NewFields

Saskatchewan Water Security Agency
Saskatchewan Research Council

Basin Transfer Analysis

Demonstration Projects in Southern Saskatchewan

Prepared By:

NewFields Canada Mining & Environment
Suite 204, 640 Broadway Avenue
Saskatoon, Saskatchewan
Canada
S7N 1A9

March 2023

680.0034.000

680.0034.000

Virginia Wittrock, M.Sc.
Climate Research Specialist – Research Scientist – Group Lead
Saskatchewan Research Council
Bay 2D, 820 51st St. East
Saskatoon, SK S7K 0X8

Date: March 31, 2023

RE: Basin Transfer Analysis

Ms. Wittrock,

This report is presented to the Saskatchewan Research Council (SRC) and presents the results of NewFields Canada Mining & Environment ULC (NewFields) assessment of hydrological changes due to agricultural drainage works. This work is presented to SRC in support of on-going work with the Saskatchewan Water Security Agency (WSA).

If you have any questions or require additional information, please contact the undersigned.

Best Regards,

NewFields Canada

Prepared By:

Tyrel J. Lloyd, M.Eng, P.Eng.
Senior Water Resources Engineer

Reviewed By:

Erin Moss Tressel, M.Eng., P.Eng., P.Geo.
Senior Geological Engineer

TJL/EMT/tjl

https://newfields365-my.sharepoint.com/personal/tlloyd_newfields_com/Documents/680.0034.000 - SRC - WSA Demonstration Project/Report/WSA - Split Reports/Basin Transfer Docs/Draft Report - 23 03 31 - WSA Demonstration Sites Basin Transfer.docx

TABLE OF CONTENTS

1. INTRODUCTION

The Saskatchewan Water Security Agency (WSA) is a crown corporation responsible for managing, reviewing and assessing water related matters for the province of Saskatchewan. Their purview covers a broad spectrum including hydrological monitoring, flood impact assessment and general water quality, among many other responsibilities. WSA is working with the Saskatchewan Research Council (SRC) to understand the potential changes to hydrological regimes as a result of drainage of "prairie pothole" geography in agricultural lands. SRC has retained NewFields Canada Mining & Environment ULC (NewFields) to complete an assessment of the potential effect of changes from those drainage works. This report discusses work completed for that effort.

2. BACKGROUND

Southern Saskatchewan consists of dominantly arable agricultural land and in many areas is commonly described as a "prairie pothole" geography. It is theorized that these potholes were formed during recession of ice from the last glaciation where pockets of ice were deposited within the soil matrix and, as they melted, formed local depressions in the ground surface. The depressions, in hydrologic terms, created storage pockets that would collect and retain water during runoff events.

These depressions range in both their temporal and volumetric magnitude: some will be infrequently filled with little noticeable difference to surrounding terrain while others will be large and retain water permanently thus creating wetlands with markedly different vegetation and ecological potential. These depressions reduce the arable acreage from agricultural land for traditionally grown crops in Saskatchewan. Historically, agricultural producers have augmented their land to reduce or eliminate the storage in these pockets thus increasing their arable acreage. Often this practice was completed without permit from regulatory authorities.

Recently, Saskatchewan has experienced flooding events of sufficient magnitude to cause substantial damages to infrastructure. In many cases, complainants claim the magnitude of damages was worsened as a result of agricultural drainage projects that were completed without permit. This project seeks to understand the potential changes in hydrological regime for four demonstration projects where drainage works have been completed (with regulatory permission). These works are well understood by WSA from a technical perspective. WSA is developing an Agricultural Water Management Mitigation Policy which will be informed by the demonstration and research projects. These demonstration projects are implementing mitigation tools, including wetland retention and flow controls, and are being evaluated on a wide range of policy implications, including agronomic/economics, infrastructure, water quality, downstream flooding and habitat management. This specific study evaluates wetland retention and the use of flow controls to manage water quality and flooding outcomes.

3. SCOPE OF THIS PROJECT

This project assessed four demonstration projects identified as: 1) Arm River Farms (ARF) near Bethune, SK; 2) Gust Farms (Gust) near Davidson, SK; 3) Fort-a-la-Corne (FALC) near Melfort, SK; and, 4) Bauche near Redvers, SK. The demonstration projects have retained wetlands of 57%, 52%, 31% and 48% for ARF, Gust, FALC and Bauche, respectively. The WSA provided two grants to SRC to support this work.

Grant WSA-2020-0046 was provided to complete:

- Detailed hydrologic modelling for the ARF project for the temporal period 2009 to 2019, comparing pre-drainage, current condition and a fully drained site configuration; and,
- Water quality assessment for a simplistic estimate of the potential change in loadings based on changes to the flow regime.

Grant WSA-2021-0258 was provided to complete:

- Delineation of Gross Drainage Area (GDA) and Effective Drainage Area (EDA) for each of the four projects at varying temporal scales and potential augmentations (i.e.: drainage works).
- Basin transfer will be completed for each demonstration project for return period peak flows and annual flow volume.

This report provides the results for Grant WSA-2021-0258 and should be considered adjacent to the Hydrological Modelling Assessment report (Grant WSA-2020-0046; NewFields, 2023). This scope has deviated from the original proposal based on conversations with WSA and SRC and the deviations are the same for both WSA grants. The majority of these changes relate to methodology and were determined through discussion between WSA, SRC and NewFields. The most notable deviation from the proposal methodology is the lack of an evapotranspiration component for ground surface water losses. This component is not included due to challenges observed during model checks where the water losses from the system are substantial and limit the potential to generate runoff from ground surfaces. Other deviations related to available climatic and hydrometric data dependent on the status of the existing records, as well as the source relative to a particular demonstration project.

Most of the data used for this project work were provided by WSA and SRC. Data provided included:

- Light Detection and Ranging (LiDAR) derived Digital Elevation Models (DEM);
- Various vector data packages (i.e. wetlands, drainage works, project boundaries, etc.) with associated geographical information system (GIS) data;
- Climate data local to each demonstration project;
- Return period peak flood and annual volume estimates;
- Various reporting data sources; and,
- Access to various imagery and topographic information.

4. TEMPORAL SCALES AND DRAINAGE AREA DELINEATION

Drainage areas were derived for each of the four demonstration projects based on a combination of the DEMs provided and data from either of the Shuttle Radar Topographic Mission (SRTM) or National Topographic Service (NTS) 1:50k map products. Delineations were completed through a combination of manual interpretation or automated function through the Global Mapper software system (v22.1 and v23.1). Drainage area maps were developed for each of the project areas and in most cases depict GDA and EDA through pre-drainage, current and fully drained scenarios.

Pre-drainage, as a temporal period (Scenario 1), is defined as a point of time prior to the presence of drainage works (i.e.: ditching, French drains, etc.) but includes surface features such as roadways, cross-drainage structures related to roadways, dugouts, etc. The current period (Scenario 2) is defined based on the existing condition as presented in the DEM sources available (i.e.: LiDAR, SRTM and NTS). A fully drained condition (Scenario 3) is based on discussion with WSA and, in some cases, is approximately equivalent to the GDA.

Figures 1 through 5 (Appendix 1) present the EDA and GDA for each project area. At the Gust Farms project (Figure 2) the west portion of the drainage, west of the highway, is presented separately from the main area as a potential future augmentation area. The fully drained scenario for Gust Farms does not include the full GDA and also includes a portion of watershed not within the current GDA. Basin transfer results for Gust Farms are presented with respect to main drainage and west drainage as shown on Figure 2.

The Bauche project has multiple drainage outlets in its pre-drainage configuration. The EDAs associated with these outlets, as well as the GDA, are presented in Figure 4. Figure 5 presents the remaining delineations for temporal phases of the Bauche project including a scenario for pumped influence on the project.

5. BASIN TRANSFER ESTIMATES

5.1. Peak Flow Return Period Estimates

Daily and instantaneous return period flow estimates were estimated using basin transfer methodology for each of the projects. These estimates were completed based on EDA as it can be expected that EDA has a more dominant influence over peak flow events. The results of the peak flow estimate are presented in Table 1 (Appendix 2). Table 1 also indicates the source station used in the basin transfer estimate for each project site. In all cases, increasing amounts of drainage substantially increased peak flows across all event sizes. Peak flow increased from 1.4 to 9.7 times the pre-drainage magnitude as compared to the current period scenario. The fully drained scenarios were higher. In the current period scenario, landowners are reducing potential downstream impacts that would be posed by a fully drained scenario by retaining water within the project.

5.2. Annual Return Period Flow Volumes

Annual return period flow volumes were estimated using basin transfer methodology for each of the demonstration projects. WSA provided a spreadsheet which incorporates ratios for the EDA and GDA. The results of the annual flow volumes estimate are presented in Table 2 (Appendix 2), as well as the sources station for the basin transfer. The spreadsheet predicts that, in most cases, flow volumes increase especially during more frequent return periods; however, the nature of the calculation indicates that some flow volumes decrease in rarer return period events. While this may be a probable occurrence, NewFields expects that this is a limitation of the calculation.

6. LIMITATIONS

NewFields Canada Mining & Environment ULC (NewFields) has prepared this document in a manner consistent with the level of care and skill ordinarily exercised by the engineering and geoscience

professions practicing in similar conditions within the jurisdiction that the services are provided, subject to time limits and physical constraints applicable to this work. No other warranty, express or implied, is made.

This document was prepared by NewFields for the sole benefit of SRC and WSA. It represents NewFields professional judgement based on the knowledge and information available at the time of preparation. NewFields has no responsibility for any unauthorized use or modification of this document. Third parties relying on this document do so at their own risk.

Factual data, interpretations, suggestions, recommendations and opinions expressed in this document pertain to the specific project, site conditions, design objectives, development and purpose provided to NewFields by SRC and are not applicable to any other project or site location. Reference must be made to the entire document to properly understand the factual data, interpretations, suggestions, recommendations and opinions presented herein. Interpretations, suggestions, recommendations and opinions presented in this document were partially based on information provided by SRC and WSA. NewFields has no responsibility for the accuracy of the information provided to it.

SRC may make copies of this document in such quantities reasonably necessary to conduct business specifically related to the subject of this document or in support of or in response to regulatory inquiries and proceedings. Electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore no party can rely solely on the electronic media versions of this document.

7. CLOSURE

NewFields would like to thank SRC and WSA for the support its personnel provided during this assessment. We trust that this information meets your needs at this time. Should any portion of this report require further information or clarification, please do not hesitate to contact the undersigned.

Sincerely,

NewFields Canada Mining & Environment ULC

Prepared by:

Tyrel J. Lloyd, M.Eng., P.Eng.

Senior Water Resources Engineer

Reviewed by:

Erin Moss Tressel, M.Eng., P.Eng., P.Geo.

Senior Geological Engineer

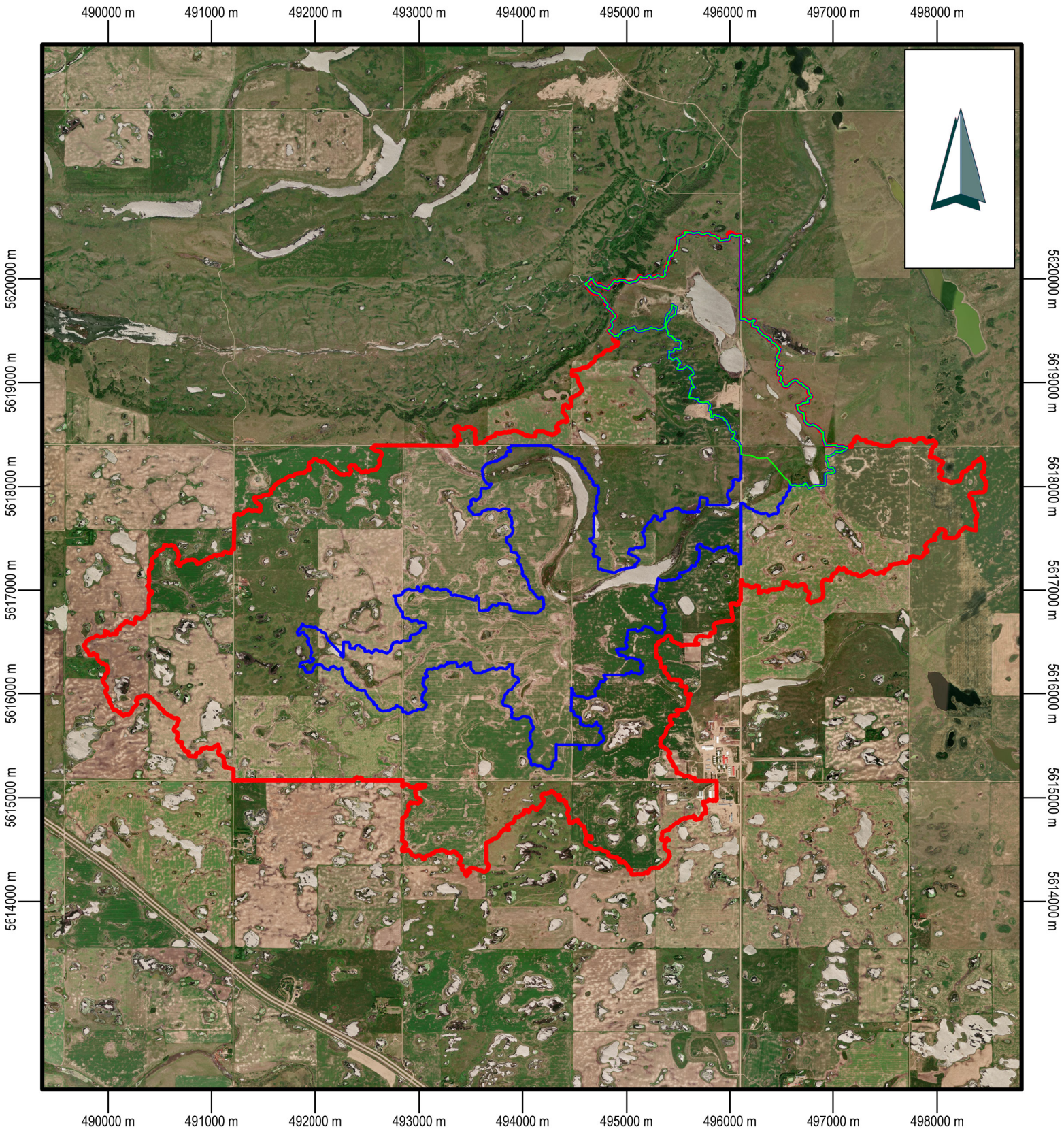
TJL/EMT/tjl

8. REFERENCES

NewFields Mining & Environment ULC. 2023. Hydrological Modelling Assessment – Demonstration Projects in Southern Saskatchewan. Saskatoon, SK. March 2023. Project Number: 680.0034.000.

APPENDIX 1

REPORT FIGURES



Legend:

- EDA - Arm River - Current
- EDA - Arm River - Pre-Drainage
- GDA - Arm River

0.0 km 0.5 km 1.0 km 1.5 km 2.0 km 2.5 km 3.0 km

NewFields

Date: June 19, 2022

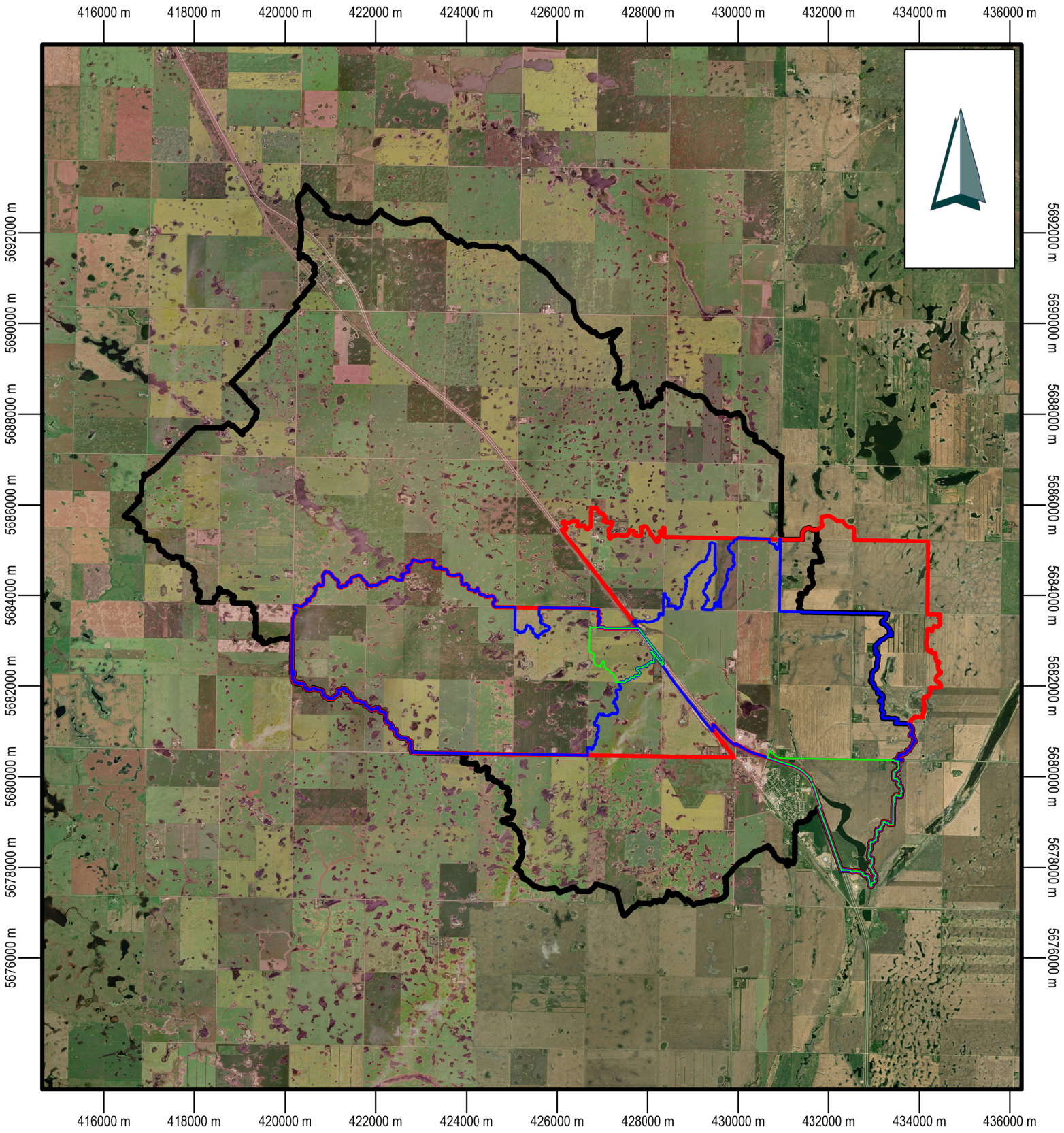
Project Number: 680.000034.000

Figure Title: Arm River Drainage Areas

Projection: UTM NAD83 Zone 13
References: Aerial Imagery from Global Mapper

Figure: 1

Revision: 0



Legend:

- EDA - Gust Farms - Current
- EDA - Gust Farms - Fully Drained
- EDA - Gust Farms - Pre-Drainage
- GDA - Gust Farms

0.0 km 1.0 km 2.0 km 3.0 km 4.0 km 5.0 km 6.0 km 7.0 km

NewFields

Date: June 19, 2022

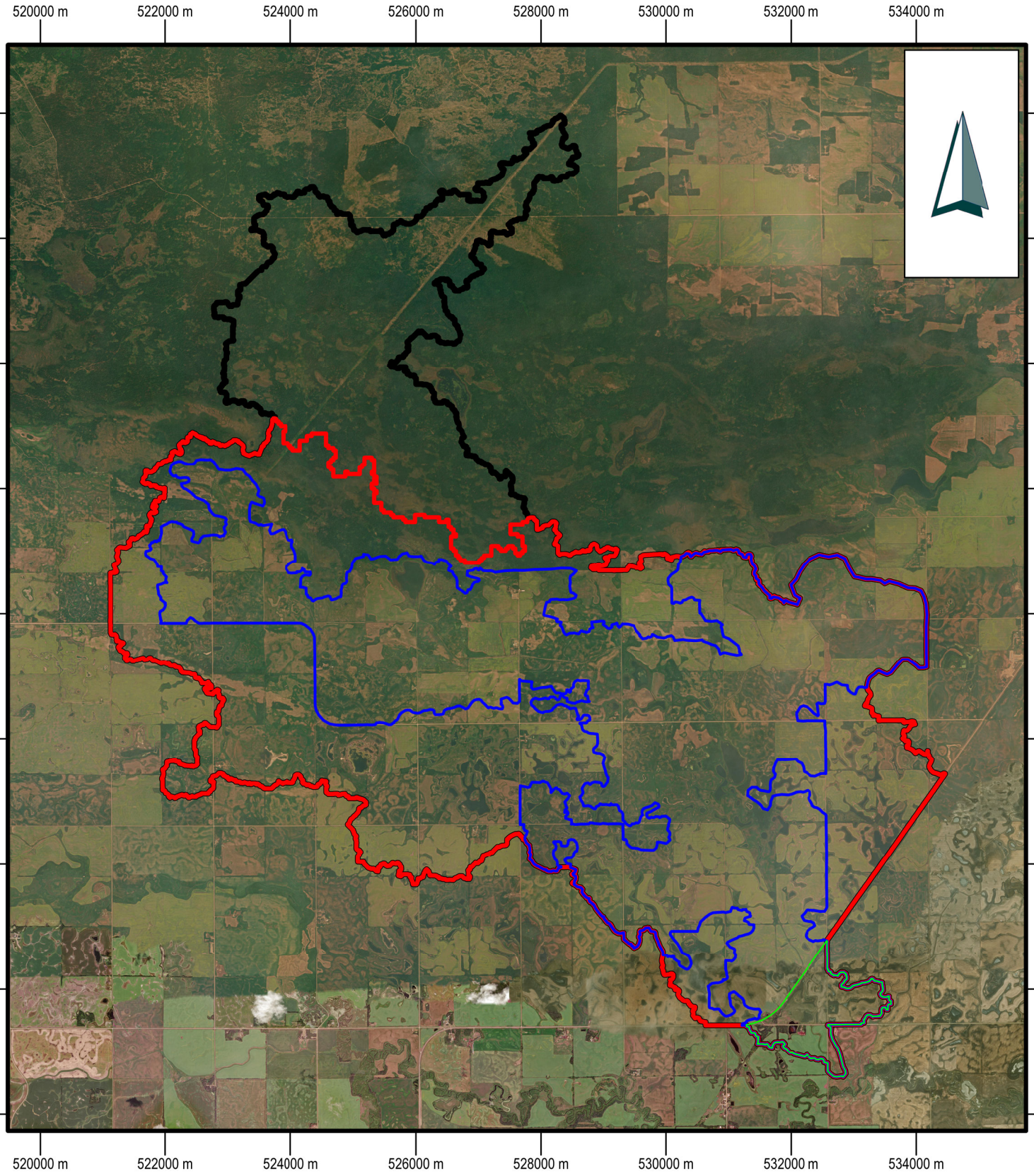
Project Number: 680.000034.000

Figure Title: Gust Farms Drainage Areas

Projection: UTM NAD83 Zone 13
References: Aerial Imagery from Global Mapper

Figure: 2

Revision: 0



Legend:

- EDA - Fort-a-la-Corne - Current
- EDA - Fort-a-la-Corne - Fully Drained
- EDA - Fort-a-la-Corne - Pre-Drainage
- GDA - Fort-a-la-Corne

0.0 km 1.0 km 2.0 km 3.0 km 4.0 km 5.0 km

NewFields

Date: June 19, 2022

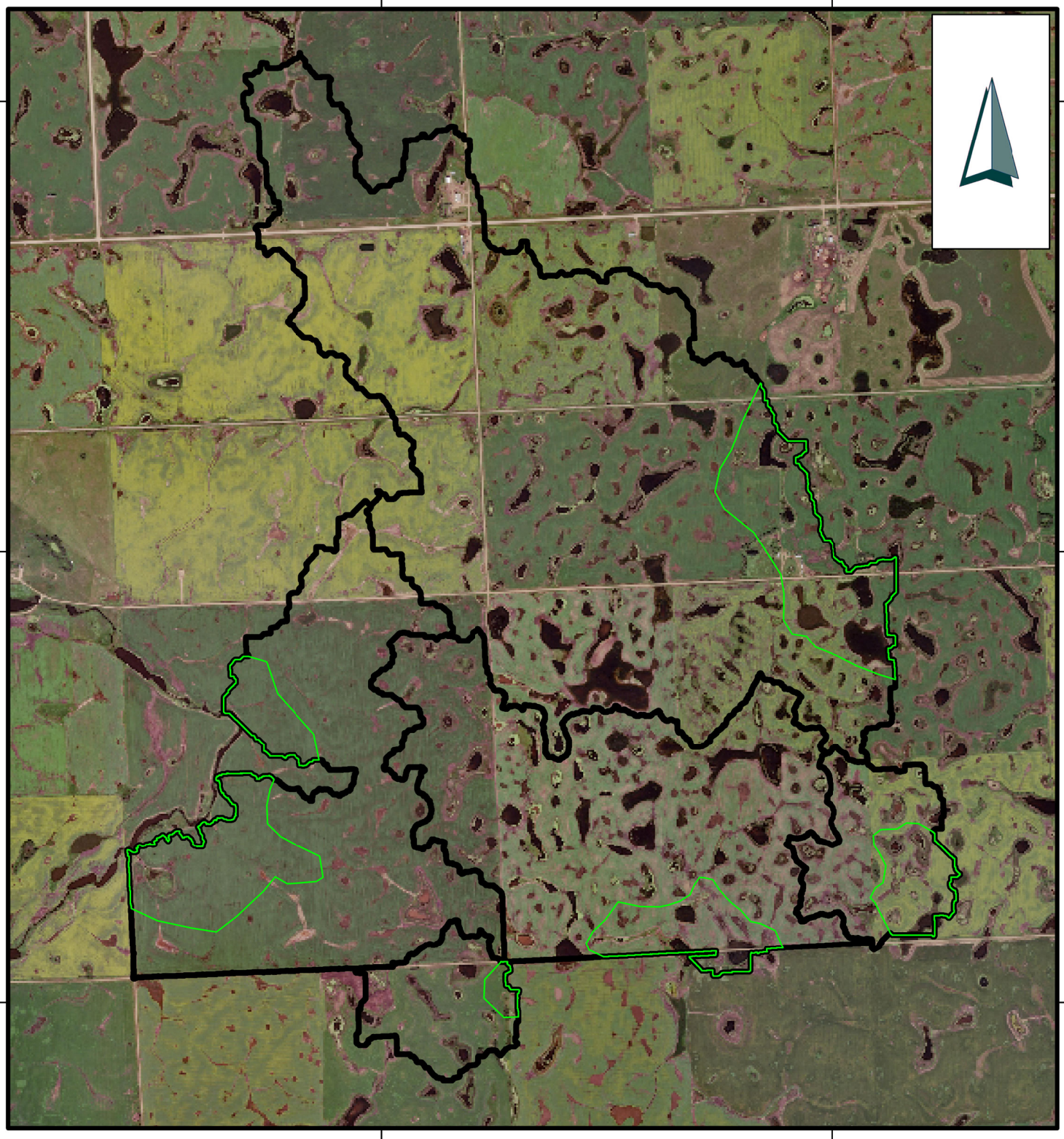
Project Number: 680.000034.000

Figure Title: Fort-a-la-Corne Drainage Areas

Projection: UTM NAD83 Zone 13
References: Aerial Imagery from Global Mapper

Figure: 3

Revision: 0



Legend:
- EDA - Bauche - Pre-Drainage
- GDA - Bauche

0 m 250 m 500 m 750 m 1000 m 1250 m 1500 m

NewFields

Date: June 19, 2022

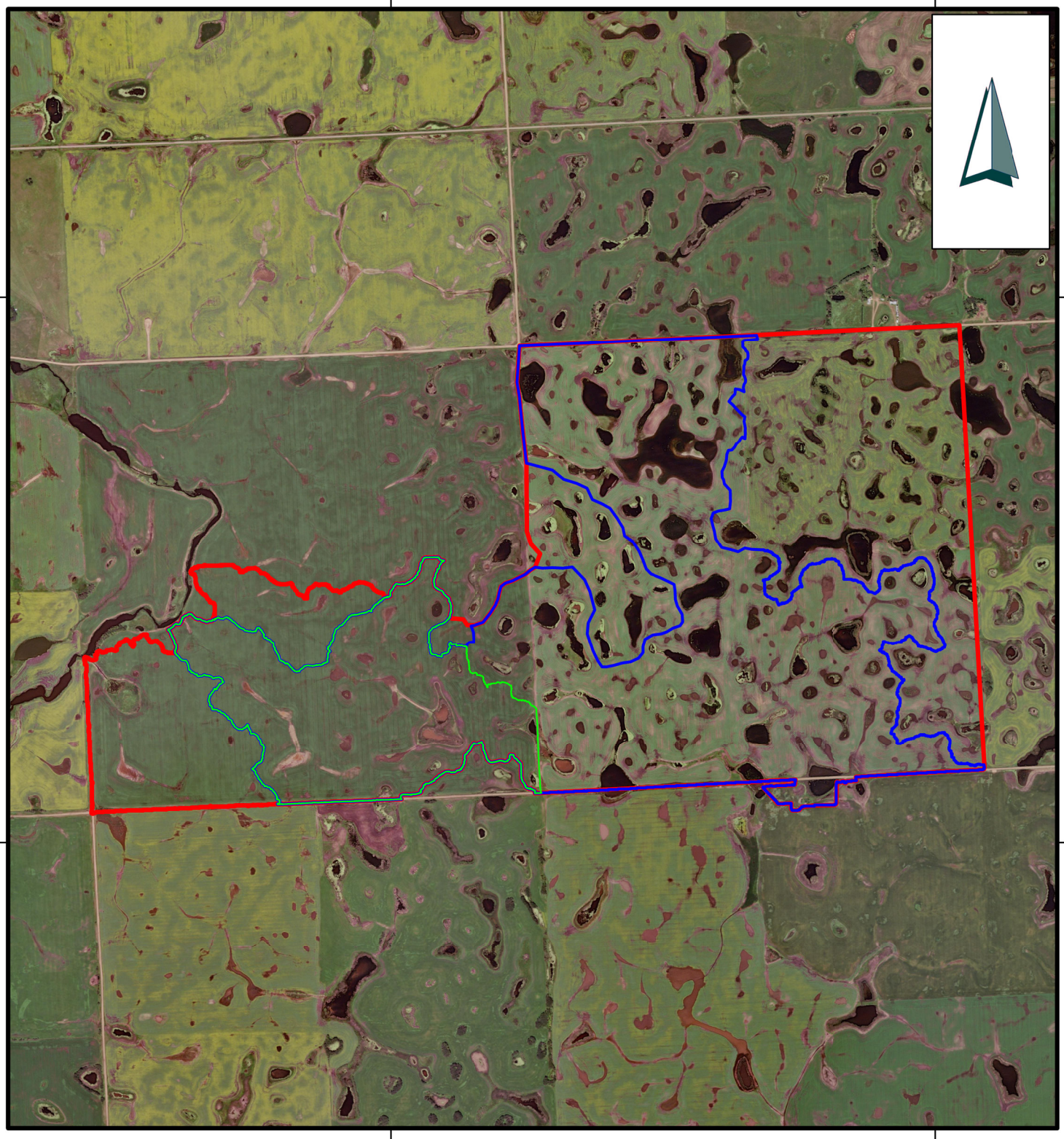
Project Number: 680.000034.000

Figure Title: Bauche Drainage Areas - GDA and Pre-Drainage EDA

Projection: UTM NAD83 Zone 13
References: Aerial Imagery from Global Mapper

Figure: 4

Revision: 0



Legend:

- EDA - Bauche - Current with Pumping
- EDA - Bauche - Current without Pumping
- EDA - Bauche - Fully Drained

0 m 250 m 500 m 750 m 1000 m 1250 m

NewFields

Date: August 10, 2022

Project Number: 680.000034.000

Figure Title: Bauche Drainage Areas - Post-Augmentation EDA and GDA

Projection: UTM NAD83 Zone 13
References: Aerial Imagery from Global Mapper

Figure: 5

Revision: 0

APPENDIX 2

REPORT TABLES

Table 1: Basin Transfer – Return Period Peak Discharge

Demonstration Project	Source Station	Peak Percent Increase (%)	Description	Drainage Area (km²)	Daily Peak Discharge (m³/s)					Instantaneous Peak Discharge (m³/s)				
					1:2	1:5	1:10	1:25	1:50	1:2	1:5	1:10	1:25	1:50
Arm River Farms	05JG015 KNOX COULEE NEAR TUXFORD	75	EDA - Pre-Drainage	2.195	0.094	0.229	0.347	0.521	0.646	0.165	0.400	0.608	0.912	1.131
			EDA - Current	6.901	0.223	0.539	0.819	1.229	1.524	0.390	0.943	1.434	2.151	2.667
			Fully Drained (GDA)	23.853	0.566	1.368	2.080	3.120	3.868	0.990	2.395	3.640	5.460	6.769
Bauche	05NF010 ANTLER RIVER NEAR WAUCHOPE	11	EDA - Southwest Minor Catchment	0.317	0.019	0.081	0.140	0.226	0.301	0.021	0.089	0.155	0.251	0.334
			EDA - Northwest Minor Catchment	0.133	0.010	0.042	0.073	0.118	0.157	0.011	0.047	0.081	0.131	0.174
			EDA - Without Pump	0.634	0.033	0.136	0.235	0.379	0.506	0.036	0.150	0.261	0.421	0.562
			EDA - Current - All Areas (with pumping)	2.282	0.085	0.354	0.614	0.992	1.322	0.094	0.393	0.681	1.101	1.468
			Fully Drained	3.866	0.126	0.526	0.912	1.473	1.963	0.140	0.584	1.012	1.635	2.179
Fort-a-la-Corne	05KB006 LEATHER RIVER NEAR STAR CITY	25	GDA	88.164	4.556	9.198	12.792	18.001	22.431	5.694	11.497	15.990	22.502	28.039
			Pre-Drainage - EDA	1.909	0.257	0.519	0.722	1.016	1.266	0.321	0.649	0.903	1.270	1.583
			Post-Augmentation - Main EDA	39.610	2.500	5.047	7.020	9.879	12.309	3.125	6.309	8.775	12.348	15.387
			Fully Drained	71.361	3.887	7.849	10.916	15.362	19.141	4.859	9.811	13.645	19.202	23.927
Gust Farms	05JG014 ISKWAO CREEK NEAR CRAIK	15	GDA	148.800	2.083	5.513	8.821	13.967	18.991	2.395	6.340	10.145	16.062	21.839
			Pre-Drainage - EDA	3.609	0.128	0.339	0.542	0.858	1.167	0.147	0.390	0.623	0.987	1.342
			Post-Augmentation - Main EDA	20.784	0.476	1.260	2.015	3.191	4.339	0.547	1.449	2.318	3.670	4.990
			West Portion - GDA	22.696	0.508	1.346	2.153	3.409	4.635	0.585	1.547	2.476	3.920	5.330
			West Portion - Pre-Drainage - EDA	1.288	0.059	0.156	0.250	0.396	0.539	0.068	0.180	0.288	0.456	0.620
			Fully Drained - West and Main	60.711	1.063	2.815	4.503	7.130	9.695	1.223	3.237	5.179	8.200	11.149

Table 2: Basin Transfer – Return Period Annual High Flow Volumes

Demonstration Project	Source Station	GDA (km^2)	EDA (km^2)	Annual High Volume (dam^3)					Description	Drainage Area (km^2)	Annual High Volume (dam^3)				
				1:2	1:5	1:10	1:25	1:50			1:2	1:5	1:10	1:25	1:50
Arm River Farms	05JG015 KNOX COULEE NEAR TUXFORD	41.0	10.7	40	370	1000	1300	1500	EDA - Pre-Drainage	2.2	8.2	114.0	360.3	545.4	684.8
									EDA - Current	6.9	25.8	232.4	619.5	792.7	905.5
									Fully Drained (GDA)	23.9	89.3	660.3	1556.9	1687.0	1703.9
Bauche	05NF010 ANTLER RIVER NEAR WAUCHOPE	347.5	133.7	1750	5120	8780	16060	24410	EDA - Southwest Minor Catchment	0.3	3.9	24.0	52.0	117.8	200.5
									EDA - Northwest Minor Catchment	0.1	1.3	18.4	44.3	107.4	188.3
									EDA - Without Pump	0.6	7.9	32.4	63.6	133.4	218.9
									EDA - Current - All Areas (with pumping)	2.3	30.1	79.8	129.5	221.8	322.9
									Fully Drained	3.9	51.0	124.4	191.5	305.0	420.7
Fort-a-la-Corne	05KB006 LEATHER RIVER NEAR STAR CITY	161.9	121.1	5510	10380	13670	17910	21120	GDA	88.2	4013.1	7041.8	8927.5	11180.4	12804.4
									Pre-Drainage - EDA	1.9	86.4	1656.7	3179.9	5653.9	7762.3
									Post-Augmentation - Main EDA	39.6	1801.8	4009.2	5690.7	8068.1	9964.9
									Fully Drained	71.4	3248.7	5993.5	7808.6	10104.6	11822.8
Gust Farms	05JG014 ISKWAO CREEK NEAR CRAIK	370.3	113.5	1280	3350	5010	7310	9120	GDA	148.8	1678.1	3563.5	4700.6	5815.2	6442.5
									Pre-Drainage - EDA	3.6	40.6	443.5	919.2	1765.9	2534.0
									Post-Augmentation - Main EDA	20.8	234.6	813.1	1367.1	2245.6	2997.0
									West Portion - GDA	22.7	256.0	853.9	1416.6	2298.6	3048.1
									West Portion - Pre-Drainage - EDA	1.3	14.7	394.1	859.3	1701.8	2472.1
									Fully Drained - West and Main	60.7	684.5	1670.4	2406.2	3358.3	4071.0