were expanded to the north. A hydraulic model did not exist for Bear Creek in this expanded area; therefore, an existing conditions model was created based on LiDAR data provided by The City in combination with AT data and field data collected by Matrix. The model domain extends from immediately upstream of 132 Avenue (Township Road 720) to approximately 1.6 km north (upstream) of Township Road 722, an approximate channel length of 9.4 km. The downstream boundary of this model domain matches with the upstream boundary of the Northwest Hydraulic Consultants Ltd. (NHC 2007) flood risk study. Figure 3 shows the model extent for the present study.

4.2 Selected Model

The HEC-RAS Version 5.0.3 software package was used in this study to generate flood elevations for floodplain hazard mapping. Collection and processing of data, computational procedures, and analysis of computed profiles were carried out according to guidelines published by Hydrologic Engineering Centre, U.S. Army Corps of Engineers. As input data, HEC-RAS requires cross-section geometry, channel reach lengths, roughness coefficients for the main channel and overbank areas, as well as upstream and downstream boundary conditions. The following sections summarize the model setup.

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Easting (m)

252000 253000 254000 255000 256000

Northing (m)

1127000 1126000 1125000 1124000 1123000 1122000 1121000

Township Road 723

Range Road 65

Range Road 64

Township Road 722 Bridge

New Highway 43x Bridges

Township Road 722

Grande Prairie City Limit

Highway 43X

43X

Country Roads RV Park Private Bridge

Range Road 63

Twp. 72

Access to 01-07-072-06W6

Access to 13-05-072-06W6

Township Road 721

116 Street / Range Road 63 Bridge

Bear River

Hughes Lake

Township Road 720

Township Road 720 Bridge

Township Road 715A

116 Street

Twp. 71

Rg. 6
W6M

- Hydraulic Modeling Domain
- Water Body
- Watercourse
- Community Boundary
- Highway
- Road
- Hydraulic Structure Location

1:20,000 metres
200 0 200 400
North American 1983 CSRS 10TM

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City of Grande Prairie
Bear Creek Corridor Assessment

Hydraulic Modeling Domain

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Figure 3

4.3 Topography

The LiDAR data provided by The City was used as the basis for the hydraulic model development and floodplain mapping. To fill in the gaps not covered by the data from The City, bare earth elevation data was downloaded from the County of Grande Prairie LiDAR Open Data catalogue (OpenGP) for a few quarter sections as LAS files containing location coordinates and elevation. The LiDAR data was converted and stitched into one complete bare earth digital terrain model. The vintage of the LiDAR provided by The City was May 2014. The vintage of the data downloaded from OpenGP is May 2013 and May 2014. Review of the metadata provided by The City indicates the two LiDAR datasets originated from the same source.

The City and County's LiDAR data has a stated horizontal accuracy of 35 cm (95%) and a fundamental vertical accuracy on flat hard surfaces of 20 cm (95%). The final mosaic was created with a 1 m resolution. The quoted projection was UTM 11 NAD 83 (CSRS), with a CGVD28 vertical datum. Terrain data and mapping was translated into the City of Grande Prairie NAD 83 (CSRS) 10TM projection

To build a georeferenced HEC-RAS model, the river centreline was digitized in GIS using the stitched LiDAR surface and aerial photos for reference.

Cross-section locations and extents were drawn in GIS based on the digitized centreline and features observed in the LiDAR data. The cross-sections were drawn from left to right looking downstream and were labelled from downstream to upstream based on the distance from the downstream end.

Best modelling practices were used to select appropriate cross-section locations. For example, cross-section locations were selected such that they represent average channel conditions for the reach, ignoring isolated depressions, ponds, etc. The cross-sections were oriented such that they are perpendicular to flood flow and span the anticipated extent of major flows.

Cross-sections were also included in the model immediately upstream and downstream of each of the bridge crossings and along the top of road at each bridge.

HEC-RAS geometry files were generated from the GIS data and included a polyline of the river reach, polylines representing the cross-sections, and a raster of the terrain from which the cross-sections were cut. The geometry file was then imported to HEC-RAS.

Since LiDAR does not penetrate the water surface, an estimate of the low flow channel below the LiDAR generated surface was incorporated into the model cross-sections. The depths of the low flow channel varied between 1.66 and 3.08 m below the LiDAR generated surface and were based on the following sources of information:

- The City of Grande Prairie Flood Risk Mapping Study (NHC 2007) indicated the thalweg immediately upstream of 132 Avenue to be 654.35 m.

- A field measurement of the thalweg at the County Roads RV Park Bridge was approximated as 657.74 m.

- The thalweg at the new Highway 43X bridges was approximated to be 658.70 m as indicated in the design drawings.

- The thalweg at the new Township Road 722 bridge was approximated to be 658.70 m as indicated in the design drawings.

4.4 Boundary Conditions

Boundary conditions must be established for hydraulic model development. Boundary conditions are required to perform steady flow calculations and to establish the starting water surface at the upstream and downstream limits of a river system. Ideally, a HEC-RAS model should originate far enough downstream so that it accounts for any downstream influence on upstream water levels.

The downstream boundary condition for the Bear Creek model for the 1:100 year design storm was assigned a value of 659.61 m based on the current flood hazard mapping (NHC 2007). The 1:200 year design storm flow profile used the normal depth based on energy grade line slope as the previous study did not run the 1:200 year event.

The upstream boundary condition for both flow profiles used normal depth based on channel slope.

4.5 Design Flow

The developed model was applied to simulate water levels during 1:100 year and 1:200 year floods. The inflow to the hydraulic model was adopted from the *Grande Prairie Reservoir Feasibility Study* (Golder 2012) in which the 1:100 year flow is recorded as 112.8 m^3/s. For reference, the NHC (2007) study used 104 m^3/s and 110 m^3/s as 1:100 year flood for the upper and lower extent of their study area. This study did not include the 1:200 year flow and therefore it was linearly extrapolated by plotting the 1:2 year through 1:100 year values (Golder 2012) on log-normal graphing paper. A summary of the inflows are shown in Table 3.

TABLE 3 Estimated Flood Peak Flow for Various Return Periods

Return Period	Flow (m^3/s)
1:2 year	17.2
1:5 year	34.2
1:10 year	48.3
1:25 year	70.1
1:50 year	89.7
1:100 year	112.8
1:200 year	145.0

4.6 Structures

Four bridges were modelled within the study area: the 116 Street bridge; a private bridge within the Country Roads RV Park; the Highway 43x bridges (westbound and eastbound lanes); and the Township Road 722 bridge. The Hydrotechnical Information System (HIS) tool available from AT was used to obtain data for the 116 Street bridge. The HIS tool provides basic information about all bridges owned by AT and includes bridge information including span, cell width, number of piers, deck thickness, deck width (in the direction of flow), and geographic coordinates. Bridge design drawings for the Highway 43X bridges and the replacement Township Road 722 bridge were provided by The City on July 4, 2018. Table 4 summarizes the bridge data incorporated into the model including the source of the data.

TABLE 4 Structure Data

Location	Total Span (m)	Number of Piers	Pier Width (m)	Deck Thickness (m)	Deck Width (m)	Source
116 St ID 71654	29.0	2	1.75	0.8	7.7	HIS Tool
Country Roads RV Bridge	18.3	-	-	0.8	6.0	Matrix (October 2017)
Highway 43X Bridges (WBL & EBL)	30.0	-	-	2.3	23.2	AT Design Drawings (dated April 7, 2016)
Twp. Rd 722 ID 07301	43.2	2	0.31	1.2	9.2	AT Design Drawings (dated April 7, 2016)

4.7 Hydraulic Modelling

4.7.1 Expansion and Contraction Coefficients

Transition losses occur when the flow experiences expansion or contraction from cross-section to cross-section such as it does in the vicinity of a bridge. The software incorporates this type of loss into its solution through the application of an expansion or contraction. The contraction and expansion due to changes in the cross-sectional geometry is a typical cause for the loss of energy between two cross-sections. The expansion and contraction coefficients normally reflect the ratio of the expansion and contraction of the effective flow areas between two cross-sections. These losses are evaluated in HEC-RAS by multiplying expansion/contraction coefficients by the difference in velocity head between two cross-sections. These coefficients range from 0.1 for gradual transition to 0.8 for an abrupt change. Consistent with standard modelling practice, the expansion and contraction coefficients for regular cross-sections were 0.3 and 0.1, respectively. To account for expansion and contraction of flow through the bridges, expansion and contraction coefficients were changed to 0.5 and 0.3, respectively, for the cross-section upstream of the structures and both cross-sections associated with the structure.

4.7.2 Manning's Roughness

Channel and floodplain roughness coefficients in terms of Manning's roughness (n) coefficients are used to calculate energy losses between cross-sections due to friction. The roughness coefficients depend on a number of factors including surface roughness, vegetation, channel irregularities, degree of meander, size, and shape of the channel. Manning's n values were assigned in accordance with typical literature values (Chow 1959). A value of 0.035 was assigned to the main channel, while the overbanks were assigned values of 0.040 to represent the relatively clear banks dominated by cultivated areas, the golf course and other cleared areas. The areas with thick brush are contained within the valley and are typically overflow areas that will fill after 116 Street overtops near the Bear Creek Golf Club.

The Manning's roughness values were selected in concert with preliminary hydraulic modelling results, and they differ significantly from the downstream flood hazard hydraulic model developed by others. The preliminary hydraulic modelling results indicate floodplain depth on the order of 1 m or more. The relatively deep flow results in a lower effective roughness. This characteristic lower effective roughness for deep water is well-documented in the literature. Therefore, the selected roughness is intended to be representative of high flow conditions. The effective roughness may be much greater during other lower flow conditions.

4.7.3 Model Validation

High Water Marks

The HEC-RAS model was validated based on available high water mark information from the June 1990 flood event (AT 2017) at the Township Road 722 bridge. Due to lack of flow monitoring data along the modelled reach, review of historic rainfall data from Environment Canada's meteorological station at Grande Prairie Airport (Station ID 3072920) was completed to estimate the return period of the 1990 flood event. This review revealed that 95.7 mm of rainfall was recorded between June 10 and June 12, 1990, with the maximum of 59.3 mm occurring on June 11, 1990. Using the City of Grande Prairie IDF parameters, the storm event was estimated to be in the range of a 1:2 to 1:5 year return period event, assuming 36-hour duration.

The data recorded on June 15, 1990, indicates that the water level at the Township Road 722 bridge was measured to be 2.0 m below the bridge deck. A comparison of the modelled 1:2 and 1:5 year results using the previous Township Road 722 bridge geometry is shown below in Table 5.

TABLE 5 Water Level Data at Township Road 722 Bridge

Return Period	Deck Elevation (m)	Modelled Water Elevation (m)	Modelled Freeboard Deck to Water Level (m)	June 1990 Measured Freeboard Deck to Water Level (m)
1:2 year	662.92	660.66	2.26	2.0
1:5 year	662.92	661.48	1.44	2.0

Based on the validation results summarized above, the modelling results indicate good agreement with the measured data; therefore, model parameter adjustment was not required. The modelled 1:2 year water level is 0.26 m lower than the 1990 high water mark, while the modelled 1:5 year water level was 0.56 m higher the 1990 high water mark.

Variations in the modelled water levels compared to observed high water mark may be due to unknown bed elevations at the time of the 1990 flood, lack of flow data associated with the 1990 flood, and differences in bridges within the study area. The 116 Street bridge was constructed in 2000 (HIS 2017), 10 years after the high water mark was recorded upstream, which may impact the water levels in the study reach. Additionally, channelization has occurred in the vicinity of 132 Avenue (downstream end of model extent) and abandoned meanders of Bear Creek are present to the west of 116 Street. These changes may account for inconsistencies between measured and modelled data.

Sensitivity Analysis

The flood hazard mapping for the estimated 1:100 year flood was matched to the existing downstream flood hazard map previously developed for the City of Grande Prairie. The relative accuracy of the mapping is expected to be within 0.3 m.

A sensitivity assessment was used to confirm the assumed relative accuracy of the flood inundation results. The results can be affected by several factors, including the following:

- Design flood estimates
- Channel effective roughness
- Floodplain effective roughness
- Channel depth (not surveyed)

Design flood estimates were based on previous flood estimates prepared for the City of Grande Prairie, relying on upstream stream flow gauging station data from Environment Canada. Although the upstream watershed is relatively large, large floods are attenuated by Bear Lake. Bear Lake temporarily stores water during high flow, whereby a large volume of water is needed to raise the lake level before causing a downstream flow increase. Grande Prairie Creek is also known to back up into Bear Lake during high flow. In this way, flood hazard mapping is relatively insensitive to the design flood estimates because Bear Lake effectively attenuates or dampens the effect of high runoff from the upstream watershed.

A typical channel effective roughness of 0.035 (Manning's coefficient) was selected for the main channel flow. The results are relatively insensitive to +/- 20% changes in channel roughness. The results are more sensitive to other factors.

The floodplain effective roughness depends on the type and density of vegetation, and also on the depth of flow across the floodplain. Roughness values of 0.1 or greater are possible for thick vegetation

and shallow flow. However, the initial hydraulic modelling results indicated a depth of flow greater than 1 m across most of the floodplain areas within the confined valley for Bear Creek. Some of these floodplain areas consist of minimal vegetation cover. The effective roughness was therefore assumed to be relatively low. The relative sensitivity of a 25% increase from 0.04 to 0.05 was tested as part of a scenario for the sensitivity assessment.

Channel depth is typically surveyed as part of a flood hazard mapping study. In this case, a channel survey was not completed. Instead, the available LiDAR topography was used to represent the channel width and depth. LiDAR topography provides overland elevation accuracy of +/- 0.1 m after corrections are made for vegetation canopy cover. No such corrections are available for water surfaces. Therefore, the LiDAR surface represents the surface of the water at the time of the LiDAR survey.

By using the LiDAR water surface for the flood hydraulic modelling, it was assumed that the flood inundation results would be conservatively high if the channel conveyance capacity was ignored for the wetted area of the channel below the LiDAR surface. This assumption was put forward due to the relatively sluggish flow of the creek, beaver dam activity and other woody debris along the creek, and dense vegetation obscuring the shoreline in many locations.

Some channel depth was assumed in combination with the selected channel roughness: 2 m average channel depth. Together, the channel depth and roughness assumptions were adjusted to match the results of previous downstream flood hazard mapping. The relative sensitivity of channel depth was also tested as part of a scenario for the sensitivity assessment.

Scenarios for the sensitivity assessment consisted of combinations of assumptions to validate the relative accuracy of the flood hazard mapping. First, the estimated flood elevations are equivalent to a deeper 3 m channel with higher roughness (0.045 channel, 0.05 floodplain). This scenario represents conditions if the channel bed is mobilized during the flood. For the second scenario, the flood level would be about 0.35 m greater if the model assumed 0 m channel depth. The channel depth below the LiDAR surface is greater than 0 m, so this test is assumed to be outside the relative accuracy limits. The scenario results are illustrated on Figure 4.

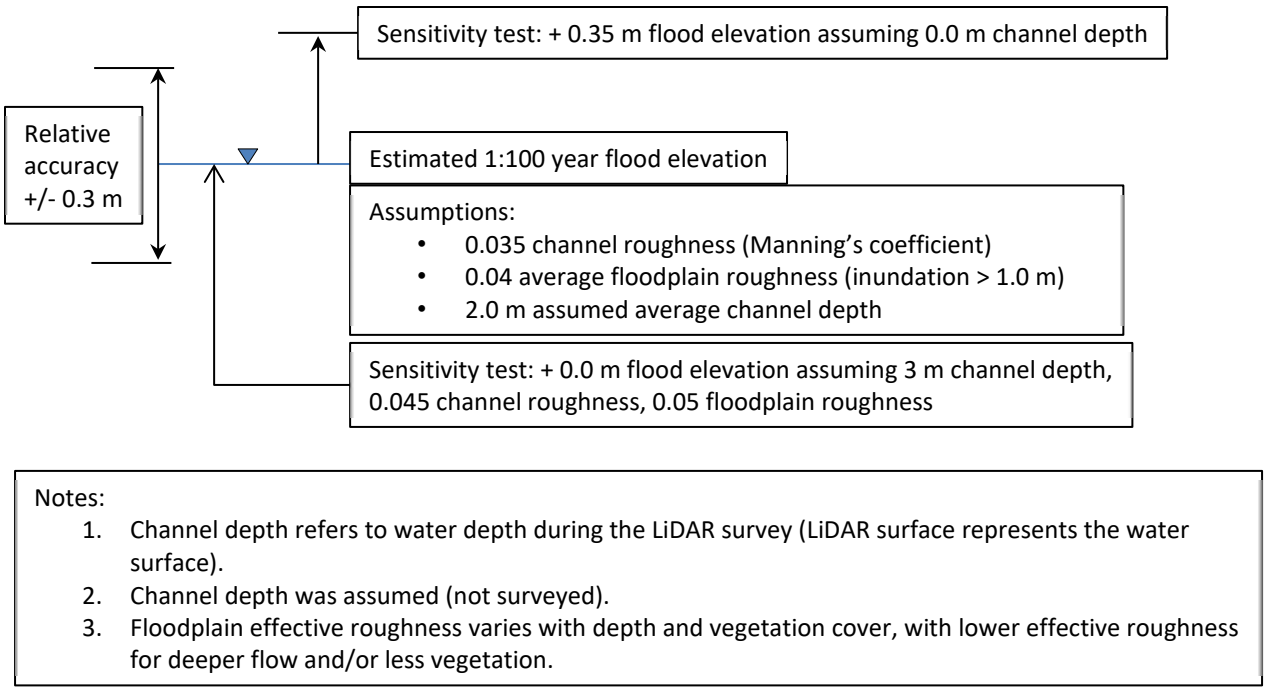

FIGURE 4 Summary of Sensitivity Assessment Results

The sensitivity assessment scenarios indicate that the City of Grande Prairie can reasonably expect that the estimated flood hazards are within 0.3 m elevation for the 1:100 year flood levels along the Bear Creek corridor. The flood levels were calibrated to match the available downstream flood hazard mapping, to account for relatively deep flow across the floodplain (i.e., low effective roughness), and to account for some flow along the main channel.

Refinements to the flood hazard mapping data were possible but were neglected in favour of relatively conservative assumptions and consistency with downstream model results. One of these possible refinements is a detailed channel survey. The survey may improve the accuracy of the data, but is not expected to improve the flood hazard mapping by a significant margin. As well, higher than expected downstream flood levels are also unlikely because of the floodplain configuration along 116 Street near the Bear Creek Golf Club and RV Park where the floodplain West of 116 Street is most likely to fill after 116 Street is overtopped. This will provide some (off-channel) flood storage during peak flow conditions. The dynamic nature of this off-channel storage is not accounted for, based on the standard hydraulic modelling methods for flood hazard mapping.

4.7.4 Encroachment Analysis

Matrix used the encroachment analysis feature in HEC-RAS to determine the extent of the floodway and flood fringe using the following the Flood Hazard Identification Program Guidelines (AENV 2011):

- The floodway consists of areas where the water is 1 m deep or greater and the local velocities are 1 m/s or faster.

- The flood fringe is area along the edge of the floodway with depths less than 1 m and velocities less than 1 m/s.

- The restricted floodway water surface profiles under encroachment conditions cannot be higher than 0.3 m above the unrestricted natural water surface profiles for the design flood.

4.7.5 Water Surface Profiles

Water surface profiles for the 1:100 year and 1:200 year return period floods were computed for existing conditions. Results were verified by checking cross-section and profile printouts, flooded top widths, and changes in flow distribution. The inundation boundary for the 1:100 year and 1:200 year floods was then exported from the HEC-RAS model using RAS Mapper for hazard map generation.

4.8 Floodplain Hazard Maps

Flood hazard maps for the 1:100 year flood were developed from the hydraulic model results and checked using aerial photographs in areas of uncertainty, especially at the downstream study area location that transitions to the existing flood hazard map. Also included on the flood maps are the cross-section lines and numbers, flood control structures, overtopping points, depth estimates at selected structures or properties, and the limits of overland flow. Flood risk maps are provided in Appendix C for the 1:100 year return period flood. Mapping of the 1:200 year flood inundation extent is provided Appendix D. The supporting digital data was provided to the City separately. The water surface elevation triangulated irregular network and flood depth grids for the flood scenarios were provided in ArcGIS 10.1 compatible formats (ArcGIS 10.1 map project file [.mxd] and geodatabase). The flood construction level isolines were provided to The City as a shapefile or geodatabase feature class. The flood hazard designation grid identifying hazard management zones were provided in ArcGIS 10.1 compatible formats (ArcGIS 10.1 map project file [.mxd] and geodatabase).

5 GEOHAZARD ASSESSMENT

Significant erosion at various locations along the Bear Creek corridor was noted during field inspection. Causes of erosion include massive landslides, erosion due to discharges at outfall structures, erosion along Bear Creek, and erosion due to overland flow.

A desktop geohazard assessment was used to identify future management priorities related to geotechnical, erosion, and geomorphological considerations. The geotechnical hazards consist of slope stability issues along the Bear Creek corridor downstream of the reservoir. The geomorphological assessment considers potential realignment or lateral migration of the Bear Creek channel upstream of the reservoir.

5.1 Geotechnical Assessment

The available geotechnical assessment report indicates that from a geotechnical perspective, the Bear Creek valley is characterized by numerous mass wasting events, including slumps, sloughs, and landslides. Many of the events have been triggered, initiated, or exacerbated by erosion of the toe of the slope at the creek. However, the geology of the area is problematic is several ways:

- The high plastic glacial tills exhibit a significant strain softening behaviour, meaning that after initial straining the strength of the soil will suffer strength loss.

- The subsurface stratigraphy is interbedded with slickensides, which are thin layers of soil that has been sheared and exhibit residual (low) strengths. The slickensides may be the result of soil movements in recent times, or due to glacier thrusting over 10,000 years ago.

Thus, while streambank erosion may be a significant factor in the mass wasting processes, the subsurface geology complicates the processes and the extent to which soil movements may extend. Large landslides may extend further back from the crest of the slope than what might be typically expected when considered from the viewpoint of “well-behaved” soil masses.

There are certain urban factors that negatively impact slope stability along the Bear Creek corridor. Two important ones are uncontrolled discharge of stormwater and irrigation. To reduce surface erosion and infiltration of surface water that will raise the groundwater level, stormwater discharge should be appropriately managed. Stormwater should be carried to the creek level in storm sewer pipes or conveyed along the surface in confined and armoured surface channels so that erosion does not occur. Damaged stormwater outfalls and storm sewer pipes should be repaired. Landscape irrigations systems are often the cause of slope failures due to the saturation of the ground and increases in groundwater levels. Underground irrigation systems often have leaks and thus provide a continuous source of water to the subsurface. This will saturate the ground, which may lower the soil strength, and increase the groundwater level that will also reduce soil resistance to slope movement.

5.2 Geomorphological Assessment

A desktop geomorphological assessment was used to identify potential areas of concern. The assessment was based on an interpretation of historical aerial photographs to document lateral migration of Bear Creek within the valley upstream of the reservoir where future development has the potential to encroach on the river, and potential erosion was assessed downstream of the reservoir where Bear Creek has the potential to impact infrastructure.

Historical aerial photographs for the years of 1951, 1976, 1989, 1993, 2012, and 2014 were available to delineate the top of bank locations of Bear Creek upstream of the reservoir. The map interpretations are provided in Appendix E. As shown on the map interpretations, Bear Creek has a relatively wide corridor of lateral migration activity within the confines of the valley. Upstream of the reservoir, Bear Creek has a

wider active zone of relict channels and oxbows with abandoned terraces, but the overall channel alignment has been relatively stable within an unconfined valley. The relative stability is likely due to the upstream presence of Bear Lake, which is a relatively large water body that attenuates large flood events. The resulting flood peaks are much smaller due to temporary water storage in the lake. This affects the flood peak along the Bear Lake outlet and along Grande Prairie Creek which sometimes flows back into Beak Lake near the confluence with Bear Creek.

Downstream of the reservoir, the geomorphological assessment was based on site observations on May 23, 2018. The observations followed a high flow event in the spring of 2018, during which the City was forced to control access along the valley pathways. The magnitude of the flood event was not estimated.

5.3 Recommended Next Steps to Manage Erosion along Bear Creek Corridor

Some areas along the Bear Creek corridor are recommended for additional assessments based on the geotechnical and geomorphological assessments. These areas of concern and recommended next steps are listed below in Table 6 by geographic order from south to north and include the recommended implementation priority by approximate year.

TABLE 6 Erosion Mitigation Recommendations and Implementation Priority

Recommendation #	Description & Recommendation	Implementation Priority
1	South Bear Creek at the end of 100 Street has an A-Jacks™ bank revetment along the left bank toe of the embankment (downstream of the bridge); this style of revetment material will have large voids that cause increased erosion along the bank (A-Jacks are intended for shoreline protection against wave action); recommend filling the voids with rock.	2019 (Preventative)
2	South Bear Creek at the end of 100 Street, bridge foundations are not imminently threatened by the river; the proposed rock protection around the piers will not protect the foundations from bank erosion; recommend river training spurs near the bank to prevent migration of the river toward the bridge piers.	2019 (Important)
3	68 Avenue bridge crossing configuration is recommended to resolve the following issues: • downstream bank erosion near the pedestrian bridge, with continued erosion expected • erosion at toe of left bank embankment at the downstream end of the existing riprap protection • finished surface under the bridge has not been reclaimed • there is a drainage issue along the right bank downstream of the bridge, resulting in gullying by flow at the end of a drain pipe • configuration of rock armour along the right bank under the bridge results in the rock embankment completely blocking and diverting the river toward the left bridge piers	2018 (Important)
4	Recommend a detailed slope stability assessment for the escarpment at west end of 80 Avenue on the east side of the Bear Creek corridor.	2019 (Assessment)

5	Trailer park drainage near 81 Avenue is partially uncontrolled near existing landslides; recommend that the City work with landowner to divert surface drainage from existing landslide area.	2019 (Preventative)
6	Gabion wall downstream of 84 Avenue is in good condition, but the existing erosion control blanket (ECB) is not a sufficient permanent measure to prevent erosion behind the gabion wall; recommend installing a 'tie-back' or 'key-in' at both the upstream and downstream ends of the gabion wall. This is a pro-active measure.	2018 (Preventative)
7	The 84 Avenue bridge erosion protection gabions are sliding into the river. Recommend survey the slumping gabions and river bed, confirm the hydraulic conveyance capacity under the bridge, inspect the design drawings to determine the possible source of the downstream standing wave – which may indicate progressive scour head cutting of a deeper channel; consider re-design of the pathway and erosion protection to match 108 Street.	**2019 (Highest risk)**
8	Pathway near 88 Avenue is threatened by bank erosion that has formed a vertical cliff about 4 m from the edge of the pathway; recommend to realign pathway near 88 Avenue prior to slope failure.	2020 (Preventative)
9	Rough trail failures (2) below pathway near 89 Avenue is expected to continue eroding; recommend closing the rough trail, removing the fencing, and installing large woody debris to discourage users.	2018 (Low effort with high benefit)
10	Recommend a slope stability assessment for the escarpment at the south end of 102 Street near its intersection with 90 Avenue.	2019 (Assessment)
11	Street drainage at the end of 102 Street is causing gullying down the adjacent meander scar; recommend adding a curb across the end of the road.	2018 (Low effort with high benefit)
12	Culvert drain under pathway is causing gullying near 97 Avenue; recommend extending the culvert to the river.	2018 (Low effort with high benefit)
13	Bank failure along 116 Street at 132 Avenue along northbound lane. Recommend bank stabilization.	2019 (Preventative)
14	Recommend the following monitoring priorities: • private property near large meander scar at the end of 76 Avenue (west side of the valley) • large existing landslides near trailer parks near 81 Avenue • 84 Avenue bridge erosion protection • scour at 99 Avenue bridge pier	2018 (Assessment)
15	Reclamation best practices: • use ECB for temporary use only, specify biodegradable mesh • willow staking along river banks wherever the bank is visible (e.g., Elks lodge shoreline, near the museum)	2018 (Preventative)
16	Consider removing the relic embankment (left bank) from pipe crossing near 92 Avenue because the creek is constricted at this location and is unusually straight, resulting in a high concentration of new bank erosion at the nearby downstream meander bends; removing the embankment will help to activate and utilize the remaining floodplain along the left bank.	2021 (Preventative)

17	Recommended monitoring stations: • re-activate the reservoir water level station with telemetry • confirm the water level basis for the rating curves of the dam gates based on the original design (i.e., water level near the gate, or level pool reservoir elevation upstream of the gates) • re-install the reservoir staff gauge to match the water level basis for the rating curves • survey the telemetry water level station to match the staff gauge • install flow measurement station downstream of dam at the first pedestrian bridge • install flow measurement station upstream of the reservoir at 132 Avenue or Township Road 722 • coordinate with Alberta Environmental and Parks for access to Bear Lake water level station records (station 07GE004 Bear Lake near Clairmont) and potential real time telemetry • coordinate with Water Survey of Canada (WSC) for access to Grande Prairie Creek flow records (station 07GE003 Grande Prairie Creek near Sexsmith) and potential real time telemetry	2019 (Monitoring)
18	Confirm the condition/existence of Ducks Unlimited weir at Bear Lake; if the weir stoplog structure exists, work with stakeholders to establish appropriate rules for operating the stoplogs.	2019 (Monitoring)

An arrangement of monitoring stations will provide the City with the following flood preparedness tools:

- Reservoir water level in real-time for gate operations (real-time flood operating rules may need to be established and documented).
- Flow monitoring station downstream of the dam to confirm the relative magnitude of a flood event (i.e., 10-year versus 100-year return period).
- Flow monitoring station upstream of the dam to confirm that gate releases at the dam did not exceed the natural flood peak.
- Bear Lake water levels to confirm that dam gate operations do not affect Bear Lake (an analysis of flow versus level may be necessary to demonstrate this fact).
- Grande Prairie Creek station flow may be used for advance flood warning of about 18 hours (requires telemetry at the WSC station).

Slope stability issues have also occurred at other areas along the Bear Creek corridor, including properties adjacent to the reservoir. These localized slope stability issues have been identified and repaired as they occur. The above list of recommended next steps is intended to highlight longer term and pro-active management priorities.

The recommendations are noted on the map sheets in Appendix F. Photographs of the erosion areas along Bear Creek corridor are provided in Appendix B.

6 DEVELOPMENT SETBACK RECOMMENDATIONS

Setback limits for future development are recommended for discussion purposes based on our interpretation of the assessment results and similar setback guidelines in other Alberta jurisdictions. The setback limits are based on typical standard practice, combined with changes based on geomorphological observations of potential issues along Bear Creek. Overall, the setback limits represent the limit of channel migration plus a stable valley wall slope plus a distance for safety purposes. The recommended setback distances are provided in Appendix F.

The recommended setback recommendations vary from the upstream undeveloped river corridor with a relatively unconfined valley, to the downstream developed portions of the City with a confined and entrenched valley. The upstream reach includes the corridor from the north City limit at the boundary between the Dominion Land Survey sections 17-072-06 W6M and 20-072-06 W6M to Township Road 720. The downstream reach extends from Highway 43 to the southern city limit, just east of 100 street/Range Road 61.

The intention of the development setbacks is for the City to actively manage any future development within the setback. Ideally, no additional development should occur within the setbacks to avoid potential damage to property due to river migration, flooding, bank erosion, and landslides.

The following criteria were used to define the recommended setback limits:

Basis for upstream setback locations (Appendix F | Sheet 1 - 7):

- geomorphology and environmental rules
- Alberta Environment and Park's *Stepping Back from the Water* (ESRD 2012) setback recommendations for permanent water bodies (20 m), intermittent streams (6 m), and mapped ephemeral channels (6 m) from AltaLIS 20k centreline processes, based on geomorphological interpretation
- natural features mapping (O2 Planning + Design Inc. 2012)
- water body delineated as limit of active channel movement
- flood hazard (100 year) and inundation (200 year) mapping

Basis for downstream setback locations (Appendix F | Sheet 7 - 12):

- edge of valley escarpment
- locations of significant landslides (Geohazard)
- local drainage issues that may contribute to reduced slope stability
- geotechnical recommendations (Parkland Geotechnical Ltd. 2010)

7 CONCLUSIONS

The following conclusions were drawn from the results of this study:

- Erosion due to flow from outfall structures has been identified as the key mode of failure for outfall damage. Other noted types of failure are erosion along Bear Creek, slope stability, storm sewer pipe damage, structural damage on the outlet structure, and possible damage along the storm sewer line.

- Out of 58 outfalls assessed, 14 outfalls have been classified as having major damage, 13 outfalls have been classified as moderate damage, 22 classified with minor damage, and 9 outfalls with no damage. Priority repairs will be assigned by the City.

- A flood routing model using HEC-RAS modelling software was developed to develop flood risk map during a 1:100 year flood. The modelling results were validated against measured high water mark within the study area during the 1990 flood and a sensitivity analysis was completed by varying Manning's roughness coefficient.

- The geohazard assessments of geotechnical and geomorphological hazards were to identify next steps for geotechnical investigations and erosion control, and to provide the basis for setback limits on future development.

- Recommended setback distances are presented for discussion purposes. These recommendations have not been accepted by the City.

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APPENDIX A
Outfall Assessment Report

Stormwater Outfall Assessment along the Bear Creek within the City of Grande Prairie

Prepared by:

Westhoff Engineering Resources, Inc.

Land & Water Resources Management Consultants

Stormwater Outfall Assessment along the Bear Creek within the City of Grande Prairie

Final Report
July 16, 2018

Prepared for:

The City of Grande Prairie

File: WER116-82

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Corporate Authorization

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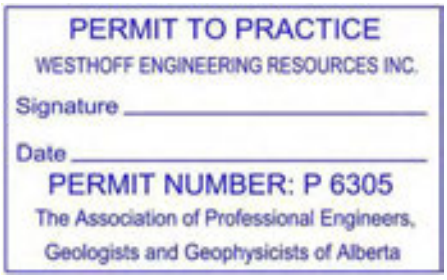

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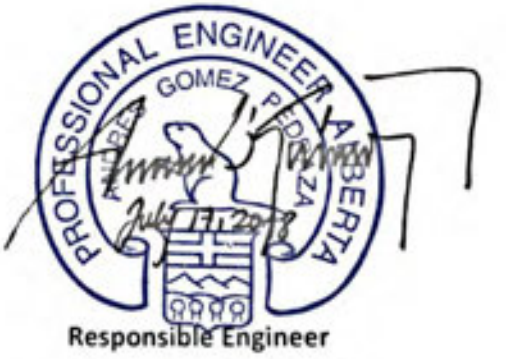

Analysis and report prepared by Andres Gomez, P.Eng., PMP, CPESC.

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Executive Summary

Matrix Solutions, Inc. (Matrix) in association with Westhoff Engineering Resources, Inc. (Westhoff) has been retained by The City of Grande Prairie to provide Engineering Services for the Bear Creek Corridor Assessment.

As a component of the Bear Creek Corridor Assessment project, an inspection of the stormwater outfalls along the Bear Creek within the City of Grande Prairie limits was conducted, and an engineering assessment was provided based on standard methods.

The purpose of the inspection was to document existing outfall conditions, assess outfall damage and identify the causes of damage, and recommend next steps to rehabilitate erosion issues that are expected to worsen over time.

An assessment team from Westhoff and Matrix visited a total of 66 outfall sites on the Bear Creek in October 2017. Out of the 66 sites, 58 outfalls were found and inspected, and 8 were reported as decommissioned or not found. The locations of the outfalls were based on a previous outfall inspection report completed by ParklandGeo in 2009 and a site meeting with the City Project Manager (PM) during the fieldwork. The 2009 report was used as a reference to identify, compare, and update the current condition of the outfalls.

As part of the inspections, Westhoff documented the condition of the outfall components (pipe, pre-cast flared ends, cast-in-place structures, gabions, riprap, handrails, grates, etc.), the instability factors on the surrounding slopes, the erosion caused by sewer or creek flows, and other relevant information to assess the level of damage (major, moderate, minor, or no damage).

In addition to the level of damage, notes were made on the size of the outfall, accessibility to complete rehabilitation works, public safety, environmental issues, potential to affect infrastructure, and ongoing maintenance. All outfalls were scored in terms of their status, and a list showing priority ranking was prepared.

Table 1 provides the summary of the number of outfalls by level of damage.

Table 1: Summary Statistics for All Outfalls – Bear Creek Corridor

Level of Damage	No. Outfalls
Major	14
Moderate	13
Minor	22
No damage	9
Missing / Decomissioned	8
Total inspected	66

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1 Introduction

The City of Grande Prairie (the City) commissioned Matrix Solutions, Inc. (Matrix) in association with Westhoff Engineering Resources, Inc. (Westhoff) to provide engineering services for the Bear Creek Corridor Assessment. The project has four main components: geohazard assessment, outfall assessment, floodplain hazard mapping, and setback limits for development along Bear Creek upstream of the old City limits.

Westhoff conducted the outfall assessment component of the project with a representative from Matrix during the fieldwork. The initial scope included the inspection of about 30 outfalls; however, there were many more outfalls as identified in the report by ParklandGeo in 2009. Therefore, Matrix and the City agreed to conduct the inspection of all stormwater outfalls along Bear Creek within the City limits. Upon completion, a total of 66 outfall locations were documented.

The scope of work for the outfall assessment included the following:

- Develop a safe plan for the site inspection as per Matrix Standards;
- Undertake a shoreline-based inspection based on information provided by the City, and complete a level of damage assessment;
- Rank each outfall, and prioritize the outfalls that are in need of repair; and
- Report the observations.

The format of this report is as follows:

- Section 2 describes the methodology of the inspections and the approach for developing a priority ranking for each outfall.
- Section 3 provides a summary list of those outfalls with major, moderate, minor, and no damage.
- Section 4 provides a detailed description of the outfalls that have major damage.
- Section 5 provides a detailed description of those outfalls that have moderate damage.
- Section 6 provides the priority ranking for repairs.

1.1 Project Site

The Project Site encompasses the Bear Creek Corridor within the City limits. Figure 1 shows a plan view of the outfall locations.

2 Methodology

2.1 Overview of the Outfall Inspections

The outfall inspections assess the condition of each stormwater outfall on Bear Creek and prioritize the repair works.

The City provided the previous stormwater outfall report prepared by ParklandGeo in 2009 (also available on the City website). The report was used to provide background information as it contained inspection findings and location of the outfalls. The locations were used to prepare a geo-referenced map of the outfalls, which was used to find the outfalls in the field using smartphone mapping apps.

Figure 1 to Figure 7 in Appendix A show the location of the 66 outfalls visited on Bear Creek. The site inspection was conducted in October 2017 and consisted of the following:

- Vehicle access to selected locations and shoreline-based inspections of the 60 outfalls were identified on the inspection report by ParklandGeo (2009). Six additional outfalls were inspected: three were found during field observations and three outfalls were identified by the City Project Manager.
- Eight outfalls were not found by visual inspection. The current status of these outfalls was investigated by the City PM during a site meeting on October 4th, 2017. After the meeting, seven outfalls were presumed to be decommissioned or abandoned, and one was found to be buried. A City crew was dispatched to clean up the area, so the inspection could be completed.
- The outfall identification numbering from the 2009 report was kept the same to ease cross-referencing and aid any future consultation. A consecutive numbering ID was assigned after the last outfall registered in the 2009 report to identify new outfalls.
- The location coordinates were updated for those outfalls that were new or had inaccurate or missing coordinates. Updated coordinates are highlighted in yellow in the Field Notes (Appendix B).
- The level of damage was the primary assessment of the inspection (i.e., major, moderate, minor, or no damage) based on the status of the pipe, apron, headwall, wingwalls, railing, permanent erosion and sediment control (ESC) measures, erosion issues caused by sewer or creek flows, and an overview of the possible issues related to slope stability.
- The following were also assessed for each outfall: access restriction for rehabilitation works, risk of affecting nearby infrastructure, size of the outfall catchment, potential safety hazards, and maintenance and environmental issues.
- Photographs were taken at each outfall location. Photographs and processed information from the field inspection were included in the KML file for visual consultation using Google Earth.

2.2 Outfall Level of Damage Assessment

To evaluate the level of damage of an outfall, Westhoff reviewed the assessment matrix presented in the 2009 report. Four levels of outfall conditions were used: critical, high, improvement, and monitor. The conditions were based on whether immediate action was required and the cost of the repair works.

The current assessment will be exclusively based on the visual inspection findings. No cost estimates are incorporated.

Major Damage

Outfalls are either not functioning according to the original design or are partially functioning. They are likely to fail or cease to function if repair works are not conducted soon. Major works or complete reconstruction is usually required at this level of damage.

Moderate Damage

Outfalls are currently functioning or partially functioning, but there is some level of damage to the outfall or adjacent river bank or bed. It is possible that the outfall condition will worsen if no action is taken over a 1- to 5-year term.

Minor Damage

Outfalls have minor deficiencies, which are relatively easy to repair; e.g., there is minor local scouring around the structure or there is poor vegetation coverage along the channel. There is no compromise to the capacity or functionality of the outfall as observed.

No Damage

Outfalls are currently functioning with no observable deficiencies. Routine monitoring is recommended for these outfalls as part of a regular outfall maintenance schedule.

2.3 Priority Ranking of Outfalls

In addition to the level of damage, five additional assessment criteria were considered. Weighting factors were assigned to determine the priority ranking for each outfall. Thus, an order for repairs was determined. Table 2 summarizes the criteria weighting system, noting that each assessment criterion was weighted according to its relative importance. The associated score was between 1 and 10. The most heavily weighted criteria were those affecting public safety, the potential to affect infrastructure, and the extent of the damage at the outfall.

The weighted scores were then added to give the total score for the outfall.

Table 2: Assessment Criteria List and Weighting System

Assessment Criterion	Weighting
The potential to affect infrastructure	10
The size of the catchment relative to the outfall	5
The potential to affect public safety	10
Environmental considerations	3
Ongoing maintenance issues	4
Level of damage	10

2.3.1 The potential to affect infrastructure criterion

Infrastructure can be affected by outfall issues. Table 3 presents the scoring system for this criterion considering the type of adjacent infrastructure.

Table 3: Scoring System for the Potential to Affect Infrastructure Criterion

Score	Description of Critical Land Use in the Catchment	Example Outfall
0	No infrastructure (e.g., fields)	37
3	Recreational areas (e.g., Muskoseepi Park), public attractions (e.g., museum), and public buildings (e.g., churches)	16
7	Commercial, industrial areas, and main roads (e.g., 100 St)	19
10	Hospitals, water, and wastewater treatment plants	-

2.3.2 The size of the catchment relative to the outfall criterion

If the contributing catchment area is large relative to the outfall, more issues could be caused if the outfall is malfunctioning. The size of the sewer at the outfall was assumed to be proportional to the catchment area to define the scoring system for this criterion. As described below, the larger the sewer size, the higher the score.

Table 4: Scoring System for the Size of Catchment Relative to the Outfall Criterion

Score	Outfall Size Range (mm)	Example Outfall
2	≤300	20
4	301-600	41
6	601-1000	23
8	1001-1400	37
10	>1400	24

2.3.3 The potential to affect public safety criterion

This criterion ranks the likelihood that damage at the outfall will affect public safety. A high score is assigned when public safety could be compromised.

Table 5: Scoring System for the Potential to Affect Public Safety Criterion

Score	Description of Public Safety Hazard and Consequence	Example Outfall
0	Minimal risk to the public other than normal hazards related to all stormwater outfalls.	58
3	Minor damage to the outfall, the outfall is difficult to access or remote, unlikely to cause injury to general public.	43
7	Moderate or minor damage to the outfall, public may come in close proximity to the outfall, could cause injury to an unaware general public.	39
10	Major damage to the outfall, unstable slope in the vicinity of the outfall, general public in close proximity to the damaged outfall, could cause significant injury to the public, the outfall should be cordoned off until repaired.	5

2.3.4 Environmental considerations criterion

Higher scores indicate a greater negative impact on fish, wildlife, and the riparian corridor.

2.3.5 Ongoing maintenance issues criterion

More ongoing maintenance efforts are required for the outfalls that are susceptible to being blocked by sediments or submerged. Table 6 summarizes the scoring system for this criterion.

Table 6: Scoring System for the Ongoing Maintenance Issues Criterion

Score	Description of Potential Maintenance Issue	Example Outfall
0	No maintenance issues	2
3	Downstream channel requires maintenance	46
7	Outfall was overgrown or there was vegetation build up at the time of the site visit	26
10	Stormwater outfall was blocked or partially blocked with sediment.	19

2.3.6 Level of damage criterion

A higher score is assigned for outfalls that have a greater level of damage. Table 7 shows the scoring system for this criterion.

Table 7: Scoring System for the Level of Damage Criterion

Score	Damage Classification	Example Outfall
0	No Damage	64
3	Minor Damage	54
7	Moderate Damage	13
10	Major Damage	41

3 Summary of Outfalls within Each Damage Classification

Westhoff inspected a total of 66 outfalls on Bear Creek within the City limits. As described in the following sections, 14 outfalls were classified as having major damage, 13 outfalls had moderate damage, 22 had minor damage, and 9 outfalls had no damage. Section 3.5 provides a list of the 8 outfalls that were decommissioned or not found during the inspection.

3.1 Summary List of Outfalls with Major Damage

Table 8 lists the 14 outfalls that had major damage, and Section 4 provides details of the outfall damage and a summary of the proposed repairs for each outfall.

Table 8: Summary of Outfalls with Major Damage

No.	Outfall ID
1	1
2	5
3	8
4	14
5	19
6	24
7	28

No.	Outfall ID
8	33
9	39
10	41
11	44
12	50
13	52
14	53

3.2 Summary List of Outfalls with Moderate Damage

Table 9 lists the 13 outfalls that had moderate damage, and Section 5 provides details of the outfall damage and a summary of the proposed repairs for each outfall.

Table 9: Summary of Outfalls with Moderate Damage

No.	Outfall ID
1	10
2	13
3	17
4	20
5	25
6	30
7	34

No.	Outfall ID
8	37
9	40
10	46
11	48
12	56
13	59

3.3 Summary List of Outfalls with Minor Damage

Table 10 lists the 22 outfalls that had minor damage.

Table 10: Summary of Outfalls with Minor Damage

No.	Outfall ID
1	2
2	6
3	7
4	9
5	12
6	15
7	16
8	18

No.	Outfall ID
9	21
10	23
11	26
12	27
13	42
14	43
15	45
16	51

No.	Outfall ID
17	54
18	55
19	57
20	58
21	61
22	65

3.4 Summary List of Outfalls with No Damage

Table 11 lists the 9 outfalls that had no damage.

Table 11: Summary of Outfalls with No Damage

No.	Outfall ID
1	3
2	11
3	22
4	35
5	60

No.	Outfall ID
6	62
7	63
8	64
9	66

3.5 Decommissioned and Missing Outfalls

Table 12 lists the 8 outfalls that were included in the 2009 report but could not be found during the 2017 inspection. In the report, Outfalls # 4 and 14 were reported as not found; Outfall # 47 was indicated as abandoned; and no inspection report was included for Outfalls # 43, 49, 59, and 60. The assessment team met the City PM during the fieldwork to review the list of missing outfalls. The City PM agreed to assume that Outfall # 4 was buried and the other seven were decommissioned.

Table 12: Decommissioned and Missing Outfalls

No.	Outfall ID
1	4
2	29
3	31
4	32

No.	Outfall ID
5	36
6	38
7	47
8	49

3.6 Types of failure

Table 13 summarizes the types of failure identified during the outfall inspections. Sewer erosion, defined as the flow exiting the outfall structure and causing erosion immediately downstream of the physical structure, was present as one of the causes of failure in outfalls. Creek erosion, defined as creek flow causing erosion at or surrounding the outfall structure, was identified at several outfalls. Other noted types of failure were slope stability, pipe damage, structural damage on the outlet structure, and possible damage along the storm sewer line.

Table 13: Types of Failure

Type of Failure	Total # of outfalls
Sewer erosion	25
Sewer erosion, creek erosion	3
Sewer erosion, creek erosion, structural damage	1
Sewer erosion, sewer/pipe damage	2
Creek erosion, slope stability	2
Creek erosion, slope stability, sewer/pipe damage	1
Slope stability	3
Slope stability, sewer/pipe damage	1
Sewer/pipe damage	4
None	16
Unknown (not inspected)	8
Grand Total	**66**

Table 14 presents general recommendations depending on the type of failure. These recommendations, combined with the specific notes, summarize the proposed corrective actions for each outfall.

Table 14: Recommended Actions per Type of Failure

Type of Failure	Recommended Actions
Sewer erosion	• Investigate the cause of the problem (e.g., excessive stormwater flow or design problems at the outfall). Consider completion of hydraulic assessment to determine the extent of the protection, size of rock material and/or other proposed measures • Inspect scour beneath the apron and along the discharge channel • Identify pipe exposure and whether erosion has extended to the surrounding areas, • Clean up and remove damaged elements • Complete engineering designs as required to re-construct base and protect the channel and surrounding bank
Creek erosion	• Investigate the cause of the problem (e.g., creek under morphological changes or local high velocity and shear stress) • Include creek morphology assessment in those areas where banks experience changes because of creek re-alignments, widening or shortening processes and • Provide the scour protection at the toe to stabilize slope below the outfall
Slope stability	• Conduct geotechnical assessment to determine cause and propose a long-term solution • Integrate the outfall repairs with the recommended works to stabilize the slope
Sewer/pipe damage	• Investigate the cause(s) of the pipe failure • Replace pipe sections that are severely damaged • Patch concrete holes in pipes where structural condition is not yet compromised to prevent rebar corrosion, public safety hazards, and sediments entering the sewer system • Reconnect pipe sections that have been separated from the sewer line or outfall
Structural damage	• Investigate cause of damage to determine long-term solution • Replace damaged structures where pre-cast flared ends are broken or cast-in-place outfalls have failed as a result of external constraints (e.g., undermining, slope sinking, apron erosion)

4 Detailed Description of Outfalls with Major Damage

The following section provides detailed descriptions of the outfalls that have major damage and the recommended repairs. The outfalls with major damage are listed in Table 8.

4.1 Outfall 1

Inspected: 2-Oct-2017

Description:

Outfall 1 is located on the left bank of Bear Creek, approximately 15 m west of the pathway. There is good access from the parking lot west of 108 St and 117 Ave.

Outfall 1 had a 1500 mm diameter corrugated steel pipe connected to a gabion outfall structure that discharged directly into the creek. The gabion structure of the outfall has partially settled because of the scour action at the base. Wingwalls and hand rails leaned toward the creek due to undercutting.

A similar condition was identified during the 2009 inspection and at that time the outfall was classified as Category 3: Improvement.

Types of Failure Identified:

Sewer erosion, creek erosion, and structural damage.

Recommended Actions:

- Remove gabion baskets from headwall and wing walls
- Engineer a design so that the toe is protected from scour action and a base is provided for the outfall and pipe
- Replace the outfall structure as per the engineering design
- Refer to Table 14 for general recommended actions based on type of failure

4.2 Outfall 5

Inspected: 2-Oct-2017

Description:

Outfall 5 is located on the left bank of Bear Creek, approximately 10 m south of and behind the Grande Prairie Regional Tourism Association Building. There is good access from the parking lot of the building.

Outfall 5 had an 800 mm diameter corrugated steel pipe that discharged directly onto the creek slope. The pipe was surrounded by dense vegetation and was buried below the spring line. A significant slope stability issue was observed uphill, caused by soils slumping down. A big hole was observed in the backyard of the building because of the slope failure. The affected area was isolated by a fence at the time of the inspection.

The 2009 inspection report classified Outfall 5 as Category 2: High.

Types of Failure Identified:

Slope stability, sewer/pipe damage.

Recommended Actions:

Immediate attention is required due the proximity of the damages to the building and exterior areas.

- Conduct a detailed inspection of the sewer line to determine the current condition and potential damage along the line affecting the slope stability
- Assess slope stability to determine causes of failure
- Refer to Table 14 for general recommended actions based on type of failure

4.3 Outfall 8

Inspected: 2-Oct-2017

Description:

Outfall 8 is located on the left bank of the reservoir, south of Dewit Dr. There is good access from an existing pathway that runs along the left bank of the reservoir.

Outfall 8 had a 600 mm diameter corrugated steel pipe that discharged onto the slope. The pipe was corroded at the bottom, allowing sewer flow to drain underneath the pipe, eroding the rock material at the base of the pipe. Approximately 3 m of pipe were exposed. Sinking soils were observed surrounding the outfall.

The 2009 inspection report classified Outfall 8 as Category 2: High. However, the pipe material and outfall appearance from past pictures were different compared to the current finds.

Types of Failure Identified:

Sewer erosion.

Recommended Actions:

- Replace the segment of pipe that is corroded
- Reconstruct the base for the pipe and install a permanent ESC cover at the outlet
- Assess slope stability to identify soil failure patterns
- Refer to Table 14 for general recommended actions based on type of failure

4.4 Outfall 14


Inspected: 6-Oct-2017

Description:

Outfall 14 is located on the left bank of Bear Creek at Muskoseepi Park north of 102 Ave. There is good access from an existing pathway that runs along the left bank of the creek.

Outfall 14 had a 300 mm diameter concrete pipe with a concrete outfall at the end that discharged directly into the creek. The outfall was surrounded by dense vegetation, and bank erosion was observed along the upper slope; soils slumped down in some locations. The wingwalls were becoming detached from the headwall as a result of the sinking slope.

During the inspection, part of the vegetation was removed behind the outfall to observe some holes. After the vegetation was removed, a significant orange colored stream began to flow around the concrete structure, suggesting a pipe breakage behind the outfall.

Due to the difficulty in finding the outfall, the assistance of a City crew was required to identify it. Outfall 14 was not found during the 2009 inspection.

Types of Failure Identified:

Creek erosion, slope stability, sewer/pipe damage.

Recommended Actions:

- Clear outfall from surrounding vegetation and conduct a detailed inspection along the pipeline to verify if the pipe is broken
- Investigate source of orange matter observed in the sewer flow
- Regrade and repair outfall damages and reinstall/replace outfall structure; provide permanent ESC protection along the channel
- Refer to Table 14 for general recommended actions based on type of failure

4.5 Outfall 19

Inspected: 6-Oct-2017

Description:

Outfall 19 is located on the right bank of Bear Creek, north of 100 Ave. There is good access from the GP Museum access road.

Outfall 19 had a 300 mm diameter corrugated steel pipe that discharged directly onto the creek slope. The pipe was completely buried, and therefore, the assistance of the City was required to locate and partially uncover it to complete the visual inspection. Sediments had accumulated in the pipe.

The 2009 inspection report classified Outfall 19 as Category 3: Improvement.

Types of Failure Identified:

Unknown, the pipe could be buried as a result of the surrounding landscape works.

Recommended Actions:

- Uncover the pipe and remove sediment; conduct a detailed inspection to identify additional issues and proceed with repair works as needed
- Provide ESC protection at the outlet due the steep slope at this location

4.6 Outfall 24

Inspected: 6-Oct-2017

Description:

Outfall 24 is located on the left bank of Bear Creek, south of the pedestrian bridge. There is good access from an existing pathway that runs along the left bank of the creek.

Outfall 24 had a 1500 mm diameter concrete pipe that discharged directly into the creek. Scour was observed along the concrete surface of the apron. The gabion baskets along the discharge channel were broken and the riprap was partially washed out. Garbage was stuck on the gabion wires.

Water marks showed that high flows surpassed the wingwall height, eroding the soils at the back of the outfall. In addition, some gabion baskets leaned down the slope because of the undermining action of the sewer flow.

The 2009 inspection report classified Outfall 24 as Category 1: Critical.

Types of Failure Identified:

Sewer erosion.

Recommended Actions:

- Regrade discharge channel, place base material at the eroded locations, and repair damaged gabion baskets and mattresses along the wingwalls and discharge channel
- Patch rills along the concrete apron and pipe to avoid rebar exposure
- Remove garbage from the gabions and mattresses
- Refer to Table 14 for general recommended actions based on type of failure

4.7 Outfall 28

Inspected: 3-Oct-2017

Description:

Outfall 28 is located on the left bank of Bear Creek, south of 93 Ave. There is good access from 102 St.

Outfall 28 had a 600 mm diameter corrugated steel pipe that discharged directly into a round pool and channel connected to Bear Creek. The pipe was overhung as a result of the slope scour. Significant erosion around the pipe and on the slopes resulted in vertical banks more than 2 m high.

The 2009 inspection report classified Outfall 28 as Category 1: Critical.

Types of Failure Identified:

Sewer erosion.

Recommended Actions:

- Regrade the slope to stabilize bank erosion and the vertical walls around the pipe
- Provide a concrete outfall structure sized in relation to the size of the pipe and sewer flows
- Include shore and channel protection in the outfall design
- Refer to Table 14 for general recommended actions based on type of failure

4.8 Outfall 33


Inspected: 4-Oct-2017

Description:

Outfall 33 is located on the left bank of Bear Creek, east of 90 Ave. There is good access from 102 St.

Outfall 33 had a 250 mm diameter concrete pipe that discharged onto a vegetated slope. The overhanging pipe was broken at the end, and approximately 1 m of the pipe was exposed.

The 2009 inspection report classified Outfall 33 as Category 4: Monitor. However, the condition of the outfall has significantly worsened since 2009 when the pipe was not exposed nor damaged.

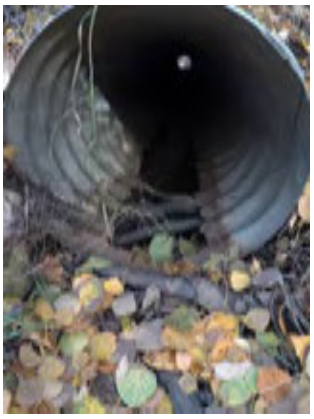
Types of Failure Identified:

Sewer/pipe damage.

Recommended Actions:

- Replace the section of broken pipe and regrade around the pipe to provide a base for the outlet
- Refer to Table 14 for general recommended actions based on type of failure

4.9 Outfall 39

Inspected: 4-Oct-2017

Description:

Outfall 39 is essentially the outlet of a culvert crossing under the existing pathway. There is good access from an existing pathway that runs along the Muskoseepi Park.

Outfall 39 had a 400 mm diameter corrugated steel pipe that discharged into a tributary channel of Bear Creek. The bottom of the pipe was severely rusted and broken; hence, stormwater flowed beneath the pipe. A vertical slope was observed at the outlet, presumably as a result of the sewer flow scour. Cracking of the asphalt was identified perpendicular to the pathway alignment above the culvert.

The 2009 inspection report classified Outfall 39 as Category 3: Improvement. Most of the same deficiencies were detected at that time.

Types of Failure Identified:

Sewer erosion, sewer/pipe damage.

Recommended Actions:

- Replace culvert because of severe corrosion
- Regrade and install permanent ESC protection on both sides of the culvert
- Consider installing handrails on both sides of the pathway to prevent users from falling in the channel
- Refer to Table 14 for general recommended actions based on type of failure

4.10 Outfall 41

Inspected: 5-Oct-2017

Description:

Outfall 41 is located on the left bank of Bear Creek, northwest of 79 Ave. There is poor land access as the vegetation is dense from the pathway to the outfall location.

Outfall 41 had a 400 mm diameter corrugated steel pipe that discharged directly into Bear Creek. Most of the damage to the outfall was related to slope instability and erosion near the creek. Scour at the toe resulted in the slumping of the surrounding soils. The concrete structure of the outfall was collapsing because of the loss of material at the base. The pipe was corroded, broken at the top and bottom, and was becoming disconnected from the outfall.

The 2009 inspection report classified Outfall 41 as Category 3: Improvement. Most of the same deficiencies were also detected at that time, and the report indicated that slope failure had been observed since 2007.

Types of Failure Identified:

Creek erosion, slope stability.

Recommended Actions:

- Conduct a geotechnical assessment to determine further causes of bank instability to propose engineered solution
- Replace the damaged sections of the pipe, concrete outfall, and gabion mattresses.
- Refer to Table 14 for general recommended actions based on type of failure

4.11 Outfall 44

Inspected: 5-Oct-2017

Description:

Outfall 44 is located on the right bank of Bear Creek, east of 75a Ave. There is fair land access from an existing pathway that runs along the Muskoseepi Park.

Outfall 44 had a 1200 mm diameter corrugated steel pipe that discharged directly into a round pool and channel connected to Bear Creek. Approximately 2 m of the pipe was exposed due to the undermining at the base; significant erosion was observed around the pipe and slopes resulting in vertical banks more than 2 m high.

Along the discharge channel, riprap, concrete debris, and broken wires from gabions blocked half of the creek channel. Bent and broken vegetation was a sign of the strength of high sewer flows.

The 2009 inspection report classified Outfall 44 as Category 3: Improvement. The issues mentioned above were also identified in 2009, but they were less severe at that time.

Types of Failure Identified:

Sewer erosion, creek erosion.

Recommended Actions:

- Remove the riprap and debris from the creek to ensure unrestricted flow and reduce potential scour of the left bank to minimize changes on the creek channel
- Regrade the slope to stabilize bank erosion and regrade the vertical walls around the pipe
- Provide a concrete outfall structure due to the size of the pipe and sewer flows
- Include shore and channel protection in the outfall design
- Refer to Table 14 for general recommended actions based on type of failure

4.12 Outfall 50

Inspected: 5-Oct-2017

Description:

Outfall 50 is located on the left bank of Bear Creek, south of 68 Ave. There is good access from 100 St.

Outfall 50 had a 400 mm diameter pipe and a concrete flared end that discharged into a ditch. The outfall was buried above the springline by sediments from earthworks in progress (part of a pathway construction parallel to 68 Ave). The pipe material could not be confirmed under the outfall conditions. The grate was obstructed by garbage.

The 2009 inspection report classified Outfall 50 as Category 1: Critical. Site conditions have changed significantly as a result of the construction.

Types of Failure Identified:

None.

Recommended Actions:

- Conduct a pipe and outfall inspection after the completion of the construction and complete rehab works as required
- Remove garbage from grate

4.13 Outfall 52

Inspected: 5-Oct-2017

Description:

Outfall 52 is located on the right bank of Bear Creek, south of 68 Ave. There is good access from an existing pathway.

Outfall 52 had a 300 mm diameter PVC pipe with a concrete flared end that discharged onto the creek slope. Similar to Outfall 50, Outfall 52 was affected by the ongoing pathway construction parallel to 68 Ave. Bare soils were exposed around and below the outfall. The flared end was severely broken, leaving the rebar exposed and corroding.

Rill erosion was observed below the outfall, along the bare soils on the slope.

The 2009 inspection report classified Outfall 52 as Category 4: Monitor. Site conditions have changed significantly as a result of the construction.

Types of Failure Identified:

Sewer erosion, sewer/pipe damage.

Recommended Actions:

- Conduct a pipe inspection after the completion of the construction
- Regrade and provide vegetation coverage on the slope
- Replace the flared end
- Provide ESC protection along the discharge channel
- Refer to Table 14 for general recommended actions based on type of failure

4.14 Outfall 53

Inspected: 5-Oct-2017

Description:

Outfall 53 is located on the left bank of Bear Creek, north of the pedestrian bridge. There is good access from an existing pathway.

Outfall 53 had a 300 mm diameter and a PVC pipe with a concrete flared end that discharged onto the creek slope. The flared end was disconnected from the pipe and severely damaged, and the grate was blocked by cobbles.

Moderate erosion around the outfall suggested some slope stability issues at this location.

A shiny, thick, yellow fluid was observed discharging from the sewer.

The 2009 inspection report classified Outfall 53 as Category 4: Monitor as no major issues were observed at that time.

Types of Failure Identified:

Sewer erosion.

Recommended Actions:

- Regrade, replace flared end, and clean grate from debris
- Monitor erosion along the channel once unrestricted flow is reestablished
- Investigate source of yellow fluid and verify if sewer is connected to a sanitary line or some other line that is not stormwater
- Refer to Table 14 for general recommended actions based on type of failure

5 Detailed Description and Recommended Action for Outfalls with Moderate Damage

5.1 Outfall 10

Outfall 10 is located on the right bank of the reservoir, northeast of the Grande Prairie Regional College. There is good access from an existing pathway.

Outfall 10 had a 450 mm diameter PVC pipe with a concrete structure at the outlet that discharged into a narrow channel before the reservoir. The rock material on the apron was washed out, leaving exposed the concrete base and a synthetic fabric layer.

The recommended actions include reviewing the outfall design and current flow conditions to determine any design adjustment for reconstructing the apron. In addition, an extension of the permanent ESC measures along the discharge channel shall be evaluated to protect the slopes from scour action by sewer flows.

The 2009 inspection report classified Outfall 10 as Category 2: High.

5.2 Outfall 13

Outfall 13 is located on the left bank of Bear Creek, west of 105 Ave. There is good access from an existing pathway that runs along the left bank of the creek.

Outfall 13 had a 1000 mm diameter PVC pipe with a fiberglass flared end that discharged directly into the creek. Riprap around the flared end and along the discharge channel was partially washed out. The flared end was exposed, and the surrounding land was not well graded. Minor damage on the grate was observed.

The recommended actions include regrading backfill around the flared end to prevent scour from behind and below the structure, placing riprap along the discharge channel to control the scour from the sewer, and providing vegetation coverage on the bare patches around the outfall.

The 2009 inspection report classified Outfall 13 as Category 3: Improvement. The PVC pipe and fiber glass flared end were installed after the 2009 assessment.

5.3 Outfall 17

Outfall 17 is located on the right bank of Bear Creek, northeast of the South Peace Regional Archives Society building. There is good access from an existing pathway and a pedestrian bridge.

Outfall 17 had an 800 mm diameter corrugated steel pipe with a concrete outlet structure that discharged directly into the creek. Creek and sewer flows eroded the underside of the apron. The surrounding soils have slumped as a result of the scour by the creek at the toe.

The recommended actions include reconstructing the base of the apron and routinely monitoring the outfall condition given the slope stability issues.

The 2009 inspection report classified Outfall 17 as Category 2: High.

5.4 Outfall 20

Outfall 20 is located on the left bank of Bear Creek, between 99 Ave. and 100 Ave. There is good access from an existing pathway that runs along the left bank of the creek.

Outfall 20 had a 300 mm diameter corrugated steel pipe that discharged directly into the creek. Approximately 2 m of the pipe was crushed, possibly by excessive loading from above. Light vegetation coverage was present along the channel.

The recommended actions include replacing the damaged segment of the pipe, providing additional vegetation cover, and monitoring scour along the channel.

The 2009 inspection report classified Outfall 20 as Category 1: Critical. The pipe could not be found at that time, so it was assumed to be blocked.

5.5 Outfall 25

Outfall 25 is located on the right bank of Bear Creek, south of the pedestrian bridge. There is poor site access due a steep slope and dense vegetation.

Outfall 25 had an 800 mm diameter corrugated steel pipe that discharged directly into the creek. The pipe looked dry at the time of the inspection; however, water was flowing underneath the pipe to the apron surface. Scour rills were observed along the apron and undercutting beneath the apron. Minor corrosion was present at the bottom of the pipe.

The recommended actions include conducting a detailed assessment to determine the source of the flow shown on the apron and the flow's relation to the undermining at the base, and inspecting the area to determine if there is water leakage along the sewer line before the outlet.

The 2009 inspection report classified Outfall 25 as Category 2: High.

5.6 Outfall 30

Outfall 30 is located on the left bank of Bear Creek, west of 92 Ave. There is good access from 102 St.

Outfall 30 had a 300 mm diameter PVC pipe that discharged into a channel along a green area. The pipe was undercut at the base. Some rill erosion was observed along the channel leaning to the downhill grassed area. The outlet was hidden by dense grass around it; the grass was a hazard to users of the public pathway and green areas.

The recommended actions include regrading, installing permanent ESC protection along the discharge channel, providing the outlet with a flared end to dissipate sewer flows, and fencing the outfall to prevent public access.

The 2009 inspection report classified Outfall 30 as Category 1: Critical.

5.7 Outfall 34

Outfall 34 is located on the left bank of Bear Creek, northwest of 89 Ave. There is poor site access due to a steep bank, fallen trees, and dead vegetation.

Outfall 34 had a 400 mm diameter corrugated steel pipe that discharged onto a green area. The pipe was partially blocked by soil hanging from vegetation roots. Scour, which was likely caused by sewer flow and runoff along the bare areas, was observed around the pipe.

The recommended actions include clearing vegetation and blocking soils around the pipe; regrading and providing a flared end and ESC protection on the channel; and possibly realigning the sewer, tying it to the collector draining to Outfall 35, located less than 10 m away.

The 2009 inspection report classified Outfall 34 as Category 1: Critical.

5.8 Outfall 37

Outfall 37 is located on the right bank of Bear Creek, west of 88 Ave. There is poor site access due to the outfall being a long distance from the closest pathway and road.

Outfall 37 had a 1200 mm diameter PVC pipe with a recently built concrete outlet structure (concrete stamp indicates 2015) that discharged into a tributary channel to Bear Creek. Riprap along the discharge channel was partially washed out; furthermore, the channel turned at almost 180° causing high scour along the steep bank, which was barely vegetated.

The recommended actions include conducting a detailed engineering assessment to determine additional improvements. During the assessment, engineers should note that the riprap mattresses installed along the channel are being damaged under high sewer flows even though a baffled outlet exists at the outfall acting as an energy dissipator.

The 2009 inspection report classified Outfall 37 as Category 2: High. However, since this report, the outfall conditions have changed considerably as the outfall structure was replaced.

5.9 Outfall 40

Outfall 40 is located on the left bank of Bear Creek, south of 84 Ave. There is good access from an existing pathway that runs along the left bank of the creek.

Outfall 40 had a 450 mm diameter concrete pipe with a precast flared end that discharged onto a green area. Sediments built up above the springline, and the pipe was broken at the end, exposing some of the rebar.

The recommended actions include cleaning the pipe from sediments to ensure free flow from the sewer and repairing concrete or replacing the flared end to avoid further rebar corrosion.

The 2009 inspection report classified Outfall 40 as Category 2: High; the report described similar issues to the ones mentioned above.

5.10 Outfall 46

Outfall 46 is located on the left bank of Bear Creek, west of 75 Ave. There is good access from 100 St.

Outfall 46 had a 900 mm diameter PVC pipe with a concrete outlet structure that discharged directly into Bear Creek. Most of the deficiencies identified in the 2009 report have been addressed and a new outfall structure has been installed. However, erosion by the creek was still undercutting the toe of the slope, resulting in breaks in the concrete slab along the slope channel. The concrete slab was also becoming disconnected from the apron, so sewer flow was able to leak underneath the apron.

Approximately 20 m of creek bank protection with a vegetated concrete mattress was observed on each side of the outfall. In addition, although A-jacks were placed along the toe of the slope, some of them seemed to be washed out and the scour was becoming worse.

The recommended actions include, in the short term, installing a concrete joint filler between the apron and the concrete slab to prevent sewer flows from undermining the base of the concrete slab and reviewing previous geotechnical assessments to determine if further scour protection is needed at the toe of the slope.

The 2009 inspection report classified Outfall 46 as Category 1: Critical; however, the outfall has been replaced since the report.

5.11 Outfall 48

Outfall 48 is located on the left bank of Bear Creek, south of the pedestrian bridge. There is good access from an existing pathway that runs around the creek.

Outfall 48 had a 1200 mm diameter corrugated steel pipe with a concrete outlet structure that discharged directly into Bear Creek. The headwall and apron were disconnected from the pipe. Some concrete breakages and undermining occurred on the apron and wingwalls. Vegetation built up on the apron. Slope stability issues caused the gabion baskets along the upstream bank to sink. Moderate sewer erosion was also observed along the channel.

The recommended actions include conducting a geotechnical slope assessment to address the displacement of the outfall and surrounding bank, repairing concrete damages as a short-term action to prevent sewer flows from undermining the apron, and providing permanent ESC protection along the channel.

The 2009 inspection report classified Outfall 48 as Category 2: High; similar deficiencies were documented at that time.

5.12 Outfall 56

Outfall 56 is located on the left bank of Bear Creek, south of 84 Ave. There is good access from an existing pathway that runs around the creek.

Outfall 56 had a 450 mm diameter PVC pipe with a concrete flared end that discharged onto a green area. The flared end was disconnected from the pipe. Minor erosion was observed along the channel, which was partially covered by cobbles and vegetation; the vegetation cover could be a hazard for people walking around.

The recommended actions include reconnecting the flared end to the pipe, placing additional cobbles along the discharge channel to control erosion, and installing fencing or a sign to advise the public about the outfall location.

The 2009 inspection report classified Outfall 56 as Category 1: Critical.

5.13 Outfall 59

Outfall 59 is located on the left bank of the reservoir. There is good access from an existing pathway that runs along the left bank of the creek.

Outfall 59 had a 600 mm diameter corrugated steel pipe that discharged into a pool before the reservoir. Undermining below the pipe was possibly caused by sewer flow scour or by level fluctuation in the pool at the outlet. Local bank erosion was observed around the pipe as well.

The recommended actions include constructing an outfall structure or permanent erosion protection at the pipe outlet to dissipate energy from sewer flows and conducting routine monitoring to identify worsening erosion and prevent damage to the nearby pathway crossing.

The 2009 inspection report indicated the location of Outfall 59, however, no inspection report was included.

6 Priority Ranking List for Repair

Table 15 presents the proposed prioritization list for the outfall repairs. Weighting factors (WF) are indicated under each assessment criterion.

Table 15: Prioritization List for Outfall Repairs

Outfall ID (2017)	Initial Damage Classification	Potential to affect infrastructure (WF=10)	Size of the catchment (WF=5)	Public Safety (WF=10)	Environmental (WF=3)	Maintenance (WF=4)	Extent of damage (WF=10)	Total Score*	Priority Ranking
50	Major	7	4	7	2	10	10	306	1
5	Major	3	6	10	2	7	10	294	2
39	Major	3	4	7	2	3	10	238	3
1	Major	7	10	0	2	3	10	238	3
52	Major	7	2	0	5	10	10	235	5
44	Major	3	8	0	7	10	10	231	6
24	Major	3	10	0	5	7	10	223	7
19	Major	7	2	0	0	10	10	220	8
8	Major	7	4	0	3	3	10	211	9
53	Major	3	2	0	10	10	10	210	10
59	Moderate	3	4	7	2	3	7	208	11
40	Moderate	7	4	0	0	10	7	200	12
41	Major	3	4	0	3	10	10	199	13
14	Major	3	2	0	8	7	10	192	14
30	Moderate	3	2	7	0	3	7	192	14
56	Moderate	7	4	0	0	3	7	172	16
28	Major	3	4	0	3	3	10	171	17
48	Moderate	3	8	0	0	7	7	168	18
7	Minor	7	4	3	0	3	3	162	19
43	Minor	3	10	3	3	3	3	161	20
37	Moderate	0	8	0	3	10	7	159	21
46	Moderate	3	6	0	4	3	7	154	22
33	Major	3	2	0	0	3	10	152	23
18	Minor	7	8	0	0	3	3	152	23
25	Moderate	3	6	0	3	3	7	151	25
2	Minor	7	10	0	0	0	3	150	26
17	Moderate	3	6	0	2	3	7	148	27
13	Moderate	3	6	0	2	3	7	148	27
10	Moderate	3	4	0	2	3	7	138	29
34	Moderate	3	4	0	0	3	7	132	30
3	No damage	7	10	0	0	3	0	132	30
20	Moderate	3	2	0	2	3	7	128	32
51	Minor	3	4	3	2	3	3	128	32
54	Minor	3	4	0	10	3	3	122	34
23	Minor	3	6	0	0	7	3	118	35
21	Minor	3	4	0	2	7	3	114	36
42	Minor	3	4	0	2	7	3	114	36
6	Minor	3	2	3	0	3	3	112	38
16	Minor	3	2	0	0	10	3	110	39
26	Minor	3	4	0	0	7	3	108	40
55	Minor	3	4	0	0	7	3	108	40
58	Minor	3	4	0	0	7	3	108	40
12	Minor	3	4	0	2	3	3	98	43
15	Minor	3	4	0	2	3	3	98	43
57	Minor	3	4	0	2	3	3	98	43
61	Minor	3	4	0	2	3	3	98	43
66	No damage	3	6	0	2	7	0	94	47
9	Minor	3	4	0	0	3	3	92	48
45	Minor	3	6	0	0	0	3	90	49
65	Minor	3	4	0	0	0	3	80	50
63	No damage	7	2	0	0	0	0	80	50
27	Minor	3	2	0	0	0	3	70	52
62	No damage	3	6	0	2	0	0	66	53
11	No damage	3	4	0	0	3	0	62	54
60	No damage	3	2	0	0	3	0	52	55
35	No damage	3	4	0	0	0	0	50	56
64	No damage	3	4	0	0	0	0	50	56
22	No damage	3	2	0	0	0	0	40	58

*Total score is calculated by multiplying the individual scores by the weight of each criterion and then adding all the products

7 Bear Creek Morphological Changes

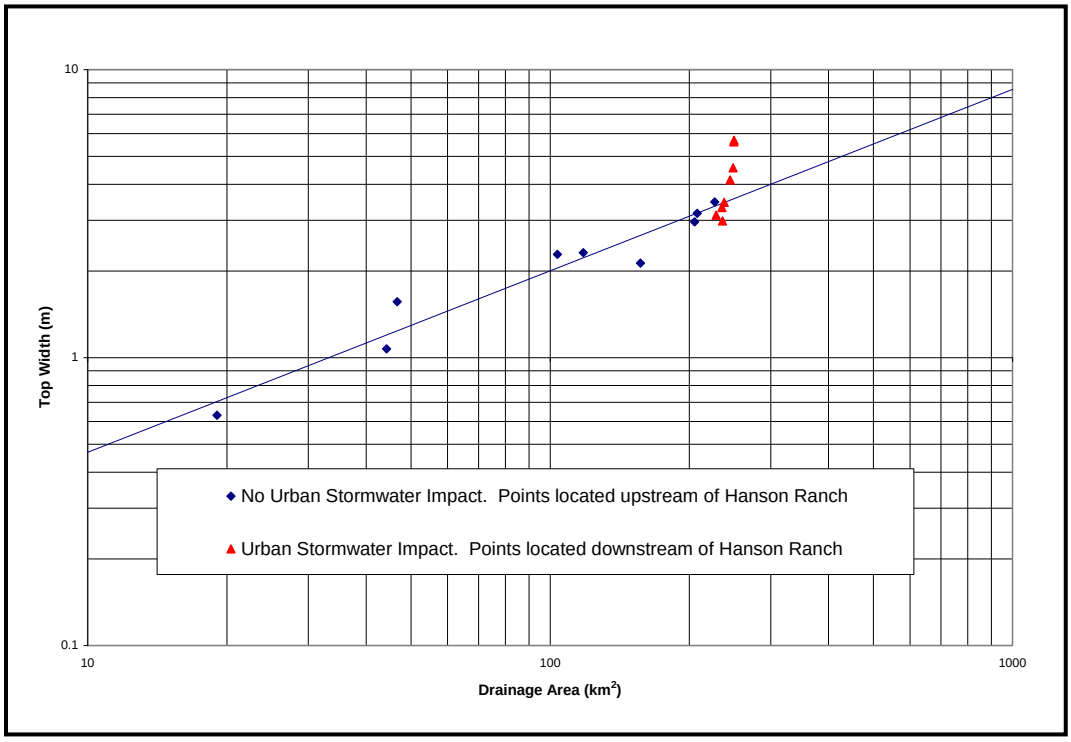
As described in the report, erosion due to the creek has caused the failure or damage of various outfalls. As this type of erosion may be local, a review of previous reports shows that, at least for some reaches, the creek may be undergoing a general morphological change.

Changes in channel width and depth are the effects of urbanization on creek morphology as has been widely reported in the literature. These changes affect the overall geometry of creek meanders and, depending on the magnitude of the urbanization, may create overall unstable bank conditions.

As recommended in this report, local protection against creek scour is required at various locations, but it should also be determined if the creek is currently under general unstable conditions. In this case, other measures for the entire creek may be required.

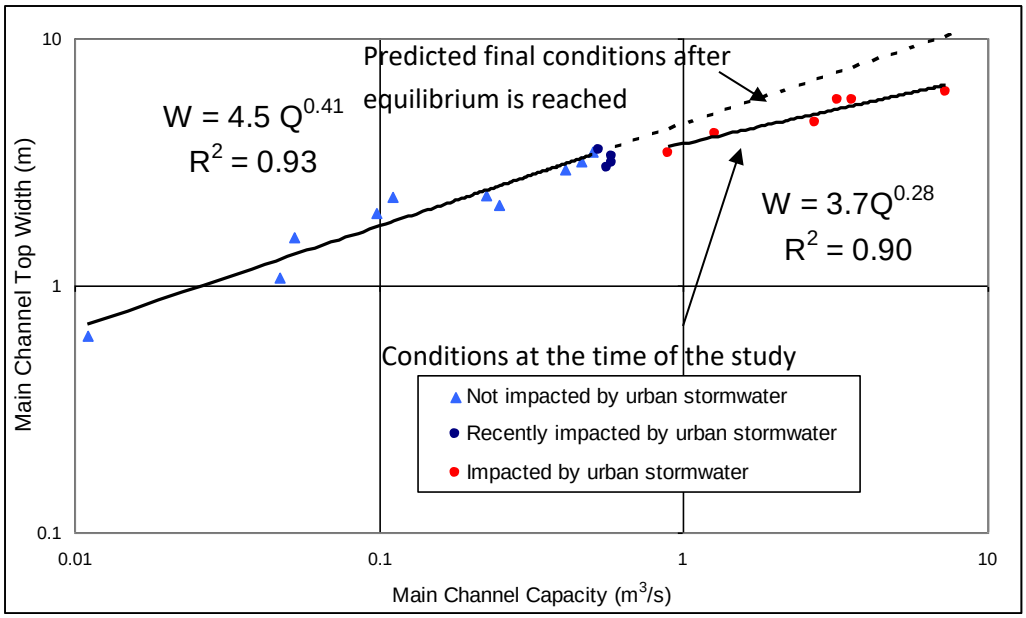
Graph 1 shows an example of how urbanization has changed the geometry of the West Nose Creek in Calgary. For urbanized reaches of the creek, the channel width is substantially greater than the trend for natural reaches.

Graph 1 Top Width as a Function of Drainage Area



Graph 2 shows how an overall widening process could be detected and final channel geometry be predicted. Red dots show the relationship between dominant discharge and channel width for urbanized reaches of the creek at the time of the study. The channel width at urbanized reaches was smaller than the trend of natural reaches. Field visits at the time of the study showed an overall erosion process along the banks of urbanized reaches.

Graph 2 Top Width as a Function of Dominant Discharge



In principle, four main categories of alternatives to address overall potential creek widening can be distinguished:

- Do nothing and leave the creek to adjust itself to the changing hydrologic regime; the creek will reach a new dynamic equilibrium in due time. Reaching a dynamic equilibrium could take 10 years or 100 years. The creek will only achieve this equilibrium once changes in the hydrologic regime have stabilized. Due to the continuing developmental pressures in the watershed, the hydrologic regime will continue to change, and hence, the channel and riparian areas will be subjected to ever-increasing runoff volumes and erosion.

- Pre-design the creek for future conditions. This option would require the pre-excavation of the creek to achieve future width conditions.

- Strengthen the riffle zones of the creek to stop deepening processes. This option would produce a general reduction in flow velocities and shear stress upstream of the riffles, thereby reducing the pressure on the outfalls at risk.

- Change the stormwater management design criteria to reduce flows to the creek. This option may be achieved by runoff volume control.

8 Conclusion and Recommendations

From the assessment, the following is concluded:

- A total of 66 outfall sites on Bear Creek were visited in October 2017. Out of the 66 outfalls, 58 were found and inspected and 8 were reported as decommissioned or not found.
- All the inspected outfalls were classified based on the level of damage. Fourteen outfalls were classified as having major damage, 13 were classified as having moderate damage, 22 were classified as having minor damage, and 9 had no damage.
- A priority ranking was completed based on the following criteria: level of damage, risk of affecting nearby infrastructure, size of the outfall catchment, potential safety hazards for the public, and maintenance and environmental issues.
- Sewer erosion was identified as the major cause of damage, followed by creek erosion. Other contributing factors were slope stability, pipe damage, structural damage on the outlet structure, and possible damage along the storm sewer line.

The following is recommended:

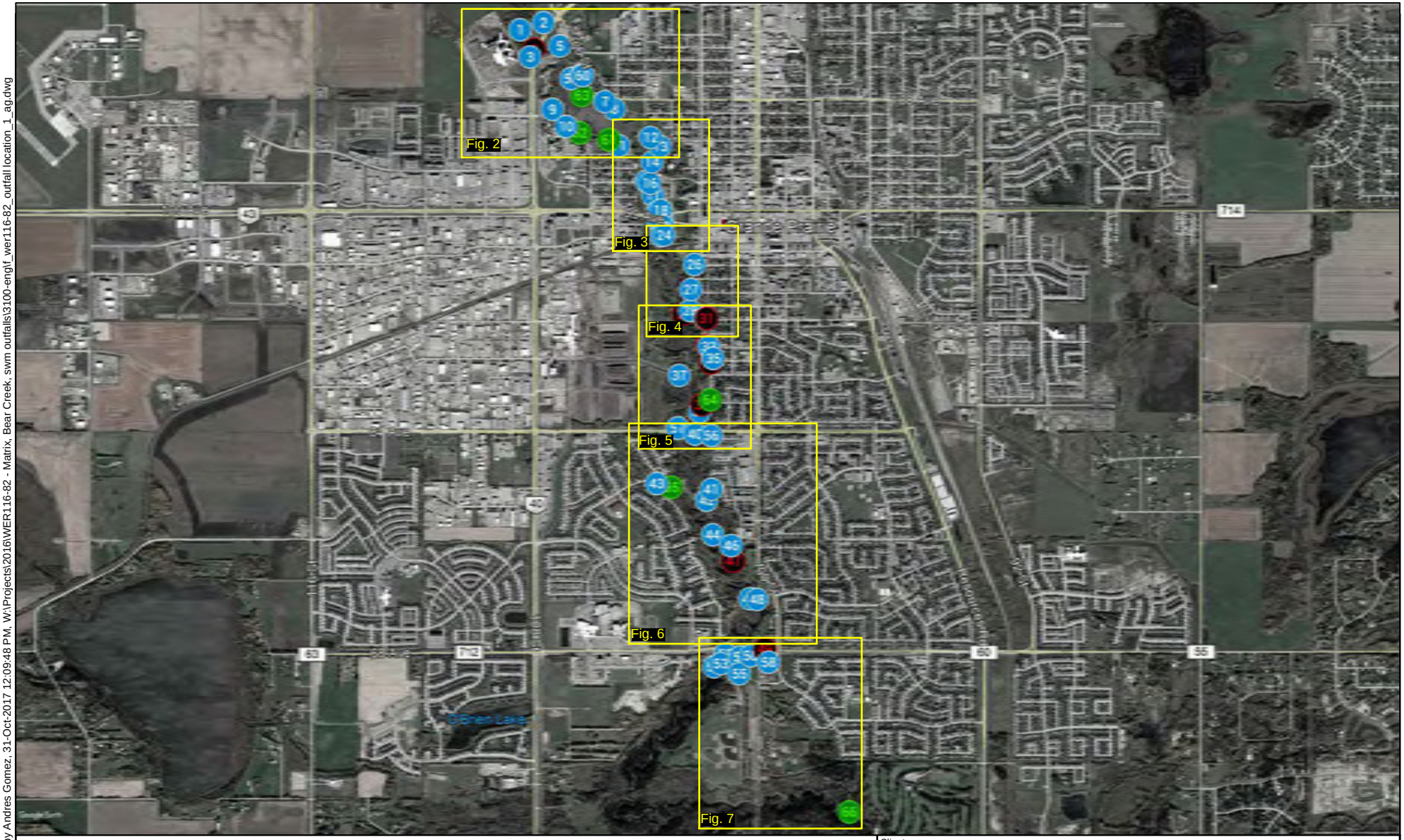
- A morphologic study of the creek is recommended to determine if Bear Creek is under a general widening process due to urbanization or any other factors.

9 References

Parkland Geotechnical Ltd. (ParklandGeo, 2010). 2009 Bear Creek Corridor Outfall Inspection Report, City of Grande Prairie.

Appendix A Outfall Location Plans

- **Figure 1: Outfall Location Plan – General**
- **Figure 2: Outfall Location Plan – 111 Ave. to Reservoir**
- **Figure 3: Outfall Location Plan – Reservoir to 99 Ave.**
- **Figure 4: Outfall Location Plan – 99 Ave. to 92 Ave.**
- **Figure 5: Outfall Location Plan – 92 Ave. to 84 Ave.**
- **Figure 6: Outfall Location Plan – 84 Ave. to 68 Ave.**
- **Figure 7: Outfall Location Plan – 68 Ave. to 60 Ave.**



LEGEND

- 3 Outfall ID and location
- 61 Outfall ID and location (not included in 2009 report)
- 31 Decommissioned and Missing Outfall

Client: MATRIX SOLUTIONS INC.

Project: STORMWATER OUTFALL ASSESSMENT ALONG THE BEAR CREEK WITHIN THE CITY OF GRANDE PRAIRIE

Title: OUTFALL LOCATION PLAN

Date:	Project No:	Scale:	Figure No:
31-10-2017	WER116-82	N.T.S.	Fig 1

Consultant: **Westhoff Engineering Resources, Inc.**
Land & Water Resources Management Consultants

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LEGEND

- 3 Outfall ID and location
- 61 Outfall ID and location (not included in 2009 report)
- 31 Decommissioned or Missing Outfall

Client: MATRIX SOLUTIONS INC.

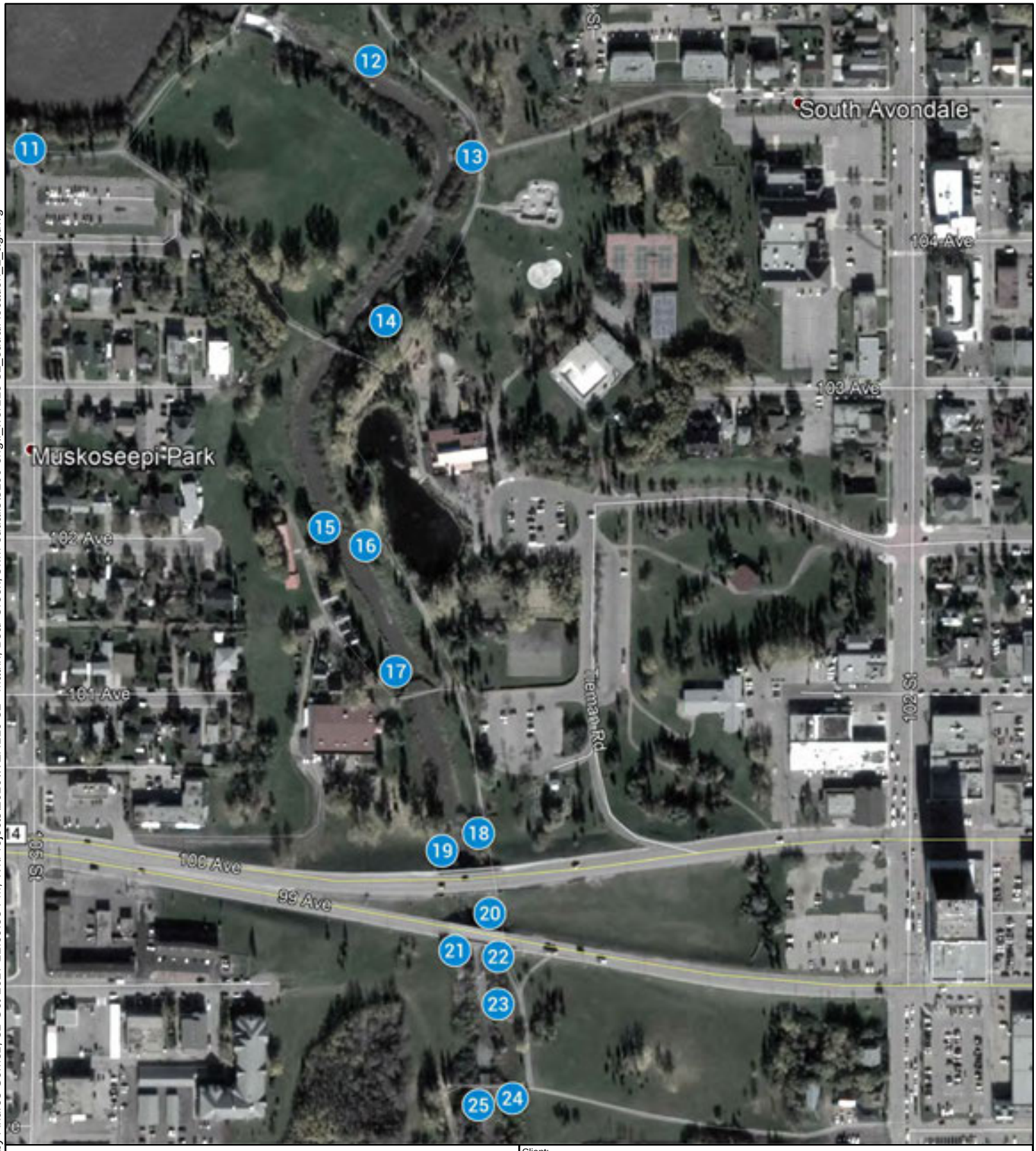
Project: STORMWATER OUTFALL ASSESSMENT ALONG THE BEAR CREEK WITHIN THE CITY OF GRANDE PRAIRIE

Title: OUTFALL LOCATION PLAN
117 AVE TO RESERVOIR

Date:	Project No:	Scale:	Figure No:
31-10-2017	WER116-82	N.T.S.	Fig 2

Consultant:

Westhoff Engineering Resources, Inc.
Land & Water Resources Management Consultants



LEGEND

- 3 Outfall ID and location
- 61 Outfall ID and location (not included in 2009 report)
- 31 Decommissioned or Missing Outfall

Client: MATRIX SOLUTIONS INC.

Project: STORMWATER OUTFALL ASSESSMENT ALONG THE BEAR CREEK WITHIN THE CITY OF GRANDE PRAIRIE

Title: OUTFALL LOCATION PLAN
RESERVOIR TO 99 AVE.

Date:	Project No:	Scale:	Figure No:
31-10-2017	WER116-82	N.T.S.	Fig 3

Consultant: **Westhoff Engineering Resources, Inc.**
Land & Water Resources Management Consultants

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LEGEND

- 3 Outfall ID and location
- 61 Outfall ID and location (not included in 2009 report)
- 31 Decommissioned or Missing Outfall

Client: MATRIX SOLUTIONS INC.

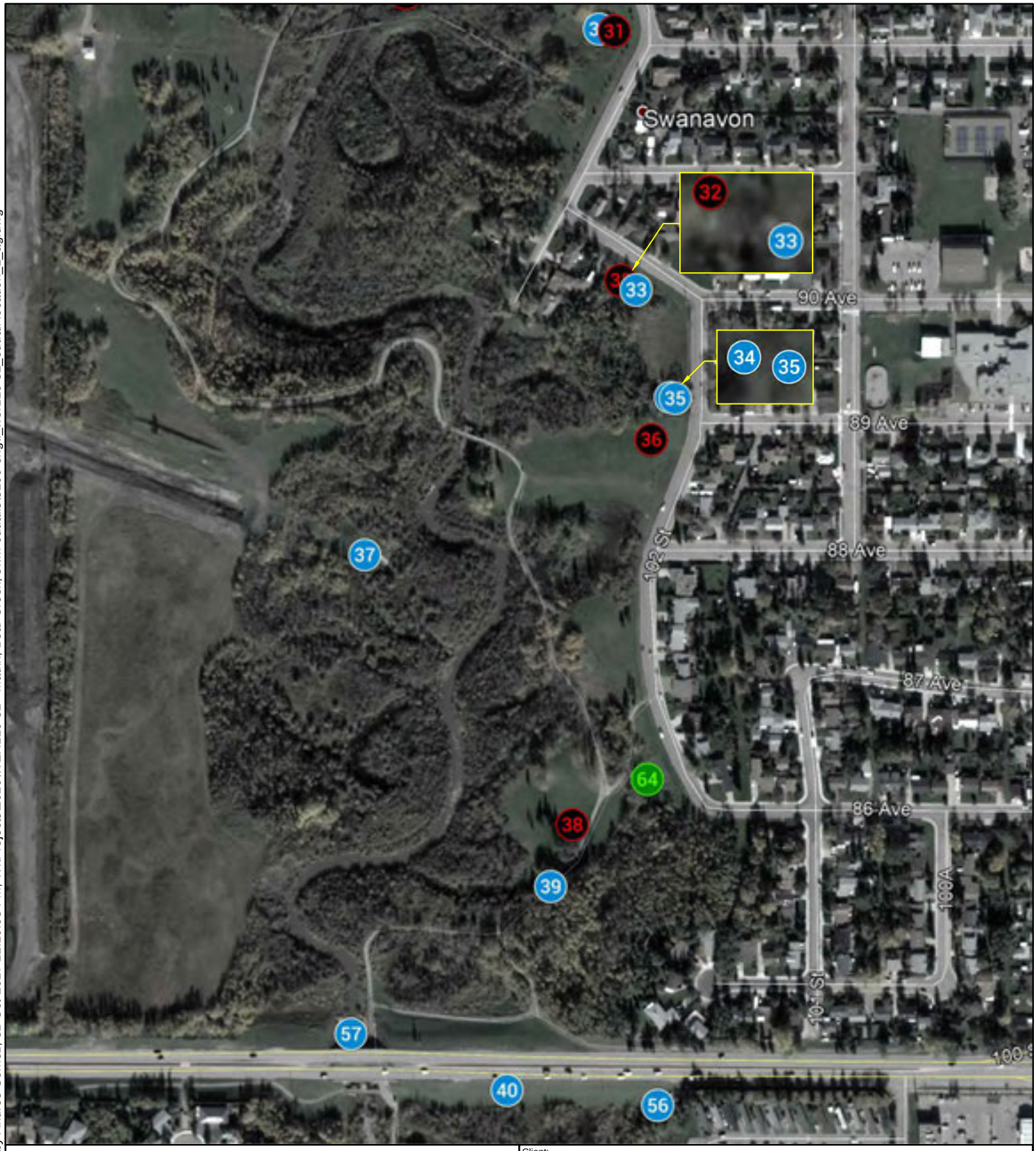
Project: STORMWATER OUTFALL ASSESSMENT ALONG THE BEAR CREEK WITHIN THE CITY OF GRANDE PRAIRIE

Title: OUTFALL LOCATION PLAN
99 AVE. TO 92 AVE.

Date:	Project No:	Scale:	Figure No:
31-10-2017	WER116-82	N.T.S.	Fig 4

Consultant: **Westhoff Engineering Resources, Inc.**
Land & Water Resources Management Consultants

Original Size ANSI A (8.5" x 11") Printed by Andres Gomez, 31-Oct-2017 12:10:04 PM, W:\Projects\2016\WER116-82 - Matrix, Bear Creek, swm outfalls\3100-engl\f_wer116-82_outfall location_1_ag.dwg



LEGEND

- 3 Outfall ID and location
- 61 Outfall ID and location (not included in 2009 report)
- 31 Decommissioned or Missing Outfall

Client: MATRIX SOLUTIONS INC.

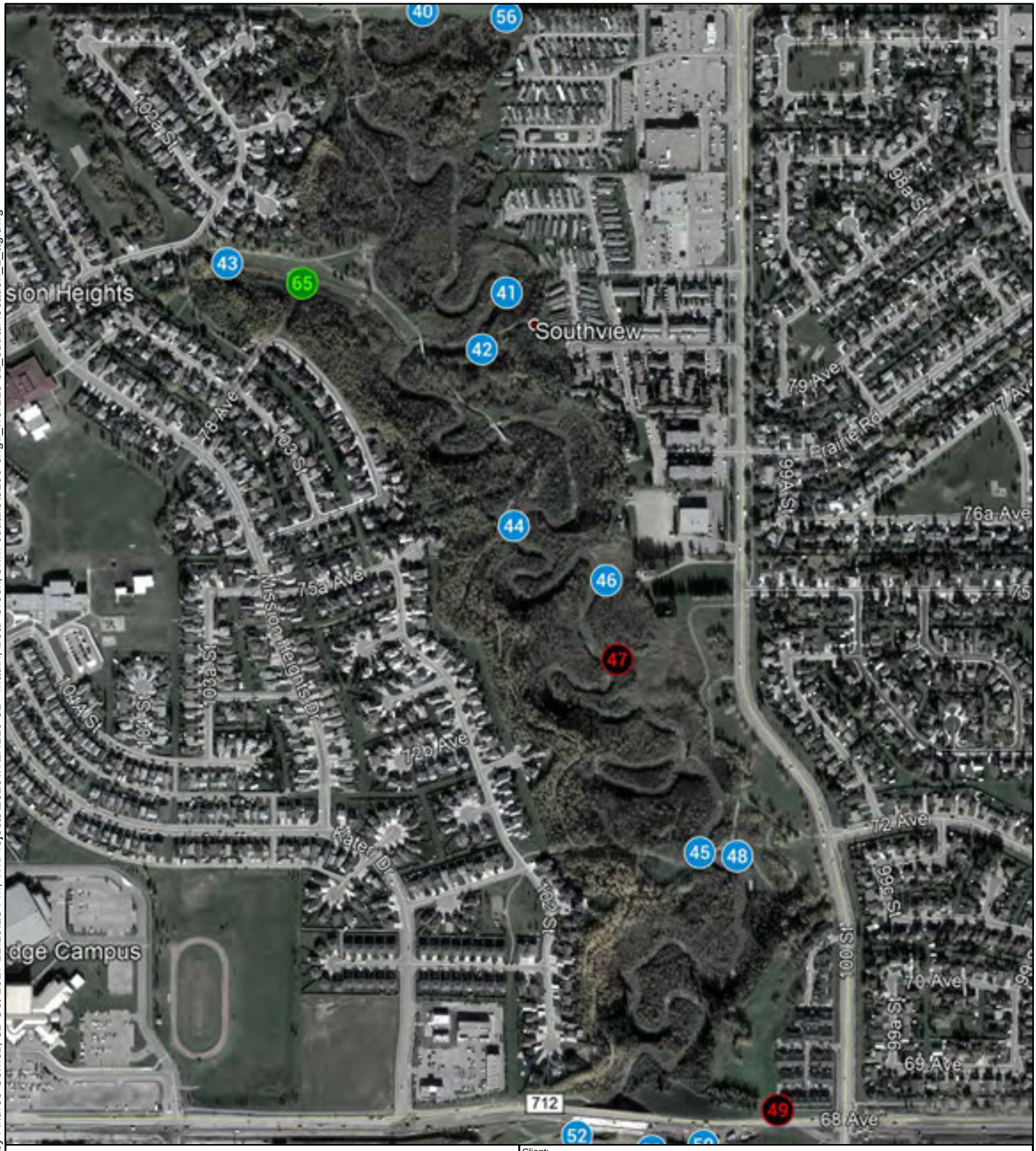
Project: STORMWATER OUTFALL ASSESSMENT ALONG THE BEAR CREEK WITHIN THE CITY OF GRANDE PRAIRIE

Title: OUTFALL LOCATION PLAN
92 AVE. TO 84 AVE.

Date:	Project No:	Scale:	Figure No:
31-10-2017	WER116-82	N.T.S.	Fig 5

Consultant: **Westhoff Engineering Resources, Inc.**
Land & Water Resources Management Consultants

Original Size ANSI A (8.5" x 11") Printed by Andres Gomez, 31-Oct-2017 12:10:08 PM, W:\Projects\2016\WER116-82 - Matrix, Bear Creek, swm outfalls\3100-engl\f_wer116-82_outfall location_1_ag.dwg



LEGEND

- 3 Outfall ID and location
- 61 Outfall ID and location (not included in 2009 report)
- 31 Decommissioned or Missing Outfall

Client: MATRIX SOLUTIONS INC.

Project: STORMWATER OUTFALL ASSESSMENT ALONG THE BEAR CREEK WITHIN THE CITY OF GRANDE PRAIRIE

Title: OUTFALL LOCATION PLAN
84 AVE TO 68 AVE.

Date:	Project No:	Scale:	Figure No:
31-10-2017	WER116-82	N.T.S.	Fig 6

Consultant: **Westhoff Engineering Resources, Inc.**
Land & Water Resources Management Consultants

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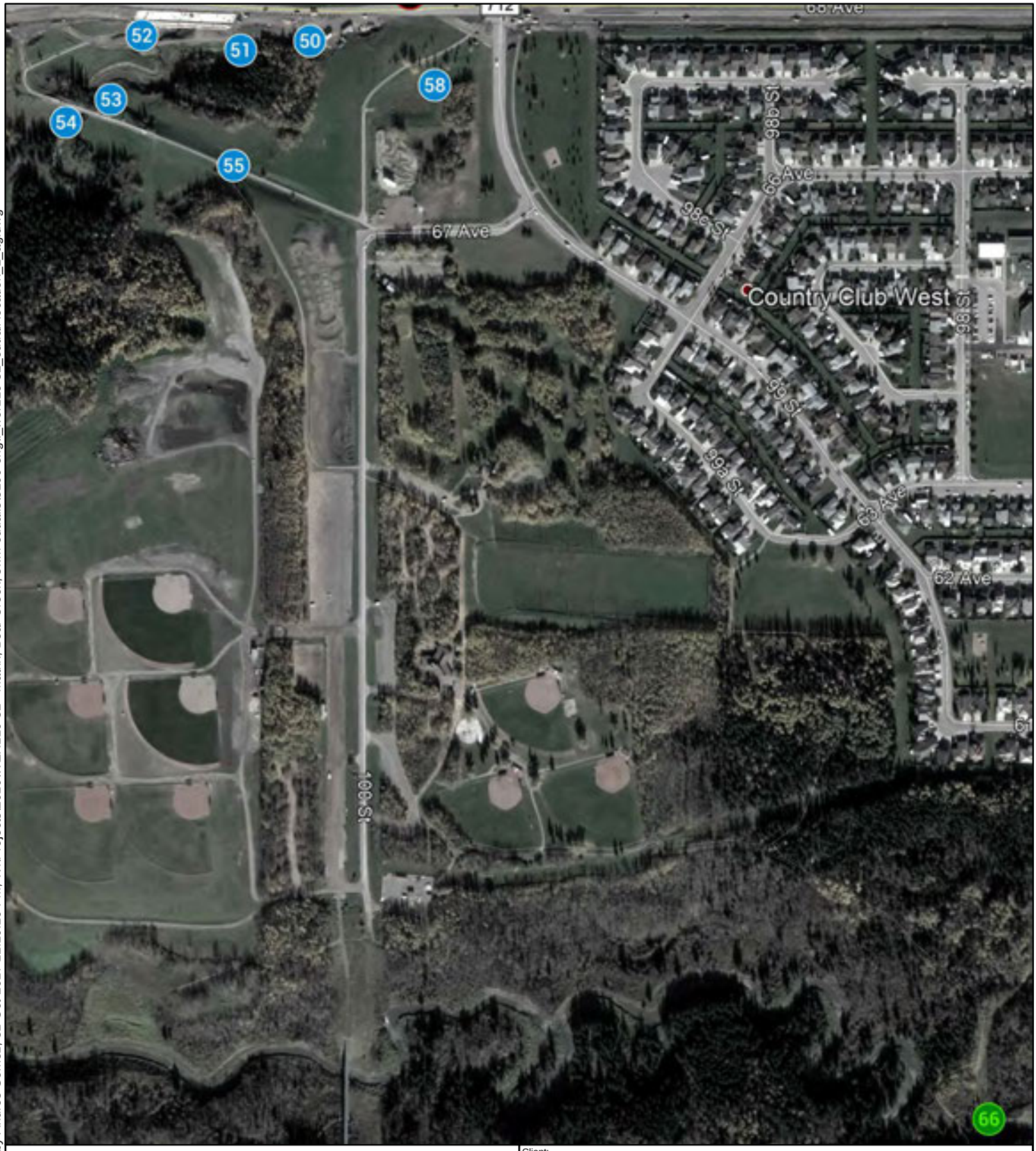

LEGEND

- 3 Outfall ID and location
- 61 Outfall ID and location (not included in 2009 report)
- 31 Decommissioned or Missing Outfall

Client: MATRIX SOLUTIONS INC.

Project: STORMWATER OUTFALL ASSESSMENT ALONG THE BEAR CREEK WITHIN THE CITY OF GRANDE PRAIRIE

Title: OUTFALL LOCATION PLAN
68 AVE. TO 60 AVE.

Date:	Project No:	Scale:	Figure No:
31-10-2017	WER116-82	N.T.S.	Fig 7

Consultant: **Westhoff Engineering Resources, Inc.**
Land & Water Resources Management Consultants

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Appendix B Inspection Field Notes

Table 16: Bear Creek Outfall Inspection – Field Notes

Outfall ID (2017)	GPS Location Updated	UTM (X)	UTM (Y)	Location Description	Date inspected	Found	Sign Condition	Access Condition	Pipe Size/Dia. (mm)	Conduit Type	Pipe Material	Pipe Condition	Pipe Exposed
1	No	383970	6116629	East of Bear Creek, west of Hwy 43, and west of pathway	2-Oct-17	Yes	Missing	Good	1500	Round	CSP	Good	Yes
2	No	384144	6116676	Between regional pathway and Hwy 43	2-Oct-17	Yes	Missing	Good	1800	Round	Concrete	Good	No
3	No	384039	6116426	South of Bear Creek, and west of Hwy 43	2-Oct-17	Yes	Missing	Good	1600	Round	Concrete	Good	No
4	No	384069	6116483	South of Bear Creek, west of Hwy 43, and east of Outfall 3	2-Oct-17	No	Missing	Good	Unknown	Unknown	Unknown	Unknown	Unknown
5	No	384259	6116502	East of Bear Creek, east of Hwy 43, and south of GP Regional Tourism Association Building	2-Oct-17	Yes	Missing	Poor	800	Round	CSP	Unknown	No
6	Yes	384412	6116279	East of the reservoir, west of 106 St., and north of 109 Ave.	2-Oct-17	Yes	Missing	Good	300	Round	Concrete	Poor	No
7	No	384581	6116085	North of the reservoir, south of 108 Ave., and southwest of Dewit Dr.	2-Oct-17	Yes	Missing	Fair	370	Round	Concrete	Good	No
8	No	384649	6116029	North of the reservoir, and south of 108 Ave., Dewit Dr., and pathway	2-Oct-17	Yes	Missing	Fair	600	Round	CSP	Poor	Yes
9	No	384193	6116038	West of the reservoir, east of the pathway, and northwest of outfall 10	2-Oct-17	Yes	Missing	Good	600	Round	Concrete	Good	No
10	No	384291	6115909	South of the reservoir, and northeast of GP Regional College	2-Oct-17	Yes	Missing	Good	450	Round	PVC	Good	No
11	No	384674	6115758	South of the reservoir, and north of 104 Ave., 105 St.,	2-Oct-17	Yes	Missing	Good	600	Round	CSP	Good	No
12	No	384895	6115821	North of Bear Creek, west of 103 St., northwest of 105 Ave., and west of pathway	2-Oct-17	Yes	Missing	Fair	450	Round	CSP	Good	No
13	No	384979	6115746	East of Bear Creek, and west of 105 Ave. and pathway	3-Oct-17	Yes	Missing	Fair	1000	Round	PVC	Good	No
14	Yes	384914	6115644	East of Bear Creek, north or Muskoseepi Park Pond, and west of pathway	6-Oct-17	Yes	Missing	Poor	300	Round	Concrete	Unknown	No
15	No	384870	6115492	West of Bear Creek, and east of 102 Ave.	3-Oct-17	Yes	Missing	Fair	400	Round	CSP	Good	No
16	No	384873	6115445	East of Bear Creek, and west of Muskoseepi Park Pond and pathway	3-Oct-17	Yes	Missing	Fair	200	Round	PVC	Good	No
17	No	384917	6115391	West of Bear Creek, and east of 101 Ave.	3-Oct-17	Yes	Missing	Fair	800	Round	CSP	Good	No
18	No	384936	6115251	East of Bear Creek, and north of 100 Ave.	3-Oct-17	Yes	Missing	Fair	1200	Round	CSP	Good	No
19	Yes	384936	6115258	West of Bear Creek, and north of 100 Ave.	6-Oct-17	Yes	Missing	Good	300	Round	CSP	Unknown	No

Bear Creek Outfall Inspection – Field Notes (Cont.)

Outfall ID (2017)	Pipe Buried or Silted In	Apron/Flared End Condition	Handrail Condition	Headwall Condition	Wingwall Condition	Retaining Wall Condition	Grate Condition	Riprap Condition	Bank Erosion	Erosion by Creek	Erosion by Sewer Flow	Scour Holes	Upland landscape and Veg. Condition	Safety Hazard Identified	Existing Level of Damage
1	No	Unknown	Poor	Poor	Poor	N/A	Poor	N/A	No	Likely	Likely	No	Good	No	Major
2	Partially	N/A	N/A	N/A	N/A	N/A	Good	Good	No	N/A	Minor	No	Good	No	Minor
3	No	Good	Good	Good	Fair	N/A	N/A	N/A	No	No	No	No	Good	No	No damage
4	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	No	Unknown
5	Yes	Unknown	N/A	N/A	Unknown	N/A	N/A	N/A	Yes	No	Likely	No	Poor	No	Major
6	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Yes	N/A	Yes	No	Good	No	Minor
7	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A	No	No	Yes	No	Good	No	Minor
8	No	N/A	N/A	N/A	N/A	N/A	Poor	Poor	Yes	No	Yes	Yes	Fair	No	Major
9	No	Fair	N/A	N/A	Good	N/A	N/A	Poor	No	No	Yes	Yes	Good	No	Minor
10	No	Poor	N/A	Good	Good	N/A	Good	N/A	No	No	Yes	No	Good	No	Moderate
11	Partially	N/A	N/A	N/A	N/A	N/A	N/A	N/A	No	No	No	No	Good	No	No damage
12	No	Good	N/A	N/A	Good	N/A	Poor	Poor	No	No	Yes	Yes	Good	No	Minor
13	No	Fair	N/A	N/A	N/A	N/A	Fair	Poor	No	No	Yes	Yes	Good	No	Moderate
14	Yes	Poor	N/A	Poor	Poor	N/A	N/A	N/A	Yes	Likely	Likely	Yes	Poor	No	Major
15	Yes	Unknown	N/A	N/A	N/A	N/A	N/A	N/A	No	No	No	No	Fair	No	Minor
16	Yes	N/A	N/A	N/A	N/A	N/A	Good	Fair	No	No	No	No	Good	No	Minor
17	No	Good	N/A	N/A	N/A	N/A	Fair	N/A	Yes	Yes	Likely	Yes	Fair	No	Moderate
18	Yes	Good	N/A	Good	Good	N/A	Good	N/A	No	Minor	No	No	Good	No	Minor
19	Yes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	No	No	No	No	Good	No	Major

Bear Creek Outfall Inspection – Field Notes (Cont.)

Outfall ID (2017)	Type of Failure	Comments	Recommended Actions
1	Sewer erosion, Creek erosion, Structural Damage	• Gabion baskets conforming to the outfall structure have settled because of the scour action at the base • Outfall condition is similar to the condition noted in 2009, so it seems that the sewer flow is not causing additional damage	• Remove gabion baskets from headwall and wing walls • Engineer a design such that the toe is protected from scour action, and provide a base for the outfall and pipe • Replace outfall structure as per engineering design
2	None	• Minor erosion was observed along the drainage channel • Slopes were stable even though the riprap was not uniformly placed around the pipe	• Clean sediments from the bottom of the pipe
3	None	• Outfall has been upgraded: the CSP pipe observed in 2009 has been replaced by a concrete pipe • Top of the east wingwall (gabion baskets) slightly leaned toward the outlet • Some sediment was stocked on top of the apron	• Conduct ongoing maintenance to remove sediments retained behind the weir wall installed at the edge the apron
4	Unknown (not inspected)	• The outfall could not be found at the coordinates provided; same situation was indicated on the 2009 report • No signs of erosion were identified, and vegetation was well established in the surrounding area	• Uncover the outfall structure and conduct the assessment
5	Slope stability, Sewer/pipe damage	• About third of the pipe was buried under sediments • The pipe was surrounded by dense vegetation • Soils were slumping down on the upland area along the sewer line up to the manhole • The area was fenced off as damage extended to the building backyard.	• Immediate attention is required due to the proximity of the damage to the building and exterior areas designated for the public • Conduct a detailed inspection of the sewer line to determine current conditions and required rehab works • Assess slope stability to determine causes of failure
6	Sewer erosion	• Beside the pipe, minor local erosion has occurred on bare soils exposed due to the shade from tall vegetation along the ditch and low coverage at the ground level • The pipe was damaged around the edge	• Provide temporary ESC matting around the pipe and plant vegetation to stabilize the base of the slope • Plant vegetation along the ditch to reduce the potential of sediment transport to the reservoir
7	Sewer erosion	• The pipe was surrounded by overgrown grass • Minor erosion was observed beneath the pipe • There were some erosion holes along the discharge channel between the cobbles and on unprotected spots • Pictures from the 2009 assessment report are not consistent with the outfall at this location	•Extend the cobble layer or the ESC protection along the discharge channel to minimize erosion by the sewer
8	Sewer erosion	• The pipe was corroded at the bottom, allowing water to drain underneath the pipe and eroding the rock material at the base • Approximately 3 m of pipe was exposed • Slumping of surrounding slopes was observed • The pipe material and appearance are different compared to the 2009 report	• Replace the segment of pipe that is corroded • Reconstruct a base for the pipe and permanent ESC cover at the outlet • Assess slope stability to identify soil failure patterns
9	Sewer erosion	• Sewer flow caused some undermining below the concrete flared end • Scour of cobbles and soils occurred along the discharge channel • Outfall classified as minor damage as the conditions remain similar to those observed in 2009	• Install riprap along the channel to halt further erosion
10	Sewer erosion	• Rock material on the apron has been washed out, leaving exposed the concrete base and a synthetic fabric layer • Wingwall marks showed the level of apron coverage by sewer flows	• Review the outfall design and current flow conditions to determine design adjustments for reconstructing the apron • Extend the permanent ESC measures along the discharge channel to protect the slopes from the scour action of the sewer flow
11	None	• There was debris at the bottom of the pipe and dense vegetation around the outfall	• Clear vegetation and remove debris from the pipe
12	Sewer erosion	• There was some erosion along the discharge channel (riprap cobbles) • A long segment of the left bank was protected with gabion mattresses	• Reposition riprap along the discharge channel to halt sewer scour • Inspect and repair broken gabion mattresses around the outfall
13	Sewer erosion	• A PVC pipe and fiber glass flared end were installed after the 2009 assessment • Riprap around the flared end and along the discharge channel was partially washed out • The flared end was exposed, and the surrounding land was not well graded • There was minor damage to the grate	• Regrade the backfill around the flared end to prevent scour from behind and below the structure • Place riprap along the discharge channel to control the scour from the sewer • Provide vegetation coverage on the bare patches around the outfall
14	Creek erosion, Slope stability, Sewer/pipe damage	• Outfall was surrounded by dense vegetation • Bank erosion was identified along the upper slope, and soil was slumping down in some locations • Wingwalls were becoming detached from the headwall as a result of the sinking slope • Stagnant water was on the apron • During the inspection, part of the vegetation was removed behind the outfall to inspect some holes; a significant flow was generated around the concrete structure, suggesting a broken pipe behind the outfall	• Conduct a geotechnical assessment to solve slope stability issues • Clear vegetation from around outfall and conduct a detailed inspection of the pipeline to verify if the pipe is broken • Investigate the source of the orange matter observed in the sewer flow • Regrade, repair outfall damages, reinstall/replace outfall structure, and provide permanent ESC protection along the channel
15	Slope stability	• Sediments were deposited along the pipe • Slope failure extended to the north and south of the outfall • Pictures from the 2009 report and the current assessment observed the slumping of soil blocks in front of the outfall	• Monitor the condition of outfall given the slope stability issues • Clean sediments to allow for unrestricted flow through the pipe
16	None	• Sediments were built up to about half the height of the pipe • The grate was blocked by dead vegetation	• Remove debris from the pipe and garbage from the grate
17	Sewer erosion, Creek erosion	• Slope failure extended to the north and south of the outfall • Creek and sewer flows eroded the underside of the apron	• Monitor the condition of outfall condition given the slope stability issues • Reconstruct the base of the apron
18	Sewer erosion	• Minor sediments and gravel have built up in the pipe • Minor erosion has occurred along the channel	• Monitor the erosion along the channel, backfill holes with rock cobbles or other ESC protection to prevent sewer flow scour
19	None	• The pipe was completely buried; a City crew located and partially cleared it out for visual inspection • Sediment has built up in the pipe	• Uncover outfall and remove sediments from the pipe, conduct a detailed inspection to identify additional issues and proceed with repair works as needed • Provide ESC protection at the outlet because of the steep slope at the pipe location

Bear Creek Outfall Inspection – Field Notes (Cont.)

Outfall ID (2017)	GPS Location Updated	UTM (X)	UTM (Y)	Location Description	Date inspected	Found	Sign Condition	Access Condition	Pipe Size/Dia. (mm)	Conduit Type	Pipe Material	Pipe Condition	Pipe Exposed
20	No	384978	6115222	East of Bear Creek, and north of 99 Ave.	4-Oct-17	Yes	Missing	Fair	300	Round	CSP	Poor	No
21	No	384960	6115201	West of Bear Creek, and south of 99 Ave.	3-Oct-17	Yes	Missing	Fair	400	Round	CSP	Fair	No
22	No	384983	6115192	East of Bear Creek, and south of 99 Ave.	3-Oct-17	Yes	Missing	Fair	250	Round	Concrete	Good	No
23	No	384996	6115158	East of Bear Creek, and south of 99 Ave. and outfall 22	3-Oct-17	Yes	Missing	Fair	900	Round	Concrete	Good	No
24	No	384994	6115096	East of Bear Creek, and south of the pedestrian bridge	3-Oct-17	Yes	Missing	Fair	1500	Round	Concrete	Good	No
25	No	384932	6115045	West of Bear Creek, and south of the pedestrian bridge	3-Oct-17	Yes	Missing	Poor	800	Round	CSP	Fair	No
26	No	385205	6114876	West of 102 St., and south of 96 Ave.	3-Oct-17	Yes	Missing	Fair	400	Round	CSP	Poor	No
27	No	385180	6114695	West of 102 St., and north of 94 Ave.	3-Oct-17	Yes	Missing	Fair	300	Round	PVC	Good	No
28	No	385172	6114540	East of Bear Creek, west of 102 St., and south of 93 Ave.	3-Oct-17	Yes	Missing	Fair	600	Round	CSP	Fair	Yes
29	No	385121	6114512	East of Bear Creek, and southwest of outfall 28	3-Oct-17	No	Missing	Poor	Unknown	Unknown	Unknown	Unknown	Unknown
30	No	385276	6114476	East of Bear Creek, and west of 102 St. and 92 Ave.	3-Oct-17	Yes	Missing	Fair	300	Round	PVC	Good	Yes
31	No	385288	6114475	East of Bear Creek, west of 102 St. and 92 Ave., and east of outfall 30	3-Oct-17	No	Missing	Fair	Unknown	Unknown	Unknown	Unknown	Unknown
32	No	385288	6114276	South of 102 St. and 90 Ave.	4-Oct-17	No	Missing	Fair	Unknown	Unknown	Unknown	Unknown	Unknown
33	No	385300	6114267	South of 102 St. and 90 Ave.	4-Oct-17	Yes	Missing	Fair	250	Round	Concrete	Poor	Yes
34	No	385328	6114180	West of 102 St., and north of 89 Ave.	4-Oct-17	Yes	Missing	Poor	400	Round	CSP	Fair	No
35	No	385330	6114178	West of 102 St., and north of 89 Ave.	4-Oct-17	Yes	Missing	Poor	600	Round	PVC	Good	No
36	No	385309	6114147	West of 102 St., and south of 89 Ave.	4-Oct-17	No	Missing	Fair	Unknown	Unknown	Unknown	Unknown	Unknown
37	No	385081	6114060	West of Bear Creek and 88 Ave.	4-Oct-17	Yes	Missing	Poor	1200	Round	PVC	Good	No
38	No	385238	6113842	East of Bear Creek, west of 102 St., south of 86 Ave., and west of the pathway	4-Oct-17	No	Missing	Good	Unknown	Unknown	Unknown	Unknown	Unknown
39	Yes	385219	6113799	East of Bear Creek, and north of 84 Ave.	4-Oct-17	Yes	Missing	Fair	400	Round	CSP	Poor	No
40	No	385180	6113629	East of Bear Creek, and south of 84 Ave.	4-Oct-17	Yes	Missing	Good	450	Round	Concrete	Poor	No

Bear Creek Outfall Inspection – Field Notes (Cont.)

Outfall ID (2017)	Pipe Buried or Silted In	Apron/Flared End Condition	Handrail Condition	Headwall Condition	Wingwall Condition	Retaining Wall Condition	Grate Condition	Riprap Condition	Bank Erosion	Erosion by Creek	Erosion by Sewer Flow	Scour Holes	Upland landscape and Veg. Condition	Safety Hazard Identified	Existing Level of Damage
20	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A	No	No	Minor	No	Good	No	Moderate
21	Yes	Good	N/A	N/A	N/A	N/A	Fair	N/A	Yes	No	No	No	Good	No	Minor
22	No	N/A	N/A	N/A	N/A	N/A	N/A	Fair	Yes	No	Likely	Yes	Fair	No	No damage
23	No	Good	N/A	N/A	N/A	N/A	Good	Fair	No	No	Likely	No	Fair	No	Minor
24	No	Fair	N/A	Good	Good	N/A	Good	Poor	No	No	Yes	Yes	Good	No	Major
25	No	Fair	N/A	Fair	Fair	N/A	Fair	N/A	No	No	Likely	Yes	Good	No	Moderate
26	Yes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	No	No	No	No	Fair	No	Minor
27	No	N/A	N/A	N/A	N/A	N/A	N/A	Fair	No	No	Likely	No	Fair	No	Minor
28	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Yes	No	Yes	Yes	Fair	No	Major
29	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	No	Unknown
30	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A	No	No	Yes	No	Good	Yes	Moderate
31	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	No	Unknown
32	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	No	Unknown
33	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A	No	No	Likely	No	Fair	No	Major
34	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A	No	No	Yes	No	Fair	No	Moderate
35	No	N/A	N/A	N/A	N/A	N/A	N/A	Good	No	No	No	No	Good	No	No damage
36	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	No	Unknown
37	No	Good	Good	Good	Good	N/A	N/A	Good	No	No	Yes	No	Good	No	Moderate
38	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	No	Unknown
39	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A	No	No	Yes	No	Good	Yes	Major
40	Yes	Fair	N/A	N/A	N/A	N/A	N/A	N/A	No	No	No	No	Good	No	Moderate

Bear Creek Outfall Inspection – Field Notes (Cont.)

Outfall ID (2017)	Type of Failure	Comments	Recommended Actions
20	None	• Pipe was smashed along ~ 1-2 m from the end • There was light vegetation coverage along the channel • Gabion mattresses were present along the bank	• Replace the damaged segment of the pipe • Monitor scour along the channel • Provide additional vegetation cover
21	None	• Sediment and gravels were built up in pipe, some corrosion was observed • Gabion mattresses were sinking down ~3 m above the outfall • Gabion mattresses were present along the bank (99 Ave. and 100 Ave. ROW)	• Assess slope stability at this location, and verify if soil failure is also related to potential damages on the sewer line before the outlet
22	Sewer erosion	• Minor erosion occurred on the gabion mattress at the outlet • There were bare soils at the base of the pipe	• Routinely monitor outfall
23	None	• Grate was replaced after 2009 inspection • Sediment and vegetation were built up on the apron • There was a big step from the apron end to channel • The wingwalls were disconnected from the concrete blocks; no structural damage was observed	• Clear the apron of sediments and vegetation to allow unrestricted flow • Regrade the step from the apron to the channel by placing additional cobbles
24	Sewer erosion	• Scour was observed along the concrete surface of the apron • The gabion baskets were broken, and riprap was washed out along the discharge channel • Garbage was stuck on the gabion wires • Water marks indicated high flows have surpassed the wingwall height and have eroded the soils at the back of the outfall • Some gabion baskets were leaning down the slope because of the undermining action of the sewer flow	• Regrade the discharge channel, place a base material at the eroded locations, and replace the damaged gabion baskets and mattresses along the wingwalls and discharge channel • Patch rills on the concrete apron and pipe to avoid rebar exposure • Clear garbage from the gabions and mattresses
25	Sewer erosion	• The pipe was dry, but underground flow was coming below the pipe to the apron • Scour rills were observed along the apron surface • Undercutting occurred beneath the apron • Minor corrosion was observed at the bottom of the pipe	• Conduct a detailed assessment to determine the source of the flow shown on the apron and the source's relation to the undermining at the base • Look to see if there is some water leaking along the sewer line before the outlet
26	None	• Vegetation was built up in the pipe, indicating rare and low flows • Moderate corrosion was observed along the pipe	• Routinely monitor the outfall
27	Sewer erosion	• The pipe has been replaced since the 2009 inspection • Minor local scour was observed along the cobble and soil layer along the channel	• Routinely monitor the outfall
28	Sewer erosion	• There was a vertical slope at the pipe location and an unstable slope behind the outfall • The pipe was overhanging the slope • The outfall emptied into a round pool • There was a steep fall from the pipe invert to the bottom of the pool/channel (~ 2 m)	• Design a new outfall structure and include surrounding bank protection and permanent ESC protection along the discharge channel
29	Unknown (not inspected)	• The outfall could not be found at the coordinates provided • During the field assessment, the City confirmed that the outfall was decommissioned	• None
30	Sewer erosion	• Undercutting of the base of the pipe was observed • Some rill erosion along the channel leaning to the downhill grassy area was observed • The outlet was hidden by dense grass, which was a hazard to users of the public pathway and green areas	• Regrade, and install a permanent ESC protection along the discharge channel • Provide the outlet with a flared end to dissipate sewer flow • Fence off the outfall to block public assess
31	Unknown (not inspected)	• The outfall could not be found at the coordinates provided • During the field assessment, the City confirmed that the outfall was decommissioned	• Remove outfall from the active outfall list
32	Unknown (not inspected)	• The outfall could not be found at the coordinates provided • During the field assessment, the City confirmed that the outfall was decommissioned	• Remove outfall from the active outfall list
33	Sewer/pipe damage	• The pipe was overhung by ~1 m • The end of the pipe was broken	• Replace the broken section of the pipe, regrade around the outfall, and provide a base for the outlet
34	Sewer erosion	• The pipe was partially blocked by soil hanging from vegetation roots on top of the outfall • Scour around the pipe was likely caused by sewer flow and runoff along the bare areas • A lot of fallen trees and dead vegetation surrounded the outfall	• Clear vegetation and blocking soils from around the pipe • Regrade and provide a flared end and ESC protection on the channel • Consider realigning the sewer and tie the outfall to the collector draining to outfall 35, located less than 10 m away
35	None	• The pipe and cobble along the channel was in good condition	• Routinely monitor outfall
36	Unknown (not inspected)	• The outfall could not be found at the coordinates provided • During the field assessment, the City confirmed that the outfall was decommissioned	• Remove outfall from the active outfall list
37	Sewer erosion	• A concrete stamp indicated the outfall was constructed in 2015 • Riprap along the discharge channel was partially washed out • The channel turned at almost 180° causing high scour along the steep bank, which was barely covered by vegetation	• Provide a detailed engineering assessment to determine additional improvements to be installed along the channel or at the outlet to dissipate sewer flow energy and reduce scour action along the discharge channel and at the downstream unprotected areas
38	Unknown (not inspected)	• The outfall could not be found at the coordinates provided • During the field assessment, the City confirmed that the outfall was decommissioned	• Remove the outfall from the active outfall list
39	Sewer erosion, Sewer/pipe damage	• The outfall was a culvert crossing below the pathway • The pipe was rusted along the bottom • There was a vertical step from the north outlet to the channel • Cracks were observed on the pathway pavement above the crossing	• Replace the pipe because the pipe is severely corroded • Regrade and install permanent ESC protection on both sides of the culvert • Consider installing handrails on both sides of the pathway to prevent users falling into the channel
40	Sewer erosion	• Sediment filled ~60% of the pipe • The pipe was broken at the end, and the rebar was exposed	• Clear the pipe of sediments to ensure free flow • Repair the concrete or replace the flared end to avoid rebar corrosion

Bear Creek Outfall Inspection – Field Notes (Cont.)

Outfall ID (2017)	GPS Location Updated	UTM (X)	UTM (Y)	Location Description	Date inspected	Found	Sign Condition	Access Condition	Pipe Size/Dia. (mm)	Conduit Type	Pipe Material	Pipe Condition	Pipe Exposed
41	No	385291	6113220	East of Bear Creek, west of 100 St., and north of 79 Ave. and the pathway	5-Oct-17	Yes	Missing	Poor	400	Round	CSP	Poor	Yes
42	No	385250	6113149	East of Bear Creek, west of 100 St. and 79 Ave., and north of the pathway	5-Oct-17	Yes	Missing	Fair	600	Round	CSP	Fair	No
43	Yes	384890	6113269	East of Michaelis Blvd., northwest of 103 St., ~70 m east of the pathway entrance on Michaelis Blvd.	6-Oct-17	Yes	Missing	Good	1800	Round	Concrete	Fair	No
44	Yes	385292	6112885	West of Bear Creek, a n d east of 75a Ave. and the pathway	5-Oct-17	Yes	Missing	Fair	1200	Round	CSP	Good	Yes
45	No	385549	6112408	West of Bear Creek, and north of the pedestrian bridge	5-Oct-17	Yes	Missing	Fair	700	Round	Concrete	Fair	No
46	No	385424	6112803	East of Bear Creek, and west of 75 Ave.	5-Oct-17	Yes	Missing	Fair	900	Round	PVC	Good	No
47	No	385437	6112690	East of Bear Creek, west of 100 St., and south of 75 Ave.	5-Oct-17	No	Missing	Fair	Unknown	Unknown	Unknown	Unknown	Unknown
48	No	385592	6112409	East of Bear Creek, and south of 72 Ave. and the pedestrian bridge	5-Oct-17	Yes	Missing	Fair	1200	Round	CSP	Good	No
49	No			East of Bear Creek, north of 68 Ave., and west of 100 St.	5-Oct-17	No	Missing	Good	Unknown	Unknown	Unknown	Unknown	Unknown
50	No	385542	6111991	East of Bear Creek, and southeast of 68 Ave. bridge	5-Oct-17	Yes	Missing	Good	400	Round	Unknown	Unknown	No
51	No	385468	6111984	East of Bear Creek, southeast of 68 Ave. bridge, and west of outfall 50	5-Oct-17	Yes	Missing	Good	350	Round	Unknown	Unknown	No
52	Yes	385361	6112004	West of Bear Creek, and southwest of 68 Ave. bridge	5-Oct-17	Yes	Missing	Good	300	Round	Unknown	Unknown	No
53	Yes	385326	6111941	East of Bear Creek, south of 68 Ave., and north of the pedestrian bridge	5-Oct-17	Yes	Missing	Good	300	Round	PVC	Good	Yes
54	No	385267	6111911	West of Bear Creek, and south of 68 Ave. and the pedestrian bridge	5-Oct-17	Yes	Missing	Fair	600	Round	PVC	Good	No
55	Yes	385456	6111861	~125 m south of outfall 51, beside the pathway	5-Oct-17	Yes	Missing	Good	350	Round	Concrete	Fair	No

Bear Creek Outfall Inspection – Field Notes (Cont.)

Outfall ID (2017)	Pipe Buried or Silted In	Apron/Flared End Condition	Handrail Condition	Headwall Condition	Wingwall Condition	Retaining Wall Condition	Grate Condition	Riprap Condition	Bank Erosion	Erosion by Creek	Erosion by Sewer Flow	Scour Holes	Upland landscape and Veg. Condition	Safety Hazard Identified	Existing Level of Damage
41	No	Poor	N/A	Poor	Fair	N/A	Poor	Poor	Yes	Yes	No	Yes	Fair	No	Major
42	No	Fair	N/A	Fair	Good	N/A	Fair	N/A	No	No	Minor	No	Good	No	Minor
43	Likely	N/A	N/A	N/A	N/A	N/A	N/A	Fair	Yes	No	No	No	Fair	No	Minor
44	No	N/A	N/A	N/A	N/A	N/A	N/A	Poor	Yes	Likely	Yes	Yes	Good	No	Major
45	Yes	N/A	N/A	N/A	N/A	N/A	Poor	N/A	No	No	No	No	Good	No	Minor
46	No	Good	Good	Good	Good	N/A	N/A	N/A	No	Likely	No	No	Good	No	Moderate
47	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	No	Unknown
48	No	Fair	N/A	Fair	Fair	N/A	Fair	N/A	No	No	Yes	No	Fair	No	Moderate
49	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	No	Unknown
50	Yes	Poor	N/A	N/A	N/A	N/A	Poor	N/A	No	No	Yes	No	Poor	No	Major
51	No	Poor	N/A	N/A	N/A	N/A	Fair	Fair	No	No	Yes	No	Poor	No	Minor
52	No	Poor	N/A	N/A	N/A	N/A	Poor	N/A	No	No	Yes	No	Poor	No	Major
53	No	Poor	N/A	N/A	N/A	N/A	Good	Fair	No	No	Yes	No	Good	No	Major
54	No	Good	N/A	Good	Good	N/A	Good	Fair	No	No	Yes	No	Good	No	Minor
55	No	Missing	N/A	N/A	N/A	N/A	N/A	N/A	No	No	No	No	Good	No	Minor

Bear Creek Outfall Inspection – Field Notes (Cont.)

Outfall ID (2017)	Type of Failure	Comments	Recommended Actions
41	Creek erosion, Slope stability	• The slope was unstable due to creek erosion and undercutting of the toe • The gabion mattress were shifting • The outfall structure was displaced because of the sloughing of supporting soils • The 2009 report indicated that slope failure had been observed since 2007 • The pipe was corroded and broken at the top and bottom	• Conduct a geotechnical assessment to determine further causes of bank instability and propose an engineered solution • Address slope stabilization by replacing the damaged section of the pipe, concrete outfall, and gabion mattresses.
42	Sewer erosion	• Some cracks were observed on the concrete headwall • Sediments were built up on the concrete apron	• Clear sediments from the apron to ensure unrestricted flow • Monitor the concrete headwall for additional cracks
43	Slope stability	• The pipe was submerged and buried below the springline • The outfall emptied into a channel • Backwater along the channel was controlled by 3 gabion crossings downstream • The pipe had some holes and breaks at the end, exposing the rebar • Some slope instability was observed in the uplands	• Patch broken concrete • Monitor the pipe to identify possibly undermining at the base that was not observed during the inspection.
44	Sewer erosion, Creek erosion	• ~2 m of pipe was exposed due to undermining of the base and bank erosion • The outfall emptied into a round pool • There was a vertical bank at the pipe location, > 2 m from pipe to bed • Erosion around the structure and outlet channel was observed • Riprap, concrete debris, and broken wires from gabions were washed out and blocking half of the creek channel • Broken and bent vegetation occurred as a result of high sewer flows	• Remove the riprap and debris from the creek to ensure unrestricted flow, to reduce potential scour of the left bank, and to minimize potential changes to the creek channel • Regrade the slope to stabilize bank erosion and the vertical walls around the pipe • Provide a concrete outfall structure because of the size of the pipe and sewer flows • Include shore and channel protection in the outfall design
45	Sewer/pipe damage	• Vegetation was built up in the pipe: the 2009 report indicated that the outfall was no longer in use • The grate was broken	• Cover the pipe if the outfall is abandoned
46	Creek erosion, Slope stability	• Most of the deficiencies identified in the 2009 report have been addressed and a new outfall structure has been constructed • Erosion by the creek was still undercutting the toe of the slope, the concrete slab poured along the slope channel showed some breakages and was becoming disconnected from the apron, so sewer flow could leak under the concrete • The creek bank was protected with a vegetated concrete mattress along ~20 m each side of the outfall, and A-jacks were installed along the toe, some of them seemed to be washed out. Vegetation looked well established, but the scour was progressing at the toe	• Immediate short-term action: Place a concrete joint filler between the apron and concrete slab below to prevent flow from sewer from undermining the base of the concrete slab • Conduct a geotechnical assessment to incorporate additional scour protection at the toe
47	Unknown (not inspected)	• The outfall could not be found at the coordinates provided, it was reported as abandoned in the 2009 report • During the field assessment, the City confirmed that the outfall was decommissioned	• Remove the outfall from the active outfall list
48	Slope stability	• The headwall and apron were disconnected from the pipe • Concrete breakages on the apron and wingwalls were observed • Undermining was occurring underneath the apron and wingwalls • Vegetation was built up on the apron • Moderate erosion along the channel from sewer flow was observed • The gabion baskets on the upstream bank were slumping down • The grate was missing a rebar (it had fallen down in the channel)	• Conduct a geotechnical slope assessment to address the displacement of the outfall and surrounding bank • Repair damages to the concrete to prevent sewer flows from undermining the apron (short-term solution) • Provide permanent ESC protection along the channel
49	Unknown (not inspected)	• The outfall could not be found at the coordinates provided, it was not included in the 2009 report • During the field assessment, the City confirmed that the outfall was decommissioned	• Remove the outfall from the active outfall list
50	None	• The pathway parallel to 68 Ave. was under construction • The outfall was buried above the springline by the earthworks in progress • The grate was obstructed by garbage, the pipe could not be inspected	• Conduct a pipe and outfall inspection after completion of construction works
51	Sewer erosion	• The pathway parallel to 68 Ave. was under construction • The flared end and concrete slab below were broken at the end, and the rebar was exposed and corroded • The grate was partially obstructed by garbage, the pipe could not be inspected • Minor erosion along the channel was observed	• Repair the broken concrete • Inspect the pipe and outfall after completion of works • Routinely monitor the scour along the channel
52	Sewer erosion, Sewer/pipe damage	• The pathway parallel to 68 Ave. was under construction, bare soils were exposed • The flared end was severely broken, and the rebar was exposed and corroded • Rill erosion downstream of the outfall along the bare soils on the slope was observed	• Conduct a pipe inspection after completion of works • Regrade and provide vegetation coverage on the slope • Replace the flared end • Provide ESC protection along the discharge channel
53	Sewer erosion	• The flared end was disconnected from the pipe and severely damaged • The grate was blocked by riprap cobbles • A shiny, thick, yellow fluid was observed from the sewer • Moderate erosion around the outfall suggested some slope stability issues	• Regrade, replace the flared end, and clear the grate of debris • Monitor erosion along the channel once unrestricted flow is re-established • Investigate the source of the rare flow observed, verify if sewer is connected to sanitary or another none-stormwater line • Conduct a geotechnical slope assessment to address the instability of the slope
54	Sewer erosion	• Undermining below the apron was observed • Vegetation was built up on the apron • The sewer flow was a yellow color • The grate was partially blocked by concrete block	• Backfill the base of the apron to prevent further scour • Clean the grate and apron surface to allow unrestricted flow • Investigate the source of the yellow sewer flow
55	Sewer/pipe damage	• The outfall was a culvert crossing below the pathway • The pipe was broken on the end and seemed to be disconnected from a section inside • The pipe was built up with sediments below the springline • The condition of the culvert looked different compared to the pictures from the 2009 report: no riprap and flared end were in place	• Clear the pipe of debris • Realign the pipe section if required • Routinely monitor the outfall

Bear Creek Outfall Inspection – Field Notes (Cont.)

Outfall ID (2017)	GPS Location Updated	UTM (X)	UTM (Y)	Location Description	Date inspected	Found	Sign Condition	Access Condition	Pipe Size/Dia. (mm)	Conduit Type	Pipe Material	Pipe Condition	Pipe Exposed
56	No	385304	6113621	East of Bear Creek and Outfall 40, and south of 84 Ave.	4-Oct-17	Yes	Missing	Good	450	Round	PVC	Good	No
57	No	385055	6113676	West of Bear Creek, and north of 84 Ave.	4-Oct-17	Yes	Missing	Poor	450	Round	Concrete	Good	No
58	No	385674	6111940	South of 68 Ave, and west of 100 St.	5-Oct-17	Yes	Missing	Good	500	Round	PVC	Good	Yes
59	Yes	384339	6116263	East of the reservoir, west of the pathway, and west of outfalls 6 and 60	2-Oct-17	Yes	Missing	Fair	600	Round	CSP	Fair	Yes
60	Yes	384421	6116283	East of the reservoir, west of 106 St., north of 109 Ave., and approx. 10 m east of outfall 6	2-Oct-17	Yes	Missing	Fair	300	Round	Concrete	Fair	No
61	Yes	384606	6115801	South of the reservoir, and approx. 80 m northwest of outfall 11	2-Oct-17	Yes	Missing	Poor	600	Round	CSP	Fair	Yes
62	Yes	384391	6115858	South of the reservoir, and approx. 110 m southeast of outfall 10	2-Oct-17	Yes	Missing	Poor	900	Round	CSP	Fair	Yes
63	Yes	384412	6116131	East of the reservoir, west of 108 Ave., and south of the pathway	6-Oct-17	Yes	Missing	Fair	300	Round	PVC	Good	No
64	Yes	385304	6113879	West of 102 St., north of 86 Ave., and east of the pathway	4-Oct-17	Yes	Missing	Good	450	Round	Concrete	Good	No
65	Yes	384992	6113244	Southeast of Michaelis Blvd., and ~ 100 m east of outfall 43	6-Oct-17	Yes	Missing	Fair	600	Round	CSP	Poor	No
66	Yes	386238	6110809	North of Bear Creek, west of GP Golf and Country Club, and east of the pathway	5-Oct-17	Yes	Missing	Fair	900	Round	CSP	Fair	No

Bear Creek Outfall Inspection – Field Notes (Cont.)

Outfall ID (2017)	Pipe Buried or Silted In	Apron/Flared End Condition	Handrail Condition	Headwall Condition	Wingwall Condition	Retaining Wall Condition	Grate Condition	Riprap Condition	Bank Erosion	Erosion by Creek	Erosion by Sewer Flow	Scour Holes	Upland landscape and Veg. Condition	Safety Hazard Identified	Existing Level of Damage
56	No	Poor	N/A	N/A	N/A	N/A	N/A	Poor	No	No	Yes	No	Good	Yes	Moderate
57	No	Poor	N/A	N/A	N/A	N/A	N/A	N/A	No	No	Likely	No	Good	No	Minor
58	Yes	Poor	N/A	N/A	N/A	N/A	Fair	N/A	No	No	No	No	Good	No	Minor
59	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Yes	No	Yes	No	Good	No	Moderate
60	No	N/A	N/A	N/A	N/A	N/A	N/A	Fair	No	No	Yes	No	Good	No	No damage
61	No	N/A	N/A	N/A	N/A	N/A	Fair	Poor	No	Likely	Likely	No	Good	No	Minor
62	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A	No	No	No	No	Good	No	No damage
63	No	Good	N/A	N/A	N/A	N/A	N/A	Fair	No	No	No	No	Good	No	No damage
64	No	Good	N/A	Good	Good	N/A	N/A	Good	No	No	No	No	Good	No	No damage
65	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A	No	No	No	No	Good	No	Minor
66	No	Good	N/A	Good	Good	N/A	Fair	Fair	No	No	No	No	Good	No	No damage

Bear Creek Outfall Inspection – Field Notes (Cont.)

Outfall ID (2017)	Type of Failure	Comments	Recommended Actions
56	Sewer erosion	• The flared end was disconnected from the pipe • Minor erosion along the channel was partially covered by cobbles and vegetation • The outfall was covered by vegetation, which could be a hazard for the public	• Reinstall the flared end • Place additional cobbles along the discharge channel to control erosion • Fence off or install a sign to advise the public about the outfall location
57	Sewer erosion	• The flared end seemed to be disconnected from the pipe • Minor erosion was observed along the discharge channel	• Reinstall the flared end if required • Provide additional ESC protection at the outlet to prevent further scour by the sewer
58	Sewer erosion	• The flared end was detached from the pipe • Sediments were built up on the flared end and pipe below the springline • The grate was blocked by sediment and dead vegetation • Moderate erosion around the pipe was observed	• Regrade the base of the outfall, relocate and reconnect the flared end to the pipe • Clean the pipe, flared end, and grate from sediments and debris • Provide ESC protection on the surrounding slope
59	Sewer erosion	• Undermining below the pipe was possibly caused by sewer flow or pool at the outlet • Local bank erosion around the pipe was observed	• Construct an outfall structure or permanent erosion protection cover at the pipe outlet to dissipate the energy from the sewer flow and reduce local erosion • Monitor for ongoing erosion as the outfall is close to the pathway crossing.
60	None	• Minor local erosion at the outlet, due to shade from tall vegetation along the ditch and low coverage at the ground level, was observed	• Plant vegetation along the ditch to reduce potential sediment transport to the reservoir
61	Sewer erosion, Creek erosion	• Some minor erosion was observed underneath the pipe • Access was via a steep slope	• Monitor sewer flows and evaluate the convenience of constructing an outfall structure in case the installed riprap layer does not provide enough scour protection
62	None	• There were no signs of erosion around the pipe or surrounding area • Water marks on the pipe denoted low sewer flows • The sewer emptied into a round pool	• Monitor any potential erosion issues, provide permanent ESC measures as required to protect the shore around the outlet
63	None	• There were no signs of erosion around the pipe or surrounding area • The City reported that this outfall was recently installed	• Routinely monitor the outfall
64	None	• The outfall was recently built and in good condition	• Routinely monitor the outfall
65	Sewer/pipe damage	• The pipe had some deformities due to ground/external pressure and some holes and damage at the end • Vegetation was well established at the channel	• Replace the damaged section of the pipe
66	None	• Minor vegetation was built up on the apron • The outfall looked to be in good condition	• Clear vegetation and sediments from the apron • Routinely monitor the outfall

Appendix C Bear Creek Outfall Photographs

- Outfalls with Major Damage
- Outfalls with Moderate Damage

C.1 Outfalls with Major Level of Damage

Outfall 1:

Photo 1.

Photo 2.

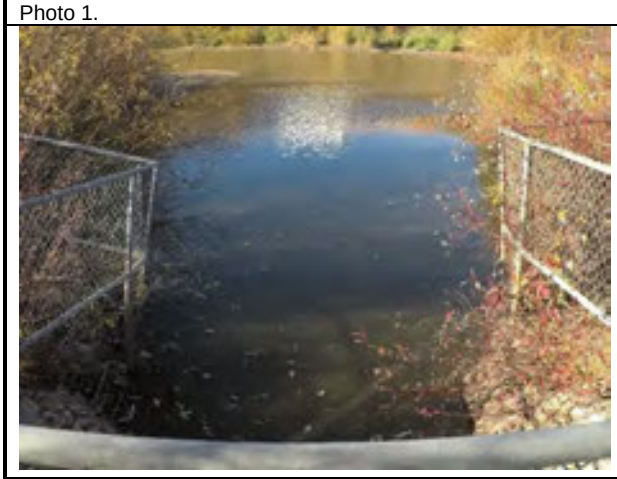


Photo 3.

Photo 4.

Photo 5.

Photo 6.

Outfall 5:

Photo 1.

Photo 2.

Photo 3.

Photo 4.

Photo 5.

Photo 6.

Outfall 8:

Photo 1.

Photo 2.

Photo 3.

Photo 4.

Photo 5.

Photo 6.

Outfall 14:

Photo 1.

Photo 2.

Photo 3.

Photo 4.

Outfall 19:

Photo 1.

Photo 2.

Photo 3.

Photo 4.

Outfall 24:

Photo 1.

Photo 2.

Photo 3.

Photo 4.

Photo 5.

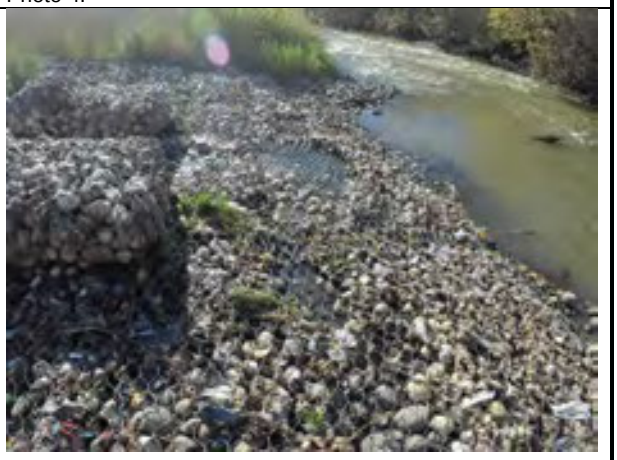


Photo 6.

Outfall 28:

Photo 1.

Photo 2.

Photo 3.

Photo 4.

Outfall 33:

Photo 1.

Photo 2.

Photo 3.

Photo 4.

Photo 5.

Photo 6.

Outfall 39:

Photo 1.

Photo 2.

Photo 3.

Photo 4.

Outfall 41:

Photo 1.

Photo 2.

Photo 3.

Photo 4.

Photo 5.

Photo 6.

Outfall 44:

Photo 1.

Photo 2.

Photo 3.

Photo 4.

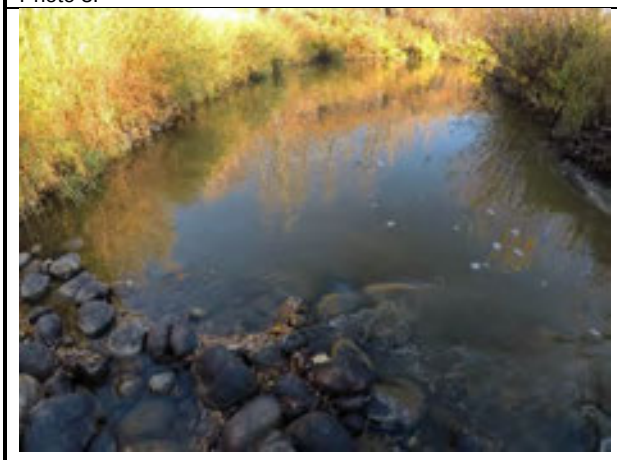


Photo 5.

Photo 6.

Outfall 50:

Photo 1.

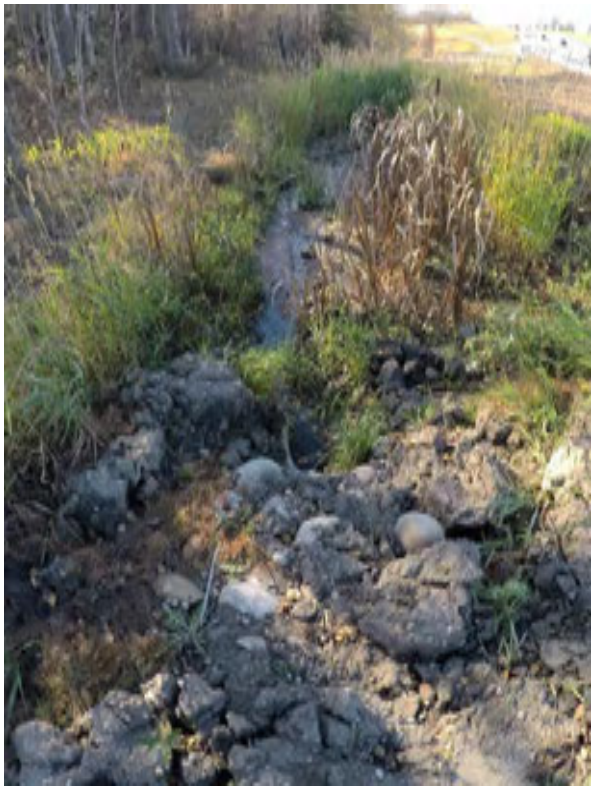


Photo 2.

Photo 3.

Photo 4.

Outfall 52:

Photo 1.

Photo 2.

Photo 3.

Photo 4.

Outfall 53:

Photo 1.

Photo 2.

Photo 3.

Photo 4.

C.2 Outfalls with Moderate Level of Damage

Outfall 10:

Photo 1.

Photo 2.

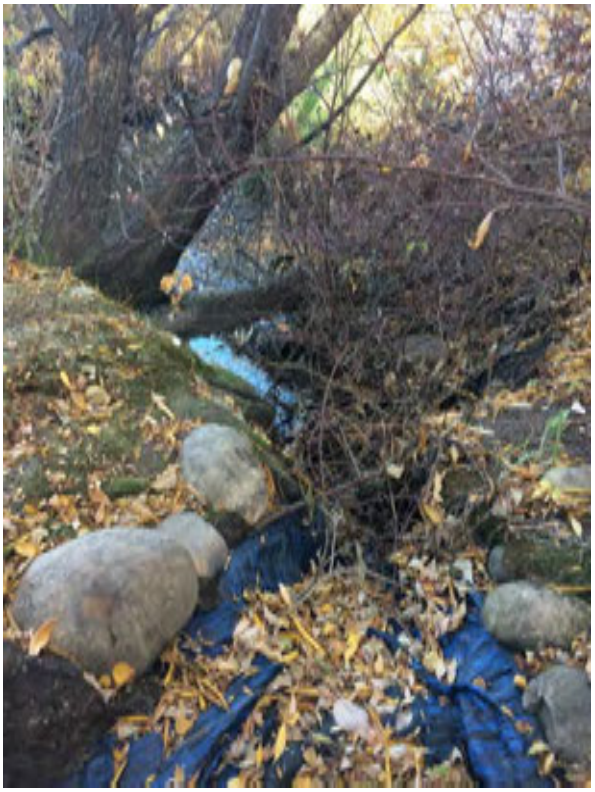


Photo 4.

Photo 3.

Photo 5.

Outfall 13:

Photo 1.

Photo 2.

Photo 3.

Photo 4.

Photo 5.

Photo 6.

Outfall 17:

Photo 1.

Photo 2.

Photo 3.

Photo 4.

Photo 5.

Photo 6.

Outfall 20:

Photo 1.

Photo 2.

Photo 3.

Photo 4.

Outfall 25:

Photo 1.

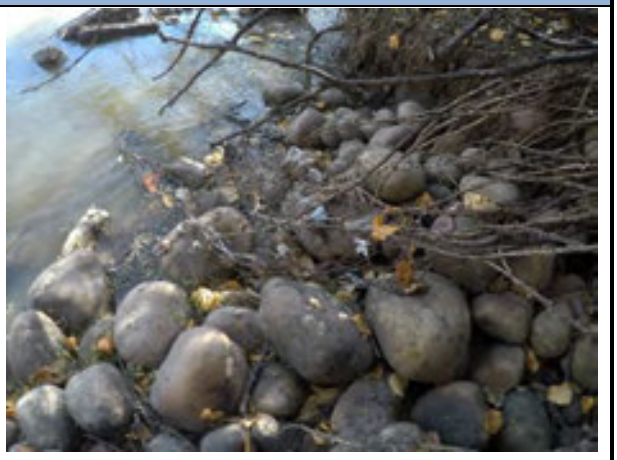


Photo 2.

Photo 3.

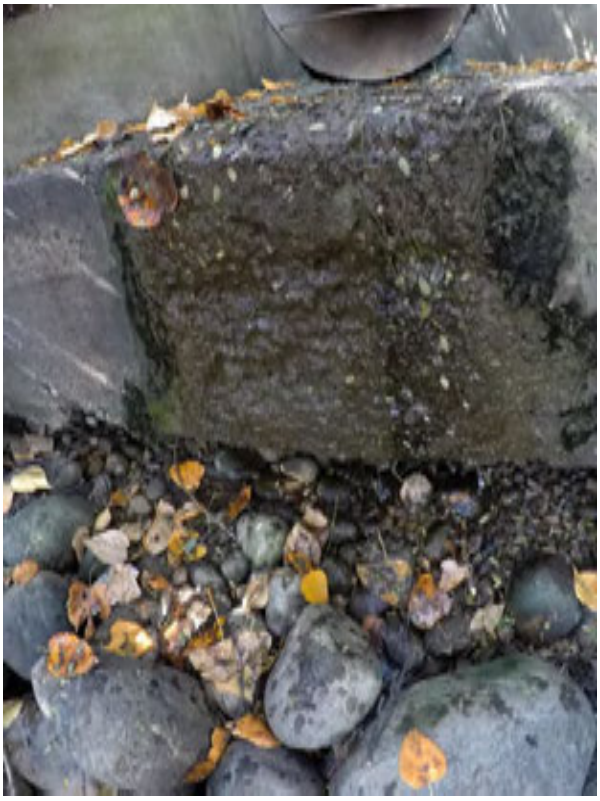


Photo 4.

Outfall 30:

Photo 1.

Photo 2.

Photo 3.

Photo 4.

Outfall 34:

Photo 1.

Photo 2.

Photo 3.

Outfall 37:

Photo 1.

Photo 2.

Photo 3.

Photo 4.

Photo 5.

Photo 6.

Outfall 40:

Photo 1.

Photo 2.

Photo 3.

Outfall 46:

Photo 1.

Photo 2.

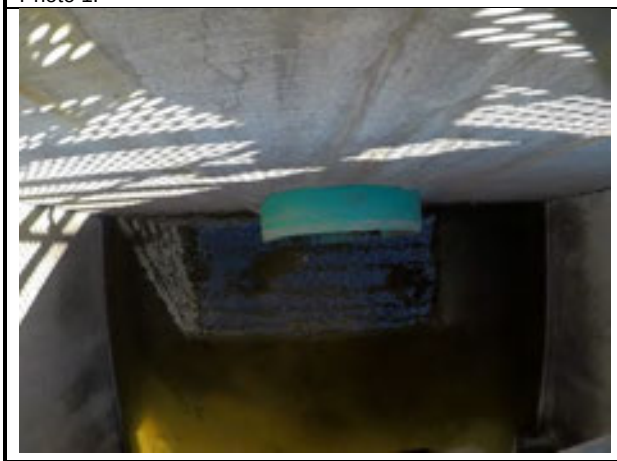


Photo 3.

Photo 4.

Photo 5.

Photo 6.

Outfall 46:

Photo 7.

Photo 8.

Photo 9.

Photo 10.

Outfall 48:

Photo 1.

Photo 2.

Photo 3.

Photo 4.

Photo 5.

Photo 6.

Outfall 56:

Photo 1.

Photo 2.

Photo 3.

Photo 4.

Outfall 59:

Photo 7.

Photo 8.

APPENDIX B
Bear Creek Corridor Site Photographs - May 23, 2018

Matrix Solutions Inc. - May 23, 2018

1. South Bear Creek bridge - downstream.

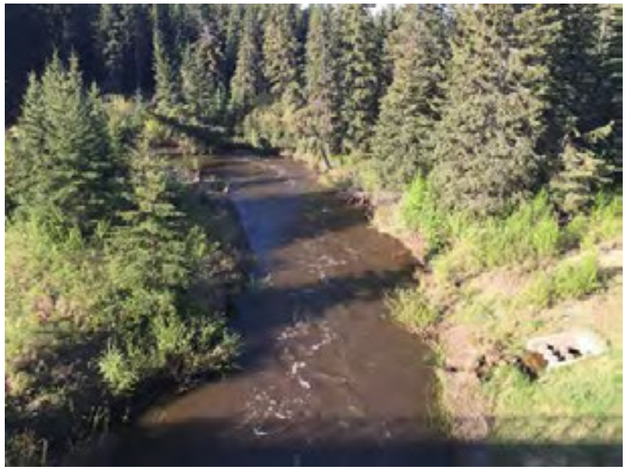
Matrix Solutions Inc. - May 23, 2018

2. South Bear Creek bridge - upstream meander scar.

Matrix Solutions Inc. - May 23, 2018

3. 68 Avenue bridge.

Matrix Solutions Inc. - May 23, 2018



4. Outfall 52 near 68 Avenue bridge.

Matrix Solutions Inc. - May 23, 2018

5. Bear Creek left bank conditions between 68 Avenue and pedestrian bridge.

Matrix Solutions Inc. - May 23, 2018

6. Local drainage issue (foreground) and left bank erosion (background).

Matrix Solutions Inc. - May 23, 2018

7. Erosion along embankment toe, below 68 Avenue bridge, left bank.

Matrix Solutions Inc. - May 23, 2018

8. 68 Avenue bridge opening.

Matrix Solutions Inc. - May 23, 2018

9. Drainage issue under 68 Avenue bridge.

Matrix Solutions Inc. - May 23, 2018

10. Upstream erosion near rock embankment upstream of 68 Avenue bridge, right bank.

Matrix Solutions Inc. - May 23, 2018

11. Rock embankment under 68 Avenue bridge.

Matrix Solutions Inc. - May 23, 2018

12. Fill material under 68 Avenue bridge.

Matrix Solutions Inc. - May 23, 2018

13. Caution: buried water line downstream of 68 Avenue bridge.

Matrix Solutions Inc. - May 23, 2018

14. Bank protection and slope rehabilitation near 72 Avenue (photograph from pedestrian bridge).

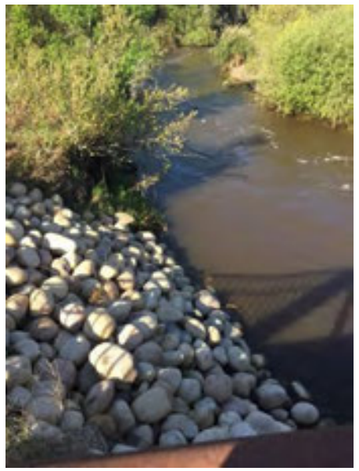
Matrix Solutions Inc. - May 23, 2018

15. Erosion at pedestrian bridge near 72 Avenue.

Matrix Solutions Inc. - May 23, 2018

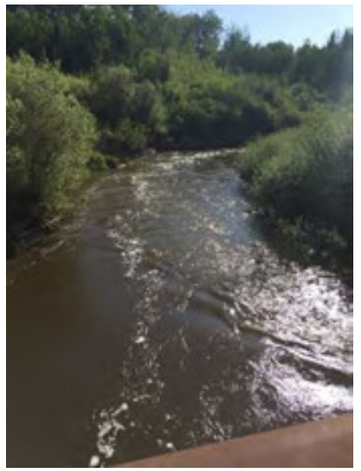
16. Upstream channel conditions at pedestrian bridge near 72 Avenue.

Matrix Solutions Inc. - May 23, 2018



17. Erosion protection at pedestrian bridge near 79 Avenue, right bank upstream of bridge.

Matrix Solutions Inc. - May 23, 2018



18. Bank conditions downstream of pedestrian bridge near 79 Avenue.

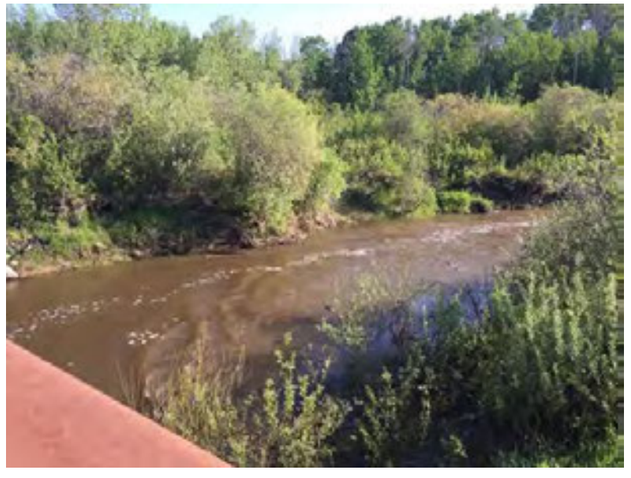
Matrix Solutions Inc. - May 23, 2018

19. Pedestrian bridge near 79 Avenue.

Matrix Solutions Inc. - May 23, 2018

20. Erosion protection at pedestrian bridge near 79 Avenue.

Matrix Solutions Inc. - May 23, 2018



21. Pedestrian bridge near 79 Avenue downstream left bank condition.

Matrix Solutions Inc. - May 23, 2018

22. Bank conditions upstream of pedestrian bridge near 84 Avenue bridge.

Matrix Solutions Inc. - May 23, 2018

23. Gabion bank protection along right bank upstream of pedestrian bridge, near 84 Avenue bridge.

Matrix Solutions Inc. - May 23, 2018

24. Gabion bank protection details.

Matrix Solutions Inc. - May 23, 2018

25. Pathway tension cracks between wetland and river, below 84 Avenue.

Matrix Solutions Inc. - May 23, 2018

26. Pedestrian bridge and standing wave at 84 Avenue bridge.

Matrix Solutions Inc. - May 23, 2018

27. Pedestrian bridge and river head drops at 84 Avenue bridge.

Matrix Solutions Inc. - May 23, 2018

28. 84 Avenue bridge.

Matrix Solutions Inc. - May 23, 2018

29. 84 Avenue bridge pathway tension cracking at sloughing gabion mattress.

Matrix Solutions Inc. - May 23, 2018

30. 84 Avenue bridge pathway tension cracking at sloughing gabion mattress.

Matrix Solutions Inc. - May 23, 2018

31. 84 Avenue bridge left abutment gap at sloughing gabion mattress.

Matrix Solutions Inc. - May 23, 2018

32. 84 Avenue bridge pathway, facing downstream.

Matrix Solutions Inc. - May 23, 2018

33. Meander scar along west valley wall near 84 Avenue bridge.

Matrix Solutions Inc. - May 23, 2018

34. Bank conditions near pedestrian bridge near 89 Avenue.

Matrix Solutions Inc. - May 23, 2018

35. Trail closure near 89 Avenue.

Matrix Solutions Inc. - May 23, 2018

36. Train closure near 89 Avenue.

Matrix Solutions Inc. - May 23, 2018

37. Upstream trail closure near 89 Avenue.

Matrix Solutions Inc. - May 23, 2018

38. Relic embankment from former pipe crossing.

Matrix Solutions Inc. - May 23, 2018

39. Downstream bank conditions at pedestrian bridge near 94 Avenue.

Matrix Solutions Inc. - May 23, 2018

40. Upstream bank conditions at pedestrian bridge near 94 Avenue.

Matrix Solutions Inc. - May 23, 2018

41. Bank erosion downstream of old rail bridge.

Matrix Solutions Inc. - May 23, 2018

42. Bear Creek at old rail bridge.

Matrix Solutions Inc. - May 23, 2018

43. Bank conditions upstream of pedestrian bridge near 99 Avenue bridge.

Matrix Solutions Inc. - May 23, 2018

44. Outfall 22, gabion damage.

Matrix Solutions Inc. - May 23, 2018

45. Pathway approach to 99 Avenue bridge, south side.

Matrix Solutions Inc. - May 23, 2018

46. Potential scour at 99 Avenue bridge pier.

Matrix Solutions Inc. - May 23, 2018

47. 99 Avenue bridge pier gabion conditions.

Matrix Solutions Inc. - May 23, 2018

48. 99 Avenue bridge gabion mattress conditions at left bridge abutment (east side).

Matrix Solutions Inc. - May 23, 2018

49. Pathway between 99 Avenue bridge and 100 Avenue bridge, facing south.

Matrix Solutions Inc. - May 23, 2018

50. Local drainage to pathway between 99 Avenue bridge and 100 Avenue bridge.

Matrix Solutions Inc. - May 23, 2018

51. Pathway approach to 100 Avenue bridge.

Matrix Solutions Inc. - May 23, 2018

52. Pathway buckling under 100 Avenue bridge.

Matrix Solutions Inc. - May 23, 2018

53. Bank conditions upstream of 100 Avenue bridge near museum.

Matrix Solutions Inc. - May 23, 2018

54. Bank conditions upstream of pedestrian bridge near dam.

Matrix Solutions Inc. - May 23, 2018

55. Bank conditions downstream of pedestrian bridge near dam.

Matrix Solutions Inc. - May 23, 2018

56. Bioengineering bank protection along pathway below dam.

Matrix Solutions Inc. - May 23, 2018

57. Local drainage at Elks Lodge along reservoir.

Matrix Solutions Inc. - May 23, 2018

58. Pedestrian bridge across reservoir, facing south.

Matrix Solutions Inc. - May 23, 2018

59. Pedestrian bridge across reservoir, facing north.

Matrix Solutions Inc. - May 23, 2018

60. Reservoir view from Grande Prairie College.

Matrix Solutions Inc. - May 23, 2018

61. Dam spillway.

Matrix Solutions Inc. - May 23, 2018

62. Dam gates.

Matrix Solutions Inc. - May 23, 2018

63. Meander scar near end of 102 Street.

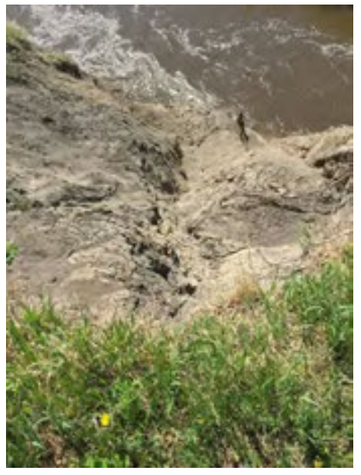
Matrix Solutions Inc. - May 23, 2018

64. Path of local drainage from 102 Street to meander scar.

Matrix Solutions Inc. - May 23, 2018

65. End of 102 Street.

Matrix Solutions Inc. - May 23, 2018



66. Gully below 102 Street.

Matrix Solutions Inc. - May 23, 2018

67. Pathway at bank erosion near 88 Avenue.

Matrix Solutions Inc. - May 23, 2018

68. Landslide near trailer park.

Matrix Solutions Inc. - May 23, 2018

69. Suspended utilities at landslide near trailer park.

Matrix Solutions Inc. - May 23, 2018

70. Upstream erosion near landslide at trailer park.

Matrix Solutions Inc. - May 23, 2018

71. Trailer park at landslide.

Matrix Solutions Inc. - May 23, 2018

72. Trailer park at landslide.

Matrix Solutions Inc. - May 23, 2018

73. Bank conditions upstream of pedestrian bridge near 79 Avenue.

Matrix Solutions Inc. - May 23, 2018

74. Reclaimed slope near 75 Avenue.

Matrix Solutions Inc. - May 23, 2018

75. Reclaimed bank near 75 Avenue.

Matrix Solutions Inc. - May 24, 2018

76. South Bear Creek utility/pedestrian bridge upstream side.

Matrix Solutions Inc. - May 24, 2018

77. South Bear Creek utility/pedestrian bridge downstream side.

Matrix Solutions Inc. - May 24, 2018

78. Outfall 1.

Matrix Solutions Inc. - May 24, 2018

79. Reclamation at Outfall 1.

Matrix Solutions Inc. - May 24, 2018

80. Pathway and gabion wall under bridge at 108 Street.

Matrix Solutions Inc. - May 24, 2018

81. Bridge at 132 Avenue.

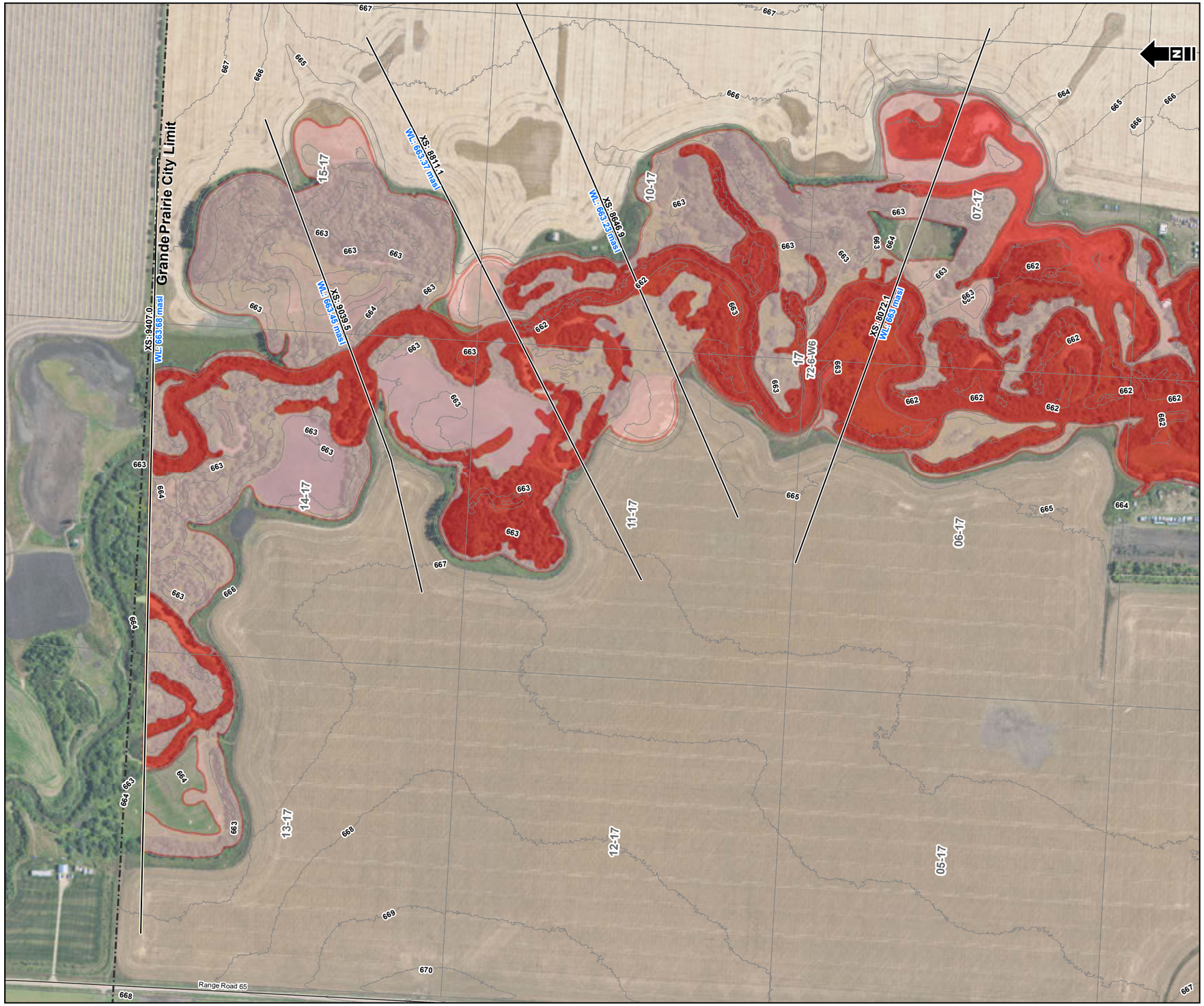
Matrix Solutions Inc. - May 24, 2018

82. 132 Avenue bridge missing erosion protection under bridge, left bank.

Matrix Solutions Inc. - May 24, 2018

83. Bank failure upstream of 132 Avenue bridge.

APPENDIX C
1:100 Year Flood Risk Maps



Flood Fringe | 100 Year Encroachment (Matrix 2017)
Floodway | 100 Year Encroachment (Matrix 2017)
Cross Section (Matrix 2017)
Study Domain Limit (Matrix 2017)
Community Boundary
Contour Interval (masl)
Road

Coordinate System: North American 1983 CSRS 10TM
Projection: Transverse Mercator
Datum: North American 1983 CSRS
False Easting: 500,000.0000
False Northing: -5,000,000.0000
Central Meridian: -115.0000
Scale Factor: 0.9992
Latitude Of Origin: 0.0000
Units: Meter

1:5,000 metres
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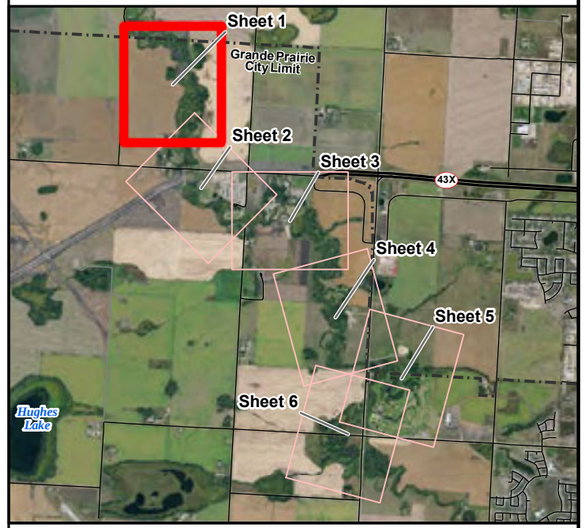

Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

City of Grande Prairie
Bear Creek Corridor Assessment

100 Year Flood Risk - Sheet 1

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Bender	A. Chan

Figure C-1

Flood Fringe | 100 Year Encroachment (Matrix 2017)
Floodway | 100 Year Encroachment (Matrix 2017)
Cross Section (Matrix 2017)
Study Domain Limit (Matrix 2017)
Community Boundary
Contour Interval (masl)
Road
Hydraulic Structure Location

Coordinate System: North American 1983 CSRS 10TM
Projection: Transverse Mercator
Datum: North American 1983 CSRS
False Easting: 500,000.0000
False Northing: -5,000,000.0000
Central Meridian: -115.0000
Scale Factor: 0.9992
Latitude Of Origin: 0.0000
Units: Meter

1:5,000 metres
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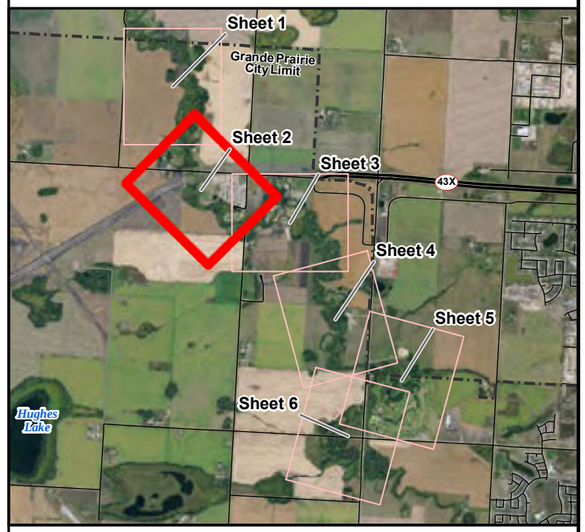


Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

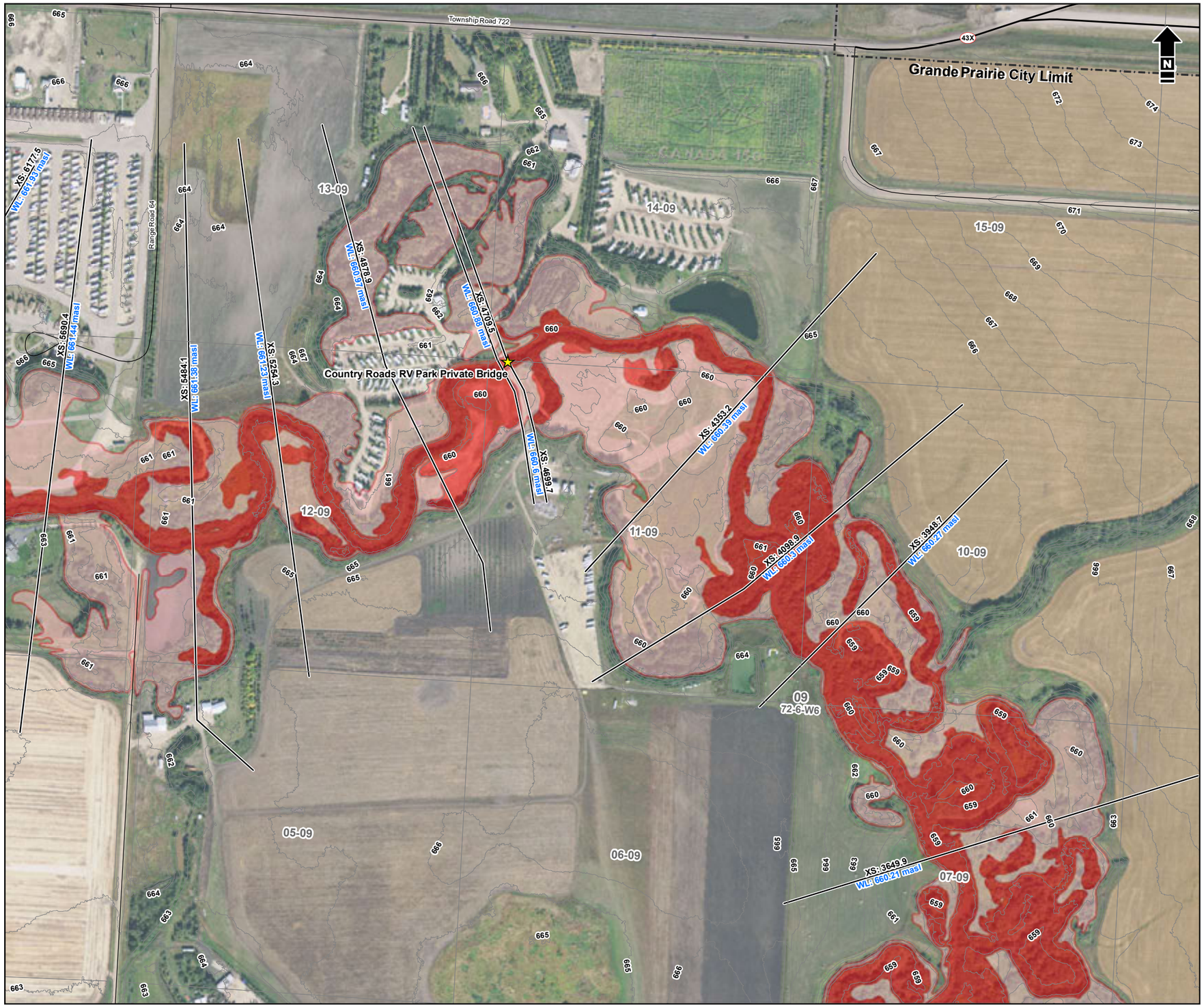
City of Grande Prairie
Bear Creek Corridor Assessment

100 Year Flood Risk - Sheet 2

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Bender	A. Chan

Figure C-2

I:\City of Grande Prairie\24079\Figures And Tables\HYD\2017 Report\Bear Creek Corridor Assessment\Appendix C-1_100_Year_Flood_Risk.mxd - Tabloid_L - 20-Aug-18, 02:59 PM - mwilkinson - TD005



Flood Fringe | 100 Year Encroachment (Matrix 2017)
Floodway | 100 Year Encroachment (Matrix 2017)
Cross Section (Matrix 2017)
Study Domain Limit (Matrix 2017)
Community Boundary
Contour Interval (masl)
Highway
Road
Hydraulic Structure Location

Coordinate System: North American 1983 CSRS 10TM
Projection: Transverse Mercator
Datum: North American 1983 CSRS
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False Northing: -5,000,000.0000
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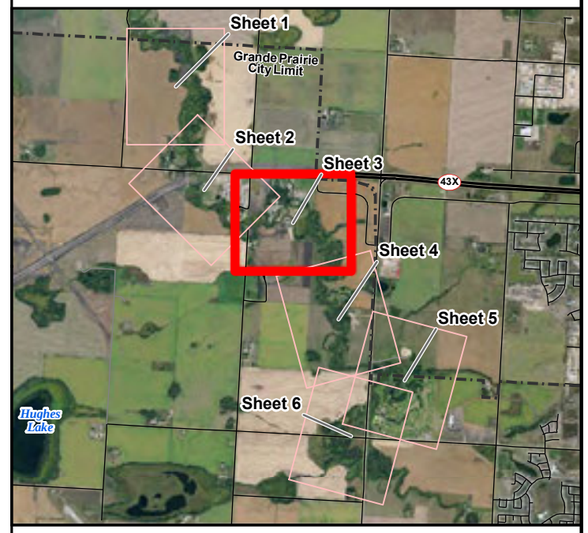
Units: Meter

1:5,000 metres
50 0 50 100



Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

City of Grande Prairie
Bear Creek Corridor Assessment

100 Year Flood Risk - Sheet 3

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Bender	A. Chan

Figure C-3

Flood Fringe | 100 Year Encroachment (Matrix 2017)
Floodway | 100 Year Encroachment (Matrix 2017)
Cross Section (Matrix 2017)
Study Domain Limit (Matrix 2017)
Community Boundary
Contour Interval (masl)
Road
Industry Road
Hydraulic Structure Location

Coordinate System: North American 1983 CSRS 10TM
Projection: Transverse Mercator
Datum: North American 1983 CSRS
False Easting: 500,000.0000
False Northing: -5,000,000.0000
Central Meridian: -115.0000
Scale Factor: 0.9992
Latitude Of Origin: 0.0000
Units: Meter

1:5,000 metres
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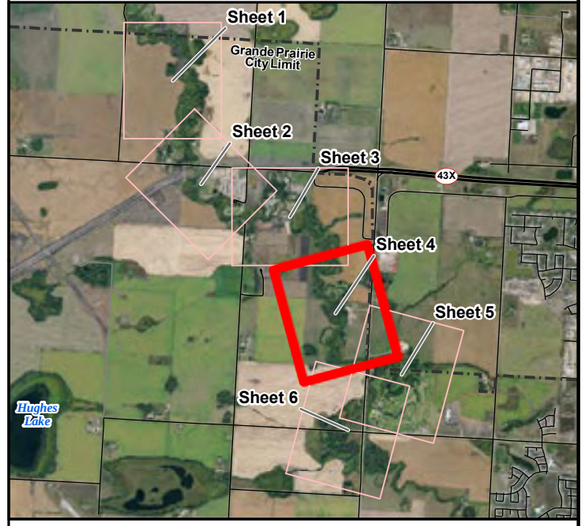


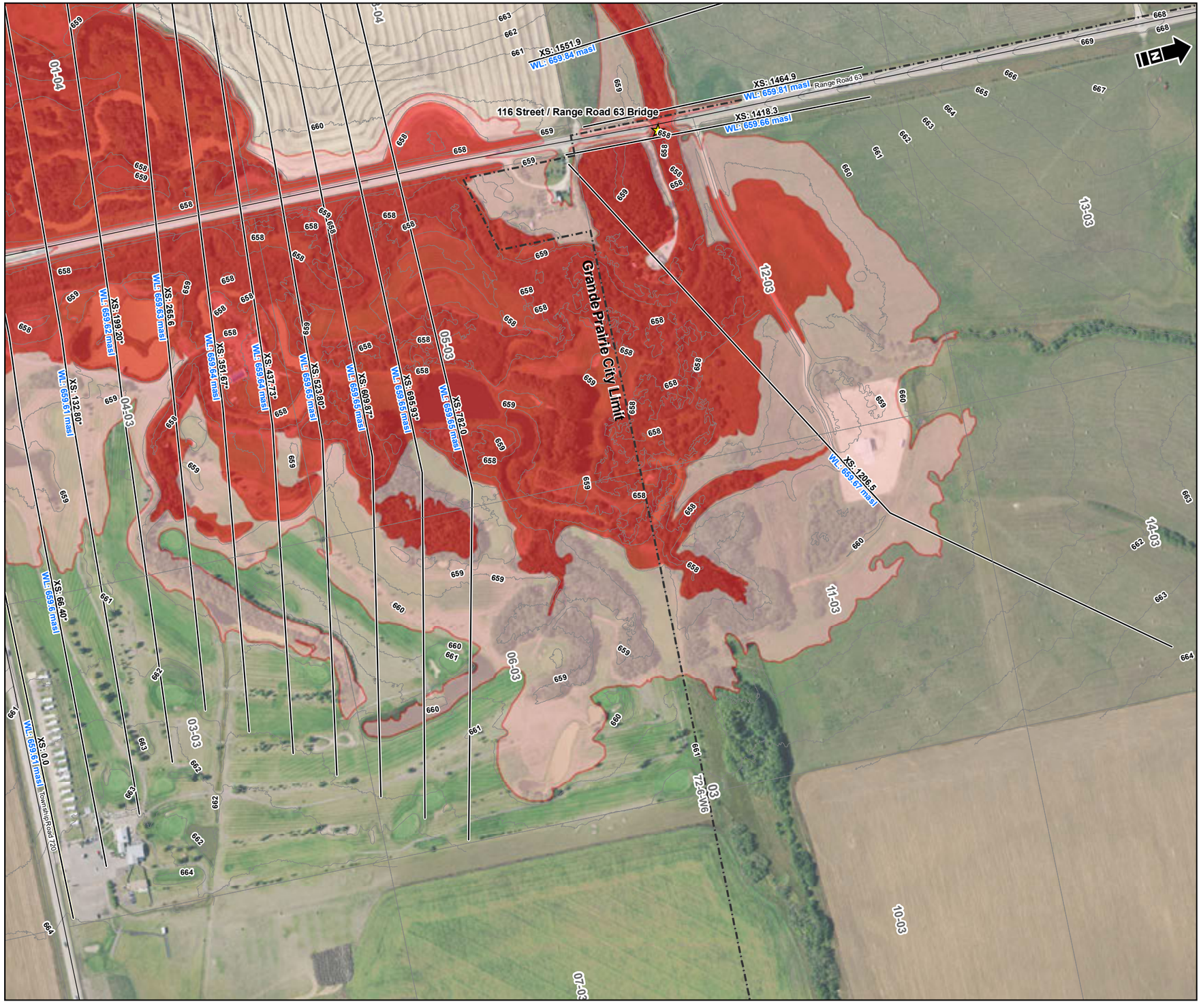
Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

City of Grande Prairie
Bear Creek Corridor Assessment

100 Year Flood Risk - Sheet 4

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Bender	A. Chan

Figure C-4



Flood Fringe | 100 Year Encroachment (Matrix 2017)
Floodway | 100 Year Encroachment (Matrix 2017)
Cross Section (Matrix 2017)
Study Domain Limit (Matrix 2017)
Community Boundary
Contour Interval (masl)
Road
Industry Road
Hydraulic Structure Location

Coordinate System: North American 1983 CSRS 10TM
Projection: Transverse Mercator
Datum: North American 1983 CSRS
False Easting: 500,000.0000
False Northing: -5,000,000.0000
Central Meridian: -115.0000
Scale Factor: 0.9992
Latitude Of Origin: 0.0000
Units: Meter

1:5,000 metres
50 0 50 100

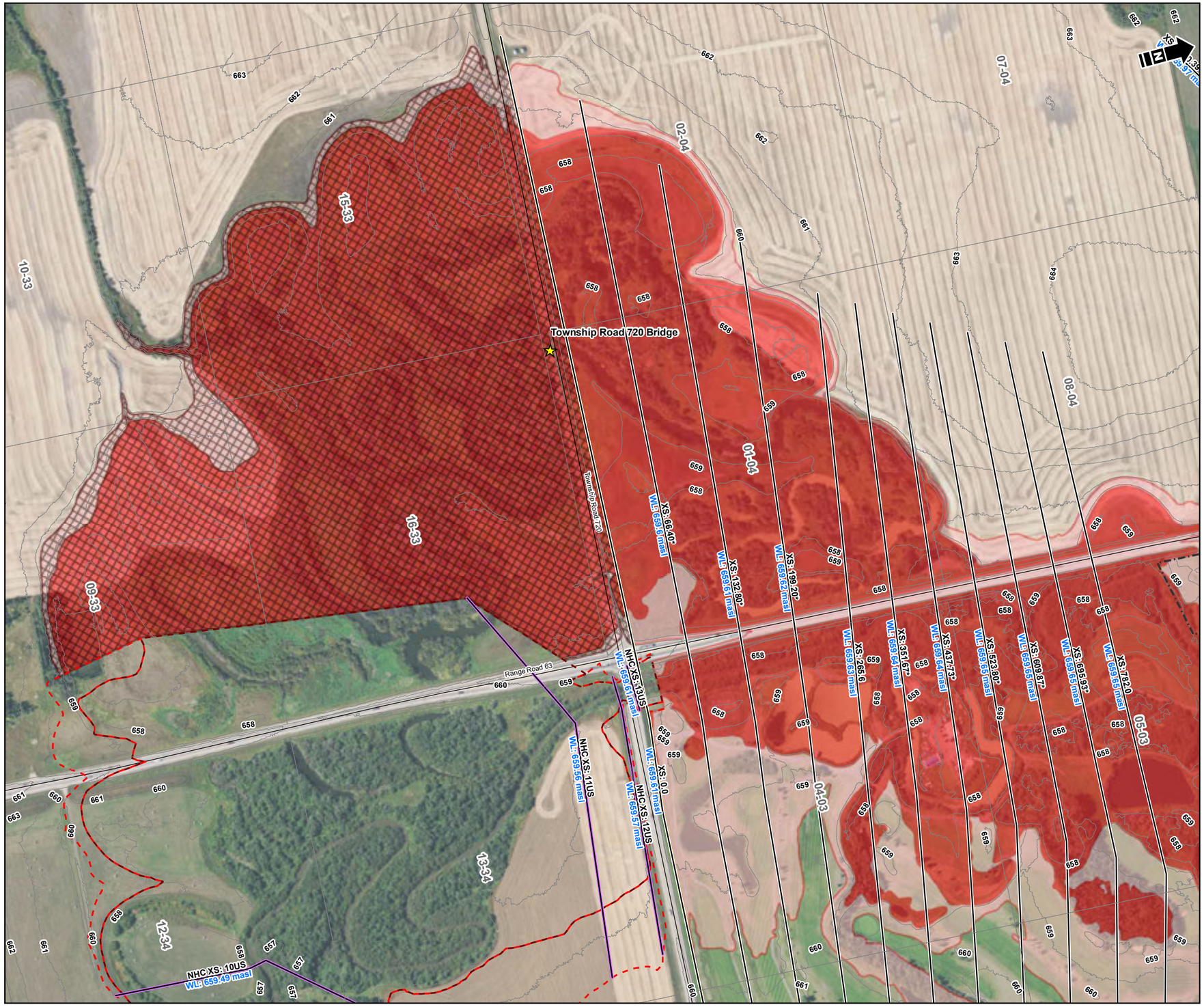
Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

City of Grande Prairie
Bear Creek Corridor Assessment

100 Year Flood Risk - Sheet 5

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Bender	A. Chan

Figure C-5



- Flood Fringe | 100 Year Encroachment (Matrix 2017)
- Floodway | 100 Year Encroachment (Matrix 2017)
- Flood Fringe | 100 Year Encroachment (NHC 2007)
- Floodway | 100 Year Encroachment (NHC 2007)
- Area Interpolated Between Matrix & NHC Hydraulic Models
- Cross Section (Matrix 2017)
- Study Domain Limit (Matrix 2017)
- Cross Section (NHC 2007)
- Community Boundary
- Contour Interval (masl)
- Road
- Hydraulic Structure Location

Coordinate System: North American 1983 CSRS 10TM
Projection: Transverse Mercator
Datum: North American 1983 CSRS
False Easting: 500,000.0000
False Northing: -5,000,000.0000
Central Meridian: -115.0000
Scale Factor: 0.9992
Latitude Of Origin: 0.0000
Units: Meter

1:5,000 metres
50 0 50 100

Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

City of Grande Prairie
Bear Creek Corridor Assessment

100 Year Flood Risk - Sheet 6

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Bender	A. Chan

Figure C-6

APPENDIX D
1:200 Year Flood Inundation Maps

Direct Flood Inundation Area | 200 Year Natural
Cross Section (Matrix 2017)
Study Domain Limit (Matrix 2017)
Community Boundary
Contour Interval (masl)
Road

Coordinate System: North American 1983 CSRS 10TM
Projection: Transverse Mercator
Datum: North American 1983 CSRS
False Easting: 500,000.0000
False Northing: -5,000,000.0000
Central Meridian: -115.0000
Scale Factor: 0.9992
Latitude Of Origin: 0.0000
Units: Meter

1:5,000 metres
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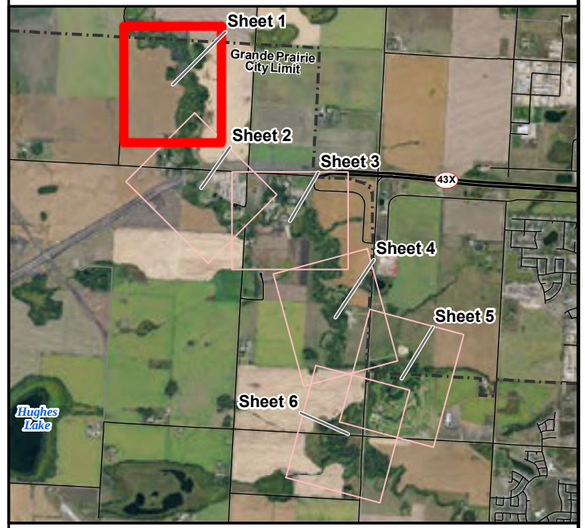

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City of Grande Prairie
Bear Creek Corridor Assessment

200 Year Inundation - Sheet 1

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Bender	A. Chan

Figure D-1

Direct Flood Inundation Area | 200 Year Natural
Cross Section (Matrix 2017)
Study Domain Limit (Matrix 2017)
Community Boundary
Contour Interval (masl)
Road
Hydraulic Structure Location

Coordinate System: North American 1983 CSRS 10TM
Projection: Transverse Mercator
Datum: North American 1983 CSRS
False Easting: 500,000.0000
False Northing: -5,000,000.0000
Central Meridian: -115.0000
Scale Factor: 0.9992
Latitude Of Origin: 0.0000
Units: Meter

1:5,000 metres
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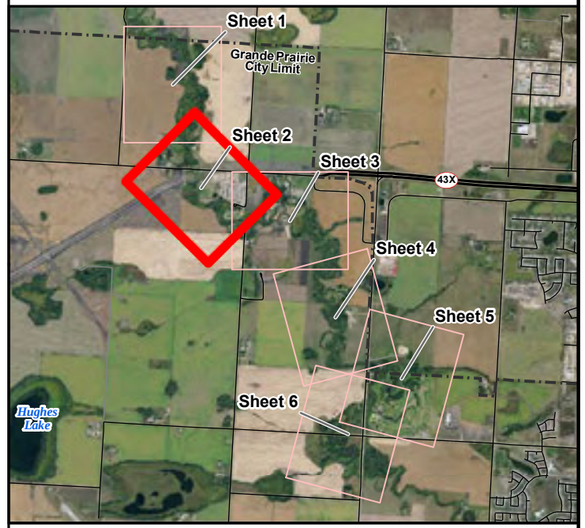

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City of Grande Prairie
Bear Creek Corridor Assessment

200 Year Inundation - Sheet 2

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Bender	A. Chan

Figure D-2

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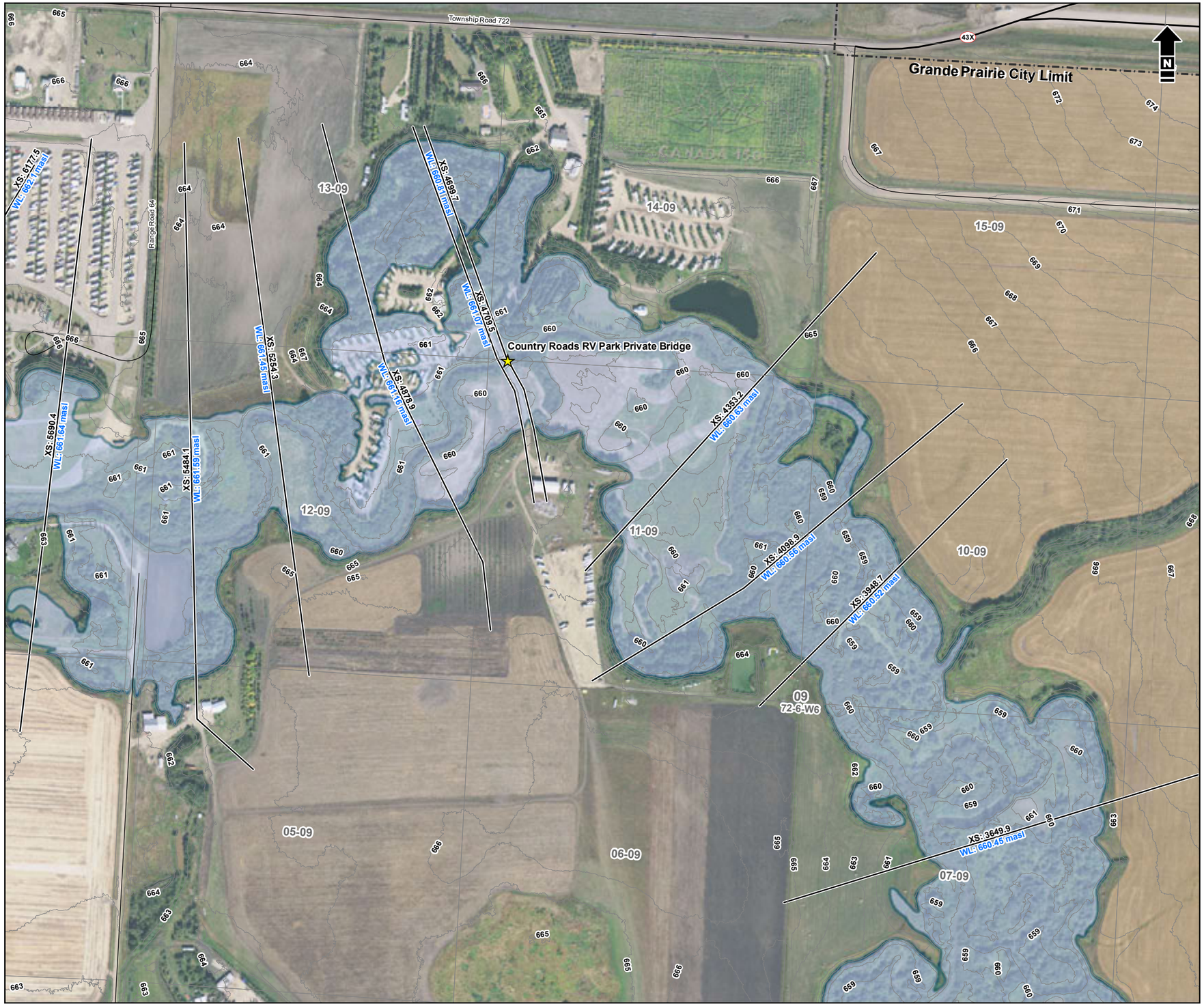

Direct Flood Inundation Area | 200 Year Natural
Cross Section (Matrix 2017)
Study Domain Limit (Matrix 2017)
Community Boundary
Contour Interval (masl)
Highway
Road
Hydraulic Structure Location

Coordinate System: North American 1983 CSRS 10TM
Projection: Transverse Mercator
Datum: North American 1983 CSRS
False Easting: 500,000.0000
False Northing: -5,000,000.0000
Central Meridian: -115.0000
Scale Factor: 0.9992
Latitude Of Origin: 0.0000
Units: Meter

1:5,000 metres
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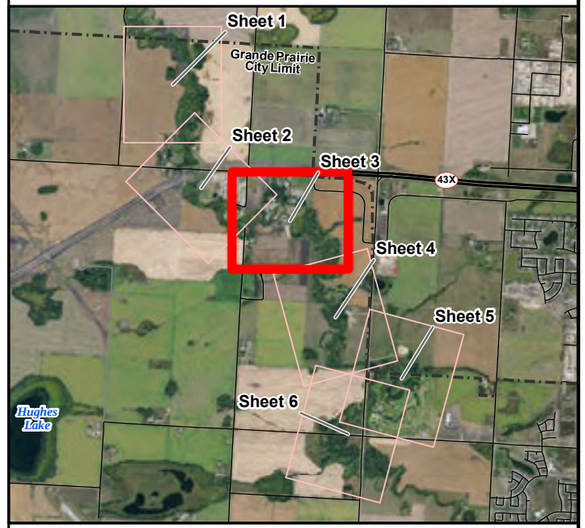

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City of Grande Prairie
Bear Creek Corridor Assessment

200 Year Inundation - Sheet 3

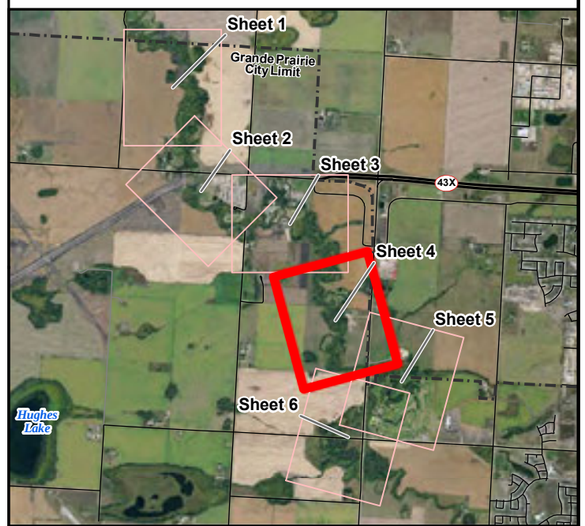
Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Bender	A. Chan

Figure D-3

Direct Flood Inundation Area | 200 Year Natural
Cross Section (Matrix 2017)
Study Domain Limit (Matrix 2017)
Community Boundary
Contour Interval (masl)
Road
Industry Road
Hydraulic Structure Location

Coordinate System: North American 1983 CSRS 10TM
Projection: Transverse Mercator
Datum: North American 1983 CSRS
False Easting: 500,000.0000
False Northing: -5,000,000.0000
Central Meridian: -115.0000
Scale Factor: 0.9992
Latitude Of Origin: 0.0000
Units: Meter

1:5,000 metres
50 0 50 100



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City of Grande Prairie
Bear Creek Corridor Assessment

200 Year Inundation - Sheet 4

Date:	Project:	Submitter:	Reviewer:
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Figure D-4

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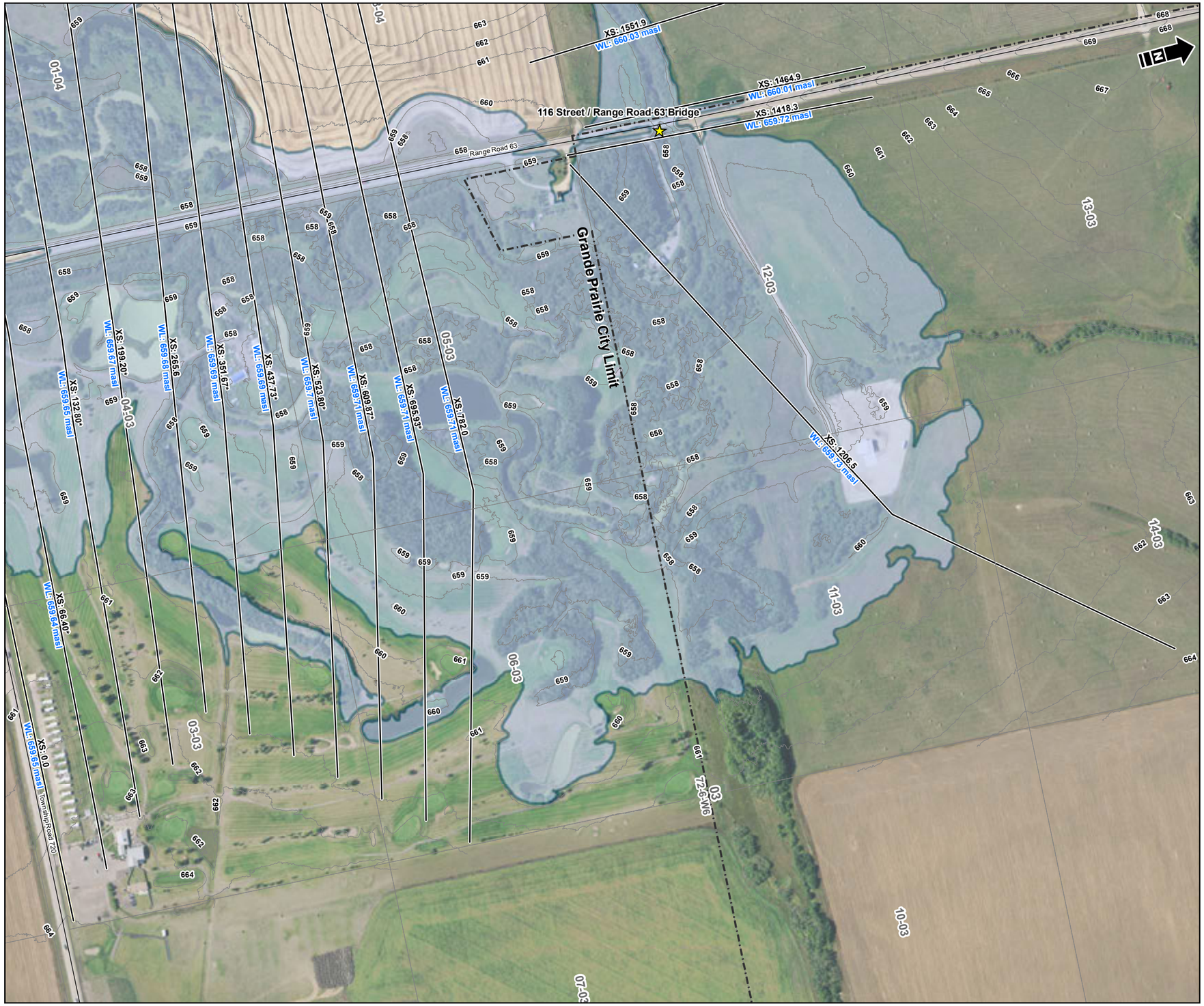

Direct Flood Inundation Area | 200 Year Natural
Cross Section (Matrix 2017)
Study Domain Limit (Matrix 2017)
Community Boundary
Contour Interval (masl)
Road
Industry Road
Hydraulic Structure Location

Coordinate System: North American 1983 CSRS 10TM
Projection: Transverse Mercator
Datum: North American 1983 CSRS
False Easting: 500,000.0000
False Northing: -5,000,000.0000
Central Meridian: -115.0000
Scale Factor: 0.9992
Latitude Of Origin: 0.0000
Units: Meter

1:5,000 metres
50 0 50 100

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City of Grande Prairie
Bear Creek Corridor Assessment

200 Year Inundation - Sheet 5

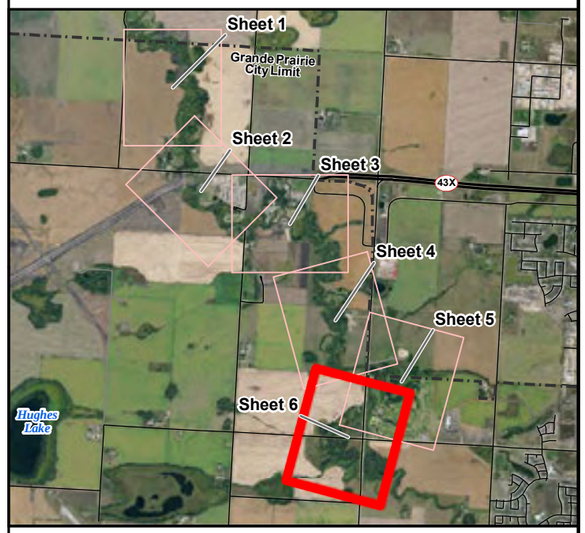
Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Bender	A. Chan

Figure D-5

Direct Flood Inundation Area | 200 Year Natural
Cross Section (Matrix 2017)
Study Domain Limit (Matrix 2017)
Community Boundary
Contour Interval (masl)
Road
Hydraulic Structure Location

Coordinate System: North American 1983 CSRS 10TM
Projection: Transverse Mercator
Datum: North American 1983 CSRS
False Easting: 500,000.0000
False Northing: -5,000,000.0000
Central Meridian: -115.0000
Scale Factor: 0.9992
Latitude Of Origin: 0.0000
Units: Meter

1:5,000 metres
50 0 50 100



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City of Grande Prairie
Bear Creek Corridor Assessment

200 Year Inundation - Sheet 6

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Bender	A. Chan

Figure D-6

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APPENDIX E
Delineated Historical Banklines

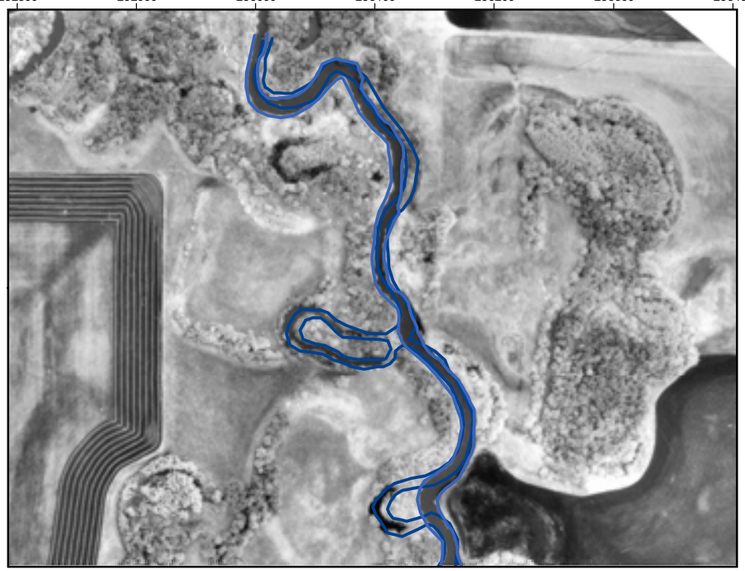
Easting (m)

252800 252900 253000 253100 253200 253300 253400

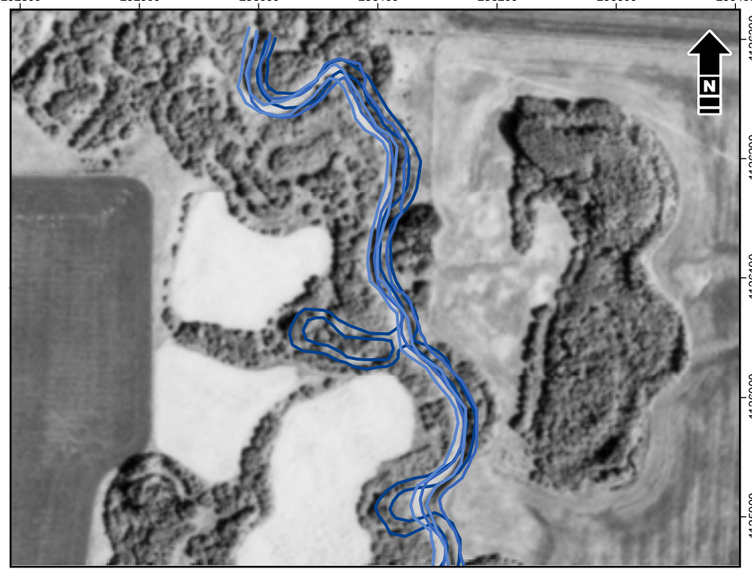
Northing (m)

1126300 1126200 1126100 1126000 1125900

1951 Aerial Photograph (AEP)



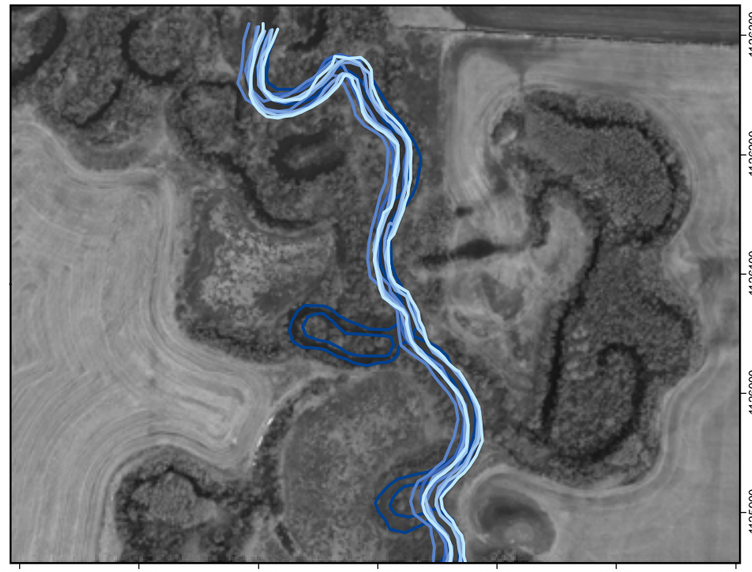
1976 Aerial Photograph (AEP)



1989 Aerial Photograph (AEP)

1993 Aerial Photograph (AEP)

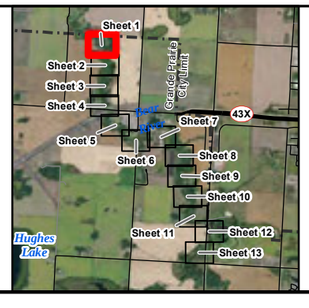
2012 Aerial Photograph (Valtus)



2014 Aerial Photograph (City of Grande Prairie)

Year

- Bankline Delineation - 1951 Aerial Photograph
- Bankline Delineation - 1976 Aerial Photograph
- Bankline Delineation - 1989 Aerial Photograph
- Bankline Delineation - 1993 Aerial Photograph
- Bankline Delineation - 2012 Aerial Photograph
- Bankline Delineation - 2014 Aerial Photograph



1:5,000

m

50 0 50 100

North American 1983 CSRS 10TM

Reference: Imagery (1951, 1976, 1989, 1993) obtained from Alberta Environment and Parks © (2018) used under license. Imagery (2012) obtained from Valtus © (2018) used under license. Imagery (2014) obtained from City of Grande Prairie © (2018) used under license.

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City of Grande Prairie
Bear Creek Corridor Assessment

Delineated Historic Banklines
Sheet 1

Date:	Project:	Submitter:	Reviewer:
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Figure E-1

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Easting (m)

252900 253000 253100 253200 253300 253400

Northing (m)

1125800 1125700 1125600 1125500

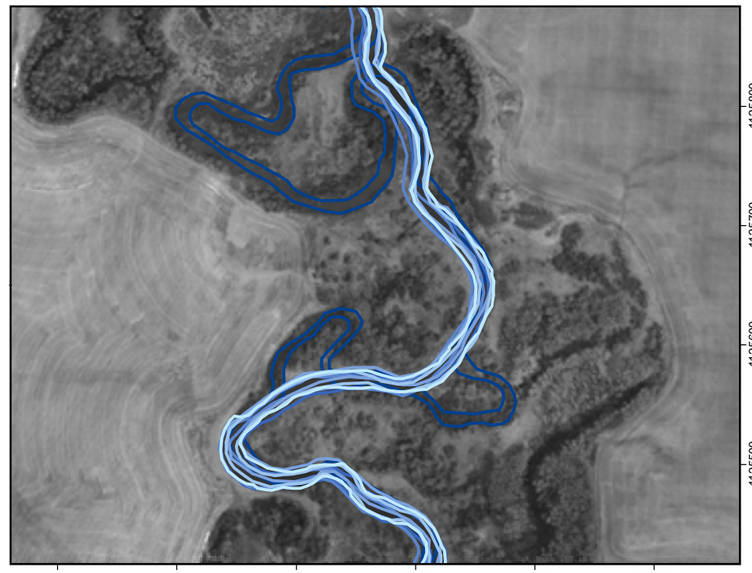
1951 Aerial Photograph (AEP)

1976 Aerial Photograph (AEP)

1989 Aerial Photograph (AEP)

1993 Aerial Photograph (AEP)

2012 Aerial Photograph (Valtus)



2014 Aerial Photograph (City of Grande Prairie)

Year

- Bankline Delineation - 1951 Aerial Photograph
- Bankline Delineation - 1976 Aerial Photograph
- Bankline Delineation - 1989 Aerial Photograph
- Bankline Delineation - 1993 Aerial Photograph
- Bankline Delineation - 2012 Aerial Photograph
- Bankline Delineation - 2014 Aerial Photograph

1:5,000

m 50 0 50 100

North American 1983 CSRS 10TM

Reference: Imagery (1951, 1976, 1989, 1993) obtained from Alberta Environment and Parks © (2018) used under license. Imagery (2012) obtained from Valtus © (2018) used under license. Imagery (2014) obtained from City of Grande Prairie © (2018) used under license.

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City of Grande Prairie
Bear Creek Corridor Assessment

Delineated Historic Banklines
Sheet 2

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Shome	A. Chan

Figure E-2

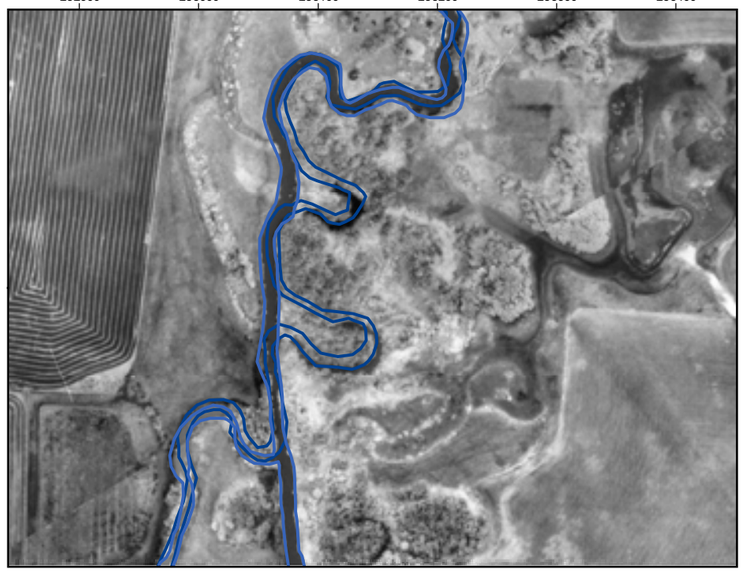
Easting (m)

Northing (m)

252900 253000 253100 253200 253300 253400

1125400 1125300 1125200 1125100 1125000

1951 Aerial Photograph (AEP)



1976 Aerial Photograph (AEP)

1989 Aerial Photograph (AEP)

1993 Aerial Photograph (AEP)

2012 Aerial Photograph (Valtus)

2014 Aerial Photograph (City of Grande Prairie)

Year

- Bankline Delineation - 1951 Aerial Photograph
- Bankline Delineation - 1976 Aerial Photograph
- Bankline Delineation - 1989 Aerial Photograph
- Bankline Delineation - 1993 Aerial Photograph
- Bankline Delineation - 2012 Aerial Photograph
- Bankline Delineation - 2014 Aerial Photograph

1:5,000 m

50 0 50 100

North American 1983 CSRS 10TM

Reference: Imagery (1951, 1976, 1989, 1993) obtained from Alberta Environment and Parks © (2018) used under license. Imagery (2012) obtained from Valtus © (2018) used under license. Imagery (2014) obtained from City of Grande Prairie © (2018) used under license.

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City of Grande Prairie
Bear Creek Corridor Assessment

Delineated Historic Banklines
Sheet 3

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Shome	A. Chan

Figure E-3

I:\City\GrandPrairie\24079\Figures\ArcFiles\HYD\2017\Report\BearCreekCorridorAssessment\Appendix-E-Delineated_Historic_Banklines.mxd - Letter P - 20-Aug-18, 03:51 PM - mwilkinson

Easting (m)

Northing (m)

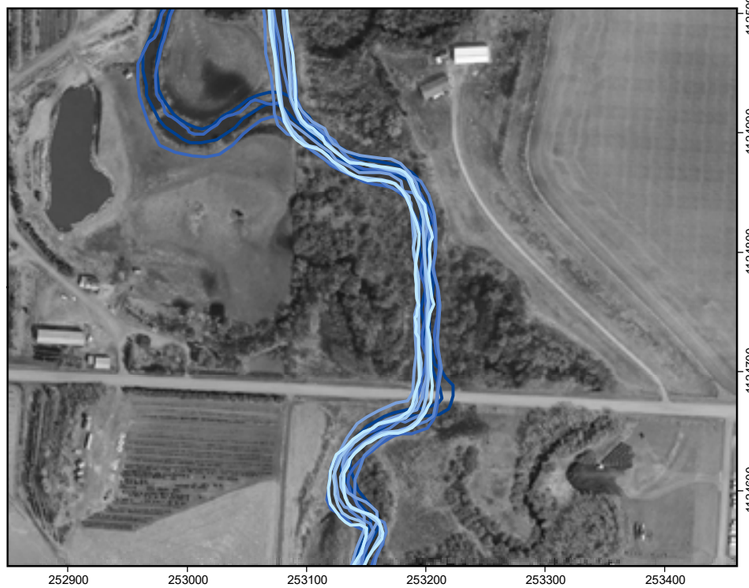
1951 Aerial Photograph (AEP)

1976 Aerial Photograph (AEP)

1989 Aerial Photograph (AEP)

1993 Aerial Photograph (AEP)

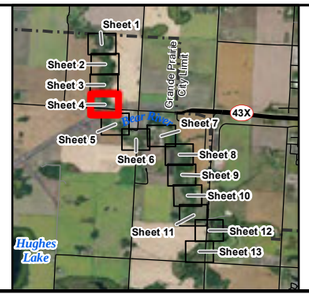
2012 Aerial Photograph (Valtus)



2014 Aerial Photograph (City of Grande Prairie)

Year

- Bankline Delineation - 1951 Aerial Photograph
- Bankline Delineation - 1976 Aerial Photograph
- Bankline Delineation - 1989 Aerial Photograph
- Bankline Delineation - 1993 Aerial Photograph
- Bankline Delineation - 2012 Aerial Photograph
- Bankline Delineation - 2014 Aerial Photograph



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50 0 50 100 m

North American 1983 CSRS 10TM

Reference: Imagery (1951, 1976, 1989, 1993) obtained from Alberta Environment and Parks © (2018) used under license. Imagery (2012) obtained from Valtus © (2018) used under license. Imagery (2014) obtained from City of Grande Prairie © (2018) used under license.

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City of Grande Prairie
Bear Creek Corridor Assessment

Delineated Historic Banklines
Sheet 4

Date:	Project:	Submitter:	Reviewer:
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Figure E-4

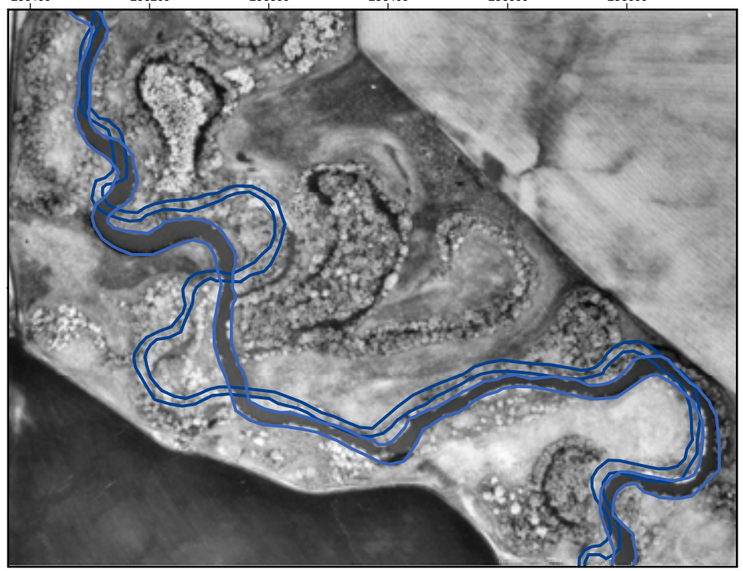
Easting (m)

Northing (m)

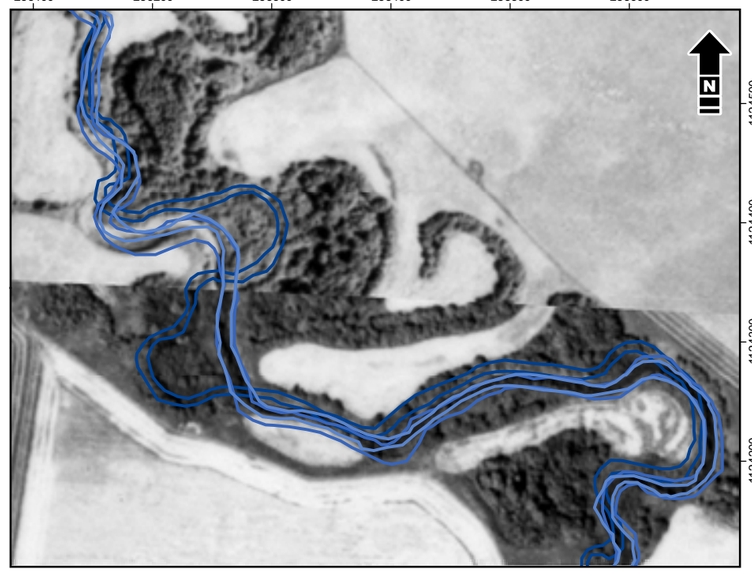
253100 253200 253300 253400 253500 253600

1124500 1124400 1124300 1124200

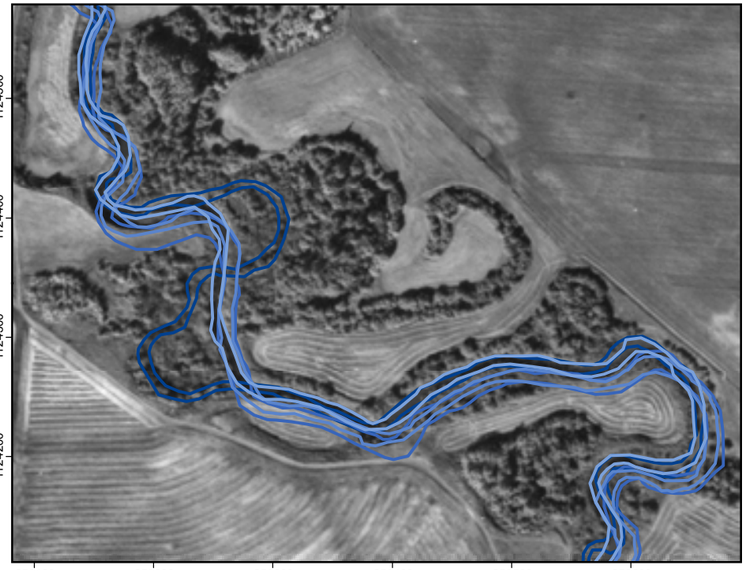
1951 Aerial Photograph (AEP)



1976 Aerial Photograph (AEP)

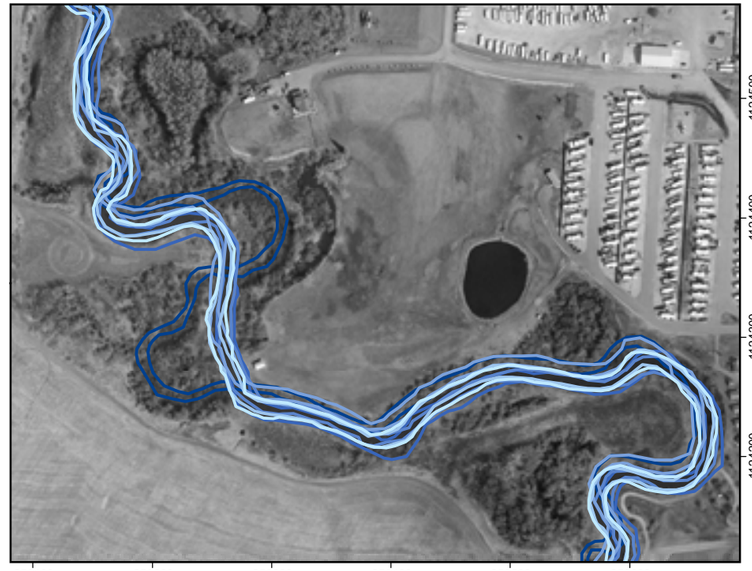


1989 Aerial Photograph (AEP)



1993 Aerial Photograph (AEP)

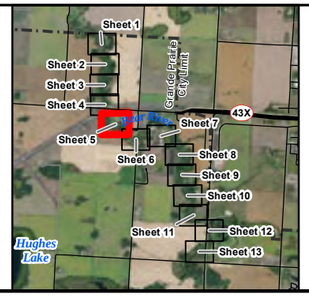
2012 Aerial Photograph (Valtus)



2014 Aerial Photograph (City of Grande Prairie)

Year

- Bankline Delineation - 1951 Aerial Photograph
- Bankline Delineation - 1976 Aerial Photograph
- Bankline Delineation - 1989 Aerial Photograph
- Bankline Delineation - 1993 Aerial Photograph
- Bankline Delineation - 2012 Aerial Photograph
- Bankline Delineation - 2014 Aerial Photograph



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North American 1983 CSRS 10TM

Reference: Imagery (1951, 1976, 1989, 1993) obtained from Alberta Environment and Parks © (2018) used under license. Imagery (2012) obtained from Valtus © (2018) used under license. Imagery (2014) obtained from City of Grande Prairie © (2018) used under license.

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City of Grande Prairie
Bear Creek Corridor Assessment

Delineated Historic Banklines
Sheet 5

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Shome	A. Chan

Figure E-5

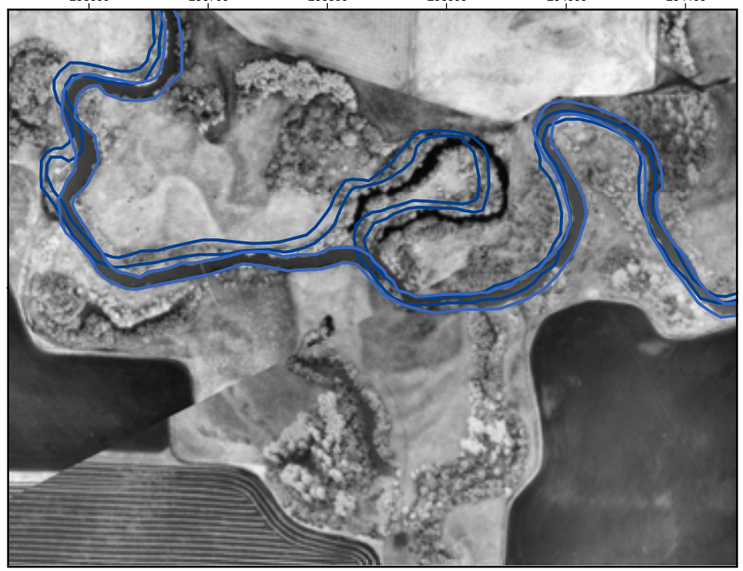
Easting (m)

Northing (m)

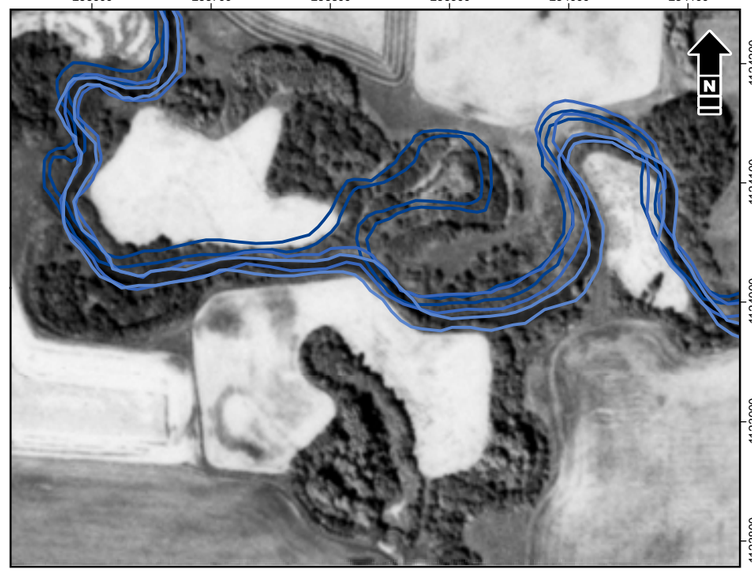
253600 253700 253800 253900 254000 254100

1124200 1124100 1124000 1123900 1123800

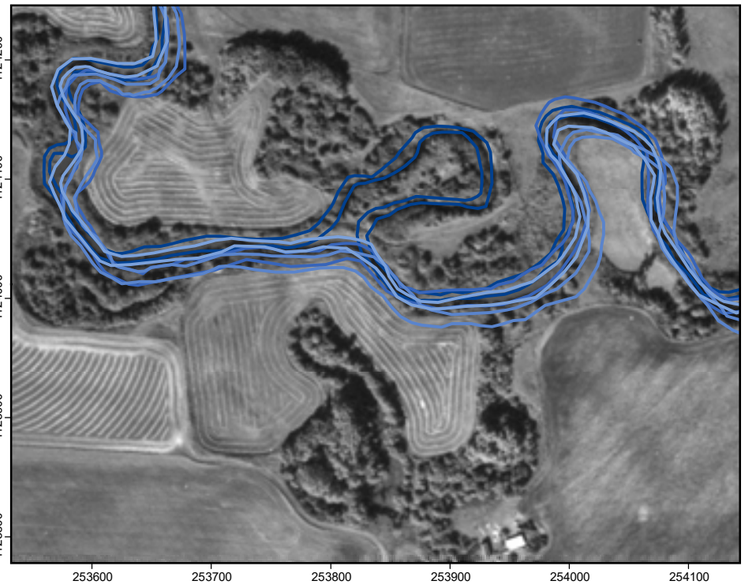
1951 Aerial Photograph (AEP)



1976 Aerial Photograph (AEP)



1989 Aerial Photograph (AEP)



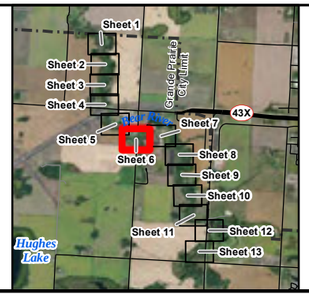
1993 Aerial Photograph (AEP)

2012 Aerial Photograph (Valtus)

2014 Aerial Photograph (City of Grande Prairie)

Year

- Bankline Delineation - 1951 Aerial Photograph
- Bankline Delineation - 1976 Aerial Photograph
- Bankline Delineation - 1989 Aerial Photograph
- Bankline Delineation - 1993 Aerial Photograph
- Bankline Delineation - 2012 Aerial Photograph
- Bankline Delineation - 2014 Aerial Photograph



1:5,000

50 0 50 100 m

North American 1983 CSRS 10TM

Reference: Imagery (1951, 1976, 1989, 1993) obtained from Alberta Environment and Parks © (2018) used under license. Imagery (2012) obtained from Valtus © (2018) used under license. Imagery (2014) obtained from City of Grande Prairie © (2018) used under license.

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City of Grande Prairie
Bear Creek Corridor Assessment

Delineated Historic Banklines
Sheet 6

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Shome	A. Chan

Figure E-6

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Easting (m)

Northing (m)

254100 254200 254300 254400 254500 254600 254700

1124300 1124200 1124100 1124000 1123900

1951 Aerial Photograph (AEP)

1976 Aerial Photograph (AEP)

1989 Aerial Photograph (AEP)

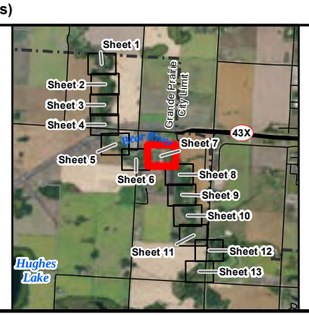
1993 Aerial Photograph (AEP)

2012 Aerial Photograph (Valtus)

2014 Aerial Photograph (City of Grande Prairie)

Year

- Bankline Delineation - 1951 Aerial Photograph
- Bankline Delineation - 1976 Aerial Photograph
- Bankline Delineation - 1989 Aerial Photograph
- Bankline Delineation - 1993 Aerial Photograph
- Bankline Delineation - 2012 Aerial Photograph
- Bankline Delineation - 2014 Aerial Photograph



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50 0 50 100

North American 1983 CSRS 10TM

Reference: Imagery (1951, 1976, 1989, 1993) obtained from Alberta Environment and Parks © (2018) used under license. Imagery (2012) obtained from Valtus © (2018) used under license. Imagery (2014) obtained from City of Grande Prairie © (2018) used under license.

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Bear Creek Corridor Assessment

Delineated Historic Banklines
Sheet 7

Date:	Project:	Submitter:	Reviewer:
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Figure E-7

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Easting (m)

Northing (m)

254500 254600 254700 254800 254900 255000

1123900 1123800 1123700 1123600 1123500

1951 Aerial Photograph (AEP)

1976 Aerial Photograph (AEP)

1989 Aerial Photograph (AEP)

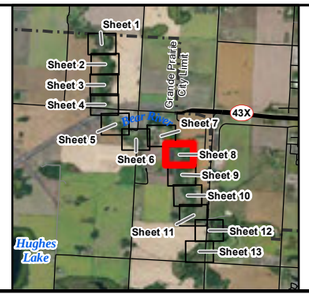
1993 Aerial Photograph (AEP)

2012 Aerial Photograph (Valtus)

2014 Aerial Photograph (City of Grande Prairie)

Year

- Bankline Delineation - 1951 Aerial Photograph
- Bankline Delineation - 1976 Aerial Photograph
- Bankline Delineation - 1989 Aerial Photograph
- Bankline Delineation - 1993 Aerial Photograph
- Bankline Delineation - 2012 Aerial Photograph
- Bankline Delineation - 2014 Aerial Photograph



1:5,000

50 0 50 100 m

North American 1983 CSRS 10TM

Reference: Imagery (1951, 1976, 1989, 1993) obtained from Alberta Environment and Parks © (2018) used under license. Imagery (2012) obtained from Valtus © (2018) used under license. Imagery (2014) obtained from City of Grande Prairie © (2018) used under license.

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City of Grande Prairie
Bear Creek Corridor Assessment

Delineated Historic Banklines
Sheet 8

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Shome	A. Chan

Figure E-8

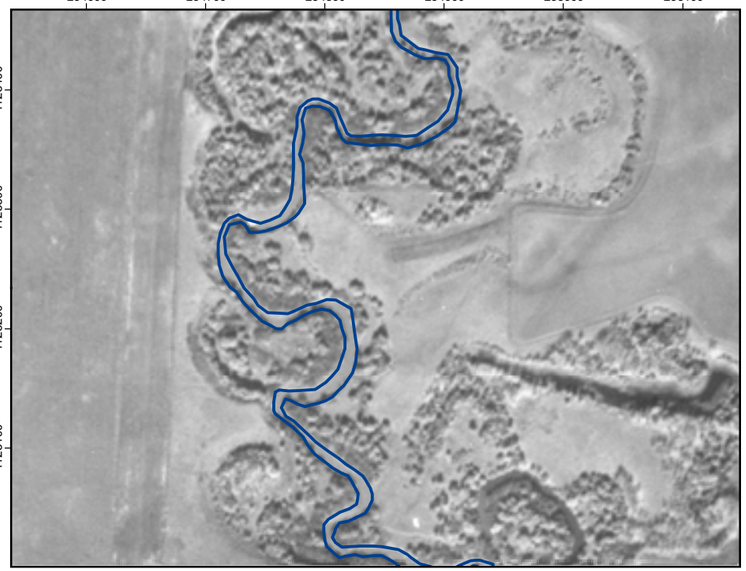
I:\City of Grande Prairie\24079\Figures And Tables\HYD\2017 Report\Bear Creek Corridor Assessment\Appendix E-Delineated Historic Banklines.mxd - Letter_P - 20-Aug-18, 03:52 PM - mwilkinson

Easting (m)

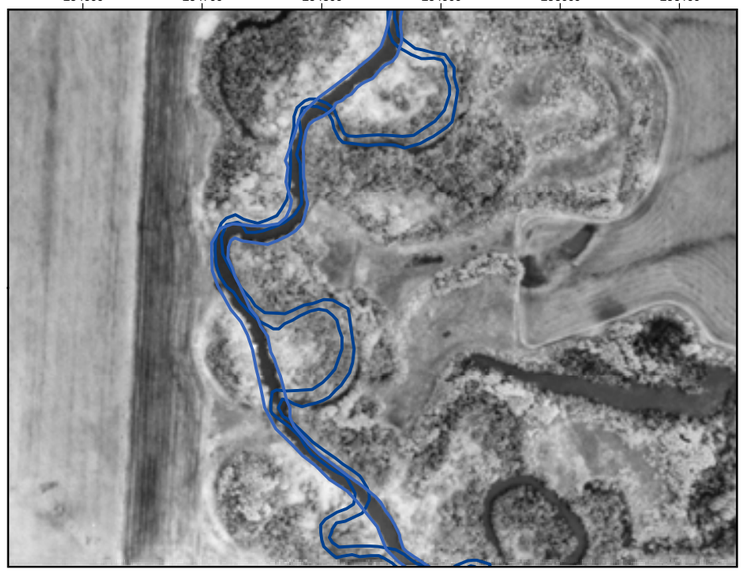
Northing (m)

254600 254700 254800 254900 255000 255100

1123400 1123300 1123200 1123100

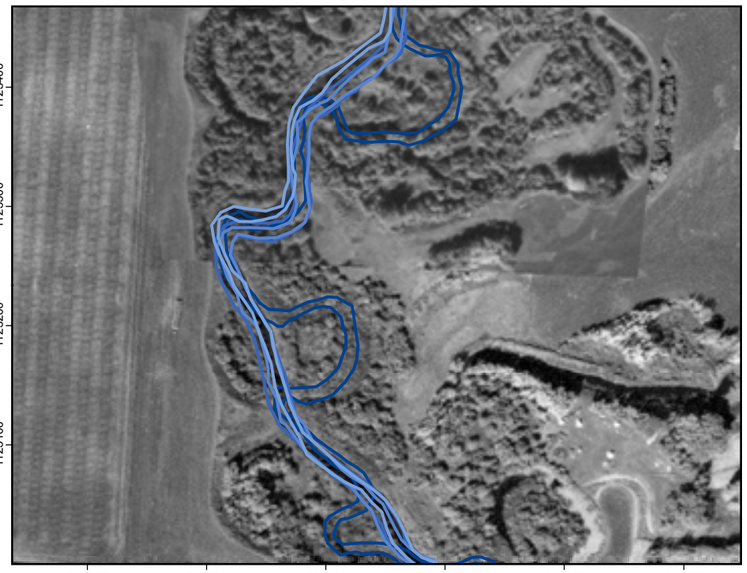


1951 Aerial Photograph (AEP)



1976 Aerial Photograph (AEP)

1989 Aerial Photograph (AEP)



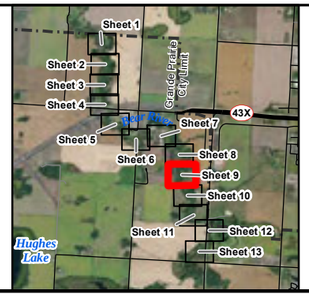
1993 Aerial Photograph (AEP)

2012 Aerial Photograph (Valtus)

2014 Aerial Photograph (City of Grande Prairie)

Year

- Bankline Delineation - 1951 Aerial Photograph
- Bankline Delineation - 1976 Aerial Photograph
- Bankline Delineation - 1989 Aerial Photograph
- Bankline Delineation - 1993 Aerial Photograph
- Bankline Delineation - 2012 Aerial Photograph
- Bankline Delineation - 2014 Aerial Photograph



1:5,000

50 0 50 100 m

North American 1983 CSRS 10TM

Reference: Imagery (1951, 1976, 1989, 1993) obtained from Alberta Environment and Parks © (2018) used under license. Imagery (2012) obtained from Valtus © (2018) used under license. Imagery (2014) obtained from City of Grande Prairie © (2018) used under license.

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City of Grande Prairie
Bear Creek Corridor Assessment

Delineated Historic Banklines
Sheet 9

Date:	Project:	Submitter:	Reviewer:
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Figure E-9

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Easting (m)

Northing (m)

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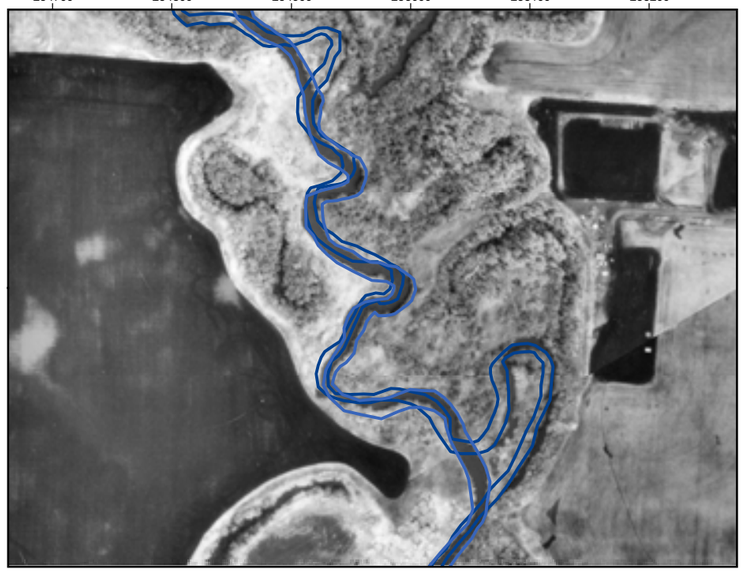
1123000 1122900 1122800 1122700 1122600

1951 Aerial Photograph (AEP)

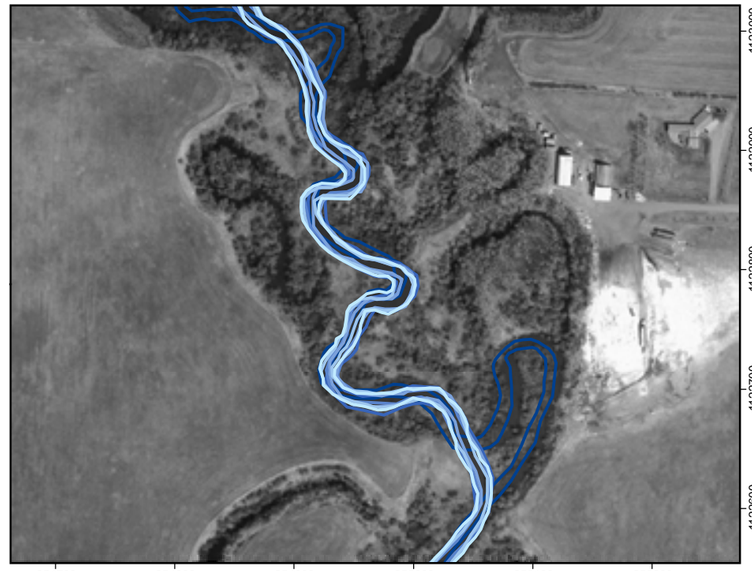


1976 Aerial Photograph (AEP)

1989 Aerial Photograph (AEP)

1993 Aerial Photograph (AEP)

2012 Aerial Photograph (Valtus)



2014 Aerial Photograph (City of Grande Prairie)

Year

- Bankline Delineation - 1951 Aerial Photograph
- Bankline Delineation - 1976 Aerial Photograph
- Bankline Delineation - 1989 Aerial Photograph
- Bankline Delineation - 1993 Aerial Photograph
- Bankline Delineation - 2012 Aerial Photograph
- Bankline Delineation - 2014 Aerial Photograph

1:5,000 m

50 0 50 100

North American 1983 CSRS 10TM

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City of Grande Prairie
Bear Creek Corridor Assessment

Delineated Historic Banklines
Sheet 10

Date:	Project:	Submitter:	Reviewer:
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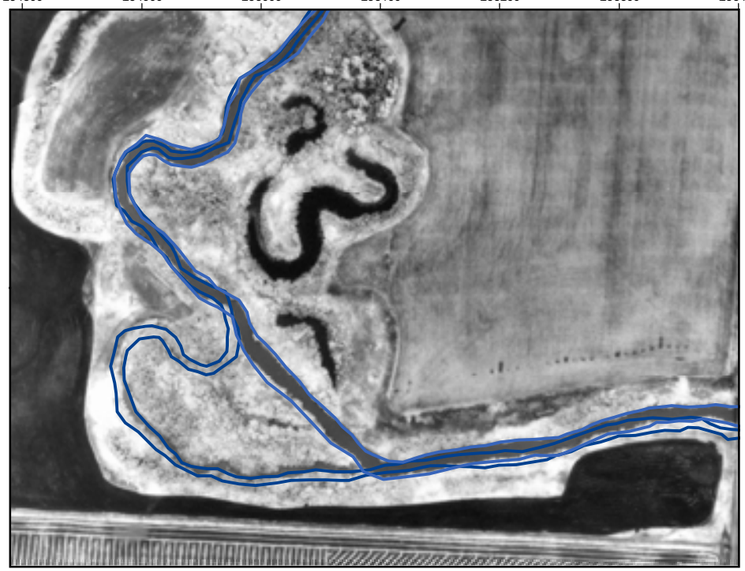
Figure E-10

I:\City\GrandPrairie\24079\Figures\And\Tables\HYD\2017\Report\BearCreekCorridorAssessment\Appendix-E-Delineated_Historic_Banklines.mxd - Letter P - 20-Aug-18, 03:52 PM - mwilkinson

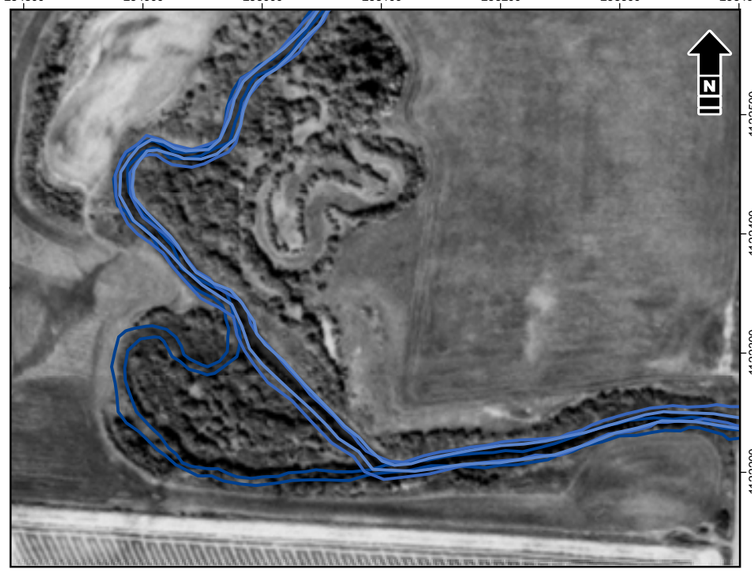
Easting (m)

Northing (m)

1951 Aerial Photograph (AEP)



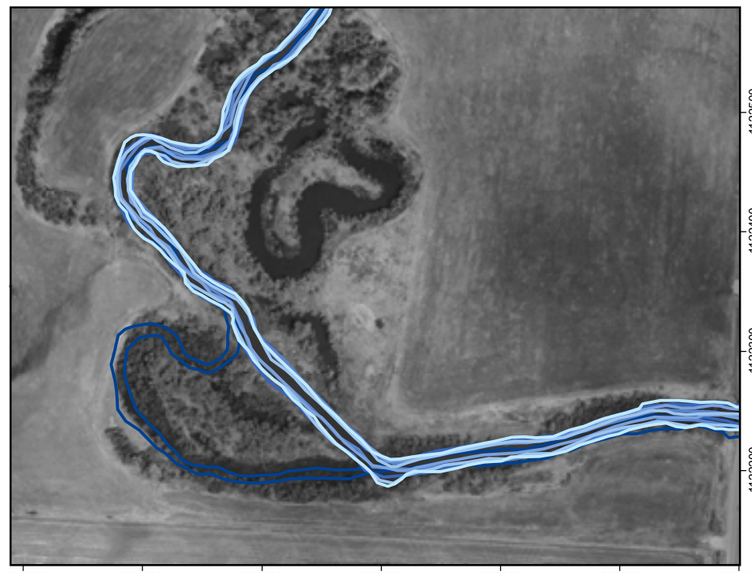
1976 Aerial Photograph (AEP)



1989 Aerial Photograph (AEP)

1993 Aerial Photograph (AEP)

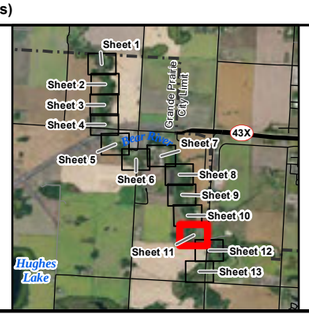
2012 Aerial Photograph (Valtus)



2014 Aerial Photograph (City of Grande Prairie)

Year

- Bankline Delineation - 1951 Aerial Photograph
- Bankline Delineation - 1976 Aerial Photograph
- Bankline Delineation - 1989 Aerial Photograph
- Bankline Delineation - 1993 Aerial Photograph
- Bankline Delineation - 2012 Aerial Photograph
- Bankline Delineation - 2014 Aerial Photograph



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50 0 50 100 m

North American 1983 CSRS 10TM

Reference: Imagery (1951, 1976, 1989, 1993) obtained from Alberta Environment and Parks © (2018) used under license. Imagery (2012) obtained from Valtus © (2018) used under license. Imagery (2014) obtained from City of Grande Prairie © (2018) used under license.

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City of Grande Prairie
Bear Creek Corridor Assessment

Delineated Historic Banklines
Sheet 11

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Shome	A. Chan

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Figure E-11

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Easting (m)

Northing (m)

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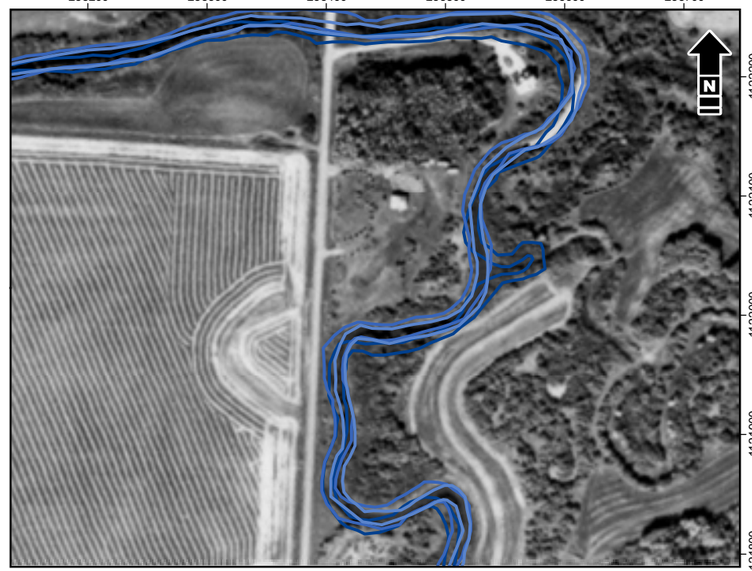
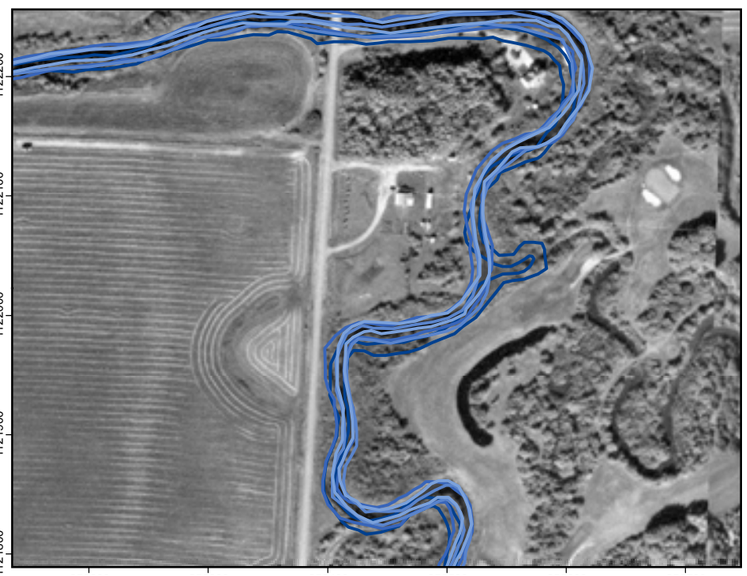
1951 Aerial Photograph (AEP)

1976 Aerial Photograph (AEP)

1989 Aerial Photograph (AEP)

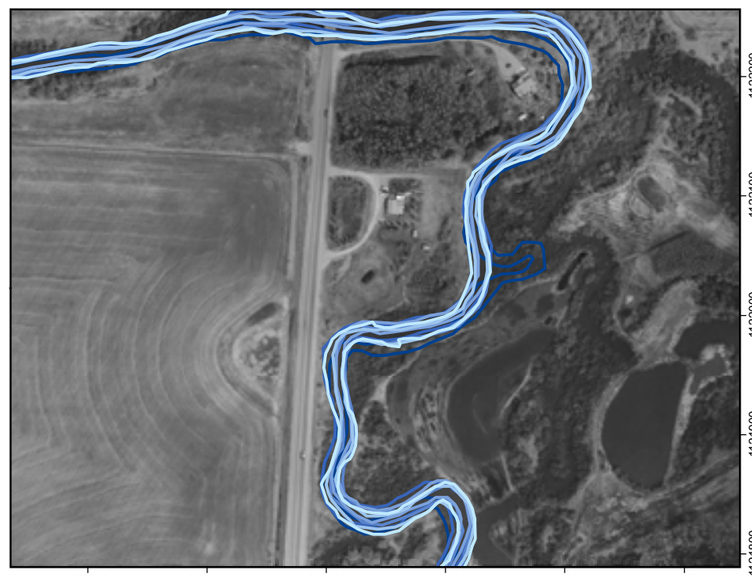


1993 Aerial Photograph (AEP)



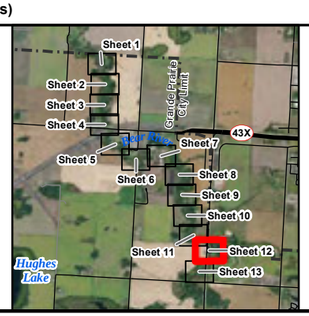
2012 Aerial Photograph (Valtus)

2014 Aerial Photograph (City of Grande Prairie)



Year

- Bankline Delineation - 1951 Aerial Photograph
- Bankline Delineation - 1976 Aerial Photograph
- Bankline Delineation - 1989 Aerial Photograph
- Bankline Delineation - 1993 Aerial Photograph
- Bankline Delineation - 2012 Aerial Photograph
- Bankline Delineation - 2014 Aerial Photograph



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m 50 0 50 100

North American 1983 CSRS 10TM

Reference: Imagery (1951, 1976, 1989, 1993) obtained from Alberta Environment and Parks © (2018) used under license. Imagery (2012) obtained from Valtus © (2018) used under license. Imagery (2014) obtained from City of Grande Prairie © (2018) used under license.

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City of Grande Prairie
Bear Creek Corridor Assessment

Delineated Historic Banklines
Sheet 12

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Shome	A. Chan

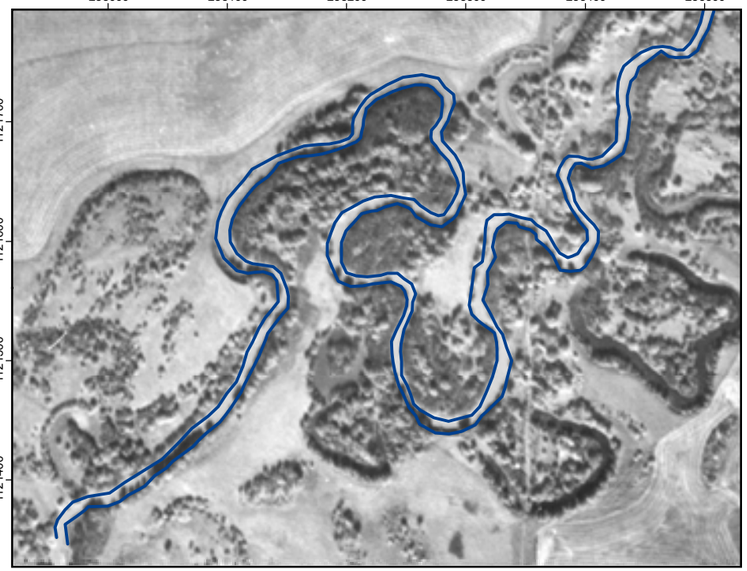
Figure E-12

Easting (m)

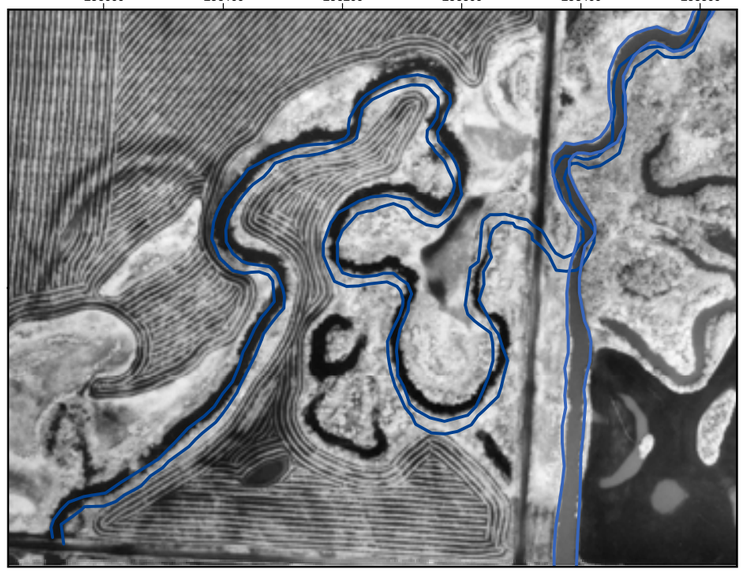
Northing (m)

255000 255100 255200 255300 255400 255500

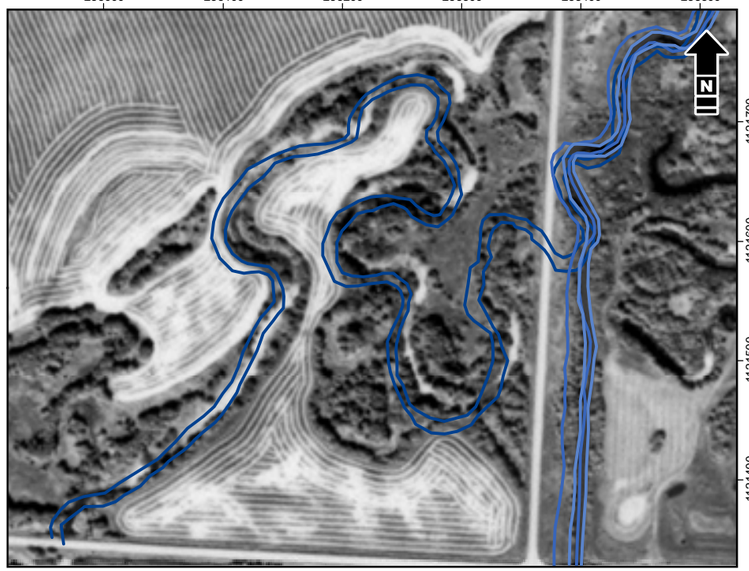
1121700 1121600 1121500 1121400



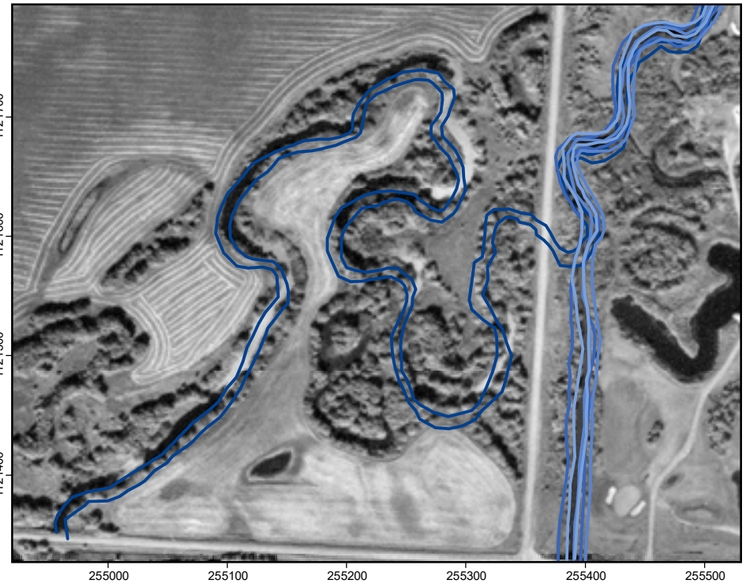
1951 Aerial Photograph (AEP)



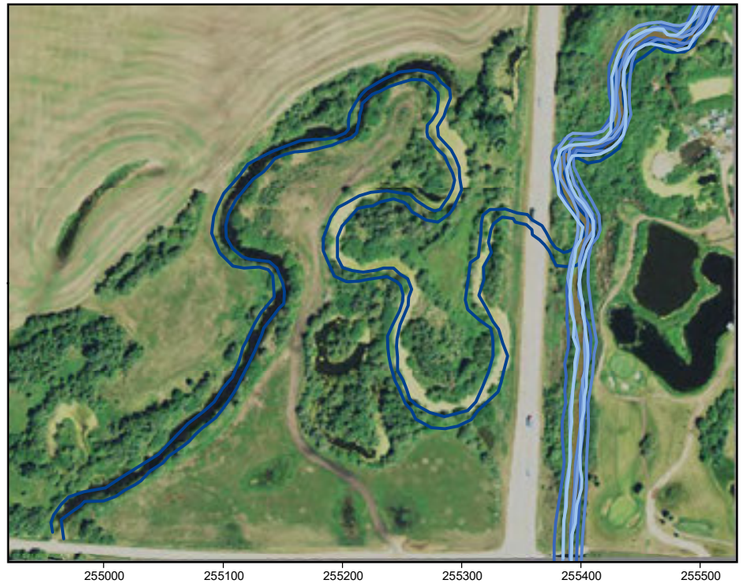
1976 Aerial Photograph (AEP)



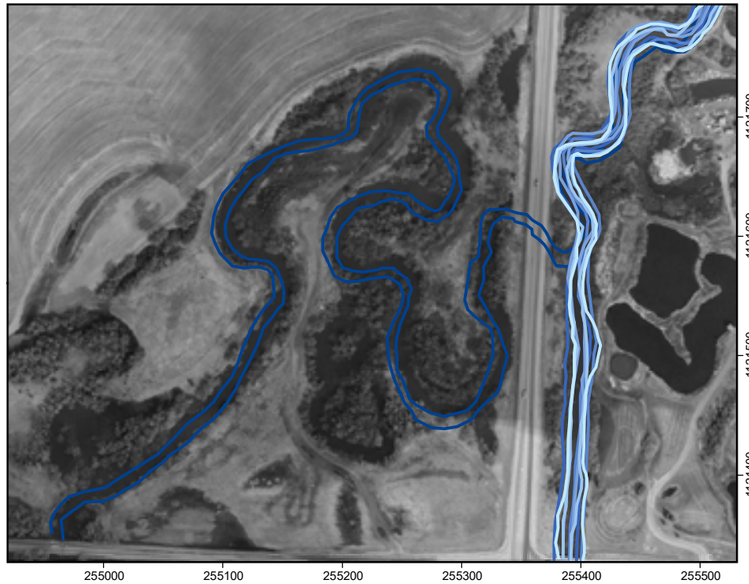
1989 Aerial Photograph (AEP)



1993 Aerial Photograph (AEP)



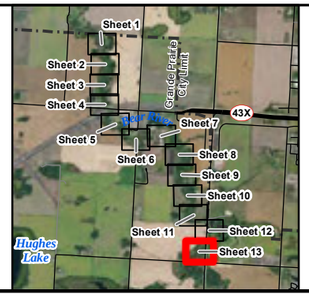
2012 Aerial Photograph (Valtus)



2014 Aerial Photograph (City of Grande Prairie)

Year

- Bankline Delineation - 1951 Aerial Photograph
- Bankline Delineation - 1976 Aerial Photograph
- Bankline Delineation - 1989 Aerial Photograph
- Bankline Delineation - 1993 Aerial Photograph
- Bankline Delineation - 2012 Aerial Photograph
- Bankline Delineation - 2014 Aerial Photograph



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North American 1983 CSRS 10TM

Reference: Imagery (1951, 1976, 1989, 1993) obtained from Alberta Environment and Parks © (2018) used under license. Imagery (2012) obtained from Valtus © (2018) used under license. Imagery (2014) obtained from City of Grande Prairie © (2018) used under license.

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City of Grande Prairie
Bear Creek Corridor Assessment

Delineated Historic Banklines Sheet 13

Date:	Project:	Submitter:	Reviewer:
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Figure E-13

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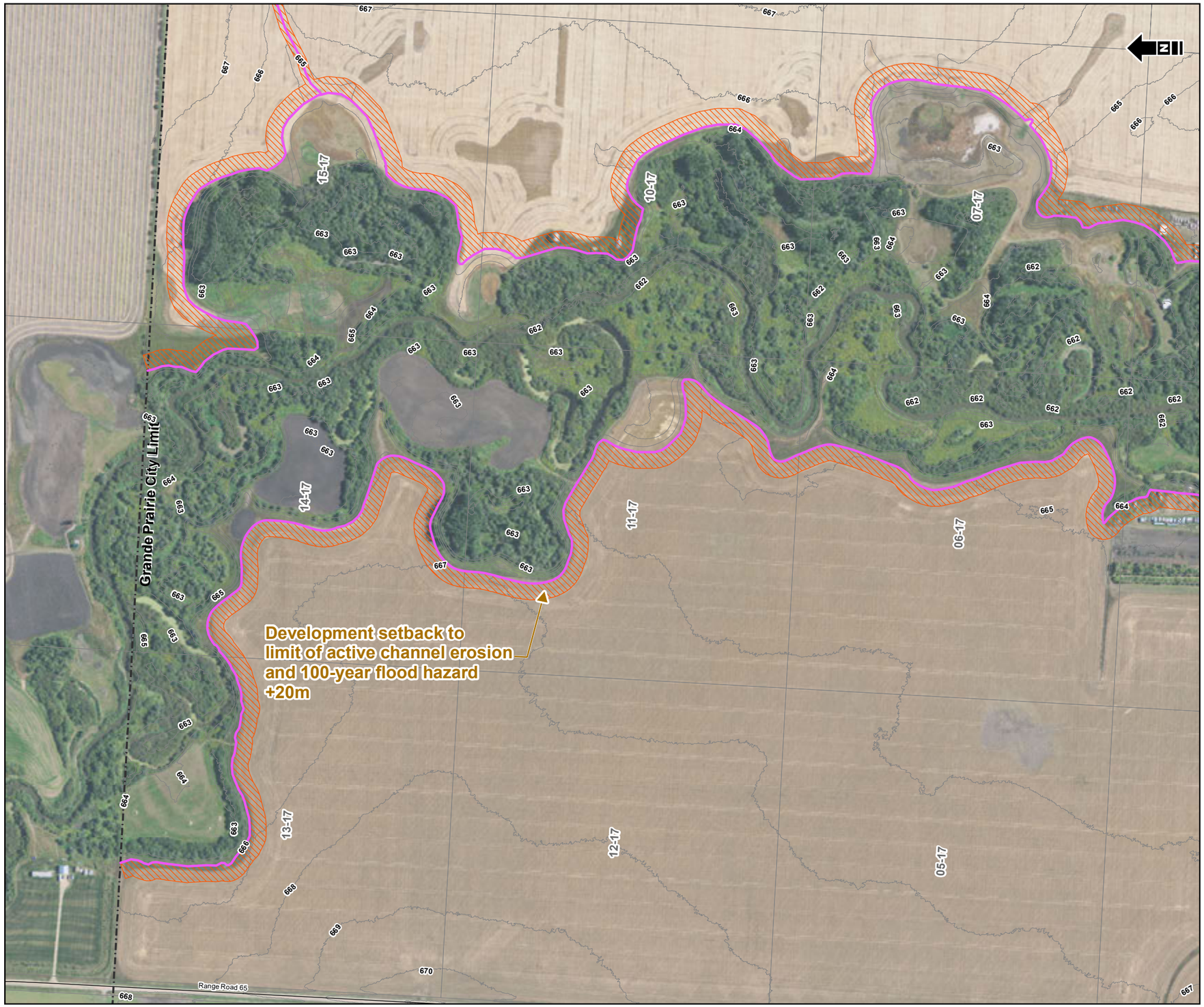
APPENDIX F
Recommended Setback Distances



Setback
Community Boundary
Contour Interval (1m)
Road

Limit of Active Channel Erosion
Upstream

Upstream basis for setback locations:
1. Alberta Environment stepping back from the water setback recommendations for permanent water bodies (20m) intermittent streams (6m), and mapped ephemeral channels (6m) from AltaLIS 20k centreline
2. 100 year flood hazard and 200 year inundation areas
3. Natural features mapping (O2, 2012)
4. Water body delineated as limit of active channel

Coordinate System: North American 1983 CSRS 10TM
Projection: Transverse Mercator
Datum: North American 1983 CSRS
False Easting: 500,000.0000
False Northing: -5,000,000.0000
Central Meridian: -115.0000
Scale Factor: 0.9992
Latitude Of Origin: 0.0000
Units: Meter

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metres
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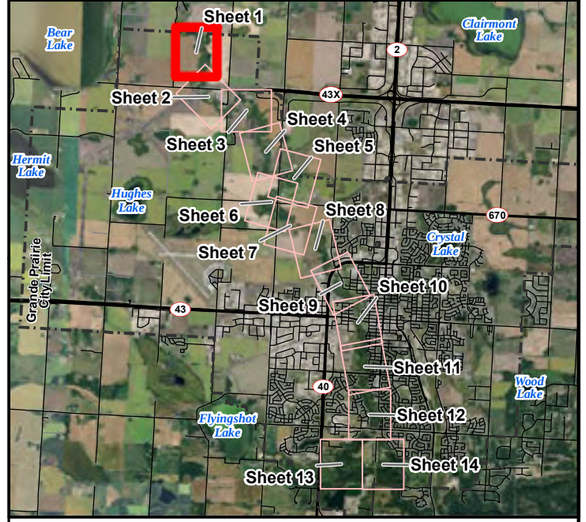

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City of Grande Prairie
Bear Creek Corridor Assessment

Bear Creek Upstream Development Setbacks - Sheet 1

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Bender	A. Chan

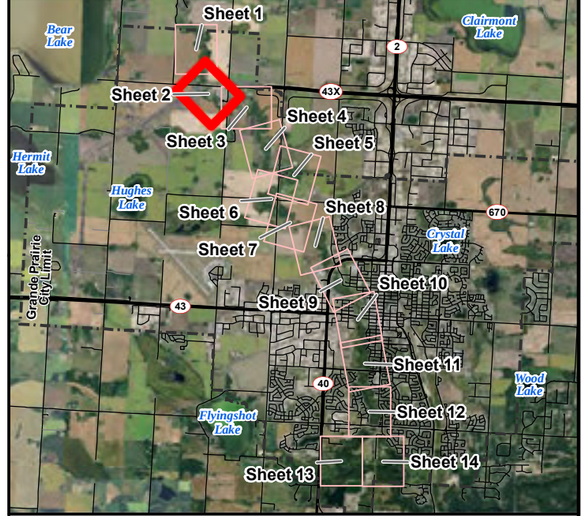
Figure F-1

Setback
Community Boundary
Contour Interval (1m)
Road
Limit of Active Channel Erosion
Upstream

Upstream basis for setback locations:
1. Alberta Environment stepping back from the water setback recommendations for permanent water bodies (20m) intermittent streams (6m), and mapped ephemeral channels (6m) from AltaLIS 20k centreline
2. 100 year flood hazard and 200 year inundation areas
3. Natural features mapping (O2, 2012)
4. Water body delineated as limit of active channel

Coordinate System: North American 1983 CSRS 10TM
Projection: Transverse Mercator
Datum: North American 1983 CSRS
False Easting: 500,000.0000
False Northing: -5,000,000.0000
Central Meridian: -115.0000
Scale Factor: 0.9992
Latitude Of Origin: 0.0000
Units: Meter

1:5,000 metres
50 0 50 100



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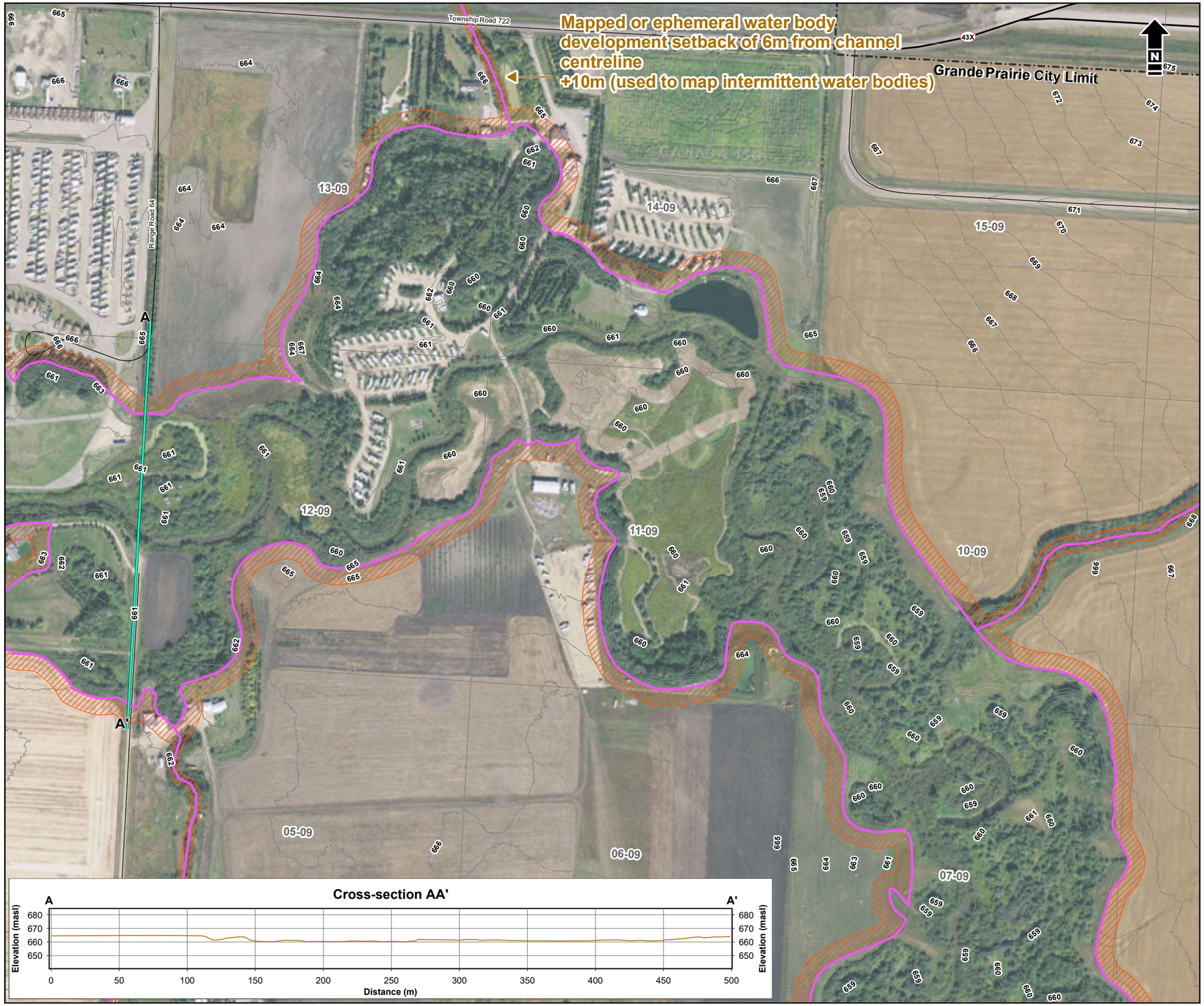
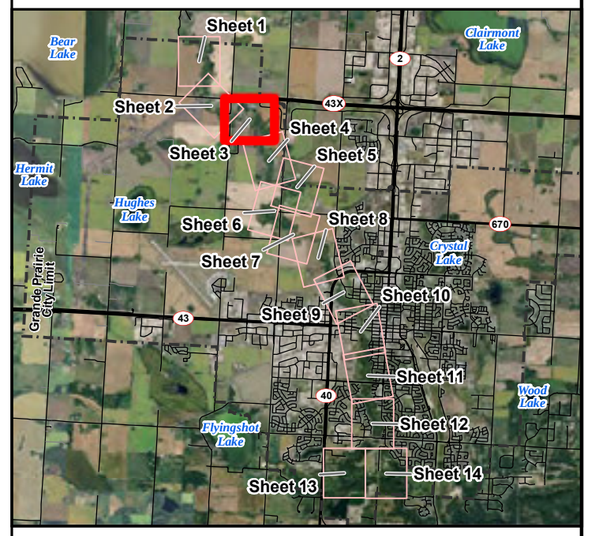
City of Grande Prairie
Bear Creek Corridor Assessment

Bear Creek Upstream Development Setbacks - Sheet 2

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Bender	A. Chan

Figure F-2





Setback
Community Boundary
Contour Interval (1m)
Setback Cross-Section
Highway
Road

Limit of Active Channel Erosion
Upstream

Upstream basis for setback locations:
1. Alberta Environment stepping back from the water setback recommendations for permanent water bodies (20m) intermittent streams (6m), and mapped ephemeral channels (6m) from AltaLIS 20k centreline
2. 100 year flood hazard and 200 year inundation areas
3. Natural features mapping (O2, 2012)
4. Water body delineated as limit of active channel

Coordinate System: North American 1983 CSRS 10TM
Projection: Transverse Mercator
Datum: North American 1983 CSRS
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Latitude Of Origin: 0.0000
Units: Meter

1:5,000 metres
50 0 50 100

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City of Grande Prairie
Bear Creek Corridor Assessment

Bear Creek Upstream Development Setbacks - Sheet 3

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Bender	A. Chan

Figure F-3

Setback
Community Boundary
Contour Interval (1m)
Setback Cross-Section
Road
Industry Road

Limit of Active Channel Erosion

Upstream

Upstream basis for setback locations:
1. Alberta Environment stepping back from the water setback recommendations for permanent water bodies (20m) intermittent streams (6m), and mapped ephemeral channels (6m) from AltaLIS 20k centreline
2. 100 year flood hazard and 200 year inundation areas
3. Natural features mapping (O2, 2012)
4. Water body delineated as limit of active channel

Coordinate System: North American 1983 CSRS 10TM
Projection: Transverse Mercator
Datum: North American 1983 CSRS
False Easting: 500,000.0000
False Northing: -5,000,000.0000
Central Meridian: -115.0000
Scale Factor: 0.9992
Latitude Of Origin: 0.0000
Units: Meter

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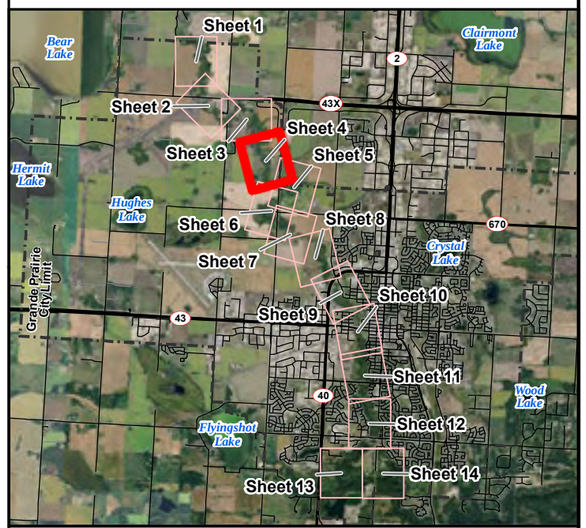

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City of Grande Prairie
Bear Creek Corridor Assessment

Bear Creek Upstream Development Setbacks - Sheet 4

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Bender	A. Chan

Figure F-4

Setback
Community Boundary
Contour Interval (1m)
Setback Cross-Section
Road
Industry Road

Limit of Active Channel Erosion

Upstream

Upstream basis for setback locations:
1. Alberta Environment stepping back from the water setback recommendations for permanent water bodies (20m) intermittent streams (6m), and mapped ephemeral channels (6m) from AltaLIS 20k centreline
2. 100 year flood hazard and 200 year inundation areas
3. Natural features mapping (O2, 2012)
4. Water body delineated as limit of active channel

Coordinate System: North American 1983 CSRS 10TM
Projection: Transverse Mercator
Datum: North American 1983 CSRS
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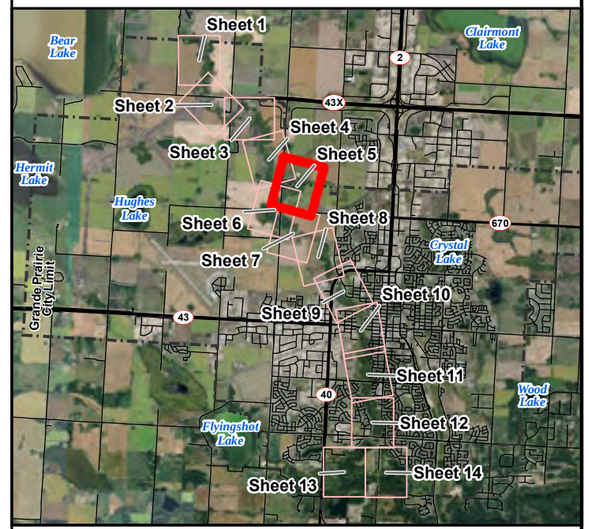
False Northing: -5,000,000.0000
Central Meridian: -115.0000
Scale Factor: 0.9992
Latitude Of Origin: 0.0000
Units: Meter

1:5,000
metres
50 0 50 100



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City of Grande Prairie
Bear Creek Corridor Assessment

Bear Creek Upstream Development Setbacks - Sheet 5

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Bender	A. Chan

Figure F-5

Setback
Community Boundary
Contour Interval (1m)
Road
Limit of Active Channel Erosion
Upstream

Upstream basis for setback locations:
1. Alberta Environment stepping back from the water setback recommendations for permanent water bodies (20m) intermittent streams (6m), and mapped ephemeral channels (6m) from AltaLIS 20k centreline
2. 100 year flood hazard and 200 year inundation areas
3. Natural features mapping (O2, 2012)
4. Water body delineated as limit of active channel

Coordinate System: North American 1983 CSRS 10TM
Projection: Transverse Mercator
Datum: North American 1983 CSRS
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Units: Meter

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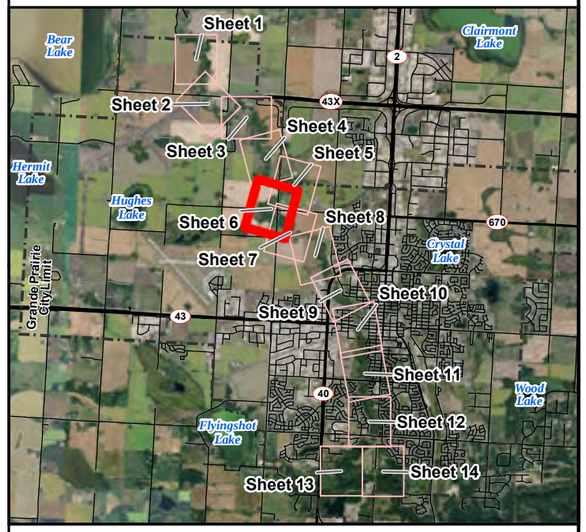

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City of Grande Prairie
Bear Creek Corridor Assessment

Bear Creek Upstream Development Setbacks - Sheet 6

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Bender	A. Chan

Figure F-6

Setback
Community Boundary
Contour Interval (1m)
Road

Limit of Active Channel Erosion

Downstream (Updated from Parkland Geo 2010)
Upstream

Upstream basis for setback locations:
1. Alberta Environment stepping back from the water setback recommendations for permanent water bodies (20m) intermittent streams (6m), and mapped ephemeral channels (6m) from AltaLIS 20k centreline
2. 100 year flood hazard and 200 year inundation areas
3. Natural features mapping (O2, 2012)
4. Water body delineated as limit of active channel

Downstream basis for setback locations:
1. Edge of valley escarpment
2. Locations of significant landslides
3. Local drainage issues that may contribute to reduced slope stability
4. Geotechnical recommendations (Parkland Geo, 2010)
5. Limited to Bear Creek corridor from Hwy 43 to city limit

Coordinate System: North American 1983 CSRS 10TM
Projection: Transverse Mercator
Datum: North American 1983 CSRS
False Easting: 500,000.0000
False Northing: -5,000,000.0000
Central Meridian: -115.0000
Scale Factor: 0.9992
Latitude Of Origin: 0.0000
Units: Meter

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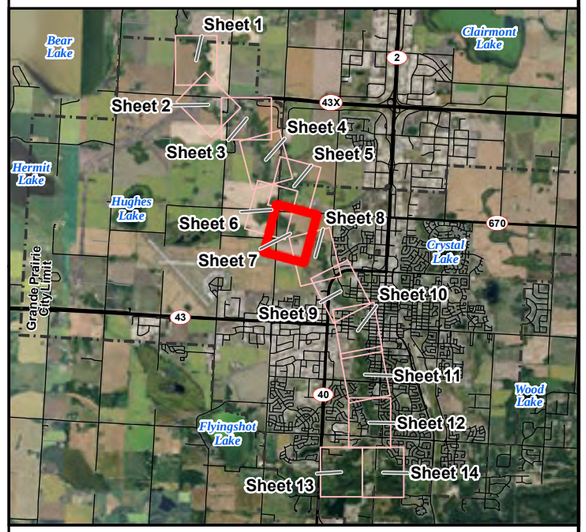

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City of Grande Prairie
Bear Creek Corridor Assessment

Bear Creek Upstream Development Setbacks - Sheet 7

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Bender	A. Chan

Figure F-7

Setback
Community Boundary
Contour Interval (1m)
Highway
Road

Limit of Active Channel Erosion

Downstream (Updated from Parkland Geo 2010)
Upstream

Downstream basis for setback locations:
1. Edge of valley escarpment
2. Locations of significant landslides
3. Local drainage issues that may contribute to reduced slope stability
4. Geotechnical recommendations (Parkland Geo, 2010)
5. Limited to Bear Creek corridor from Hwy 43 to city limit

Coordinate System: North American 1983 CSRS 10TM
Projection: Transverse Mercator
Datum: North American 1983 CSRS
False Easting: 500,000.0000
False Northing: -5,000,000.0000
Central Meridian: -115.0000
Scale Factor: 0.9992
Latitude Of Origin: 0.0000
Units: Meter

1:5,000 metres
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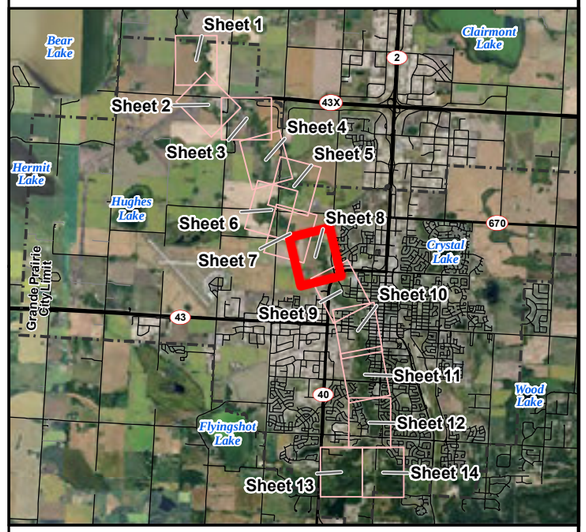

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City of Grande Prairie
Bear Creek Corridor Assessment

Bear Creek Upstream Development Setbacks - Sheet 8

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Bender	A. Chan

Figure F-8

I:\City\of\GrandePrairie\24079\Figures\And\Tables\HYD\2017\Report\BearCreekCorridorAssessment\Appendix-F-Bear_Creek_Upstream_Development_Setbacks.mxd - Tabloid_L - 20-Aug-18, 03:54 PM - mwilkinson - TED005

Setback
Community Boundary
Contour Interval (1m)
Highway
Road

Limit of Active Channel Erosion

Downstream (Updated from Parkland Geo 2010)

Downstream basis for setback locations:
1. Edge of valley escarpment
2. Locations of significant landslides
3. Local drainage issues that may contribute to reduced slope stability
4. Geotechnical recommendations (Parkland Geo, 2010)
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False Easting: 500,000.0000
False Northing: -5,000,000.0000
Central Meridian: -115.0000
Scale Factor: 0.9992
Latitude Of Origin: 0.0000
Units: Meter

1:5,000 metres
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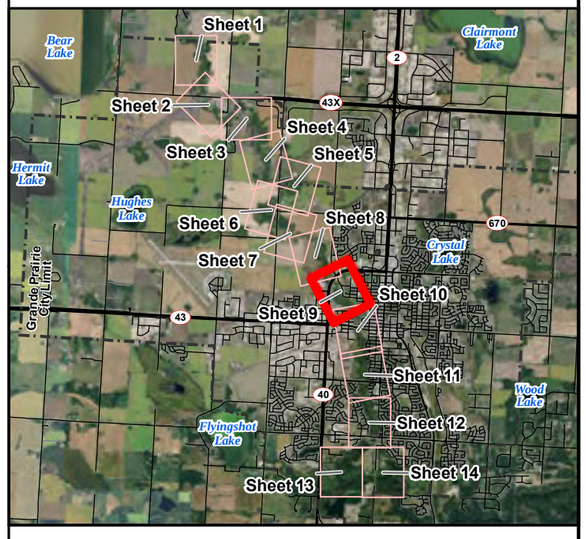

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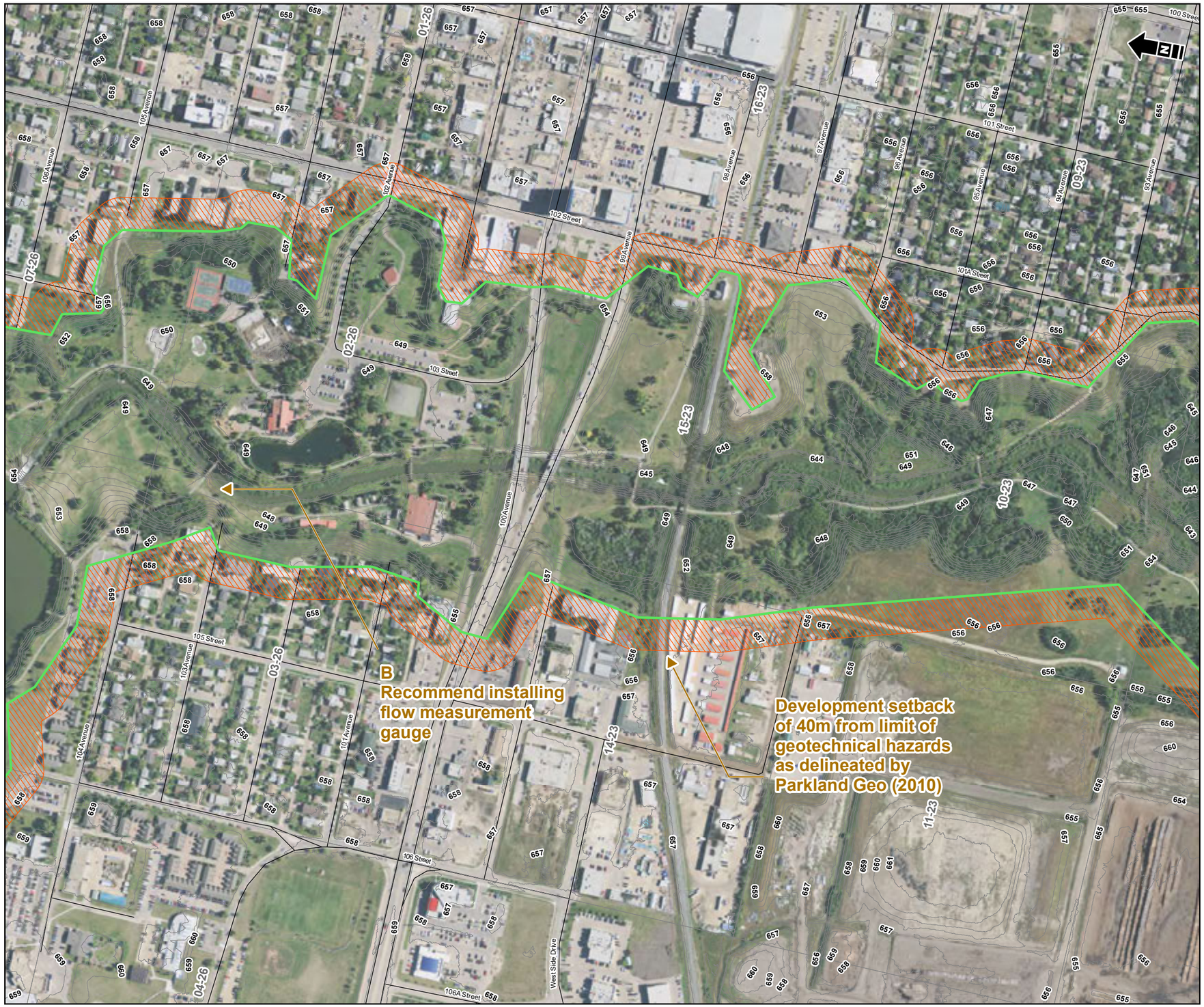
City of Grande Prairie
Bear Creek Corridor Assessment

Bear Creek Upstream Development Setbacks - Sheet 9

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Bender	A. Chan

Figure F-9



Setback
Community Boundary
Contour Interval (1m)
Road

Limit of Active Channel Erosion
Downstream (Updated from Parkland Geo 2010)

Downstream basis for setback locations:
1. Edge of valley escarpment
2. Locations of significant landslides
3. Local drainage issues that may contribute to reduced slope stability
4. Geotechnical recommendations (Parkland Geo, 2010)
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Projection: Transverse Mercator
Datum: North American 1983 CSRS
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False Northing: -5,000,000.0000
Central Meridian: -115.0000
Scale Factor: 0.9992
Latitude Of Origin: 0.0000
Units: Meter

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metres
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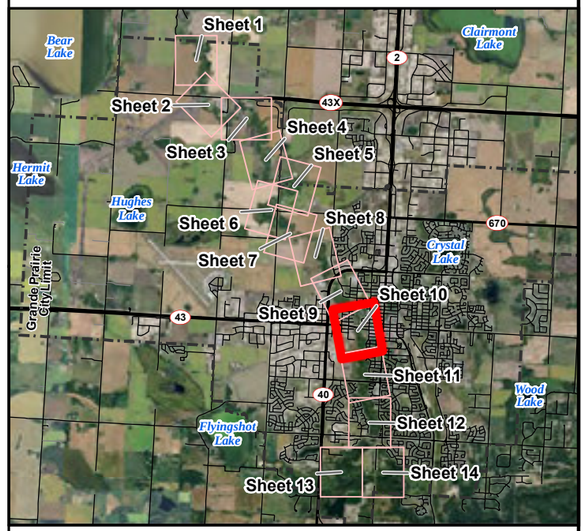

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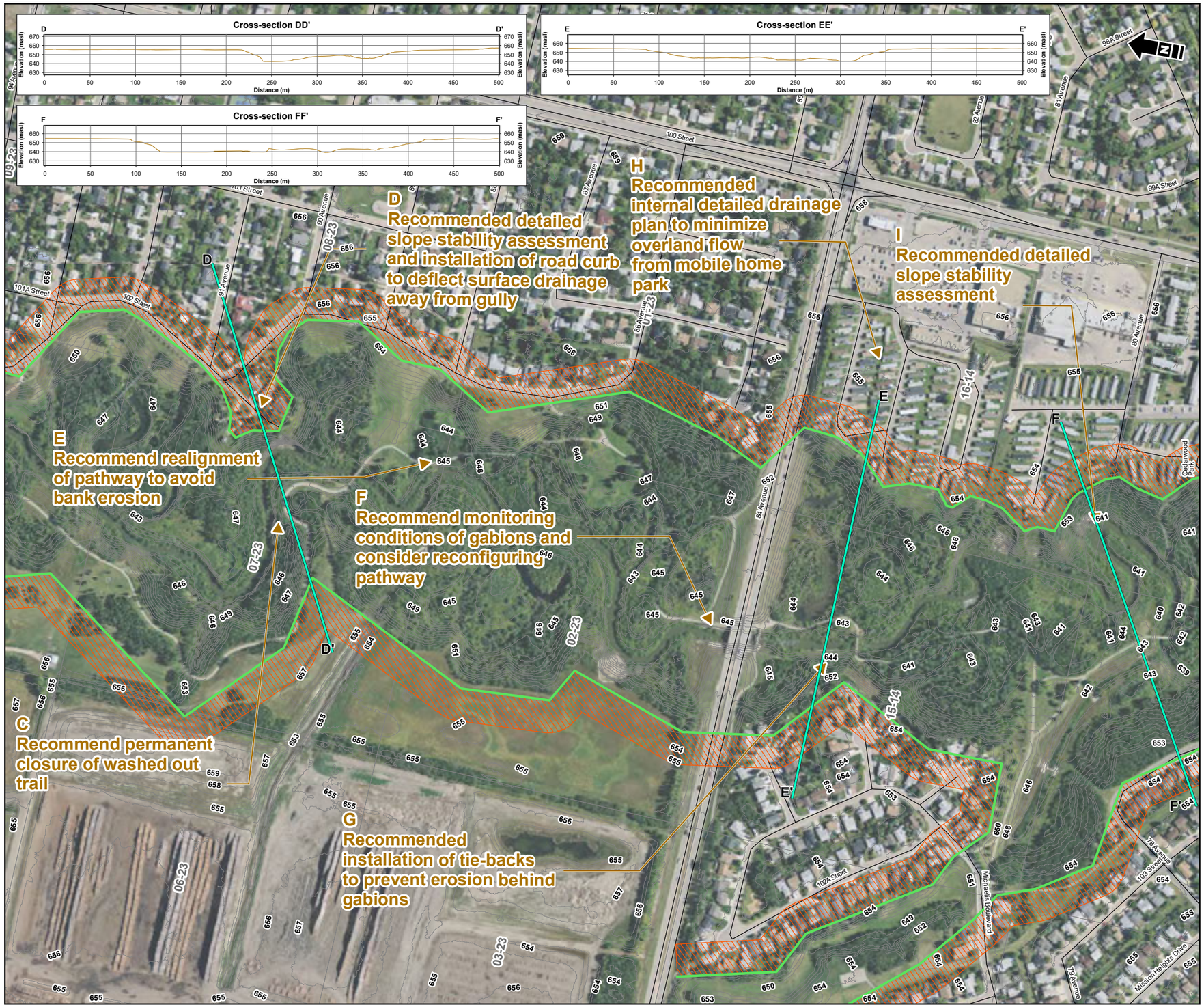
City of Grande Prairie
Bear Creek Corridor Assessment

Bear Creek Upstream Development Setbacks - Sheet 10

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Bender	A. Chan

Figure F-10



Setback
Community Boundary
Contour Interval (1m)
Setback Cross-Section
Road

Limit of Active Channel Erosion

Downstream (Updated from Parkland Geo 2010)

Downstream basis for setback locations:
1. Edge of valley escarpment
2. Locations of significant landslides
3. Local drainage issues that may contribute to reduced slope stability
4. Geotechnical recommendations (Parkland Geo, 2010)
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Coordinate System: North American 1983 CSRS 10TM
Projection: Transverse Mercator
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False Easting: 500,000.0000
False Northing: -5,000,000.0000
Central Meridian: -115.0000
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Latitude Of Origin: 0.0000
Units: Meter

1:5,000 metres
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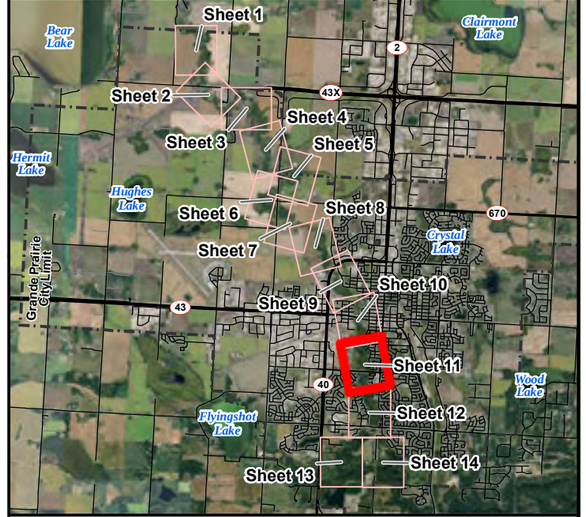

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City of Grande Prairie
Bear Creek Corridor Assessment

Bear Creek Upstream Development Setbacks - Sheet 11

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Bender	A. Chan

Figure F-11

Setback
Community Boundary
Contour Interval (1m)
Road

Limit of Active Channel Erosion
Downstream (Updated from Parkland Geo 2010)

Downstream basis for setback locations:
1. Edge of valley escarpment
2. Locations of significant landslides
3. Local drainage issues that may contribute to reduced slope stability
4. Geotechnical recommendations (Parkland Geo, 2010)
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Projection: Transverse Mercator
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False Easting: 500,000.0000
False Northing: -5,000,000.0000
Central Meridian: -115.0000
Scale Factor: 0.9992
Latitude Of Origin: 0.0000
Units: Meter

1:5,000
metres
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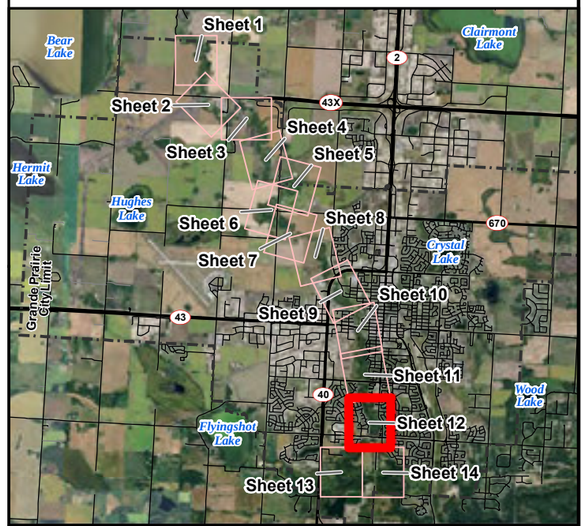

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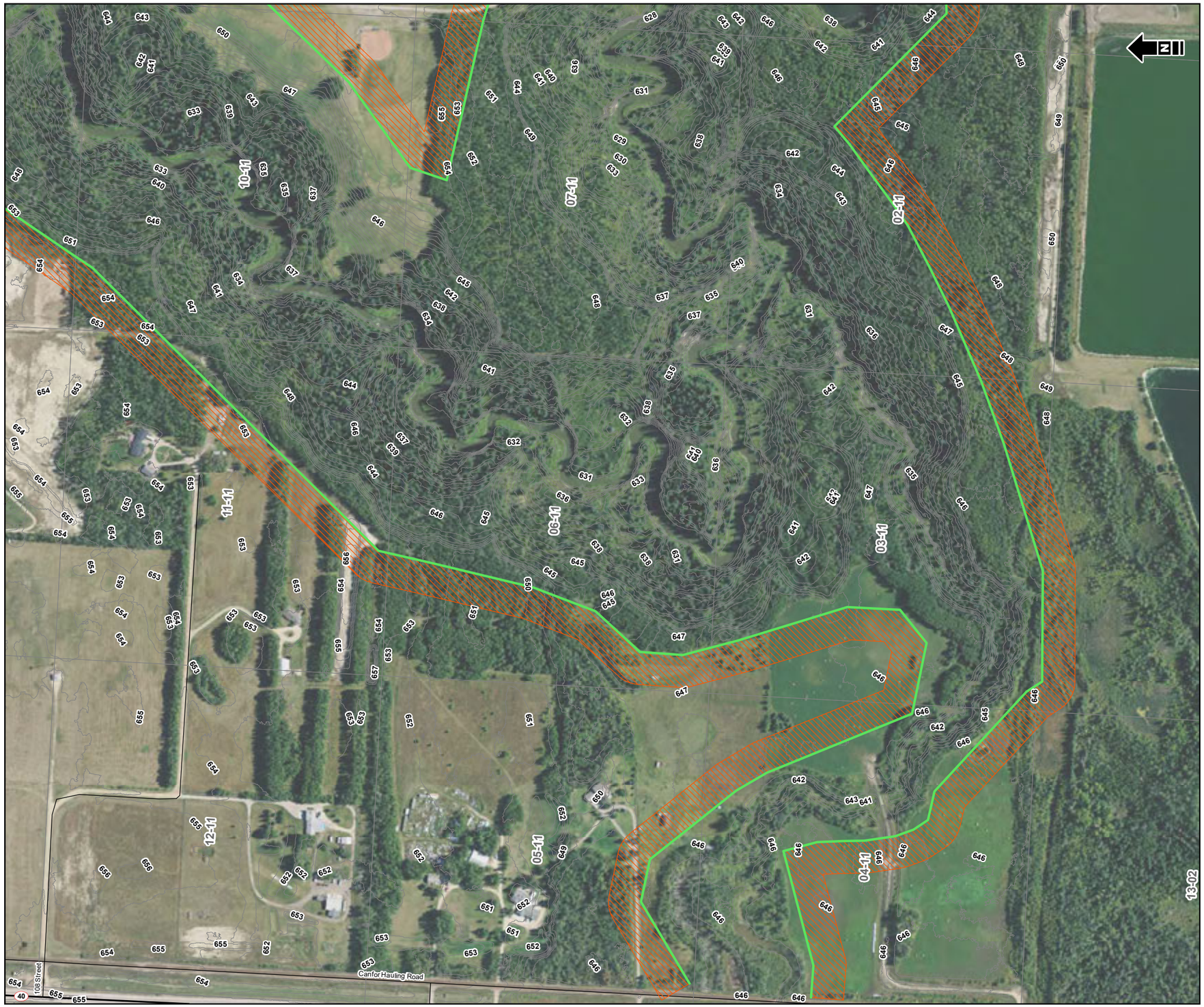
City of Grande Prairie
Bear Creek Corridor Assessment

Bear Creek Upstream Development Setbacks - Sheet 12

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Bender	A. Chan

Figure F-12



Setback
Community Boundary
Contour Interval (1m)
Highway
Road

Limit of Active Channel Erosion

Downstream (Updated from Parkland Geo 2010)

Downstream basis for setback locations:
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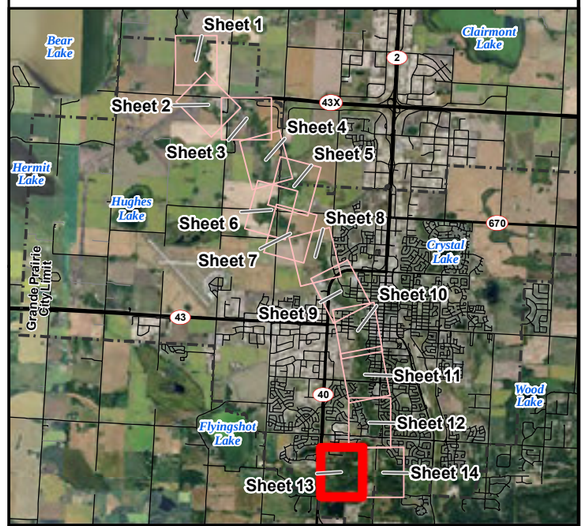
Scale Factor: 0.9992
Latitude Of Origin: 0.0000
Units: Meter

1:5,000
metres
50 0 50 100



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City of Grande Prairie
Bear Creek Corridor Assessment

Bear Creek Upstream Development Setbacks - Sheet 13

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Bender	A. Chan

Figure F-13

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Setback
Community Boundary
Contour Interval (1m)
Setback Cross-Section
Road

Limit of Active Channel Erosion

Downstream (Updated from Parkland Geo 2010)

Downstream basis for setback locations:

1. Edge of valley escarpment
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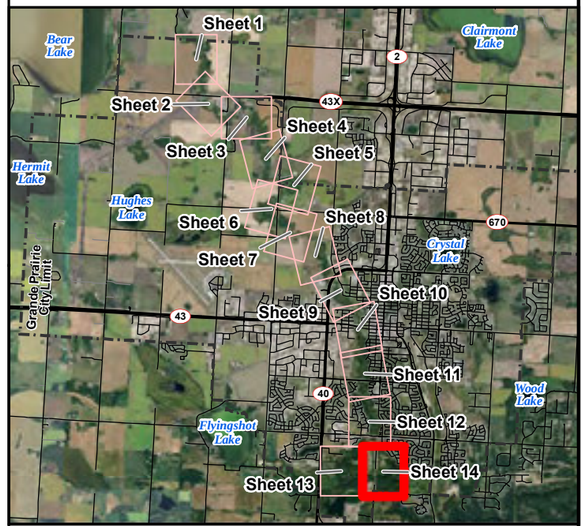
Latitude Of Origin: 0.0000
Units: Meter

1:5,000
metres
50 0 50 100



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City of Grande Prairie
Bear Creek Corridor Assessment

Bear Creek Upstream Development Setbacks - Sheet 14

Date:	Project:	Submitter:	Reviewer:
Aug 2018	24079	M. Bender	A. Chan

Figure F-14