File CG3525

RM of Prince Albert No. 461

Slope Stability Assessment of North Saskatchewan River South Banks

Clifton

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Clifton Engineering Group Inc.

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Permission to Consult held by:

Discipline	Sk. Reg. No.	Signature
Geotechnical	6876	

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Executive Summary

Riverbank instability along the North Saskatchewan River in the Prince Albert area has been a problem since deglaciation almost 12,000 years ago. The primary factors contributing to the continued landslide activity within the study area include the river downcutting through the low shear strength lacustrine-alluvial clays and silts along the riverbank to erode and unload the slope toe, precipitation and spring snowmelt resulting in increased surface infiltration and higher pore water pressures in the valley wall slopes, urban/transportation development leading to increased surface runoff and poor drainage on the unstable slopes and developments which increase loading from fill placement along the upper valley wall.

In 2008, Clifton Engineering Group Inc. (Clifton) was hired by the Rural Municipality of Prince Albert, Saskatchewan No. 461 (R.M.) to complete a slope stability assessment on the southern shore of the North Saskatchewan River within the R.M. The objective of the assessment was to identify areas of slope instability along the river. Since the 2008 assessment, the R.M. had notified Clifton that the study area has experienced various slope instability issues which has affected existing properties, limited new development, and created safety issues due to unstable slopes. Deep seated landslide movement is evident throughout the study area at specific locations, with previous slope inclinometers monitored from 2017 to 2019 indicating large landslide movement at the lacustrine clay - till contact at around 30 mbgs (Clifton File No. R5999).

This report presents the results of the 2021 to 2022 comprehensive slope stability assessment of the south banks of the North Saskatchewan River within the R.M. boundaries. The length of riverbank assessed was approximately 75 km long (31 km^2) (Appendix A: Figure A1). The objective was to identify areas of slope instability and potential instability along the North Saskatchewan River south banks using an integrated desktop, advanced remote sensing, field, and 2D/3D Geographic Information Systems (GIS) technique.

Following preliminary desktop analysis and GIS hazard mapping, Clifton conducted an integrated onsite field assessment on September 14th, 2021. The purpose was to ground truth potential stability concerns where satellite and aerial imagery had been limited, assess terrain polygons, deploy a UAV in inaccessible locations and perform an overall inspection of unstable areas to provide an updated conceptual site map. The primary objective of the field program was to provide a more detailed characterization of slope instability features identified during a desktop study and to determine whether these features are active, recently active, or inactive. The appearance of features on acquired temporal (e.g., 1991, 1992, 2014, 2017, 2018, and 2021) satellite datasets (e.g., orthomosaic, LiDAR, DEM, RADAR, etc.) provided some indication of the age of instability and rate of movement. Final hazard maps included unstable (U) slopes where there was evidence of ongoing geohazard activity or evidence that slope movement had occurred in the past and probable unstable (PU) were indicated where geohazards may be present or may occur in the future.

This geotechnical report concludes with updated comprehensive stability assessment maps to identify unstable slopes and movement since 2008 along the southern riverbank. Preliminary recommendations of

potential setback limits, instrumentation, and monitoring are provided for the general study area but site-specific geotechnical assessments have to be conducted for each proposed development before proceeding.

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1.0 Introduction

Riverbank instability along the North Saskatchewan River in the Prince Albert area has been a problem since deglaciation almost 12,000 years ago. The primary factors contributing to the continued landslide activity within the study area include the river downcutting through the low shear strength lacustrine-alluvial clays and silts along the riverbank to erode and unload the slope toe, precipitation and spring snowmelt resulting in increased surface infiltration and higher pore-water pressures in the valley wall slopes, urban/transportation development leading to increased surface runoff and poor drainage on the unstable slopes and developments which increase loading from fill placement along the upper valley wall.

This report presents the results of the comprehensive slope stability assessment of the North Saskatchewan River south banks within the Rural Municipality of Prince Albert, Saskatchewan No. 461 (R.M.) boundaries. An overview of the overall stability assessment study area is shown in Appendix A: Figure A1. The length of the riverbank that was assessed was approximately 75 km long (31 km^2). Clifton Engineering Group Inc. (Clifton) received authorization to proceed with the assessment from the R.M. via email by Mr. Jason Kaptein on June 21st, 2021 (Clifton Contract File No. PC3498).

The primary objective of the assessment was to identify areas of slope instability and potential instability along the North Saskatchewan River using an integrated desktop, advanced remote sensing, field work, and Geographic Information Systems (GIS) technique. This report also provides preliminary calculations of potential setback limits (e.g., buffer zones) from mapped unstable slopes, conclusions and recommendations arising from the work.

1.1 Initiation and Purpose

In 2008, Clifton was hired by the R.M. to complete a stability assessment on the southern shore of the North Saskatchewan River within the R.M. boundaries. The objective of the assessment was to identify areas of slope instability and potential instability along the North Saskatchewan River using aerial photography and existing geological and topographical data. The results of the report submitted on September 26th, 2008, classified the riverbank as either *Landslide, Probable Landslide or Stable* based on available topographical and geological mapping and visual analysis of air photos (Clifton File No. S1615).

The recommended actions from the initial 2008 work were:

- An onsite inspection by a qualified geotechnical engineer prior to any site considered for development along the riverbank to identify potential stability concerns that may not have been apparent in the air photos due to dense vegetation;
- Recommended field investigation to characterize the site and provide the basis for development of remedial options and/or construction methods; and

- Strategic monitoring recommendations and instrumentation installation in highly susceptible areas along the southern riverbank.

Since the 2008 assessment, the R.M. notified Clifton in 2021 that the study area had experienced various slope instability issues which has affected existing properties, limited new development, and created safety issues due to unstable slopes. The R.M. hired Clifton to take advantage of new technologies, including advanced remote sensing techniques (e.g., LiDAR, aerial photographs, UAV, photogrammetry, satellite datasets, RADAR etc.), to reassess the coverage area from the previous study and generate a report and series of maps showing areas of instability and probable slope instability similar to the deliverables of the 2008 report. In addition to identifying and characterizing the southern riverbank, the R.M. requested a more detailed slope assessment for approximately 4 km (~2.3 km^2) along the southern bank immediately east of the Prince Albert city limits (Appendix A: Figure 1A) where there have been impacts to residences properties. The legal Saskatchewan Land Description of this detailed assessment area is from SW 19-48-25-W2M to NW 21-48-25-W2M.

1.2 Methodology

The integrated desktop, field, advanced remote sensing, GIS, and geotechnical/geohazard site characterization was carried out using the following methodologies:

- Compiled and reviewed all readily available data, records, and reports;
- Conducted a preliminary desktop Terrain Stability Mapping (e.g., Unstable, Probable Unstable and Stable) within a GIS database utilizing archived and updated remote sensing datasets (e.g., LiDAR, aerial photographs, satellite imagery/DEMs, RADAR, UAV, etc.). Unstable (U) slopes were indicated where there was evidence of ongoing geohazard activity or evidence that slope movement had occurred in the past. Probable Unstable (PU) were indicated where geohazards may be present or may occur in the future and Stable areas were identified where the site appeared stable or there was a low likelihood of geohazards occurring in the future;
- Conducted an integrated field and advanced remote sensing (e.g., UAV, hand-held LiDAR, photogrammetry, etc.) site visit on September 14th, 2021 with results correlated to slope instability issues provided within an interactive secured web-based platform;
- Evaluated the information, conducted 2D/3D satellite imagery mapping and change detection analysis; and
- Prepared a geotechnical report with updated comprehensive stability assessment maps to identify unstable slopes and movement since 2008 along the proposed southern riverbank.

A Geographic Information System (GIS), namely QGIS 3.16.1-Hannover with GRASS 7.8.4 (2021), was utilized to manage, analyze, and visualize all the data collected for the site. The field, remote sensing stations, hiking tracks, slope instability features, structural measurements, damage/morphological features, and photographs have been all embedded within the GIS database and displayed on the provided hazard maps. Multi-sensor remote sensing data and raster Digital Elevation Models (DEMs) were utilized to create GIS hillshade, slope, aspect, elevation, and curvature maps. These thematic maps were used to extract various cross-sectional slope profiles for input into preliminary setback limit calculations (e.g., potentially unstable setbacks) overall site characterization and final terrain hazard maps. GIS data files, including mapped features and terrain hazard polygons are provided in Appendix C.

1.3 Scope of Work

A phased approach was used to assess the slope stability of the study area. Phase 1 entailed a compilation of pertinent and ascertainable data and characterization of the site to provide updated site hazard maps since the previous Clifton 2008 engineering report. Phase II was subject to the findings of Phase 1 and consisted of detailed field terrain mapping throughout unstable slope and geohazard locations with a focus on an approximately 4 km section along the southern bank immediately east of the Prince Albert city limits (Appendix A: Figure 1A). Phase III, if necessary, would provide recommendations and installation of slope monitoring devices and remediation techniques to stabilize the slope along the mapped unstable zones. The scope of work for this slope stability assessment study included Phase I and Phase II.

The objectives for this study are summarized as follows:

- Review pertinent and ascertainable data information (e.g., aerial photographs, high-resolution satellite imagery, DEMs, and LiDAR datasets) since the previous 2008 report to evaluate movement and instability features (e.g., piping, tension cracks, active gullies/erosion, exposed scarps, inclined/disturbed vegetation, etc.) along the southern river bank within the study area (Appendix A: Figure 1A);
- Evaluate and provide a series of maps showing areas along the southern bank that are currently stable, susceptible (probable unstable), and currently active (unstable);
- Complete an onsite site inspection by qualified geotechnical engineers to ground truth potential stability concerns where satellite and aerial imagery is limited (e.g., covered by vegetation, low-resolution, temporal gaps, etc.), validate terrain polygons, deploy a UAV in inaccessible locations and overall inspection of unstable areas to provide an updated conceptual GIS site model;
- Evaluate and assess the site topography, surficial drainage, geology and groundwater regime from the site visit and analyzed datasets, to identify drainage patterns and also historical precipitation and irrigation patterns in the higher elevations above the southern river bank slope; and
- Compiling the above into a report including final hazard maps, conclusions and recommendations arising from the work.

2.0 Study Area Background

2.1 Location and Access

This report presents the results of the slope stability assessment of the south banks of the North Saskatchewan River within the R.M. boundaries. An overview of the study area is shown in Appendix A: Figure A1. The assessed riverbank fell within the land locations listed in Table 2.1. The length of riverbank assessed was approximately 75 km (31 km^2). The banks located within the City of Prince Albert's city limits and beyond the R.M. limits were excluded. During fieldwork, Clifton used a Notice Letter by Jason Kaptein of the R.M (dated September 13th, 2021), that summarized the purpose of the work, to access and in some cases, deploy a UAV for aerial imagery of the site.

Table 2.1 – Study Area Land Locations

Lot No. / Section	Township	Range	Meridian
Lots 1 through 3	48	28	W2
Lots 4 through 51	48	27	W2
Sections 19, 20, 21, 25, 26, 27, 28, 33, 34, 35, 36	48	25	W2
Sections 25, 26, 30, 31, 32, 33, 34, 35, 36	48	24	W2
Section 13	49	24A	W2
Sections 17, 18, 19, 20, 21, 22, 25, 26, 27, 28, 36	49	23	W2
Sections 13, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30	49	22	W2

2.2 Topography, Surficial and Bedrock Geology

The study area is located on the south bank of the North Saskatchewan River, with the topography rising approximately 45 m from the river to the upland (minimum elevation 380 masl (east mapping extent) river; max elevation ~465 masl uplands). The site is within the Carrot River Lowland, characterized by undulating to moderately rolling uplands, with the lower slopes having a hummocky horst and graben morphology, characteristic of deep-seated landslide terrain in meta-stable condition (Ellis and Clayton, 1970).

The North Saskatchewan River Valley was formed during the Wisconsinan deglaciation. As glaciers retreated north-eastward, the channel was eroded as a spillway that flowed into Glacial Lake Saskatchewan approximately 12,000 years ago (Christiansen, 1979). In the years since deglaciation, the river valley has been further eroded and North Saskatchewan River Alluvium has deposited. It is has widely reported that valley walls in Saskatchewan host numerous retrogressive landslides (Clifton et al., 1981; Eckel, 1985).

The geology within the study area consists of, in descending order, surficial stratified drift layers of sand and silt overlying silt and clay. The silt and clay are underlain by the tills of the Battleford and Floral Formations of the Saskatoon Group. The Sutherland Group underlies the Saskatoon Group in most areas. The underlying bedrock is the Second White Speckled Shale of the Lea Park Formation. Areas of disturbed bedrock are present from the western R.M. boundary to the eastern side of the City of Prince Albert.

The sand and silt drift layer are approximately 5 m to 20 m thick along the south bank of the North Saskatchewan River. The underlying silt and clay layer is approximately 5 m to 50 m thick; therefore, the contact between the silt and clay layer and the underlying till varies between 10 m and 70 m below ground surface. The Saskatoon Group and Sutherland Group tills extend about 50 m to 100 m below the silt and clay drift, at which point the Lea Park Formation is encountered.

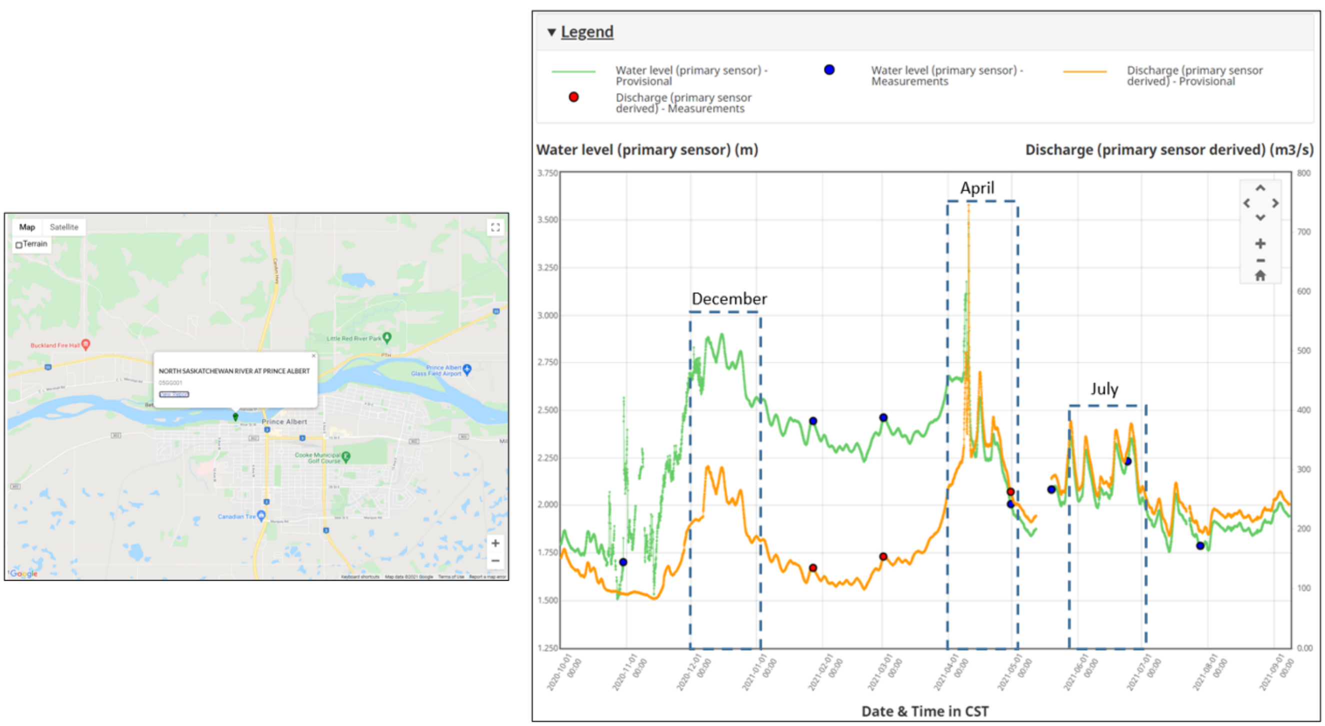
Landslides along the river valley wall east and west of Prince Albert are seated in the highly plastic glaciolacustrine clay located above the Saskatoon Group till. Deep seated landslide movement monitored through subsurface slope inclinometers from 2017 to 2019 indicated large landslide movements in the highly plastic clay directly above the clay-clay till contact at ~29 mbgs within the study area (Clifton File No. R5999).

2.3 Climate, Hydrogeology, and River Discharge/Water Levels

Prince Albert experiences a cold and temperate humid continental climate, with cold winters lasting five months of the year and warm summers. The study area has a significant amount of rainfall during the year, with the most precipitation in June and July (~90 mm).

The North Saskatchewan River functions as a discharge receptor for many of the aquifer systems in the area. The primary source of groundwater is from the Swan River Group drift aquifer, with seepage and springs due to gravity drainage along the north facing slope of the south riverbank in the study area. The groundwater discharge may cause piping failures. Vertical infiltration from precipitation recharges the surficial aquifer within the stratified drift. There is a direct relationship between the infiltration and increased slope failures, with slope movement measurements indicating movement rates are highest in late spring and early summer during the wetter months.

The North Saskatchewan River may experience flooding due to runoff from the eastern slopes of the Rocky Mountains. In Saskatchewan, such floods tend to take place with the melt of the mountain snowpack in June and July. Government of Canada Hydrometric Stations along the North Saskatchewan River in Prince Albert SK (05GG001) have been utilized to identify historical and current trends with river water level and flow rate (discharge) that play a critical role in erosion and slope movement. As displayed in Figure B1, there is a direct correlation between elevated water levels and river peak flow rates, namely in April and July. The average water level (above the monitoring sensor) and discharge is 2 m and 200 m^3/s, respectively (Figure B1). More recently (2021), the April snowmelt (spring runoff) correlated to an increase in water level of 3.5 m and a discharge of 750 m^3/s (Figure B1). A three-month lag is noted for the second rise in water level and discharge in July due increased rainfall and mountain snowmelt, also referred to as ‘freshet’. The influence of peak water levels and discharge variations in late spring and early summer directly impact pore-water pressures and undercutting of the riverbanks, leading to slope movement and failures. Groundwater levels within the surficial aquifer tend to rise due to an ‘urbanization effect’, which includes factors such as pavement/building surface runoff, irrigation of lawns, gardens, and agriculture fields and possibly due to leakage from water mains. These trends in increased water levels, precipitation, and river discharge correlate to increased awareness for potential slope movement and monitoring during April-May and July-August.



DATE	DRAWN BY	REVIEWED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-05	JM	AK	As Shown	CG3525	B1

CLIENT	R.M. OF PRINCE ALBERT No. 461
SITE	2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS
TITLE	North Saskatchewan River water level and flow rates from the Prince Albert, SK Hydrometric Station (05GG001) (Data from Environment and Climate Change Canada Historical Hydrometric Database).

Figure B1 – North Saskatchewan River water level and flow rates from the Prince Albert, SK Hydrometric Station (05GG001) (Data from Environment and Climate Change Canada Historical Hydrometric Database).

3.0 Field Inspection Program

3.1 Objectives

The field program was conducted on September 14th, 2021, by Clifton professional staff Senior Geotechnical Engineer Allen Kelly P.Eng., P.Geo., and Intermediate Engineering Geologist Jesse Mysiorek MSc., P.Geo. The primary objective of the field program was to provide a more detailed characterization of potential slope instability features identified during the desktop study and to determine whether these features were active, recently active, or inactive through aerial and ground inspection. The appearance of slope instability features on acquired temporal (e.g., 1991, 1992, 2014, 2017, 2018, and 2021) satellite datasets (e.g., georeferenced orthomosaic, LiDAR, DEMs) provided some indication of the age of instability and rate of movement.

Additionally, disturbance of vegetation visible on aerial photographs, which is typically manifested by changes in tone (on panchromatic imagery) or colour (on colour images), provided information on how recent the slope activity was. However, confirmation of landslide activity can only be provided by ground inspection or low altitude UAV flights. Such information includes disturbed/tilted ('drunken') trees, fresh scarps, tension cracks, and seepage.

The secondary objective was to ground-truth types of instability and their associated materials and to refine the boundaries of features identified during prior desktop mapping.

In addition to identifying and characterizing the southern riverbank, the R.M. had requested a detailed slope assessment for approximately 4 km (~2.3 km^2) immediately east of the Prince Albert city limits (Appendix A: Figure 1A) where there have been impacts to residences. The legal land description of this detailed assessment area is from SW 19-48-25-W2M to NW 21-48-25-W2M. Clifton staff mapped this area in detail, both during the desktop study and fieldwork visit.

3.2 Features Inspected

Using previous reports, aerial photographs, satellite datasets (e.g., archived, and high-resolution September 2021 imagery), bare-earth LiDAR, and aerial photographs, Clifton completed preliminary terrain stability mapping prior to field inspection utilizing GIS analysis. The preliminary maps identified areas along the study area that were unstable, potentially unstable, and stable. In addition to the slope stability maps, instability features such as tension cracks, scarps, surficial erosion, and recent ground movement were identified with the advanced satellite datasets and change detection. Clifton uploaded the spatial GIS files onto a field iPad with GIS embedded software, which allowed real-time GPS tracking and positioning to ground-truth the unstable, potentially unstable, and instability features in the field. Features were investigated in the field by ground inspection, UAV flyovers, and truck. The onsite inspection by qualified engineers with slope stability mapping experience along the riverbank were vital to the project to identify potential stability concerns that may not have been apparent in the preliminary desktop mapping due to dense vegetation.

3.3 Information Collected

The principal types of information collected at potential slope instability sites were types and extents of geology, possible indicators of instability (e.g., geomorphic features and condition of vegetation), and basic metrics such as scarp height, tension crack dilation, etc. Exposed soil and rock material forming these features, where present, were also recorded. The time spent investigating a particular potential slope instability feature depended on the nature of investigation (ground survey or UAV flyovers), level of activity, size of landslide, difficulty of terrain, and accessibility; time spent on each feature ranged from several minutes to an hour. GPS locations of each field site was obtained both by handheld Garmin GPS and the GIS software embedded on the iPad. Each field assessment site had first been grouped as a slope polygon (e.g., S1, S2, etc.) based on similar terrain and stability classification. Furthermore, during inspection of each slope polygon, instability features (e.g., tension cracks, scarps, seepage, etc.) were noted and photographed as a point of interest (POI).

UAV inspections were limited to visual observation and consequently were rapid but thorough. As many as five passes were made over individual features to observe and photograph them from different vantage points and to facilitate on-site discussion. Over major instability features (e.g., landslides, scarps, erosion, slumping, tension cracks, tilted trees, etc.), the pilot held the UAV stationary over features to allow for more detailed observation and development of 3D photogrammetry models. The imagery obtained during the site inspection was uploaded to a secured web-based UAV photogrammetry platform, allowing Clifton to map unstable terrain on a georeferenced map that has been provided to the client for interactive viewing of the overall site inspection in conjunction with this report. Annotated field photographs are provided in Appendix D (photographs and UAV assisted). Clifton has uploaded georeferenced UAV high-resolution imagery of the September 14th 2021 site investigation to a secured interactive web-based platform, with the link sent via email and can be accessed at the following hyperlinks: Full project link and critical unstable slopes link.

4.0 Results and Discussion

4.1 Summary of Results

Final hazard map drawings provided in Appendix A present the results of the 2021-2022 comprehensive slope stability assessment of the south banks of the North Saskatchewan River within the R.M. boundaries. Appendix A1 provides terrain hazard polygons and features mapped during field inspection with June 5th, 2018, base imagery (ESRI, 2022). Appendix A2 provides the final drawings overlaid on September 22nd, 2021, high-resolution SkySat satellite imagery (https://www.planet.com/products/hi-res-monitoring/) Clifton acquired for the project to identify change and unstable slopes.

Observations and assessments of the 150 features investigated during the field program are summarized in Section 4.2 and Appendix C. Assessment of the possible hazard is based on a combination of proximity to the high riverbank erosion found on the outside curves, field observations of instability type and age, and interpretations and measurements made during desktop mapping. Features of specific concern (unstable terrain) throughout the study area and within the detailed mapping location are listed in Table 4.1 and Appendix C. Annotated photographs for features investigated during the field inspection are included in Appendices B and D.

Results indicated 29 unstable slope sites (desktop and field work) that made up 16 unstable terrain polygons that were approximately 5 km2 in total area. Moreover, within these 16 unstable polygons, 24 landslides were identified, with extents ground truthed in the field (0.65 km2 area of disturbed ground). The average characteristic and morphology of the slopes assessed within the study area have a height of 40 m, length of 205 m and ~20° slope angle.

Approximately 12.5 km^2 in total area was classified as potentially unstable, which includes a ‘buffer’ or ‘setback’ distance upslope of identified unstable terrain. Although setback/buffer zones must be assessed for each slope site in detail, which was not in the scope of this project, preliminary setback calculations using the method by de Lugt et al. (1993) indicated an average setback distance of ~65 m upslope from unstable slope crests with a net lateral river toe erosion (E) of 0.3 m/year (Appendices A and C).

The primary factors contributing to the continued landslide activity within the study area include the river downcutting through the low shear strength lacustrine-alluvial clays and silts along the riverbank to erode and unload the slope toe, precipitation and spring snowmelt resulting in increased surface infiltration and higher pore-water pressures in the valley wall slopes, urban/transportation development leading to increased surface runoff and poor drainage on the unstable slopes and developments which increase loading from fill placement along the upper valley wall.

Table 4.1 – Summary of Hazard Mapping Throughout the Study Area

Lot No. / Section	Township	Range	Meridian	Slope Polygon Group	Site ID (S)	POI	Comments	Stability Classification	Clifton Reference Figures
SE 24	48	26	W2	A	1, 1a, 1b, 2, 3	1, 2, 3, 4, 5, 6, 7, 8, 9, 10,	Localized slumping, tension cracks, tilted trees, and scarps. Damaged houses and cracked pavement. Deep seated landslide movement evident with previous slope inclinometer monitoring.	Unstable	A1.1, A2.1, B2

Table 4.1 – Summary of Hazard Mapping Throughout the Study Area

Lot No. / Section	Township	Range	Meridian	Slope Polygon Group	Site ID (S)	POI	Comments	Stability Classification	Clifton Reference Figures
						11, 12			
SW 19	48	25	W2	A	4	13, 14	Damaged houses and multiple tension cracks. Major tension crack NE-SW direction formed between 2011 to 2021 approximately 25 m length and 30 cm dilation (width).	Unstable	A1.1, A2.1, B3
SE 19	48	25	W2	A	5	15	Cracks near driveway and pavement. Tilted trees and scarps evident immediately north of residence property.	Potentially Unstable	A1.1, A2.1
SE 19	48	25	W2	B	6, 6c	16, 19	Undulating horst and graben terrain with landslide blocks, pooling of water, tension cracks, and disturbed trees.	Unstable	A1.1, A2.1, B4
SW 20	48	25	W2	B	6a, 6b,	17, 18	Localized slumping, river erosion, scarps, tension cracks, and disturbed trees. Property removed due to foundation issues due to ground deformation.	Unstable	A1.1, A2.1, B4
NE 20, SW 28	48	25	W2	B	7	20, 21	River erosion undercutting bank with disturbed vegetation and local slumping. Major scarp causing damage to concrete gate.	Unstable	A1.1, A2.1, B5
SW 20	48	25	W2	B	8a, 8b, 8c	22, 23, 24	Undulating horst and graben terrain with landslide blocks, pooling	Unstable	A1.1, A2.1, B6

Table 4.1 – Summary of Hazard Mapping Throughout the Study Area									
Lot No. / Section	**Township**	**Range**	**Meridian**	**Slope Polygon Group**	**Site ID (S)**	**POI**	**Comments**	**Stability Classification**	**Clifton Reference Figures**
							of water, tension cracks, multiple large-scale scarp and disturbed trees.		
NW 20	48	25	W2	B	8d, 8e, 8f, 8g	25, 26, 27, 28, 29	Highly unstable slope within 300 m of the river including major repetitive and continuous landslide blocks with scarps nearly 60 m long, 3 m dilation (width), and 4 m height trending NE-SW. River erosion evident with failing banks and tilted trees.	Unstable	A1.1, A2.1. B6
LOTS 20-41	48	27	W2	C	9, 10	30, 31	Hummock and undulating terrain with horst and grabens. Highway had been relocated due to slope deformation. Continued erosion of river along bank and evident scarps, tilted trees, and tension cracks.	Unstable	A1.0, A2.0; B8
LOTS 12-19	48	27	W2	D	11	32	Localized scarps, irregular undulating terrain with flood potential. Previous river meander and high water table.	Potentially Unstable	A1.0, A2.0
LOTS 9-11	48	27	W2	E	12	33, 34, 35	Gullying and surficial erosion evident. Slope has undulating morphology with horst – graben and tilted trees. Within 50 m upslope the riverbank unstable terrain with riverbank erosion,	Potentially Unstable	A1.0, A2.0

Table 4.1 – Summary of Hazard Mapping Throughout the Study Area

Lot No. / Section	Township	Range	Meridian	Slope Polygon Group	Site ID (S)	POI	Comments	Stability Classification	Clifton Reference Figures
							scarps, falling trees, and tension cracks. This 50 m zone unstable to West R.M. limit.		
LOTS 1-9	48	27, 28	W2	E	12a, 13	36, 37	The slope had recently experienced a large-scale landslide, which had directly affected a property. The house had been relocated safely approximately 165 m away upslope from the unstable slope headscarp. Multiple historical landslides evident throughout 3 km section along riverbank (160 m from river).	Unstable	A1.0, A2.0; B7
NW 35, NE 35, NW 30, NE 30	48	24, 25	W2	F	14	38	Localized slumps, scarps, tension cracks, and tilted trees near highway. Evident hummocky horst and graben morphology, indicative of slope movement (oriented NE-SW).	Unstable	A1.1, A2.1; B9
SE 35, NW 25, SW 36, NE 25, SE36	48	24	W2	G	15	39	Landslide terrain with defined lateral extents. Tilted trees, scarps, and tension cracks. Major outside bend riverbank continuous erosion.	Unstable	A1.2, A2.2, B10
SE 19, SW 20, SE 20, NW 21	49	23	W2	Q	25	N/A	Gullying causing surficial erosion, undulating terrain, tilted trees and scarps. River erosion	Potentially Unstable	A1.3, A2.3, B11

Table 4.1 – Summary of Hazard Mapping Throughout the Study Area

Lot No. / Section	Township	Range	Meridian	Slope Polygon Group	Site ID (S)	POI	Comments	Stability Classification	Clifton Reference Figures
							causing potential instability.		
NE 21, NW 22, SE 27	49	23	W2	P	24	N/A	Localized debris slides, historical circular failures with scarps. Major riverbank erosion due to outside meander causing bank instability.	Potentially Unstable	A1.3, A2.3, B12
SE 27, SW 26	49	23	W2	O	23	N/A	Historical slumps and scarps, tilted trees, riverbank erosion continuously eroding/undercutting slope.	Potentially Unstable	A1.3, A2.3, B13
NE 26, NW 25	49	23	W2	N	22	N/A	Localized slumps and historical slope instability evident along outside cut bank. Clear scarps indicative of movement.	Potentially Unstable	A1.3, A2.3, B14
NE 30, SE 30	49	22	W2	H	16	40	Continuous erosion along outside riverbank, multiple translational slope failures (landslides), scarps evident towards the east near the upper slope, tilted trees.	Unstable	A1.3, A2.3, B15
SE 29	49	22	W2	M	21	N/A	Multiple circular landslides with scars, continuous surficial erosion leading to deeper gullying. Outside riverbank eroding and undercutting toe of slope.	Unstable	A1.3, A2.3, B16
NW 21, NE 21 SE28	49	22	W2	L	20	N/A	Entire slope along outside bend of river altered by landslide activity.	Unstable	A1.3, A2.3; B17

Table 4.1 – Summary of Hazard Mapping Throughout the Study Area

Lot No. / Section	Township	Range	Meridian	Slope Polygon Group	Site ID (S)	POI	Comments	Stability Classification	Clifton Reference Figures
							Continuous river erosion and undercutting of slope, leading to progressive slope instability.		
NW 22, SW 22, SE 22, NE 22	49	22	W2	K	19	N/A	Gullying and surficial erosion evident with features such as circular translational landslides. Continuous river erosion leading to slope failure.	Unstable	A1.4, A2.4, B18
SW 23	49	22	W2	I	17	41	Large slump landslide blocks, tilted trees, and translational debris slides evident. Entire outside bank continuous river erosion leading to progressive slope movement.	Unstable	A1.4, A2.4, B19
SW 24, SE 24, NW 13, NE 13	49	22	W2	J	18	42	Multiple active large-scale slumps, and river erosion. Landslide blocks with tilted trees. Scarps near upper slope road.	Unstable	A1.4, A2.4, B20

Refer to Appendix A for final hazard maps, Appendix B for site figures, Appendix C for complete detailed site investigation datasets and Appendix D for field annotated photographs.

4.2 Detailed Field Ground Truthed Unstable Polygons

Clifton conducted a field reconnaissance traverse to ground-truth unstable features identified within the desktop study and GIS hazard mapping (Table 4.1). The following section provides a summary of the field inspection through selected unstable areas that include the requested detailed slope assessment terrain approximately 4 km (~2.3 km^2) along the southern bank immediately east of the Prince Albert city limits with reference to photographs, UAV imagery, and final drawings outlined within Table 4.1. For detailed information of all sites inspected, refer to the final stability maps (Appendix A), site summary datasets (Appendix C), and field annotated photographs (Appendix D).

4.2.1 SE 24-48-26-W2M: Active Slumps, Tension Cracks, and Deep-Seated Landslide

Throughout the field inspection, evidence of landslide activity in the surrounding area identified in desktop review and GIS mapping was confirmed with localized landslides (slumps) (POI 4), tension cracks (POI 1), tilted trees (POI 4), damaged houses (POI 1,5), foundations, roadways, cracked pavement and scarps (POI 3) (Figure A1.1; A2.1; B2). A major tension crack, approximately 20 m long and 15 cm dilation (width) trending northeast to southwest was identified nearly 12 m east of a residence house (Figure B2). The slope is characterized as undulating to moderately rolling in the uplands, with the mid to lower slopes having a hummocky horst and graben morphology (landslide blocks), characteristic of deep-seated landslide terrain in a meta-stable condition. Deep seated landslide movement is evident with previous slope inclinometers monitored from 2017 to 2019 indicating landslide movement at a shear zone at ~29 mbgs (Clifton File No. R5999).

Figure B2 – Identified instability features along unstable slope within SE 24 – 48 - 26 – W2.

4.2.2 SW 19-48-25-W2M: Tension Cracks, Scarps, Deep-Seated Landslide

The slope is characterized as undulating to moderately rolling in the uplands, with the mid to lower slopes having a hummocky horst and graben morphology, characteristic of deep-seated landslide terrain blocks in a meta-stable condition. The field inspection was focused near a house on the uplands adjacent Highway 302 which had visible cracks, foundation issues, deformed window frames, and buckled shingles (Figure A1.1; A2.1; B3). Multiple tension cracks were identified in previous reports, GIS mapping and field inspection, with the smaller crack west of the house approximately 10 m long and 1 cm dilation (width) trending east to west. A large tension crack, approximately 25 m long and 30 cm dilation (width) trending northeast to southwest was identified east of the house on the high-resolution satellite imagery and ground truthed during the field inspection (Figure A1.1; A2.1; B3; POI 14). When the more recent (east) major tension crack (POI 14) formed is unknown, although, based on available reports and satellite imagery, it appears that the crack developed between 2011 to 2021. This slope is classified as unstable, and with limited subsurface datasets, the nature of the movement is unknown without site specific geotechnical investigation and monitoring.

Figure B3 – Identified major tension crack along unstable slope within SW 19 - 48 - 26 – W2.

4.2.3 SE 19-48-25-W2M to SW 20-48-25-W2M: Slumps, Riverbank Erosion, Scarps, and Deep-Seated Landslide

Clifton was informed by the RM that a resident was removed from the property due to ground movement. This area had clear evidence of slope instability identified during the desktop study and hazard mapping. During the field inspection, Clifton staff confirmed the presence of major slope instability features including localized landslides (slumps) (POI 18), scarps (POI 17), river erosion, disturbed trees, and tension cracks (POI 18, 19) (Figure A1.1; A2.1; B4). A major tension crack, approximately 20 m long and 30 cm dilation (width) trending northeast to southwest was identified intersecting the access road to the property (POI 19). The slope is characterized by a hummocky horst and graben morphology (landslide blocks) associated with deep-seated landslide terrain in a meta-stable condition (Figure B4). This type of ground deformation has the same surficial instability features that are seen throughout the entire lower riverbank, with scarps, tension cracks, tilted trees and horst and graben linear features following a similar orientation (e.g., northeast to southwest).

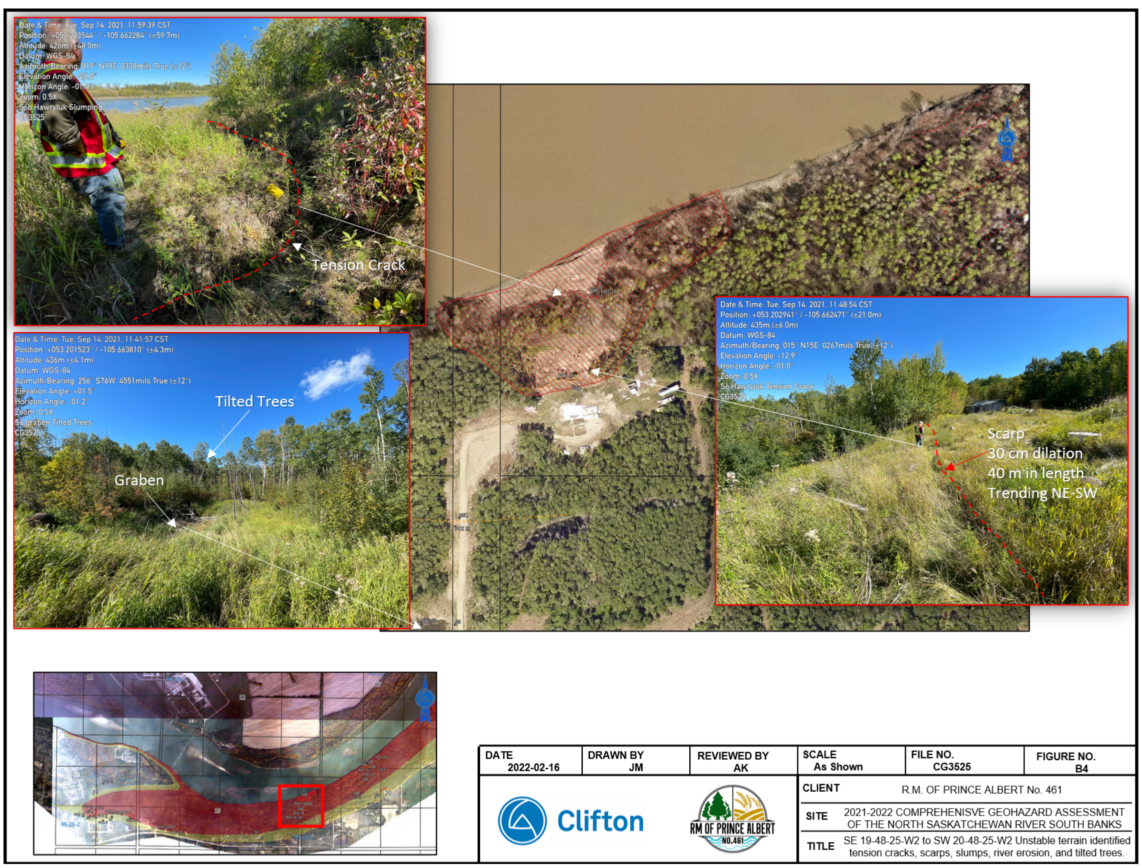


Figure B4 – September 14th, 2021, Clifton field ground-truthed and GIS mapped slope instability features along the North Saskatchewan River south slope (SE 19-48-25-W2 to SW 20-48-25-W2).

4.2.4 NE 20-48-25-W2M to SW 28-48-25-W2M: Tilted Fences, Slumps, River erosion, Landslides

The RM informed Clifton that cracks were observed on the tilted concrete fence along the road. Clifton was able to identify changes in this area, classifying the slope as unstable during the desktop review and GIS mapping because of large linear landslide features such as scarps and grabens, river erosion, and slumps (Figure A1.1; A2.1; B5). During the field inspection, Clifton staff confirmed the unstable ground features, which included a tension crack trending northeast to southwest that intersected and damaged a concrete fence (POI 20) as well as tilted trees, slumps, and river bank erosion (Figure B5).

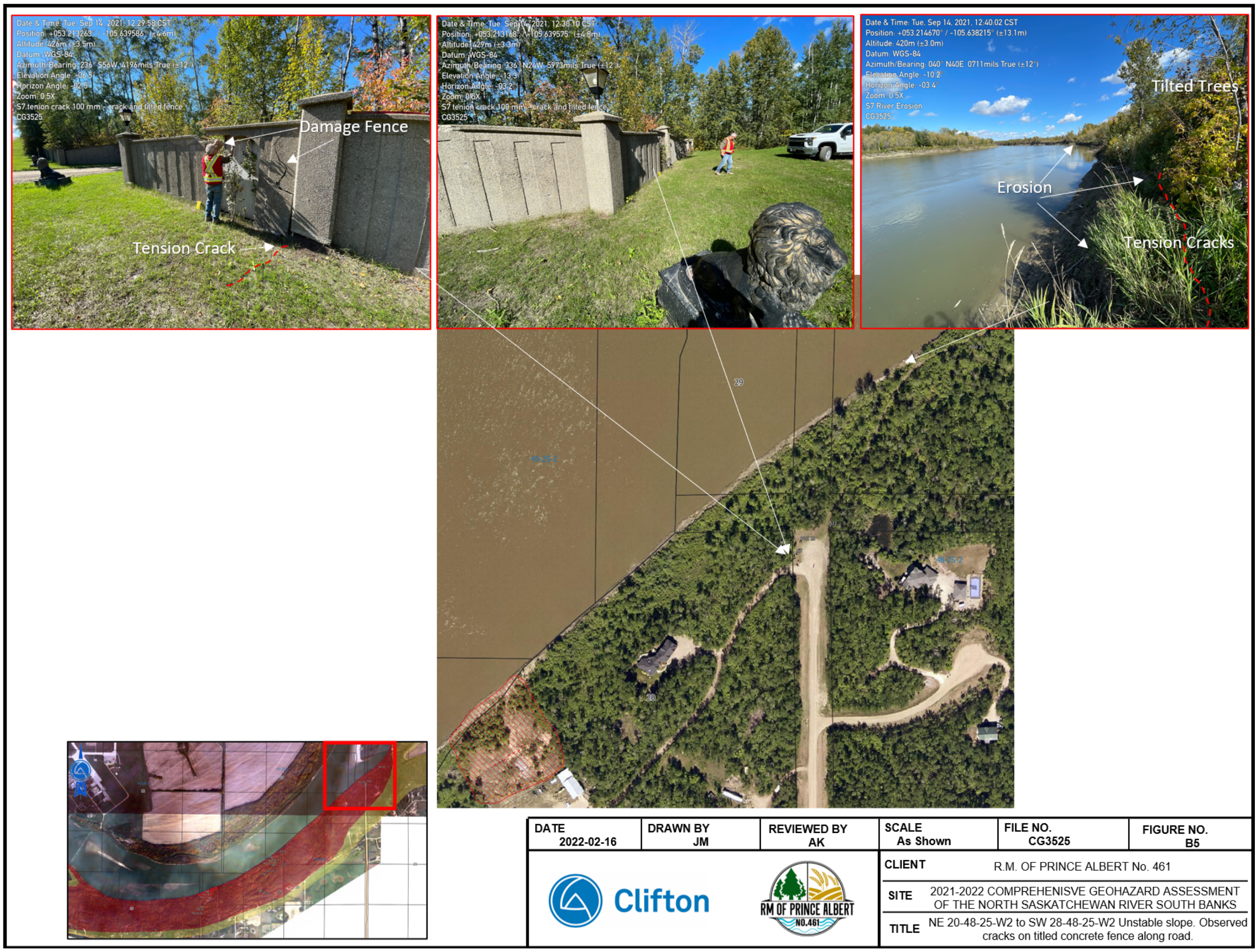


Figure B5 – Identified major slope instability features along unstable slope causing slope deformation and property damage.

4.2.5 SW 20-48-25-W2M to NW 20-48-25-W2M: Tension Cracks, Scarps, River Erosion, Landslides

Prior to the field inspection, Clifton was able to identify mid to lower undulating and hummocky landslide slopes within 300 m of the river throughout the area (Appendix A1.1; A2.1). The main landslide features evident on satellite imagery and confirmed during the field inspection included multiple repetitive, large scale (e.g., nearly 60 m long, 3 m dilation, 4 m high and trending northeast-southwest) tension cracks, and scarps that made up hummocky horst and graben landslide blocks characteristic of deep-seated landslide terrain and progressive failure near the toe of the slope (river) (Figure A1.1, A2.1; B6). This area is highly unstable due to progressive slope movement and continuous undercutting/erosion of the outside bend of the river.

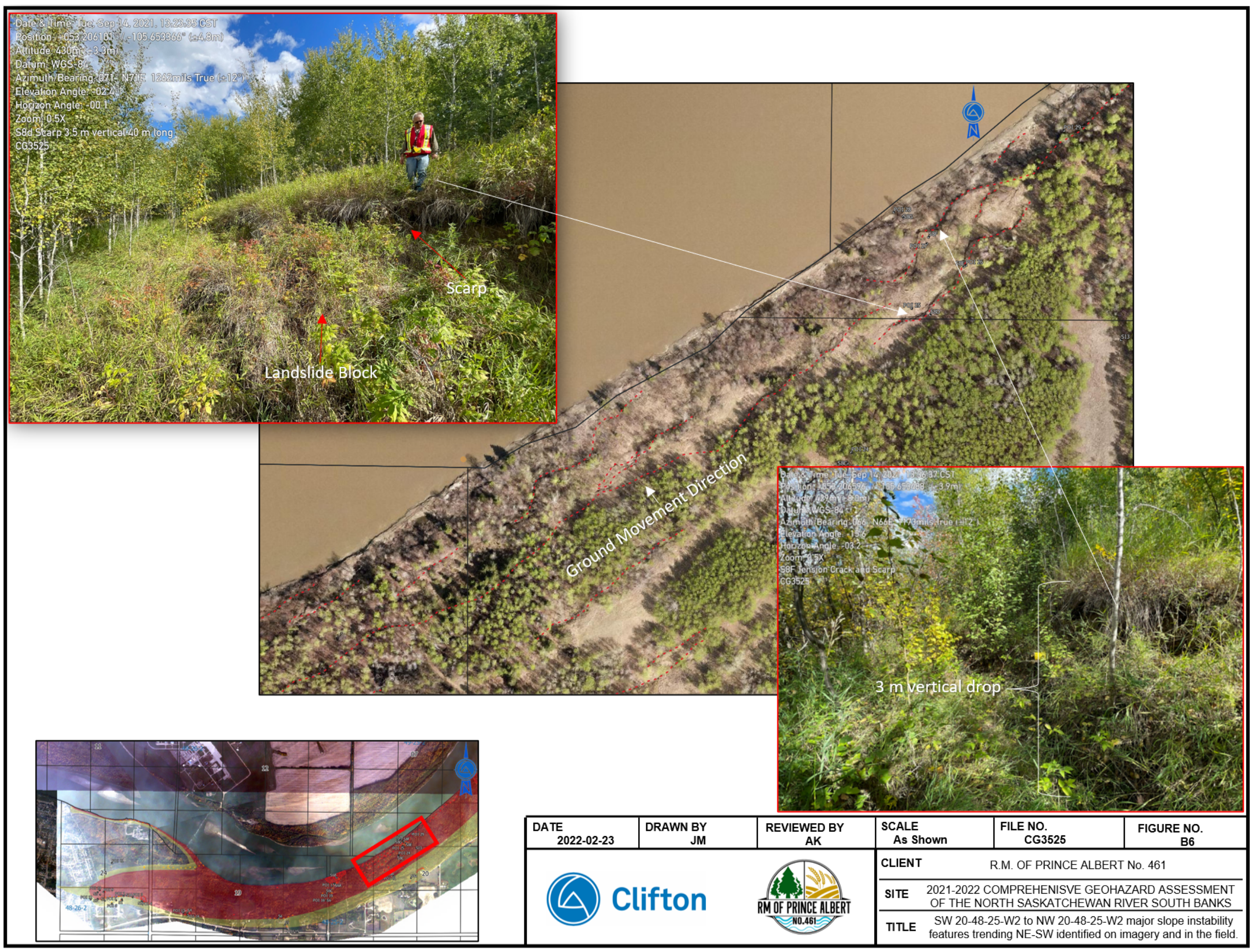


Figure B6 – Identified major slope instability features (scarps, tension cracks, tilted trees, and landslide blocks) along a highly unstable slope. Note the repetitive northeast-southwest orientation of the landslide deformation blocks.

4.2.6 West RM Limit to LOTS 1 to 9-48-27/28-W2M: Active and Historical Landslides, Scarps, Tilted Trees, River Erosion

Desktop review, remote sensing, GIS mapping and background information revealed that this slope had recently experienced a large-scale (e.g., 160 m length, 60 m width, 40 m height) translational landslide, which had directly affected the residence (Figure B7; A1.0; A2.0; POI 36, 37). Although the house was not directly damaged from the landslide, it had to be relocated approximately 165 m south (upslope) of the recent landslide headscarp (unstable terrain boundary) (Figure B7). Clifton ground-truthed this area by foot and deployed a quadcopter UAV to assess the current stability. As shown in Figure B7, the entire slope, including approximately 160 m upslope from the riverbank, from the western RM of PA boundary to 3 km east had experienced similar historical landslides. Although the date of the historical landslides is unknown, the dense vegetation and mature trees on the landslides indicate they occurred over 50 years ago.

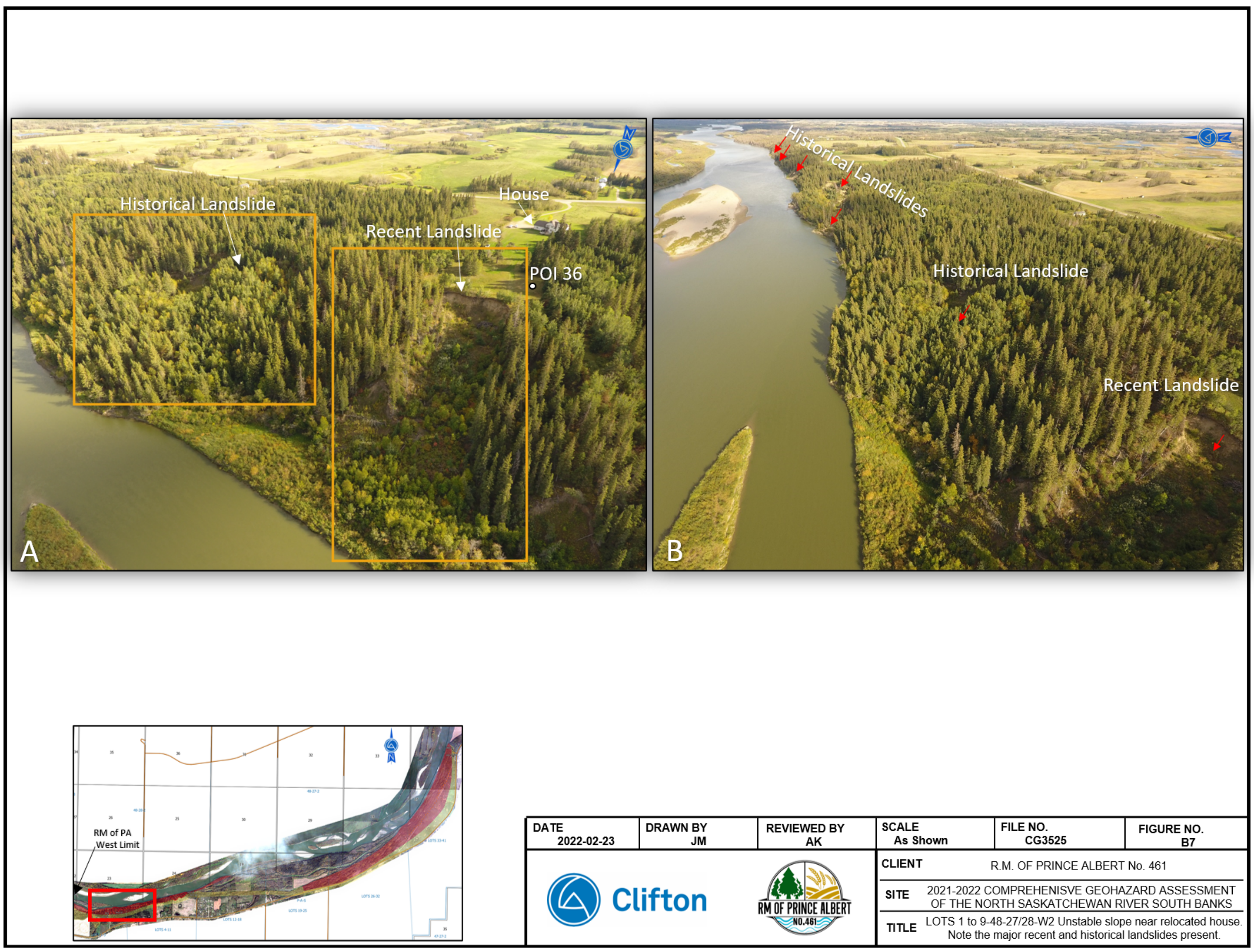


Figure B7 – Unstable slope near relocated house. Note the major recent and historical landslides present.

5.0 Discussion and Recommendations

5.1 Summary of Slope Failure Mechanisms

Landslides are common along the south valley wall of the North Saskatchewan River in the R.M. because of a combination of geology and landslide triggering mechanisms. The thick sequence of highly plastic glacio-lacustrine clay throughout the study area has a low shear strength and is prone to the development of landslides when subject to the following triggering mechanisms:

- Changes to the ground surface or loading along the valley wall and crest which could include:
  - Removal of material at the toe of the slope through river erosion which removes the buttress supporting the slope above;
  - Lower water levels in the river which reduces the mass of water at the toe of the slope that buttresses the valley wall;
  - Erosion of the valley wall from inadequate erosion protection against surface runoff; and,
  - Development which adds fill loads to the upper valley wall and crest to increase the driving force for landslides or removal of soil in the lower portion of the slope to remove the buttress soil mass supporting the slope.
- Higher groundwater tables increase landslide activity as a result of:
  - Snow melt and extreme rainfall events that increase seasonal infiltration;
  - Urbanization which may introduce more water into the groundwater system through leaky water utilities, swimming pools, septic tanks, irrigation systems and lawn/garden watering; and,
  - Poor site surface drainage that allows water to pond on surface, leading to increased infiltration.

The sensitivity of an area to these landslide triggers will depend on size of the change and whether or not the potential instability is a new landslide or reactivation of an existing landslide. Further details on the triggering mechanisms are provided in the following sections.

Ground Surface and Loading

Changes to the ground surface and loading conditions include excavation, placing fill, site grading to accommodate surface water drainage and a drop in river level. Natural removal of soil or loss of supporting load at the toe of the landslide can be caused by erosion from surface water drainage or rivers and the lowering of river levels that reduce the mass of water. Site grading to build houses and infrastructure may remove soil at the slope toe which reduces the buttress supporting the slope. Instability can also result if additional fill or loads are placed along the valley wall crest or upper reaches of the slope in the unstable and potentially unstable areas. While increased loading rarely occurs in nature, it becomes a significant factor in new developments where fill is imported or redistributed to create a relatively level area large enough to construct a house or yard.

In areas where there are landslides, significant quantities of earth should not be added to an area, since this will increase those forces driving the landslide movement. At the crest of an unstable slope a development setback should be established by a site-specific assessment to delineate a zone where there is no development or filling allowed. Preliminary calculations for setbacks are included in Appendix C but the setbacks would have to be confirmed on a site-by-site basis for each proposed development. If regrading is required within this crest setback zone, then the regrading should be achieved by excavation to unload the top of the slope and removal of the fill from the setback area.

Slopes should not be over steepened. Excavations at the bottom of slopes or on a slope must consider the stability of the slope above. Very stiff or hard soil will typically stand when excavated, even if the excavated slope is close to vertical. However, this must be considered a temporary condition, since the slope will eventually return to an angle that is close to the original slope by erosion or from small local failures.

Overall site grading must ensure that surface runoff does not pond or enter exposed unstable crest scarps. Construction development will tend to concentrate runoff as it flows across roofs and paved areas. Erosion control measures must be incorporated into areas where surface runoff has concentrated so that gullies are not created to alter the slope geometry. River erosion can be addressed with armouring to prevent the loss of the riverbank.

Groundwater

Practices to maintain or lower the groundwater table are important in landslide terrain. The irrigation of slopes to maintain lawn or gardens should be reduced to a minimum that is necessary to sustain vegetation. Xeriscaping can be practiced to minimize watering.

Water utilities, septic tanks, irrigation systems should be monitored for leaks and repaired to prevent an increase in the groundwater table. Swimming pools should not be located on landslide terrain in case they leak, nor should the water from emptying the pools be discharged onto the slopes.

Poor site drainage can increase the groundwater levels as water ponding can increase the rate of infiltration. Site grading should be completed to the minimum required to maintain site drainage.

Location

In unstable areas where landslides have occurred there is a risk that landslides may occur in the future. Should movement occur, individual slump blocks within the landslide will usually move independently of each other at differing rates. In order to minimize the potential for damage, should movement occur, it is important to locate any structure so that it is entirely on one landslide slump block. If a structure straddles the boundary between two landslide blocks on a landslide head scarp, severe damage can occur as the blocks may be moving at different rates. However, it is difficult to predict with any certainty whether a structure located only on one landslide block will sustain damage related to movement associated with vertical and horizontal movement of the landslide block. The location of the boundaries between landslide blocks is imprecise so buildings must be set well back from the perceived block boundaries.

Reactivation of landslide movement may not always occur along existing failure planes. New landslide head scarps can appear within previously intact landslide blocks depending on existing conditions and changes associated with erosion, groundwater levels and other factors.

5.2 Landslide Considerations and Development

Development in unstable and potentially unstable terrain as mapped in the appended slope stability maps may increase the landslide risk within these areas, and the impact that development may have on slope stability and site infrastructure may not be confined within property boundaries and impact adjoining infrastructure.

The stability assessment provided herein is based on available topographical and geological mapping, air photos, satellite imagery and UAV photos supplemented with site inspections of select locations to ground truth the desktop information. The slopes along the North Saskatchewan River are heavily treed and often inaccessible; therefore, identifying small-scale landslides was difficult. It is recommended that any site considered for development along the riverbank and crest undergo an onsite inspection by a qualified geotechnical engineer to identify any potential stability concerns that may not have been apparent from the aforementioned desktop study and ground truthing. Any proposed development should be reviewed for its potential impact to the riverbank stability based on the aforementioned triggering mechanisms. Locations identified as stable in the appended stability maps may become unstable through site disturbance during development. If stability concerns are present, then a site-specific field geotechnical investigation is recommended to characterize the site and provide the basis for the development of remedial options and/or construction recommendations. Instrumentation to assess and monitor instability may need to be installed as part of the field investigation.

5.3 Recommendations

Based on the presence of active landslides along the south slope of the North Saskatchewan River Valley, Clifton recommends the following actions for the monitoring of priority sites:

- Utilize an integrated, multi-sensor, remote sensing, GIS and field methodology to monitor slope movement;
- Utilize and integrate both subsurface and surface slope monitoring methodologies;
- Implement UAV assisted photogrammetry and/or LiDAR campaigns with surveyed ground control points/pins to conduct change detection analysis and identify current and future hazards;
    - Provide datasets and results on a secured web-based platform that the user and client can interact, comment, and discuss datasets throughout the entirety of the project.
- Install soil-extensometer to measure change across major tension cracks and scarps;
- Implement GNSS-based millimetric (sub-mm accuracy) and real-time movement sensor Geocubes (https://ophelia-sensors.com/geocube-solution);

  - Implement results on Geo3 platform which allows the user to control installed devices, view graphs, set notifications, print reports and export data. Give access to data to relevant stakeholders so that informed decisions can be taken on the spot.
  - Integrate with UAV SfM and LiDAR models.
- Install a series of screw piles to act as monuments that would not be subject to frost effects. Utilize existing nearby survey monument (outside the river valley on stable terrain) to be able to track any movement of the new monuments across the site;
- Investigate the possibility of obtaining InSAR data for the site to assess site wide movements at the ground surface. The study area is a good candidate for InSAR analysis as there is extensive flat developed areas on the uplands that would serve as good reflective surfaces. This would be used to help define the extent of the current and recently active movement zones;
- Utilize previously drilled boreholes with SI casings (wherever accessible and functioning), obtain previous slope movement readings and manually measure the SIs to identify the location of shear zones and their rate of movement. Once this is completed, implement digital in-place inclinometer system which will allow real-time tracking (https://rstinstruments.com/product/mems-digital-in-place-inclinometer-system/);
  - RST's new, MEMS Digital In-Place Inclinometer (IPI) System is designed to reliably measure lateral movement in and around landslides, particularly when continuous remote monitoring is required. It provides an early warning for movements, essential for identifying ground deformation and protecting infrastructure and people; and
- Monitor groundwater levels and porewater pressures.

We recommend annual site inspections coupled with UAV missions at priority sites: Inspection either in the spring before the grass and vegetation starts to grow or in the fall after the leaves have fallen. These timeframes maximize the opportunity to identify ground movements such as tension cracks or bulging, both for visual inspections and UAV scanning. This ongoing monitoring is aimed to catch progression of geohazards early so that action can be taken to identify hazards; included in this work would be collecting data from SIs and VWPs. UAV work would be conducted separately so that data could be reviewed prior to the visual site inspections; areas of concern identified from the site models can then be assessed by visual inspection.

Further information of some of the remote sensing technology is provided in the following sections.

5.3.1 Visual and Remote Sensing (UAV)

During recent decades, rapidly developing remote sensing (RS) techniques, including Unmanned Aerial Vehicle Light Detection and Ranging (UAV-LiDAR) and UAV Structure-from-Motion (UAV-SfM) are being progressively employed for slope stability applications. These methods allow acquisition of three-dimensional (3D) data sets from previously inaccessible terrain with survey georeferenced accuracy. Results are accessible to users on a secured web-based 3D point cloud/model analysis online platform.

UAVs are becoming very popular as they provide a low-cost, quick, and safe alternative to obtain high-resolution data with minimized occlusion areas in inaccessible sites. In addition to the UAV's onboard GPS, ground control points (GCP) targets can be placed throughout the site and monitored utilizing total stations and Trimble GNSS surveying equipment to provide highly accurate volume, elevation, orientation, and linear calculations. Unravelling surface change and linking progressive slope instability with geomorphic processes of erosion and deposition, requires the comparison of a minimum of two-point clouds, collected at different times. Various computer software can be used to successfully import remote sensing surface datasets for deformation and direction to complete a change detection analysis. Moreover, previous acquired surface data in the area (e.g., LiDAR), may be utilized as a base layer for future comparison.

Light Detection and Ranging (LiDAR), involves the emission of a laser pulse which travels towards a desired object and is reflected back to the laser scanner. By analyzing the direction and attitude of the scanner (pitch, roll and yaw), and the time of arrival of each back-scattered signal, the position of multiple reflective surfaces in 3D space are automatically computed and stored as point clouds. The range, resolution, repeatability and high accuracy 3D point cloud representation of a site has made TLS one of the most utilized techniques in engineering projects and displacement monitoring.

Remote Sensing Models can be further utilized to extract slope profiles, AutoCAD drawings/contours, hazard mapping, change detection analysis, and to create thematic maps (e.g., slope, aspect, hillshade, etc.) in a GIS geodatabase. Flight plans are archived and can be duplicated for future studies, enabling various data analysis including 3D volumes, ground-subsidence, cut/fill and change detection analysis to identify movement.

6.0 Limitations

This report was prepared by Clifton Engineering Inc. for the use of the R.M. of Prince Albert No. 461. The material in it reflects Clifton Engineering Inc. best judgment available to it at the time of preparation. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Clifton Engineering Group Inc. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

The enclosed report contains the results of our slope assessments as well as certain recommendations arising out of such assessments. Incorporation of any or all of our assessments into any design does not constitute us as designers or co-designers of such elements, nor does it mean that such design is appropriate in geotechnical terms. The designers of such elements must consider the appropriateness of our recommendations in light of all design criteria known to them, many of which may not be known to us. Our mandate has been to investigate and recommend, which we have completed by means of this report. We have had no mandate to design or review the design of any elements of the proposed work and accept no responsibility for such design or design review.

This report has been prepared in accordance with generally accepted standard engineering practice common to the local area. No other warranty, express or implied is made.

7.0 Reference List

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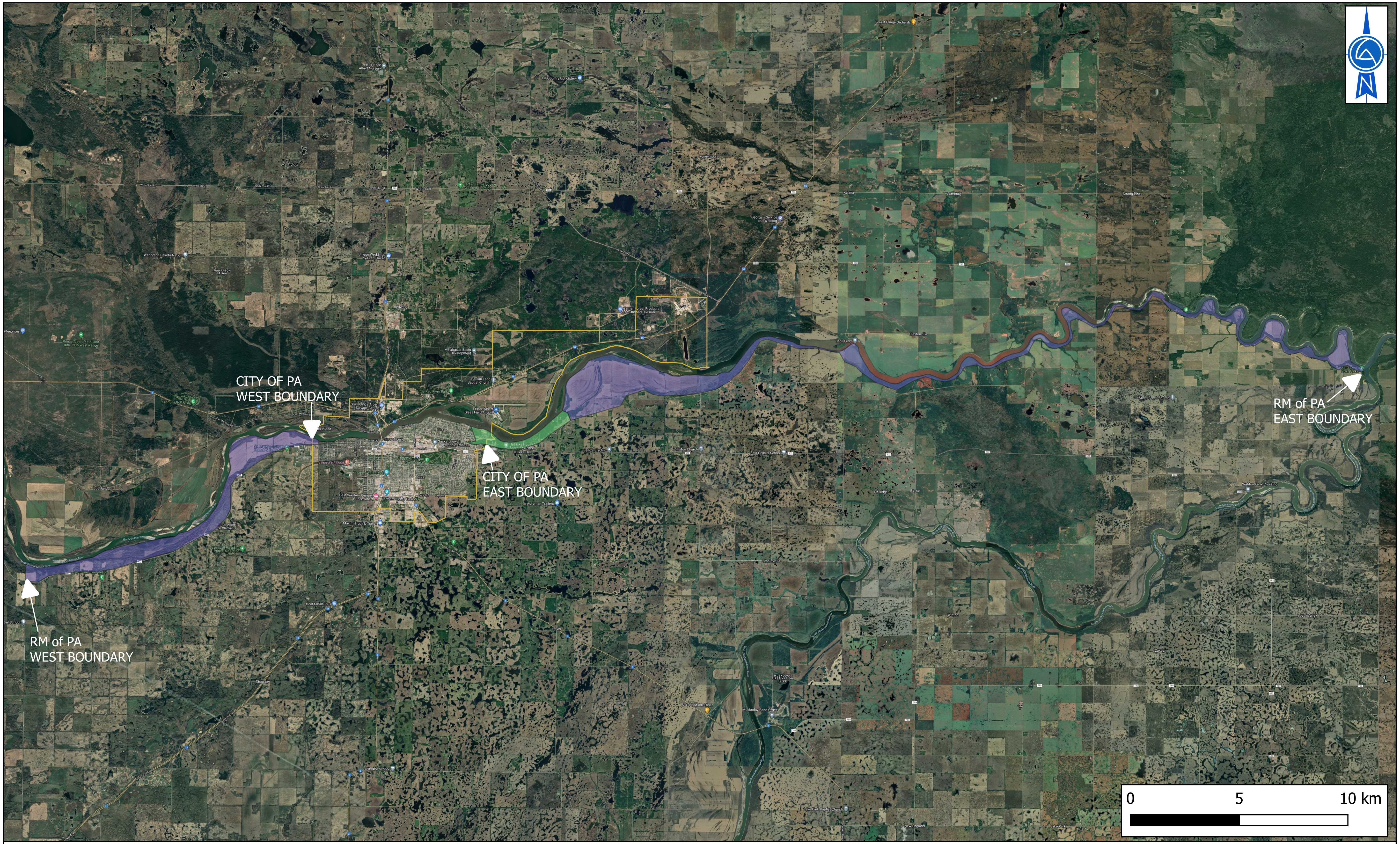
Appendix A
Slope Stability Maps

Clifton



LEGEND

2021-2022 Clifton Slope Stability Mapping Area

Detailed Mapping Extent

Mapping Extent

Urban Municipality

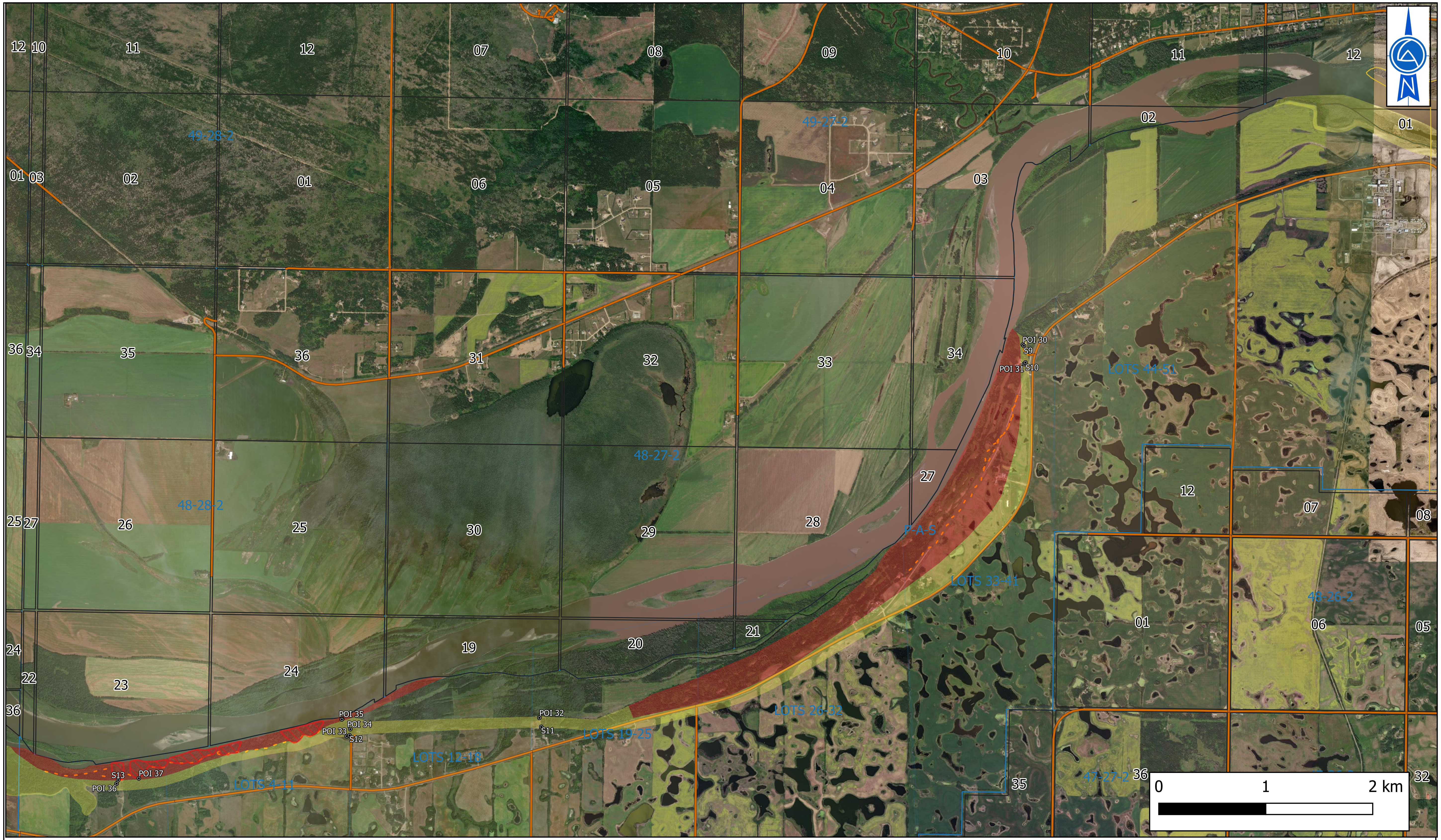
2018-06-05_ World Satellite Imagery (ESRI)

NOTE:
1. CLIFTON MAPPING LIMIT(S) DO NOT CONTAIN SLOPES WITHIN CITY of PRINCE ALBERT (PA), SK LIMITS.
2. CLIFTON SLOPE STABILITY MAPPING LIMIT(S) DO NOT EXTEND RM of PA WEST AND EAST BOUNDARIES.

DATE	DRAWN BY	APPROVED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-02	JM	AK	As Shown	CG3525	A1

Clifton

CLIENT	RM OF PRINCE ALBERT No. 461
SITE	2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS
TITLE	2021-2022 CLIFTON SLOPE STABILITY ASSESSMENT OVERVIEW MAP OF R.M. PRINCE ALBERT, SK.



LEGEND

2021-2022 Clifton Slope Stability Mapping
- Unstable
- Potentially Unstable
- 14-SEP-21 Clifton GPS Fieldwork Stations

Geohazards Identified
- Delinated Landslides
- Scarps

Transport (SK GeoHub)
- Expressway / Highway

Cadastral
- sk_quarter
- sk_section
- sk_township

2018-06-05_World Satellite Imagery (Base)

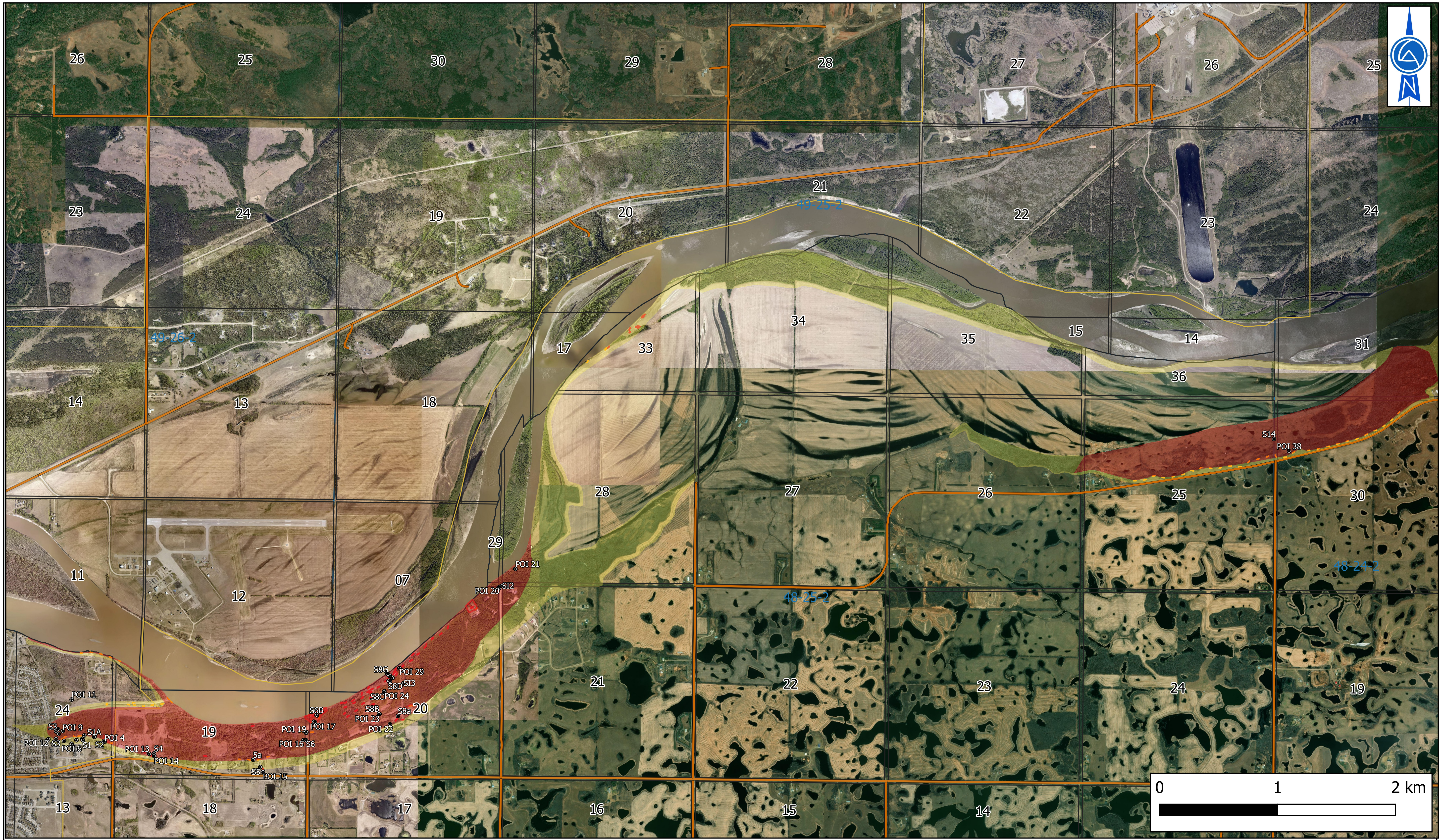
DATE	DRAWN BY	APPROVED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-02	JM	AK	As Shown	CG3525	A1.0

Clifton

CLIENT: RM OF PRINCE ALBERT No. 461

SITE: 2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS

TITLE: SLOPE STABILITY ASSESSMENT MAP FROM WEST RM of PA LIMIT TO TWP 48 - RGE 27 - W2



LEGEND

2021-2022 Clifton Slope Stability Mapping

- Unstable
- Potentially Unstable
- 14-SEP-21 Clifton GPS Fieldwork Stations

Geohazards Identified

- Delinated Landslides
- Scarps
- Tension Cracks

Transport (SK GeoHub)

- Expressway / Highway

Cadastral

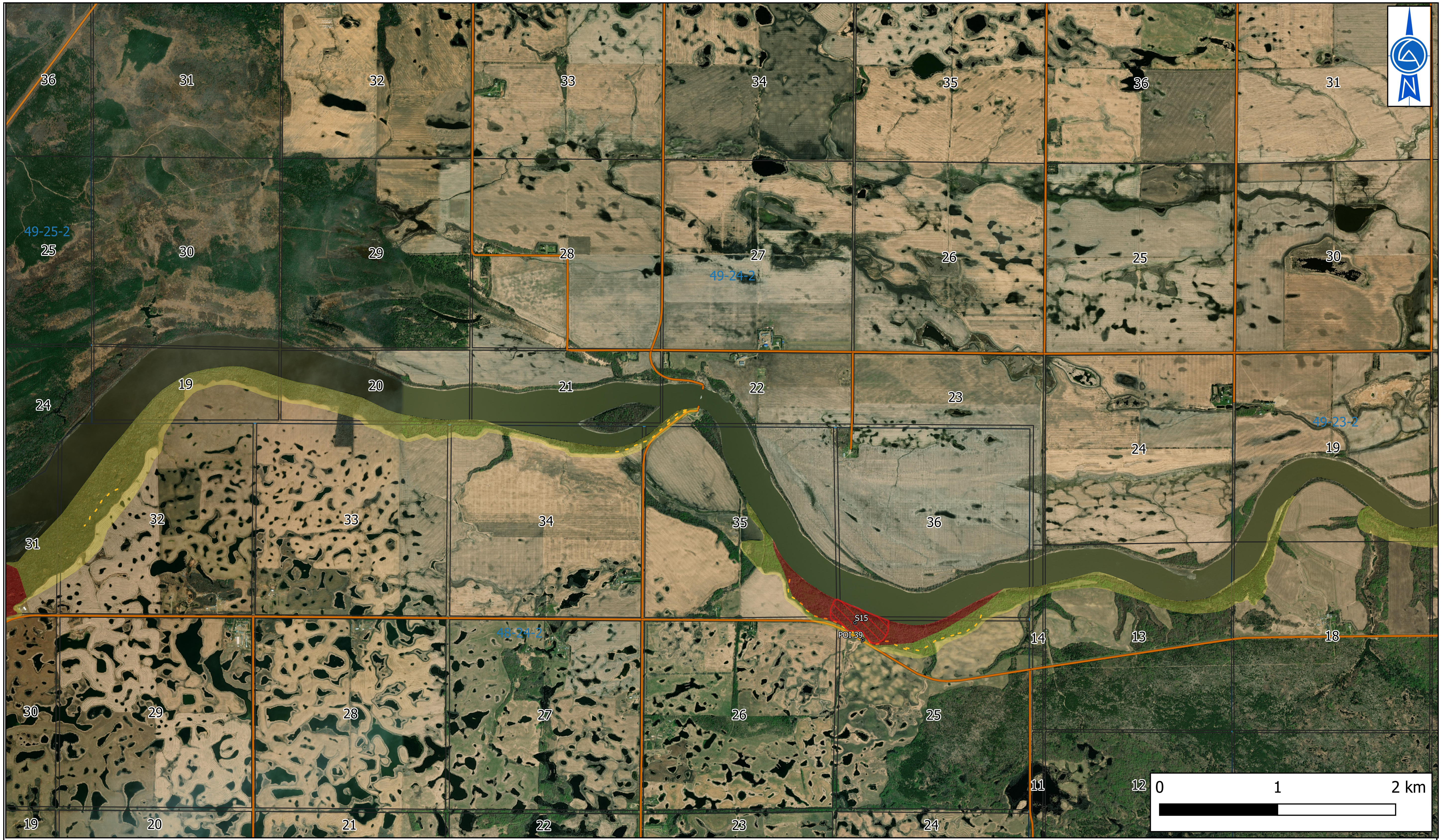
- sk_quarter
- sk_section
- sk_township

2018-06-05_World Satellite Imagery (Base)

DATE	DRAWN BY	APPROVED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-02	JM	AK	As Shown	CG3525	A1.1

Clifton

CLIENT	RM OF PRINCE ALBERT No. 461
SITE	2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS
TITLE	SLOPE STABILITY ASSESSMENT MAP FROM TWP 48 - RGE 26 - W2 TO TWP 48 - RGE 24 - W2



LEGEND

2021-2022 Clifton Slope Stability Mapping
- Unstable
- Potentially Unstable
- 14-SEP-21 Clifton GPS Fieldwork Stations

Geohazards Identified
- Delinated Landslides
- Scarps

Transport (SK GeoHub)
- Expressway / Highway

Cadastral
- sk_quarter
- sk_section
- sk_township

2018-06-05_World Satellite Imagery (Base)

DATE	DRAWN BY	APPROVED BY	SCALE	FILE NO.	FIGURE NO.
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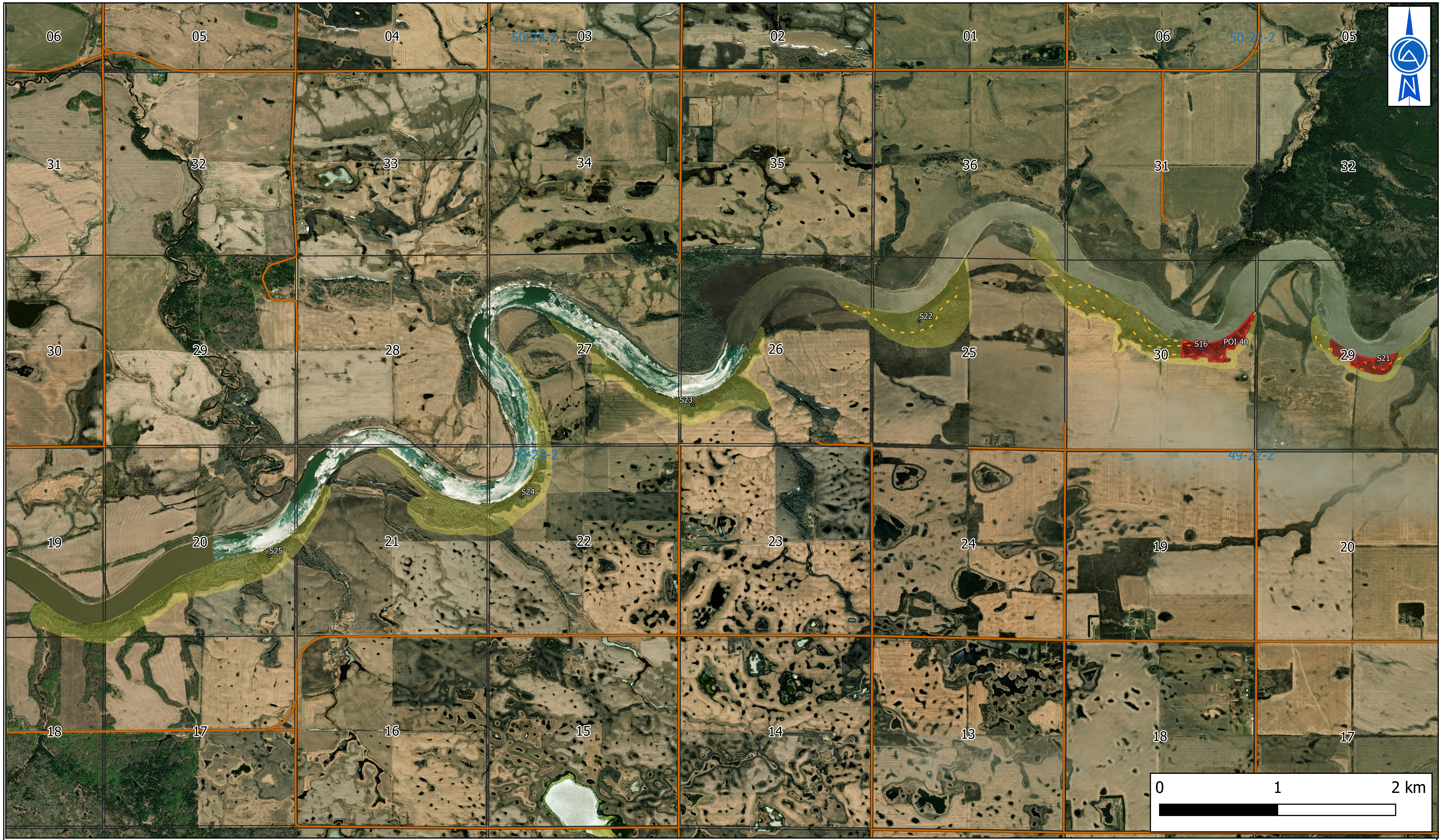
Clifton

CLIENT: RM OF PRINCE ALBERT No. 461

SITE: 2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS

TITLE: SLOPE STABILITY ASSESSMENT MAP FROM TWP 48 - RGE 24 - W2 TO TWP 49 - RGE 23 - W2



LEGEND

2021-2022 Clifton Slope Stability Mapping
Unstable
Potentially Unstable
14-SEP-21 Clifton GPS Fieldwork Stations

Geohazards Identified
Delinated Landslides
Scarps

Transport (SK GeoHub)
Expressway / Highway

Cadastral
sk_quarter
sk_section
sk_township

2018-06-05_World Satellite Imagery (Base)

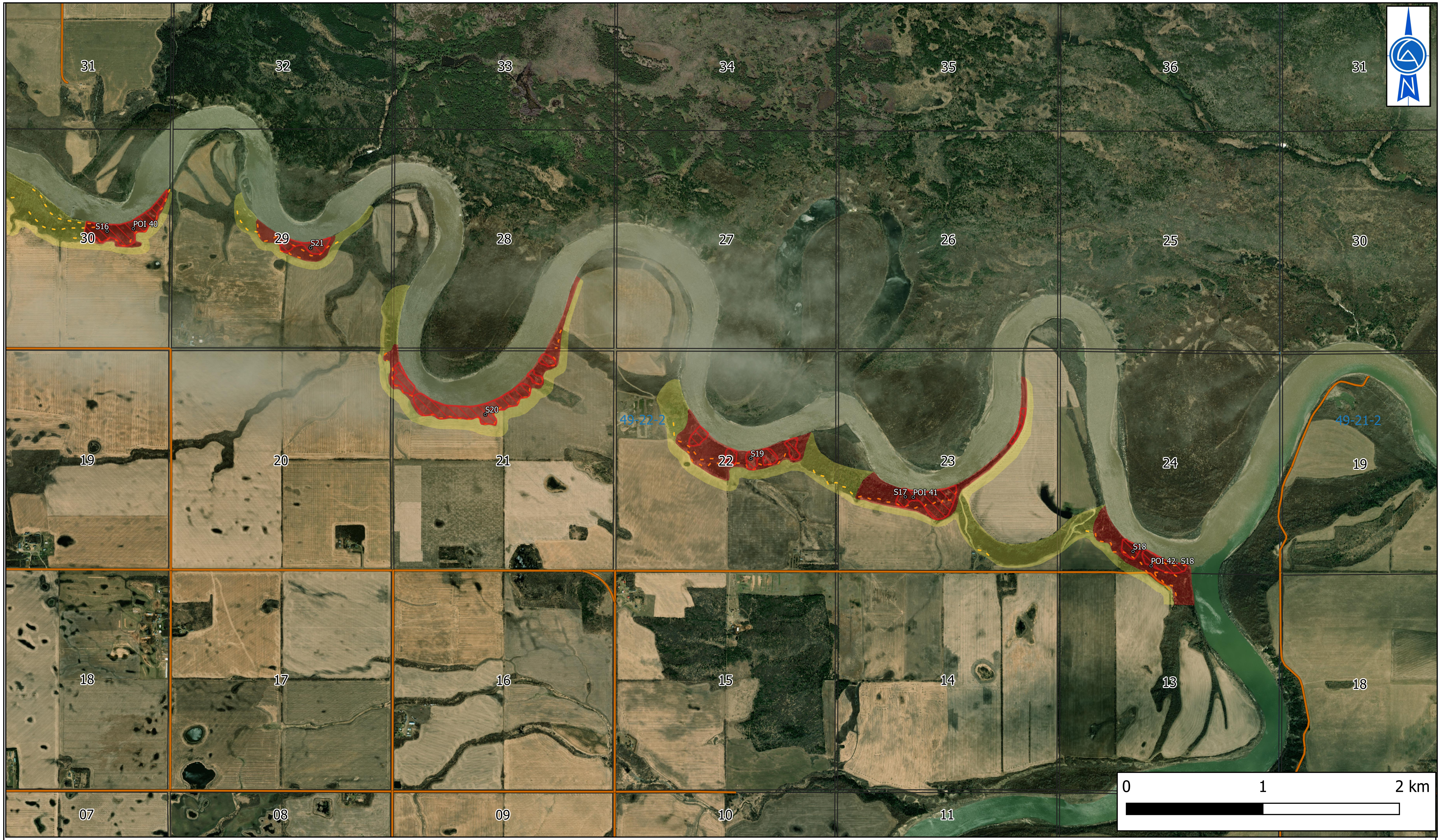
DATE	DRAWN BY	APPROVED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-02	JM	AK	As Shown	CG3525	A1.3

Clifton

CLIENT RM OF PRINCE ALBERT No. 461

SITE 2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS

TITLE SLOPE STABILITY ASSESSMENT MAP FROM TWP 49 - RGE 23 - W2 TO TWP 49 - RGE 22 - W2



LEGEND

2021-2022 Clifton Slope Stability Mapping
- Unstable
- Potentially Unstable
- 14-SEP-21 Clifton GPS Fieldwork Stations

Geohazards Identified
- Delinated Landslides
- Scarps

Transport (SK GeoHub)
- Expressway / Highway

Cadastral
- sk_quarter
- sk_section
- sk_township

2018-06-05_World Satellite Imagery (Base)

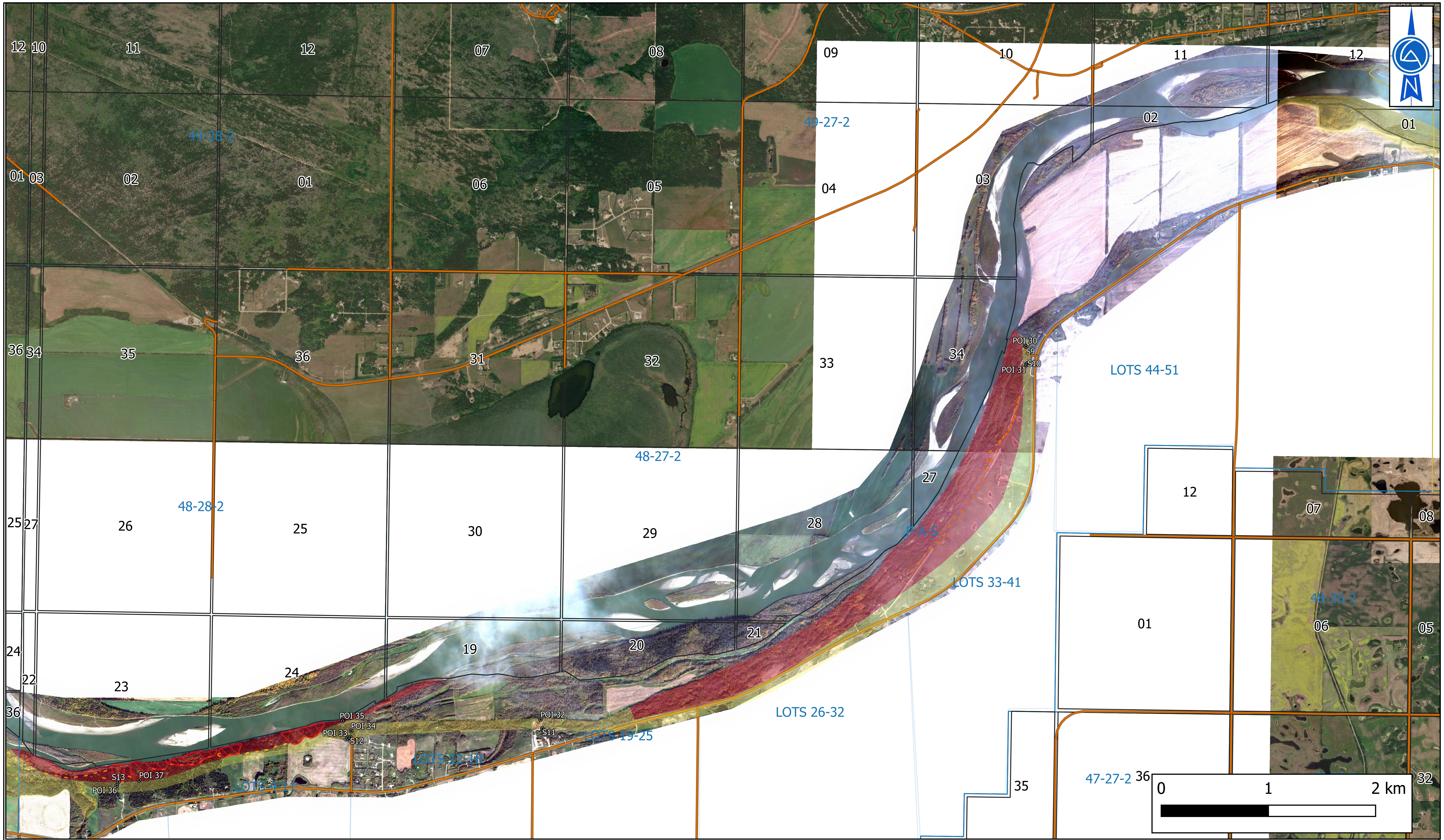
DATE	DRAWN BY	APPROVED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-02	JM	AK	As Shown	CG3525	A1.4

Clifton

CLIENT: RM OF PRINCE ALBERT No. 461

SITE: 2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS

TITLE: SLOPE STABILITY ASSESSMENT MAP FROM TWP 49 - RGE 22 - W2 TO EAST RM of PA LIMIT



LEGEND

2021-2022 Clifton Slope Stability Mapping
- Unstable
- Potentially Unstable
- 14-SEP-21 Clifton GPS Fieldwork Stations

Geohazards Identified
- Delinated Landslides
- Scarps

Transport (SK GeoHub)
- Expressway / Highway

Cadastral
- sk_quarter
- sk_section
- sk_township

2021-09-22_SkySat Satellite Imagery
2018-06-05_World Satellite Imagery (Base)

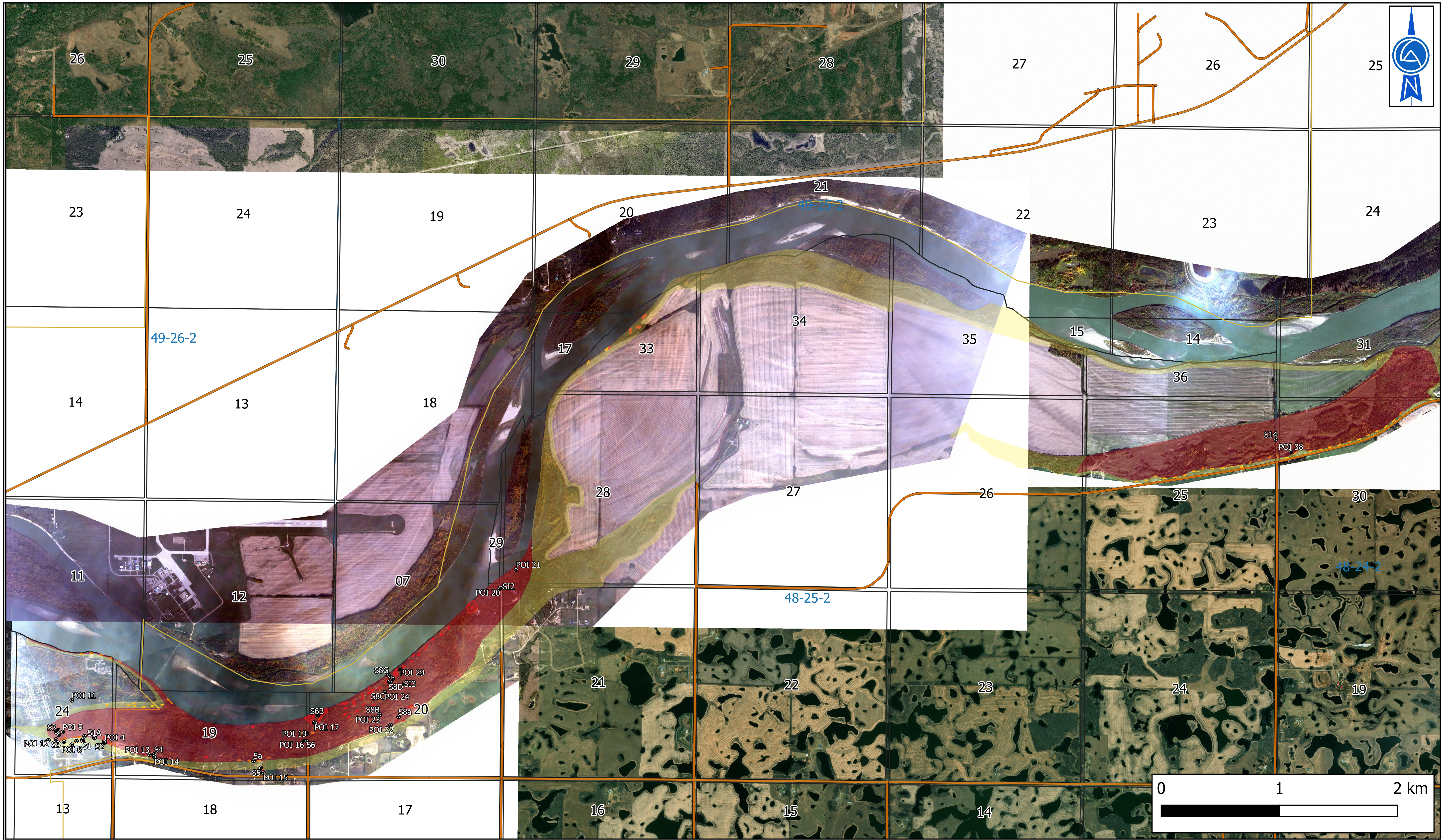
DATE	DRAWN BY	APPROVED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-02	JM	AK	As Shown	CG3525	A2.0

Clifton

CLIENT: RM OF PRINCE ALBERT No. 461

SITE: 2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS

TITLE: SLOPE STABILITY ASSESSMENT MAP FROM WEST RM of PA LIMIT TO TWP 48 - RGE 27 - W2



LEGEND

2021-2022 Clifton Slope Stability Mapping	Geohazards Identified	Transport (SK GeoHub)	
Unstable	Delinated Landslides	Expressway / Highway	sk_section
Potentially Unstable	Scarps	Cadastral	sk_township
14-SEP-21 Clifton GPS Fieldwork Stations	Tension Cracks	sk_quarter	

2021-09-22_SkySat Satellite Imagery
2018-06-05_World Satellite Imagery (Base)

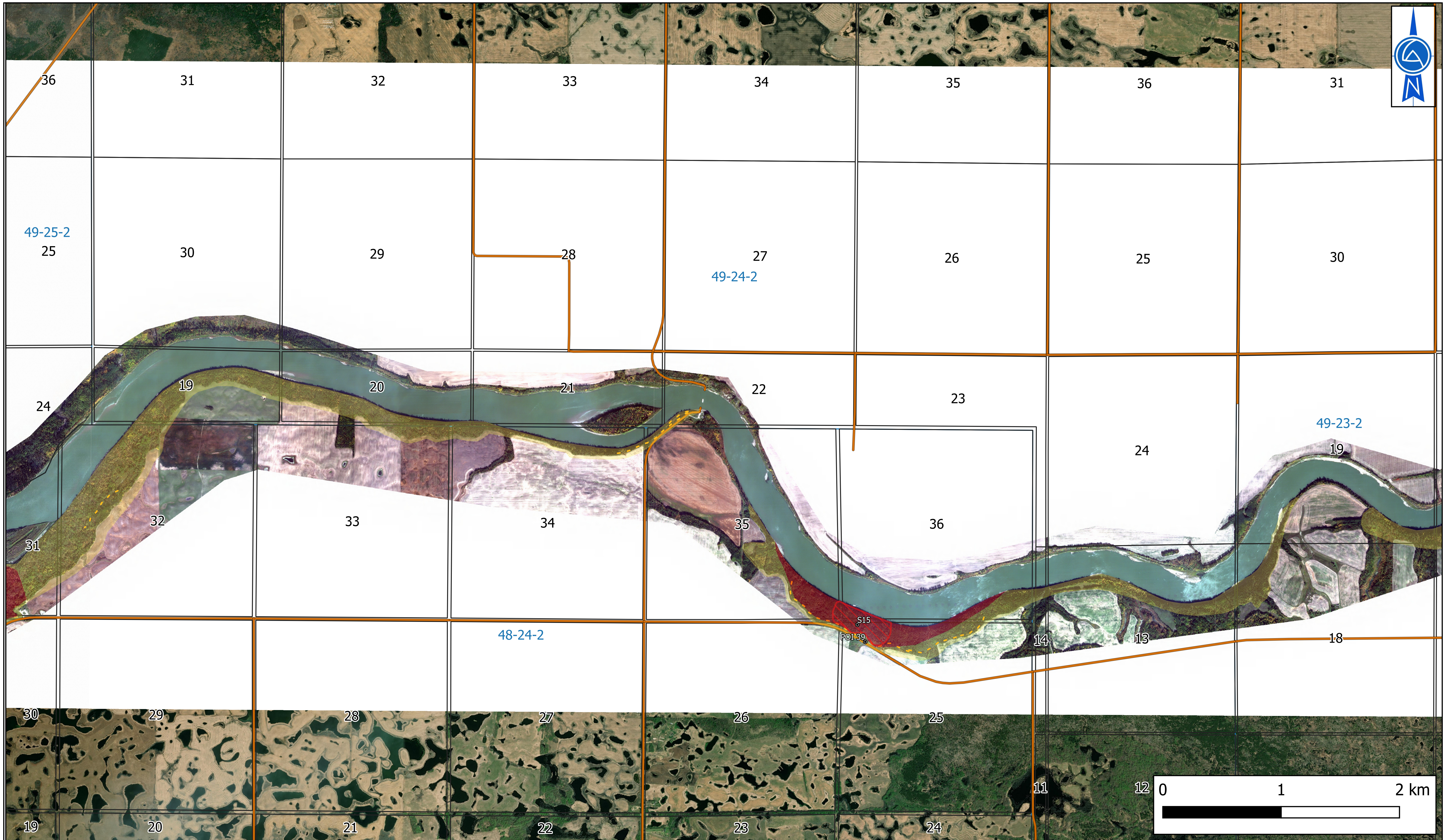
DATE	DRAWN BY	APPROVED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-02	JM	AK	As Shown	CG3525	A2.1

Clifton

CLIENT RM OF PRINCE ALBERT No. 461

SITE 2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS

TITLE SLOPE STABILITY ASSESSMENT MAP FROM TWP 48 - RGE 26 - W2 TO TWP 48 - RGE 24 - W2



LEGEND

2021-2022 Clifton Slope Stability Mapping
- Unstable
- Potentially Unstable
- 14-SEP-21 Clifton GPS Fieldwork Stations

Geohazards Identified
- Delinated Landslides
- Scarps

Transport (SK GeoHub)
- Expressway / Highway

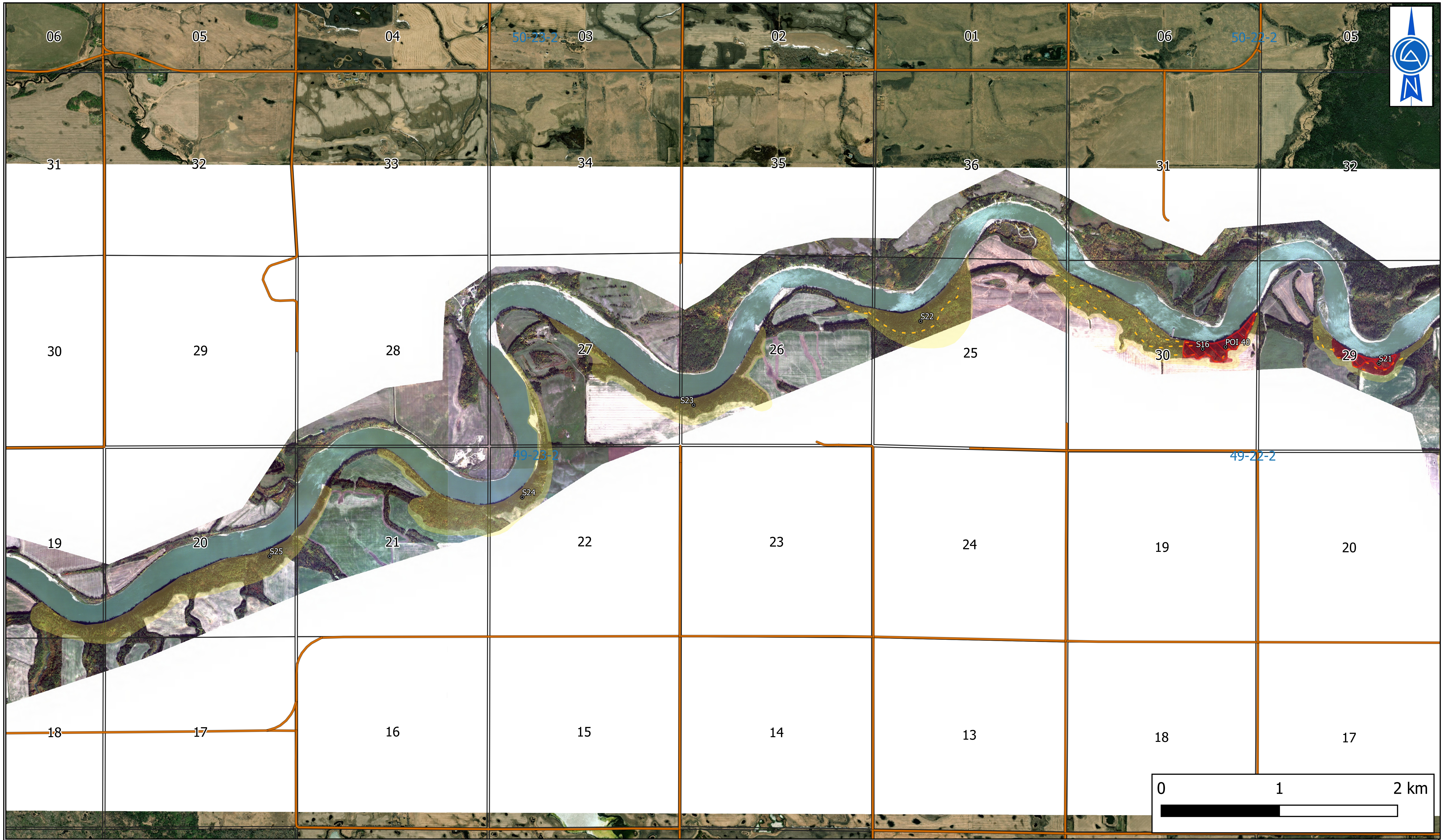
Cadastral
- sk_quarter
- sk_section
- sk_township

2021-09-22_SkySat Satellite Imagery
2018-06-05_World Satellite Imagery (Base)

DATE	DRAWN BY	APPROVED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-02	JM	AK	As Shown	CG3525	A2.2

Clifton

CLIENT	RM OF PRINCE ALBERT No. 461
SITE	2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS
TITLE	SLOPE STABILITY ASSESSMENT MAP FROM TWP 48 - RGE 24 - W2 TO TWP 49 - RGE 23 - W2



LEGEND

2021-2022 Clifton Slope Stability Mapping
- Unstable
- Potentially Unstable
- 14-SEP-21 Clifton GPS Fieldwork Stations

Geohazards Identified
- Delineated Landslides
- Scarps

Transport (SK GeoHub)
- Expressway / Highway

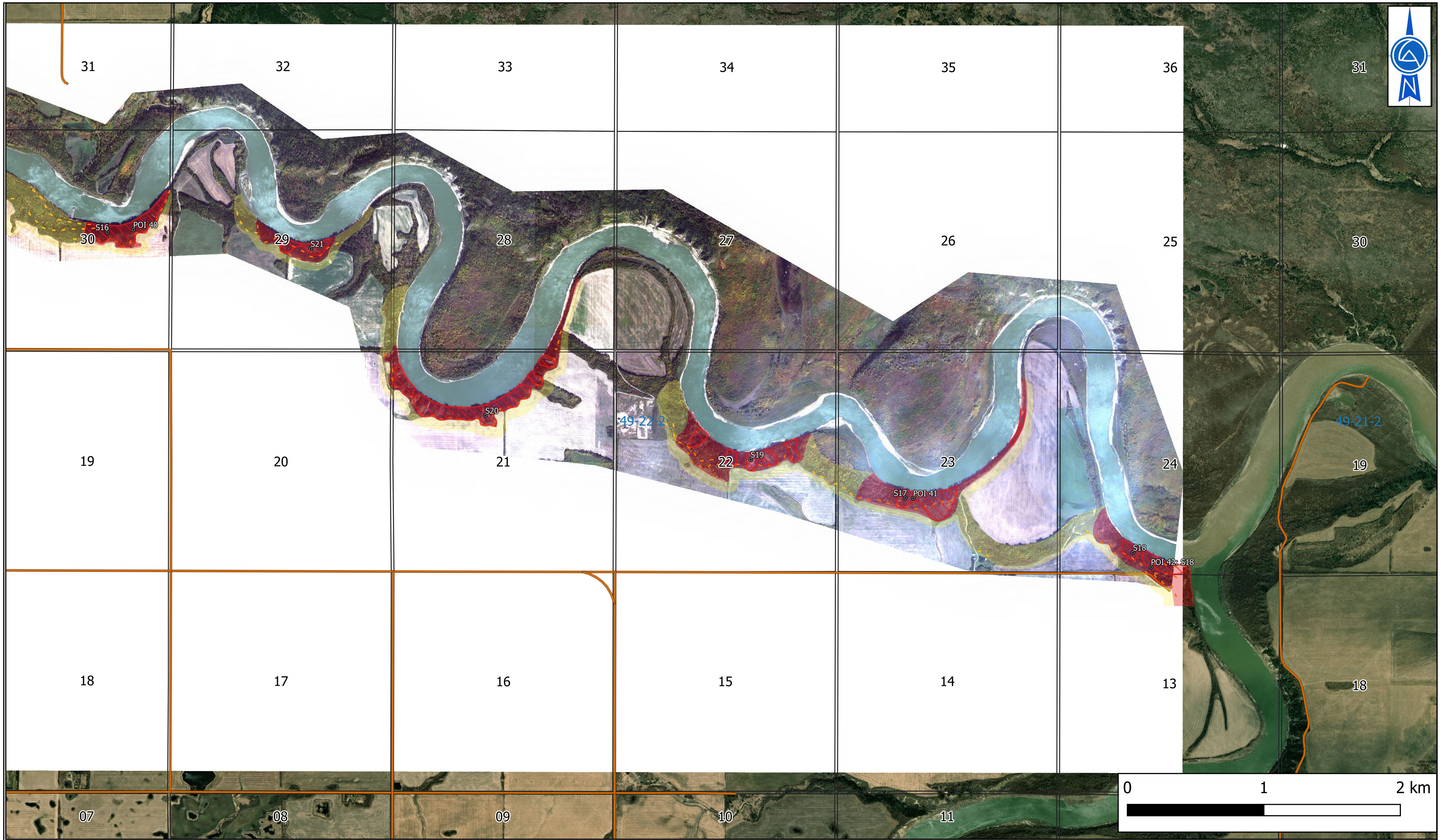
Cadastral
- sk_quarter
- sk_section
- sk_township

2021-09-22_SkySat Satellite Imagery
2018-06-05_World Satellite Imagery (Base)

DATE	DRAWN BY	APPROVED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-02	JM	AK	As Shown	CG3525	A2.3

Clifton

CLIENT	RM OF PRINCE ALBERT No. 461
SITE	2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS
TITLE	SLOPE STABILITY ASSESSMENT MAP FROM TWP 49 - RGE 23 - W2 TO TWP 49 - RGE 22 - W2



LEGEND

2021-2022 Clifton Slope Stability Mapping
- Unstable
- Potentially Unstable
- 14-SEP-21 Clifton GPS Fieldwork Stations

Geohazards Identified
- Delinated Landslides
- Scarps

Transport (SK GeoHub)
- Expressway / Highway

Cadastral
- sk_quarter
- sk_section
- sk_township

2021-09-22_SkySat Satellite Imagery
2018-06-05_World Satellite Imagery (Base)

DATE	DRAWN BY	APPROVED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-02	JM	AK	As Shown	CG3525	A2.4

Clifton

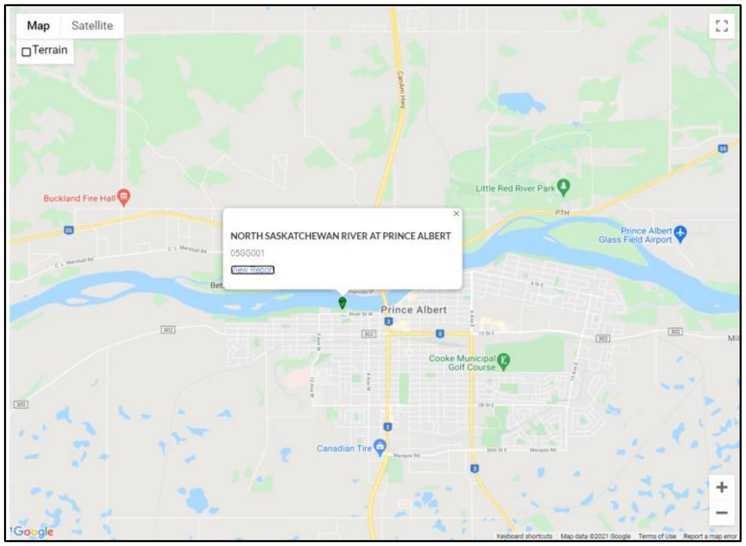
CLIENT RM OF PRINCE ALBERT No. 461

SITE 2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS

TITLE SLOPE STABILITY ASSESSMENT MAP FROM TWP 49 - RGE 22 - W2 TO EAST RM of PA LIMIT

Appendix B
Figures

Clifton



DATE	DRAWN BY	REVIEWED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-05	JM	AK	As Shown	CG3525	B1

Clifton

RM OF PRINCE ALBERT NO.461

CLIENT	R.M. OF PRINCE ALBERT No. 461
SITE	2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS
TITLE	North Saskatchewan River water level and flow rates from the Prince Albert, SK Hydrometric Station (05GG001) (Data from Environment and Climate Change Canada Historical Hydrometric Database).

DATE	DRAWN BY	REVIEWED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-09	JM	AK	As Shown	CG3525	B2

Clifton

RM OF PRINCE ALBERT NO.461

CLIENT	R.M. OF PRINCE ALBERT No. 461
SITE	2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS
TITLE	SE24-48-26-W2 Unstable terrain with evident instability features (photographs obtained September 14th, 2021, inspection).

DATE	DRAWN BY	REVIEWED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-16	JM	AK	As Shown	CG3525	B3

Clifton

RM OF PRINCE ALBERT NO.461

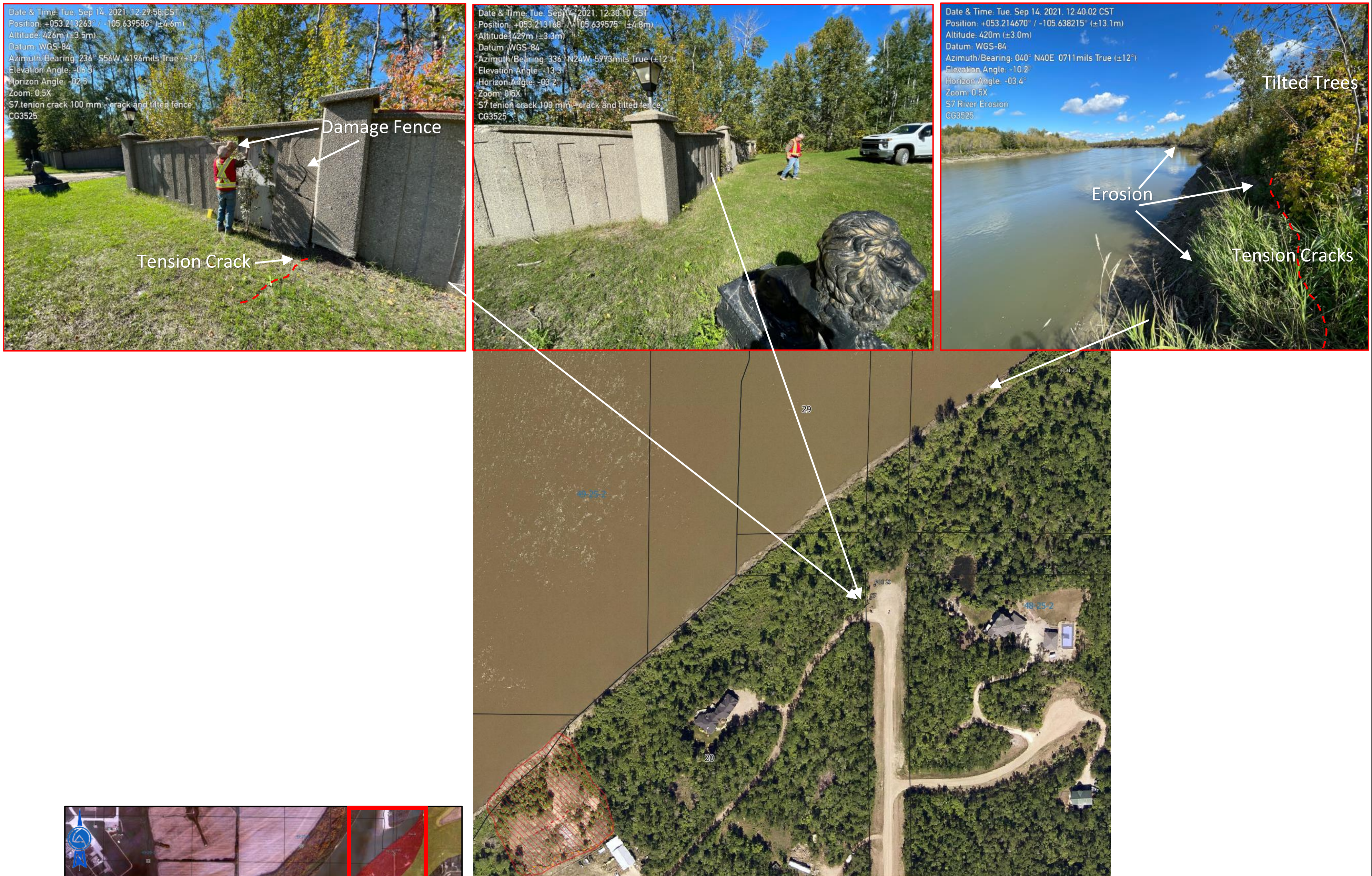
CLIENT	R.M. OF PRINCE ALBERT No. 461
SITE	2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS
TITLE	SW 19-48-26-W2 Unstable terrain with evident tension crack A) Satellite Imagery and B) September 14th, 2021, inspection).

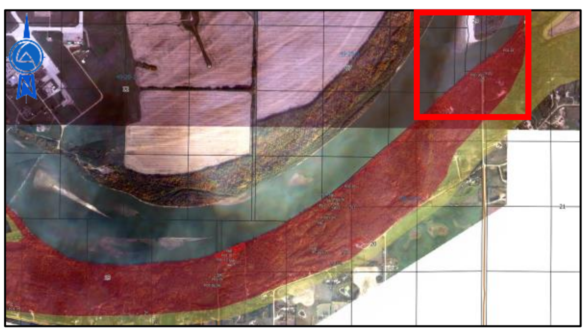
DATE	DRAWN BY	REVIEWED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-16	JM	AK	As Shown	CG3525	B4

Clifton

RM OF PRINCE ALBERT NO.461

CLIENT	R.M. OF PRINCE ALBERT No. 461
SITE	2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS
TITLE	SE 19-48-25-W2 to SW 20-48-25-W2 Unstable terrain identified tension cracks, scarps, slumps, river erosion, and tilted trees.



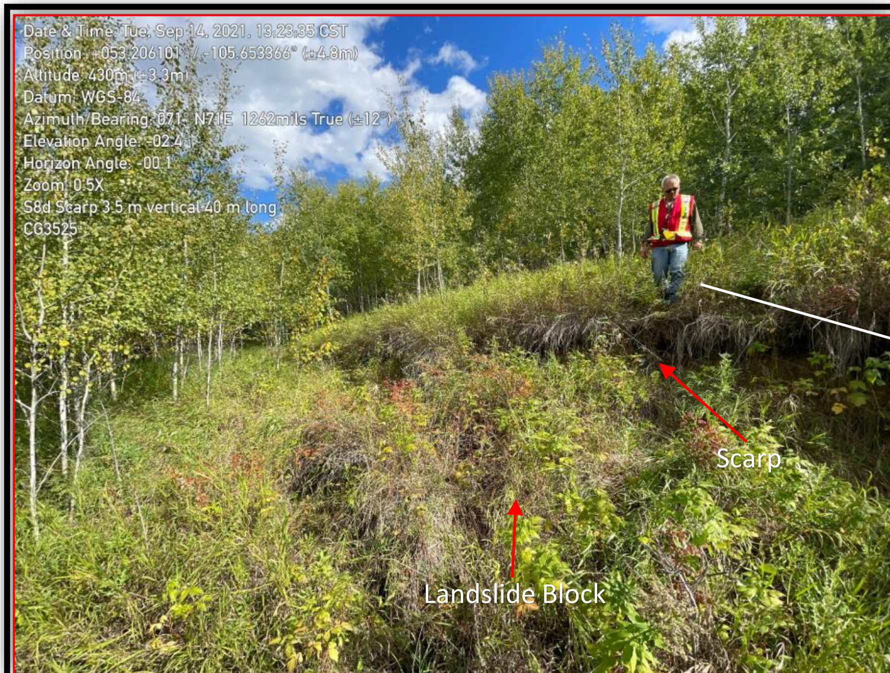


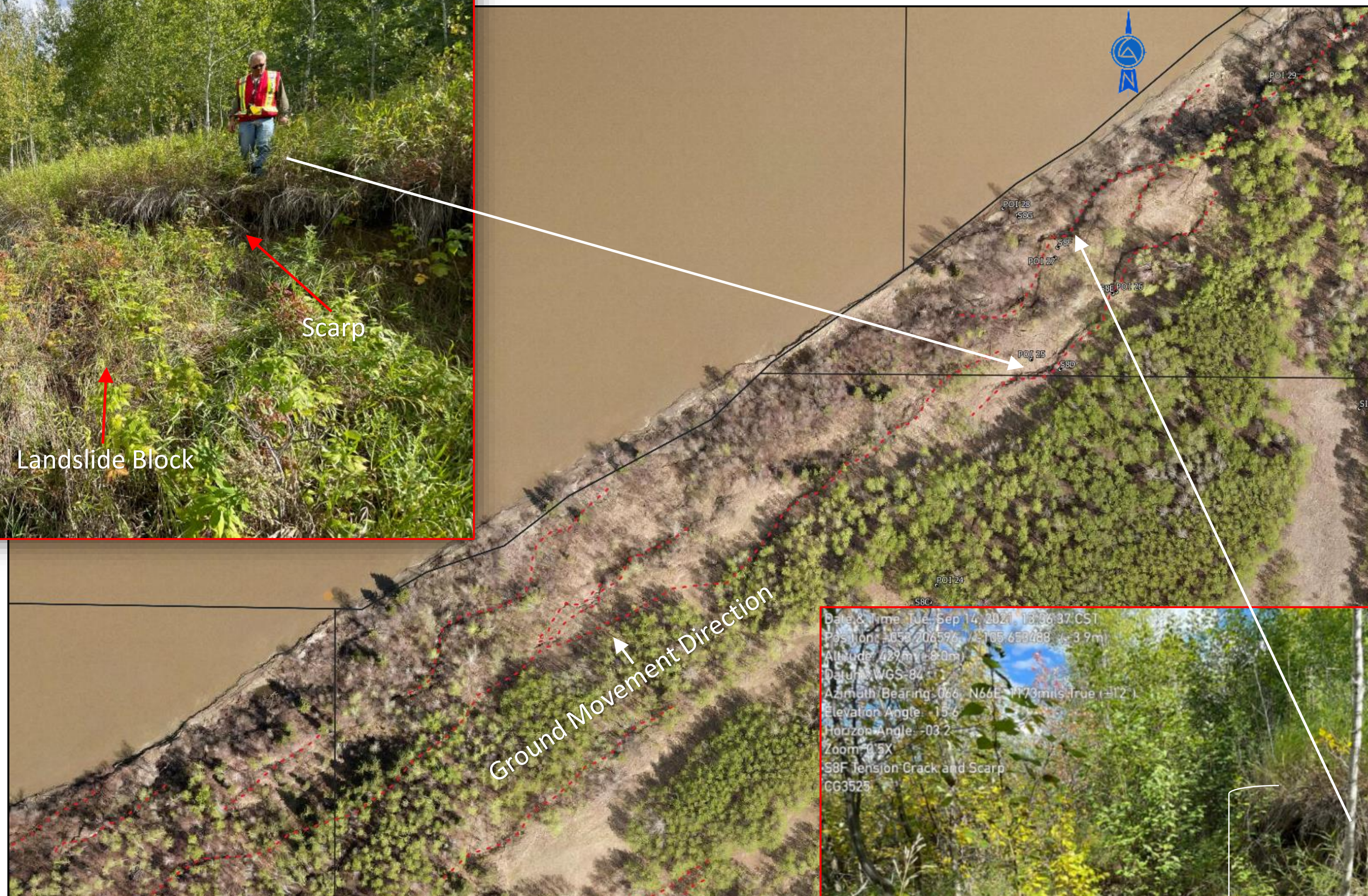
DATE	DRAWN BY	REVIEWED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-16	JM	AK	As Shown	CG3525	B5

Clifton

RM OF PRINCE ALBERT NO. 461

CLIENT	R.M. OF PRINCE ALBERT No. 461
SITE	2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS
TITLE	NE 20-48-25-W2 to SW 28-48-25-W2 Unstable slope. Observed cracks on titled concrete fence along road.



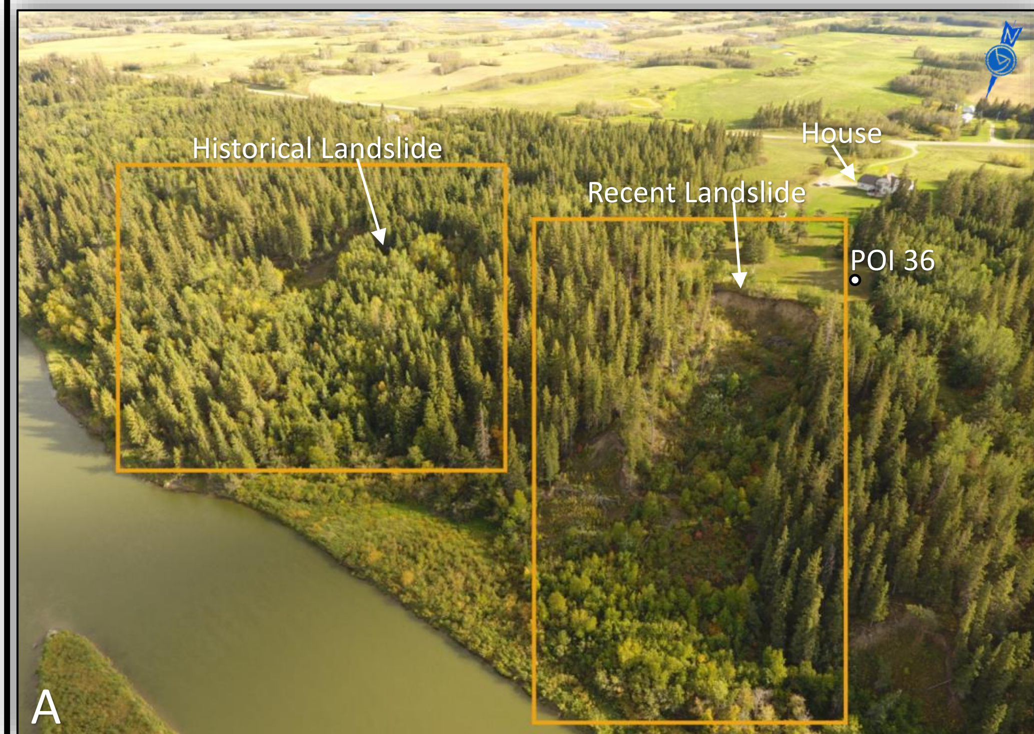


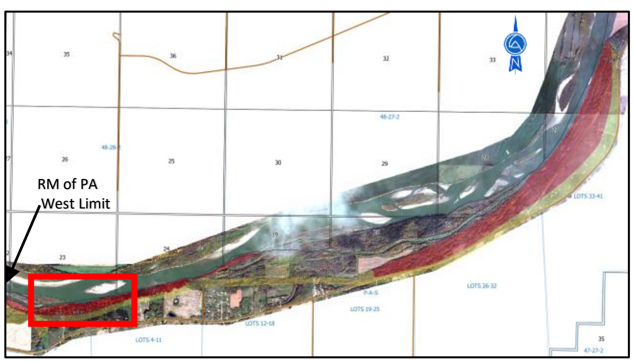
DATE	DRAWN BY	REVIEWED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-23	JM	AK	As Shown	CG3525	B6

Clifton

RM OF PRINCE ALBERT NO.461

CLIENT	R.M. OF PRINCE ALBERT No. 461
SITE	2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS
TITLE	SW 20-48-25-W2 to NW 20-48-25-W2 major slope instability features trending NE-SW identified on imagery and in the field.



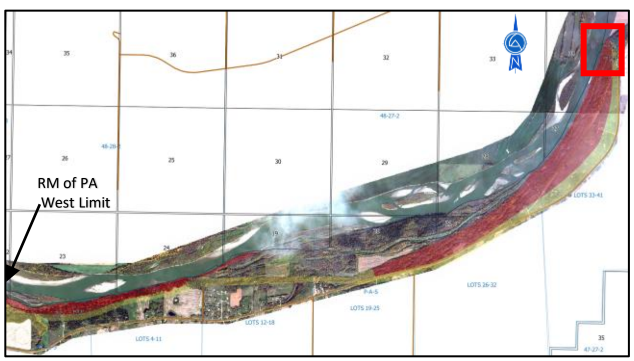


DATE	DRAWN BY	REVIEWED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-23	JM	AK	As Shown	CG3525	B7

Clifton

RM OF PRINCE ALBERT NO.461

CLIENT	R.M. OF PRINCE ALBERT No. 461
SITE	2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS
TITLE	LOTS 1 to 9-48-27/28-W2 Unstable slope near relocated house. Note the major recent and historical landslides present.



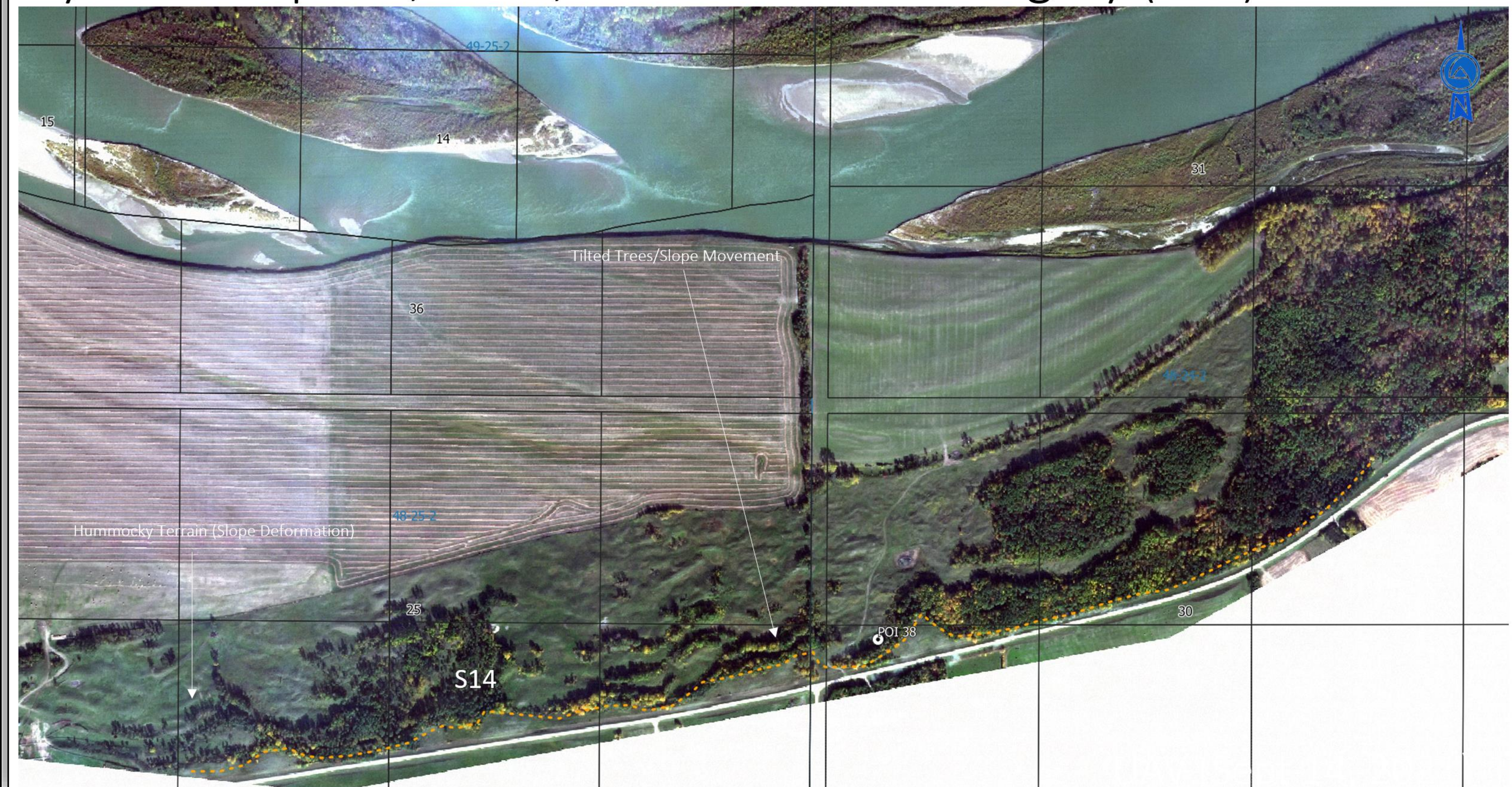
DATE	DRAWN BY	REVIEWED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-23	JM	AK	As Shown	CG3525	B8

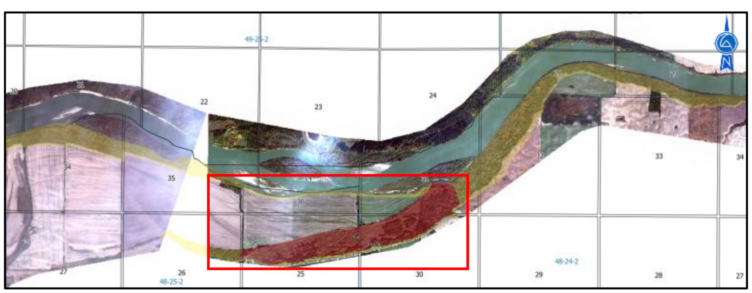
Clifton

RM OF PRINCE ALBERT NO.461

CLIENT	R.M. OF PRINCE ALBERT No. 461
SITE	2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS
TITLE	LOTS 20 to 31-48-27-W2 Unstable slope near relocated highway. Note the tilted trees and undulating/hummock terrain.

Skywatch Sept 22, 2021, Georeferenced Imagery (S14)



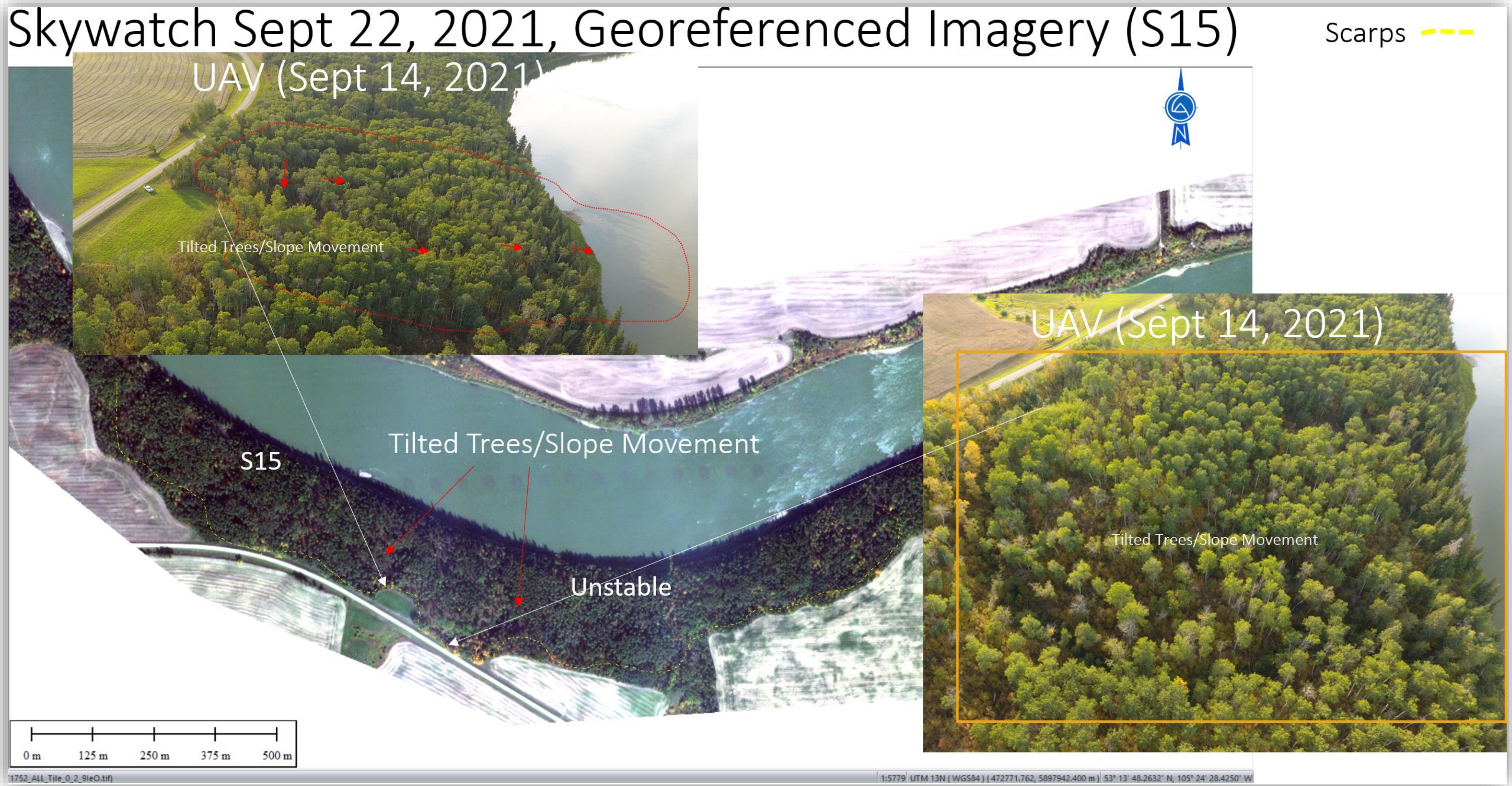


DATE	DRAWN BY	REVIEWED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-23	JM	AK	As Shown	CG3525	B9

Clifton

RM OF PRINCE ALBERT NO.461

CLIENT	R.M. OF PRINCE ALBERT No. 461
SITE	2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS
TITLE	NW 25-48-25-W2 to NE-30-48-24-2-W2 Unstable slope near highway (September 22, 2021, Satellite Imagery).



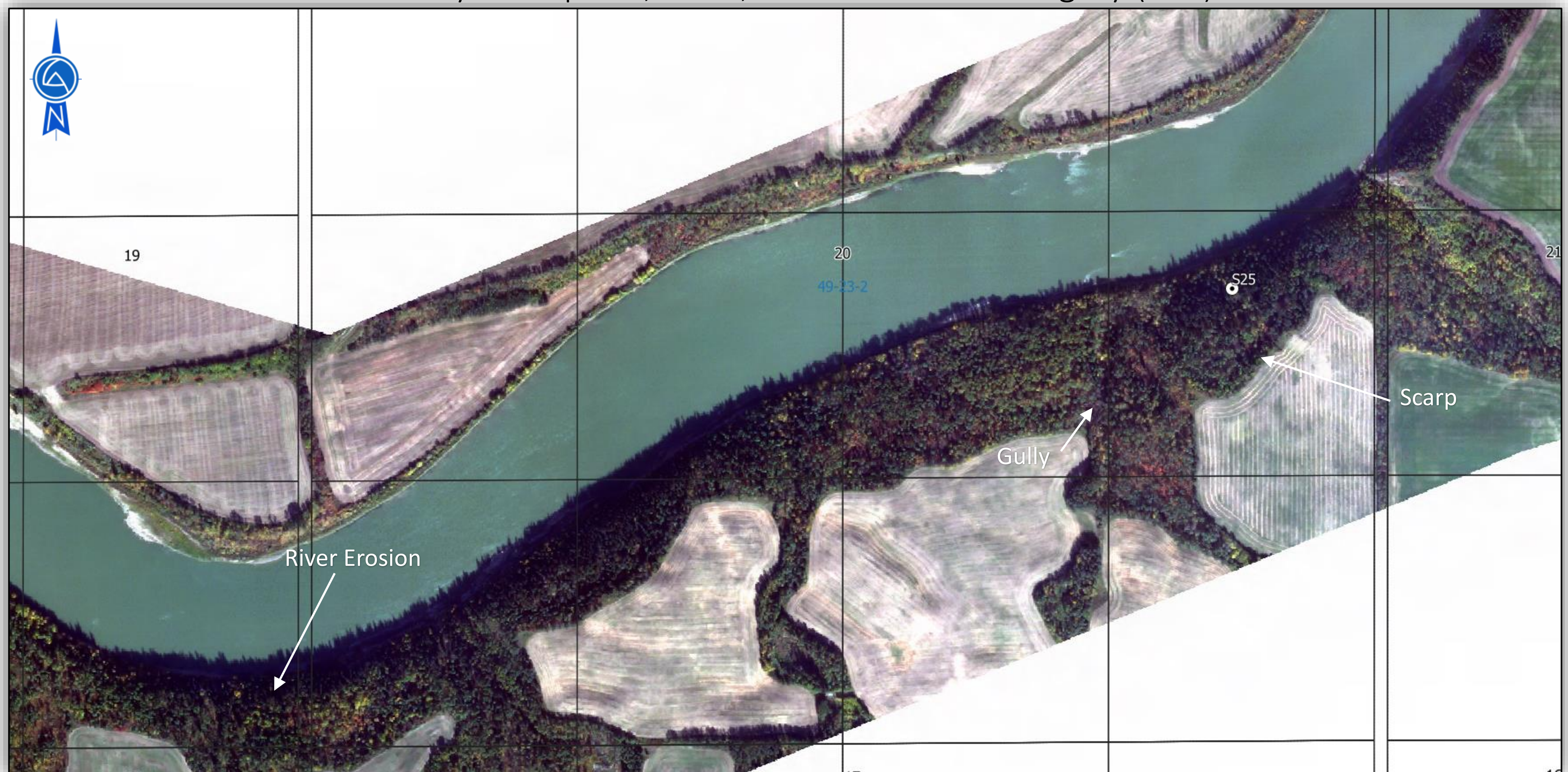
DATE	DRAWN BY	REVIEWED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-23	JM	AK	As Shown	CG3525	B10

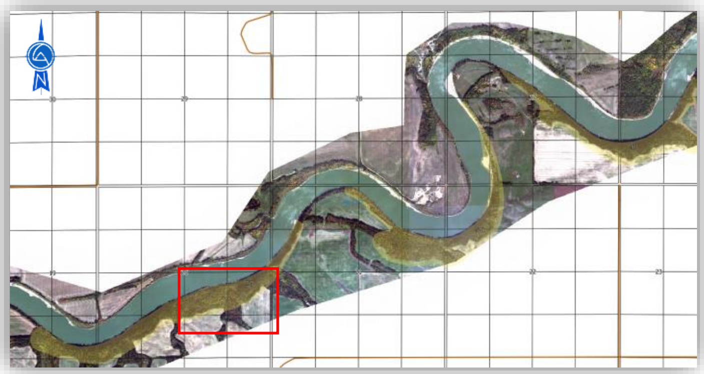
Clifton

RM OF PRINCE ALBERT NO.461

CLIENT	R.M. OF PRINCE ALBERT No. 461
SITE	2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS
TITLE	SE 35-48-24-W2 to SE-36-48-24-2-W2 Unstable slope with evident landslide activity, scarps, tension cracks and river erosion

SkySat Sept 22, 2021, Georeferenced Imagery (S25)





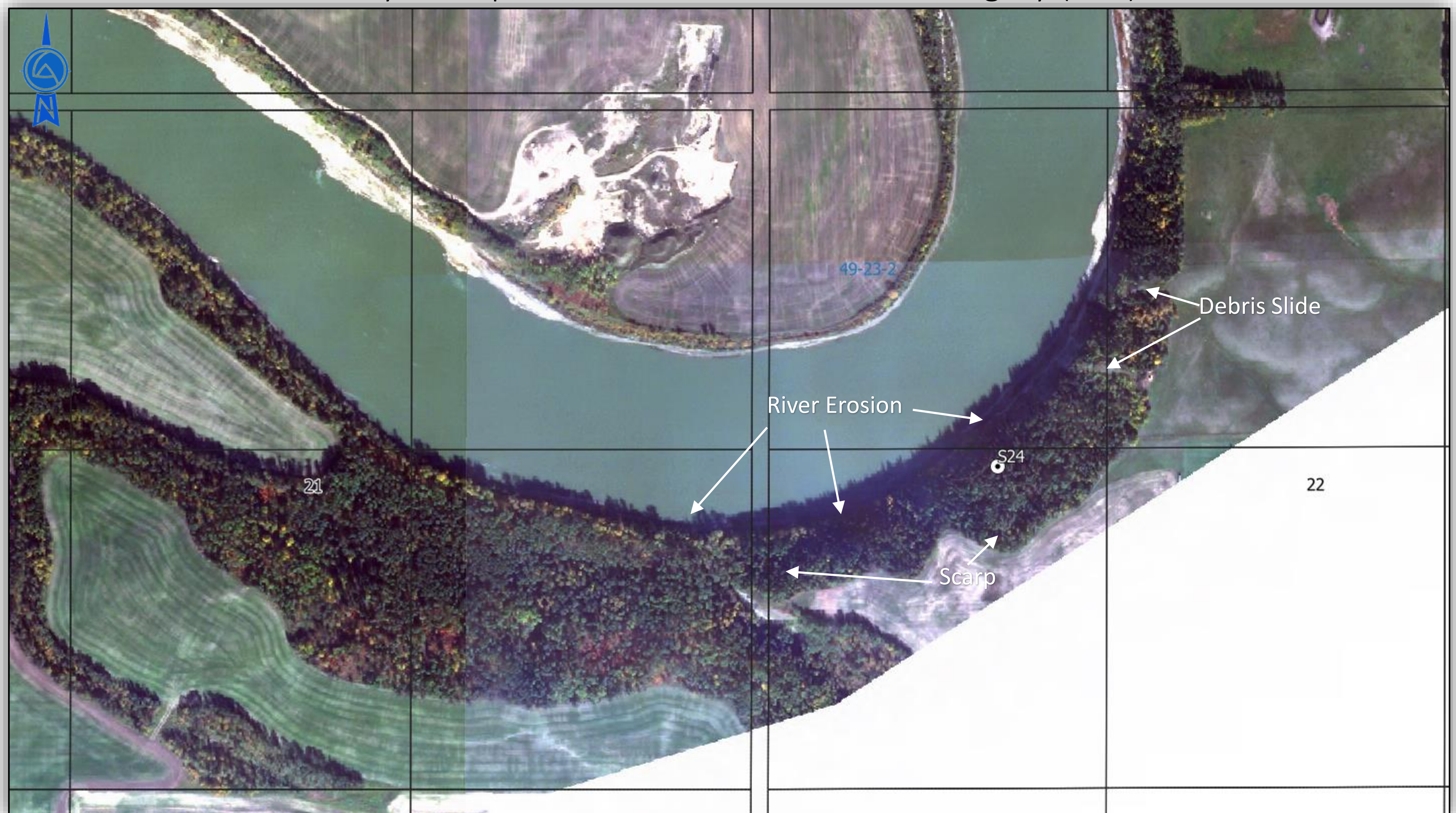
DATE	DRAWN BY	REVIEWED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-23	JM	AK	As Shown	CG3525	B11

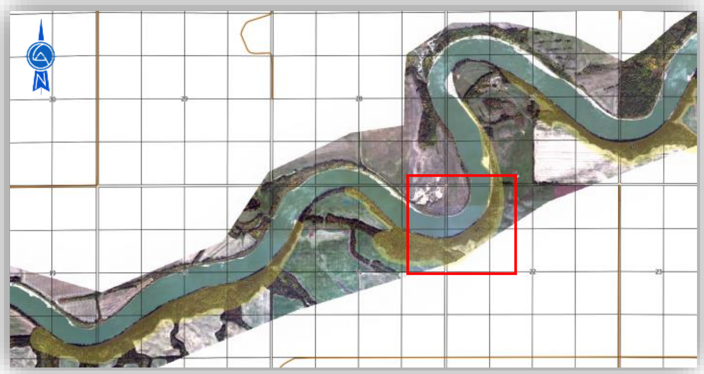
Clifton

RM OF PRINCE ALBERT NO. 461

CLIENT	R.M. OF PRINCE ALBERT No. 461
SITE	2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS
TITLE	SE 20-49-23-W2 to NW 21-49-23-W2 (S25) Potentially unstable slope with river erosion, gullying, and scarps.

SkySat Sept 22, 2021, Georeferenced Imagery (S24)





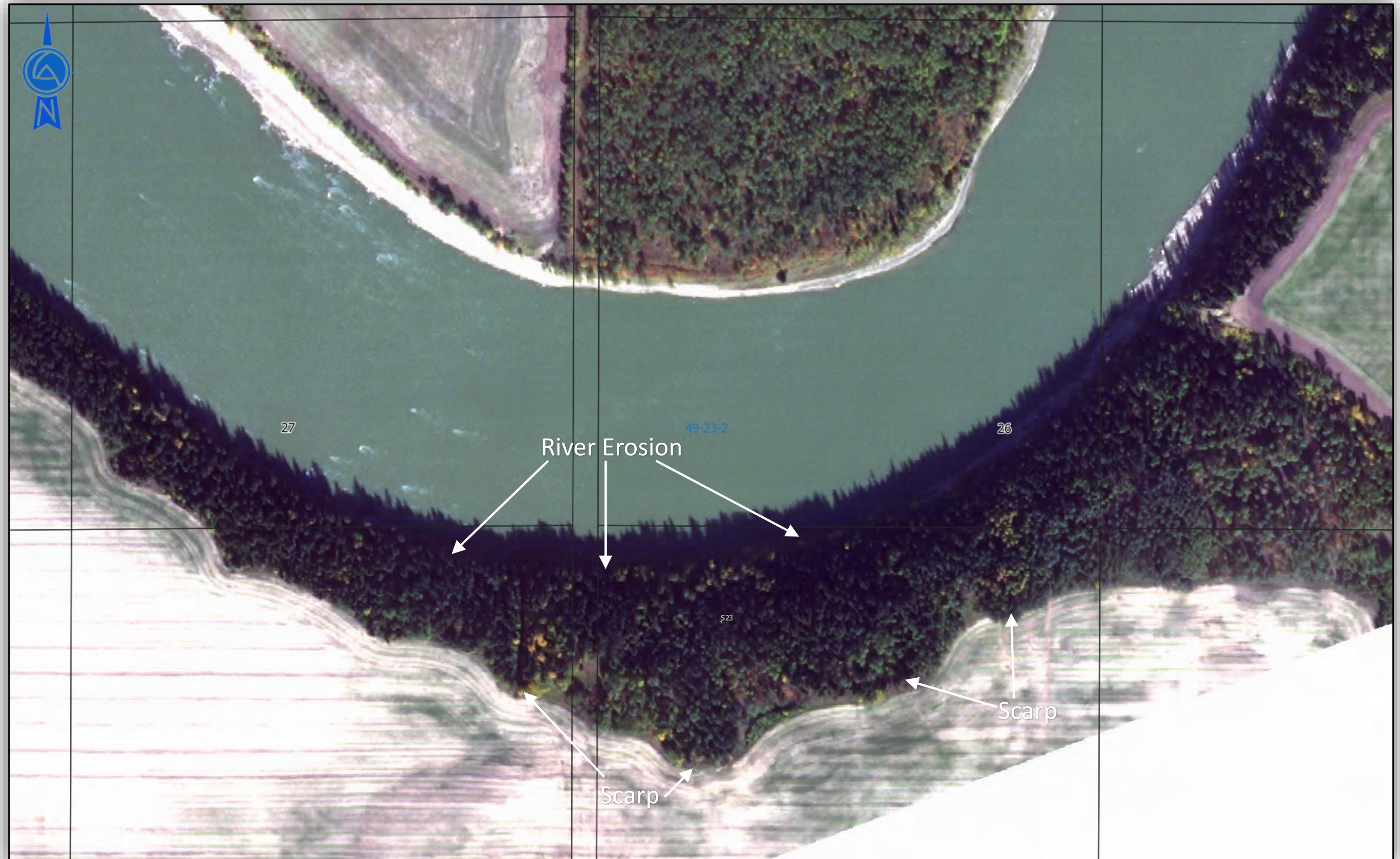
DATE	DRAWN BY	REVIEWED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-23	JM	AK	As Shown	CG3525	B12

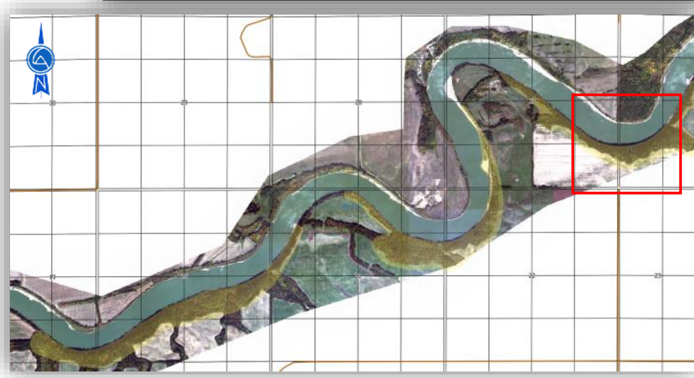
Clifton

RM OF PRINCE ALBERT NO.461

CLIENT	R.M. OF PRINCE ALBERT No. 461
SITE	2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS
TITLE	NE 21-49-23-W2 to NW 22-49-23-W2 (S24) Potentially unstable slope with debris slides, river erosion, gullying, and scarps.

SkySat Sept 22, 2021, Georeferenced Imagery (S23)





DATE	DRAWN BY	REVIEWED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-23	JM	AK	As Shown	CG3525	B13

Clifton

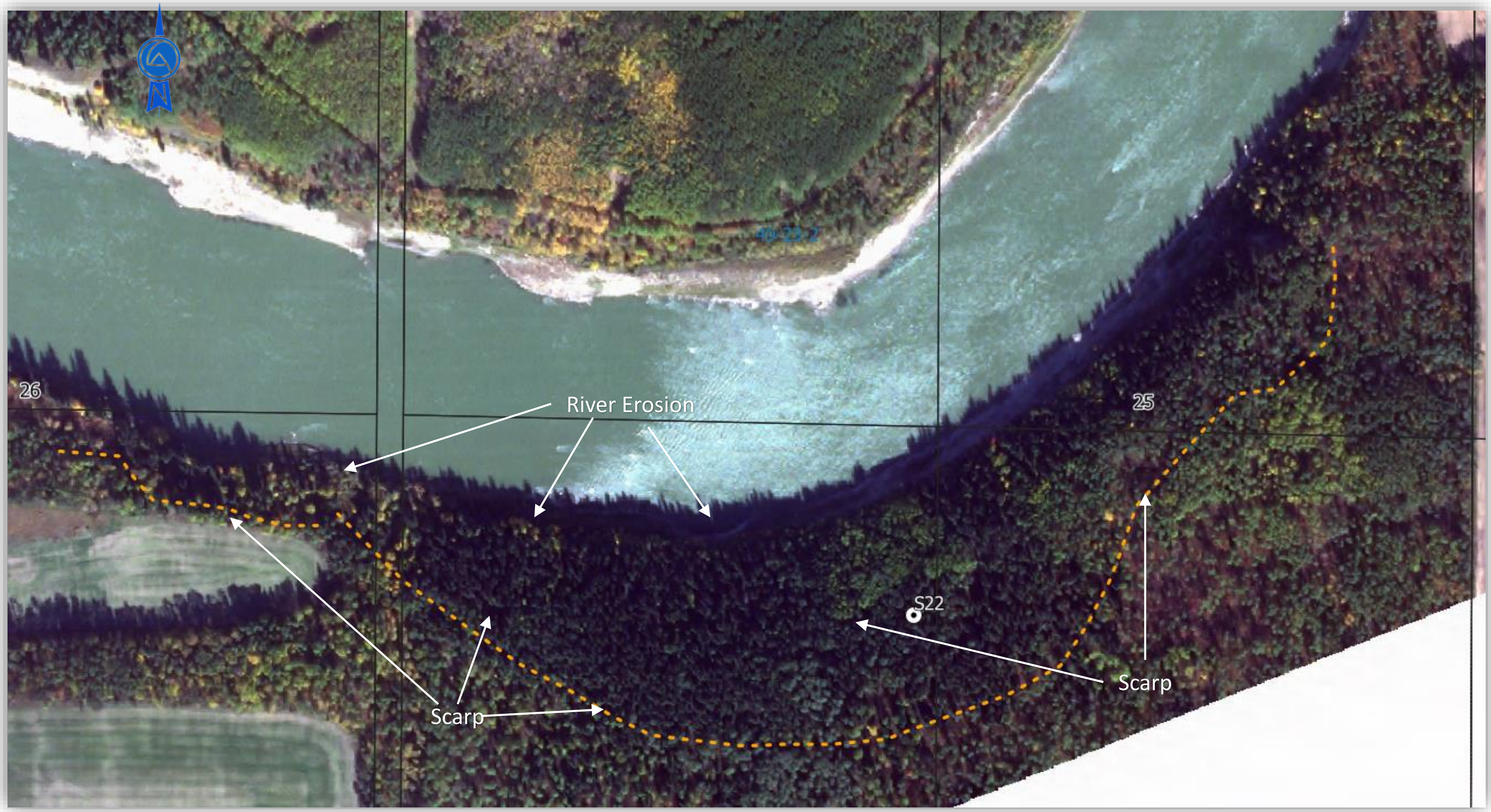
RM OF PRINCE ALBERT NO.461

CLIENT R.M. OF PRINCE ALBERT No. 461

SITE 2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS

TITLE SE 27-49-23-W2 to SW 26-49-23-W2 (S23) Potentially unstable slope with historical slumps, scars, and river erosion.

SkySat Sept 22, 2021, Georeferenced Imagery (S22)



DATE	DRAWN BY	REVIEWED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-23	JM	AK	As Shown	CG3525	B14

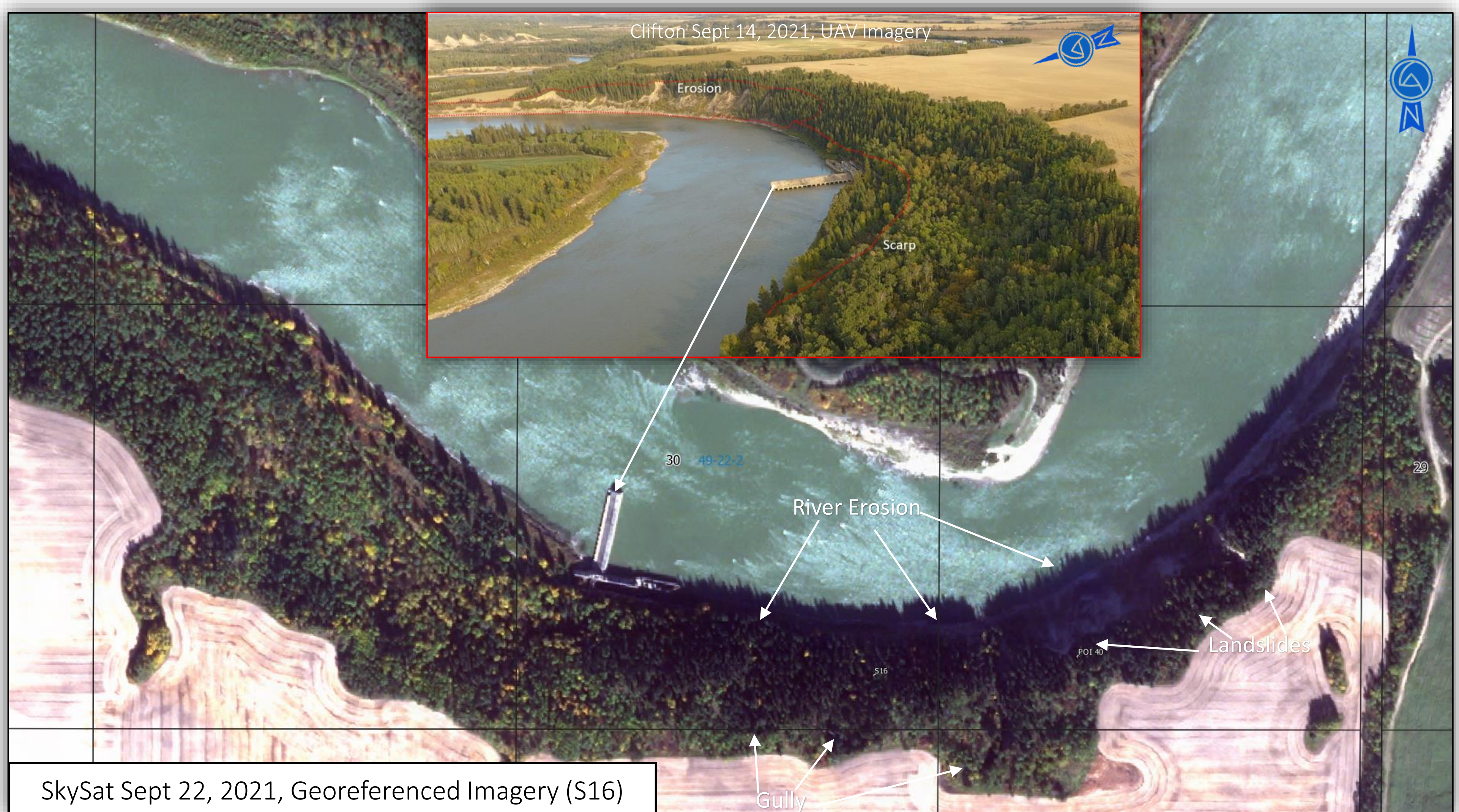
Clifton

RM OF PRINCE ALBERT NO.461

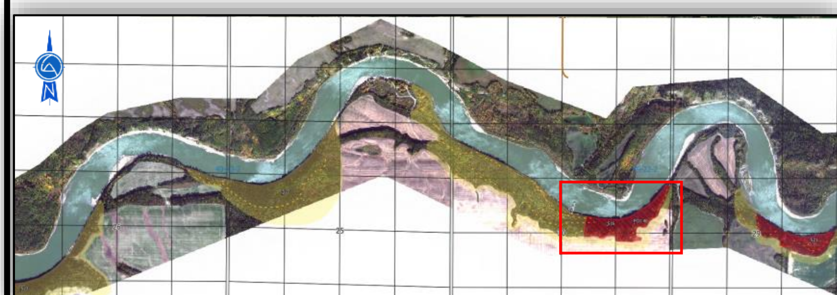
CLIENT R.M. OF PRINCE ALBERT No. 461

SITE 2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS

TITLE NE 26-49-23-W2 to NW 25-49-23-W2 (S22) Potentially unstable slope with historical slumps, scarps, and river erosion.



SkySat Sept 22, 2021, Georeferenced Imagery (S16)



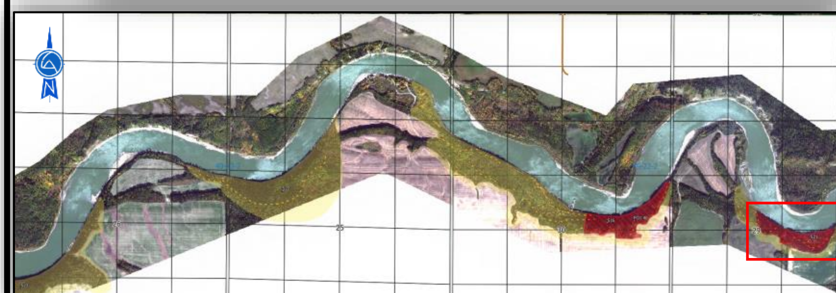
DATE	DRAWN BY	REVIEWED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-23	JM	AK	As Shown	CG3525	B15

Clifton

RM OF PRINCE ALBERT NO. 461

CLIENT	R.M. OF PRINCE ALBERT No. 461
SITE	2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS
TITLE	NE 30-49-22-W2 to NW 25-49-23-W2 (S16) Unstable slope evident active and historical landslides, gullying, and erosion.

SkySat Sept 22, 2021, Georeferenced Imagery (S21)

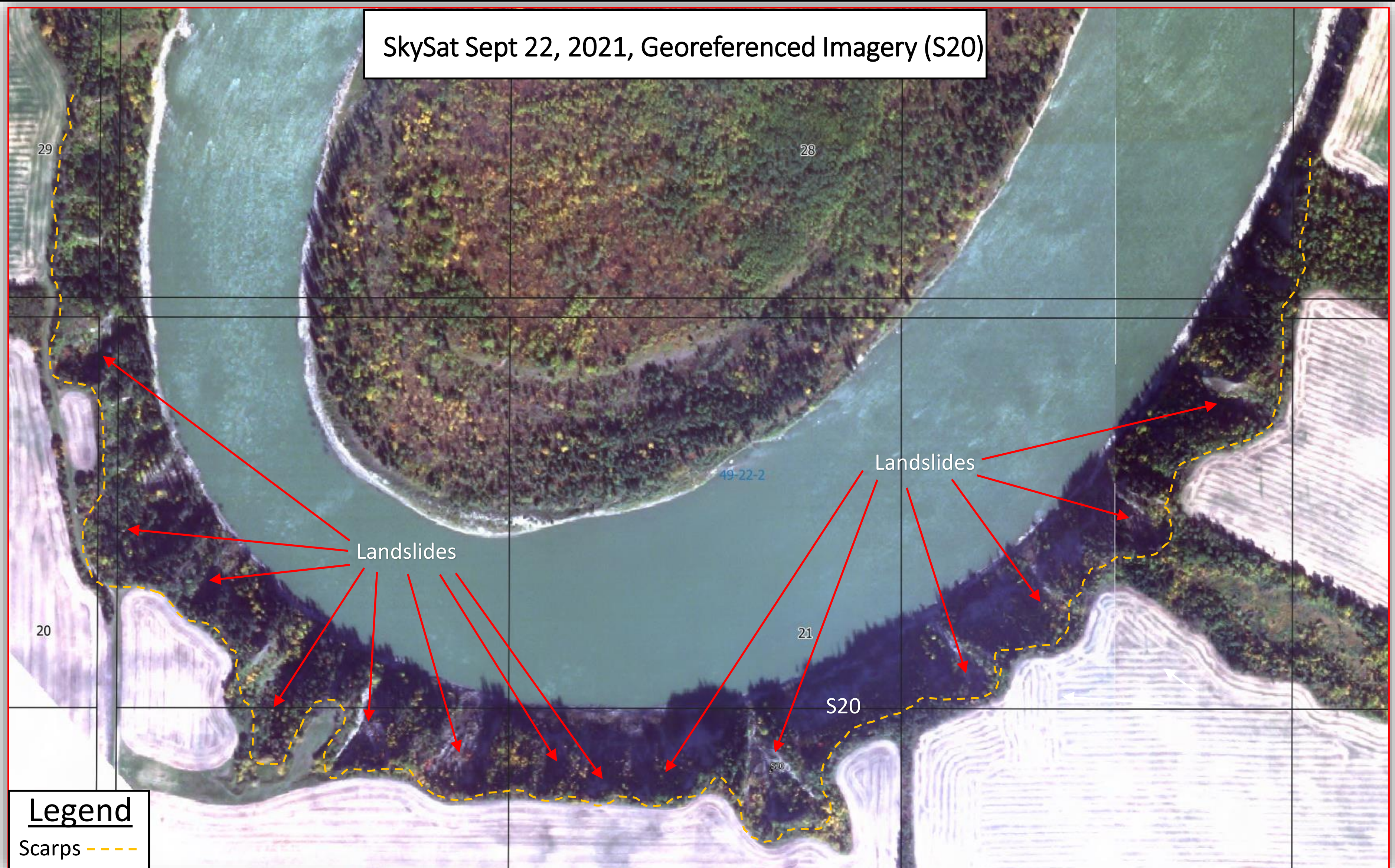


DATE 2022-02-23	DRAWN BY JM	REVIEWED BY AK	SCALE As Shown	FILE NO. CG3525	FIGURE NO. B16

Clifton

RM OF PRINCE ALBERT NO. 461

CLIENT	R.M. OF PRINCE ALBERT No. 461
SITE	2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS
TITLE	SE 29-49-22-W2 (S21) Unstable slope with multiple landslides, scarps, tilted trees and continuous river erosion.

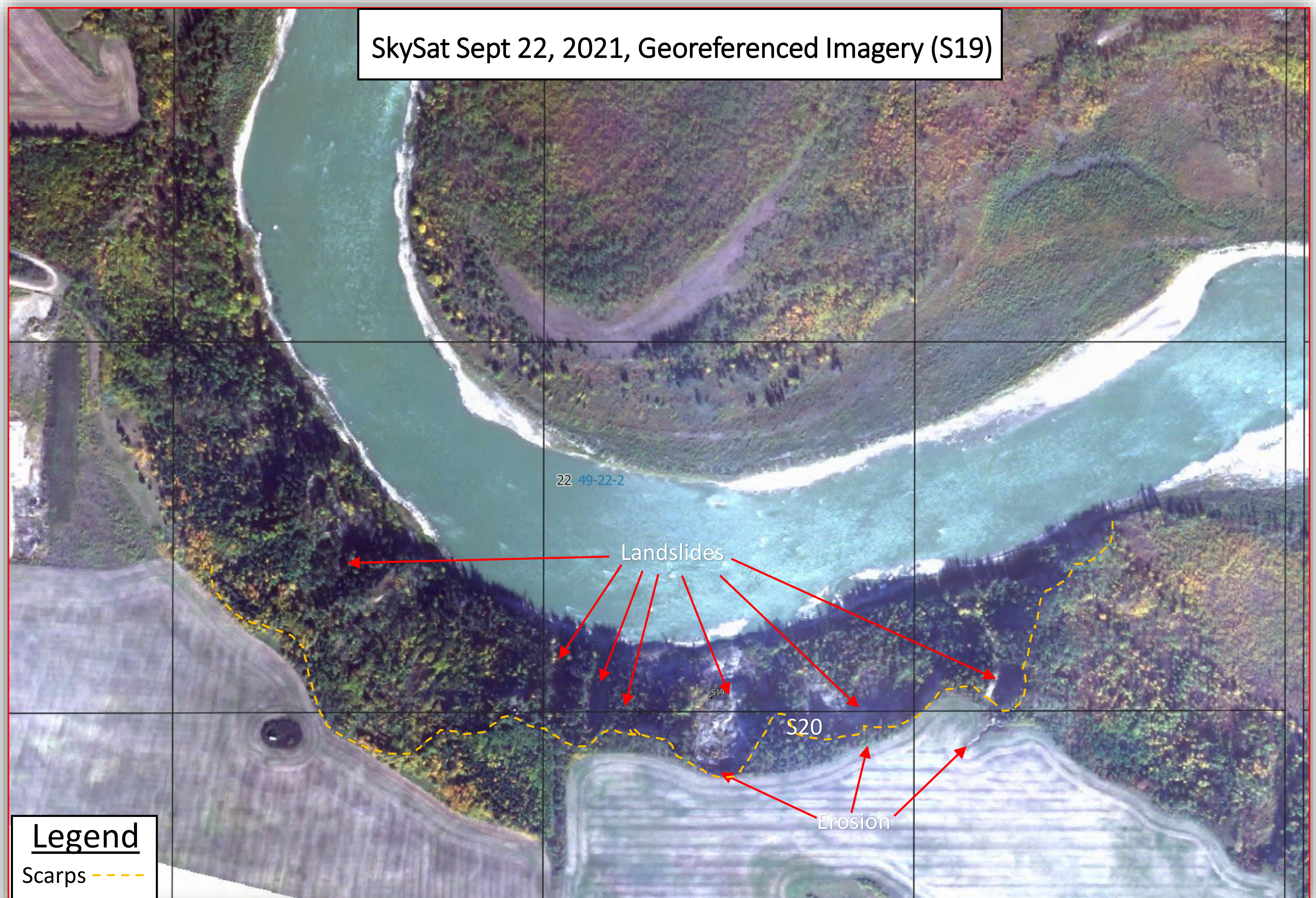


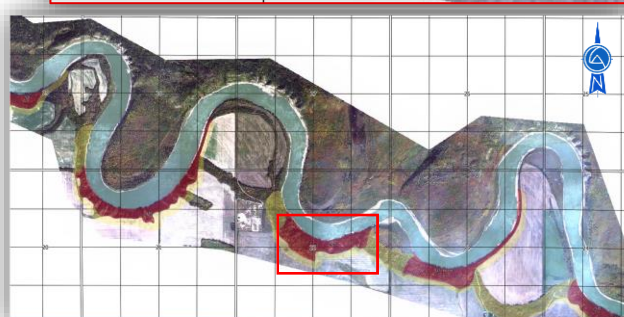
DATE	DRAWN BY	REVIEWED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-23	JM	AK	As Shown	CG3525	B17

Clifton

RM OF PRINCE ALBERT NO.461

CLIENT	R.M. OF PRINCE ALBERT No. 461
SITE	2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS
TITLE	NW 21-49-22-W2 to NE 21-49-22-W2 (S20) Unstable slope with entire bank altered by landslides and continuous river erosion.



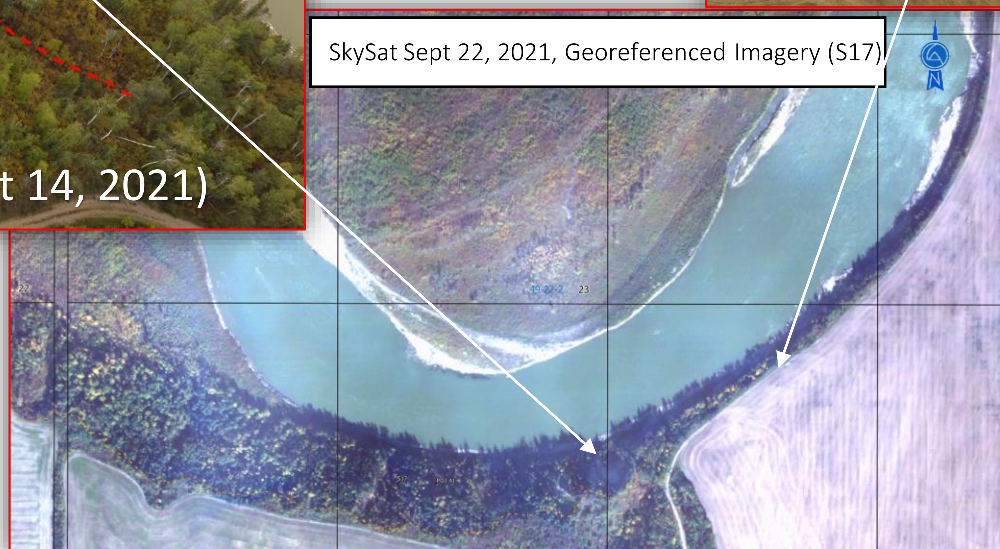


DATE 2022-02-23	DRAWN BY JM	REVIEWED BY AK	SCALE As Shown	FILE NO. CG3525	FIGURE NO. B18

Clifton

RM OF PRINCE ALBERT NO. 461

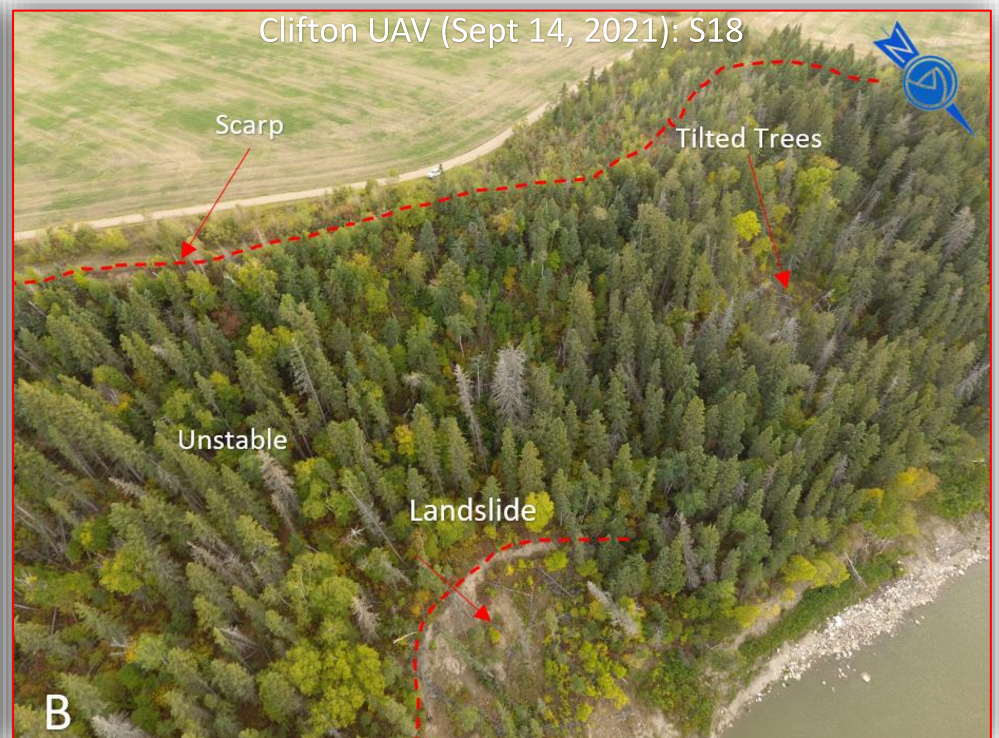
CLIENT	R.M. OF PRINCE ALBERT No. 461
SITE	2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS
TITLE	NW/SW 22-49-22-W2 to NE/SE 22-49-22-W2 (S19) Unstable slope with multiple landslides, scarps, and river erosion.

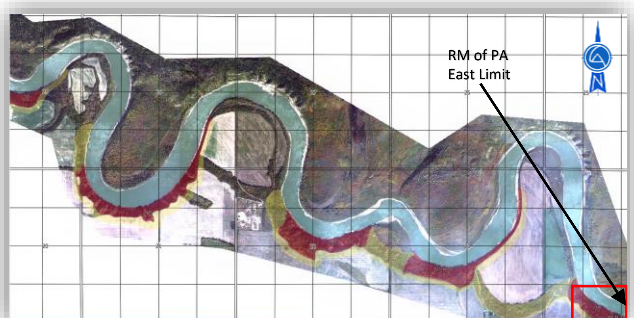


DATE	DRAWN BY	REVIEWED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-23	JM	AK	As Shown	CG3525	B19

Clifton | RM OF PRINCE ALBERT NO.461

CLIENT	R.M. OF PRINCE ALBERT No. 461
SITE	2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS
TITLE	SW 23-49-22-W2 to NE 23-49-22-W2 (S17) Unstable slope with multiple debris slides, large slump blocks, and tilted trees.





DATE	DRAWN BY	REVIEWED BY	SCALE	FILE NO.	FIGURE NO.
2022-02-23	JM	AK	As Shown	CG3525	B20

Clifton

RM OF PRINCE ALBERT NO.461

CLIENT	R.M. OF PRINCE ALBERT No. 461
SITE	2021-2022 COMPREHENISVE GEOHAZARD ASSESSMENT OF THE NORTH SASKATCHEWAN RIVER SOUTH BANKS
TITLE	SW 24-49-22-W2 to NE 13-49-22-W2 (S18) Unstable slope with multiple debris slides, large slump blocks, and tilted trees.

Appendix C
Supplementary Datasets

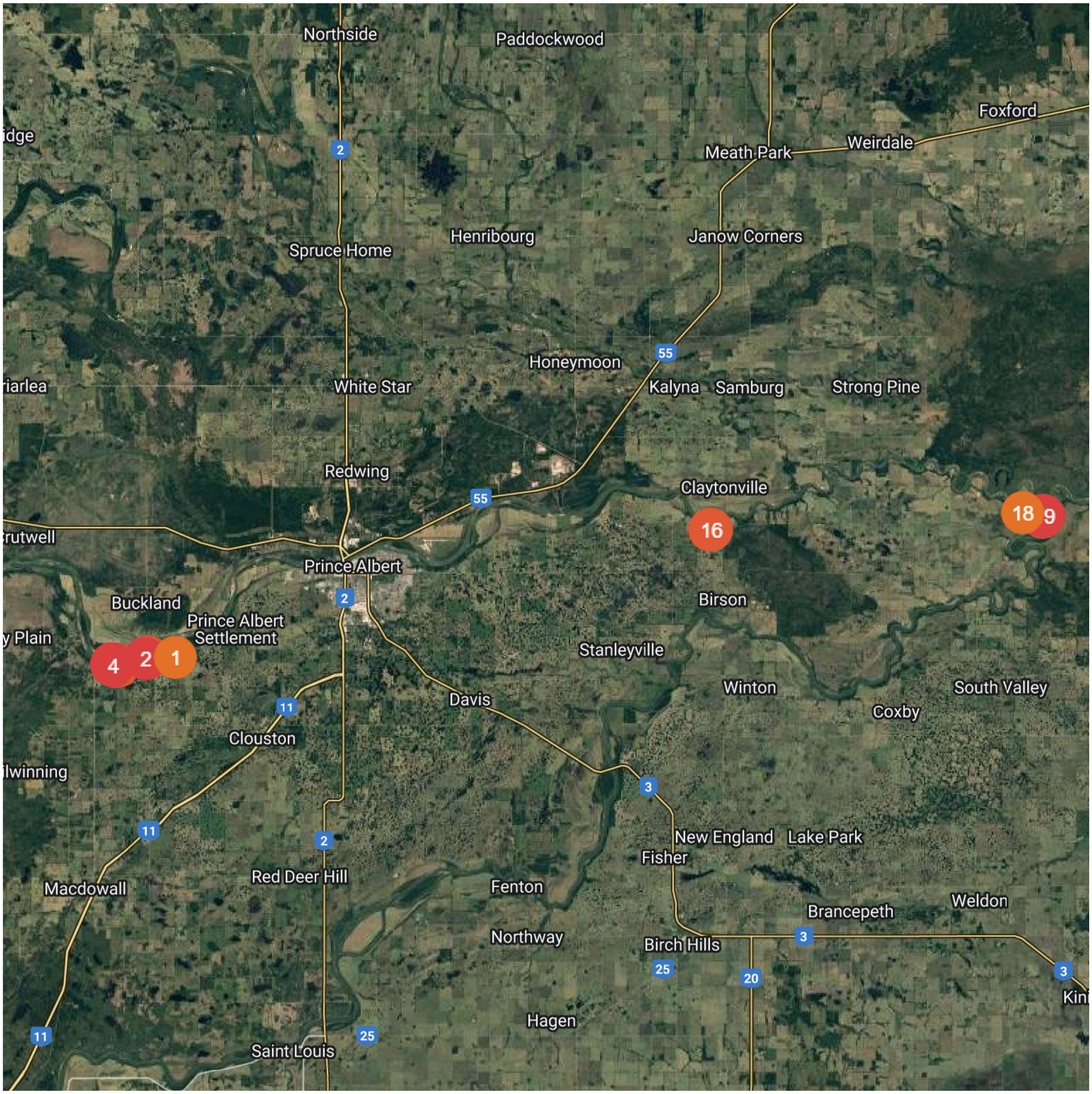
Clifton

Clifton Engineering Group

CG3526 RM of Prince Albert SK Geohazard Mapping Issue Report

Created on April 4, 2022

Captured on September 14, 2021


Northside
Paddockwood
Foxford
idge
Meath Park
Weirdale
Henribourg
Janow Corners
Spruce Home
Honeymoon
iarlea
White Star
Kalyna
Samburg
Strong Pine
Redwing
Claytonville
18
9
16
rutwell
Prince Albert
Buckland
Birson
Prince Albert Settlement
y Plain
4
2
1
Stanleyville
Winton
South Valley
Davis
Coxby
Clouston
ilwinning
New England
Lake Park
Fisher
Macdowall
Red Deer Hill
Fenton
Weldon
Brancepeth
Northway
Birch Hills
Kin
Hagen
Saint Louis

Type	Count
Erosion	3
Landslide	15
River Erosion	2

No.	Type	Severity	Created	Status	Cost of Repair
1	Erosion	3 - Moderate	November 17, 2021	Open	—
2	River Erosion	5 - Critical	November 17, 2021	Open	—
3	River Erosion	4 - Major	November 17, 2021	Open	—
4	Landslide	5 - Critical	November 17, 2021	Open	—
5	Landslide	5 - Critical	November 17, 2021	Open	—
6	Landslide	5 - Critical	November 17, 2021	Open	—
7	Landslide	5 - Critical	November 17, 2021	Open	—
9	Landslide	5 - Critical	November 17, 2021	Open	—
10	Landslide	5 - Critical	November 17, 2021	Open	—
11	Landslide	5 - Critical	November 17, 2021	Open	—
12	Landslide	4 - Major	November 17, 2021	Open	—
13	Landslide	5 - Critical	November 17, 2021	Open	—
14	Landslide	3 - Moderate	November 17, 2021	Open	—
15	Landslide	4 - Major	November 17, 2021	Open	—
16	Landslide	4 - Major	December 1, 2021	Open	—
17	Landslide	4 - Major	December 1, 2021	Open	—
18	Erosion	3 - Moderate	December 3, 2021	Open	—
19	Landslide	5 - Critical	December 3, 2021	Open	—
20	Erosion	5 - Critical	December 3, 2021	Open	—
22	Landslide	4 - Major	December 3, 2021	Open	—

Total: $0.00

20 - Erosion

Open 5 - Critical

Sep 14, 2021 at 5:37pm

Details

Summary:	Scarp
Created:	Dec 3, 2021, 11:29am by Jess Mysiorek
Cost of Repair:	—
Coordinates:	53.23523, -105.08787

18 - Erosion

Open

3 - Moderate

Sep 14, 2021 at 5:37pm

Details

Summary: **Meandering river will continue to erode outside cut-bank . Retrogressive failure as toe continues to become under-cut**

Created: **Dec 3, 2021, 10:43am by Jess Mysiorek**

Cost of Repair: **—**

Coordinates: **53.23754, -105.10759**

1 - Erosion

Open 3 - Moderate

Sep 14, 2021 at 5:37pm

Details

Summary:	POI 32: S11 Slope Issue - Local
Created:	Nov 17, 2021, 3:37pm by Jess Mysiorek
Cost of Repair:	—
Coordinates:	53.15361, -105.93002

22 - Landslide

Open

4 - Major

Sep 14, 2021 at 5:37pm

Details

Summary:	Scarp - River Erosion - Tilted Trees- Unstable Slope
Created:	Dec 3, 2021, 11:30am by Jess Mysiorek
Cost of Repair:	—
Coordinates:	53.23502, -105.08879

19 - Landslide

Open 5 - Critical

Sep 14, 2021 at 5:37pm

Details

Summary:	Slope failure due to undercutting of outside river bank - retrogressive failure
Created:	Dec 3, 2021, 11:28am by Jess Mysiorek
Cost of Repair:	—
Coordinates:	53.23554, -105.08716

17 - Landslide Open 4 - Major

Sep 14, 2021 at 5:37pm

Details

Summary:	**POI 39: Slope deformation along outside cut-bank of river..**
Created:	**Dec 1, 2021, 4:07pm by Jess Mysiorek**
Cost of Repair:	**—**
Coordinates:	**53.22735, -105.41046**

16 - Landslide

Open

4 - Major

Sep 14, 2021 at 5:37pm

Details

Summary: **POI 39: Historical slope failure on outside cut-bank of river. Note previous debris deposit into river (toe).**

Created: **Dec 1, 2021, 4:06pm by Jess Mysiorek**

Cost of Repair: **—**

Coordinates: **53.22746, -105.41033**

15 - Landslide

Open | 4 - Major

Sep 14, 2021 at 5:37pm

Details

Summary: **S12: Note the entire riverbank towards east has experienced historical and current landslides/deformation**

Created: **Nov 17, 2021, 4:47pm by Jess Mysiorek**

Cost of Repair: **—**

Coordinates: **53.14819, -105.98564**

14 - Landslide

Open 3 - Moderate

Sep 14, 2021 at 5:37pm

Details

Summary: **S12: Note the entire riverbank towards east has experienced historical and current landslides/deformation**

Created: **Nov 17, 2021, 4:47pm by Jess Mysiorek**

Cost of Repair: **—**

Coordinates: **53.14842, -105.98889**

13 - Landslide

Open 5 - Critical

Sep 14, 2021 at 5:37pm

Details

Summary: **S12: Note the entire riverbank towards east has experienced historical and current landslides/deformation**

Created: **Nov 17, 2021, 4:46pm by Jess Mysiorek**

Cost of Repair: **—**

Coordinates: **53.14842, -105.98889**

12 - Landslide

Open

4 - Major

Sep 14, 2021 at 5:37pm

Details

Summary: **S12: Note the entire riverbank towards east has experienced historical and current landslides/deformation**

Created: **Nov 17, 2021, 4:46pm by Jess Mysiorek**

Cost of Repair: **—**

Coordinates: **53.14842, -105.98889**

11 - Landslide

Open 5 - Critical

Sep 14, 2021 at 5:37pm

Details

Summary:	**Recent Landslide**
Created:	**Nov 17, 2021, 4:34pm by Jess Mysiorek**
Cost of Repair:	**—**
Coordinates:	**53.14888, -105.99177**

10 - Landslide

Open

5 - Critical

Sep 14, 2021 at 5:37pm

Details

Summary:	Historical (>100 year) Slope Failure
Created:	Nov 17, 2021, 4:34pm by Jess Mysiorek
Cost of Repair:	—
Coordinates:	53.14888, -105.99177

9 - Landslide

Open 5 - Critical

Sep 14, 2021 at 5:37pm

Details

Summary:	Recent Slope Failure
Created:	Nov 17, 2021, 4:33pm by Jess Mysiorek
Cost of Repair:	—
Coordinates:	53.14888, -105.99177

7 - Landslide

Open

5 - Critical

Sep 14, 2021 at 5:37pm

Details

Summary:	Recent Slope Failure
Created:	Nov 17, 2021, 4:33pm by Jess Mysiorek
Cost of Repair:	—
Coordinates:	53.14888, -105.99177

6 - Landslide

Open 5 - Critical

Sep 14, 2021 at 5:37pm

Details

Summary:	POI 36: S13 Landslide, similar morphology as historical landslide to the east
Created:	Nov 17, 2021, 4:27pm by Jess Mysiorek
Cost of Repair:	—
Coordinates:	53.14950, -105.99124

5 - Landslide

Open 5 - Critical

Sep 14, 2021 at 5:37pm

Details

Summary:	POI 37: S13 Historical Landslide, same failure type as ferris landslide. Slope prone to failure
Created:	Nov 17, 2021, 4:26pm by Jess Mysiorek
Cost of Repair:	—
Coordinates:	53.14950, -105.99124

4 - Landslide

Open 5 - Critical

Sep 14, 2021 at 5:37pm

Details

Summary:	POI 36: S13 Slope Failure, Landslide, Circular Failure
Created:	Nov 17, 2021, 4:24pm by Jess Mysiorek
Cost of Repair:	—
Coordinates:	53.14848, -105.99046

3 - River Erosion

Open

4 - Major

Sep 14, 2021 at 5:37pm

Details

Summary:	POI 35: S12a Scarps, River Bank Erosion, Tilted Trees
Created:	Nov 17, 2021, 3:59pm by Jess Mysiorek
Cost of Repair:	—
Coordinates:	53.15305, -105.95603

2 - River Erosion

Open 5 - Critical

Sep 14, 2021 at 5:37pm

Details

Summary:	POI 35: S12a Scarps, River Bank Erosion, Tilted Trees
Created:	Nov 17, 2021, 3:58pm by Jess Mysiorek
Cost of Repair:	—
Coordinates:	53.15276, -105.95849

Appendix D
Field Reconnaissance Terrestrial and UAV Photographs

Clifton

Clifton

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