RED DEER COUNTY AND MARKERVILLE FLOOD STUDY

Prepared for:
ALBERTA ENVIRONMENT AND PROTECTED AREAS

Prepared by:
MATRIX SOLUTIONS INC., A MONTROSE ENVIRONMENTAL COMPANY

Version 1.0
March 2024
Edmonton, Alberta

Suite 200, 5083 Windermere Blvd. SW
Edmonton, AB, Canada T6W 0J5
T 780.490.6830 F 780.465.2973
www.matrix-solutions.com

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PROFESSIONAL ENGINEER ALBERTA — PAMELA ROGERS 75254 — 22 March 2024

PROFESSIONAL ENGINEER ALBERTA — MANAS L. SHOME 57054 — 22 March 2024

Pamela Rogers M.Eng., P.Eng. **Water Resources Engineer**	**reviewed by** **Manas Shome, Ph.D., P.Eng.** **Principal Water Resources Engineer**

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MATRIX SOLUTIONS INC.
RM SIGNATURE:
RM APEGA ID #: 57054
DATE: 22 March 2024
PERMIT NUMBER: P005540
The Association of Professional Engineers and Geoscientists of Alberta (APEGA)

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CONTRIBUTORS

Name	Job Title	Role
Manas Shome, Ph.D., P.Eng.	Principal Water Resources Engineer	Senior technical review, project direction, co-author and authenticated professional
Brandyn Coates, M.Eng., P.Eng.	Water Resources Engineer	Project Manager and technical review
Sabrina Rashid Sheonty, E.I.T.	Water Resources Engineer	Hydraulic modelling
Pamela Rogers, M.Eng. P.Eng.	Water Resources Engineer	Hydraulic modelling; co-author of the report
Karen Hofbauer, M.Sc., P.Eng.	Senior Water Resources Engineer	Hydraulic modelling review
Matt Wilkinson, MGIS	GIS Specialist	Map and database creation and organization
Dylan Bosak, B.Sc.	GIS Specialist	Map and database creation and organization

VERSION CONTROL

Version	Date	Issue Type	Filename	Description
V0.1	16-Feb-2024	Draft	35374-531 Red Deer County & Markerville FS R 2024-02-16 draft V0.1.docx	Issued to client for review
V1.0	22-Mar-2024	Final	35374-531 Red Deer County & Markerville FS R 2024-03-22 final V1.0.docx	Issued to client as final

CREDITS AND ACKNOWLEDGEMENTS

Matrix Solutions Inc. expresses thanks to Jim Choles, M.Sc., P.Eng., CFM, of Alberta Environment and Protected Areas (EPA) for providing overall study guidance and management throughout the project duration.

The field survey was conducted by Measurement Sciences Inc. (MSI). Hydraulic modelling was led by Pamela Rogers, M.Eng., P.Eng. with technical guidance provided by Karen Hofbauer, M.Sc., P.Eng., and contributions by Sabrina Rashid Sheonty, E.I.T. Map and database creation and organization was completed by Dylan Bosak, B.Sc., with technical guidance provided by Matthew Wilkinson, MGIS. Overall study management was completed by Brandyn Coates, M.Sc., P.Eng., and senior technical review and project direction was provided by Manas Shome, Ph.D., P.Eng.

Note: This study was completed by the Government of Alberta under the provincial Flood Hazard Identification Program, the goals of which include enhancement of public safety and reduction of future flood damages through the identification of river and flood hazards. The study was co-funded by the Government of Canada through the federal Flood Hazard Identification and Mapping Program.

EXECUTIVE SUMMARY

Matrix Solutions Inc., a Montrose Environmental company, was retained by the Government of Alberta (GoA) to conduct the Red Deer County and Markerville Flood Study. This flood study is one of several similar studies completed as part of a larger effort by GoA to identify flood hazard areas in communities throughout Alberta to increase public safety and reduce future flood related damages. Information required to complete this study was gathered collectively by Matrix, Measurement Sciences Inc. (MSI), key project stakeholders, and GoA (including LiDAR provider Airborne Imaging).

The purpose of the Red Deer County and Markerville Flood Study is to assess and identify flood hazards along the Red Deer River and its tributaries (Little Red Deer River and Medicine River) through Red Deer County including the Hamlet of Markerville. The scope of the study includes flood hazards along the 46 km of the Red Deer River, 32 km of the Little Red Deer River, and 33 km of the Medicine River through Red Deer County, including the Hamlet of Markerville.

The study reach of the Red Deer River extends from the outlet of Dickson Dam in NW 34-35-02 W4M downstream to the northern boundary of NW 35-37-28 W4M. The Little Red Deer River study reach extends from the southern boundary of SE 05-35-02 W4M downstream to its confluence with the Red Deer River and the Medicine River study reach extends from the northern boundary of SW-16-37-02 W4M downstream to its confluence with the Red Deer River.

As a part of the Red Deer River and Upper Red Deer Flood Hazard Studies, Golder (2021) conducted a hydrologic assessment and prepared a hydrology assessment report, titled Open Water Flood Hydrology Assessment – Red Deer River and Upper Red Deer River Hazard Studies. This report provided the 1:2, 1:5, 1:10, 1:20, 1:35, 1:50, 1:75, 1:100, 1:200, 1:350, 1:500, 1:750, and 1:1,000 naturalized and regulated flood frequency estimates for the Red Deer River through the current study reach, as well as the flood frequency estimates for the Little Red Deer River and the Medicine River through the current study reach corresponding to these same return periods. As directed by the GoA, these flood frequency estimates were used in the current study. Flood frequencies for natural flows or naturalized flows are typically used for flood hazard mapping. For this study, in concurrence with EPA, flood frequencies under regulated conditions were selected for hydraulic modelling and flood hazard mapping. Selection of flood frequency estimates under regulated flow conditions is consistent with the flood hazard study completed for the lower Red Deer River.

The hydraulic model and resulting map products were constructed using LiDAR data provided by GoA and surveyed cross-sections, and hydraulic structure data collected by MSI under Matrix's supervision. All surveyed data was tied together using Alberta Survey Control Network (ASCN) benchmarks that were surveyed independently during the various data collection phases. A total of 259 cross sections were surveyed, of which 77 are located on the Little Red Deer River, 70 are located on the Medicine River, and 112 are located on the Red Deer River. Cross sections were extended into the floodplain based on the digital terrain model (DTM) provided to Matrix by EPA. The HEC-RAS hydraulic modelling software (version

6.3.1; USACE 2022) was used to simulate flood levels through the model reach for flood events associated with various return periods ranging from the 1:2-year to the 1:1,000-year flood. The hydraulic model was calibrated and validated against surveyed highwater marks (HWMs) and the corresponding peak discharge for major events that occurred on the Red Deer River, Little Red Deer River, and Medicine River. The source of data used for the assessment were HWMs obtained from EPA. HWMs observed during the 1990, 2005, and 2013 flood events were selected to calibrate the developed hydraulic model.

Survey and base data collection documentation is provided in Appendix A and the hydrologic assessment report is provided in Appendix B. Open water flood frequency maps for the 2-year to 1,000-year flood events are provided in Appendix C. The 1:100-year design flood profile was used in preparing design flood hazard maps for the study area. Floodway criteria maps are provided in Appendix D and design flood hazard maps are provided in Appendix E.

Along the upper Medicine River, the floodway generally encompasses the entire 100-year inundation area with minimal flood fringe. The governing floodway criteria along the upper Medicine River alternates between the depth criteria and no viable flood fringe. No historic floodway has been defined along the upper Medicine River reach; in the lower Medicine River, the current floodway is coincident with the historic floodway. Several flood fringe areas are located in low-lying areas and upstream/downstream of road crossings along the Medicine River; areas of high hazard flood fringe (>1 m depth) are present at several locations.

Along the upper Little Red Deer River, the governing floodway criteria alternates between depth, velocity and no viable flood fringe. No historic floodway has been defined along the upper Little Red Deer River reach and several flood fringe areas are observed in low-lying areas, through inside channel bends and upstream/downstream of bisecting roads. Historic floodway is defined in the lower Little Red Deer River; in this area, the current floodway is coincident with the historic floodway. Several flood fringe areas are observed through low-lying historic meander scars, inside channel bends and upstream/downstream of road crossings. Areas of high hazard flood fringe (>1 m depth and > 1 m/s velocity) are present along the Little Red Deer River at several locations.

Along the Red Deer River, the floodway generally encompasses the entire 100-year inundation area with minimal flood fringe located in low-lying areas and through inside channel bends. Generally, the current floodway is coincident with the historic floodway along the Red Deer River, with a few exceptions. Areas of high hazard flood fringe (>1 m depth) are present along the Red Deer River at several locations.

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1 INTRODUCTION

Matrix Solutions Inc., a Montrose Environmental company, was retained by the Government of Alberta (GoA) to conduct the Red Deer County and Markerville Flood Study. Key stakeholders for this project include the GoA and Red Deer County. This flood study is one of several similar studies completed as part of a larger effort by GoA to identify flood hazard areas in communities throughout Alberta to increase public safety and reduce future flood related damages. Information required to complete this study was gathered collectively by Matrix, MSI (surveying subcontractor), key project stakeholders, and GoA (including its providers of topography and aerial photography information).

1.1 Study Background

A flood hazard study for the Red Deer River and its tributaries, Little Red Deer River, and Medicine River was completed in 2007 (AMEC 2007). The extent of the current study along the Red Deer River is similar to the AMEC (2007) flood risk mapping study, but the upstream extents along the Little Red Deer River and the Medicine River are greater than those in the AMEC (2007) study. Since that time, GoA has updated flood hazard identification methodology and expanded the scope of its Flood Hazard Identification Program (FHIP). This study is conducted under the FHIP, utilizing the following documents:

- Red Deer County and Markerville Flood Study – Terms of Reference (TOR; EPA 2022)
- FHIP Guidelines (AEP 2022)

1.2 Study Objectives

The key study objectives included the following:

- Survey and base data collection:
  - surveying river cross-sections
  - surveying hydraulic structures
  - integrating survey and digital terrain model (DTM) data
- Open water hydraulic modelling:
  - documenting open water flood history
  - creating, calibrating, and validating a HEC-RAS hydraulic model for the Red Deer River and its tributaries (Little Red Deer River and Medicine River)
  - simulating 13 flood frequency estimates and creating associated water surface profiles
- Open water flood inundation mapping:
  - preparing flood inundation maps for the specified flood frequency events
  - preparing associated electronic GIS data

- Design flood hazard mapping:
  - preparing flood hazard and floodway criteria maps based on various floodway delineation criteria for the 1:100 year design open water flood
- Reporting and documentation:
  - preparing a study report and associated electronic GIS study file and digital deliverables database to document methods and results

1.3 Study Area and Reach

Figure 1 shows the study area and includes the following study reaches:

1) 46 km reach of the Red Deer River, from the outlet of Dickson Dam in NW 34-35-02 W4M downstream to the northern boundary of NW 35-37-28 W4M.

2) 32 km reach of Little Red Deer River, from the southern boundary of SE 05-35-02 W4M downstream to its confluence with the Red Deer River.

3) 33 km reach of Medicine River, from the northern boundary of SW 16-37-02 W4M downstream to its confluence with the Red Deer River.

The study reach of the Red Deer River extends from the outlet of Dickson Dam in NW 34-35-02 W4M downstream to the northern boundary of NW 35-37-28 W4M. The Little Red Deer River study reach extends from the southern boundary of SE 05-35-02 W4M downstream to its confluence with the Red Deer River and the Medicine River study reach extends from the northern boundary of SW 16-37-02 W4M downstream to its confluence with the Red Deer River.

The Red Deer River originates in the Rocky Mountains in Banff National Park, Alberta and flows east through the foothills and the City of Red Deer and discharges to the South Saskatchewan River within the Province of Saskatchewan. Flows in the Red Deer River have been regulated by the Dickson Dam since 1983. The Red Deer River is joined by the Medicine and Little Red Deer rivers downstream of the Dickson Dam before flowing northeast to the City of Red Deer. Within the study reach between Dickson Dam and the City of Red Deer, the Red Deer River has a meandering channel pattern. The catchment area upstream of the Red Deer River study reach is composed of mountains, foothills and prairie-type terrain. A Water Survey of Canada (WSC) streamflow gauging station 05CC002 (Red Deer River at Red Deer) is located just downstream of the study reach in the City of Red Deer and has been operating since 1913. This gauge is located downstream of the study reach but gives an indication of the historical peak discharge magnitudes within the study reach. Based on a review of historical streamflow data, past flood events affecting the Red Deer River study reach have been primarily open water floods. Based on the historical gauge records, large flood events usually occur from May through August, although annual peak discharges have been recorded as early as April and as late as September. The drainage area of the Red Deer River at the downstream boundary of the study area is 10,966 km^2.

The Little Red Deer River is a tributary to the Red Deer River and originates in the foothills west of Water Valley. The river flows east out of the foothills and then north/northeast to the confluence with the Red Deer River. The catchment area upstream of the Little Red Deer River study reach is composed of foothills and agricultural prairie-type terrain. A WSC gauging station 05CB001 (Little Red Deer River near the Mouth) is located within the study reach, approximately 9 km from the confluence with the Red Deer River and has been operating since 1961.

Based on a review of historical streamflow data, past flood events affecting the Little Red Deer River study reach have been primarily open water floods. Based on the gauge records, large flood events usually occur from April through July, although annual peak discharges have been recorded as early as March and as late as September. The drainage area of the Little Red Deer River at its confluence with the Red Deer River is 2,580 km^2.

The Medicine River is a tributary to the Red Deer River and originates at Medicine Lake in prairie-type terrain. The river flows south and east past Eckville and through the hamlet of Markerville to the confluence with the Red Deer River (approximately 2 km downstream of the Little Red Deer River confluence). The catchment area upstream of the Medicine River study reach is composed of agricultural prairie-type terrain. A WSC streamflow gauging station 05CC007 (Medicine River near Eckville) is located approximately 30 km upstream of the Hamlet of Markerville.

Based on a review of historical floods, past flood events affecting the Medicine River study reach have been primarily open water floods. Based on the gauge records, large flood events usually occur from April through July, although annual peak discharges have been recorded as early as March and as late as September. The drainage area of the Medicine River at its confluence with the Red Deer River is 2,760 km^2.

2 SURVEY AND BASE DATA COLLECTION

Matrix conducted a site visit with GoA and MSI staff on September 29 and 30, 2022, to inform the survey work. This included confirming the proposed cross-section locations that were identified during the initial desktop review of the study reach imagery and topography, identifying hydraulic structures to be included in the project, and refining the survey scope. No flood control structures were identified along any of the rivers within the study reach.

The survey work was completed in October and November 2022; MSI led the data collection and quality management process under Matrix's supervision and direction. Data collected along the study reach during the survey included the following:

- river cross-sections
- hydraulic structure (bridges) geometry
- WSC hydrometric station benchmarks
- GoA highwater mark benchmarks

- ASCN benchmarks
- associated georeferenced photographs

The scope of work for survey and base data collection did not include the collection of LiDAR topography data. This information was provided to Matrix by the GoA to inform the Red Deer County and Markerville Flood Study.

2.1 Procedures and Methodology

A brief overview of the procedures and methodology of the various parts of the survey work is summarized below. All survey data collected for the study met the standards and accuracy described in the FHIP:

- Ground survey data have an absolute positional accuracy of ±0.05 m, at 95% confidence. Bathymetric survey data have an absolute positional accuracy of ±0.15 m.

- All survey data is reported using the appropriate local 3-Degree Transverse Mercator (3TM) zone referenced horizontally to the Canadian Spatial Reference System (CSRS; Government of Canada 2018), North American Datum of 1983, Epoch 2002 (NAD83 [CSRS], Epoch 2002). Vertically, the data is referenced to the Canadian Geodetic Vertical Datum of 1928 (CGVD28). Ellipsoidal heights will be transformed to CGVD28 orthometric heights using the HTv2.0 hybrid geoid model.

- The Alberta Survey Control Network (ASCN) was used for the survey control for the project. ASCN benchmarks were surveyed using a static Global Navigation Satellite System (GNSS) measurement at a minimum of 4 hours in duration and 2 hours of redundancy.

Summarized quality assurance and accuracy quantification documentation related to the control survey and the daily survey activities is provided in Appendix A.

2.1.1 Benchmarks

The ASCN benchmarks used for the project's survey control are listed in Table A; each benchmark was ground-surveyed by MSI. A comparison of elevations confirmed consistency between the reported and surveyed values. The MSI benchmark elevations were adopted for this project.

TABLE A Alberta Survey Control Network Benchmarks for Survey Control

ASCN Benchmark ID	3TM Coordinates (m; NAD 83 (CSRS) 3TM 112)		ASCN Elevation (m)	MSI Surveyed Elevation (m)	Difference (m)
	Easting	Northing			
46284	-173.608	5,768,838.622	905.698	905.744	0.046
104927	-9,932.260	5,769,133.450	917.131	917.125	-0.006
191734	6,233.686	5,782,167.221	910.721	910.771	0.050
229575	-19,440.749	5,759,420.320	971.620	971.602	-0.018

Benchmarks established by the GoA were also measured by MSI (Table B); several previously established benchmarks were not located and are presumed destroyed. A comparison of elevations confirmed consistency between the reported and surveyed values.

TABLE B Government of Alberta Highwater Mark Benchmarks

GoA Benchmark Name	Approximate 3TM Coordinates (m; NAD 83 (CSRS) 3TM 112)		GoA Surveyed Elevation (m)	MSI Surveyed Elevation (m)	Difference (m)
	Easting	Northing			
99-C-111	-8467.448	5772354.708	901.210	901.127	0.083
TBM-ME-82-11	-8475.917	5772367.475	901.997	902.036	-0.039

2.2 Cross-sections

Channel and overbank cross-sectional geometry, including near overbank topography and channel bathymetry, were surveyed at locations identified in the approved survey plan using a combination of conventional and echo sounding survey methods.

A combination of the Leica® GS14s GNSS Real-Time Kinematic (RTK) GPS System, and Hemisphere S621 and S321 antennas were used for the collection of most survey data. An echosounder was not used to collect the bathymetry data due to low flow depths encountered at the time of survey. The combined accuracy of points collected met the requirements listed in Section 2.1.

2.3 Hydraulic Structures

Hydraulic structure surveys were completed using standard RTK equipment. An inventory of surveyed hydraulic structures is provided in Table C, listed upstream to downstream; and the structures are shown on Figure 2. The nine bridges listed below are included in the model.

- Highway 592 and Highway 54 bridges over the Red Deer River.
- An abandoned Canadian Pacific Railway rail bridge near the downstream end of the study reach on the Red Deer River.

- Township Road 354 (also called Little Red Deer Road) and Township Road 352 bridges on the Little Red Deer River.

- Highway 54, Township Road 364A and Township Road 370 road bridges and one pedestrian bridge on the Medicine River.

TABLE C Hydraulic Structure Details

Hydraulic Structure Name	River Reach	Bounding River Stations (m)	Approximate 3TM Coordinates (m; NAD 83 (CSRS) 3TM 112)	
			Northing	Easting
Township Road 370 Bridge	Medicine River	20842 and 20804	-13169.311	5778859.541
Pedestrian River Bridge		16120 and 16114	-11848.290	5776542.007
Township Road 364A Bridge		16028 and 16007	5776463.134	-11900.210
Highway 54 Bridge		7141 and 7123	-8430.968	5772362.463
Township Road 352 Bridge	Little Red Deer River	23493 and 23465	-15915.340	5762679.630
Township Road 354 Bridge		9401 and 9387	-9638.687	5765871.399
Highway 54 Bridge	Red Deer River	25120 and 25105	1007.494	5770516.933
Highway 592 Bridge		14714 and 14696	2184.417	5778801.203
Abandoned Train Bridge		5365 and 5333	5859.080	5785913.283

2.4 Flood Control Structures

No flood control structures are located within the study reach.

3 FLOOD HYDROLOGY

3.1 Flooding History

3.1.1 Historical Floods

Several historical floods along the Red Deer River, Little Red Deer River, and Medicine River have occurred during the period of record. The largest instantaneous flood peak discharge of 1,930 m^3/s on the Red Deer River occurred in June 1915. Regulation of the river began in 1983 with the construction of the Dickson Dam. Since regulation, the largest flood discharge of 1,510 m^3/s occurred in 2005; the second largest flood discharge was 1,290 m^3/s in 2013; the third largest flood discharge was 908 m^3/s in 1990; the fourth largest flood discharge was 678 m^3/s in 1999; and the fifth largest flood discharge was 608 m^3/s in 1986.

The largest instantaneous flood peak discharge of 452 m^3/s on the Little Red Deer occurred in June 2005. This was the single largest flood event that has been recorded since this gauge was installed in 1961. The second largest flood discharge of 218 m^3/s occurred in 2013; the third largest flood discharge of 215 m^3/s occurred in 2011; the fourth largest flood discharge of 188 m^3/s occurred in 2008; and the fifth largest flood discharge of 173 m^3/s occurred in 2007.

For the Medicine River, the largest instantaneous flood peak discharge of 236 m^3/s occurred in July 1990. The second largest flood discharge of 214 m^3/s occurred in 2007; the third largest flood discharge of 1986 208 m^3/s occurred in 1986; the fourth largest flood discharge of 163 m^3/s occurred in 2020 and the fifth largest flood discharge of 160 m^3/s occurred in 1982.

3.1.2 Recent Floods

No major flood events have occurred on the Red Deer River since 2013. No major flood events have occurred on the Little Red Deer River and Medicine River since 2020.

3.1.3 Ice Jam Floods

Based on a review of historical background information, there is no indication of significant ice jam flooding through the study reach on the Red Deer River, Little Red Deer River or Medicine River. Ice jam flood analysis was not included within the project TOR.

3.2 Flood Frequency Analysis

3.2.1 Overview

The flood frequency estimates for the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750-, and 1,000-year open water floods with confidence intervals are required at key locations along the Red Deer River, Little Red Deer River and Medicine River throughout the study reach. Included as Appendix B in this report, Matrix (2023) provided detailed information on the selection of key locations along these rivers within the study area. The key locations are shown on Figure 2 and include the following:

- at the upstream study area boundary on the Red Deer River located immediately downstream of Dickson Dam
- below the confluence location of the Red Deer River and Little Red Deer River
- below the confluence location of the Red Deer River and Medicine River
- at a location about 15 km downstream of the Medicine River confluence
- at the upstream study area boundary on the Little Red Deer River
- at the upstream study area boundary on the Medicine River

3.2.2 Flood Frequency Flow Estimates

As a part of the Red Deer River and Upper Red Deer Flood Hazard Studies, Golder (2021) conducted a hydrologic assessment and prepared a hydrology assessment report, titled Open Water Flood Hydrology Assessment – Red Deer River and Upper Red Deer River Hazard Studies. This report provided the 1:2, 1:5, 1:10, 1:20, 1:35, 1:50, 1:75, 1:100, 1:200, 1:350, 1:500, 1:750, and 1:1,000 naturalized and regulated flood frequency estimates for the Red Deer River through the current study reach, as well as the flood frequency estimates for the Little Red Deer River and the Medicine River through the current study reach corresponding to these same return periods. These flood frequency estimates were used for hydraulic modelling and flood hazard mapping for the current study. Flood frequencies for natural flows or naturalized flows are typically used for flood hazard mapping. For this study, in concurrence with EPA, flood frequencies under regulated conditions were selected for hydraulic modelling and flood hazard mapping. Selection of flood frequency estimates under regulated flow conditions is consistent with the flood hazard study completed for the lower Red Deer River.

A summary of the flood frequency estimates adopted for this study is provided below in Table D.

TABLE D Flood Frequency Estimates

Return Period (Year)	At the Upstream Boundary on the Little Red Deer River (m^3/s)	At the Upstream Boundary on the Medicine River (m^3/s)	At the Upstream Boundary on Red Deer River d/s of Dickson Dam (m^3/s)	Red Deer River d/s of Little Red Deer River Confluence (m^3/s)	Red Deer River d/s of Medicine River Confluence (m^3/s)	Red Deer River Near the d/s Boundary (m^3/s)
2	58.6	87.8	185	234	290	282
5	125	156	355	402	478	457
10	184	209	512	534	619	586
20	252	267	696	676	768	720
35	316	318	811	1,130	1,270	1,200
50	360	353	966	1,330	1,480	1,390
75	414	394	1,160	1,570	1,750	1,630
100	455	424	1,310	1,760	1,950	1,820
200	563	503	1,830	2,390	2,620	2,390
350	661	571	2,250	2,900	3,150	2,830
500	728	618	2,470	3,180	3,460	3,100
750	810	673	2,920	3,700	4,000	3,500
1,000	871	714	3,250	4,110	4,420	3,810

3.2.3 Comparison to Previous Study

Naturalized flood frequency estimates were previously derived and used for hydraulic modelling and mapping in the 2007 flood hazard study (AMEC 2007). The current study utilized flood frequency estimates under regulated flow conditions. A comparison of flood frequency estimates along various reaches of the study area indicates that previously used flood frequency estimates are different than the flood frequency estimates adopted in this study. For example, Table E presents a comparison of the 100-year design flood at hydraulic model inflow locations.

TABLE E Comparison of 100-year Design Discharges at Model Inflow Locations

Location	100-year Design Discharge (m^3/s)	
	2007 Study	Current Study
At the Upstream Boundary on the Little Red Deer River	419	455
At the Upstream Boundary on the Medicine River	283	424
At the Upstream Boundary on the Red Deer River	1,450	1,310
Red Deer River d/s of Little Red Deer River Confluence	1,750	1,760
Red Deer River d/s of Medicine Deer River Confluence	1,750	1,950
Red Deer River 10 km u/s of the downstream study area boundary	1,750	1,820

The magnitudes of the 1:100-year design floods adopted in the 2007 study (AMEC 2007) and in the current study along the Red Deer River and Little Red Deer River are comparable. However, the 1:100-year design flood for the Medicine River used in the current study is about 1.5 times the design flood magnitude adopted in the previous study.

4 HYDRAULIC MODELLING

4.1 Available Data

4.1.1 Digital Terrain Model

A 0.5 m grid DTM was procured by EPA and provided to Matrix for use in flood inundation mapping. The horizontal coordinates were provided in Alberta 3TM referenced to NAD83; vertical coordinates are referenced to CGVD28.

Though the DTM has already undergone independent quality control to ensure compliance with the FHIP guidelines accuracy standards, the DTM was compared to surveyed overbank elevations to confirm that the DTM is suitable for use in cross-section extraction and flood mapping. Generally, good agreement was observed between the DTM and overbank surveyed elevations. For the majority of the comparison points (86%), the DTM derived elevations were up to 0.3 m higher than the ground survey, which indicates that the vegetation in these areas was not penetrated by the LiDAR. Larger differences in elevation (ranging from 0.3 m to 1.0 m) were observed in areas of steep surfaces such as along channel banks or roadway embankments. In our experience, these elevation differences are considered to be consistent with those encountered in similar conditions and the DTM was considered acceptable for use in flood mapping.

4.1.2 Existing Models

As mentioned in Section 1.1, a flood hazard study was undertaken in 2007 and a HEC-RAS hydraulic model was developed to calculate water surface profiles and delineate the floodway and flood fringe boundary for the 100-year flood. The developed model was provided to Matrix by EPA and was reviewed to compare and confirm hydraulic parameters selected for use in the current hydraulic model.

4.1.3 Highwater Marks

HWMs related to several flood events were collected by EPA. HWMs on the Little Red Deer River are available for 1990 and 2005 flood events. HWMs on the Red Deer River are available for 1990, 2005, and 2013 flood events. HWMs on the Medicine River are available for the 1990 and 2005 flood events. Locations of the HWMs selected for model calibration are provided on Figure 2; Table F provides a summary of the HWM data and Table G provides corresponding flows for each event.

TABLE F Highwater Mark Data and Flows

Alberta Environment and Parks Highwater Mark	River Station (m)	Observed Water Surface Elevation (m)
Medicine River – 1990 Flood Event (Q = 236 m^3/s)		
1990-MED-11B	7,141	897.57
Medicine River - 2005 Flood Event (Q = 275 m^3/s)		
2005-MED-28A	16,007	898.38
2005-MED-11A	7,123	898.12
Little Red Deer River - 1990 Flood Event (Q = 136 m^3/s)		
1990-LRD-54B	23,493	934.65
Little Red Deer River - 2005 Flood Event (Q = 542 m^3/s)		
2005-LRD-54B	23,493	935.50
Red Deer River - 1990 Flood Event (Q = 908 m^3/s)		
1990-RDR-62B	25,120	884.78
1990-RDR-35B	14,714	876.66
Red Deer River - 2005 Flood Event (Q = 1,510 m^3/s)		
2005-RDR-86	37,722	895.92
2005-RDR-82	35,419	895.09
2005-RDR-77	32,971	893.14
2005-RDR-68	27,841	889.21
2005-RDR-27	11,520	875.75
2005-RDR-13	6,100	870.70
2005-RDR-11A	5,333	869.30
Red Deer River - 2013 Flood Event (Q = 1,290 m^3/s)		
2013-RDR-86	37,722	895.46
2013-RDR-68	27,841	888.98
2013-RDR-62A	25,105	886.34
2013-RDR-35A	14,696	877.88

TABLE G Discharge Values Adopted for Model Calibration & Validation

River	Flood Event	Discharge (m^3/s)				
		RDR U/S of LRDR	RDR D/S of LRDR	RDR D/S of MED	LRDR	MED
Red Deer River	1990 (June 4, 1990)	754	890	908	136	18.4
	2005 (June 19, 2005)	1,030	1,480	1,510	452	29.6
	2013 (June 22, 2013)	1,140	1,281	1,290	145	8.8
Little Red Deer River	1990 (June 4, 1990)	754	890	908	136	18.4
	2005 (June 19, 2005)	1,030	1,480	1,510	452	29.6
Medicine River	1990 (July 6, 1990)	48.2	61	297	12.8	236
	2005 (April 6, 2005)	16.1	26	136	9.9	110

RDR Red Deer River
LRDR Little Red Deer River
MED Medicine River
U/S Upstream
D/S Downstream

4.1.4 Gauge Data and Rating Curves

As discussed in Section 1.3, WSC gauge 05CB001 (Little Red Deer River near the Mouth) is located within the study reach at the Township Road 354 bridge. Field recorded stage and discharge data for the gauge was provided by the WSC office for a period spanning January 1996 to May 2023. The maximum recorded discharge at the gauge was 452 m^3/s on the Little Red Deer occurred in June 2005, which represents a return period near the 100-year flood. The stage data was transformed to geodetic elevations based on a gauge datum elevation of 904.948 m. The rating curve based on recorded discharge-elevation data at the 05CB001 gauge is presented on Figure 3, along with the current (2021) and past rating curves (1991, 1995, 1999, 2000, 2005, and 2010) developed by the WSC.

4.2 River and Valley Features

4.2.1 General Description

The modelled reach can be divided into two generalized areas: upstream and downstream of the Red Deer River confluence with the Medicine River and Little Red Deer River. The Red Deer River is situated in a streamcut valley with a wide floodplain and a pool riffle morphology (Kellerhals et al. 1972). Upstream of the confluence, the upper Red Deer River is irregularly meandering with frequent point bars. The bed slope along the upper Red Deer River is approximately 0.00140 m/m. Downstream of the confluence, the lower Red Deer River exhibits a mild winding pattern within a frequently confined valley (Kellerhals et al.

1972). Several point bars and mid-channel islands are situated in the lower Red Deer River and the bed slope is approximately 0.0009 m/m. The Medicine River exhibits an irregular winding pattern and is occasionally confined within a streamcut valley (Kellerhals et al. 1972). The Little Red Deer River is an irregular, frequently confined channel with a pool riffle morphology and occasional islands (Kellerhals et al. 1972). The bed slope along the Little Red Deer River is approximately 0.0014 m/m.

4.2.2 Channel Characteristics

The Red Deer River has a bankfull width and depth ranging from about 45 to 180 m and 1.0 to 3.4 m, respectively. The substrate is comprised of primarily gravel; the bank material is predominantly sand and gravel. The Medicine River has a bankfull width and depth ranging from about 25 to 60 m and 1.2 to 3.1 m, respectively. The channel substrate is comprised predominantly of sand with local gravel; the banks are comprised of silt and sand with gravel deposits. The Little Red Deer River has a bankfull width and depth ranging from about 20 to 110 m and 0.4 to 2.0 m, respectively. The channel substrate is predominantly gravel; the banks are comprised of gravel overlain by silt and sand (Kellerhals et al. 1972). For most of the study reach, the banks of the Medicine River, Little Red Deer River, and Red Deer River are vegetated with typical riparian vegetation (i.e., grasses and shrubs) adjacent to interspersed areas of mixed wood trees and cultivated land.

4.2.3 Floodplain Characteristics

In the Medicine River, the floodplain is mostly cultivated terrain with some forested areas. The Markerville townsite is located on the left floodplain immediately upstream of the Township Road 364A bridge. Several properties are located within the floodplains of the Medicine River. In the Little Red Deer River, the floodplain is mostly cultivated and partially forested. Several residences in the upper Little Red Deer River are located within the floodplain. In the Red Deer River, the floodplains are wide and open and comprise partly cultivated and partly forested areas; a campground and several properties and buildings are situated in the lower Red Deer River floodplains.

4.2.4 Anthropogenic Features

A total of nine bridges are located within the study reach, including one rail bridge, seven vehicle bridges, and one pedestrian bridge (refer to Table 1 for details). Dickson Dam is located at the upstream extent of the Red Deer River study reach. Though the bridge embankments and decks are situated sufficiently high so as not to be overtopped during the flood events, low-lying road segments in the overbanks are overtopped at several bridge locations (discussed further in Section 5.3.1).

4.3 Model Construction

4.3.1 Methodology

The HEC-RAS hydraulic modelling software ((version 6.3.1; USACE 2022) was used to simulate flood levels through the model reach for flood events associated with various return periods ranging from the 2-year to the 1,000-year flood. HEC-RAS is a hydraulic model that solves 1D or 2D flow equations of conservation of mass and conservation of momentum representing the physical laws governing open channel flows. Specific capabilities include 1) calculation of subcritical, super critical and mixed flow conditions; 2) modelling of effect of obstructions and structures such as bridges, culverts, and flood control structures such as weirs; and 3) modelling of effect of changes in channel geometry due to encroachments, channelization, and flood control dikes or levees. For this project, a 1D HEC-RAS model was developed to simulate flow conditions through the study reach. HEC-GeoRas in ArcGIS Desktop was used to translate merged topographic survey and LiDAR datasets into geometry files to be imported to HEC-RAS.

The downstream model boundary on the Red Deer River was extended over 3 km downstream of the study reach boundary so that any uncertainty in the downstream boundary conditions does not impact simulated water levels within the study reach.

4.3.2 Geometric Base Data

4.3.2.1 Cross-section Data

A total of 259 cross-sections were identified for surveying, of which 77 are located on the Little Red Deer River, 70 are located on the Medicine River, and 112 are located on the Red Deer River. Cross-sections were extended into the floodplain based on the DTM provided to Matrix by EPA.

The combined channel and floodplain data often amounted to more than 500 points per cross-section. The *minimize area change* point routine in HEC-RAS was used to filter the cross-section data; final sections were examined to ensure that they retained surveyed channel data and appropriately represented the channel geometry.

Ineffective areas were applied at select cross sections to reflect offline ponding areas that do not actively convey flow. In addition, ineffective areas were placed around bridge crossings using the approach outlined in the HEC-RAS Hydraulic Reference Manual (USACE 2022). Levees were also applied to select cross sections to prevent flooding from extending into overbank locations that cannot be inundated from upstream or downstream modelled cross sections.

4.3.2.2 Bridge Data

Nine bridges throughout the study reaches were included in the hydraulic model (Table 1). Model input data for bridges was obtained from survey data collected by MSI in October 2022.

Contraction and expansion coefficients of 0.1 and 0.3, respectively, were adopted for gradual transitions through the study reach. These coefficients were increased to 0.3 and 0.5 around all bridge crossings, at which abrupt changes in the effective flow area are encountered.

4.3.2.3 Flood Control Structures

No flood control structures are located within the study area.

4.3.3 Calibration

4.3.3.1 Methodology

Model calibration is an iterative process conducted to ensure that the model is providing representative flow behaviour based on comparison of simulated and observed water surface elevations. Though Manning roughness is the primary calibration parameter, adjustments to the ineffective flow area and expansion/contraction coefficients may also be required. Ineffective flow areas were initially defined based on visual inspection of the DTM and were adjusted slightly during the calibration process. Though sufficient adjustment to these parameters may be feasible to match observed water levels very closely, it is important to maintain gradual variations in roughness throughout the study reach and assign reasonable roughness values in the model for the given conditions.

The hydraulic model was calibrated and validated against surveyed HWMs and the corresponding peak discharge for major events that occurred on the Red Deer River, Little Red Deer River, and Medicine River. The source of data used for the assessment were HWMs obtained from EPA. HWMs observed during the 1990, 2005, and 2013 flood events were selected to calibrate the HEC-RAS model, as detailed in Table F.

Hydraulic modelling of the lower Red Deer River was recently undertaken by EPA, for which model results were provided to Matrix. Given that both models have an overlapping boundary, a rating curve generated from the lower Red Deer River model was adopted as the downstream boundary condition for the current model. This approach provides consistent water surface profiles for the overlapping areas simulated in both studies. A channel roughness of 0.035 on the Red Deer, 0.03 on the Little Red Deer River, and 0.023 on the Medicine River provided the best overall fit to the observed HWMs for all discharges. Overbank roughness was selected based on aerial imagery and photographs collected during the survey based on guidance provided in Chow (1959).

4.3.3.2 Calibration Results

Figures 4 (Medicine River), Figure 5 (Little Red Deer River), and Figure 6 (lower Red Deer River) provide comparisons of the simulated water surface profiles and observed HWMs for the calibration and validation model runs. The simulated and observed water surface elevations are summarized below and in Table 2.

Medicine River

For the 1990 event on the Medicine River, the difference between observed and simulated water level at RS 7141 (Highway 54 bridge) was 0.51 m. For the 2005 event, the difference in water level at RS 16007 and 7123 was 0.59 and -1.16 m, respectively.

Little Red Deer River

For the 1990 event on the Little Red Deer River, the difference in water level at RS 23493 (Township Road 352 bridge) was -0.97 m. For the 2005 event, the difference in water level at RS 23493 was -0.71 m, respectively.

Red Deer River

For the 1990 event on the Red Deer River, the difference in water level at RS 25120 and 14714 was 0.55 m and 0.13 m, respectively. Several HWMs were available below the confluence on the Red Deer River for both the 2005 and 2013 events. For the 2005 event, the difference in water level ranged from -0.77 m to 0.92 m; for the 2013 event, the difference in water levels ranged from -0.92 m to 1.09 m.

4.3.4 Flood Frequency Profiles

Figures 7, 8, and 9 provide the simulated water surface profiles for the 2-year to 1,000-year flood discharges on the Medicine River, Little Red Deer River, and Red Deer River, respectively. Tables 3A, 3B, and 3C provide the water surface elevations at each model cross-section for the range of flood events simulated on the Medicine River, Little Red Deer River, and Red Deer River, respectively. The Little Red Deer River gauging station (05CB001) rating curve, including hydraulic model outputs for the range of modelled discharges, is presented on Figure 3.

4.3.5 Model Sensitivity

Sensitivity analyses were conducted to evaluate the impact of estimated model parameters on simulated water levels for the 100-year design flood and included the following:

- Variation of the downstream water level (± 0.25 m and 0.5 m)
- Variation of the Manning roughness values (± 20%)

Figure 10 and Table 4 provides a comparison of the simulated water surface profiles for the variable downstream boundary conditions (i.e., initial rating curve elevations ±0.25 m and ±0.5 m). The deviation in water surface elevation from the calibrated 1:100-year flood profile diminishes to less than 0.05 m by RS 2505 (RDR006; downstream mapping boundary) on the Red Deer River.

The channel roughness adopted for the calibrated profile on the Red Deer River is 0.035; the alternate channel roughness values investigated here are 0.028 and 0.042. The channel roughness adopted for the calibrated profile on the Little Red Deer River is 0.03; the alternate channel roughness values investigatedare 0.024 and 0.036. The channel roughness adopted for the calibrated profile on the Medicine River is 0.023; the alternate channel roughness values investigated are 0.018 and 0.028. Figures 11 (Medicine River), 12 (Little Red Deer River), and 13 (Red Deer River) and Tables 5A/5B/5C provide a comparison of the simulated water surface profiles for the variable channel roughness values.

For the Medicine River, the average and maximum differences in water surface elevations are -0.27 m and 0.44 m, respectively, for the lower value of n = 0.018; these differences are 0.19 m and 0.30 m for the higher value of n = 0.028. For the Little Red Deer River, the average and maximum differences in water surface elevations are -0.13 m and -0.41 m, respectively, for the lower value of n = 0.024; these differences are 0.11 m and 0.34 m for the higher value of n = 0.036. For the Red Deer River, the average and maximum differences in water surface elevations as compared to the calibrated profile are -0.33 m and -0.66 m, respectively, for the lower value of n = 0.028; these differences are 0.25 m and 0.55 m for the higher value of n = 0.042.

Figures 14 (Medicine River), 15 (Little Red Deer River), and 16 (Red Deer River), and Tables 6A/6B/6C provide a comparison of the simulated water surface profiles for the variable overbank roughness conditions (±20%). For the Red Deer River, the average and maximum differences in water surface elevations as compared to the calibrated profile are -0.14 m and -0.29 m, respectively, for the lowered overbank roughness values while these differences are 0.11 m and 0.23 m for the raised overbank roughness values. For the Little Red Deer River, the average and maximum differences in water surface elevation is -0.11 m and -0.22 m, respectively, for the lowered overbank roughness values while these differences are 0.10 m and 0.20 m, respectively, for the raised overbank roughness values. For the Medicine River, the average and maximum differences in water surface elevation is -0.13 m and -0.18 m, respectively, for the lowered overbank roughness values while these differences are 0.10 m and 0.14 m, respectively, for the raised overbank roughness values. The variations reported herein are considered to be within the expected modelling accuracy.

It is concluded that the hydraulic model based on the assigned overbank and channel roughness values and downstream boundary conditions can be confidently used for developing flood inundation and flood hazard maps for the study reach.

5 FLOOD INUNDATION MAPS

5.1 Methodology

The flood surface profiles for all open water inundation scenarios modelled along the Medicine River, Little Red Deer River, and Red Deer River were interpolated and translated to inundation boundaries through ArcGIS Desktop 10.8.2. For each of the 13 flood inundation scenarios, an initial water surface elevation was generated using the automated triangulated irregular network (TIN) interpolation tools based on results from the hydraulic model using the 3D Analyst extension. The resulting water surface elevation TINs were then translated into a grid format adhering to raster resolution and snapping environments in ArcGIS to ensure all grid outputs are correctly aligned with the input terrain data. The DTM was then subtracted from the interpolated water surface elevation grid to calculate the flood depth grid. The DTM product compared against the interpolated water surface does not have the bathymetry of the channel represented in the topographic surface. When LiDAR is acquired, it can only return the surface of water and not the elevation of the bottom of the channel. As such, the flood depth values calculated in the channel will not be representative of the full flood depth. From the flood depth grid, a first estimate of the inundation extent grid was defined by identifying cells greater than zero. Cells less than zero are indicative of the topography being higher than the modelled water surface elevation. By reclassifying the flood depth surface, the inundation extent grid for a given inundation scenario were delineated with the same resolution as the original DTM. The inundation grid extent was then converted into a polygon, where it was run through a smoothing algorithm (PAEK; 15 m) and a polygon/polygon hole filter (<100 sq. m holes or polygons are removed unless otherwise flagged [see Section 5.3]).

Manual adjustments to the flood profile to accommodate backwater flood and overtopping are described in Section 5.2.

5.2 Water Surface Elevation TIN Modifications

The initial inundation extent was inspected to identify areas of backwater flooding where manual TIN modifications are required to modify water surface elevation where level pooling is expected. To address these areas, the TIN water surface elevation was manipulated through the addition of breaklines and areas of constant water level elevation. In areas where there is a single overtopping point that was otherwise hydraulically confined (e.g., inundation spills over a road at a single location and pools behind it), the TIN surface was adjusted to a level surface in the area behind the road based on the elevation of that overtopping point. Areas where there are multiple overtopping points (e.g., the inundation spills at one point, continues flowing downgrade, and spills again to reconnect with the main channel) were adjusted so that the gradient between the upstream and downstream overtopping points was equal to the gradient in the main channel. The elevation at the overtopping point was based on the interpolated water level surface at upstream and downstream overtopping points. Table H describes where and what type of manual TIN modifications were applied.

TABLE H TIN Profile Modification Summary Table

Location	Description	Side of Channel	Inundation Scenario	Overtopping Point
Medicine River				
RS 21071 to RS 20098	At Township Road 370	Left	5 to 50-yr	Single
RS 18858 to RS 17962	West of Range Road 21	Left	20-Year	Single
RS 17038 to RS 16547	West of Range Road 21	Left	20-Year	Single
RS 6351 to RS 5447	East of Range Road 20	Right	2-Year	Single
RS 1690 to RS 1242	Northeast of Range Road 15	Right	2-Year	Single
RS 1690 to RS 734	Northeast of Range Road 15	Right	2-Year	Single
Little Red Deer River				
RS 32010 to RS 30830	East of Range Road 25	Left	50 to 1000-yr	Single
RS 30830 to RS 28995	East of Range Road 25	Left	5 to 35-yr	Single
RS 26659 to RS 25747	East of Range Road 24	Right	20-yr	Single
RS 23925 to RS 23502	South of Township Road 352	Right	750 to 1000-yr	Single
RS 23925 to RS 22561	At Township Road 352	Right	20 to 500-yr	Single
RS 22561 to RS 20040	North of Township Road 352	Right	2 to 350-yr	Single
RS 20040 to RS 19385	South of Range Road 23	Left	2-yr	Single
RS 16189 to RS 15715	West of Range Road 21	Right	5-yr	Single
RS 15233 to RS 13896	North of Township Road 352	Right	2 to 200-yr	Single
RS 5958 to RS 5484	East of Range Road 21	Left	5-yr	Single
RS 4581 to RS 3863	East of Range Road 21	Left	5-yr	Single
RS 2750 to RS 2103	North of Township Road 360	Right	5-yr	Single
RS 2103 to RS 1017	Southeast of Range Road 20	Left	2-yr	Single
Red Deer River				
RS: 47648 to RS: 46832	East of Range Road 23	Right	2-yr	Single
RS: 46572 to RS: 45657	South of Range Road 22	Right	2 to 10-yr	Single
RS: 43714 to RS: 43223	South of Highway 54	Right	2-yr	Single
RS: 40862 to Confluence	South of Highway 54	Left	2 to 100-yr	Single
RS: 40862 to RS: 40190	South of Range Road 20	Right	2-yr	Single
RS: 40190 to RS: 38713	East of Range Road 20	Left	2-yr	Single
RS: 24523 to RS: 23352	East of Highway 54	Left	2-yr	Single
RS: 17391 to RS: 16169	East of Range Road 285	Left	35-yr	Single
RS: 13529 to RS: 11520	Northeast of Range Road 284	Right	20 to 75-yr	Single

5.3 Flood Inundation Areas

Open water flood inundation maps for the 2-year to 1,000-year flood events are presented in Appendix C.

5.3.1 Key Observations

A summary of key observations from the open water inundation maps is presented below:

- Several residences along both banks of the Little Red Deer River are impacted by flooding at the 35-year flood and higher (mapsheets 1 and 2). Additional residences in the vicinity (mapsheet 3) begin to be impacted at the 100-year flood.

- A residence along the right bank of the Medicine River near River Road is impacted at the 10-year flood and higher (mapsheet 11). Several additional residences along both banks of the Medicine River are impacted at the 20-year flood and higher (mapsheet 10).

- A residence and access road located on the left bank of the Red Deer River is impacted at the 10-year flood and higher (mapsheet 8). Two residences along the left (south of Highway 54) and right bank (near Range Road 15) of the Medicine River are impacted at the 10-year flood and higher (mapsheet 16).

- A campground south of Highway 592 along the right bank of the Red Deer River is impacted at the 20-year flood and higher (mapsheet 23). Another property north of the highway is impacted at the 35-year flood and higher.

- A residence along the right bank of the Medicine River near Range Road 20 is impacted at the 35-year flood and higher (mapsheet 15). A residence along the right bank of the Red Deer River near 37216 C&E Trail is impacted at the 35-year flood and higher (mapsheet 25).

- A residence along the left bank of the Medicine River is impacted at the 50-year flood and higher (mapsheet 13). Access to a residence on the right bank of the Red Deer River on Range Road 284 is impacted at the 50-year flood and higher (mapsheet 24).

- A residence on the right bank of the Red Deer River is impacted at the 200-year flood and higher. Additional residences along the Red Deer River are impacted at the 350-year and higher: near Township Road 355A (mapsheet 19); and near Township Road 374 (mapsheet 26) at the 500-year flood and higher.

Flood impacts to bridges are summarized below:

- Medicine River
    - ✦ Township Road 370 Bridge – road segment in left overbank overtopped at the 500-year flood and higher
    - ✦ Pedestrian Bridge – road segment in right overbank overtopped at the 100-year flood and higher
    - ✦ Township Road 364A Bridge – bridge/road not overtopped
    - ✦ Highway 54 Bridge – bridge/road not overtopped
    - Little Red Deer River
    - ✦ Township Road 352 Bridge – road segment in right overbank overtopped at the 20-year flood and higher
    - ✦ Township Road 354 Bridge – bridge/road not overtopped
    - Red Deer River
    - ✦ Highway 54 Bridge – bridge/road not overtopped
    - ✦ Township Road 370 Bridge – road segment in right overbank overtopped at the 500-year flood and higher
    - ✦ Abandoned Rail Bridge – bridge not overtopped

5.3.2 Flood Polygon Discontinuities

Flood polygon discontinuities refer to those areas that are topographically isolated from the directly inundated areas but hydraulically connected via a hydraulic structure such as a culvert.

Several culverts affecting otherwise isolated areas were identified throughout the study area based on a review of aerial imagery; note that these culverts were not surveyed or field verified. All of these identified culverts are shown on the open water flood inundation maps and their associated isolated areas were included in the inundation mapping. There are potentially other culverts that were not identified during aerial imagery review that may result in inundation of isolated areas that are not shown on the maps. However, these areas were removed from the maps because hydraulic connection could not be confirmed, or because inundation within these areas would not meaningfully affect nearby landowners or stakeholders.

6 FLOODWAY DETERMINATION

6.1 Design Flood Selection

Flood hazard identification involves delineation of floodway and flood fringe zones for a specified design flood. As per the FHIP guidelines (AEP 2022), the 100-year flood was adopted as the open water design flood and is defined based on flood statistics available at the time of the study. A description of key terms from the FHIP guidelines (AEP 2022), incorporating technical changes as indicated in the TOR (EPA 2022) regarding how floodways are mapped in Alberta is provided in sections below.

6.2 Floodway and Flood Fringe Terminology

Flood hazard mapping identifies the area flooded during the design flood event and is typically divided into floodway and fringe zones. Flood hazard maps can also show additional flood hazard information including areas of relatively high hazard within the flood fringe and incremental areas at risk for more severe floods, like the 200-year and 500-year floods. Flood hazard mapping is typically used for long-term flood hazard area management and land use planning.

- Floodway: when a floodway is first defined on a flood hazard map, it typically represents the area of highest flood hazards where flows are deepest, fastest, and most destructive during the 100-year design flood. The floodway generally includes the main channel of a stream and a portion of the adjacent overbank area. Previously mapped floodways do not typically become larger when a flood hazard map is updated, even if the flood hazard area gets larger or design flood levels get higher.

- Flood fringe: the flood fringe is the portion of the flood hazard area outside of the floodway. The flood fringe typically represents areas with shallower, slower, and less destructive flooding during the 100-year design flood. However, areas with deep or fast-moving water may also be identified as high hazard flood fringe within the flood fringe. Areas at risk behind flood berms may also be mapped as protected flood fringe areas.

- Design flood levels: design flood levels are the computed water levels associated with the design flood.

6.3 Flood Hazard Identification

6.3.1 Floodway Determination Criteria

The computed water levels associated with the design flood are used as the design flood levels in flood hazard identification and mapping process. Some important factors considered in floodway determination criteria include the following:

- In areas being mapped for the first time, the floodway typically represents the area of highest hazard where flows are deepest, fastest, and most destructive during the design flood. The following criteria, based on those described in current FHIP guidelines, are used to delineate the floodway in such cases:
  - Areas in which the depth of water exceeds 1 m, or the flow velocities are greater than 1 m/s, shall be part of the floodway. Exceptions may be made for small backwater areas, ineffective flow areas, and to support creation of a hydraulically smooth floodway.
  - In no case should the floodway extend into the main channel area.
  - For reaches of supercritical flow, the floodway boundary should correspond to the edge of inundation or the main channel, whichever is larger.
- When a flood hazard map is updated, an existing floodway will not change in most circumstances. Exceptions to this would be:
  - A floodway could get larger if main channel shifts outside of a previously defined floodway.
  - A floodway could get smaller if an area of previously defined floodway is no longer flooded by the design flood.
- Areas of deeper or faster moving water outside of the floodway are identified as high hazard flood fringe. These high hazard flood fringe zones are identified in all areas, whether they are newly mapped or have an existing floodway. The depth and velocity criteria used to define high hazard flood fringe zones are aligned with the 1 m depth and 1 m/s velocity floodway determination criteria for newly-mapped areas.
- All areas protected by dedicated flood berms that are not overtopped during the design flood are excluded from the floodway. Areas behind flood berms will still be mapped as flooded if they are overtopped, but areas at risk of flooding behind dedicated flood berms that are not overtopped will be mapped as a protected flood fringe zone.

Flood hazard maps were previously developed for the full extent of the Red Deer River and partial extents of the Little Red Deer and Medicine Rivers. No flood control structures are located within the study reach. Floodway stations were selected using the above-mentioned factors and considering geomorphic and landscape features under the design flood levels along the Medicine River (Table 7A), Little Red Deer River (Table 7B) and Red Deer River (Table 7C).

6.3.2 Design Flood Profile

Tables 8A, 8B, and 8C list the water surface elevations computed for the 100-year design floods on the Medicine River, Little Red Deer River, and Red Deer River, respectively. The water surface profiles for the Medicine River, Little Red Deer River and Red Deer River are plotted on Figures 17, 18, and 19, respectively.

6.3.3 Floodway Criteria Maps

Floodway criteria maps are a tool for determining floodway and flood fringe extents for the design flood including boundaries of high hazard flood fringe and protected flood fringe areas. The Open Water Floodway Criteria Maps (Sheet 1 to Sheet 16, Appendix D) provided in the Maps and Drawings section of this report show:

- inundation extents of the 100-year open water design flood
- areas where the depth of water is 1 m or greater and the corresponding 1 m depth contour
- the portions of each cross-section where the computed velocity is 1 m/s or greater
- the proposed floodway boundary, as well as the floodway stations corresponding to the floodway determination criteria
- isolated areas of non-flooded, high ground (i.e., “dry” areas) within the design flood extent
- the location and extent of all cross-sections used in the HEC-RAS model
- additional information concerning flood criteria maps are provided in the section below

6.3.4 Flood Hazard Maps

Flood hazard maps for the 100-year design flood are provided in Appendix E. The floodway is primarily governed by the 1 m depth contour for the study reach. Manual adjustments to the floodway boundary were made in some locations in consultation with AEP to maintain a hydraulically smooth floodway between cross-sections; this resulted in some areas with flow depths greater than 1 m being classified as flood fringe. These areas are categorized as high hazard flood fringe zone.

6.3.4.1 Areas within the Floodway

Medicine River

Along the upper Medicine River (i.e., upstream of Township Road 370), the floodway generally encompasses the entire 100-year inundation area with minimal flood fringe. No historic floodway has been defined along this upper Medicine River reach. The floodway varies in width from about 33 m to

1,180 m with depth and no viable flood fringe as the governing criteria. Between Township Roads 370 and 364A, depth remains the governing floodway criteria though more flood fringe areas are noted in low-lying areas and upstream/downstream of the road crossings. Historic floodway is defined in the lower Medicine River, from RS 16547 downstream to the confluence; the current floodway is coincident with the historic floodway through this reach. Floodplain impacted by the floodway generally consists of cultivated or forested land; one residence (mapsheet 11) is situated within the floodway extents on the left bank of the Medicine River.

Little Red Deer River

Along the upper Little Red Deer River (i.e., upstream of RS 12500), the floodway varies in width from 30 m to 1,265 m with depth, velocity and no viable flood fringe as the governing criteria. No historic floodway has been defined along this upper Little Red Deer River reach and several flood fringe areas are observed in low-lying areas, through inside channel bends and upstream/downstream of bisecting roads. Historic floodway is defined in the lower Little Red Deer River, from RS 12500 downstream to the confluence; the current floodway is coincident with the historic floodway through this reach. Floodplain impacted by the floodway generally consists of cultivated or forested land; several residences and outbuildings are situated within the floodway along the Little Red Deer River (mapsheets 1 and 5).

Red Deer River

Along the Red Deer River, the floodway generally encompasses the entire 100-year inundation area with minimal flood fringe. The floodway generally inundates the floodplains and varies in width from about 105 up to 1,620 m (nearing the confluence). Historic floodway is available along the entire Red Deer River reach. Generally, the current floodway is coincident with the historic floodway along the Red Deer River, with a few exceptions:

- Right bank near RS 46572 (mapsheet 8)
- Left and right bank approaching the confluence (RS 44198 and RS 43223 to 40862; mapsheet 9)
- Right bank near RS 19659 (mapsheet 22)
- Left bank near RS 13127 (mapsheet 24)

Floodplain impacted by the floodway generally consists of cultivated or forested land, though several residences and outbuildings are situated within the floodway along the Red Deer River (mapsheets 8, 16, 23, 24, and 25). Further, there appears to be a campground situated within the floodway on the right bank of the Red Deer River (mapsheet 23).

6.3.4.2 Areas within the Flood Fringe

Medicine River

As noted above, several flood fringe areas are located in low-lying areas and upstream/downstream of road crossings. Areas of high hazard flood fringe (>1 m depth) are present along the Medicine River at the following locations:

- Right bank near RS 32001 (mapsheet 11)
- Left bank near RS 25653 and 25456 (mapsheet 12)
- Left bank, upstream and downstream of Township Road 370 (mapsheet 12)
- Left bank near RS 18393 (mapsheet 13)
- Left and right bank, upstream and downstream of Township Road 364A, near the Hamlet of Markerville (mapsheet 13)
- Left and right bank, upstream and downstream of Highway 54 (mapsheet 15 and 16)
- Throughout the lower Medicine River (mapsheet 14, 15 and 16)

Little Red Deer River

Several flood fringe areas are observed through low-lying historic meander scars, inside channel bends and upstream/downstream of road crossings. Areas of high hazard flood fringe (>1 m depth and > 1 m/s velocity) are present along the Little Red Deer River at the following locations:

- Throughout the upper Little Red Deer River (mapsheets 1 to 4)
- Right bank near RS 7070 (mapsheet 6)

Red Deer River

There is minimal flood fringe located along the Red Deer River, with the exception of some low-lying areas or through inside channel bends. Areas of high hazard flood fringe (>1 m depth) are present along the Red Deer River at the following locations:

- Right bank near RS 49602 (mapsheet 8)
- Left bank near the Medicine River confluence (mapsheet 10)
- Throughout the lower Red Deer River (mapsheets 17 to 27)

7 POTENTIAL CLIMATE CHANGE IMPACTS

Climate change projections for Alberta generally predict an increase in annual temperatures and precipitation as well as increased intensity and frequency of extreme events (Alberta WaterPortal 2018). Potential impacts on the Red Deer River basin includes higher spring flows and lower summer, fall and winter flows (Alberta WaterPortal 2018). Golder (2021) provided a qualitative interpretation of climate and hydrologic projections for the study area. Based on a review of flow data recorded from 1912 to 2016 on the Red Deer River, the magnitude of annual peak flows in the basin are not increasing with time and the timing of annual peak flows is similar to historic trends (Golder 2021).

In an effort to quantify potential impacts, the 100-year flood magnitude was increased by 10% and 20% with resulting water levels compared to the baseline elevations. Table I provides a summary of the average increase in water level (as compared to baseline water levels) in the Medicine River, Little Red Deer River, and Red Deer River for an increase of 10% and 20% to the 100-year flood discharge. Based on these results, it would be reasonable to apply a freeboard 0.5 m to simulated design water levels when attempting to account for climate change concerns. This freeboard has not been incorporated in the flood mapping presented herein.

TABLE I Computed Water Levels for Potential Climate Change Impacts

	Water Level Difference (m)[1]	
	10% Increase	20% Increase
Medicine River	**Q = 466 m^3/s**	**Q = 509 m^3/s**
Average	0.15	0.32
Little Red Deer River	**Q = 501 m^3/s**	**Q = 546 m^3/s**
Average	0.11	0.21
Red Deer River (RS 50219 to 37722)	**Q = 1,441 m^3/s**	**Q = 1,572 m^3/s**
Average	0.13	0.26
Red Deer River (RS 37722 to 35419)	**Q = 1,936 m^3/s**	**Q = 2,112 m^3/s**
Average	0.23	0.46
Red Deer River (RS 35419 to 18542)	**Q = 2,145 m^3/s**	**Q = 2,340 m^3/s**
Average	0.26	0.51
Red Deer River (RS 18542 to 0)	**Q = 2,002 m^3/s**	**Q = 2,184 m^3/s**
Average	0.22	0.48

1. As compared to baseline water levels.

8 CONCLUSIONS

Flow estimates for the 2-year to 1,000-year flood events on the Red Deer River, Little Red Deer River, and Medicine River were obtained from Golder (2021) and used for hydraulic modelling.

The hydraulic model and resulting map products were constructed using LiDAR data provided by GoA and surveyed cross-sections, and hydraulic structure data collected by MSI under Matrix's supervision. All surveyed data was tied together using ASCN benchmarks that were surveyed independently during the various data collection phases. The hydraulic model was calibrated using surveyed HWMs collected during the 1990, 2005, and 2013 flood events.

A summary of major conclusions from the open water inundation maps (Appendix C) for the 2-year to 1,000-year flood events is presented below:

- Several residences along both banks of the Little Red Deer River are impacted by flooding at the 35-year flood and higher (mapsheets 1 and 2). Additional residences in the vicinity (mapsheet 3) begin to be impacted at the 100-year flood.

- A residence along the right bank of the Medicine River near River Road is impacted at the 10-year flood and higher (mapsheet 11). Several additional residences along both banks of the Medicine River are impacted at the 20-year flood and higher (mapsheet 10).

- A residence and access road located on the left bank of the Red Deer River is impacted at the 10-year flood and higher (mapsheet 8). Two residences along the left (south of Highway 54) and right bank (near Range Road 15) of the Medicine River are impacted at the 10-year flood and higher (mapsheet 16).

- A campground south of Highway 592 along the right bank of the Red Deer River is impacted at the 20-year flood and higher (mapsheet 23). Another property north of the highway is impacted at the 35-year flood and higher.

- A residence along the right bank of the Medicine River near Range Road 20 is impacted at the 35-year flood and higher (mapsheet 15). A residence along the right bank of the Red Deer River near 37216 C&E Trail is impacted at the 35-year flood and higher (mapsheet 25).

- A residence along the left bank of the Medicine River is impacted at the 50-year flood and higher (mapsheet 13). Access to a residence on the right bank of the Red Deer River on Range Road 284 is impacted at the 50-year flood and higher (mapsheet 24).

- A residence on the right bank of the Red Deer River is impacted at the 200-year flood and higher. Additional residences along the Red Deer River are impacted at the 350-year and higher: near Township Road 355A (mapsheet 19); and near Township Road 374 (mapsheet 26) at the 500-year flood and higher.

Flood impacts to bridges are summarized below:

- Medicine River
  - Township Road 370 Bridge – road segment in left overbank overtopped at the 500-year flood and higher
  - Pedestrian Bridge – road segment in right overbank overtopped at the 100-year flood and higher
  - Township Road 364A Bridge – bridge/road not overtopped
  - Highway 54 Bridge – bridge/road not overtopped

- Little Red Deer River
  - Township Road 352 Bridge – road segment in right overbank overtopped at the 20-year flood and higher
  - Township Road 354 Bridge – bridge/road not overtopped

- Red Deer River
  - Highway 54 Bridge – bridge/road not overtopped
  - Township Road 370 Bridge – road segment in right overbank overtopped at the 500-year flood and higher
  - Abandoned Rail Bridge – bridge not overtopped

The 1:100-year design flood profile was used in preparing flood hazard maps for the study area. Floodway criteria maps are provided in Appendix D and design flood hazard maps are provided in Appendix E. Along the upper Medicine River, the floodway generally encompasses the entire 100-year inundation area with minimal flood fringe. The governing floodway criteria along the upper Medicine River is the depth criteria. No historic floodway has been defined along this upper Medicine River reach; in the lower Medicine River, the current floodway is coincident with the historic floodway. Several flood fringe areas are located in low-lying areas and upstream/downstream of road crossings along the Medicine River; areas of high hazard flood fringe (>1 m depth) are present at several locations.

Along the upper Little Red Deer River, the governing floodway criteria is depth. No historic floodway has been defined along the upper Little Red Deer River reach and several flood fringe areas are observed in low-lying areas, through inside channel bends and upstream/downstream of bisecting roads. Historic floodway is defined in the lower Little Red Deer River; in this area, the current floodway is coincident with the historic floodway. Several flood fringe areas are observed through low-lying historic meander scars, inside channel bends and upstream/downstream of road crossings. Areas of high hazard flood fringe (>1 m depth and > 1 m/s velocity) are present along the Little Red Deer River at several locations.

Along the Red Deer River, the floodway generally encompasses the entire 100-year inundation area with minimal flood fringe located in low-lying areas and through inside channel bends. Historic floodway is available along the entire Red Deer River reach. Generally, the current floodway is coincident with the historic floodway along the Red Deer River, with a few exceptions. Areas of high hazard flood fringe (>1 m depth) are present along the Red Deer River at several locations.

9 REFERENCES

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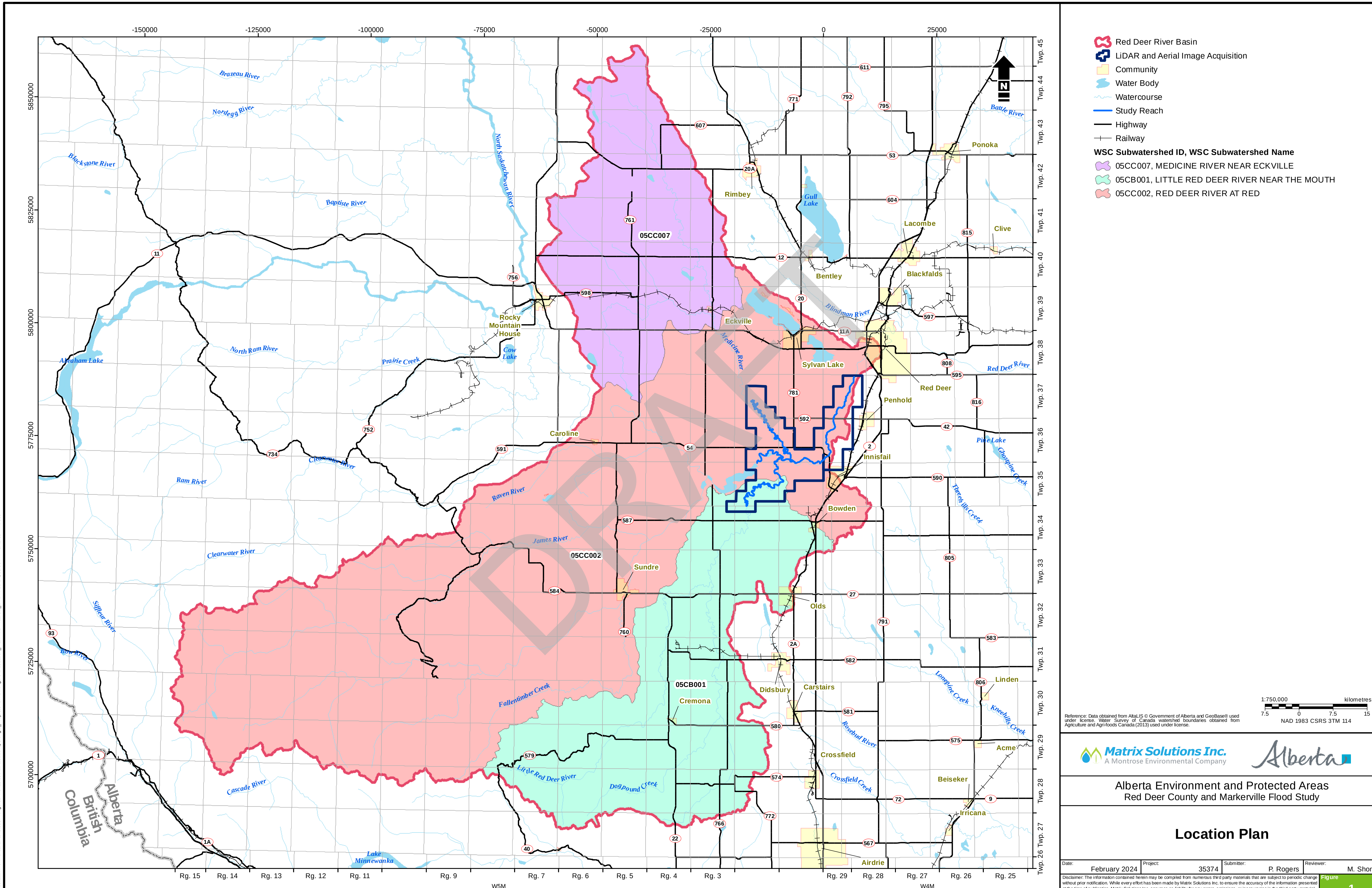
Red Deer River Basin
LiDAR and Aerial Image Acquisition
Community
Water Body
Watercourse
Study Reach
Highway
Railway
WSC Subwatershed ID, WSC Subwatershed Name
05CC007, MEDICINE RIVER NEAR ECKVILLE
05CB001, LITTLE RED DEER RIVER NEAR THE MOUTH
05CC002, RED DEER RIVER AT RED
05CC007
05CC002
05CB001
DRAFT
N
1:750,000
kilometres
7.5
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7.5
15
NAD 1983 CSRS 3TM 114
Reference: Data obtained from AltaLIS © Government of Alberta and GeoBase® used under license. Water Survey of Canada watershed boundaries obtained from Agriculture and Agri-foods Canada (2013) used under license.
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Alberta
Alberta Environment and Protected Areas
Red Deer County and Markerville Flood Study
Location Plan
Date: February 2024
Project: 35374
Submitter: P. Rogers
Reviewer: M. Shome
Figure 1
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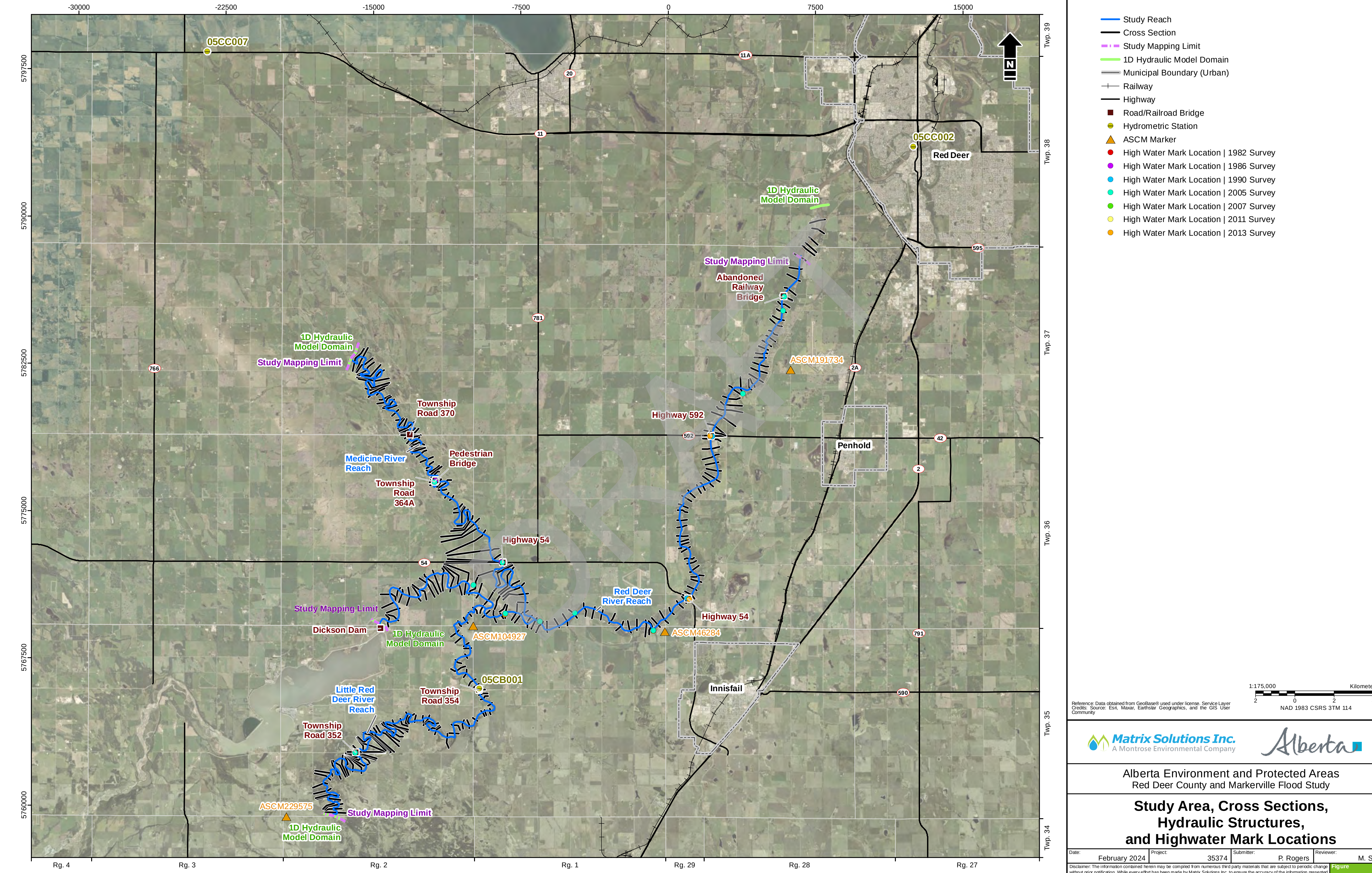
W4M
Ponoka
Rimbey
Gull Lake
Lacombe
Clive
Bentley
Blackfalds
Eckville
Rocky Mountain House
Cow Lake
Sylvan Lake
Red Deer
Penhold
Caroline
Innisfail
Pine Lake
Bowden
Sundre
Olds
Didsbury
Carstairs
Cremona
Linden
Crossfield
Acme
Beiseker
Irricana
Airdrie
Abraham Lake
Lake Minnewanka
Alberta
British Columbia
Brazeau River
Nordegg River
Blackstone River
Baptiste River
North Saskatchewan River
North Ram River
Prairie Creek
Ram River
Clearwater River
Raven River
James River
Siffleur River
Bow River
Fallentimber Creek
Cascade River
Little Red Deer River
Dogpound Creek
Medicine River
Blindman River
Red Deer River
Battle River
Ghostpine Creek
Threehills Creek
Lonepine Creek
Kneehills Creek
Rosebud River
Crossfield Creek



Reference: Data obtained from GeoBase® used under license. Service Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

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Alberta Environment and Protected Areas
Red Deer County and Markerville Flood Study

Study Area, Cross Sections, Hydraulic Structures, and Highwater Mark Locations

Date: February 2024	Project: 35374	Submitter: P. Rogers	Reviewer: M. Shome

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Figure 2

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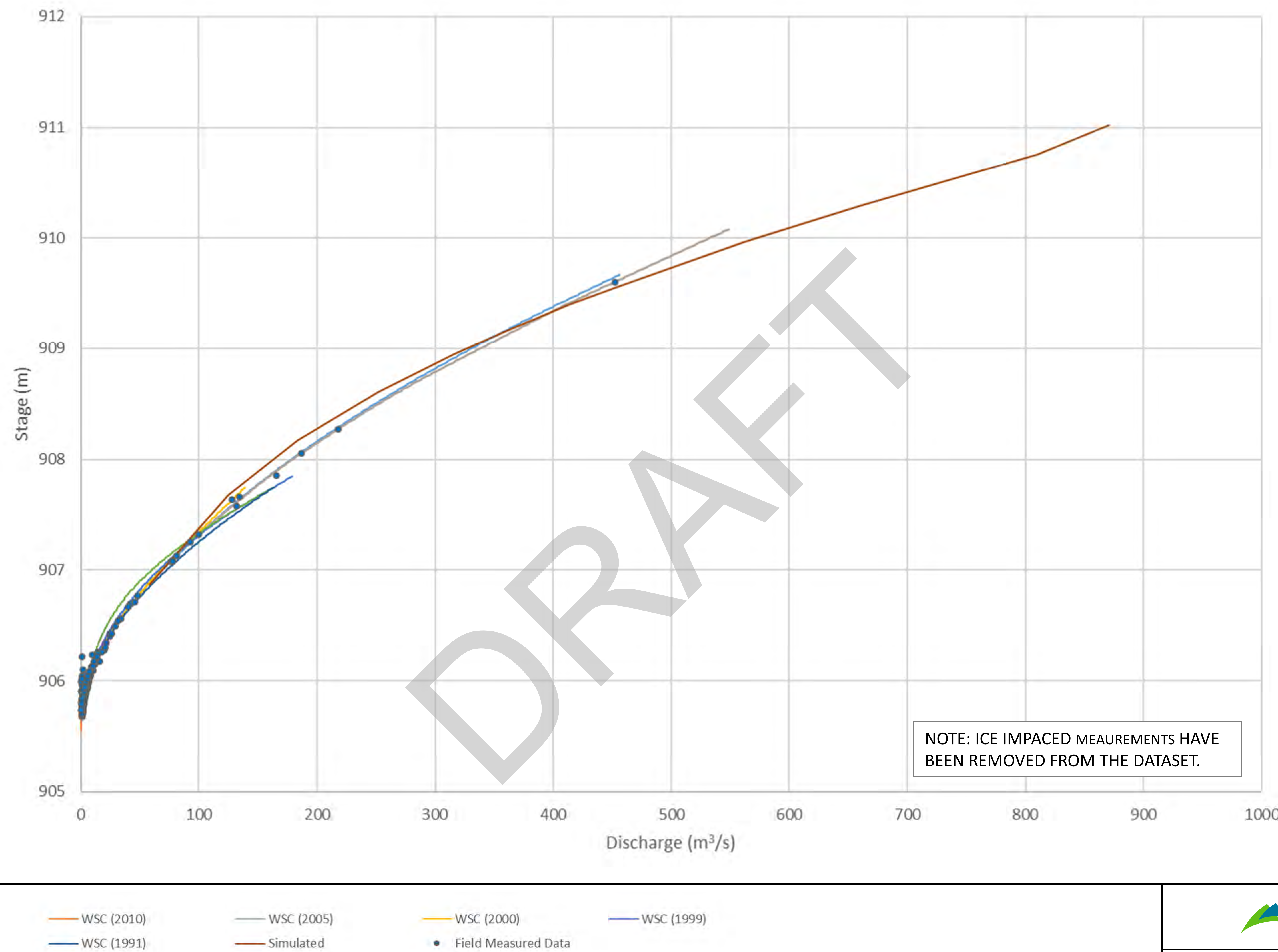

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Little Red Deer River near the Mouth (05CB001), Rating Curve

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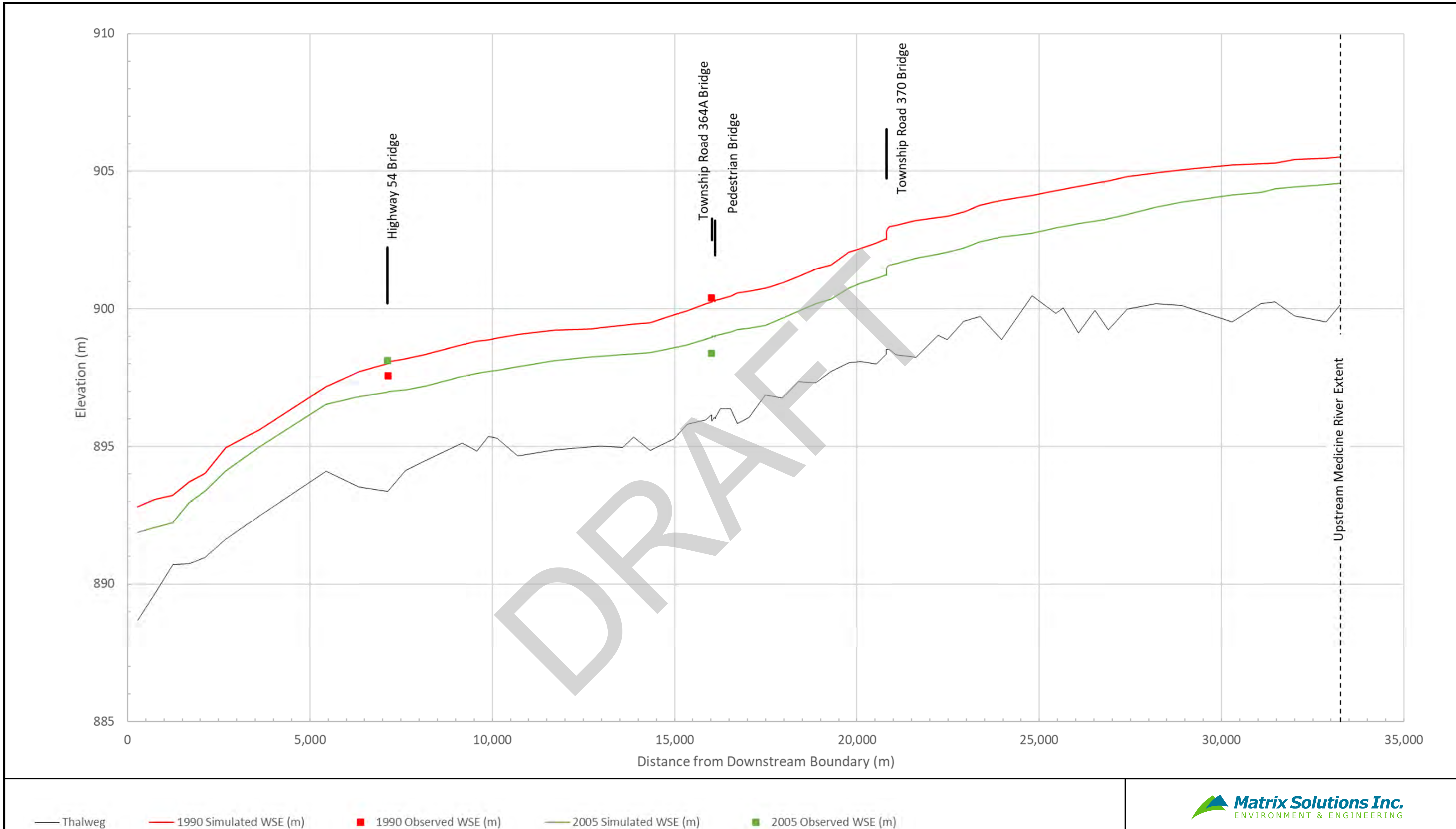
Figure 3



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Red Deer County and Markerville Flood Study

Calibration Profiles
Medicine River

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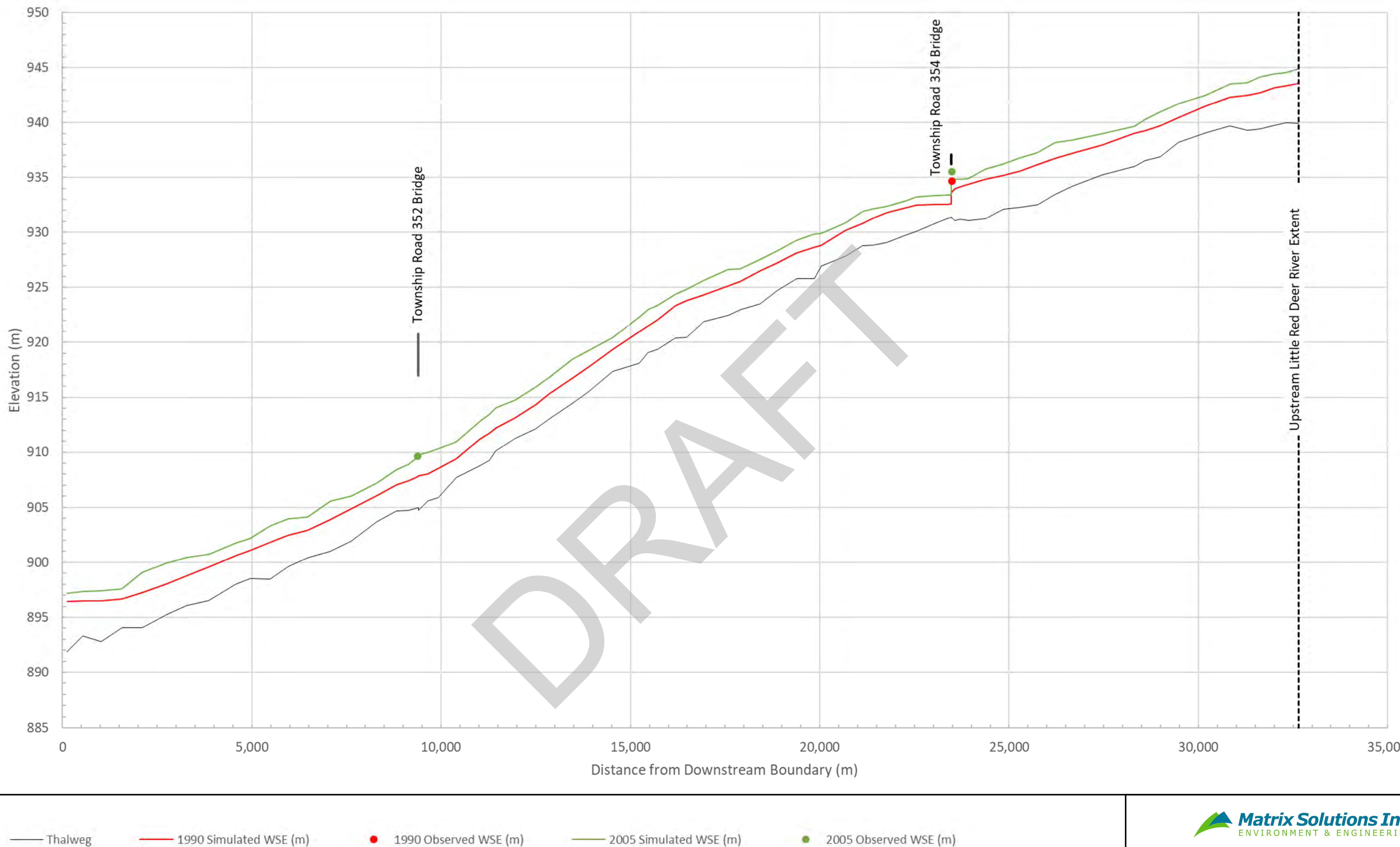
Figure 4



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Little Red Deer River

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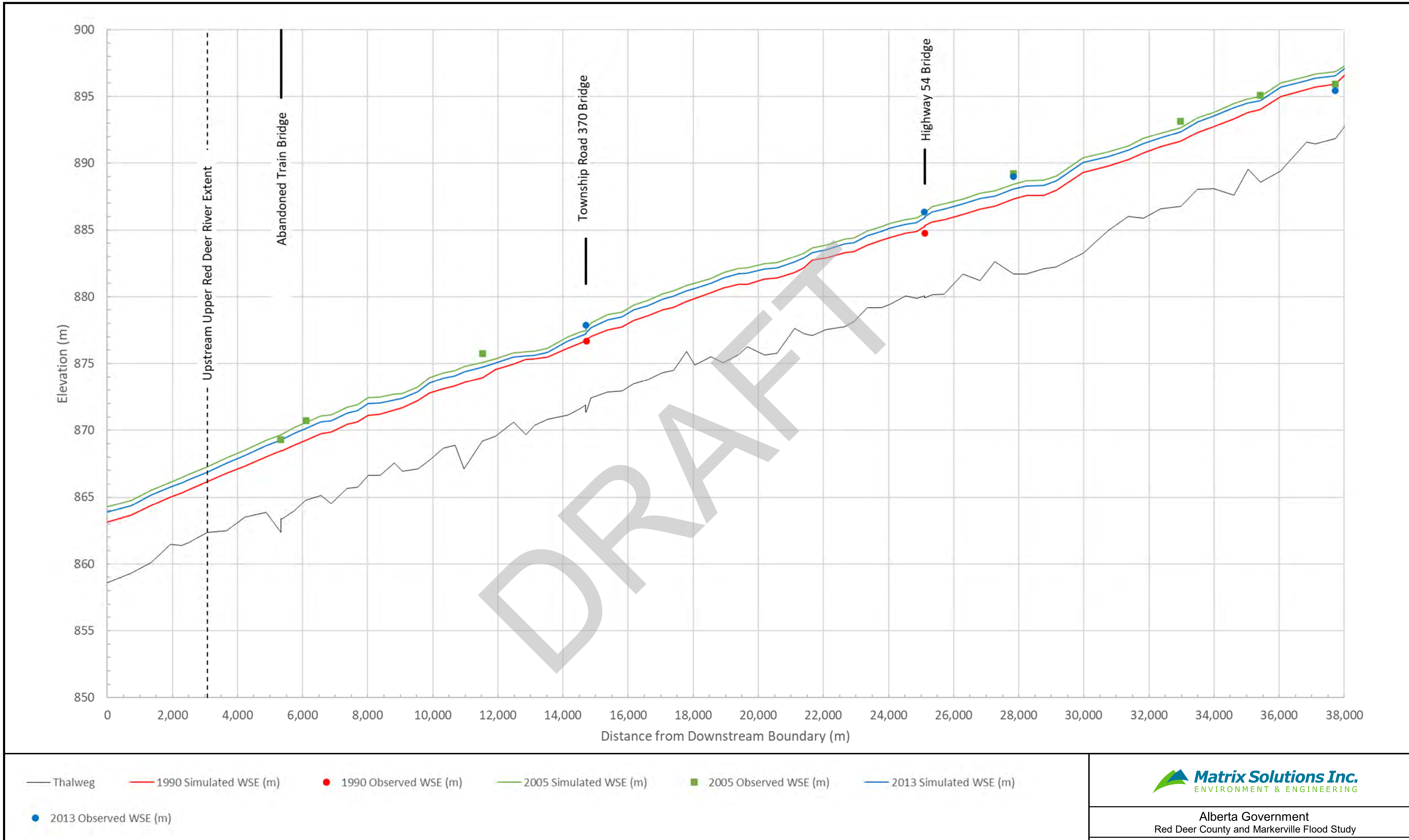
Figure 5

Classification: Public



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Calibration Profiles
lower Red Deer River

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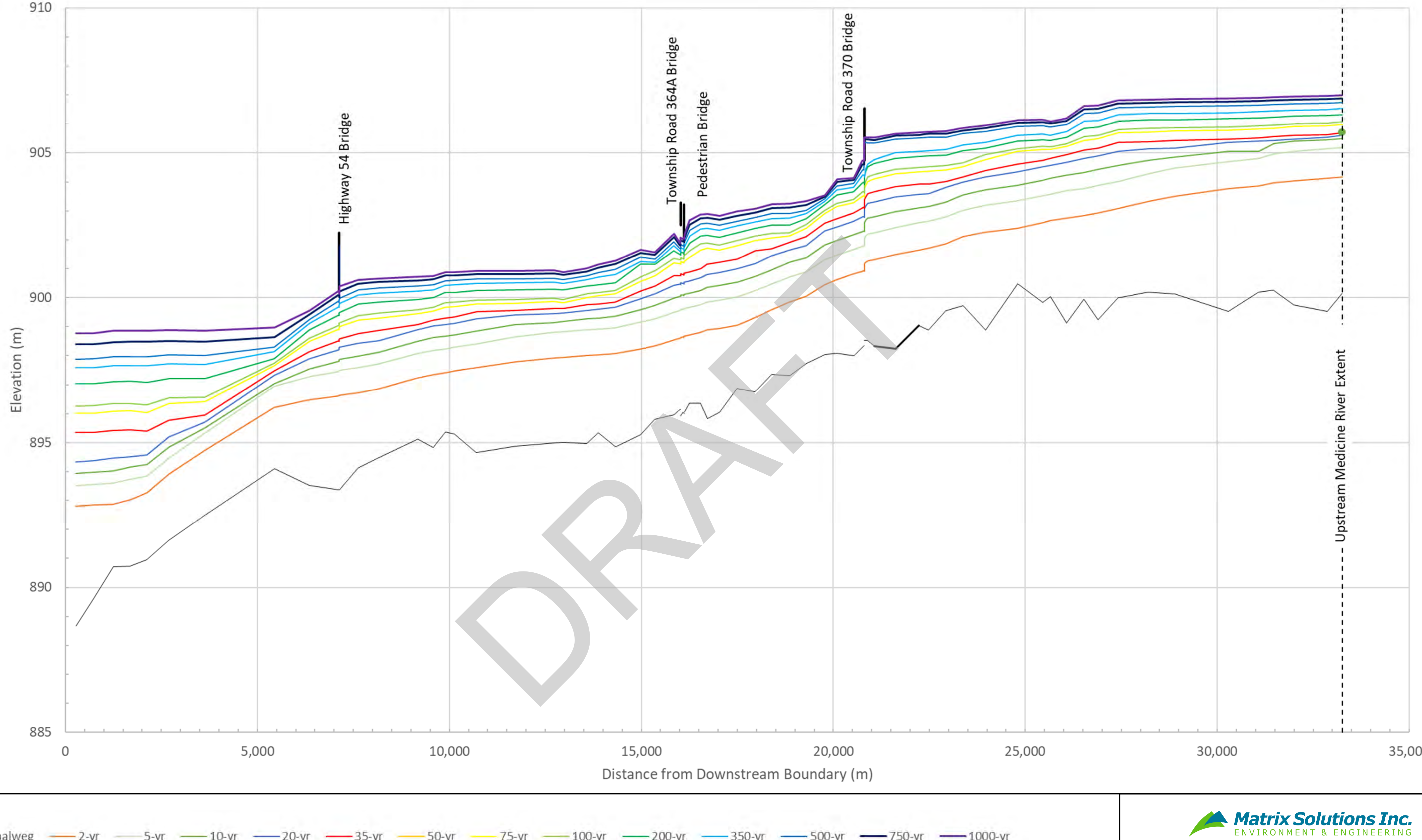
Figure 6



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Flood Frequency Profiles
Medicine River

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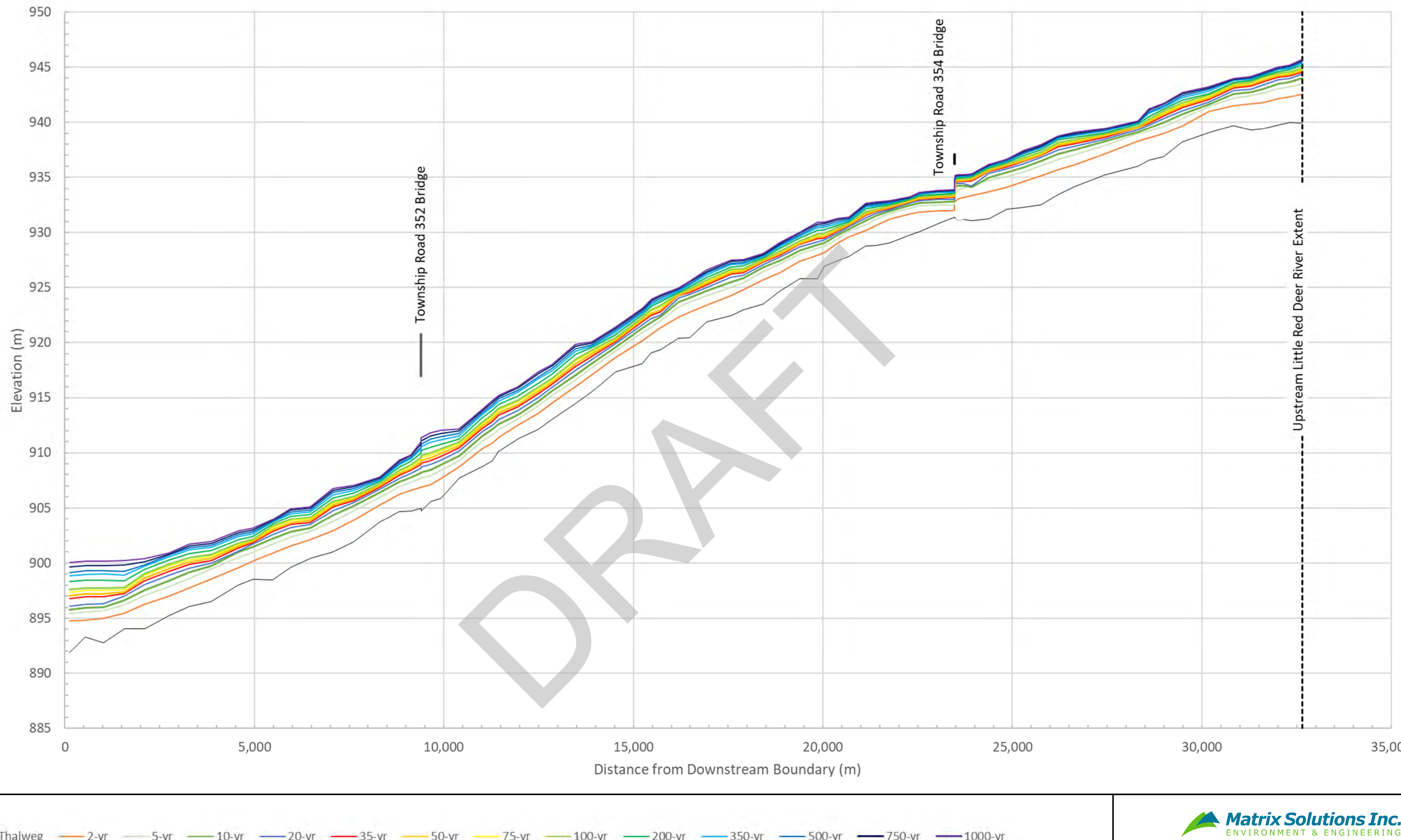
Figure 7



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Flood Frequency Profiles
Little Red Deer River

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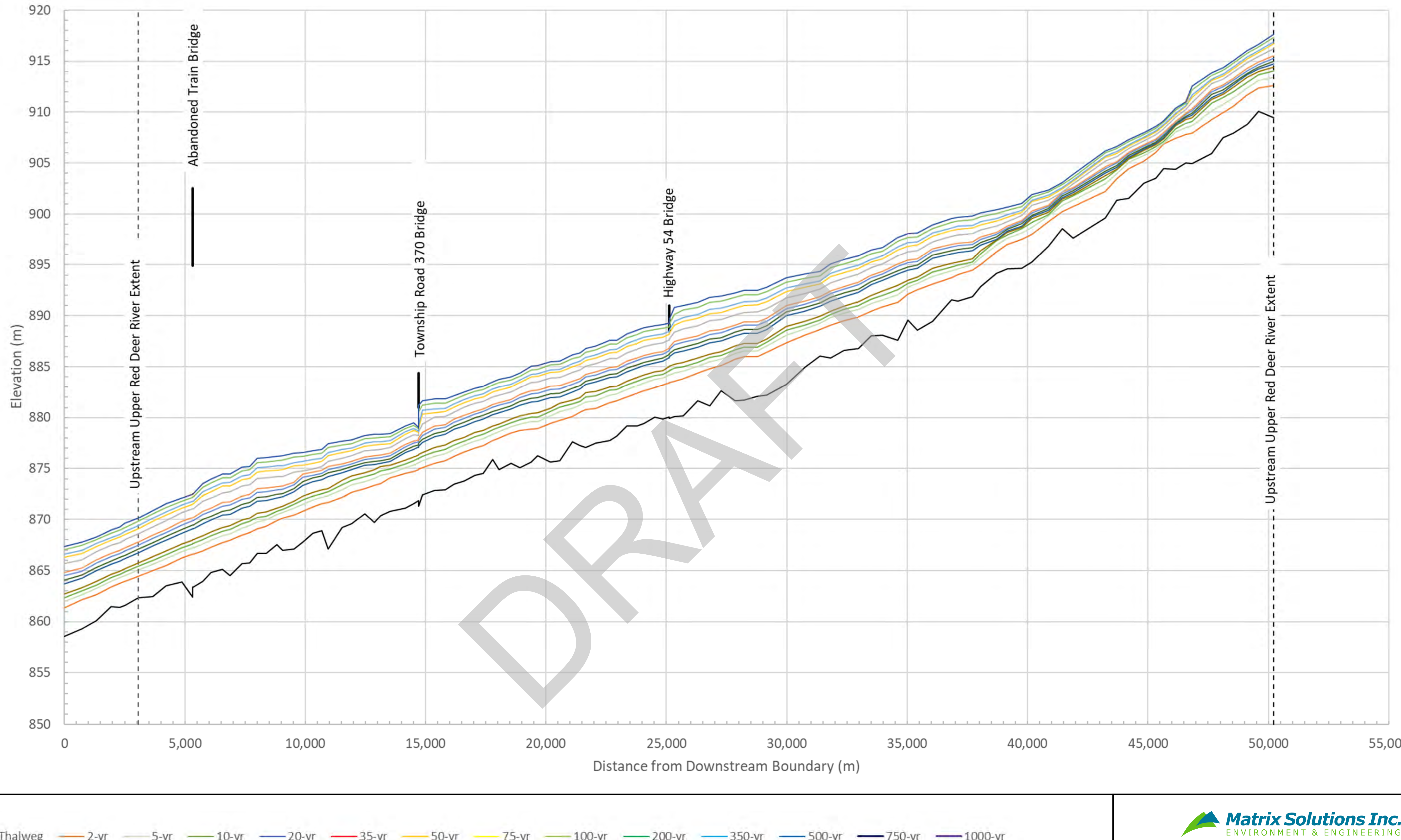
Figure 8



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Flood Frequency Profiles
Red Deer River

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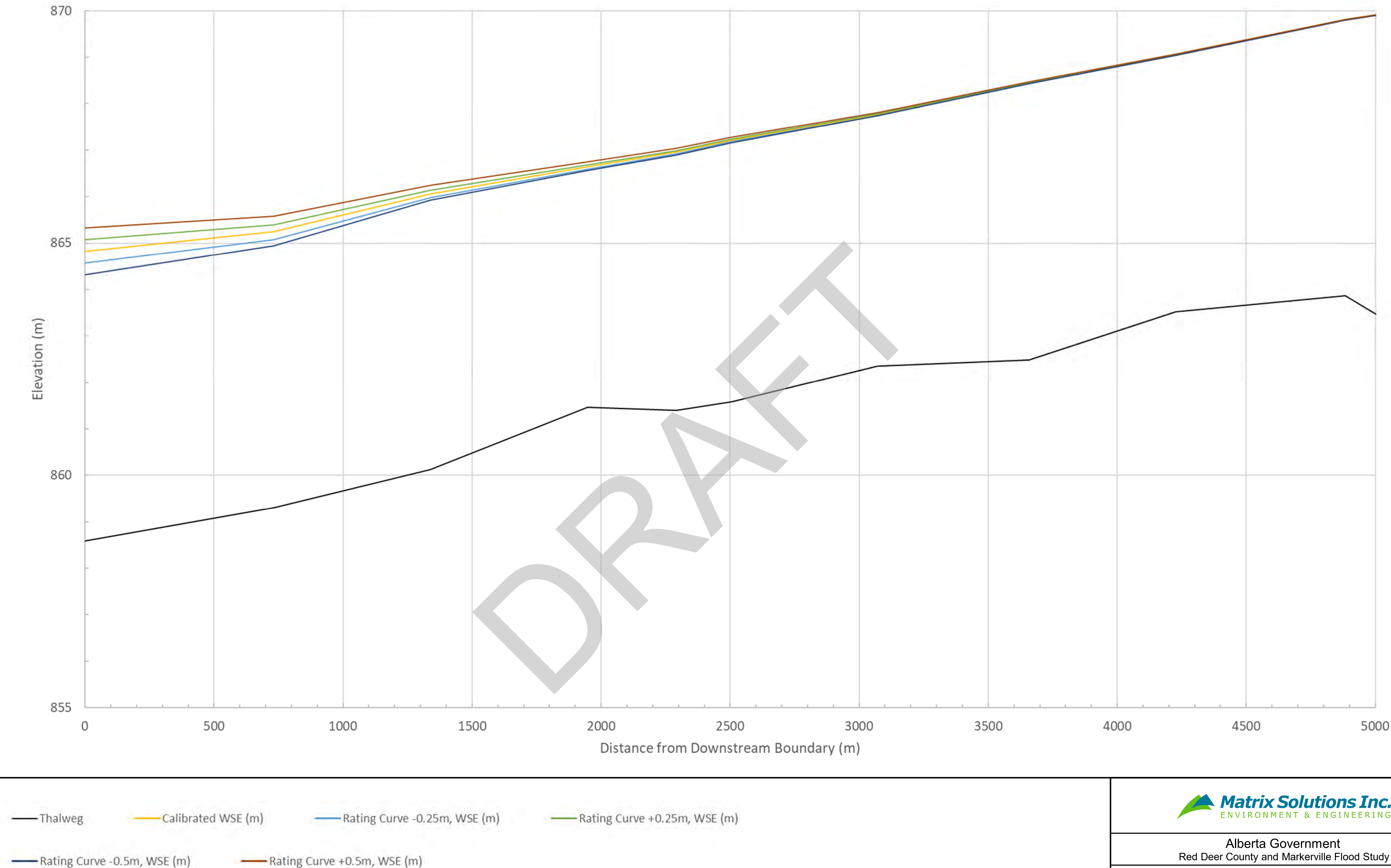
Figure 9



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Sensitivity Analysis Profiles
Variable Downstream Boundary Conditions
Red Deer River

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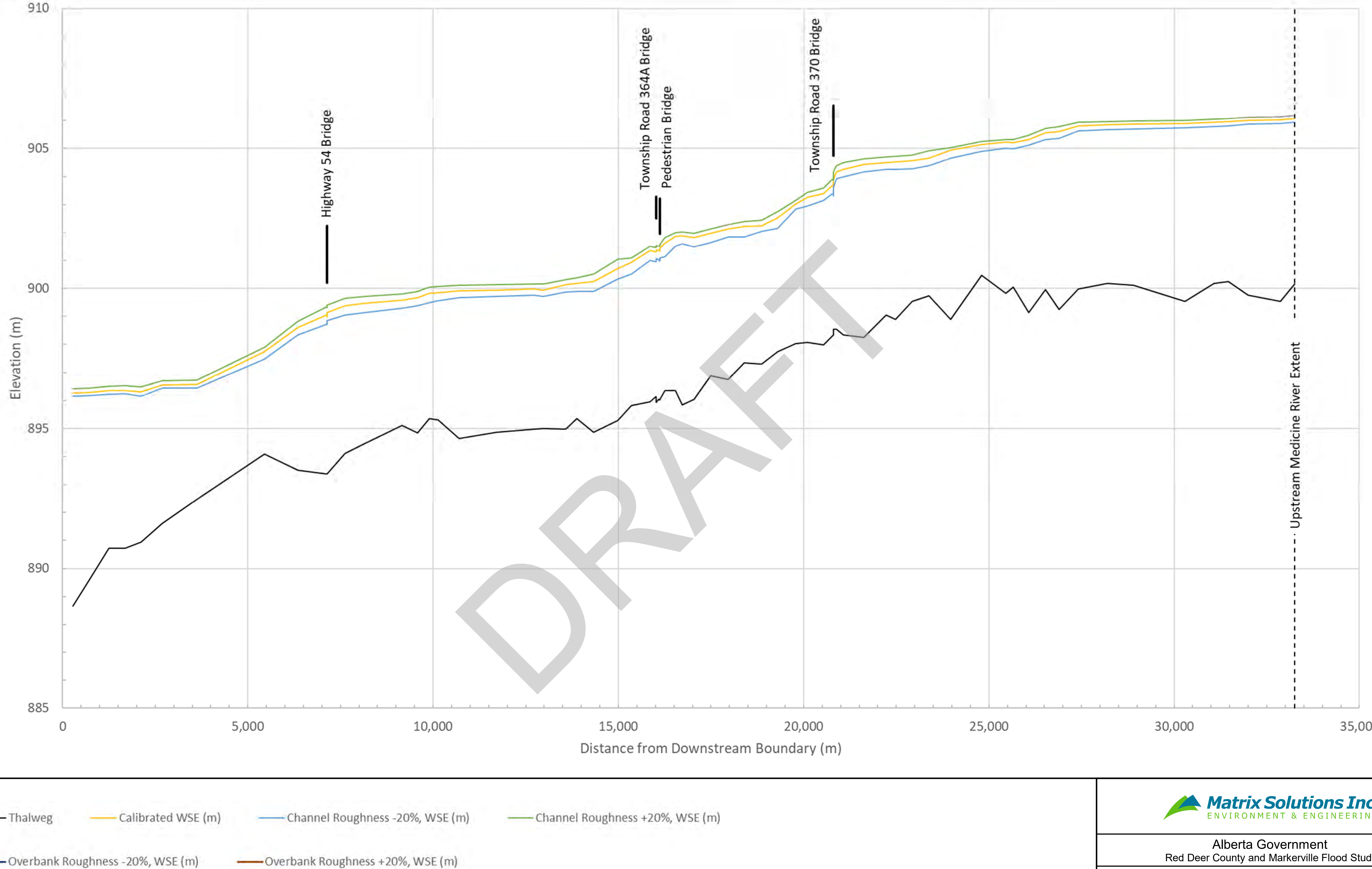
Figure 10



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Sensitivity Analysis Profiles
Variable Channel Manning Roughness
Medicine River

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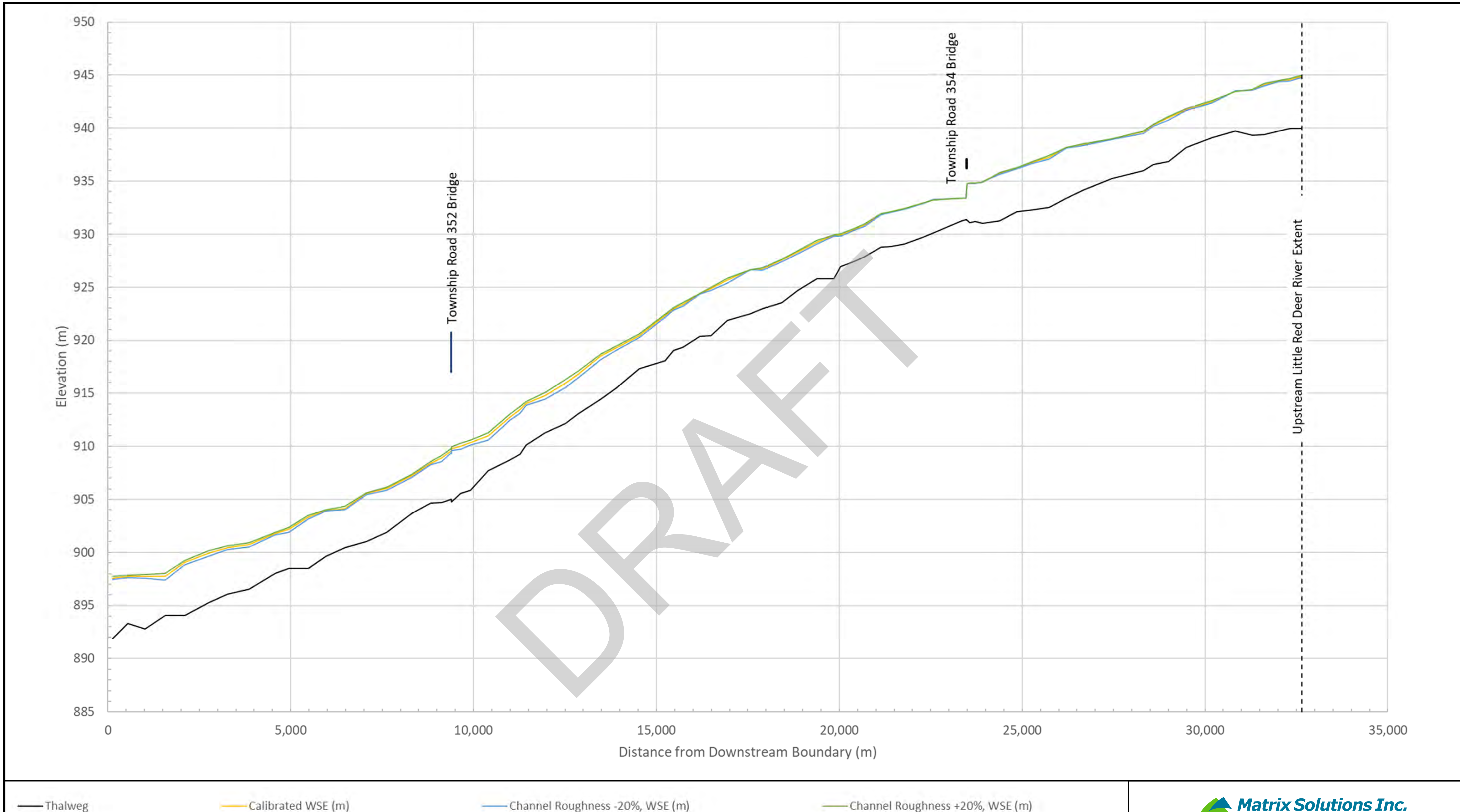
Figure 11



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Sensitivity Analysis Profiles
Variable Channel Manning Roughness
Little Red Deer River

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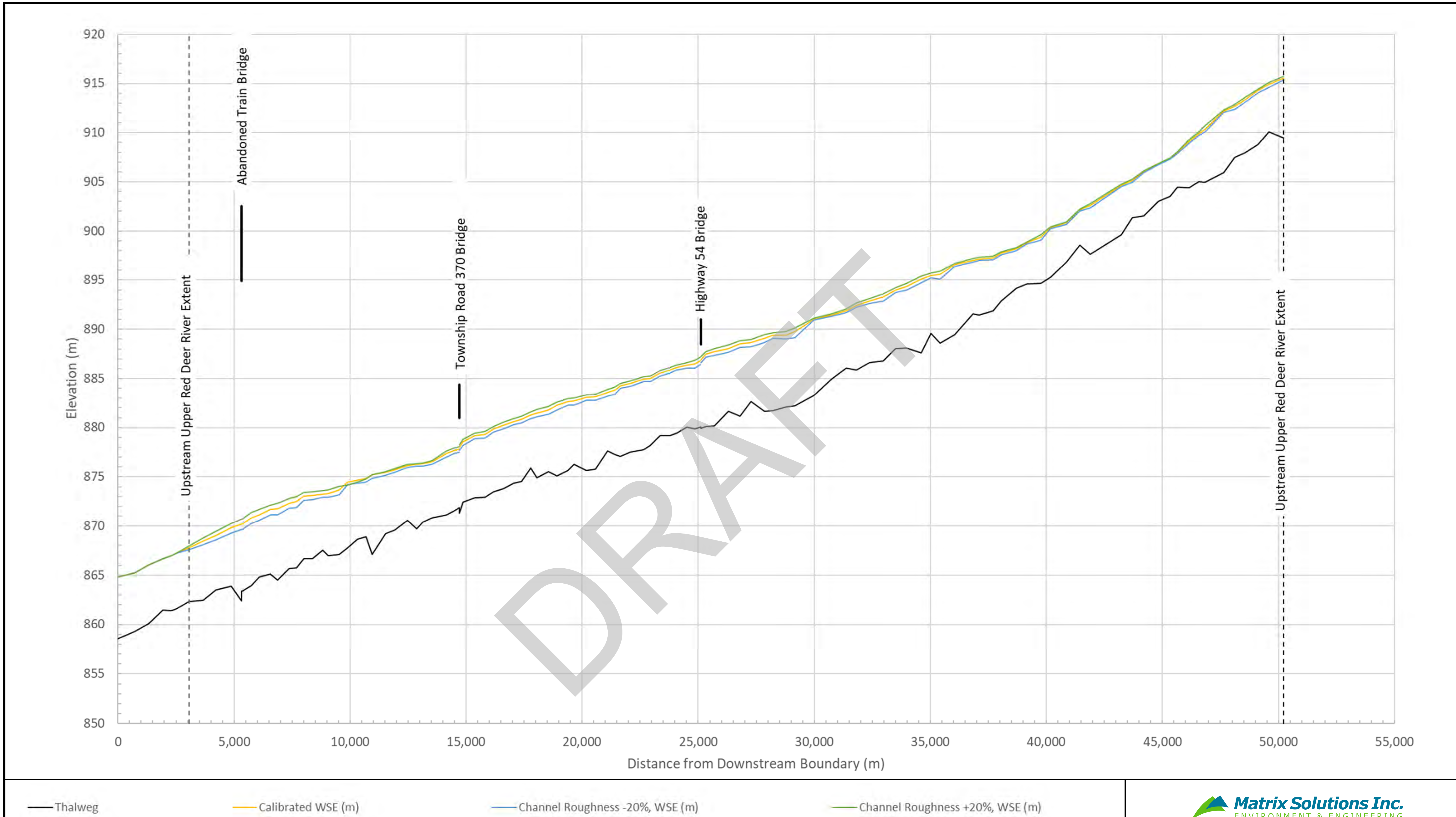
Figure 12



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Sensitivity Analysis Profiles
Variable Channel Manning Roughness
Red Deer River

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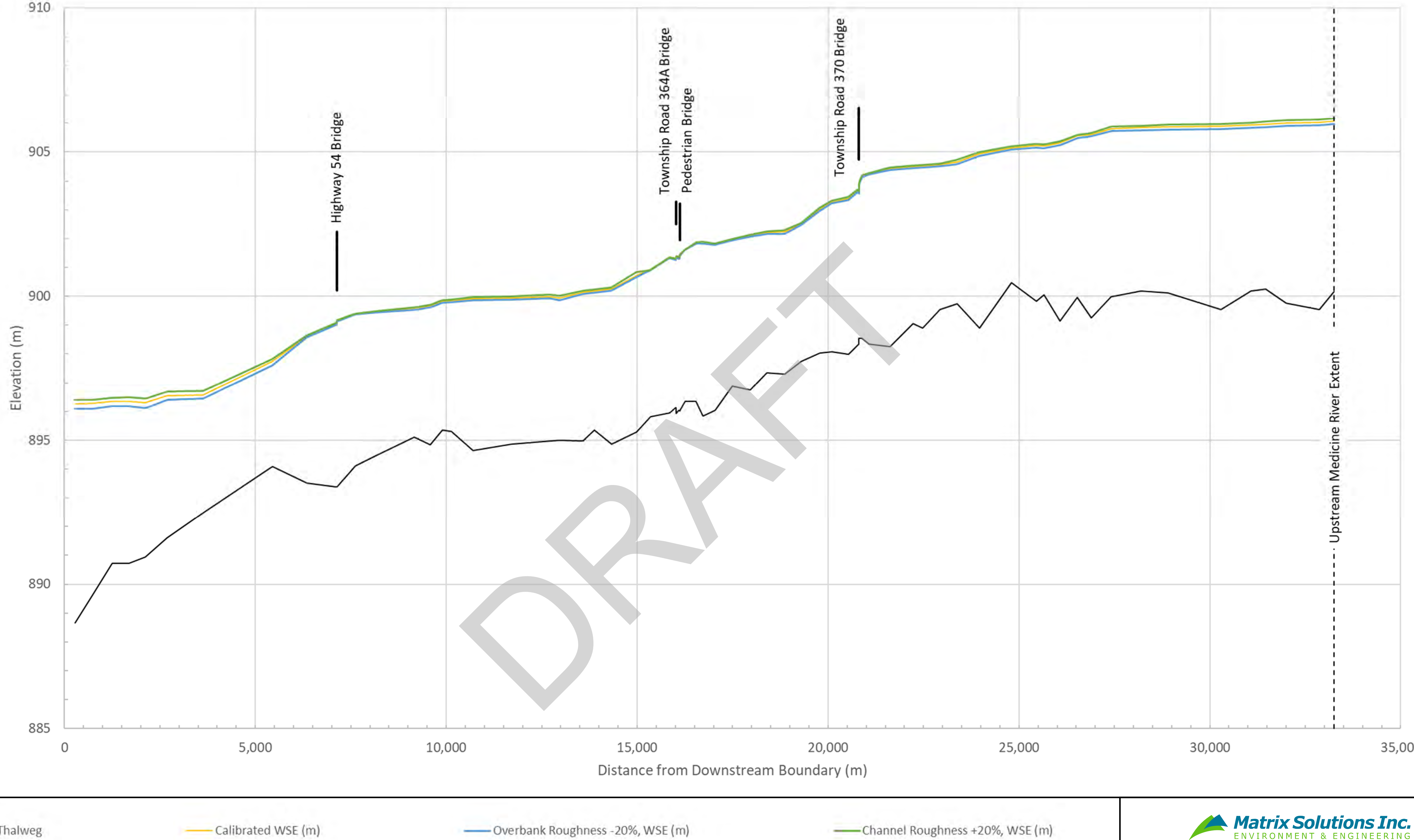
Figure 13



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Sensitivity Analysis Profiles
Variable Overbank Manning Roughness
Medicine River

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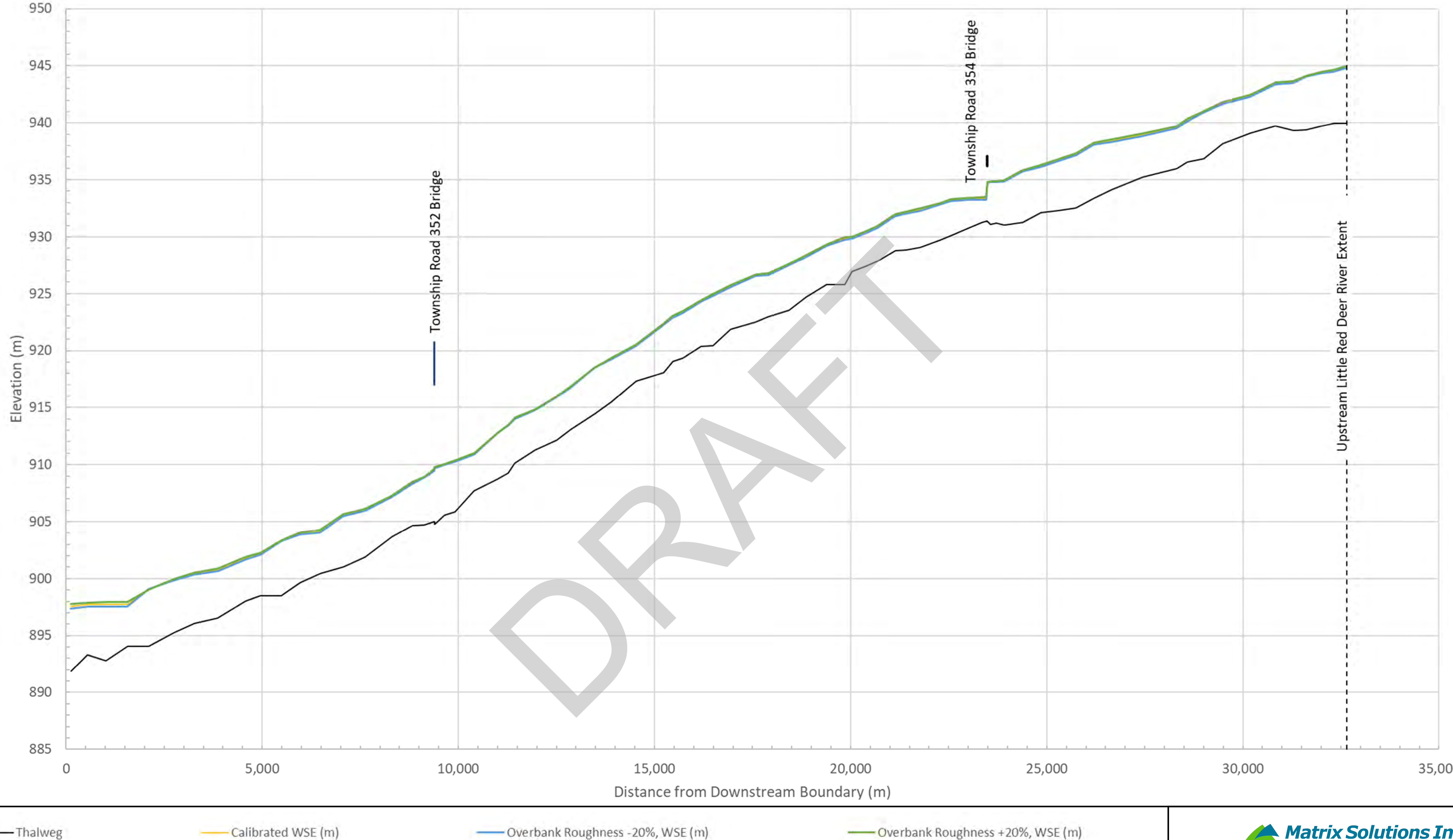
Figure 14



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Red Deer County and Markerville Flood Study

Sensitivity Analysis Profiles
Variable Overbank Manning Roughness
Little Red Deer River

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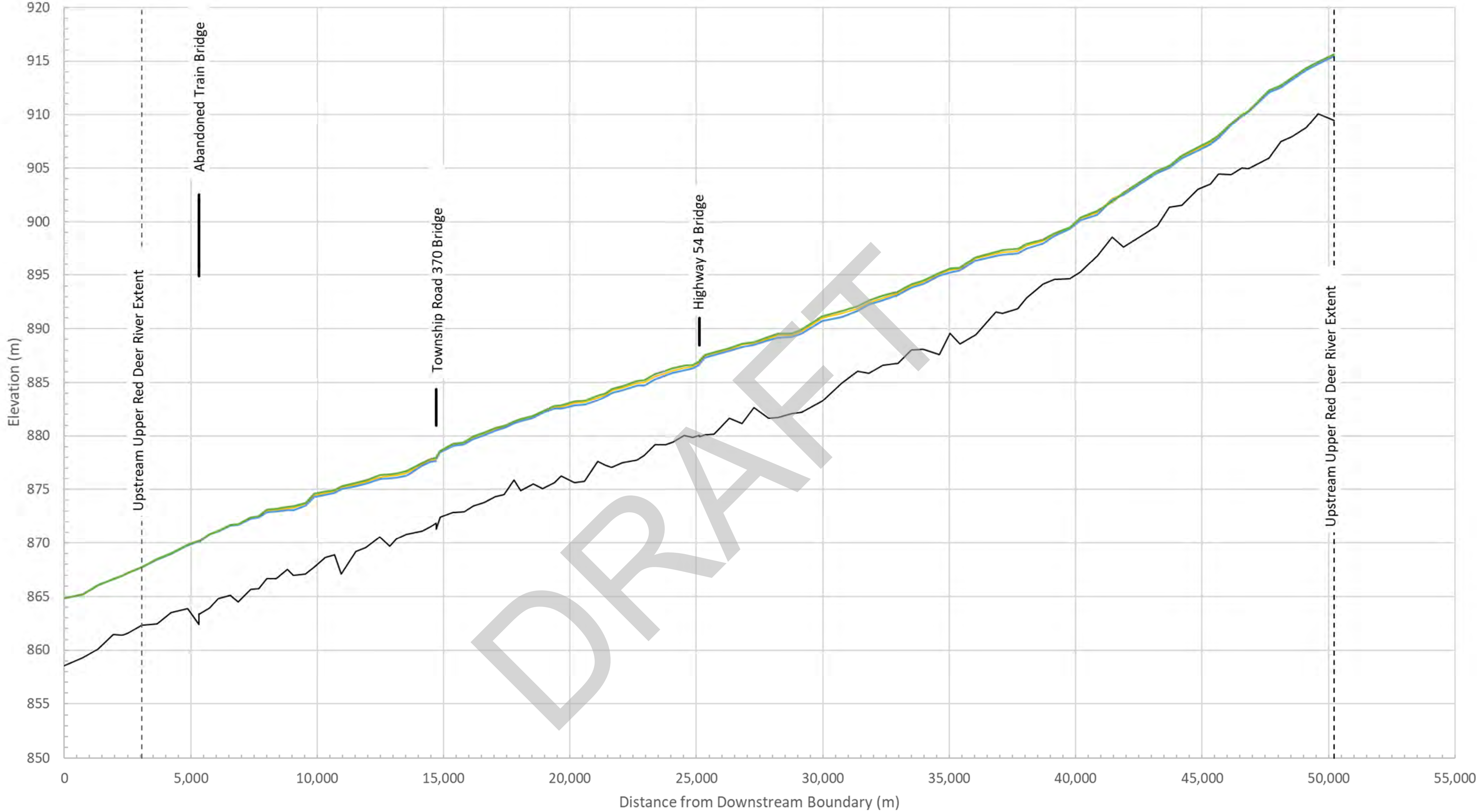
Figure 15



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Sensitivity Analysis Profiles
Variable Overbank Manning Roughness
Red Deer River

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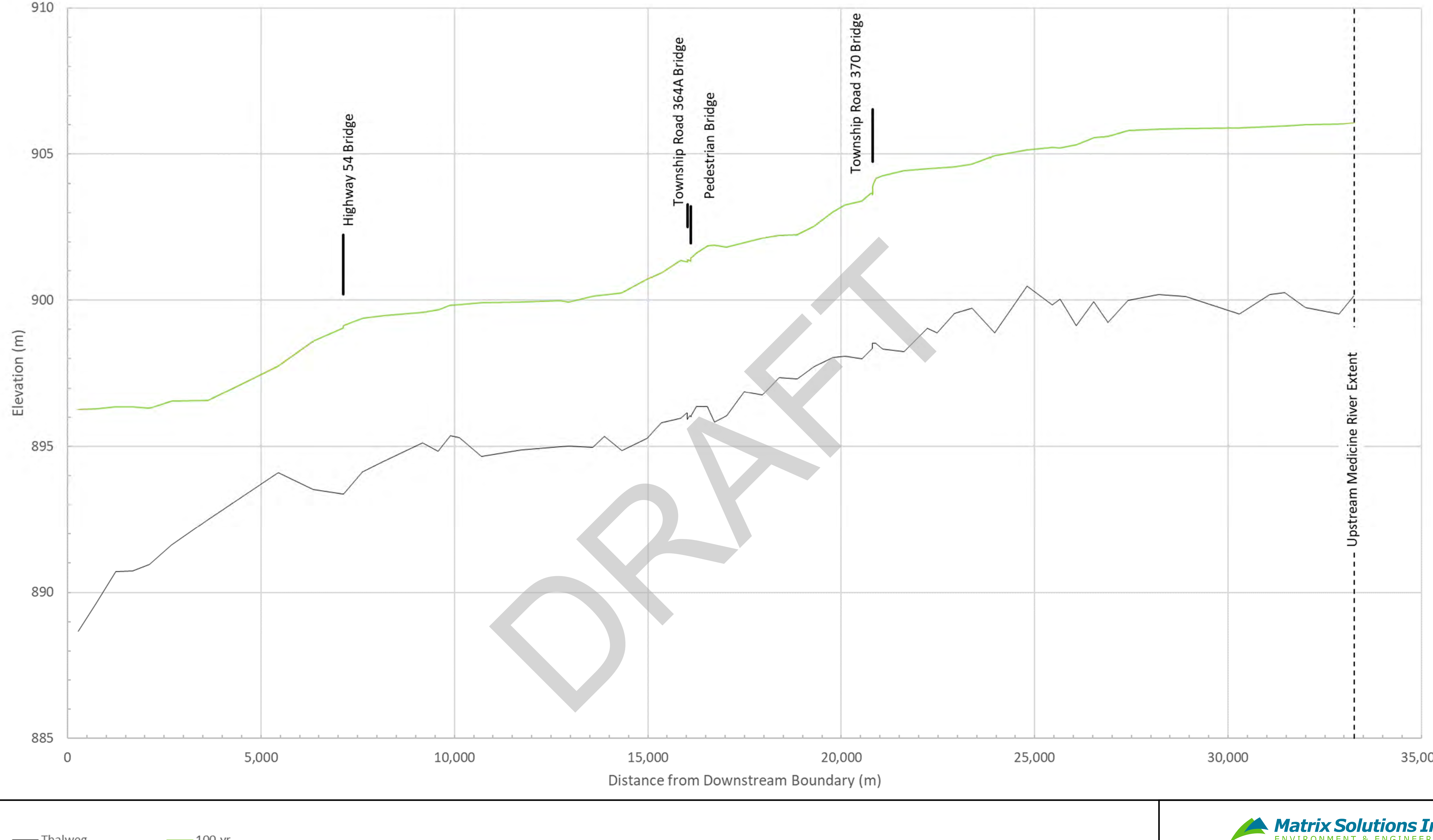
Figure 16



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Red Deer County and Markerville Flood Study

Design Flood Profile
Medicine River

Date:	Project:	Submitter:	Reviewer:
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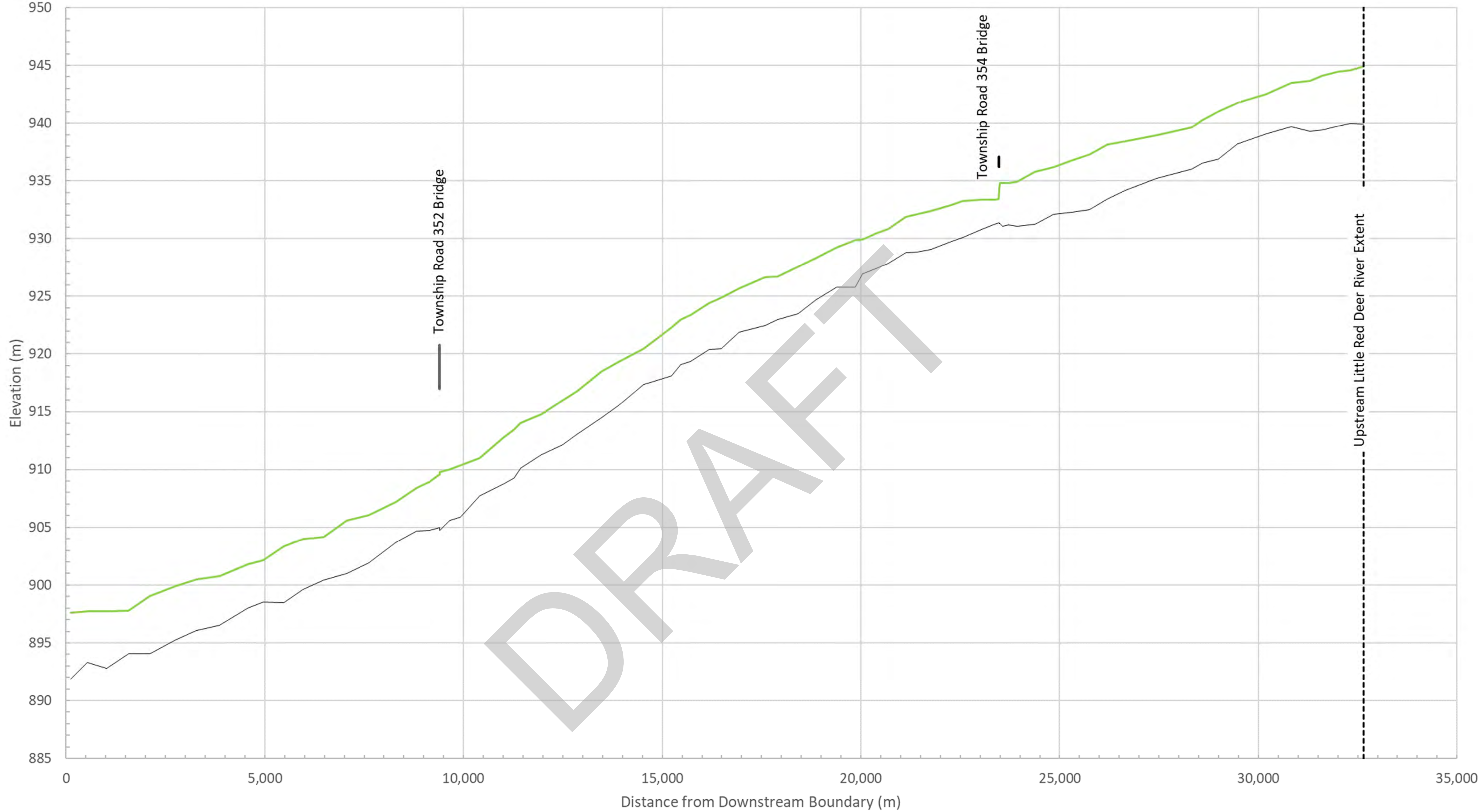
Figure 17



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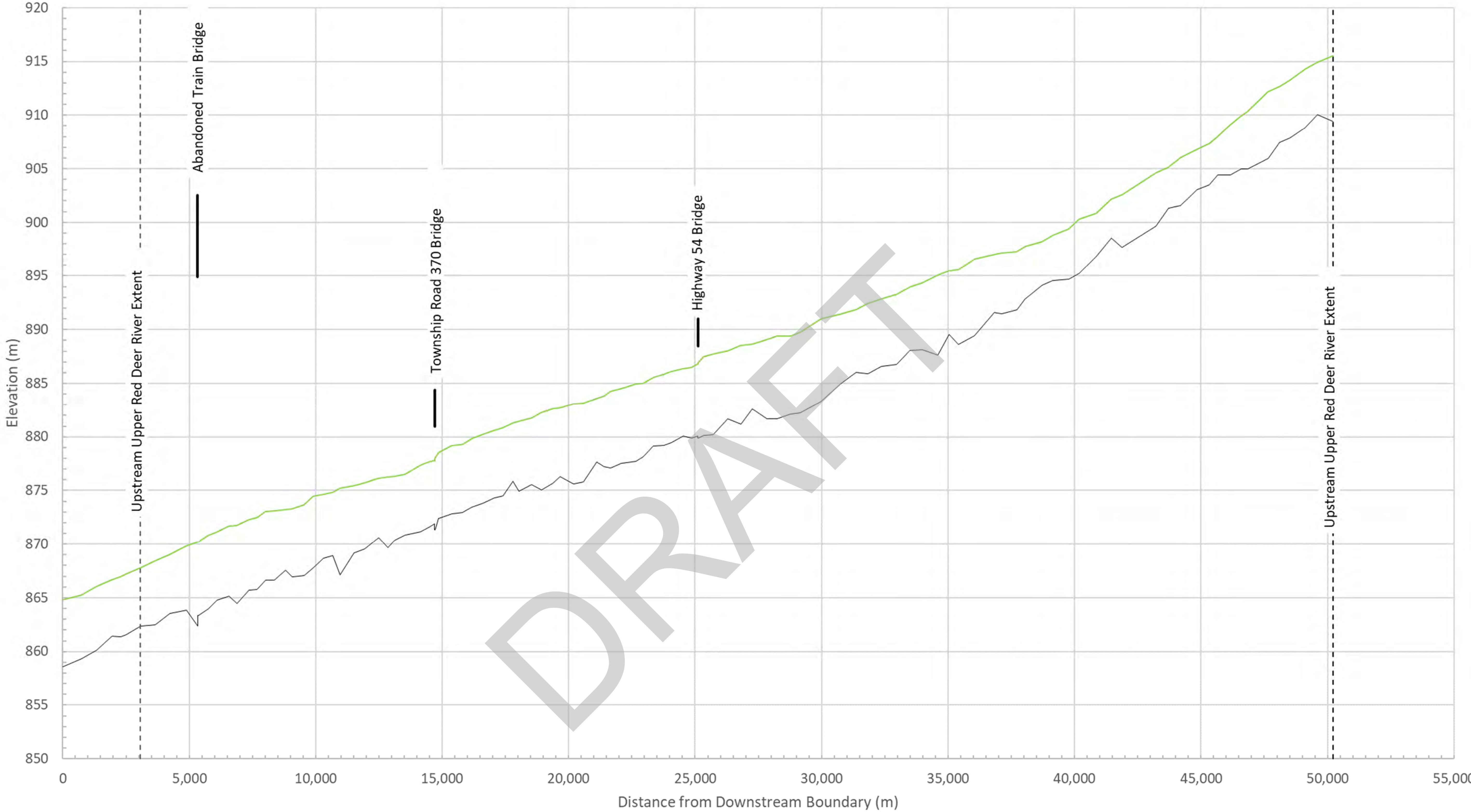
Alberta Government
Red Deer County and Markerville Flood Study

Design Flood Profile
Little Red Deer River

Date:	Project:	Submitter:	Reviewer:
March 2024	35374	P.Rogers	M.Shome

Figure 18



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Alberta Government
Red Deer County and Markerville Flood Study

Design Flood Profile
Red Deer River

Date:	Project:	Submitter:	Reviewer:
March 2024	35374	P.Rogers	M.Shome

Figure 19

TABLE 1: BRIDGE DETAILS

River	Bridge Name	Bounding Cross Sections	Details
Little Red Deer	Township Road 354 Bridge	9401.121 and 9386.807	• 86.65 m long concrete bridge with two concrete piers • Deck width of 11.4 m • Average low chord elevation, El. 916.98 m • Average high chord elevation, El. 920.77 m
	Township Road 352 Bridge	23492.98 and 23465.1	• 58.94 m long concrete bridge with concrete pier • Deck width of 9.9 m • Average low chord elevation, El. 937.06 m • Average high chord elevation, El. 936.22 m
Medicine	Highway 54 Bridge	7140.563 and 7123.366	• 68m long concrete bridge with two concrete piers • Deck width of 11.7 m • Average low chord elevation, El. 900.21 m • Average high chord elevation, El. 902.23 m
	Township Road 364A Bridge	16027.9 and 16007.45	• 62.37 m long concrete bridge with two concrete piers • Deck width of 6.8 m • Average low chord elevation, El. 902.5 m • Average high chord elevation , El. 903.28 m
	Pedestrian River Bridge	16120.31 and 16113.64	• 54.21 m long concrete bridge with two concrete piers • Deck width of 3.0 m • Average low chord elevation, El. 901.96 m • Average high chord elevation, El. 903.22 m
	Township Road 370 Bridge	20841.77 and 20804.43	• 51.96 m long concrete bridge with two concrete piers • Deck width of 10.4 m • Average low chord elevation, El. 904.74 m • Average high chord elevation, El. 906.54 m
Red Deer	Abandoned Train Bridge	5364.9 and 5333.35	• 666.05 m long timber trestle bridge with hexagonal steel piers • Deck width of 5.4 m • Average low chord elevation, El. 894.9 m • Average high chord elevation, El. 902.5 m
	Township Road 370 Bridge	14714.49 and 14696.46	• 149.74 m long concrete bridge with four concrete piers • Deck width of 10.2 m • Average low chord elevation, El. 880.97 m • Average high chord elevation, El. 884.37 m
	Highway 54 Bridge	25119.89 and 25105.02	• 141.87 m long concrete bridge with three concrete piers • Deck width of 10.1 m • Average low chord elevation, El. 888.45 m • Average high chord elevation, El. 891.03 m

TABLE 2: CALIBRATION RESULTS

AEP Highwater Mark	River Station	Simulated WSE[1] (m)	Observed WSE (m)	Difference (m)
Medicine River - 1990 Flood Event (Q = 236 m3/s)				
1990-MED-11B	7140.563	898.08	897.57	0.51
Medicine River - 2005 Flood Event (Q = 275 m3/s)				
2005-MED-28A	16007.45	898.97	898.38	0.59
2005-MED-11A	7123.366	896.96	898.12	-1.16
Little Red Deer River - 1990 Flood Event (Q = 136 m3/s)				
1990-LRD-54B	23492.98	933.68	934.65	-0.97
Little Red Deer River - 2005 Flood Event (Q = 542 m3/s)				
2005-LRD-54B	23492.98	934.79	935.50	-0.71
Red Deer River - 1990 Flood Event (Q = 908 m3/s)				
1990-RDR-62B	25119.89	885.33	884.78	0.55
1990-RDR-35B	14714.49	876.79	876.66	0.13
Red Deer River - 2005 Flood Event (Q = 1510 m3/s)				
2005-RDR-86	37721.636	896.84	895.92	0.92
2005-RDR-82	35419.07	894.99	895.09	-0.10
2005-RDR-77	32971.012	892.68	893.14	-0.46
2005-RDR-68	27841.09	888.44	889.21	-0.77
2005-RDR-27	11520.43	875.09	875.75	-0.66
2005-RDR-13	6100.29	870.57	870.70	-0.13
2005-RDR-11A	5333.35	869.67	869.30	0.37
Red Deer River - 2013 Flood Event (Q = 1290 m3/s)				
2013-RDR-86	37721.636	896.56	895.46	1.09
2013-RDR-68	27841.09	888.06	888.98	-0.92
2013-RDR-62A	25105.02	885.92	886.34	-0.42
2013-RDR-35A	14696.455	877.23	877.88	-0.65

1. WSE = water surface elevation

TABLE 3A: COMPUTED FLOOD FREQUENCY WATER SURFACE ELEVATIONS, MEDICINE RIVER

Cross-Section	River Station (m)	Water Surface Elevation (m)												
		2-year flood	5-year flood	10-year flood	20-year flood	35-year flood	50-year flood	75-year flood	100-year flood	200-year flood	350-year flood	500-year flood	750-year flood	1000-year flood
MED067	33253	904.16	905.18	905.49	905.60	905.70	905.86	905.97	906.08	906.33	906.53	906.74	906.88	906.99
MED066	32861	904.13	905.13	905.45	905.55	905.64	905.79	905.93	906.04	906.29	906.50	906.71	906.85	906.96
MED065	32001	904.04	905.06	905.41	905.48	905.61	905.77	905.91	906.01	906.27	906.48	906.69	906.84	906.95
MED064	31469	903.97	904.96	905.31	905.44	905.56	905.72	905.86	905.97	906.24	906.45	906.67	906.82	906.92
MED063	31083	903.86	904.80	905.06	905.41	905.52	905.69	905.83	905.94	906.21	906.42	906.64	906.79	906.90
MED062	30292	903.77	904.71	905.06	905.36	905.47	905.65	905.78	905.90	906.17	906.39	906.62	906.76	906.87
MED061	28899	903.51	904.47	904.86	905.16	905.42	905.61	905.75	905.87	906.15	906.37	906.60	906.75	906.85
MED060	28200	903.33	904.27	904.74	905.15	905.39	905.58	905.73	905.85	906.13	906.35	906.58	906.73	906.84
MED059	27420	903.08	904.02	904.57	905.05	905.35	905.55	905.69	905.81	906.10	906.32	906.56	906.71	906.82
MED058	26899	902.92	903.88	904.42	904.89	905.17	905.37	905.49	905.61	905.89	906.12	906.38	906.52	906.63
MED057	26533	902.83	903.78	904.32	904.80	905.10	905.31	905.43	905.56	905.85	906.08	906.35	906.50	906.61
MED056	26081	902.76	903.69	904.23	904.69	904.94	905.14	905.23	905.33	905.55	905.73	905.99	906.10	906.18
MED055	25653	902.66	903.58	904.12	904.57	904.81	905.01	905.11	905.21	905.43	905.61	905.90	906.01	906.09
MED054	25456	902.60	903.52	904.06	904.52	904.75	904.94	905.11	905.22	905.46	905.65	905.95	906.07	906.15
MED053	24799	902.40	903.35	903.89	904.35	904.62	904.82	905.04	905.15	905.40	905.60	905.91	906.03	906.12
MED052	23964	902.26	903.20	903.73	904.17	904.39	904.58	904.77	904.94	905.17	905.37	905.74	905.86	905.94
MED051	23380	902.11	903.02	903.55	903.98	904.18	904.35	904.53	904.66	905.07	905.27	905.66	905.78	905.86
MED050	22931	901.87	902.79	903.31	903.80	904.02	904.22	904.41	904.56	904.92	905.11	905.55	905.66	905.74
MED049	22485	901.71	902.64	903.15	903.60	903.93	904.15	904.36	904.52	904.89	905.08	905.54	905.65	905.73
MED048	22231	901.64	902.59	903.11	903.56	903.92	904.14	904.34	904.50	904.87	905.06	905.51	905.62	905.70
MED047	21617	901.49	902.42	902.97	903.48	903.83	904.06	904.27	904.43	904.81	905.00	905.48	905.59	905.66
MED046	21071	901.31	902.24	902.79	903.31	903.66	903.89	904.10	904.26	904.63	904.77	905.34	905.45	905.52
MED045	20891	901.27	902.20	902.75	903.26	903.60	903.82	904.02	904.17	904.52	904.61	905.35	905.46	905.53
MED044B	20842	901.22	902.14	902.68	903.17	903.49	903.70	903.88	904.03	904.36	904.45	905.36	905.46	905.53
MED044A	20804	900.92	901.79	902.31	902.80	903.13	903.34	903.52	903.66	903.98	904.23	904.41	904.60	904.73
MED043	20762	900.91	901.77	902.29	902.79	903.11	903.32	903.51	903.65	903.97	904.22	904.40	904.59	904.73
MED042	20535	900.81	901.66	902.17	902.64	902.93	903.12	903.27	903.40	903.65	903.82	903.95	904.07	904.14
MED041	20098	900.63	901.47	901.97	902.45	902.72	902.90	903.15	903.27	903.54	903.73	903.87	904.01	904.09
MED038	18858	899.85	900.71	901.22	901.65	901.90	902.05	902.13	902.25	902.50	902.74	902.92	903.11	903.25
MED037	18393	899.59	900.47	900.97	901.44	901.68	901.83	902.07	902.23	902.50	902.73	902.90	903.08	903.22
MED036	17962	899.32	900.24	900.74	901.18	901.62	901.78	901.97	902.12	902.39	902.61	902.77	902.95	903.08
MED035	17492	899.06	900.02	900.53	900.99	901.34	901.58	901.79	901.97	902.24	902.48	902.65	902.84	902.97
MED032	16547	898.81	899.76	900.25	900.68	901.01	901.39	901.64	901.86	902.13	902.37	902.54	902.74	902.88
MED031	16254	898.72	899.67	900.16	900.57	900.88	901.08	901.40	901.63	901.89	902.13	902.32	902.52	902.67
MED030B	16120	898.67	899.63	900.11	900.53	900.83	901.03	901.25	901.43	901.58	901.74	901.88	902.04	902.16
MED030A	16114	898.63	899.59	900.08	900.49	900.79	900.97	901.20	901.34	901.54	901.68	901.82	901.99	902.11
MED029	16084	898.64	899.60	900.08	900.49	900.80	900.99	901.21	901.36	901.54	901.68	901.81	901.94	902.04
MED028B	16028	898.64	899.60	900.09	900.51	900.82	901.01	901.24	901.38	901.58	901.72	901.85	901.99	902.08
MED028A	16007	898.61	899.57	900.05	900.46	900.76	900.95	901.17	901.31	901.48	901.59	901.69	901.81	901.89
MED027	15848	898.53	899.49	899.98	900.42	900.75	900.96	901.20	901.35	901.63	901.80	901.93	902.09	902.20
MED026	15351	898.34	899.28	899.74	900.13	900.40	900.56	900.76	900.94	901.15	901.23	901.34	901.47	901.56

Cross-Section	River Station (m)	Water Surface Elevation (m)												
		2-year flood	5-year flood	10-year flood	20-year flood	35-year flood	50-year flood	75-year flood	100-year flood	200-year flood	350-year flood	500-year flood	750-year flood	1000-year flood
MED025	14979	898.23	899.15	899.59	899.97	900.22	900.37	900.57	900.72	901.15	901.25	901.39	901.55	901.66
MED024	14323	898.08	898.97	899.35	899.66	899.86	899.96	900.13	900.25	900.51	900.81	900.97	901.16	901.28
MED023	13881	898.03	898.92	899.30	899.60	899.79	899.89	900.06	900.19	900.45	900.72	900.86	901.03	901.14
MED020	12724	897.92	898.80	899.15	899.46	899.62	899.70	899.87	899.99	900.30	900.53	900.67	900.84	900.94
MED019	11712	897.79	898.65	899.08	899.39	899.55	899.64	899.81	899.94	900.26	900.51	900.65	900.81	900.92
MED018	10703	897.60	898.41	898.85	899.27	899.51	899.59	899.78	899.91	900.25	900.49	900.64	900.80	900.91
MED017	10132	897.47	898.29	898.72	899.13	899.34	899.50	899.70	899.84	900.19	900.45	900.60	900.78	900.89
MED016	9894	897.40	898.24	898.67	899.08	899.29	899.44	899.67	899.82	900.17	900.43	900.59	900.76	900.87
MED015	9581	897.34	898.18	898.62	899.03	899.23	899.34	899.53	899.66	900.01	900.27	900.44	900.63	900.75
MED014	9170	897.23	898.08	898.50	898.89	899.06	899.24	899.44	899.58	899.93	900.23	900.40	900.60	900.72
MED013	8163	896.85	897.71	898.12	898.52	898.86	899.07	899.30	899.46	899.84	900.16	900.34	900.54	900.66
MED012	7622	896.72	897.59	897.98	898.43	898.76	898.98	899.22	899.38	899.77	900.10	900.28	900.48	900.61
MED011B	7141	896.65	897.50	897.88	898.29	898.59	898.79	899.00	899.15	899.50	899.80	899.98	900.22	900.39
MED011A	7123	896.62	897.45	897.81	898.22	898.51	898.70	898.91	899.05	899.40	899.70	899.89	900.10	900.23
MED010	6351	896.49	897.28	897.55	897.90	898.15	898.31	898.49	898.61	898.90	899.12	899.26	899.42	899.54
MED009	5447	896.22	896.94	897.04	897.32	897.47	897.56	897.65	897.73	897.90	898.13	898.30	898.64	898.98
MED007	3628	894.73	895.34	895.52	895.70	895.95	896.15	896.42	896.57	897.21	897.71	898.00	898.49	898.86
MED006	2692	893.90	894.48	894.84	895.19	895.77	896.04	896.34	896.55	897.22	897.73	898.02	898.51	898.88
MED005	2125	893.27	893.85	894.23	894.58	895.39	895.69	896.05	896.30	897.09	897.66	897.97	898.49	898.87
MED004	1690	893.02	893.72	894.15	894.51	895.45	895.75	896.11	896.36	897.11	897.66	897.97	898.48	898.86
MED003	1242	892.87	893.60	894.02	894.46	895.42	895.73	896.09	896.34	897.10	897.65	897.96	898.47	898.85
MED002	734	892.84	893.56	893.97	894.38	895.36	895.66	896.02	896.27	897.03	897.58	897.89	898.40	898.78
MED001	272	892.80	893.51	893.93	894.33	895.34	895.65	896.01	896.26	897.03	897.58	897.89	898.40	898.78

TABLE 3B: COMPUTED FLOOD FREQUENCY WATER SURFACE ELEVATIONS, LITTLE RED DEER RIVER

Cross-Section	River Station (m)	Water Surface Elevation (m)												
		2-year flood	5-year flood	10-year flood	20-year flood	35-year flood	50-year flood	75-year flood	100-year flood	200-year flood	350-year flood	500-year flood	750-year flood	1000-year flood
LRD075	32643	942.54	943.47	943.97	944.38	944.53	944.67	944.82	944.92	945.15	945.35	945.47	945.60	945.69
LRD074	32311	942.33	943.23	943.65	943.96	944.21	944.34	944.47	944.56	944.75	944.90	945.01	945.12	945.19
LRD073	32010	942.14	943.05	943.50	943.87	944.09	944.22	944.35	944.43	944.60	944.75	944.85	944.94	945.01
LRD072	31618	941.80	942.63	943.04	943.38	943.67	943.83	944.01	944.12	944.20	944.31	944.37	944.46	944.52
LRD071	31294	941.67	942.40	942.73	943.01	943.26	943.40	943.55	943.63	943.77	943.91	943.99	944.09	944.14
LRD070	30830	941.52	942.21	942.55	942.86	943.13	943.26	943.42	943.49	943.65	943.78	943.85	943.94	943.98
LRD069	30188	940.96	941.43	941.64	941.86	942.06	942.19	942.36	942.48	942.61	942.83	942.97	943.13	943.24
LRD068	29482	939.69	940.37	940.74	941.07	941.31	941.46	941.63	941.76	942.02	942.25	942.39	942.56	942.68
LRD067	28995	938.98	939.63	939.99	940.32	940.57	940.72	940.88	940.99	941.22	941.40	941.51	941.64	941.73
LRD066	28591	938.54	939.19	939.45	939.71	939.91	940.03	940.17	940.28	940.55	940.79	940.92	941.08	941.19
LRD065	28316	938.30	938.95	939.14	939.33	939.46	939.53	939.60	939.65	939.85	939.94	940.00	940.07	940.11
LRD064	27439	937.14	937.88	938.24	938.44	938.63	938.74	938.87	938.95	939.03	939.18	939.27	939.37	939.44
LRD063	26659	936.17	937.08	937.49	937.82	938.06	938.19	938.33	938.43	938.63	938.78	938.88	938.99	939.06
LRD062	26204	935.67	936.65	937.11	937.49	937.76	937.92	938.06	938.16	938.39	938.53	938.62	938.70	938.77
LRD061	25747	935.13	936.06	936.45	936.78	936.98	937.08	937.20	937.28	937.46	937.66	937.73	937.85	937.93
LRD060	25297	934.64	935.48	935.87	936.22	936.42	936.55	936.69	936.77	936.97	937.12	937.22	937.32	937.40
LRD059	24848	934.12	935.08	935.45	935.77	935.93	936.05	936.16	936.21	936.35	936.46	936.53	936.60	936.65
LRD058	24382	933.69	934.70	934.99	935.38	935.54	935.60	935.73	935.77	935.88	935.97	936.07	936.11	936.16
LRD057	23925	933.34	934.25	934.10	934.20	934.67	934.83	934.85	934.93	935.07	935.17	935.16	935.27	935.30
LRD056	23710	933.19	934.02	934.22	934.44	934.59	934.68	934.77	934.83	934.96	935.05	935.12	935.19	935.24
LRD055	23572	933.07	933.84	934.22	934.44	934.59	934.68	934.76	934.83	934.95	935.05	935.11	935.18	935.23
LRD054B	23493	932.85	933.58	934.20	934.41	934.56	934.65	934.73	934.79	934.91	934.99	935.06	935.12	935.16
LRD054A	23465	932.03	932.52	932.80	933.02	933.16	933.25	933.34	933.40	933.55	933.67	933.74	933.83	933.88
LRD053	23356	931.99	932.51	932.79	933.01	933.15	933.24	933.33	933.39	933.54	933.66	933.73	933.81	933.87
LRD052	23027	931.96	932.49	932.77	932.97	933.12	933.20	933.28	933.35	933.49	933.61	933.68	933.76	933.81
LRD051	22561	931.86	932.41	932.69	932.89	933.02	933.10	933.17	933.24	933.36	933.48	933.54	933.61	933.66
LRD050	22285	931.70	932.21	932.45	932.65	932.74	932.80	932.86	932.91	933.01	933.09	933.13	933.18	933.22
LRD049	21767	931.20	931.75	931.92	932.06	932.20	932.27	932.34	932.39	932.52	932.63	932.71	932.81	932.89
LRD048	21409	930.64	931.20	931.52	931.75	931.90	931.99	932.06	932.12	932.29	932.45	932.55	932.67	932.76
LRD047	21132	930.18	930.73	931.06	931.34	931.55	931.67	931.81	931.90	932.11	932.30	932.41	932.54	932.63
LRD046	20683	929.62	930.13	930.35	930.52	930.65	930.73	930.81	930.87	931.01	931.12	931.20	931.31	931.39
LRD045	20380	929.03	929.45	929.75	929.98	930.14	930.23	930.34	930.43	930.64	930.84	930.98	931.14	931.27
LRD044	20040	928.19	928.77	929.05	929.30	929.51	929.65	929.82	929.94	930.22	930.46	930.62	930.81	930.94
LRD043	19849	927.95	928.58	928.89	929.18	929.42	929.57	929.74	929.87	930.17	930.42	930.59	930.78	930.92
LRD042	19385	927.36	928.04	928.36	928.69	928.90	929.02	929.17	929.26	929.50	929.69	929.80	929.93	930.02
LRD041	18868	926.34	927.14	927.49	927.75	927.96	928.08	928.22	928.32	928.56	928.75	928.87	929.01	929.11
LRD040	18426	925.73	926.46	926.83	927.10	927.29	927.38	927.49	927.55	927.72	927.85	927.93	928.02	928.10
LRD039	17897	924.77	925.44	925.85	926.13	926.37	926.48	926.61	926.72	926.96	927.15	927.27	927.42	927.53
LRD038	17580	924.26	925.03	925.53	925.92	926.22	926.40	926.51	926.63	926.88	927.08	927.21	927.36	927.47
LRD037	16941	923.43	924.26	924.69	925.01	925.25	925.39	925.56	925.68	925.96	926.18	926.32	926.48	926.61
LRD036	16488	922.81	923.70	924.08	924.37	924.58	924.69	924.79	924.88	925.09	925.27	925.38	925.51	925.60

Cross-Section	River Station (m)	Water Surface Elevation (m)												
		2-year flood	5-year flood	10-year flood	20-year flood	35-year flood	50-year flood	75-year flood	100-year flood	200-year flood	350-year flood	500-year flood	750-year flood	1000-year flood
LRD035	16189	922.33	923.24	923.67	924.02	924.25	924.33	924.35	924.39	924.54	924.68	924.77	924.88	924.97
LRD034	15715	921.36	921.98	922.35	922.50	922.77	923.00	923.25	923.38	923.67	923.90	924.04	924.22	924.33
LRD033	15466	920.75	921.42	921.84	922.19	922.49	922.66	922.88	922.99	923.27	923.48	923.62	923.82	923.92
LRD032	15233	920.19	920.92	921.32	921.65	921.91	922.05	922.23	922.32	922.56	922.74	922.86	923.02	923.11
LRD031	14525	918.64	919.24	919.58	919.90	920.11	920.22	920.35	920.45	920.71	920.95	921.10	921.27	921.41
LRD030	13896	917.11	917.73	918.12	918.49	918.78	918.97	919.19	919.30	919.57	919.67	919.80	919.96	920.07
LRD029	13470	915.98	916.65	917.10	917.52	917.86	918.08	918.33	918.51	918.93	919.22	919.44	919.69	919.87
LRD028	12856	914.51	915.19	915.62	915.97	916.26	916.44	916.65	916.80	917.16	917.47	917.66	917.88	918.04
LRD027	12500	913.58	914.27	914.67	915.05	915.36	915.56	915.79	915.96	916.38	916.74	916.95	917.21	917.39
LRD026	11955	912.50	913.07	913.48	913.85	914.17	914.37	914.62	914.78	915.17	915.47	915.67	915.87	916.02
LRD025	11443	911.39	912.13	912.61	913.05	913.40	913.61	913.89	914.05	914.42	914.70	914.91	915.09	915.20
LRD024	11274	910.90	911.67	912.12	912.53	912.86	913.07	913.29	913.47	913.87	914.18	914.34	914.57	914.74
LRD023	11010	910.40	911.09	911.52	911.94	912.24	912.42	912.64	912.79	913.19	913.47	913.63	913.83	913.95
LRD022	10401	908.70	909.30	909.72	910.13	910.44	910.63	910.83	910.96	911.27	911.54	911.74	911.98	912.18
LRD021	9921	907.66	908.42	908.90	909.34	909.72	909.95	910.23	910.34	910.79	911.20	911.47	911.78	912.04
LRD020	9646	907.09	907.94	908.45	908.92	909.30	909.53	909.80	910.01	910.51	910.95	911.22	911.54	911.82
LRD019B	9401	906.91	907.75	908.25	908.72	909.09	909.32	909.57	909.75	910.20	910.57	910.80	911.08	911.33
LRD019A	9387	906.87	907.68	908.17	908.61	908.95	909.16	909.40	909.56	909.97	910.30	910.51	910.76	911.02
LRD018	9129	906.61	907.34	907.75	908.13	908.42	908.59	908.77	908.90	909.21	909.45	909.58	909.73	909.80
LRD017	8823	906.24	906.95	907.36	907.71	907.98	908.13	908.30	908.41	908.70	908.94	909.09	909.26	909.36
LRD016	8308	905.28	905.97	906.38	906.73	906.91	907.02	907.14	907.22	907.39	907.53	907.61	907.71	907.81
LRD015	7617	903.90	904.75	905.17	905.52	905.66	905.79	905.94	906.05	906.34	906.58	906.75	906.94	907.08
LRD014	7070	902.94	903.79	904.30	904.76	905.10	905.25	905.45	905.59	905.93	906.21	906.39	906.60	906.75
LRD013	6480	902.11	902.84	903.19	903.47	903.69	903.84	904.01	904.13	904.41	904.64	904.79	904.96	905.08
LRD012	5958	901.54	902.35	902.86	903.21	903.47	903.64	903.83	903.97	904.26	904.50	904.65	904.83	904.95
LRD011	5484	900.91	901.70	902.21	902.55	902.84	903.02	903.22	903.35	903.56	903.70	903.79	903.90	903.98
LRD010	4953	900.15	900.97	901.43	901.72	901.86	901.96	902.07	902.16	902.41	902.65	902.81	903.00	903.14
LRD009	4581	899.61	900.51	901.02	901.11	901.35	901.50	901.67	901.79	902.11	902.38	902.55	902.74	902.89
LRD008	3863	898.56	899.49	899.74	899.99	900.24	900.41	900.61	900.76	901.12	901.42	901.61	901.77	901.94
LRD007	3277	897.74	898.63	899.13	899.53	899.85	900.06	900.30	900.48	900.87	901.18	901.38	901.53	901.69
LRD006	2750	896.98	897.87	898.44	898.91	899.27	899.50	899.75	899.93	900.30	900.58	900.75	900.79	900.92
LRD005	2103	896.28	897.06	897.57	898.03	898.41	898.64	898.89	899.06	899.40	899.69	899.85	900.11	900.39
LRD004	1565	895.47	896.23	896.65	897.01	897.26	897.40	897.60	897.75	898.38	898.91	899.23	899.81	900.20
LRD003	1017	895.02	895.68	896.02	896.34	896.95	897.21	897.52	897.75	898.46	899.00	899.29	899.79	900.17
LRD002	539	894.85	895.54	895.92	896.26	896.92	897.19	897.50	897.73	898.45	898.98	899.27	899.78	900.15
LRD001	121	894.77	895.43	895.78	896.09	896.78	897.05	897.35	897.58	898.31	898.85	899.14	899.64	900.02

TABLE 3C: COMPUTED FLOOD FREQUENCY WATER SURFACE ELEVATIONS, RED DEER RIVER

Cross-Section	River Station (m)	Water Surface Elevation (m)												
		2-year flood	5-year flood	10-year flood	20-year flood	35-year flood	50-year flood	75-year flood	100-year flood	200-year flood	350-year flood	500-year flood	750-year flood	1000-year flood
RDR109	50219	912.59	913.43	914.01	914.44	914.71	914.98	915.31	915.54	916.22	916.70	916.92	917.35	917.65
RDR108	49602	912.34	913.09	913.64	913.98	914.22	914.42	914.69	914.88	915.44	915.83	916.02	916.39	916.64
RDR107	49105	911.69	912.37	912.92	913.41	913.70	913.78	914.06	914.27	914.84	915.23	915.42	915.79	916.05
RDR106	48532	910.59	911.37	911.99	912.45	912.71	912.85	913.11	913.30	913.89	914.26	914.44	914.80	915.05
RDR105	48110	909.93	910.76	911.45	911.76	911.93	912.20	912.46	912.65	913.24	913.56	913.74	914.09	914.34
RDR104	47648	909.27	910.14	910.87	911.28	911.44	911.72	912.00	912.20	912.83	913.09	913.26	913.61	913.87
RDR103	46832	907.92	908.64	909.08	909.45	909.70	909.87	910.14	910.35	910.92	911.46	911.71	912.20	912.53
RDR102	46572	907.77	908.48	908.90	909.26	909.46	909.56	909.76	909.90	910.29	910.55	910.66	910.87	911.00
RDR101	46157	907.40	908.01	908.37	908.64	908.79	908.91	909.00	909.12	909.50	909.78	909.92	910.19	910.37
RDR100	45657	906.85	906.93	907.12	907.36	907.48	907.64	907.82	907.95	908.35	908.63	908.77	909.04	909.12
RDR099	45324	906.05	906.37	906.64	906.77	906.91	907.05	907.23	907.36	907.76	908.02	908.15	908.41	908.61
RDR098	44835	905.22	905.73	905.97	906.25	906.35	906.50	906.68	906.80	907.19	907.40	907.53	907.78	907.95
RDR097	44198	904.45	905.08	905.39	905.45	905.58	905.74	905.91	906.03	906.40	906.68	906.83	907.10	907.29
RDR096	43714	903.45	903.96	904.30	904.41	904.59	904.77	904.99	905.13	905.60	905.95	906.11	906.42	906.61
RDR095	43223	902.22	902.95	903.45	903.78	904.02	904.20	904.47	904.64	905.16	905.53	905.69	905.99	906.17
RDR094	41886	900.71	901.34	901.77	901.92	902.10	902.27	902.45	902.59	902.97	903.23	903.35	903.61	903.86
RDR093	41450	900.26	900.88	901.30	901.45	901.61	901.79	901.99	902.14	902.16	902.45	902.59	902.87	903.07
RDR092	40862	899.26	899.79	899.90	900.19	900.33	900.51	900.71	900.85	901.34	901.69	901.84	902.14	902.35
RDR091	40190	897.99	898.71	899.16	899.52	899.74	899.86	900.12	900.30	900.86	901.23	901.37	901.66	901.88
RDR090	39763	897.53	898.15	898.56	898.69	898.84	899.04	899.25	899.40	899.83	900.17	900.37	900.76	901.05
RDR089	39145	897.00	897.61	897.95	898.18	898.34	898.47	898.65	898.79	899.27	899.67	899.90	900.33	900.65
RDR088	38713	896.30	896.96	897.37	897.42	897.53	897.75	898.01	898.20	898.83	899.31	899.58	900.05	900.41
RDR087	38046	895.03	895.70	896.07	896.38	896.96	897.21	897.51	897.73	898.43	898.96	899.24	899.73	900.10
RDR086	37722	894.50	895.06	895.30	895.59	896.40	896.70	897.04	897.29	898.05	898.60	898.89	899.40	899.78
RDR085	37112	894.04	894.61	894.96	895.30	896.22	896.54	896.90	897.15	897.94	898.50	898.80	899.32	899.71
RDR084	36841	893.75	894.39	894.77	895.13	896.07	896.39	896.76	897.01	897.79	898.35	898.65	899.16	899.54
RDR083	36044	893.10	893.83	894.26	894.66	895.65	895.96	896.31	896.55	897.29	897.81	898.11	898.59	898.95
RDR082	35419	892.56	893.16	893.48	893.80	894.66	894.95	895.32	895.58	896.36	896.93	897.24	897.75	898.13
RDR081	35038	892.11	892.81	893.15	893.50	894.49	894.80	895.20	895.47	896.28	896.85	897.17	897.69	898.08
RDR080	34605	891.33	892.08	892.54	892.97	894.12	894.42	894.83	895.10	895.91	896.48	896.79	897.30	897.69
RDR079	33990	890.87	891.58	892.01	892.41	893.50	893.76	894.12	894.36	895.08	895.60	895.88	896.36	896.72
RDR078	33492	890.46	891.18	891.60	891.99	893.08	893.37	893.74	893.98	894.72	895.26	895.55	896.05	896.43
RDR077	32971	889.91	890.61	891.00	891.36	892.33	892.64	893.03	893.29	894.09	894.66	894.97	895.50	895.90
RDR076	32367	889.51	890.25	890.60	890.95	891.90	892.24	892.63	892.88	893.68	894.25	894.57	895.11	895.52
RDR075	31827	889.09	889.80	890.11	890.47	891.46	891.81	892.21	892.46	893.27	893.85	894.17	894.71	895.12
RDR074	31367	888.65	889.25	889.61	889.96	890.94	891.27	891.65	891.86	892.60	893.13	893.43	893.94	894.32
RDR073	30753	888.11	888.72	889.10	889.46	890.47	890.80	891.16	891.41	892.20	892.78	893.11	893.67	894.08
RDR072	29976	887.35	888.11	888.57	888.98	890.04	890.36	890.73	890.98	891.78	892.38	892.71	893.29	893.71
RDR071	29154	886.41	887.06	887.42	887.74	888.66	889.02	889.45	889.75	890.69	891.38	891.74	892.37	892.82
RDR070	28768	886.00	886.53	886.93	887.29	888.30	888.68	889.11	889.42	890.37	891.06	891.41	892.05	892.50
RDR069	28229	885.99	886.53	886.92	887.27	888.27	888.65	889.08	889.38	890.34	891.03	891.39	892.03	892.49

Cross-Section	River Station (m)	Water Surface Elevation (m)												
		2-year flood	5-year flood	10-year flood	20-year flood	35-year flood	50-year flood	75-year flood	100-year flood	200-year flood	350-year flood	500-year flood	750-year flood	1000-year flood
RDR068	27841	885.73	886.32	886.70	887.04	888.02	888.39	888.81	889.11	890.05	890.73	891.11	891.78	892.26
RDR067	27270	885.14	885.76	886.13	886.48	887.51	887.87	888.32	888.64	889.63	890.34	890.73	891.43	891.91
RDR066	26811	884.81	885.49	885.91	886.26	887.34	887.72	888.17	888.50	889.50	890.21	890.61	891.32	891.80
RDR065	26290	884.40	885.05	885.46	885.85	886.92	887.29	887.74	888.06	889.05	889.75	890.14	890.84	891.32
RDR064	25704	883.82	884.58	885.03	885.45	886.54	886.92	887.38	887.71	888.72	889.43	889.83	890.55	891.03
RDR063	25335	883.60	884.40	884.85	885.27	886.34	886.70	887.14	887.46	888.42	889.10	889.47	890.17	890.79
RDR062B	25120	883.45	884.21	884.64	885.03	885.97	886.28	886.66	886.93	887.73	888.29	888.59	889.23	889.66
RDR062A	25105	883.41	884.17	884.59	884.98	885.89	886.19	886.55	886.81	887.59	888.14	888.44	888.92	889.28
RDR061	24863	883.19	883.91	884.28	884.64	885.53	885.85	886.24	886.51	887.33	887.92	888.24	888.77	889.16
RDR060	24523	882.98	883.74	884.12	884.49	885.38	885.71	886.10	886.37	887.20	887.79	888.11	888.64	889.03
RDR059	24056	882.64	883.41	883.82	884.20	885.12	885.46	885.86	886.14	886.99	887.58	887.91	888.45	888.85
RDR058	23777	882.39	883.13	883.58	883.97	884.87	885.20	885.60	885.88	886.72	887.31	887.64	888.17	888.56
RDR057	23352	882.04	882.79	883.23	883.58	884.53	884.87	885.27	885.55	886.39	886.98	887.31	887.84	888.23
RDR056	22940	881.64	882.32	882.76	883.08	884.00	884.34	884.73	885.01	885.83	886.41	886.73	887.23	887.61
RDR055	22653	881.44	882.21	882.68	883.01	883.93	884.28	884.68	884.96	885.79	886.37	886.69	887.21	887.59
RDR054	22080	880.90	881.68	882.14	882.61	883.50	883.83	884.22	884.49	885.30	885.86	886.17	886.67	887.04
RDR053	21655	880.77	881.56	882.02	882.45	883.28	883.60	883.98	884.26	885.06	885.62	885.93	886.43	886.80
RDR052	21403	880.51	881.20	881.61	881.99	882.84	883.17	883.57	883.85	884.66	885.22	885.53	886.02	886.38
RDR051	21109	880.14	880.89	881.32	881.71	882.51	882.87	883.29	883.59	884.42	884.98	885.30	885.79	886.15
RDR050	20573	879.76	880.58	881.02	881.41	882.05	882.41	882.84	883.13	883.95	884.48	884.78	885.23	885.57
RDR049	20186	879.42	880.18	880.58	880.94	881.96	882.33	882.75	883.06	883.88	884.42	884.72	885.17	885.52
RDR048	19659	878.96	879.64	880.07	880.47	881.60	881.98	882.40	882.71	883.52	884.04	884.33	884.77	885.10
RDR047	19377	878.89	879.60	880.03	880.43	881.55	881.93	882.36	882.66	883.47	883.99	884.28	884.72	885.05
RDR046	18921	878.72	879.39	879.79	880.15	881.22	881.57	881.98	882.27	882.98	883.44	883.72	884.09	884.40
RDR045	18542	878.50	879.12	879.50	879.85	880.84	881.16	881.53	881.78	882.51	883.00	883.29	883.70	884.03
RDR044	18045	878.03	878.64	879.03	879.39	880.47	880.81	881.22	881.48	882.24	882.73	883.02	883.43	883.76
RDR043	17790	877.73	878.37	878.78	879.16	880.27	880.62	881.03	881.28	882.04	882.52	882.80	883.21	883.53
RDR042	17391	877.28	877.94	878.36	878.74	879.86	880.21	880.59	880.83	881.57	882.03	882.32	882.74	883.08
RDR041	17057	877.04	877.72	878.14	878.53	879.64	880.00	880.38	880.63	881.38	881.84	882.13	882.56	882.90
RDR040	16602	876.63	877.30	877.71	878.09	879.18	879.52	879.93	880.22	881.01	881.48	881.77	882.21	882.55
RDR039	16169	876.23	876.91	877.35	877.74	878.84	879.18	879.57	879.84	880.57	881.03	881.33	881.80	882.17
RDR038	15812	875.80	876.47	876.90	877.29	878.35	878.66	879.05	879.31	880.13	880.58	880.93	881.44	881.85
RDR037	15367	875.51	876.20	876.65	877.05	878.10	878.45	878.86	879.18	880.04	880.50	880.87	881.40	881.82
RDR036	14866	875.09	875.77	876.21	876.60	877.54	877.87	878.26	878.55	879.36	880.34	880.71	881.25	881.68
RDR035B	14714	874.95	875.61	876.04	876.41	877.21	877.48	877.78	878.01	878.61	878.99	879.31	880.59	881.20
RDR035A	14696	874.92	875.57	875.99	876.36	877.11	877.35	877.61	877.81	878.28	878.55	878.69	878.93	879.05
RDR034	14499	874.74	875.35	875.76	876.15	876.91	877.18	877.49	877.72	878.33	878.72	878.93	879.22	879.46
RDR033	14148	874.53	875.07	875.47	875.84	876.55	876.84	877.15	877.38	877.95	878.37	878.60	878.94	879.20
RDR032	13529	874.08	874.50	874.95	875.34	875.72	875.98	876.28	876.51	877.06	877.47	877.73	878.11	878.41
RDR031	13127	873.57	874.33	874.80	875.22	875.50	875.77	876.08	876.32	876.90	877.37	877.65	878.06	878.39
RDR030	12862	873.33	874.06	874.50	874.90	875.43	875.71	876.02	876.26	876.85	877.32	877.61	878.02	878.35
RDR029	12475	873.02	873.76	874.21	874.62	875.32	875.61	875.92	876.17	876.75	877.22	877.51	877.92	878.25

Cross-Section	River Station (m)	Water Surface Elevation (m)												
		2-year flood	5-year flood	10-year flood	20-year flood	35-year flood	50-year flood	75-year flood	100-year flood	200-year flood	350-year flood	500-year flood	750-year flood	1000-year flood
RDR028	11928	872.65	873.40	873.85	874.27	874.92	875.21	875.49	875.73	876.26	876.74	877.03	877.46	877.80
RDR027	11520	872.16	872.94	873.41	873.84	874.57	874.90	875.21	875.49	876.04	876.57	876.88	877.33	877.70
RDR026	10959	871.69	872.34	872.73	873.07	874.21	874.57	874.89	875.19	875.71	876.27	876.59	877.06	877.44
RDR025	10679	871.55	872.19	872.57	872.91	873.92	874.26	874.53	874.82	875.19	875.72	876.04	876.50	876.88
RDR024	10319	871.26	871.91	872.30	872.67	873.74	874.10	874.35	874.65	874.98	875.55	875.88	876.36	876.76
RDR023	9898	870.80	871.51	871.92	872.30	873.39	873.74	874.18	874.49	874.75	875.35	875.70	876.19	876.60
RDR022	9537	870.47	871.10	871.47	871.81	872.75	873.05	873.39	873.65	874.66	875.26	875.62	876.12	876.53
RDR021	9066	870.12	870.69	871.02	871.31	872.22	872.55	872.97	873.30	874.23	874.90	875.28	875.81	876.24
RDR020	8811	869.89	870.48	870.81	871.11	872.11	872.47	872.91	873.25	874.20	874.87	875.25	875.78	876.22
RDR019	8374	869.32	869.96	870.35	870.73	871.87	872.27	872.74	873.10	874.08	874.76	875.14	875.66	876.10
RDR018	8016	869.08	869.79	870.22	870.62	871.79	872.19	872.67	873.02	874.01	874.68	875.06	875.59	876.03
RDR017	7685	868.74	869.39	869.80	870.17	871.29	871.67	872.13	872.48	873.42	874.05	874.40	874.89	875.20
RDR016	7371	868.46	869.13	869.55	869.95	871.11	871.51	871.98	872.33	873.29	873.93	874.30	874.80	875.17
RDR015	6881	867.99	868.61	869.00	869.38	870.54	870.94	871.41	871.77	872.71	873.33	873.66	874.12	874.46
RDR014	6563	867.75	868.41	868.83	869.22	870.42	870.83	871.31	871.67	872.64	873.27	873.63	874.11	874.46
RDR013	6100	867.26	867.95	868.38	868.77	869.93	870.33	870.80	871.15	872.13	872.74	873.10	873.59	873.98
RDR012	5758	866.94	867.61	868.03	868.42	869.60	870.01	870.48	870.84	871.80	872.38	872.72	873.19	873.56
RDR011B	5365	866.60	867.25	867.65	868.02	869.11	869.48	869.91	870.22	871.08	871.56	871.83	872.24	872.53
RDR011A	5333	866.59	867.23	867.63	868.00	869.09	869.45	869.88	870.19	871.04	871.52	871.79	872.18	872.48
RDR010	4885	866.21	866.83	867.22	867.58	868.68	869.05	869.49	869.81	870.68	871.15	871.42	871.81	872.13
RDR009	4227	865.52	866.14	866.53	866.89	867.96	868.32	868.74	869.05	869.87	870.42	870.73	871.17	871.53
RDR008	3657	865.01	865.62	866.00	866.35	867.39	867.74	868.15	868.45	869.30	869.85	870.16	870.60	870.88
RDR007	3070	864.45	865.05	865.41	865.74	866.74	867.07	867.47	867.76	868.58	869.10	869.40	869.84	870.11
RDR006	2505	863.93	864.50	864.84	865.17	866.17	866.51	866.91	867.21	868.03	868.54	868.82	869.23	869.64
RDR005	2292	863.74	864.30	864.64	864.96	865.94	866.28	866.67	866.96	867.75	868.26	868.55	868.96	869.24
RDR004	1948	863.41	863.95	864.29	864.61	865.60	865.94	866.34	866.64	867.46	867.95	868.23	868.65	868.94
RDR003	1337	862.63	863.23	863.60	863.94	864.98	865.33	865.75	866.05	866.89	867.36	867.63	868.02	868.29
RDR002	730	862.12	862.66	862.99	863.30	864.24	864.57	864.96	865.24	866.05	866.65	867.01	867.46	867.77
RDR001	0	861.37	861.98	862.35	862.69	863.72	864.08	864.51	864.82	865.69	866.28	866.62	867.06	867.34

TABLE 4: SENSITIVITY ANALYSIS, VARIABLE DOWNSTREAM BOUNDARY CONDITION AT 1:100 YR FLOOD

River Station	Simulated WSE at 1:100-yr Flood (m)				
	Rating Curve -0.5m	Rating Curve -0.25m	Calibrated Profile	Rating Curve +0.25m	Rating Curve +0.5m
Red Deer River					
5333.35 RDR011A	870.19	870.19	870.19	870.19	870.20
4885.02 RDR010	869.80	869.81	869.81	869.81	869.82
4227.32 RDR009	869.04	869.04	869.05	869.05	869.06
3657.4 RDR008	868.44	868.44	868.45	868.46	868.47
3069.72 RDR007	867.74	867.75	867.76	867.78	867.81
2505.23 RDR006	867.16	867.18	867.21	867.23	867.28
2292.09 RDR005	866.90	866.92	866.96	866.98	867.04
1947.85 RDR004	866.57	866.59	866.64	866.68	866.75
1337.08 RDR003	865.92	865.97	866.05	866.13	866.24
730.21 RDR002	864.95	865.07	865.24	865.39	865.57
0 RDR001	864.32	864.57	864.82	865.07	865.32
average difference	-0.08	-0.05		0.04	0.10
maximum difference	-0.50	-0.25		0.25	0.50

TABLE 5A: SENSITIVITY ANALYSIS, VARIABLE CHANNEL MANNING ROUGHNESS AT 1:100 YR FLOOD, MEDICINE RIVER

Cross Section	River Station	Simulated WSE at 1:100-yr Flood (m)		
		Channel Roughness -20%	Calibrated Profile	Channel Roughness +20%
		$n_{channel}$ = 0.018	$n_{channel}$ = 0.023	$n_{channel}$ = 0.028
MED067	33253.11	905.93	906.08	906.18
MED066	32861.16	905.89	906.04	906.14
MED065	32000.58	905.87	906.01	906.11
MED064	31468.75	905.81	905.97	906.08
MED063	31082.61	905.78	905.94	906.05
MED062	30291.89	905.73	905.90	906.01
MED061	28899.33	905.70	905.87	905.98
MED060	28199.55	905.67	905.85	905.97
MED059	27419.95	905.62	905.81	905.94
MED058	26899.14	905.36	905.61	905.78
MED057	26532.54	905.31	905.56	905.72
MED056	26080.72	905.12	905.33	905.47
MED055	25653.03	904.99	905.21	905.33
MED054	25455.59	905.01	905.22	905.33
MED053	24798.82	904.89	905.15	905.25
MED052	23964.02	904.65	904.94	905.04
MED051	23379.66	904.40	904.66	904.92
MED050	22931.17	904.28	904.56	904.77
MED049	22485.04	904.26	904.52	904.72
MED048	22231.42	904.25	904.50	904.70
MED047	21617.42	904.18	904.43	904.64
MED046	21070.82	903.98	904.26	904.49
MED045	20890.75	903.91	904.17	904.39
MED044B	20841.77	903.75	904.03	904.27
Bridge	20810.00			
MED044A	20804.43	903.38	903.66	903.90
MED043	20762.22	903.37	903.65	903.88
MED042	20535.00	903.15	903.40	903.60
MED041	20097.55	902.95	903.27	903.44
MED040	19779.50	902.84	903.02	903.14
MED039	19295.25	902.15	902.52	902.75
MED038	18857.51	902.05	902.25	902.45
MED037	18392.96	901.84	902.23	902.40
MED036	17961.80	901.85	902.12	902.28
MED035	17492.38	901.65	901.97	902.14
MED034	17037.58	901.50	901.83	901.97
MED033	16715.32	901.60	901.88	902.01
MED032	16546.90	901.51	901.86	902.00
MED031	16254.46	901.13	901.63	901.81
MED030B	16120.31	901.08	901.43	901.58
Bridge	16115.00			
MED030A	16113.64	900.99	901.34	901.52
MED029	16084.13	901.01	901.36	901.51
MED028B	16027.90	901.06	901.38	901.53
Bridge	16020.00			
MED028A	16007.45	900.96	901.31	901.46
MED027	15848.04	900.99	901.35	901.50
MED026	15351.38	900.52	900.94	901.10
MED025	14979.10	900.35	900.72	901.04

Cross Section	River Station	Simulated WSE at 1:100-yr Flood (m)		
		Channel Roughness -20%	Calibrated Profile	Channel Roughness +20%
MED024	14323.15	899.89	900.25	900.51
MED023	13881.12	899.90	900.19	900.38
MED022	13578.37	899.87	900.14	900.31
MED021	12974.92	899.73	899.95	900.16
MED020	12723.99	899.77	899.99	900.17
MED019	11712.27	899.72	899.94	900.13
MED018	10702.67	899.67	899.91	900.11
MED017	10131.73	899.56	899.84	900.06
MED016	9894.27	899.49	899.82	900.04
MED015	9581.27	899.38	899.66	899.90
MED014	9169.58	899.29	899.58	899.81
MED013	8163.01	899.15	899.46	899.71
MED012	7621.91	899.06	899.38	899.64
MED011B	7140.56	898.85	899.15	899.41
Bridge	7130.00			
MED011A	7123.37	898.72	899.05	899.33
MED010	6350.81	898.34	898.61	898.83
MED009	5446.71	897.48	897.73	897.90
MED007	3627.92	896.44	896.57	896.73
MED006	2692.12	896.43	896.55	896.69
MED005	2124.88	896.14	896.30	896.49
MED004	1690.13	896.24	896.36	896.52
MED003	1242.14	896.22	896.34	896.50
MED002	734.23	896.16	896.27	896.43
MED001	271.51	896.16	896.26	896.41
average difference		-0.25		0.17
maximum difference		-0.50		0.32

TABLE 5B: SENSITIVITY ANALYSIS, VARIABLE CHANNEL MANNING ROUGHNESS AT 1:100 YR FLOOD, LITTLE RED DEER RIVER

Cross Section	River Station	Simulated WSE at 1:100-yr Flood (m)		
		Channel Roughness -20%	Calibrated Profile	Channel Roughness +20%
		$n_{channel}$ = 0.024	$n_{channel}$ = 0.030	$n_{channel}$ = 0.036
LRD075	32643.42	944.82	944.92	945.00
LRD074	32310.99	944.44	944.56	944.66
LRD073	32009.86	944.37	944.43	944.49
LRD072	31617.99	943.97	944.12	944.20
LRD071	31294.25	943.59	943.63	943.67
LRD070	30829.77	943.54	943.49	943.47
LRD069	30188.17	942.40	942.48	942.63
LRD068	29482.38	941.68	941.76	941.84
LRD067	28994.71	940.79	940.99	941.13
LRD066	28590.84	940.20	940.28	940.38
LRD065	28315.81	939.49	939.65	939.74
LRD064	27438.99	938.90	938.95	938.99
LRD063	26658.89	938.34	938.43	938.50
LRD062	26204.33	938.13	938.16	938.19
LRD061	25747.29	937.07	937.28	937.41
LRD060	25296.69	936.65	936.77	936.85
LRD059	24847.80	936.17	936.21	936.25
LRD058	24381.56	935.64	935.77	935.83
LRD057	23925.10	934.96	934.93	934.90
LRD056	23709.71	934.80	934.83	934.85
LRD055	23571.73	934.80	934.83	934.84
LRD054B	23493.00	934.77	934.79	934.80
Bridge	23480.00			
LRD054A	23465.12	933.41	933.40	933.41
LRD053	23356.45	933.41	933.39	933.39
LRD052	23027.16	933.35	933.35	933.35
LRD051	22561.26	933.25	933.24	933.23
LRD050	22285.44	932.89	932.91	932.93
LRD049	21767.32	932.35	932.39	932.42
LRD048	21409.37	932.07	932.12	932.16
LRD047	21131.78	931.83	931.90	931.94
LRD046	20683.46	930.74	930.87	930.97
LRD045	20379.61	930.33	930.43	930.49
LRD044	20039.56	929.82	929.94	930.03
LRD043	19848.59	929.81	929.87	929.92
LRD042	19385.41	929.09	929.26	929.40
LRD041	18867.70	928.17	928.32	928.43
LRD040	18425.77	927.41	927.55	927.64
LRD039	17896.86	926.62	926.72	926.82
LRD038	17580.43	926.64	926.63	926.68
LRD037	16941.09	925.40	925.68	925.86
LRD036	16487.60	924.71	924.88	925.00
LRD035	16188.59	924.36	924.39	924.43
LRD034	15715.26	923.20	923.38	923.53
LRD033	15465.60	922.88	922.99	923.08
LRD032	15233.21	922.18	922.32	922.45
LRD031	14524.88	920.24	920.45	920.60
LRD030	13896.11	919.07	919.30	919.46
LRD029	13470.47	918.20	918.51	918.73
LRD028	12856.03	916.47	916.80	917.10
LRD027	12500.29	915.55	915.96	916.30
LRD026	11954.62	914.42	914.78	915.08
LRD025	11442.71	913.86	914.05	914.22
LRD024	11273.96	913.13	913.47	913.76

Cross Section	River Station	Simulated WSE at 1:100-yr Flood (m)		
		Channel Roughness -20%	Calibrated Profile	Channel Roughness +20%
LRD023	11010.17	912.51	912.79	913.06
LRD022	10400.51	910.61	910.96	911.25
LRD021	9921.31	910.15	910.34	910.58
LRD020	9646.01	909.72	910.01	910.28
LRD019B	9401.12	909.59	909.75	909.94
Bridge	9395.00			
LRD019A	9386.81	909.37	909.56	909.77
LRD018	9129.48	908.56	908.90	909.16
LRD017	8822.89	908.26	908.41	908.55
LRD016	8308.30	907.09	907.22	907.37
LRD015	7617.03	905.89	906.05	906.16
LRD014	7069.92	905.48	905.59	905.65
LRD013	6479.72	904.01	904.13	904.37
LRD012	5957.99	903.88	903.97	904.04
LRD011	5483.82	903.17	903.35	903.48
LRD010	4953.07	901.91	902.16	902.34
LRD009	4581.11	901.65	901.79	901.91
LRD008	3862.55	900.51	900.76	900.94
LRD007	3276.80	900.28	900.48	900.63
LRD006	2749.86	899.64	899.93	900.15
LRD005	2102.70	898.82	899.06	899.25
LRD004	1565.39	897.41	897.75	898.03
LRD003	1016.98	897.59	897.75	897.91
LRD002	539.23	897.61	897.73	897.86
LRD001	120.51	897.46	897.58	897.72
average difference		-0.14		0.12
maximum difference		-0.41		0.33

TABLE 5C: SENSITIVITY ANALYSIS, VARIABLE CHANNEL MANNING ROUGHNESS AT 1:100 YR FLOOD, RED DEER RIVER

Cross Section	River Station	Simulated WSE at 1:100-yr Flood (m)		
		Channel Roughness -20%	Calibrated Profile	Channel Roughness +20%
		$n_{channel}$ = 0.028	$n_{channel}$ = 0.035	$n_{channel}$ = 0.042
RDR109	50218.74	915.34	915.54	915.69
RDR108	49602.34	914.62	914.88	915.08
RDR107	49105.13	914.02	914.27	914.44
RDR106	48532.13	913.05	913.30	913.53
RDR105	48109.64	912.38	912.65	912.84
RDR104	47648.39	912.09	912.20	912.30
RDR103	46831.56	910.07	910.35	910.67
RDR102	46571.85	909.69	909.90	910.09
RDR101	46156.59	908.93	909.12	909.25
RDR100	45656.74	907.82	907.95	908.03
RDR099	45323.63	907.26	907.36	907.43
RDR098	44834.59	906.75	906.80	906.85
RDR097	44197.53	905.96	906.03	906.09
RDR096	43714.10	904.92	905.13	905.26
RDR095	43223.22	904.51	904.64	904.73
RDR094	41885.84	902.31	902.59	902.78
RDR093	41449.53	902.04	902.14	902.23
RDR092	40861.57	900.66	900.85	900.94
RDR091	40190.45	900.21	900.30	900.41
RDR090	39763.21	899.09	899.40	899.60
RDR089	39145.18	898.69	898.79	898.88
RDR088	38713.30	898.02	898.20	898.33
RDR087	38045.59	897.59	897.73	897.86
RDR086	37721.64	897.06	897.29	897.47
RDR085	37112.15	897.00	897.15	897.31
RDR084	36841.14	896.83	897.01	897.19
RDR083	36043.75	896.40	896.55	896.73
RDR082	35419.07	895.07	895.58	895.91
RDR081	35038.01	895.19	895.47	895.71
RDR080	34604.87	894.71	895.10	895.38
RDR079	33989.56	894.00	894.36	894.66
RDR078	33491.89	893.70	893.98	894.23
RDR077	32971.01	892.87	893.29	893.61
RDR076	32366.90	892.64	892.88	893.10
RDR075	31826.57	892.22	892.46	892.68
RDR074	31367.30	891.68	891.86	892.08
RDR073	30752.55	891.30	891.41	891.57
RDR072	29976.11	890.94	890.98	891.12
RDR071	29153.77	889.14	889.75	890.14
RDR070	28767.94	889.00	889.42	889.75
RDR069	28229.10	889.09	889.38	889.66
RDR068	27841.09	888.68	889.11	889.45
RDR067	27269.94	888.24	888.64	888.99
RDR066	26811.24	888.16	888.50	888.81
RDR065	26289.99	887.64	888.06	888.42
RDR064	25704.30	887.37	887.71	888.03
RDR063	25334.58	887.17	887.46	887.75
RDR062B	25119.90	886.59	886.93	887.24
Bridge	25110.00			
RDR062A	25105.02	886.41	886.81	887.15
RDR061	24862.84	886.04	886.51	886.85
RDR060	24523.27	886.07	886.37	886.62
RDR059	24055.69	885.86	886.14	886.36
RDR058	23776.91	885.59	885.88	886.12
RDR057	23352.27	885.27	885.55	885.77
RDR056	22939.96	884.68	885.01	885.27
RDR055	22652.90	884.69	884.96	885.17
RDR054	22080.46	884.19	884.49	884.73
RDR053	21654.55	883.99	884.26	884.49
RDR052	21403.28	883.40	883.85	884.16

Cross Section	River Station	Simulated WSE at 1:100-yr Flood (m)		
		Channel Roughness -20%	Calibrated Profile	Channel Roughness +20%
RDR051	21109.04	883.20	883.59	883.87
RDR050	20573.39	882.76	883.13	883.41
RDR049	20186.31	882.74	883.06	883.30
RDR048	19658.68	882.30	882.71	883.00
RDR047	19377.16	882.29	882.66	882.94
RDR046	18920.81	881.78	882.27	882.60
RDR045	18541.73	881.34	881.78	882.16
RDR044	18045.12	881.09	881.48	881.81
RDR043	17790.40	880.92	881.28	881.61
RDR042	17390.93	880.47	880.83	881.16
RDR041	17057.01	880.32	880.63	880.90
RDR040	16602.19	879.85	880.22	880.52
RDR039	16168.59	879.53	879.84	880.09
RDR038	15811.90	878.92	879.31	879.61
RDR037	15366.92	878.86	879.18	879.41
RDR036	14866.17	878.18	878.55	878.81
RDR035B	14714.49	877.71	878.01	878.25
Bridge	14700.00			
RDR035A	14696.46	877.48	877.81	878.05
RDR034	14498.85	877.39	877.72	877.95
RDR033	14148.40	877.02	877.38	877.61
RDR032	13528.62	876.24	876.51	876.67
RDR031	13127.07	876.10	876.32	876.41
RDR030	12861.96	876.06	876.26	876.34
RDR029	12475.30	875.97	876.17	876.24
RDR028	11928.01	875.43	875.73	875.84
RDR027	11520.43	875.17	875.49	875.54
RDR026	10959.43	874.84	875.19	875.20
RDR025	10679.27	874.45	874.82	874.77
RDR024	10318.95	874.36	874.65	874.46
RDR023	9897.90	874.22	874.49	874.17
RDR022	9537.43	873.19	873.65	874.06
RDR021	9066.37	872.91	873.30	873.66
RDR020	8811.41	872.90	873.25	873.59
RDR019	8374.00	872.68	873.10	873.47
RDR018	8016.03	872.64	873.02	873.39
RDR017	7684.66	871.89	872.48	872.97
RDR016	7370.54	871.82	872.33	872.79
RDR015	6881.20	871.12	871.77	872.28
RDR014	6562.62	871.14	871.67	872.14
RDR013	6100.29	870.57	871.15	871.67
RDR012	5758.35	870.23	870.84	871.35
RDR011B	5364.90	869.66	870.22	870.72
Bridge	5335.00			
RDR011A	5333.35	869.64	870.19	870.68
RDR010	4885.02	869.30	869.81	870.25
RDR009	4227.32	868.59	869.05	869.46
RDR008	3657.40	868.09	868.45	868.79
RDR007	3069.72	867.57	867.76	867.96
RDR006	2505.23	867.21	867.21	867.21
RDR005	2292.09	866.96	866.96	866.96
RDR004	1947.85	866.64	866.64	866.64
RDR003	1337.08	866.05	866.05	866.05
RDR002	730.21	865.24	865.24	865.24
RDR001	0	864.82	864.82	864.82
average difference		-0.30		0.23
maximum difference		-0.65		0.52

TABLE 6A: SENSITIVITY ANALYSIS, VARIABLE OVERBANK MANNING ROUGHNESS AT 1:100 YR FLOOD, MEDICINE RIVER

Cross Section	River Station	Simulated WSE at 1:100-yr Flood (m)		
		Overbank Roughness -20%	Calibrated Profile	Channel Roughness +20%
MED067	33253.11	905.96	906.08	906.18
MED066	32861.16	905.92	906.04	906.13
MED065	32000.58	905.90	906.01	906.11
MED064	31468.75	905.86	905.97	906.05
MED063	31082.61	905.84	905.94	906.02
MED062	30291.89	905.80	905.90	905.98
MED061	28899.33	905.78	905.87	905.94
MED060	28199.55	905.76	905.85	905.92
MED059	27419.95	905.73	905.81	905.88
MED058	26899.14	905.54	905.61	905.66
MED057	26532.54	905.49	905.56	905.61
MED056	26080.72	905.25	905.33	905.38
MED055	25653.03	905.13	905.21	905.27
MED054	25455.59	905.15	905.22	905.28
MED053	24798.82	905.08	905.15	905.21
MED052	23964.02	904.87	904.94	905.00
MED051	23379.66	904.58	904.66	904.72
MED050	22931.17	904.50	904.56	904.61
MED049	22485.04	904.47	904.52	904.56
MED048	22231.42	904.45	904.50	904.54
MED047	21617.42	904.39	904.43	904.46
MED046	21070.82	904.23	904.26	904.28
MED045	20890.75	904.14	904.17	904.19
MED044B	20841.77	904.00	904.03	904.06
Bridge	20810.00			
MED044A	20804.43	903.62	903.66	903.70
MED043	20762.22	903.61	903.65	903.68
MED042	20535.00	903.33	903.40	903.44
MED041	20097.55	903.22	903.27	903.30
MED040	19779.50	902.95	903.02	903.07
MED039	19295.25	902.47	902.52	902.55
MED038	18857.51	902.16	902.25	902.30
MED037	18392.96	902.16	902.23	902.26
MED036	17961.80	902.07	902.12	902.14
MED035	17492.38	901.93	901.97	901.98
MED034	17037.58	901.78	901.83	901.84
MED033	16715.32	901.84	901.88	901.89
MED032	16546.90	901.83	901.86	901.86
MED031	16254.46	901.60	901.63	901.61
MED030B	16120.31	901.39	901.43	901.43
Bridge	16115.00			
MED030A	16113.64	901.29	901.34	901.34
MED029	16084.13	901.30	901.36	901.35
MED028B	16027.90	901.33	901.38	901.38
Bridge	16020.00			
MED028A	16007.45	901.26	901.31	901.30
MED027	15848.04	901.32	901.35	901.34
MED026	15351.38	900.89	900.94	900.90
MED025	14979.10	900.66	900.72	900.83
MED024	14323.15	900.19	900.25	900.30
MED023	13881.12	900.12	900.19	900.25
MED022	13578.37	900.07	900.14	900.20
MED021	12974.92	899.86	899.95	900.02
MED020	12723.99	899.92	899.99	900.06
MED019	11712.27	899.88	899.94	900.00

Cross Section	River Station	Simulated WSE at 1:100-yr Flood (m)		
		Overbank Roughness -20%	Calibrated Profile	Channel Roughness +20%
MED018	10702.67	899.85	899.91	899.97
MED017	10131.73	899.79	899.84	899.88
MED016	9894.27	899.77	899.82	899.86
MED015	9581.27	899.61	899.66	899.71
MED014	9169.58	899.53	899.58	899.62
MED013	8163.01	899.44	899.46	899.48
MED012	7621.91	899.37	899.38	899.39
MED011B	7140.56	899.12	899.15	899.17
Bridge	7130.00			
MED011A	7123.37	899.03	899.05	899.08
MED010	6350.81	898.58	898.61	898.64
MED009	5446.71	897.61	897.73	897.81
MED007	3627.92	896.45	896.57	896.71
MED006	2692.12	896.40	896.55	896.69
MED005	2124.88	896.12	896.30	896.44
MED004	1690.13	896.19	896.36	896.50
MED003	1242.14	896.17	896.34	896.48
MED002	734.23	896.10	896.27	896.41
MED001	271.51	896.09	896.26	896.40
average difference		-0.07		0.05
maximum difference		-0.18		0.14

TABLE 6B: SENSITIVITY ANALYSIS, VARIABLE OVERBANK MANNING ROUGHNESS AT 1:100 YR FLOOD, LITTLE RED DEER RIVER

Cross Section	River Station	Simulated WSE at 1:100-yr Flood (m)		
		Overbank Roughness -20%	Calibrated Profile	Channel Roughness +20%
LRD075	32643.42	944.83	944.92	945.00
LRD074	32310.99	944.47	944.56	944.64
LRD073	32009.86	944.35	944.43	944.50
LRD072	31617.99	944.05	944.12	944.15
LRD071	31294.25	943.51	943.63	943.66
LRD070	30829.77	943.41	943.49	943.55
LRD069	30188.17	942.31	942.48	942.46
LRD068	29482.38	941.64	941.76	941.85
LRD067	28994.71	940.92	940.99	941.05
LRD066	28590.84	940.16	940.28	940.38
LRD065	28315.81	939.55	939.65	939.72
LRD064	27438.99	938.84	938.95	939.05
LRD063	26658.89	938.33	938.43	938.52
LRD062	26204.33	938.09	938.16	938.24
LRD061	25747.29	937.15	937.28	937.37
LRD060	25296.69	936.68	936.77	936.84
LRD059	24847.80	936.13	936.21	936.28
LRD058	24381.56	935.70	935.77	935.83
LRD057	23925.10	934.88	934.93	934.95
LRD056	23709.71	934.80	934.83	934.87
LRD055	23571.73	934.79	934.83	934.86
LRD054B	23493.00	934.77	934.79	934.81
Bridge	23480.00			
LRD054A	23465.12	933.27	933.40	933.52
LRD053	23356.45	933.27	933.39	933.50
LRD052	23027.16	933.24	933.35	933.44
LRD051	22561.26	933.14	933.24	933.32
LRD050	22285.44	932.83	932.91	932.98
LRD049	21767.32	932.30	932.39	932.47
LRD048	21409.37	932.03	932.12	932.20
LRD047	21131.78	931.79	931.90	931.98
LRD046	20683.46	930.80	930.87	930.93
LRD045	20379.61	930.32	930.43	930.51
LRD044	20039.56	929.84	929.94	930.02
LRD043	19848.59	929.76	929.87	929.95
LRD042	19385.41	929.19	929.26	929.32
LRD041	18867.70	928.22	928.32	928.40
LRD040	18425.77	927.48	927.55	927.61
LRD039	17896.86	926.62	926.72	926.79
LRD038	17580.43	926.55	926.63	926.69
LRD037	16941.09	925.60	925.68	925.75
LRD036	16487.60	924.79	924.88	924.95
LRD035	16188.59	924.31	924.39	924.46
LRD034	15715.26	923.27	923.38	923.46
LRD033	15465.60	922.91	922.99	923.06
LRD032	15233.21	922.25	922.32	922.38
LRD031	14524.88	920.39	920.45	920.50
LRD030	13896.11	919.24	919.30	919.34
LRD029	13470.47	918.49	918.51	918.53
LRD028	12856.03	916.73	916.80	916.84
LRD027	12500.29	915.94	915.96	915.98
LRD026	11954.62	914.76	914.78	914.80
LRD025	11442.71	913.99	914.05	914.11
LRD024	11273.96	913.42	913.47	913.51
LRD023	11010.17	912.78	912.79	912.80

Cross Section	River Station	Simulated WSE at 1:100-yr Flood (m)		
		Overbank Roughness -20%	Calibrated Profile	Channel Roughness +20%
LRD022	10400.51	910.91	910.96	911.00
LRD021	9921.31	910.27	910.34	910.40
LRD020	9646.01	909.96	910.01	910.04
LRD019B	9401.12	909.69	909.75	909.80
Bridge	9395.00			
LRD019A	9386.81	909.49	909.56	909.62
LRD018	9129.48	908.88	908.90	908.92
LRD017	8822.89	908.33	908.41	908.48
LRD016	8308.30	907.17	907.22	907.26
LRD015	7617.03	905.94	906.05	906.14
LRD014	7069.92	905.51	905.59	905.65
LRD013	6479.72	904.03	904.13	904.27
LRD012	5957.99	903.86	903.97	904.05
LRD011	5483.82	903.30	903.35	903.38
LRD010	4953.07	902.07	902.16	902.24
LRD009	4581.11	901.67	901.79	901.90
LRD008	3862.55	900.64	900.76	900.86
LRD007	3276.80	900.37	900.48	900.56
LRD006	2749.86	899.87	899.93	899.97
LRD005	2102.70	899.07	899.06	899.05
LRD004	1565.39	897.53	897.75	897.95
LRD003	1016.98	897.55	897.75	897.92
LRD002	539.23	897.52	897.73	897.91
LRD001	120.51	897.36	897.58	897.77
average difference		-0.09		0.07
maximum difference		-0.23		0.20

TABLE 6C: SENSITIVITY ANALYSIS, VARIABLE OVERBANK MANNING ROUGHNESS AT 1:100 YR FLOOD, RED DEER RIVER

Cross Section	River Station	Simulated WSE at 1:100-yr Flood (m)		
		Overbank Roughness -20%	Calibrated Profile	Channel Roughness +20%
RDR109	50218.74	915.41	915.54	915.63
RDR108	49602.34	914.77	914.88	914.96
RDR107	49105.13	914.17	914.27	914.34
RDR106	48532.13	913.22	913.30	913.37
RDR105	48109.64	912.55	912.65	912.73
RDR104	47648.39	912.09	912.20	912.29
RDR103	46831.56	910.30	910.35	910.38
RDR102	46571.85	909.83	909.90	909.96
RDR101	46156.59	909.05	909.12	909.18
RDR100	45656.74	907.81	907.95	908.07
RDR099	45323.63	907.20	907.36	907.49
RDR098	44834.59	906.66	906.80	906.92
RDR097	44197.53	905.89	906.03	906.14
RDR096	43714.10	905.04	905.13	905.21
RDR095	43223.22	904.54	904.64	904.72
RDR094	41885.84	902.49	902.59	902.65
RDR093	41449.53	902.06	902.14	901.88
RDR092	40861.57	900.66	900.85	900.98
RDR091	40190.45	900.16	900.30	900.42
RDR090	39763.21	899.31	899.40	899.47
RDR089	39145.18	898.68	898.79	898.90
RDR088	38713.30	898.00	898.20	898.37
RDR087	38045.59	897.51	897.73	897.92
RDR086	37721.64	897.06	897.29	897.47
RDR085	37112.15	896.93	897.15	897.34
RDR084	36841.14	896.81	897.01	897.18
RDR083	36043.75	896.38	896.55	896.69
RDR082	35419.07	895.42	895.58	895.71
RDR081	35038.01	895.28	895.47	895.62
RDR080	34604.87	894.96	895.10	895.21
RDR079	33989.56	894.22	894.36	894.48
RDR078	33491.89	893.83	893.98	894.12
RDR077	32971.01	893.13	893.29	893.44
RDR076	32366.90	892.66	892.88	893.07
RDR075	31826.57	892.25	892.46	892.65
RDR074	31367.30	891.65	891.86	892.07
RDR073	30752.55	891.13	891.41	891.64
RDR072	29976.11	890.73	890.98	891.17
RDR071	29153.77	889.55	889.75	889.91
RDR070	28767.94	889.23	889.42	889.57
RDR069	28229.10	889.18	889.38	889.55
RDR068	27841.09	888.96	889.11	889.23
RDR067	27269.94	888.49	888.64	888.77
RDR066	26811.24	888.34	888.50	888.63
RDR065	26289.99	887.93	888.06	888.18
RDR064	25704.30	887.57	887.71	887.84
RDR063	25334.58	887.30	887.46	887.60
RDR062B	25119.90	886.74	886.93	887.09
Bridge	25110.00			
RDR062A	25105.02	886.63	886.81	886.97
RDR061	24862.84	886.32	886.51	886.67
RDR060	24523.27	886.13	886.37	886.57
RDR059	24055.69	885.90	886.14	886.33
RDR058	23776.91	885.66	885.88	886.07
RDR057	23352.27	885.31	885.55	885.75
RDR056	22939.96	884.74	885.01	885.23
RDR055	22652.90	884.71	884.96	885.16
RDR054	22080.46	884.29	884.49	884.66
RDR053	21654.55	884.06	884.26	884.42

Cross Section	River Station	Simulated WSE at 1:100-yr Flood (m)		
		Overbank Roughness -20%	Calibrated Profile	Channel Roughness +20%
RDR052	21403.28	883.66	883.85	884.01
RDR051	21109.04	883.37	883.59	883.77
RDR050	20573.39	882.94	883.13	883.30
RDR049	20186.31	882.86	883.06	883.22
RDR048	19658.68	882.56	882.71	882.83
RDR047	19377.16	882.52	882.66	882.78
RDR046	18920.81	882.19	882.27	882.33
RDR045	18541.73	881.70	881.78	881.86
RDR044	18045.12	881.40	881.48	881.57
RDR043	17790.40	881.21	881.28	881.38
RDR042	17390.93	880.75	880.83	880.94
RDR041	17057.01	880.50	880.63	880.75
RDR040	16602.19	880.06	880.22	880.35
RDR039	16168.59	879.70	879.84	879.95
RDR038	15811.90	879.20	879.31	879.40
RDR037	15366.92	879.07	879.18	879.27
RDR036	14866.17	878.48	878.55	878.60
RDR035B	14714.49	877.90	878.01	878.12
Bridge	14700.00			
RDR035A	14696.46	877.65	877.81	877.94
RDR034	14498.85	877.57	877.72	877.85
RDR033	14148.40	877.26	877.38	877.49
RDR032	13528.62	876.27	876.51	876.70
RDR031	13127.07	876.10	876.32	876.50
RDR030	12861.96	876.05	876.26	876.43
RDR029	12475.30	875.96	876.17	876.33
RDR028	11928.01	875.56	875.73	875.88
RDR027	11520.43	875.31	875.49	875.63
RDR026	10959.43	875.05	875.19	875.31
RDR025	10679.27	874.67	874.82	874.94
RDR024	10318.95	874.49	874.65	874.79
RDR023	9897.90	874.34	874.49	874.62
RDR022	9537.43	873.50	873.65	873.77
RDR021	9066.37	873.10	873.30	873.46
RDR020	8811.41	873.07	873.25	873.40
RDR019	8374.00	872.96	873.10	873.20
RDR018	8016.03	872.90	873.02	873.12
RDR017	7684.66	872.40	872.48	872.53
RDR016	7370.54	872.26	872.33	872.39
RDR015	6881.20	871.74	871.77	871.78
RDR014	6562.62	871.63	871.67	871.71
RDR013	6100.29	871.12	871.15	871.18
RDR012	5758.35	870.83	870.84	870.84
RDR011B	5364.90	870.19	870.22	870.25
Bridge	5335.00			
RDR011A	5333.35	870.15	870.19	870.22
RDR010	4885.02	869.77	869.81	869.83
RDR009	4227.32	869.02	869.05	869.07
RDR008	3657.40	868.42	868.45	868.47
RDR007	3069.72	867.74	867.76	867.78
RDR006	2505.23	867.21	867.21	867.21
RDR005	2292.09	866.96	866.96	866.96
RDR004	1947.85	866.64	866.64	866.64
RDR003	1337.08	866.05	866.05	866.05
RDR002	730.21	865.24	865.24	865.24
RDR001	0	864.82	864.82	864.82
average difference		-0.14		0.11
maximum difference		-0.28		0.23

TABLE 7A: FLOODWAY STATIONS AND LIMITING FLOODWAY DETERMINATION CRITERIA, MEDICINE RIVER

Cross Section	River Station	Cross Section Length (m)	1 m Depth Criteria		1 m/s Velocity Criteria		Historic Floodway		Selected Floodway Extents (m)		Governing Floodway Criteria	
			Left Station	Right Station	Left Station	Right Station	Left Station	Right Station	Left Station	Right Station	Left Station	Right Station
MED067	33253.11	1,260.0	197.9	845.8	-	-	-	-	194.2	1,217.3	no viable flood fringe	no viable flood fringe
MED066	32861.16	1,329.5	371.9	1,092.5	849.7	872.8	-	-	351.9	1,100.1	no viable flood fringe	hydraulically smoothed
MED065	32000.58	1,385.9	211.8	1,341.4	532.8	537.9	-	-	207.6	1,223.9	no viable flood fringe	hydraulically smoothed
MED064	31468.75	1,142.3	72.2	1,033.9	576.9	600.3	-	-	64.2	1,028.5	no viable flood fringe	hydraulically smoothed
MED063	31082.61	1,078.5	20.1	1,046.4	509.9	524.9	-	-	15.8	1,052.1	no viable flood fringe	no viable flood fringe
MED062	30291.89	1,396.7	194.9	1,385.9	1,284.0	1,294.6	-	-	205.4	1,388.7	hydraulically smoothed	no viable flood fringe
MED061	28899.33	1,601.8	96.8	1,264.5	-	-	-	-	84.4	1,267.5	hydraulically smoothed	no viable flood fringe
MED060	28199.55	1,646.1	486.6	1,351.4	780.4	787.9	-	-	480.3	1,364.2	no viable flood fringe	no viable flood fringe
MED059	27419.95	1,839.3	986.2	1,633.2	1,374.1	1,393.9	-	-	971.6	1,653.7	hydraulically smoothed	no viable flood fringe
MED058	26899.14	1,305.1	1,080.0	1,251.4	1,123.4	1,159.1	-	-	956.9	1,254.6	hydraulically smoothed	no viable flood fringe
MED057	26532.54	1,239.5	780.3	1,100.1	1,058.1	1,095.5	-	-	780.3	1,102.7	depth	no viable flood fringe
MED056	26080.72	549.0	327.0	473.6	347.6	383.8	-	-	327.0	473.6	depth	depth
MED055	25653.03	603.2	341.4	450.5	342.7	386.0	-	-	341.4	454.5	depth	no viable flood fringe
MED054	25455.59	856.9	428.9	835.4	440.8	480.8	-	-	428.9	838.7	depth	no viable flood fringe
MED053	24798.82	719.9	44.5	600.7	47.6	91.9	-	-	43.5	608.9	no viable flood fringe	no viable flood fringe
MED052	23964.02	726.7	509.1	612.3	571.0	609.4	-	-	256.5	613.4	hydraulically smoothed	no viable flood fringe
MED051	23379.66	475.9	163.6	442.7	170.1	207.2	-	-	161.6	447.5	no viable flood fringe	no viable flood fringe
MED050	22931.17	405.8	121.6	336.5	162.2	192.9	-	-	121.6	346.9	depth	no viable flood fringe
MED049	22485.04	589.7	188.1	529.8	497.6	527.9	-	-	173.2	530.8	hydraulically smoothed	no viable flood fringe
MED048	22231.42	777.0	212.0	492.3	445.0	480.3	-	-	201.3	494.4	hydraulically smoothed	hydraulically smoothed
MED047	21617.42	917.7	117.4	368.5	127.8	158.0	-	-	114.5	536.4	no viable flood fringe	no viable flood fringe
MED046	21070.82	867.1	298.7	450.2	358.3	395.0	-	-	298.7	470.4	depth	no viable flood fringe
MED045	20890.75	1,006.2	526.2	621.5	531.1	568.2	-	-	526.2	632.1	depth	no viable flood fringe
MED044B	20841.77	1,005.5	538.7	602.5	543.5	578.3	-	-	538.7	622.6	depth	no viable flood fringe
MED044A	20804.43	1,004.2	548.3	595.1	553.5	592.8	-	-	548.3	600.5	depth	no viable flood fringe
MED043	20762.22	777.8	470.9	529.3	480.7	515.9	-	-	470.9	532.6	depth	no viable flood fringe
MED042	20535.00	771.2	462.1	562.0	527.9	561.0	-	-	462.1	562.6	depth	no viable flood fringe
MED041	20097.55	660.3	57.6	162.5	105.0	137.9	-	-	49.7	162.5	no viable flood fringe	depth
MED040	19779.50	746.4	140.7	235.8	148.4	185.0	-	-	139.5	241.1	no viable flood fringe	no viable flood fringe
MED039	19295.25	776.4	617.1	756.4	625.2	650.4	-	-	614.9	759.1	no viable flood fringe	no viable flood fringe
MED038	18857.51	785.0	682.6	724.0	690.4	723.5	-	-	682.6	725.0	depth	no viable flood fringe
MED037	18392.96	638.2	307.4	414.0	322.7	354.6	-	-	307.4	418.4	depth	no viable flood fringe
MED036	17961.80	693.6	292.4	489.4	296.3	329.4	-	-	289.1	491.9	no viable flood fringe	no viable flood fringe
MED035	17492.38	532.0	97.0	364.0	327.3	362.8	-	-	64.4	364.8	no viable flood fringe	no viable flood fringe
MED034	17037.58	765.1	644.4	692.2	646.9	685.0	-	-	210.6	694.5	no viable flood fringe	no viable flood fringe
MED033	16715.32	801.6	209.0	737.8	700.4	731.0	-	-	205.9	740.1	no viable flood fringe	no viable flood fringe
MED032	16546.90	561.2	20.7	381.9	346.3	373.4	-	-	16.4	381.9	no viable flood fringe	depth
MED031	16254.46	445.7	111.6	154.0	113.9	149.7	114.2	152.1	114.2	152.1	historic floodway	
MED030B	16120.31	538.9	247.2	289.9	249.8	285.8	249.9	290.1	249.9	290.1	historic floodway	
MED030A	16113.64	555.8	273.3	316.2	275.8	318.1	275.4	315.7	275.4	315.7	historic floodway	
MED029	16084.13	551.2	288.4	335.6	295.0	329.4	294.9	335.1	294.9	335.1	historic floodway	

Cross Section	River Station	Cross Section Length (m)	1 m Depth Criteria		1 m/s Velocity Criteria		Historic Floodway		Selected Floodway Extents (m)		Governing Floodway Criteria	
			Left Station	Right Station	Left Station	Right Station	Left Station	Right Station	Left Station	Right Station	Left Station	Right Station
MED028B	16027.90	630.8	339.1	394.7	346.8	390.7	352.3	393.5	352.3	393.5	historic floodway	
MED028A	16007.45	646.7	361.7	415.2	371.8	410.2	372.4	414.4	372.4	414.4	historic floodway	
MED027	15848.04	705.5	487.0	671.3	500.0	538.7	503.9	537.1	503.9	537.1	historic floodway	
MED026	15351.38	502.3	159.5	202.6	161.3	195.3	161.4	201.3	161.4	201.3	historic floodway	
MED025	14979.10	817.9	256.3	299.2	256.3	294.1	257.3	297.3	257.3	297.3	historic floodway	
MED024	14323.15	408.7	269.3	317.4	282.1	310.4	273.1	321.5	273.1	321.5	historic floodway	
MED023	13881.12	336.4	153.1	205.5	158.5	199.6	151.4	205.3	151.4	205.3	historic floodway	
MED022	13578.37	314.6	114.8	199.1	146.4	189.5	138.8	198.8	138.8	198.8	historic floodway	
MED021	12974.92	508.0	238.7	435.9	244.6	289.8	242.7	352.4	242.7	352.4	historic floodway	
MED020	12723.99	725.6	390.4	641.2	397.0	441.7	395.6	623.5	395.6	623.5	historic floodway	
MED019	11712.27	1,223.1	464.5	935.7	894.5	930.6	477.8	932.6	477.8	932.6	historic floodway	
MED018	10702.67	1,540.2	37.9	872.1	-	-	42.3	809.9	42.3	809.9	historic floodway	
MED017	10131.73	1,529.2	166.6	702.3	243.6	286.5	165.1	509.1	165.1	509.1	historic floodway	
MED016	9894.27	2,281.4	47.9	508.1	317.8	359.5	267.8	498.3	267.8	498.3	historic floodway	
MED015	9581.27	2,069.4	55.9	191.5	58.1	110.0	56.3	182.1	56.3	182.1	historic floodway	
MED014	9169.58	2,353.2	44.3	232.3	176.2	228.5	84.8	235.9	84.8	235.9	historic floodway	
MED013	8163.01	2,663.4	43.0	539.4	414.6	448.9	115.3	507.6	115.3	507.6	historic floodway	
MED012	7621.91	2,817.9	74.4	454.9	409.0	451.5	79.2	448.4	79.2	448.4	historic floodway	
MED011B	7140.56	3,077.7	164.1	220.8	165.3	215.0	165.6	216.0	165.6	216.0	historic floodway	
MED011A	7123.37	3,085.4	150.7	206.9	154.0	195.6	152.2	203.9	152.2	203.9	historic floodway	
MED010	6350.81	1,874.3	1,004.7	1,053.1	1,007.1	1,046.9	364.5	1,047.8	364.5	1,047.8	historic floodway	
MED009	5446.71	1,935.9	1,672.0	1,727.8	1,683.6	1,733.2	324.9	confluence	324.9	confluence	historic floodway	confluence
MED007	3627.92	1,667.8	153.7	326.2	154.1	189.0	160.7	confluence	160.7	confluence	historic floodway	confluence
MED006	2692.12	1,212.8	58.0	581.4	551.8	575.3	57.1	confluence	57.1	confluence	historic floodway	confluence
MED005	2124.88	1,324.2	201.2	323.2	205.6	245.3	206.0	confluence	206.0	confluence	historic floodway	confluence
MED004	1690.13	1,389.6	126.0	433.7	149.7	153.7	130.6	confluence	130.6	confluence	historic floodway	confluence
MED003	1242.14	529.5	92.0	-	-	-	94.3	confluence	94.3	confluence	historic floodway	confluence
MED002	734.23	312.7	109.5	-	199.0	247.9	119.9	confluence	119.9	confluence	historic floodway	confluence
MED001	271.51	345.0	61.1	-	69.9	99.1	67.1	confluence	67.1	confluence	historic floodway	confluence

TABLE 7B: FLOODWAY STATIONS AND LIMITING FLOODWAY DETERMINATION CRITERIA, LITTLE RED DEER RIVER

Cross Section	River Station	Cross Section Length (m)	1 m Depth Criteria		1 m/s Velocity Criteria		Historic Floodway		Selected Floodway Extents (m)		Governing Floodway Criteria	
			Left Station	Right Station	Left Station	Right Station	Left Station	Right Station	Left Station	Right Station	Left Station	Right Station
LRD075	32643.42	1,046.8	421.9	640.5	419.7	447.0	-	-	419.7	643.1	no viable flood fringe	no viable flood fringe
LRD074	32310.99	1,049.8	475.8	617.7	568.7	617.2	-	-	475.8	618.2	depth	no viable flood fringe
LRD073	32009.86	870.3	397.6	644.5	424.5	464.0	-	-	402.0	647.1	hydraulically smoothed	no viable flood fringe
LRD072	31617.99	977.0	626.5	815.3	779.6	814.4	-	-	626.5	815.3	depth	depth
LRD071	31294.25	1,046.7	662.5	724.5	652.7	723.5	-	-	662.5	724.5	depth	depth
LRD070	30829.77	1,256.7	92.0	1,166.9	615.4	647.1	-	-	89.4	804.9	no viable flood fringe	no viable flood fringe
LRD069	30188.17	1,244.9	149.3	1,201.8	1,107.8	1,201.2	-	-	147.1	1,202.8	no viable flood fringe	no viable flood fringe
LRD068	29482.38	936.0	222.8	895.3	653.7	703.6	-	-	221.0	896.4	no viable flood fringe	no viable flood fringe
LRD067	28994.71	795.9	575.9	718.3	576.8	672.9	-	-	574.6	721.7	no viable flood fringe	no viable flood fringe
LRD066	28590.84	885.4	689.2	756.7	690.9	757.8	-	-	689.2	757.8	depth	no viable flood fringe
LRD065	28315.81	993.5	687.7	832.9	685.0	834.4	-	-	685.0	834.4	velocity	no viable flood fringe
LRD064	27438.99	1,061.5	414.7	933.2	817.8	845.1	-	-	414.7	933.2	depth	depth
LRD063	26658.89	1,083.2	121.1	905.6	122.0	152.8	-	-	121.1	905.6	depth	depth
LRD062	26204.33	1,111.1	144.8	953.7	145.7	178.4	-	-	143.3	953.7	no viable flood fringe	depth
LRD061	25747.29	1,163.7	587.0	1,026.4	607.4	640.4	-	-	562.0	1,046.2	hydraulically smoothed	hydraulically smoothed
LRD060	25296.69	1,001.1	888.0	946.0	915.8	944.9	-	-	883.0	948.1	hydraulically smoothed	no viable flood fringe
LRD059	24847.80	1,326.2	1,149.8	1,234.1	1,189.8	1,232.7	-	-	1,149.8	1,235.7	depth	no viable flood fringe
LRD058	24381.56	1,337.5	1,181.1	1,212.1	1,182.0	1,211.7	-	-	1,176.6	1,214.4	hydraulically smoothed	no viable flood fringe
LRD057	23925.10	1,480.8	832.4	862.7	824.5	862.8	-	-	824.5	865.5	velocity	no viable flood fringe
LRD056	23709.71	1,649.1	625.9	660.3	630.6	656.7	-	-	625.9	660.3	depth	depth
LRD055	23571.73	1,648.7	515.7	545.8	-	-	-	-	512.5	545.8	no viable flood fringe	depth
LRD054B	23493.00	1,911.5	413.9	445.1	-	-	-	-	410.4	445.1	no viable flood fringe	depth
LRD054A	23465.12	1,911.3	424.2	450.1	423.6	449.0	-	-	422.2	451.1	no viable flood fringe	no viable flood fringe
LRD053	23356.45	1,753.2	301.0	322.1	305.4	307.5	-	-	299.1	330.6	no viable flood fringe	no viable flood fringe
LRD052	23027.16	1,948.1	687.3	792.8	753.7	789.6	-	-	683.5	795.8	hydraulically smoothed	no viable flood fringe
LRD051	22561.26	1,625.7	681.7	712.9	684.3	709.4	-	-	681.7	712.9	depth	depth
LRD050	22285.44	1,933.0	561.6	1,448.3	560.7	593.0	-	-	548.2	1,450.4	no viable flood fringe	no viable flood fringe
LRD049	21767.32	1,783.2	29.2	1,250.1	28.9	55.6	-	-	27.8	1,253.7	no viable flood fringe	no viable flood fringe
LRD048	21409.37	1,558.3	46.2	1,072.3	64.2	92.2	-	-	44.1	1,111.1	no viable flood fringe	hydraulically smoothed
LRD047	21131.78	1,739.7	330.0	1,205.1	329.1	364.9	-	-	329.1	1,329.1	velocity	hydraulically smoothed
LRD046	20683.46	1,602.4	441.3	1,461.7	452.3	493.7	-	-	441.3	1,492.0	depth	no viable flood fringe
LRD045	20379.61	1,358.3	35.9	1,299.0	398.8	751.8	-	-	33.3	1,299.0	no viable flood fringe	depth
LRD044	20039.56	1,335.4	48.5	1,259.8	661.1	719.4	-	-	46.5	1,219.4	no viable flood fringe	hydraulically smoothed
LRD043	19848.59	1,261.0	35.2	1,232.3	520.7	544.1	-	-	33.4	1,241.0	no viable flood fringe	no viable flood fringe
LRD042	19385.41	1,381.8	75.9	1,244.3	182.6	279.7	-	-	70.6	1,246.2	no viable flood fringe	hydraulically smoothed
LRD041	18867.70	1,032.9	74.0	912.0	125.6	210.3	-	-	70.4	933.2	no viable flood fringe	hydraulically smoothed
LRD040	18425.77	591.5	49.6	499.8	50.1	224.1	-	-	48.8	542.7	no viable flood fringe	no viable flood fringe
LRD039	17896.86	757.6	86.7	689.8	85.7	130.3	-	-	85.7	703.9	velocity	no viable flood fringe
LRD038	17580.43	691.1	94.2	615.9	138.7	178.6	-	-	88.4	621.6	no viable flood fringe	no viable flood fringe
LRD037	16941.09	367.2	100.1	322.2	284.6	321.8	-	-	100.1	323.2	depth	no viable flood fringe
LRD036	16487.60	407.8	108.0	350.8	189.5	224.6	-	-	104.6	350.8	no viable flood fringe	depth

Cross Section	River Station	Cross Section Length (m)	1 m Depth Criteria		1 m/s Velocity Criteria		Historic Floodway		Selected Floodway Extents (m)		Governing Floodway Criteria	
			Left Station	Right Station	Left Station	Right Station	Left Station	Right Station	Left Station	Right Station	Left Station	Right Station
LRD035	16188.59	585.2	129.8	444.0	130.5	169.5	-	-	128.4	447.2	no viable flood fringe	no viable flood fringe
LRD034	15715.26	733.6	137.0	684.9	137.2	168.5	-	-	135.8	686.2	no viable flood fringe	no viable flood fringe
LRD033	15465.60	640.8	252.0	574.3	254.3	304.1	-	-	252.0	575.7	depth	no viable flood fringe
LRD032	15233.21	499.0	277.8	375.4	286.6	375.1	-	-	277.8	381.2	depth	no viable flood fringe
LRD031	14524.88	758.0	154.1	232.9	89.5	233.5	-	-	139.1	232.9	velocity	depth
LRD030	13896.11	491.3	253.6	314.0	259.5	315.4	-	-	253.6	315.4	depth	no viable flood fringe
LRD029	13470.47	624.4	70.3	153.9	94.2	133.3	-	-	68.9	153.9	no viable flood fringe	depth
LRD028	12856.03	467.4	112.4	164.2	116.0	149.9	-	-	111.5	164.2	no viable flood fringe	depth
LRD027	12500.29	451.4	288.1	376.1	287.0	322.6	287.2	295.2	287.2	376.1	historic floodway	depth
LRD026	11954.62	278.3	165.4	225.3	164.6	216.1	169.0	230.6	169.0	230.6	historic floodway	
LRD025	11442.71	323.6	56.7	114.9	58.1	109.0	58.4	110.6	58.4	110.6	historic floodway	
LRD024	11273.96	277.9	13.3	63.8	14.1	60.1	15.7	63.8	15.7	63.8	historic floodway	
LRD023	11010.17	292.0	47.8	121.2	89.9	122.1	50.2	123.0	50.2	122.8	historic floodway	
LRD022	10400.51	259.7	155.2	208.2	147.4	209.3	145.7	205.6	145.7	205.6	historic floodway	
LRD021	9921.31	448.3	75.0	174.0	125.7	165.9	81.6	175.3	81.6	175.3	historic floodway	
LRD020	9646.01	456.4	46.0	104.1	46.3	105.2	47.8	109.5	47.8	109.5	historic floodway	
LRD019B	9401.12	517.4	160.7	210.9	163.1	209.2	164.0	210.7	164.0	210.7	historic floodway	
LRD019A	9386.81	492.9	154.5	200.3	155.3	198.6	157.5	202.8	157.5	202.8	historic floodway	
LRD018	9129.48	382.3	222.9	296.5	219.4	296.8	222.4	291.8	222.4	291.8	historic floodway	
LRD017	8822.89	524.4	359.5	415.9	359.2	416.4	349.3	452.9	349.3	435.2	historic floodway	no viable flood fringe
LRD016	8308.30	437.4	112.3	277.3	114.9	278.5	119.1	276.9	119.1	276.9	historic floodway	
LRD015	7617.03	801.4	81.9	432.7	309.9	351.0	89.3	430.1	89.3	430.1	historic floodway	
LRD014	7069.92	377.7	55.8	320.0	57.3	84.8	61.2	162.3	61.2	162.3	historic floodway	
LRD013	6479.72	253.7	87.1	178.9	108.1	136.3	16.7	153.1	16.7	153.1	historic floodway	
LRD012	5957.99	371.6	77.9	337.3	305.1	336.6	88.0	335.1	88.0	335.1	historic floodway	
LRD011	5483.82	331.6	70.4	279.1	71.1	99.3	75.7	276.2	75.7	276.2	historic floodway	
LRD010	4953.07	525.3	385.9	483.8	427.8	483.5	328.4	478.6	328.4	478.6	historic floodway	
LRD009	4581.11	522.2	116.2	457.3	316.8	356.3	90.3	449.0	90.3	449.0	historic floodway	
LRD008	3862.55	320.1	42.8	258.9	43.0	70.7	45.3	262.6	45.3	260.6	historic floodway	no viable flood fringe
LRD007	3276.80	373.4	78.9	256.0	221.0	255.1	84.2	252.9	84.2	252.9	historic floodway	
LRD006	2749.86	238.0	27.4	187.7	27.9	61.1	31.6	180.9	31.6	180.9	historic floodway	
LRD004	1565.39	408.8	7.8	52.3	9.1	43.1	15.0	55.6	15.0	55.6	historic floodway	
LRD003	1016.98	516.1	-	313.3	271.9	311.9	confluence	310.9	confluence	310.9	confluence	historic floodway
LRD002	539.23	644.6	-	450.3	-	-	confluence	449.8	confluence	449.8	confluence	historic floodway
LRD001	120.51	356.2	-	196.9	143.1	194.9	confluence	194.0	confluence	194.0	confluence	historic floodway

TABLE 7C: FLOODWAY STATIONS AND LIMITING FLOODWAY DETERMINATION CRITERIA, RED DEER RIVER

Cross Section	River Station	Cross Section Length (m)	1 m Depth Criteria		1 m/s Velocity Criteria		Historic Floodway		Selected Floodway Extents (m)		Governing Floodway Criteria	
			Left Station	Right Station	Left Station	Right Station	Left Station	Right Station	Left Station	Right Station	Left Station	Right Station
RDR109	50218.74	855.9	88.5	753.3	172.6	502.2	88.5	753.3	88.5	753.3	historic floodway	
RDR108	49602.34	686.4	152.0	422.8	327.1	422.2	123.3	466.7	123.3	464.5	historic floodway	
RDR107	49105.13	702.1	138.3	655.8	564.4	655.7	109.2	657.6	109.2	657.6	historic floodway	
RDR106	48532.13	699.5	154.8	634.9	552.1	632.4	93.3	632.4	93.3	632.4	historic floodway	
RDR105	48109.64	747.9	170.7	717.5	634.4	715.7	102.6	709.5	102.6	709.5	historic floodway	
RDR104	47648.39	965.2	103.0	920.3	409.5	529.3	102.0	916.1	102.0	916.1	historic floodway	
RDR103	46831.56	719.5	90.7	403.5	91.5	158.7	93.1	658.2	93.1	639.3	historic floodway	no viable flood fringe
RDR102	46571.85	693.2	40.4	294.0	127.4	237.6	41.3	649.3	41.3	573.6	historic floodway	no viable flood fringe
RDR101	46156.59	947.1	59.6	795.5	316.9	514.7	63.2	900.4	63.2	900.4	historic floodway	
RDR100	45656.74	929.2	367.5	903.1	404.4	738.9	372.2	898.0	372.2	898.0	historic floodway	
RDR099	45323.63	1,159.7	276.9	870.6	377.7	810.8	275.0	886.2	275.0	886.2	historic floodway	no viable flood fringe
RDR098	44834.59	1,281.7	49.1	1,057.4	478.5	727.2	53.6	1,089.2	53.6	1,089.2	historic floodway	
RDR097	44197.53	1,258.1	85.6	1,063.3	87.6	463.8	86.1	1,110.5	86.1	1,069.3	historic floodway	hydraulically smoothed
RDR096	43714.10	1,150.9	115.0	1,091.6	149.2	223.1	91.9	1,083.3	91.9	1,083.3	historic floodway	
RDR095	43223.22	1,198.6	156.1	1,153.4	206.9	352.5	64.6	1,148.2	67.3	1,148.2	no viable flood fringe	historic floodway
RDR094	41885.84	1,553.7	105.5	1,348.8	1,275.9	1,350.5	72.5	1,344.9	100.0	1,344.9	no viable flood fringe	historic floodway
RDR093	41449.53	1,954.3	268.7	1,884.5	1,228.3	1,618.7	89.3	1,879.0	259.4	1,879.0	no viable flood fringe	historic floodway
RDR092	40861.57	2,457.6	886.4	2,410.6	1,628.3	1,903.2	126.4	2,404.6	880.0	2,404.6	no viable flood fringe	historic floodway
RDR091	40190.45	1,181.1	32.8	1,119.0	798.3	1,113.6	35.3	1,120.9	35.3	1,120.1	historic floodway	no viable flood fringe
RDR090	39763.21	787.8	124.1	632.1	37.4	629.9	confluence	632.1	confluence	632.1	confluence	historic floodway
RDR089	39145.18	910.3	150.1	909.1	473.7	650.0	confluence	901.2	confluence	901.2	confluence	historic floodway
RDR088	38713.30	830.1	395.7	-	397.9	564.4	confluence	confluence	confluence	confluence	confluence	
RDR087	38045.59	501.4	-	-	218.2	450.7	confluence	confluence	confluence	confluence	confluence	
RDR086	37721.64	676.9	-	468.6	215.7	445.4	confluence	463.4	confluence	463.4	confluence	historic floodway
RDR085	37112.15	932.7	-	883.4	382.7	480.3	confluence	874.7	confluence	874.7	confluence	historic floodway
RDR084	36841.14	646.6	-	604.2	38.3	184.5	confluence	601.0	confluence	601.0	confluence	historic floodway
RDR083	36043.75	344.6	-	323.9	84.3	318.7	confluence	317.3	confluence	317.3	confluence	historic floodway
RDR082	35419.07	629.8	64.9	578.0	67.1	143.7	67.9	578.6	67.9	578.6	historic floodway	
RDR081	35038.01	677.3	51.4	625.5	87.5	275.2	55.7	617.9	55.7	617.9	historic floodway	
RDR080	34604.87	558.7	53.2	471.3	333.5	467.2	72.9	466.1	72.9	466.1	historic floodway	
RDR079	33989.56	520.1	96.9	468.9	370.0	467.9	235.3	462.7	235.3	462.7	historic floodway	
RDR078	33491.89	631.3	58.7	577.1	55.9	464.7	62.5	544.6	62.5	544.6	historic floodway	
RDR077	32971.01	589.2	76.7	486.7	80.9	487.7	240.7	477.3	240.7	477.3	historic floodway	
RDR076	32366.90	693.4	90.5	642.3	145.4	311.1	97.7	632.6	97.7	632.6	historic floodway	
RDR075	31826.57	598.2	65.3	544.9	68.3	164.7	69.7	539.6	69.7	539.6	historic floodway	
RDR074	31367.30	502.2	91.4	428.8	124.5	203.4	87.4	434.6	87.4	430.0	historic floodway	no viable flood fringe
RDR073	30752.55	596.7	78.1	557.3	351.0	536.5	284.7	558.1	284.7	558.1	historic floodway	
RDR072	29976.11	619.3	65.0	577.1	68.0	273.3	73.2	520.3	73.2	520.3	historic floodway	
RDR071	29153.77	626.3	67.6	556.1	468.7	552.0	72.0	551.0	72.0	551.0	historic floodway	
RDR070	28767.94	552.8	74.8	478.4	364.1	475.9	80.4	470.1	80.4	470.1	historic floodway	
RDR069	28229.10	845.3	60.2	662.9	65.2	213.7	63.5	659.0	63.5	659.0	historic floodway	

Cross Section	River Station	Cross Section Length (m)	1 m Depth Criteria		1 m/s Velocity Criteria		Historic Floodway		Selected Floodway Extents (m)		Governing Floodway Criteria	
			Left Station	Right Station	Left Station	Right Station	Left Station	Right Station	Left Station	Right Station	Left Station	Right Station
RDR068	27841.09	837.9	361.6	759.1	369.8	426.6	61.8	754.2	61.8	754.2	historic floodway	
RDR067	27269.94	624.6	52.3	546.4	416.0	543.2	55.0	542.8	55.0	542.8	historic floodway	
RDR066	26811.24	780.3	55.4	553.8	361.5	545.8	59.9	551.2	59.9	551.2	historic floodway	
RDR065	26289.99	454.9	51.3	399.4	250.8	342.7	56.8	391.3	56.8	391.3	historic floodway	
RDR064	25704.30	488.7	80.0	434.5	86.0	224.2	85.0	430.8	85.0	430.8	historic floodway	
RDR063	25334.58	422.0	52.0	374.6	159.8	283.4	56.8	363.3	56.8	363.3	historic floodway	
RDR062B	25119.90	477.2	262.6	389.1	259.8	386.1	266.1	387.0	266.1	387.0	historic floodway	
RDR062A	25105.02	484.7	272.2	397.8	275.9	396.0	274.9	396.5	274.9	396.5	historic floodway	
RDR061	24862.84	636.4	57.8	421.2	343.9	418.2	59.4	417.9	59.4	417.9	historic floodway	
RDR060	24523.27	510.1	60.6	443.2	297.3	439.1	64.9	443.0	64.9	443.0	historic floodway	
RDR059	24055.69	563.6	46.8	495.7	282.4	490.7	51.2	494.2	51.2	494.2	historic floodway	
RDR058	23776.91	673.8	71.7	562.1	309.2	417.4	75.9	568.8	75.9	568.8	historic floodway	
RDR057	23352.27	591.4	69.4	537.0	111.1	219.6	72.3	523.9	72.3	523.9	historic floodway	
RDR056	22939.96	498.1	60.6	445.3	63.9	137.8	65.0	437.2	65.0	437.2	historic floodway	
RDR055	22652.90	538.4	65.5	476.4	144.4	267.9	101.7	470.9	101.7	470.9	historic floodway	
RDR054	22080.46	511.0	49.8	449.1	326.5	445.8	62.1	429.7	62.1	429.7	historic floodway	
RDR053	21654.55	688.7	77.4	635.6	186.0	289.5	81.3	632.9	81.3	632.9	historic floodway	
RDR052	21403.28	557.8	61.5	490.3	62.2	172.3	65.1	491.0	65.1	491.0	historic floodway	
RDR051	21109.04	574.6	88.9	493.9	88.4	238.1	91.7	484.4	91.7	484.4	historic floodway	
RDR050	20573.39	511.6	64.5	421.6	236.5	358.7	70.9	405.9	70.9	405.9	historic floodway	
RDR049	20186.31	503.8	77.4	422.3	79.5	319.0	78.5	420.6	78.5	420.6	historic floodway	
RDR048	19658.68	533.3	80.4	377.7	85.4	306.5	84.3	388.6	84.3	388.6	historic floodway	
RDR047	19377.16	530.3	60.1	422.7	66.0	278.8	66.9	400.8	66.9	400.8	historic floodway	
RDR046	18920.81	572.1	75.7	351.0	80.5	207.0	80.4	345.1	80.4	345.1	historic floodway	
RDR045	18541.73	535.7	79.0	240.0	83.0	196.8	81.1	239.9	81.1	239.9	historic floodway	
RDR044	18045.12	473.4	59.5	383.3	63.3	262.2	63.2	376.3	63.2	376.3	historic floodway	
RDR043	17790.40	452.7	97.6	403.5	122.6	261.3	118.7	398.7	118.7	398.7	historic floodway	
RDR042	17390.93	755.2	176.9	666.3	440.3	548.6	242.5	669.9	242.5	667.7	historic floodway	
RDR041	17057.01	887.2	172.8	717.2	576.5	714.4	183.8	724.7	183.8	718.6	historic floodway	no viable flood fringe
RDR040	16602.19	763.4	202.3	657.0	495.4	654.3	206.0	651.3	206.0	651.3	historic floodway	
RDR039	16168.59	671.5	434.8	630.9	507.0	624.8	437.3	622.6	437.3	622.6	historic floodway	
RDR038	15811.90	894.5	472.8	802.1	463.1	571.0	473.7	792.9	473.7	792.9	historic floodway	
RDR037	15366.92	878.1	316.5	802.6	324.0	508.5	317.1	699.4	317.1	699.4	historic floodway	
RDR036	14866.17	934.7	339.1	750.3	336.9	511.5	346.8	702.2	346.8	702.2	historic floodway	
RDR035B	14714.49	1,204.4	392.2	507.3	390.8	513.2	393.7	503.1	393.7	503.1	historic floodway	
RDR035A	14696.46	1,201.1	394.6	501.8	392.1	504.9	396.7	502.3	396.7	502.3	historic floodway	
RDR034	14498.85	1,116.3	363.2	771.3	364.8	667.5	366.6	727.4	366.6	727.4	historic floodway	
RDR033	14148.40	1,135.2	330.6	662.0	328.5	663.4	332.5	829.9	332.5	829.9	historic floodway	
RDR032	13528.62	1,444.2	503.0	1,357.3	566.5	732.2	497.2	1,359.9	499.9	1,359.9	no viable flood fringe	historic floodway
RDR031	13127.07	1,382.4	275.1	1,269.3	274.1	558.2	242.8	1,269.3	274.1	1,269.3	no viable flood fringe	historic floodway
RDR030	12861.96	1,148.6	149.3	1,067.0	236.1	316.2	148.7	1,060.3	148.7	1,060.3	historic floodway	
RDR029	12475.30	916.2	200.4	851.8	210.3	459.1	203.4	846.3	203.4	846.3	historic floodway	

Cross Section	River Station	Cross Section Length (m)	1 m Depth Criteria		1 m/s Velocity Criteria		Historic Floodway		Selected Floodway Extents (m)		Governing Floodway Criteria	
			Left Station	Right Station	Left Station	Right Station	Left Station	Right Station	Left Station	Right Station	Left Station	Right Station
RDR028	11928.01	798.1	164.2	652.7	177.4	302.3	105.0	655.1	105.0	654.5	historic floodway	
RDR027	11520.43	937.5	94.0	761.0	112.0	564.6	94.4	772.9	94.4	772.9	historic floodway	
RDR026	10959.43	592.7	41.1	525.7	254.2	515.2	45.1	520.7	45.1	520.7	historic floodway	
RDR025	10679.27	498.0	81.7	398.1	277.2	395.2	87.6	424.9	87.6	424.9	historic floodway	
RDR024	10318.95	814.1	232.0	739.2	475.3	612.7	238.1	727.3	238.1	727.3	historic floodway	
RDR023	9897.90	869.5	349.2	767.7	450.5	692.1	365.1	761.4	365.1	761.4	historic floodway	
RDR022	9537.43	828.5	325.9	746.3	317.6	446.9	338.4	737.3	338.4	737.3	historic floodway	
RDR021	9066.37	605.6	243.2	535.5	241.2	531.6	154.3	531.9	154.3	531.9	historic floodway	
RDR020	8811.41	617.2	83.7	521.8	329.8	517.6	89.7	520.5	89.7	520.5	historic floodway	
RDR019	8374.00	544.9	48.6	435.0	53.1	436.2	55.5	425.6	55.5	425.6	historic floodway	
RDR018	8016.03	551.6	80.9	399.6	86.8	386.5	83.3	391.5	83.3	391.5	historic floodway	
RDR017	7684.66	570.7	103.6	351.9	102.2	187.6	105.1	343.0	105.1	343.0	historic floodway	
RDR016	7370.54	549.1	168.8	428.6	172.6	331.4	171.9	423.1	171.9	423.1	historic floodway	
RDR015	6881.20	732.5	412.1	650.6	573.3	652.0	419.0	641.3	419.0	641.3	historic floodway	
RDR014	6562.62	631.1	386.2	562.7	398.5	558.0	389.0	562.2	389.0	562.2	historic floodway	
RDR013	6100.29	537.3	211.6	378.0	217.7	373.4	211.8	373.7	211.8	373.7	historic floodway	
RDR012	5758.35	702.6	121.8	325.2	231.1	326.4	136.4	319.3	136.4	319.3	historic floodway	
RDR011B	5364.90	679.7	114.1	241.4	120.8	215.1	114.8	242.9	114.8	242.9	historic floodway	
RDR011A	5333.35	672.5	109.1	233.9	113.9	208.6	111.1	240.1	111.1	240.1	historic floodway	
RDR010	4885.02	708.5	144.9	311.5	149.2	302.3	145.9	314.9	145.9	313.4	historic floodway	
RDR009	4227.32	743.2	497.6	657.9	534.1	644.8	497.2	655.8	497.2	655.8	historic floodway	
RDR008	3657.40	671.8	433.9	578.8	432.7	573.2	437.1	571.2	437.1	571.2	historic floodway	
RDR007	3069.72	797.4	306.3	487.0	304.8	434.1	312.5	472.4	312.5	472.4	historic floodway	
RDR006	2505.23	803.6	83.1	242.0	83.4	229.4	86.6	235.6	86.6	235.6	historic floodway	

TABLE 8A: DESIGN FLOOD WATER SURFACE ELEVATIONS, MEDICINE RIVER

Cross-Section	River Station (m)	100-year Water Surface Elevation (m)
MED067	33253	906.08
MED066	32861	906.04
MED065	32001	906.01
MED064	31469	905.97
MED063	31083	905.94
MED062	30292	905.90
MED061	28899	905.87
MED060	28200	905.85
MED059	27420	905.81
MED058	26899	905.61
MED057	26533	905.56
MED056	26081	905.33
MED055	25653	905.21
MED054	25456	905.22
MED053	24799	905.15
MED052	23964	904.94
MED051	23380	904.66
MED050	22931	904.56
MED049	22485	904.52
MED048	22231	904.50
MED047	21617	904.43
MED046	21071	904.26
MED045	20891	904.17
MED044B	20842	904.03
MED044A	20804	903.66
MED043	20762	903.65
MED042	20535	903.40
MED041	20098	903.27
MED038	18858	902.25
MED037	18393	902.23
MED036	17962	902.12
MED035	17492	901.97
MED032	16547	901.86
MED031	16254	901.63
MED030B	16120	901.43
MED030A	16114	901.34
MED029	16084	901.36
MED028B	16028	901.38
MED028A	16007	901.31
MED027	15848	901.35
MED026	15351	900.94

Cross-Section	River Station (m)	100-year Water Surface Elevation (m)
MED025	14979	900.72
MED024	14323	900.25
MED023	13881	900.19
MED020	12724	899.99
MED019	11712	899.94
MED018	10703	899.91
MED017	10132	899.84
MED016	9894	899.82
MED015	9581	899.66
MED014	9170	899.58
MED013	8163	899.46
MED012	7622	899.38
MED011B	7141	899.15
MED011A	7123	899.05
MED010	6351	898.61
MED009	5447	897.73
MED007	3628	896.57
MED006	2692	896.55
MED005	2125	896.30
MED004	1690	896.36
MED003	1242	896.34
MED002	734	896.27
MED001	272	896.26

TABLE 8B: DESIGN FLOOD WATER SURFACE ELEVATIONS, LITTLE RED DEER RIVER

Cross-Section	River Station (m)	100-year Water Surface Elevation (m)
LRD075	32643	944.92
LRD074	32311	944.56
LRD073	32010	944.43
LRD072	31618	944.12
LRD071	31294	943.63
LRD070	30830	943.49
LRD069	30188	942.48
LRD068	29482	941.76
LRD067	28995	940.99
LRD066	28591	940.28
LRD065	28316	939.65
LRD064	27439	938.95
LRD063	26659	938.43
LRD062	26204	938.16
LRD061	25747	937.28
LRD060	25297	936.77
LRD059	24848	936.21
LRD058	24382	935.77
LRD057	23925	934.93
LRD056	23710	934.83
LRD055	23572	934.83
LRD054B	23493	934.79
LRD054A	23465	933.40
LRD053	23356	933.39
LRD052	23027	933.35
LRD051	22561	933.24
LRD050	22285	932.91
LRD049	21767	932.39
LRD048	21409	932.12
LRD047	21132	931.90
LRD046	20683	930.87
LRD045	20380	930.43
LRD044	20040	929.94
LRD043	19849	929.87
LRD042	19385	929.26
LRD041	18868	928.32
LRD040	18426	927.55
LRD039	17897	926.72
LRD038	17580	926.63
LRD037	16941	925.68
LRD036	16488	924.88

Cross-Section	River Station (m)	100-year Water Surface Elevation (m)
LRD035	16189	924.39
LRD034	15715	923.38
LRD033	15466	922.99
LRD032	15233	922.32
LRD031	14525	920.45
LRD030	13896	919.30
LRD029	13470	918.51
LRD028	12856	916.80
LRD027	12500	915.96
LRD026	11955	914.78
LRD025	11443	914.05
LRD024	11274	913.47
LRD023	11010	912.79
LRD022	10401	910.96
LRD021	9921	910.34
LRD020	9646	910.01
LRD019B	9401	909.75
LRD019A	9387	909.56
LRD018	9129	908.90
LRD017	8823	908.41
LRD016	8308	907.22
LRD015	7617	906.05
LRD014	7070	905.59
LRD013	6480	904.13
LRD012	5958	903.97
LRD011	5484	903.35
LRD010	4953	902.16
LRD009	4581	901.79
LRD008	3863	900.76
LRD007	3277	900.48
LRD006	2750	899.93
LRD005	2103	899.06
LRD004	1565	897.75
LRD003	1017	897.75
LRD002	539	897.73
LRD001	121	897.58

TABLE 8C: DESIGN FLOOD WATER SURFACE ELEVATIONS, RED DEER RIVER

Cross-Section	River Station (m)	100-year Water Surface Elevation (m)
RDR109	50219	915.54
RDR108	49602	914.88
RDR107	49105	914.27
RDR106	48532	913.30
RDR105	48110	912.65
RDR104	47648	912.20
RDR103	46832	910.35
RDR102	46572	909.90
RDR101	46157	909.12
RDR100	45657	907.95
RDR099	45324	907.36
RDR098	44835	906.80
RDR097	44198	906.03
RDR096	43714	905.13
RDR095	43223	904.64
RDR094	41886	902.59
RDR093	41450	902.14
RDR092	40862	900.85
RDR091	40190	900.30
RDR090	39763	899.40
RDR089	39145	898.79
RDR088	38713	898.20
RDR087	38046	897.73
RDR086	37722	897.29
RDR085	37112	897.15
RDR084	36841	897.01
RDR083	36044	896.55
RDR082	35419	895.58
RDR081	35038	895.47
RDR080	34605	895.10
RDR079	33990	894.36
RDR078	33492	893.98
RDR077	32971	893.29
RDR076	32367	892.88
RDR075	31827	892.46
RDR074	31367	891.86
RDR073	30753	891.41
RDR072	29976	890.98
RDR071	29154	889.75
RDR070	28768	889.42
RDR069	28229	889.38
RDR068	27841	889.11
RDR067	27270	888.64
RDR066	26811	888.50
RDR065	26290	888.06
RDR064	25704	887.71
RDR063	25335	887.46
RDR062B	25120	886.93
RDR062A	25105	886.81
RDR061	24863	886.51
RDR060	24523	886.37
RDR059	24056	886.14
RDR058	23777	885.88
RDR057	23352	885.55
RDR056	22940	885.01
RDR055	22653	884.96

Cross-Section	River Station (m)	100-year Water Surface Elevation (m)
RDR054	22080	884.49
RDR053	21655	884.26
RDR052	21403	883.85
RDR051	21109	883.59
RDR050	20573	883.13
RDR049	20186	883.06
RDR048	19659	882.71
RDR047	19377	882.66
RDR046	18921	882.27
RDR045	18542	881.78
RDR044	18045	881.48
RDR043	17790	881.28
RDR042	17391	880.83
RDR041	17057	880.63
RDR040	16602	880.22
RDR039	16169	879.84
RDR038	15812	879.31
RDR037	15367	879.18
RDR036	14866	878.55
RDR035B	14714	878.01
RDR035A	14696	877.81
RDR034	14499	877.72
RDR033	14148	877.38
RDR032	13529	876.51
RDR031	13127	876.32
RDR030	12862	876.26
RDR029	12475	876.17
RDR028	11928	875.73
RDR027	11520	875.49
RDR026	10959	875.19
RDR025	10679	874.82
RDR024	10319	874.65
RDR023	9898	874.49
RDR022	9537	873.65
RDR021	9066	873.30
RDR020	8811	873.25
RDR019	8374	873.10
RDR018	8016	873.02
RDR017	7685	872.48
RDR016	7371	872.33
RDR015	6881	871.77
RDR014	6563	871.67
RDR013	6100	871.15
RDR012	5758	870.84
RDR011B	5365	870.22
RDR011A	5333	870.19
RDR010	4885	869.81
RDR009	4227	869.05
RDR008	3657	868.45
RDR007	3070	867.76
RDR006	2505	867.21
RDR005	2292	866.96
RDR004	1948	866.64
RDR003	1337	866.05
RDR002	730	865.24
RDR001	0	864.82

APPENDIX A
Survey and Base Data Collection Documentation

CSRS-PPP 3.50.3 (2022-03-04)

CP102840.22o
CP100

Data Start	Data End	Duration of Observations
2022-10-11 16:36:00.00	2022-10-11 23:35:00.00	6:59:00
Processing Time		**Product Type**
20:32:05 UTC 2022/11/01		NRCan/IGS Final
Observations	**Frequency**	**Mode**
Phase and Code	Double	Static

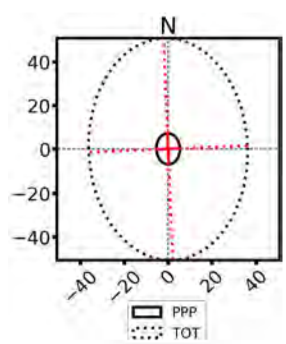
Elevation Cut-Off	Rejected Epochs	Fixed Ambiguities	Estimation Steps
7.5 degrees	0.00 %	96.26 %	30.00 sec

Antenna Model	APC to ARP	ARP to Marker
LEIAS10 NONE	L1 = 0.058 m L2 = 0.056 m	H:1.637m / E:0.000m / N:0.000m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for CP102840.22o

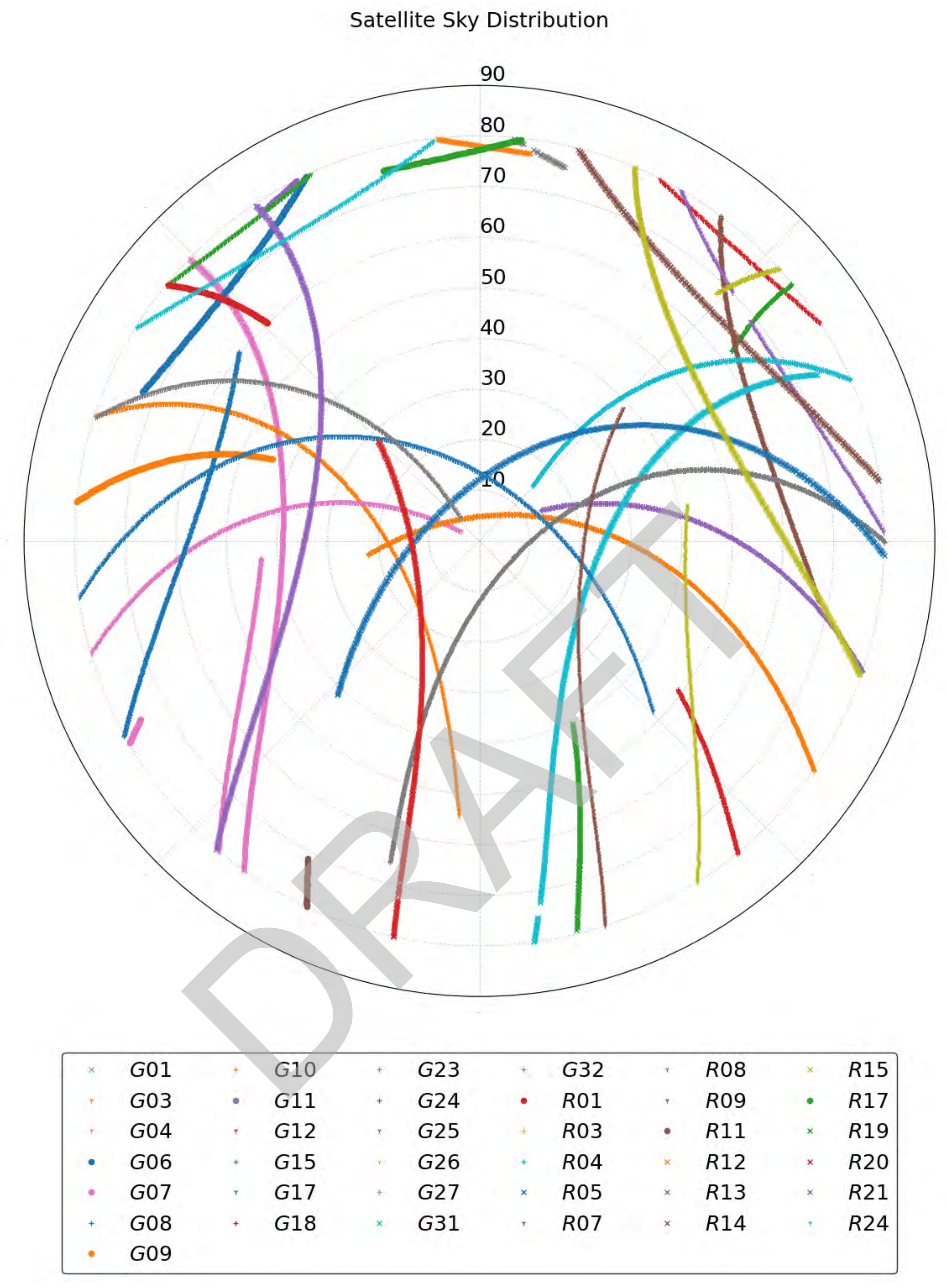
	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2002.0)†	52° 4' 19.68458"	-113° 59' 28.52816"	878.167 m
SIG_PPP(95%)‡	0.006 m	0.004 m	0.018 m
SIG_TOT(95%)‡	0.041 m	0.029 m	0.031 m
A priori*	52° 4' 19.68032"	-113° 59' 28.57176"	876.395 m
Estimated – A priori	0.132 m	0.830 m	1.772 m

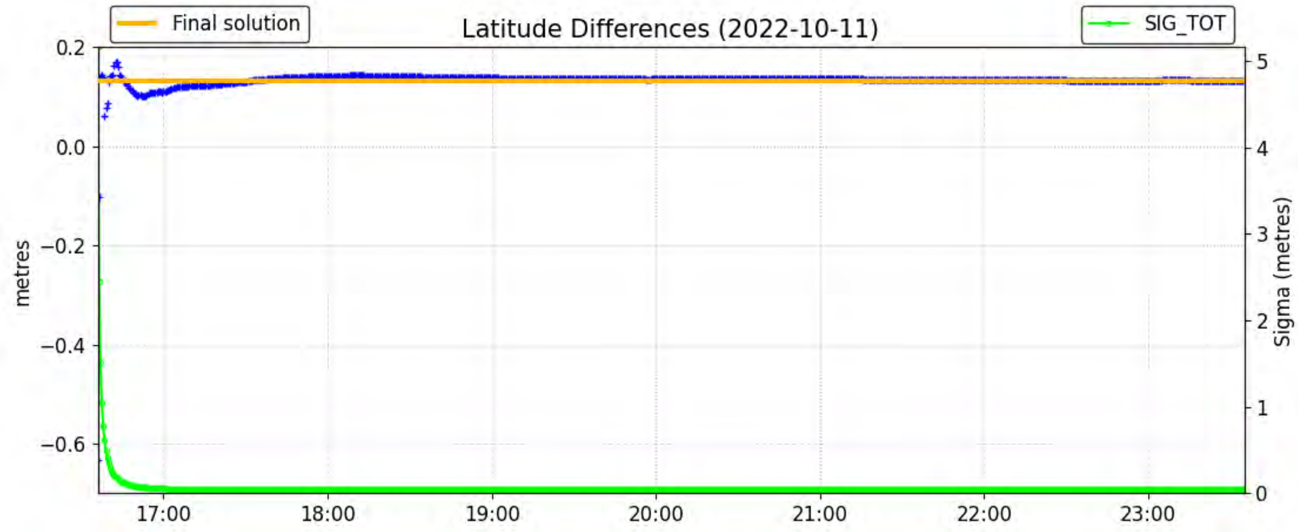
Orthometric Height CGVD28 (HTv2.0)†	95% PPP Error Ellipse (mm) semi-major: 7 mm semi-minor: 5 mm semi-major azimuth: -2° 9' 38.06"	95% TOT Error Ellipse (mm) semi-major: 51 mm semi-minor: 36 mm semi-major azimuth: -2° 37' 56.66"	UTM (North) Zone 12
896.135 m (click for height reference information)			5773283.923 m (N) 295001.460 m (E) Scale Factors 1.00011592 (point) 0.99997835 (combined)

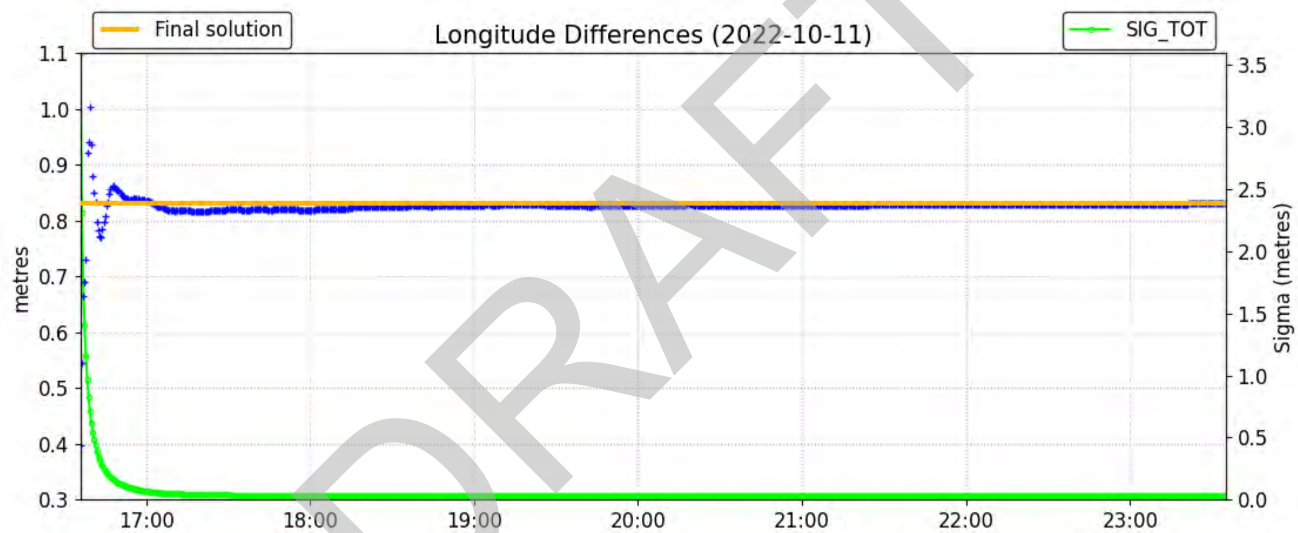
*(Coordinates from RINEX header used as a priori position)

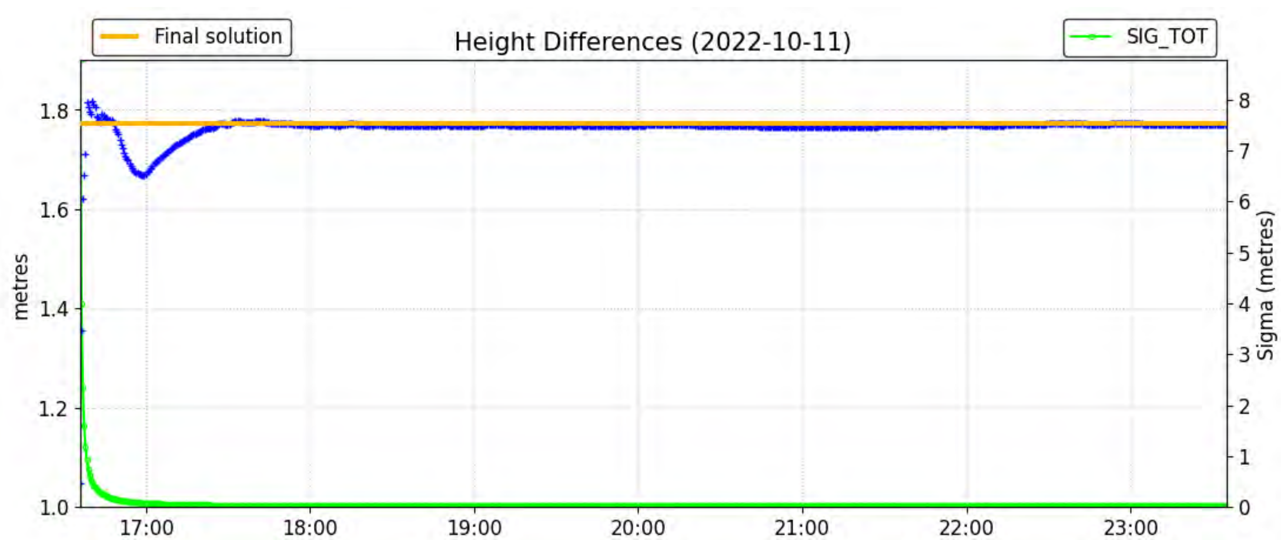
†(Epoch transformation using velocity grid NAD83v70VG (click for documentation))

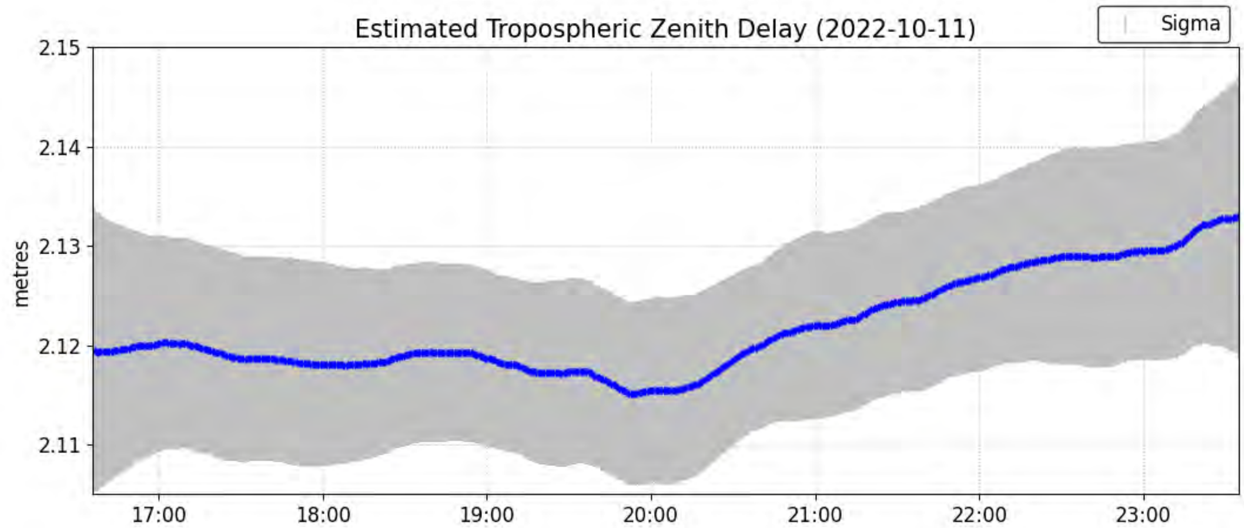
‡SIG_PPP indicates PPP-derived uncertainties, SIG_TOT incorporates uncertainties from epoch transformation

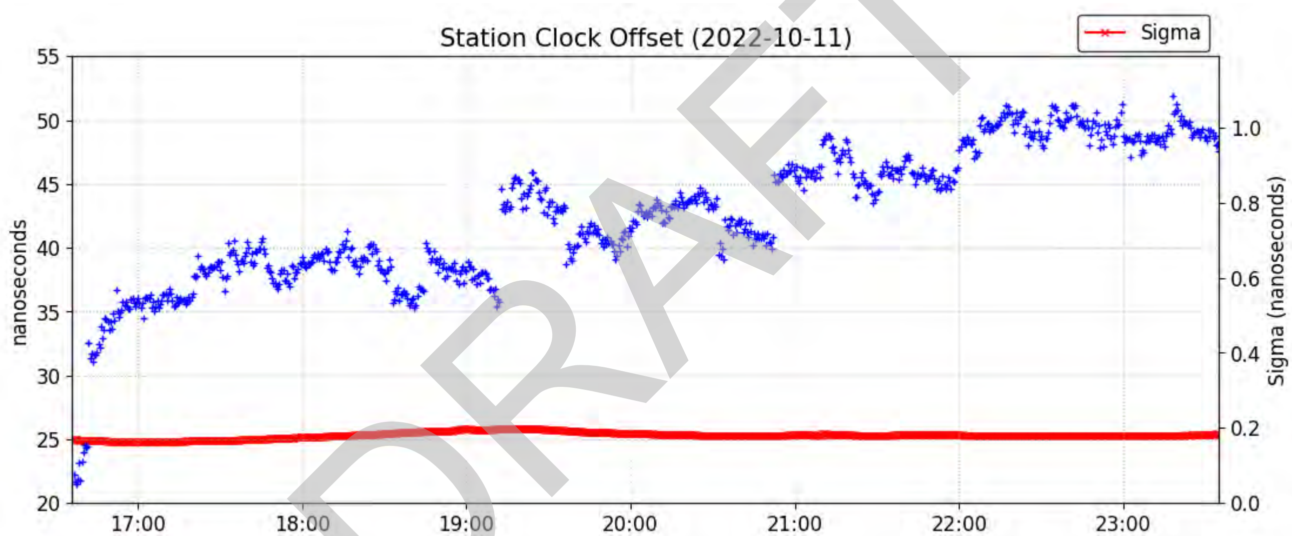

Satellite Sky Distribution
90
80
70
60
50
40
30
20
10
G01 G10 G23 G32 R08 R15
G03 G11 G24 R01 R09 R17
G04 G12 G25 R03 R11 R19
G06 G15 G26 R04 R12 R20
G07 G17 G27 R05 R13 R21
G08 G18 G31 R07 R14 R24
G09

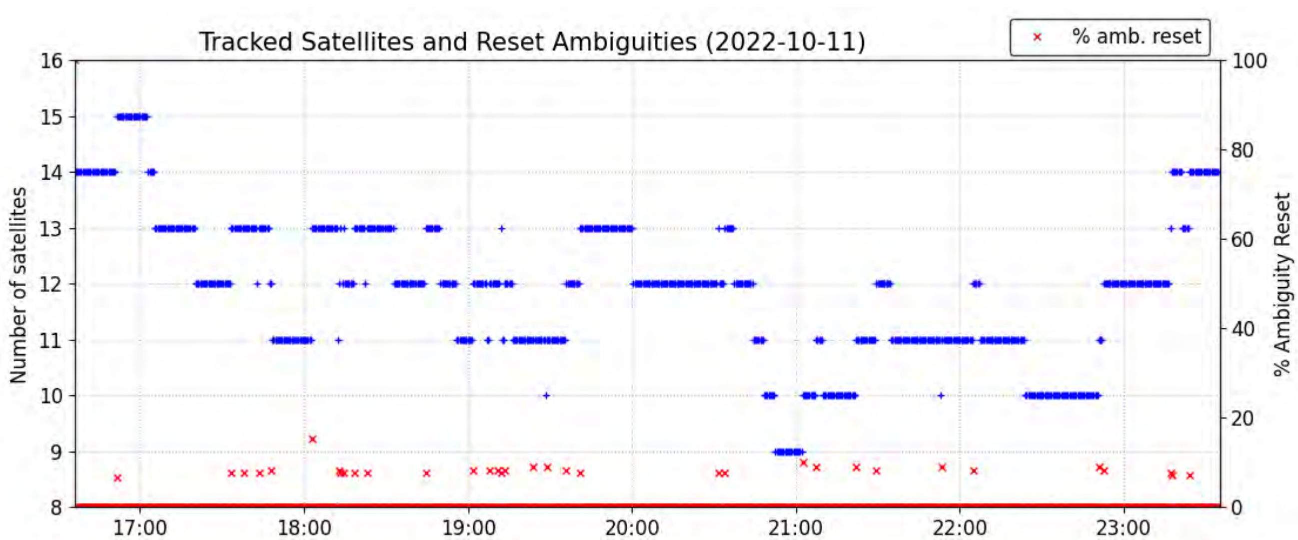

Latitude Differences (2022-10-11)
Final solution
SIG_TOT
metres
Sigma (metres)
17:00
18:00
19:00
20:00
21:00
22:00
23:00

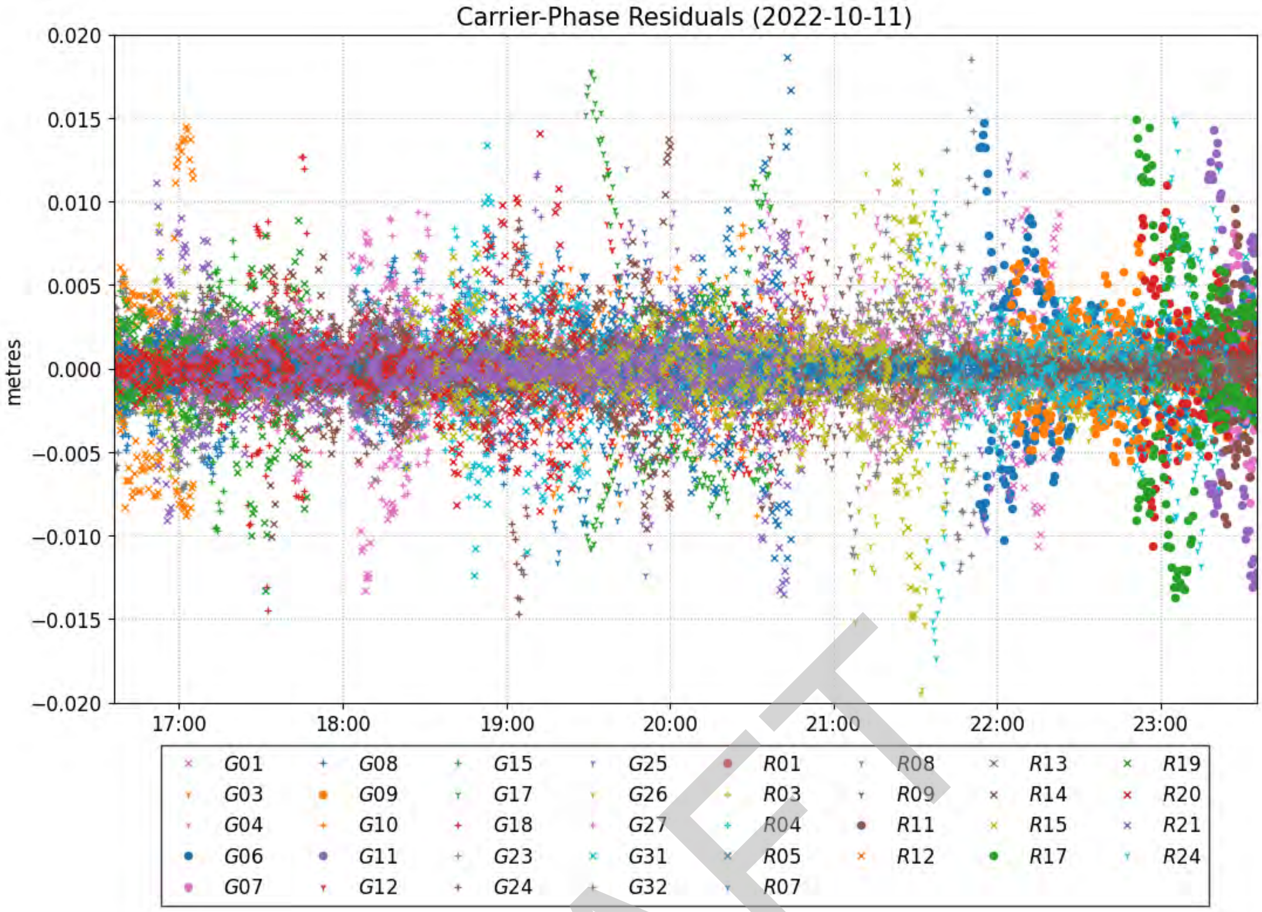

Longitude Differences (2022-10-11)
Final solution
SIG_TOT
metres
Sigma (metres)
17:00
18:00
19:00
20:00
21:00
22:00
23:00

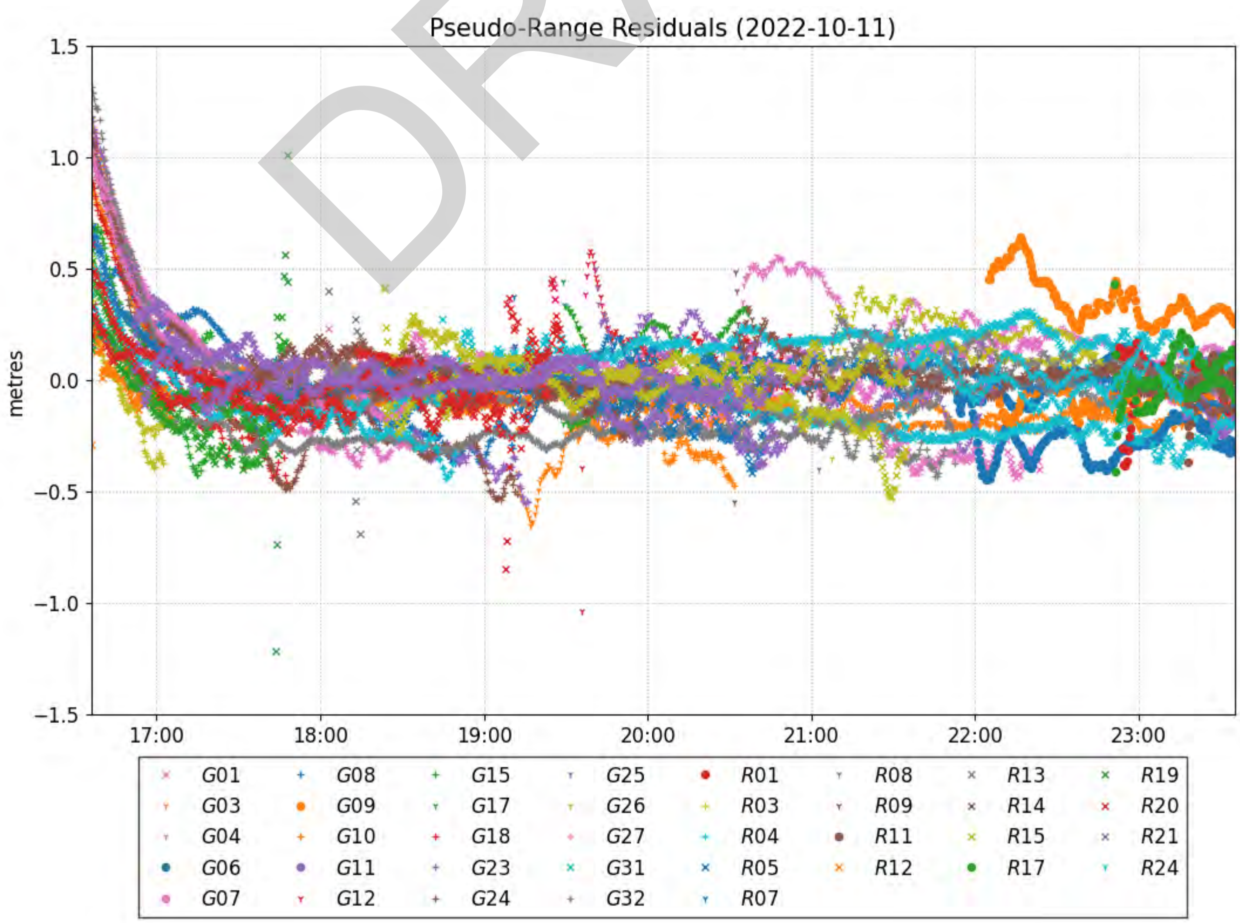

Height Differences (2022-10-11)
Final solution
SIG_TOT
metres
Sigma (metres)
17:00
18:00
19:00
20:00
21:00
22:00
23:00

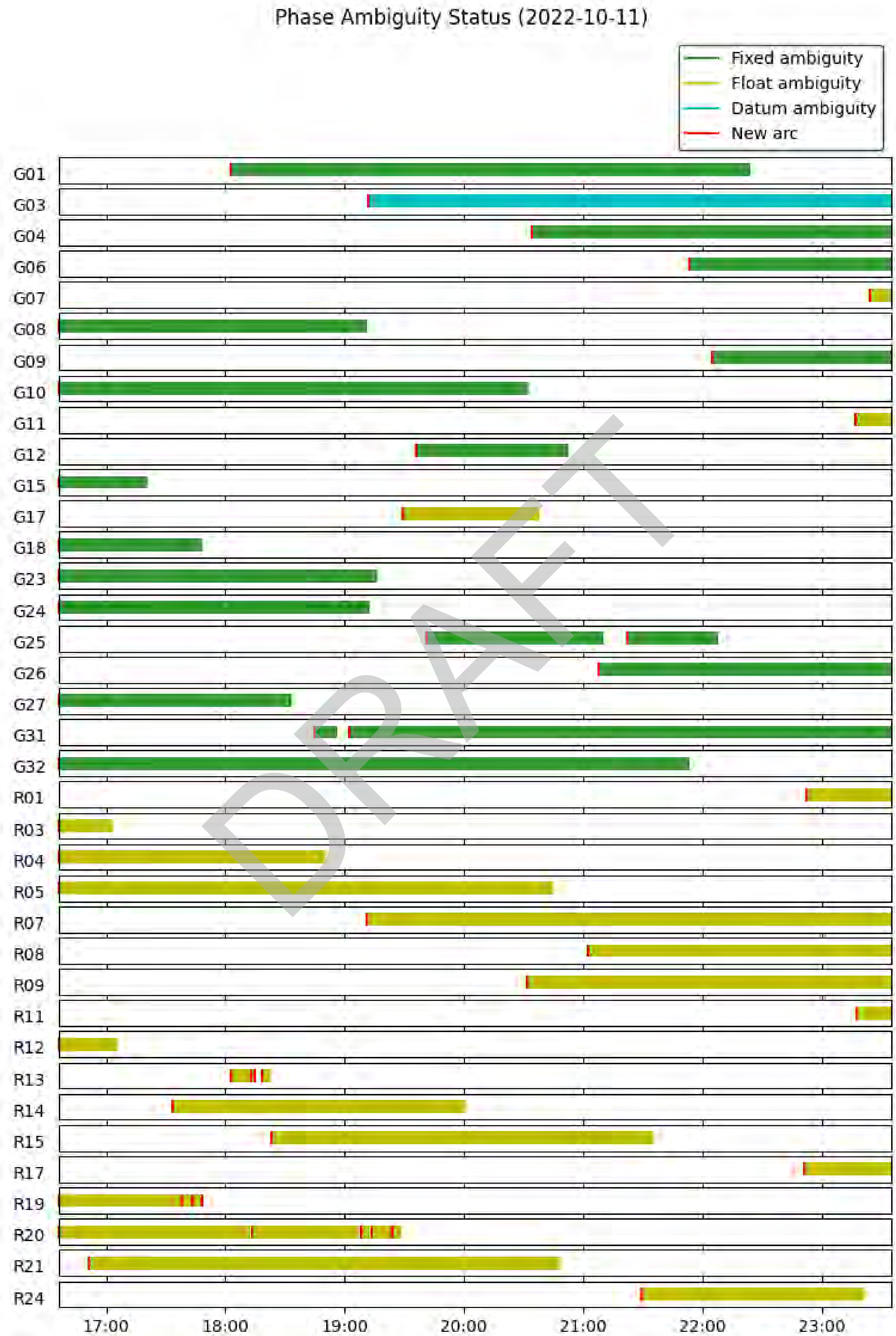

Estimated Tropospheric Zenith Delay (2022-10-11)
Sigma
metres
2.15
2.14
2.13
2.12
2.11
17:00
18:00
19:00
20:00
21:00
22:00
23:00


Station Clock Offset (2022-10-11)
Sigma
nanoseconds
Sigma (nanoseconds)
55
50
45
40
35
30
25
20
1.0
0.8
0.6
0.4
0.2
0.0
17:00
18:00
19:00
20:00
21:00
22:00
23:00
DRAFT


Tracked Satellites and Reset Ambiguities (2022-10-11)
% amb. reset
Number of satellites
% Ambiguity Reset
16
15
14
13
12
11
10
9
8
100
80
60
40
20
0
17:00
18:00
19:00
20:00
21:00
22:00
23:00


Carrier-Phase Residuals (2022-10-11)
metres
0.020
0.015
0.010
0.005
0.000
−0.005
−0.010
−0.015
−0.020
17:00
18:00
19:00
20:00
21:00
22:00
23:00
G01 G08 G15 G25 R01 R08 R13 R19
G03 G09 G17 G26 R03 R09 R14 R20
G04 G10 G18 G27 R04 R11 R15 R21
G06 G11 G23 G31 R05 R12 R17 R24
G07 G12 G24 G32 R07


Pseudo-Range Residuals (2022-10-11)
metres
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
17:00
18:00
19:00
20:00
21:00
22:00
23:00
G01 G08 G15 G25 R01 R08 R13 R19
G03 G09 G17 G26 R03 R09 R14 R20
G04 G10 G18 G27 R04 R11 R15 R21
G06 G11 G23 G31 R05 R12 R17 R24
G07 G12 G24 G32 R07



Phase Ambiguity Status (2022-10-11)
Fixed ambiguity
Float ambiguity
Datum ambiguity
New arc
G01
G03
G04
G06
G07
G08
G09
G10
G11
G12
G15
G17
G18
G23
G24
G25
G26
G27
G31
G32
R01
R03
R04
R05
R07
R08
R09
R11
R12
R13
R14
R15
R17
R19
R20
R21
R24
17:00
18:00
19:00
20:00
21:00
22:00
23:00
DRAFT

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Canadian Geodetic Survey
Surveyor General Branch
Natural Resources Canada
Government of Canada
588 Booth Street, Room 334
Ottawa, Ontario K1A 0Y7
Phone: 343-292-6617
Email: geodeticinformation-informationgeodesique@nrcan-rncan.gc.ca

Natural Resources Canada   Ressources naturelles Canada   Canada

CSRS-PPP 3.50.3 (2022-03-04)

CP101.22o
CP101

Data Start	Data End	Duration of Observations
2022-10-11 17:06:00.00	2022-10-11 19:22:00.00	2:16:00
Processing Time		**Product Type**
20:31:39 UTC 2022/11/01		NRCan/IGS Final
Observations	**Frequency**	**Mode**
Phase and Code	Double	Static

Elevation Cut-Off	Rejected Epochs	Fixed Ambiguities	Estimation Steps
7.5 degrees	0.00 %	95.92 %	30.00 sec

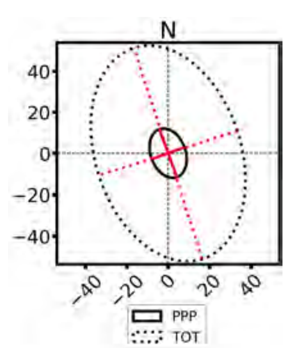
Antenna Model	APC to ARP	ARP to Marker
HEMS321	L1 = 0.132 m L2 = 0.139 m	H:1.594m / E:0.000m / N:0.000m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for CP101.22o

	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2002.0)†	52° 1' 40.72831"	-114° 8' 9.91073"	904.984 m
SIG_PPP(95%)‡	0.010 m	0.007 m	0.031 m
SIG_TOT(95%)‡	0.042 m	0.030 m	0.040 m
A priori*	52° 1' 40.76118"	-114° 8' 9.96176"	906.620 m
Estimated – A priori	-1.016 m	0.973 m	-1.636 m

Orthometric Height CGVD28 (HTv2.0)†	95% PPP Error Ellipse (mm)	95% TOT Error Ellipse (mm)	UTM (North) Zone 11
	semi-major: 12 mm semi-minor: 8 mm semi-major azimuth: -20° 48' 46.73"	semi-major: 54 mm semi-minor: 35 mm semi-major azimuth: -17° 6' 0.93"	
922.568 m (click for height reference information)			5768022.409 m (N) 696466.809 m (E) Scale Factors 1.00007387 (point) 0.99993211 (combined)

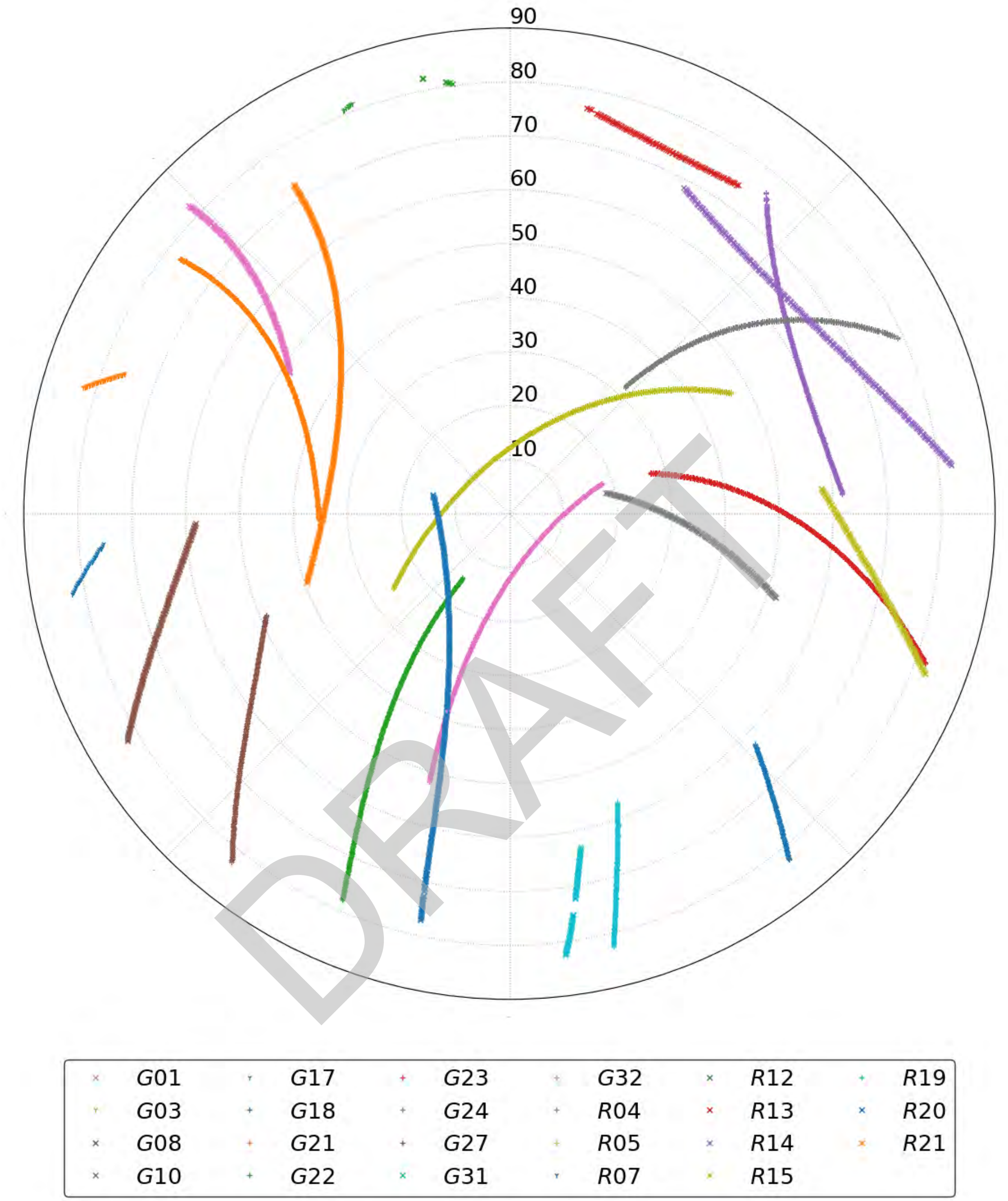


*(Coordinates from RINEX header used as a priori position)

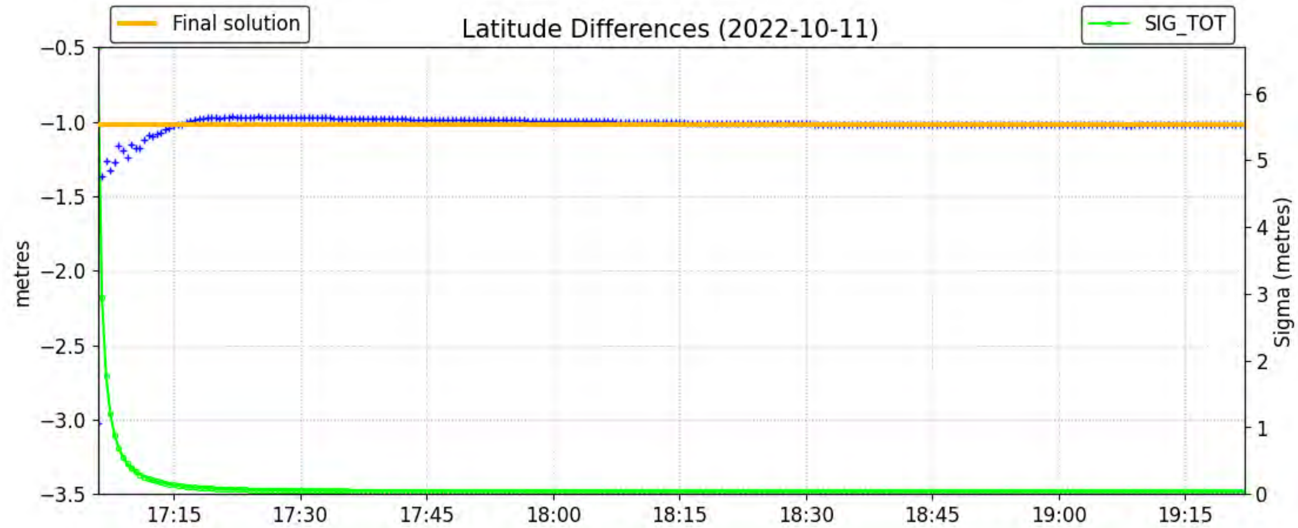
†(Epoch transformation using velocity grid NAD83v70VG (click for documentation))

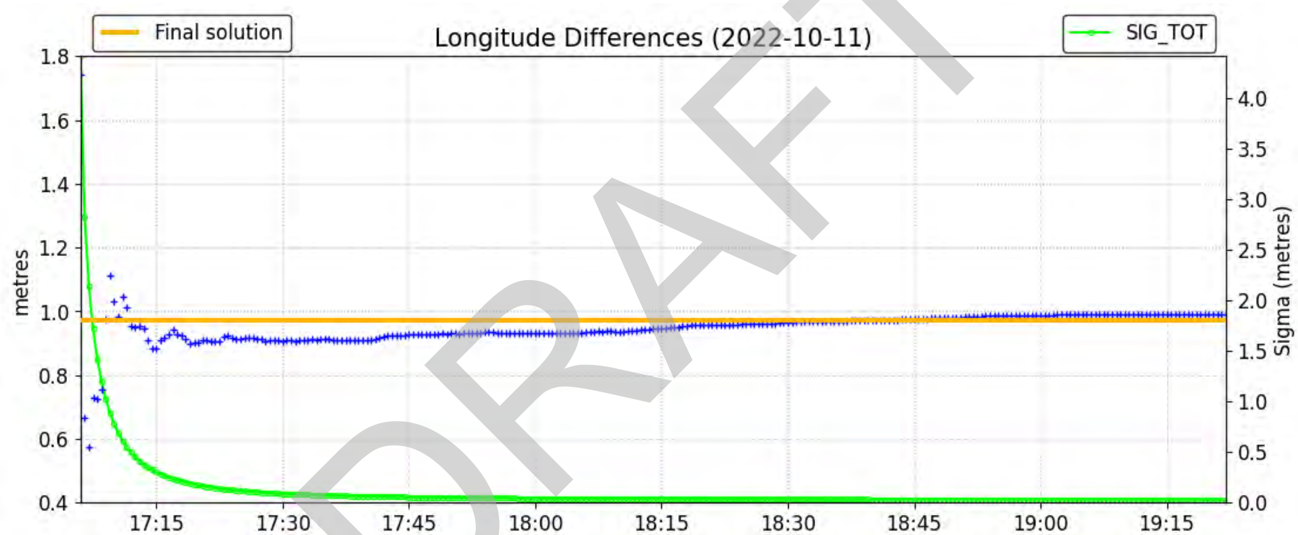
‡SIG_PPP indicates PPP-derived uncertainties, SIG_TOT incorporates uncertainties from epoch transformation

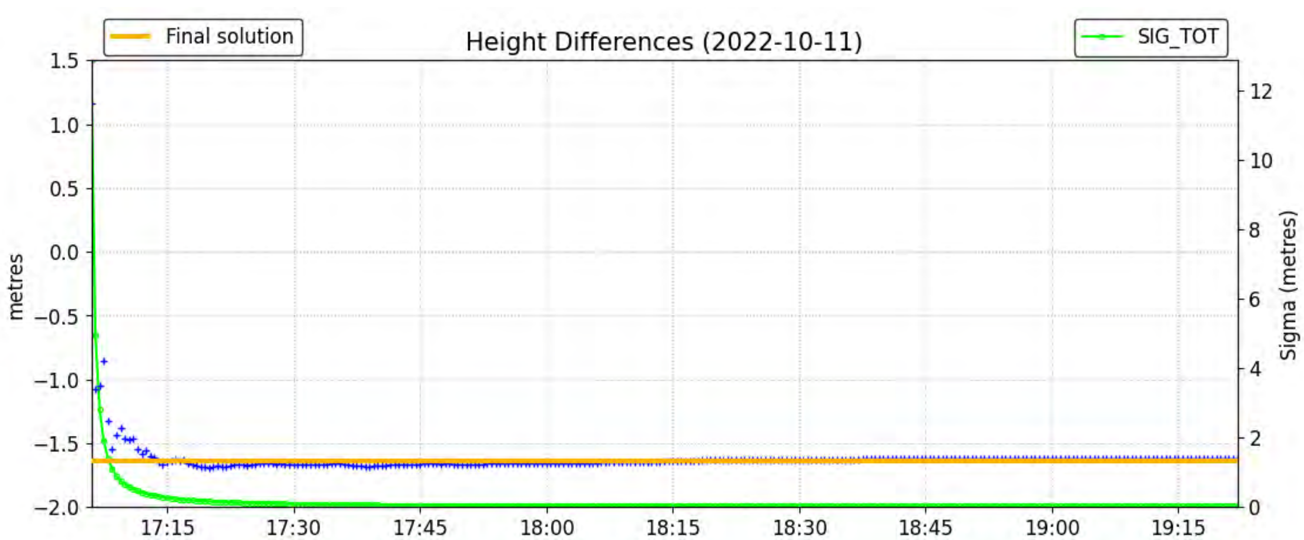
Satellite Sky Distribution

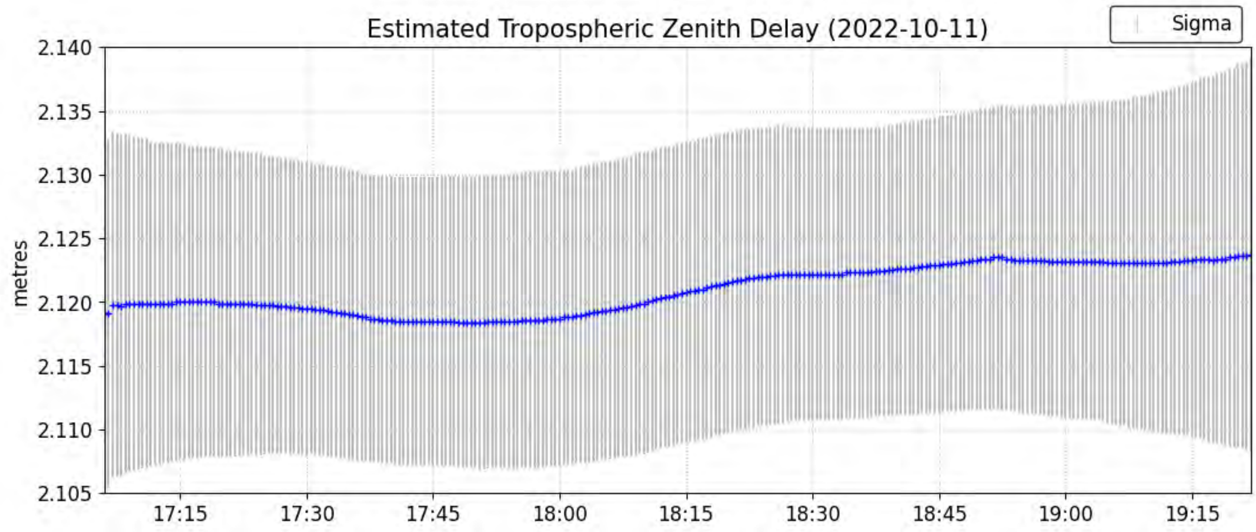


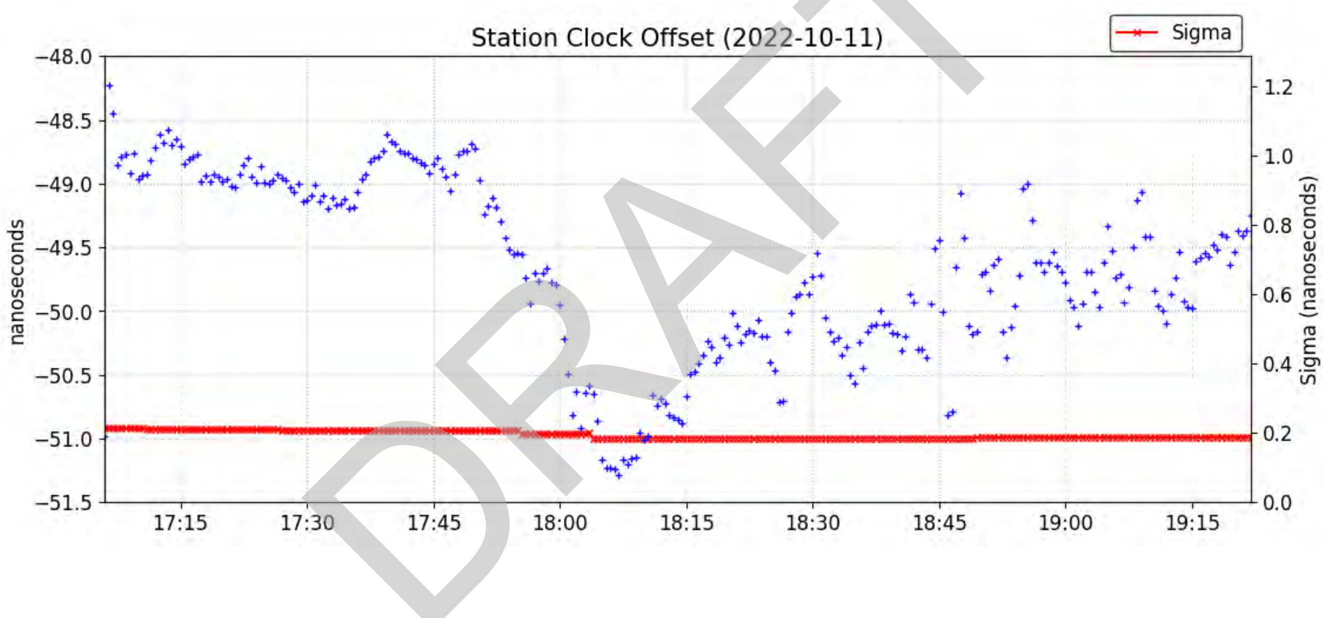
Classification: Public

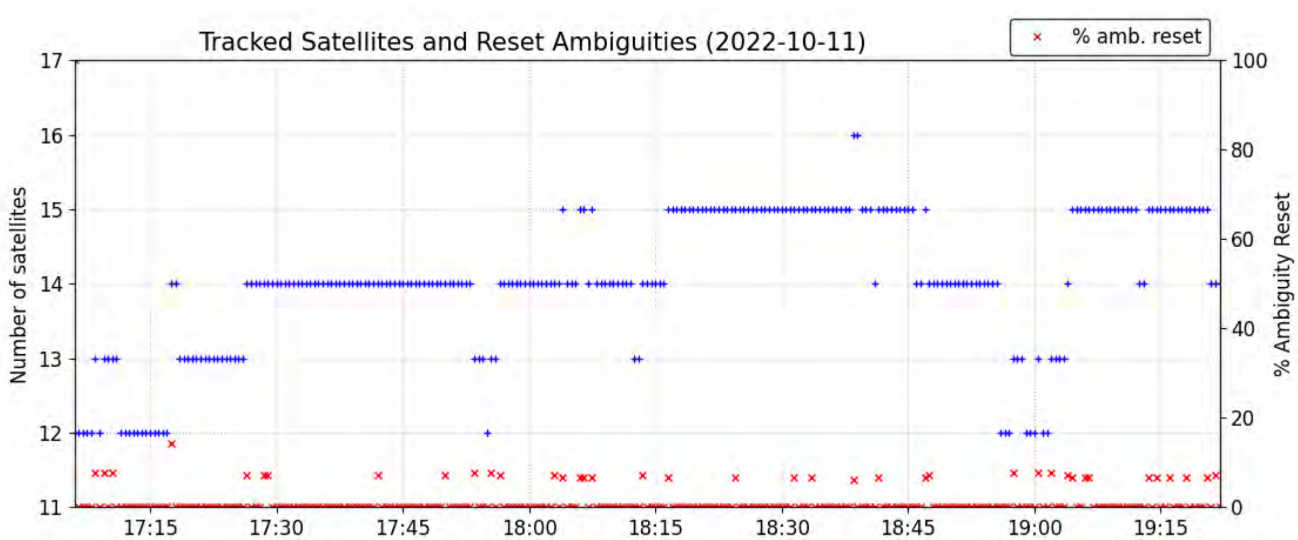

Final solution
Latitude Differences (2022-10-11)
SIG_TOT
metres
Sigma (metres)
−0.5
−1.0
−1.5
−2.0
−2.5
−3.0
−3.5
6
5
4
3
2
1
0
17:15
17:30
17:45
18:00
18:15
18:30
18:45
19:00
19:15

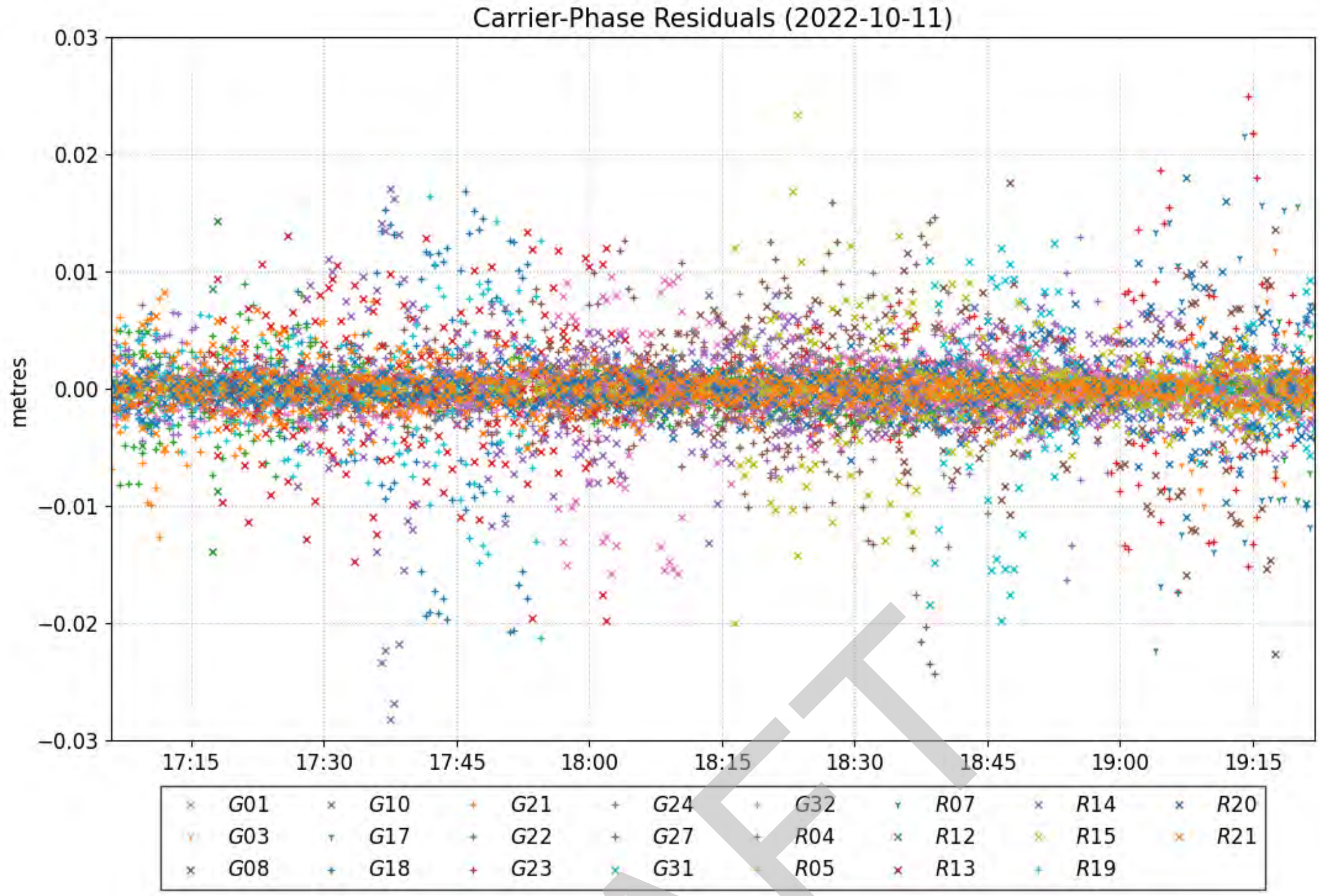

Final solution
Longitude Differences (2022-10-11)
SIG_TOT
DRAFT
metres
Sigma (metres)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
17:15
17:30
17:45
18:00
18:15
18:30
18:45
19:00
19:15

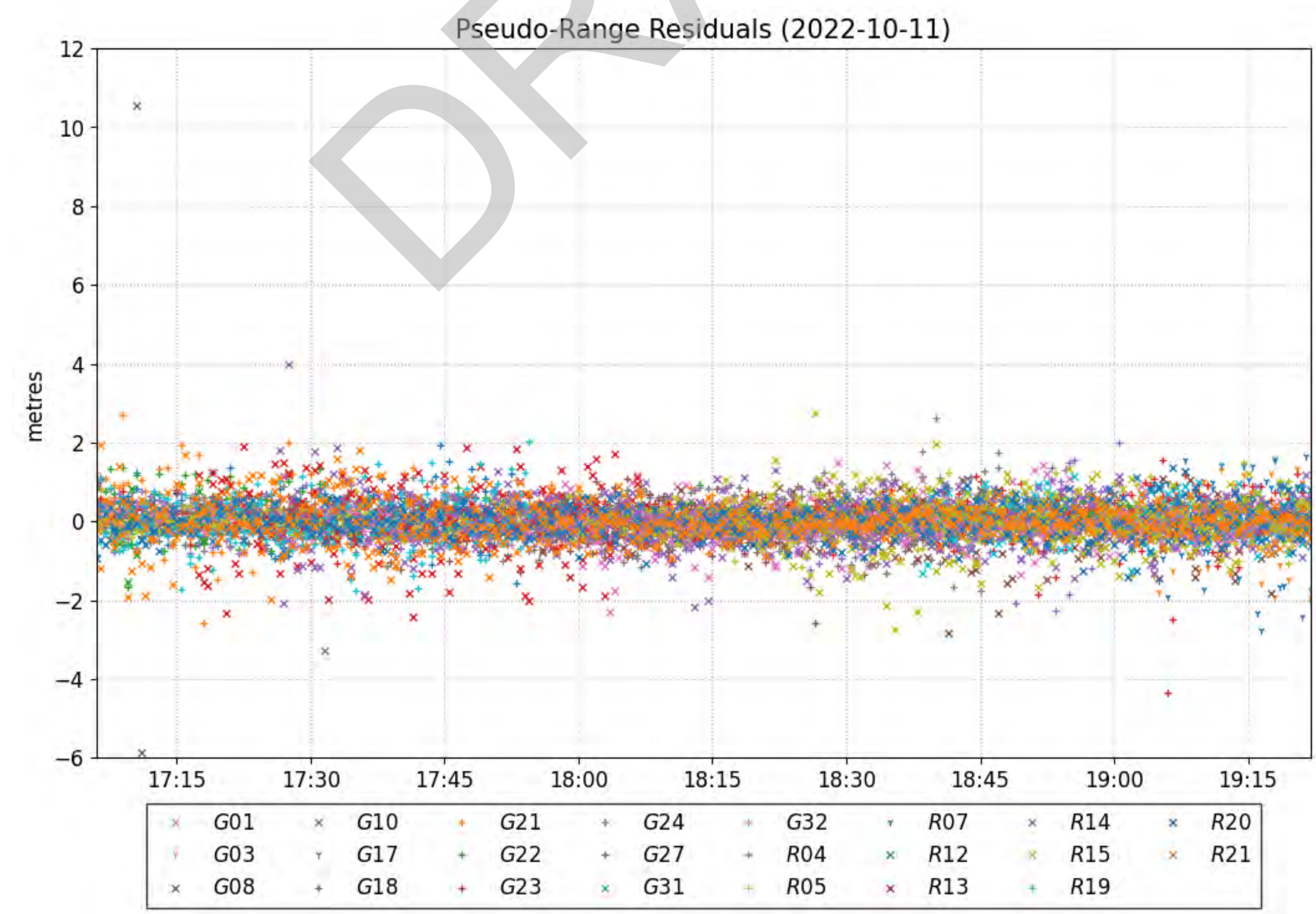

Final solution
Height Differences (2022-10-11)
SIG_TOT
metres
Sigma (metres)
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
12
10
8
6
4
2
0
17:15
17:30
17:45
18:00
18:15
18:30
18:45
19:00
19:15

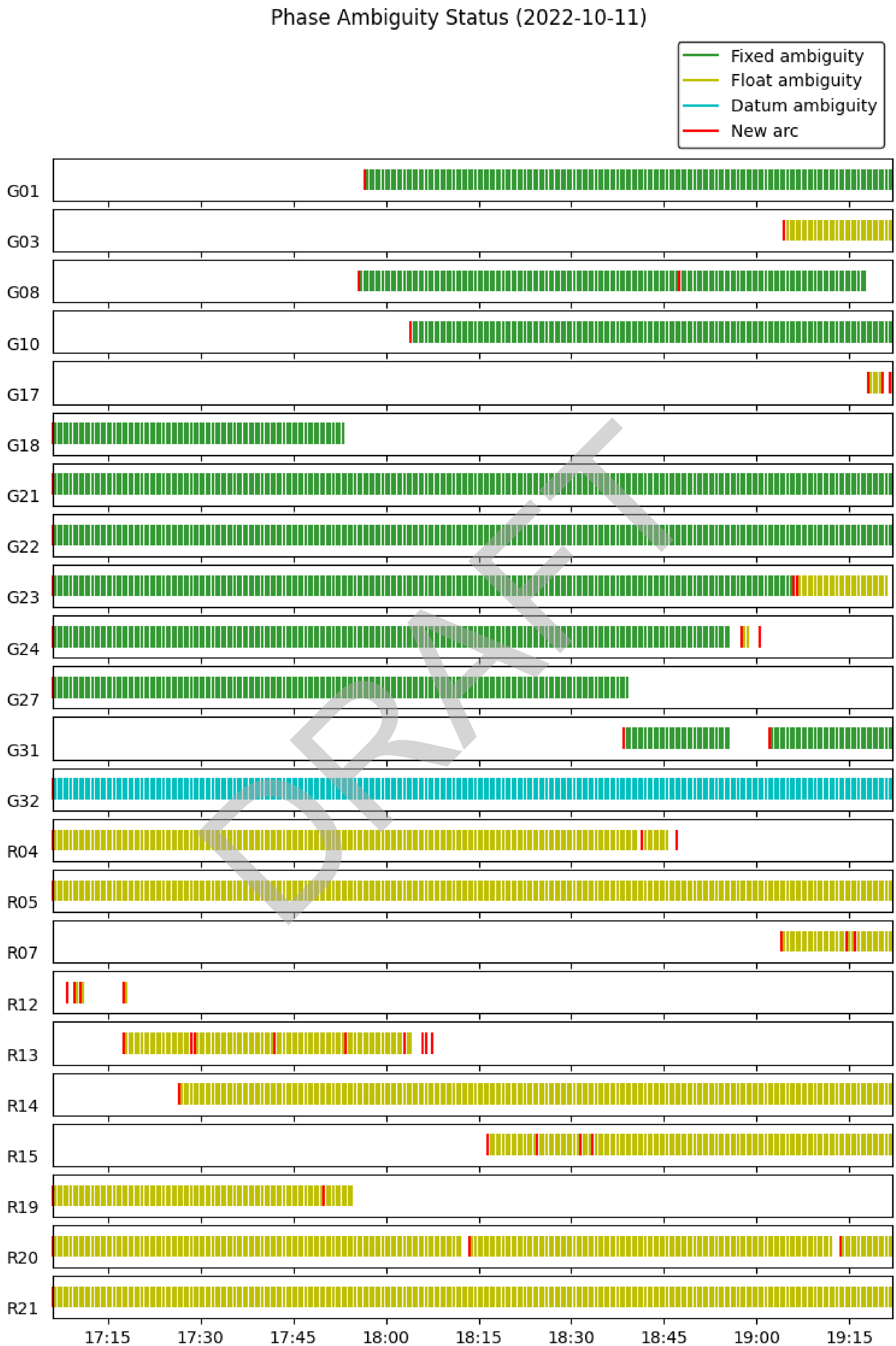

Estimated Tropospheric Zenith Delay (2022-10-11)
Sigma
metres
2.140
2.135
2.130
2.125
2.120
2.115
2.110
2.105
17:15
17:30
17:45
18:00
18:15
18:30
18:45
19:00
19:15


Station Clock Offset (2022-10-11)
Sigma
nanoseconds
Sigma (nanoseconds)
−48.0
−48.5
−49.0
−49.5
−50.0
−50.5
−51.0
−51.5
1.2
1.0
0.8
0.6
0.4
0.2
0.0
17:15
17:30
17:45
18:00
18:15
18:30
18:45
19:00
19:15
DRAFT


Tracked Satellites and Reset Ambiguities (2022-10-11)
% amb. reset
Number of satellites
% Ambiguity Reset
17
16
15
14
13
12
11
100
80
60
40
20
0
17:15
17:30
17:45
18:00
18:15
18:30
18:45
19:00
19:15


Carrier-Phase Residuals (2022-10-11)
metres
0.03
0.02
0.01
0.00
−0.01
−0.02
−0.03
17:15
17:30
17:45
18:00
18:15
18:30
18:45
19:00
19:15
G01 G10 G21 G24 G32 R07 R14 R20
G03 G17 G22 G27 R04 R12 R15 R21
G08 G18 G23 G31 R05 R13 R19


Pseudo-Range Residuals (2022-10-11)
metres
12
10
8
6
4
2
0
−2
−4
−6
17:15
17:30
17:45
18:00
18:15
18:30
18:45
19:00
19:15
G01 G10 G21 G24 G32 R07 R14 R20
G03 G17 G22 G27 R04 R12 R15 R21
G08 G18 G23 G31 R05 R13 R19



Classification: Public

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Natural Resources Canada
Government of Canada
588 Booth Street, Room 334
Ottawa, Ontario K1A 0Y7
Phone: 343-292-6617
Email: geodeticinformation-informationgeodesique@nrcan-rncan.gc.ca

Natural Resources Canada Ressources naturelles Canada

Canada

CSRS-PPP 3.50.3 (2022-03-04)

CP102.22o
D1820-03176-01-020

Data Start	Data End	Duration of Observations
2022-10-11 17:29:00.00	2022-10-11 19:53:30.00	2:24:30
Processing Time		**Product Type**
20:31:41 UTC 2022/11/01		NRCan/IGS Final
Observations	**Frequency**	**Mode**
Phase and Code	Double	Static

Elevation Cut-Off	Rejected Epochs	Fixed Ambiguities	Estimation Steps
7.5 degrees	0.00 %	95.66 %	30.00 sec

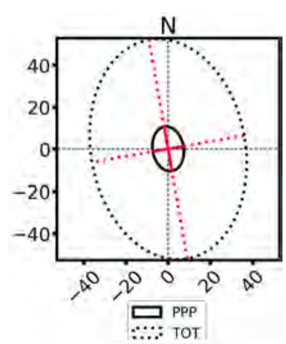
Antenna Model	APC to ARP	ARP to Marker
HEMS321	L1 = 0.132 m L2 = 0.139 m	H:1.540m / E:0.000m / N:0.000m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for CP102.22o

	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2002.0)†	51° 59' 55.87509"	-114° 13' 26.07175"	916.255 m
SIG_PPP(95%)‡	0.009 m	0.006 m	0.024 m
SIG_TOT(95%)‡	0.042 m	0.030 m	0.034 m
A priori*	51° 59' 55.90837"	-114° 13' 26.14516"	917.444 m
Estimated – A priori	-1.029 m	1.400 m	-1.189 m

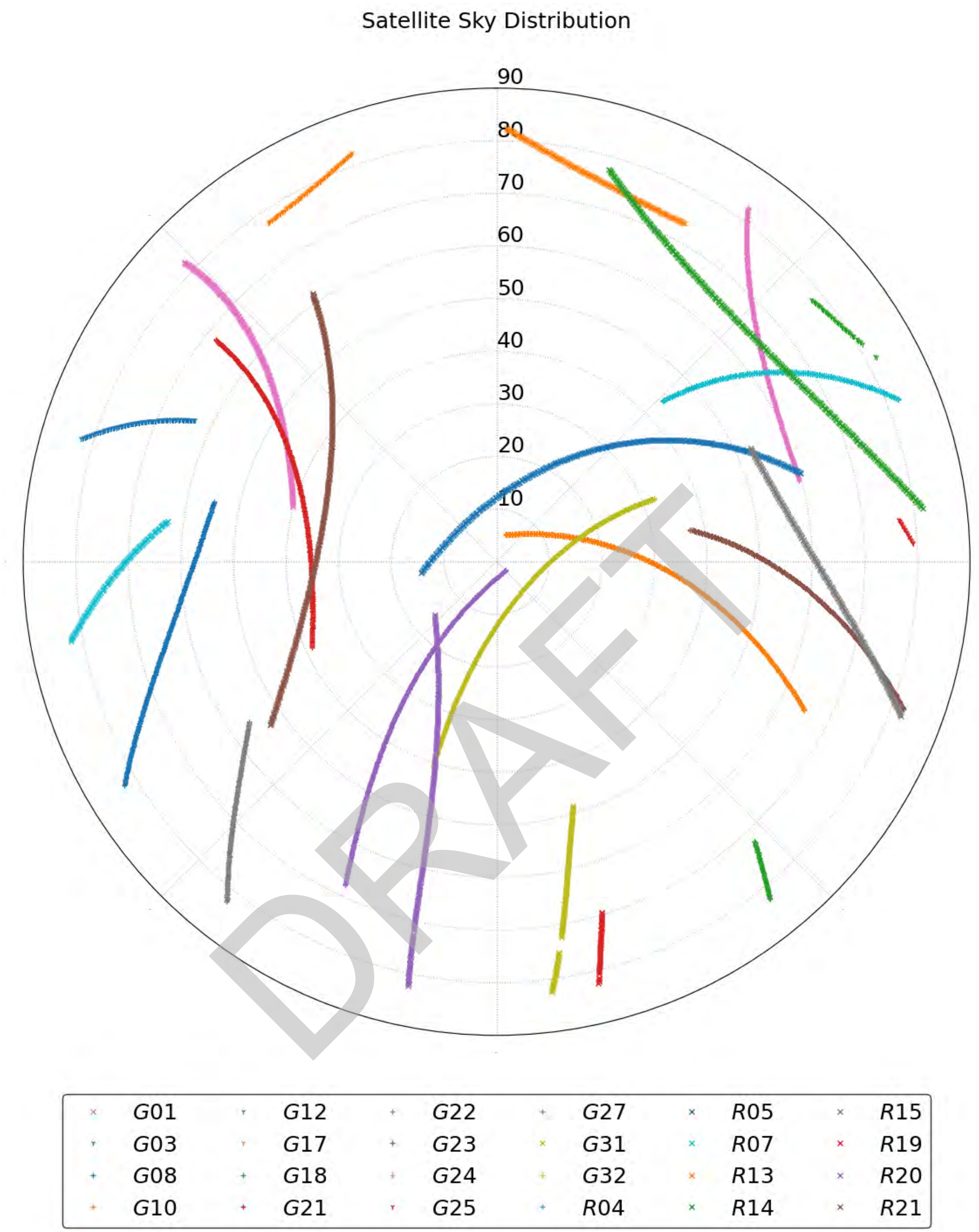
Orthometric Height CGVD28 (HTv2.0)†	95% PPP Error Ellipse (mm)	95% TOT Error Ellipse (mm)	UTM (North) Zone 11
	semi-major: 11 mm semi-minor: 7 mm semi-major azimuth: -9° 16' 30.53"	semi-major: 53 mm semi-minor: 37 mm semi-major azimuth: -9° 4' 8.58"	
933.578 m (click for height reference information)			5764549.958 m (N) 690567.045 m (E) Scale Factors 1.00004584 (point) 0.99990232 (combined)

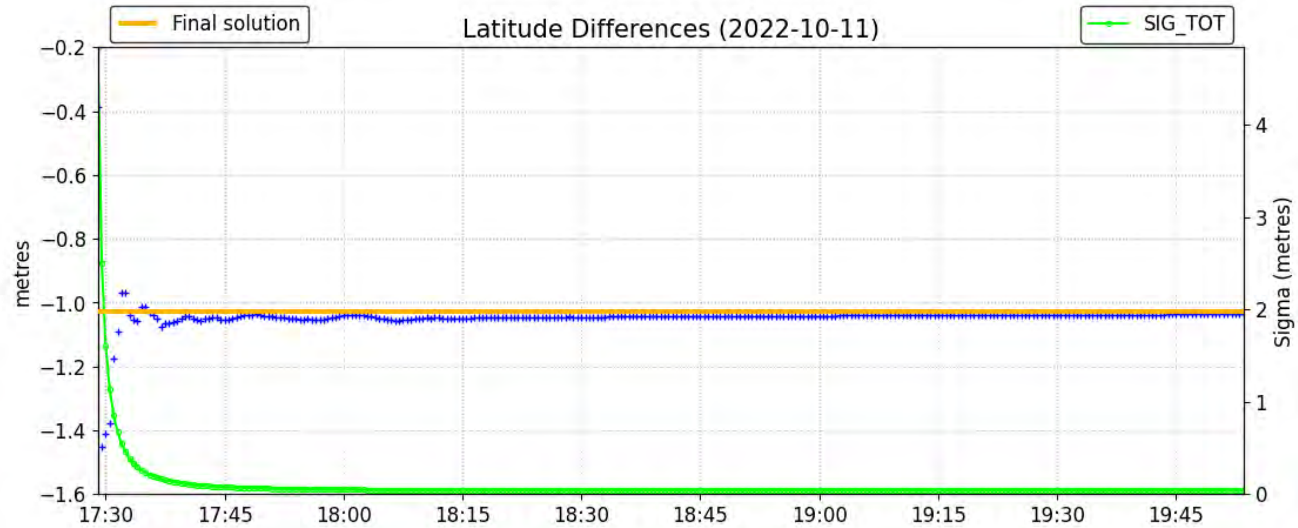


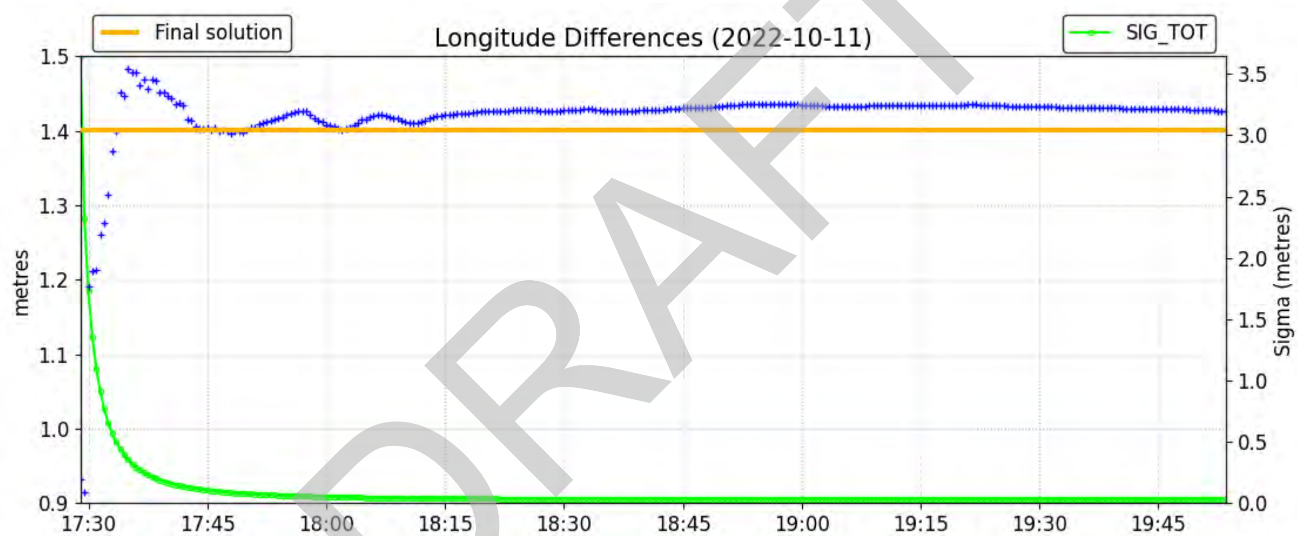
*(Coordinates from RINEX header used as a priori position)

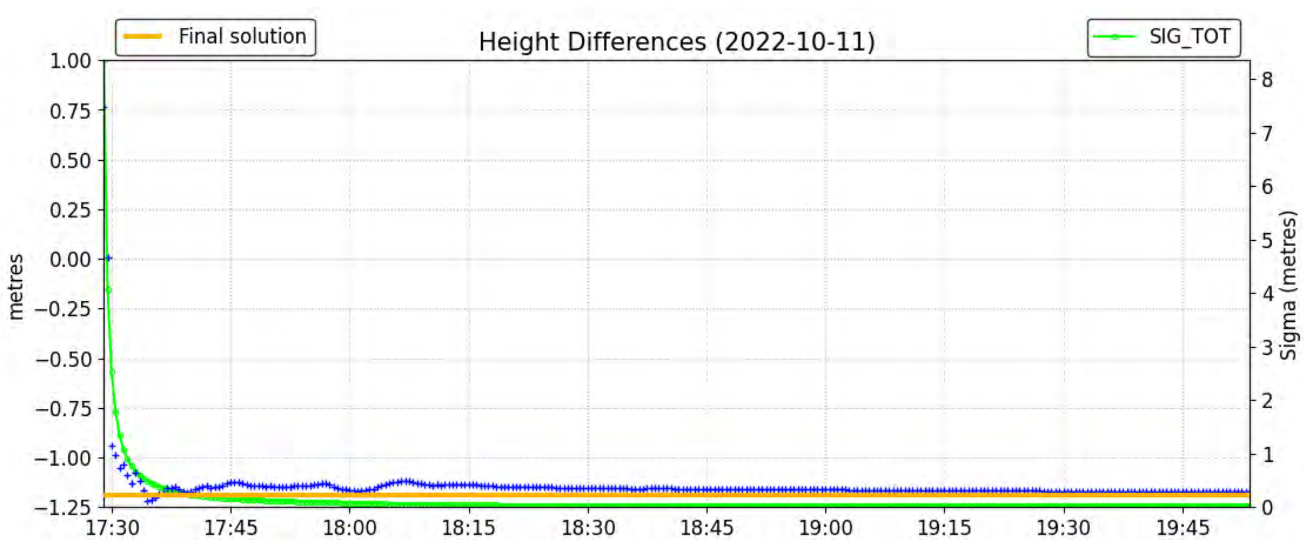
†(Epoch transformation using velocity grid NAD83v70VG (click for documentation))

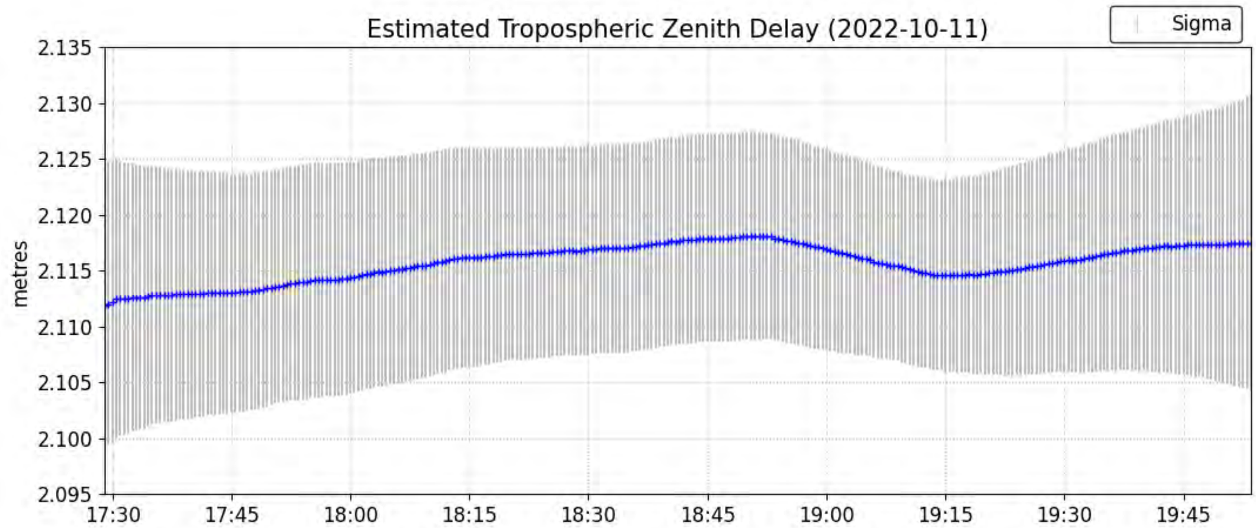
‡SIG_PPP indicates PPP-derived uncertainties, SIG_TOT incorporates uncertainties from epoch transformation

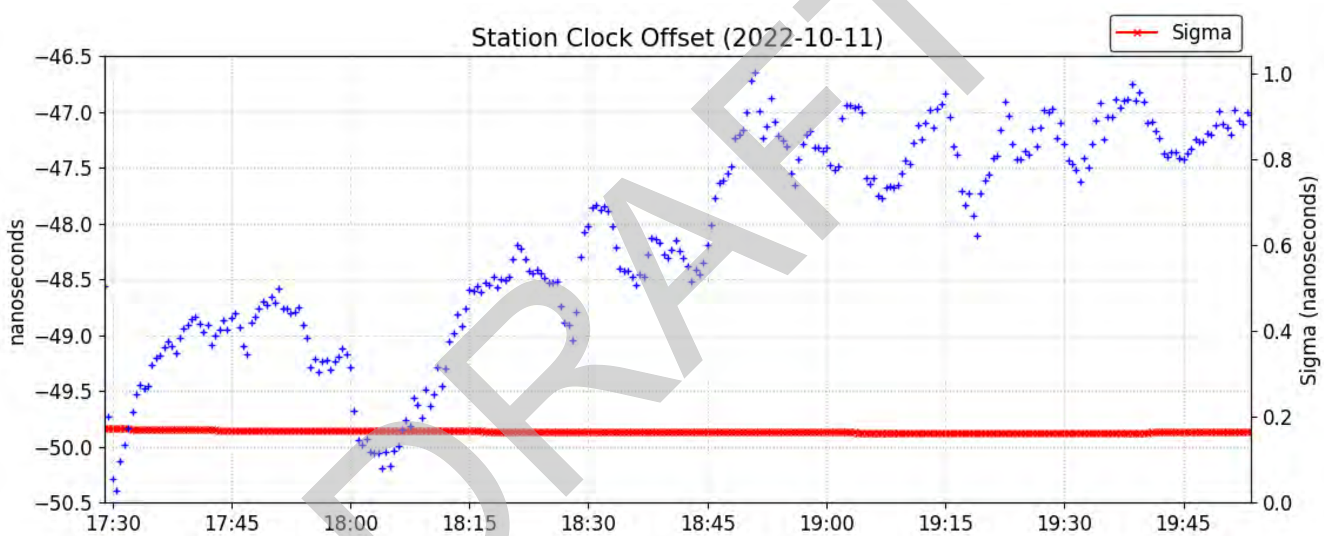

Satellite Sky Distribution
90
80
70
60
50
40
30
20
10
G01
G03
G08
G10
G12
G17
G18
G21
G22
G23
G24
G25
G27
G31
G32
R04
R05
R07
R13
R14
R15
R19
R20
R21

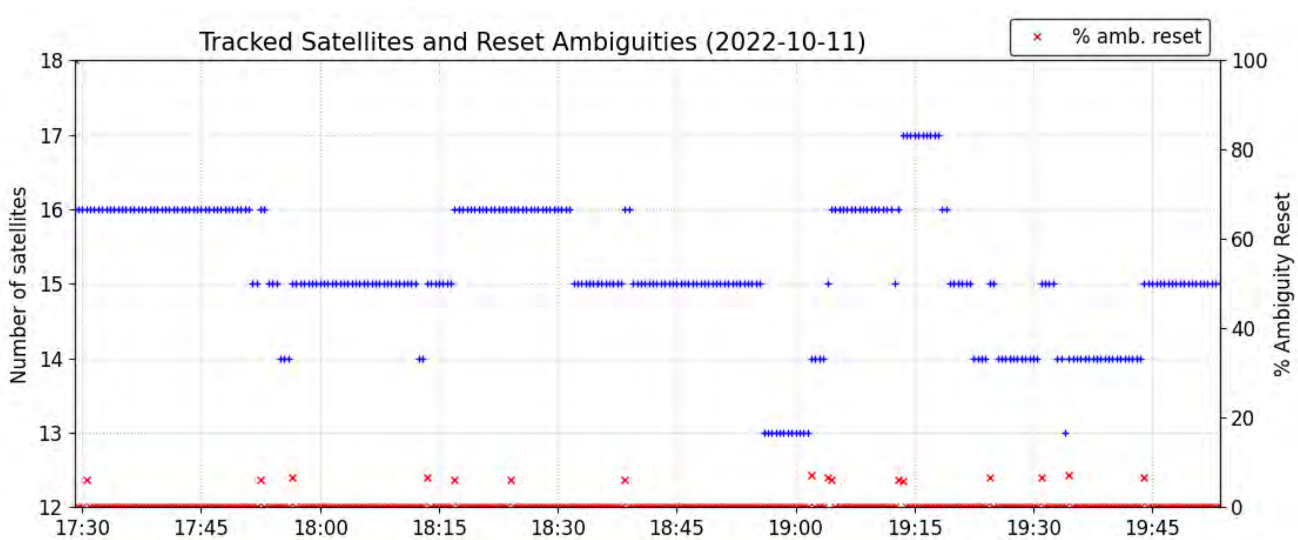

Final solution
Latitude Differences (2022-10-11)
SIG_TOT
metres
Sigma (metres)
−0.2
−0.4
−0.6
−0.8
−1.0
−1.2
−1.4
−1.6
4
3
2
1
0
17:30
17:45
18:00
18:15
18:30
18:45
19:00
19:15
19:30
19:45

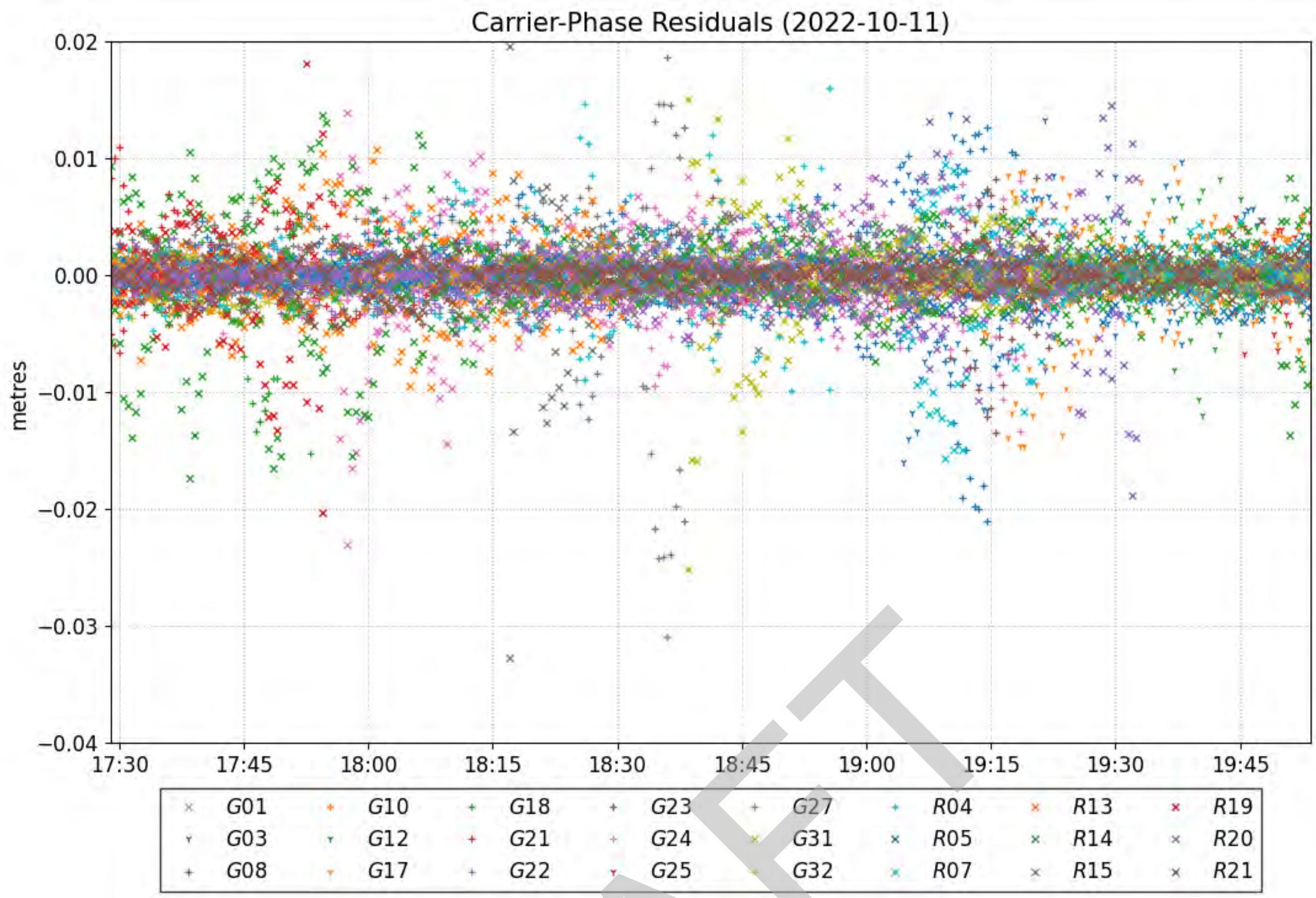

Final solution
Longitude Differences (2022-10-11)
SIG_TOT
metres
Sigma (metres)
1.5
1.4
1.3
1.2
1.1
1.0
0.9
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
17:30
17:45
18:00
18:15
18:30
18:45
19:00
19:15
19:30
19:45
DRAFT

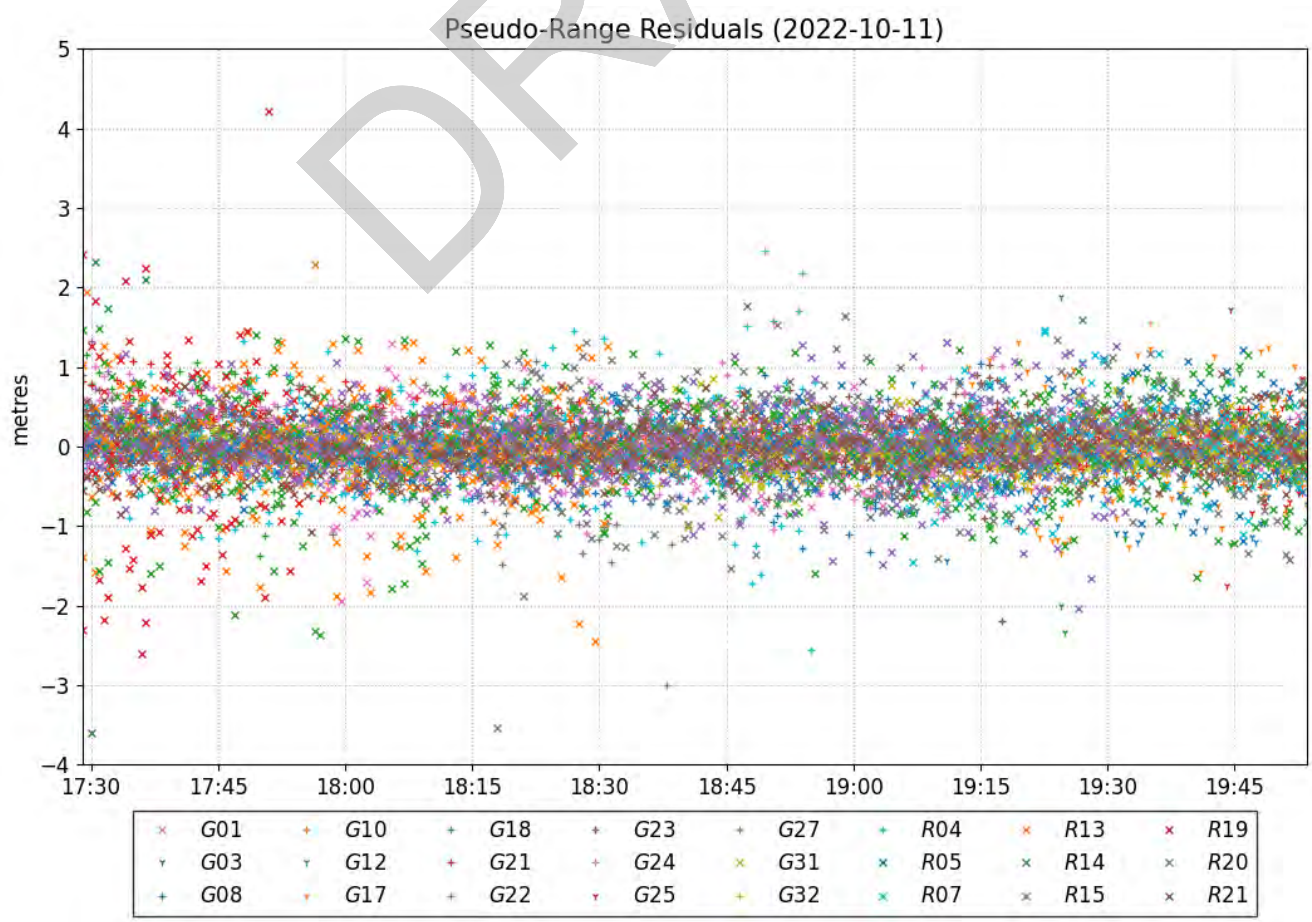

Final solution
Height Differences (2022-10-11)
SIG_TOT
metres
Sigma (metres)
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
−1.25
8
7
6
5
4
3
2
1
0
17:30
17:45
18:00
18:15
18:30
18:45
19:00
19:15
19:30
19:45

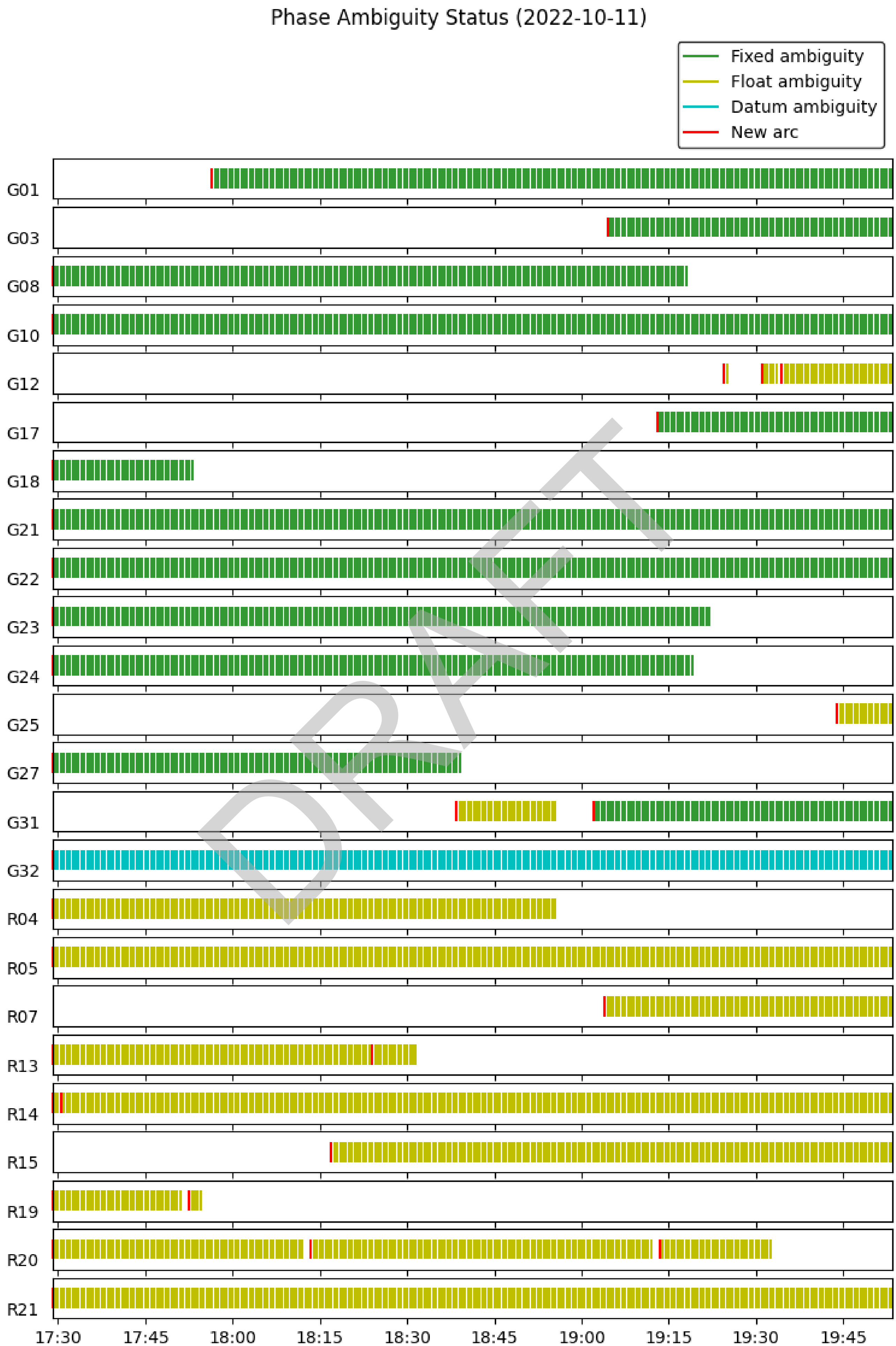

Estimated Tropospheric Zenith Delay (2022-10-11)
Sigma
metres
2.135
2.130
2.125
2.120
2.115
2.110
2.105
2.100
2.095
17:30
17:45
18:00
18:15
18:30
18:45
19:00
19:15
19:30
19:45


Station Clock Offset (2022-10-11)
Sigma
nanoseconds
Sigma (nanoseconds)
−46.5
−47.0
−47.5
−48.0
−48.5
−49.0
−49.5
−50.0
−50.5
1.0
0.8
0.6
0.4
0.2
0.0
17:30
17:45
18:00
18:15
18:30
18:45
19:00
19:15
19:30
19:45


Tracked Satellites and Reset Ambiguities (2022-10-11)
% amb. reset
Number of satellites
% Ambiguity Reset
18
17
16
15
14
13
12
100
80
60
40
20
0
17:30
17:45
18:00
18:15
18:30
18:45
19:00
19:15
19:30
19:45


Carrier-Phase Residuals (2022-10-11)
metres
0.02
0.01
0.00
−0.01
−0.02
−0.03
−0.04
17:30
17:45
18:00
18:15
18:30
18:45
19:00
19:15
19:30
19:45
G01
G10
G18
G23
G27
R04
R13
R19
G03
G12
G21
G24
G31
R05
R14
R20
G08
G17
G22
G25
G32
R07
R15
R21


Pseudo-Range Residuals (2022-10-11)
metres
5
4
3
2
1
0
−1
−2
−3
−4
17:30
17:45
18:00
18:15
18:30
18:45
19:00
19:15
19:30
19:45
G01
G10
G18
G23
G27
R04
R13
R19
G03
G12
G21
G24
G31
R05
R14
R20
G08
G17
G22
G25
G32
R07
R15
R21


Phase Ambiguity Status (2022-10-11)
Fixed ambiguity
Float ambiguity
Datum ambiguity
New arc
G01
G03
G08
G10
G12
G17
G18
G21
G22
G23
G24
G25
G27
G31
G32
R04
R05
R07
R13
R14
R15
R19
R20
R21
17:30
17:45
18:00
18:15
18:30
18:45
19:00
19:15
19:30
19:45
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Geodetic Integrated Services
Canadian Geodetic Survey
Surveyor General Branch
Natural Resources Canada
Government of Canada
588 Booth Street, Room 334
Ottawa, Ontario K1A 0Y7
Phone: 343-292-6617
Email: geodeticinformation-informationgeodesique@nrcan-rncan.gc.ca

Natural Resources Canada   Ressources naturelles Canada   Canada

CSRS-PPP 3.50.3 (2022-03-04)

CP103.22o
D1821-03177-01-034

Data Start	Data End	Duration of Observations
2022-10-11 20:44:30.00	2022-10-11 22:46:00.00	2:01:30
Processing Time		**Product Type**
20:31:39 UTC 2022/11/01		NRCan/IGS Final
Observations	**Frequency**	**Mode**
Phase and Code	Double	Static

Elevation Cut-Off	Rejected Epochs	Fixed Ambiguities	Estimation Steps
7.5 degrees	0.00 %	95.12 %	30.00 sec

Antenna Model	APC to ARP	ARP to Marker
HEMS321	L1 = 0.132 m L2 = 0.139 m	H:1.529m / E:0.000m / N:0.000m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for CP103.22o

	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2002.0)†	52° 5' 9.53836"	-114° 7' 39.17714"	881.630 m
SIG_PPP(95%)‡	0.012 m	0.007 m	0.033 m
SIG_TOT(95%)‡	0.042 m	0.030 m	0.041 m
A priori*	52° 5' 9.58533"	-114° 7' 39.25864"	884.277 m
Estimated – A priori	-1.452 m	1.552 m	-2.647 m

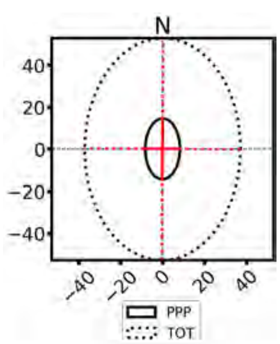
Orthometric Height CGVD28 (HTv2.0)†

899.303 m

(click for height reference information)

95% PPP Error Ellipse (mm)
semi-major: 14 mm
semi-minor: 8 mm
semi-major azimuth: 0° 17' 21.17"

95% TOT Error Ellipse (mm)
semi-major: 53 mm
semi-minor: 37 mm
semi-major azimuth: 0° 28' 33.68"



UTM (North) Zone 11

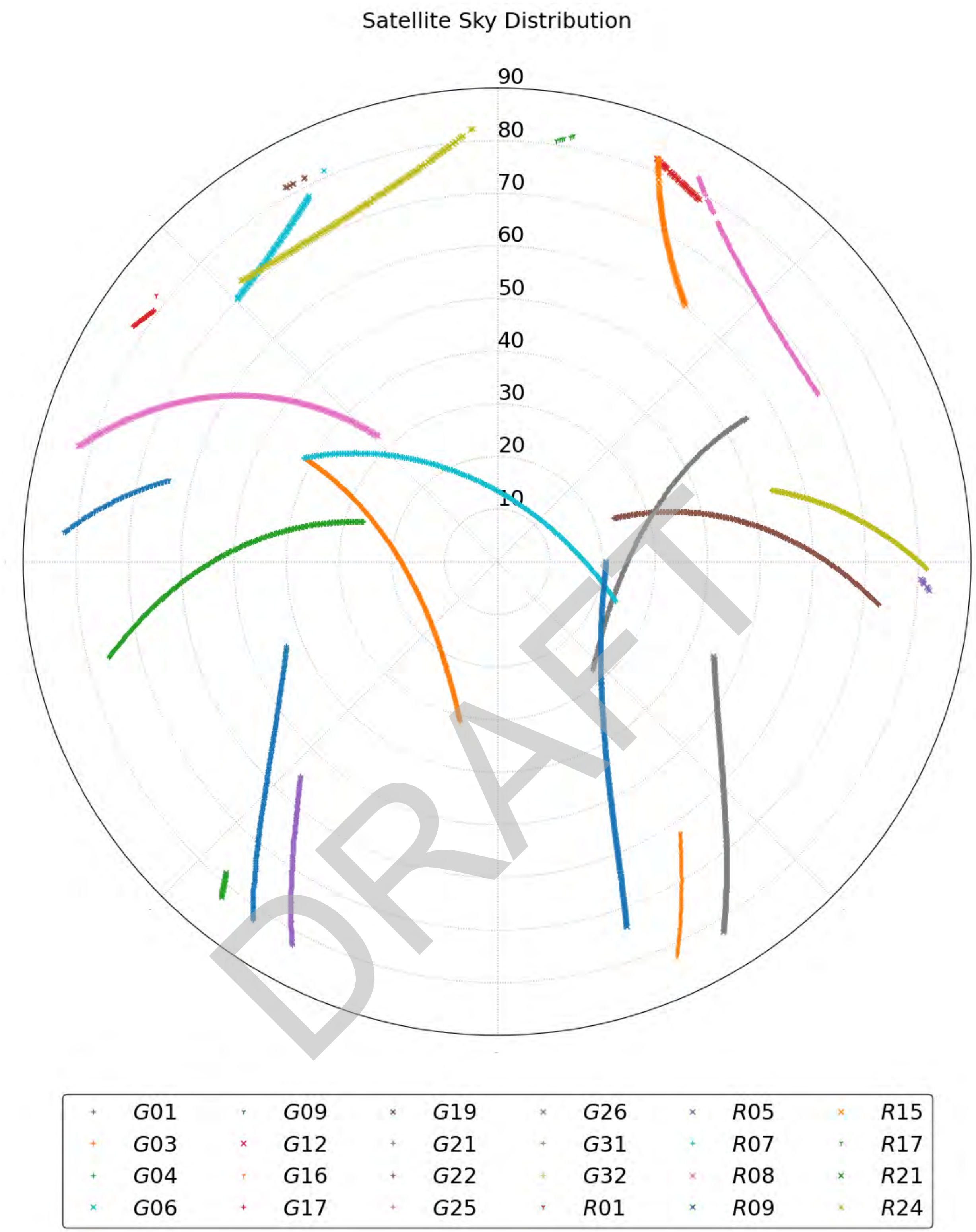
5774494.858 m (N)
696797.144 m (E)

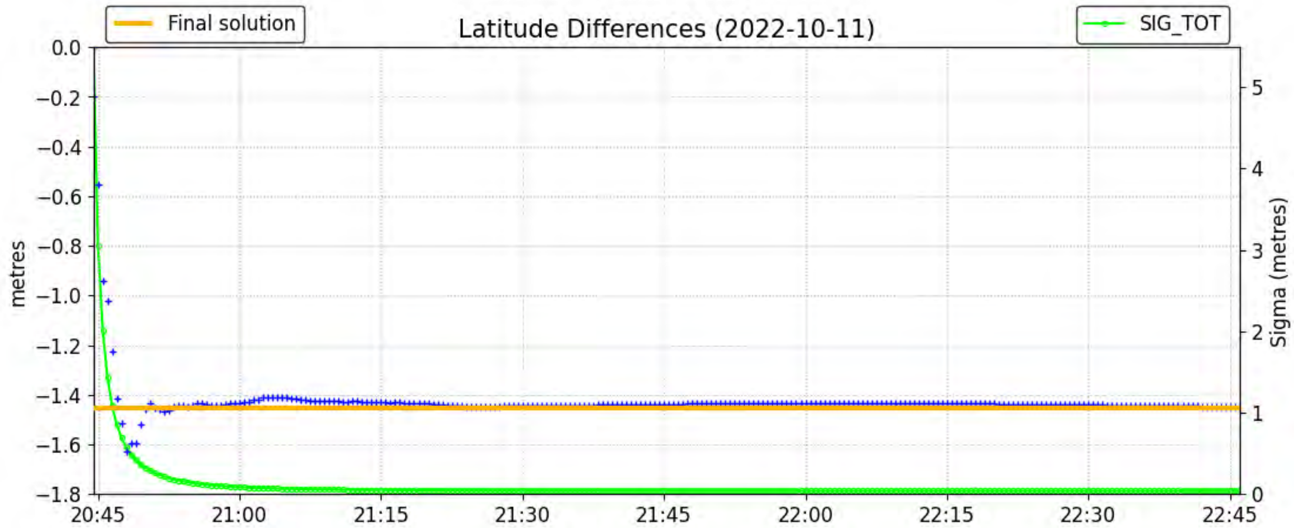
Scale Factors
1.00007546 (point)
0.99993736 (combined)

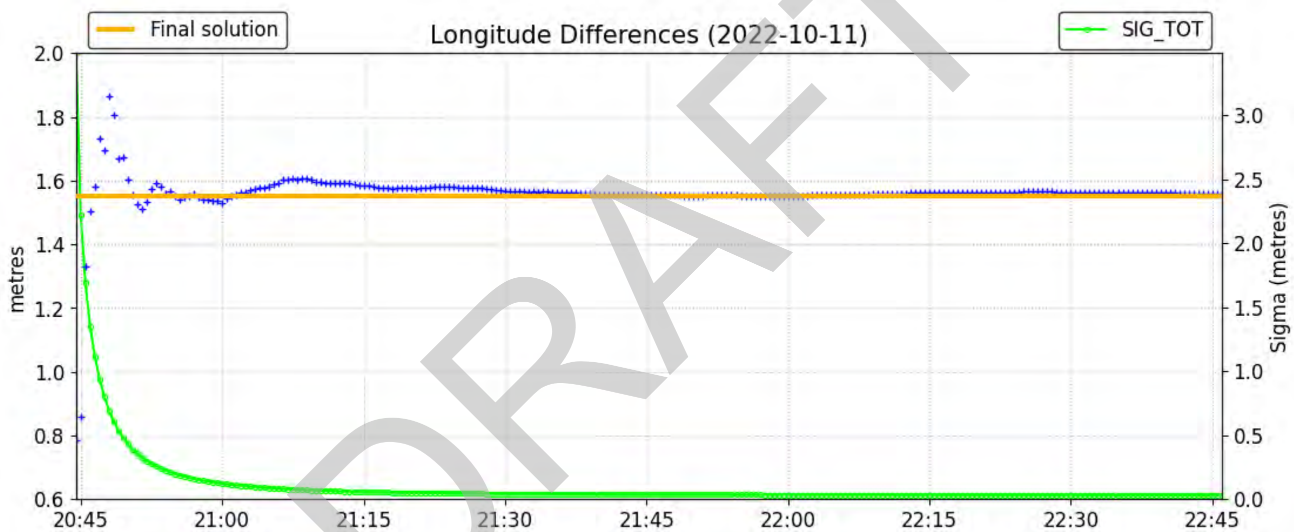
*(Coordinates from RINEX header used as a priori position)

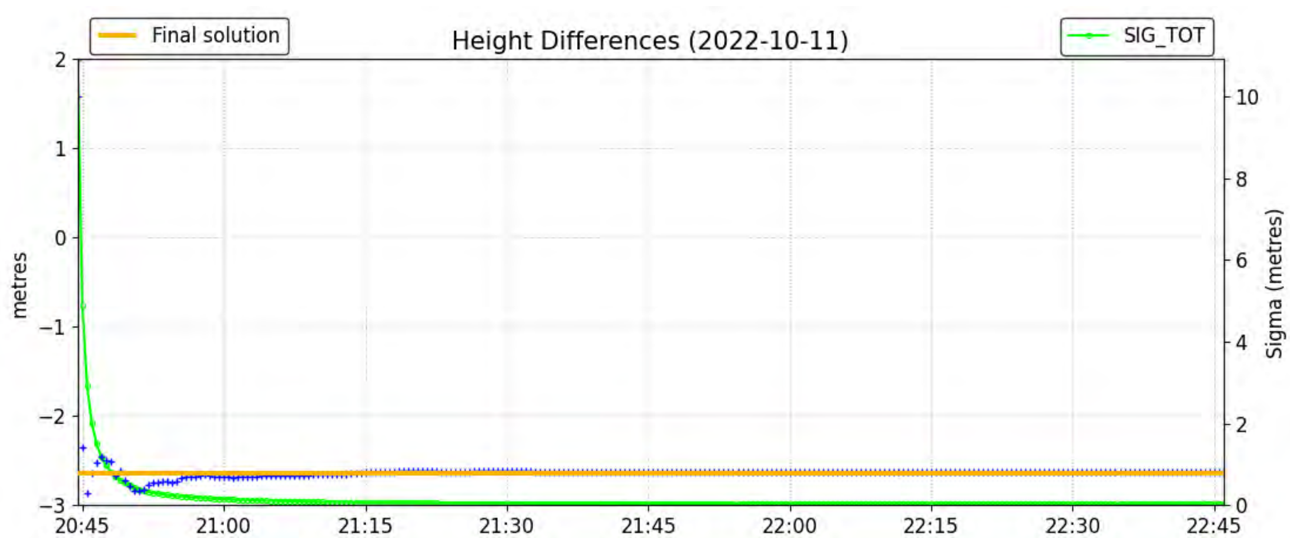
†(Epoch transformation using velocity grid NAD83v70VG (click for documentation))

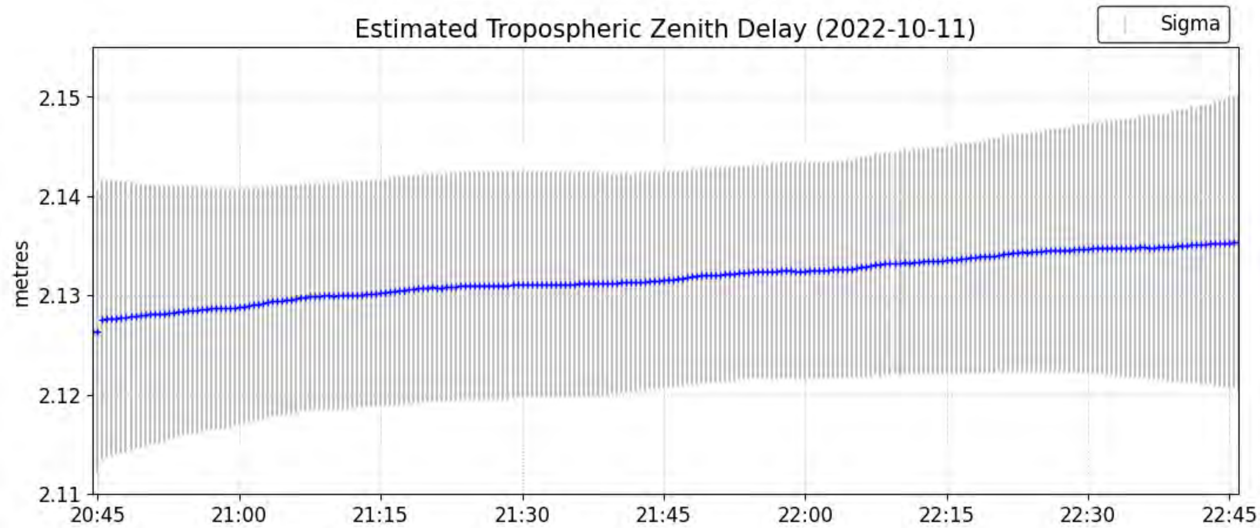
‡SIG_PPP indicates PPP-derived uncertainties, SIG_TOT incorporates uncertainties from epoch transformation


Satellite Sky Distribution
90
80
70
60
50
40
30
20
10
G01
G03
G04
G06
G09
G12
G16
G17
G19
G21
G22
G25
G26
G31
G32
R01
R05
R07
R08
R09
R15
R17
R21
R24

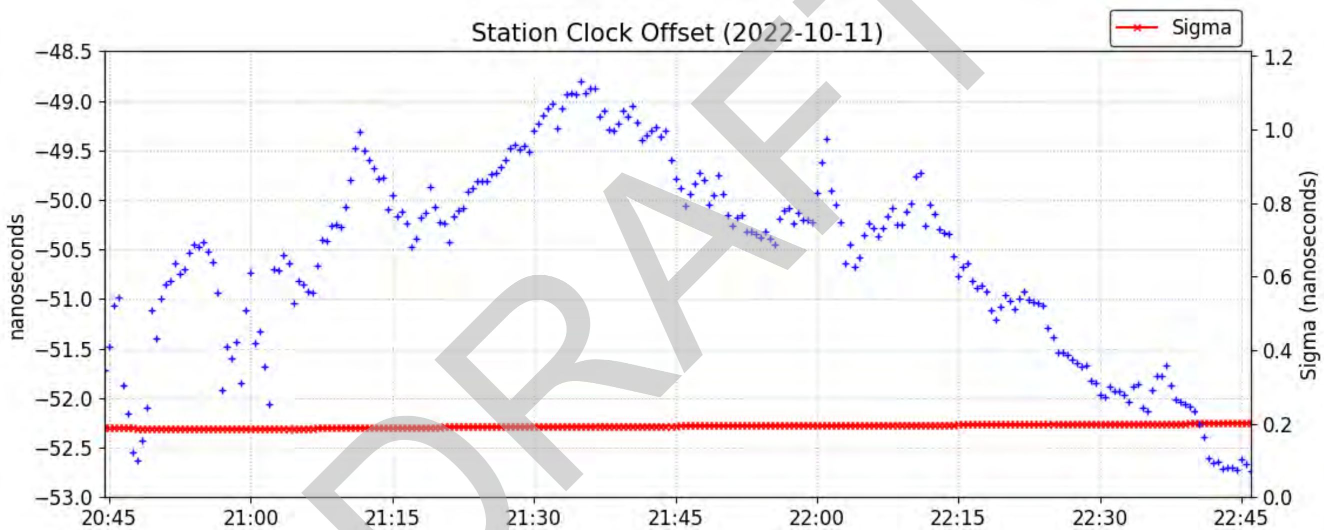

Final solution
Latitude Differences (2022-10-11)
SIG_TOT
metres
Sigma (metres)
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
−1.2
−1.4
−1.6
−1.8
5
4
3
2
1
0
20:45
21:00
21:15
21:30
21:45
22:00
22:15
22:30
22:45


Final solution
Longitude Differences (2022-10-11)
SIG_TOT
metres
Sigma (metres)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
3.0
2.5
2.0
1.5
1.0
0.5
0.0
20:45
21:00
21:15
21:30
21:45
22:00
22:15
22:30
22:45

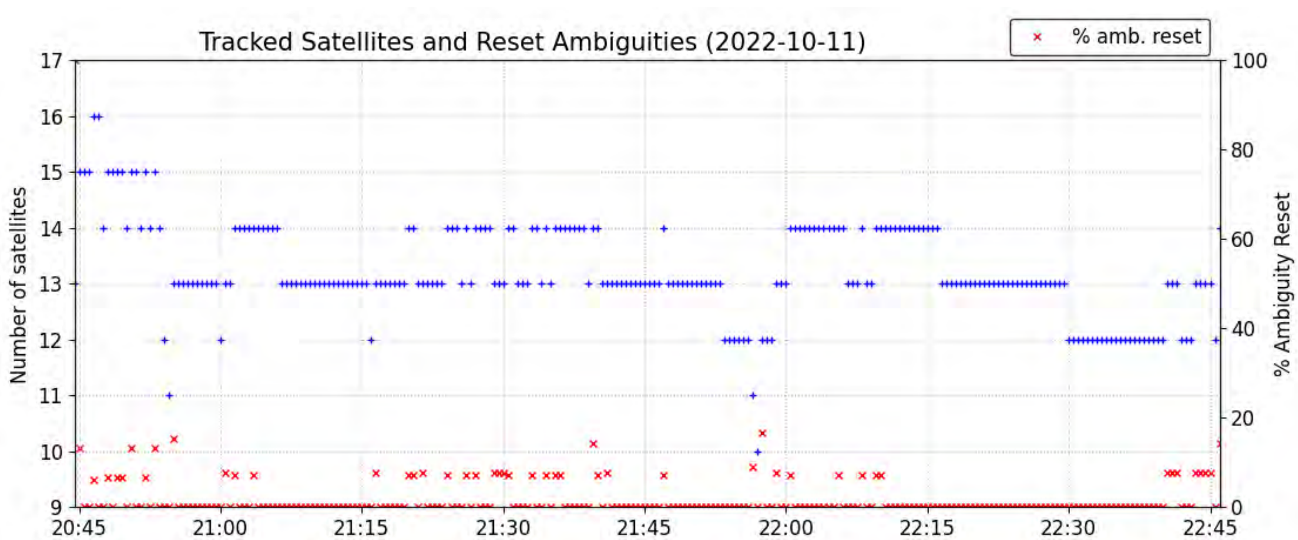

Final solution
Height Differences (2022-10-11)
SIG_TOT
metres
Sigma (metres)
2
1
0
−1
−2
−3
10
8
6
4
2
0
20:45
21:00
21:15
21:30
21:45
22:00
22:15
22:30
22:45



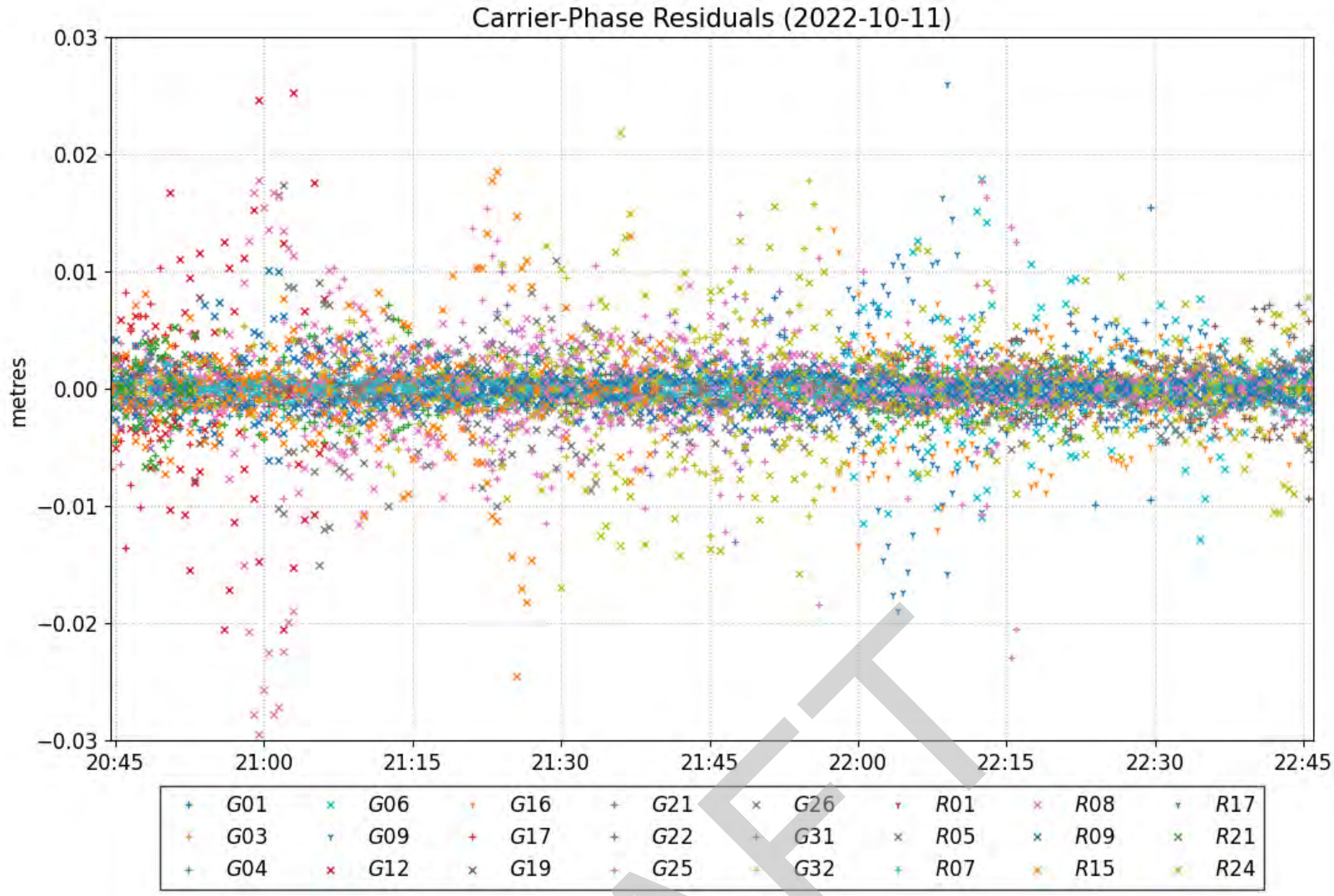
Estimated Tropospheric Zenith Delay (2022-10-11)
Sigma
metres
2.15
2.14
2.13
2.12
2.11
20:45
21:00
21:15
21:30
21:45
22:00
22:15
22:30
22:45



Station Clock Offset (2022-10-11)
Sigma
nanoseconds
Sigma (nanoseconds)
−48.5
−49.0
−49.5
−50.0
−50.5
−51.0
−51.5
−52.0
−52.5
−53.0
1.2
1.0
0.8
0.6
0.4
0.2
0.0
20:45
21:00
21:15
21:30
21:45
22:00
22:15
22:30
22:45

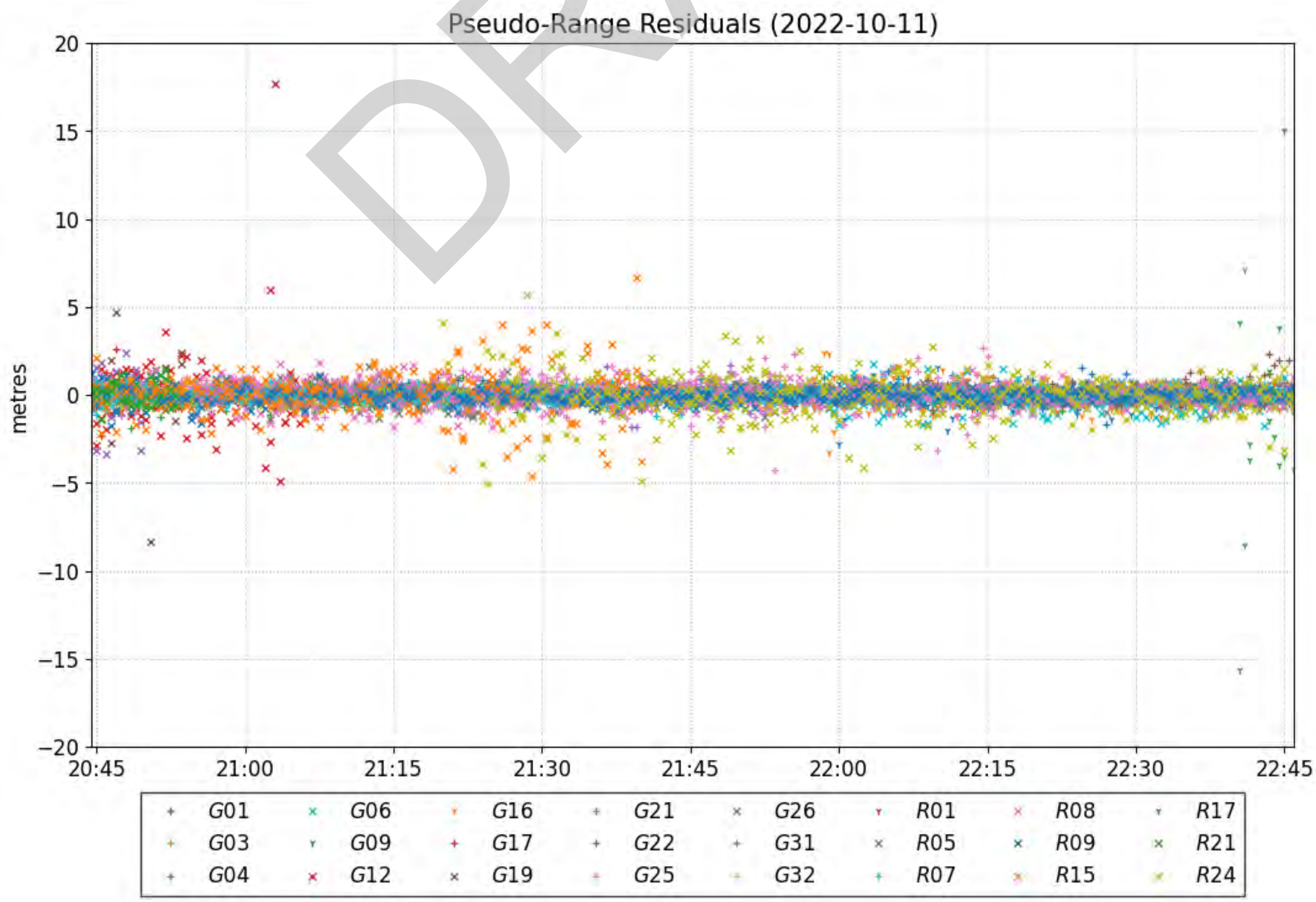


Tracked Satellites and Reset Ambiguities (2022-10-11)
% amb. reset
Number of satellites
% Ambiguity Reset
17
16
15
14
13
12
11
10
9
100
80
60
40
20
0
20:45
21:00
21:15
21:30
21:45
22:00
22:15
22:30
22:45

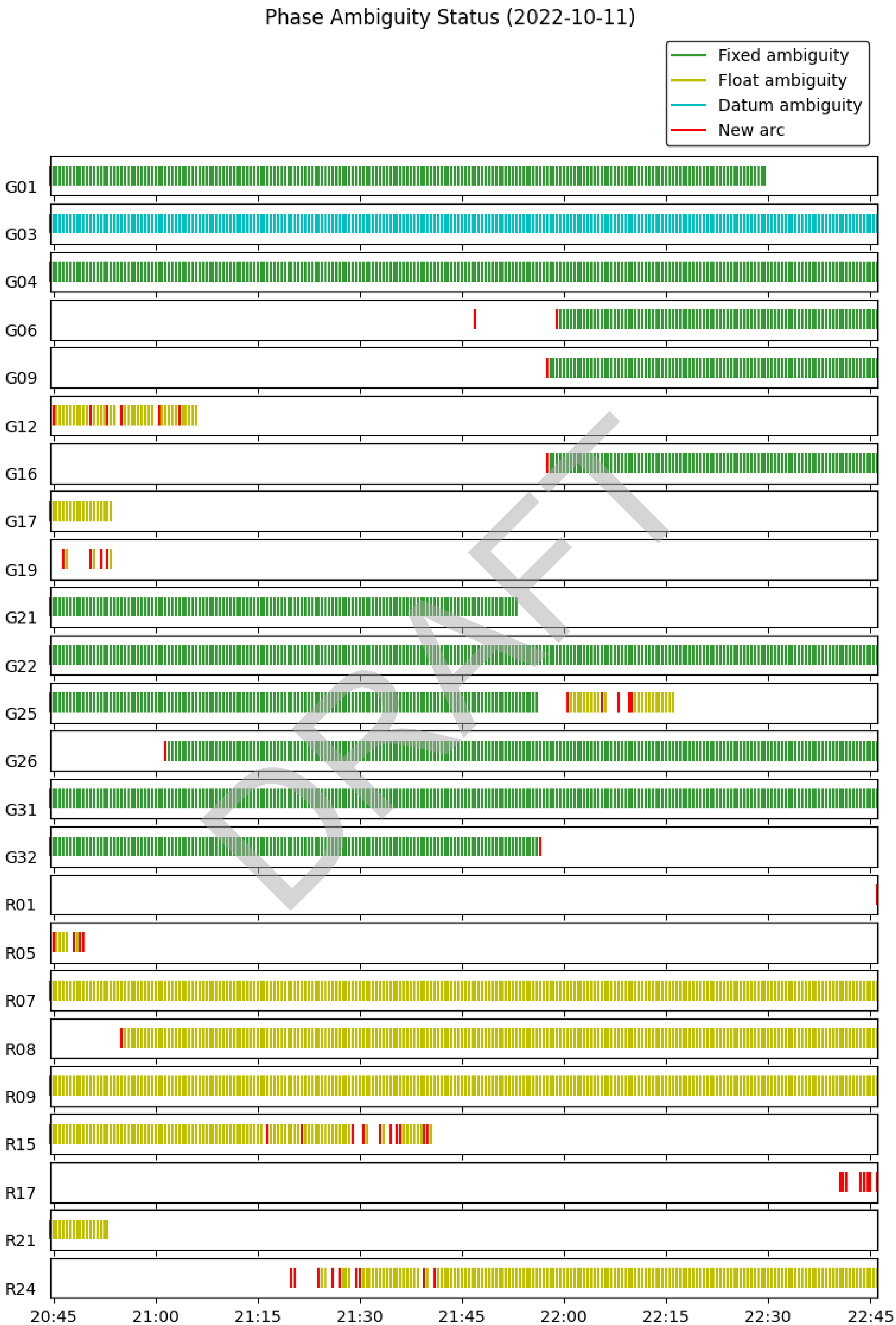


Carrier-Phase Residuals (2022-10-11)
metres
0.03
0.02
0.01
0.00
−0.01
−0.02
−0.03
20:45
21:00
21:15
21:30
21:45
22:00
22:15
22:30
22:45
G01 G06 G16 G21 G26 R01 R08 R17
G03 G09 G17 G22 G31 R05 R09 R21
G04 G12 G19 G25 G32 R07 R15 R24

DRAFT



Pseudo-Range Residuals (2022-10-11)
metres
20
15
10
5
0
−5
−10
−15
−20
20:45
21:00
21:15
21:30
21:45
22:00
22:15
22:30
22:45
G01 G06 G16 G21 G26 R01 R08 R17
G03 G09 G17 G22 G31 R05 R09 R21
G04 G12 G19 G25 G32 R07 R15 R24


Phase Ambiguity Status (2022-10-11)
Fixed ambiguity
Float ambiguity
Datum ambiguity
New arc
G01
G03
G04
G06
G09
G12
G16
G17
G19
G21
G22
G25
G26
G31
G32
R01
R05
R07
R08
R09
R15
R17
R21
R24
20:45
21:00
21:15
21:30
21:45
22:00
22:15
22:30
22:45
DRAFT

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Canadian Geodetic Survey
Surveyor General Branch
Natural Resources Canada
Government of Canada
588 Booth Street, Room 334
Ottawa, Ontario K1A 0Y7
Phone: 343-292-6617
Email: geodeticinformation-informationgeodesique@nrcan-rncan.gc.ca

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CSRS-PPP 3.50.3 (2022-03-04)

CP104.22o
D1820-03176-01-020

Data Start	Data End	Duration of Observations
2022-10-11 21:15:30.00	2022-10-11 23:17:30.00	2:02:00
Processing Time		**Product Type**
20:31:39 UTC 2022/11/01		NRCan/IGS Final
Observations	**Frequency**	**Mode**
Phase and Code	Double	Static

Elevation Cut-Off	Rejected Epochs	Fixed Ambiguities	Estimation Steps
7.5 degrees	0.00 %	96.33 %	30.00 sec

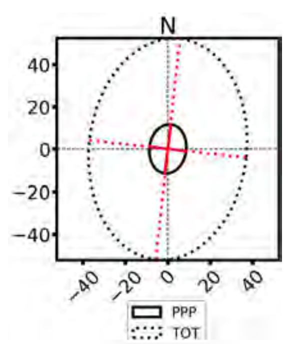
Antenna Model	APC to ARP	ARP to Marker
HEMS321	L1 = 0.132 m L2 = 0.139 m	H:1.492m / E:0.000m / N:0.000m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for CP104.22o

	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2002.0)†	52° 7' 22.59991"	-114° 10' 27.52146"	885.081 m
SIG_PPP(95%)‡	0.009 m	0.007 m	0.030 m
SIG_TOT(95%)‡	0.042 m	0.030 m	0.039 m
A priori*	52° 7' 22.62735"	-114° 10' 27.60395"	886.579 m
Estimated – A priori	-0.848 m	1.569 m	-1.498 m

Orthometric Height CGVD28 (HTv2.0)†	95% PPP Error Ellipse (mm)	95% TOT Error Ellipse (mm)	UTM (North) Zone 11
	semi-major: 12 mm semi-minor: 9 mm semi-major azimuth: 7° 21' 20.08"	semi-major: 52 mm semi-minor: 37 mm semi-major azimuth: 6° 14' 38.83"	
902.671 m (click for height reference information)			5778478.910 m (N) 693433.932 m (E) Scale Factors 1.00005934 (point) 0.99992070 (combined)

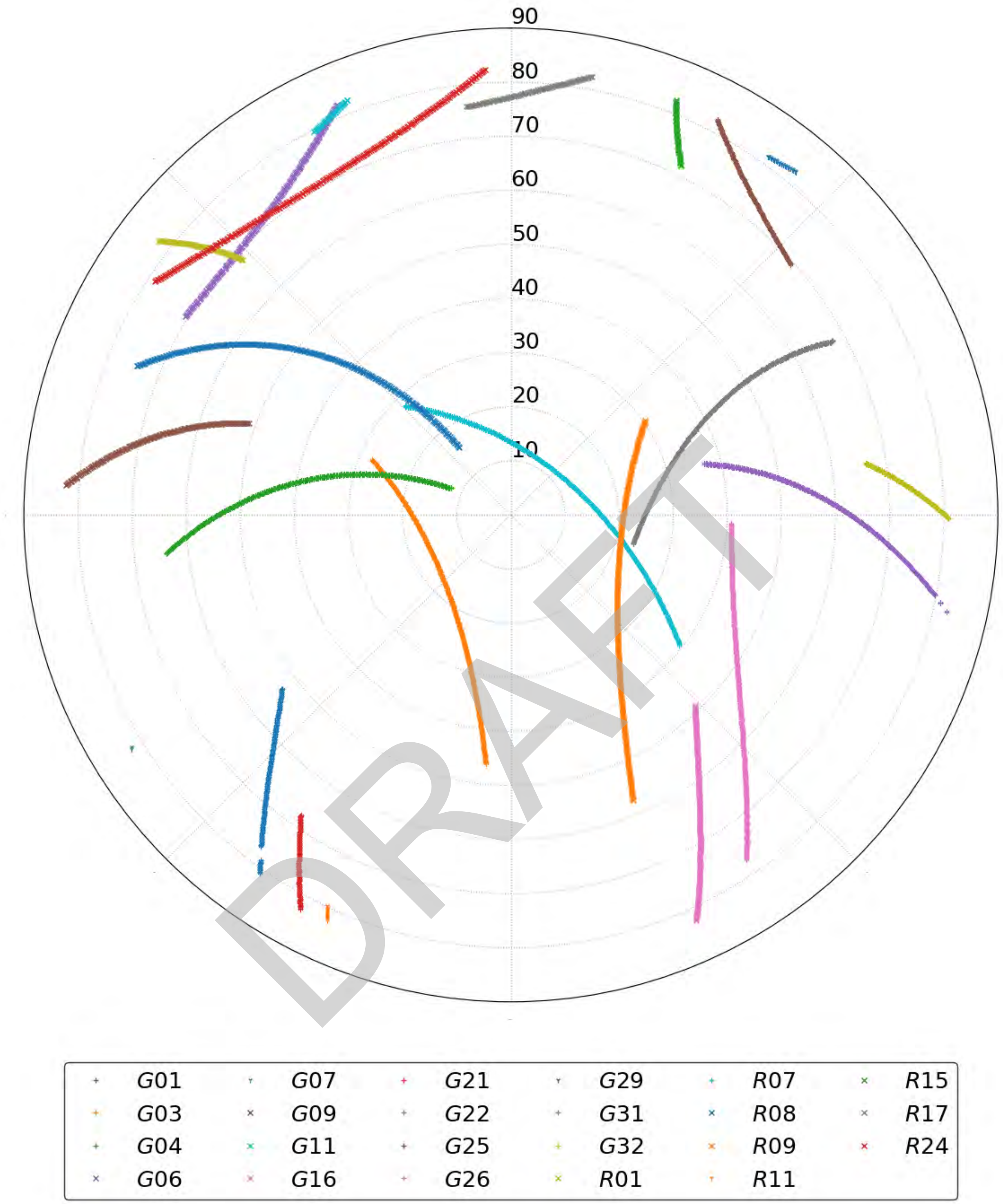


*(Coordinates from RINEX header used as a priori position)

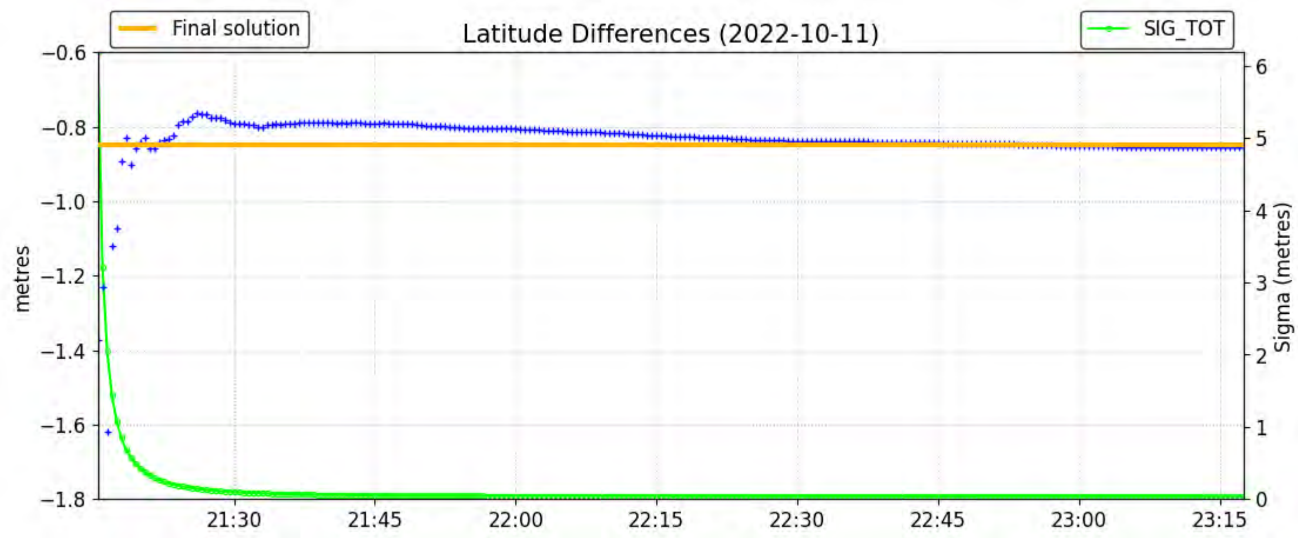
†(Epoch transformation using velocity grid NAD83v70VG (click for documentation))

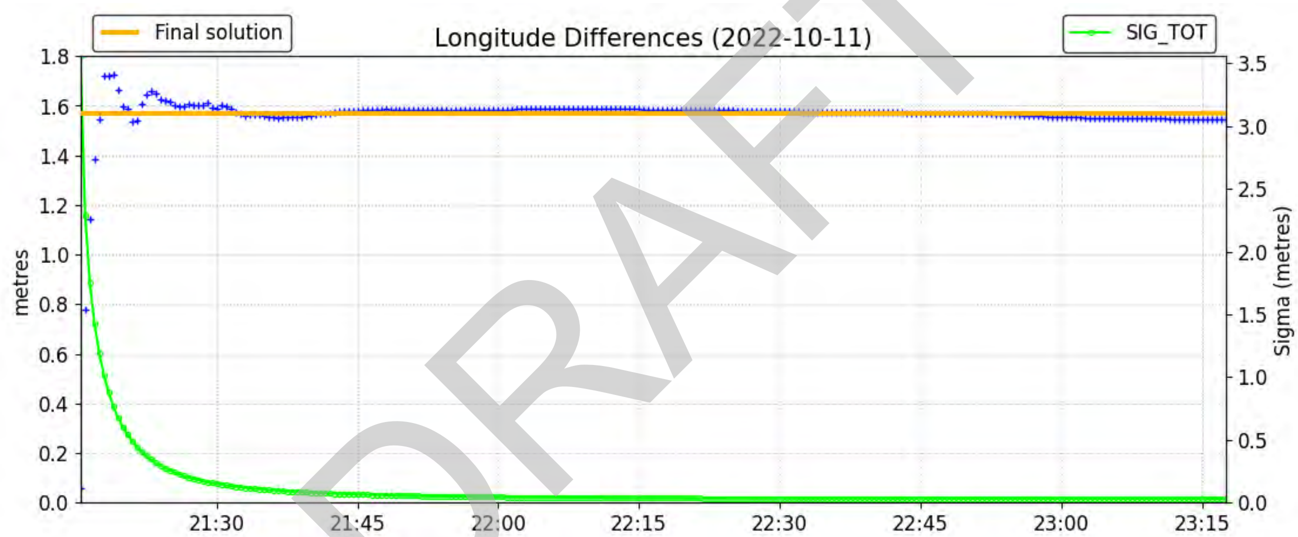
‡SIG_PPP indicates PPP-derived uncertainties, SIG_TOT incorporates uncertainties from epoch transformation

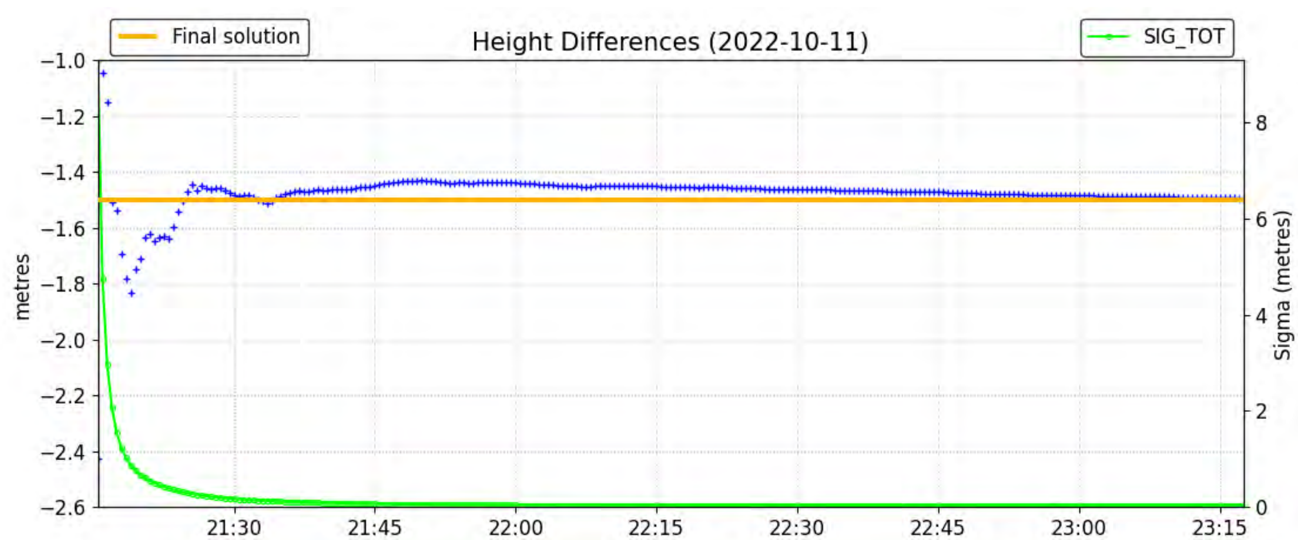
Satellite Sky Distribution

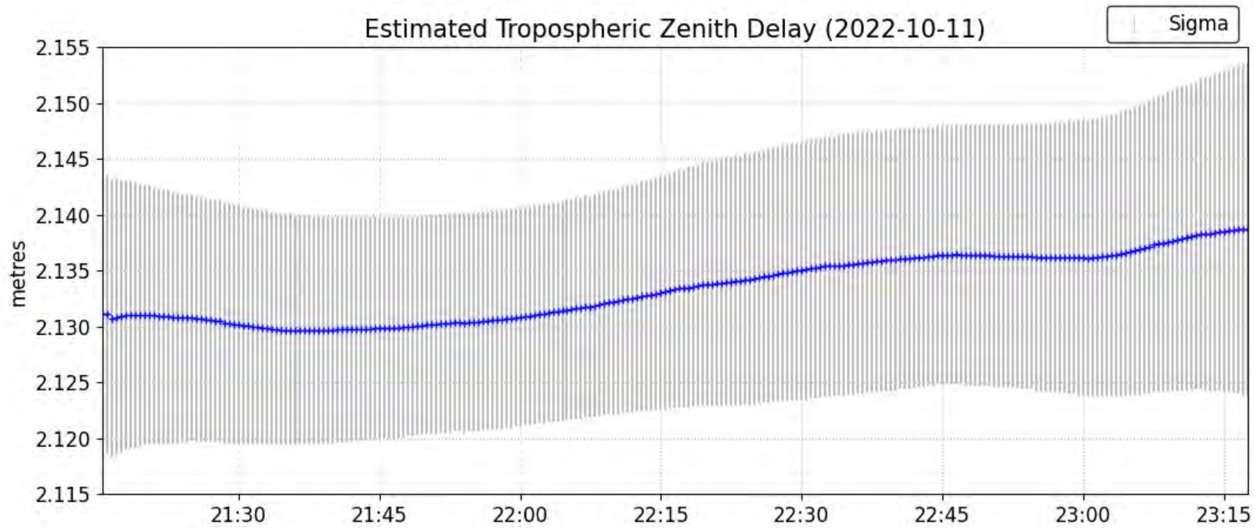


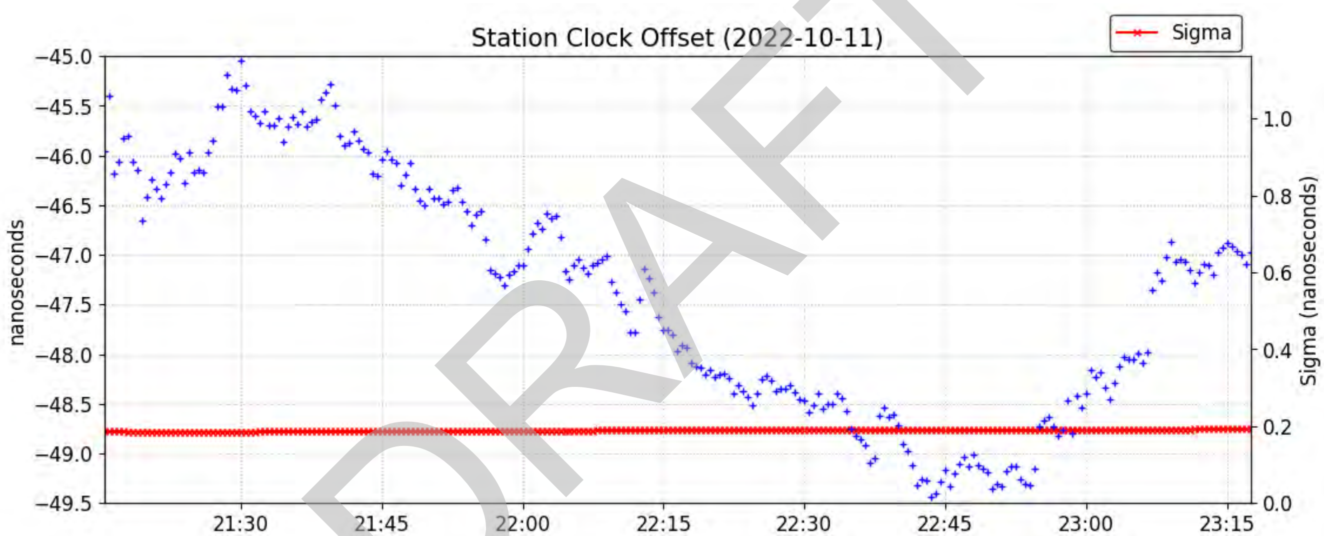
Classification: Public

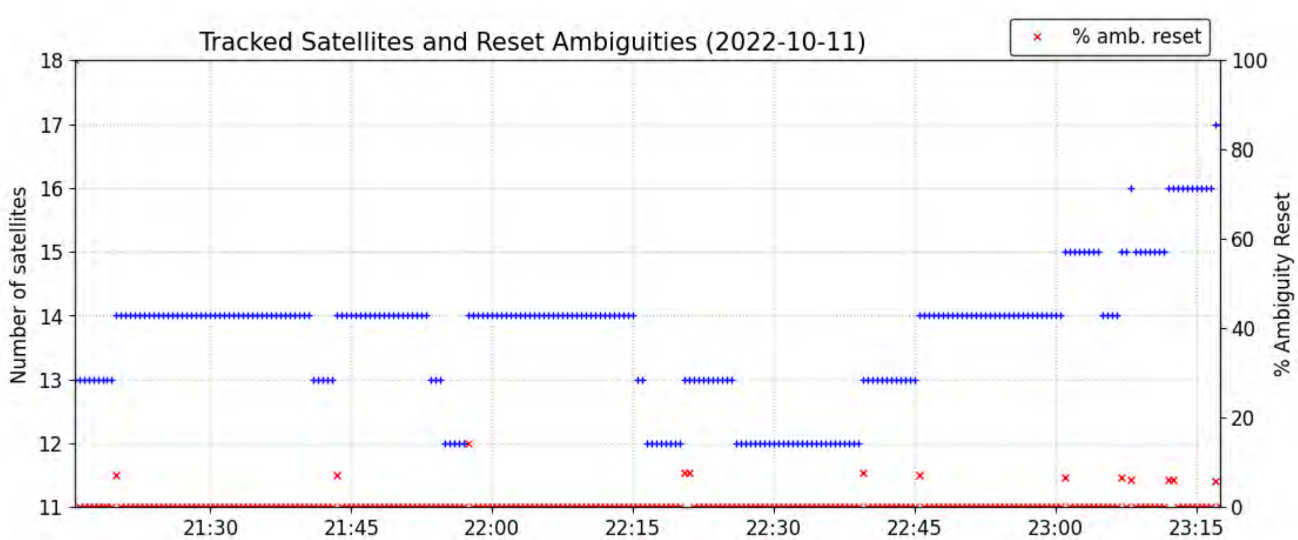

Final solution
Latitude Differences (2022-10-11)
SIG_TOT
metres
Sigma (metres)
21:30
21:45
22:00
22:15
22:30
22:45
23:00
23:15

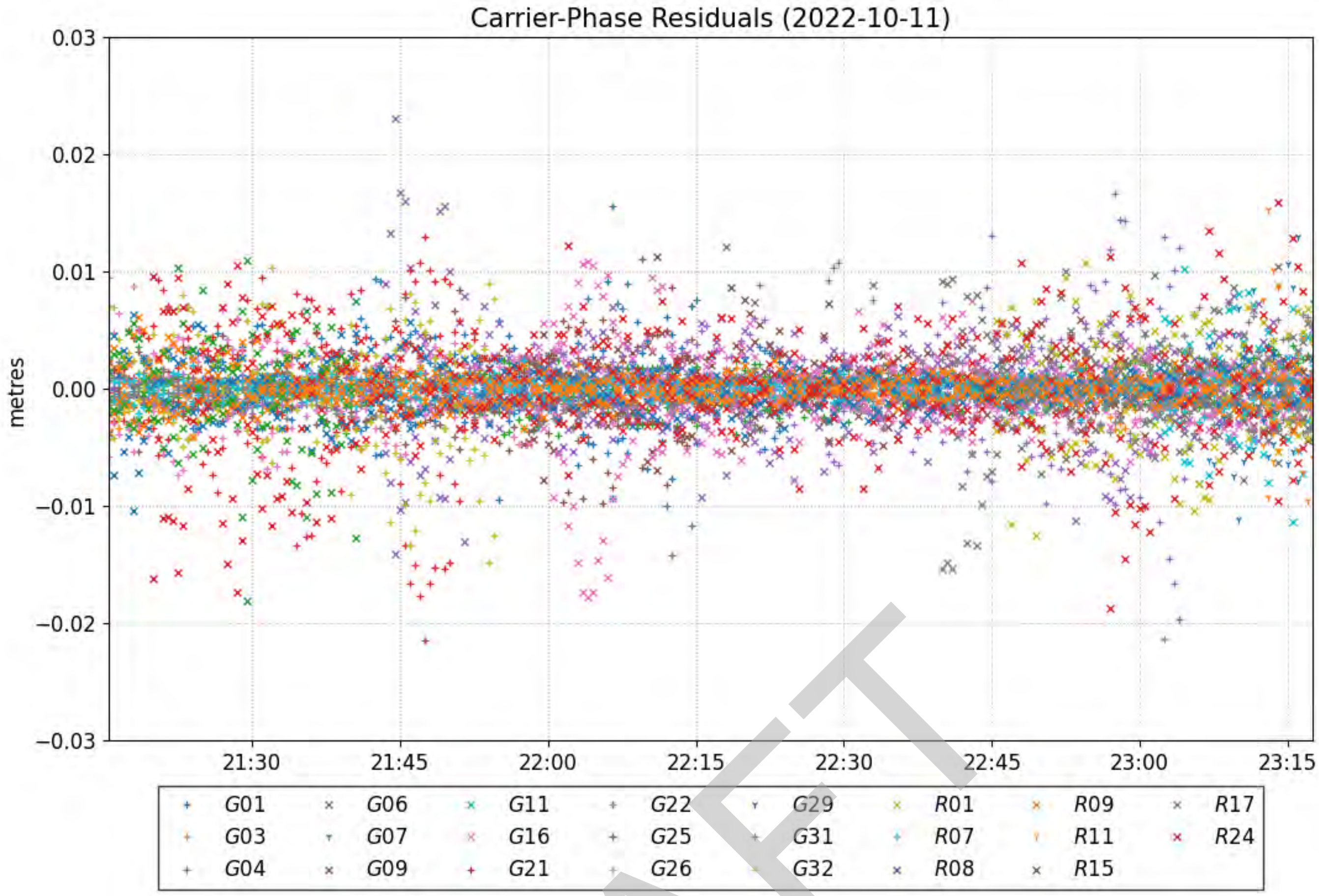

Final solution
Longitude Differences (2022-10-11)
SIG_TOT
metres
Sigma (metres)
21:30
21:45
22:00
22:15
22:30
22:45
23:00
23:15

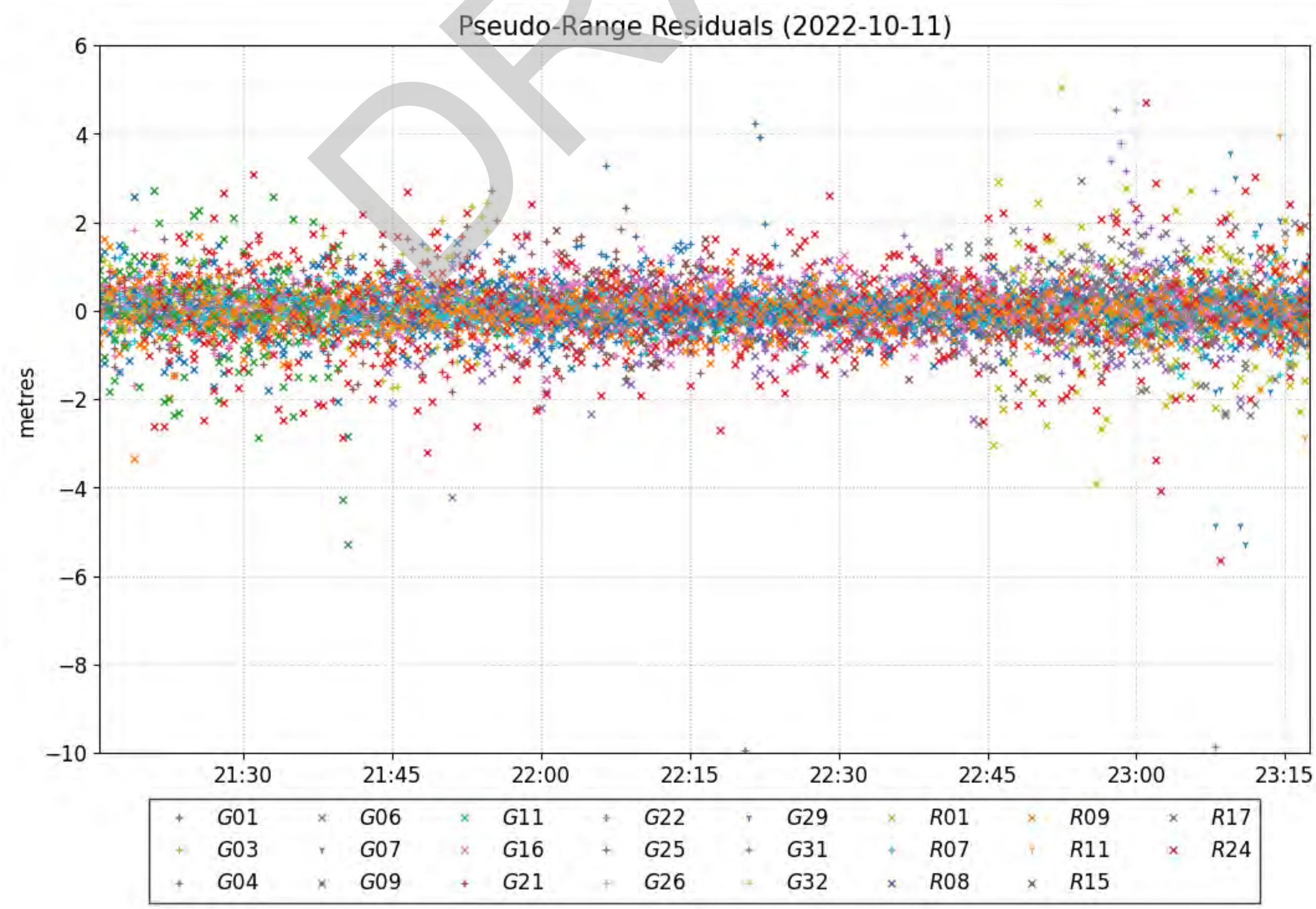

Final solution
Height Differences (2022-10-11)
SIG_TOT
metres
Sigma (metres)
21:30
21:45
22:00
22:15
22:30
22:45
23:00
23:15

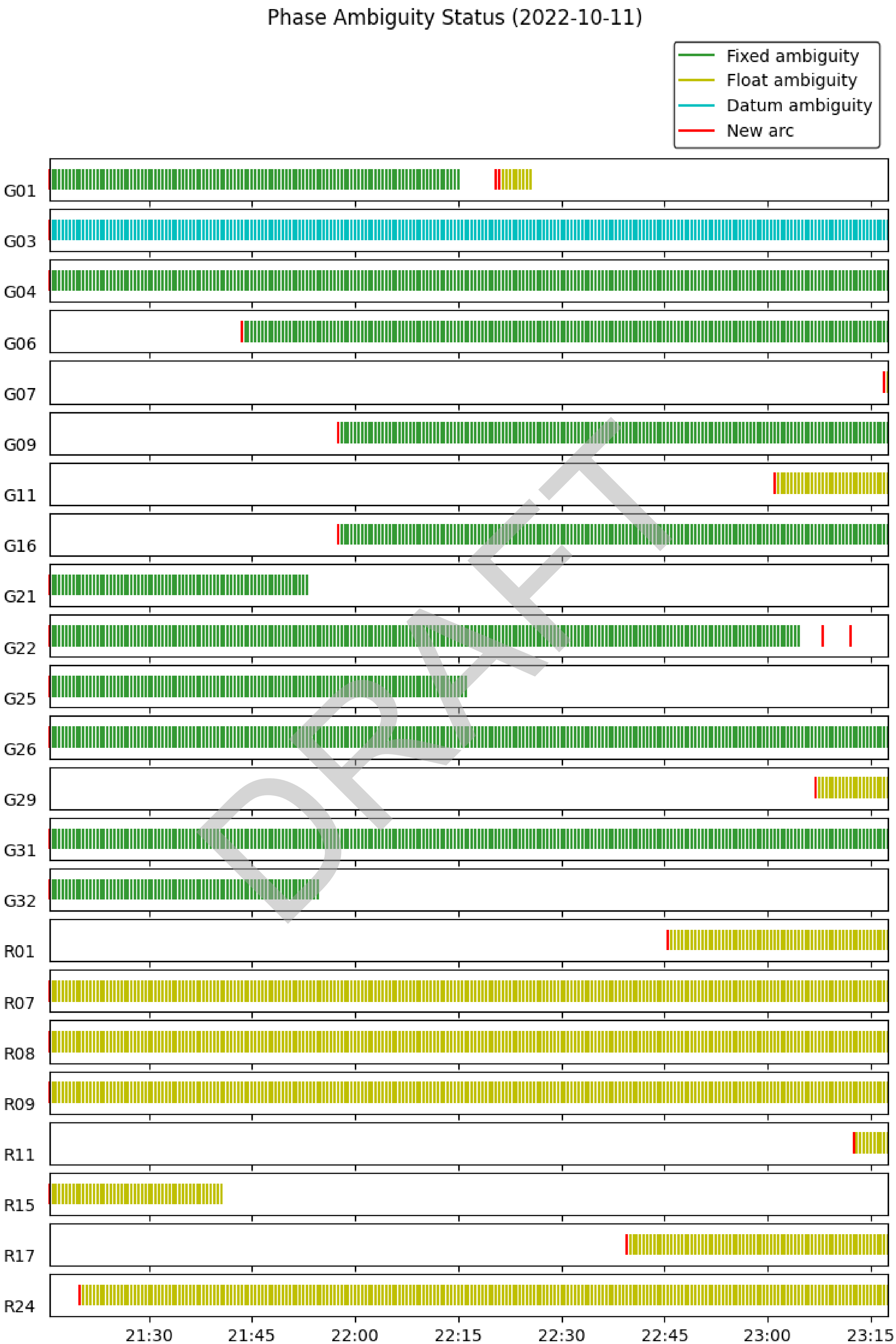

Estimated Tropospheric Zenith Delay (2022-10-11)
Sigma
metres
2.155
2.150
2.145
2.140
2.135
2.130
2.125
2.120
2.115
21:30
21:45
22:00
22:15
22:30
22:45
23:00
23:15


Station Clock Offset (2022-10-11)
Sigma
nanoseconds
Sigma (nanoseconds)
−45.0
−45.5
−46.0
−46.5
−47.0
−47.5
−48.0
−48.5
−49.0
−49.5
1.0
0.8
0.6
0.4
0.2
0.0
21:30
21:45
22:00
22:15
22:30
22:45
23:00
23:15


Tracked Satellites and Reset Ambiguities (2022-10-11)
% amb. reset
Number of satellites
% Ambiguity Reset
18
17
16
15
14
13
12
11
100
80
60
40
20
0
21:30
21:45
22:00
22:15
22:30
22:45
23:00
23:15


Carrier-Phase Residuals (2022-10-11)
metres
0.03
0.02
0.01
0.00
−0.01
−0.02
−0.03
21:30
21:45
22:00
22:15
22:30
22:45
23:00
23:15
G01
G06
G11
G22
G29
R01
R09
R17
G03
G07
G16
G25
G31
R07
R11
R24
G04
G09
G21
G26
G32
R08
R15


Pseudo-Range Residuals (2022-10-11)
metres
6
4
2
0
−2
−4
−6
−8
−10
21:30
21:45
22:00
22:15
22:30
22:45
23:00
23:15
G01
G06
G11
G22
G29
R01
R09
R17
G03
G07
G16
G25
G31
R07
R11
R24
G04
G09
G21
G26
G32
R08
R15



Phase Ambiguity Status (2022-10-11)
Fixed ambiguity
Float ambiguity
Datum ambiguity
New arc
G01
G03
G04
G06
G07
G09
G11
G16
G21
G22
G25
G26
G29
G31
G32
R01
R07
R08
R09
R11
R15
R17
R24
21:30
21:45
22:00
22:15
22:30
22:45
23:00
23:15
DRAFT

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Geodetic Integrated Services
Canadian Geodetic Survey
Surveyor General Branch
Natural Resources Canada
Government of Canada
588 Booth Street, Room 334
Ottawa, Ontario K1A 0Y7
Phone: 343-292-6617
Email: geodeticinformation-informationgeodesique@nrcan-rncan.gc.ca

Natural Resources Canada   Ressources naturelles Canada   Canada

CSRS-PPP 3.50.3 (2022-03-04)

CP105.22o
D1821-03177-01-034

Data Start	Data End	Duration of Observations
2022-10-12 15:15:00.00	2022-10-12 21:24:30.00	6:09:30
Processing Time		**Product Type**
20:32:20 UTC 2022/11/01		NRCan/IGS Final
Observations	**Frequency**	**Mode**
Phase and Code	Double	Static

Elevation Cut-Off	Rejected Epochs	Fixed Ambiguities	Estimation Steps
7.5 degrees	0.00 %	95.88 %	30.00 sec

Antenna Model	APC to ARP	ARP to Marker
HEMS321	L1 = 0.132 m L2 = 0.139 m	H:1.543m / E:0.000m / N:0.000m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for CP105.22o

	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2002.0)†	52° 8' 39.16339"	-113° 58' 9.50039"	865.070 m
SIG_PPP(95%)‡	0.005 m	0.004 m	0.015 m
SIG_TOT(95%)‡	0.040 m	0.029 m	0.029 m
A priori*	52° 8' 39.17976"	-113° 58' 9.56007"	866.646 m
Estimated – A priori	-0.506 m	1.135 m	-1.576 m

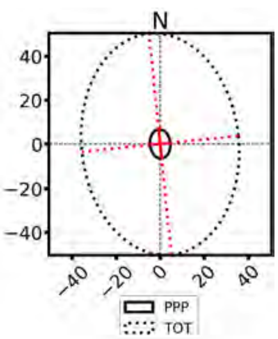
Orthometric Height CGVD28 (HTv2.0)†

883.157 m

(click for height reference information)

95% PPP Error Ellipse (mm)
semi-major: 7 mm
semi-minor: 5 mm
semi-major azimuth: -5° 33' 55.2"

95% TOT Error Ellipse (mm)
semi-major: 50 mm
semi-minor: 36 mm
semi-major azimuth: -5° 14' 30.46"



UTM (North) Zone 12

5781236.321 m (N)
296833.627 m (E)

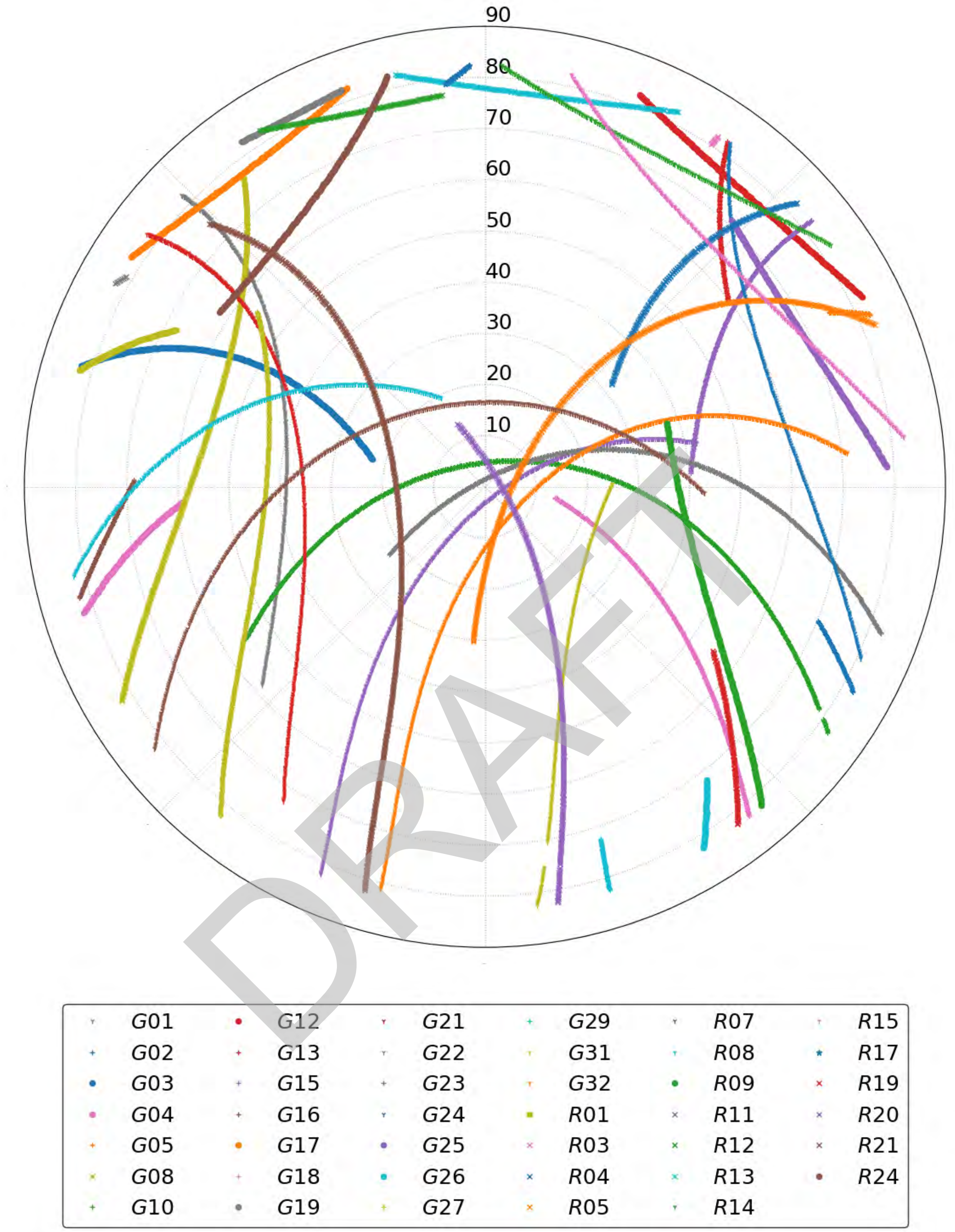
Scale Factors
1.00010673 (point)
0.99997122 (combined)

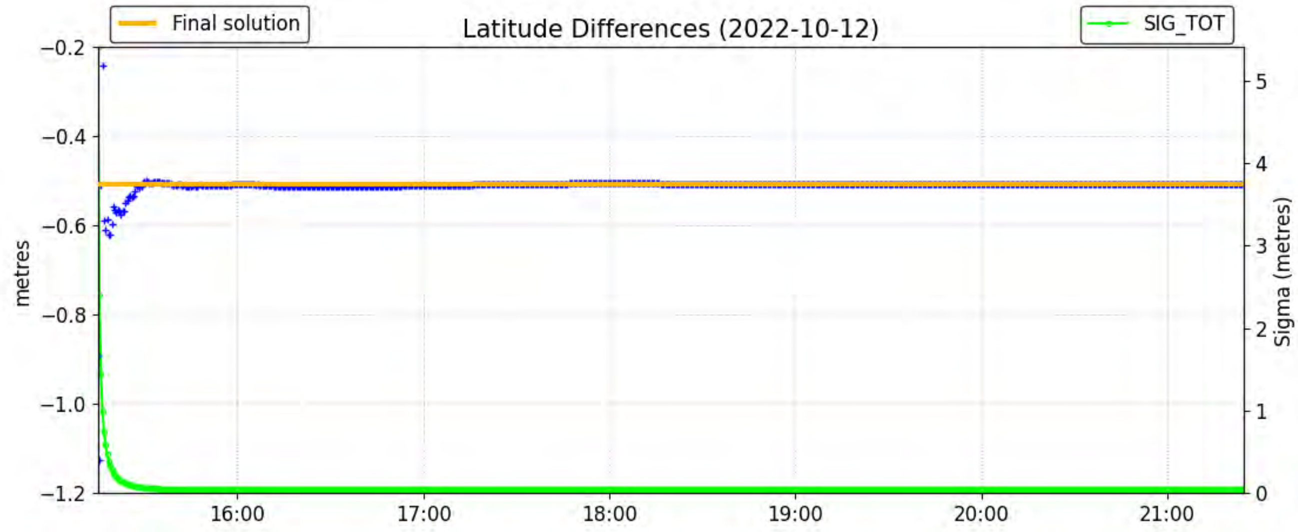
*(Coordinates from RINEX header used as a priori position)

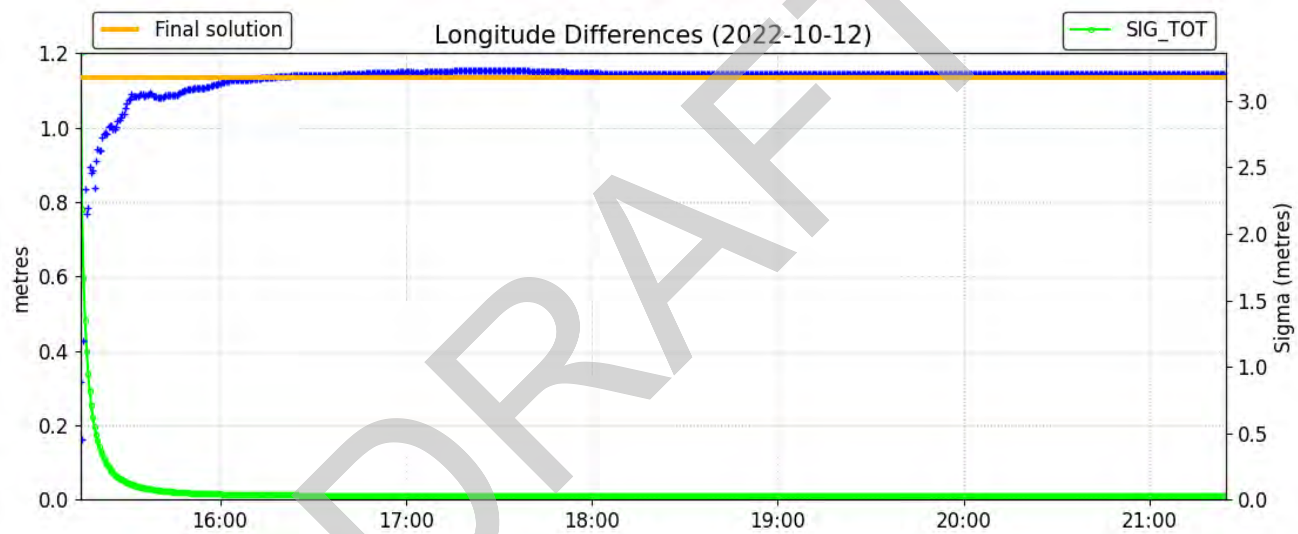
†(Epoch transformation using velocity grid NAD83v70VG (click for documentation))

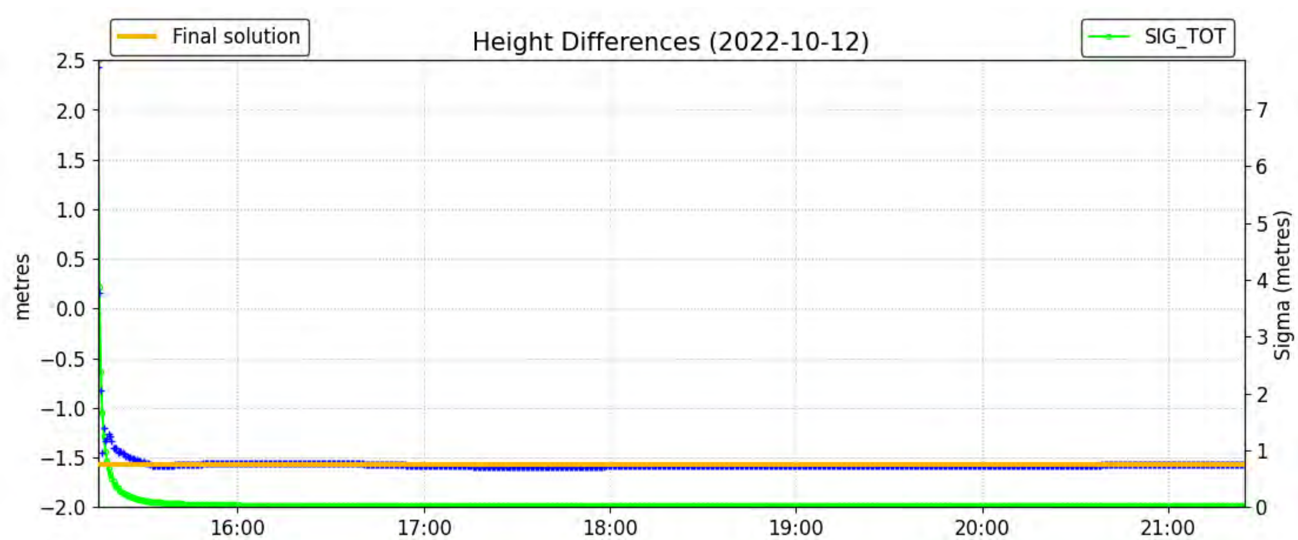
‡SIG_PPP indicates PPP-derived uncertainties, SIG_TOT incorporates uncertainties from epoch transformation

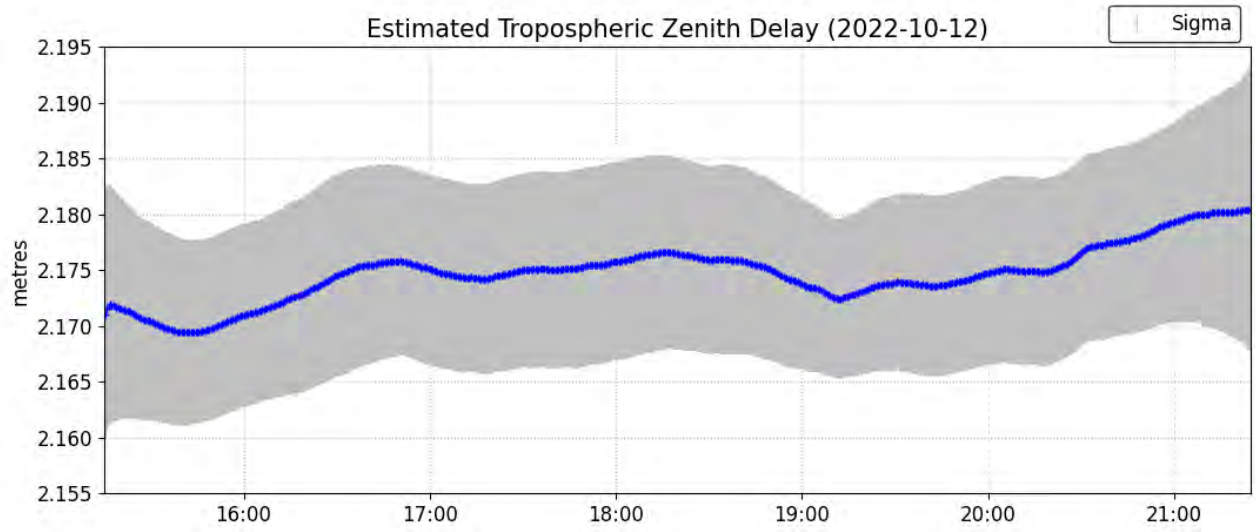
Satellite Sky Distribution

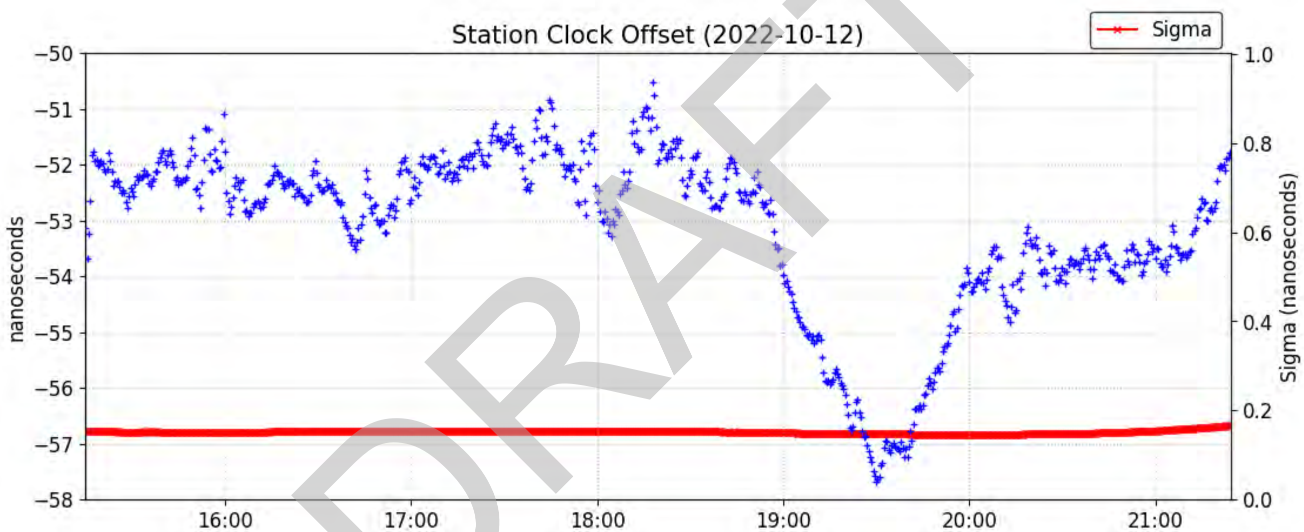



Latitude Differences (2022-10-12)
Final solution
SIG_TOT
metres
Sigma (metres)
−0.2
−0.4
−0.6
−0.8
−1.0
−1.2
0
1
2
3
4
5
16:00
17:00
18:00
19:00
20:00
21:00

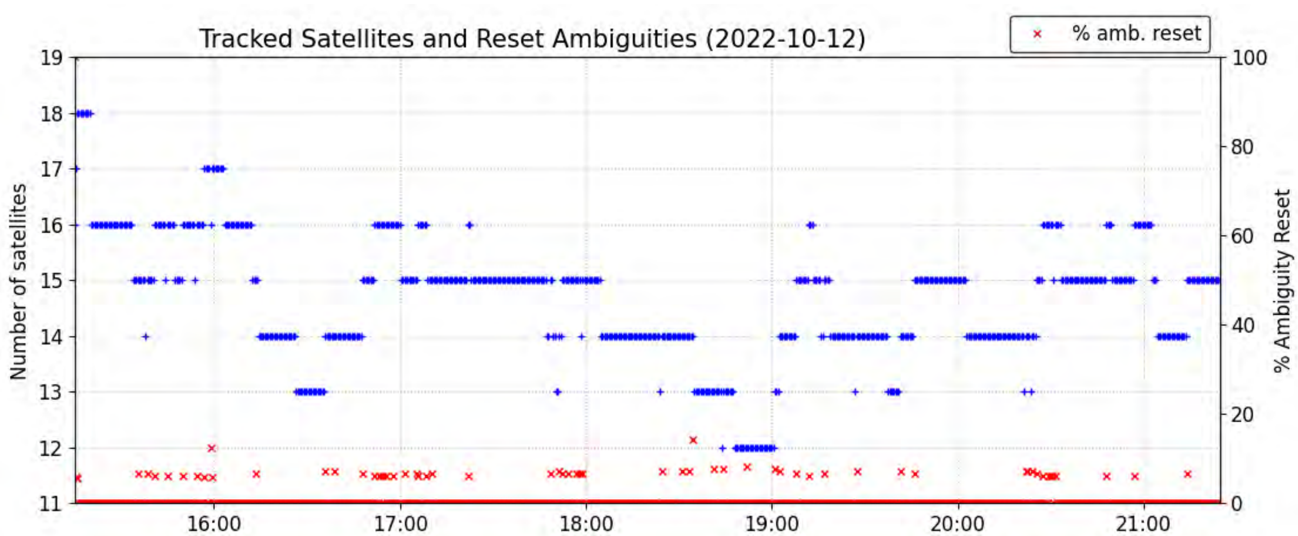

Longitude Differences (2022-10-12)
Final solution
SIG_TOT
metres
Sigma (metres)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
3.0
2.5
2.0
1.5
1.0
0.5
0.0
16:00
17:00
18:00
19:00
20:00
21:00

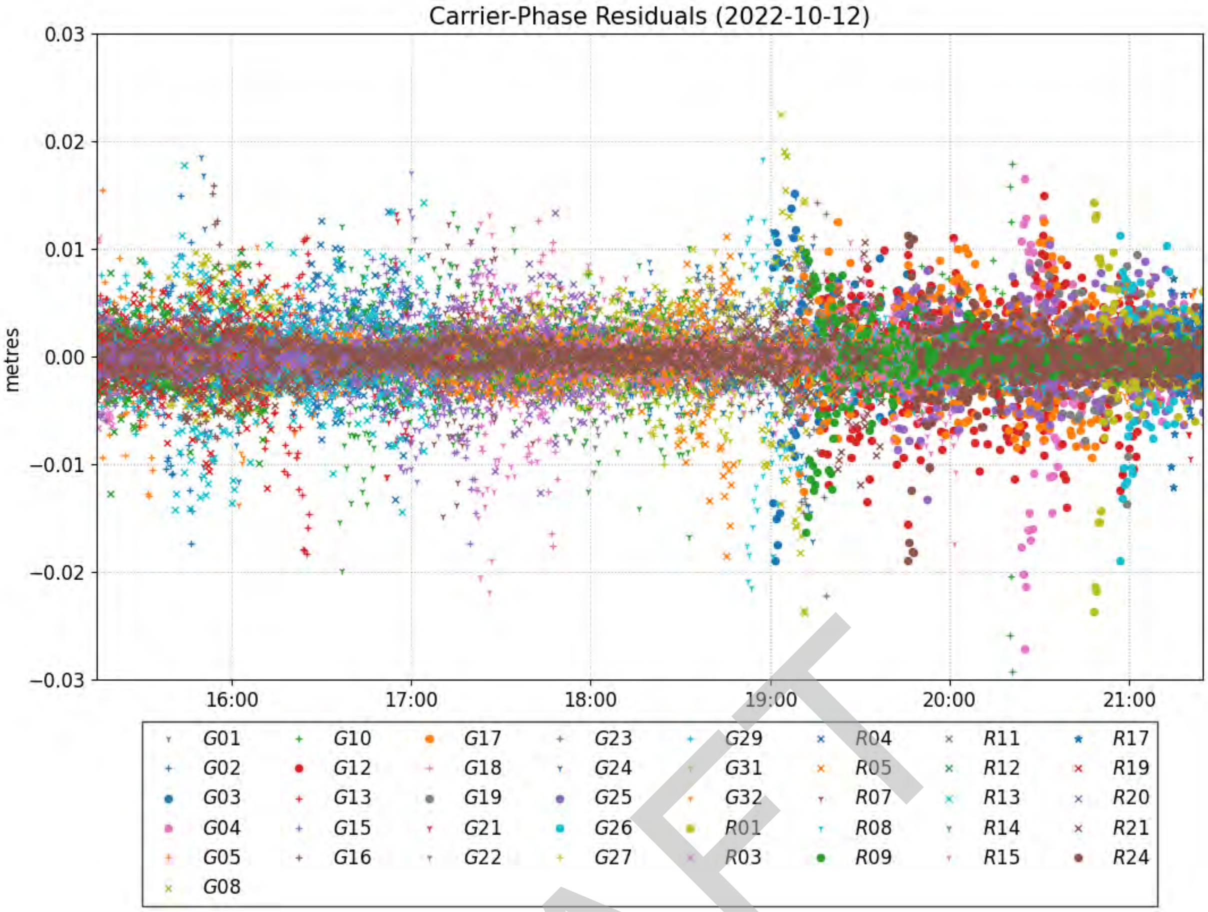

Height Differences (2022-10-12)
Final solution
SIG_TOT
metres
Sigma (metres)
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
0
1
2
3
4
5
6
7
16:00
17:00
18:00
19:00
20:00
21:00

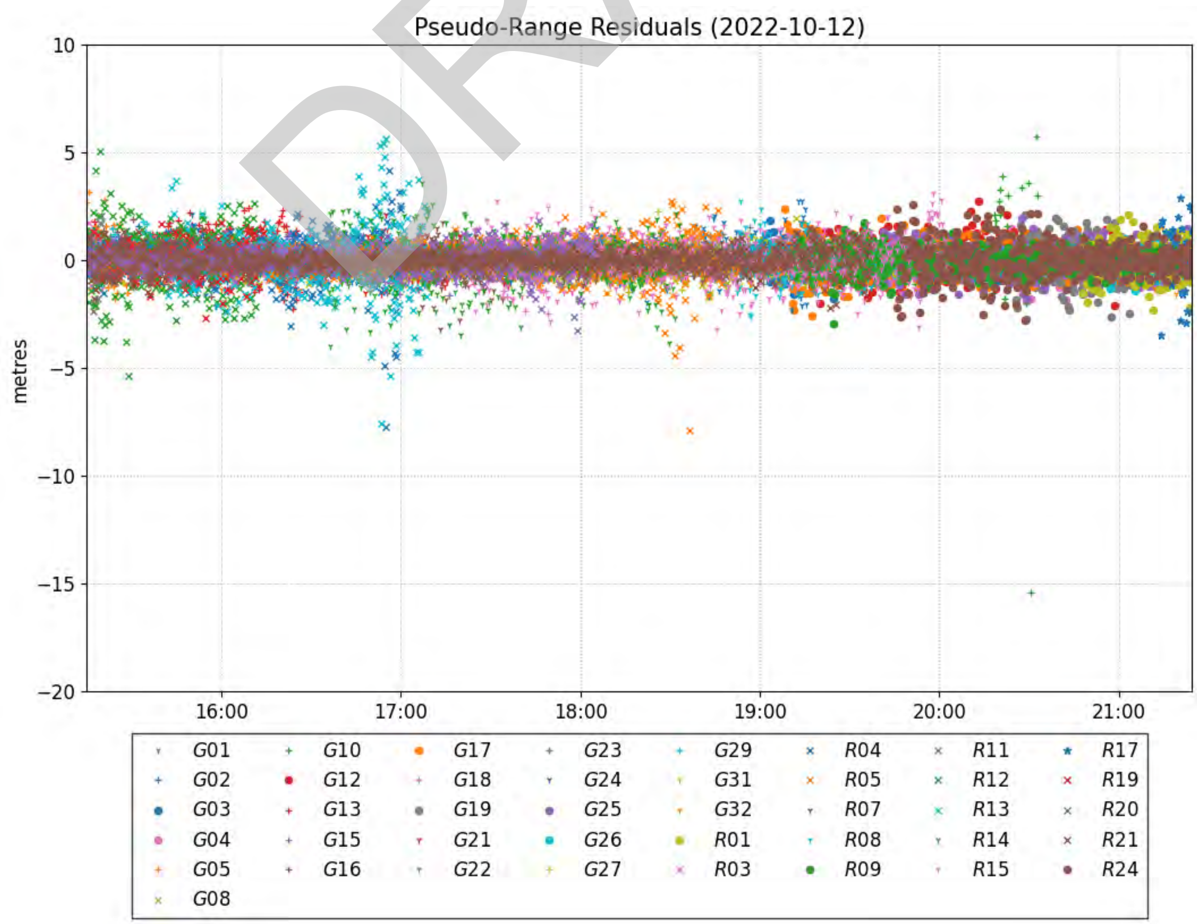

Estimated Tropospheric Zenith Delay (2022-10-12)
Sigma
metres
2.195
2.190
2.185
2.180
2.175
2.170
2.165
2.160
2.155
16:00
17:00
18:00
19:00
20:00
21:00

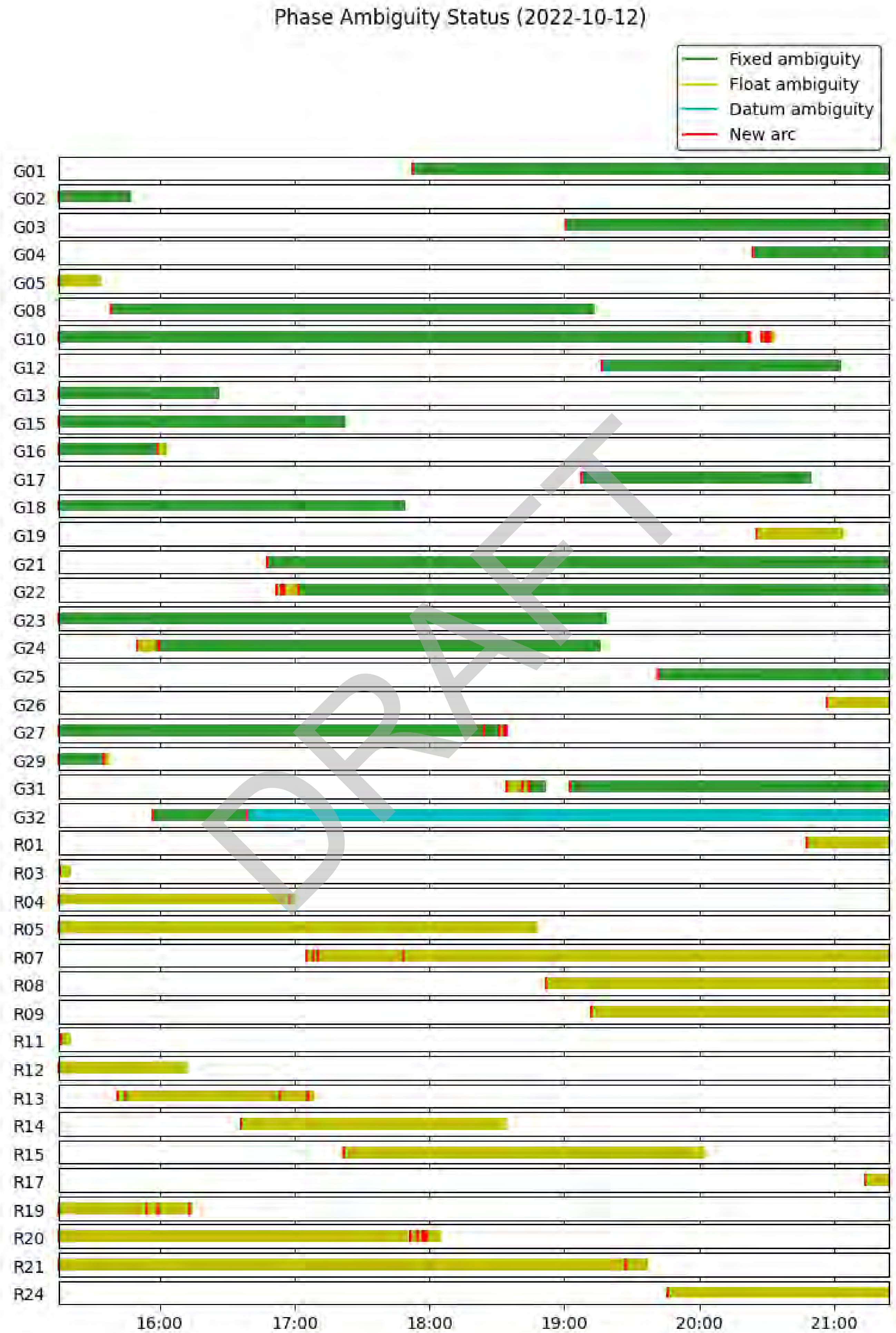

Station Clock Offset (2022-10-12)
Sigma
nanoseconds
Sigma (nanoseconds)
−50
−51
−52
−53
−54
−55
−56
−57
−58
1.0
0.8
0.6
0.4
0.2
0.0
16:00
17:00
18:00
19:00
20:00
21:00

DRAFT


Tracked Satellites and Reset Ambiguities (2022-10-12)
% amb. reset
Number of satellites
% Ambiguity Reset
19
18
17
16
15
14
13
12
11
100
80
60
40
20
0
16:00
17:00
18:00
19:00
20:00
21:00


Carrier-Phase Residuals (2022-10-12)
metres
0.03
0.02
0.01
0.00
−0.01
−0.02
−0.03
16:00
17:00
18:00
19:00
20:00
21:00
G01 G10 G17 G23 G29 R04 R11 R17
G02 G12 G18 G24 G31 R05 R12 R19
G03 G13 G19 G25 G32 R07 R13 R20
G04 G15 G21 G26 R01 R08 R14 R21
G05 G16 G22 G27 R03 R09 R15 R24
G08


Pseudo-Range Residuals (2022-10-12)
metres
10
5
0
−5
−10
−15
−20
16:00
17:00
18:00
19:00
20:00
21:00
G01 G10 G17 G23 G29 R04 R11 R17
G02 G12 G18 G24 G31 R05 R12 R19
G03 G13 G19 G25 G32 R07 R13 R20
G04 G15 G21 G26 R01 R08 R14 R21
G05 G16 G22 G27 R03 R09 R15 R24
G08


Phase Ambiguity Status (2022-10-12)
Fixed ambiguity
Float ambiguity
Datum ambiguity
New arc
G01
G02
G03
G04
G05
G08
G10
G12
G13
G15
G16
G17
G18
G19
G21
G22
G23
G24
G25
G26
G27
G29
G31
G32
R01
R03
R04
R05
R07
R08
R09
R11
R12
R13
R14
R15
R17
R19
R20
R21
R24
16:00
17:00
18:00
19:00
20:00
21:00
DRAFT

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CSRS-PPP 3.50.3 (2022-03-04)

CP106.22o
D1820-03176-01-020

Data Start	Data End	Duration of Observations
2022-10-12 15:51:30.00	2022-10-12 21:09:00.00	5:17:30
Processing Time		**Product Type**
20:32:14 UTC 2022/11/01		NRCan/IGS Final
Observations	**Frequency**	**Mode**
Phase and Code	Double	Static

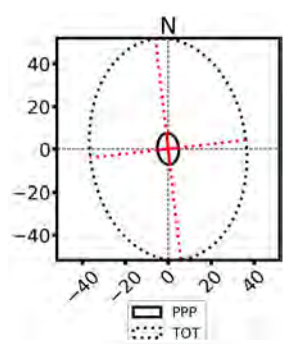
Elevation Cut-Off	Rejected Epochs	Fixed Ambiguities	Estimation Steps
7.5 degrees	0.00 %	96.04 %	30.00 sec

Antenna Model	APC to ARP	ARP to Marker
HEMS321	L1 = 0.132 m L2 = 0.139 m	H:1.626m / E:0.000m / N:0.000m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for CP106.22o

	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2002.0)†	52° 3' 32.56309"	-114° 12' 37.14501"	897.483 m
SIG_PPP(95%)‡	0.006 m	0.004 m	0.016 m
SIG_TOT(95%)‡	0.041 m	0.029 m	0.030 m
A priori*	52° 3' 32.58684"	-114° 12' 37.20966"	899.295 m
Estimated – A priori	-0.734 m	1.232 m	-1.812 m

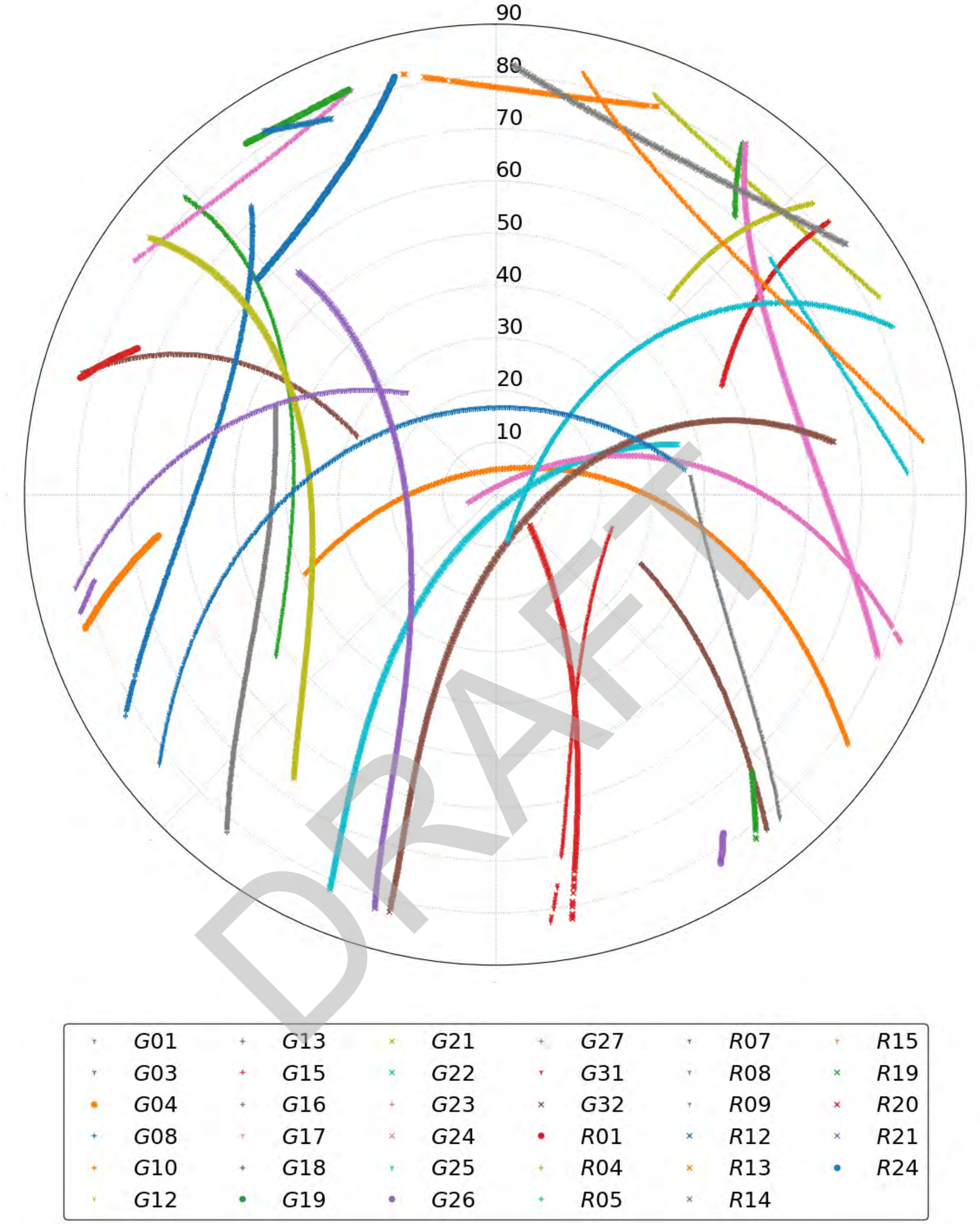
Orthometric Height CGVD28 (HTv2.0)†	95% PPP Error Ellipse (mm)	95% TOT Error Ellipse (mm)	UTM (North) Zone 11
	semi-major: 7 mm semi-minor: 5 mm semi-major azimuth: -5° 13' 40.29"	semi-major: 52 mm semi-minor: 36 mm semi-major azimuth: -6° 26' 8.7"	
914.907 m (click for height reference information)			5771278.422 m (N) 691242.728 m (E) Scale Factors 1.00004900 (point) 0.99990842 (combined)

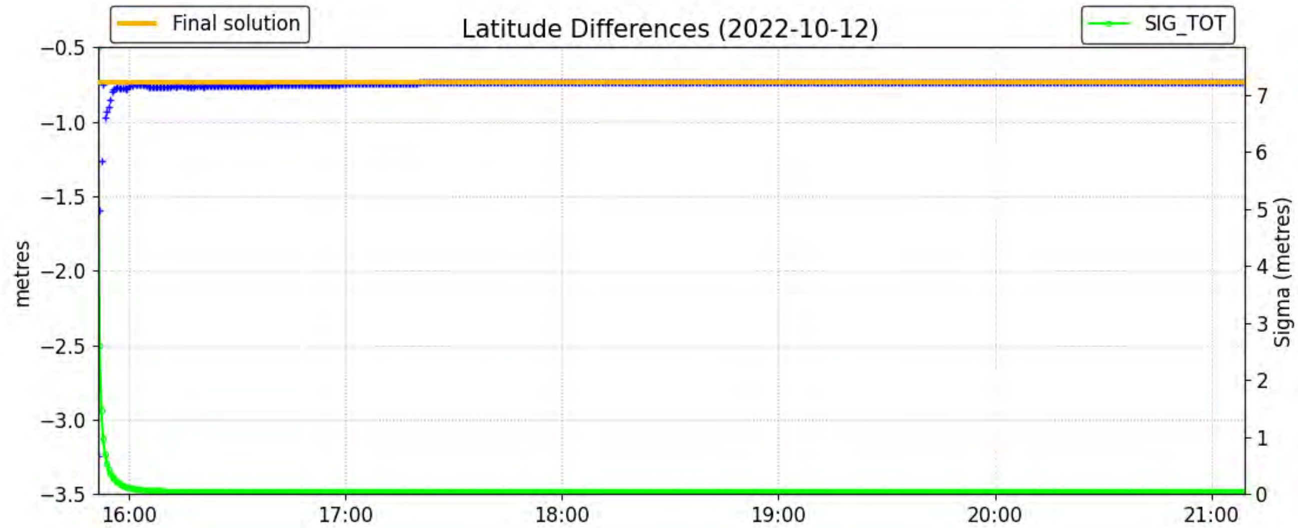
*(Coordinates from RINEX header used as a priori position)

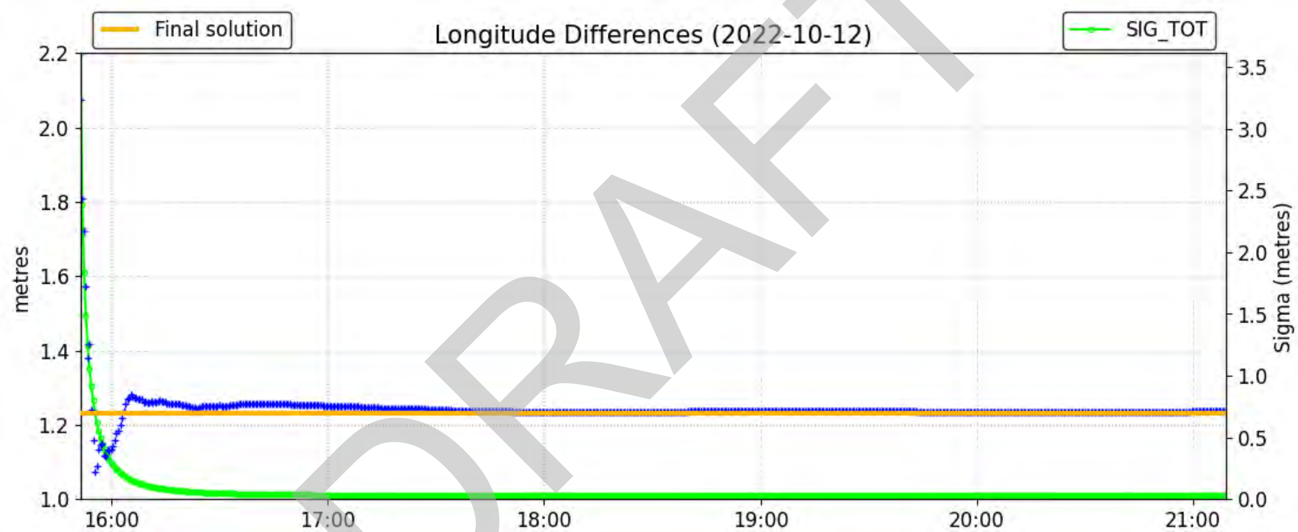
†(Epoch transformation using velocity grid NAD83v70VG (click for documentation))

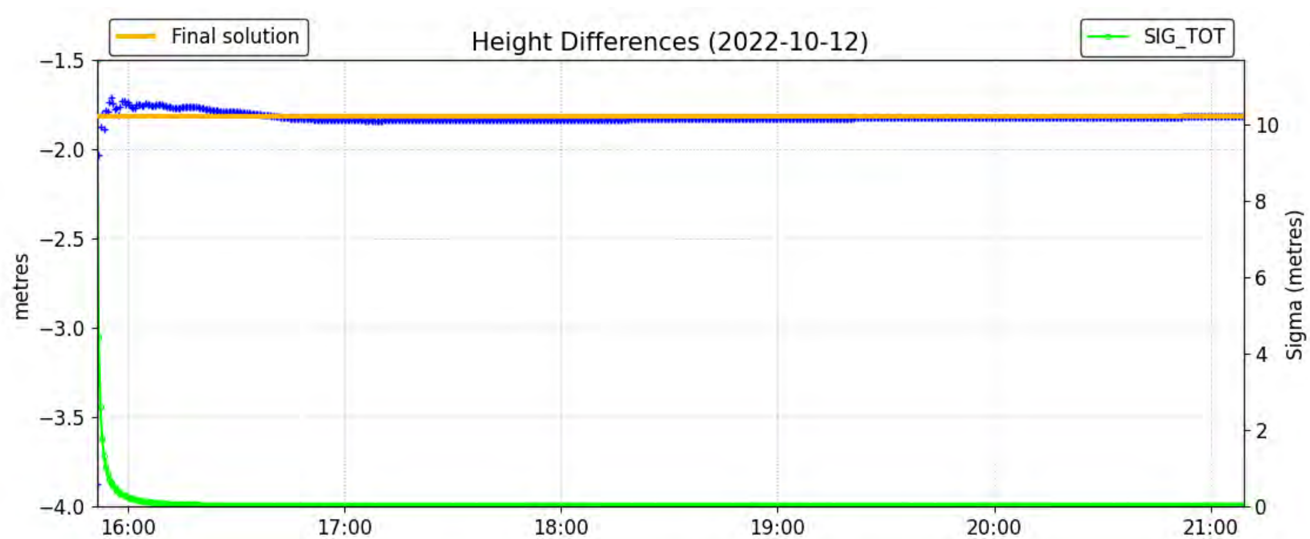
‡SIG_PPP indicates PPP-derived uncertainties, SIG_TOT incorporates uncertainties from epoch transformation

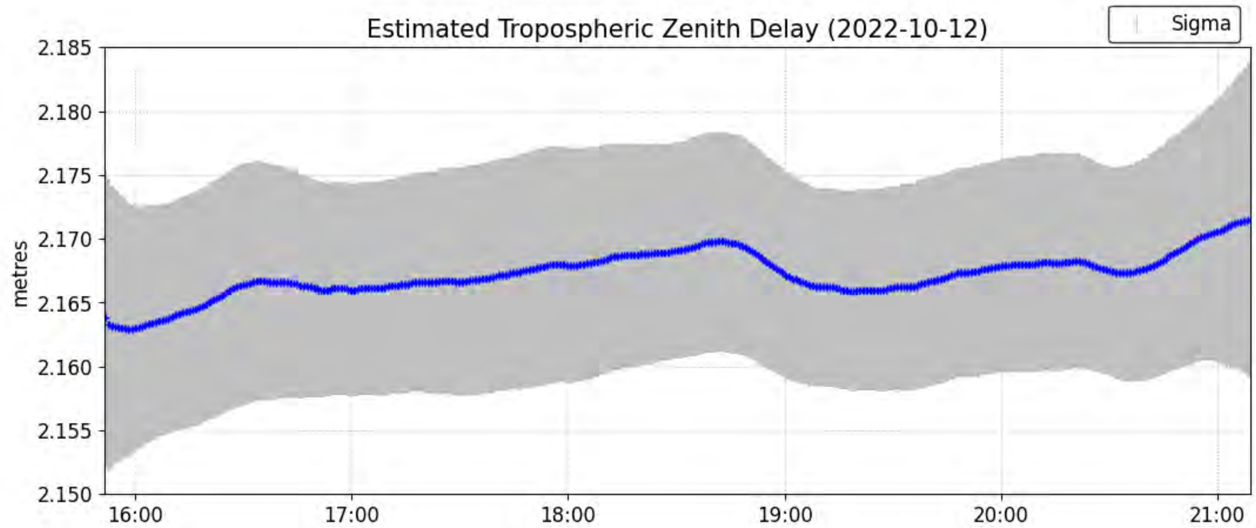
Satellite Sky Distribution

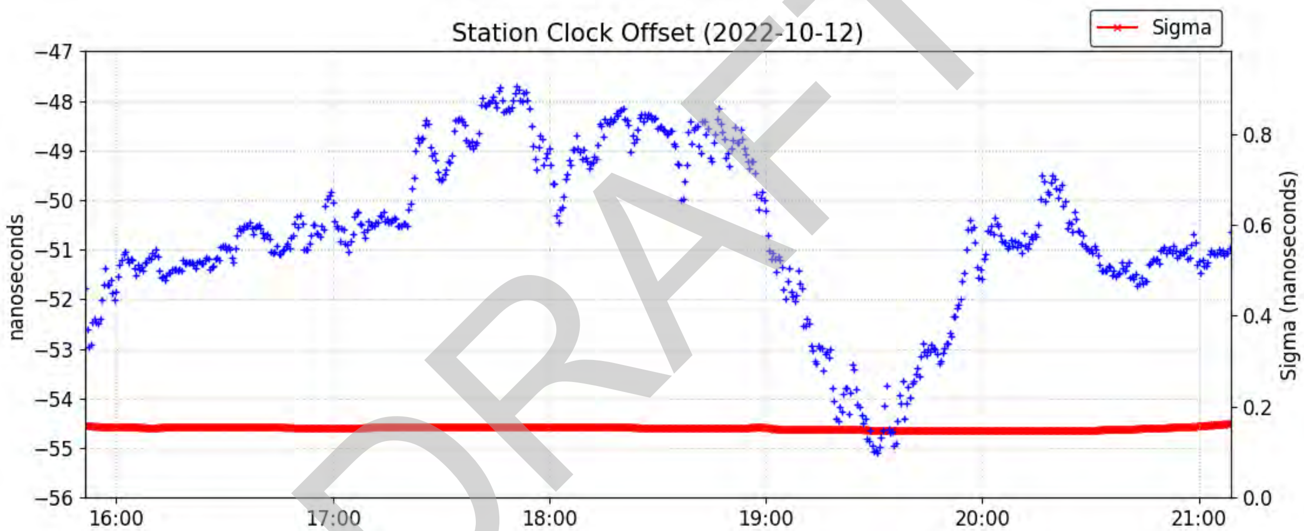


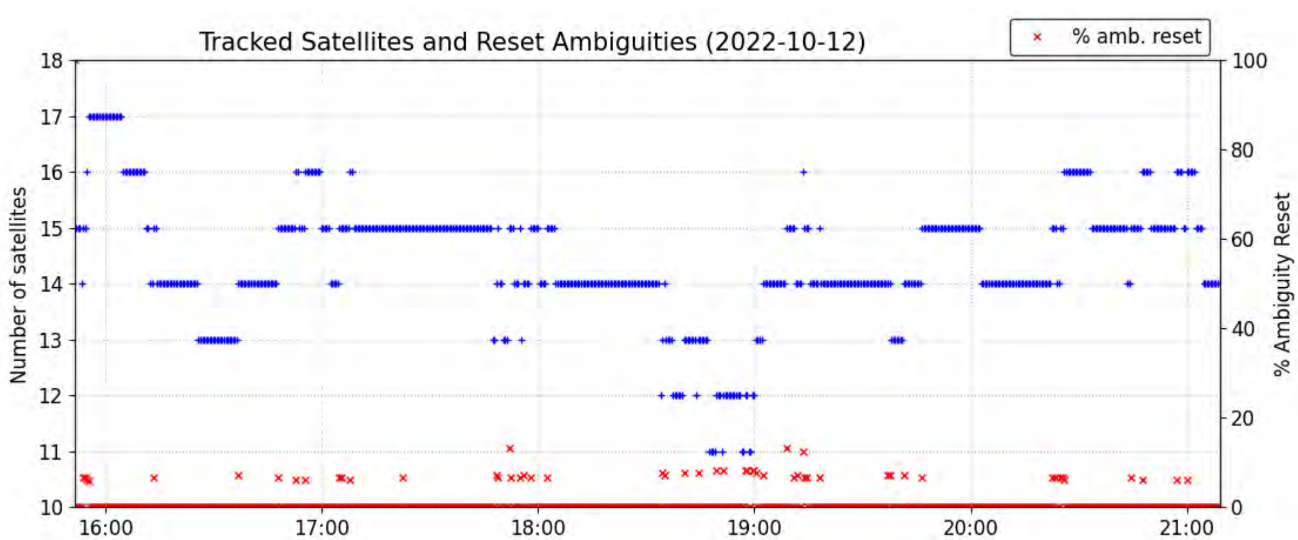

Latitude Differences (2022-10-12)
Final solution
SIG_TOT
metres
Sigma (metres)
−0.5
−1.0
−1.5
−2.0
−2.5
−3.0
−3.5
7
6
5
4
3
2
1
0
16:00
17:00
18:00
19:00
20:00
21:00


Longitude Differences (2022-10-12)
Final solution
SIG_TOT
metres
Sigma (metres)
2.2
2.0
1.8
1.6
1.4
1.2
1.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
16:00
17:00
18:00
19:00
20:00
21:00
DRAFT

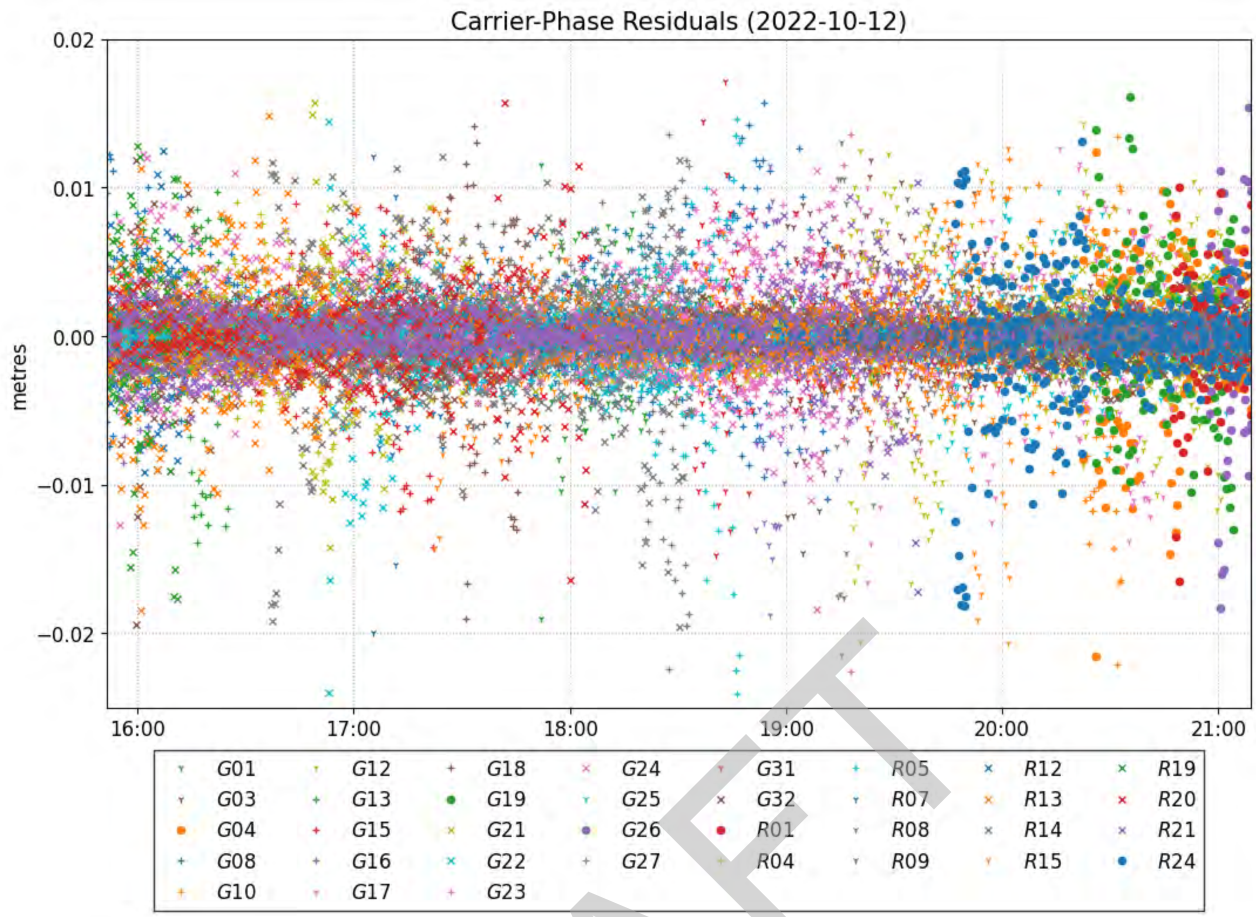

Height Differences (2022-10-12)
Final solution
SIG_TOT
metres
Sigma (metres)
−1.5
−2.0
−2.5
−3.0
−3.5
−4.0
10
8
6
4
2
0
16:00
17:00
18:00
19:00
20:00
21:00

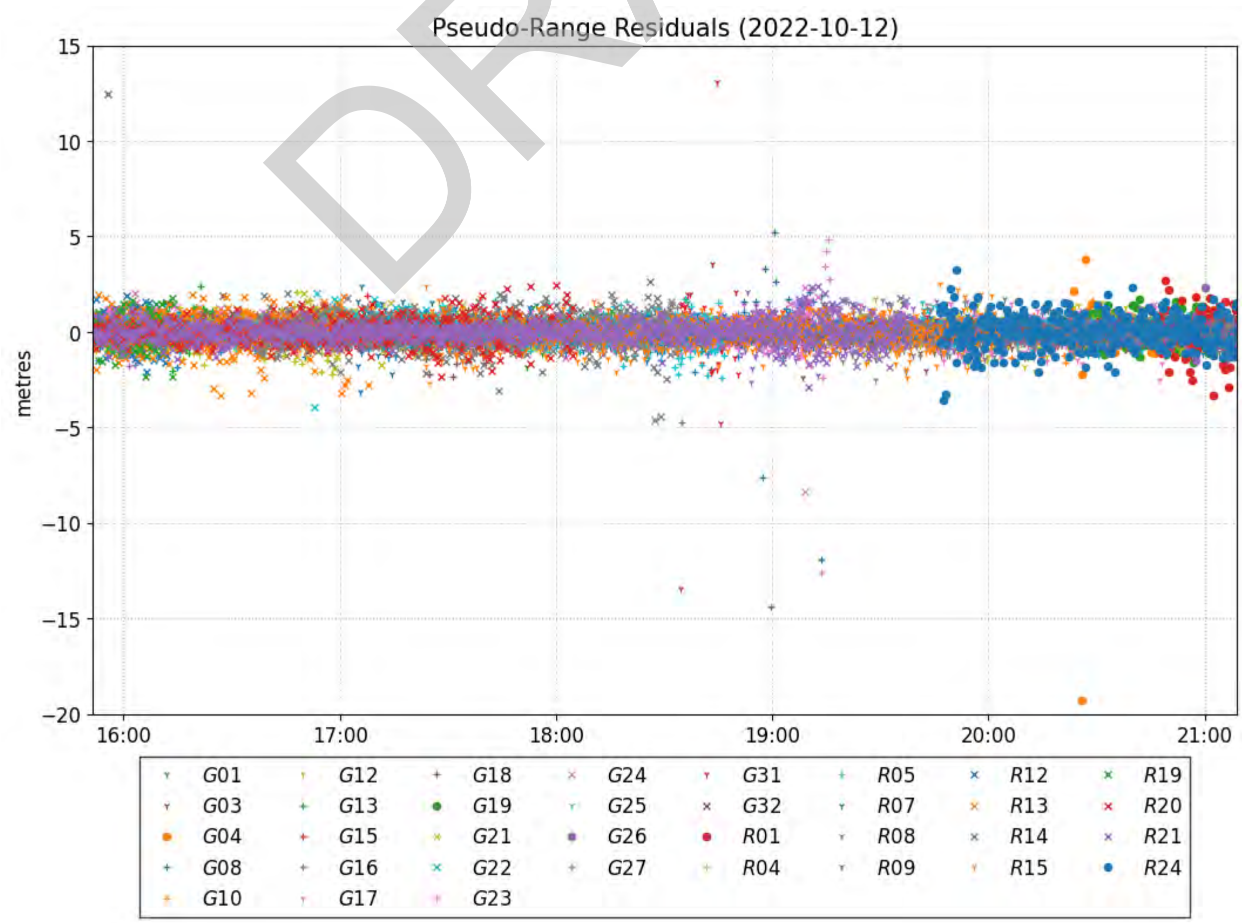


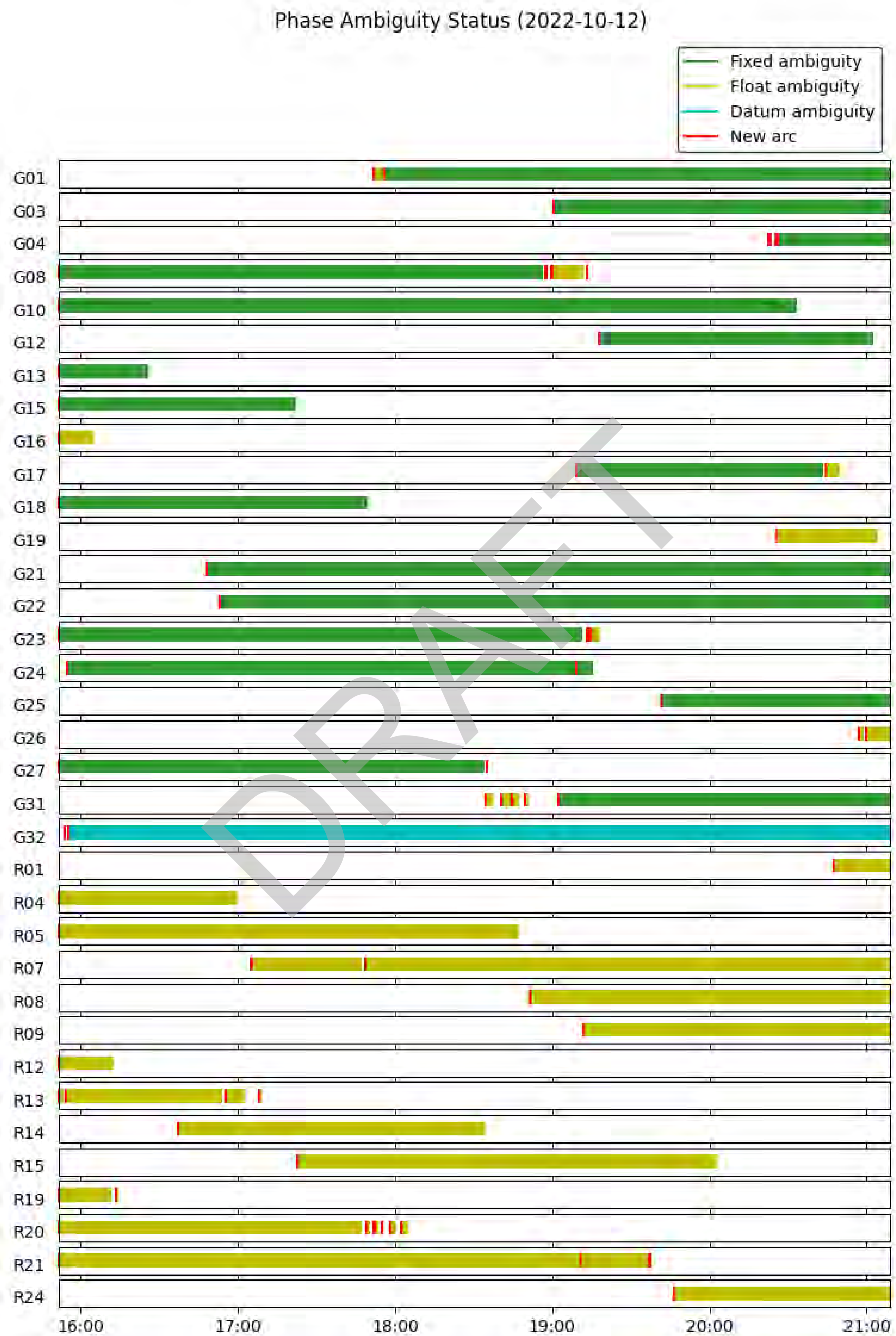




Classification: Public


Carrier-Phase Residuals (2022-10-12)
metres
0.02
0.01
0.00
−0.01
−0.02
16:00
17:00
18:00
19:00
20:00
21:00
G01 G03 G04 G08 G10 G12 G13 G15 G16 G17 G18 G19 G21 G22 G23 G24 G25 G26 G27 G31 G32 R01 R04 R05 R07 R08 R09 R12 R13 R14 R15 R19 R20 R21 R24


Pseudo-Range Residuals (2022-10-12)
metres
15
10
5
0
−5
−10
−15
−20
16:00
17:00
18:00
19:00
20:00
21:00
G01 G03 G04 G08 G10 G12 G13 G15 G16 G17 G18 G19 G21 G22 G23 G24 G25 G26 G27 G31 G32 R01 R04 R05 R07 R08 R09 R12 R13 R14 R15 R19 R20 R21 R24


Phase Ambiguity Status (2022-10-12)
Fixed ambiguity
Float ambiguity
Datum ambiguity
New arc
G01
G03
G04
G08
G10
G12
G13
G15
G16
G17
G18
G19
G21
G22
G23
G24
G25
G26
G27
G31
G32
R01
R04
R05
R07
R08
R09
R12
R13
R14
R15
R19
R20
R21
R24
16:00
17:00
18:00
19:00
20:00
21:00
DRAFT

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BRIDGE INFORMATION SHEET

Project: Red Deer Flood Study

Location: Hwy 54 Medicine River

Cross Section:

Surveyor: MSI_M.Biggs

Overall Dimensions

Abutment to Abutment Span 71.45 m

Outside to Outside Width 10.75 m

Elevation Data

	Top Asphalt of Curb or Solid Guard Rail		Low Chord	
Left Abutment	902.35	m	900.55	m
Midspan	902.19	m	900.39	m
Right Abutment	902.05	m	900.25	m

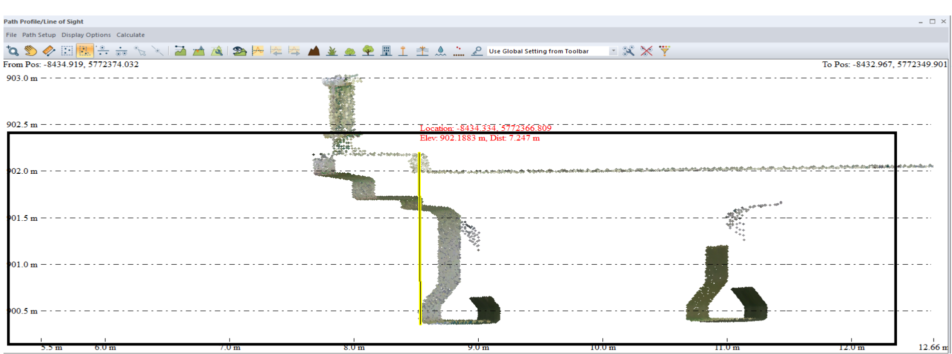
Note: For arch type bridges, additional shots should be taken between abutments and midspan. Provide a sketch.

Pier Description

Number 2 Width 23.1 m

Type Concrete (i.e. pile bent, timber truss, concrete cylinder)

Nose Shape Circular (i.e. rectangular, circular, wedge)



BRIDGE INFORMATION SHEET

Project: Red Deer Flood Study

Location: Hwy 54 Medicine River

Cross Section:

Surveyor: MSI_M.Biggs

Overall Dimensions

Abutment to Abutment Span 71.45 m

Outside to Outside Width 10.75 m

Elevation Data

	Top Asphalt of Curb or Solid Guard Rail		Low Chord	
Left Abutment	902.35	m	900.55	m
Midspan	902.19	m	900.39	m
Right Abutment	902.05	m	900.25	m

Note: For arch type bridges, additional shots should be taken between abutments and midspan. Provide a sketch.

Pier Description

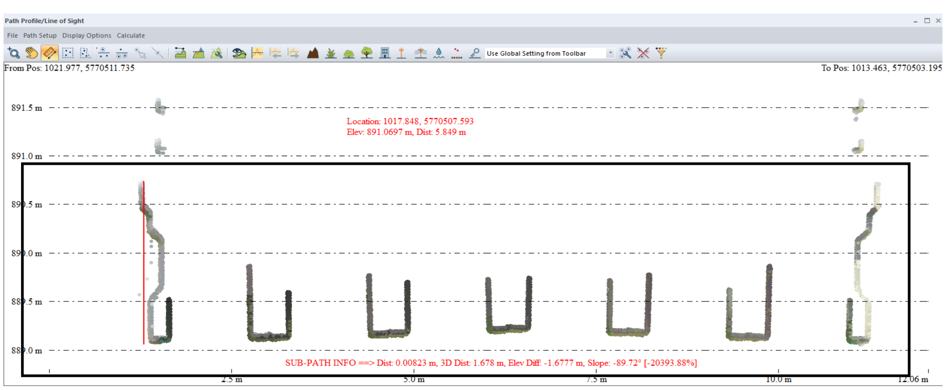
Number 2

Left to middle/Middle to right

Width 23.1 m

Type Concrete (i.e. pile bent, timber truss, concrete cylinder)

Nose Shape Circular (i.e. rectangular, circular, wedge)



BRIDGE INFORMATION SHEET

Project: Red Deer Flood Study
Location: Hwy 54 Medicine River
Cross Section:
Surveyor: MSI_M.Biggs

Overall Dimensions

Abutment to Abutment Span: 71.45 m
Outside to Outside Width: 10.75 m

Elevation Data

	Top Asphalt of Curb or Solid Guard Rail	Low Chord
Left Abutment	902.35 m	900.55 m
Midspan	902.19 m	900.39 m
Right Abutment	902.05 m	900.25 m

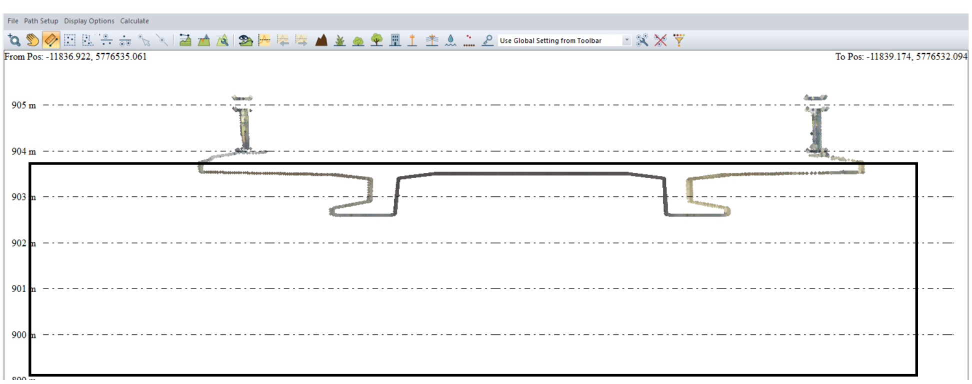
Note: For arch type bridges, additional shots should be taken between abutments and midspan. Provide a sketch.

Pier Description

Number: 2 Width: 23.1 m

Type: Concrete (i.e. pile bent, timber truss, concrete cylinder)

Nose Shape: Circular (i.e. rectangular, circular, wedge)



BRIDGE INFORMATION SHEET

Project: Red Deer Flood Study

Cross Section:

Location: Hwy 54 Medicine River

Surveyor: MSI_M.Biggs

Overall Dimensions

Abutment to Abutment Span 71.45 m

Outside to Outside Width 10.75 m

Elevation Data

	Top Asphalt of Curb or Solid Guard Rail		Low Chord	
Left Abutment	902.35	m	900.55	m
Midspan	902.19	m	900.39	m
Right Abutment	902.05	m	900.25	m

Note: For arch type bridges, additional shots should be taken between abutments and midspan. Provide a sketch.

Pier Description

Number 2 Width 23.1 m

Type Concrete (i.e. pile bent, timber truss, concrete cylinder)

Nose Shape Circular (i.e. rectangular, circular, wedge)

BRIDGE INFORMATION SHEET

Project: Red Deer Flood Study

Location: Hwy 54 Medicine River

Cross Section:

Surveyor: MSI_M.Biggs

Overall Dimensions

Abutment to Abutment Span 71.45 m

Outside to Outside Width 10.75 m

Elevation Data

	Top Asphalt of Curb or Solid Guard Rail	Low Chord
Left Abutment	902.35 m	900.55 m
Midspan	902.19 m	900.39 m
Right Abutment	902.05 m	900.25 m

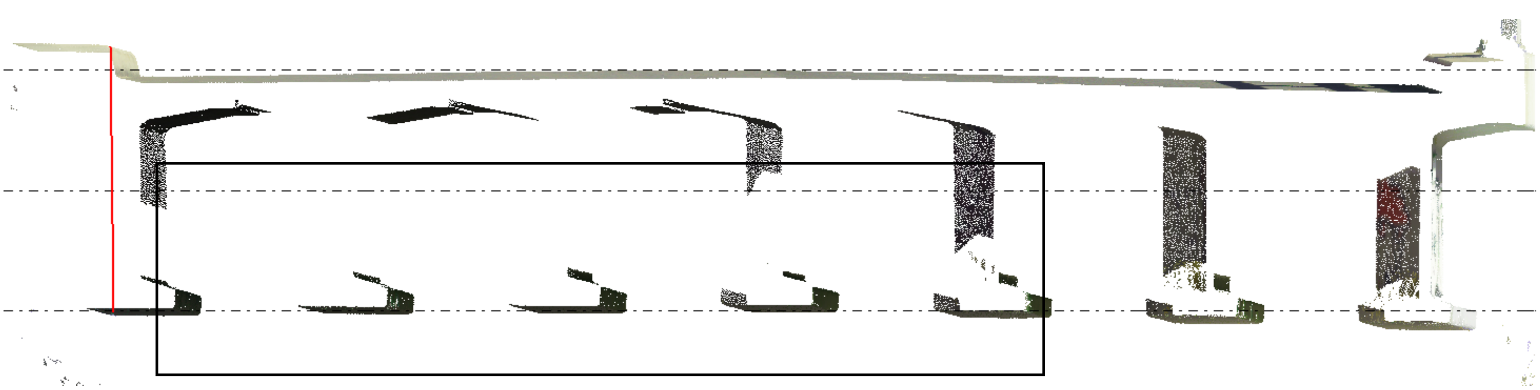
Note: For arch type bridges, additional shots should be taken between abutments and midspan. Provide a sketch.

Pier Description

Number 2 Width 23.1 m

Type Concrete (i.e. pile bent, timber truss, concrete cylinder)

Nose Shape Circular (i.e. rectangular, circular, wedge)



BRIDGE INFORMATION SHEET

Project: Red Deer Flood Study

Location: Hwy 54 Medicine River

Cross Section:

Surveyor: MSI_M.Biggs

Overall Dimensions

Abutment to Abutment Span: 71.45 m

Outside to Outside Width: 10.75 m

Elevation Data

	Top Asphalt of Curb or Solid Guard Rail	Low Chord
Left Abutment	902.35 m	900.55 m
Midspan	902.19 m	900.39 m
Right Abutment	902.05 m	900.25 m

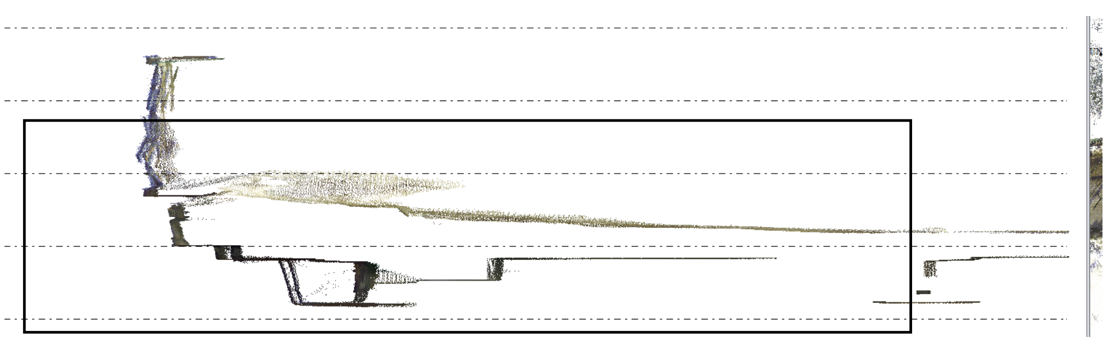
Note: For arch type bridges, additional shots should be taken between abutments and midspan. Provide a sketch.

Pier Description

Number: 2 Width: 23.1 m

Type: Concrete (i.e. pile bent, timber truss, concrete cylinder)

Nose Shape: Circular (i.e. rectangular, circular, wedge)



BRIDGE INFORMATION SHEET

Project:	Red Deer Flood Study	Cross Section:	
Location:	Hwy 54 Medicine River	Surveyor:	MSI_M.Biggs

Overall Dimensions

Abutment to Abutment Span	71.45	m
Outside to Outside Width	10.75	m

Elevation Data

	Top Asphalt of Curb or Solid Guard Rail		Low Chord	
Left Abutment	902.35	m	900.55	m
Midspan	902.19	m	900.39	m
Right Abutment	902.05	m	900.25	m

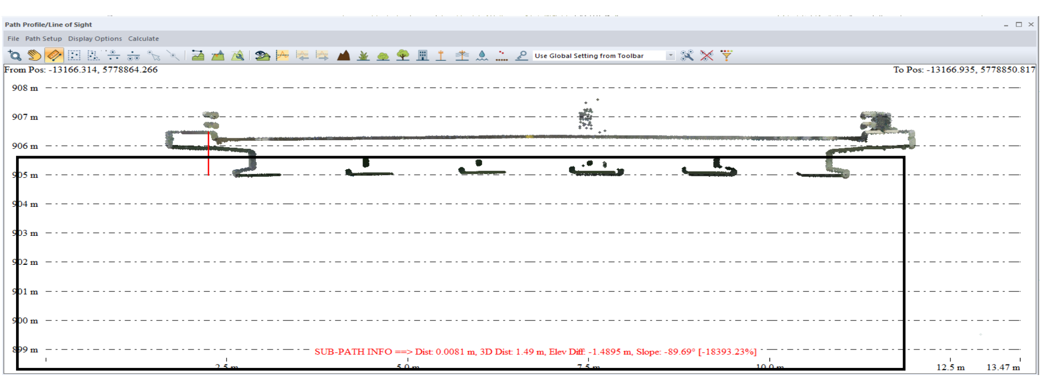
Note: For arch type bridges, additional shots should be taken between abutments and midspan. Provide a sketch.

Pier Description

Number 2 Width 23.1 m

Type Concrete (i.e. pile bent, timber truss, concrete cylinder)

Nose Shape Circular (i.e. rectangular, circular, wedge)



BRIDGE INFORMATION SHEET

Project: Red Deer Flood Study

Location: Hwy 54 Medicine River

Cross Section:

Surveyor: MSI_M.Biggs

Overall Dimensions

Abutment to Abutment Span 71.45 m

Outside to Outside Width 10.75 m

Elevation Data

	Top Asphalt of Curb or Solid Guard Rail		Low Chord	
Left Abutment	902.35	m	900.55	m
Midspan	902.19	m	900.39	m
Right Abutment	902.05	m	900.25	m

Note: For arch type bridges, additional shots should be taken between abutments and midspan. Provide a sketch.

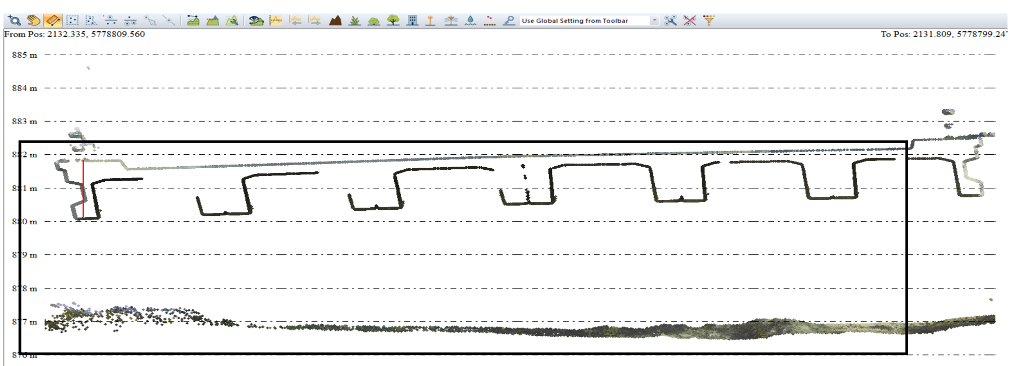
Pier Description

Left to left mid/left mid to right mid/right mid to right

Number 2 Width 23.1 m

Type Concrete (i.e. pile bent, timber truss, concrete cylinder)

Nose Shape Circular (i.e. rectangular, circular, wedge)



APPENDIX B
Hydrology Report

Version 1.0
May 5, 2023 Matrix 31781-531

Jim Choles, M.Eng., P.Eng., CFM
ALBERTA ENVIRONMENT AND PROTECTED AREAS
Floor 11, Oxbridge Place
9820 - 106 St. NW
Edmonton, AB T5K 2J6

Subject: Red Deer County and Markerville Flood Study, Hydrologic Assessment

Dear Jim:

1 INTRODUCTION

Matrix Solutions Inc. was retained by Alberta Environment and Protected Areas (EPA) to assess and identify flood hazards along the Red Deer River and its tributaries (Little Red Deer River and Medicine River) through Red Deer County including Markerville. Figure 1 shows the study area and includes the following study reaches:

1) 46 km reach of the Red Deer River, from the outlet of Dickson Dam in NW 34-35-02 W4M downstream to the northern boundary of NW 35-37-28 W4M.

2) 32 km reach of Little Red Deer River, from the southern boundary of SE 05-35-02 W4M downstream to its confluence with the Red Deer River.

3) 33 km reach of Medicine River, from the northern boundary of SW 16-37-02 W4M downstream to its confluence with the Red Deer River.

The extent of the current study along the Red Deer River is similar to the AMEC (2007) flood risk mapping study, with the exception of the upstream extents along the Little Red Deer River and the Medicine River, which are extended in the current study. As a part of the Red Deer River and Upper Red Deer Flood Hazard Studies, Golder Associates (2021) conducted a hydrologic assessment and prepared a hydrology assessment report, titled *Open Water Flood Hydrology Assessment - Red Deer River and Upper Red Deer River Hazard Studies*. Golder (2021) provided updated flood frequency estimates at various locations along the Red Deer River, Little Red Deer River, and Medicine River within the current study extents. These flood frequency estimates will be used for hydraulic modelling and flood hazard mapping for the current study. No additional open water hydrology assessment was carried out as a part of the current study, in accordance with the Terms of Reference (TOR; EPA 2022).

2 OVERVIEW OF RIVERS AND HISTORY OF FLOODING

A brief description of the Red Deer River, Little Red Deer River, and Medicine River and their history of flooding is provided below.

2.1 Red Deer River

Originating in the Rocky Mountains in Banff National Park, Alberta, the Red Deer River flows east through the foothills and the City of Red Deer, discharging to the South Saskatchewan River within the Province of Saskatchewan. Flows in the Red Deer River have been regulated by Dickson Dam since 1983. The Red Deer River is joined by the Medicine and Little Red Deer rivers downstream of Dickson Dam before flowing northeast toward the City of Red Deer. The Red Deer River has an irregular meandering pattern with occasional mid-channel bars and point bars within the study reach between Dickson Dam and the City of Red Deer.

The catchment area upstream of the Red Deer River study reach is composed of mountains, foothills, and prairie-type terrain. A Water Survey of Canada (WSC) streamflow gauging station 05CC002 (Red Deer River at Red Deer) is located just downstream of the study reach in the City of Red Deer and has been operating since 1913. This gauge is located downstream of the study reach but gives an indication of the historical peak discharge magnitudes within the study reach. Though the Red Deer River is subject to local flooding due to ice-jam conditions, the primary flood mechanism impacting the Red Deer River is open water flooding. Based on the historical gauge records, large flood events usually occur from May through August, although annual peak discharges have been recorded as early as April and as late as September.

Several large flood events have been reported since installation of the gauging station. The largest instantaneous flood peak discharge of 1,930 m^3/s occurred in June 1915. Regulation of the river began in 1983 with the construction of the Dickson Dam. Since regulation, the largest instantaneous flood peak discharge of 1,510 m^3/s occurred in 2005; the second largest instantaneous flood discharge was 1,290 m^3/s in 2013 and the third largest instantaneous flood discharge was 908 m^3/s in 1990.

2.2 Little Red Deer River

The Little Red Deer River is a tributary to the Red Deer River and originates in the foothills west of Water Valley. The river flows east out of the foothills and then north/northeast to the confluence with the Red Deer River. The catchment area upstream of the Little Red Deer River study reach is composed of foothills and agricultural prairie-type terrain. WSC gauging station 05CB001 (Little Red Deer River near the mouth) is located within the study reach, approximately 9 km from the confluence with the Red Deer River.

Based on a review of historical streamflow data, past flood events affecting the Little Red Deer River study reach have been primarily open water floods. Based on the gauge records, large flood events usually occur from April through July, although annual peak discharges have been recorded as early as March and as late as September.

The WSC gauge on the Little Red Deer River near the mouth (05CB001) has been operating since 1961. The largest instantaneous flood peak discharge of 452 m^3/s occurred in June 2005. This was the single largest flood event that has been recorded since this gauge was installed. The second largest flood discharge of 218 m^3/s occurred in 2013; the third largest flood discharge of 215 m^3/s occurred in 2011; the fourth largest flood discharge of 188 m^3/s occurred in 2008; the fifth largest flood discharge of 173 m^3/s occurred in 2007; and the sixth largest flood discharge of 162 m^3/s occurred in 2020.

2.3 Medicine River

The Medicine River is a tributary to the Red Deer River and originates at Medicine Lake in prairie-type terrain. The river flows south and east past Eckville, and through Markerville to the confluence with the Red Deer River (approximately 2 km downstream of the Little Red Deer River confluence). The catchment area upstream of the Medicine River study reach is composed of agricultural prairie-type terrain. WSC streamflow gauging station 05CC007 (Medicine River near Eckville) is located approximately 30 km upstream of the Town of Markerville.

Based on the gauge records, large flood events usually occur from April through July, although annual peak discharges have been recorded as early as March and as late as September.

The WSC gauge on the Medicine River near Eckville has been operating since 1962. This gauge is located upstream of the study reach but gives a general indication of the historical peak discharge magnitudes within the study reach. The largest instantaneous flood peak discharge of 236 m^3/s occurred in July 1990. The second largest flood discharge of 214 m^3/s occurred in 2007; the third largest flood discharge of 1986 208 m^3/s occurred in 1986; the fourth largest flood discharge of 163 m^3/s occurred in 2020; and the fifth largest flood discharge of 160 m^3/s occurred in 1982.

3 FLOOD FREQUENCY ESTIMATES

As a part of the Red Deer River and Upper Red Deer Flood Hazard Studies, Golder (2021) conducted a hydrologic assessment and prepared a hydrology assessment report, titled *Open Water Flood Hydrology Assessment – Red Deer River and Upper Red Deer River Hazard Studies*. This report contains the 1:2, 1:5, 1:10, 1:20, 1:35, 1:50, 1:75, 1:100, 1:200, 1:350, 1:500, 1:750, and 1:1,000 naturalized and regulated flood frequency estimates for the Red Deer River through the current study reach, as well as the flood frequency estimates for the Little Red Deer River and the Medicine River through the current study reach corresponding to these same return periods. As stipulated in the TOR, these flood frequency estimates are to be used in the current study. No additional open water hydrologic assessment was required.

Flood frequencies for natural flows or naturalized flows are typically used for flood hazard mapping. For this study, in concurrence with EPA, flood frequencies under regulated conditions were selected for hydraulic modelling and flood hazard mapping. Selection of flood frequency estimates under regulated flow conditions is consistent with the Flood Hazard study completed for the lower Red Deer River.

Figure 1 shows the locations of derived flood frequency estimates along the Red Deer River, Little Red Deer River, and Medicine River reproduced from the Golder (2021) report. Information provided for the following nodes are pertinent for the current study:

- Node #108 representing the Red Deer River downstream of Dickson Dam.
- Node #109 representing the Red Deer River downstream of Little Red Deer River.
- Node #110 representing the Red Deer River downstream of Medicine River.
- Node #111 representing the Red Deer River near the downstream boundary of the study reach.
- Node #304 representing the Little Red Deer River at the mouth (WSC station no. 05CB001).
- Node #306 representing the Medicine River at the mouth.

Table 1 presents the flood frequency estimates at these locations.

TABLE 1 Flood Frequency Estimates (Golder 2021)

Return Period (Year)	Little Red Deer River Near the Mouth (Node 304) (m^3/s)	Medicine River Near the Mouth (Node 306) (m^3/s)	Red Deer River d/s of Dickson Dam (Node 108) (m^3/s)	Red Deer River d/s of Little Red Deer River Confluence (Node 109) (m^3/s)	Red Deer River d/s of Medicine River Confluence (Node 110) (m^3/s)	Red Deer River Near the d/s Boundary (Node 111) (m^3/s)
2	58.6	87.8	185	234	290	282
5	125	156	355	402	478	457
10	184	209	512	534	619	586
20	252	267	696	676	768	720
35	316	318	811	1,130	1,270	1,200
50	360	353	966	1,330	1,480	1,390
75	414	394	1,160	1,570	1,750	1,630
100	455	424	1,310	1,760	1,950	1,820
200	563	503	1,830	2,390	2,620	2,390
350	661	571	2,250	2,900	3,150	2,830
500	728	618	2,470	3,180	3,460	3,100
750	810	673	2,920	3,700	4,000	3,500
1,000	871	714	3,250	4,110	4,420	3,810

As seen in Table 1, significant flow attenuation takes place along the Red Deer River between Nodes 110 and 111 for return periods greater than the 1:100-year flood. Node 111 is located about 5 km downstream of the downstream study limit. Use of flood magnitudes associated with Node 111 (internal flow boundary) will potentially underpredict the flood hazards while the use of flood magnitudes associated with Node 110 (internal flow boundary) will potentially overpredict flood hazards near the downstream study boundary. To accurately represent flood frequencies between Nodes 110 and the downstream study boundary, one additional flow change location is proposed. Figure 1 shows the proposed flow change location (M-1), located about 15 km downstream of Node 110 along the Red Deer River reach. Based on a review of the Red Deer River morphology, it appears that the valley widens in the vicinity of Node M-1 and the flow would likely attenuate at that location. Flood frequency estimates at Node M-1 are thus considered to be the same as Node 111 for hydraulic modelling purposes. Table 2 presents the flood frequency estimates at Node M-1.

TABLE 2 Flood Frequency Estimates at Node M-1

Return Period (Year)	Red Deer River at Node M-1 (m^3/s)
2	282
5	457
10	586
20	720
35	1,200
50	1,390
75	1,630
100	1,820
200	2,390
350	2,830
500	3,100
750	3,500
1,000	3,810

4 CONCLUSIONS

Flood frequency estimates are required for the Red Deer County and Markerville Flood Study. The flood frequency estimates provided in the *Open Water Flood Hydrology Assessment - Red Deer River and Upper Red Deer River Hazard Studies* report (Golder 2021) have been adopted as a basis for the flood frequency estimates for use in the current study.

The flood frequency estimates reflect the most current data and methodologies available. Given the relatively short data record (in the range of 100 years), uncertainty exists for estimating flood frequencies with return periods greater than 200 years. The flood frequency estimates should be updated as more flood data become available.

Based on a review of pertinent information provided in Golder (2021) and as presented on Figure 1 and Table 1, the following conclusions are made:

- The flood frequency estimates for Node 304 (Little Red Deer River near the mouth) can be used as the upstream inflow boundary for the Little Red Deer River.
- The flood frequency estimates for Node 306 (Medicine River near the mouth) can be used as the upstream inflow boundary for the Medicine River.
- The flood frequency estimates for Node 108 (Red Deer River downstream of Dickson Dam) can be used as the upstream inflow boundary for the Red Deer River.
- The confluence of the Red Deer River and Little Red Deer River can be used as a flow change location and the flood frequency estimates for Node 109 (Red Deer River downstream of its confluence with the Little Red Deer River) can be used along the Red Deer River reach between its confluence with the Little Red Deer River and the Medicine River.
- The confluence of the Red Deer River and Medicine River can be used as a flow change location and the flood frequency estimates for Node 110 (Red Deer River downstream of its confluence with Medicine Deer River) can be used along the Red Deer River reach between its confluence with the Medicine River and Node M-1.
- The flood frequency estimates for Node M-1 can be used as the design flows along the Red Deer River between Node M-1 and the downstream study boundary.

5 CLOSURE

We trust that this letter report suits your present requirements. If you have any questions or comments, please call either of the undersigned at 780.490.6830.

Yours truly,

MATRIX SOLUTIONS INC.

05 May 2023

Manas Shome, Ph.D., P.Eng.
Principal Water Resources Engineer

Reviewed by

05 May 2023

Pamela Rogers, M.Eng., P.Eng.
Senior Water Resources Engineer

MS/eh
Attachments

PERMIT TO PRACTICE
MATRIX SOLUTIONS INC.
RM SIGNATURE:
RM APEGA ID #: 57054
DATE: 05 May 2023
PERMIT NUMBER: P005540
The Association of Professional Engineers and Geoscientists of Alberta (APEGA)

VERSION CONTROL

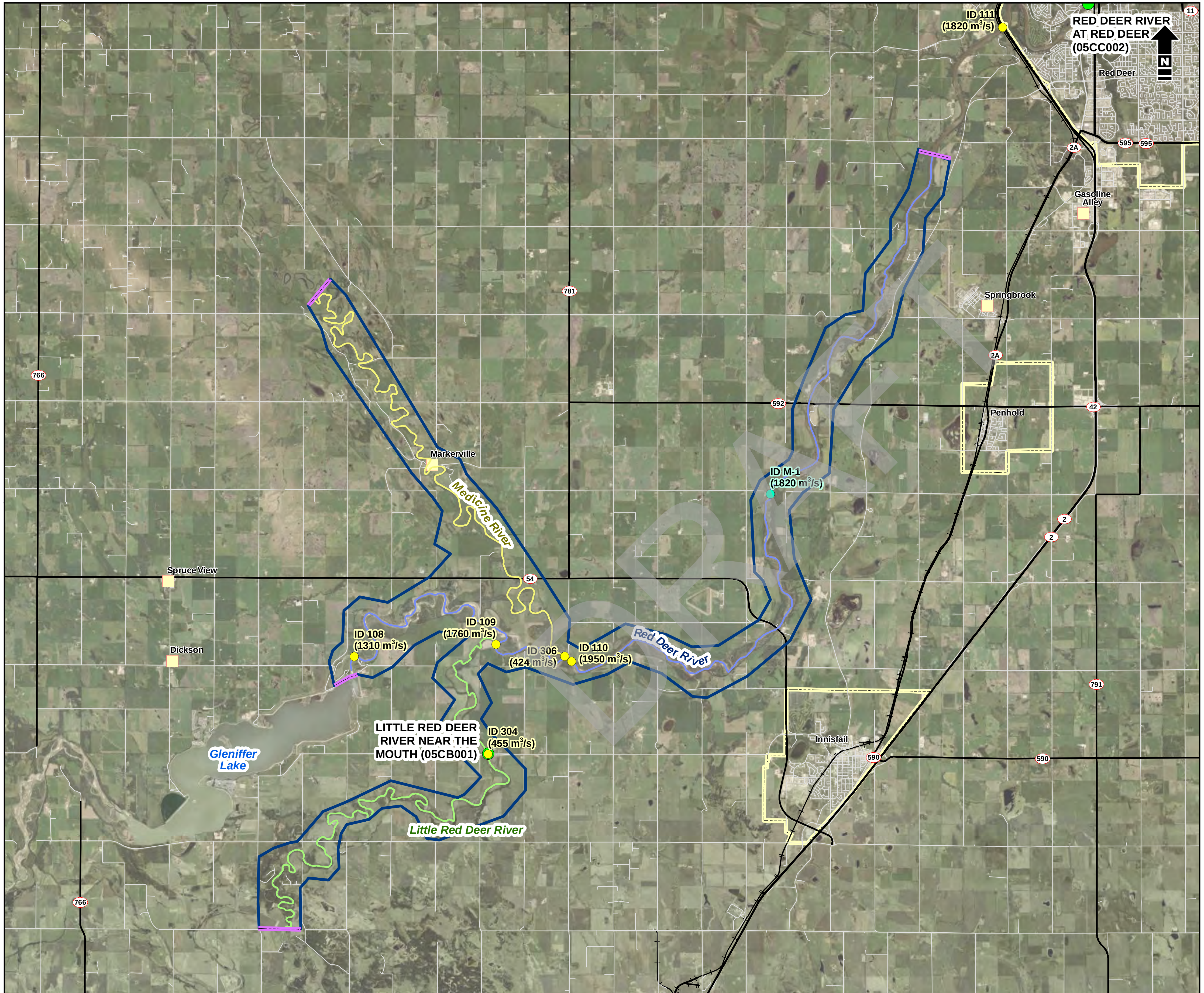
Version	Date	Issue Type	Filename	Description
V0.1	10-Apr-2023	Draft	35374-531 LR 2023-04-10 draft V0.1.docx	Issued to client for review
V1.0	05-May-2023	Final	35374-531 LR 2023-05-05 final V1.0.docx	Issued to client

REFERENCES

Alberta Environment and Protected Areas (EPA). 2022. *Red Deer River County and Markerville Flood Study - Terms of Reference*. August 2022.

Alberta Environment and Protected Areas (Golder). 2021. *Open Water Flood Hydrology Assessment - Red Deer River and Upper Red Deer River Hazard Studies*. Prepared for Alberta Environment and Parks. Calgary, Alberta. March 2021.

AMEC Earth & Environmental (AMEC). 2007. *Flood Risk Mapping Study, Red Deer River, Dickson Dam to Red Deer, Including Markerville*. Prepared for Alberta Environment. Calgary, Alberta. March 2007.



- Study Area
- Urban Muncipal Boundary
- Study Limit
- Railway
- Highway
- Road
- Community
- Hydrometric Station

Study Reaches and Extents

- Little Red Deer River
- Medicine River
- Red Deer River

Flow Change Node | 100 Year Flood

- Proposed Node
- Golder (2021)

Reference: Data obtained from Altalis © Government of Alberta, GeoBase® and GeoGratis © Department of Natural Resources Canada (all rights reserved) used under license. GDM midstream and transportation infrastructure data and well data provided ©2024 by S&P Global Commodity Insights, a division of S&P Global Inc. All rights reserved. Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community.

1:150,000 metres
1,500 0 1,500 3,000
NAD 1983 CSRS 3TM 114

Matrix Solutions Inc.
A Montrose Environmental Company

Alberta Environment and Protected Areas
Red Deer County and Markerville Flood Study

Inflow and Flow Change Nodes

Date:	Project:	Submitter:	Reviewer:
February 2024	35374	M. Wilkinson	M. Shome

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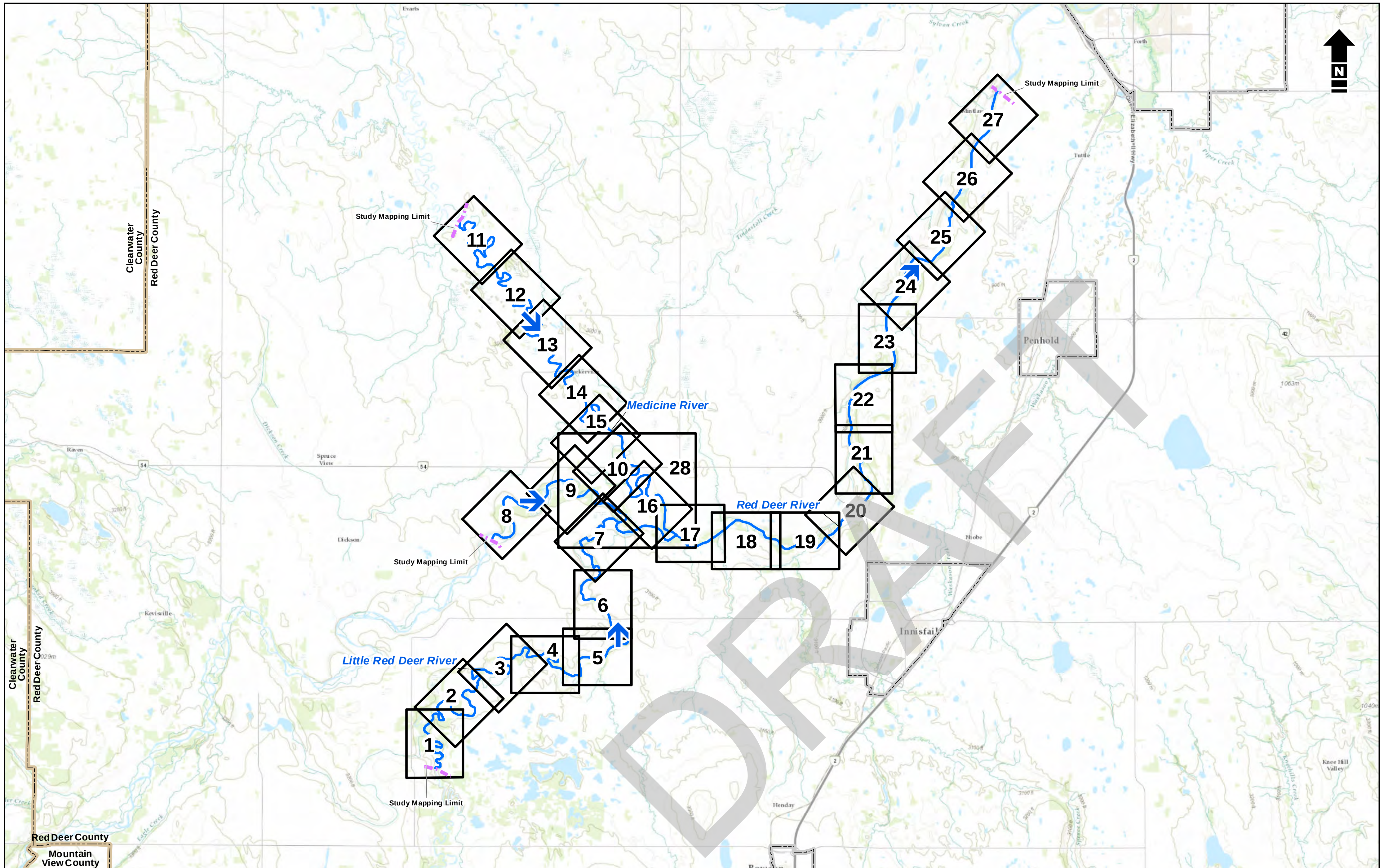
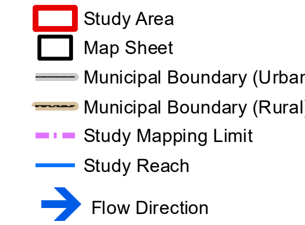
Figure 1

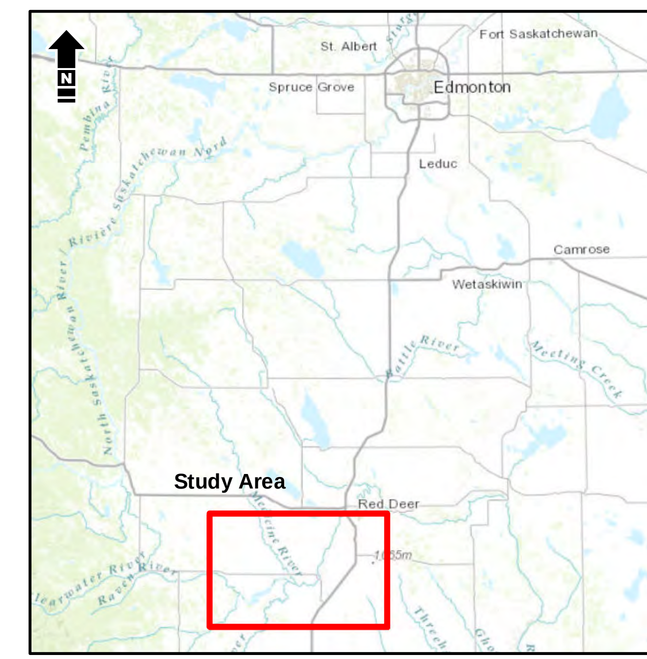
Classification: Public

APPENDIX C
Flood Inundation Maps

APPENDIX D
Floodway Criteria Maps







1:200,000 kilometres 5 0 5 10
NAD 1983 CSRS 3TM 114

Notes:

1. Please refer to the accompanying Red Deer County and Markerville Flood Hazard Study for important information concerning these maps.

2. Within the flood inundation areas shown on this map, there may be isolated pockets of high ground. To determine whether or not a particular site is subject to flooding, reference should be made to the computed flood levels in conjunction with site-specific surveys where detailed definition is required.

3. Non-riverine and local sources of water have not been considered, and structures such roads or railways can restrict water flow and affect local flood levels. Channel obstruction, local stormwater inflow, groundwater seepage or other land drainage can cause flood levels to exceed those indicated on the map. Lands adjacent to a flooded area may be subject to flooding from tributary streams not indicated on the maps.

Definitions:

Flood Hazard Map - A flood hazard map is a specific type of flood map that identifies the area flooded for the 1:100 design flood, and divides that flood hazard area into floodway and flood fringe zones. Flood hazard maps can also show additional flood hazard information, including the incremental areas at risk for more severe floods like the 1:200 and 1:500 floods. Flood hazard maps are typically used for long-term flood hazard area management and land-use planning.

Design Flood - The design flood standard in Alberta is the 1:100 flood, which is a flood that has a 1% chance of being equaled or exceeded in any given year. The design flood is typically based on the 1:100 open water flood, but it can also reflect 1:100 ice jam flood levels or be based on a historical flood event. Different sized floods have different chances of occurring – for example, a 1:200 flood has a 0.5% chance of occurring in any given year and a 1:500 flood has a 0.2% chance of occurring in any given year – but only the 1:100 design flood is used to define the floodway and flood fringe zones on flood hazard maps.

Floodway - When a floodway is first defined on a flood hazard map, it typically represents the area of highest flood hazard where flows are deepest, fastest, and most destructive during the 1:100 design flood. When a flood hazard map is updated, the floodway will not get larger in most circumstances to maintain long-term regulatory certainty, even if the flood hazard area gets larger or design flood levels get higher.

Flood Fringe - The flood fringe is the area outside of the floodway that is flooded or could be flooded during the 1:100 design flood. The flood fringe typically represents areas with shallower, slower, and less destructive flooding, but it may also include "high hazard flood fringe" areas. Areas at risk of flooding behind flood berms may also be mapped as "protected flood fringe" areas.

High Hazard Flood Fringe - The high hazard flood fringe identifies areas within the flood fringe with deeper or faster moving water than the rest of the flood fringe. High hazard flood fringe areas are likely to be most significant for flood maps that are being updated, but they may also be included in new flood maps.

Protected Flood Fringe - The protected flood fringe identifies areas that could be flooded if dedicated flood berms fail or do not work as designed during the 1:100 design flood, even if they are not overtopped. Protected flood fringe areas are part of the flood fringe and do not differentiate between areas with deeper or faster moving water and shallower or slower moving water.

References:

Data obtained from AltaLIS © Government of Alberta and GeoBase® used under license.

Base Mapping available ESRI Base Mapping and Imagery Services.
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Matrix Solutions Inc.
A Montrose Environmental Company

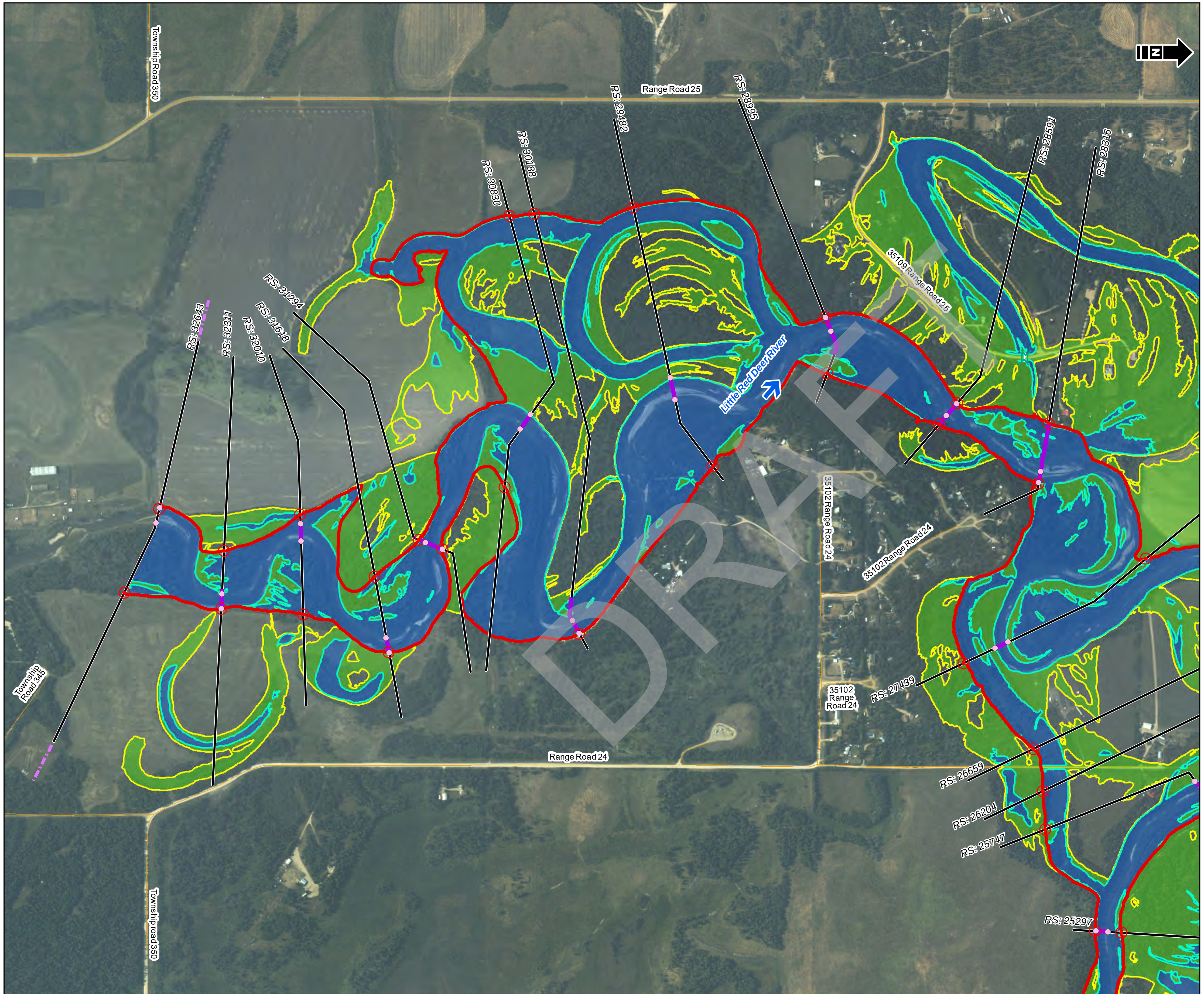
Alberta

Alberta Environment and Protected Areas
Red Deer County and Markerville Flood Study

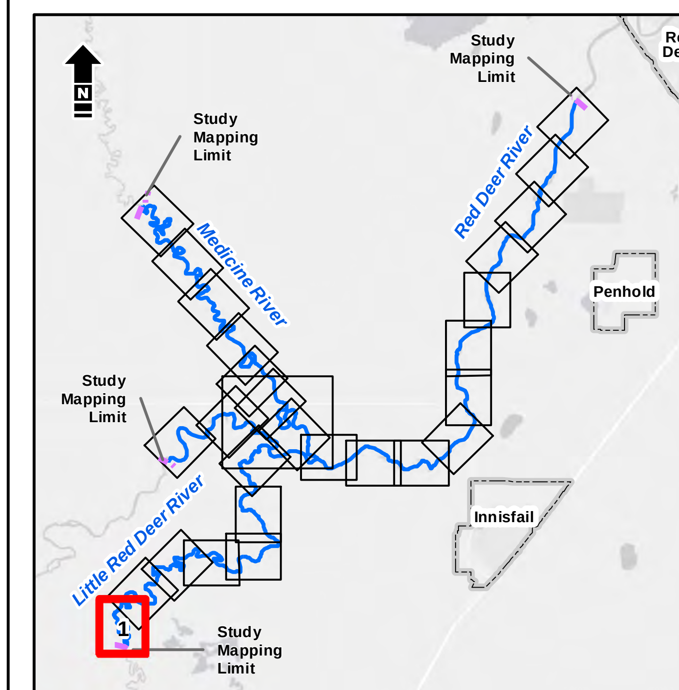
Floodway Criteria Index Map

Date:	Project:	Submitter:	Reviewer:
March 2024	35374	P. Rogers	M. Shome

Sheet INDEX



Bridge
Culvert
Cross Section Line
Study Mapping Limit
Major Road
Local Road
Flow Direction
Bank Station
Proposed Floodway Station
Previous Floodway
Proposed Floodway Boundary
100 Year Inundation - ≥1 m/s Velocity
100 Year Inundation Extent - ≥1 m Depth
100 Year Inundation Extent



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1:10,000 Kilometers
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NAD 1983 CSRS 3TM 114

Matrix Solutions Inc.
A Montrose Environmental Company

Alberta

Alberta Environment and Protected Areas
Red Deer County and Markerville Flood Study

Floodway Criteria Map

Date: March 2024	Project: 35374	Submitter: P. Rogers	Reviewer: M. Shome

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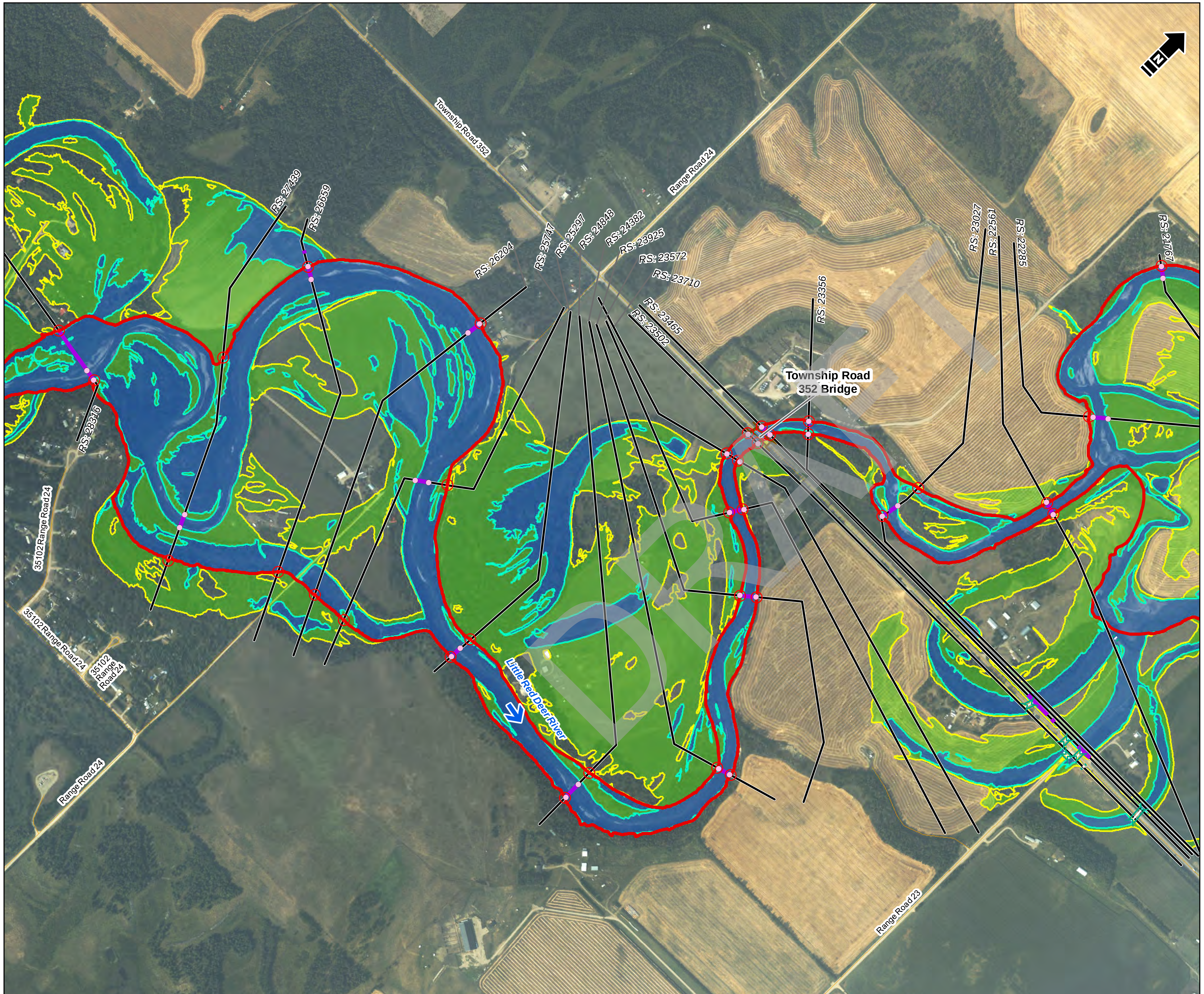

Bridge
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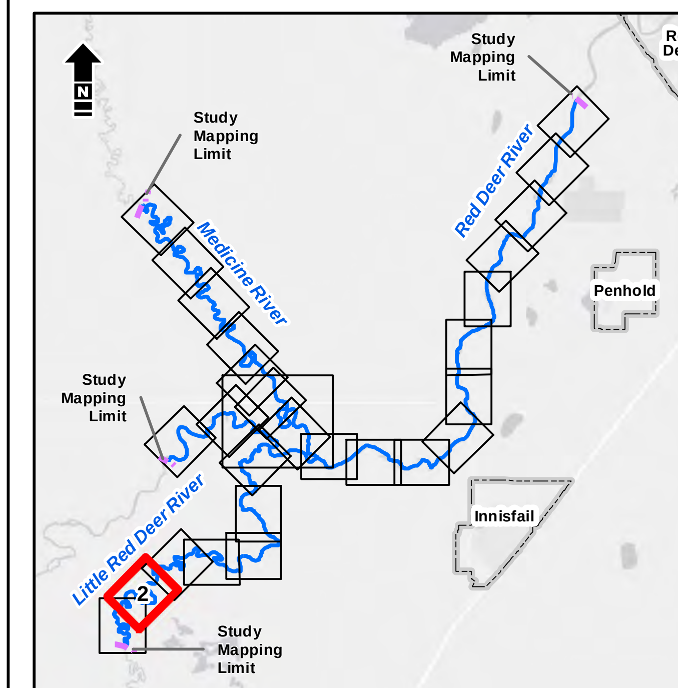
100 Year Inundation Extent



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1:10,000 Kilometers
0.1 0 0.1 0.2
NAD 1983 CSRS 3TM 114

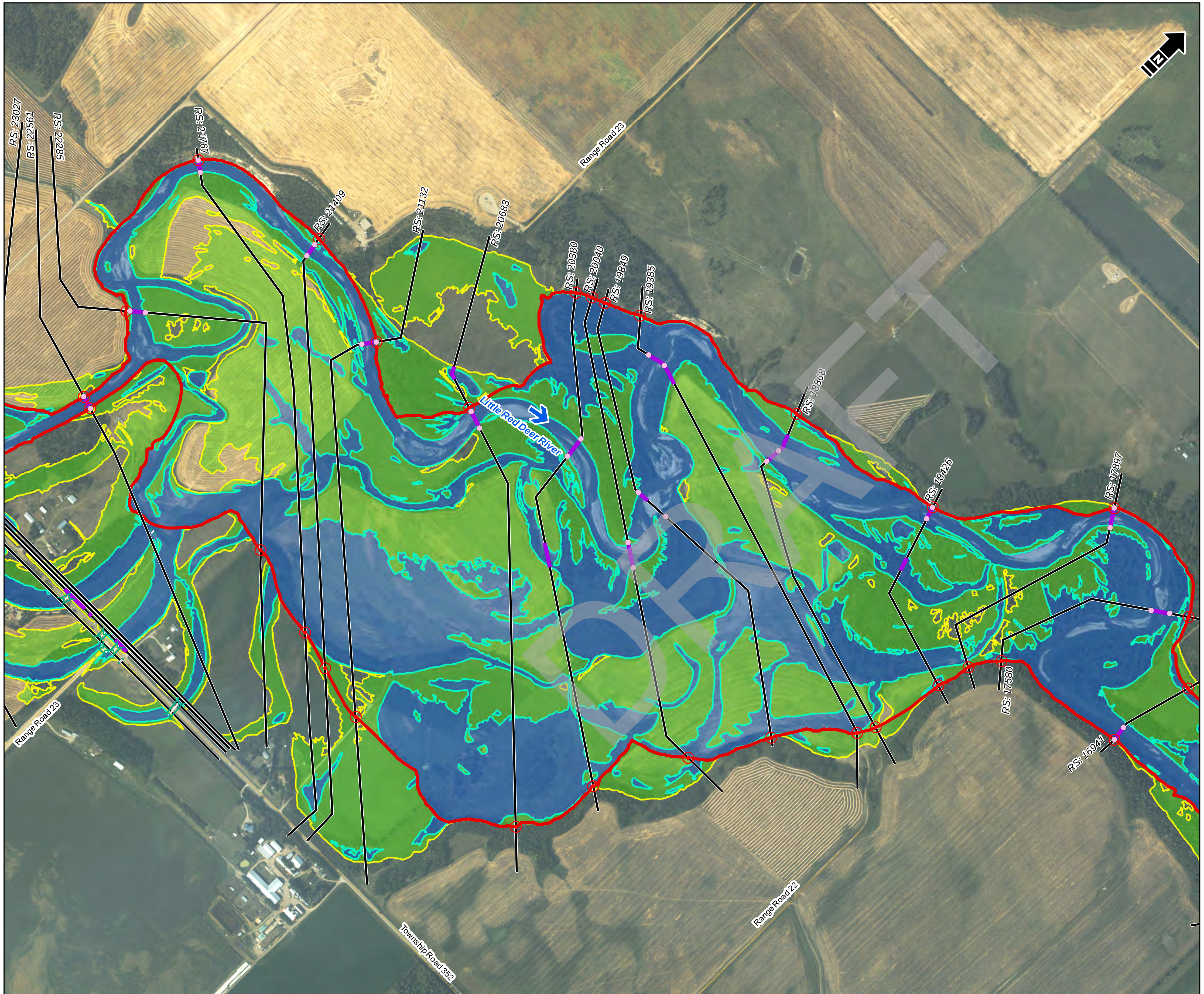
Matrix Solutions Inc.
A Montrose Environmental Company

Alberta

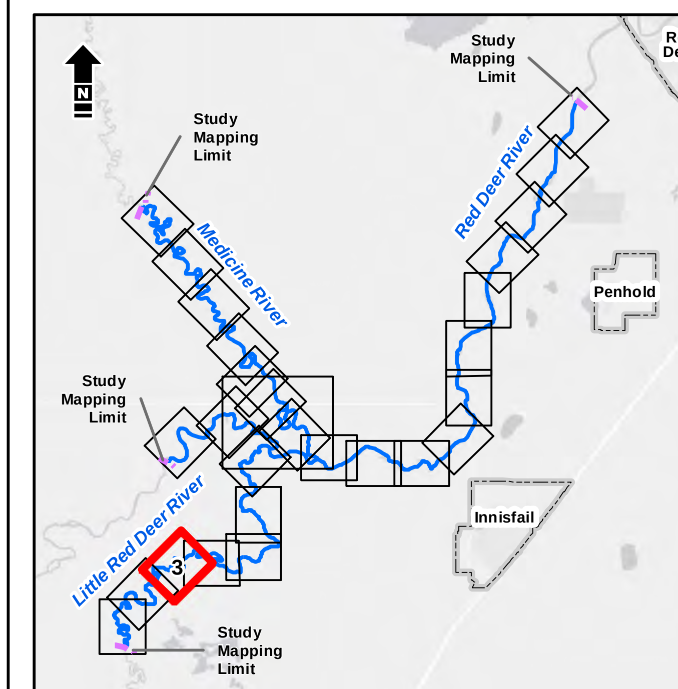
Alberta Environment and Protected Areas
Red Deer County and Markerville Flood Study

Floodway Criteria Map

Date:	Project:	Submitter:	Reviewer:
March 2024	35374	P. Rogers	M. Shome



Bridge
Culvert
Cross Section Line
Study Mapping Limit
Major Road
Local Road
Flow Direction
Bank Station
Proposed Floodway Station
Previous Floodway
Proposed Floodway Boundary
100 Year Inundation - ≥1 m/s Velocity
100 Year Inundation Extent - ≥1 m Depth
100 Year Inundation Extent



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1:10,000 Kilometers
0.1 0 0.1 0.2
NAD 1983 CSRS 3TM 114

Matrix Solutions Inc.
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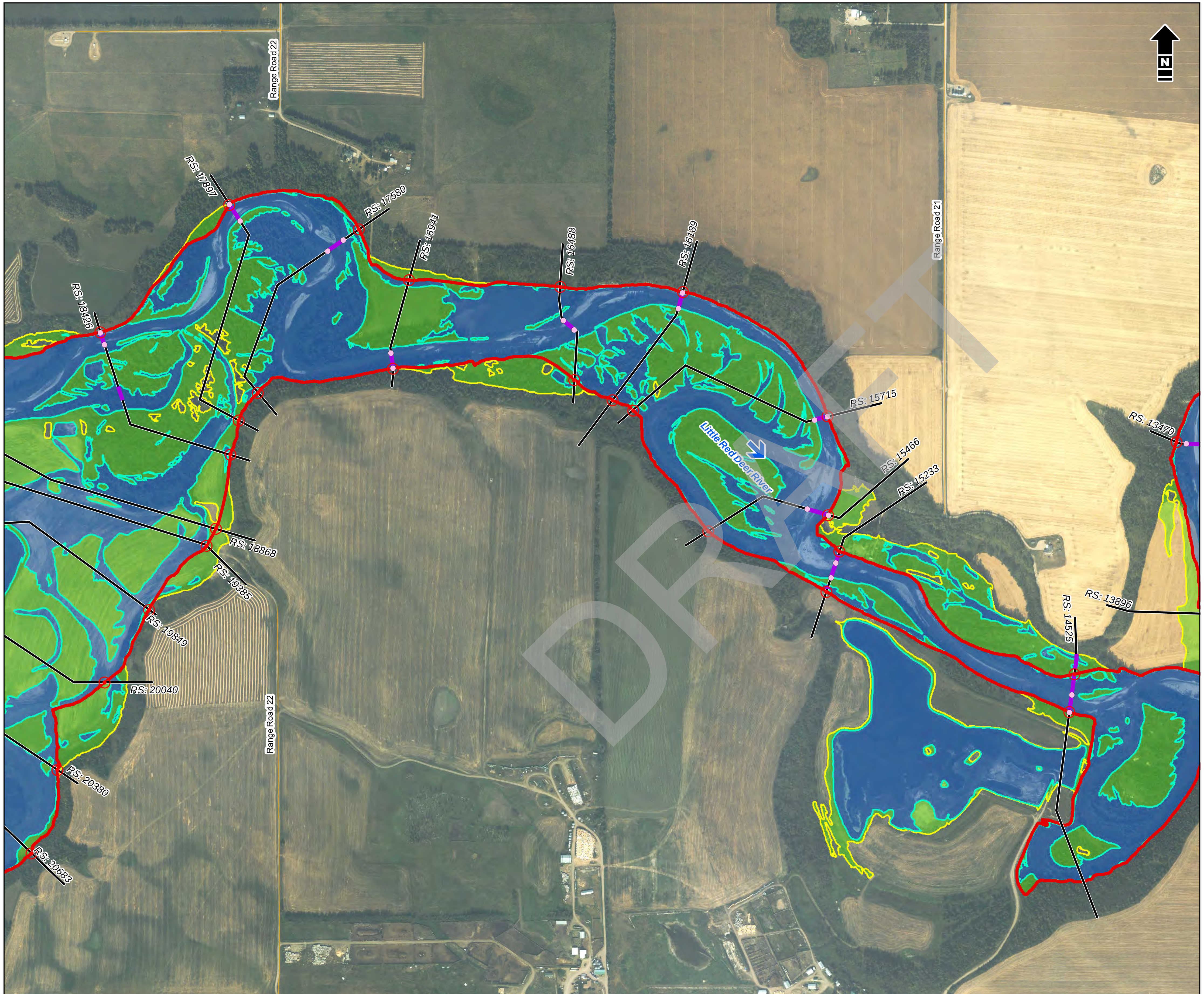
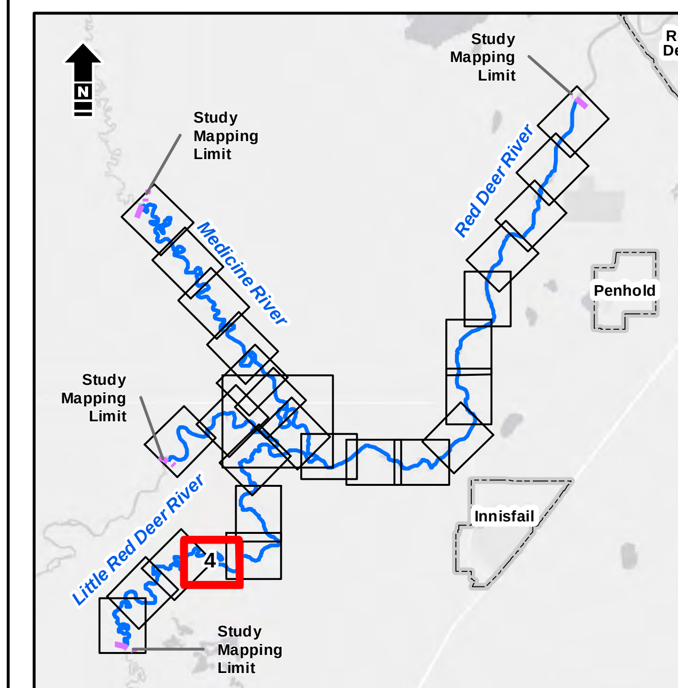
Alberta Environment and Protected Areas
Red Deer County and Markerville Flood Study

Floodway Criteria Map

Date:	Project:	Submitter:	Reviewer:
March 2024	35374	P. Rogers	M. Shome



- Bridge
- Culvert
- Cross Section Line
- Study Mapping Limit
- Major Road
- Local Road
- Flow Direction
- Bank Station
- Proposed Floodway Station
- Previous Floodway
- Proposed Floodway Boundary
- 100 Year Inundation - ≥1 m/s Velocity
- 100 Year Inundation Extent - ≥1 m Depth
- 100 Year Inundation Extent



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1:10,000 Kilometers
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NAD 1983 CSRS 3TM 114

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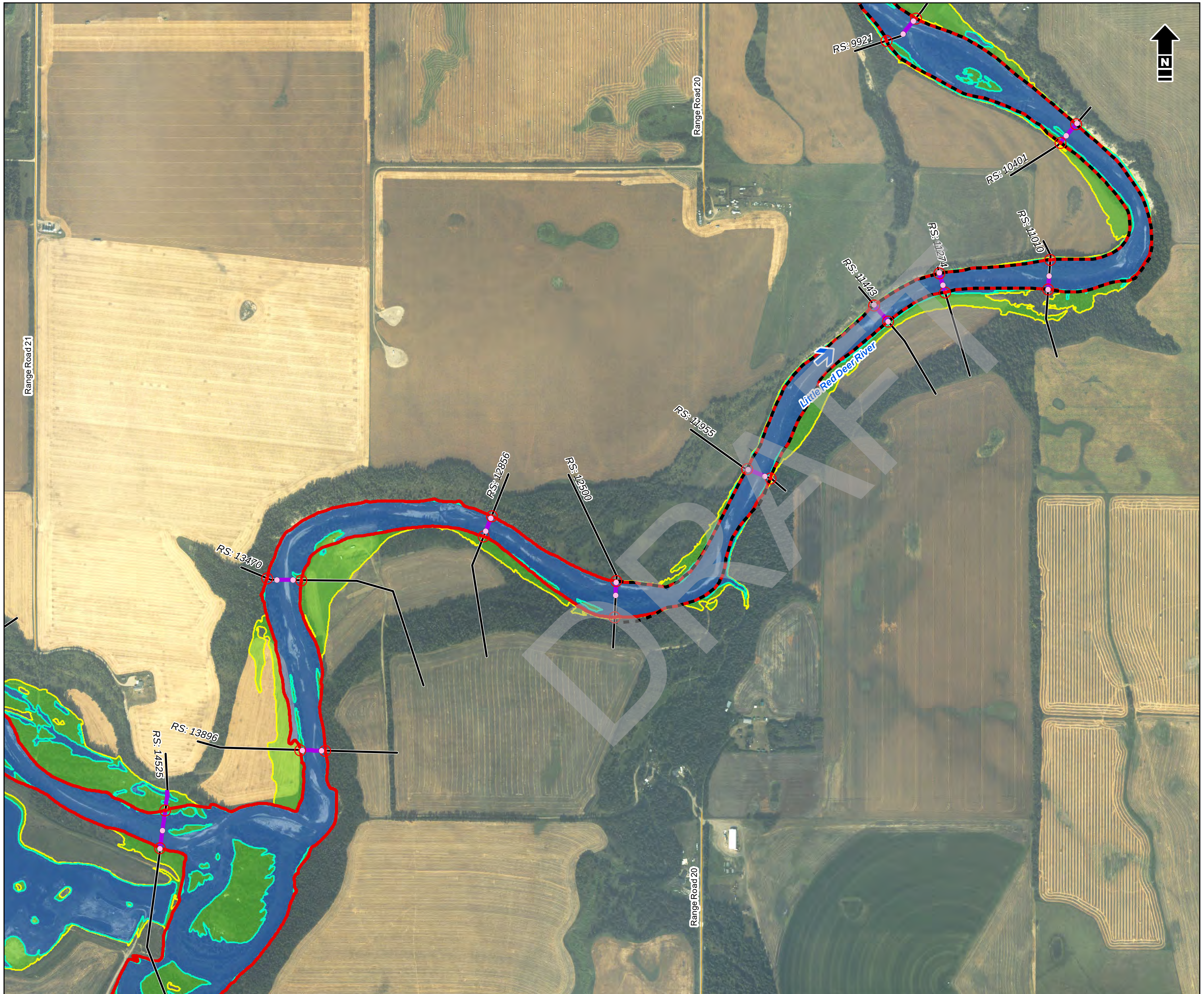
Alberta

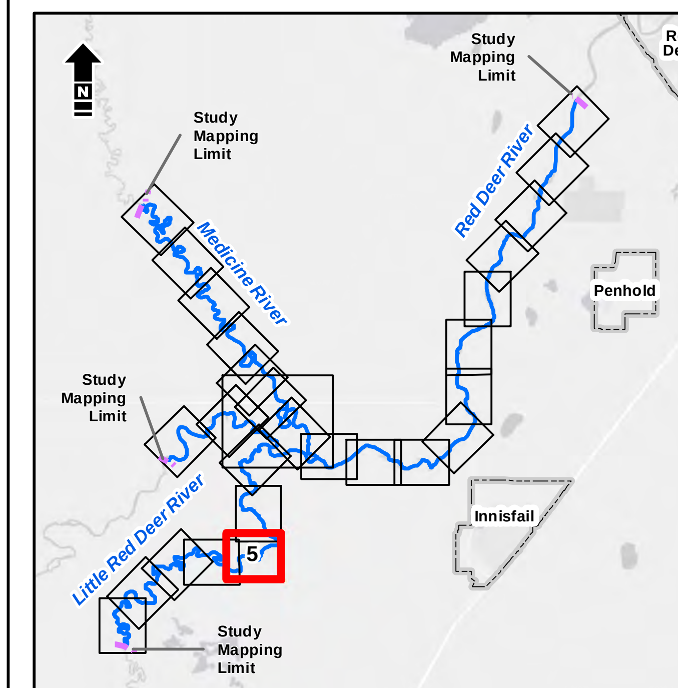
Alberta Environment and Protected Areas
Red Deer County and Markerville Flood Study

Floodway Criteria Map

Date:	Project:	Submitter:	Reviewer:
March 2024	35374	P. Rogers	M. Shome



- Bridge
- Culvert
- Cross Section Line
- Study Mapping Limit
- Major Road
- Local Road
- Flow Direction
- Bank Station
- Proposed Floodway Station
- Previous Floodway
- Proposed Floodway Boundary
- 100 Year Inundation - ≥1 m/s Velocity
- 100 Year Inundation Extent - ≥1 m Depth
- 100 Year Inundation Extent



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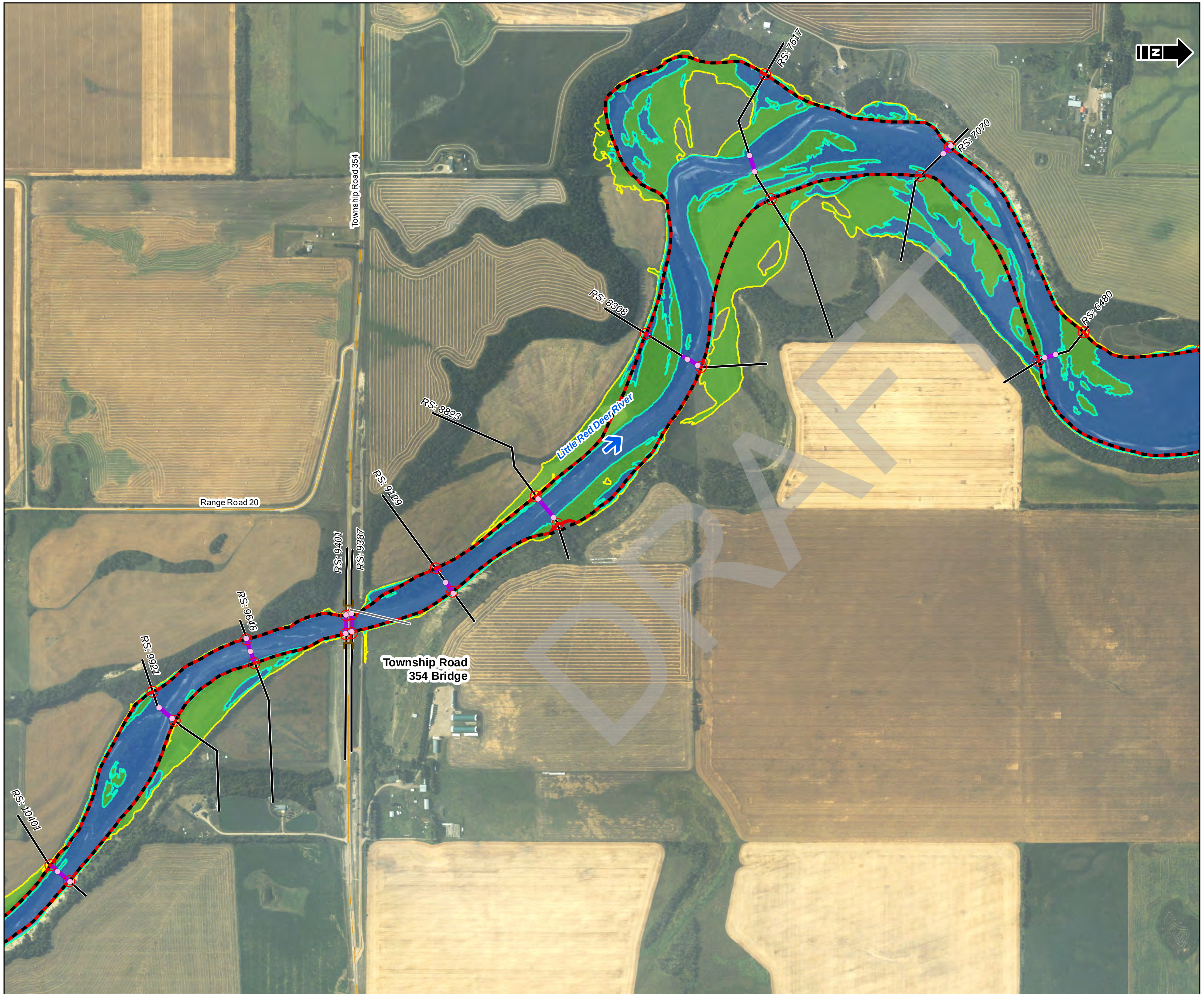

Bridge
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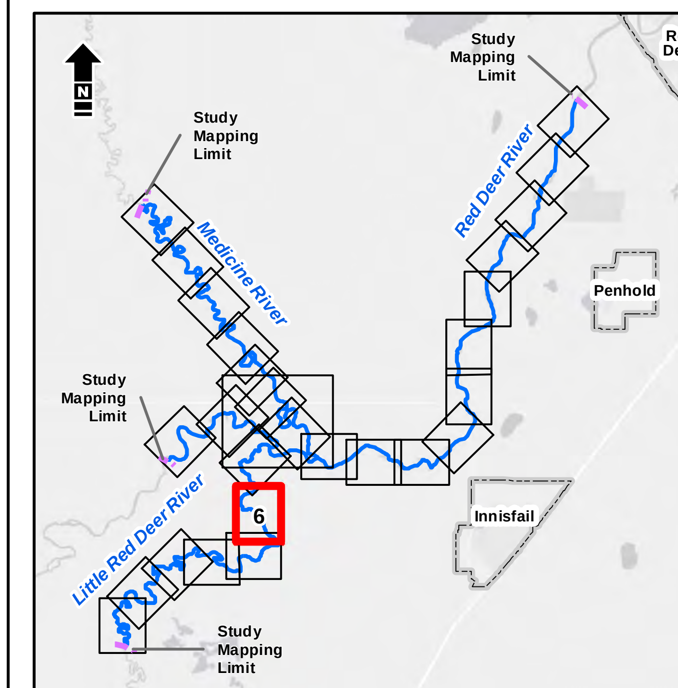

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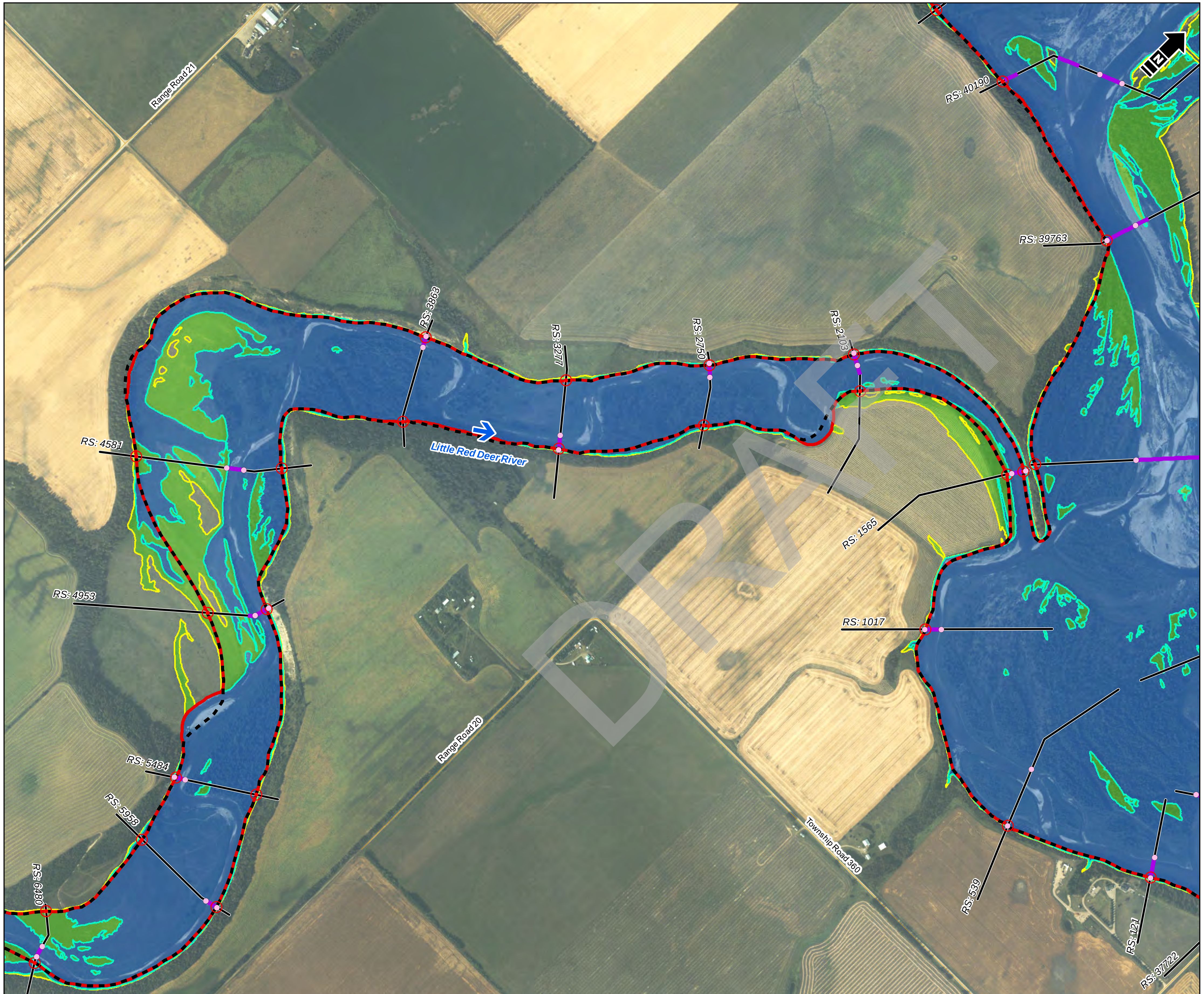

Bridge
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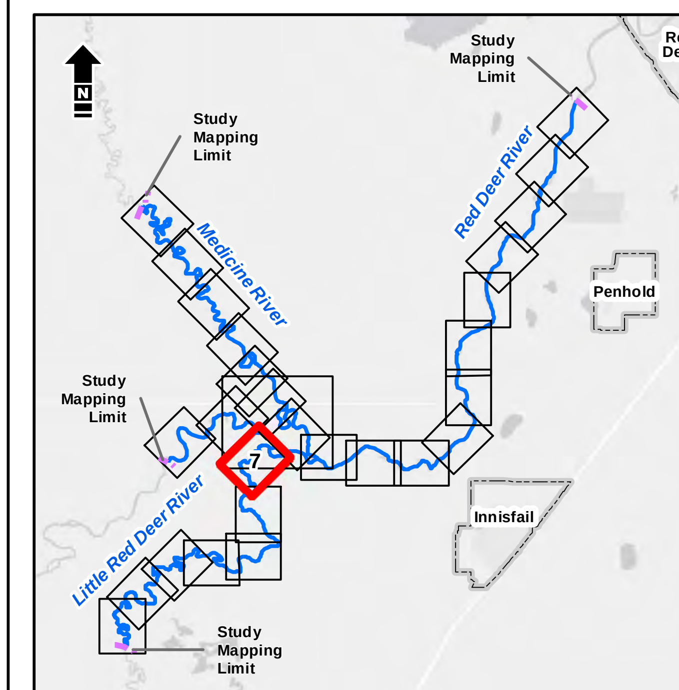

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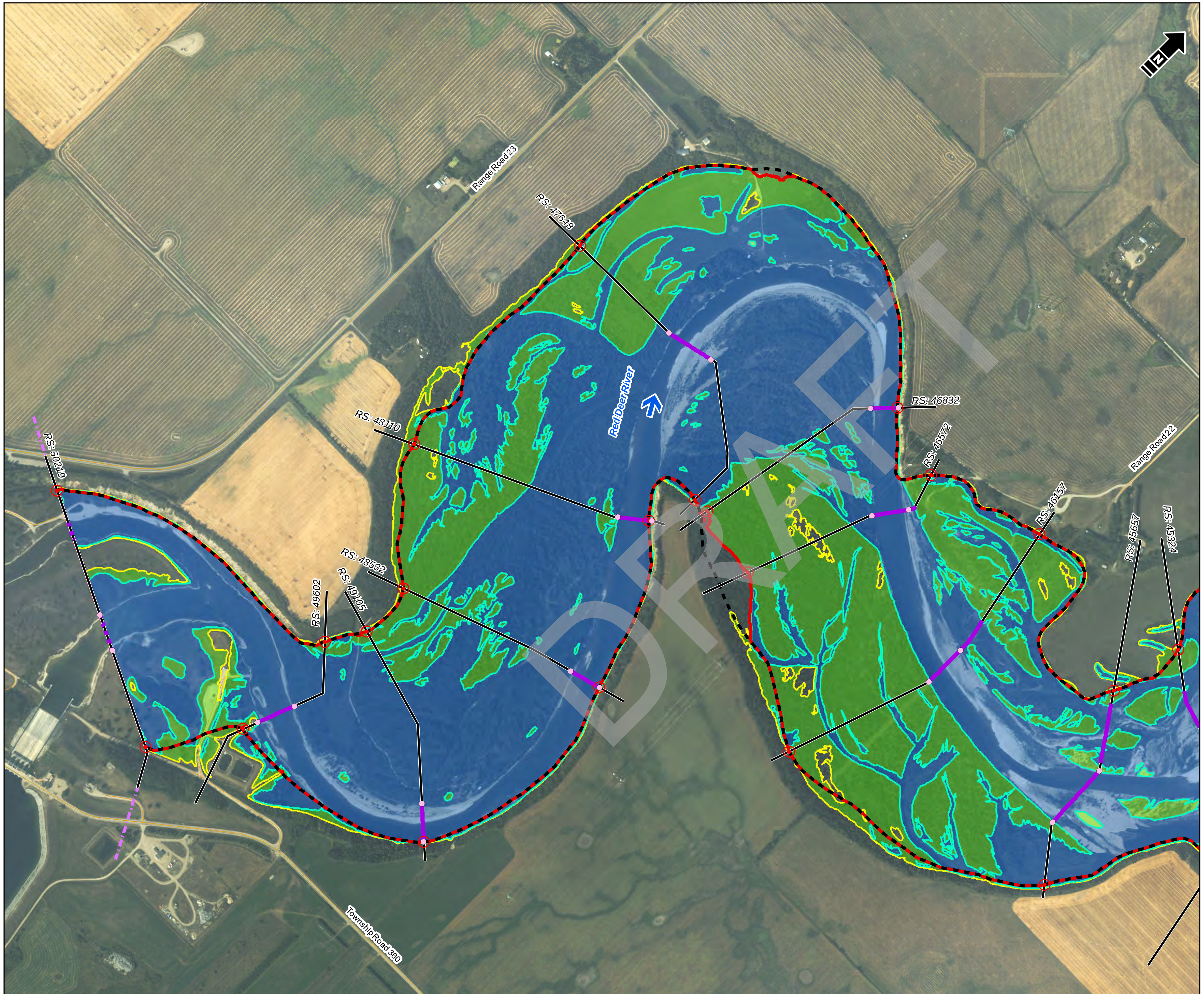

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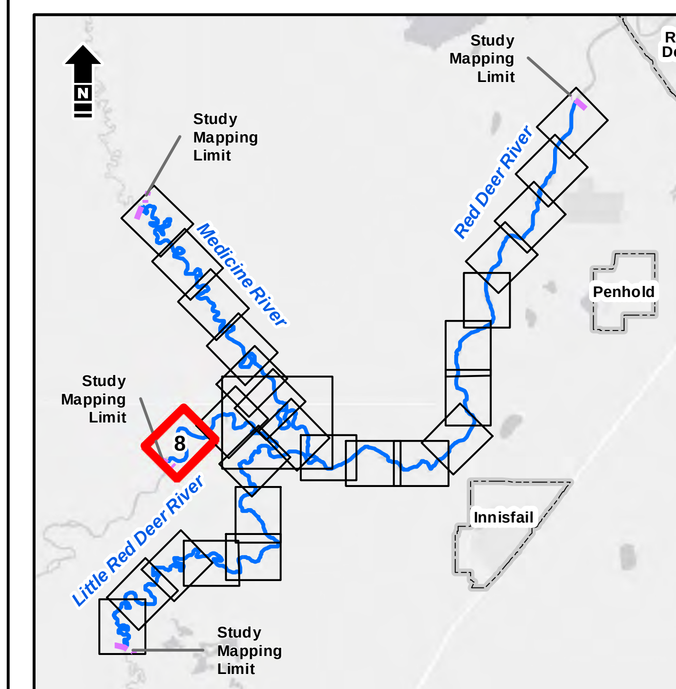

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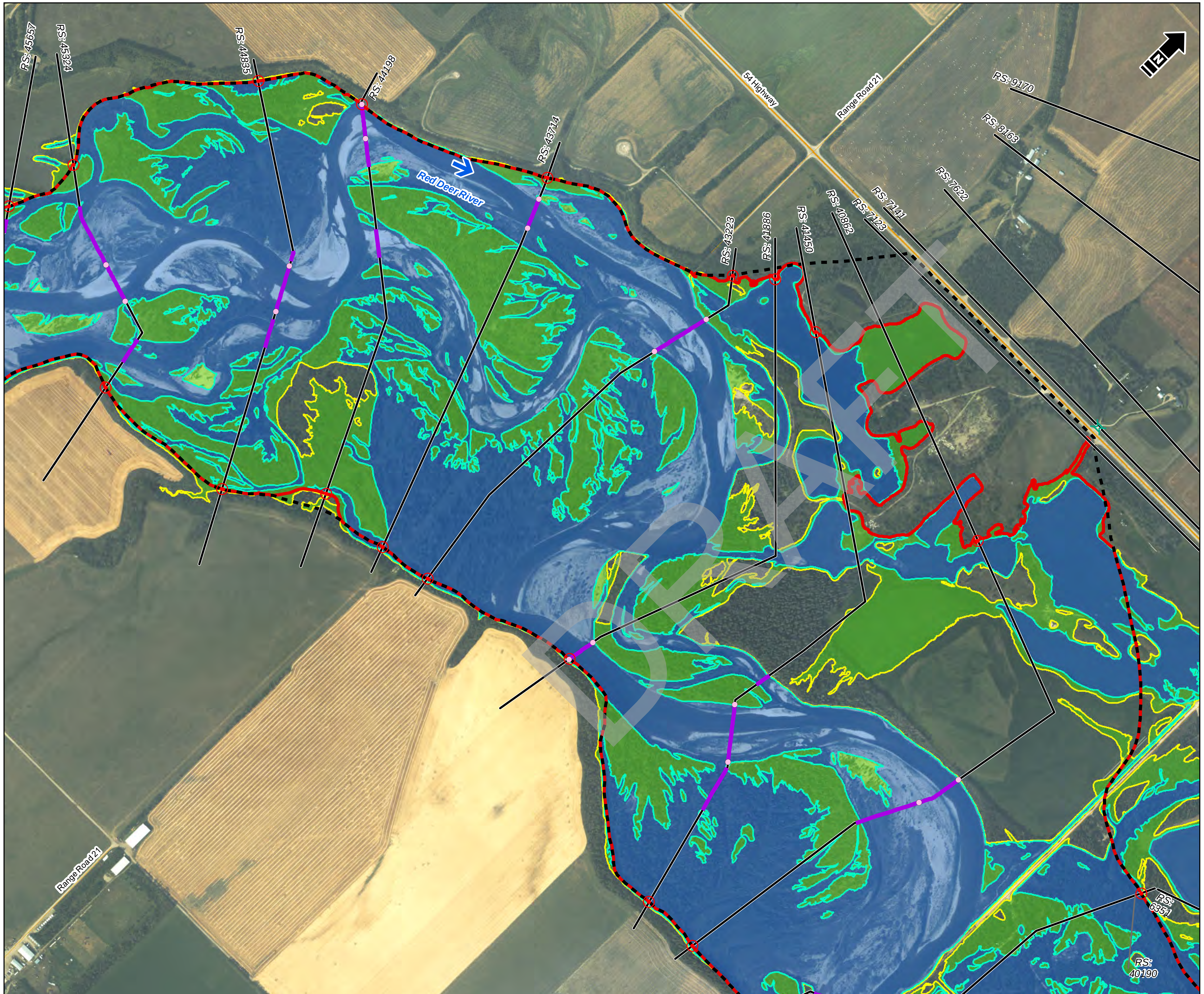

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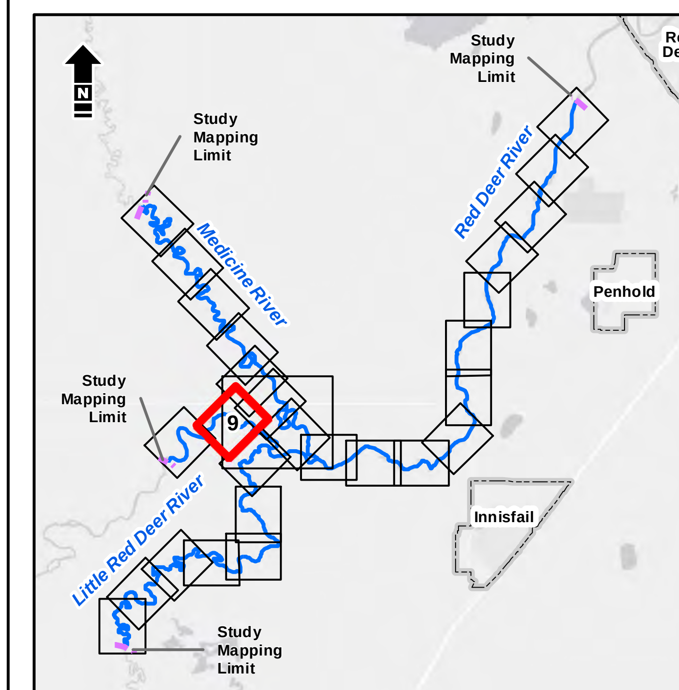

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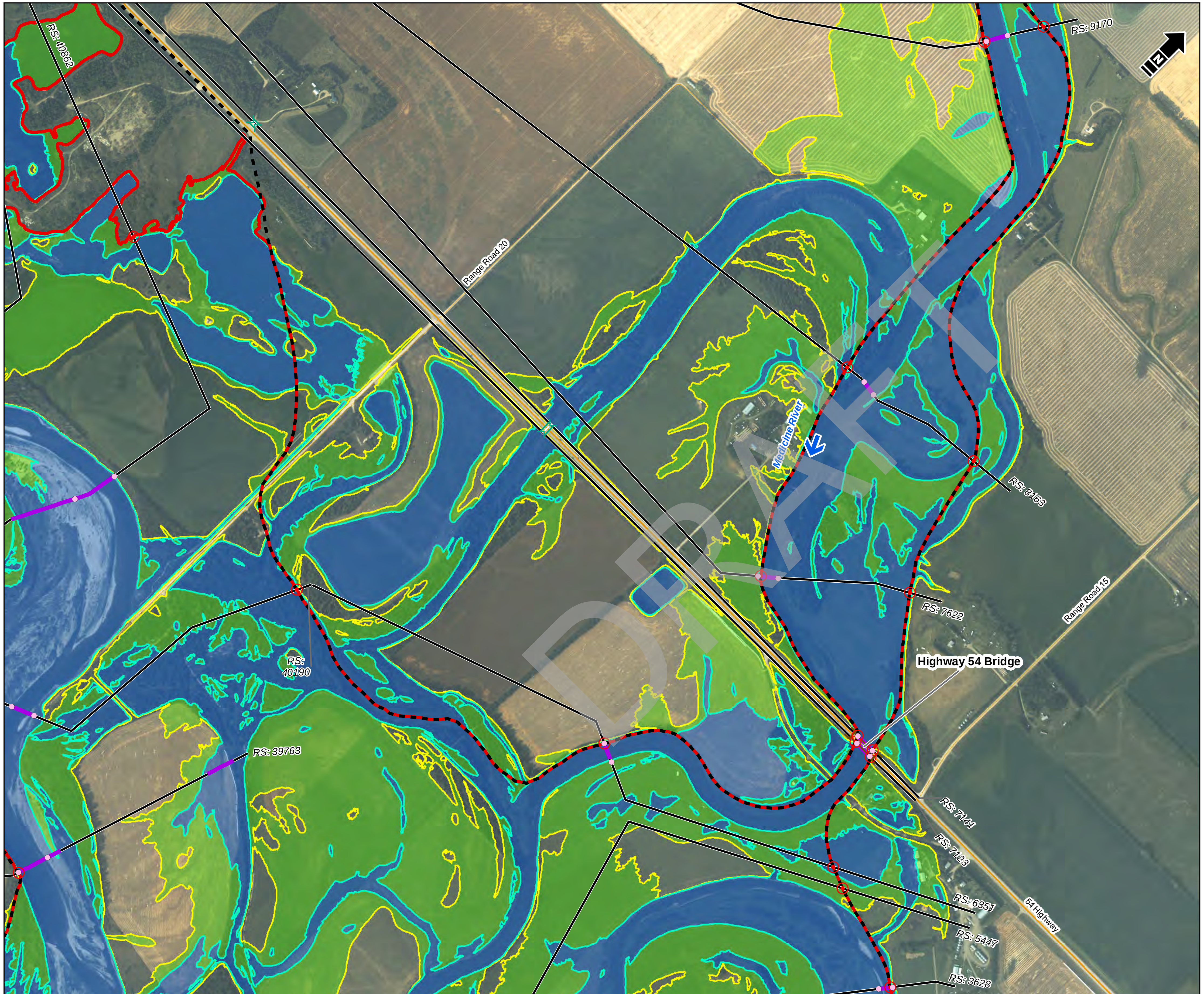

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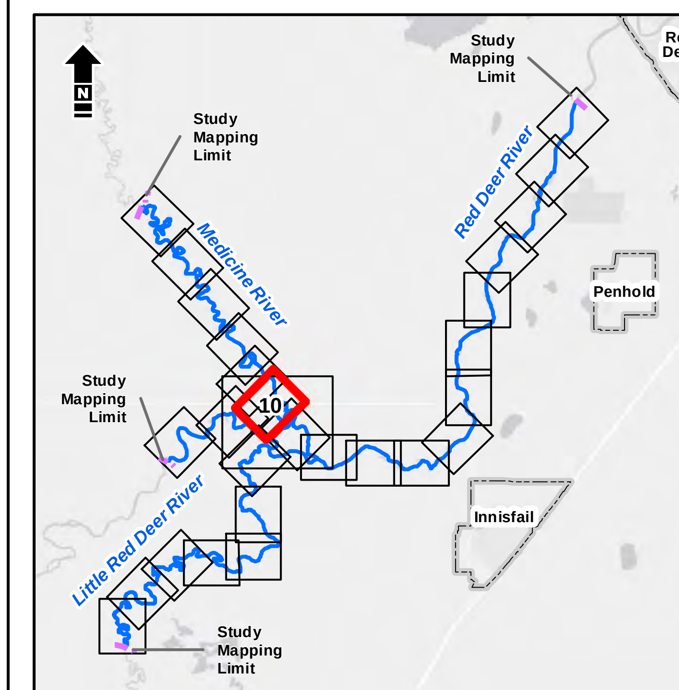

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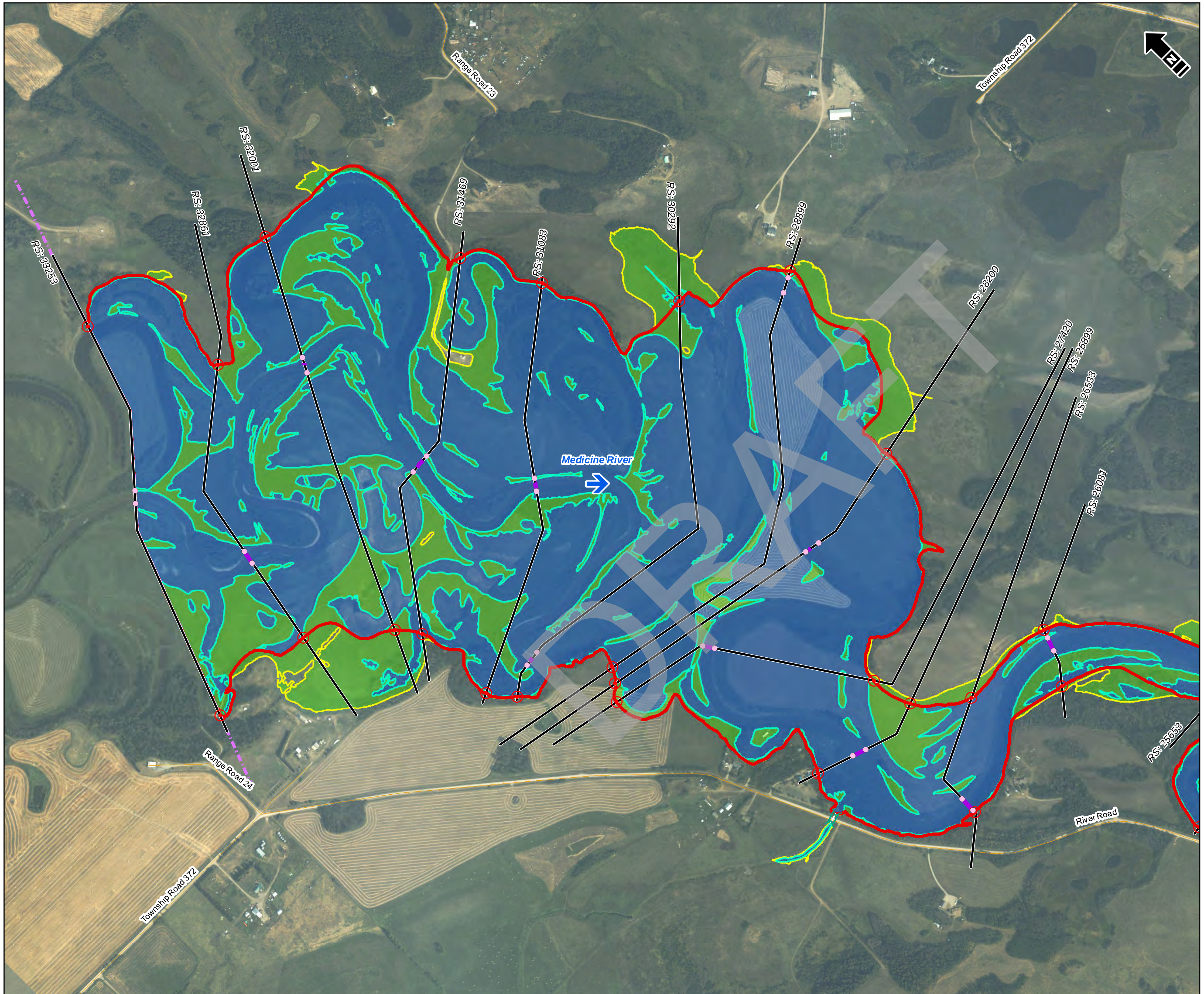

- Bridge
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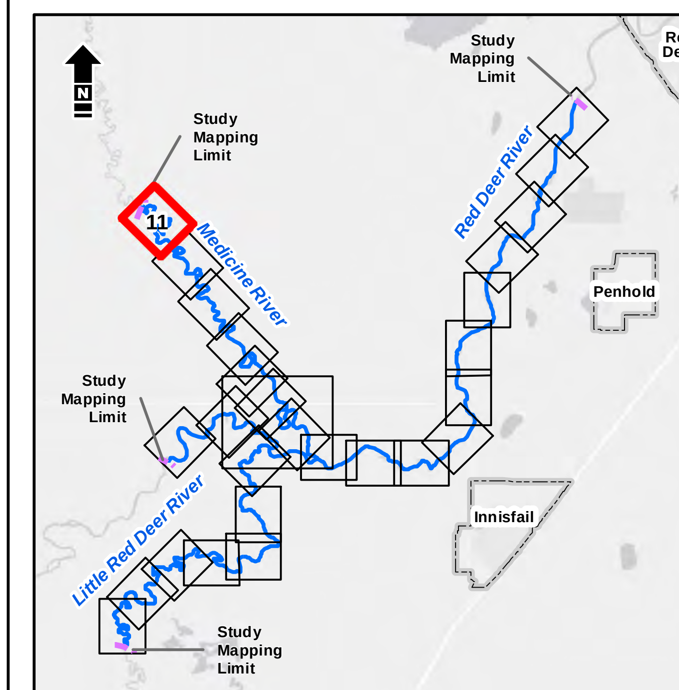

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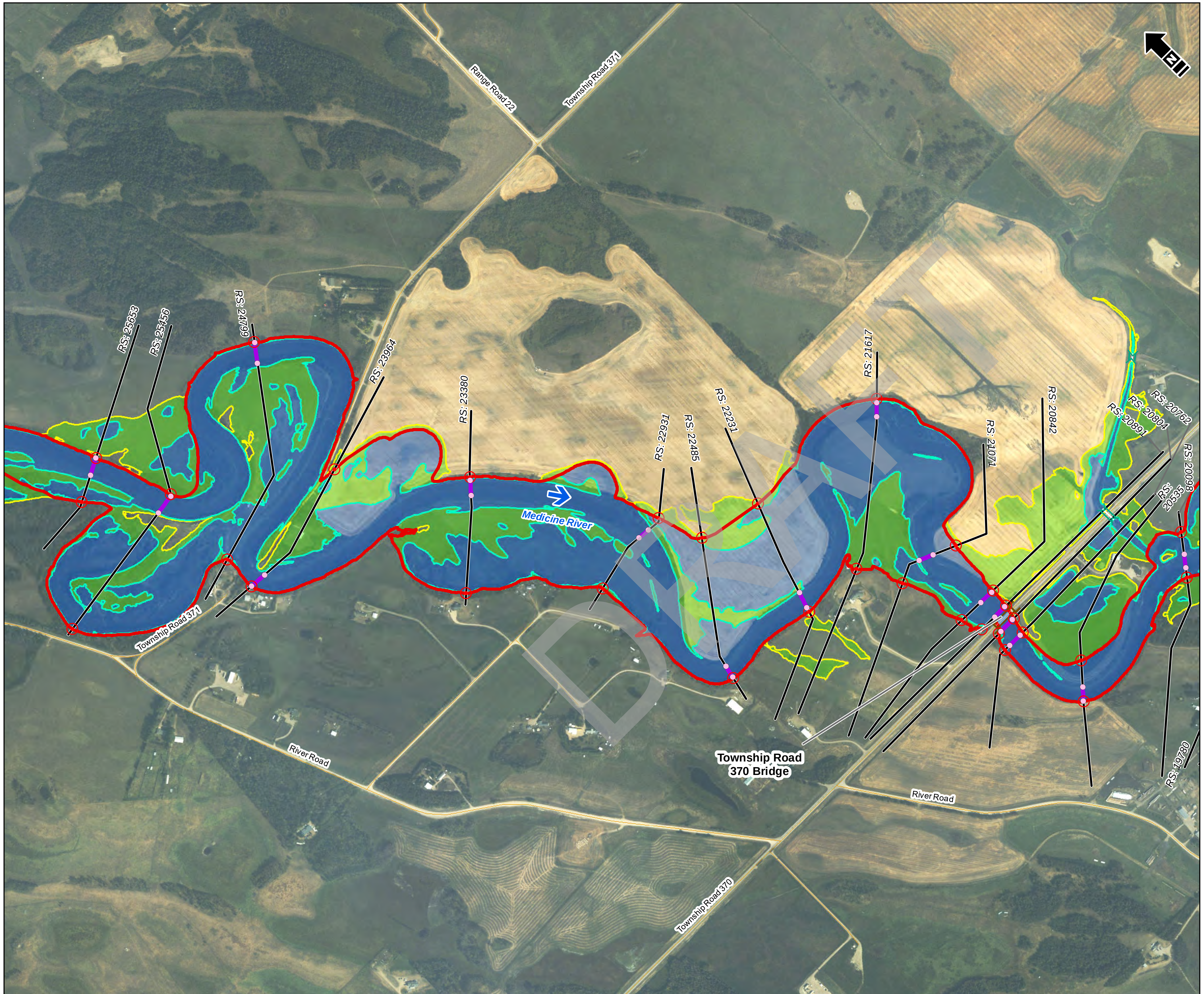

Bridge
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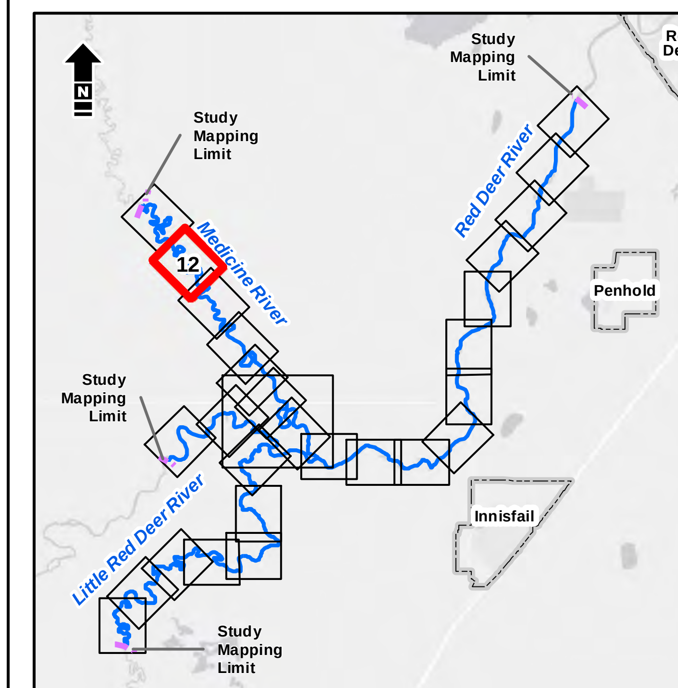

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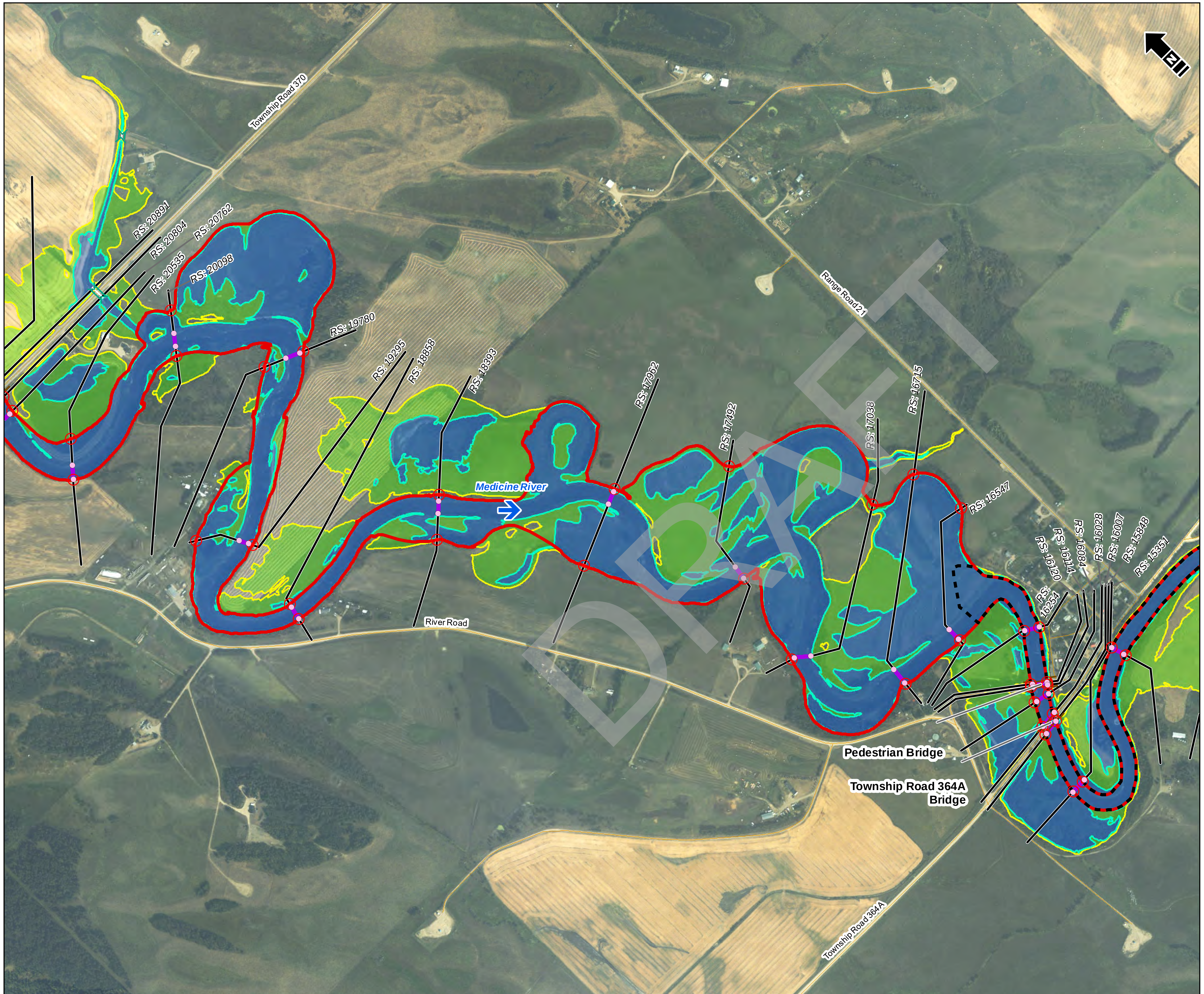
Date: March 2024	Project: 35374	Submitter: P. Rogers	Reviewer: M. Shome

Classification: Public



Bridge
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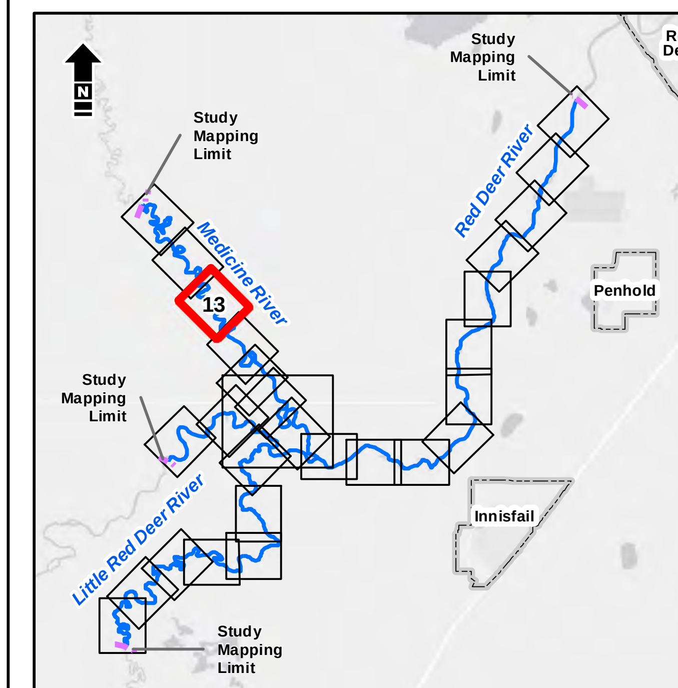

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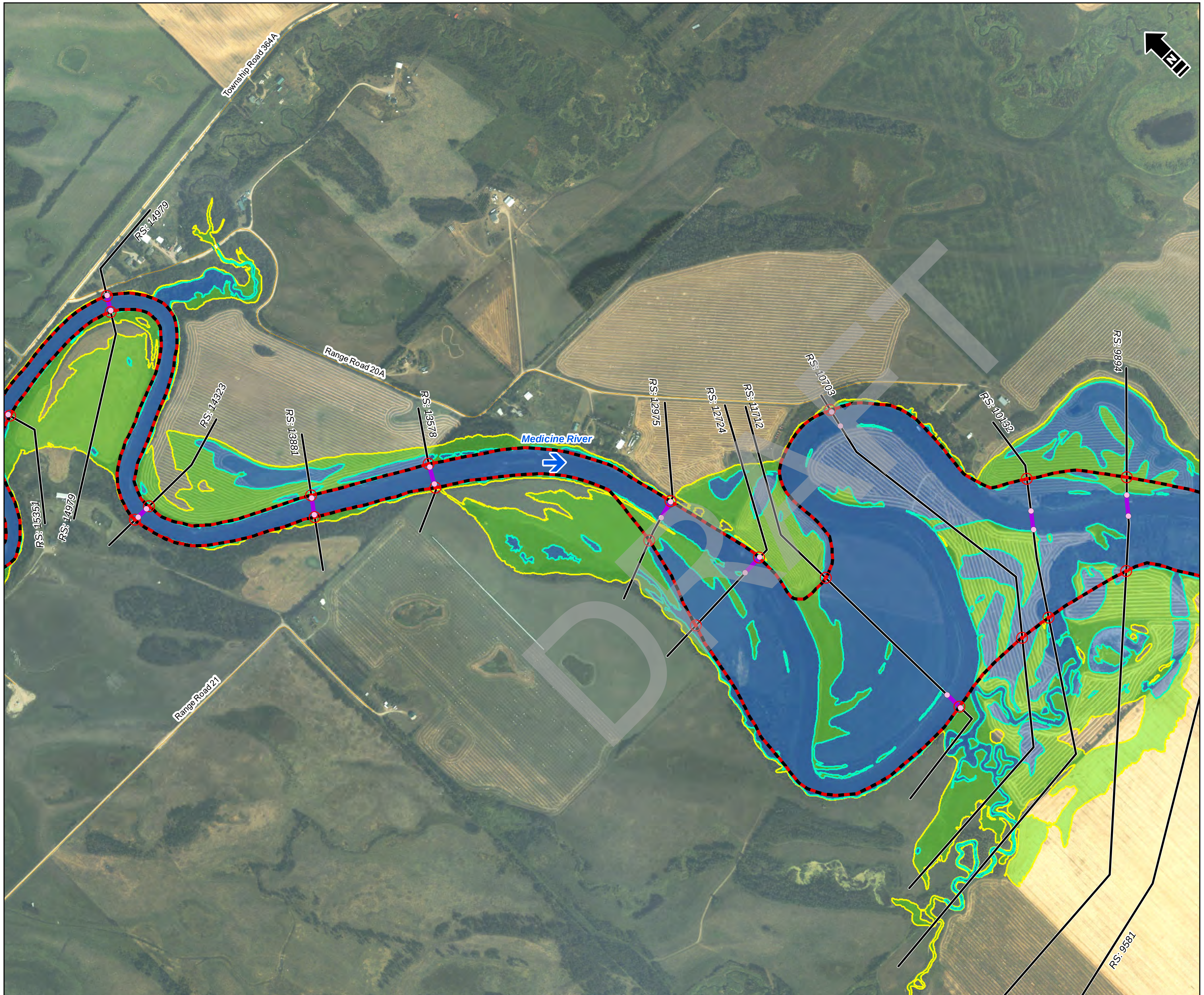

Bridge
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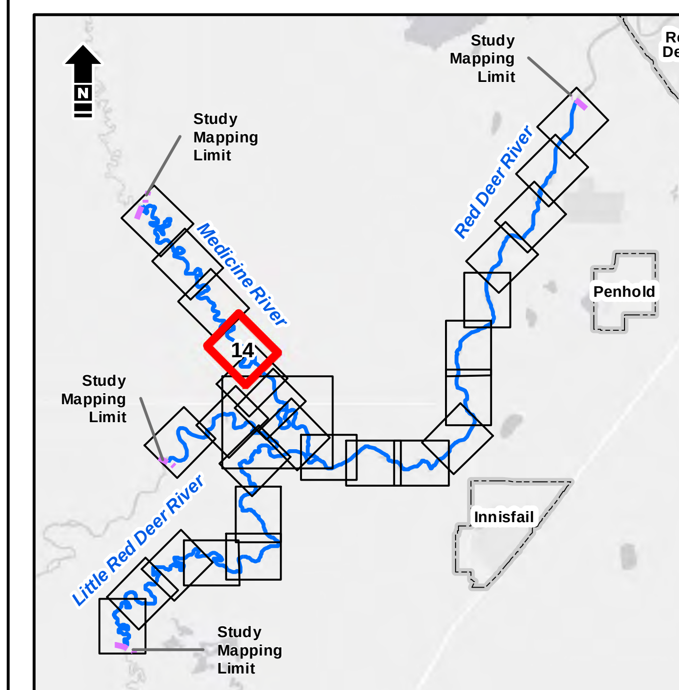

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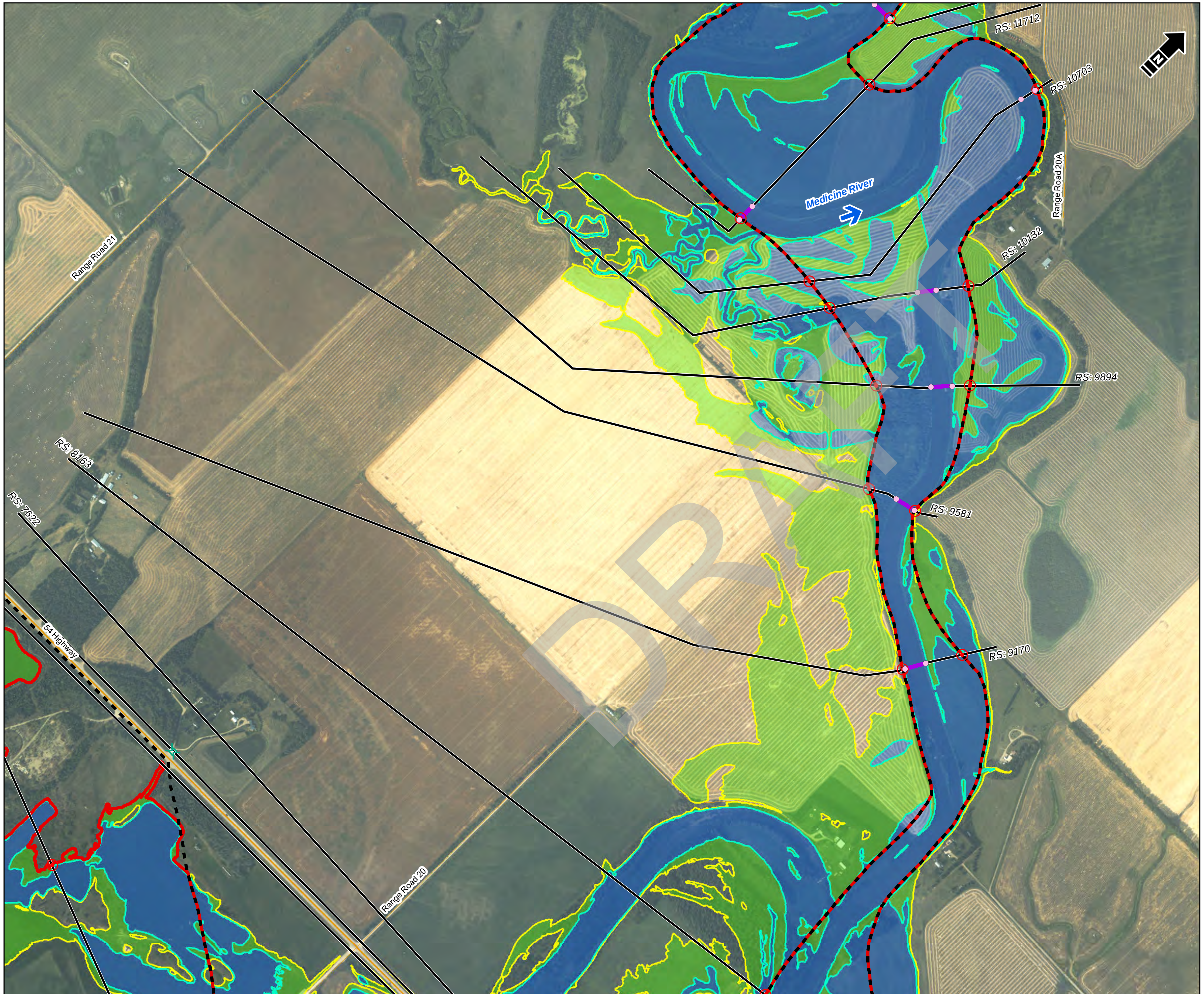

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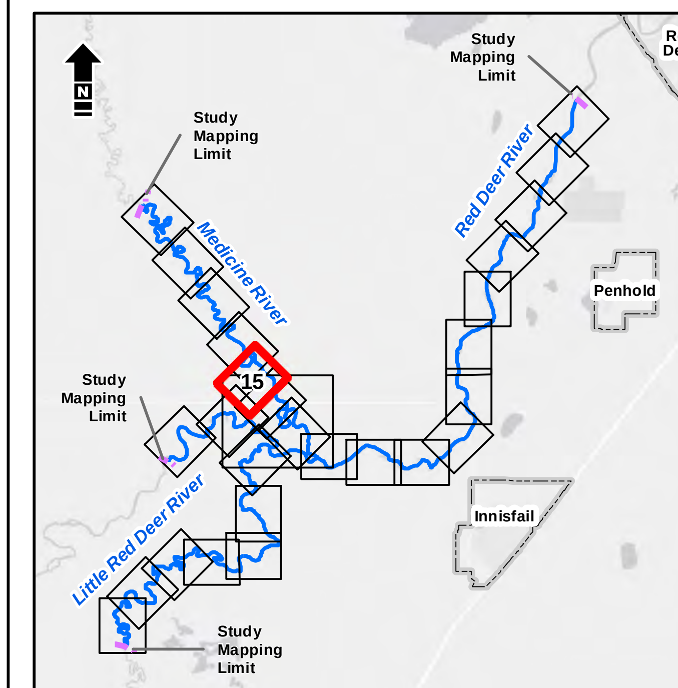

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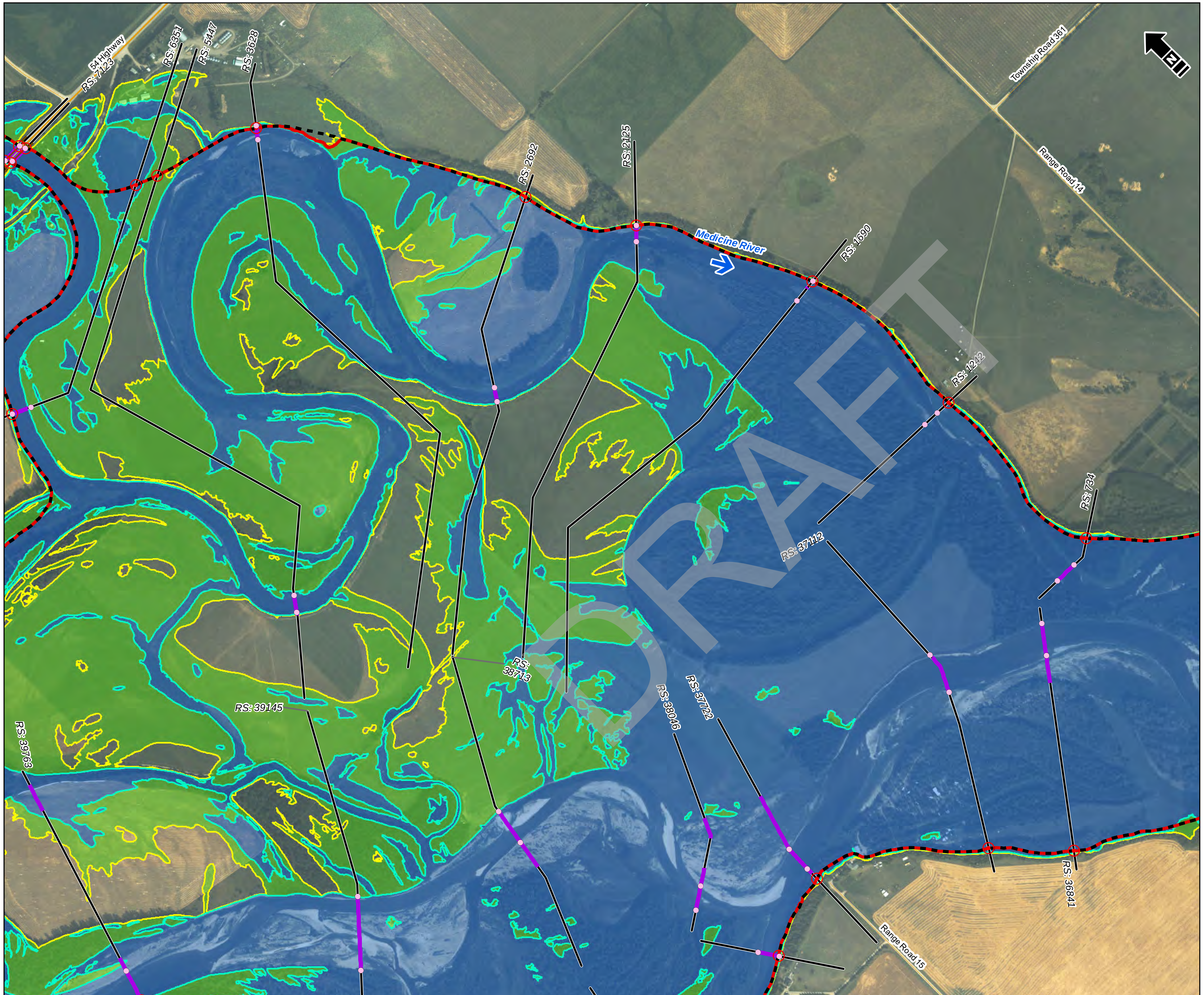

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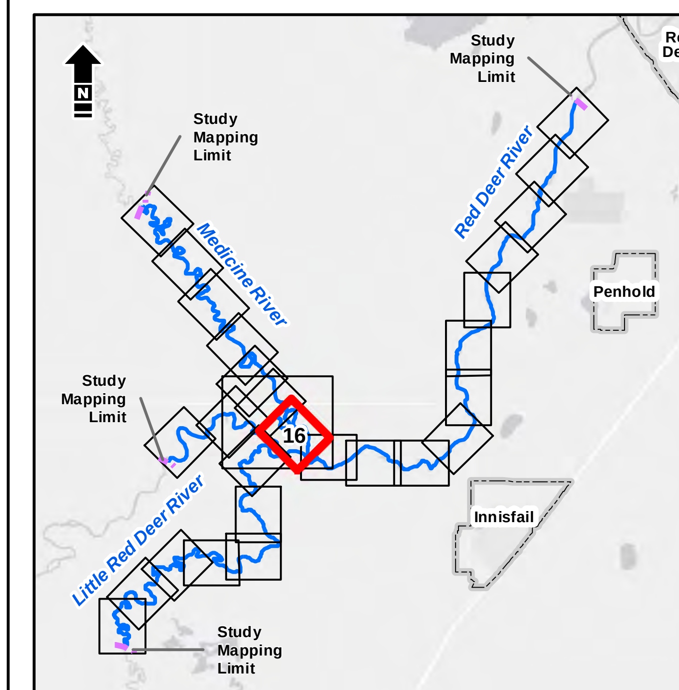

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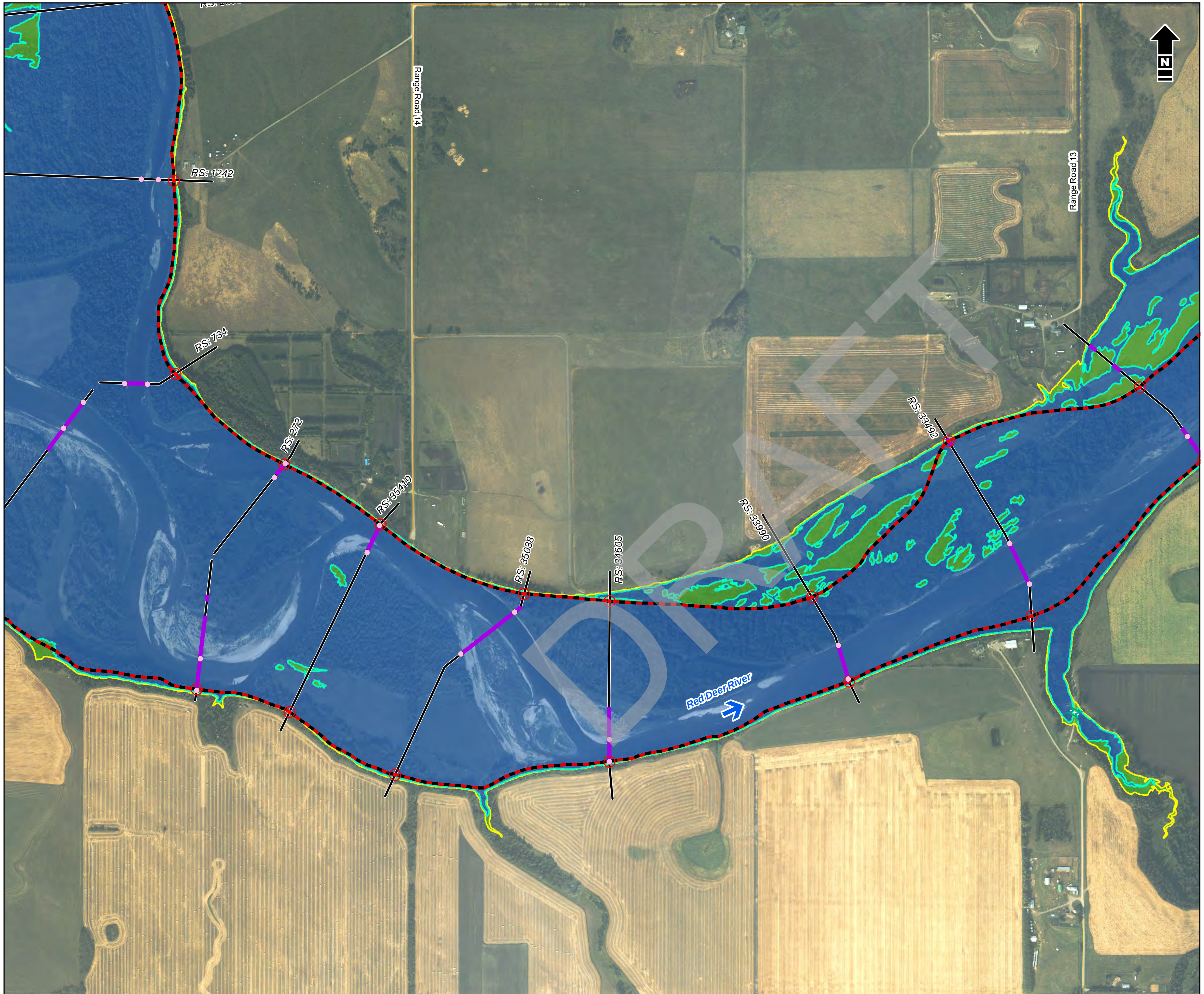

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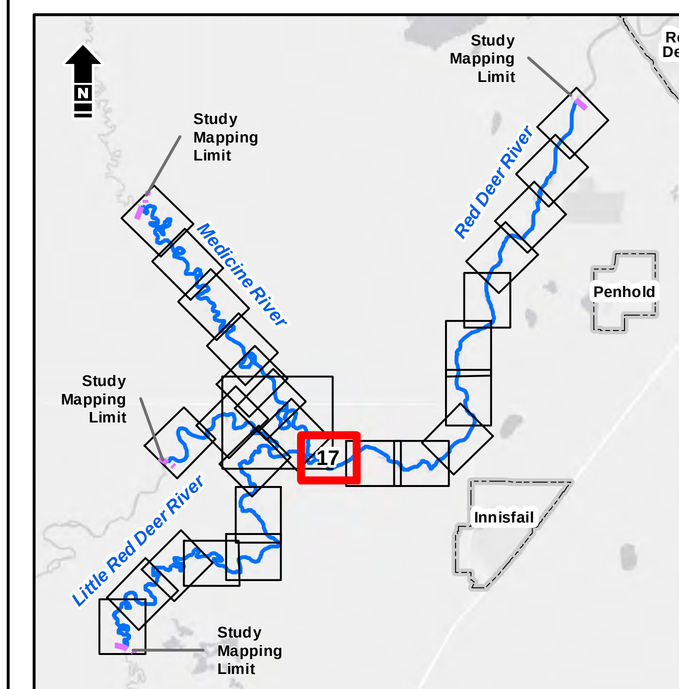

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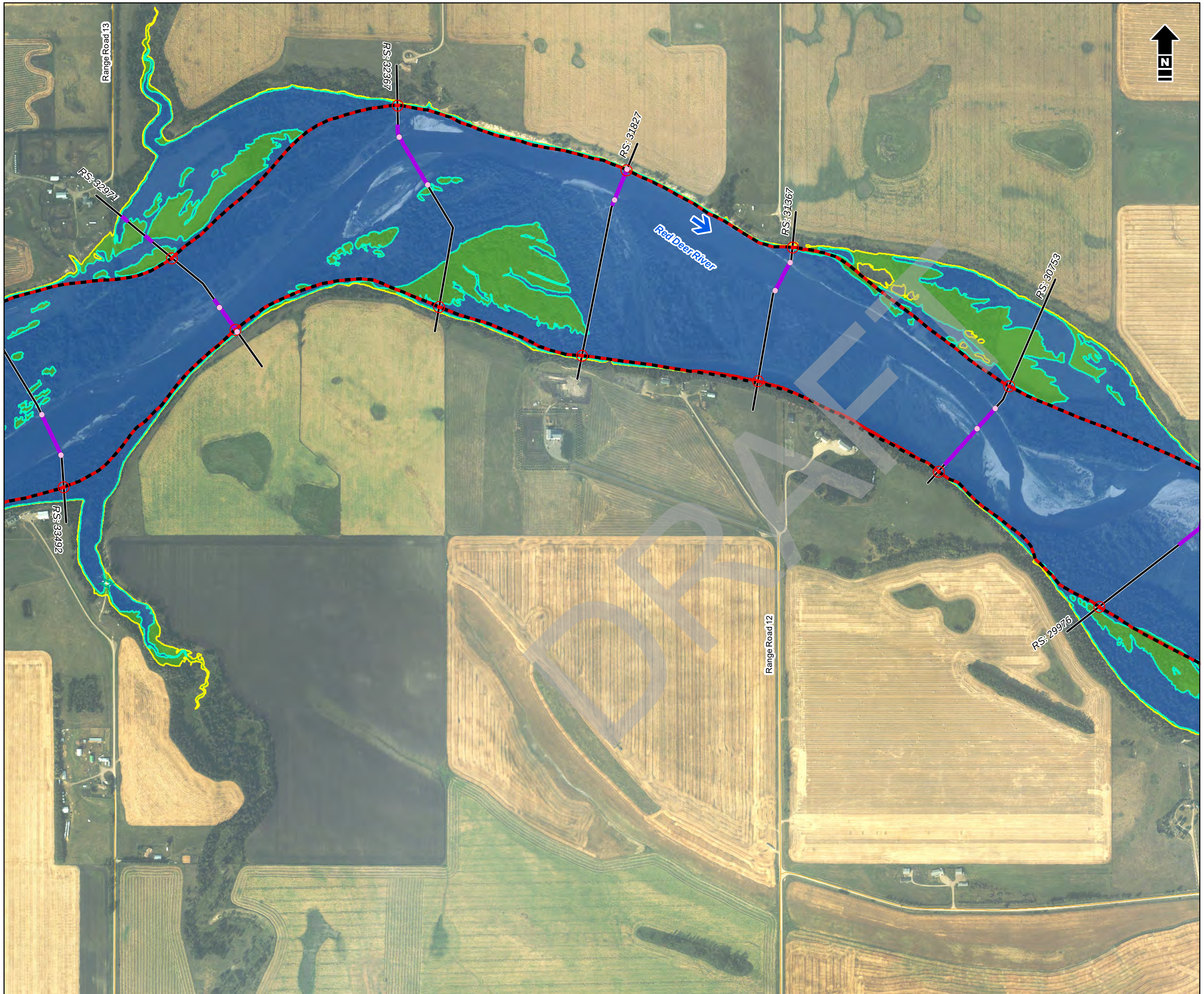

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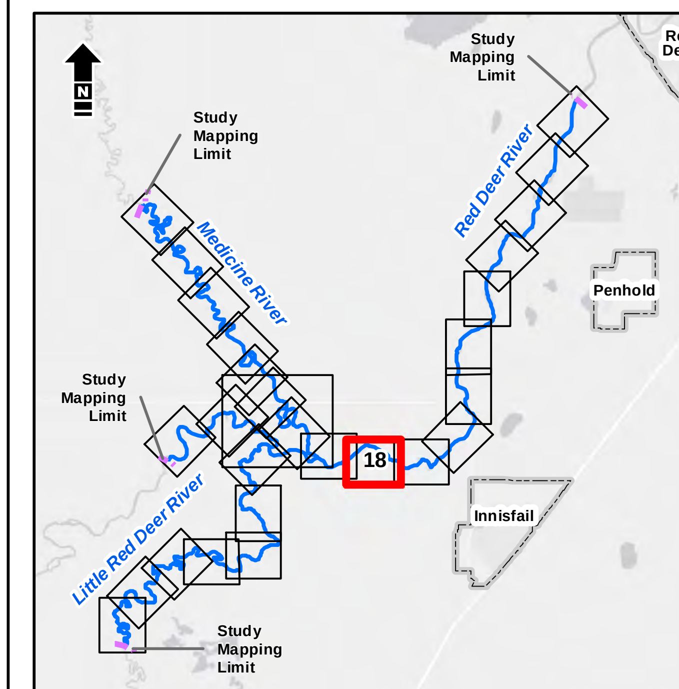

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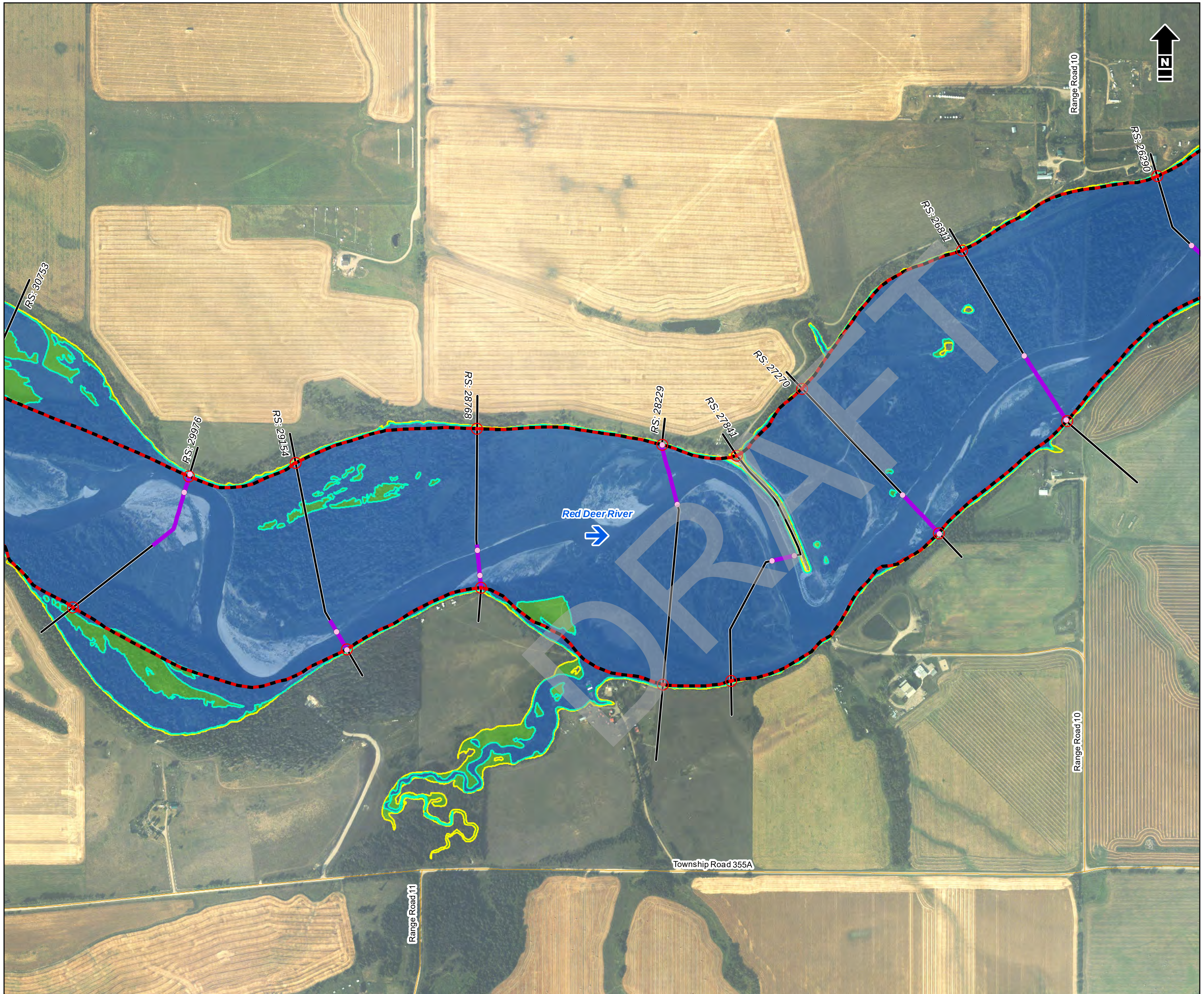

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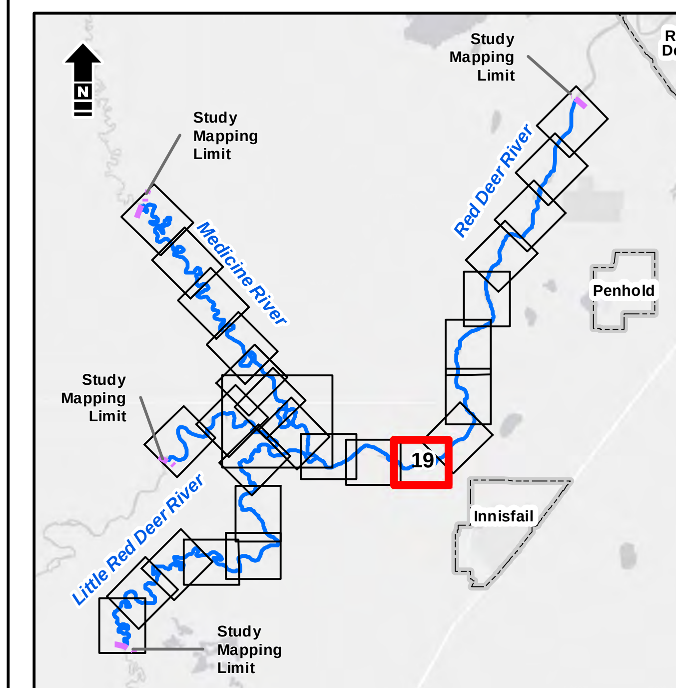

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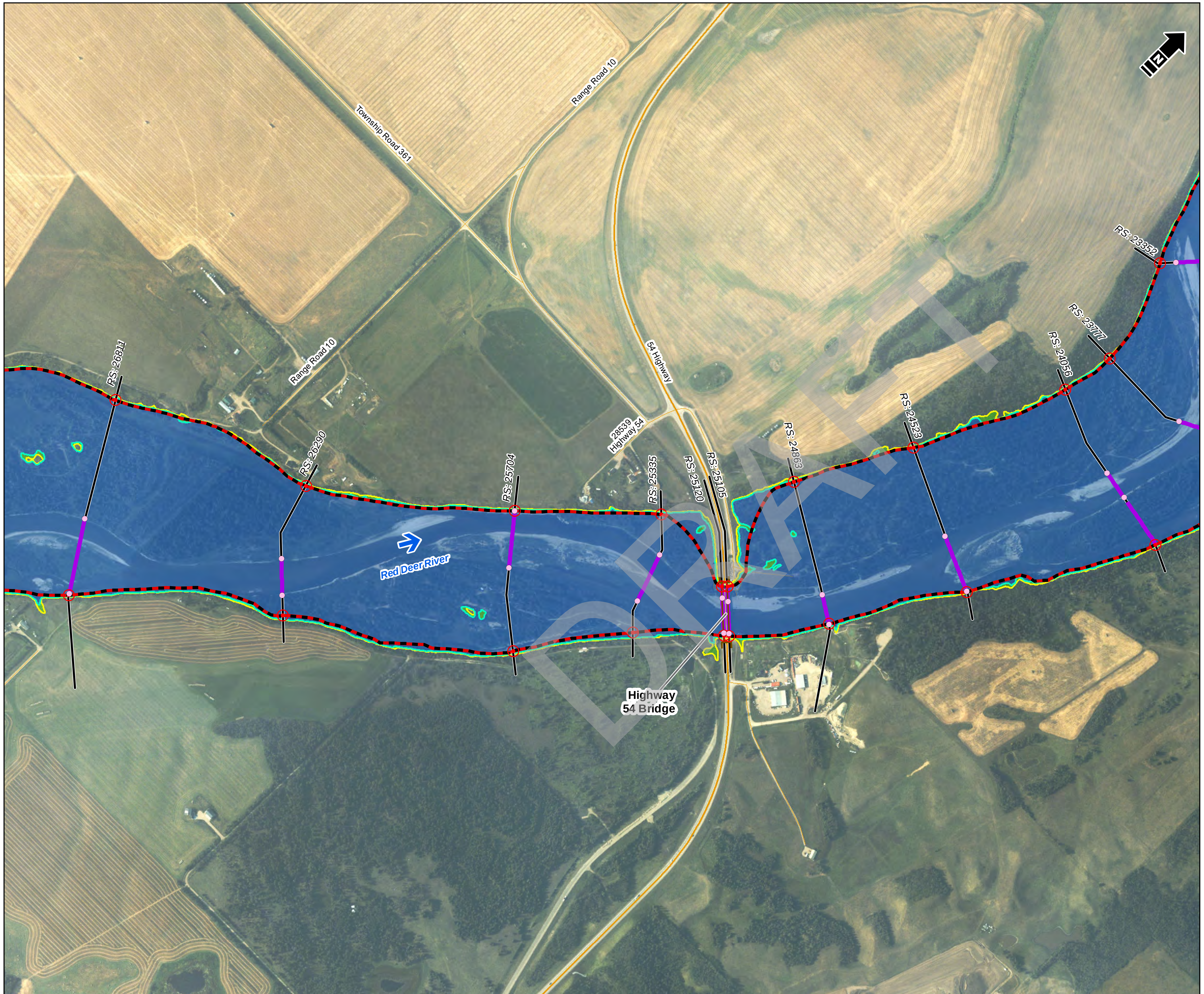
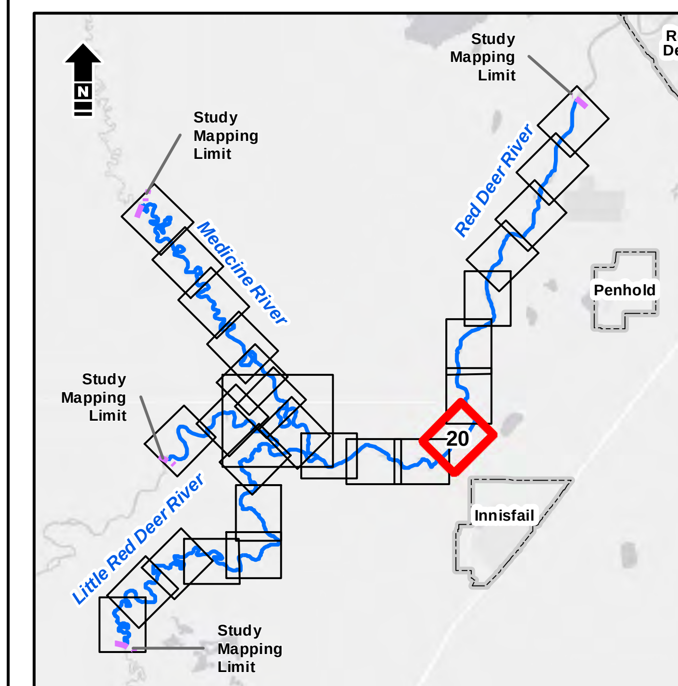


Bridge
Culvert
Cross Section Line
Study Mapping Limit
Major Road
Local Road
Flow Direction
Bank Station
Proposed Floodway Station
Previous Floodway
Proposed Floodway Boundary
100 Year Inundation - ≥1 m/s Velocity
100 Year Inundation Extent - ≥1 m Depth
100 Year Inundation Extent



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1:10,000 Kilometers
0.1 0 0.1 0.2
NAD 1983 CSRS 3TM 114

Matrix Solutions Inc.
A Montrose Environmental Company

Alberta

Alberta Environment and Protected Areas
Red Deer County and Markerville Flood Study

Floodway Criteria Map

Date:	Project:	Submitter:	Reviewer:
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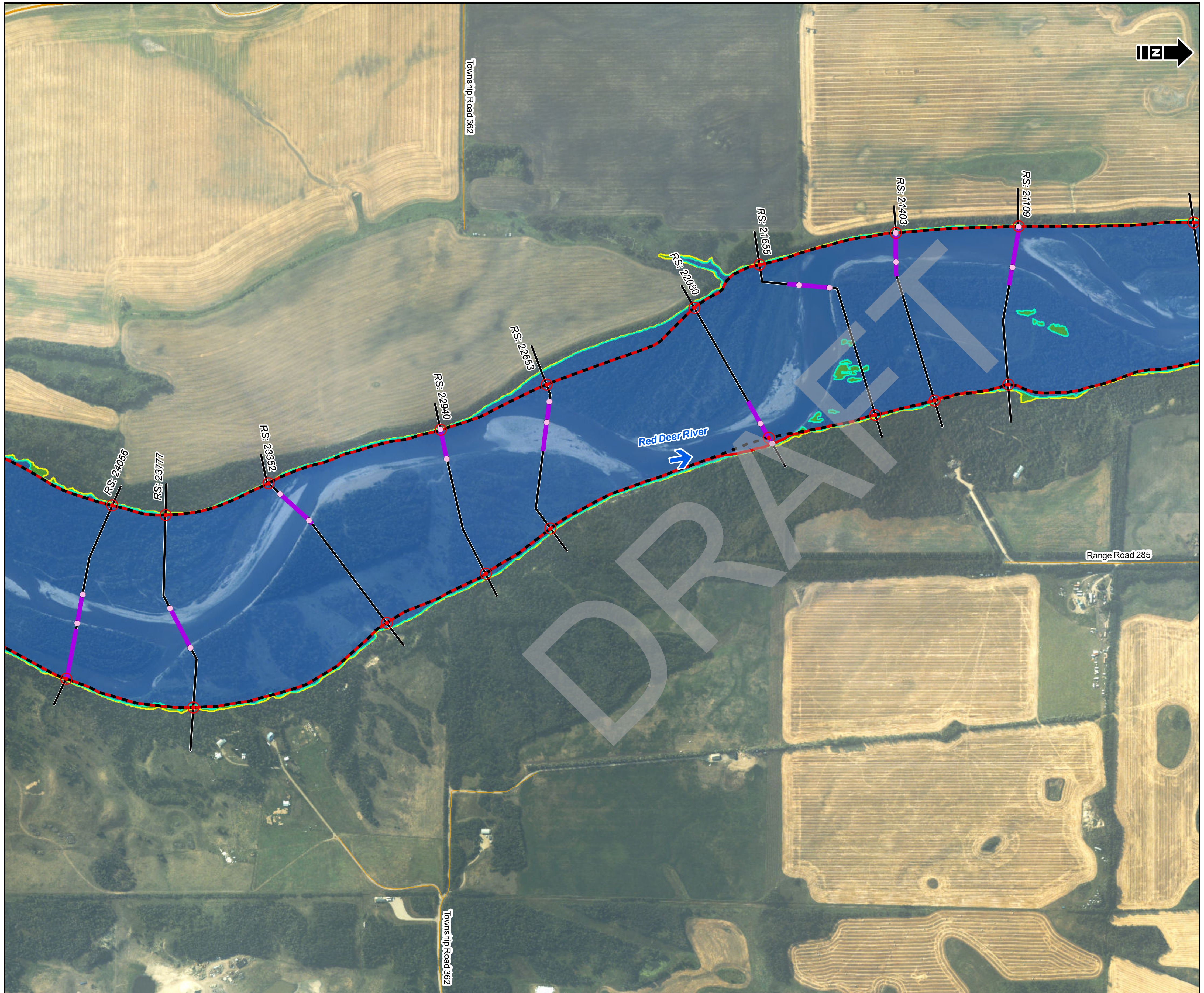
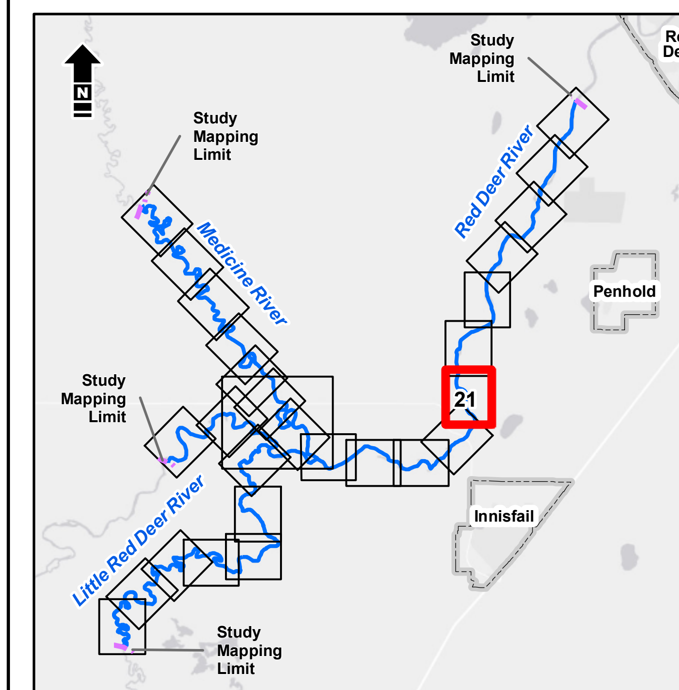
Classification: Public



Bridge
Culvert
Cross Section Line
Study Mapping Limit
Major Road
Local Road
Flow Direction
Bank Station
Proposed Floodway Station
Previous Floodway
Proposed Floodway Boundary
100 Year Inundation - ≥1 m/s Velocity
100 Year Inundation Extent - ≥1 m Depth
100 Year Inundation Extent



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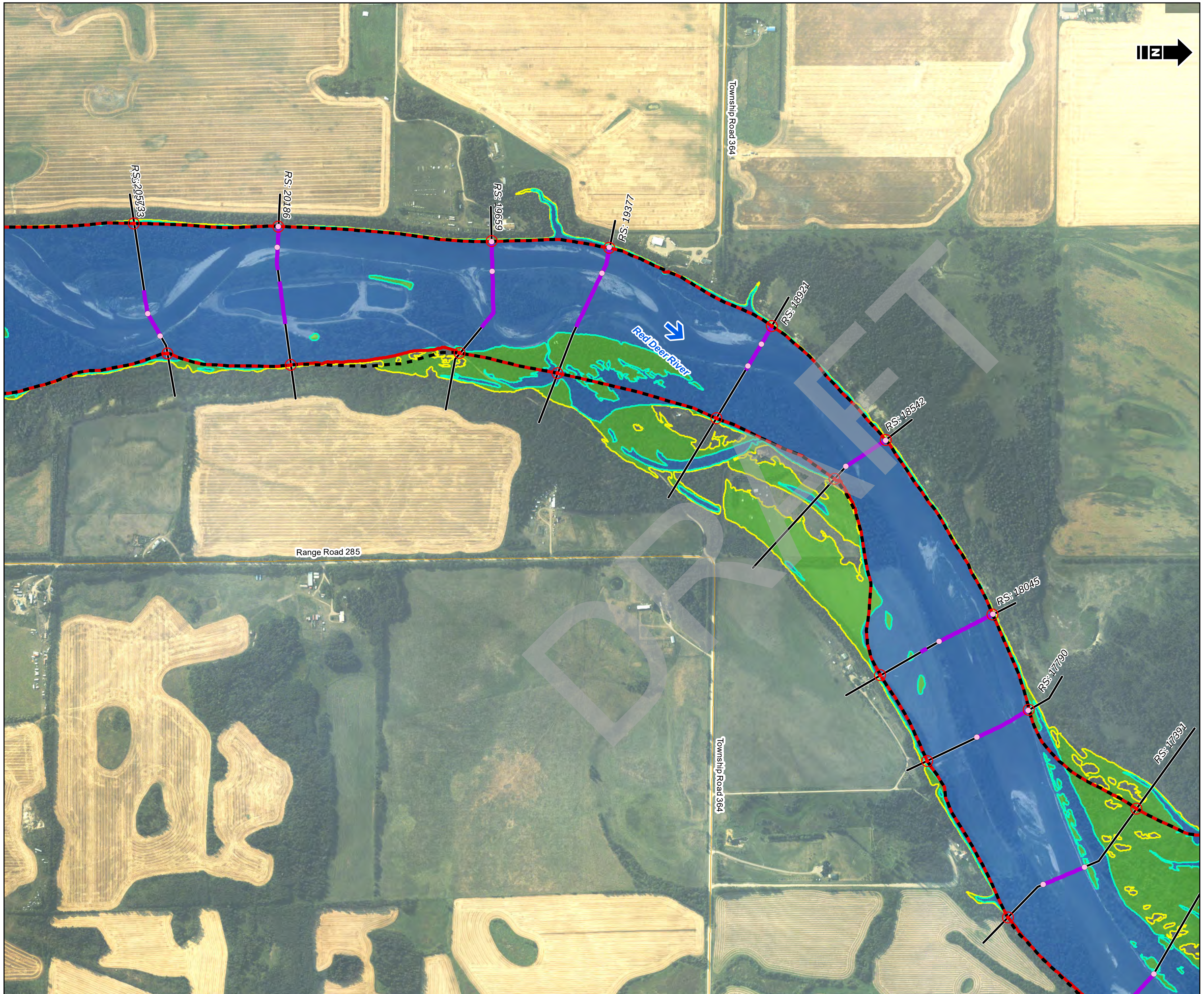
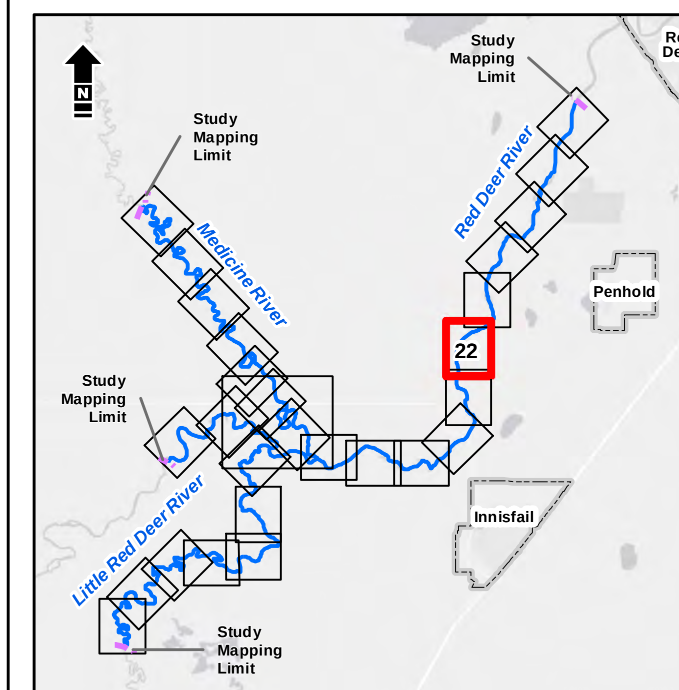


Bridge
Culvert
Cross Section Line
Study Mapping Limit
Major Road
Local Road
Flow Direction
Bank Station
Proposed Floodway Station
Previous Floodway
Proposed Floodway Boundary
100 Year Inundation - ≥1 m/s Velocity
100 Year Inundation Extent - ≥1 m Depth
100 Year Inundation Extent



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0.1 0 0.1 0.2
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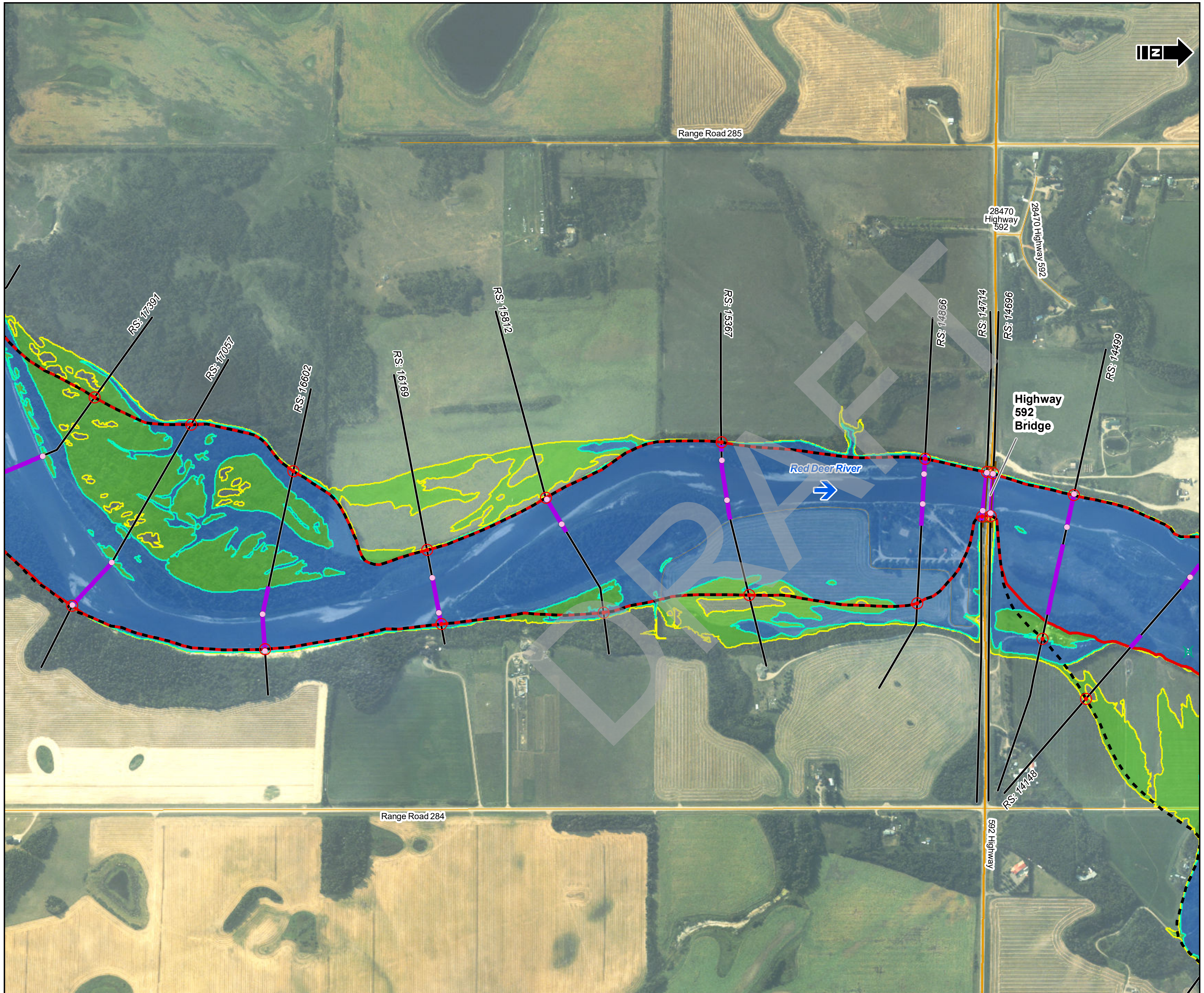
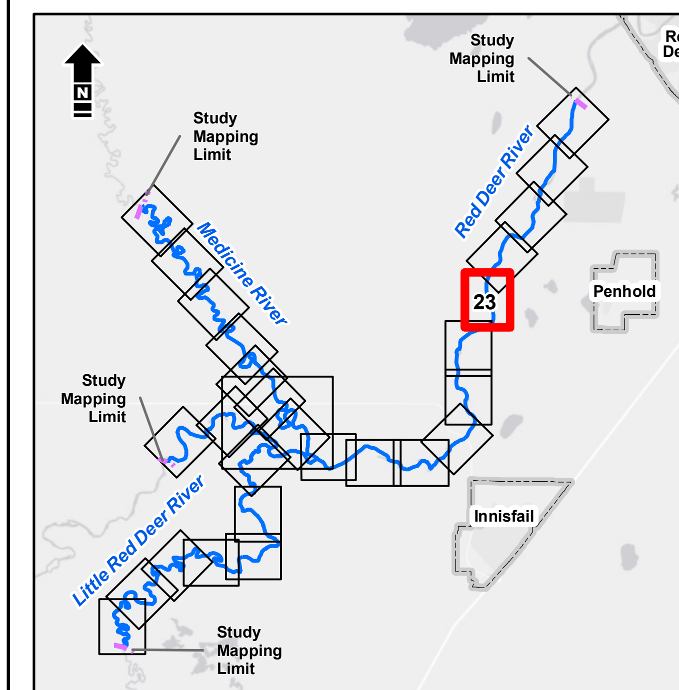


Bridge
Culvert
Cross Section Line
Study Mapping Limit
Major Road
Local Road
Flow Direction
Bank Station
Proposed Floodway Station
Previous Floodway
Proposed Floodway Boundary
100 Year Inundation - ≥1 m/s Velocity
100 Year Inundation Extent - ≥1 m Depth
100 Year Inundation Extent



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1:10,000 Kilometers
0.1 0 0.1 0.2
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Floodway Criteria Map

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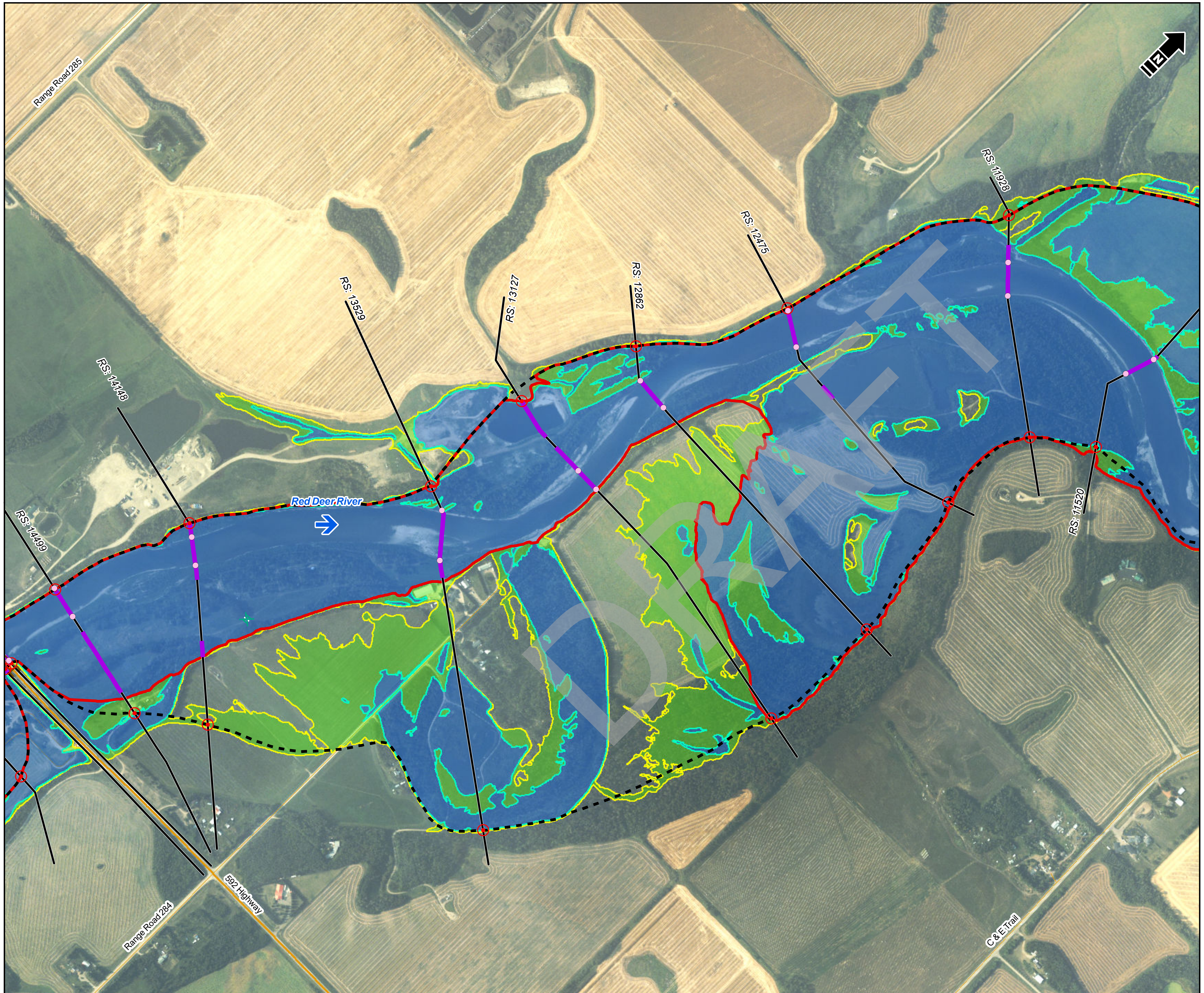
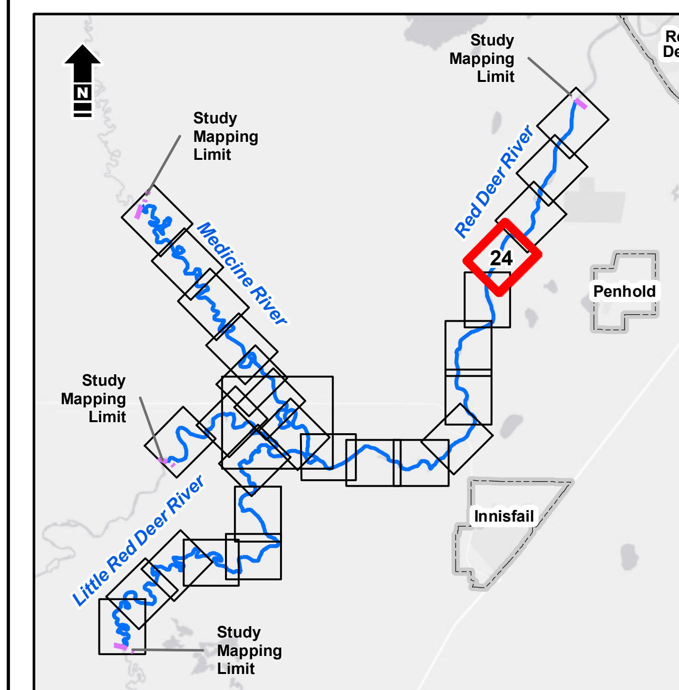


Bridge
Culvert
Cross Section Line
Study Mapping Limit
Major Road
Local Road
Flow Direction
Bank Station
Proposed Floodway Station
Previous Floodway
Proposed Floodway Boundary
100 Year Inundation - ≥1 m/s Velocity
100 Year Inundation Extent - ≥1 m Depth
100 Year Inundation Extent



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Floodway Criteria Map

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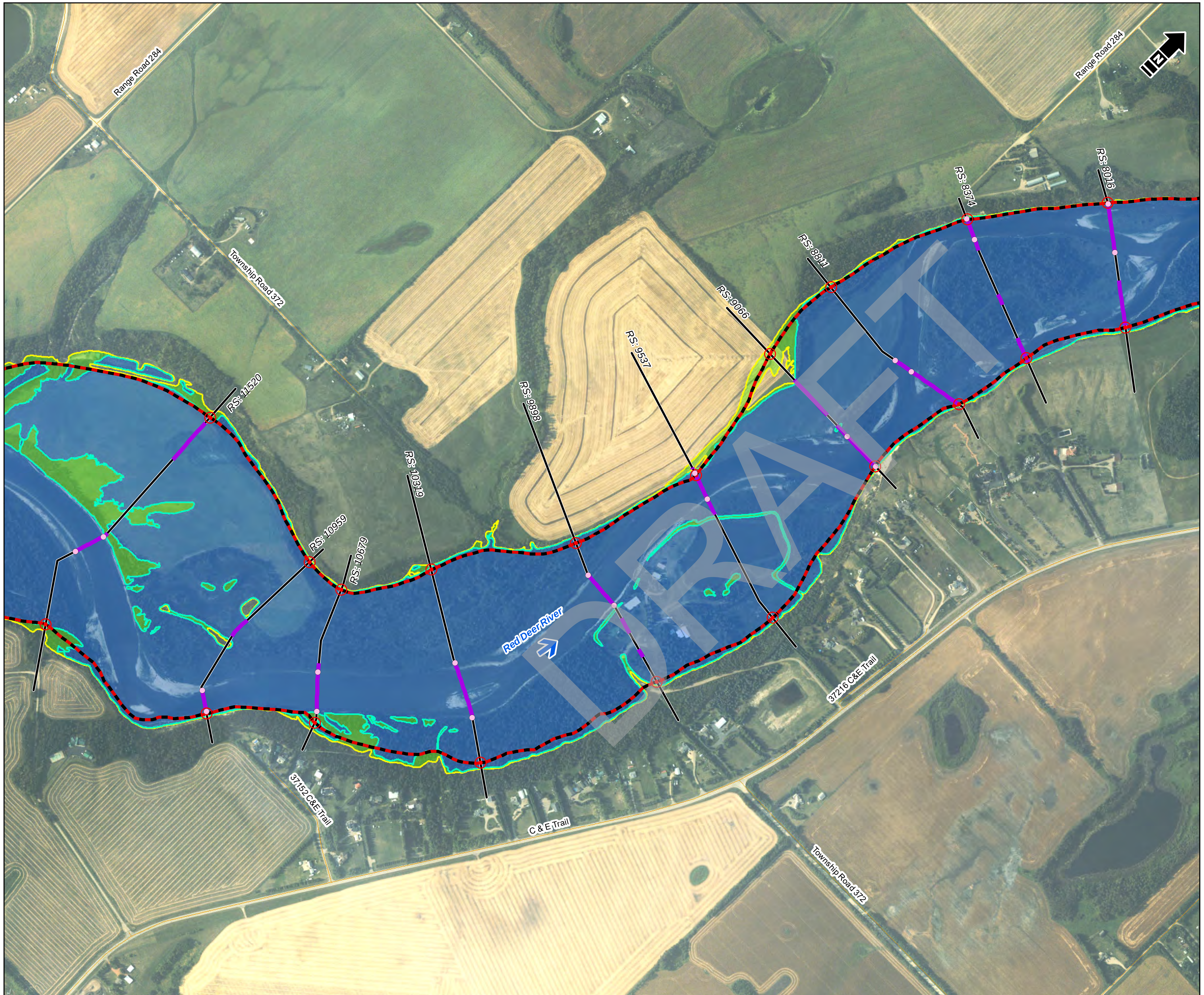
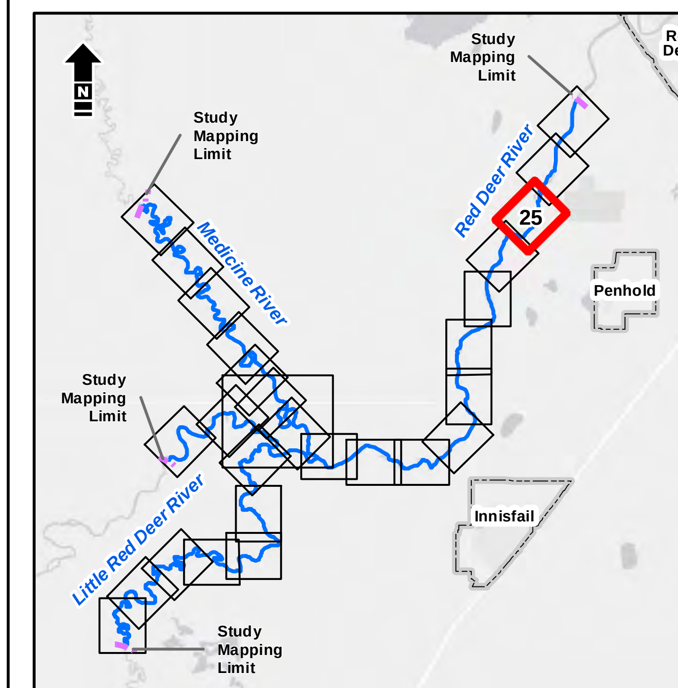


Bridge
Culvert
Cross Section Line
Study Mapping Limit
Major Road
Local Road
Flow Direction
Bank Station
Proposed Floodway Station
Previous Floodway
Proposed Floodway Boundary
100 Year Inundation - ≥1 m/s Velocity
100 Year Inundation Extent - ≥1 m Depth
100 Year Inundation Extent



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1:10,000 Kilometers
0.1 0 0.1 0.2
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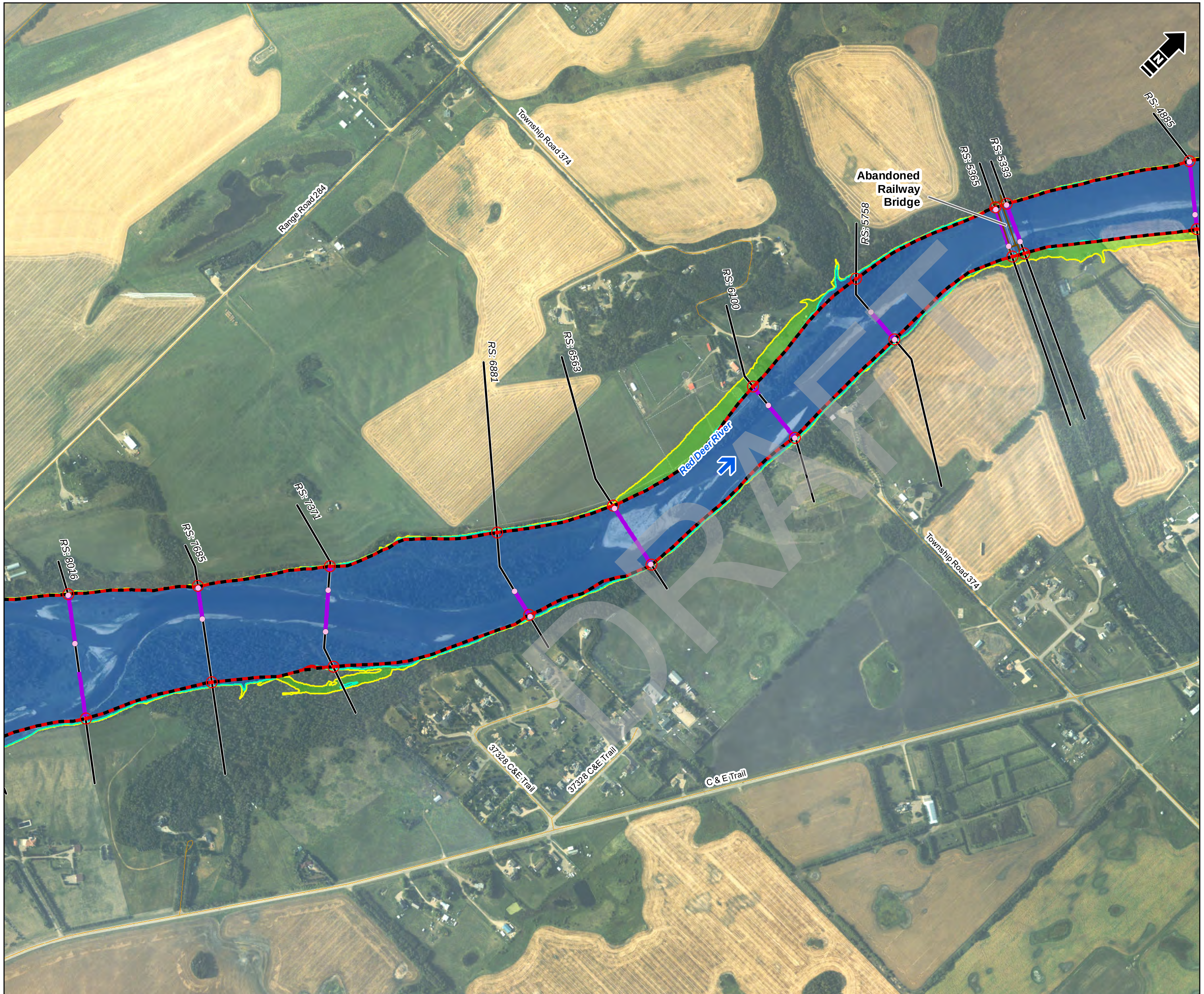
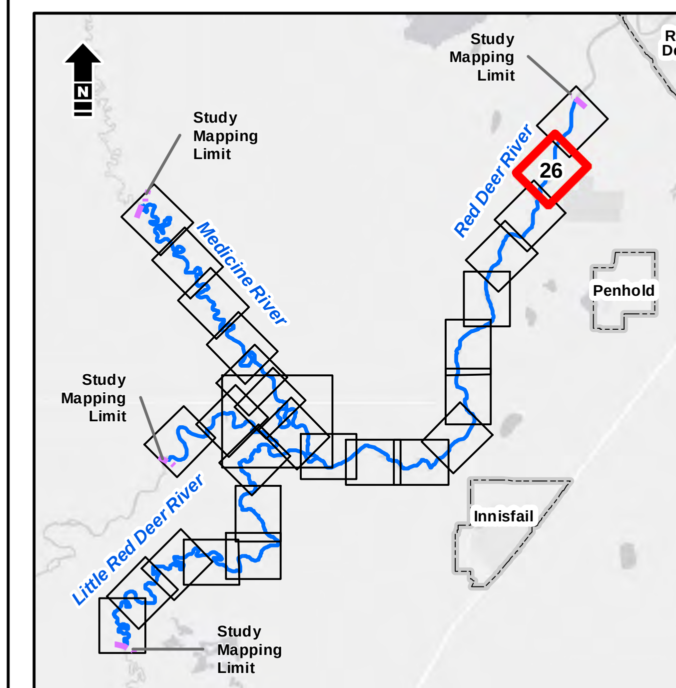


- Bridge
- Culvert
- Cross Section Line
- Study Mapping Limit
- Major Road
- Local Road
- Flow Direction
- Bank Station
- Proposed Floodway Station
- Previous Floodway
- Proposed Floodway Boundary
- 100 Year Inundation - ≥1 m/s Velocity
- 100 Year Inundation Extent - ≥1 m Depth
- 100 Year Inundation Extent



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1:10,000 Kilometers
0.1 0 0.1 0.2
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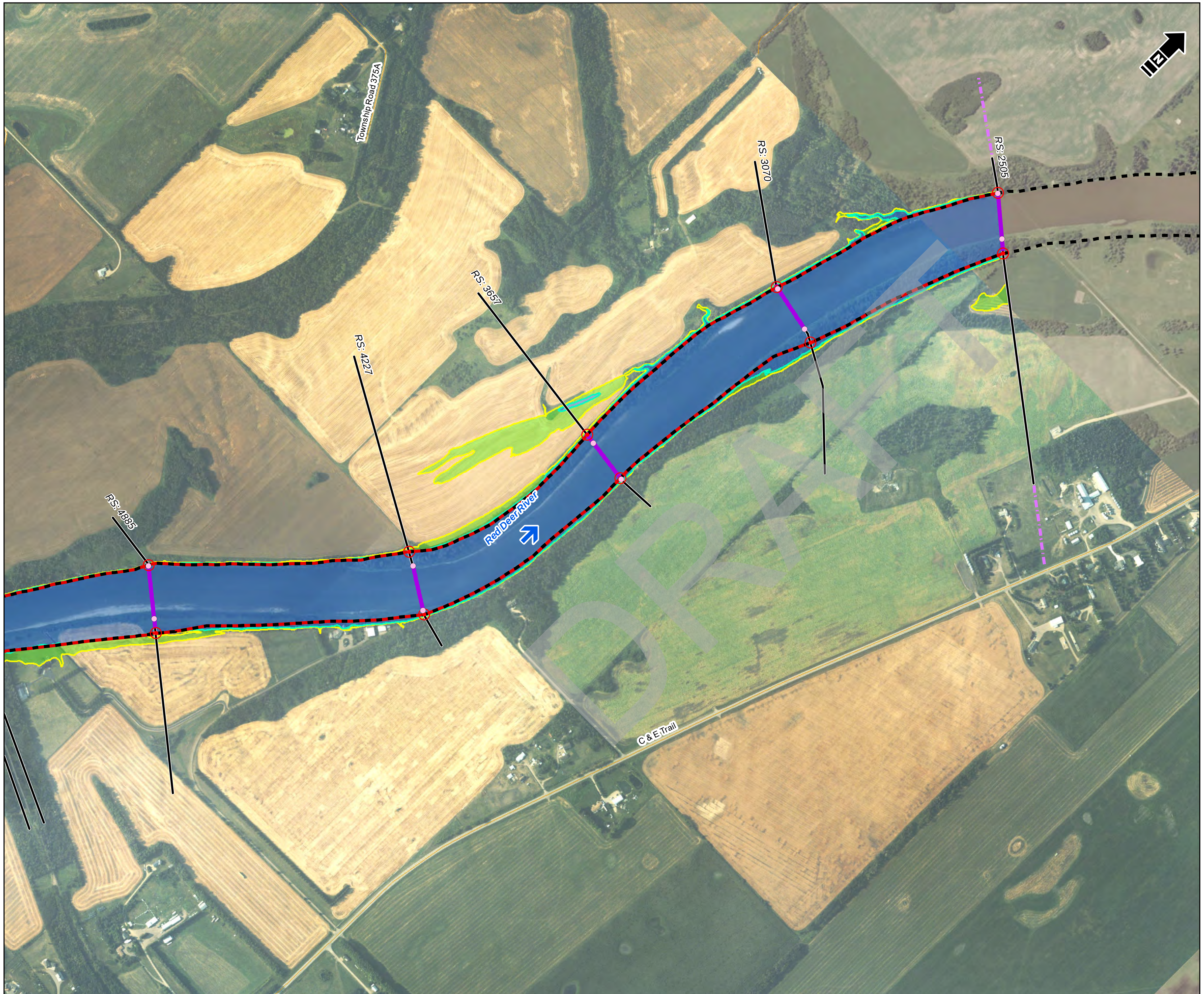
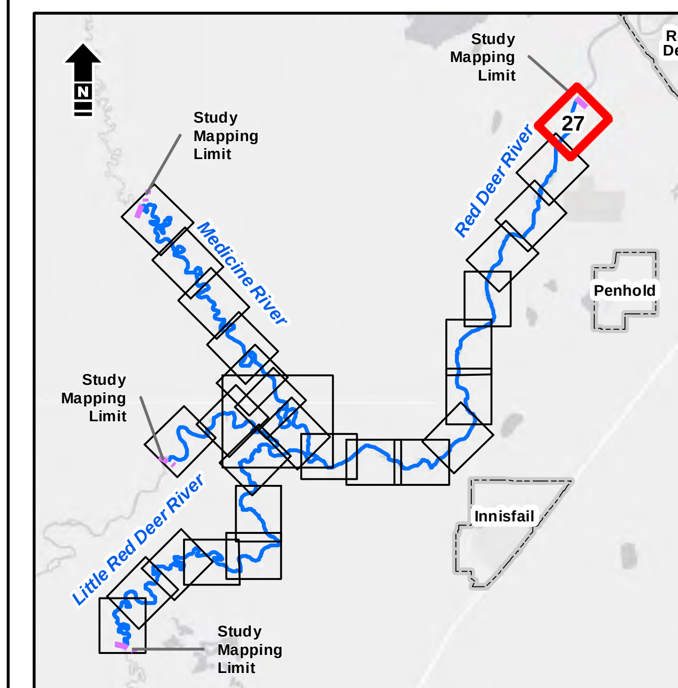


Bridge
Culvert
Cross Section Line
Study Mapping Limit
Major Road
Local Road
Flow Direction
Bank Station
Proposed Floodway Station
Previous Floodway
Proposed Floodway Boundary
100 Year Inundation - ≥1 m/s Velocity
100 Year Inundation Extent - ≥1 m Depth
100 Year Inundation Extent



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1:10,000 Kilometers
0.1 0 0.1 0.2
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Red Deer County and Markerville Flood Study

Floodway Criteria Map

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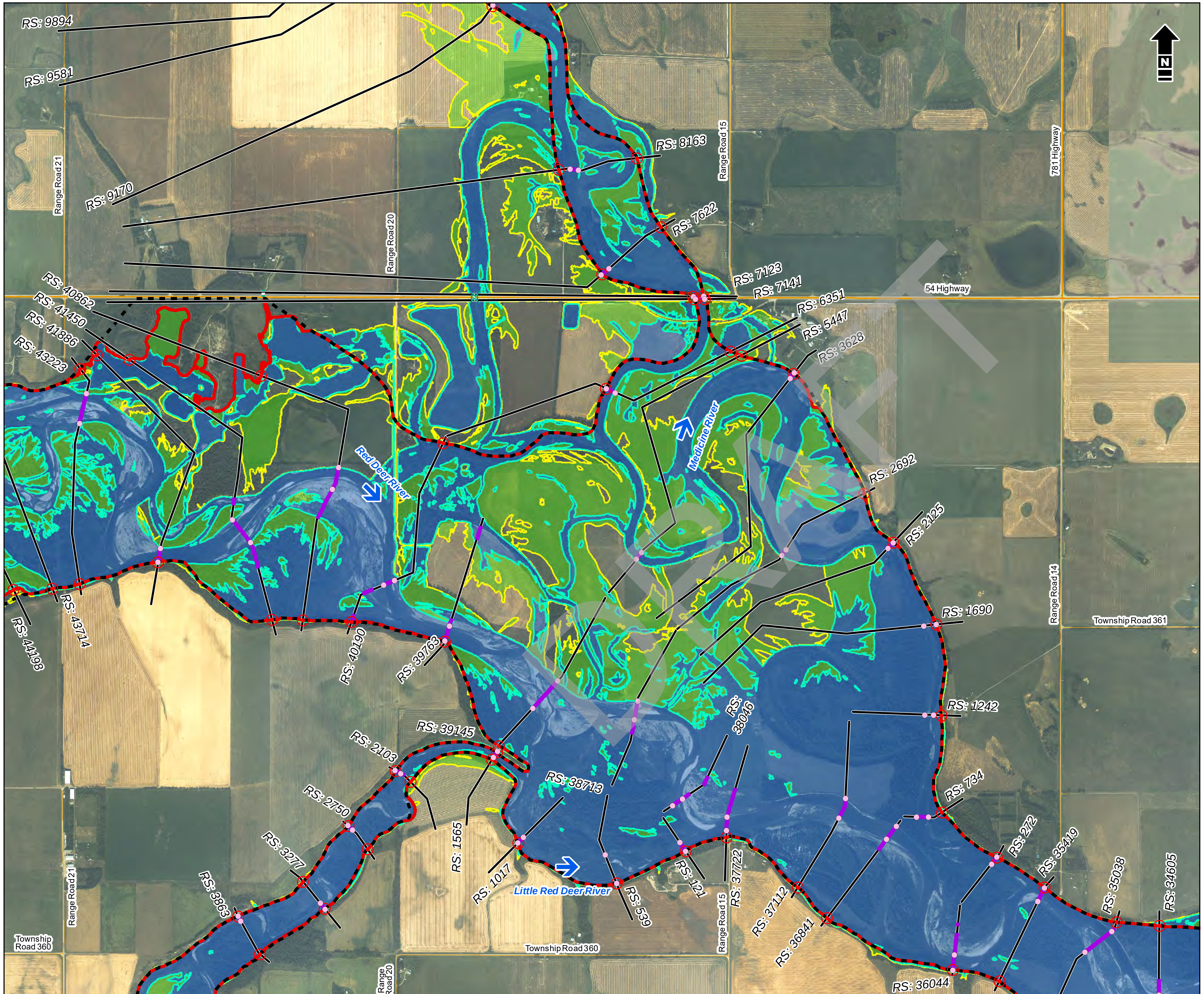
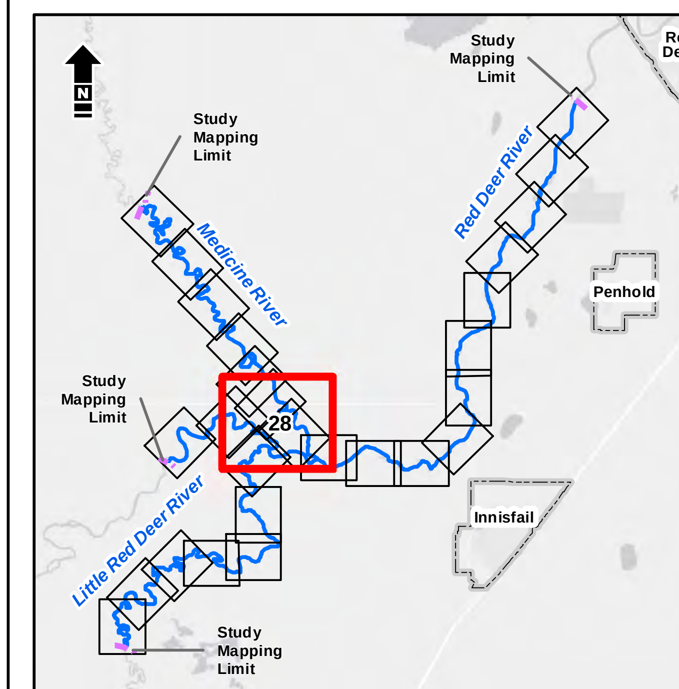


Bridge
Culvert
Cross Section Line
Study Mapping Limit
Major Road
Local Road
Flow Direction
Bank Station
Proposed Floodway Station
Previous Floodway
Proposed Floodway Boundary
100 Year Inundation - ≥1 m/s Velocity
100 Year Inundation Extent - ≥1 m Depth
100 Year Inundation Extent



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1:20,000 Kilometers
0.1 0 0.1 0.2
NAD 1983 CSRS 3TM 114

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Red Deer County and Markerville Flood Study

Floodway Criteria Map

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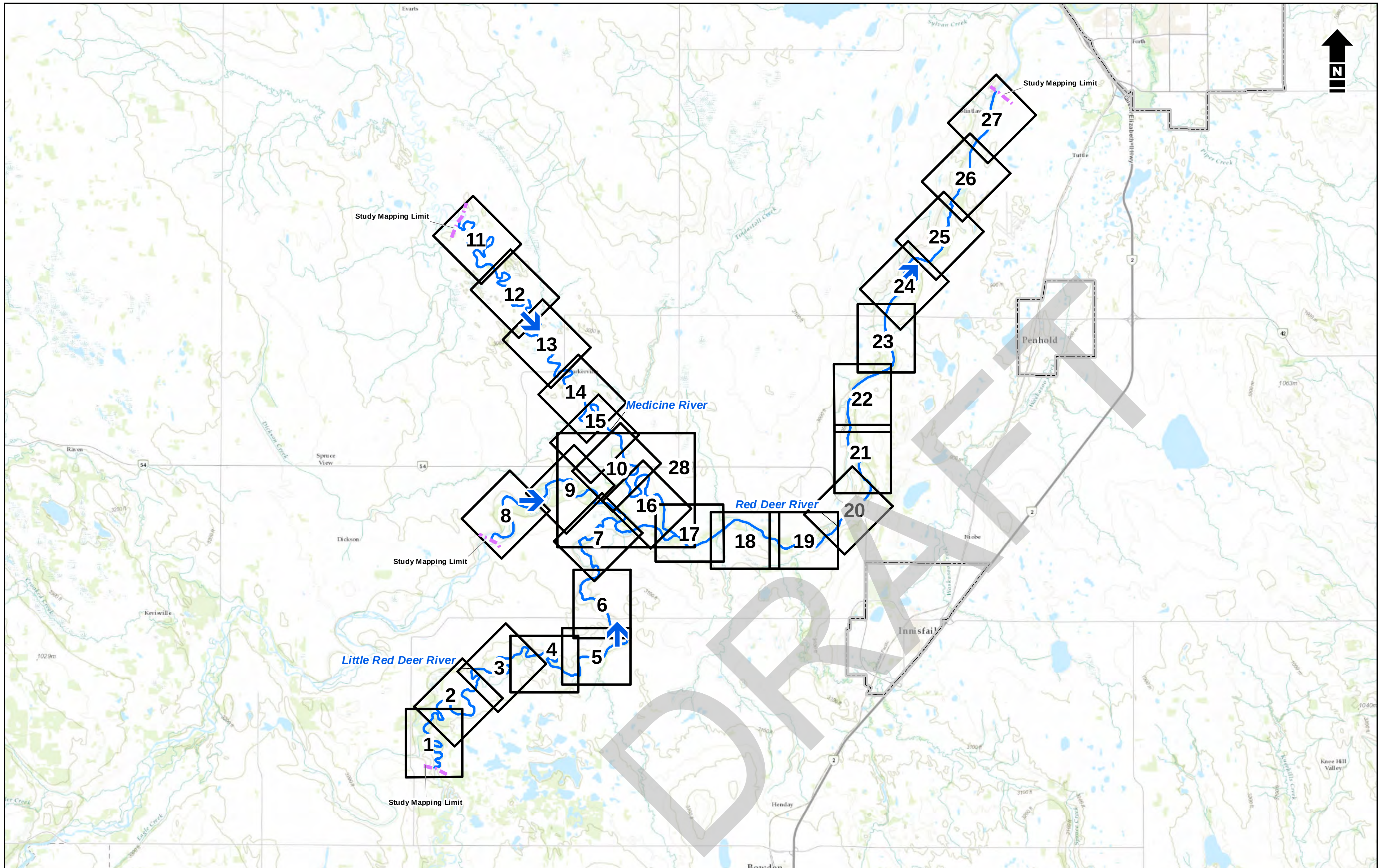
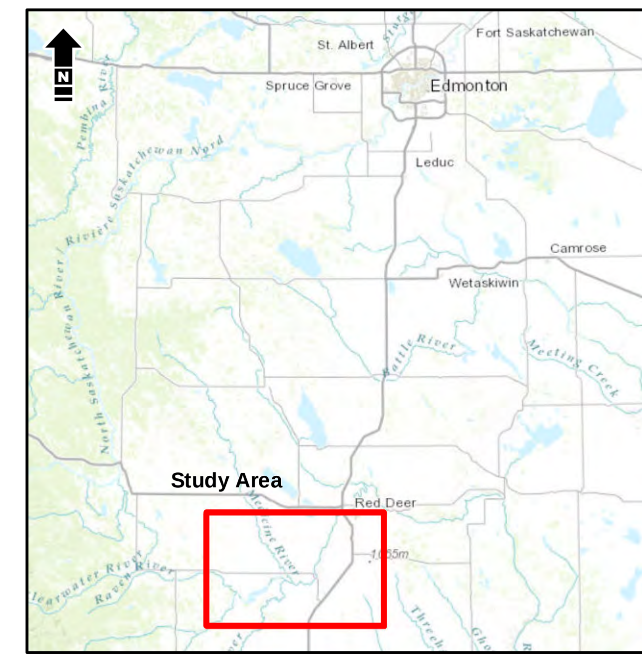
Classification: Public

APPENDIX E
Flood Hazard Maps



Study Area
Map Sheet
Study Mapping Limit
Municipal Boundary (Urban)
Study Reach
Flow Direction



1:200,000 kilometres

5 0 5 10

NAD 1983 CSRS 3TM 114

Notes:

1. Please refer to the accompanying Red Deer County and Markerville Flood Hazard Study for important information concerning these maps.

2. Within the flood inundation areas shown on this map, there may be isolated pockets of high ground. To determine whether or not a particular site is subject to flooding, reference should be made to the computed flood levels in conjunction with site-specific surveys where detailed definition is required.

3. Non-riverine and local sources of water have not been considered, and structures such roads or railways can restrict water flow and affect local flood levels. Channel obstruction, local stormwater inflow, groundwater seepage or other land drainage can cause flood levels to exceed those indicated on the map. Lands adjacent to a flooded area may be subject to flooding from tributary streams not indicated on the maps.

Definitions:

Flood Hazard Map - A flood hazard map is a specific type of flood map that identifies the area flooded for the 1:100 design flood, and divides that flood hazard area into floodway and flood fringe zones. Flood hazard maps can also show additional flood hazard information, including the incremental areas at risk for more severe floods like the 1:200 and 1:500 floods. Flood hazard maps are typically used for long-term flood hazard area management and land-use planning.

Design Flood - The design flood standard in Alberta is the 1:100 flood, which is a flood that has a 1% chance of being equaled or exceeded in any given year. The design flood is typically based on the 1:100 open water flood, but it can also reflect 1:100 ice jam flood levels or be based on a historical flood event. Different sized floods have different chances of occurring – for example, a 1:200 flood has a 0.5% chance of occurring in any given year and a 1:500 flood has a 0.2% chance of occurring in any given year – but only the 1:100 design flood is used to define the floodway and flood fringe zones on flood hazard maps.

Floodway - When a floodway is first defined on a flood hazard map, it typically represents the area of highest flood hazard where flows are deepest, fastest, and most destructive during the 1:100 design flood. When a flood hazard map is updated, the floodway will not get larger in most circumstances to maintain long-term regulatory certainty, even if the flood hazard area gets larger or design flood levels get higher.

Flood Fringe - The flood fringe is the area outside of the floodway that is flooded or could be flooded during the 1:100 design flood. The flood fringe typically represents areas with shallower, slower, and less destructive flooding, but it may also include "high hazard flood fringe" areas. Areas at risk of flooding behind flood berms may also be mapped as "protected flood fringe" areas.

High Hazard Flood Fringe - The high hazard flood fringe identifies areas within the flood fringe with deeper or faster moving water than the rest of the flood fringe. High hazard flood fringe areas are likely to be most significant for flood maps that are being updated, but they may also be included in new flood maps.

Protected Flood Fringe - The protected flood fringe identifies areas that could be flooded if dedicated flood berms fail or do not work as designed during the 1:100 design flood, even if they are not overtopped. Protected flood fringe areas are part of the flood fringe and do not differentiate between areas with deeper or faster moving water and shallower or slower moving water.

References:

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Base Mapping available ESRI Base Mapping and Imagery Services.
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

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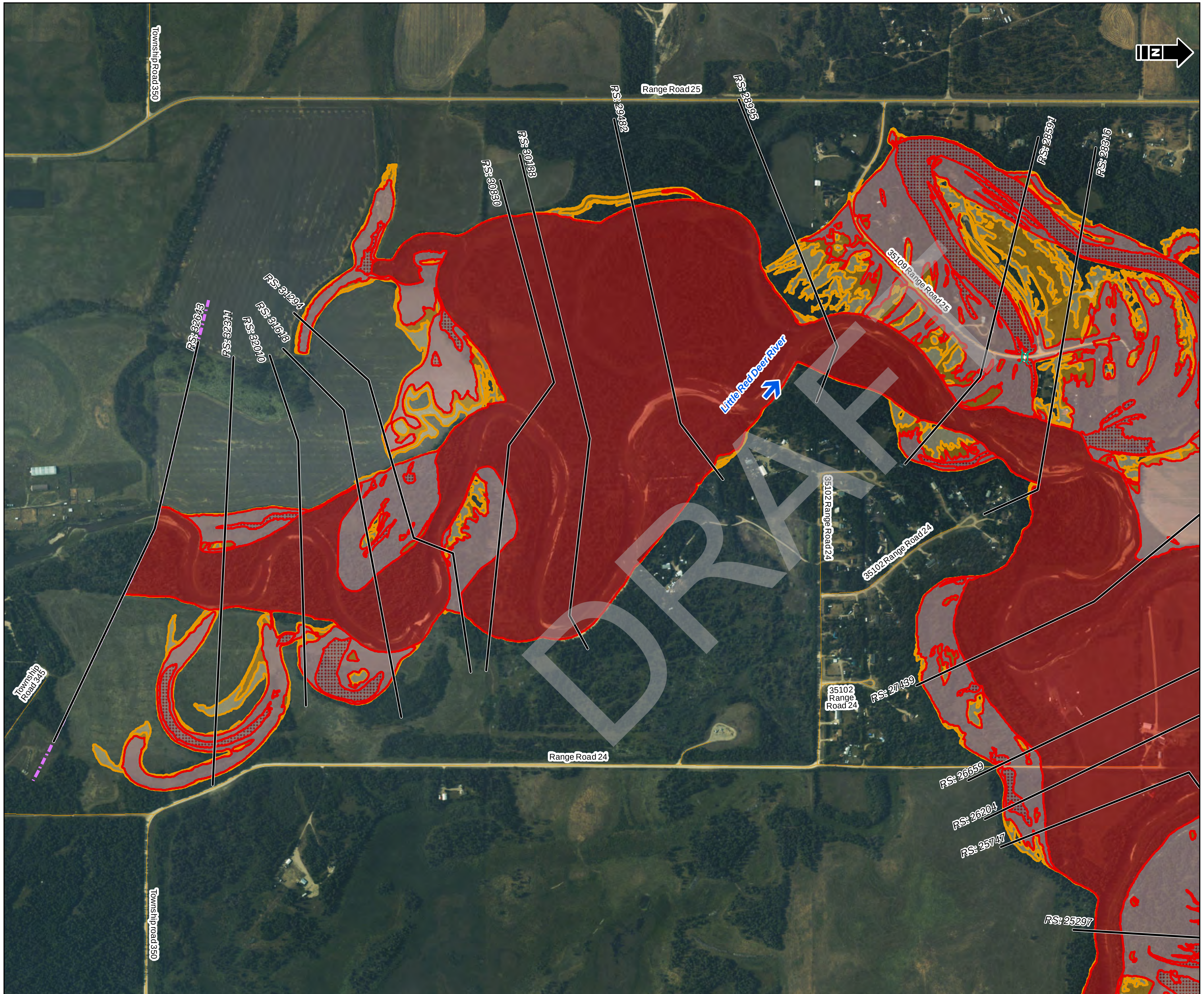
Alberta Environment and Protected Areas
Red Deer County and Markerville Flood Study

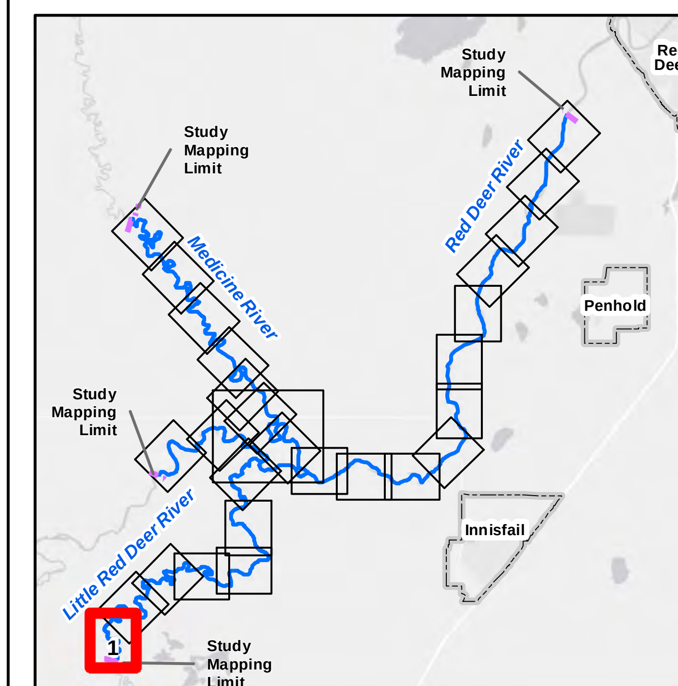
Governing Design Flood Hazard Index Map

Date:	Project:	Submitter:	Reviewer:
March 2024	35374	P. Rogers	M. Shome

Sheet
INDEX



Bridge
Culvert
Cross Section Line
Study Mapping Limit
Major Road
Local Road
Flow Direction
Floodway
Flood Fringe
High Hazard Flood Fringe
200-Year Flood Inundation Extent
500-Year Flood Inundation Extent



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1:10,000 metres
100 0 100 200
NAD 1983 CSRS 3TM 114

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Alberta Environment and Protected Areas
Red Deer County and Markerville Flood Study

Governing Design Flood Hazard Map

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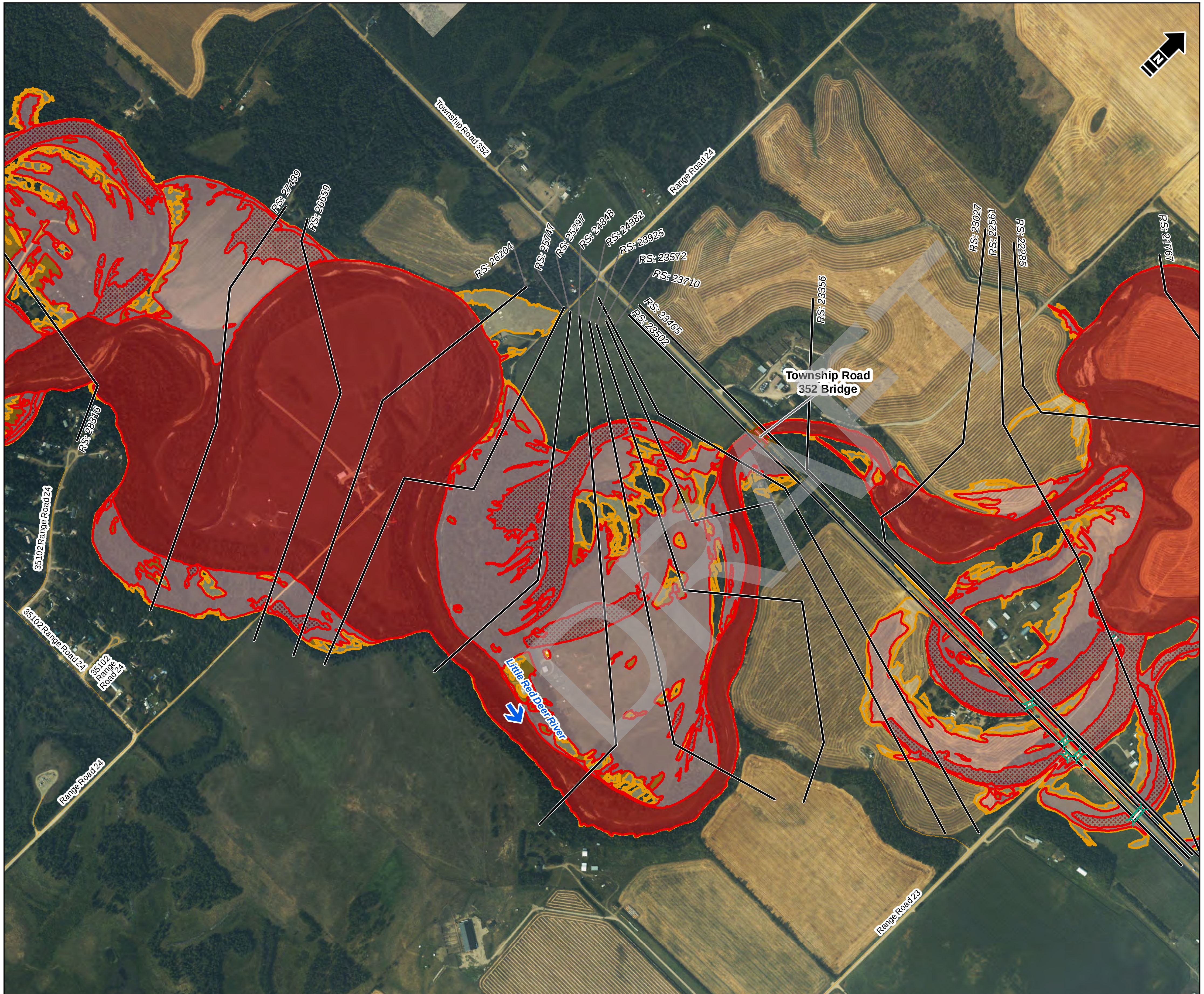
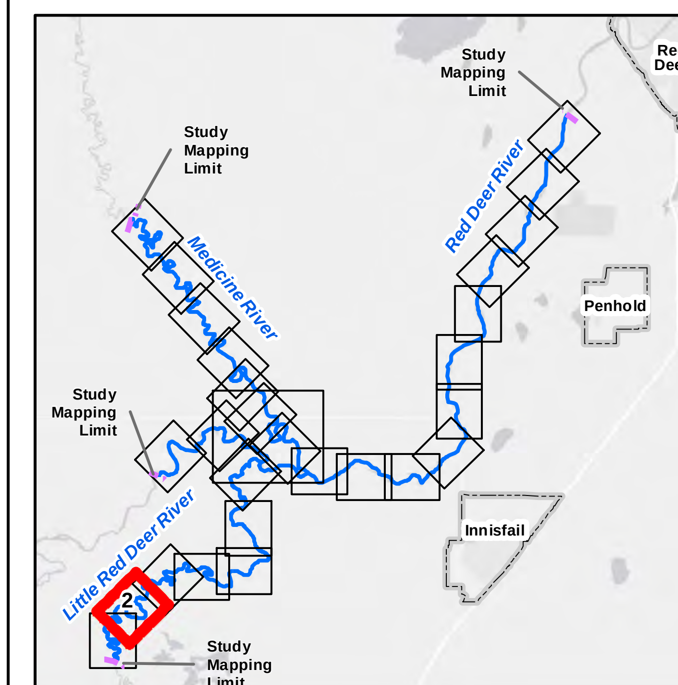


Bridge
Culvert
Cross Section Line
Study Mapping Limit
Major Road
Local Road
Flow Direction
Floodway
Flood Fringe
High Hazard Flood Fringe
200-Year Flood Inundation Extent
500-Year Flood Inundation Extent



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1:10,000 metres
100 0 100 200
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Red Deer County and Markerville Flood Study

Governing Design Flood Hazard Map

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Bridge
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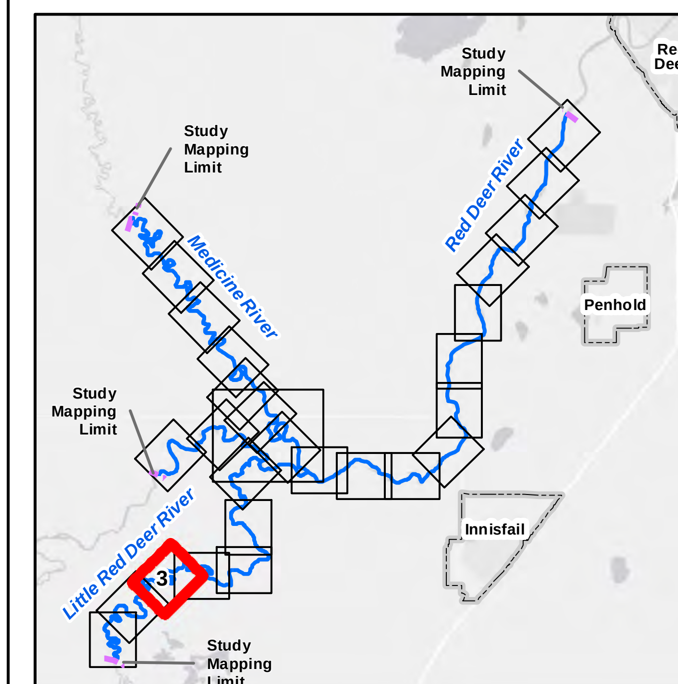
High Hazard Flood Fringe
200-Year Flood Inundation Extent
500-Year Flood Inundation Extent



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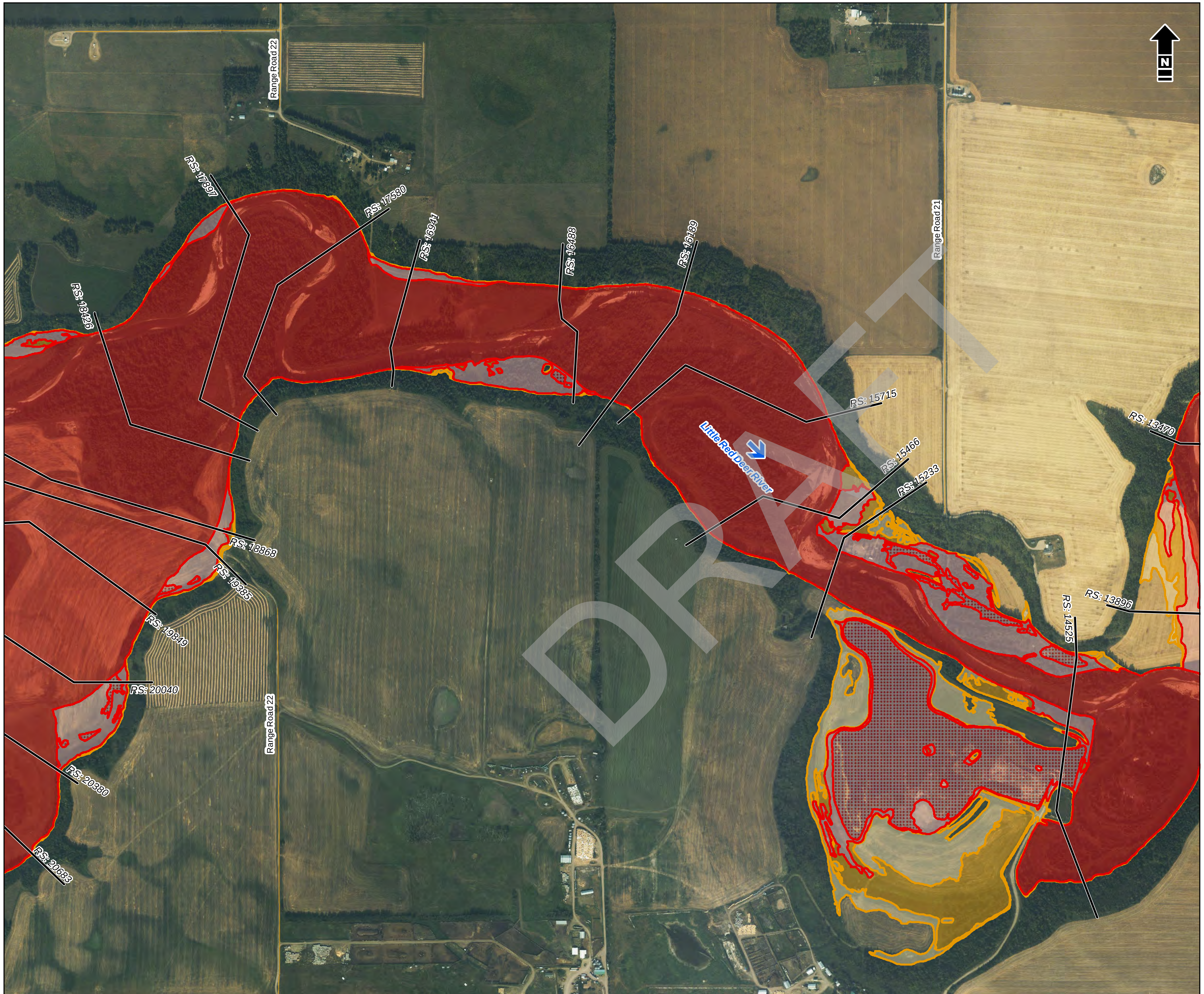
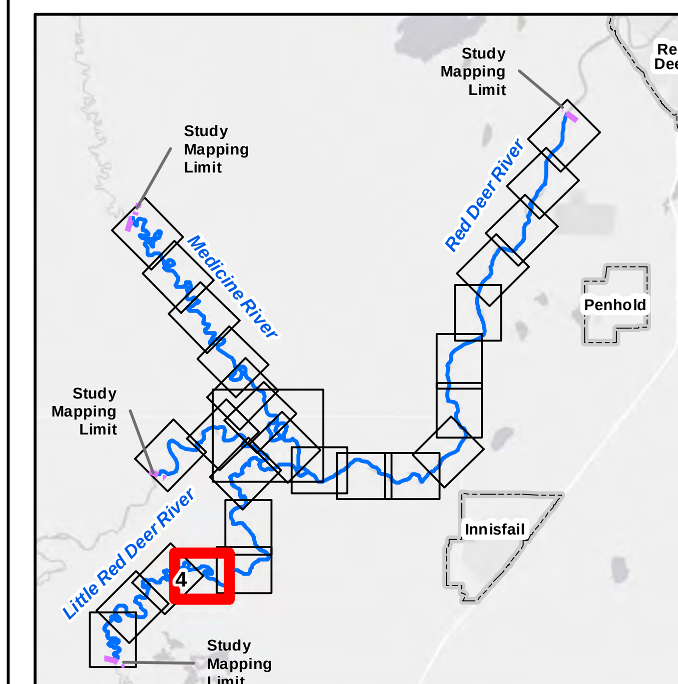


Bridge
Culvert
Cross Section Line
Study Mapping Limit
Major Road
Local Road
Flow Direction
Floodway
Flood Fringe
High Hazard Flood Fringe
200-Year Flood Inundation Extent
500-Year Flood Inundation Extent



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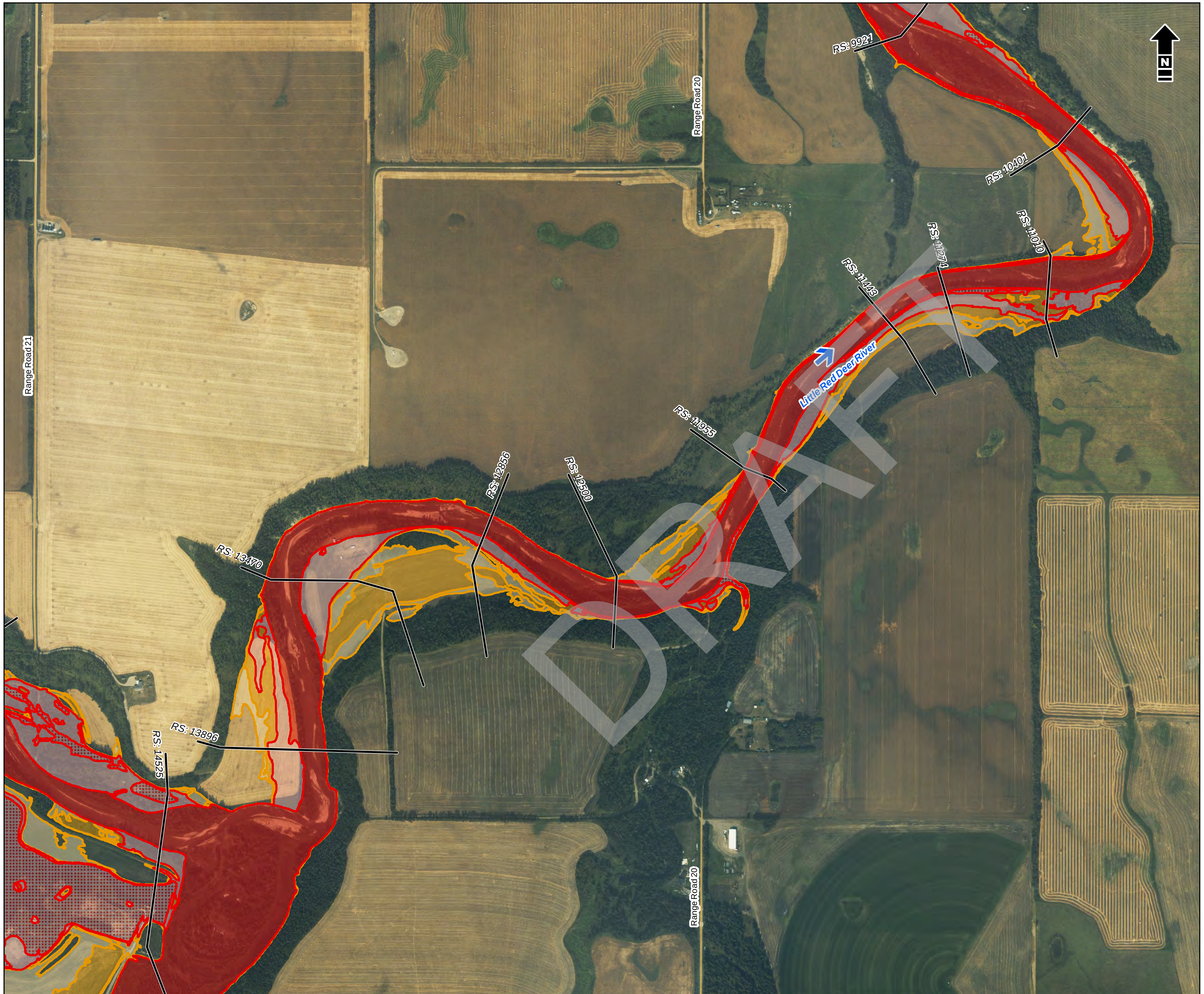
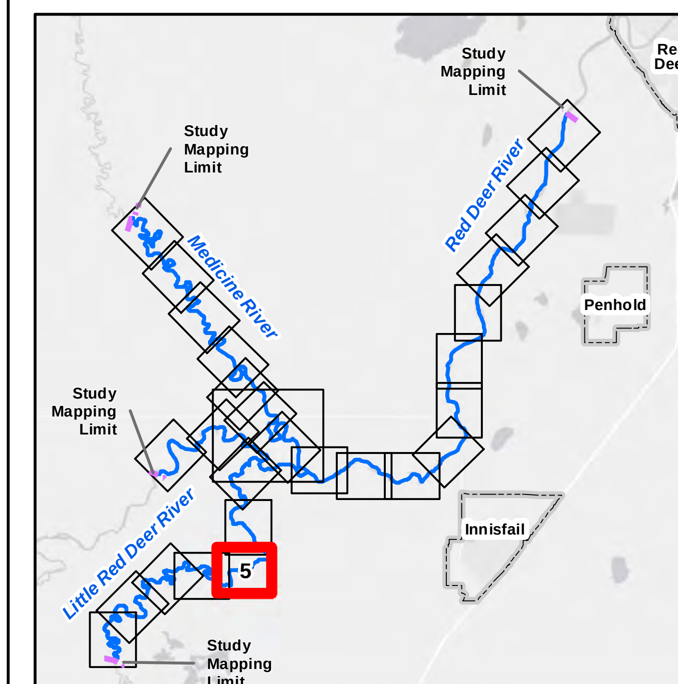


Bridge
Culvert
Cross Section Line
Study Mapping Limit
Major Road
Local Road
Flow Direction
Floodway
Flood Fringe
High Hazard Flood Fringe
200-Year Flood Inundation Extent
500-Year Flood Inundation Extent



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Alberta

Alberta Environment and Protected Areas
Red Deer County and Markerville Flood Study

Governing Design Flood Hazard Map

Date: March 2024	Project: 35374	Submitter: P. Rogers	Reviewer: M. Shome

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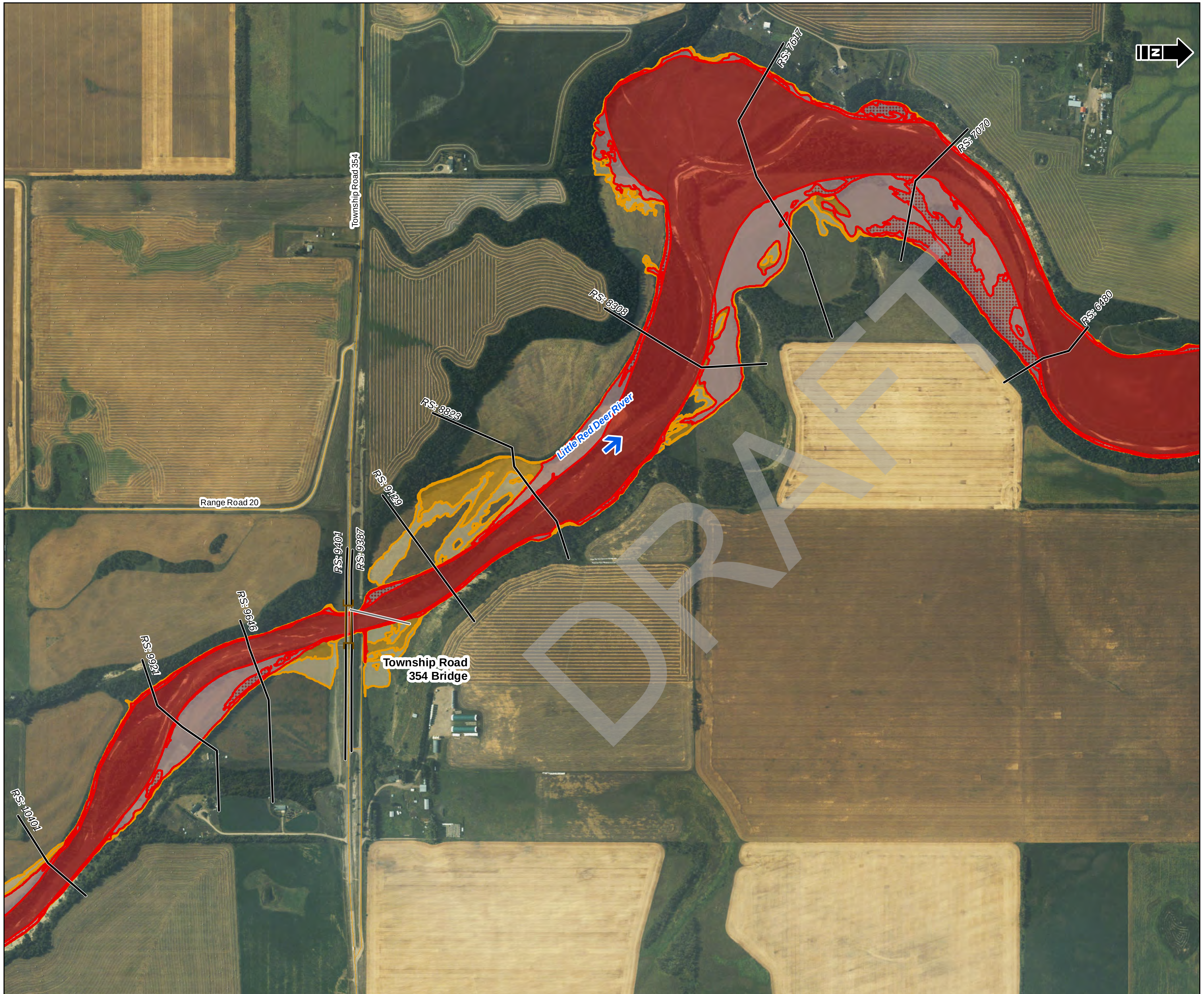
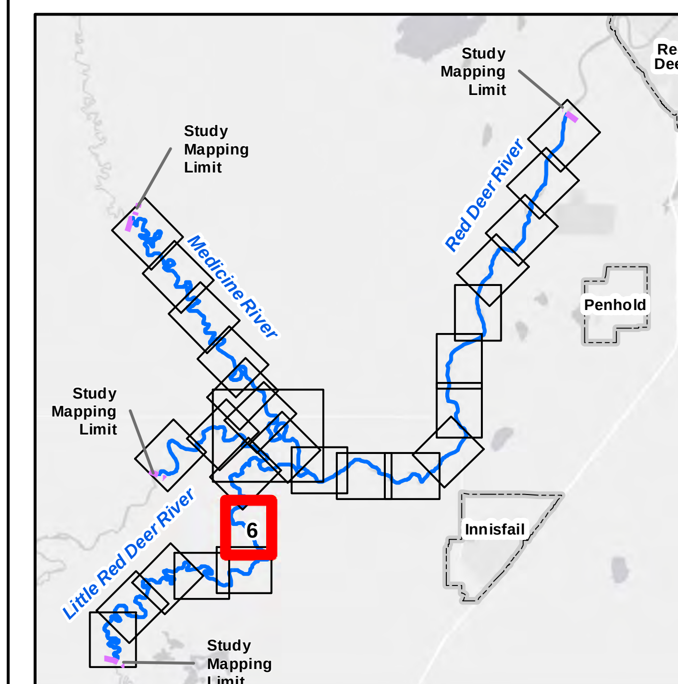


- Bridge
- Culvert
- Cross Section Line
- Study Mapping Limit
- Major Road
- Local Road
- Flow Direction
- Floodway
- Flood Fringe
- High Hazard Flood Fringe
- 200-Year Flood Inundation Extent
- 500-Year Flood Inundation Extent



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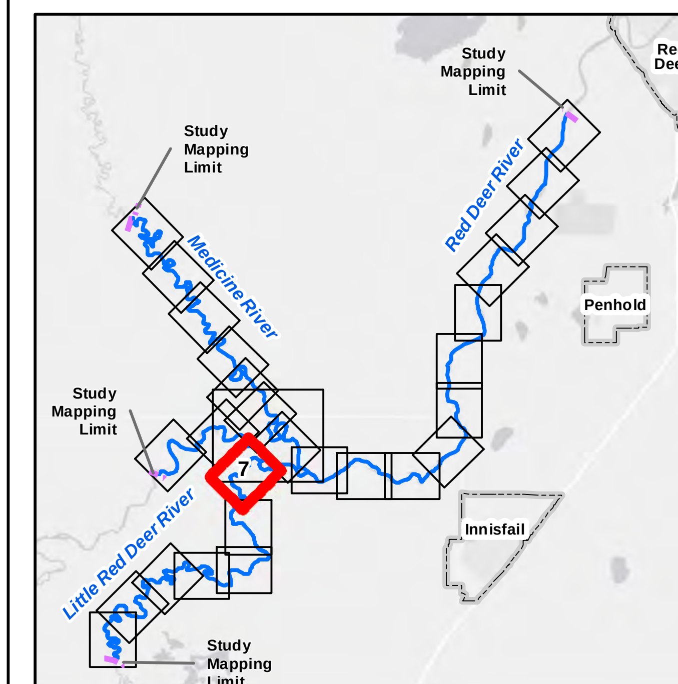

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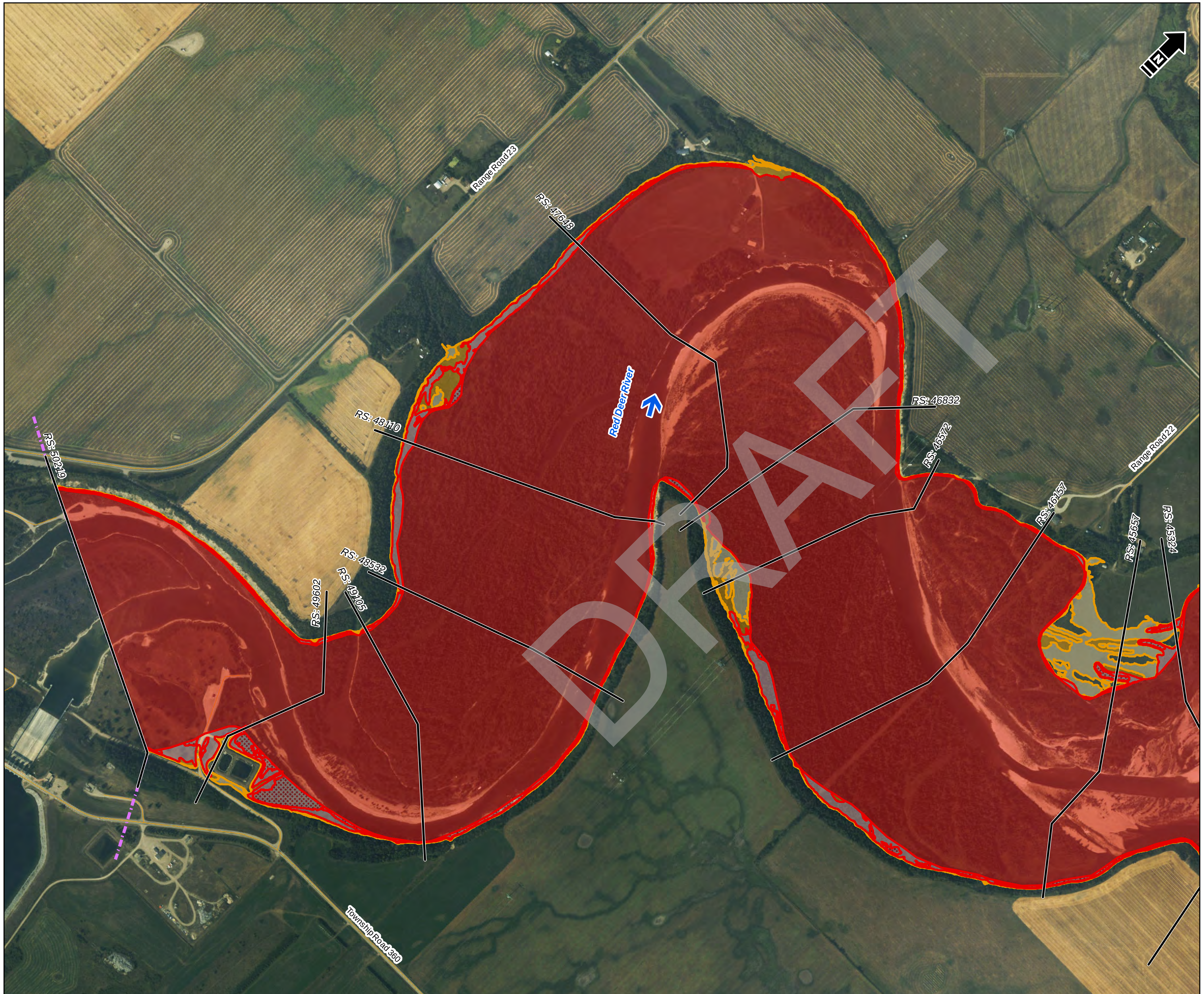

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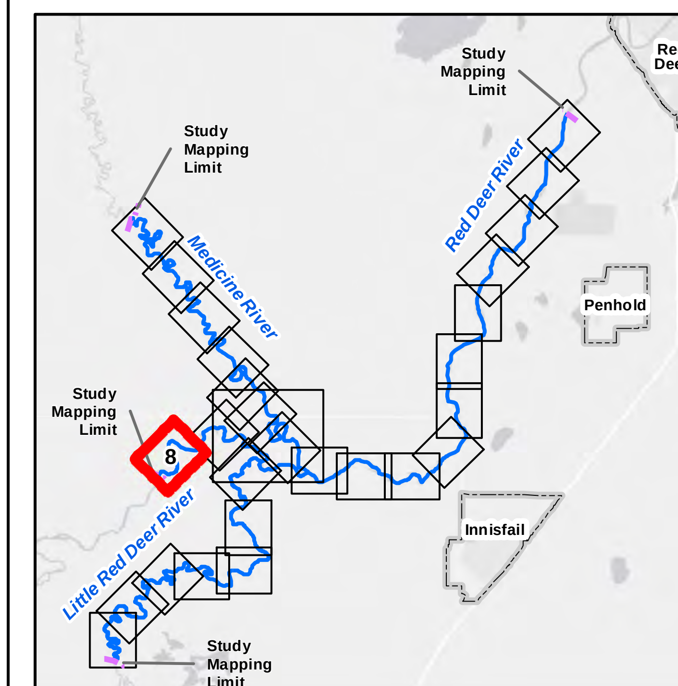

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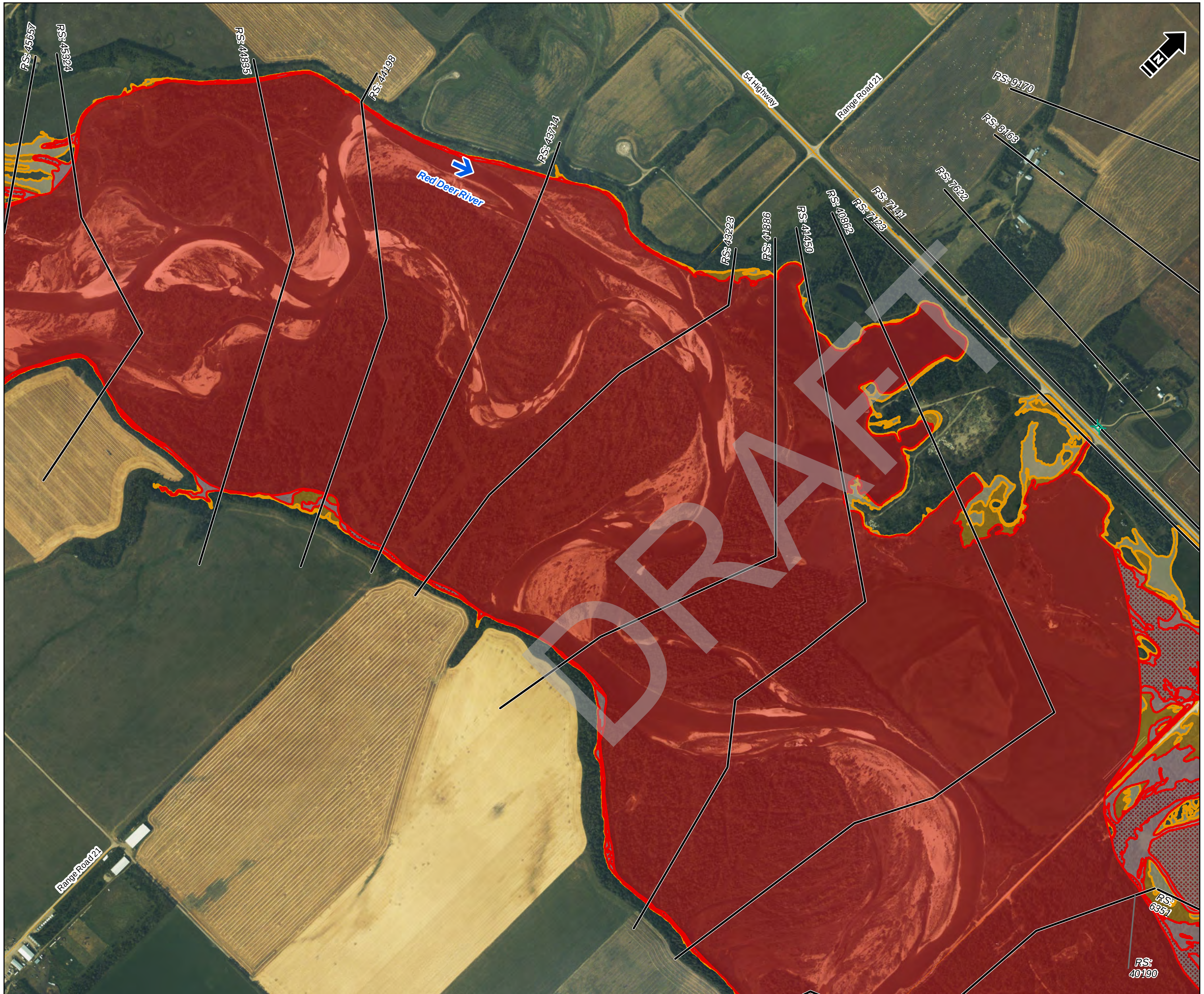

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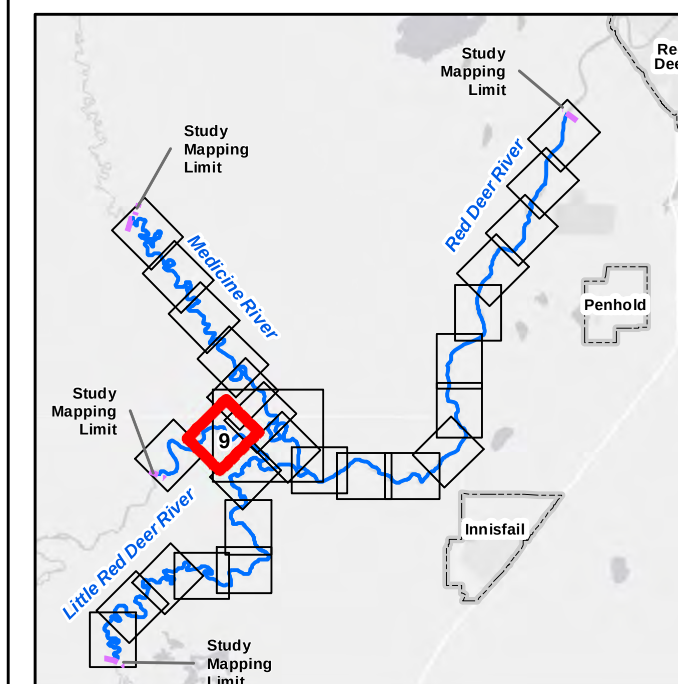

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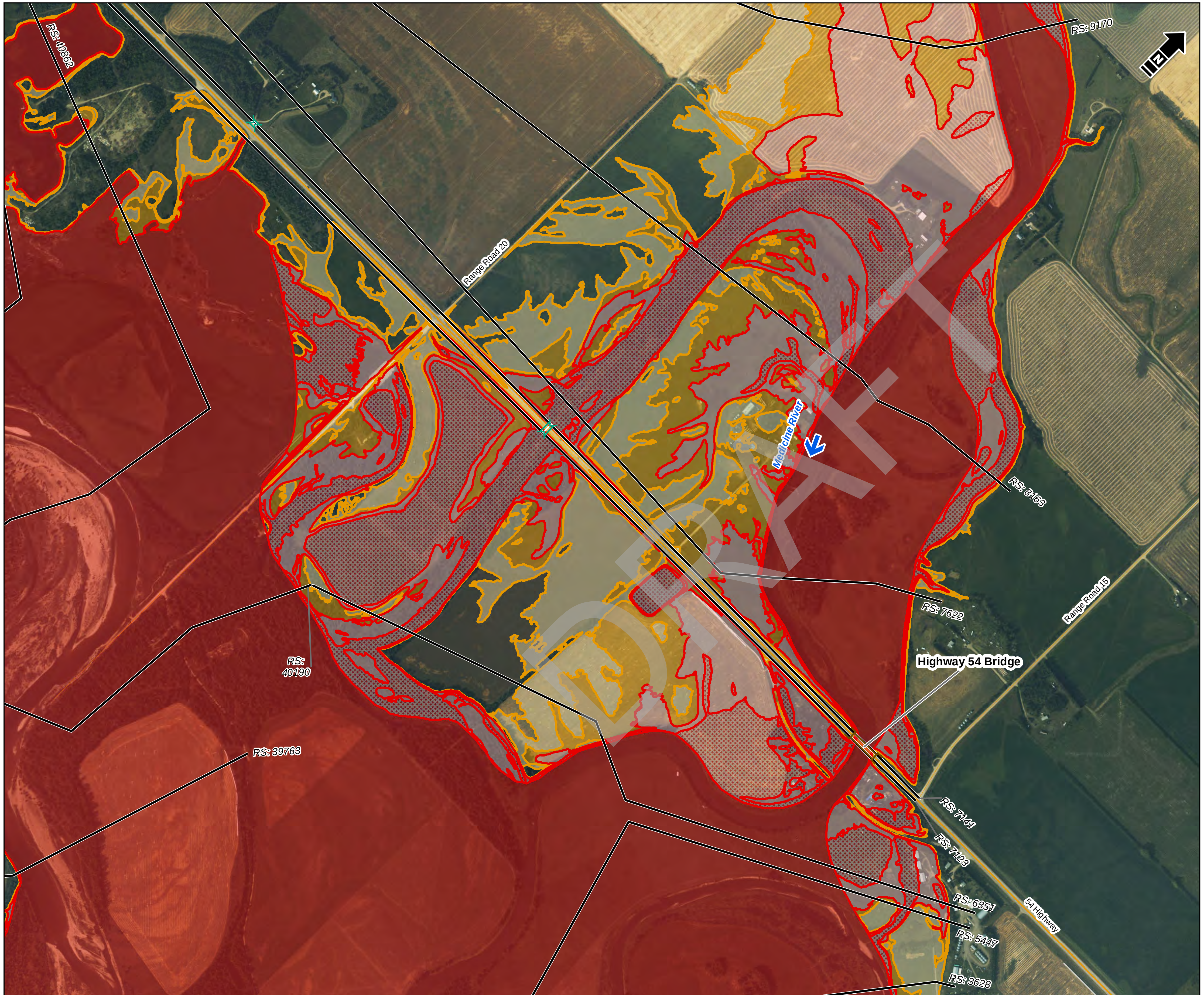

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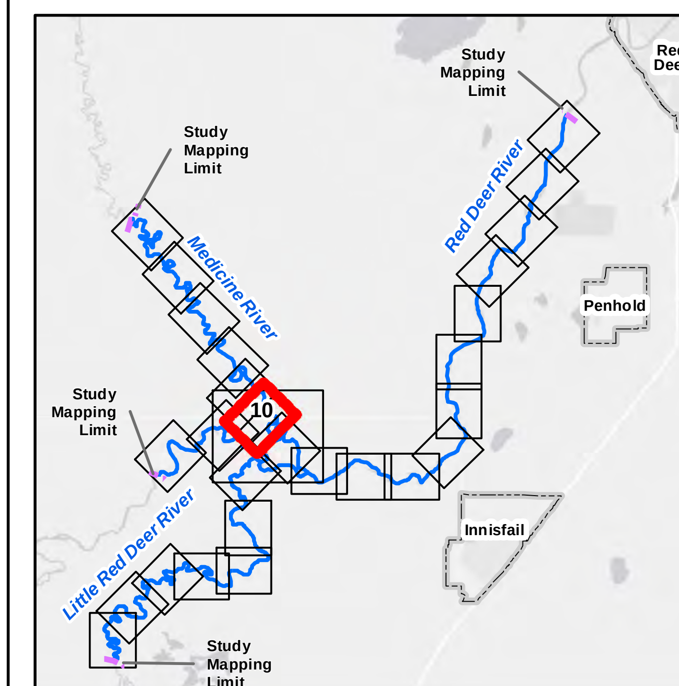

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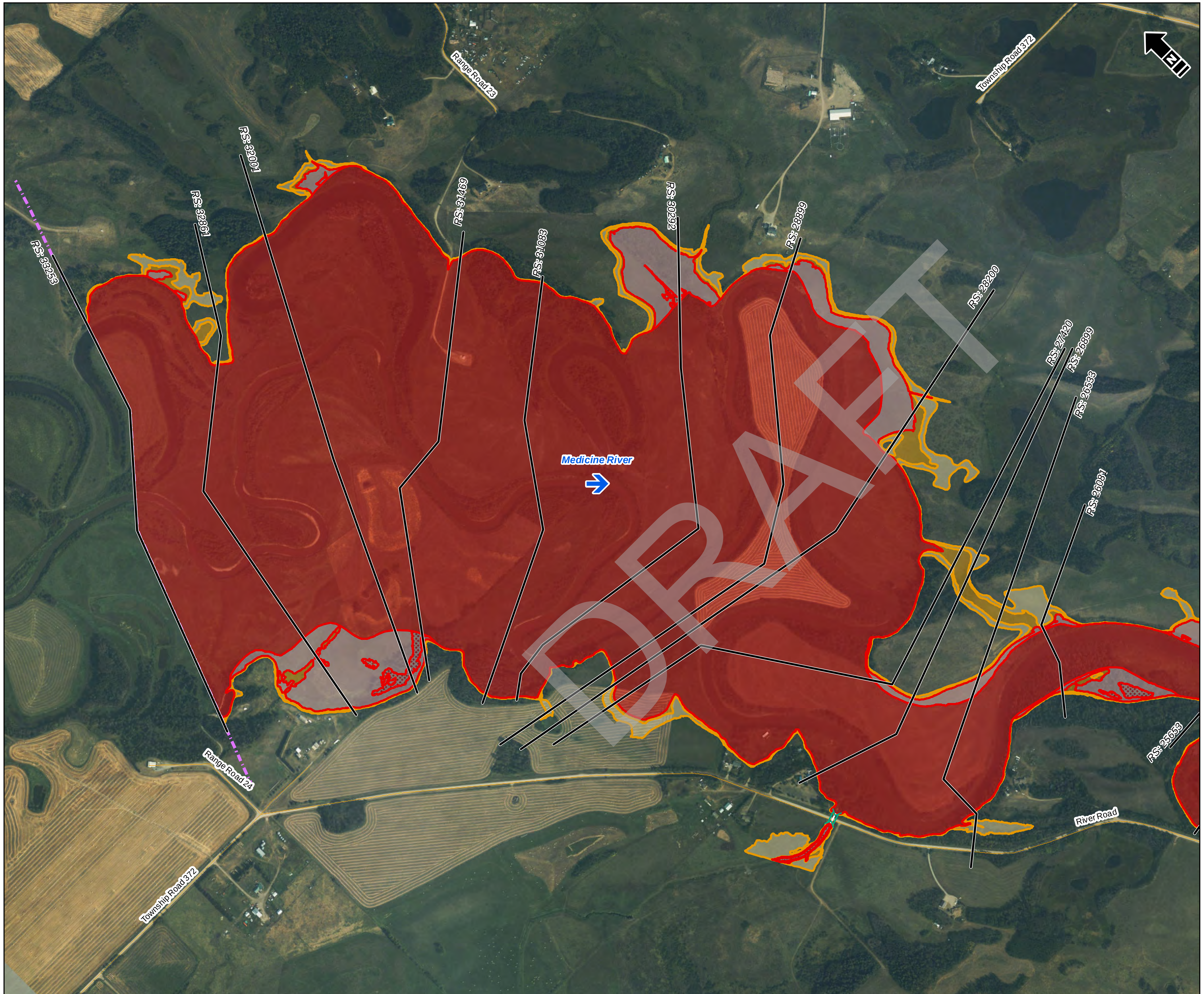

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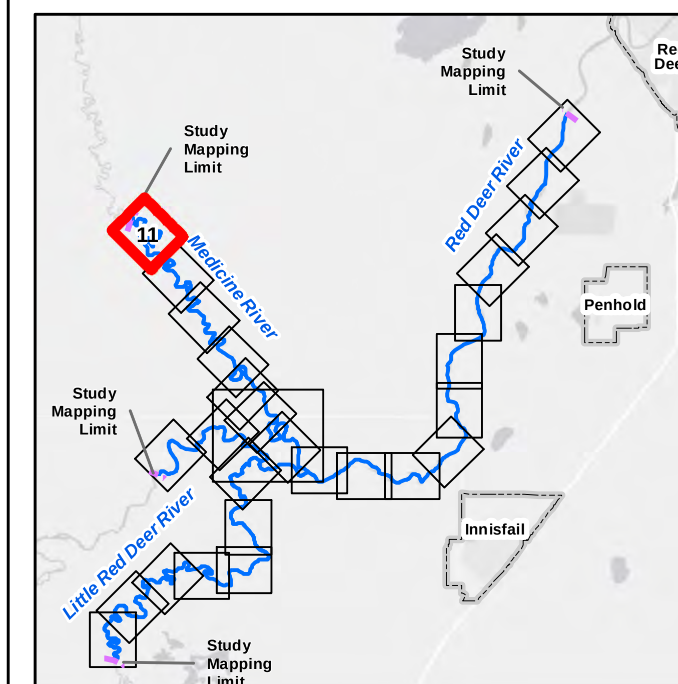

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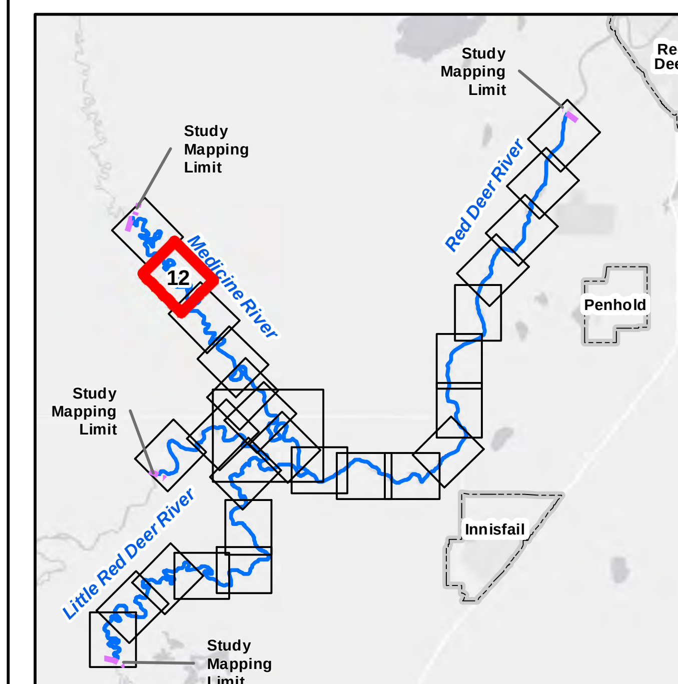

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March 2024	35374	P. Rogers	M. Shome

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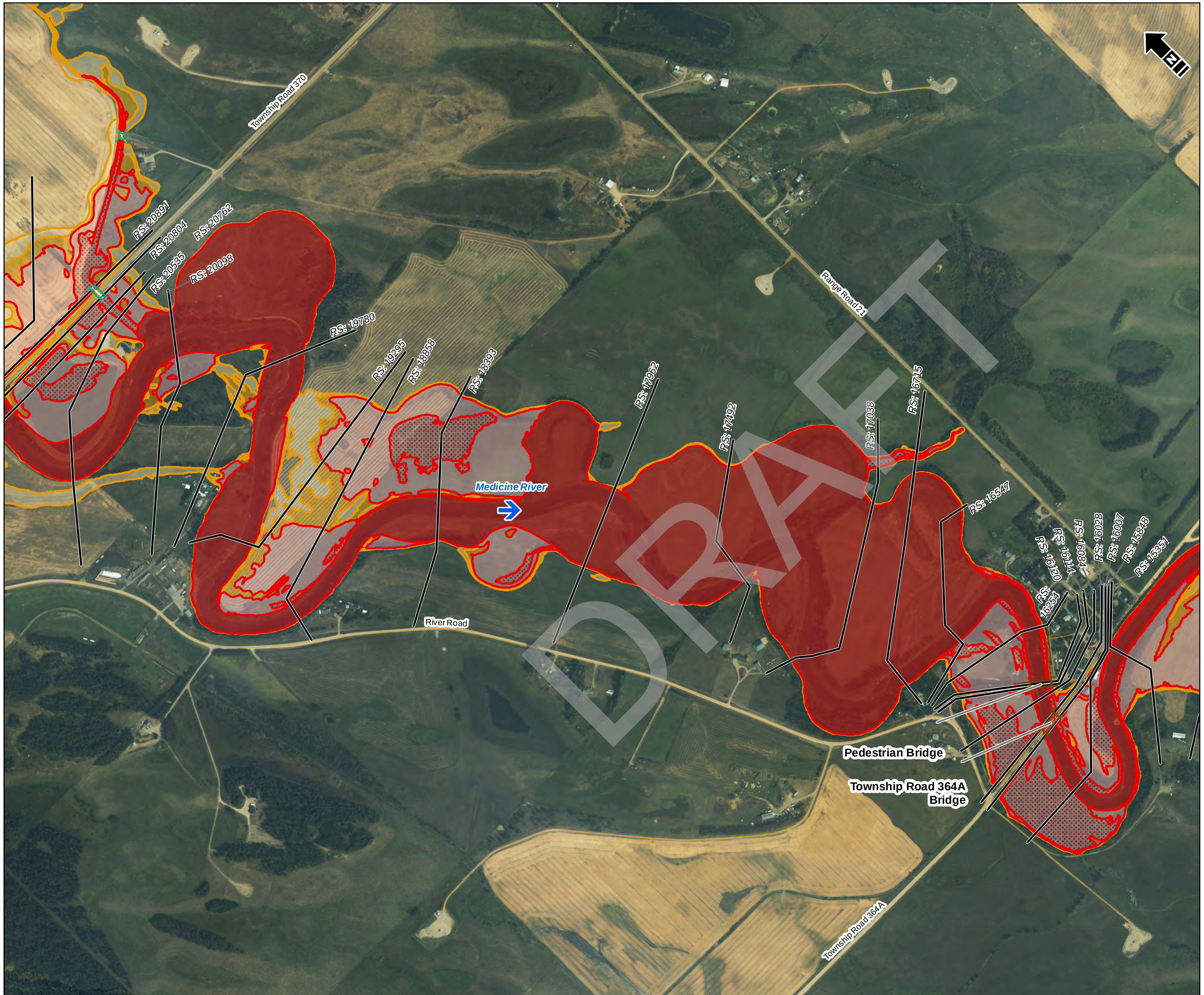

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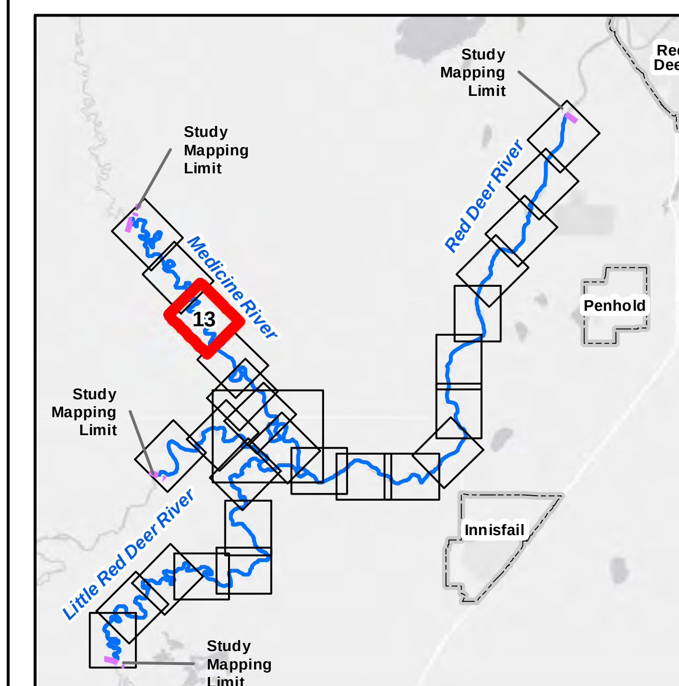

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Date: March 2024	Project: 35374	Submitter: P. Rogers	Reviewer: M. Shome

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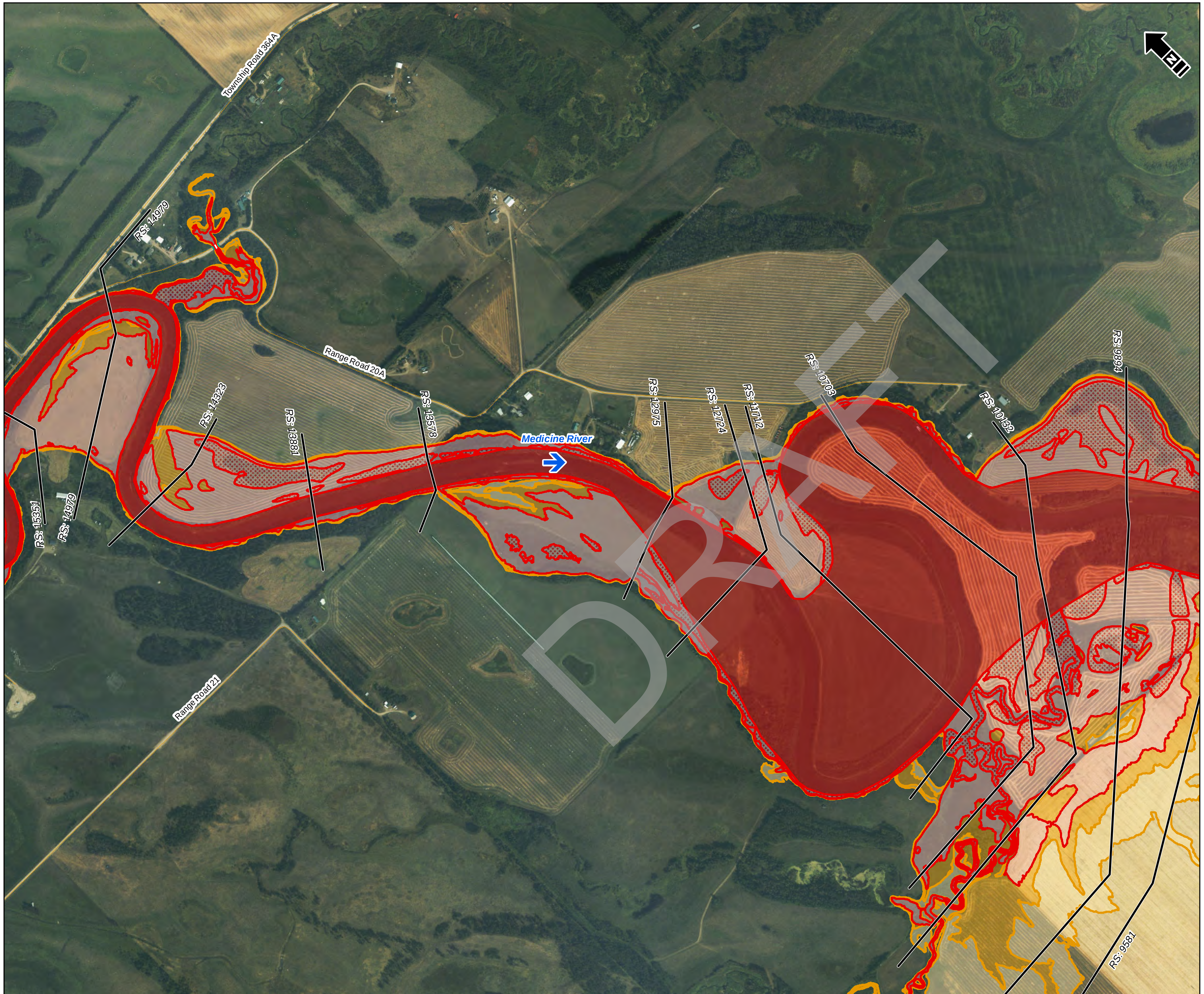

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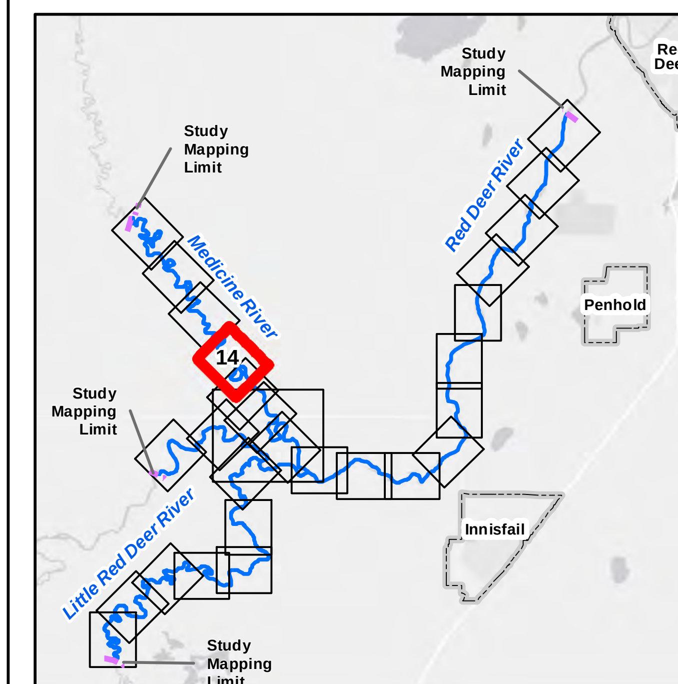

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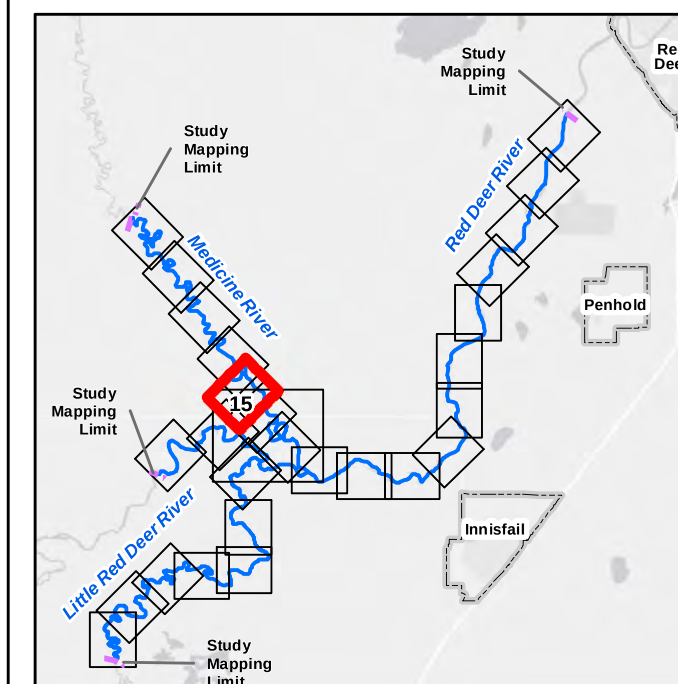

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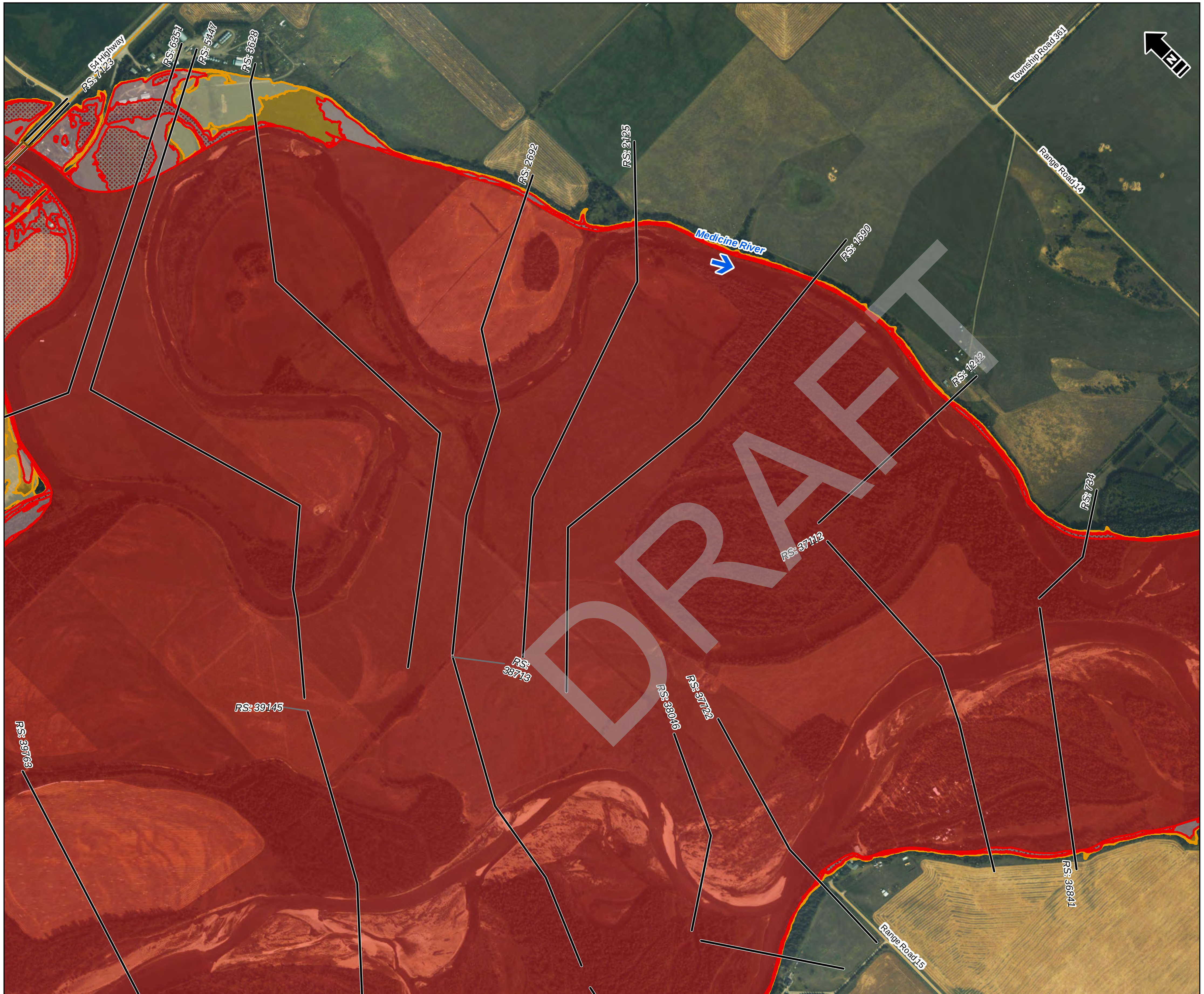

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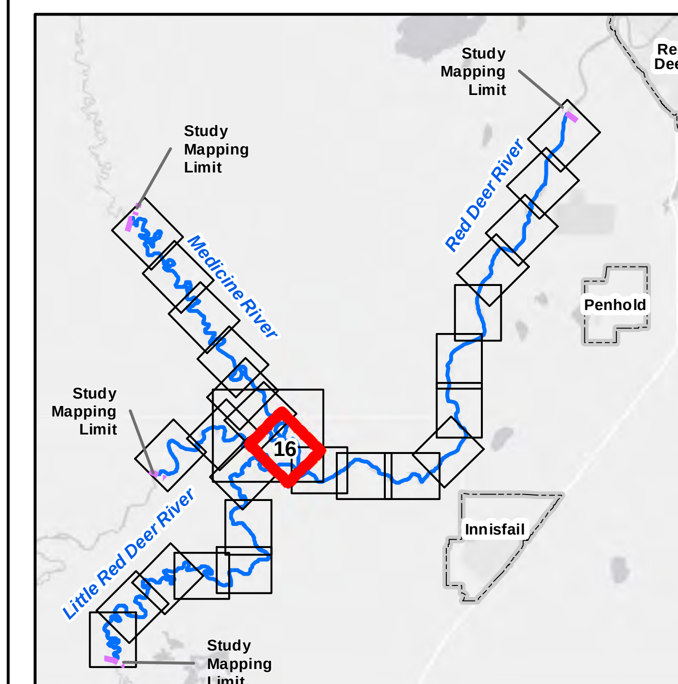

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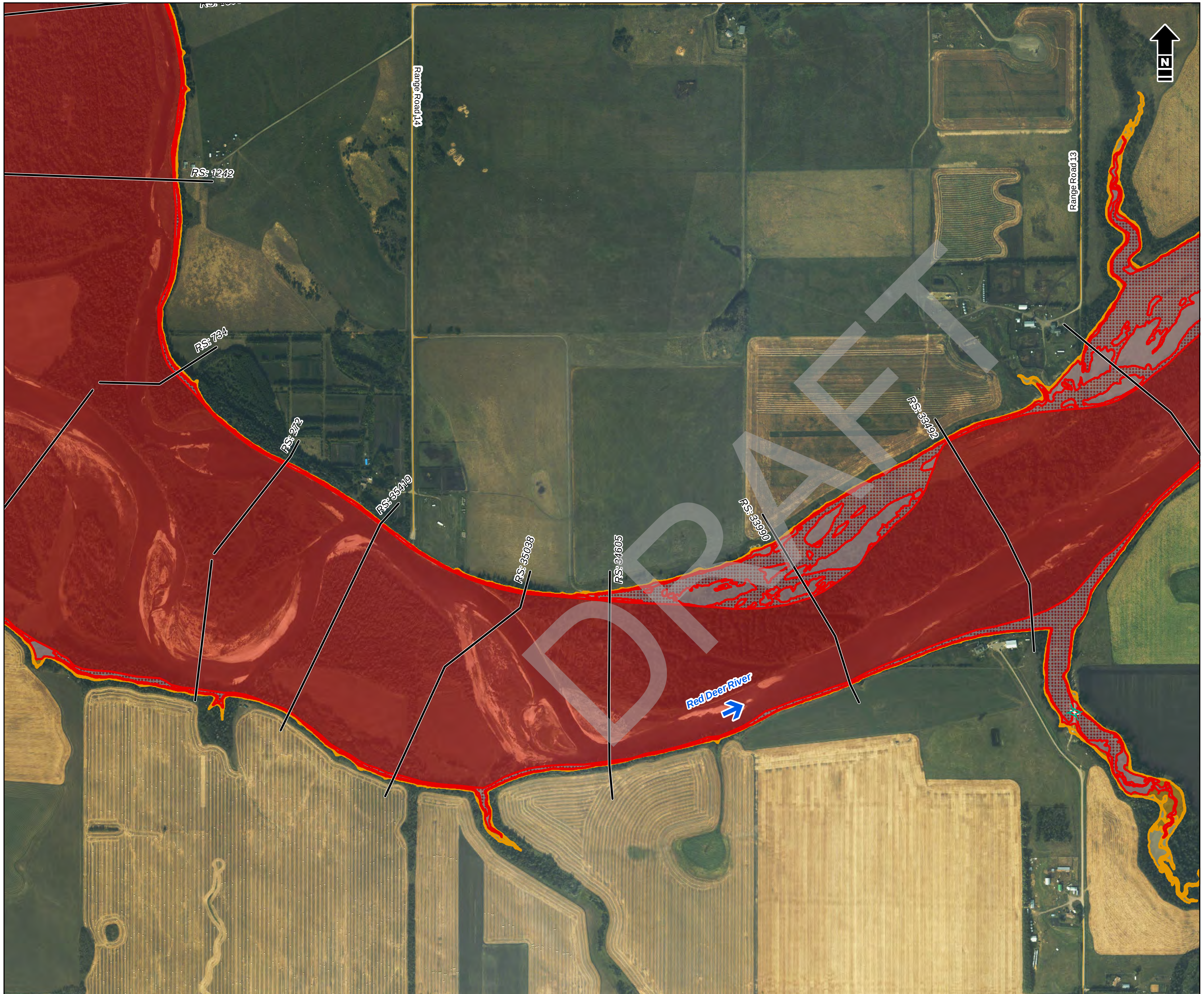

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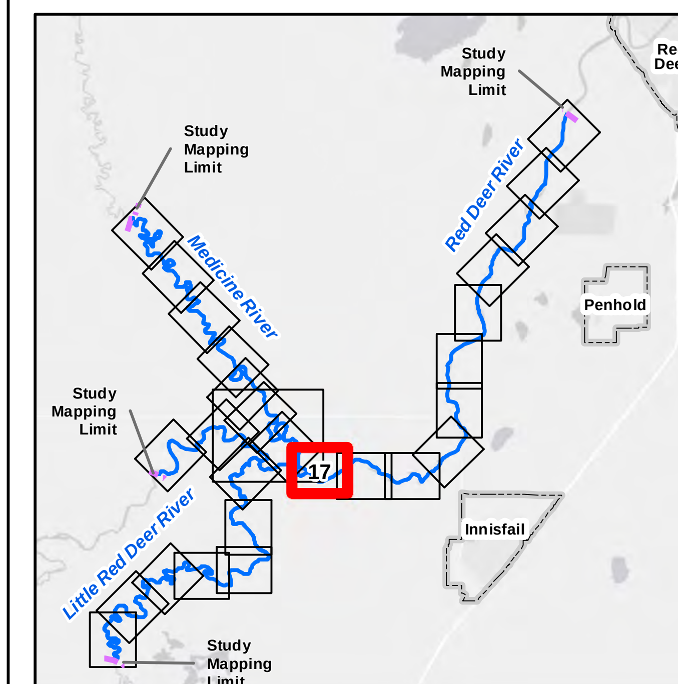

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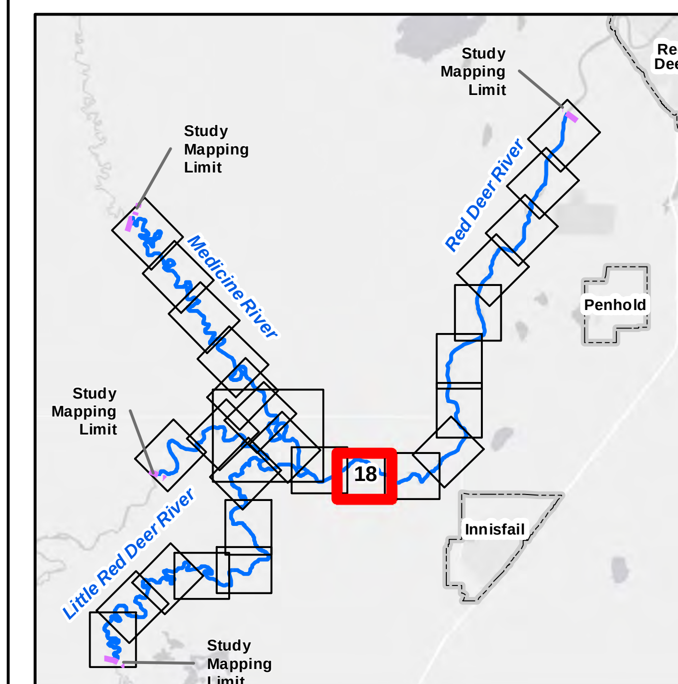

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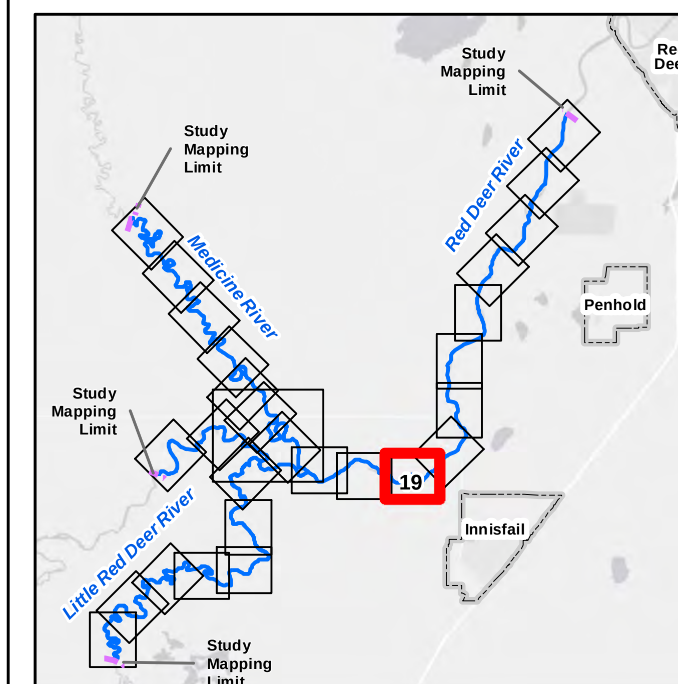

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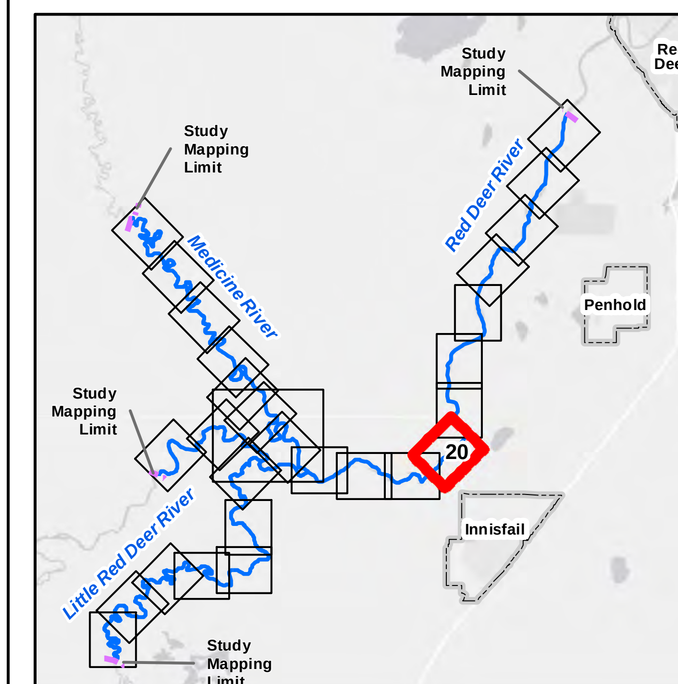

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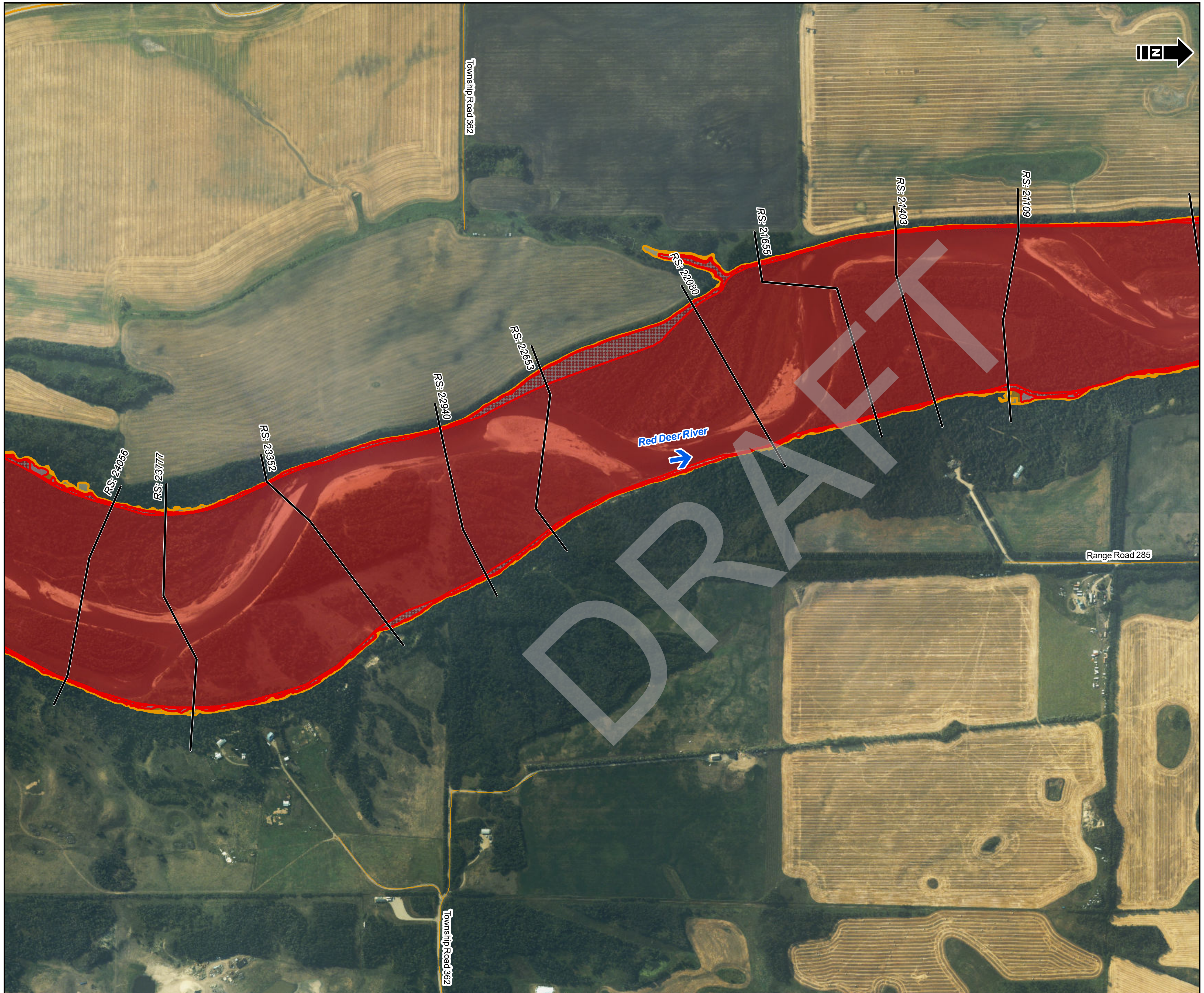

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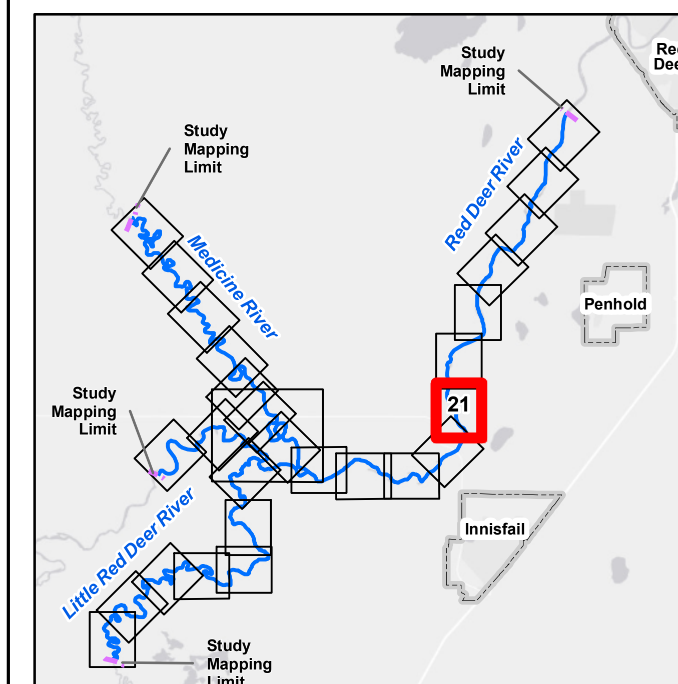

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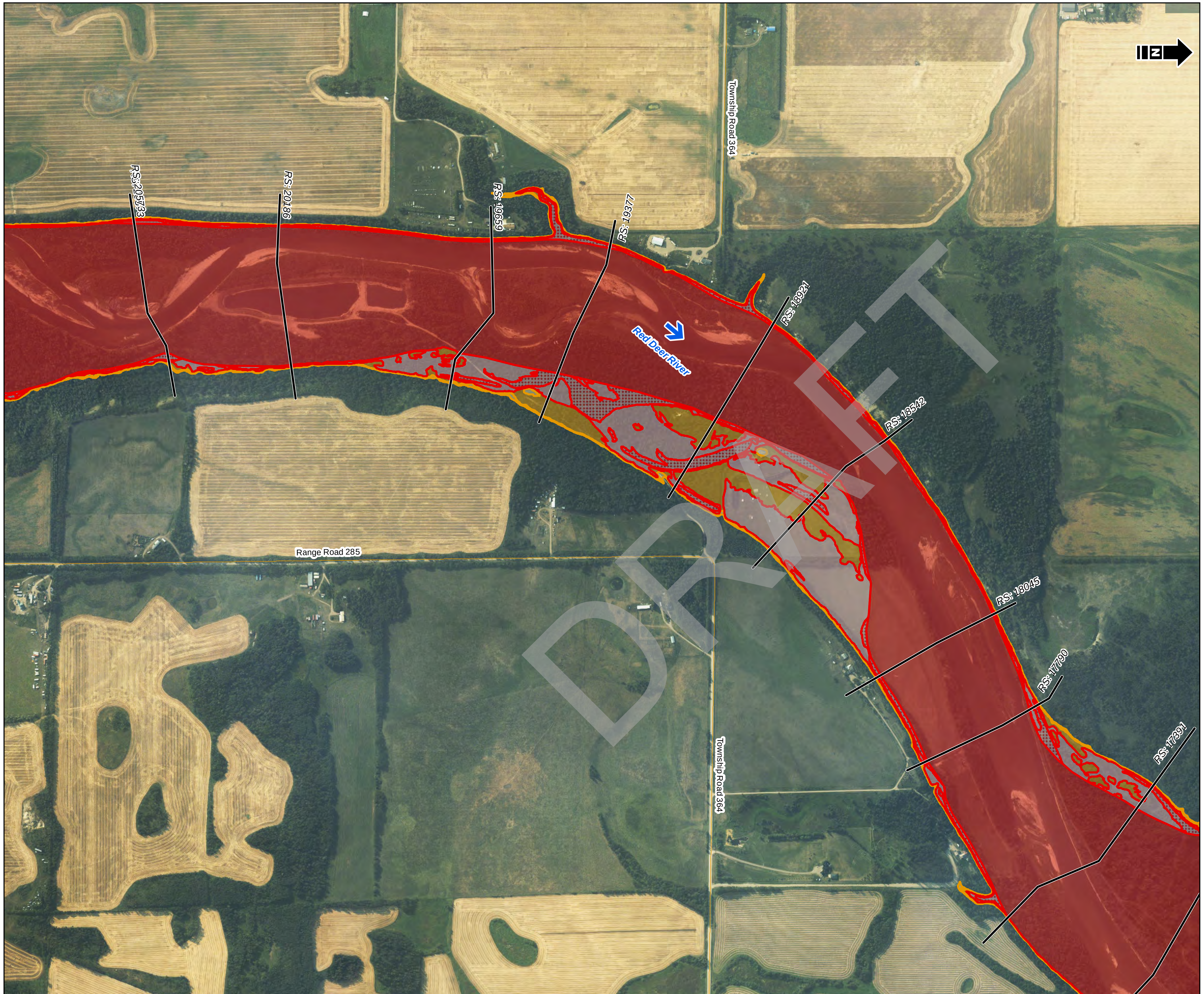

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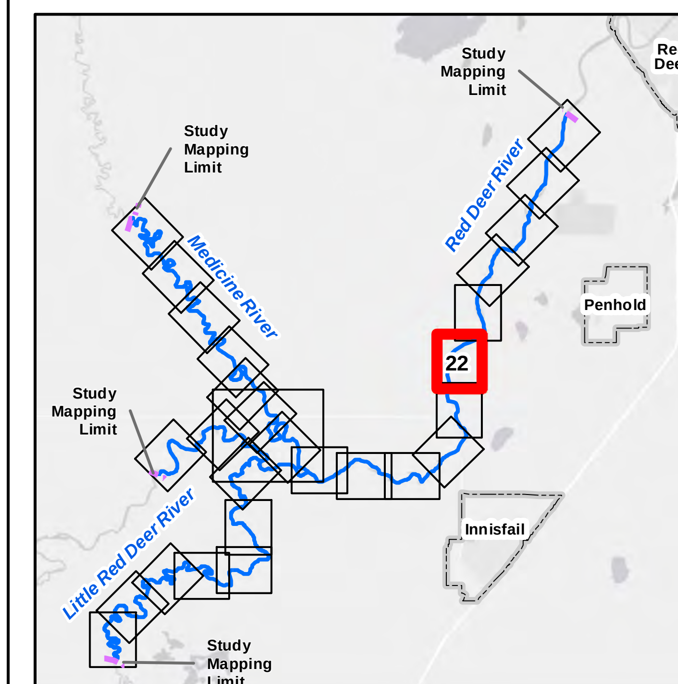

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1:10,000 metres
100 0 100 200
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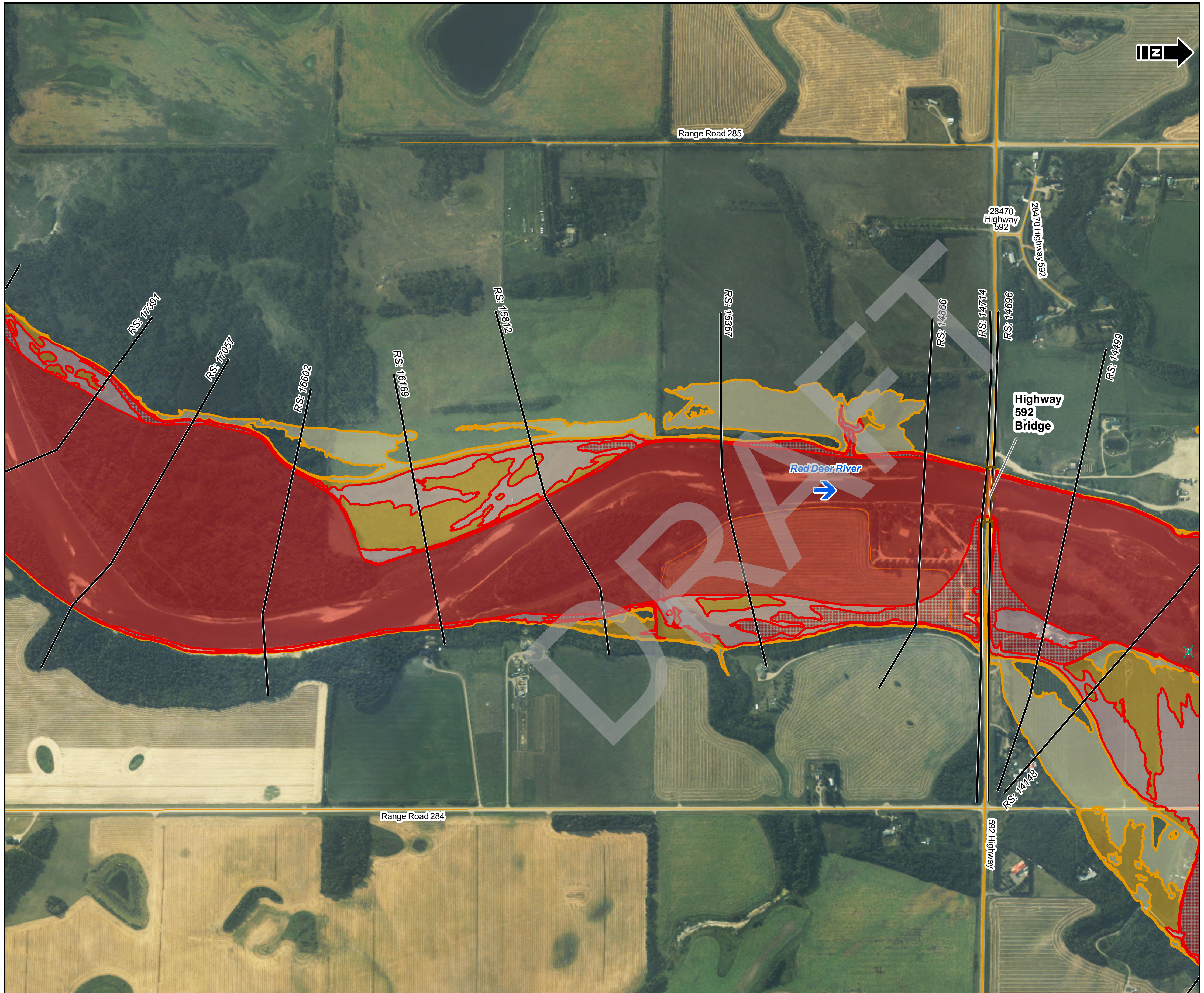
A Montrose Environmental Company

Alberta

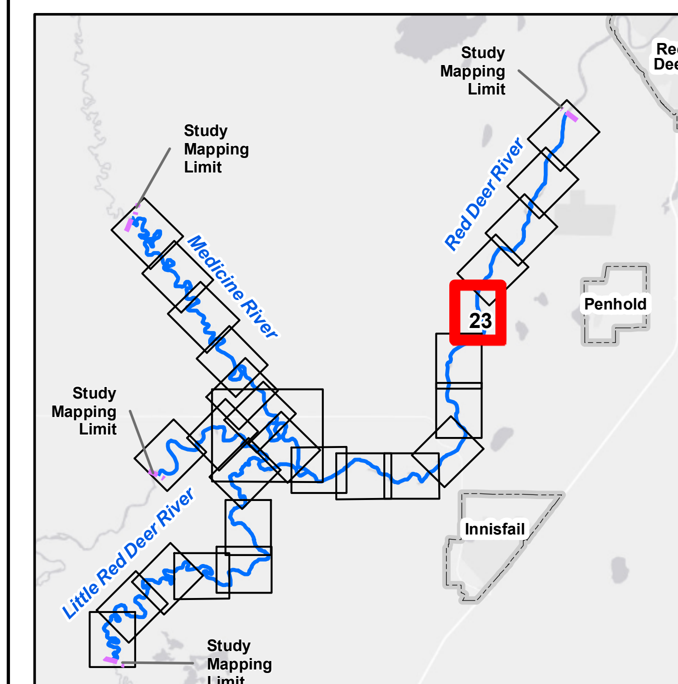
Alberta Environment and Protected Areas
Red Deer County and Markerville Flood Study

Governing Design Flood Hazard Map

Date:	Project:	Submitter:	Reviewer:
March 2024	35374	P. Rogers	M. Shome



Bridge
Culvert
Cross Section Line
Study Mapping Limit
Major Road
Local Road
Flow Direction
Floodway
Flood Fringe
High Hazard Flood Fringe
200-Year Flood Inundation Extent
500-Year Flood Inundation Extent



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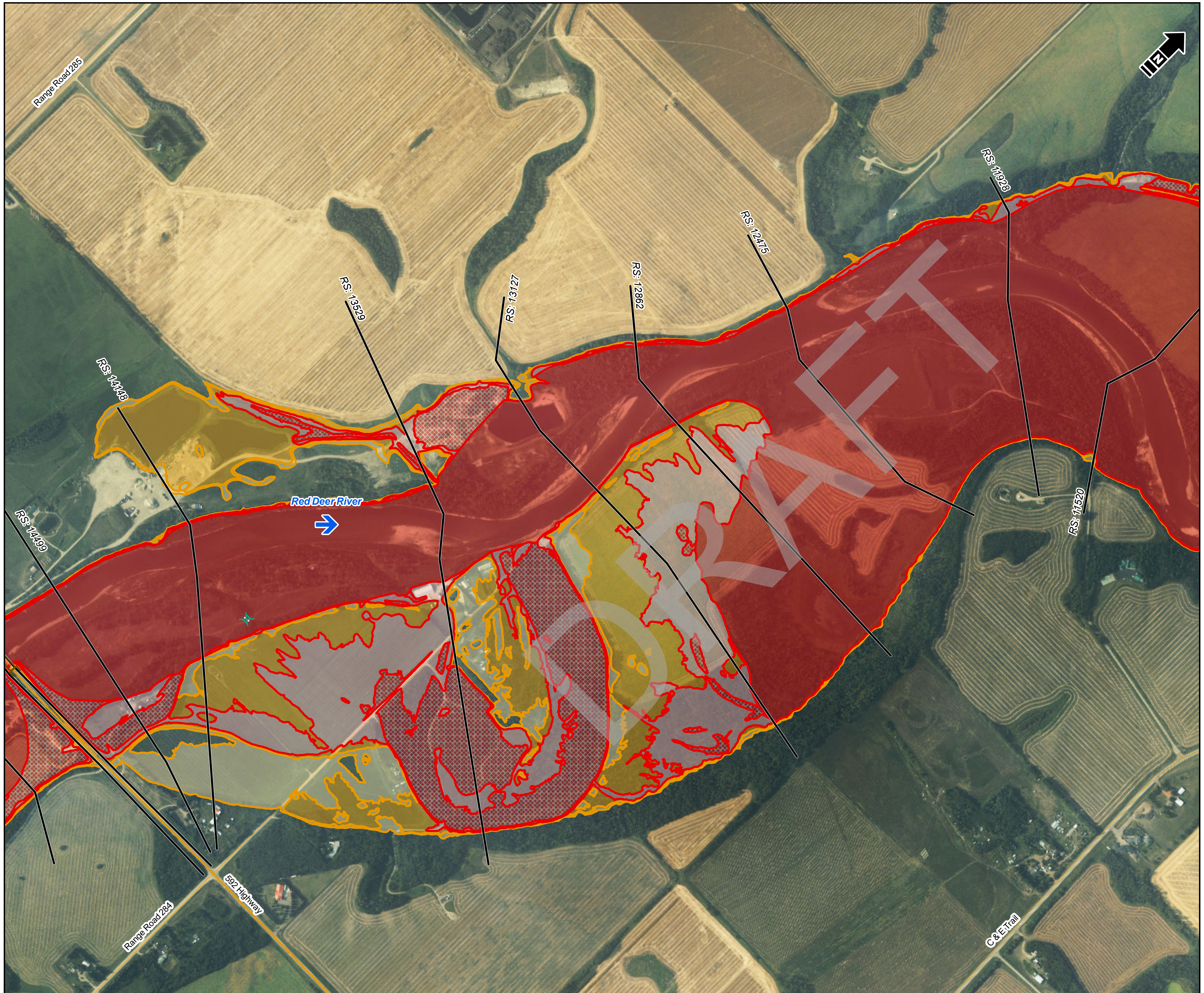
December 2024	35374	P. Rogers	M. Shome

Classification: Public



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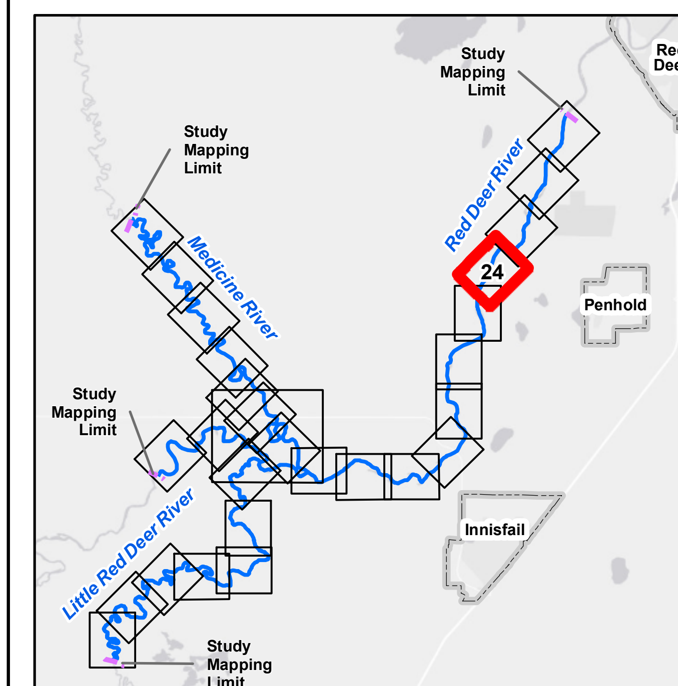

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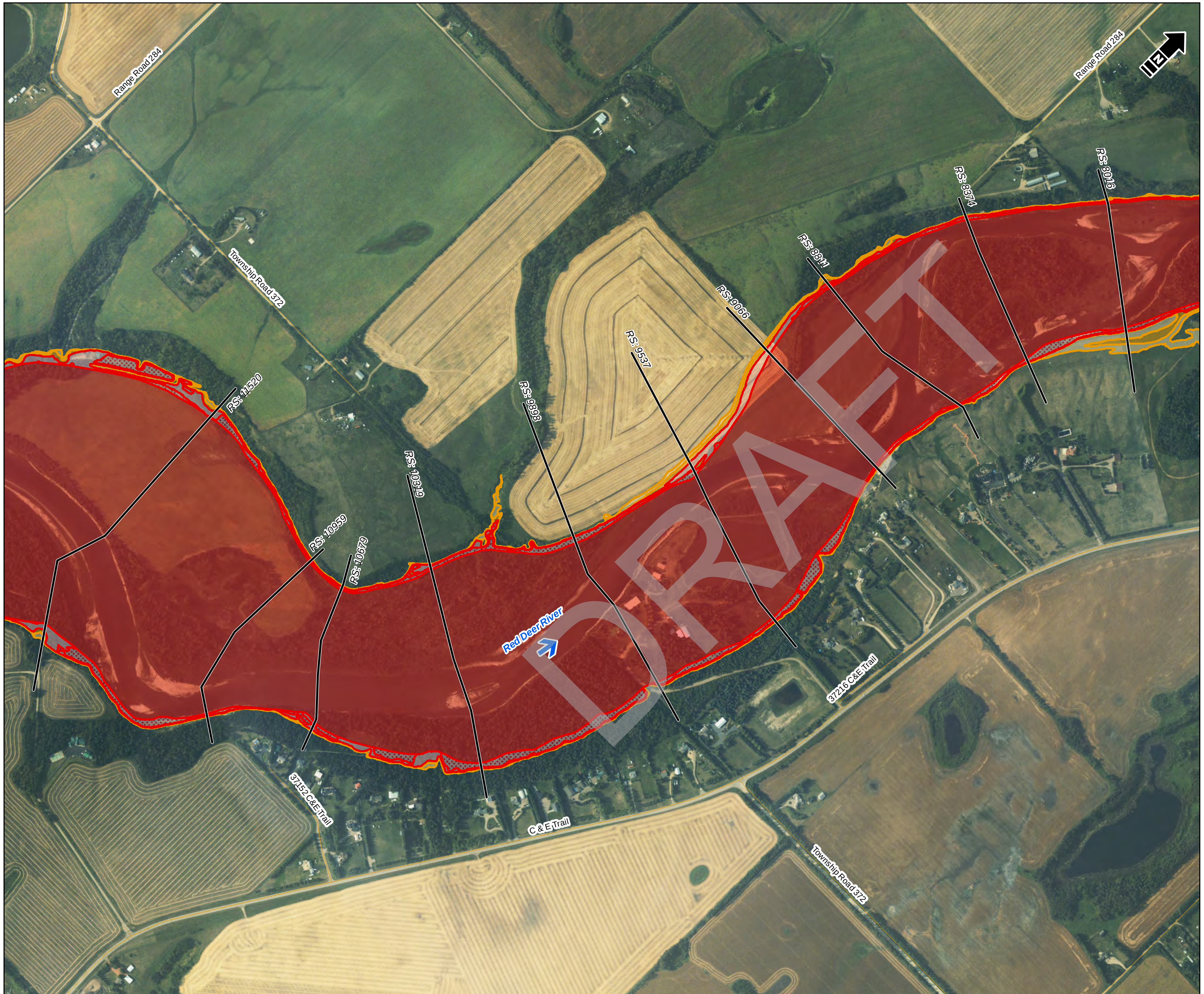

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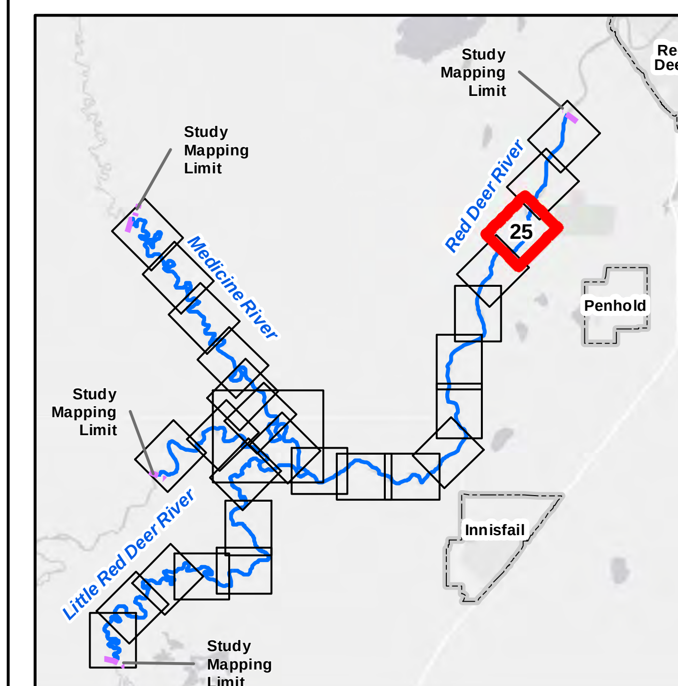

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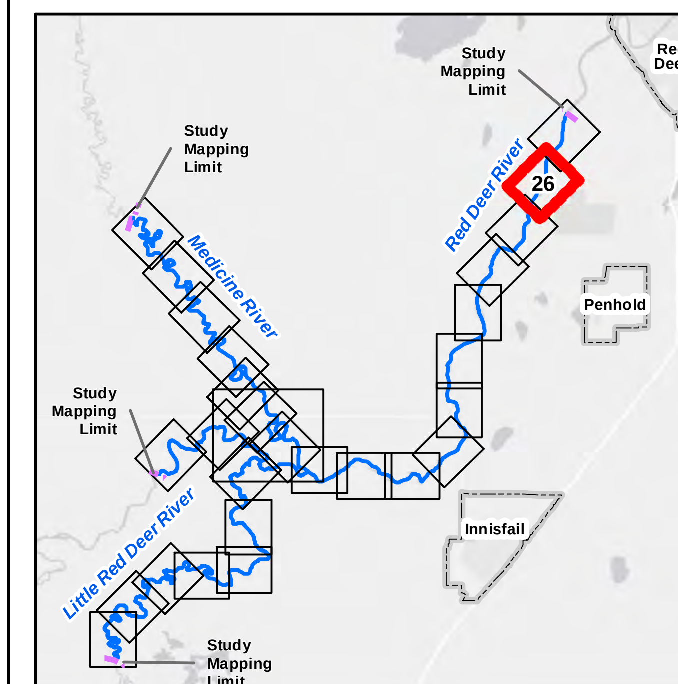

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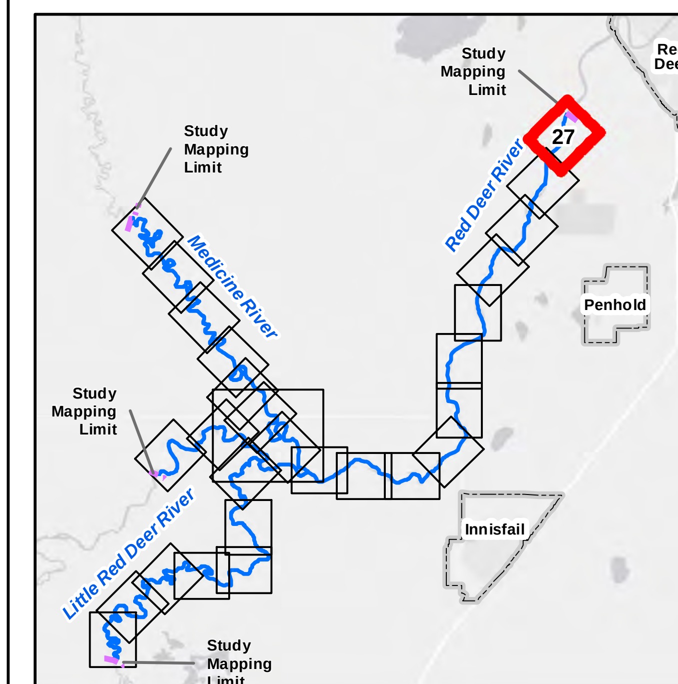

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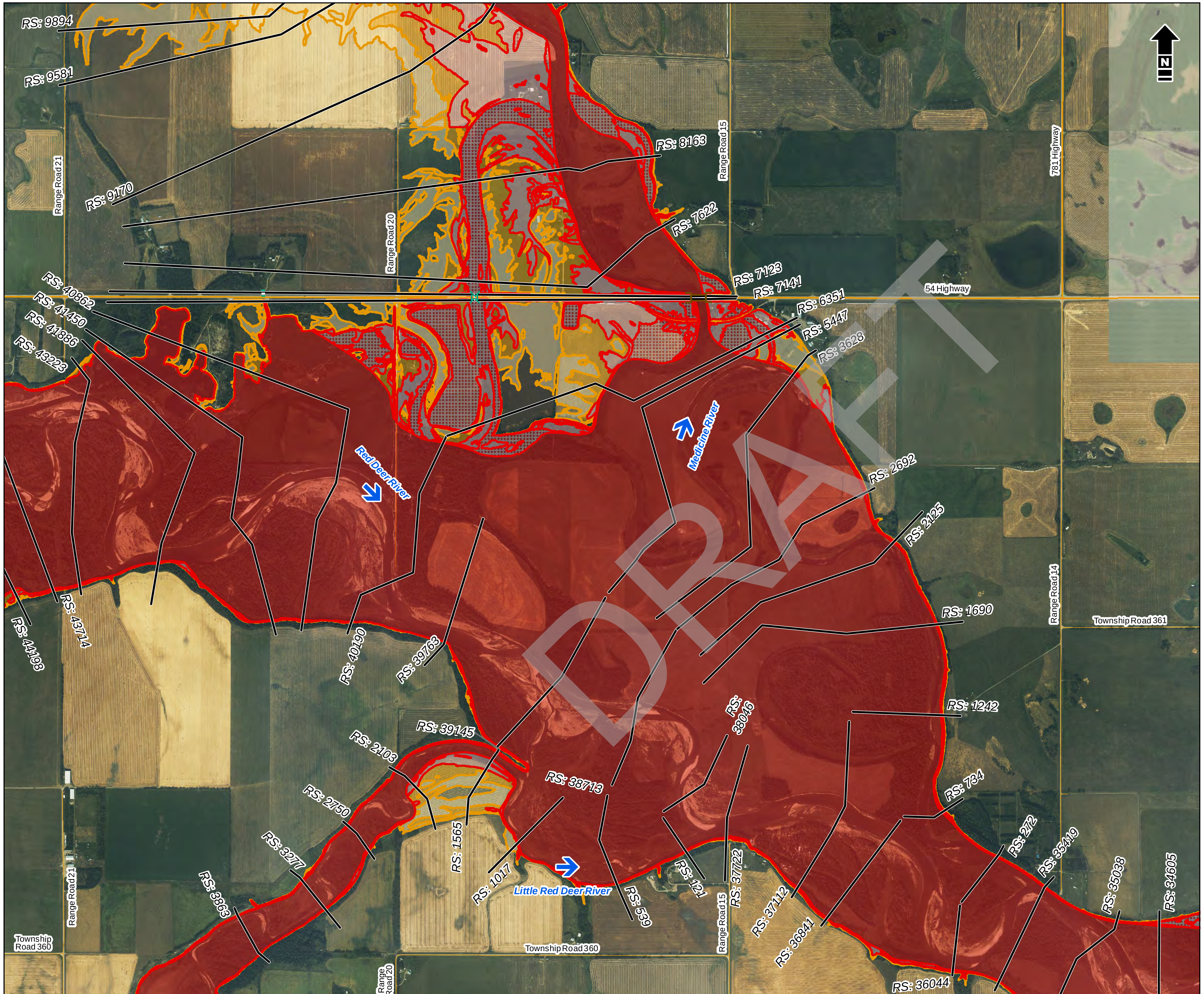

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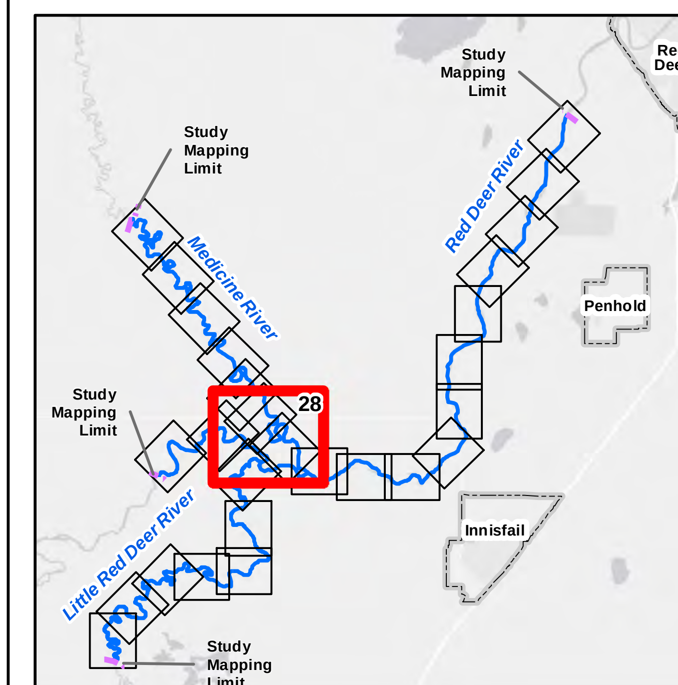

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1:20,000 metres
210 0 210 420
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