Lethbridge County

Final Report

Battersea
Master Drainage Plan

November 2022

ISL Engineering and Land Services Ltd. Is an award-winning full-service consulting firm dedicated to working with all levels of government and the private sector to deliver planning and design solutions for transportation, water, and land projects.

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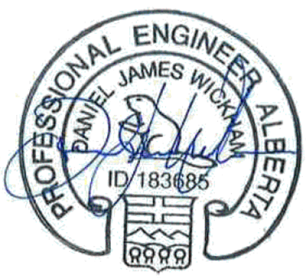

2022-11-18

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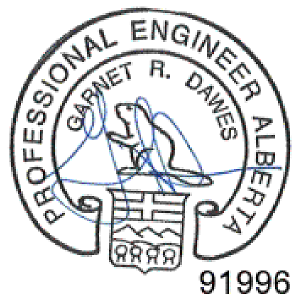

2022-11-18

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Permit to Practice
ISL Engineering and Land Services Ltd.

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Date: 2022-11-18

Permit Number P4741
The Association of Professional Engineers and Geoscientists of Alberta

Executive Summary

Introduction

Lethbridge County engaged ISL Engineering and Land Services to provide a Master Drainage Plan for the Battersea Drainage Basin. This report follows the County's existing Stormwater Master Plan (MPE, 2018), which identified major catchment areas within the County requiring further analysis. Battersea has been a victim of flooding, possibly due to its low-lying nature and flat topography, the existence of canals within natural drains, and/or the closure of LNID canals that have previously conveyed stormwater. In addition to this, due to the Battersea catchment's proximity to the Town of Picture Butte, there is potential for future development within the catchment. As such, it has also been classified by the County's Stormwater Master Plan as a high priority area for stormwater improvements.

To effectively budget and plan for upgrades in future years, the County requires a more consolidated understanding of the existing drainage problems in the Battersea catchment, as well as management solutions and associated costs. Furthermore, the MDP will assist the County in making decisions regarding development approval. This report encompasses an assessment of the current storm water system, including an identification of the existing hot spots within the study area. A prioritization of the upgrades to the existing system to address the current issues as well as to support future development within the drainage basin has been developed as part of this study to provide an efficient plan for improvement implementation which will mitigate ponding issues and ensure no downstream impacts will be incurred within the irrigation district because of the stormwater works.

Stakeholder Engagement

Several stakeholders are present within the County who may have a vested interest in, or be impacted by, stormwater works within the Battersea Drainage Basin. These include Lethbridge County, individual landowners, Alberta Transportation, Alberta Environment and Parks, Lethbridge Northern Irrigation District, and the Town of Picture Butte. Considering this, these stakeholders must be considered during the prioritization of stormwater infrastructure upgrades as well as the phasing of improvements. A stakeholder virtual engagement session (open house) was held for the Battersea MDP. The results of this engagement were considered in understanding current flooding concerns and recommendations for future upgrades.

Study Objectives

The MDP was prepared to achieve the following objectives:

- Assess existing drainage conditions and pinpoint areas of concern;
- Analyzing existing natural drainage conveyance;
- Provide cost estimates related to required infrastructure upgrades, which will also provide inputs to capital planning; and
- Comment on phasing of upgrades for the most effective implementation of The County's needs.
- Provide governing stormwater management guidelines for future development within the watershed; and
- Provide baseline stormwater modelling for the watershed to vet future development against within the context of pre-development and no-net impact.

Conclusions

The Battersea drainage system consists of entirely overland drainage (i.e., no underground piped storm system). A 2D model was constructed in InfoWorks ICM to assess the Battersea drainage system. Design rainfall events produced from The County's IDF parameters were utilized to assess the major system using a 1:100 year 24-hour Chicago rainfall distribution. Model results of the overland drainage system under the 1:100 year 24-hour Chicago design storm suggest that there are several locations throughout Battersea drainage basin that would experience surface flooding, exceed depths vs. velocity criteria, and under capacity culverts. Several notable areas of concern were flagged for further investigation and potential remediation measures.

Recommendations

Several recommendations were made based on the findings of this study. This includes the findings of the existing system assessment, and development of the proposed stormwater concept for priority areas. Additionally, 2 locations were flagged for immediate attention and culvert upgrades were prioritized into 2 categories.

For future development and any Water Act applications, impacts are to be outlined within the context of existing ponding depths outlined in this MDP. No generalized Water Act was obtained for the area due to the limited amount of proposed development, therefore developers are still required to obtain Water Acts as required, however this MDP forms the basis for existing conditions. Pre-development and "no-net increase" stormwater management design ideologies are to be compared to governing model results. Developers can deviate from the below guidelines and model results outlined in this report provided technical rational and stormwater modeling outlines how development deviates from the MDP but still achieves the intent of the design guidelines.

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1.0 Introduction

Lethbridge County (the County) engaged ISL Engineering and Land Services (ISL) to provide a Master Drainage Plan (MDP) for the Battersea Drainage Basin (Battersea). This report follows the County's existing Stormwater Master Plan (MPE, 2018), which identified major catchment areas within the County requiring further analysis. Battersea has been a victim of flooding, possibly due to its low-lying nature and flat topography, the existence of canals within natural drains, and/or the closure of LNID canals that have previously conveyed stormwater. In addition to this, due to the Battersea catchment's proximity to the Town of Picture Butte, there is potential for future development within the catchment. As such, it has also been classified by the County's Stormwater Master Plan as a high priority area for stormwater improvements.

To effectively budget and plan for upgrades in future years, the County requires a more consolidated understanding of the existing drainage problems in the Battersea catchment, as well as management solutions and associated costs. Furthermore, the MDP will assist the County in making decisions regarding development approval. This report encompasses an assessment of the current storm water system, including an identification of the existing hot spots within the study area. A prioritization of the upgrades to the existing system to address the current issues as well as to support future development within the drainage basin has been developed as part of this study to provide an efficient plan for improvement implementation which will mitigate ponding issues and ensure no downstream impacts will be incurred within the irrigation district because of the stormwater works.

1.1 Purpose of the Study

The objectives of developing the Battersea MDP include the following:

- To review and summarize existing background information on the study area
- To delineate sub-catchment areas contributing to the study area based on available topographic data
  - Potential land depressions issues are to be identified
- To conduct field reconnaissance of drainage conveyance infrastructure, including survey, where necessary
- To inventory and analyze the infrastructure under existing conditions
  - Culvert capacities should be determined and culverts lacking capacity should be identified
  - Assess existing ponding conditions
  - Assess depth vs. velocity for overland flows and identify areas exceeding limits
- To highlight and prioritize significant stormwater issues (significant ponding) within the study area
- To determine if any upgrades are required to the existing system to properly meet the needs of the County and to address existing issues
- To determine if any upgrades are required to support future development within the study area
- To ensure the planned stormwater management system meets regulatory requirements, including Alberta Environment and Parks (AEP) Water Act requirements
- To prioritise and develop a phasing plan for the required upgrades to stormwater infrastructure
- To develop cost estimates (Class D) related to the required stormwater infrastructure upgrades

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2.0 Site Description

2.1 Location

Lethbridge County is an agricultural-based rural municipality located in Southern Alberta. Pertinent urban municipalities within the County include the villages of Barons and Nobleford, the Towns of Picture Butte, Coaldale and Coalhurst, and the City of Lethbridge. Smaller communities within the County include the Hamlets of Chin, Diamond City, Fairview, Kipp, Monarch, Iron Springs, Shaughnessy, and Turin. Two significant irrigation districts exist within the county which supply irrigation-based agricultural operations with water. These include the Lethbridge Northern Irrigation District (LNID) and the St. Mary River Irrigation District (SMRID). It is critical that stormwater works within the County be coordinated with these irrigation districts, as discussed further in Section 2.3.

The Battersea Drainage Basin is in the East-Central area of the County, bounded loosely by the Oldman River to the south, Highway 25 to the north, Range Road 213 to the west, and Range Road 195 to the east. The overall study area is irrigated and consists of approximately 10,400 ha of land and can be seen in Figure 2.1. The Battersea catchment primarily consists of agricultural land with relatively flat terrain. Elevations in the study area vary moderately, ranging from 944.81 m in the west extremity of the catchment to 800.38 m in the southeast portion of the catchment. Generally, the topography falls from west to southeast, as can be seen in Figure 2.2.

2.2 Land Use

The study area is largely undeveloped with areas of farmland and residential acreages primarily used for agricultural purposes. Due to the agricultural nature of the catchment, nitrogen levels within stormwater runoff are notably high within the Battersea drain. The southwest stretches of the catchment overlap the Town of Picture Butte and include areas of industrial land use. Potential future development is anticipated within the Battersea catchment in proximity to the Town of Picture Butte, which is demonstrated in Figure 2.3. Specific details on the land use of the potential future development are not available at this time, but due to its size and proximity to industrial and residential areas within the Town of Picture Butte, it has been considered as a mix of residential and industrial land use. Table 2.1 summarizes the specific land uses within the Battersea catchment for existing and future conditions, as well as the runoff coefficient stipulated by the City of Lethbridge Design Standards (City of Lethbridge, 2016) and Stormwater Management Guidelines for the Province of Alberta (Alberta Environment, 1999) associated with each land use.

Table 2.1: Summary of Existing and Future Land Use

Land Use	Existing Area (ha)	Proposed Area (ha)	Runoff Coefficient
Paved Surfaces	108	108	0.95
Agricultural (Field)	9,517	9,371	0.20
Agricultural (Feed Lot)	168	168	0.50
Residential	115	163	0.60
Waterbodies/Wetlands	143	143	1.00
Industrial/Commercial Farmland	325	423	0.70

2.3 Stakeholders

Several stakeholders are present within the County who may have a vested interest in, or be impacted by, stormwater works within the Battersea Drainage Basin. These include Lethbridge County, individual landowners, Alberta Transportation (AT), AEP, LNID, and the Town of Picture Butte. Considering this, these stakeholders must be considered during the prioritization of stormwater infrastructure upgrades as well as the phasing of improvements. A stakeholder virtual engagement session (open house) was held for the Battersea MDP. The results of this engagement were considered in understanding current flooding concerns and recommendations for future upgrades.

Lethbridge County

By undertaking MDPs within specific drainage catchments within the County, Lethbridge County provides solutions to existing stormwater management issues. In the forefront of their focus is addressing impacts to private properties by providing a comprehensive plan to mitigate overland flooding and to ensure additional development within the catchment does not negatively impact the stormwater management system. Several instances of flooding have been noted in the Battersea catchment, which are anticipated to be caused by a lack in culvert capacity and overall conveyance issues, snow jamming, and localized low spots which collect stormwater. These shortcomings are to be ranked based on their relative effects on infrastructure, and subsequently prioritized for improvements.

Landowners

At present, ponding issues arise throughout the study area due to a lack of culvert capacity and poor conveyance, snow jamming and localized low areas within the project area. Impacts on farmsteads and agricultural fields have been noted in the past due to shortcomings with the stormwater infrastructure. Landowners generally rely on the implemented stormwater infrastructure to effectively operate such that their land is not negatively impacted due to flooding. Prioritization of stormwater upgrades should consider the impacts on private properties. Landowners were engaged through a virtual open house.

Alberta Transportation

AT is responsible for highway infrastructure within the study area. Thus, stormwater issues or improvements impacting highways will need to be coordinated with AT. AT was engaged for in person meetings during the stakeholder engagement phase of the project and was provided an opportunity to review and comment on the draft MDP.

Alberta Environment and Parks

Collaboration with AEP will be critical for the successful execution of stormwater works within the study area. AEP is the regulatory authority for stormwater management within Alberta, thus this MDP has been constructed to assist developers in obtaining Water Act approval for the stormwater improvements. AEP was engaged for in person meetings during the stakeholder engagement phase of the project and provided and opportunity to review and comment on the draft MDP.

Due to the limited amount of current development in the area, a governing water act for future impacted wetlands and formal signoff from Alberta Environment and Parks was not obtained at this time. If in future, larger developments are proposed within the area, a Water Act should be pursued.

Lethbridge Northern Irrigation District

The Battersea catchment is an irrigated area and maintains LNID infrastructure. The LNID provides an efficient and cost-effective water distribution system to users in Southern Alberta. Irrigation is supplied to water users through a network of reservoirs and conduits. Specific to the Battersea catchment, considerations are being made to fill in existing irrigation canals which must include analysis of the resultant impact on the stormwater system to ensure no stormwater conditions are worsened. Though these canals are not designed to accommodate runoff from the catchment, it is assumed they currently manage stormwater within the study area. LNID was engaged for in person meetings during the stakeholder engagement phase of the project and provided an opportunity to review and comment on the draft MDP.

The Town of Picture Butte

The Town of Picture Butte is located at the west boundary of the Battersea catchment. Given the topography of the study area, stormwater within the Battersea catchment appears to drain away from the Town of Picture Butte, though considering there is some overlap between the catchment and the Town of Picture Butte, this should be confirmed. In addition to this, additional development extending off the Town of Picture Butte is anticipated to occur within the Battersea Catchment, it must be confirmed that no negative impacts are incurred to the stormwater system as a result of this development and that infrastructure within the development area is sufficient to manage flows in the area.

2.4 Geotechnical Conditions

According to the Lethbridge County Stormwater Master Plan (MPE Engineering Ltd., 2018), the geology within the study area has been shaped by the different glaciations. The specific surficial material type within the Battersea catchment is a mix of glaciolacustrine and glaciofluvial and the topography is generally comprised of long, gentle slopes. These types of materials consist of sediments deposited by glacial meltwaters in either lakes or rivers. Glaciofluvial deposits arise from sediments moved by glaciers which are sorted and deposited by flows of melting ice. These deposits are generally stratified, and the size of particle deposited will depend on the velocity within the melt waters. Glaciolacustrine sediments are typically silts and clays which remain suspended in the water column as the bedload of a stream is deposited at the lake margin. Glaciolacustrine sediments tend to have a layered nature as different sized particles are deposited over the annual cycle. Larger particles settle in the summer when highly turbid water enters lakes due to spring melt. Freezing temperatures during the winter reduce the discharge of inbound streams, this results in calmer conditions within lakes and thus allows smaller-sized particles to settle.

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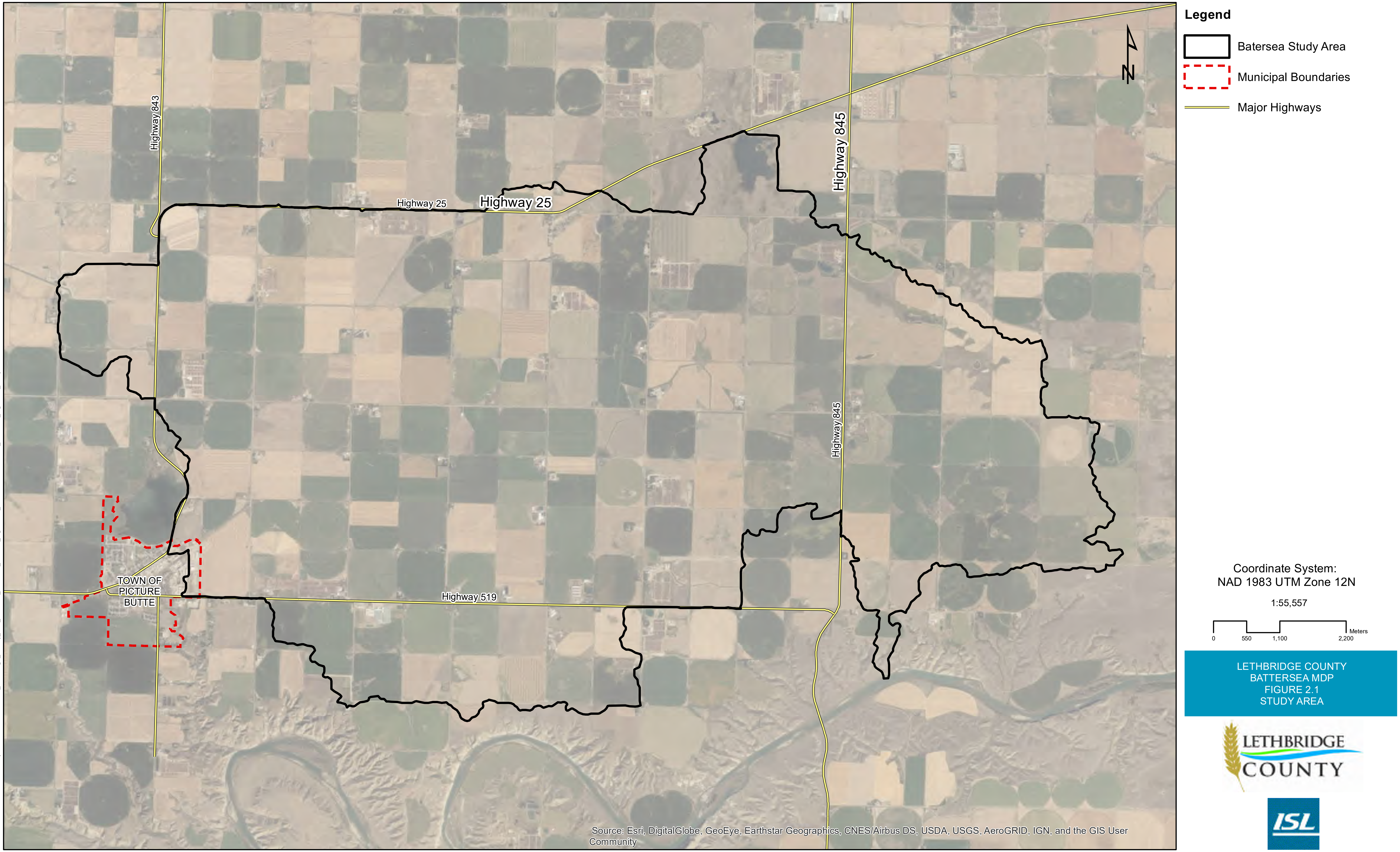

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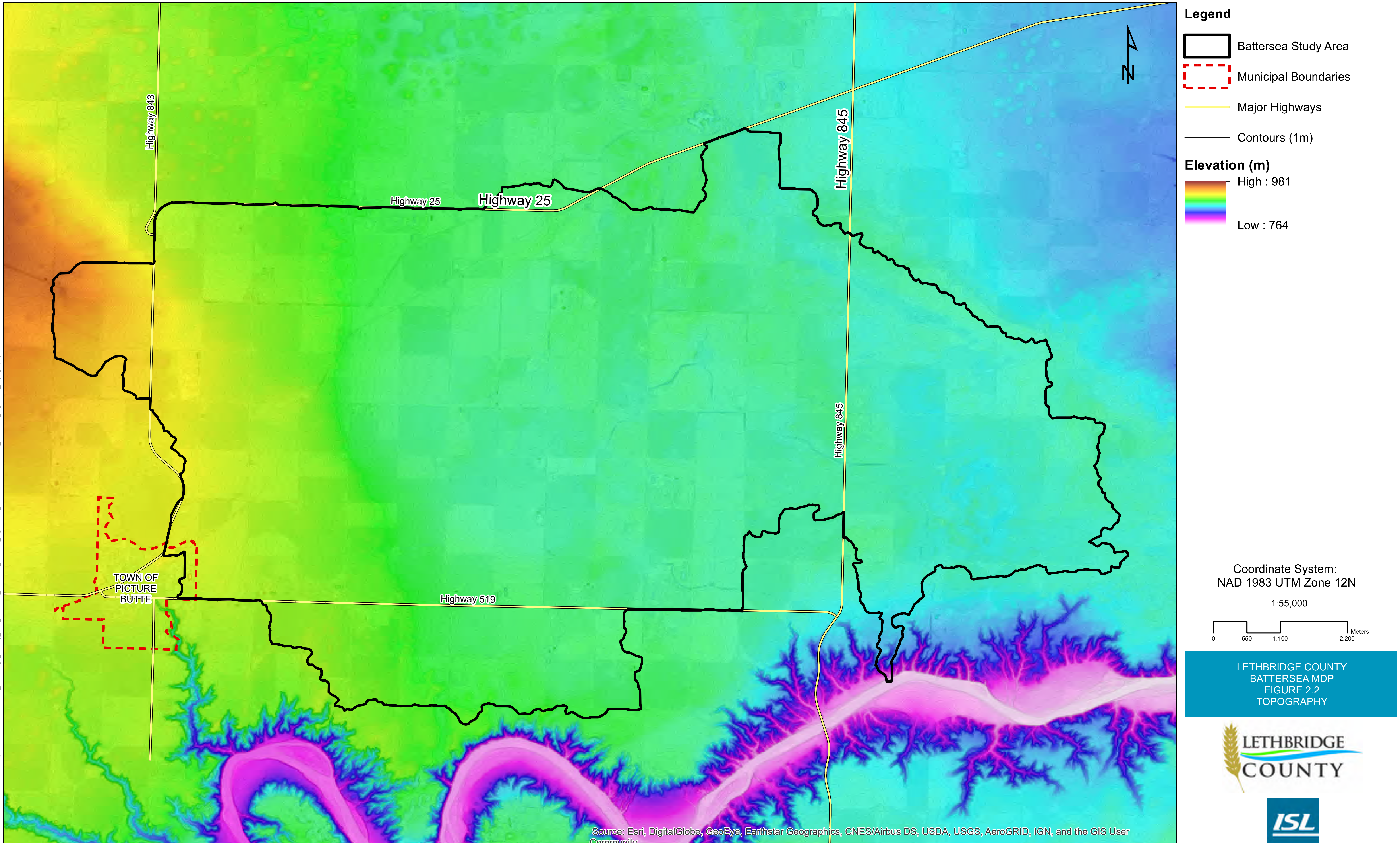
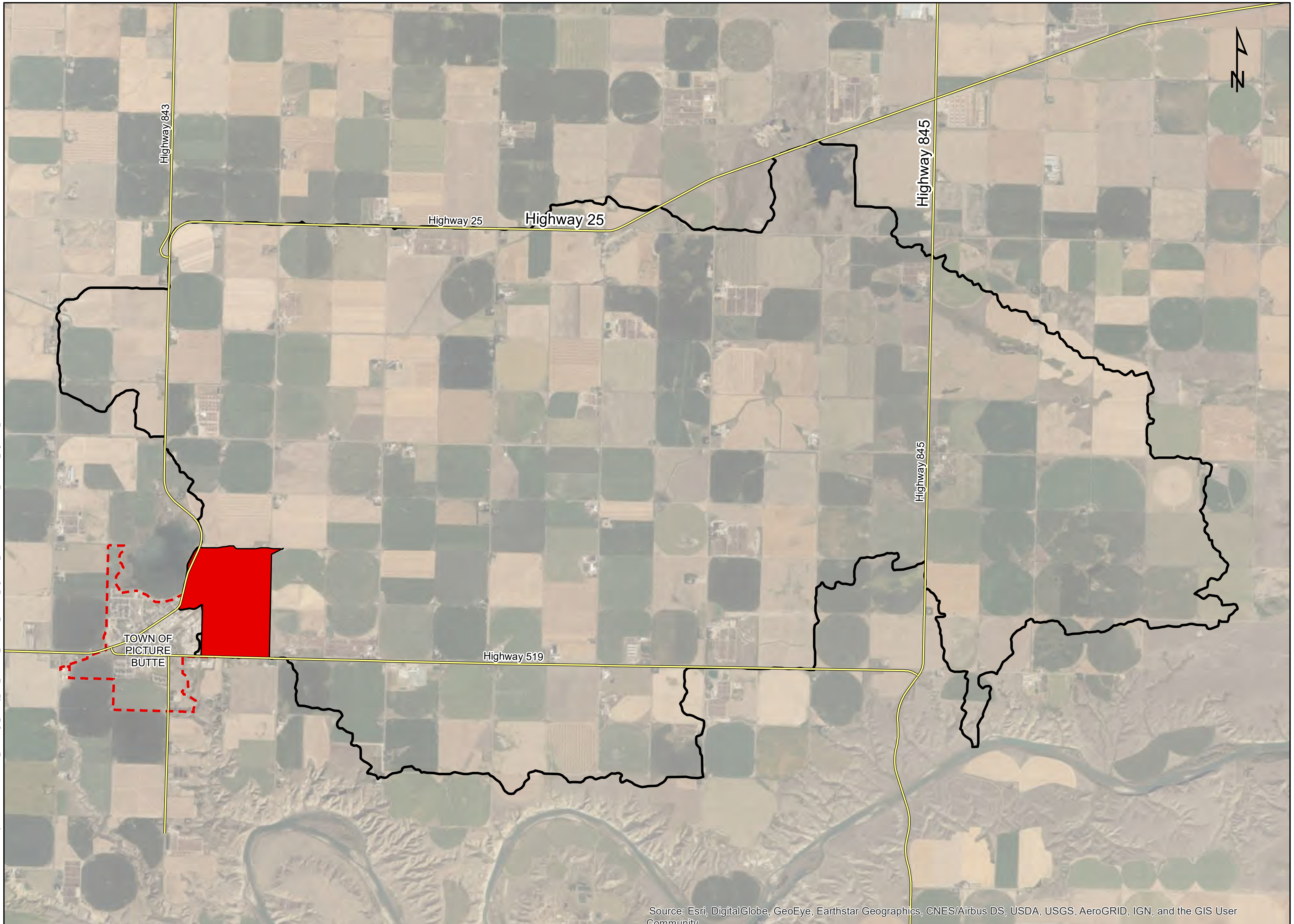


Legend
Battersea Study Area
Municipal Boundaries
Major Highways
Contours (1m)
Elevation (m)
High : 981
Low : 764
Highway 843
Highway 25
Highway 25
Highway 845
Highway 845
Highway 519
TOWN OF PICTURE BUTTE
Coordinate System:
NAD 1983 UTM Zone 12N
1:55,000
0 550 1,100 2,200 Meters
LETHBRIDGE COUNTY
BATTERSEA MDP
FIGURE 2.2
TOPOGRAPHY
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Legend

- Battersea Study Area
- Municipal Boundaries
- Major Highways
- Potential Future Development Area

Coordinate System:
NAD 1983 UTM Zone 12N

1:55,000

0 550 1,100 2,200 Meters

LETHBRIDGE COUNTY
BATTERSEA MDP
FIGURE 2.3
POTENTIAL FUTURE DEVELOPMENT

LETHBRIDGE COUNTY

ISL

3.0 Existing Stormwater System

3.1 Existing Drainage Patterns

As previously noted, the Study Area largely drains from west to east, away from the Town of Picture Butte and outlets to the Battersea drain. Existing drainage patterns and the Battersea drain are highlighted in Figure 3.1. The catchment ultimately discharges to the Oldman River, and as such, the study area is located within the Oldman River watershed as part of the Nelson-Churchill (Hudson Bay) continental drainage basin.

3.2 Stormwater Conveyance System and Existing Infrastructure

The Battersea catchment is made up of low-lying land which experiences flooding during medium and heavy rainfall events. As part of the Lethbridge County Stormwater Master Plan, several culverts at identified hotspots and along the Battersea drain in the study area were examined to highlight whether capacity constraints existed. The analysis found that many of the culverts examined were able to accommodate the 1:100 year storm event, many that were near or at capacity and only 4 that were over capacity for the 1:100 year event. Table 3.1 summarizes the hotspots and corresponding constraint responsible for the stormwater issues noted at each location as determined by the Lethbridge County Stormwater Master Plan.

Table 3.1: Hot Spot Summary (MPE Engineering Ltd., 2018)

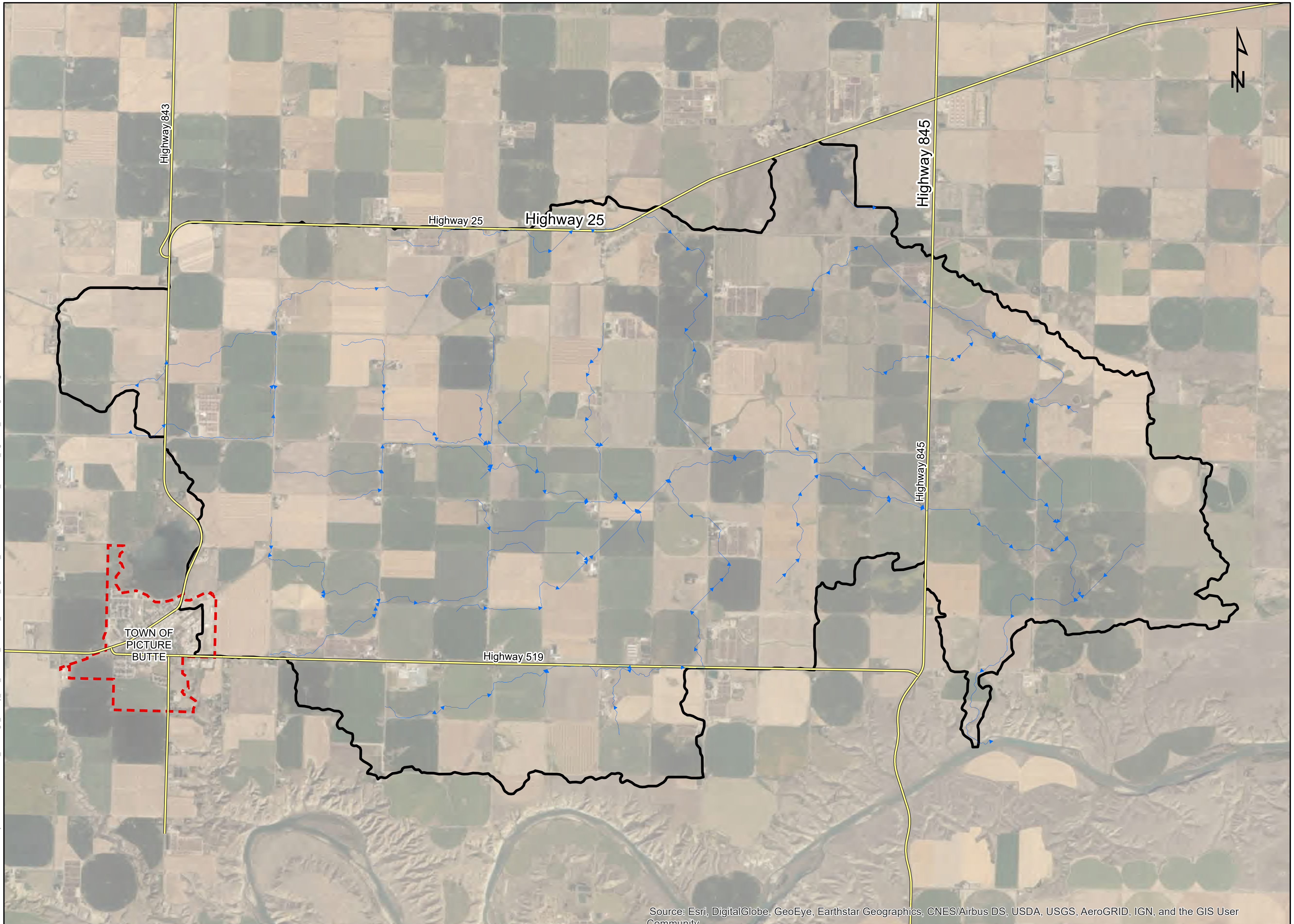
ID Number	Location	Priority	Problem	Main Infrastructure Impacted
5	SW 9-11-20 W4	1	Natural low area causes yearly ponding on farmlands and roads.	Farms, fields, roads
102	SW 15-11-20 W4	3	Localized flooding issue on farmland	Farms

ISL has continued this analysis, carrying out a detailed examination of the stormwater system within the Battersea catchment to further the understanding of the existing system performance.

3.3 Environmentally Sensitive Areas

Several existing wetlands are located within the Study Area, including several permanent water bodies. Any changes to these existing water bodies, including alteration of flow or level, change in the location of water, or infilling of wetlands, may require a Water Act approval. Prior to development or stormwater improvements, wetlands must be classified using the Alberta Wetland Classification System and assigned an ecological wetland value using the Alberta Wetland Rapid Evaluation Tool. This standardized method must be performed by a Qualified Wetland Science Practitioner to ensure that any required wetland replacement considers the loss of wetland area as well as the specific wetland function. Wetlands which have been permanently impacted by development may be replaced by stormwater management facilities (SWMF). A detailed SWMF report may be used to assist the County in gaining credit for future wetland development, offsetting the impacts to existing wetlands.

In addition to this, several sensitive watercourses exist in proximity to the study area including the Oldman River. As such, stormwater design must work to minimize the negative impacts to the ecology of any water body within the County. This study has been conducted with the goal of adhering to the recommendations of the SWMP to minimize negative impacts to the overall stormwater management system.



Legend

- Battersea Study Area
- Municipal Boundaries
- Major Highways
- Drainage Path

Coordinate System:
NAD 1983 UTM Zone 12N

1:55,000

0 550 1,100 2,200 Meters

LETHBRIDGE COUNTY
BATTERSEA MDP
FIGURE 3.1
EXISTING DRAINAGE

4.0 Hydraulic Model Development

4.1 Model Set-Up

The model used for assessing the Battersea Lake Drain was InfoWorks ICM developed by Innovyze, which was selected for its advanced capabilities associated with 2D modelling. Some of the advantages of InfoWorks ICM that were an asset for this project are summarized below:

- Effective in urban applications, InfoWorks ICM is the preferred modelling software utilized by numerous municipalities across the country.
- Ease with applying differential cell sizing.
- Rain on Mesh option is available, meaning that overland flow path assumptions are not necessarily required upfront.
- Triangular mesh elements mean that the surface can be modelled with extreme accuracy.
- Ability for terrain sensitive meshing, ensuring that changes in topography are reflected in the mesh.
- Mesh generation effectively accounts for building footprints.
- Many result formats are available, including 3D videos that can be used for presentations to stakeholders.
- There is complete integration with ArcGIS.

The model was constructed by utilizing available LiDAR data combined with confirmations from survey and certain assumptions. Section 4.1.2 describes the process that was undertaken to develop the 2D model. This includes a discussion of the features and parameters that were required as input into the mesh development process, and a summary of the mesh generation itself.

4.1.1 Road Survey

To provide an accurate representation of the surface for 2D modeling purposes, all roads within the site were surveyed. The survey was conducted by attaching equipment to a truck which captured survey points along the center of the roadway as the truck drove down every roadway within the site. The data was then processed to provide an accurate representation of each roadway which allows for a highly accurate representation of the surface in the 2D modeling. Existing culverts invert elevations were captured as part of this survey.

4.1.2 Major (2D) System Development

The major system consists of all overland drainage components including roads, ditches, culverts, surface storage elements, and receiving water bodies. The following parameters have been considered to develop a mesh, which ultimately represents the overland drainage system:

- 2D Zone
- Mesh Zones
- Roughness Zones
- Infiltration Zones

The 2D Zone represents the boundary in which the 2D analysis will occur in. The 2D Zone was digitized to be a simplified version of the proposed area. A mesh was created within a 2D Zone and represents the surface using triangulation. Each triangle is referred to as a mesh element, each with its own unique elevation, which is calculated using surface data, ultimately making each mesh element flat. Together with other mesh elements, a surface is formulated. The number of mesh elements has a direct impact on simulation run times. Various parameters can be considered when developing a mesh. For the model that has been developed as part of this MDP, these parameters include the Mesh, Roughness, and Infiltration Zones.

The Mesh Zone specifies different mesh element densities for various zones, to either increase or decrease the resolution of a zone depending on its importance. For example, in order to capture pertinent features such as the crowns of roads, roadways are generally defined by denser, smaller elements. Alternatively, greenfields that do not impact existing developments could be considered for larger mesh elements.

The Roughness Zone allows various Manning's n roughness values for different parts of the mesh. A roughness value is assigned to each mesh element depending on which Roughness Zone that mesh element is a part of. The Roughness Zone allows for a more accurate representation of different surfaces within the model.

The Infiltration Zone allows for various infiltration parameters across the mesh, depending on the different surfaces that are apparent within the mesh. Each Infiltration Zone is designated an Infiltration Surface, where an Infiltration Type can be specified. Four Infiltration Types are available along with their related parameters, including:

- Fixed
  - Fixed Runoff Coefficient
- Horton
  - Horton Initial
  - Horton Limiting
  - Horton Decay
  - Horton Recovery
- Constant Infiltration
  - Fixed Runoff Coefficient
  - Infiltration Loss Coefficient
- Green-Ampt
  - Green-Ampt Suction
  - Green-Ampt Conductivity
  - Green-Ampt Deficit

In this model, surfaces are represented through a fixed runoff coefficient, as either paved, unpaved, or field surfaces.

Default mesh, roughness, and infiltration parameters were defined in the 2D Zone to represent impervious areas such as roadways and buildings. These default parameters are stipulated below in Tables 4.1, 4.2, and 4.3. Additionally, the options to 'Apply rainfall etc. directly to mesh' and 'Terrain-sensitive meshing' were selected. The 'Apply rainfall etc. directly to mesh' option ensures that rainfall is falling directly onto the surface, which provides a more accurate representation of overland flows. The 'Terrain-sensitive meshing' option better represents the surface topography among the mesh elements.

The Mesh, Roughness, and Infiltration Zones were generated through the geospatial development type information, to be able to specify different criteria depending on the development type. It is noted that the physical boundaries of each Mesh, Roughness, and Infiltration Zone polygon are identical, however the parameters vary depending on the type of polygon (i.e., whether it is a Mesh, Roughness, or Infiltration Zone). Maintaining the same extent for each polygon type ensured there would be no errors regarding overlaps between the different polygon layers.

The parameters applied per development type are specified in Tables 4.1, 4.2, and 4.3 below for the Mesh, Roughness, and Infiltration Zones, respectively. The Mesh Zone parameters are based on ISL's experience using InfoWorks ICM, optimizing both model simulation time and level of detail. The Roughness Zone parameters are based on engineering best practices, and are consistent with past projects completed by ISL. The Infiltration Zone parameters are based on a combination of the runoff coefficients stipulated in the Stormwater Management Guidelines for the Province of Alberta (AEP, 1999)

Table 4.1: Mesh Zone Parameters per Land Use Type

Land Use	Maximum Triangle Area	Minimum Element Area
	m^2	m^2
Paved Road	20	1
Unpaved Road	20	1
Field	100	20

Table 4.2: Roughness Zone Parameters per Land Use Type

Land Use	Roughness Coefficient
Paved Road	0.016
Unpaved Road	0.023
Field	0.030

Table 4.3: Infiltration Zone Parameters per Land Use Type

Land Use	Infiltration Type	Fixed Runoff Coefficient
Paved Road	Fixed	0.85
Unpaved Road	Fixed	0.70
Field	Fixed	0.20

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5.0 Design Criteria

The design criteria used to assess the stormwater system was based primarily on Lethbridge County – Engineering Guidelines & Minimum Servicing Standards while also considering City of Lethbridge Design Standards. The design criteria selected were then used for input into the InfoWorks ICM model to design and assess the stormwater drainage system.

5.1 Design Rainfall Event

The design storms applied in this study are based on Lethbridge County's tabular design storms stipulated in the Engineering Guidelines & Minimum Servicing Standards (Lethbridge County, 2019). Table 5.1 summarizes the 1:100 year 24 hour design storm utilized for modeling purposes.

Table 5.1: Lethbridge County Tabular Design Storms, 1:100 Year 24 Hour Rainfall Distribution

Hour	Depth (mm)	Hour	Depth (mm)	Hour	Depth (mm)
1	0.1	9	6.2	17	2.8
2	0.2	10	37.0	18	1.7
3	0.3	11	21.8	19	0.0
4	0.4	12	15.7	20	0.0
5	0.6	13	9.0	21	0.0
6	0.8	14	5.6	22	0.0
7	0.9	15	4.5	23	0.0
8	1.1	16	3.4	24	0.0

In assessing the storm drainage system in the area, a design rainfall event is required to generate runoff that will subsequently enter the network. The major system is assessed to handle the runoff from storms up to the 1:100 year storm event. These return periods are consistent with many other municipalities, therefore were used in assessing the drainage in the area. The storm is set in 5-minute time steps, with the peak intensity set to a 5-minute duration for the selected storm return period.

5.2 Assessment Criteria

The performance of the major system under the existing conditions is ultimately determined based on depth vs. velocity for surface flows, and capacity of culverts.

In assessing the storm drainage system in an area, typically a 1:100 year storm is used to assess the major drainage system under large flow volumes once the system is saturated, this would typically be a 1:100 year, 24-hour event. Therefore, the existing drainage system was analyzed under the 1:100 year 24 hour event.

Peak Discharge Relative to Culvert Capacity

Peak Discharge Relative to Culvert Capacity indicates the ratio of peak flow to pipe capacity; as a corollary to this, the data can be interpreted to indicate the amount of spare capacity during peak flows. This is calculated by employing a ratio of modelled flow in the culvert and its corresponding capacity. Culverts with ratios greater than one are considered to have no spare capacity thus indicating a culvert that might require upgrading, particularly where the length of the section is long enough to cause surcharge conditions immediately upstream.

Hence, the Peak Discharge Relative to Culvert Capacity (Q/Q_{max}) with a ratio of:

- Greater than 300% – significantly over capacity
- Between 150% and 300% – over capacity
- Between 100% and 150% – slightly over capacity
- Less than 100% – spare capacity available

Depth vs. Velocity

To present and evaluate 2D assessment model results, model files were reviewed, and results data was extracted for both depth and velocity at the maxima, for the 1:100 year event. The complete model file contains velocity and depth properties at any time step within the simulation in the event they are required.

To increase public safety, the Province of Alberta has stipulated permissible depths for submerged objects in relation to water velocity. This guideline, Stormwater Management Guidelines for the Province of Alberta, 1999, was implemented to ensure that a 20 kg child would be able to withstand the force of moving water, thus preventing possible tragedies. Figure 5.1 indicates these requirements.

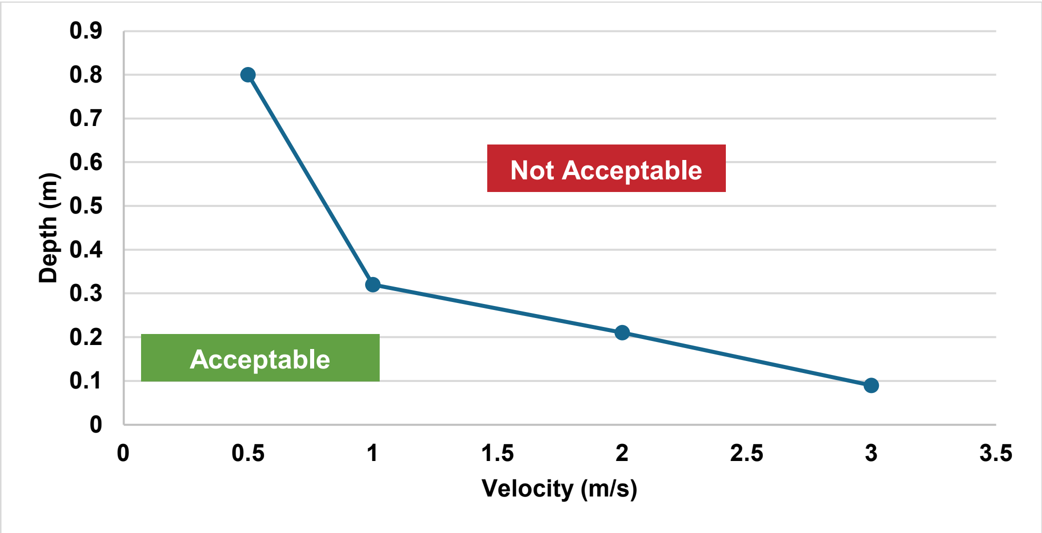


Figure 5.1: Permissible Depths for Submerged Objects

6.0 Existing System Assessment

The existing system was assessed using the design criteria stipulated above in Section 5.0. The existing system was assessed under the 1:100 year 24 hour design storm. Simulation results under the rainfall distribution are covered in the sections below.

6.1 2D Model Results

2D model results were generally analyzed relative to ponding depths, overland flow depth vs. velocity, and culvert capacities as discussed in the subsections below.

6.1.1 Ponding Depths and Overland Flows

To assess existing overland drainage system, model results were extracted at the maxima for both water depth relative to the LiDAR surface and surface flow velocity. It is noted that the maxima represent the peak depth/velocity value of each mesh element at a specific point in time. That said, the time stamps for each mesh element do not necessarily overlap, and each occurrence is independent of the next. The water depth and surface flow velocity results are illustrated in Figures 6.1 and 6.2, respectively.

The results shown in Figures 6.1 and 6.2 indicate that there are few locations throughout the study area along roadways would experience surface flooding to some extent under the 1:100 year rainfall event. Table 6.1 summarizes critical locations in terms of surface depths and velocities, while Table 6.2 details areas where there is significant impounding of water adjacent to roadways; (greater than 0.6m maximum depth); Figure 6.3 shows these data points compared to the Province's requirements and Figure 6.4 illustrates these locations geographically. Note that due to the size of the data set only depths vs. velocities that exceed the acceptable limits are shown. The extent of these areas of concern vary, depending on how many mesh elements exceed or are close to exceeding the depth-velocity criteria. In Table 6.1 below, the maximum depth and maximum velocity among all exceeded mesh elements are recorded.

Table 6.1: 1:100 Year Event 2D Modelling Critical Location - Surface Depths vs Velocities

ID	Location	Maximum Depth (m)	Maximum Velocity (m/s)	Priority
1	NE-5-11-20-4	1.25	0.497	3

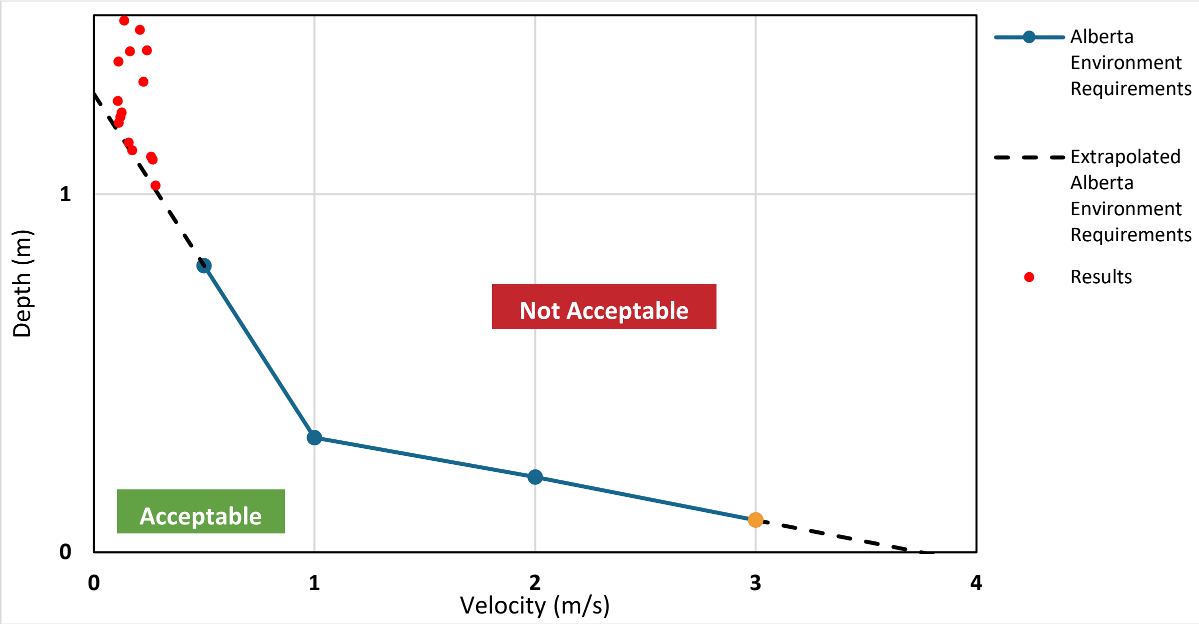


Figure 6.3: Velocity and Depth Guidelines

Table 6.2: 1:100 Year Event Modelling Critical Locations – Surface Depths

ID	Location (QTR-SEC-TWP-RGE-MER)	Maximum Depth (m)	Priority
1	NE-15-11-21-4	1.611	2
2	NE-02-11-21-4	0.978	2
3	SE-11-11-21-4	0.751	3
4	NE-11-11-21-4	0.967	3
5	NE-23-11-21-4	0.861	2
6	NE-12-11-21-4	0.720	2
7	NE-36-10-21-4	1.124	2
8	SE-07-11-20-4	0.848	2
9	SE-18-11-20-4	1.054	3
10	SE-08-11-20-4	1.012	3
11	SE-04-11-20-4	0.934	2
12	SE-16-11-20-4	1.923	2
13	NE-14-11-20-4	1.356	2

6.1.2 Culvert Capacities

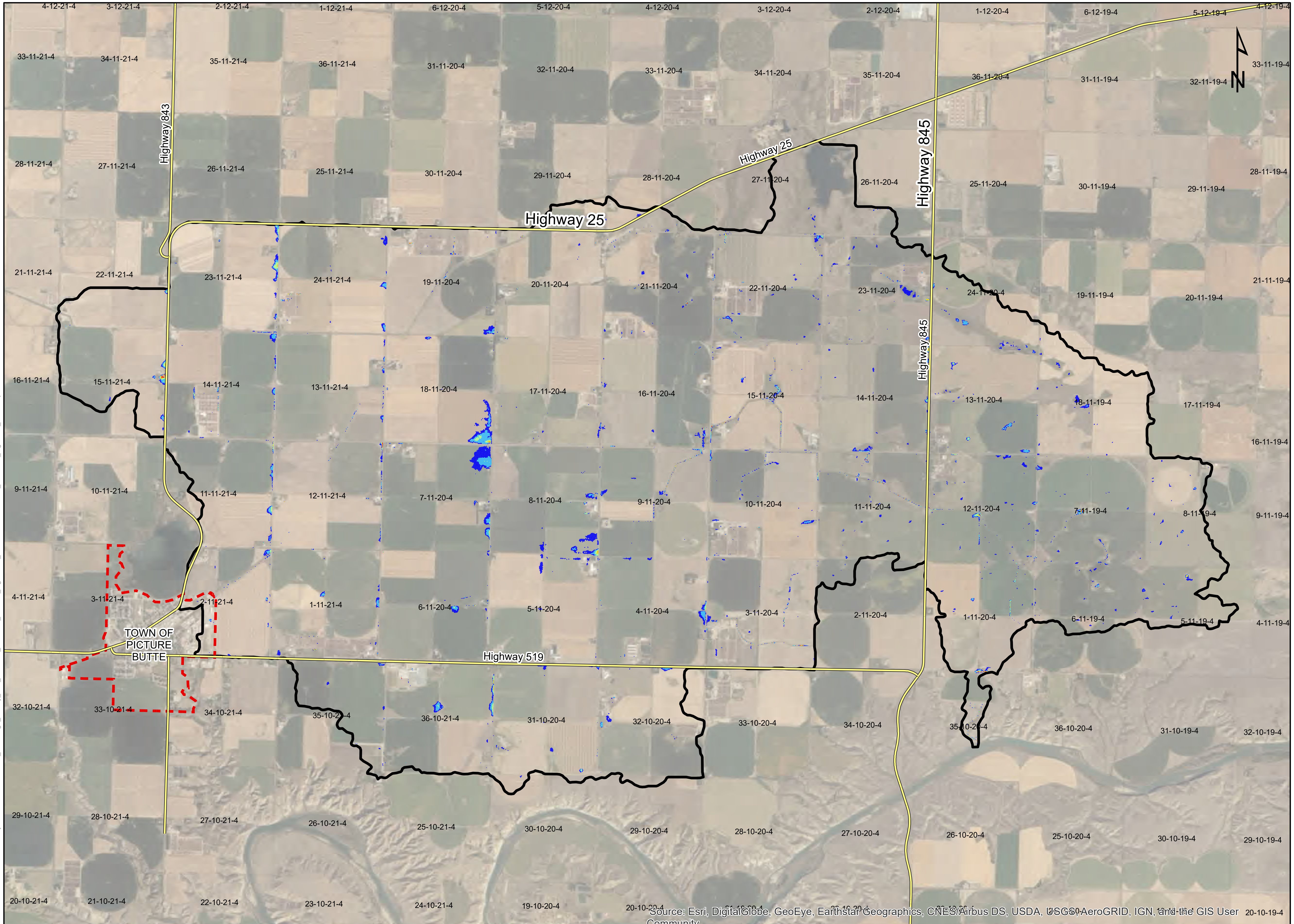
Known culverts were included in the modeling based on data obtained from the County. Table 6.3 below details model results for culverts, with under capacity culverts bolded below. Figure 6.5 is provided to reference locations. Refer to Table 7.4 for recommended sizing for proposed upgrades.

Table 6.3: Over Capacity Culverts

Culvert ID	Diameter (mm)	Capacity (m^3/s)	Max Depth (m)	Max Flow (m^3/s)	Ratio Headwater /Diameter	Remaining Capacity (%)	Priority
CUL1	**500**	**0.173**	**0.84**	**0.353**	**1.67**	**-104%**	**2**
CUL2	300	0.035	0.11	0.009	0.35	75%	-
CUL3	600	0.362	0.06	0.000	0.10	100%	-
CUL4	600	0.221	0.30	0.120	0.49	46%	-
CUL5	1200	2.331	0.14	0.015	0.12	99%	-
CUL6	800	0.528	0.36	0.250	0.45	53%	-
CUL7	450	0.182	0.29	0.132	0.64	27%	-
CUL8	600	0.329	0.15	0.018	0.25	95%	-
CUL9	**500**	**0.136**	**0.94**	**0.294**	**1.88**	**-116%**	**1**
CUL10	1200	2.620	0.12	0.001	0.10	100%	-
CUL11	1200	1.796	0.07	0.002	0.06	100%	-
CUL12	1500	3.793	0.08	0.002	0.05	100%	-
CUL13	**300**	**0.039**	**0.22**	**0.039**	**0.74**	**0%**	**2**
CUL14	600	0.456	0.60	0.001	1.00	100%	-
CUL15	300	0.028	0.31	0.004	1.03	86%	-
CUL16	750	0.398	0.04	0.001	0.06	100%	-
CUL17	1200	1.727	0.53	0.146	0.44	92%	-
CUL18	1100	0.511	0.10	0.008	0.09	98%	-
CUL19	1300	2.092	0.15	0.051	0.12	98%	-
CUL20	400	0.144	0.08	0.008	0.19	94%	-
CUL21	500	0.128	0.03	0.000	0.06	100%	-
CUL22	750	1.894	0.39	0.964	0.51	49%	-
CUL23	600	0.163	0.24	0.001	0.40	100%	-
CUL24	1000	3.455	0.52	1.768	0.52	49%	-
CUL25	1200	1.155	0.06	0.000	0.05	100%	-
CUL26	**1000**	**1.171**	**1.25**	**1.867**	**1.25**	**-59%**	**2**
CUL28	1500	2.285	0.08	0.003	0.05	100%	-
CUL29	1350	0.444	0.07	0.001	0.05	100%	-

6.2 Landowner Engagement

A virtual engagement session was carried out via a virtual open house tool to share key information and gather stakeholder and public feedback. The virtual open house tool provided participants with an interactive opportunity that simulates the experience of an in-person open house by using a 360^{o} view of a meeting room with links to display boards, questions tool and online feedback tool. Overall, the engagement session was successful in identifying some landowner concerns. A detailed summary of the engagement feedback, initial responses from ISL, and high-level solutions is included in Appendix A.



Legend

- Battersea Study
- Municipal Boundaries
- Major Highways

100 Year Ponding Depth (m)

- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.00 - 1.20

Coordinate System:
NAD 1983 UTM Zone 12N

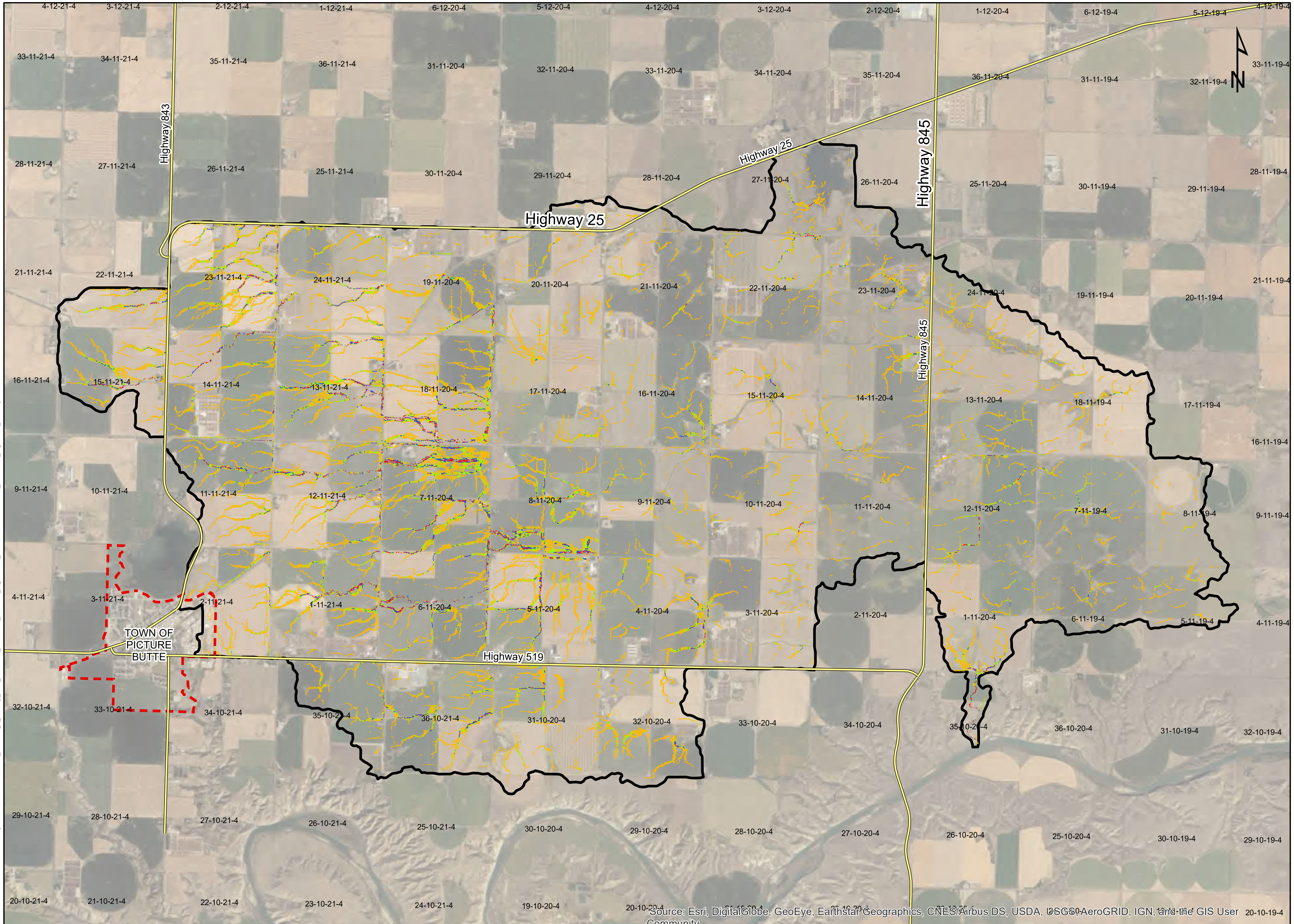
1:55,000

0 550 1,100 2,200 Meters

LETHBRIDGE COUNTY
BATTERSEA MDP
FIGURE 6.1
1:100 YEAR PONDING DEPTHS

LETHBRIDGE COUNTY

ISL



Legend

- Battersea Study Area
- Municipal Boundaries
- Major Highways

Overland Flow Velocity (m/s)

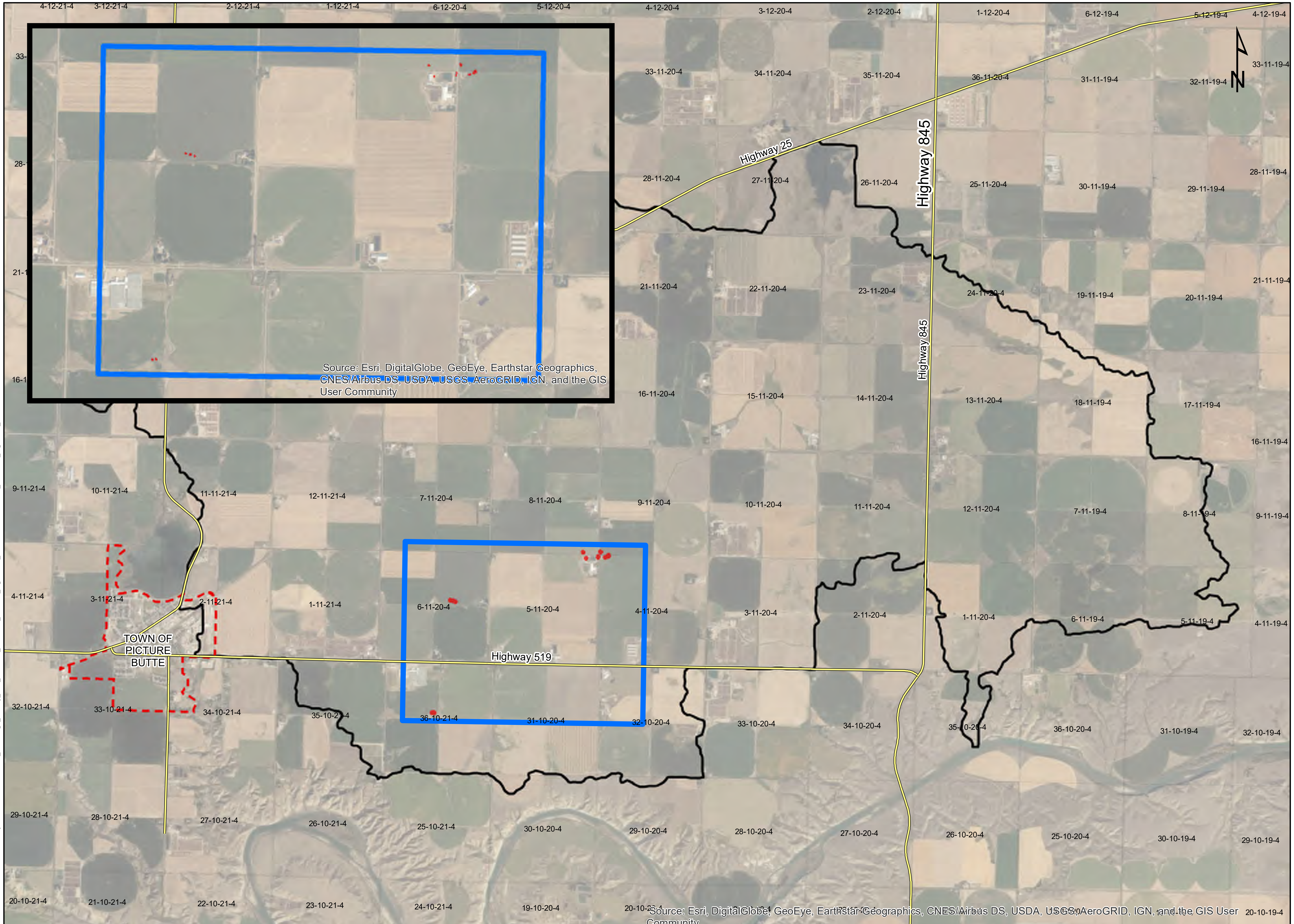
- 0.000000 - 0.030000
- 0.030001 - 0.080000
- 0.080001 - 0.130000
- 0.130001 - 0.180000
- 0.180001 - 0.230000

Coordinate System:
NAD 1983 UTM Zone 12N

1:55,000

0 550 1,100 2,200 Meters

LETHBRIDGE COUNTY
BATTERSEA MDP
FIGURE 6.2
1:100 OVERLAND FLOW VELOCITY



Legend

- Battersea Study Area
- Municipal Boundaries
- Major Highways
- Depth Vs. Velocity Limits Exceeded
- Zoomed In Area

Coordinate System:
NAD 1983 UTM Zone 12N

1:55,000

0 550 1,100 2,200 Meters

LETHBRIDGE COUNTY
BATTERSEA MDP
FIGURE 6.4
DEPTH VS. VELOCITY

LETHBRIDGE COUNTY

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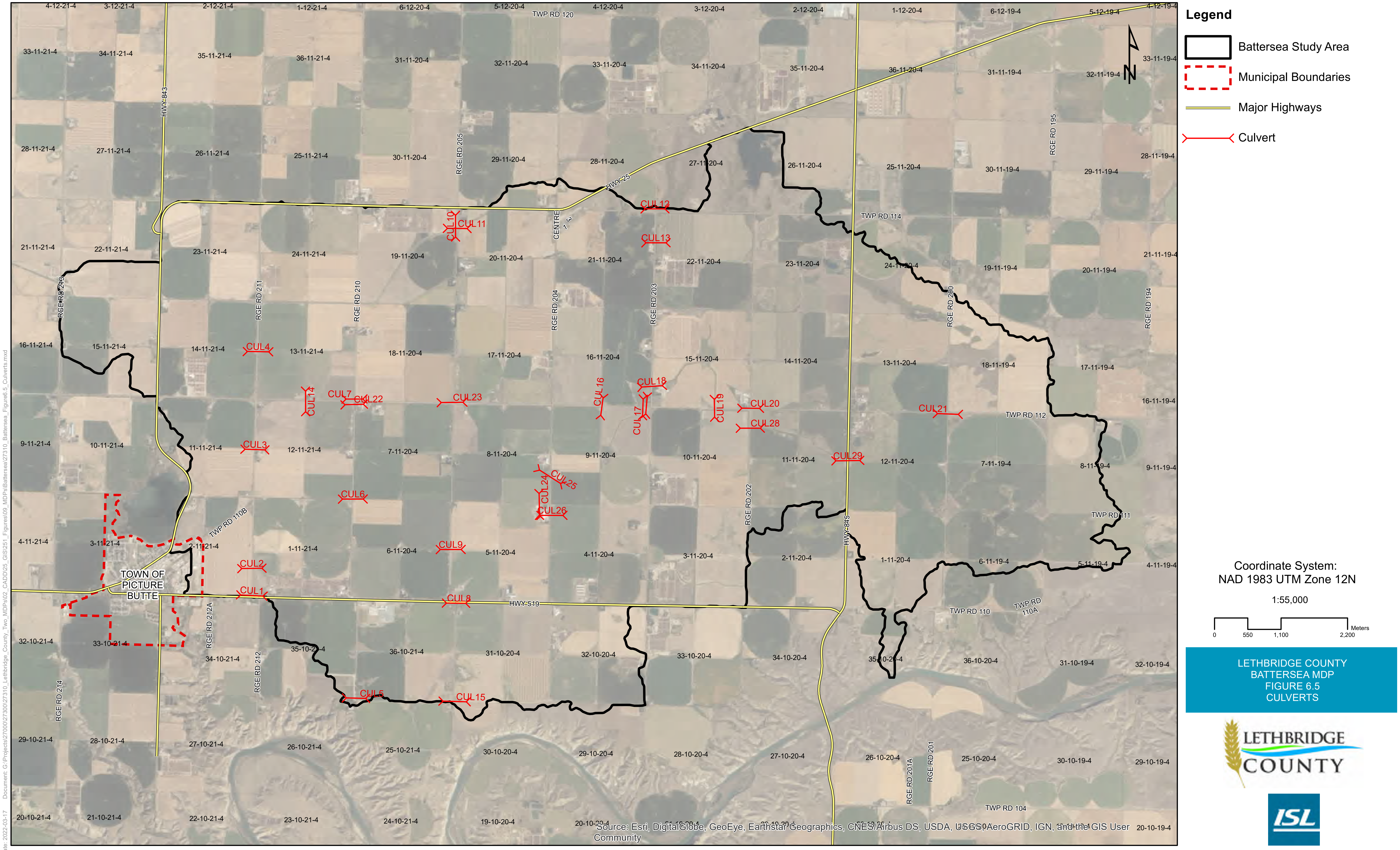
Legend
Battersea Study Area
Municipal Boundaries
Major Highways
Culvert
Coordinate System:
NAD 1983 UTM Zone 12N
1:55,000
0 550 1,100 2,200 Meters
LETHBRIDGE COUNTY
BATTERSEA MDP
FIGURE 6.5
CULVERTS
LETHBRIDGE COUNTY
ISL
TOWN OF PICTURE BUTTE
HWY 843
HWY 25
HWY 519
HWY 845
TWP RD 120
TWP RD 114
TWP RD 112
TWP RD 111
TWP RD 110
TWP RD 110A
TWP RD 110B
TWP RD 104
RGE RD 213
RGE RD 212
RGE RD 212A
RGE RD 211
RGE RD 210
RGE RD 205
RGE RD 204
RGE RD 203
RGE RD 202
RGE RD 201
RGE RD 201A
RGE RD 200
RGE RD 195
RGE RD 194
RGE RD 214
CUL1
CUL2
CUL3
CUL4
CUL5
CUL6
CUL7
CUL8
CUL9
CUL10
CUL11
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CUL21
CUL22
CUL23
CUL24
CUL25
CUL26
CUL28
CUL29
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Date: 2022-03-17 Document: G:\Projects\27000\27300\27310_Lethbridge_County_Two_MDPs\02_CADD\25_GIS\251_Figures\09_MDPs\Battersea\27310_Battersea_Figure6.5_Culverts.mxd

7.0 Recommended Drainage Improvements

7.1 Proposed Improvement Concepts

Each of the hotspots identified in Section 6.0 were ranked in terms of priority. The below sections explain the reasoning behind the priority rankings and high level commentary on how these concerns can be mitigated. Section 7.1.4 discusses some higher priority areas of concern that stuck out through the evaluation process ahead of all other areas and would require more complex solutions.

7.1.1 Depth Vs. Velocity Hotspots

There were 3 locations, as noted in Table 6.1 where depth vs. flow exceeded Alberta Environment criteria. Generally, the overland flow conditions in these areas could improve by increasing the cross section of the ditch and/or flattening out the slope of the ditch. A larger ditch cross sections allows for peak runoffs to flow at a shallower depth, decreasing the velocity. Given the typography along roadway ditches, it is unlikely that slopes can be reduced while maintaining natural drainage but is considered on a case-by-case basis.

Priorities are for depth vs. velocity based on the following; priority 1 locations are where there are compounding issues such as high ponding depths combined with high depth vs. velocity criteria, undersized culverts, or were reported during consultations and require recommended mitigation; priority 2 are areas that could potentially impact buildings/houses but no feasible or cost effective solution is available and should be monitored post major rain events; priority 3 are all other areas that are identified under the given criteria but do not warrant any further action. Note that the only instance in the modeling where depth vs. velocity was exceeded was given a priority 3 status.

7.1.2 Ponding Up Against Roadways

Ponding issues can arise for various reasons, but in most cases is due to lack of culverts to convey overland flows under roadways or an existing culvert being undersized. There can also be instances where these areas are natural low points and there may not be a practical solution. In any case, solutions need to be considered in more detail case-by-case but can at times be solved with local grading improvements and/or additions of culverts to promote positive drainage. Prior to completing any drainage works, downstream impacts must be considered in greater detail to ensure flooding issues are not passed on to other landowners. Section 7.1.4 details areas where ISL will recommend mitigation measures.

Priorities for ponding depths are based on the following; priority 1 locations are where there are compounding issues such as high ponding depths combined with high depth vs. velocity criteria, undersized culverts, or were reported during consultations and require recommended mitigation; priority 2 are areas that could potentially impact buildings/houses but no feasible and/or cost effective solution is available and should be monitored post major rain events; priority 3 are all other areas that are identified under the given criteria but do not warrant any further action.

7.1.3 Culverts

Undersized culverts can lead to ponding issues upstream which in turn can result in excess sediment accumulation and can have even greater impacts than that indicated in modeling. Generally, this can be solved with a culvert upsize, however each location must consider constraints in terms of available slope for the culvert dictated by the topography, cover relative to the roadway, depth of the roadway structure, and downstream impacts. In cases where culverts cannot be upsized, there are other options, such as twinning and or modifying the inlet to increase inlet capacity. Again prior to detailed design of any upgrades, the area should be reviewed in greater detail to determine the most optimal solution.

Priority 1 culverts are culverts that are undersized and are likely to be the reason for excessive ponding in the area and therefore immediate upgrades are recommended. Priority 2 culverts are culverts that are undersized, but not necessarily causing flooding concerns and should be monitored following major rain events. Proposed culvert upgrades were vetted through modeling to confirm no adverse impacts are created downstream.

7.1.4 Priority Drainage Issues

The following sections detail the priority drainage issues relative to modeling results and stakeholder engagement in addition to detailing the proposed mitigation.

Range Road 211

Range Road 211, south of the intersection with Township 110 reportedly experiences flooding on the west side of the roadway. Consultation with the LNID indicated that there was a water delivery canal that has been filled in (replaced with a pipeline), adjacent to the roadway on the west side. It is likely this canal conveyed drainage in the past as shown in Figure 7.1. It is recommended that a new ditch be installed adjacent to the roadway to properly convey runoff to the south/east. Additionally, modeling indicated existing Culvert 1 is undersized and is recommended to be upgraded. Concept for the improvements is detailed in Figure 7.2.

Highway 519 Crossing

There is a crossing of Highway 519, approximately 1.5 km west of Highway 845 which has recently been upgraded as Shown in Figure 7.3. The landowner downstream of this crossing has concerns about erosion through their property. It is recommended to install erosion and control measures from the highway for approximately 200m to properly convey overland flows to the downstream valley leading to the Old Man River. This also includes a proposed 800mm CSP culvert crossing an existing access road. Concept is detailed in Figure 7.4.

7.1.5 Overlapping Improvements With LNID

Some of the drainage concerns and recommended improvements overlap with the LNID, particularly the concerns and recommendations surrounding abandoned/filled in drain canal no longer in use. It is believed the removal of this canal impacted ponding against Range Road 211 and a solution is proposed per the recommendations above. Additionally, LNID was provided an opportunity to review the draft report and offer feedback relative to any concerns noted by modeling results as it relates to their infrastructure. It is important to note that due to COVID19 impacts this Master Drainage Plan project schedule was extended. Over the time it took to finalize this report, the LNID had already completed multiple upgrades to their network, which largely mitigated many existing drainage issues. The following summarizes the key technical items related to the LNID comments relative to their review of the draft MDP:

- Water quality is a concern for the LNID and in recent years have been declining landowner requests to pump or drain water into canals, ditches, and pipelines;
- Water volumes are a concern for the LNID and no longer permitting any additional drainage into its irrigation infrastructure; and
- Any takeover of existing LNID infrastructure to manage drainage must be agreed upon between the County and LNID;

7.1.6 Overlapping Improvements with Alberta Transportation

In a consultation meeting with Alberta Transportation several drainage issues along AT highways were discussed at a high level. It was discussed that in general, AT prefers to resolve drainage issues in parallel with general highway maintenance, meaning if there are upgrades planned to existing roadways and there is a benefit to addressing drainage issues at the same time, they will do so. Like LNID, AT was provided an opportunity to review this draft report and offer feedback relative to any concerns noted by modeling results as it relates to their infrastructure.

7.2 Phasing

In terms of proposed upgrades for the identified areas of concern under existing conditions, it is recommended that phasing generally starts with the high priority drainage issues in Section 7.1.4 and the follows the priority culvert upgrades Identified in Table 6.3. That said, priority 1 concerns should be dealt with first, followed by priority 2. Priority 3 generally does not require any further action.

7.2.1 Capital planning

It is recommended that capital planning focus on the priority drainage issues discussed in Section 7.1.4. Additional planning should consider a program that tackles priority 1 culvert upgrades. The county should continue to monitor priority 2 culverts and add to capital planning as required. Each level of priorities should assume a detailed engineering and design cost at 15% of the estimated cost and a 20% contingency.

7.2.2 Opinion of Probable Cost

Table 7.1 below provides a summary of the probably project costs at the date of this report relative to the proposed mitigation measures. A more detailed breakdown of the solutions is provided in the sections below, relative to the major drainage issues. Note that the construction industry has been hit with material delays, price spikes, and shortages in the last year. The County may want to apply an additional inflation factor to the probably costs outlined below at the time of capital planning.

Table 7.1: Summary of Probable Project Costs for Capital Planning

Description	Estimated Cost	Engineering Cost (15%)	Contingency (20%)	Total Cost
Range Road 211 Improvements	$125,000	$18,500	$25,000	$168,750
Highway 519 Crossing Improvements	$91,500	$13,725	$18,300	$123,525
Priority 1 Culvert Replacements	$13,000	$1,950	$2,600	$17,550
Priority 2 Culvert Replacements (Optional)	$21,000	$3,150	$4,200	$28,350

Range Road 211

This cost estimate includes general regrading and reshaping of the ditch adjacent to Highway Range Road 211, seeding and restorative works along the ditch and replacement of the culvert crossing Range Road 211 at Highway 519.

Table 7.2: Range Road 211 Crossing Detailed Probable Cost Estimate

Activity	Estimated Quantity	Cost	Notes
Culvert Replacement	18 m	$7,000	700mm CSP
Ditch Construction	1.5 km	$112,500	Assumes Net Cut/Fill
Ditch Hydroseeding	0.75 ha	$6,000	5m Ditch
Total	-	125,000	

Highway 519

This cost estimate includes ditch construction and erosion and control measures installed along the ditch for approximately 200m, and an 800mm CSP culvert crossing across an existing access road.

Table 7.3: Highway 519 Crossing Detailed Probable Cost Estimate

Activity	Estimated Quantity	Total Cost	Notes
Ditch Construction	0.2 km	$15,000	Assumes Net Cut/Fill
Erosion Protection (Riprap)	300 m^3	$70,500	Class 1 Riprap
Culvert Crossing	15 m	$6,000	800mm CSP
Total	-	$91,500	

Culvert Replacements

Table 7.4 below provides cost estimates for each individual culvert. Total for Priority 1 culverts is $13,000, and total for priority 2 culvers is $21,000.

Table 7.4: Culvert Upgrades Probable Cost Estimate

Culvert ID	Existing Diameter (mm)	Proposed Diameter (mm)	Cost Estimate	Notes	Priority
CUL1	500	700	-	See Range Road 211 Mitigation	2
CUL9	500	700	$13,000		1
CUL13	300	600	$6,500		2
CUL26	1000	1200	$14,500		2

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Legend

- Municipal Boundaries
- Major Highways
- Existing Culvert
- Contours (1m)

Coordinate System:
NAD 1983 UTM Zone 12N

1:7,000

0 70 140 280 Meters

LETHBRIDGE COUNTY
BATTERSEA MDP
FIGURE 7.1
RANGE ROAD 211
EXISTING CONDITIONS

LETHBRIDGE COUNTY

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Legend

- Municipal Boundaries
- Major Highways
- Existing Culvert
- Contours (1m)

N

Coordinate System:
NAD 1983 UTM Zone 12N

1:7,000

0 70 140 280 Meters

LETHBRIDGE COUNTY
BATTERSEA MDP
FIGURE 7.2
RANGE ROAD 211
PROPOSED MITIGATION

LETHBRIDGE COUNTY

ISL

Date: 2022-03-18

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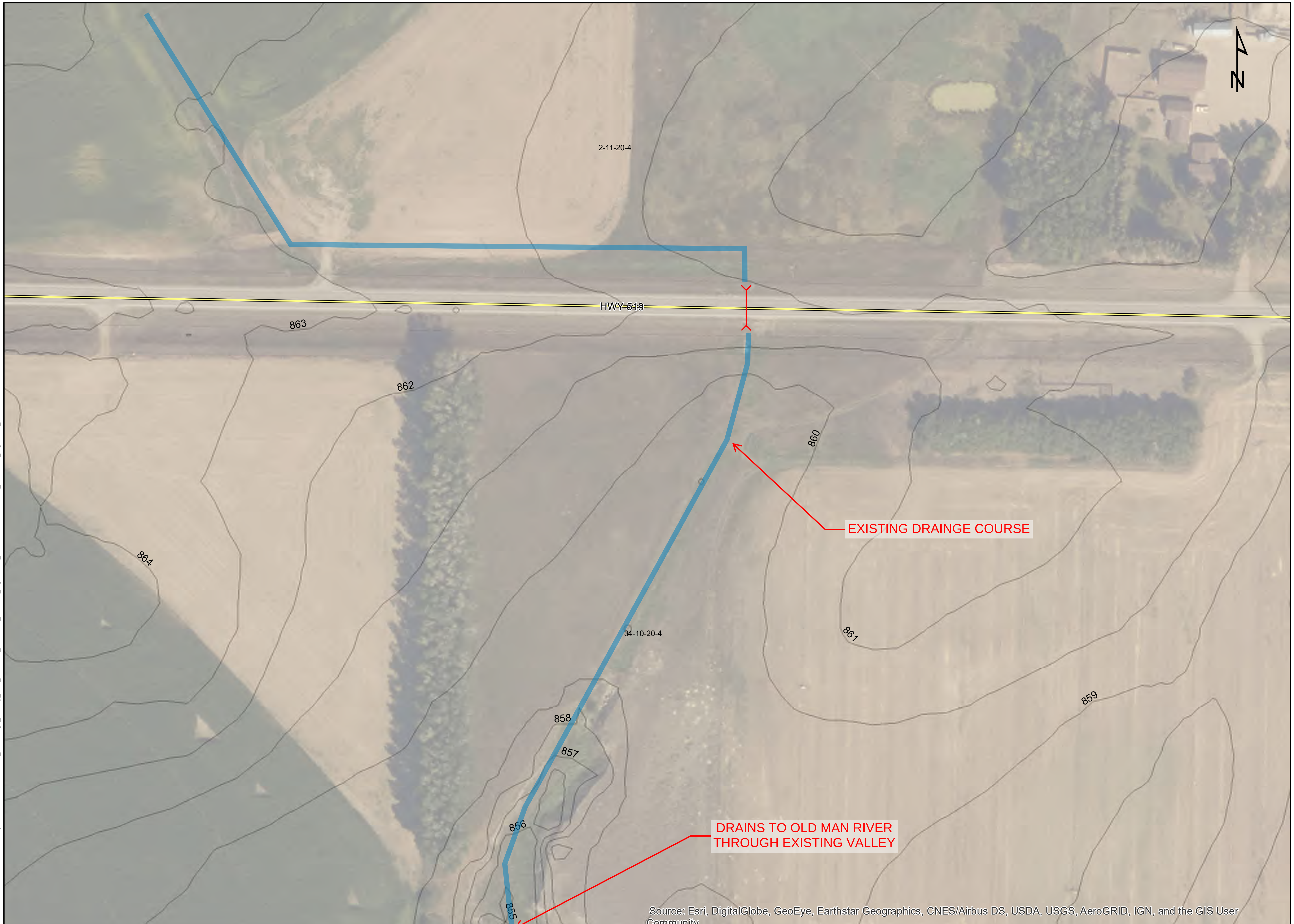


Legend

- Major Highways
- Culvert
- Contours (1m)

Coordinate System:
NAD 1983 UTM Zone 12N

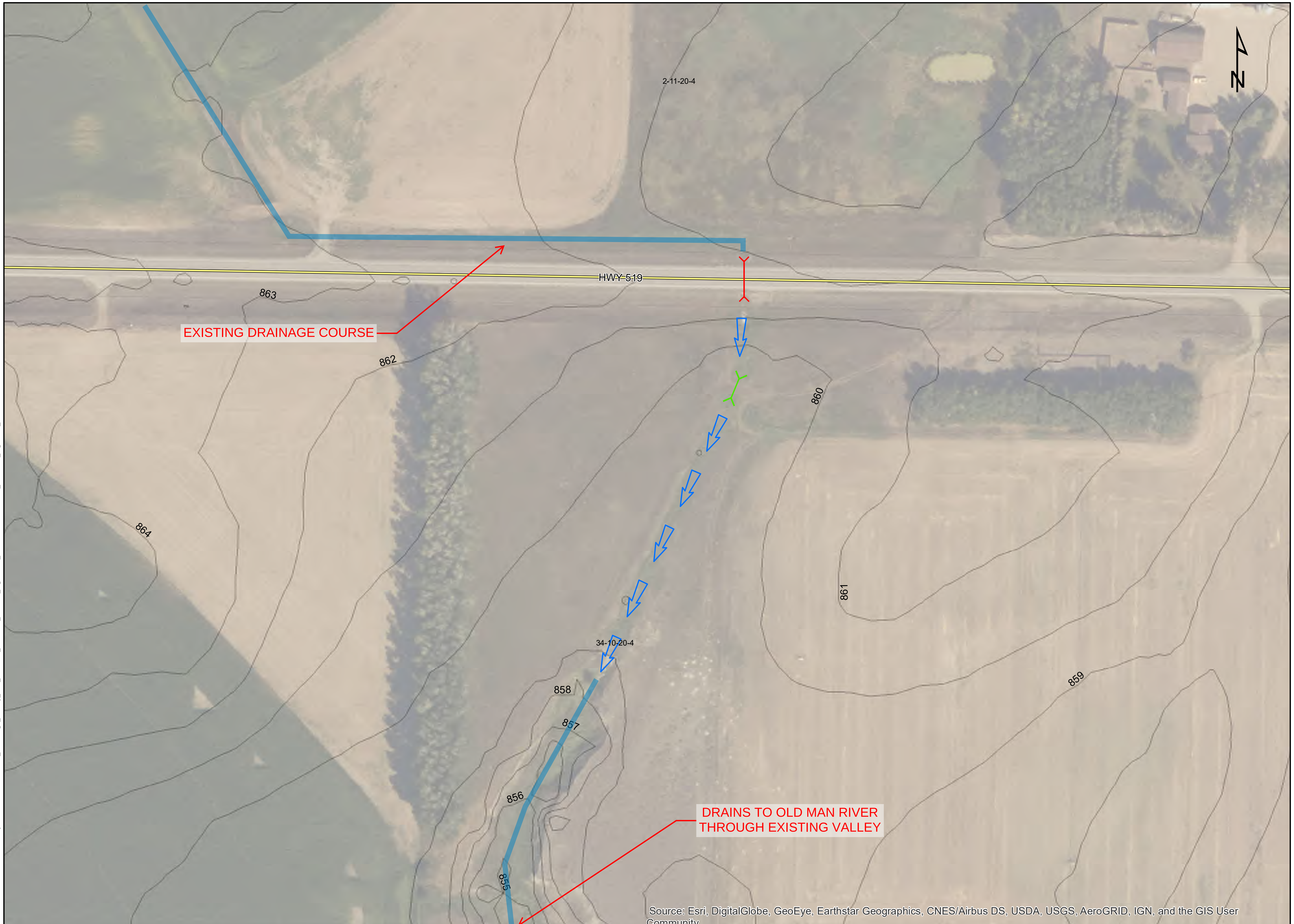
1:1,500

0 15 30 60 Meters

LETHBRIDGE COUNTY
BATTERSEA MDP
FIGURE 7.3
HIGHWAY 519
EXISTING CONDITIONS

LETHBRIDGE COUNTY

ISL



Legend

- Major Highways
- Existing Culvert
- Proposed Culvert
- Contours (1m)
- Proposed Ditch

Coordinate System:
NAD 1983 UTM Zone 12N

1:1,500

0 15 30 60 Meters

LETHBRIDGE COUNTY
BATTERSEA MDP
FIGURE 7.4
HIGHWAY 519
PROPOSED MITIGATION

LETHBRIDGE COUNTY

ISL

Date: 2022-05-12 Document: G:\Projects\27000\27300\27310_Lethbridge_County_Two_MDPs\02_CADD\25_GIS\251_Figures\09_MDPs\Battersea\27310_Battersea_Figure7.4_TWP110.mxd

8.0 Future Development Stormwater Guidelines

Future development within the Battersea Drainage Basin shall address stormwater management based on a no-net impact philosophy. This means matching existing peak runoff rates with post development runoff rates. This generally requires the use of stormwater management facilities and/or source control practices such as vegetated swales, absorbent landscapes, bioretention areas, permeable pavement, rainwater harvesting and re-use, green roofs or any other technology designed to reduce stormwater runoff. This section provides some general engineering design guidelines for post development runoff reduction solutions. This report shall act as a baseline for future development and shall be referenced to retrieve data for existing conditions. Models shall be provided to the County for reference and to be able to distribute existing condition information to future developers.

For future development and any Water Act applications, impacts are to be outlined within the context of existing ponding depths outlined in this MDP. Pre-development and "no-net increase" stormwater management design ideologies are to be compared to governing model results. Developers can deviate from the below guidelines and model results outlined in this report provided technical rational and stormwater modeling outlines how development deviates from the MDP but still achieves the intent of the design guidelines.

8.1 Design Guidelines for Future Stormwater Management Facilities

A set of design guidelines are required to govern the future stormwater conveyance management facilities in the Study Area. Numerous documents were reviewed to determine the recommended guidelines. These documents included the Stormwater Management Guidelines for the Province of Alberta (Alberta Environment, 1999), the Standards and Guidelines for Municipal Waterworks, Wastewater, and Storm Drainage Systems (Alberta Environment, 2006), the Stormwater Management & Design Manual (City of Calgary, 2011), and Engineering Guidelines & Minimum Servicing Standards (Lethbridge County, 2019). Recommended design guidelines for the stormwater management system include the following:

- **Stormwater Discharge Rates relative to model results demonstrated in this MDP:**
  - Post-development stormwater discharge flows and velocities do not exceed the existing levels.
  - Maximum outlet rate to match existing conditions.

- **Stormwater Quality Controls:**
  - Minimum removal of 85% of particles 75 microns and larger on an annual basis as per Alberta Environment standards.

- **Stormwater Management Facility Design Guidelines:**
  - <u>Wet or Dry Ponds:</u>
    - Storage volume based on the greater of 1:100 year design storm or 1:100 year continuous simulation.
    - Continuous simulation is required for any SWM concept involving infiltration or evaporation methodologies.

- Maximum storage depth of 1.5m (dry) or 2.0m (wet).
- Permanent pool depth of 1.5m at minimum; 2.5m at maximum.
- Minimum pond area of 2.0ha at Normal Water Level (NWL)
- Maximum interior side slopes of 5:1 to 7:1 (H:V) within permanent pool, 5:1 between NWL and HWL and 4:1 to 5:1 above HWL.
- Minimum effective length to width ratio of 4:1 to 5:1
- Minimum freeboard of 0.15m (alternative is to increase freeboard)
- Overflow/overland escape route provided (alternative is to increase freeboard)
- Quality control provided – Generally done by the pond, but a forebay is strongly recommended. If additional quality control is required, an oil/grit separator can be included, normally upstream of the pond.

- Measures to mitigate erosion downstream of the pond must also be incorporated.
- Permeability of $1x10^{-8}$ m/s for clay or HDPE (Or equivalent) pond lining.
- Minimum nominal thickness of 0.6m for clay liners.

- <u>Constructed Wetlands:</u>
  - Storage volume based on the greater of 1:100 year design storm and 1:00 year continuous simulation.
  - Continuous simulation is required to provide the long term statistical HWL and NWL anticipated by the facility.
  - Maximum storage depth of 1.0m. This peak depth is to be achieved infrequently to ensure long term survival of wetland ecology.
  - Permanent pool depth of 1.0m at minimum; 2.0m at maximum (varying pool depth required).
  - Minimum pond area of 2.0ha at Normal Water Level (NWL)
  - Maximum interior side slopes of 5:1 to 7:1 (H:V) within permanent pool, 5:1 between NWL and HWL and 4:1 to 5:1 above HWL.
  - Minimum effective length to width ratio of 4:1 to 5:1
  - Minimum freeboard of 0.15m (alternative is to increase freeboard)
  - Overflow/overland escape route provided (alternative is to increase freeboard)
  - Quality control provided – Generally done by the pond, but a forebay is strongly recommended. If additional quality control is required, an oil/grit separator can be included, normally upstream of the facility.
  - Water permanency zones within the wetland identified based on the wetland elevation and modelled hydrologic regime. The hydro periodicity within each zone is critical for maintaining wetland vegetation and thereby wetland function
  - Wetland vegetation to be selected based on the appropriate ecological successional stage, hydrologic regime, the surrounding land use, individual species traits, wildlife habitat potential, provincial conservation status and origin (i.e., native).
  - All vegetation zones staked-out prior to planting, with planting occurring as soon as possible after the wetland cells have been constructed and under frost free conditions.

8.2 Source Control Best Management Practices

Source control practices are becoming of increasing value in terms of stormwater management. A primary focus of these practices is sustainability in the form of pollution prevention strategies. These strategies involve the reduction of runoff volume and rate of flow as well as reduction of overall environmental impact in terms of water quality. Additional design guidelines should also be referenced from the City of Calgary's Stormwater Source Control Practices Handbook.

Evaporation Facilities

Description
Large stormwater management facilities could be designed to promote evaporation. These could either be wet or dry ponds with designs governed by continuous simulation to ensure that adequate volumes can be evaporated on an annual basis. To work properly, outlet rates must be virtually non-existent with at most an overflow provided for wet years.

Driving Forces

- Relatively simple facilities to design
- Eliminate up to virtually 100% of runoff volume
- Stormwater pollutants retained in the pond.
- Highly applicable to both residential and commercial/industrial areas.

Restraining Forces

- High amount of land required.
- Costly given the amount of land allocation required.
- Possible lack of evaporation in wet years causing problems in existing evaporation systems.

Synopsis
Evaporation facilities are very effective in limiting runoff; however they will require a significant amount of land in order to maximize surface area to allow for maximum effectiveness. As a result, they would work best in conjunction with other volume reduction methods. These facilities remove water that would otherwise ultimately reach rivers and stream, which could have a cumulative effect on the watershed. These facilities are larger are required to be much larger than conventional stormwater management facilities based on volume, to allow for full storage of 1:100 year runoff volumes with no outlet (and assuming no other practices for volume reduction exist). To ensure proper sizing of facilities detailed hydrologic and hydraulic modeling considering ambient air temperature and humidity would be required to properly estimate evaporation based on energy flux for evaporation (inclusion of humidity would allow for proper modeling in wet months). Models such as PCSWMM as well as DHI MIKE URBAN could incorporate this.

Preliminary design guidelines to this end would be:

- Active storage depth of 1.5m
- Grading details as noted previously.
- Surface area requirements of 1m^2 for every 1m^2 of impervious area as per County Standards.
- Hydraulic conductivity requirements for clay or plastic liner (HDPE) of less than 1x10-8 m/s.
- Clay liners must have a minimum nominal thickness of 0.6 m.

- Detailed long term hydraulic modelling is required to prove concept, including:
  - Up to 50 years of rainfall data is ideal, including snowpack.
  - Monthly evaporation data.
  - Statistical 1:100 year estimate of pond volumes from model results.

Stormwater Re-Use/Rainwater Harvesting

Description
Stormwater could be captured in stormwater management facilities and used for non-potable uses. Guidelines for household non-potable water usage are currently under development by Alberta Environment. This would potentially help address water supply issues in the area but would need to be assessed at the time of development as to whether suitable guidelines exist at that stage. Stormwater could certainly be used for irrigation.

Driving Forces

- Difficulty of obtaining water in Southern Alberta makes any solution that increases water supply very positive.
- Irrigation water could be readily used with minimal, if any, treatment.
- Potentially significant use of stormwater runoff.
- Stormwater pollutants retained by storage ponds.
- Highly applicable to both residential and commercial areas.

Restraining Forces

- Require storage facilities that are designed to ensure availability of water in dry years. Significant stormwater is available in wet years when it is not needed and often not enough is available in high demand dry years. Facilities would likely need to be larger than conventional stormwater management facilities to ensure security of supply.
- Guidelines for other uses (e.g., toilet flushing) generally not yet defined in Alberta.
- Irrigation users would not have demand during wet periods, thus resulting in significant amounts of runoff that must be stored.

Synopsis
Stormwater harvesting and re-use could work very well for the Study Area. For the purposes of this development, it is estimated that storage facilities would need to be larger than conventional stormwater management facilities based on volume, to allow for full storage of annual runoff flows in the statistically define “average” year (and assuming no other practices for volume reduction exist). This method of volume reduction is highly recommended for the Study Area and should be assessed in greater detail during pre-design of any development.

Bioswales/Vegetated Swales

Description
Stormwater is diverted into surface drainage swales that are vegetated. The net effect is like a combination of a grassed swale and an infiltration trench. Significant vegetation is planted to provide additional quality treatment. Ditch blocks are often installed to promote pollutant settling. Subdrains are often installed in soils with infiltration rates below 12.5mm/hr.

Driving Forces

- Provide a high amount of volume and rate control.
- Provide a high amount of stormwater pollutant control by retaining pollutants in the swales.
- Highly applicable to both residential and light commercial/industrial areas.
- Would reduce the size of stormwater management facilities downstream.

Restraining Forces

- Soils in the area may not be ideal, as a result, subdrains would likely be required but should be considered on a case-by-case basis.
- Relatively maintenance intensive (primarily to remove sediment).

Synopsis

Bioswales/vegetated swales could work very well for the Study Area but would require further review at the time of development. Geotechnical studies should be undertaken to determine suitability of infiltration techniques.

Bioretention Areas

Description

Stormwater is diverted into holding areas that allow for infiltration. Significant vegetation is planted in the area to provide additional quality treatment. Evaporation also contributes to volume reduction.

Driving Forces

- Provide a high amount of volume and rate control.
- Provide a high amount of stormwater pollutant control by retaining pollutants within the bioretention area.
- Highly applicable to both residential and light commercial areas.
- Can be used as on-lot stormwater control for commercial/residential areas.
- Would reduce the size of stormwater management facilities downstream.

Restraining Forces

- Soils in the area may not be ideal and as a result, design would carefully need to account for this.
- Relatively maintenance intensive (primarily to remove sediment).

Synopsis

Bioretention areas could work very well for the Study Area. They can be incorporated in boulevards etc. in the road network. This method of volume reduction would require further review at the time of development but could work well for the Study Area. Again, geotechnical studies should be undertaken to determine suitability of infiltration techniques.

Adsorbent Landscapes

Description

Stormwater runoff is reduced by promoting infiltration into the soil as runoff flows overland. This is often accomplished by designing for significant greenspace. Increased depth of topsoil and reduced soil compaction are also provided. This promoted infiltration and can allow the soil to work like a sponge to soak up stormwater.

Driving Forces

- Provide a high amount of volume and rate control.
- Highly applicable for light commercial areas.
- Somewhat applicable for residential areas.
- Would reduce the size of stormwater management facilities downstream.
- Minimal maintenance required.

Restraining Forces

- Do not provide much in the way of pollutant control.
- Tricky to enforce as homeowners/lot owners may modify property landscaping. This is the reason for its limited applicability in residential areas.
- Effectiveness severely reduced in wet years.

Synopsis

Absorbent landscapes could work well for the commercial/industrial areas planned within the Study Area. Given that it also does not provide much in the way of stormwater quality control, this method of volume reduction is not recommended as highly as others. It should, however, be considered for commercial/industrial areas given its strong applicability for application there as well as its limited maintenance.

Preliminary design guidelines to this end would be:

- Upstream flow should be distributed sheet flow, rather than a point source, with a maximum flow velocity of 0.9 m/s.
- Absorbent landscape areas should be either gently sloping with a grade less than or equal to 2% or act as a storage area with a maximum ponding time of 2 days.
- A minimum of 150 mm of organic compost should be introduced below 300mm of topsoil.
- Soil amendments to be used for stormwater management should be stable, mature compost from organic waste materials.
- Seasonally high groundwater table should be a minimum of 0.6 m to 0.9 m below the bottom of amended soils if filtered water is to be absorbed.

Permeable Pavement

Description

Stormwater runoff is reduced by promoting infiltration into pavement by providing a permeable surface. Stormwater is then either infiltrated into the underlying soil or diverted to a storage tank for later use in irrigation etc.

Driving Forces

- Works well for parking lots in commercial/industrial areas and residential back lanes.
- Provides a high amount of volume and rate control.
- Highly applicable for residential areas.

- Somewhat applicable for light commercial/industrial areas.
- Would reduce the size of stormwater management facilities downstream.
- Can be used as on-lot stormwater control for commercial/residential areas.

Restraining Forces
- Does not work well for higher traffic areas.
- Does not work well in areas with heavy truck traffic.
- Relatively expensive to install.
- High frequency of maintenance over time

Synopsis
Permeable pavement could work well for parking lots in commercial/industrial areas and residential back lanes. These areas would, however, make up at most a small portion of the overall Study Area. Whilst this method could work reasonably well for on-lot systems for commercial/industrial areas, it would likely have only a nominal effect when considered in the bigger picture covering the entire Study Area. Accordingly, this method of volume reduction is recommended for on-lot use in commercial/industrial areas but would need to be integrated with other volume control methods in the broader context of the Study Area stormwater management system.

Preliminary design guidelines to this end would be:
- Infiltration rate of underlying soils should be greater than or equal to 12.5 mm/hr for full exfiltration.
- Seasonally high groundwater table should be a minimum of 0.6 m below the bottom of the pavement structure if filtered water is to be infiltrated.
- The bottom of the subbase should be a minimum of 0.9m above the bedrock level.
- A slop of 1-2% should be incorporated if the system is unable to infiltrate all runoff under winter conditions.
- Annual inspections should be completed in the spring along with vacuum removal of surface sediment.

Green Roofs

Description
Stormwater runoff is reduced by using vegetated roofs to reduce runoff. Stormwater is absorbed into soil and is then either evaporated naturally or collected by a subdrain system.

Driving Forces
- Works well for roofs for larger buildings (normally commercial/industrial).
- Provides a high amount of volume and rate control, particularly for small events.
- Highly applicable for light commercial/industrial areas.
- Would reduce the size of stormwater management facilities downstream.
- Can be used as on-lot stormwater control for commercial/residential areas.

Restraining Forces

- Not applicable for residential areas.
- Does not work well under larger rainfall events.
- Does not work well in the winter.

Synopsis

Green roofs could work well for commercial/industrial areas. Whilst this method could work reasonably well for on-lot systems for commercial/industrial areas, it would likely have only a nominal effect when considered in the bigger picture covering the entire Study Area. Accordingly, this method of volume reduction is recommended for on-lot use in commercial areas but would need to be integrated with other volume control methods in the broader context of the Study Area stormwater management system.

Most highly recommended would be a combination of stormwater re-use and/or evaporation facilities planned on a larger scale over the Study Area.

9.0 Conclusions and Recommendations

ISL was commissioned by the County to complete an MDP, including an assessment of the current drainage within the Battersea drainage basin. The intent of this project is to provide The County a road map of existing infrastructure upgrades that are required to support capital planning.

The MDP was prepared to achieve the following objectives:

- Assess existing drainage conditions and pinpoint areas of concern;
- Analyzing existing natural drainage conveyance;
- Provide cost estimates related to required infrastructure upgrades, which will also provide inputs to capital planning; and
- Comment on phasing of upgrades for the most effective implementation of The County's needs.
- Provide governing stormwater management guidelines for future development within the watershed; and
- Provide baseline stormwater modelling for the watershed to vet future development against within the context of pre-development and no-net impact.

9.1 Conclusions

The Battersea drainage system consists of entirely overland drainage (i.e., no underground piped storm system). A 2D model was constructed in InfoWorks ICM to assess the Battersea drainage system. The process that was used to generate the model is described in detail in Section 4.0. Design rainfall events produced from The County's IDF parameters were utilized to assess the major system using a 1:100 year 24-hour Chicago rainfall distribution.

Model results of the overland drainage system under the 1:100 year 24-hour Chicago design storm suggest that there are several locations throughout Battersea drainage basin that would experience surface flooding, exceed depths vs. velocity criteria. Additionally, several culverts were determined to be under capacity. Several notable areas of concern were flagged for further investigation and potential remediation measures.

9.2 Recommendations

Several recommendations were made based on the findings of this study. This includes the findings of the existing system assessment, and development of the proposed stormwater concept for priority areas. Additionally, 2 locations were flagged for immediate attention and culvert upgrades were prioritized into 2 categories.

For future development and any Water Act applications, impacts are to be outlined within the context of existing ponding depths outlined in this MDP. No generalized Water Act was obtained for the area due to the limited amount of proposed development, therefore developers are still required to obtain Water Acts as required, however this MDP forms the basis for existing conditions. Pre-development and "no-net increase" stormwater management design ideologies are to be compared to governing model results. Developers can deviate from the below guidelines and model results outlined in this report provided technical rational and stormwater modeling outlines how development deviates from the MDP but still achieves the intent of the design guidelines.

10.0 References

Alberta Environment. 1999. Stormwater Management Guidelines for the Province of Alberta. Alberta.

City of Lethbridge. 2016. Design Standards. Alberta.

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MPE Engineering Ltd. 2018. Lethbridge County Stormwater Master Plan. Alberta

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APPENDIX
Public Engagement Summaries

A

Feedback ID	Are there any significant flooding issues in the Battersea study area that are not shown on our map? If so, please let us know where the flooding issues occur and provide details about the nature and frequency of the issue.	ISL Response/Comment	Figure (Y/N)	Concern related to: County (C), Lethbride North Irrigation District (LNID), or Wetlands (W)	High Level Solution
BAT1-01	No (x2 responses)	No Action.	No	N/A	N/A
BAT1-02	N/A (x2 responses)	No Action.	No	N/A	N/A
BAT1-03	NW + NE 13-11-20 W4 needs to improve drainage to the east through my land and moving SE to train to the Oldman.	These 2 quarter sections are covered heavily in existing wetlands. We would not classify this as a poor drainage as these wetlands are an important element of drainage in the area.	Yes	AEP	Natural condition, no mitigation recommended.
BAT1-04	Yes, I own NW 20-11-20 and just recently (2019) sold north portion of SW 20-11-20. Flooding would occur on a regular basis during spring runoff and at times of heavy rainfall. Both parcels have zero access to drainage and the only option would be to pump access water into the irrigation ditch. With it disappearing there will be nowhere to go with the water. Parcel to the east has similar problems. I have pictures and videos from the past to show this.	South side of this road does not appear to have a defined ditch and/or outlet. Half of road appears to drain onto adjacent land. Ditch upgrades could be warranted.	Yes	AT	Recommend further study to confirm if ditch and/or outlet upgrades could improve drainage.
BAT1-05	Flooding that happens in the spring before the ground thaws. It is essential that cleaning ditches starts on the bottom end.	Noted. No specific area mentioned to address.	No	N/A	N/A
BAT1-06	In NE 20-11-20 there is a flooding problem on the North edge, along highway 25. It happens about once every 5 years. The highway ditch fills up and floods into the field, covering up to 20 acres. Water depth can get to 1-1.5ft. The lnid currently has a main canal crossing highway 25 which also takes in a large amount runoff water draining from the west. If that canal was ever to be removed there would be major drainage concerns for NE 20-11-20 and surrounding area	Same area as BAT1-04. A closer look at drainage along this corridor could be warranted.	Yes	AT	See BAT1-04
BAT1-07	Most of the south half of 16-11-21-4 drains into the Battersea drain through a culvert crossing under the main LNID canal from NE-9-11-21-4 to NW-10-11-21-4 the south half of SW-15-11-21-4 also drains into that ditch	No specific issue noted. Also this is outside of the study area to the west.	Yes	N/A	N/A
BAT1-08	None that we are aware of	No Action.	No.	N/A	N/A
BAT1-09	Yes there are much more significant issues that are not represented on the existing pond map. In particular on the East side of NE 2-11-21 W4 & SE 2-11-21 W4, the flooding issues are much more prevalent. This has included significant standing water along the road, often resulting in flooding over the road.	Canal runs adjacent to the roadway. Flooding could be a result of canal capacity issues or downstream conveyance. Additional observation of this area could be warranted.	Yes	LNID	Recommend further assessment of the canal to identify capacity issues.
BAT1-10	N/A to us	No Action.	No	N/A	N/A
BAT1-11	I own ne 20-11-20, just south of Iron Springs. We get significant flooding along the west edge of that quarter, just south of town. You have a very small blue spot there. This flooding happens at snow melt and any heavy rain. The water runs out of Iron Springs, down the road, and into our field. We have talked to the county about adding a culvert and tying into the Battersea that runs on the west edge of SE 20-11-20	Same areas as BAT1-03 and BAT1-06. Historically flooding is spread out years apart. Drainage from low points (likely wetlands) does not appear to be connected to any outlet which would result in ponding over time.	Yes	AT	See BAT1-04
BAT1-12	There has been flooding on the north 1/2 of SW 9-11-20 during the 2002 and 2005 rain fall events due to Battersea drain running over and that's what caused the flooding up to 3/4 metres of water standing	It is unclear if this standing water would be created from channel overflow or if these are seasonal wetlands that overflow into the channel. Additionally analysis could be warranted.	Yes	LNID	Recommend further assessment of the canal to identify capacity issues.
BAT1-13	Now with pipeline replacing irrigation canals, which is a good thing! Those ditches naturally did help with drainage. Ponding is sometimes larger without the natural drainage. Drain pipe and drain tile in areas would help	Noted. No specific area mentioned to address.	No	N/A	N/A
BAT1-14	*Map below provided to illustrate existing ponding.*	Could be a disconnect in the irrigation canal. Additional consultation with ID could be warranted in this area.	Yes	LNID	Recommend assessing the continuity of flows through the canal in this area. Potential blockage could be causing the flooding.
BAT1-15	I have several concerns about the Haney / Christensen Battersea drain that runs through the Christensen NE 34-10-20 ,and the 2 other partial quarters to the south. See the attached map, and markings. From understanding my Dad, there was an initial usage agreement of some kind, that the Battersea drain would use a certain amount of land through the property. The original width of this drain usage has long since eroded wider than this agreement of width/area, creating slumpage, and has also carved steep washouts down the drain. Many years ago, there were some rock, and old tree stumps dumped into the coulee at the top/start of the coulee drain. The lasting effect on erosion is now minimal, and only helps the very top/start of the drain. Over the years, it became increasingly difficult to run cattle across the drain, as crossings either became cliffs, or became a swamp at the south/bottom, where the dirt and silt have accumulated. There used to be an access to the pasture land from under the Nolan bridge, going west into the pasture. The drain has eroded, and it is no longer passable into the pasture. I have installed an underground water line at the LNID turn out near the top of the drain, and have a winter drain out on that line. Due to water backup of the top of this Battersea drain, that drain is now becoming submerged during the winter. There are some drain crossing culverts also beside that LNID turnout , which can become full, and cause some hold back during high flows. They should be bigger, or just have one crossing culvert. I've seen some very high flows on this drain, in some springtime quick snow melts. There are other drainage issues further down, and on different coulees, where the neighbors land drains into this coulee land, causing washouts. Another drainage concern is water going under the hiway 845, and how a drainline has split apart causing slumpage on the east side of hiway 845. A couple of years ago, during a quick snow melt on farmland to the north, a large amount of water came down the west side of the 845 hiway, and went through this drain under the 845 to the east side. There could be a couple more concerns, but wanted to get this to you asap before your meeting tomorrow. I suggest a site viewing at some time to show the concerns.	It appears though work has been completed at the culvert crossing in the past. Between the culvert outlet athe the coulee downstream, the channel does not appear to be protected which is leading to the erosion. Suggest including this area in the consultations with LNID to gain their perspective on this issue and perhaps provide some info on their agreement with the landowner.	Yes	LNID	Recommend further study to upgrade channel from highway 519 to the Old Man River

Feedback ID	Are the ponding levels shown in the Battersea study area consistent with your experience?	ISL Response/Comment	Figure (Y/N)	Concern related to: County (C), Irrigation Districts (ID), or Wetlands (W)	High Level Solution
BAT2-01	Yes (x2 responses)	No Action.	No	N/A	N/A
BAT2-02	N/A (x2 responses)	No Action.	No	N/A	N/A
BAT2-03	Yes, although we have mitigated some with surface drainage.	Noted. No specific area mentioned to address.	No	N/A	N/A
BAT2-04	For my area, yes but incomplete.	Noted. No specific area mentioned to address.	No	N/A	N/A
BAT2-05	Yes, very consistent.	No Action.	No	N/A	N/A
BAT2-06	Your digital map shows a lot of puddling on the west side of the gravel roads due to the eastward slope of the land, however because o all the culverts crossing the gravel this water is not a real problem for most farmers but does accumulate in the bottom end along RR 204 and 205 where the drain starts creating a much larger problem there than your map indicates. It is from there on east where the problem exists due to old corroded and collapsing culverts that are undersized as well. Another problem is culverts installed for pivot crossings that could be replaced by bridges. Replacing culverts with PVC pipe would last longer and flow better especially in flat areas where there could be some salinity present as well	Some additional look at this area could be warranted. Description isn't very specific so difficult to pinpoint exact location of issues. Modeling and imagery appears to pinpoint the problems to (8/9/5/4)-11-20-W4	Yes	LNID/C	Recommend assessing culverts in the area.
BAT2-07	Also the area west of highway 25 is much larger, further west than your map indicates, I think.	Comment appears to be related to catchment boundary. Not necessarily relevant to the study.	No	N/A	N/A
BAT2-08	Yes the ponding levels on sw-15-11-21-4 is consistent with my experience.	No Action.	No	N/A	N/A
BAT2-09	Looks pretty accurate, as fields drain it causes other fields to be flooded again since the Battersea drain has been neglected and many culverts are badly corroded and on the verge of collapsing. Also farmers have added culverts for pivots to run over and they should be replaced with bridges. There is also drain tiles being installed that will keep putting water in the ditch slowly which will freeze up in the wintertime and prevent water from flowing freely during a quick spring melt. Question: who issued permits for these drain tiles? Do these folks even have permits??	Noted. No specific area mentioned to address. Perhaps offers some points for discussion with the ID.	No	N/A	N/A

BAT1-03
Legend
Natural wetland condition,
no mitigation recomended
200
845
Google Earth
Image S. Alberta MD s and Counties
N
700 m


BAT1-04
No clearly defined ditch or outlet. Recommend a more detailed analysis of drainage along this highway
Google Earth
© 2021 Google
1.78 m
N

BAT1-04/06
Potentially drainage concerns with the south "ditch". Recommend detailed analysis of drainage along this highway.
25
204
Iron
Centre St
Google Earth
Image S. Alberta MD s and Counties
500 m
N


BAT1-07
Legend
Study area/catchment boundary.
112
213
Google Earth
Image © 2021 Maxar Technologies
1 km
N

BAT1-09
110
Comment noted that canal often floods over roadway. Recommend further study on potential localized drainage improvements to prevent roadway over topping.
Factory Dr
Google Earth
Image © 2021 Maxar Technologies
600 m
N

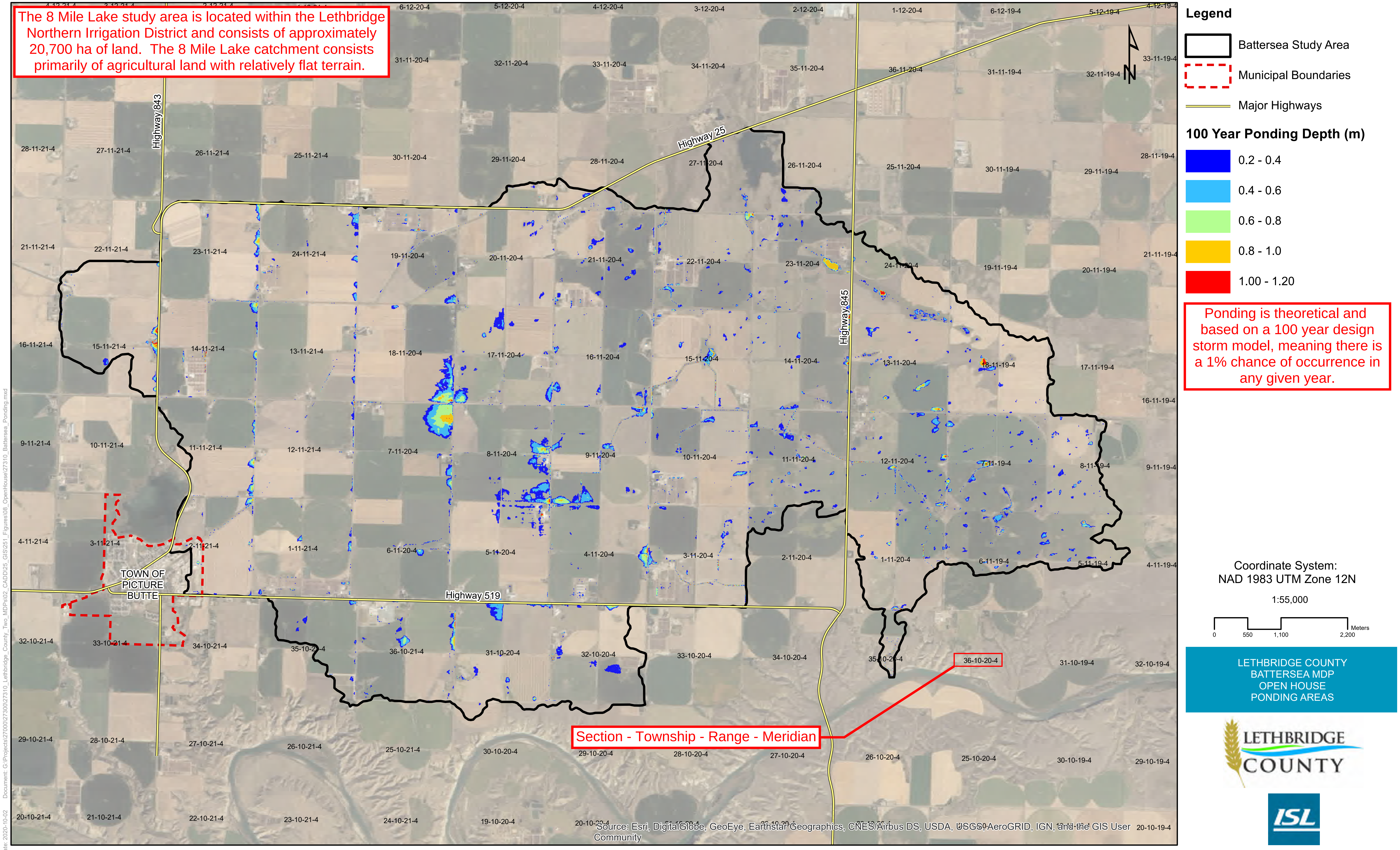

BAT1-11
No clearly defined outlet for this low point. Recommend further analysis to determine if flooding could be eased by improved ditch drainage along the highway.
Google Earth
Image S. Alberta MD s and Counties
300 m
N
Centre St


BAT1-12
Appear to be wetlands. Land owner claims canal overflows and fills in these wetlands. Recommend assessing the hydraulic connectivity of the canal to the surrounding wetlands and if improvements to the canal could ease flooding
204
Google Earth
Image S. Alberta MD's and Counties
Image © 2021 Maxar Technologies
N
500 m


BAT1-14
112
203
Landowner suggested this was a potential blockage preventing flows from the south to drain north. Recommend assessing the canal through this area to ensure positive drainage and connectivity.
Google Earth
Image S. Alberta MDs and Counties
Image © 2021 Maxar Technologies
N
700 m


BAT2-06
Recommend assessing culverts in the area to determine if any upgrades are required to improve drainage.
204
Google Earth
Image © 2021 Maxar Technologies
N
900 m


BAT1-15
Legend
Recommend assessment of this channel from the highway to the Old Man River. It is likely that erosion control measures could solve landowner concerns.
N
1.55 m
Google Earth
© 2021 Google


The 8 Mile Lake study area is located within the Lethbridge Northern Irrigation District and consists of approximately 20,700 ha of land. The 8 Mile Lake catchment consists primarily of agricultural land with relatively flat terrain.
Legend
Battersea Study Area
Municipal Boundaries
Major Highways
100 Year Ponding Depth (m)
0.2 - 0.4
0.4 - 0.6
0.6 - 0.8
0.8 - 1.0
1.00 - 1.20
Ponding is theoretical and based on a 100 year design storm model, meaning there is a 1% chance of occurrence in any given year.
Highway 843
Highway 25
Highway 845
Highway 519
TOWN OF PICTURE BUTTE
36-10-20-4
Section - Township - Range - Meridian
Coordinate System: NAD 1983 UTM Zone 12N
1:55,000
0
550
1,100
2,200
Meters
LETHBRIDGE COUNTY BATTERSEA MDP OPEN HOUSE PONDING AREAS
LETHBRIDGE COUNTY
ISL
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community