Whitehorse Escarpment Slope Geohazard Study
Whitehorse, Yukon



PRESENTED TO

City of Whitehorse

JUNE 26, 2023
ISSUED FOR USE
FILE: 704-ENG.WARC04258-01

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EXECUTIVE SUMMARY

Tetra Tech Canada Inc. was retained by the City of Whitehorse to conduct a review and provide updates to the 2002 and 2012 landslide geohazard assessments completed by EBA and Tetra Tech EBA. This request was the result of the recent increase in mass movement and slope instability along the Whitehorse Escarpment, located in the downtown area of Whitehorse, Yukon. The review also included conceptual mitigation recommendations and a slope stability monitoring program.

The Escarpment is a steep slope, about 60 m high, consisting of a natural bluff of glaciolacustrine sediment formed by downcutting of the Yukon River into glacial lake Laberge sediments. The Escarpment has a long history of many types of mass movement mechanisms that have resulted in severe impacts to infrastructure. It runs in a roughly north-south direction along the western edge of downtown Whitehorse. The stratigraphy consists of a blanket of fine, well-sorted fluvial/deltaic sand, ranging in thickness from 1 to 9 m, overlying thick glaciolacustrine sediment.

LiDAR and orthoimagery from 2013 and 2019 was provided to Tetra Tech by the City, sourced from GeoYukon – the Government of Yukon's digital map data. Up-to-date LiDAR data and orthoimagery was collected specifically for this study in September 2022.

The procedure for evaluating and updating the geohazard designation zones consisted of historical air photo review, terrain and slope instability feature mapping, elevation change detection, and landslide susceptibility modelling using GIS and machine learning techniques.

The areas upslope along the Escarpment host multiple, active mass movement processes in relic headscarps. These erosional processes include seasonal freeze/thaw cycles, groundwater seepage, slumping and sloughing of saturated soil, gullying, toppling, debris flows, and debris slides.

Six figure sets were prepared showing the results of the updated geohazard designation mapping along the Whitehorse Escarpment which Tetra Tech has divided into twelve monitoring zones of similar slope characteristics and activity:

- Figures 2a to 2m: Slope instability feature interpretation and landslide hazard designation mapping with 2022 imagery as a background;
- Figures 3a to 3m: Slope instability feature interpretation and landslide hazard designation mapping with 2022 bare earth shaded relief digital elevation model as a background;
- Figures 4a to 4m: 2013 to 2019 surface elevation change detection analysis with 2019 imagery as a background;
- Figures 5a to 5m: 2019 to 2022 surface elevation change detection analysis with 2022 imagery as a background;
- Figures 6a to 6m: Frequency Ratio landslide susceptibility model with 2022 imagery as a background; and
- Figures 7a to 7m: Machine Learning (GLM) landslide susceptibility model with 2022 imagery as a background.

This historical air photo interpretation and LiDAR data analysis coupled with the elevation change detection analysis have determined that no major changes are warranted to the 2002 and 2012 landslide hazard designation zones along the Escarpment at this time. Additional hazard designation zones were added where they previously did not exist. Active and possible slope movement mechanisms were considered, reviewing the recent mass movement history of the Escarpment based on LiDAR and air photo records currently available.

Interception ditches, settling ponds, and deflection berms have been constructed at the toe of the Escarpment subject to slope instability. The development of additional conceptual landslide hazard mitigation options based on the results of this study will be provided in a separate technical memorandum.

Annual monitoring of the Escarpment slope stability is recommended. In addition to the annual slope monitoring, recommendations for future monitoring include yearly aerial-based LiDAR data and orthoimagery survey collection and analysis, groundwater data collection and monitoring, slope modelling using Flow/R software, and site-specific subsurface geotechnical explorations with instrumentation installation. This updated yearly data should be used to update the slope geohazard assessment, including terrain feature identification, and the landslide susceptibility models on a yearly basis.

A typical schedule for the annual monitoring, data collection, processing, and planning for the following year has been developed, as presented below.

Schedule	Activity	Documentation/Reporting
Mid-March to Late June	Visual slope stability monitoring / Slope radar (scanner), geotechnical instrumentation and ground survey data analysis	Daily communication with City, EOC meetings, documentation, possible monitoring summary report
Late June	Aerial LiDAR survey and orthoimagery acquisition of the entire Escarpment	.LAS files and Orthophotos
June to August	Process LiDAR, groundwater, climate and precipitation, slope radar, and survey data	Update GIS Models and summary tables
September to December	Analysis/Mapping of LiDAR data and orthophotos	Update terrain features, geohazard report, susceptibility models, and risk assessment
January to Mid-March	Planning for monitoring activities during Spring freshet	Workplan for Spring freshet monitoring

The current snow removal and storage practices and plans across the airport area should be reviewed, as melting of the snow being stored close to the Escarpment slope break pertains to the slope stability. This should be done in cooperation with the airport authority, hydrologists, hydrogeologists, and hydrotechnical engineers for managing surface water and ground water flow within the airport property.

A risk assessment is also recommended to consider the risk posed to people, infrastructure, or other assets by the slope geohazards.

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LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of the City of Whitehorse and their agents. Tetra Tech Canada Inc. (Tetra Tech) does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than the City of Whitehorse, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this document is subject to the Limitations on the Use of this Document attached in the Appendix or Contractual Terms and Conditions executed by both parties.

1.0 INTRODUCTION

Tetra Tech Canada Inc. (Tetra Tech) was retained by the City of Whitehorse (the City) to conduct a review and provide updates to the 2002 and 2012 landslide geohazard assessments, provide conceptual mitigation recommendations, and a slope stability monitoring program for the Whitehorse Escarpment (the Escarpment), located in the downtown area of Whitehorse, Yukon, as shown on Figure 1.

Approval of this work was provided by Taylor Eshpeter through a signed contract 2022-000593 dated October 16, 2022.

This report includes findings from an updated slope geohazard assessment including re-evaluation of the three landslide hazard designation zones (Low, Moderate, High) using historical air photo and LiDAR data analysis supplementing Tetra Tech's long-term history of involvement in stability and geohazard studies for the Escarpment. The latest reports summarize the results of recent site visits and studies of the terrain and slope stability of the escarpment (Tetra Tech EBA 2012, 2014; Tetra Tech 2021a, 2021b, 2022) and reviewed previous reports on terrain stability in the area (EBA 1971, 2002, and 2012).

1.1 Project Background

The Escarpment is a steep slope, about 60 m high, consisting of a natural bluff of glaciolacustrine sediment formed by down-cutting of the Yukon River into glacial lake Laberge sediments that runs in a roughly north-south direction along the western edge of downtown Whitehorse. The glacial lake sediment was deposited during the last deglaciation approximately 10,000 years ago, and downcutting by the Yukon River has been ongoing to present day. The Escarpment bounds the western edge of downtown Whitehorse and the Marwell subdivision, which are situated between the toe of the Escarpment and the Yukon River. The Erik Nielsen Whitehorse International Airport (ENWIA) is located at the crest of the Escarpment along RSW in the downtown area, and the North Takhini subdivision is located at the crest of the Escarpment in the Marwell area.

The Escarpment separates downtown Whitehorse from the airport terrace, a plain of fluvial/deltaic sand blanket overlying the glaciolacustrine sediment (EBA 2012). Landslides and other types of mass movement events are common on the Escarpment and have been observed throughout the history of Whitehorse. Tetra Tech (formerly EBA Engineering Consultants) has completed geohazard mapping of the Escarpment, including a geohazard study of the entire escarpment in 2002, which was subsequent to earlier investigations conducted on the Escarpment in 1959 and 1971; and an updated geohazard study of the southern part of downtown Whitehorse, between Robert Service Way and Lambert Street, in 2012.

Tetra Tech completed a desktop geotechnical site evaluation and a site-specific terrain stability assessment for the property at 609 Drury Street in 2010 and the 5th and Rogers site in 2016, which included a preliminary design for an interceptor berm to retain landslide debris and reduce the probability of the site being impacted.

A letter was submitted by Tetra Tech to the City of Whitehorse (the City) on April 21, 2021, recommending monitoring of the key areas of the Escarpment for slope stability issues, which were anticipated during the spring freshet (Tetra Tech 2021a). A technical report summarizing monitoring of the Escarpment stability in 2021 was prepared by Tetra Tech and issued for use to the City in 2022 (Tetra Tech 2022).

Severe widespread mass movement activity occurred on the Escarpment in Spring 2022, with large landslides developing in several locations. Due to increased mass movement activity observed on the Escarpment in Spring 2022, the City retained Tetra Tech to carry out a new landslide hazard assessment to update the previous studies completed in 2002 and 2012.

2.0 SCOPE OF WORK

The previous landslide hazard designation mapping (EBA 2002, 2012) was updated using all available information from the terrain analysis, susceptibility maps/modelling, and ground data processing. Tetra Tech used field data collected during the 2022 landslide emergency response work for proposed landslide hazard designation mapping including re-evaluation the three landslide hazard designation zones (Low, Moderate, and High).

Conceptual escarpment mitigation recommendations are being updated and will be submitted in a separate memo. An Escarpment slope monitoring plan for Spring 2023 was developed and submitted to the City on March 30, 2023.

3.0 METHODOLOGY

3.1 Geotechnical Desktop Evaluation

The previously mentioned reports were referenced in this updated geohazard assessment. Site visits were performed by the authors in late May to early June 2022 as part of emergency slope monitoring work requested by the City and snow cover inspection was performed by Tetra Tech personnel in March and April 2023. Field verification of mapping at RSW was performed in mid-April 2023 in response to recent slope movement. Ground-truthing of the geohazard designation mapping and recent Spring 2023 failure features throughout the Escarpment was completed as part of the Spring 2023 monitoring program in early May.

3.1.1 Surficial Geology and Stratigraphy

The stratigraphy is defined as a blanket of fine, well-sorted fluvial/deltaic sand, ranging in thickness from about 1 to 9 m, overlying thick glaciolacustrine sediment (EBA 2002). The thickness of the sand is greatest in the southwest corner of the airport plateau. The glaciolacustrine sediment is stratified with thin layers of fine sand, clay, or sorted silt in beds from 2 to 8 cm thick, but in most sections appears massive. Occasional pebbles and layers of sand are found throughout (EBA 2002). Subsurface conditions may deviate and not be entirely uniform over the entire escarpment which can make it difficult to assess slope stability in specific areas.

The surficial geology presented on Figures 2a to 2m and 3a to 3m was adopted from the 2002 work.

3.2 Historical LiDAR Data and Orthoimagery Analysis

Pioneer Exploration Consultants Ltd. (Pioneer) conducted a helicopter-based aerial LiDAR and orthophoto scan of the entire Escarpment on September 14, 2022 using a Phoenix Ranger XL LiDAR system at a resolution of 250-300 pts/m^2.

The 2022 LiDAR data and orthoimagery (5 cm) was provided to Tetra Tech by Pioneer in October 2022. Tetra Tech reclassified the data to fine-tune the ground classification parameters and created a 20-cm-resolution Digital Elevation Model (DEM). The orthoimagery is seen on Figures 2a to 2m and hillshade DEM on Figures 3a and 3m.

LiDAR data and orthoimagery from 2013 and 2019 was provided to Tetra Tech by the City and was sourced from GeoYukon – the Government of Yukon's digital map data.

3.3 GIS (Geographic Information System) Analysis

GIS processing of Pioneer's data was conducted by Tetra Tech and included creating orthomosaics of the recent imagery; 0.25 m, 0.5 m, and 1.0 m raster surfaces of the digital surface model and the digital elevation models. The ArcGIS Pro environment allows for creation of 3D visual models by draping orthoimagery onto LiDAR data to aid in detecting problem areas.

3.3.1 Elevation Change Detection Analysis

Elevation change detection analysis was completed between years 2013 to 2019 and 2019 to 2022 using the available LiDAR data and the following techniques:

1. Define borders for gain/loss polygons to calculate areas and max./min. elevation differences. The threshold for polygon size was set at 10 m^2 to reduce excessive points, anomalous results, and possible noise in data;
2. Used 0.3 m elevation difference for determining elevation gain/loss (vertical accuracy of data is centimetres, horizontal is 0.20 m); and
3. Evaluating results with reference to known earthworks activities like berm construction to determine validity of the models. It was determined that some "random" unexpected results or polygon errors can be attributed to misclassification of previous years' LiDAR data by third parties.

3.3.2 Landslide Susceptibility Model

Landslide susceptibility modelling using GIS is a widely used approach for analyzing landslide-prone areas. GIS-based modelling allows the integration of different data layers including topography, geology, soil type, land use, and rainfall data to identify areas with a higher likelihood of experiencing slope failure. Eight factors that control mass movement were used in the modelling, these include: slope angle, altitude (elevation), aspect, topographic position index (TPI), landform, surficial geology, distance from tension cracks, and the height of vegetation. Climate variables such as spring freeze/thaw cycles, snowfall accumulation, and total spring precipitation and their influence on historical mass movement events identified in air photos would be valuable resources to use, but due to budget and time constraints, these variables were not included in this analysis. Adjustments and modifications to the modelling can be done at a later time, if requested, by reviewing available the historical air photo record in more detail and/or using annual LiDAR data collection. The factors have been transformed into raster data using GIS. The slope angle and other terrain factors were extracted from the most recent (2022) LiDAR data DEM (0.2 m).

The eight terrain factors that control mass movement were subdivided into classes described below:

1. Slope angles were divided into six classes: 0˚ to 2˚, 2˚ to 5˚, 5˚ to 10˚, 10˚ to 20˚, 20˚ to 30˚, and greater than 30˚;
2. Altitude was classified into eight classes using 10 m elevation intervals between 628 m and 708 m above sea level;
3. Slope aspect was classified into eight cardinal directions (North, Northeast, East, Southeast, South, Southwest, West, Northwest) and flat; so, a total of nine classes were used;
4. Topographic Position Index (TPI) was calculated following Gessler et al. (1995) and were classified into three classes (less than -0.2, -0.2 to 0.2, and greater than 0.2);
5. Landform classification consisted of 10 classes: canyons/deep incised streams, mid-slope drainages/shallow valleys, upland drainages/headwaters, U-shaped valleys, small plains, open slopes,

upper slopes, local ridges/hills in valleys, mid-slope ridges/small hills in plains, and mountain tops/high ridges;

6. Surficial geology layers from the previous studies were used where classes were based on a combination of dominant sediment types, geomorphology, and textures. There were 12 classes found and used. Where no data was available, an additional "unknown" class was used;
7. Tension cracks delineated during the terrain and slope instability hazard assessment were used with a combination of five length classes (0 to 50 m, 50 to 100 m, 100 to 200 m, 200 to 400 m and >400 m); and
8. Vegetation height was determined from the Canopy Height Model (CHM) from the LiDAR data. Five classes were used for the vegetation height variable: less than 0.2 m, 0.2 to 2 m, 2 to 5 m, 5 to 20 m, and greater than 20 m.

3.3.2.1 Frequency Ratio Model

The frequency ratio model is a statistical method used to assess the susceptibility of slopes to landslides. It assumes that the frequency of landslides is related to the spatial distribution of conditioning and triggering factors. The model calculates the frequency ratio (FR) of landslides in relation to each factor, which represents the ratio of the number of landslides that occur in areas with a certain factor to the number of landslides that occur in areas without that factor. The FR values are then combined using a weighted sum to obtain an overall susceptibility score for each area. The slope stability classes evaluated from the landslide hazard rating (unstable) was used in absence of historical landslide data to provide this comparison.

The eight conditioning factors discussed above were considered in the FR model. The FR model has been widely used in landslide susceptibility mapping studies in different regions and at various scales. It has been shown to be a reliable and effective method for identifying areas with high landslide susceptibility and can provide useful information for land use planning and disaster risk reduction.

There are several studies that have applied the FR model for landslide susceptibility mapping (e.g., Althuwaynee et al. 2012, Ayalew et al. 2005, Ohlmacher et al. 2003). The landslide parameters were processed as raster files at 0.2 m resolution. Following the methods discussed in the literature above, the final outputs have been presented in Figures 6a to 6m.

3.3.2.2 Machine Learning Generalized Linear Model

Generalized Linear Models (GLMs) have been useful machine learning (ML) methods for predicting slope instability and widely used in various studies (e.g., Bui et al. 2018, Fabbrocini et al. 2016, Kim et al. 2017, Liu et al. 2019, Park et al. 2019.). The methodology adapted in this study follows the same principals. In slope stability analysis, the goal is to predict whether a slope will fail or remain stable under certain conditions. GLMs can be used to model the relationship between predictor variables (such as slope, distance to tension cracks, landform, etc.) and the response variable (slope stability). GLMs are a flexible and powerful tool for this type of prediction because they can accommodate a wide range of data distributions and can handle both continuous and categorical predictor variables. Additionally, GLMs allow for the incorporation of prior knowledge and can handle missing data. In this project all eight variables described above were used as predictor variables. R Studio with multiple ML packages like 'caret' and 'randomForest' was used. The number of points used for creating the model at 0.2 m interval was too heavy on processing and consisted of 4 million points. Reassembling was done down to 2 m resolution, to reduce the total data processing points to approximately 1 million, allowing the models to run successfully.

The resulting model was then used to predict the probability of slope failure under specific conditions. The output from the GLM model is presented in Figures 7a to 7m.

Tetra Tech understands that additional remote access dataloggers will be installed to monitor groundwater data from the airport plateau above Taylor and Hanson Streets in 2023, with data collection beginning just prior to spring freshet (Ric Horobin via. Teams meeting April 6, 2023). It is also understood that SLR Consulting (Canada) Ltd. are preparing a groundwater model of the airport plateau as data becomes available. This groundwater data can be incorporated into the FR and GLM models to further refine landslide susceptibility models as groundwater seepage is believed to be a major factor in slope instability throughout the Escarpment if requested.

3.4 Mapping of Terrain, Slope Instability Features, and Landslide Hazard Designation

Previous landslide hazard designation mapping of the Escarpment by EBA (2002) was updated using all available information from the desktop evaluation, landslide susceptibility modelling, and GIS analysis. Field data collected during the 2022 landslide emergency response work was also used in the landslide hazard designation mapping.

Tetra Tech's methodology for the terrain, slope instability feature, and landslide hazard designation mapping update was as follows:

1. Obtain and review available information for the Escarpment, including air photos, LiDAR data, historical geohazard maps, surficial geology mapping, and previous geotechnical reports;
2. Map terrain and slope instability features using ArcGIS Pro software, which allows digital air photos to be viewed in 3D. Terrain geohazard features that are difficult to see at smaller scales using the standard stereoscope method and hard copy photographs are easy to identify and map using ArcGIS Pro's zooming feature;
3. Map terrain features and geomorphic processes that are indicative of slope instability, including mass movement and gully erosion features, groundwater seepage locations, and/or surface water drainage paths over the slopes;
4. Identify and map natural and human-induced changes over time between the selected air photo date sets. The base mapping was founded on the 2002 air photos. Each iteration of the mapping updated the base map to account for changes noted in each year of imagery reviewed (2013, 2019, and 2022). These maps were used to assist in delineating geohazard designation boundaries and slope instability features and how those boundaries and features may have changed over time;
5. LiDAR data provided by the City or the Yukon LiDAR Collection was analyzed, including an ArcGIS-based change detection analysis between 2013 and 2022 to assist with landslide hazard feature mapping in ArcGIS Pro. Bare-earth hillshade models developed from the LiDAR data allow the ability to distinguish features that might otherwise be difficult to identify in areas that are vegetated; and
6. Review and refine, if required, the landslide hazard designation zones delineated as low, moderate, or high. Each landslide hazard rating has a specified land use guideline (development planning guideline) which are abbreviated from the 2002 geohazard risk study and are presented in Table 3-1.

Table 3-1: Landslide Hazard Ratings and Land Use Guidelines

LANDSLIDE HAZARD RATING	LAND USE GUIDELINES
LOW HAZARD	Building development should be acceptable without further geohazard investigation. Mitigative structures in place up-gradient, such as ditches and berms draining to settling areas or ponds, should substantially reduce the risk. Residential foundation walls facing the Escarpment should be designed to withstand a potential surcharge of 3'x130 pcf or 390 psf and the lower sill of windows are not recommended below 1 m above grade. Recreational use and construction of trails are acceptable.
MODERATE HAZARD	Could be subject to direct or indirect impact from slide run-out, mudflow or silt fall. Building development is generally not recommended but may be permissible subject to modifications and/or mitigation techniques detailed by an adequately trained, qualified geotechnical engineer or geoscientist in a detailed site-specific study, acceptable to the City, prepared on behalf of the property owner. The risk may be acceptable under existing conditions at certain locations with mitigative measures such as, but not limited to, construction of deflection berms and reinforced concrete basement walls. Recreational use and construction of trails are generally acceptable but may require temporary and/or seasonal closures to limit exposure to slope hazards.
HIGH HAZARD	Geohazards are judged too severe to permit any building development or major use, with the exception of limited recreational access trails, properly sited, engineered and constructed. Disturbance to the slope would not be allowed, either to the soil or vegetation. Recreational access and trails are expected require temporary and/or seasonal closure to limit exposure to slope hazards.

*Abbreviated from Geohazard Risk Study, EBA, 2002 (Table 8.1).

4.0 ESCARPMENT SLOPE MONITORING ZONE OVERVIEW

Landslides and other types of slope movement have been observed practically throughout the entire Escarpment since the establishment of the Whitehorse townsite.

As shown on Figure 1, Tetra Tech has divided the Escarpment into twelve zones of similar slope characteristics and activity. The zones from south to north are named as follows:

1. Robert Service Way;
2. Drury Street;
3. Jeckell Street;
4. East Airport Access Road;
5. Main Street;
6. Wood Street;
7. Puckett's Gulch/Black Street Stairs;
8. Baxter's Gulch;
9. Two Mile Hill;
10. Takhini South;
11. Takhini Sanitary Sewer; and
12. Takhini North.

Typical primary active slope processes occurring on the Escarpment are summarized in Table 4-1 below and are summarized from geohazard study reports prepared by Tetra Tech (formerly EBA Engineering Consultants Ltd., EBA 2002, EBA 2012). The 2002 geohazard report considered zones that are similar, but not exactly the same, as the slope monitoring zones listed above and are referenced in Table 4-1.

The slope movement activity observed in 2022 is described and based on LiDAR data collected in 2022 and preliminary results of the updated historical slope movement hazard assessment and landslide susceptibility mapping.

Section 5.1 details the historical air photo and LiDAR elevation change detection analysis.

Table 4-1: Summary of Escarpment Mass Movement Processes by Slope Monitoring Zone

2002 Zone	2012 "Site"	2023 Slope Monitoring Zone	Primary Active Slope Processes (EBA 2002) and 2013, 2019, and 2023 Air Photo Review Activity	Description (EBA 2002)	2022 Activity
A1 (south) B (north)	-	Robert Service Way	▪ Progressive deformation by seasonal thawing. ▪ Rill erosion and shallow gullying. ▪ Debris slides and debris flows. ▪ Slumps and earth flows. ▪ Slow mass movement. ▪ Gullying. ▪ Toppling. ▪ **Tension cracks.** ▪ **Rapid mass movement.** ▪ **Seepage.**	▪ Active area: an interception ditch has been excavated along part of the toe of the slope to intercept mudslides. ▪ Mud Hill. Type 1 slides have not developed into deeply scalloped headscarps; the slope is capped with a high berm of fibric soil; toe of slope is over-steepened by railway/road right-of-way cut slope; toppling is a minor component of toppling; blocks are small.	▪ April 30 RSW landslide. ▪ May 16 landslide in northern portion of Zone. ▪ May 31 landslide near Robert Service campground ▪ Significant seepage. ▪ Widespread tension cracking throughout zone. ▪ RSW closed for several weeks. ▪ Cleanup of landslide debris and construction of temporary sheet pile wall along RSW in area of RSW landslide.
C	1, 2	Drury Street	▪ Progressive deformation by seasonal thawing. ▪ Rilling erosion and shallow gullying. ▪ Debris slides and debris flows. ▪ Slumps and earth flows. ▪ Slow mass movement. ▪ Gullying. ▪ Seepage. ▪ **Tension cracks.**	▪ Slide zones have been less active in recent times and are partially re-vegetated.	▪ Progressive, shallow landslides involving organic mat and shallow thickness of underlying soil. ▪ Significant tension cracking. ▪ Temporary evacuation of residences in moderate hazard zone.
C	3	Jeckell Street	▪ Progressive deformation by seasonal thawing. ▪ Rilling erosion and shallow gullying. ▪ Debris slides and debris flows. ▪ Slumps and earth flows. ▪ Slow mass movement. ▪ Gullying. ▪ Seepage. ▪ **Tension cracks.**	▪ Slide zones have been less active in recent times and are partially re-vegetated.	▪ May 28 Cliffside Park landslide. ▪ Continued tension cracking and slope movement behind St. Elias Group Home. ▪ Significant groundwater seepage. ▪ Cliffside Park destroyed. ▪ Temporary closure of 6th Avenue below Cliffside Park slide.
A2	4, 5, 6	East Airport Access Road	▪ Progressive deformation by seasonal thawing.	▪ Active area: most mudflow deposits settle on low gradient fans. No	▪ Slow mass movement along trail edge.

2002 Zone	2012 "Site"	2023 Slope Monitoring Zone	Primary Active Slope Processes (EBA 2002) and 2013, 2019, and 2023 Air Photo Review Activity	Description (EBA 2002)	2022 Activity
		(includes 5th and Rogers)	▪ Rilling erosion and shallow gullying. ▪ Slumps and earth flows. ▪ Slow mass movement. ▪ Gullying. ▪ Seepage.	interception ditches have been constructed.	▪ Multiple small slumps and earth flows. ▪ Significant groundwater seepage. ▪ Seepage channelized from existing headscarp formed significant stream near the back of the empty lot at 5th and Rogers, causing wet conditions and significant sedimentation.
D	-	Main Street	▪ Progressive deformation by seasonal thawing. ▪ Debris slides and debris flows. ▪ Gullying. ▪ Seepage. ▪ **Tension crack within headscarp.**	▪ The most active debris flow/seepage area of the escarpment. Headscarps are deeply scalloped; interception ditches and settling ponds have been constructed along the toe of the slope.	▪ Headscarp above dog park area was an area of concern. ▪ Significant groundwater seepage.
E	--	Wood Street	▪ Slumps and earth flows. ▪ Slow mass movement. ▪ Seepage. ▪ **Tension cracks.**	▪ This mainly forested section has some old slide paths that are re-vegetated.	▪ Wood Street Slide, two events occurring on May 18 and May 28. ▪ Significant groundwater seepage.
G, F	-	Puckett's Gulch / Black Street Stairs	▪ Progressive deformation by seasonal thawing. ▪ Rilling erosion and shallow gullying. ▪ Slumps and earth flows. ▪ Slow mass movement. ▪ Gullying. ▪ Seepage. ▪ **Tension cracks.**	▪ Fans and depositional zones of mass movement activity from upper slopes; most of the material is deposited from mudflows with some toppling debris.	▪ Small slump and earth flows on south side of Puckett's Gulch. ▪ No significant areas of concern along stairs.
H, I	-	Baxter's Gulch	▪ Progressive deformation by seasonal thawing. ▪ Rilling erosion and shallow gullying. ▪ Gullying. ▪ Toppling. ▪ Seepage. ▪ **Tension cracks.**	▪ Forested; some old slide paths or gullies are re-vegetated. ▪ Small toppling failures, some rilling and shallow gullying; un-vegetated.	▪ No areas of concern noted in 2022.
-	-	Two Mile Hill	▪ Progressive deformation by seasonal thawing. ▪ Rilling erosion and shallow gullying. ▪ Slow mass movement. ▪ Gullying. ▪ **Tension cracks.**	-	▪ Tension crack on slope at Chilkoot way intersection.
-	-	Takhini South	▪ Progressive deformation by seasonal thawing. ▪ Rilling erosion and shallow gullying. ▪ Slumps and earth flows. ▪ Slow mass movement.	-	▪ Progressive, shallow landslides involving organic mat and shallow thickness of underlying soil, north of historic landslide behind MacPherson Rentals.

2002 Zone	2012 "Site"	2023 Slope Monitoring Zone	Primary Active Slope Processes (EBA 2002) and 2013, 2019, and 2023 Air Photo Review Activity	Description (EBA 2002)	2022 Activity
			▪ Gullying. ▪ Seepage. ▪ **Tension cracks.**		▪ Significant tension cracking. ▪ Significant groundwater seepage.
-	-	Takhini Sanitary Sewer	▪ Debris slides and debris flows. ▪ Slumps and earth flows. ▪ Slow mass movement. ▪ Gullying. ▪ Seepage. ▪ **Tension crack.**	-	▪ Tension crack developed that intersects Trunk 1 of the Takhini sanitary sewer outfall. ▪ Construction of temporary sewer bypass line, in case of failure of sanitary sewer line.
-	-	Takhini North	▪ No slope instability features observed.	-	▪ No areas of concern noted in 2022.

5.0 SLOPE INSTABILITY FEATURE MAPPING RESULTS

The areas upslope along the Escarpment host multiple, active mass movement processes in relic headscarps (Tetra Tech 2022). These erosional processes include seasonal freeze/thaw cycles, groundwater seepage, slumping and sloughing of saturated soil, gullying, toppling, debris flows, and debris slides. Materials transported from these processes form low gradient colluvial depositional fans (runout accumulations) that extend along the length of the Escarpment.

Much of the Escarpment is forested, with the exception of the historical landslide scars, recent active headscarps, and slide transport and deposition (runout zones) downslope.

Erosion and mass movement on the Escarpment are directly related to surface and groundwater flow from catchment areas upgradient of the Escarpment (e.g., the airport plateau). Vertical percolation through the sand blanket that caps the plateau becomes horizontal where it is restricted by the underlying contact with the relatively impermeable glaciolacustrine deposit, resulting in groundwater outflow from the base of the sand, located approximately 3 m to 5 m below the crest of the Escarpment slope (Tetra Tech 2016a).

The active mass movement and erosion mechanisms on the Escarpment, including active debris flows, flow directions, and gullying are discussed in more detail in Tetra Tech's (formerly EBA) previous reports and are summarized in Table 6-1 below. The table is sourced from the 2002 report and has been updated to show specific active processes and mechanisms of slope movement and erosion observed along the Escarpment between 2013 and 2022. Mechanisms are ordered from most to least common. The rates of erosion and shallow soil stability could increase during periods of high precipitation or rapid snow melt.

As discussed in detail in the 2002 report, there are no records of deep-seated failures on the Escarpment behind the present downtown area.

Table 6-1: Mechanisms of Slope Movement on the Whitehorse Escarpment (from EBA 2002)

Mechanism	Details
Seepage/Flow	Most active during seasonal thawing, snowmelt, and/or during storms with high levels of rain. The thawing of mostly saturated sediment at the confluence of a permeable substrate with a less permeable one contributes to the most active slope mechanism in the study area. The sand layer on the surface promotes downward percolation of precipitation and flows along the top of the underlying glaciolacustrine unit which, being less pervious than the top looser sand unit, becomes saturated and increases rate of lateral ground water flow.
Progressive deformation by seasonal thawing of saturated silt	Saturated glaciolacustrine soil can develop ice lenses during the winter months, and during thawing, these soils can collapse and generate a small mudflow that transports material downslope.
Rilling and shallow gullying	These occur due to run-off or seepage or water flowing down the slope, sculpting well-defined channelized shallow erosion features extending downslope across the Escarpment face. If loose sediments exist within the path of the flowing water, sediment-laden water can develop into a mudflow. Developing features that require monitoring and erosion control.
Gullying	Gullies are small, V-shaped ravines that form by erosion caused by water flow. They are a conduit for concentrated linear mass movement – Debris flows or slides. Can be fast flowing and hazardous.
Debris slides and debris flows	Debris slides occur when a mass of colluvium becomes detached from a hillside and moves rapidly downslope by sliding along a shear plane. These slides may be triggered by heavy rain, water from snowmelt, and/or rain on snow events. A debris flow is a shallow landslide on a steep hill slope involving rapid translational displacement of material that typically results in a deposition zone extending well beyond the toe of the slope. It is characterized by the rapid flow of a mass of viscous material consisting of water, mud, sand, stones, and organic debris.
Slow mass movement	Slow mass movement along the Escarpment have rates from very slow (centimetres per year) to extremely slow (millimetres per year).
Slumps and earth flows	These involve a combination of earth movement processes and result in the downslope transport of the resulting mass, either by flow or a gliding displacement of a series of blocks (earth flow).
Toppling	Small blocks from sub-vertical cliffs on the upper escarpment slopes can detach from the slope dace and be transported down the slope face by free fall, rolling, and bouncing. The deposition zone of these blocks is typically within 2 to 10 m from the toe of slope.

5.1 Terrain Conditions and Slope Instability Features

Historical mass movement events along with anthropogenic factors have influenced slope stability throughout the Escarpment and have been documented and summarized in previous reports.

Newly mapped 2022 slope instability features, along with any changes between 2013 and 2019 and 2019 and 2022 were identified using historical air photos and LiDAR data records.

5.2 Elevation Change Detection Analysis Results

The results of the elevation change detection analysis between the 2013 and 2019, and 2019 and 2022 LiDAR-derived DEMs are illustrated in Figures 4a to 4m and 5a to 5m, respectively. Regions of yellow to red represent a decrease in ground elevation and are indicative of slumping/erosion or backscarp face regression. Areas of green to blue indicate apparent accumulation of the surficial material. Some anomalous results of the elevation change detection analysis can be attributed to misclassification or slightly different classification of LiDAR data results by third parties. The elevation change detection analysis generally agrees with the expected mass movement activities and helped refine and confirm the mapped instability features, their volumes, and how they have been altered.

It is important to continue to collect targeted, high-resolution LiDAR data along the Escarpment to match the data collected in 2022 and not rely on generic publicly available data obtained by other providers. Comparing high quality data which is collected and processed similarly is much more accurate for elevation change detection and mapping activities going forward.

5.3 Landslide Susceptibility Modelling Results

The model outputs are presented on Figures 6a to 6m and 7a to 7m. The FR and GLM model outputs are consistent with the geohazard assessments done with other methods. Among the two methods, the FR method is more of a statistical method and since the processing can be done directly using raster analysis, a 0.2 m raster resolution is kept. The GLM method required a model to be created using individual data points as it was necessary to reduce the model resolution to 2 m; the outputs appear relatively coarse; however, the results should not be affected by this processing alteration.

The cut-off thresholds for the index values are relative and have been determined based on the visual inspection of the model outputs. These threshold values will differ from site to site or project to project, but a single value has been used across the entire escarpment for consistency.

The landslide susceptibility model is applied at the areas that are susceptible to slope failures but does not consider potential impacts to downslope areas. The landslide hazard designation zones identified provides a more realistic picture of the areas that are likely to be affected by a landslide.

The models are dynamic in nature. For example, if a new tension crack is found on the slope, it can be added to the models and the outputs can be updated. Similarly, if any alteration to the slope is performed, the alteration can be modelled and the outputs from both models can be also updated. One important item that should be kept in mind is that like with any other model, the landslide susceptibility model is as good as the input data. Eight different terrain factors are used as input to both the landslide susceptibility models. These do not include any climate variables or historical landslide data. The training dataset provided is the geohazard assessment conducted for this study. This is something that can be taken up as a part of larger study to expand the model to include other variables including climate change. Such a study requires more time to collect and process the data and is beyond the scope of this project.

The landslide susceptibility hazard zone results associated with the FR and GLM models for each slope monitoring zone are described in Section 5.4 below.

5.4 Slope Monitoring Zone Instability Feature Mapping Results

A summary of the results of the updated slope instability feature mapping and elevation change detection modelling of the Escarpment for each of the slope monitoring zones are discussed in the following sections.

5.4.1 Robert Service Way Zone

The Escarpment alongside Robert Service Way (RSW) was referred to as “Mud Hill” in the 2002 report. It was described as an over-steepened glaciolacustrine silt bank, initially from the active erosion of the Yukon River channel meander and subsequently by development of the White Pass and Yukon Route Railway at the toe of the escarpment. In 1997, material at the toe of the section referred to as Mud Hill was removed to facilitate improvements to RSW. Removal of the landslide runout material along the toe of the Escarpment resulted in its over-steepening and triggered wide-spread slope instability and mass movement. Recent slope activity has confirmed that RSW is the most active segment of the Escarpment (Figures 1, 2b, 3b, 4b, and 5b).

Active seepage has been observed at the overlying sand and underlying glaciolacustrine soil contact, which is the source of active thaw-flow slides throughout the RSW zone. The active seepage and sediment flows occur in rills (i.e., small erosion channels) throughout the RSW zone.

A dry landslide occurred near the northern extent of the RSW zone on May 16, 2022. The slide debris did not reach the traffic lane of RSW but did cover the shoulder of the road. Tetra Tech monitored development of the tension crack throughout the summer of 2022 – no additional failures were observed in 2022. Additional slope failures were predicted in this area, which could originate from the large, approximately 95 m-long tension crack shown on Figure 2b and 3b. Several small, dry slope failures were indeed observed in this area in Spring 2023.

On April 30, 2022, before the 2022 slope monitoring program commenced, a large landslide (approximately 50 m long across the slope) occurred in two parts (north and south sections) along RSW, with landslide debris completely blocking RSW and the Millennium Trail and entering the Yukon River. Tetra Tech was retained to provide geotechnical engineering support for the emergency response to the RSW slide. Elevation change detection analysis shows the vertical thickness of material lost during these landslides averages 1.6 m and is up to 6.5 m, given the size of the accumulation area (approximately 1,900 m^2) this loss represents a volume of approximately 3,000 m^3. A tension crack, approximately 42 m in total length, has been identified within the southern headscarp using DEM hillshade modelling. This tension crack extends south of the existing headscarp by approximately 6 m.

A 125 m-long sheet pile wall (SPW) was installed in June 2022 as a temporary barrier to mitigate additional landslides occurring in the area surrounding the RSW landslide (Tetra Tech 2022d). The design intent of the SPW is to dissipate energy and limit the amount of debris that would impact RSW, but it must be acknowledged that there may not be sufficient catchment to stop all the debris from a large landslide.

Tension cracks have been mapped throughout the top half of the RSW Escarpment face using DEM hillshade models, observations during previous slope inspections, and aerial (drone) photography and are shown on Figures 2a and 2b and 3a and 3b. The tension cracks are located above historical landslide headscarps at the north end of the RSW Escarpment that originate at the sand and silt/clay contact and through the historical headscarps at the middle and south end of the RSW Escarpment.

Seepage, erosion, and sedimentation are common in the middle section of the RSW zone, where RSW is constrained between the toe of the slope and the outside bend in the Yukon River. Historically, large landslides have not been observed in this area, and recent slope activity results in sedimentation in the roadside ditch but does not impact traffic on RSW. Seepage has been identified within the southern headscarp of the April 30 slide.

A large landslide occurred on the Escarpment on May 31, 2022, in the area to the south of the April 30 RSW slide, and continued slope movement is expected in that area. The distance between the toe of the escarpment and RSW to the south of the SPW is relatively great, and large landslides that occurred in that area in 2021 (immediately north) and 2022 did not reach RSW. A tension crack, approximately 21 m in length, extending south of the existing 2022 headscarp has been identified using DEM hillshade modelling. A 10 m long tension crack was identified to the north of the 2021 headscarp and another 12 m long tension crack was identified at the south end of the adjacent historical headscarp immediately north (Figures 2a, 3a, 4a, 5a). The runout of any new landslides occurring to the south of the SPW are believed to be unlikely to impact RSW or affect public safety.

The RSW roadway is entirely within the high and moderate hazard zones below the RSW zone escarpment face. The line separating the high and moderate hazard zones was determined to be 26° (approximately 2H:1V slope) from the crest of the Escarpment as was used in the 2002 report. This guideline was also used along most of the Escarpment and updated based on where previous slides has occurred, areas of active erosion, or where seepage was observed at the sand and silt/clay contact. This generalized location was adjusted following more detailed assessment of local terrain characteristics (EBA 2002).

In general, most of the RSW slope monitoring zone is within the moderate or high slope susceptibility hazard index using both FR and GLM outputs, which align well with each other (Figures 6a, 6b, 7a, and 7b). The high susceptibility hazard was modelled at the sand and silt/clay interface, approximately three quarters of the way up the Escarpment, extending downwards to approximately the middle of the Escarpment. The moderate slope susceptibility hazard index extends the entire height of the Escarpment from just north of the 2022 slide area south to the bluffs located adjacent to the ball diamonds.

The southernmost extent of the RSW zone (south of the exposed bluffs) and the middle section of the main exposed RSW slope, near the bend in the roadway is within the low to moderate slope susceptibility hazard index.

5.4.2 Drury Street Zone

The Drury Street zone is located north of RSW in the area between Drury and Taylor Streets (Figure 1, 2c, 3c, 4c, and 5c).

Shallow landslides that comprised surficial vegetation and near-surface soils were observed in the Drury Street zone in 2022 and are mapped on Figures 2c and 3c. The landslides began at the southern extent of the affected area and progressed northward in segments. The slide material extended beyond the toe of slope by up to approximately 37 m. Inspections during Spring 2022 supported by the LiDAR data and air photo analysis identified tension cracks extending from the north end of the slide area approximately halfway up the Escarpment slope that could be a precursor to a large landslide developing in 2023. Elevation change detection analysis confirms slope movement in these areas.

A relatively large landslide occurred in an historical landslide headscarp near the north extent of the Drury Street zone in 2021, which is mapped on Figures 2c and 3c.

A soil berm is present at the toe of slope below the tension cracks, approximately between the 2021 and 2022 landslide paths.

Backscarp regression of approximately 8.1 m (between 2013 to 2019) and 10.0 m (between 2019 to 2022) was measured through DEM hillshade modelling and historical air photo analysis, approximately halfway upslope, above the empty lot west of the turnaround at the end of Drury Street (Figures 2c and 3c).

Surface water flow, rilling, and gullying are common within the historical landslide headscarps. Active water seepage was observed in the 2021 headscarp located at the northern end of this zone through a visual inspection of the site in March 2023, this is consistent with observations made during the previous year’s slope inspections (Tetra Tech 2021, 2022).

Increased activity on the Escarpment slopes in late May 2022 prompted the City to issue evacuation orders for the residences at 600, 604, and 609 Drury Street. Evacuation orders were lifted in June 2022, based on observations of improved conditions from ongoing visual inspections (Tetra Tech 2022b).

A site-specific assessment was carried out for the property located at 609 Drury Street in 2010. The assessment did not identify additional areas of concern immediately above the property and therefore, the high hazard zone from 2002 was adjusted to go around the dwelling (EBA 2010).

The elevation change detection analysis shows increased slope material movement rates and volumes between 2019 to 2022 compared to 2013 to 2019. The 2012 to 2019 movement can be attributed to progressive deformation by seasonal thawing, seepage, and erosion processes from the existing landslide headscarps flowing down gullies and drainage paths. The average vertical thickness of material loss from the 2021 landslide at the north end of the zone is approximately 1.2 m, material accumulation at the toe also averaged 1.2 m in vertical thickness and given the size of the area (approximately 760 m^2) this loss represents a volume of approximately 900 m^3.

The vertical thickness of material loss from the 2022 landslides in the middle of the zone averaged 1.9 m and was up to 5.1 m, the vertical thickness of material accumulation at the toe averaged approximately 1.4 m and was up to 3.7 m, given the size of the accumulation area (approximately 2,500 m^2) this loss represents a total volume of approximately 3,500 m^3.

The northern section of the Drury Street slope monitoring zone is within the high landslide susceptibility hazard index, mainly between the sand and silt/clay interface, approximately three quarters of the way up the Escarpment, and approximately halfway up the Escarpment, corresponding with the 2021 and 2022 landslide headscarps (Figures 6c and 7c). The area between the previous slope failures can be considered as highly susceptible to future failures.

According to the modelling, the area south of the 2022 Drury Street slide is less susceptible to slope failure, with some indication of moderate to high landslide susceptibility hazard index near the slope crest above the residence at 609 Drury Street and moderate landslide susceptibility index near the bottom half of the slope.

5.4.3 Jeckell Street Zone

The Jeckell Street zone extends from Hoge Street at the north to Taylor Street to the south (Figures 1, 3c, 4c, and 5c).

A terrain stability assessment for the St. Elias Adult Group Home located at the western end of Hoge Street was completed by Tetra Tech EBA in 2014.

Slope failures were observed on the Escarpment in the Jeckell Street zone in 2021. A landslide impacted the interceptor berm behind the St. Elias Group Home on May 25, 2021. During the 2021 site visit, Tetra Tech found multiple areas of the escarpment between Jeckell Street and Drury Street with visible evidence of recent or active slope movement. The slope behind Cliffside Park exhibited significant tension cracking that prompted Tetra Tech to recommend closing the park. Tension cracks were discovered, and Tetra Tech implemented survey monitoring to track slope movements. Two areas were monitored, one directly behind Cliffside Park and the other behind the group home. Slope failures did not occur in either area in 2021, but significant slope material displacement (up to about 1.2 m horizontal movement) occurred behind the group home.

The vertical thickness of material loss from the 2021 landslide which impacted the interceptor berm averaged approximately 1.0 m and was up to 2.9 m, given the size of the area (approximately 811 m^2) this loss represents a volume of approximately 800 m^3.

A large landslide (referred to as the “Jeckell Street slide” or “Cliffside slide”), which initiated from the tension cracks observed behind Cliffside Park a year earlier, occurred on May 28, 2022. The runout zone of this landslide encroached on most of Cliffside Park and almost extended across to the opposite side of 6th Avenue, approximately 45 m from the toe of the Escarpment. The accumulation of water and saturated sediment behind a silt fence at the toe of the slope added to the runout distance at this location. The runout material extended approximately halfway into the moderate hazard zone, which is consistent with the expected material movement within the moderate hazard zone and associated land use guidelines prepared for the 2002 report. This landslide was anticipated by

Tetra Tech, as the pre-failure tension crack was identified and monitored during the 2021 slope inspection work (Tetra Tech 2022). Cliffside Park was closed at the time due to the high probability of a landslide occurring. The slide was captured by a trail camera set up by the Yukon Geological Survey (https://fb.watch/diMqWC2h3K/).

The vertical thickness of material loss from the 2022 Cliffside slide averaged approximately 2.5 m and was up to 7.1 m, given the size of the area (approximately 1,750 m^2) this loss represents a volume of approximately 4,400 m^3. A tension crack transformed into a headscarp (identified as Headscarp 6 in the 2021 report) on June 18, 2021, upslope of the St. Elias adult group home between Jeckell and Hoge Streets. Although it was difficult to make valid determinations of the headscarp movements using previously installed instrumentation, it did not appear to show significant detectable movement based on observations during the Spring 2022 emergency inspections. This headscarp is located upslope of the landslide interception berm constructed west of the St. Elias adult group home near the foot of Hoge Street. The berm is a segment of a proposed continuous berm that was recommended in a previous Slope Stability Study (Tetra Tech EBA 2012) and adopted by the City for development in the south downtown area of Whitehorse.

An area of seepage was identified in a gully immediately north of the Cliffside Park slide during slope observations in March 2023, which is a yearly occurrence during spring freshet. This is located above the interceptor berm and ditch.

Tetra Tech anticipates that new landslides may occur on either side of the Cliffside slide. The area to the south had shallow slope movement and sloughing observed in 2021. A larger landslide may initiate from tension cracks extending south from the Cliffside Park slide.

In general, most of the Jeckell Street slope monitoring zone is within the moderate to high landslide susceptibility hazard index using both FR and GLM outputs (Figures 6c and 7c). The high landslide susceptibility hazard index spans this entire monitoring zone and is concentrated approximately halfway up the Escarpment slope. The GLM output is shows more moderate than high landslide susceptibility hazard index in the southern part of the zone compared to the FR model.

5.4.4 East Airport Access Road Zone

A site-specific terrain stability assessment for Block 338, 103191 CLSR YT, Rogers Street to Hoge Street (also knows as the "5th and Rogers" parcel) was prepared for the Government of Yukon and issued for use on May 30, 2016 (Tetra Tech 2016). This terrain stability assessment was updated in February 2023 and issued for use on April 20, 2023 (Tetra Tech 2023). The 5th and Rogers Parcel was divided into a northern and southern section, which are described below:

5.4.4.1 Northern Section of 5th and Rogers Parcel (Hawkins Street to Rogers Street)

Much of the slope instability activity identified along the East Airport Access Road (EAAR) zone occurs in the area between Hawkins and Rogers streets.

Backscarp regression of approximately 2.6 m (between 2013 to 2019) and 5.7 m (between 2019 to 2022) was identified through historical LiDAR and air photo analysis, approximately halfway upslope at the northwestern edge of the vacant 5th and Rogers parcel, above the former EAAR, which is currently used as a recreational walking path (Figures 2d and 3d). This area was relatively stable through 2021 but exhibited increased movement in Spring 2022. Numerous small (<10 m^3) earth flows occurred across the exposed area, and slumping was observed in some locations on the downslope side of the trail. A run-off interceptor ditch is located upslope of the EAAR, directing flow down to the dog park located at the west end of Main Street.

This analysis also determined that the toe of the Escarpment at this location has transitioned eastwards by up to approximately 50 m since 2019. Although the area is still vegetated, given the nature of the process and texture of the material, the fan is accumulating material by continual seepage from upslope backscarp faces. Significant flow of sediment-laden water is visible flowing down the slope and into the west side of the subject site during the spring. Considerable precipitation events may have the potential to increase the volume of material and possibly cause damage to property.

The Escarpment slope above the unvegetated bluffs above the EAAR was modelled as being within the moderate to high landslide susceptibility hazard index using both FR and GLM techniques (Figures 6d and 7d). The area below the EAAR was modelled as low to moderate landslide susceptibility index.

5.4.4.2 Southern Section of 5th and Rogers Parcel (Rogers Street to Hoge Street)

Historical comparative analysis of the LiDAR data (from 2013 to 2022) does not show significant changes to the toe of the Escarpment at the middle or southern sections between Rogers Street and Hoge Street. Although there has been some slow mass movement occurring at these locations between 2013 and 2022, there is no detectable change to the existing backscarps, landslide scars, or the crest of the Escarpment directly upslope of this southern section of the 5th and Rogers parcel (Figures 2d and 3d). Most of this section of the slope is heavily vegetated, which suggests long term stability under historical and current conditions, although it should be noted that recent activity at Drury and Wood Street slides shows a change of conditions can cause slope instability and in particular shallow earth movement.

Elevation changes due to cut (red) and fill (blue) of the ground for the construction of the St. Elias adult group home and fill placement (blue) for the interception berm west of the group home were detected by the analysis and are clearly visible on Figure 4d.

In general, much of the Escarpment slope at the 5th and Rogers area has not experienced much elevation change between 2013 and 2022. Most of the material movement is seen at the headscarp located at the top of the Escarpment immediately west of the area between Rogers and Lowe Streets. The average vertical thickness of material loss from the headscarp erosion is approximately 0.93 m between 2013 and 2019 and 0.68 m between 2019 and 2022. Given the size of the area (approximately 900 m^2) this loss represents volumes of 840 m^3 and 610 m^3, respectively. The material flows down the gully and drainage paths and accumulates at the toe of the Escarpment. Accumulation of material averaging 0.5 m in vertical thickness was identified at this location. Saturated ground surface conditions are evident at the toe of the Escarpment at this location throughout the spring and summer months.

Slope susceptibility modelling using the FR and GLM techniques identified that most of the Escarpment between Rogers Street and Lowe Street was within a low to moderate susceptibility hazard index. High susceptibility hazard was modelled between Lowe and Hoge Streets over the top half of the slope with low to moderate susceptibility hazards along the bottom half.

5.4.4.3 East Airport Access Road Zone Hawkins Street to Main Street

Much of the Escarpment in the northern area of the EAAR zone is forested, except for the headscarps of the active slope movement features and their transport and deposition zones downslope from the headscarps.

The detailed assessment found that terrain at this location is stable and no change to large existing headscarps were identified between 2013 and 2019 and 2022.

An old landslide headscarp is present in the north part of the EAAR zone, with a runout headed to a dwelling known as the "Purple Cabin" located at the west end of Lambert Street. One or more previous landslides that have occurred reached the EAAR trail, immediately above the Purple Cabin, but to date the cabin has not been impacted. Observations from visual inspections in 2022 did not suggest another landslide is imminent. However, continual seepage was identified from the headscarp face with slope material actively flowing down this gully to the run-off interceptor ditch, which, in turn, conveys the debris flow further down to the dog park. It should be noted that the Purple Cabin is in the moderate hazard zone and could be impacted by a large landslide.

The Escarpment above Hanson Street and the area within the historic Lambert Street slide were modelled within the high landslide susceptibility hazard index using both the FR and GLM techniques (Figures 6d and 7d). The rest of the northern portion of this monitoring zone, between Hanson and Main Street, was modelled as mainly low landslide susceptibility hazard index.

5.4.5 Main Street Zone

No significant slope activity, including retrogressive headscarp retreat, was observed in the Main Street zone (Figures 2e and 3e), between 2013 and 2022. Active seepage, gullying, and water flow have been observed from existing landslide headscarps located near the crest of the Escarpment. Evidence of material loss is shown on the elevation change detection (Figures 4e and 5e). Most active during thawing of seasonally frozen ground and snowmelt, the slow movement of saturated materials are contributing to constant water flow down the Escarpment slope face. An interception ditch and settling ponds manage water and debris flow from the Escarpment in the northern part of the Main Street zone. A dog park is present near the south end of the zone, which is not protected by the interception ditch; however, based on recent years' data, the slope above the dog park appears to be relatively stable.

Landslide susceptibility modelling has identified that most of the Escarpment slope in the Main Street zone is within the low to moderate landslide susceptibility hazard index, with intermittent high landslide susceptibility hazard index at the crest of the Escarpment near the historic Steele Street slide (Figures 6e and 7e). The area above the dog park is modelled as within the low landslide susceptibility hazard index.

5.4.6 Wood Street Zone

The Wood Street zone is located between Strickland Street to the north and south of the property at the end of Wood Street to the south. Two landslides occurred on the Escarpment at the west end of the Wood Street zone, on May 18 and 28, 2022. The first event was relatively small and slightly impacted the paved trail at the base of the slope. The second event was relatively large and covered the trail with debris with a runout of approximately 20 m from the toe of the slope.

The vertical thickness of material lost from the Wood Street slide averaged approximately 1.4 m and was up to 4.7 m, with an approximate area of 750 m^2. The vertical thickness of material accumulation at the toe averaged approximately 1.6 m and was up to 3.7 m, with an accumulation area of approximately 800 m^2. Given the size of the loss and accumulation areas, total volume of this slide was approximately 1,050 to 1,300 m^3.

A tension crack was observed and mapped on the north end of the recent landslide, near the lower third of the Escarpment slope and is shown on Figures 2e and 3e. Tetra Tech expects ongoing, minor sloughing from the area adjacent to the landslides, and potentially one or more new slides that may be similar in size to the 2022 events.

Large historical landslide headscarps with drainage flow paths are mapped near the crest of the Escarpment slope.

Most of the Escarpment slope at the Wood Street zone is densely vegetated and characterized by rapid drainage.

Landslide susceptibility modelling at the Wood Street monitoring zone has identified that most of the Escarpment slope near and north of the 2022 Wood Street slide is within the high landslide susceptibility hazard index, especially concentrated to the north of Wood Street (Figures 6e and 7e). The Escarpment to the south of Wood Street is mostly within the low landslide susceptibility hazard index.

5.4.7 Puckett's Gulch/Black Street Stairs Zone

Puckett's Gulch is located between Wheeler Street to the north and Alexander Street to the south with the Black Street stairs providing access to recreation trails located along the airport perimeter fence along the crest of the Escarpment slope. Relatively minor slope movement was observed along the south side of Puckett's Gulch during visual inspections in Spring 2022 (Figures 1, 2f, 3f, 4f, and 5f).

An area of gullying was mapped at the westernmost section of Puckett's Gulch. Several tension cracks were identified using the DEM hillshade models from 2013 and 2019, as shown on Figures 2f and 3f. Slope instability was identified on the right-hand side of the Black Street stairs leading to the crest of slope, however this appears to have stabilized over recent years. Stair foundations are in good shape (Tetra Tech 2021b).

A tension crack was identified in the landslide headscarp at the far west end of Puckett's Gulch using the 2022 DEM hillshade model, a second tension crack was identified in the 2019 DEM hillshade on the north facing slope, and a third tension crack from before 2013 was identified on the north-facing slope between the east side of the Black Street stairs and the south-facing bluff. These tension cracks are not showing movement and are not in high traffic areas.

Besides the south-facing bluff of dry silt material, this zone is mostly vegetated with grasses and trees and does not exhibit areas of mass movement activity.

Landslide susceptibility modelling at the Puckett's Gulch/Black Street Stairs monitoring zone has identified that most of the Escarpment slope within the low to moderate landslide susceptibility hazard index (Figures 6f and 7f). Intermittent high susceptibility hazard index near the west end of the Gulch, away from any infrastructure was modelled by the FR technique and some high landslide susceptibility hazard index was modelled along the south facing slope near the exposed bluff by the GLM technique.

5.4.8 Baxter's Gulch Zone

Baxter's Gulch is a heavily vegetated deep gully that incises the Escarpment approximately 150 m north of Baxter Street and is spread out over Figures 2f to 2h, 3f to 3h, 4f to 4h, and 5f to 5h.

Erosional processes such as freeze-thaw wedging and swelling of clay from saturation have resulted in toppling of small blocks of material at Baxter's Gulch, north of Puckett's Gulch. These blocks typically do not fall beyond 2 m from the toe of slope, although some moderate sized compacted silt blocks (less than 5 m^3) from sub-vertical pillars ("hoodoos") can be deposited up to 10 m from the toe of slope (EBA 2002).

Most of the historical mass movement activity at Baxter's Gulch occurs on the dry, south facing bluff. The slope includes multiple flow drainage and riling/shallow gullying erosion typically observed across the Escarpment. This area is away from permanent infrastructure or recreation trails. Small areas of debris flow headscarps and minor tension cracking were mapped on the vegetated north-facing slope using DEM hillshade models. Noticeable changes to the Escarpment crest have not been identified at the Baxter's Gulch zone between 2013 and 2022.

No areas of concern or indicators of slope instability were identified in the Baxter's Gulch zone during the 2021 or 2022 monitoring programs.

Landslide susceptibility modelling at the Baxter's Gulch monitoring zone has identified that most of the Escarpment slope is at low to moderate landslide susceptibility hazard index with intermittent high susceptibility hazard index along the northwest and south facing slopes near the mapped tension cracks (Figures 6f, 6g, 6h, and 7f, 7g, 7h).

5.4.9 Two Mile Hill Zone

The Two Mile Hill zone is located parallel to Two Mile Hill Road from Baxter's Gulch to the south to the intersection with Industrial Road to the north (Figures 1, 2i, 3i, 4i, and 5i). The Escarpment is generally densely vegetated and is well to rapidly drained. Rill erosion and shallow gullying were identified at the bluff located across the road from the parking lot entrance north of Chilkoot Way.

The northern half of Two Mile Hill is gradually sloping with no areas of concern identified through the historical air photo and LiDAR data analyses. Elevation change detection analysis does not show any areas of slope movement along the Escarpment.

A tension crack was identified on the vegetated slope above Two Mile Hill at the Chilkoot Way intersection using the DEM hillshade model. No advancement of the toe of the Escarpment or any mass movement processes were identified in other parts of this zone through the air photo interpretation, or the elevation change detection analysis since 2013.

Landslide susceptibility modelling at the Two Mile Hill monitoring zone has identified high landslide susceptibility hazard index at the southern end of the zone, along the steep vegetated slope at the Chilkoot Way intersection. The high susceptibility hazard index extends from the crest of the slope and extends down most of the slope towards the toe (Figures 6g, 6i and 7g, 7i). The exposed bluff facing Two Mile Hill Road and area at the northern part of this zone are modelled as low landslide susceptibility hazard index. The slope immediately below the bluff was identified as a moderate landslide susceptibility hazard index by the GLM technique.

5.4.10 Takhini South Zone

The Takhini South zone encompasses the Escarpment slopes from the north side of Two Mile Hill to about Tlingit Street at the base of the Escarpment, and Cambrai Place at the top of the Escarpment (Figures 1, 2j to 2k, 3j to 3k, 4j to 5k, and 5j to 5k).

Shallow landslides, similar to those observed in the Drury Street zone, occurred north of the historic Takhini East slide that took place in July 2000 behind MacPherson Rentals and extended about 34 m north across the slope. The Takhini East slide had an estimated volume of 3,000 m^3 (EBA 2002). Approximately 700 m^3 of material has been lost from the Takhini East slide headscarp between 2013 and 2019.

A second slide, about 20 m north of the Takhini East slide, took place in 2021, and was somewhat smaller than the Takhini East slide with a headscarp extending approximately 20 m across the slope. A third slide occurred between the Takhini East slide and the 2021 slide in Spring 2022, which formed a continuous headscarp from the three slides that is about 75 m long.

The debris from these slides slumped to the base of the Escarpment but did not run out for any significant distance across the forested level ground between the base of the Escarpment and the businesses along the west side of Copper Road. The existing landslide scarps continue to show sloughing, which is identifiable in the elevation change detection model (Figure 4k and 5k).

An approximately 20.4 m long tension crack was identified at the north end of the existing backscarp using the 2022 DEM hillshade model. Although Tetra Tech believes there is potential that the failure may occur in 2023 there is little immediate concern for properties or infrastructure above or below the slope at this location, however, long-term retrogression of the headscarp may eventually encroach on properties at the top of the slope. Active groundwater seepage was also observed at this location.

No slope instability features were mapped at the south end of the Takhini South zone.

Landslide susceptibility modelling at the Takhini South monitoring zone has identified areas with high landslide susceptibility hazard index at the middle of the zone, immediately north of the 2021 Takhini slide. The high landslide susceptibility hazard index covers approximately one third of the top of the slope (Figures 6j, 6k and 7j, 7k). The entire southern portion of the zone, along with the most northern section at the historical headscarps is considered a low to moderate landslide susceptibility hazard index with intermittent high landslide susceptibility hazard index near tension cracks identified just south of the Takhini East slide.

5.4.11 Takhini Sanitary Sewer Zone

The Takhini Sanitary Sewer zone extends from the boundary with the Takhini South zone up to about the northern extent of the Pepsi Softball Centre. The zone is generally well drained and vegetated (Figures 1, 2l, 3l, 4l, and 5l).

An approximately 38 m-long tension crack observed in Spring 2022 intersects a sanitary manhole and the Trunk 1 sanitary sewer main. The slope did not fail in 2022 and the sewer line remains in service, but an emergency bypass was constructed in case the slope fails and damages the sewer line. The bypass descends the Escarpment in an apparently stable area to the south of the tension crack. Tetra Tech expects additional slope movement in 2023, and the likelihood of failure resulting in damage to the sewer line and manhole is high (Tetra Tech 2022c).

Three historical landslide headscarps were mapped using the DEM hillshade models along the Takhini Sanitary Sewer zone.

The slope does not present any threat to public safety in the runout zone since landslide debris would be collected in a natural depression before impacting Mountain View Drive. However, unplanned discharge of untreated wastewater could affect public health and safety and may contravene the conditions of the City's Water Use License, and the water added to the slope could trigger additional slope failures.

Tetra Tech did not have 2022 LiDAR coverage available to complete the elevation change detection analysis in the Takhini Sanitary Sewer Zone.

Landslide susceptibility modelling at the Takhini Sanitary Sewer monitoring zone has identified high landslide susceptibility hazard index at the northern end of the zone, in the area immediately around the sanitary sewer and tension crack. The high landslide susceptibility hazard index covers most of the slope, towards the exposed bluffs to the south of the tension crack (Figures 6l and 7l). The entire southern portion of the zone is considered a low to moderate susceptibility hazard index, including the location of the emergency bypass.

5.4.12 Takhini North Zone

The Takhini North zone extends from the boundary with the Takhini Sanitary Sewer zone to the intersection of Range Road and Mountain View Drive (Figures 1, 2m, 3m, 4m, and 5m). Tetra Tech did not receive 2022 LiDAR data for this location but no areas of concern were identified in this zone during the 2022 slope stability inspections. Slope height of the Escarpment decreases to the north and this zone is densely vegetated indicating historically stable terrain conditions. Tetra Tech does not anticipate problems in this zone and there is no need for traffic control along Mountain View Road at this time. High hazard areas were delineated based on slope angle.

5.5 Updated Geohazard Assessment

Tetra Tech's 2012 Downtown study provided minor updates to the landslide hazard designation zones. Hazard represents the probability and magnitude of a slope failure occurrence and is rated as **Low (L), Moderate (M), or High (H)** (EBA, 2002). This historical air photo interpretation and LiDAR data analysis study coupled with the elevation change detection analysis have determined that no substantial changes are warranted to the 2002 and 2012 landslide hazard designation zones along the Escarpment at this time. Active and possible slope movement mechanisms were considered, reviewing the recent mass movement history of the Escarpment based on LiDAR and air photo records currently available.

The Escarpment slopes continue to experience active debris flow slides and erosion that are generally consistent with the mass movement activity described in the 2002 report. Tetra Tech considers that geohazards related to ongoing slope movement activity can be managed based on the updated landslide hazard designation zonation and land use guidelines developed by EBA in 2002.

6.0 CONCEPTUAL MITIGATION OPTIONS

Development of the conceptual landslide hazard mitigation options is included in Tetra Tech's scope of work and will be provided in a separate technical memorandum.

7.0 ESCARPMENT SLOPE MONITORING

Tetra Tech provided the Escarpment slope instability monitoring services and technical support to the City during the spring freshet in 2021 and 2022. An Escarpment slope monitoring plan was developed for Spring 2023 and submitted to the City on March 30, 2023 (Tetra Tech 2023).

Annual Escarpment slope monitoring during spring freshet is expected to be required on an ongoing basis. The 2023 Escarpment slope monitoring plan is considered to form the basis for monitoring in future years. However, the slope monitoring plan must be reviewed and modified from year to year to account for changes in the slope conditions, monitoring methods, mitigation measures implemented, etc.

It is not practical to set specific criteria for potential triggers that would require heightened monitoring along the Escarpment due to a limited amount of correlated data. The 2023 slope monitoring plan includes estimated, conservative triggers for slope movement rates, and qualitative triggers for factors such as heavy precipitation and/or warm weather during the spring that can accelerate snow melt, raise groundwater levels, and increase potential for slope failures.

8.0 ANNUAL LIDAR SURVEY

Tetra Tech recommends that the City complete an annual, aerial-based LiDAR survey and orthophoto imagery capture of the Escarpment. The annual LiDAR data should be used for change detection to keep track of current conditions and to detect potential new areas of concern on the Escarpment.

The annual LiDAR data should also be used to update the slope geohazard assessment, including terrain feature identification, and the landslide susceptibility models on a yearly basis.

Tetra Tech recommends installing ground control points throughout the Escarpment that can be surveyed at the same time as the LiDAR data collection, to improve the accuracy of the data.

The next annual LiDAR data collection should be completed in Summer 2023, after the period of expected Spring landslide activity and ideally while signs of potential slope instability, such as tension cracks, are still fresh. A second round of LiDAR data collection, if deemed necessary, must be completed before the ground becomes covered with snow in the fall.

9.0 CONCLUSIONS AND RECOMMENDATIONS

This historical air photo interpretation and LiDAR data analysis study coupled with the elevation change detection analysis, and landslide susceptibility modelling has determined that no substantial changes are warranted to the 2002 and 2012 landslide hazard designation zones along the Escarpment at this time.

The recent increase in mass movement and instability on the Escarpment means that annual slope inspections, especially during spring freshet, are justified. Tetra Tech recommends annual aerial LiDAR data collection, analysis and orthophoto imagery capture which, combined with site visits and drone-assisted photography, are helpful tools in the continued monitoring of slope instability of the Escarpment and predicting potential future movement. Collecting and monitoring groundwater data from the airport plateau should be performed and continued to determine groundwater trends which, along with updated monitoring data, can be used to update and refine the landslide susceptibility models.

The current snow removal and storage practices and plans across the airport area should be reviewed, as melting of the snow being stored close to the escarpment slope break pertains to the slope stability. This should be done in cooperation with the airport authority, hydrologists, hydrogeologists, and hydrotechnical engineers for managing surface water and ground water flow within the airport property.

Slope modelling using Flow/R software (https://www.terranum.ch/en/products/flow-r/) should be considered to supplement the current hazard assessment and landslide susceptibility modelling. Flow/R can be used to estimate the propagation of slope hazards on the regional scale, which would be useful to verify or support future updates to the existing landslide hazard designation zones.

Site-specific subsurface geotechnical and hydrogeological exploration consisting of boreholes and instrumentation installation should also be considered. Information gathered from geotechnical hydrogeological explorations can be used to add data and improve the landslide susceptibility models and also to support site-specific designs for hazard mitigation measures (e.g., at RSW zone).

Tetra Tech recommends that risk assessments be completed to consider the risk posed to people, infrastructure, or other assets by the slope geohazards discussed in this report. Risk assessments should be used to guide planning for mitigation measures that may be implemented along the Escarpment.

A recommended annual schedule of ongoing monitoring and report updates is summarized in Table 9-1 below.

Table 9-1: Recommended Annual Schedule of Ongoing Monitoring and Report Updates

Schedule	Activity	Documentation/Reporting
Mid-March to Late June	Visual slope stability monitoring / Slope radar (scanner), geotechnical instrumentation and ground survey data analysis	Daily communication with City, EOC meetings, documentation, possible monitoring summary report
Late June	Aerial LiDAR survey and orthoimagery acquisition of the entire Escarpment	.LAS files and Orthophotos
June to August	Process LiDAR, groundwater, climate and precipitation, slope radar, and survey data	Update GIS Models and summary tables
September to December	Analysis/Mapping of LiDAR data and orthophotos	Update terrain features, geohazard report, susceptibility models, and risk assessment
January to Mid-March	Planning for monitoring activities during Spring freshet,	Workplan for Spring freshet monitoring

10.0 CLOSURE

We trust this report meets your present requirements. If you have any questions or comments, please contact the undersigned.

Respectfully submitted,
Tetra Tech Canada Inc.

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LICENSEE
NT/NU

FILE: 704-ENG.WARC04258-01
2023-06-29

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PERMIT TO PRACTICE
TETRA TECH CANADA INC.
SIGNATURE
Date June 29, 2023
PERMIT NUMBER PP003
Association of Professional Engineers of Yukon

/cr

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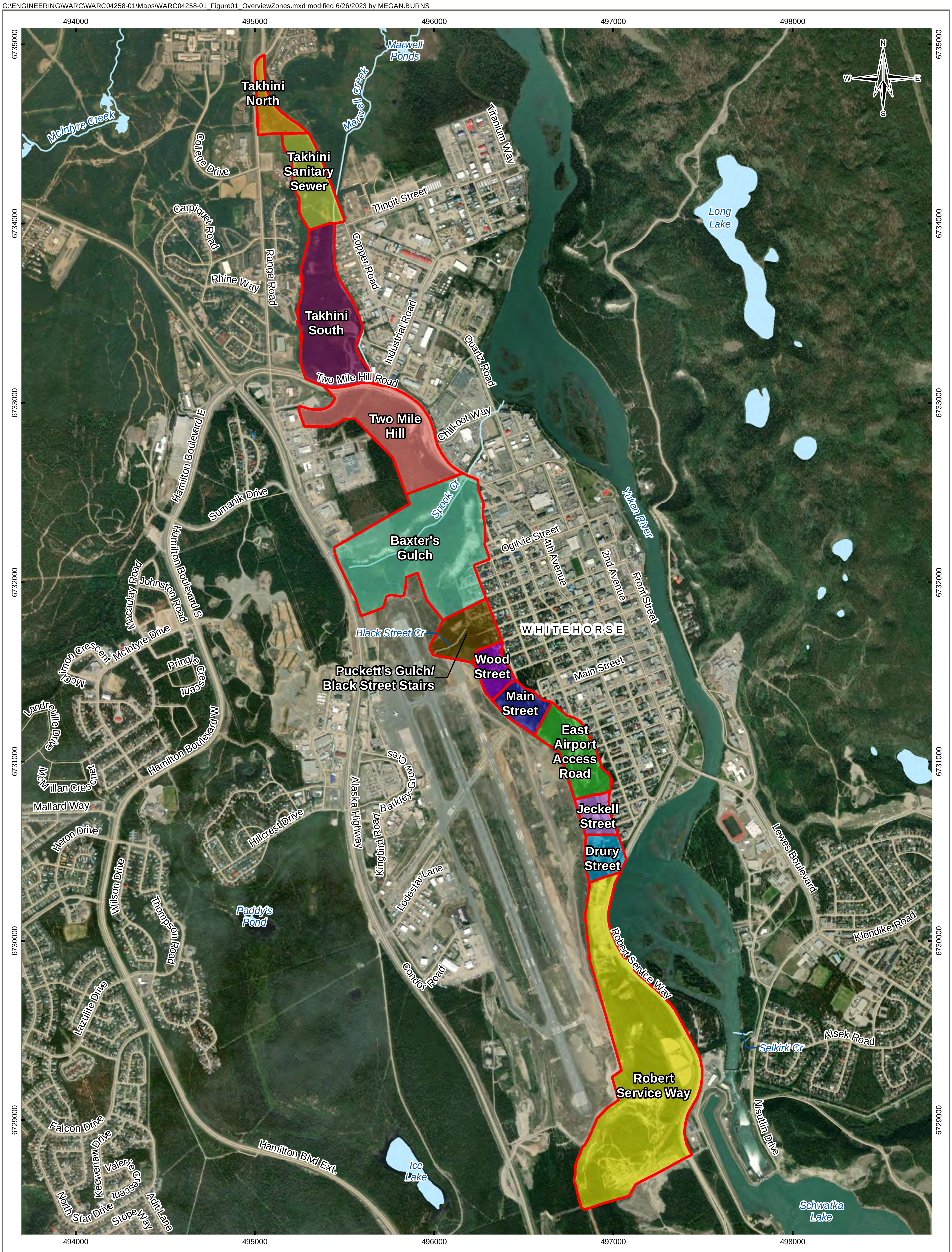
FIGURES

G:\ENGINEERING\WARC\WARC04258-01\Maps\WARC04258-01_Figure01_OverviewZones.mxd modified 6/26/2023 by MEGAN.BURNS



LEGEND

Slope Monitoring Zone

- Baxter's Gulch
- Drury Street
- East Airport Access Road
- Jeckell Street
- Main Street
- Puckett's Gulch/Black Street Stairs
- Robert Service Way
- Takhini North
- Takhini Sanitary Sewer
- Takhini South
- Two Mile Hill
- Wood Street

Base Data

- Road
- Watercourse
- Waterbody

NOTES
Base data source: Imagery provided by ESRI; Maxar (2022)
City of Whitehorse Open Data

STATUS
ISSUED FOR USE

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

Overview Showing Slope Monitoring Zones

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse THE WILDERNESS CITY

Scale: 1:20,000

400 200 0 400

Metres

FILE NO.
WARC04258-01_Figure01_OverviewZones.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 1

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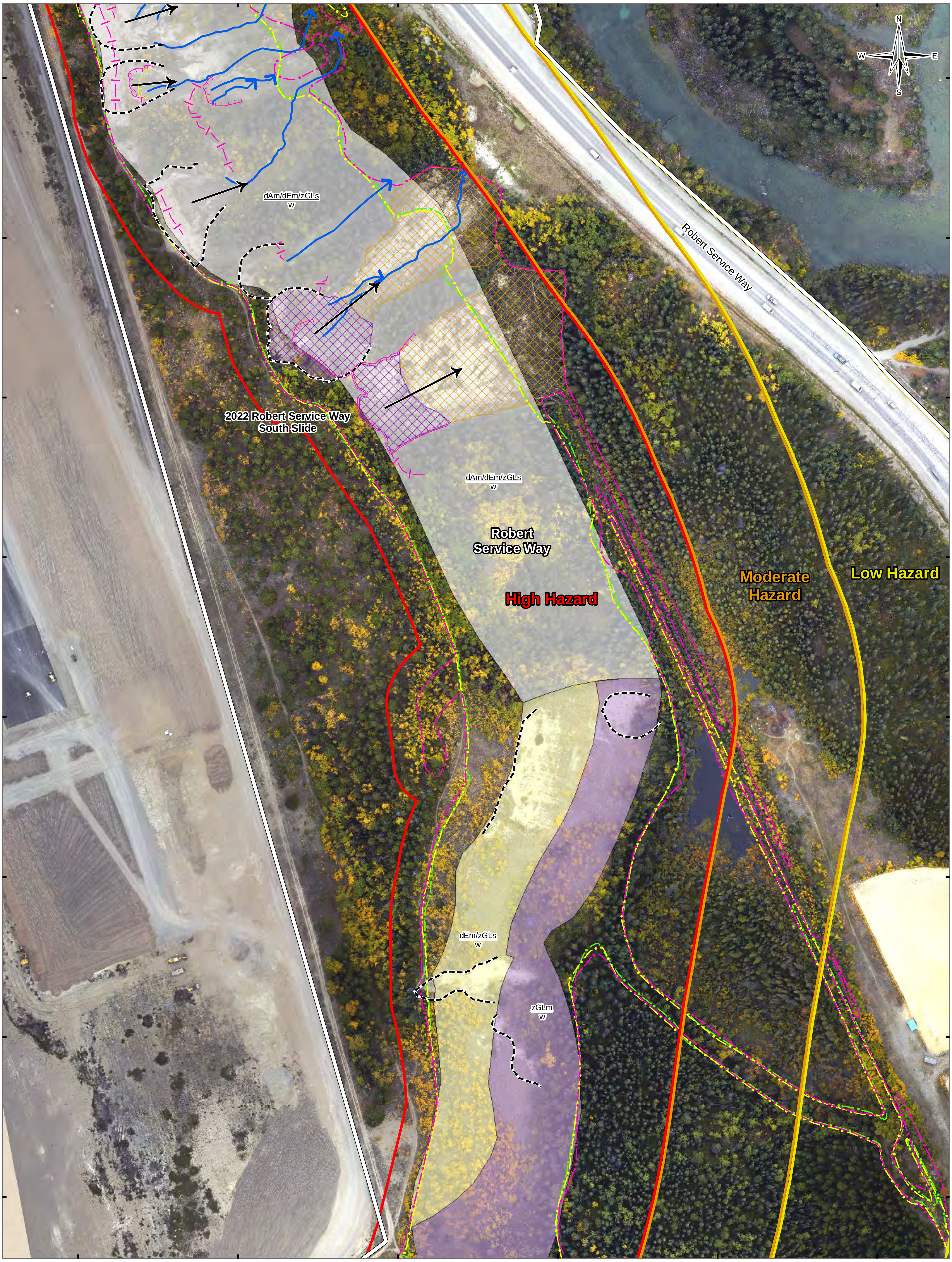

LEGEND

*See attached legend for detailed surficial geology definitions

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Surficial Material

- Eolian
- Glaciolacustrine
- Anthropogenic

STATUS
ISSUED FOR USE

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 Imagery Slope Instability Feature Interpretation and Landslide Hazard Designation

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse THE WILDERNESS CITY

Scale: 1:1,750

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Metres

TETRA TECH

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WARC04258-01_Figure02_HazardsImagery.mxd

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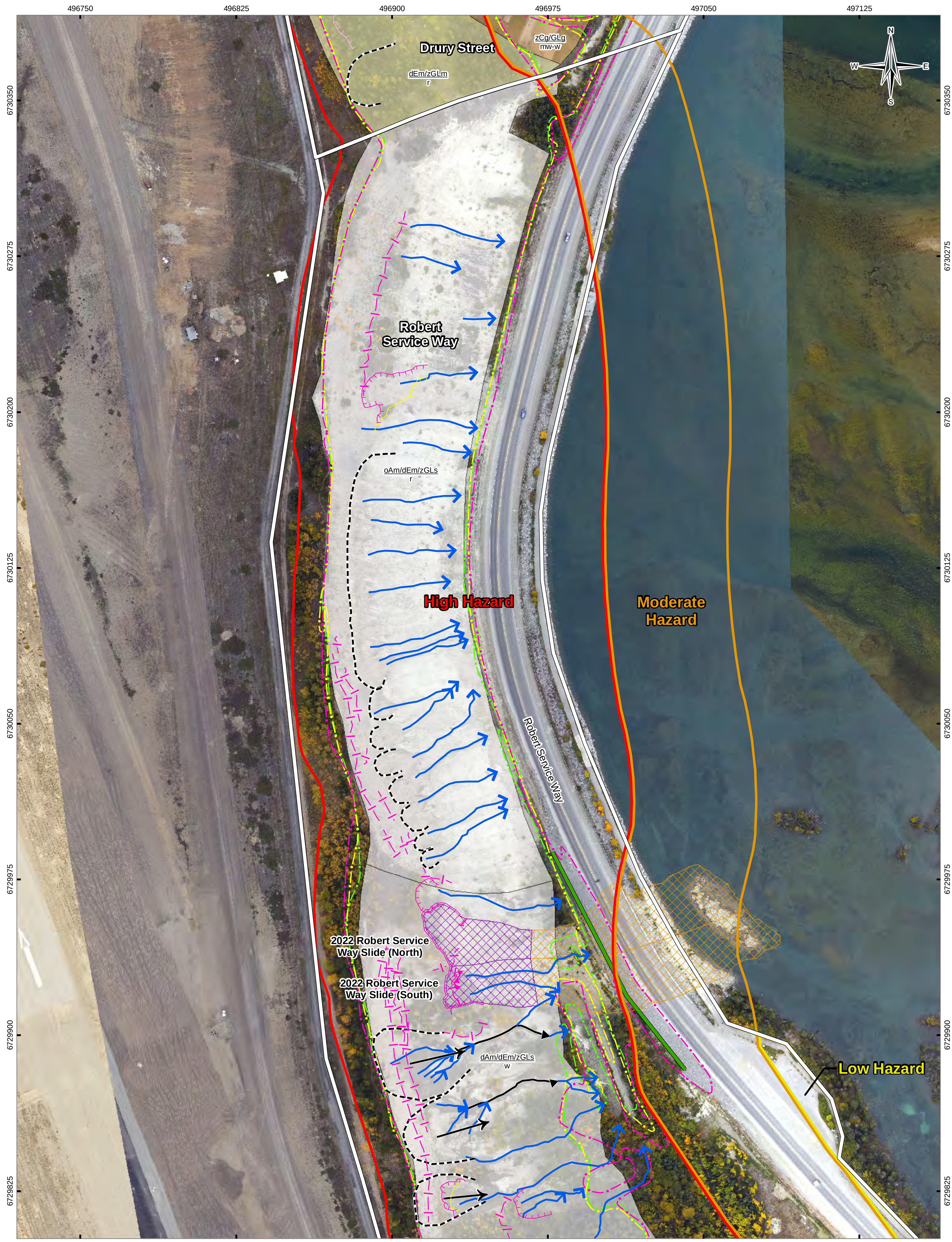
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 2a



LEGEND

*See attached legend for detailed surficial geology definitions

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Sheet-Pile Wall
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Surficial Material

- Colluvial
- Eolian
- Anthropogenic

STATUS
ISSUED FOR USE

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 Imagery
Slope Instability Feature Interpretation and Landslide Hazard Designation

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse THE WILDERNESS CITY

Scale: 1:1,750
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Metres

TETRA TECH

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DATE	PROJECT NO.			
June 26, 2023	ENG.WARC04258-01			

Figure 2b

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LEGEND

*See attached legend for detailed surficial geology definitions

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Surficial Material

- Colluvial
- Eolian
- Anthropogenic

STATUS
ISSUED FOR USE

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 Imagery Slope Instability Feature Interpretation and Landslide Hazard Designation

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750

25 12.5 0 25

Metres

TETRA TECH

FILE NO.				
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DATE	PROJECT NO.			
June 26, 2023	ENG.WARC04258-01			

Figure 2c

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LEGEND

*See attached legend for detailed surficial geology definitions

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- East Airport Access
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Surficial Material

- Colluvial
- Eolian

STATUS
ISSUED FOR USE

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 Imagery Slope Instability Feature Interpretation and Landslide Hazard Designation

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.				
WARC04258-01_Figure02_HazardsImagery.mxd				
OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1
DATE	PROJECT NO.			
June 26, 2023	ENG.WARC04258-01			

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Figure 2d

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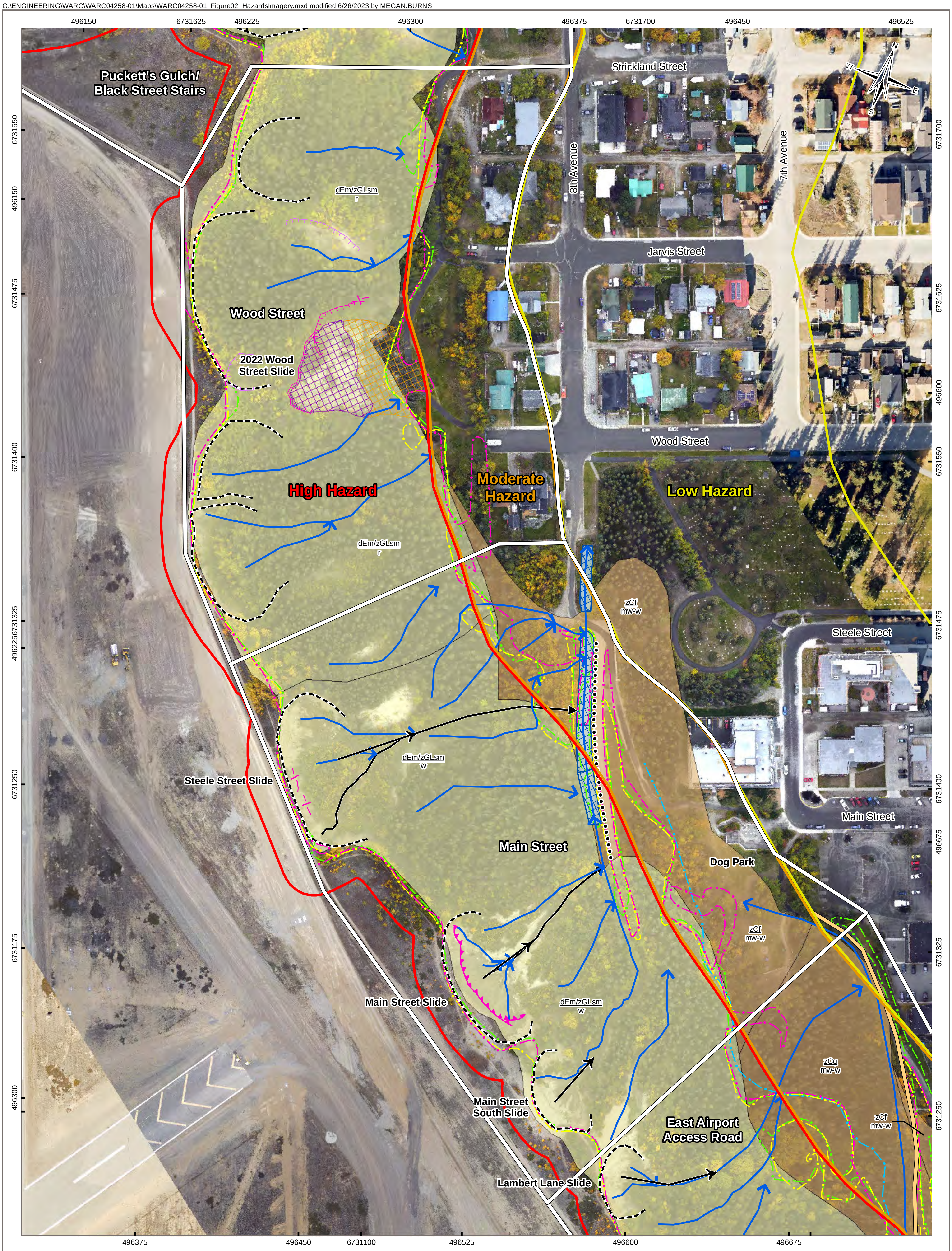

LEGEND *See attached legend for detailed surficial geology definitions

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- East Airport Access
- Settling Pond
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Surficial Material

- Colluvial
- Eolian

STATUS
ISSUED FOR USE

OVERVIEW

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Research Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 Imagery Slope Instability Feature Interpretation and Landslide Hazard Designation

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse THE WILDERNESS CITY

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure02_HazardsImagery.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 2e

G:\ENGINEERING\WARC\WARC04258-01\Maps\WARC04258-01_Figure02_HazardsImagery.mxd modified 6/26/2023 by MEGAN.BURNS

LEGEND

*See attached legend for detailed surficial geology definitions

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Surficial Material

- Colluvial
- Eolian

Base Data

- Watercourse

STATUS
ISSUED FOR USE

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 Imagery Slope Instability Feature Interpretation and Landslide Hazard Designation

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO. WARC04258-01_Figure02_HazardsImagery.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 2f

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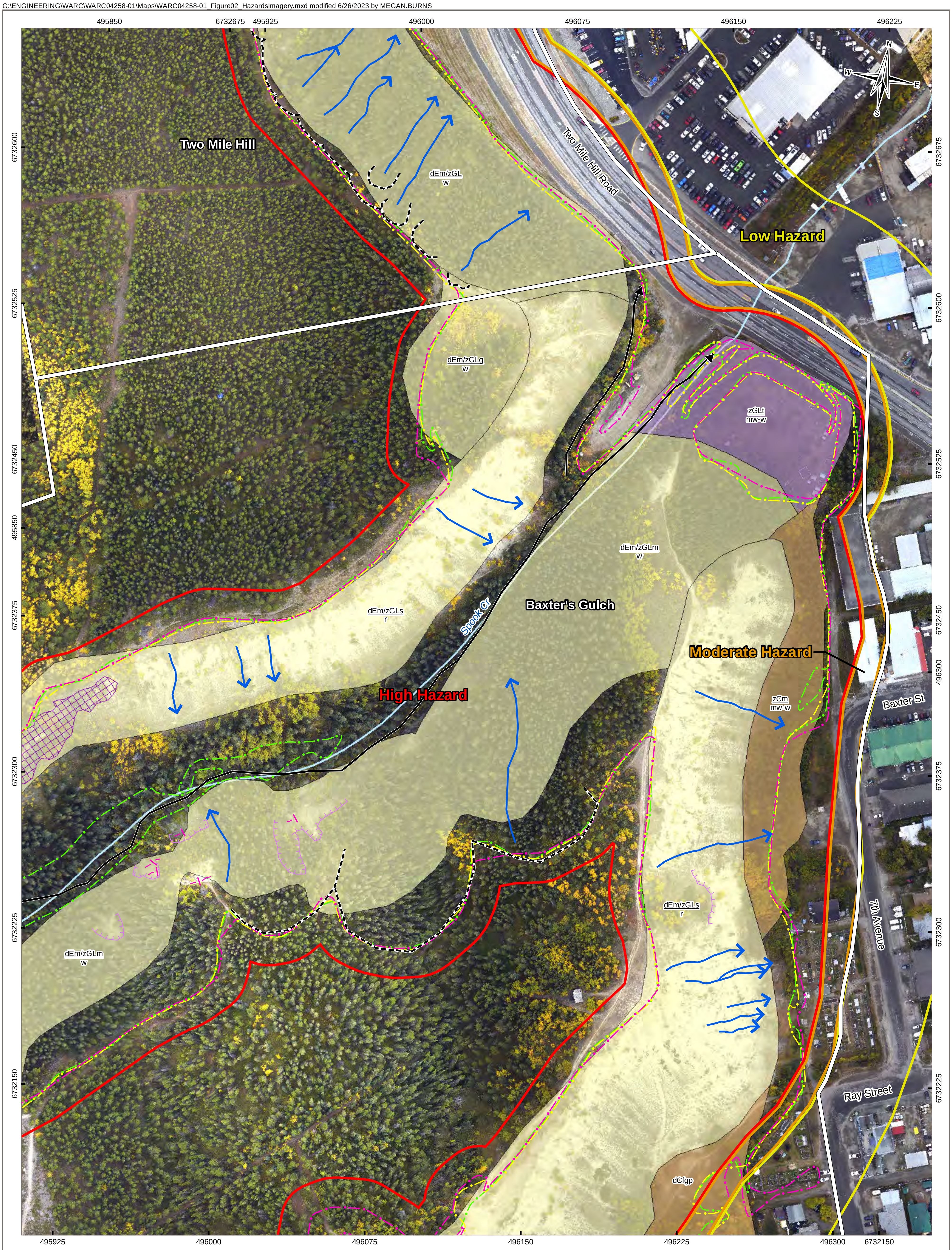

LEGEND

*See attached legend for detailed surficial geology definitions

Existing Berm
Gully
Seepage
Toe/Crest of Slope

Mass Movement Features

Debris Flow Headscarp
Landslide Scar - Active
Headscarp - Historical
Tension Crack
Debris Flow Scar
Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

2022
2021
2019
2016
2013
Pre 2013
Pre 2002
Not Dated

Flow Direction
Slope Monitoring Zone

Landslide Hazard Rating

High
Moderate
Low

Surficial Material

Colluvial
Eolian
Glaciolacustrine

Base Data

Watercourse

STATUS
ISSUED FOR USE

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 Imagery Slope Instability Feature Interpretation and Landslide Hazard Designation

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse THE WILDERNESS CITY

Scale: 1:1,750
25 12.5 0 25
Metres

TETRA TECH

FILE NO.				
WARC04258-01_Figure02_HazardsImagery.mxd				
OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1
DATE	PROJECT NO.			
June 26, 2023	ENG.WARC04258-01			

Figure 2g

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LEGEND

*See attached legend for detailed surficial geology definitions

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Culvert
- Slope Monitoring Zone

Landslide Hazard Rating

- High

Surficial Material

- Eolian

Base Data

- Watercourse

STATUS
ISSUED FOR USE

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 Imagery Slope Instability Feature Interpretation and Landslide Hazard Designation

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure02_HazardsImagery.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

TETRA TECH

Figure 2h

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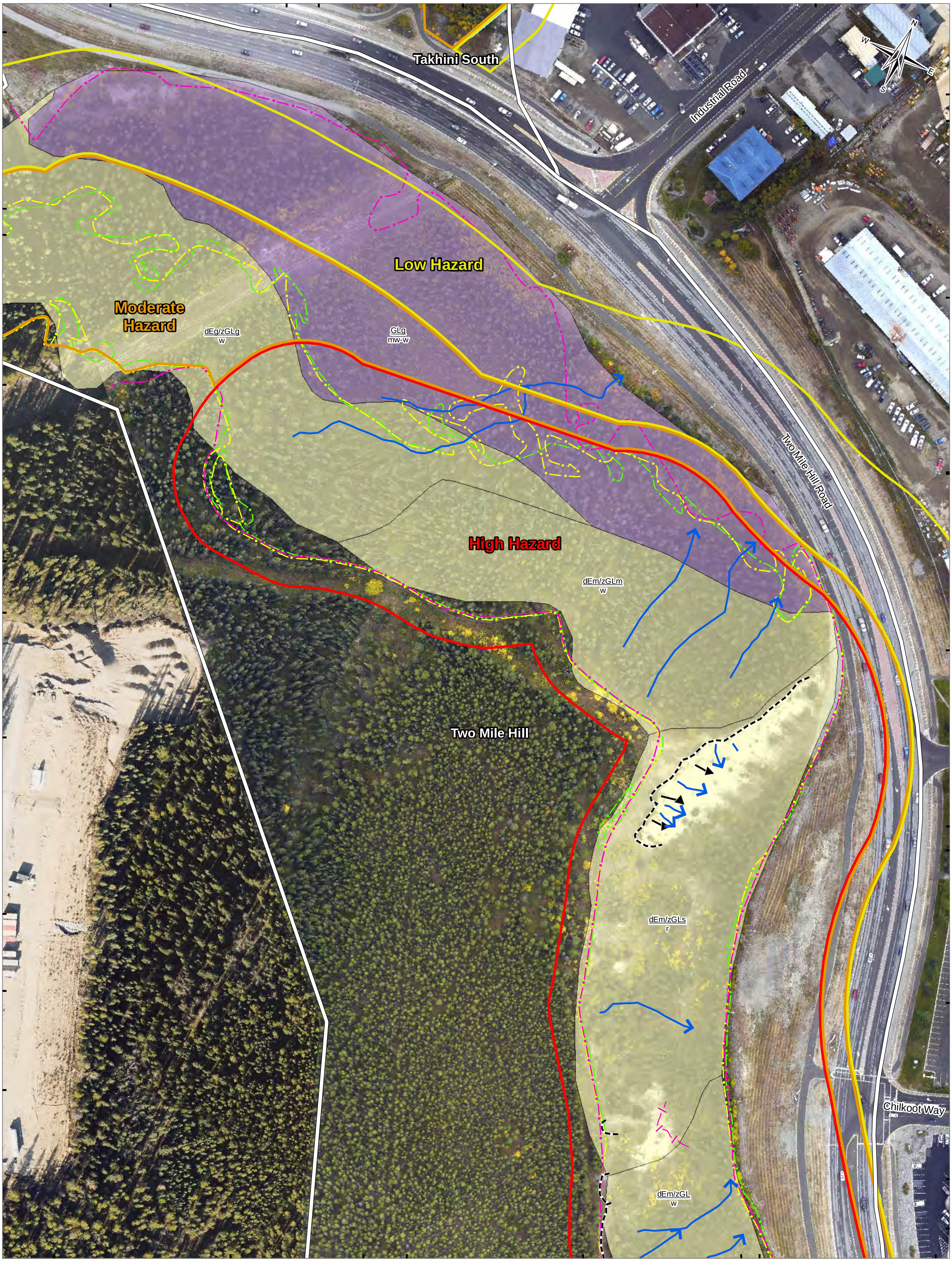

LEGEND

*See attached legend for detailed surficial geology definitions

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Surficial Material

- Eolian
- Glaciolacustrine

Base Data

- Watercourse

STATUS
ISSUED FOR USE

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 Imagery Slope Instability Feature Interpretation and Landslide Hazard Designation

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

TETRA TECH

FILE NO.				
WARC04258-01_Figure02_HazardsImagery.mxd				
OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1
DATE	PROJECT NO.			
June 26, 2023	ENG.WARC04258-01			

Figure 2i

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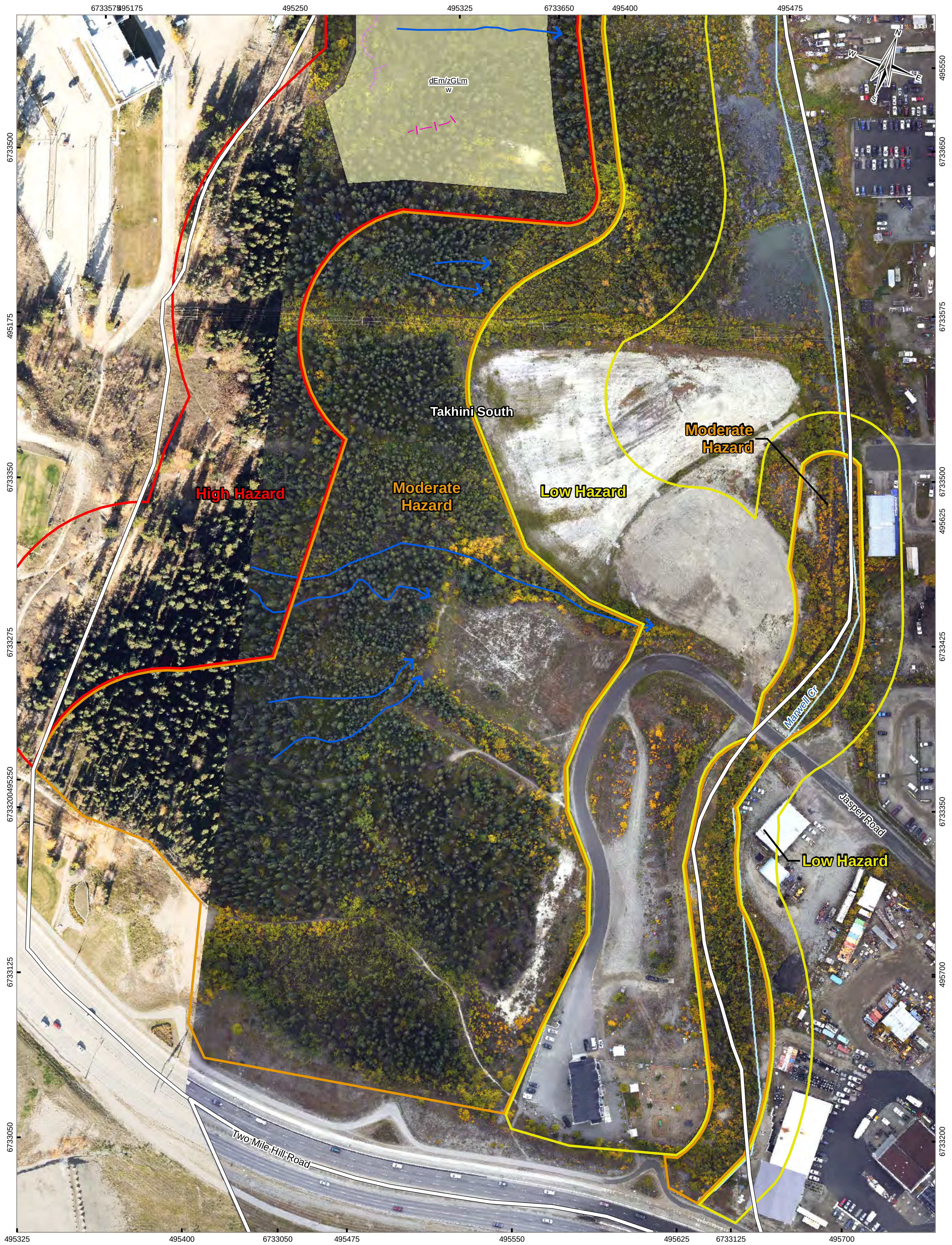

LEGEND

*See attached legend for detailed surficial geology definitions

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Surficial Material

- Eolian

Base Data

- Watercourse

STATUS
ISSUED FOR USE

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 Imagery Slope Instability Feature Interpretation and Landslide Hazard Designation

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure02_HazardsImagery.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

TETRA TECH

Figure 2j

G:\ENGINEERING\WARC\WARC04258-01\Maps\WARC04258-01_Figure02_HazardsImagery.mxd modified 6/26/2023 by MEGAN.BURNS

LEGEND

*See attached legend for detailed surficial geology definitions

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scarp - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Surficial Material

- Eolian

Base Data

- Watercourse

STATUS
ISSUED FOR USE

OVERVIEW

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 Imagery Slope Instability Feature Interpretation and Landslide Hazard Designation

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

TETRA TECH

FILE NO.
WARC04258-01_Figure02_HazardsImagery.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 2k

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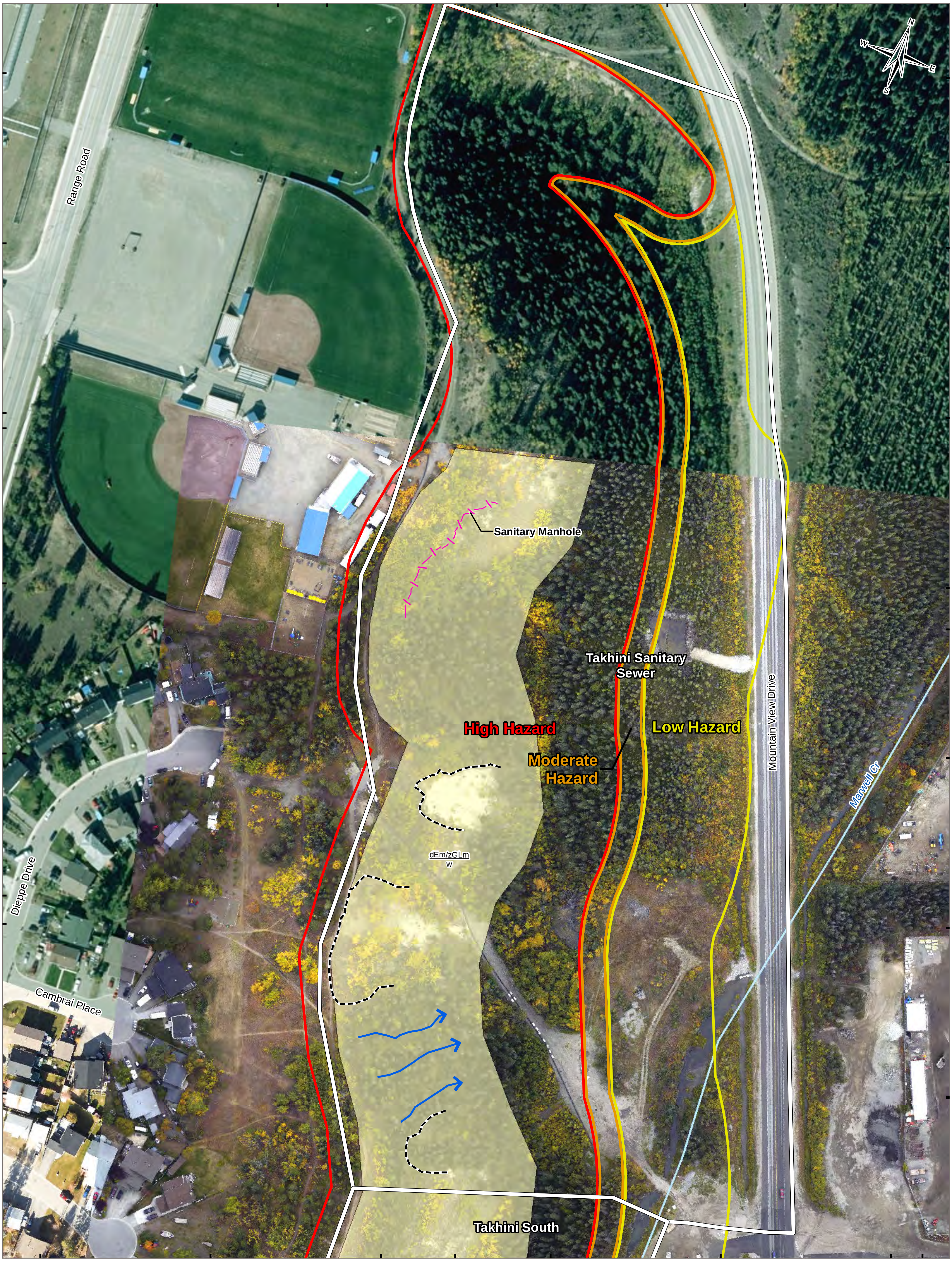

LEGEND

*See attached legend for detailed surficial geology definitions

Existing Berm
Gully
Seepage
Toe/Crest of Slope

Mass Movement Features

Debris Flow Headscarp
Landslide Scar - Active
Headscarp - Historical
Tension Crack
Debris Flow Scar
Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

2022
2021
2019
2016
2013
Pre 2013
Pre 2002
Not Dated

Flow Direction
Slope Monitoring Zone

Landslide Hazard Rating

High
Moderate
Low

Surficial Material

Eolian

Base Data

Watercourse

STATUS
ISSUED FOR USE

OVERVIEW

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 Imagery Slope Instability Feature Interpretation and Landslide Hazard Designation

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure02_HazardsImagery.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 2I

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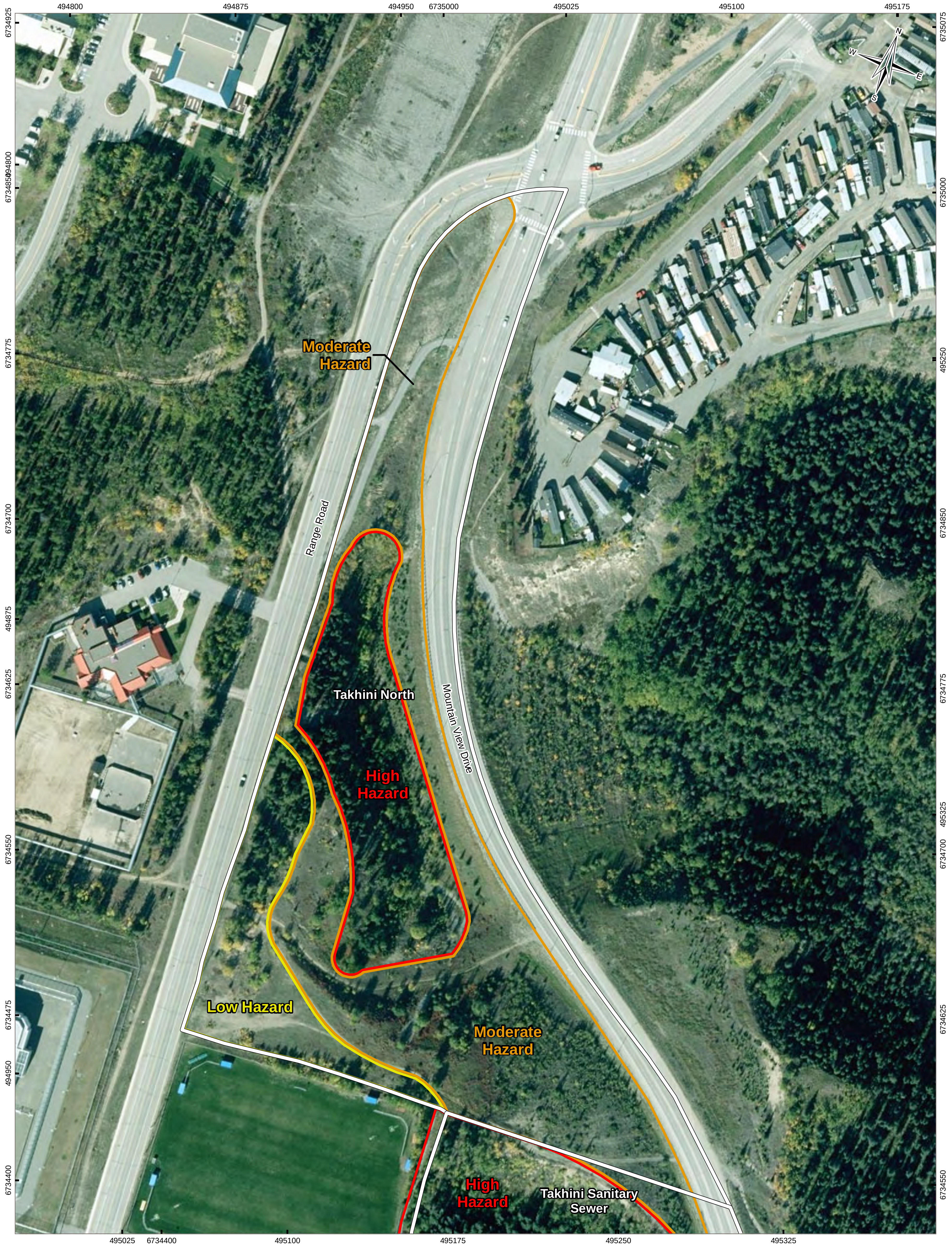

LEGEND *See attached legend for detailed surficial geology definitions

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

STATUS
ISSUED FOR USE

OVERVIEW

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 Imagery Slope Instability Feature Interpretation and Landslide Hazard Designation

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure02_HazardsImagery.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 2m

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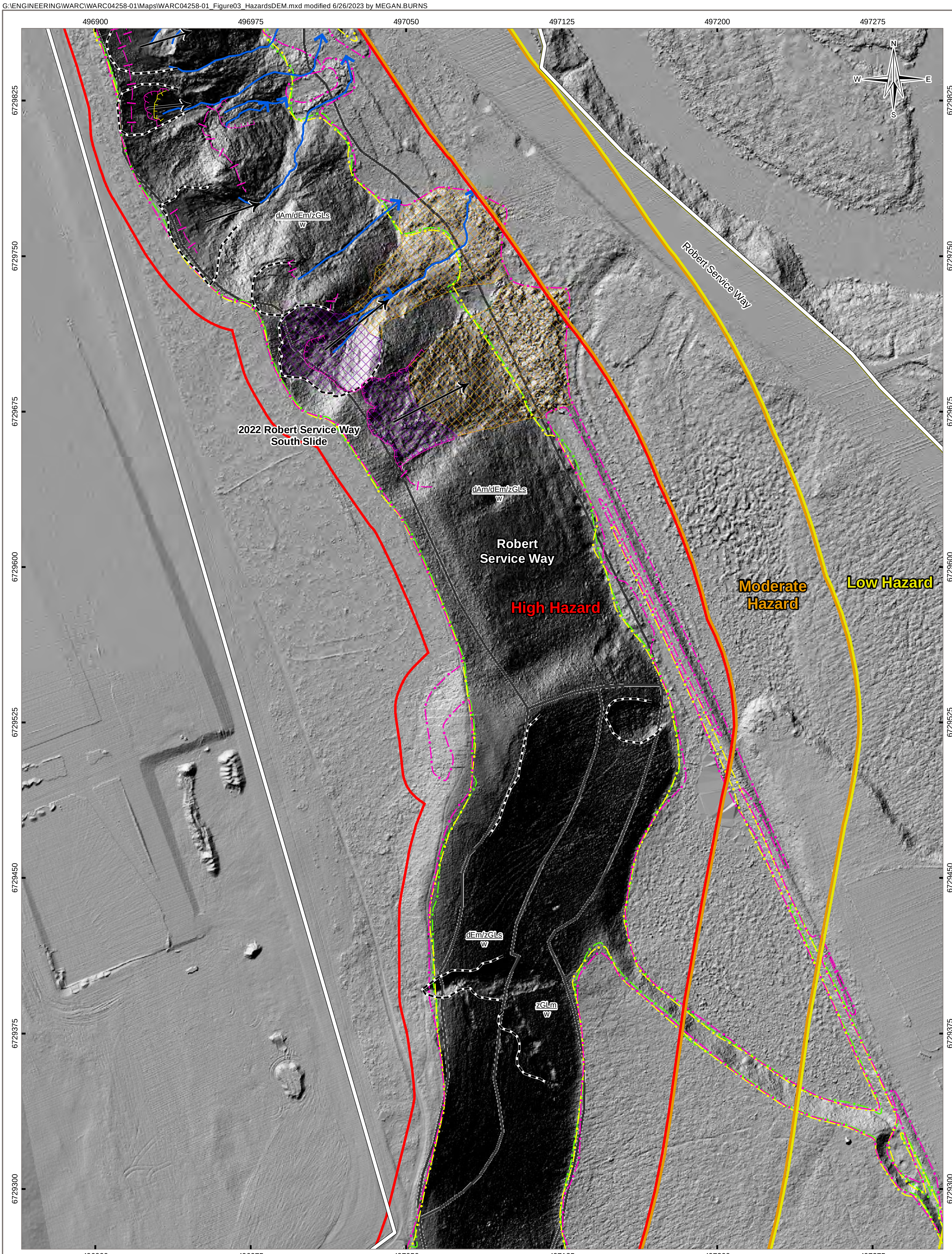

LEGEND

*See attached legend for detailed surficial geology definitions

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone
- Surficial Material

Landslide Hazard Rating

- High
- Moderate
- Low

STATUS
ISSUED FOR USE

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Digital elevation models by Tetra Tech Canada
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 DEM Slope Instability Feature Interpretation and Landslide Hazard Designation

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750

25 12.5 0 25

Metres

TETRA TECH

FILE NO.				
WARC04258-01_Figure03_HazardsDEM.mxd				
OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1
DATE	PROJECT NO.			
June 26, 2023	ENG.WARC04258-01			

Figure 3a

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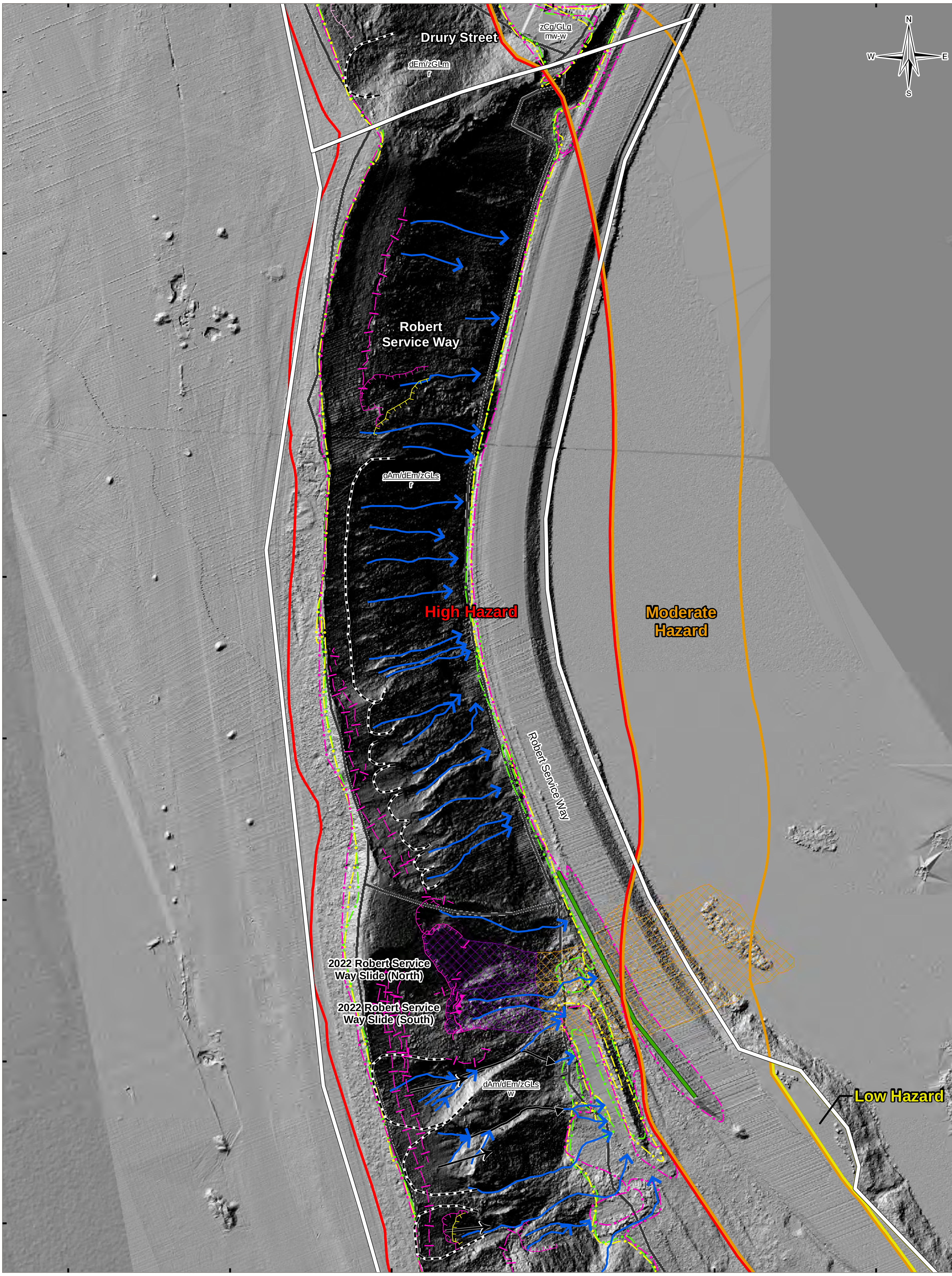


LEGEND

*See attached legend for detailed surficial geology definitions

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Sheet-Pile Wall
- Slope Monitoring Zone
- Surficial Material

Landslide Hazard Rating

- High
- Moderate
- Low

STATUS
ISSUED FOR USE

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Digital elevation models by Tetra Tech Canada
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 DEM
Slope Instability Feature Interpretation and Landslide Hazard Designation

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

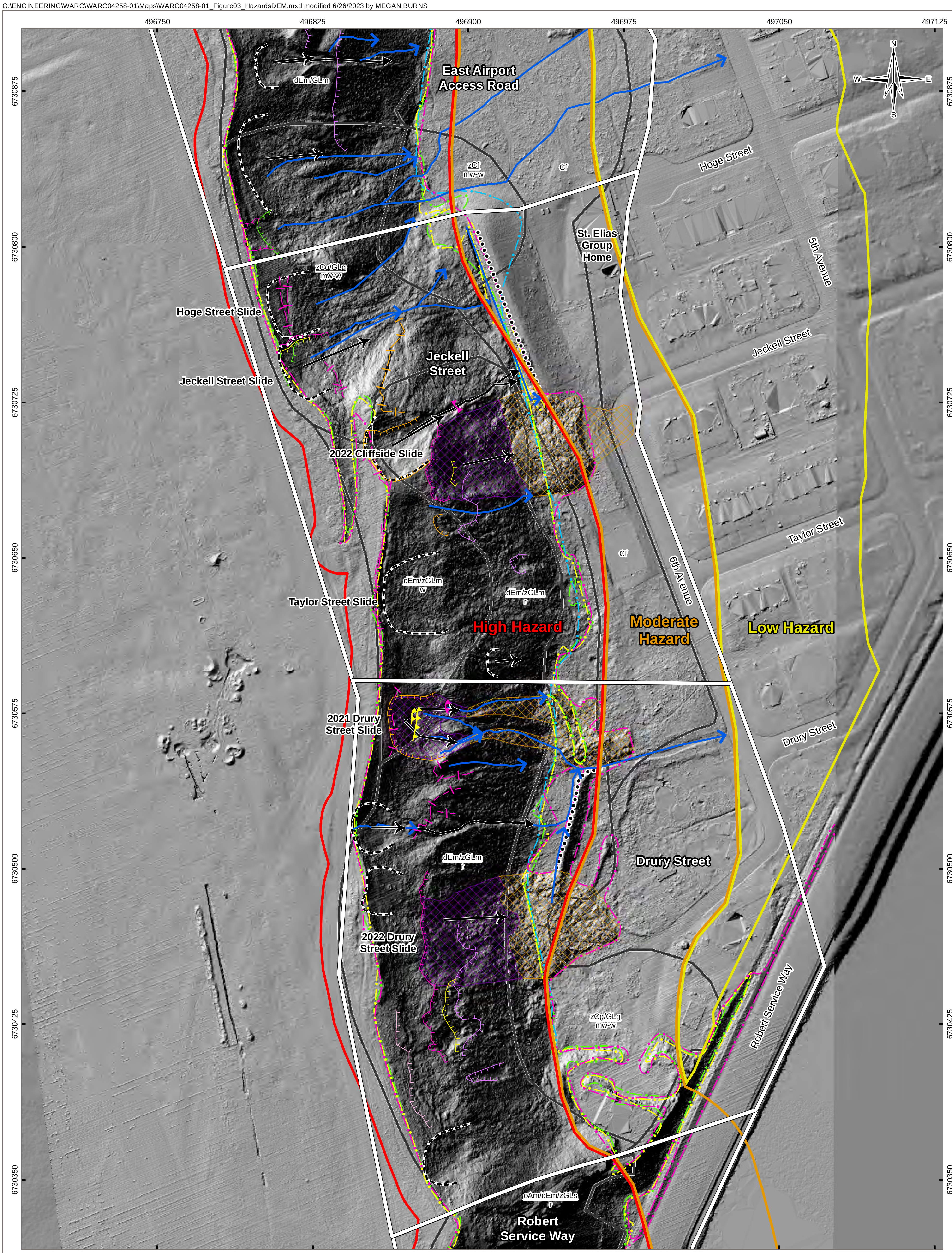
FILE NO.
WARC04258-01_Figure03_HazardsDEM.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 3b



LEGEND

*See attached legend for detailed surficial geology definitions

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone
- Surficial Material

Landslide Hazard Rating

- High
- Moderate
- Low

STATUS
ISSUED FOR USE

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Digital elevation models by Tetra Tech Canada
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 DEM Slope Instability Feature Interpretation and Landslide Hazard Designation

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure03_HazardsDEM.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

TETRA TECH

Figure 3c

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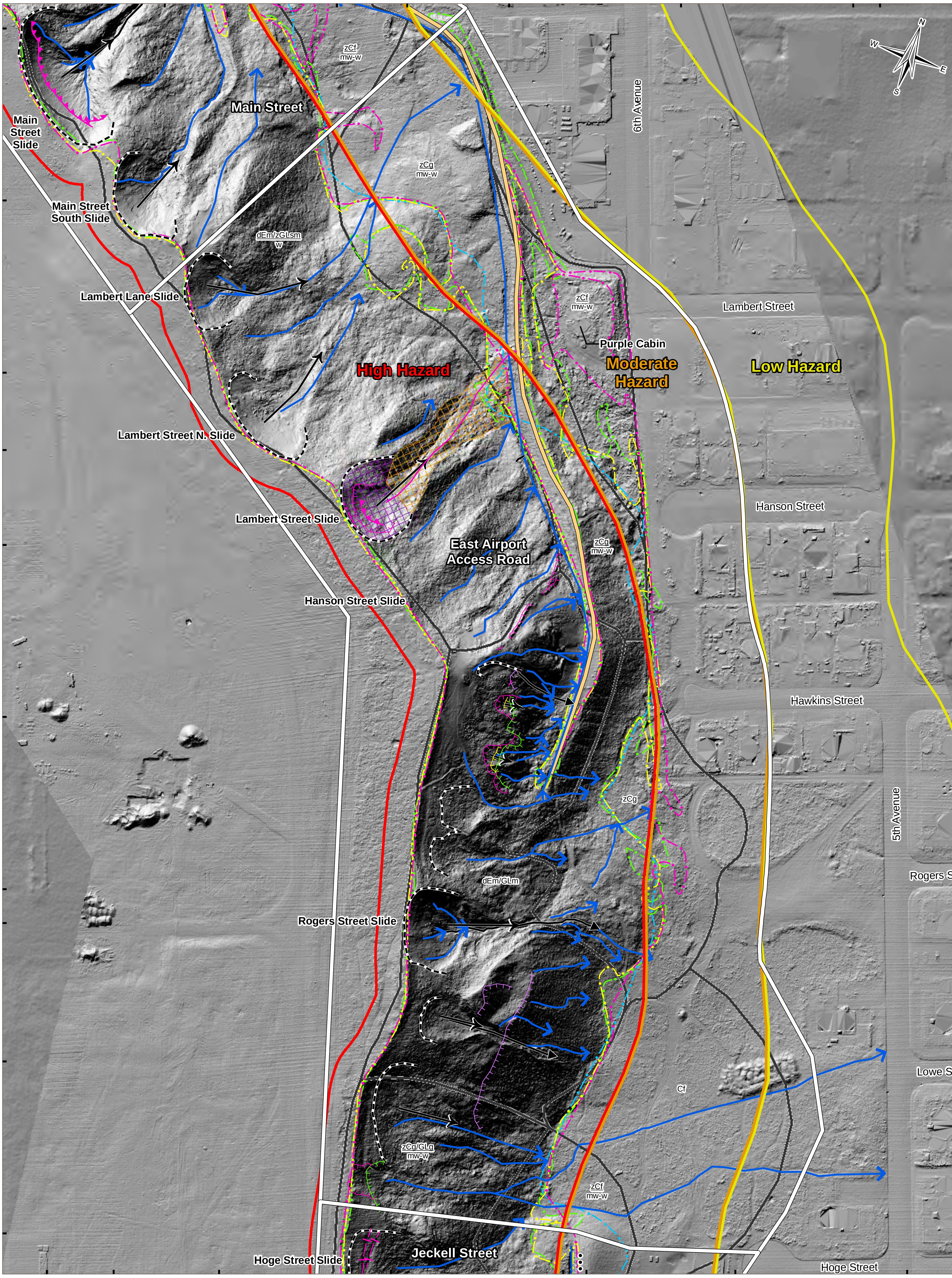

LEGEND

*See attached legend for detailed surficial geology definitions

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- East Airport Access
- Slope Monitoring Zone
- Surficial Material

Landslide Hazard Rating

- High
- Moderate
- Low

STATUS
ISSUED FOR USE

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Digital elevation models by Tetra Tech Canada
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 DEM Slope Instability Feature Interpretation and Landslide Hazard Designation

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750 — 25 12.5 0 25 Metres

FILE NO.
WARC04258-01_Figure03_HazardsDEM.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

TETRA TECH

Figure 3d

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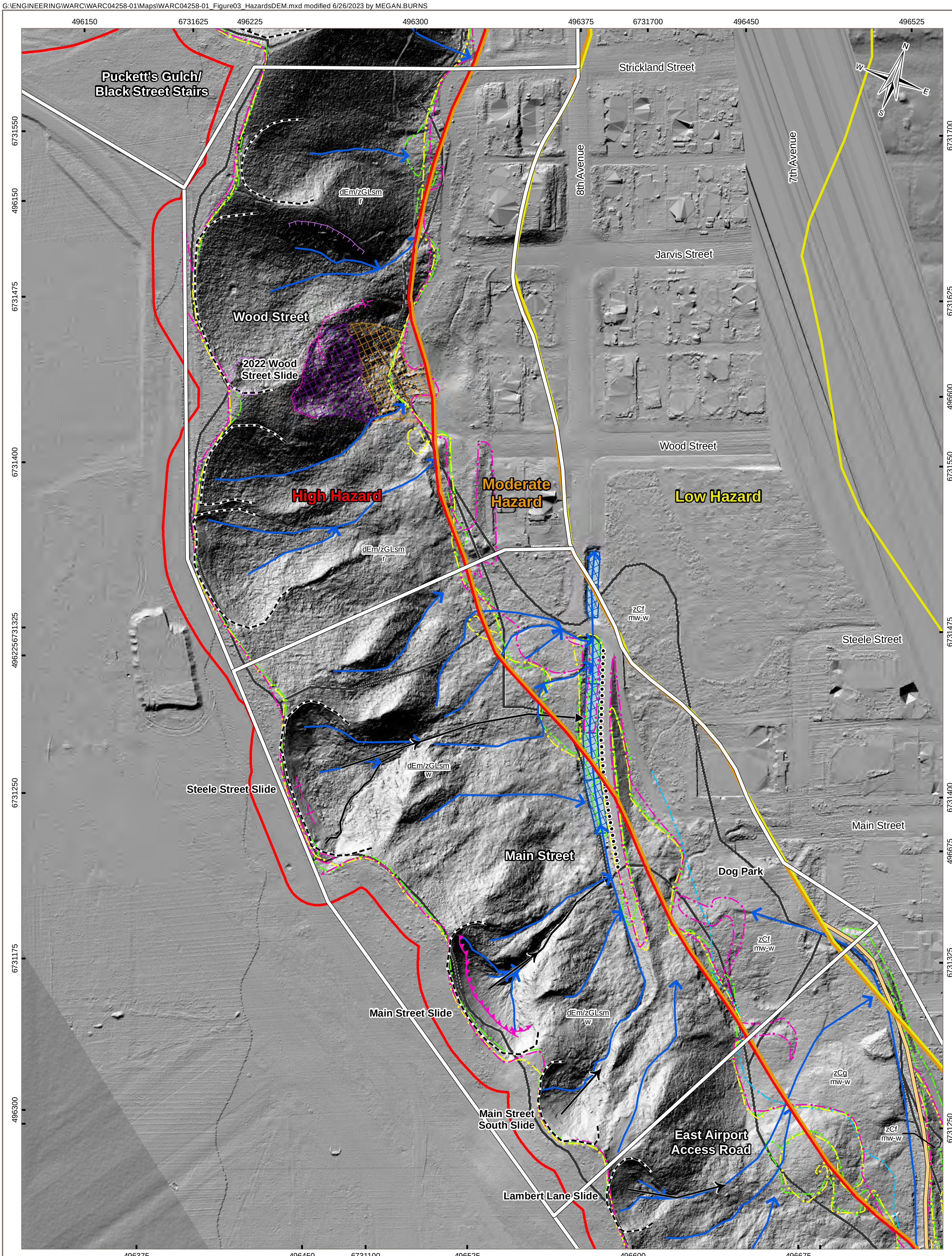


LEGEND

*See attached legend for detailed surficial geology definitions

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- East Airport Access
- Settling Pond
- Slope Monitoring Zone
- Surficial Material

Landslide Hazard Rating

- High
- Moderate
- Low

STATUS
ISSUED FOR USE

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Digital elevation models by Tetra Tech Canada
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 DEM Slope Instability Feature Interpretation and Landslide Hazard Designation

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

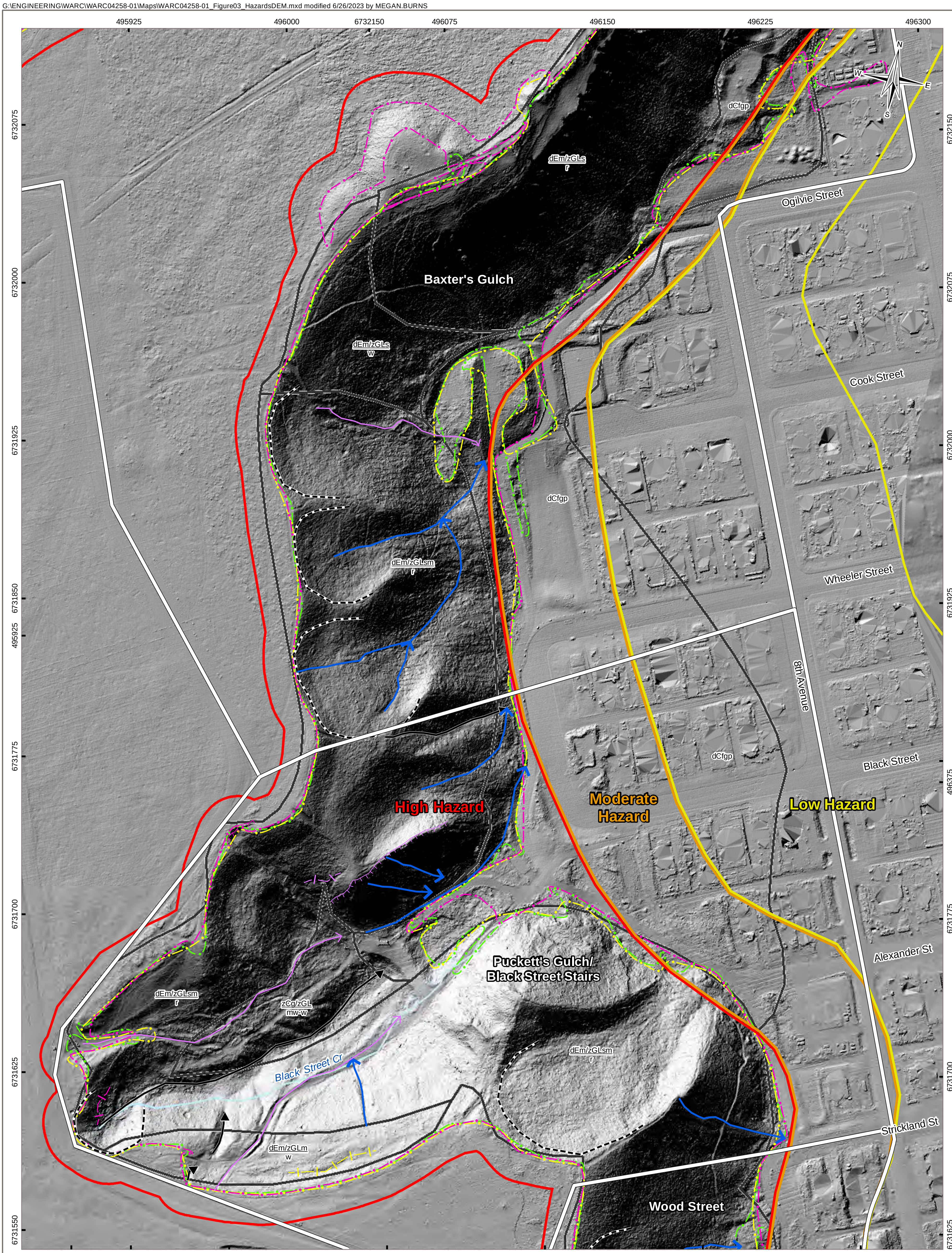
FILE NO.
WARC04258-01_Figure03_HazardsDEM.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

TETRA TECH

Figure 3e



LEGEND

*See attached legend for detailed surficial geology definitions

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone
- Surficial Material

Landslide Hazard Rating

- High
- Moderate
- Low

Base Data

- Watercourse

STATUS
ISSUED FOR USE

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Digital elevation models by Tetra Tech Canada
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 DEM
Slope Instability Feature Interpretation and Landslide Hazard Designation

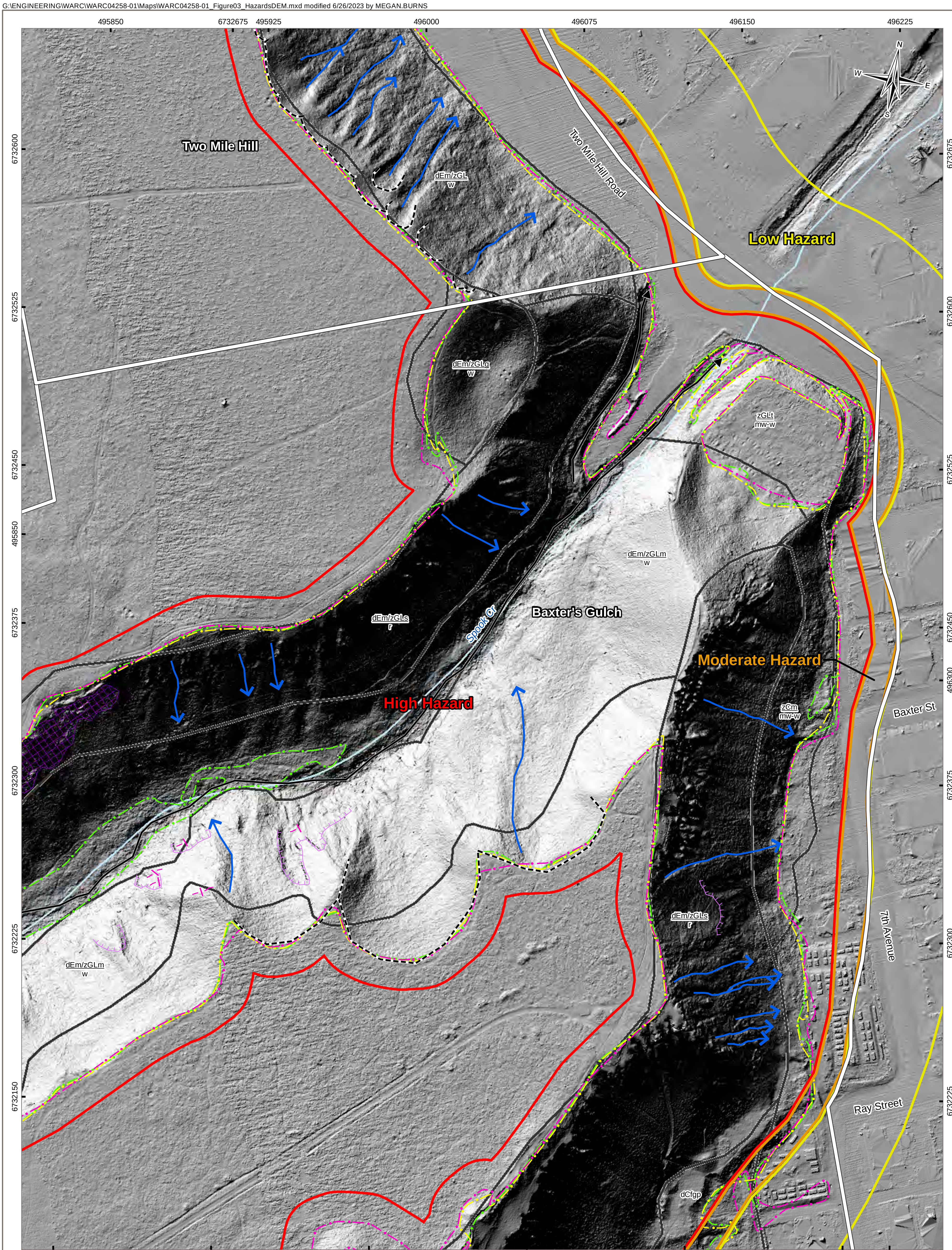
PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse THE WILDERNESS CITY

Scale: 1:1,750
25 12.5 0 25
Metres

TETRA TECH

FILE NO.				
WARC04258-01_Figure03_HazardsDEM.mxd				
OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1
DATE	PROJECT NO.			
June 26, 2023	ENG.WARC04258-01			

Figure 3f



LEGEND

*See attached legend for detailed surficial geology definitions

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone
- Surficial Material

Landslide Hazard Rating

- High
- Moderate
- Low

Base Data

- Watercourse

STATUS
ISSUED FOR USE

OVERVIEW

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Digital elevation models by Tetra Tech Canada
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 DEM
Slope Instability Feature Interpretation and Landslide Hazard Designation

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse THE WILDERNESS CITY

Scale: 1:1,750
25 12.5 0 25
Metres

TETRA TECH

FILE NO.
WARC04258-01_Figure03_HazardsDEM.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 3g

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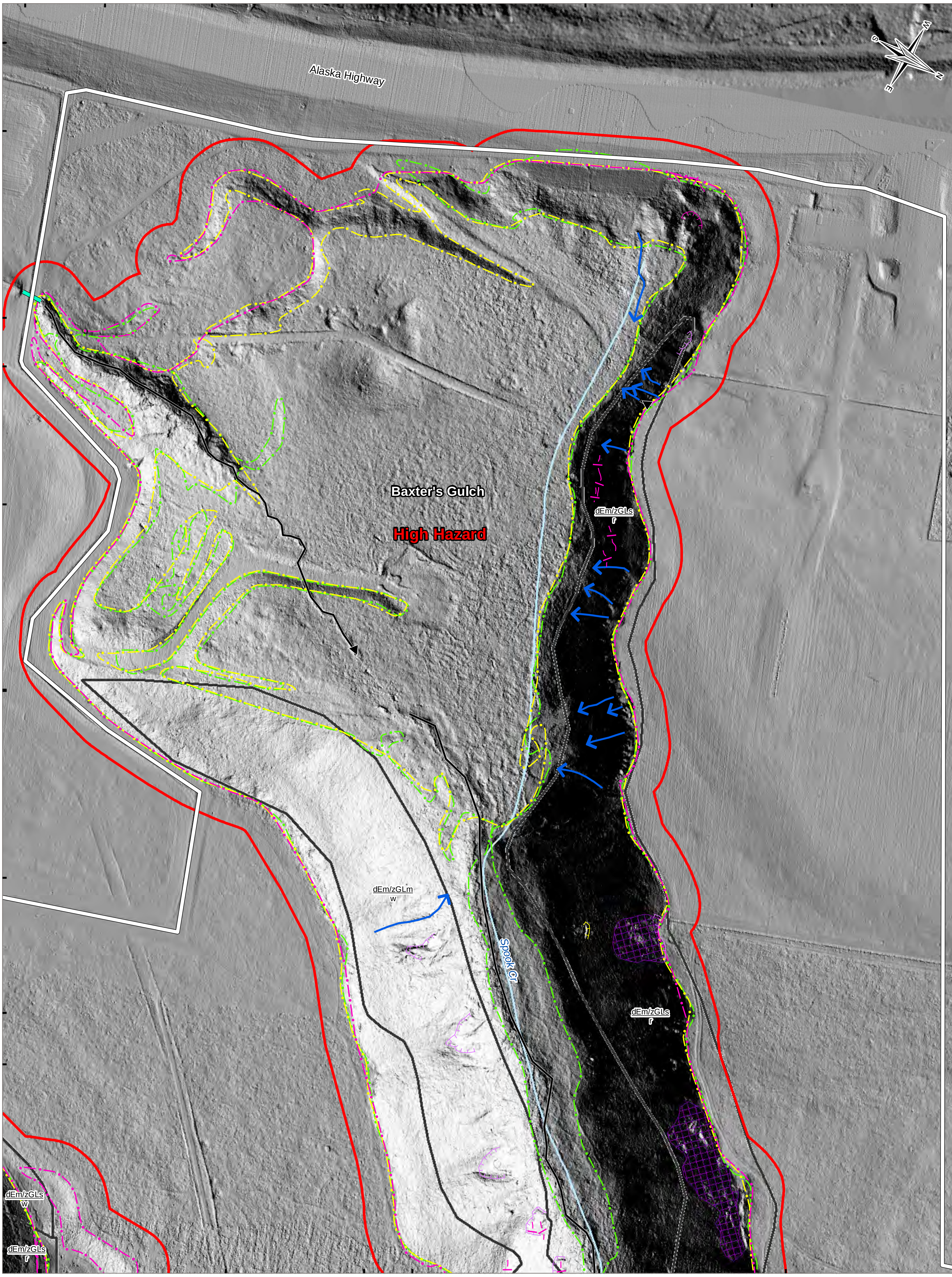

LEGEND

*See attached legend for detailed surficial geology definitions

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Culvert
- Slope Monitoring Zone
- Surficial Material

Landslide Hazard Rating

- High

Base Data

- Watercourse

STATUS
ISSUED FOR USE

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Digital elevation models by Tetra Tech Canada
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 DEM Slope Instability Feature Interpretation and Landslide Hazard Designation

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure03_HazardsDEM.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

TETRA TECH

Figure 3h

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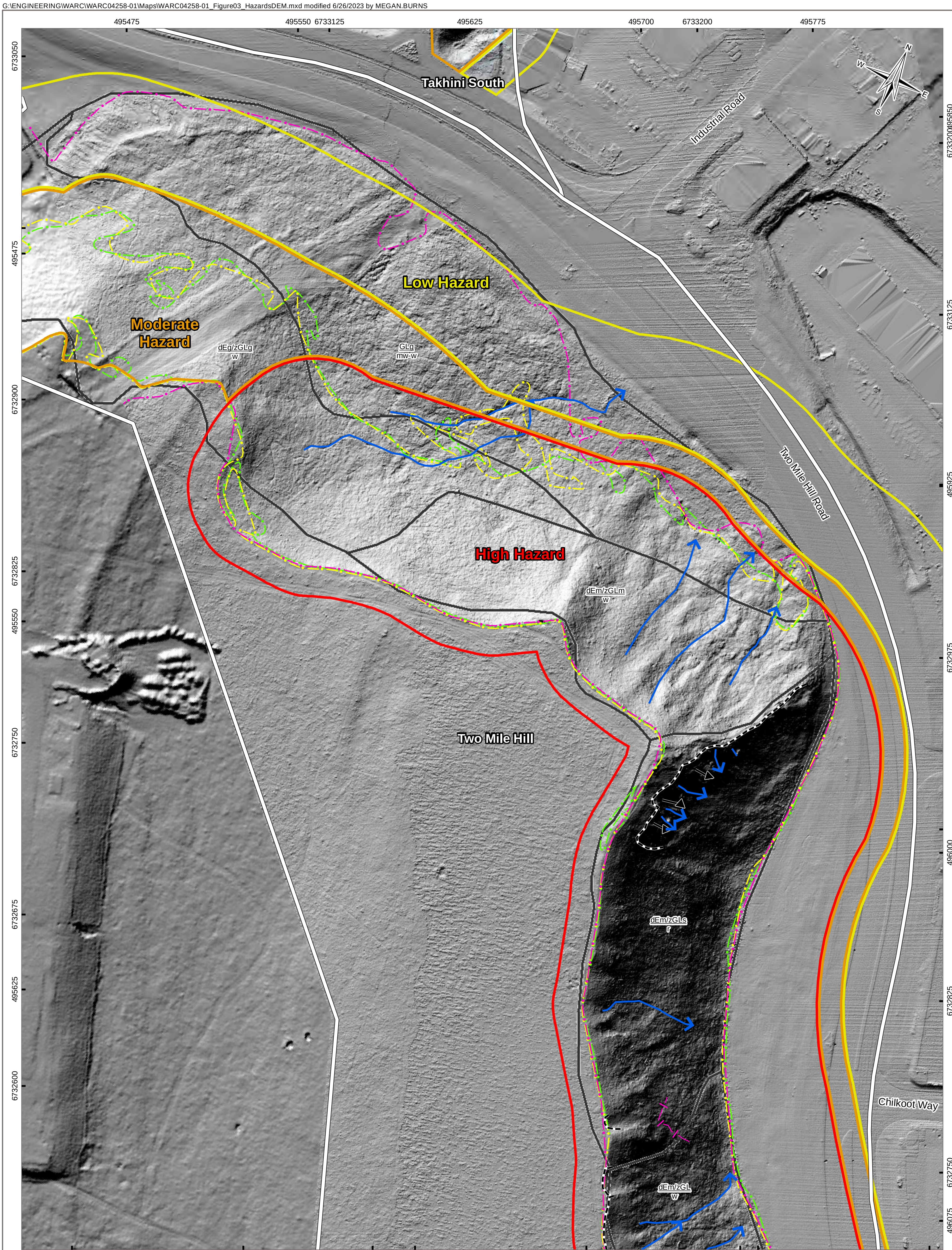

LEGEND

*See attached legend for detailed surficial geology definitions

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone
- Surficial Material

Landslide Hazard Rating

- High
- Moderate
- Low

Base Data

- Watercourse

STATUS
ISSUED FOR USE

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Digital elevation models by Tetra Tech Canada
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 DEM
Slope Instability Feature Interpretation and Landslide Hazard Designation

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure03_HazardsDEM.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 3i

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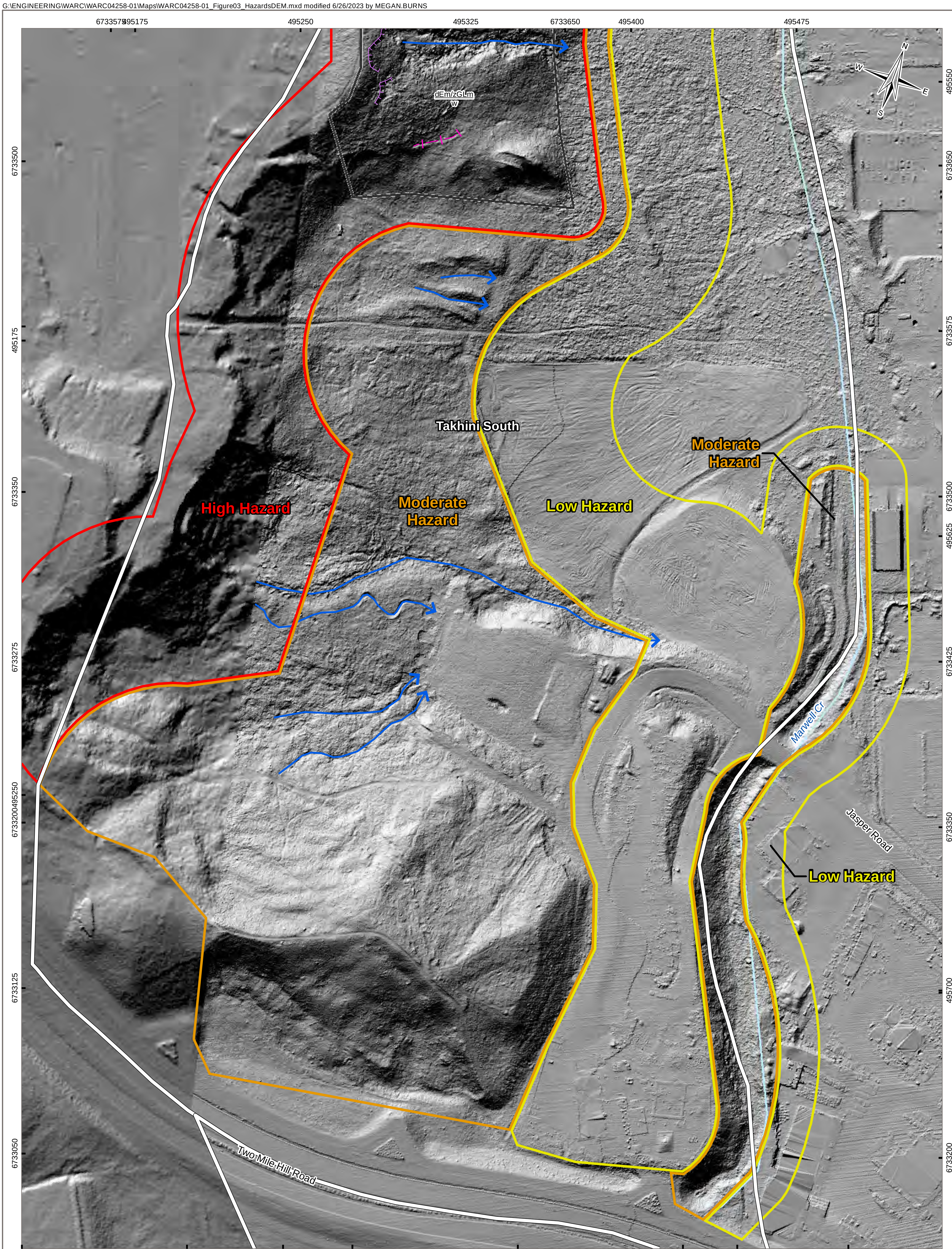

LEGEND

*See attached legend for detailed surficial geology definitions

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone
- Surficial Material

Landslide Hazard Rating

- High
- Moderate
- Low

Base Data

- Watercourse

STATUS
ISSUED FOR USE

OVERVIEW

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Digital elevation models by Tetra Tech Canada
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 DEM Slope Instability Feature Interpretation and Landslide Hazard Designation

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

TETRA TECH

FILE NO.
WARC04258-01_Figure03_HazardsDEM.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 3j

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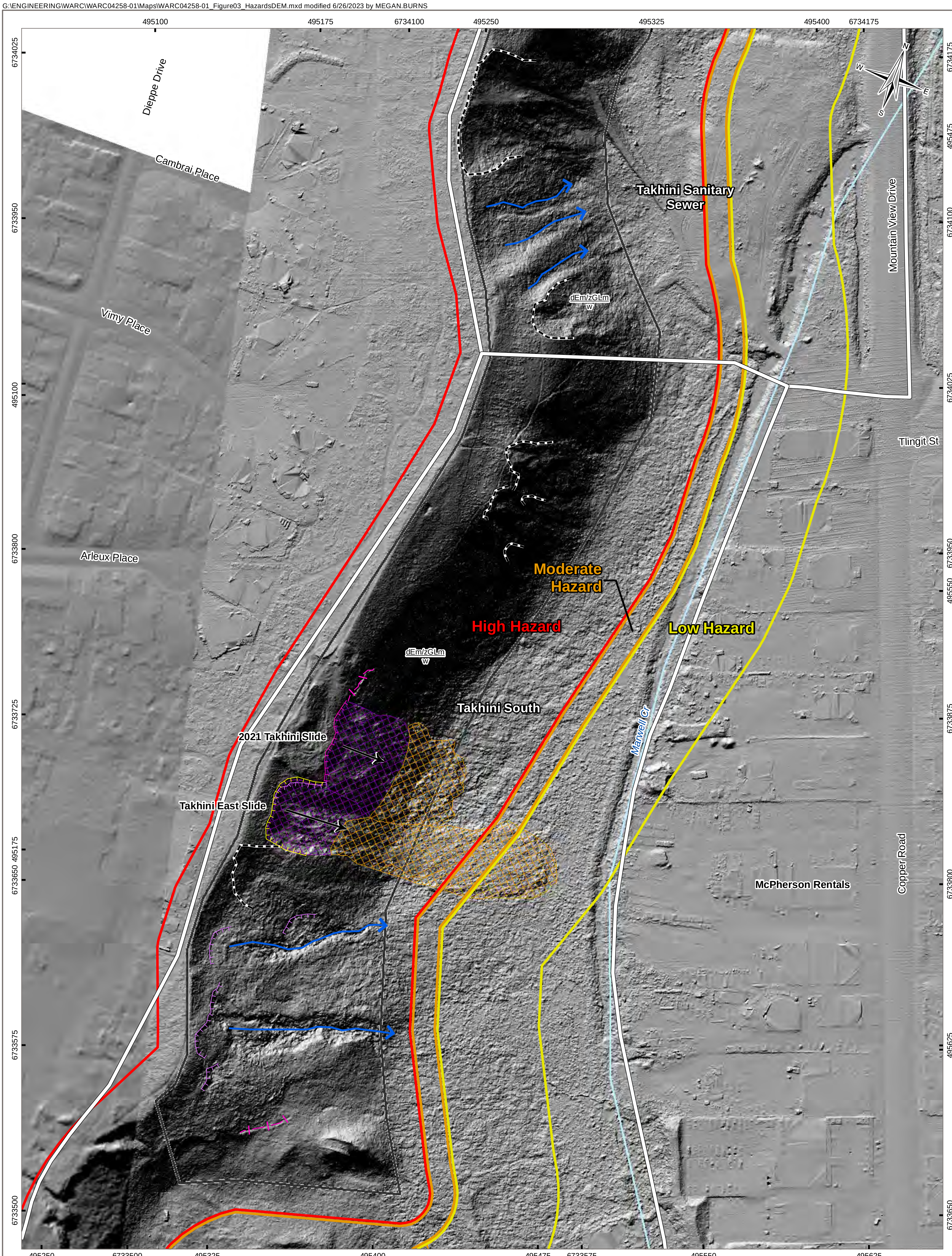

LEGEND

*See attached legend for detailed surficial geology definitions

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone
- Surficial Material

Landslide Hazard Rating

- High
- Moderate
- Low

Base Data

- Watercourse

STATUS
ISSUED FOR USE

OVERVIEW

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Digital elevation models by Tetra Tech Canada
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 DEM Slope Instability Feature Interpretation and Landslide Hazard Designation

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure03_HazardsDEM.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 3k

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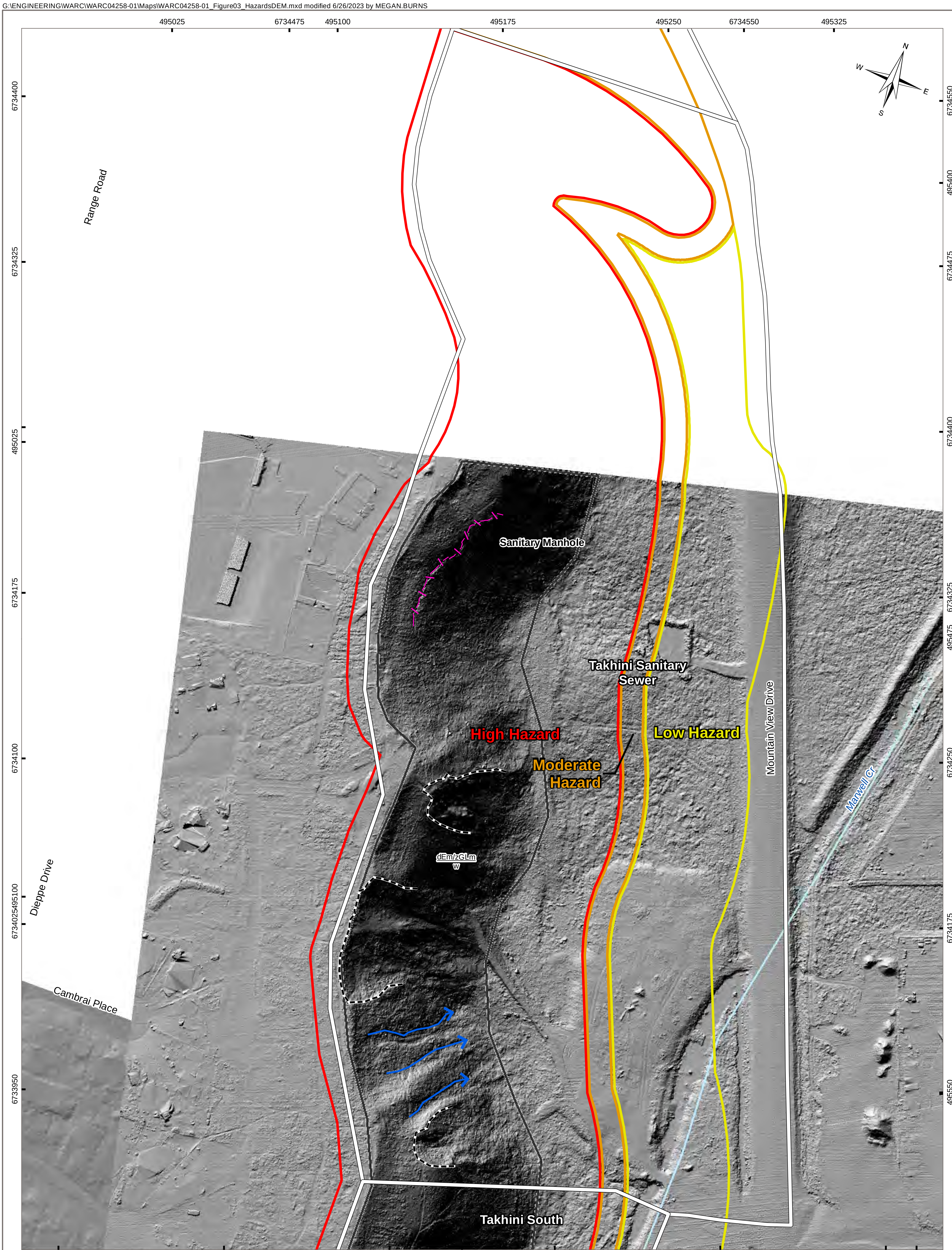


LEGEND

*See attached legend for detailed surficial geology definitions

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone
- Surficial Material

Landslide Hazard Rating

- High
- Moderate
- Low

Base Data

- Watercourse

STATUS
ISSUED FOR USE

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Digital elevation models by Tetra Tech Canada
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 DEM
Slope Instability Feature Interpretation and Landslide Hazard Designation

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

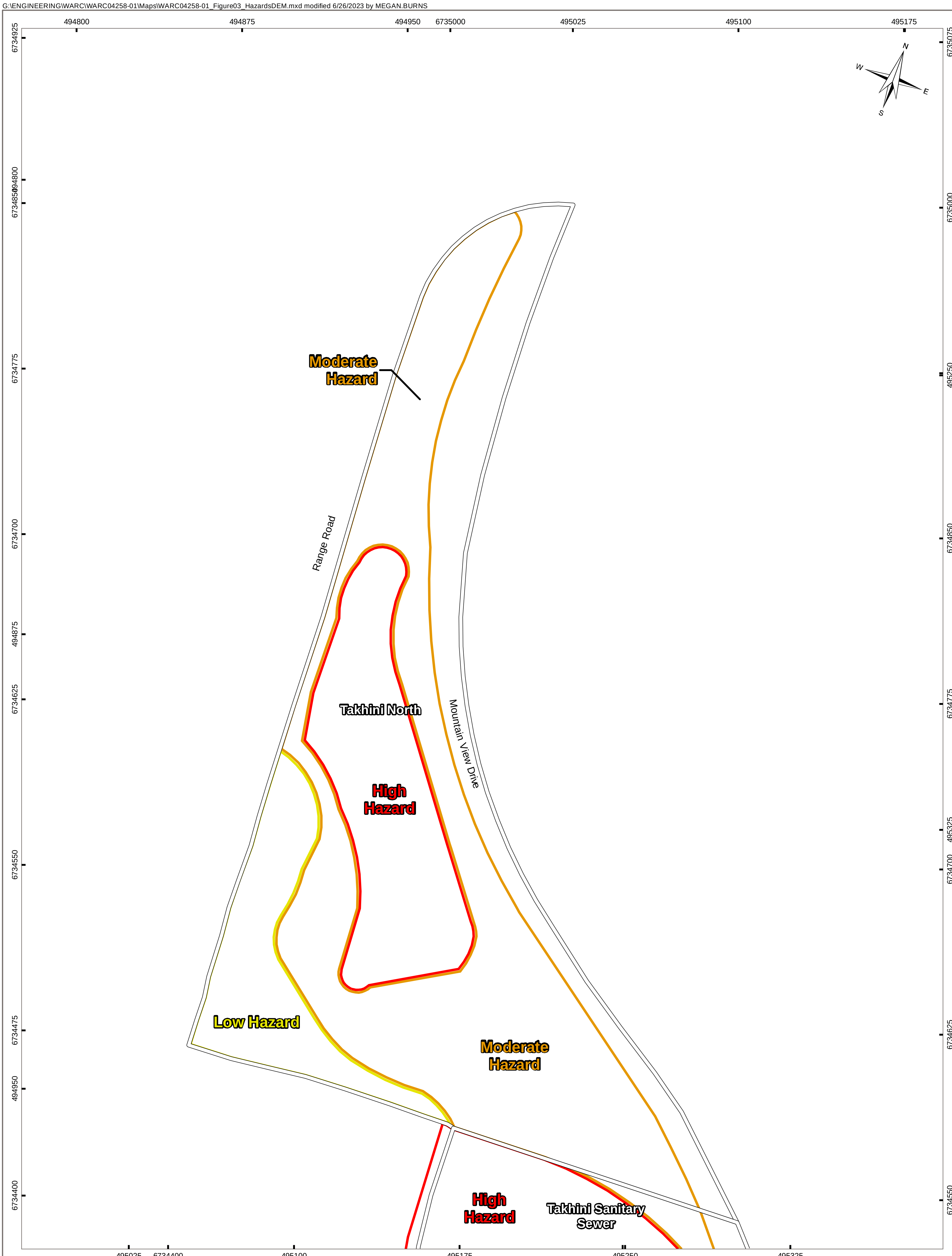
FILE NO.
WARC04258-01_Figure03_HazardsDEM.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 3l



LEGEND

*See attached legend for detailed surficial geology definitions

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

STATUS
ISSUED FOR USE

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Digital elevation models by Tetra Tech Canada
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 DEM Slope Instability Feature Interpretation and Landslide Hazard Designation

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure03_HazardsDEM.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 3m

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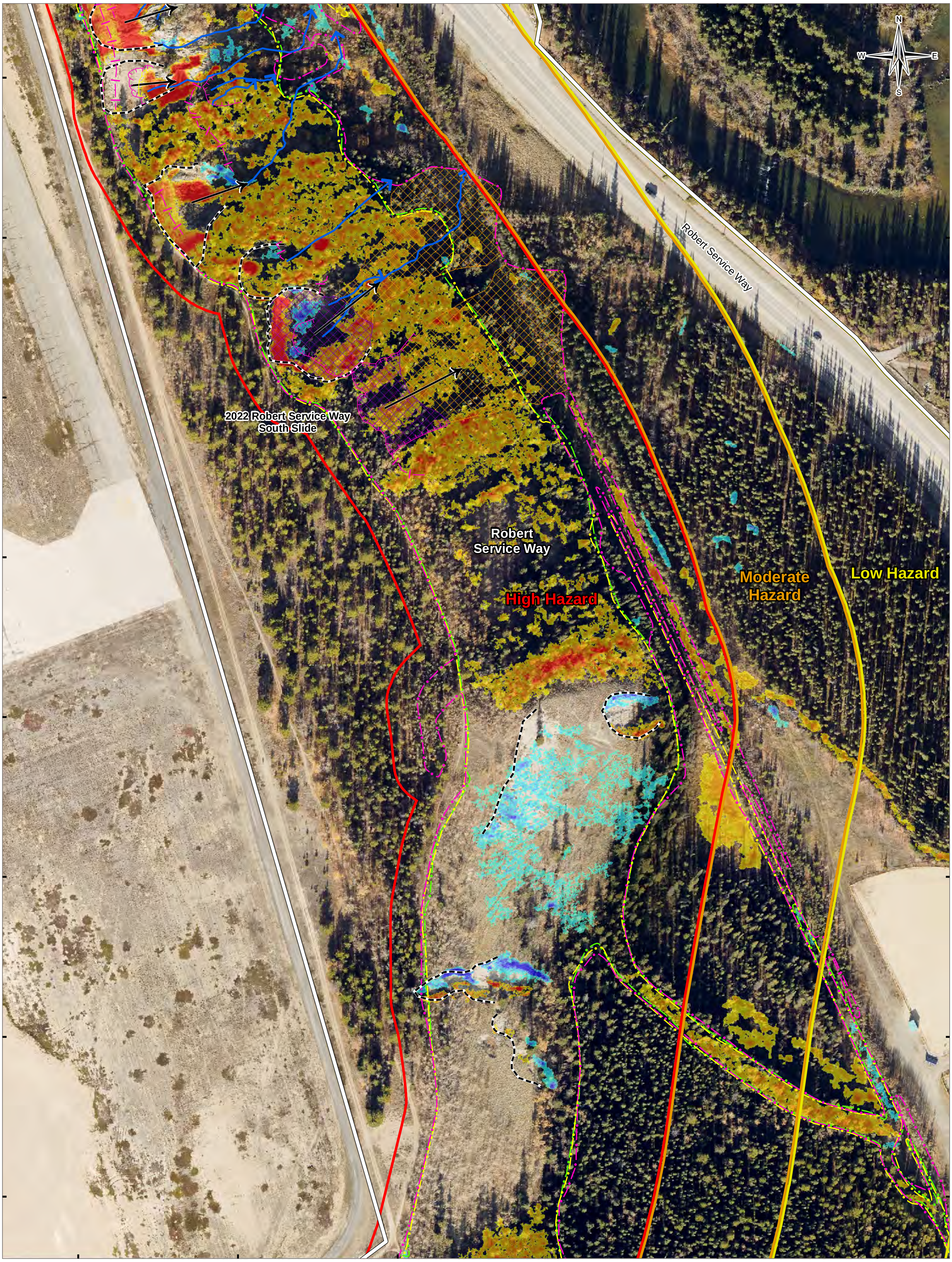

LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

STATUS
ISSUED FOR USE

2013 to 2019 Surface Elevation Change (m)

> 1

< -1

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2019 Imagery 2013-2019 Surface Elevation Change Detection Analysis

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse THE WILDERNESS CITY

Scale: 1:1,750
25 12.5 0 25
Metres

TETRA TECH

FILE NO.				
WARC04258-01_Figure04_ChgDet2019.mxd				
OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1
DATE	PROJECT NO.			
June 26, 2023	ENG.WARC04258-01			

Figure 4a

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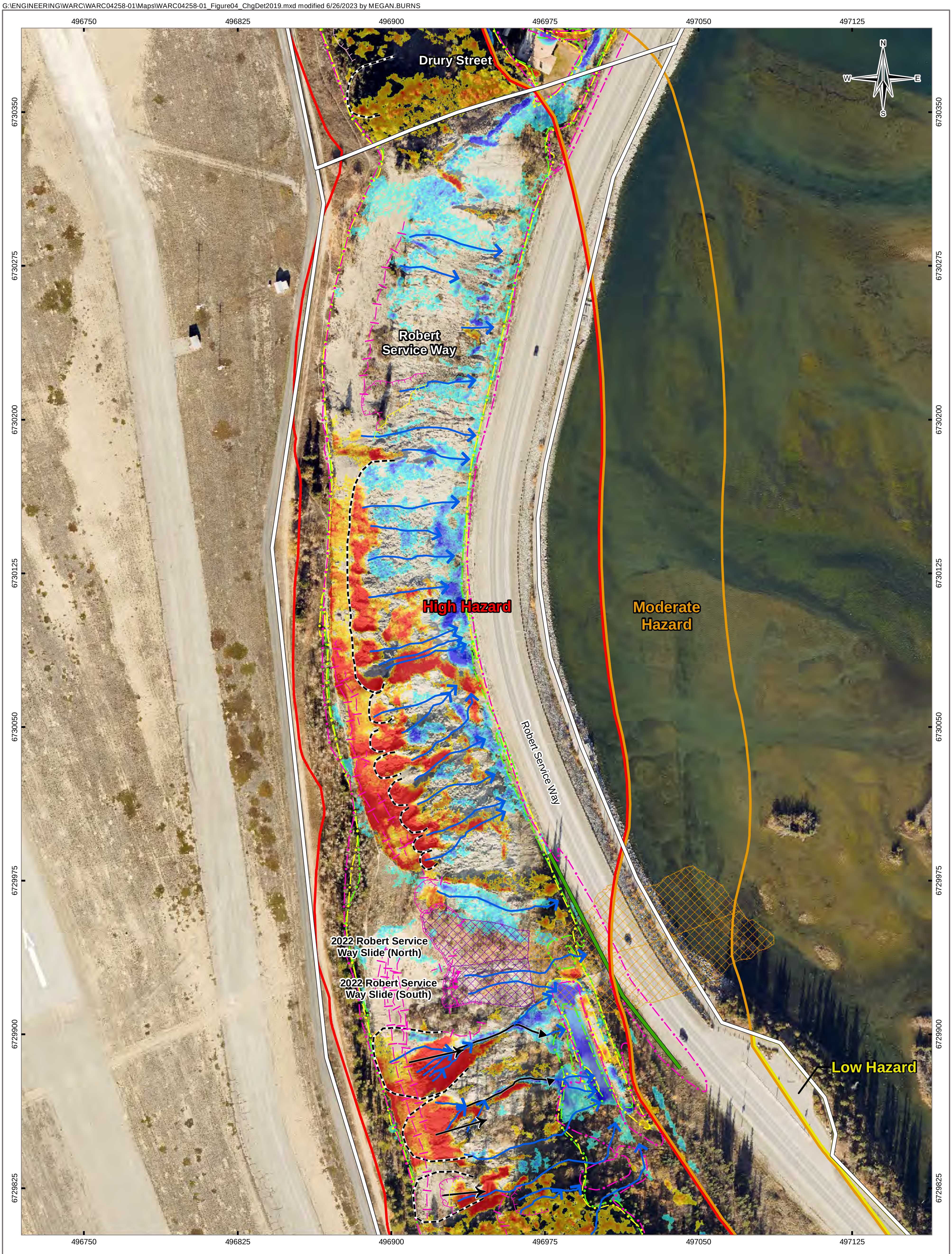

LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Sheet-Pile Wall
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

STATUS
ISSUED FOR USE

2013 to 2019
Surface Elevation Change (m)

> 1
< -1

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2019 Imagery 2013-2019 Surface Elevation Change Detection Analysis

PROJECTION: UTM Zone 8
DATUM: NAD83
CLIENT: Whitehorse — The Wilderness City

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.: WARC04258-01_Figure04_ChgDet2019.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE: June 26, 2023
PROJECT NO.: ENG.WARC04258-01

Figure 4b

G:\ENGINEERING\WARC\WARC04258-01\Maps\WARC04258-01_Figure04_ChgDet2019.mxd modified 6/26/2023 by MEGAN.BURNS

LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

STATUS
ISSUED FOR USE

2013 to 2019
Surface Elevation Change (m)

> 1

< -1

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2019 Imagery 2013-2019 Surface Elevation Change Detection Analysis

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure04_ChgDet2019.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

TETRA TECH

Figure 4c

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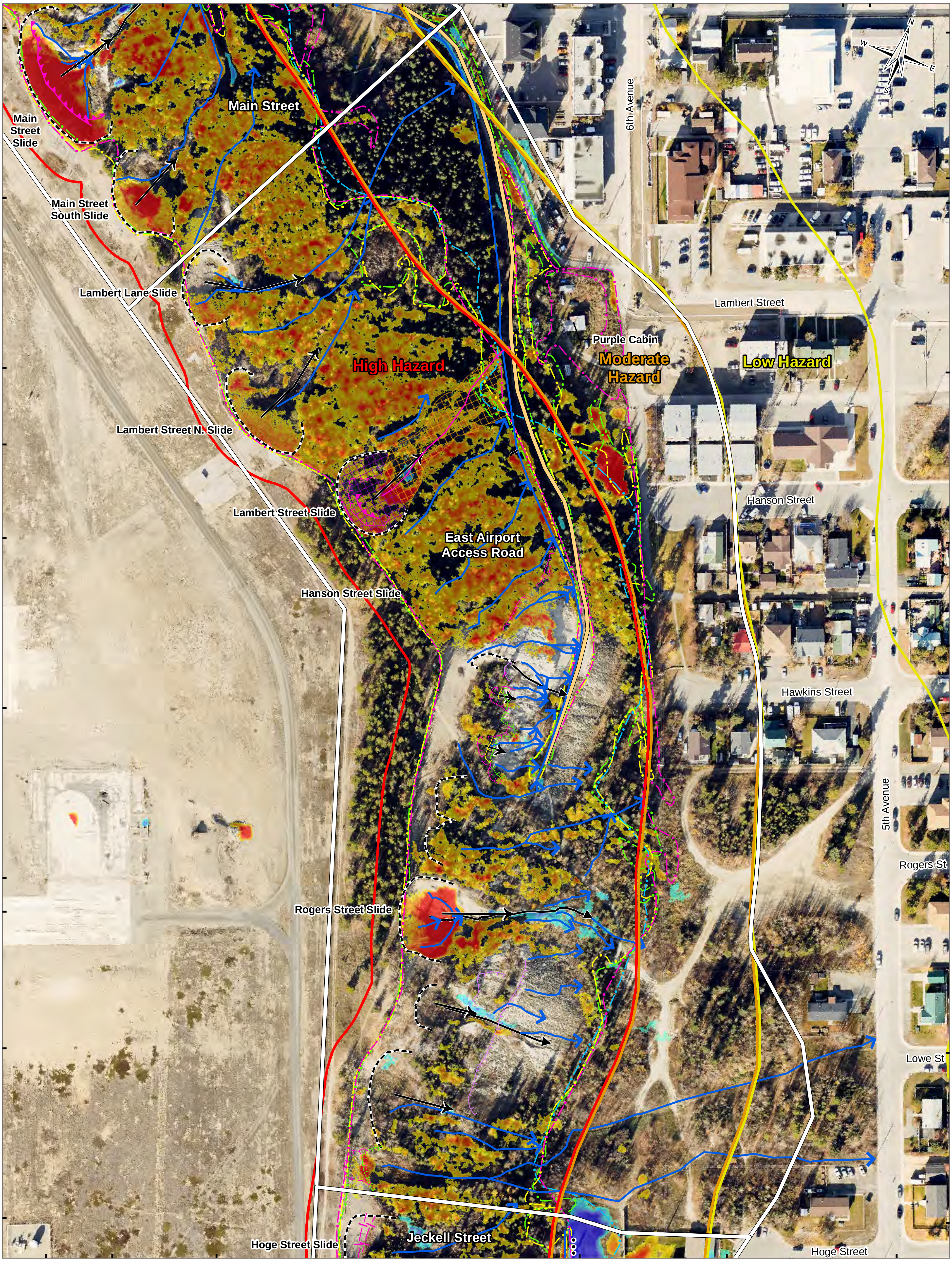

LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- East Airport Access
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

STATUS
ISSUED FOR USE

2013 to 2019 Surface Elevation Change (m)

> 1

< -1

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2019 Imagery 2013-2019 Surface Elevation Change Detection Analysis

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

TETRA TECH

FILE NO.				
WARC04258-01_Figure04_ChgDet2019.mxd				
OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1
DATE	PROJECT NO.			
June 26, 2023	ENG.WARC04258-01			

Figure 4d

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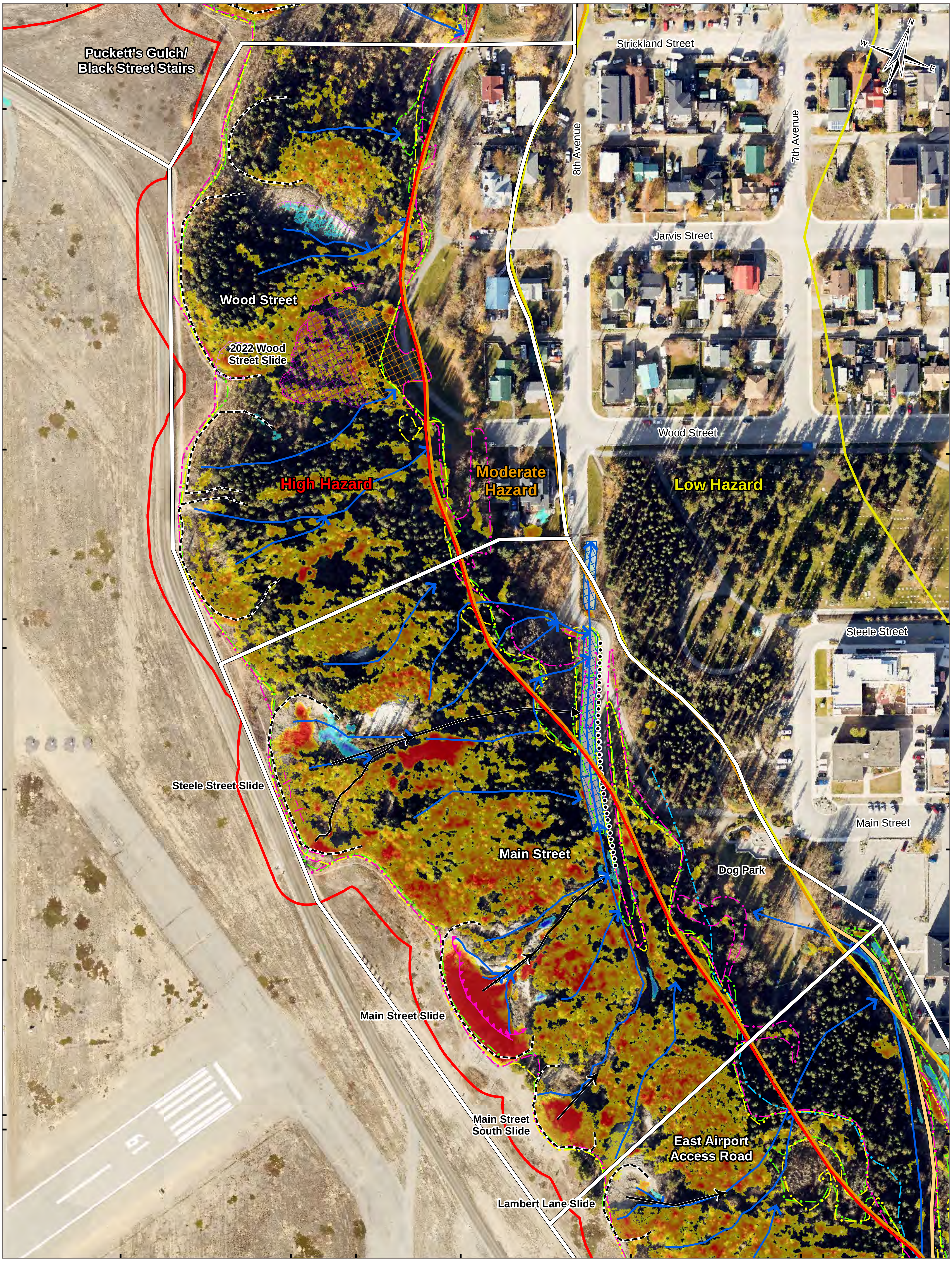


LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scarp - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- East Airport Access
- Settling Pond
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

STATUS
ISSUED FOR USE

2013 to 2019
Surface Elevation Change (m)

> 1

< -1

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2019 Imagery
2013-2019 Surface Elevation Change Detection Analysis

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse THE WILDERNESS CITY

Scale: 1:1,750
25 12.5 0 25
Metres

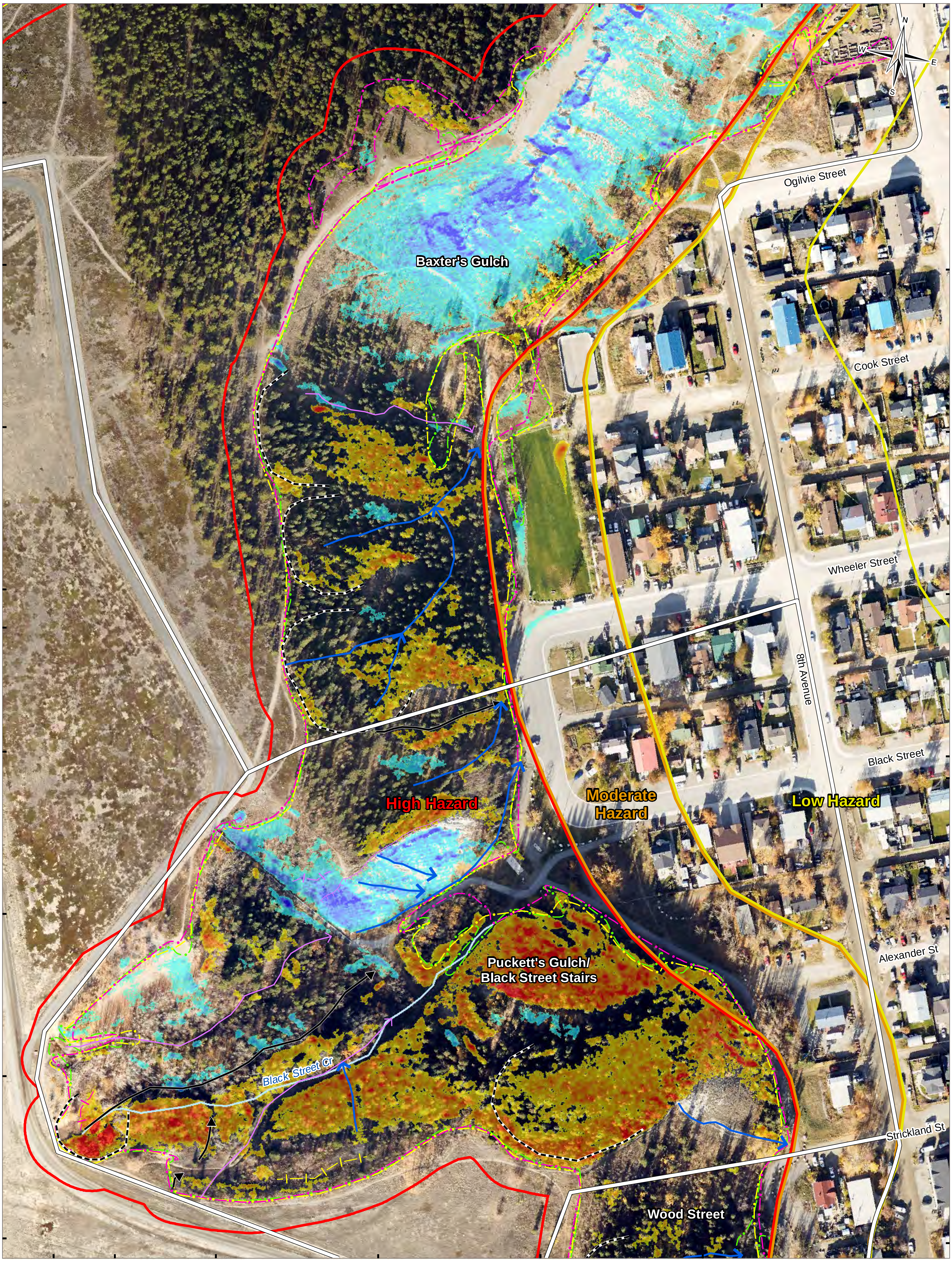
TETRA TECH

FILE NO.
WARC04258-01_Figure04_ChgDet2019.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 4e



LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Base Data

- Watercourse

2013 to 2019 Surface Elevation Change (m)

> 1

< -1

STATUS
ISSUED FOR USE

OVERVIEW

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2019 Imagery 2013-2019 Surface Elevation Change Detection Analysis

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse THE WILDERNESS CITY

Scale: 1:1,750
25 12.5 0 25
Metres

TETRA TECH

FILE NO.				
WARC04258-01_Figure04_ChgDet2019.mxd				
OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1
DATE	PROJECT NO.			
June 26, 2023	ENG.WARC04258-01			

Figure 4f

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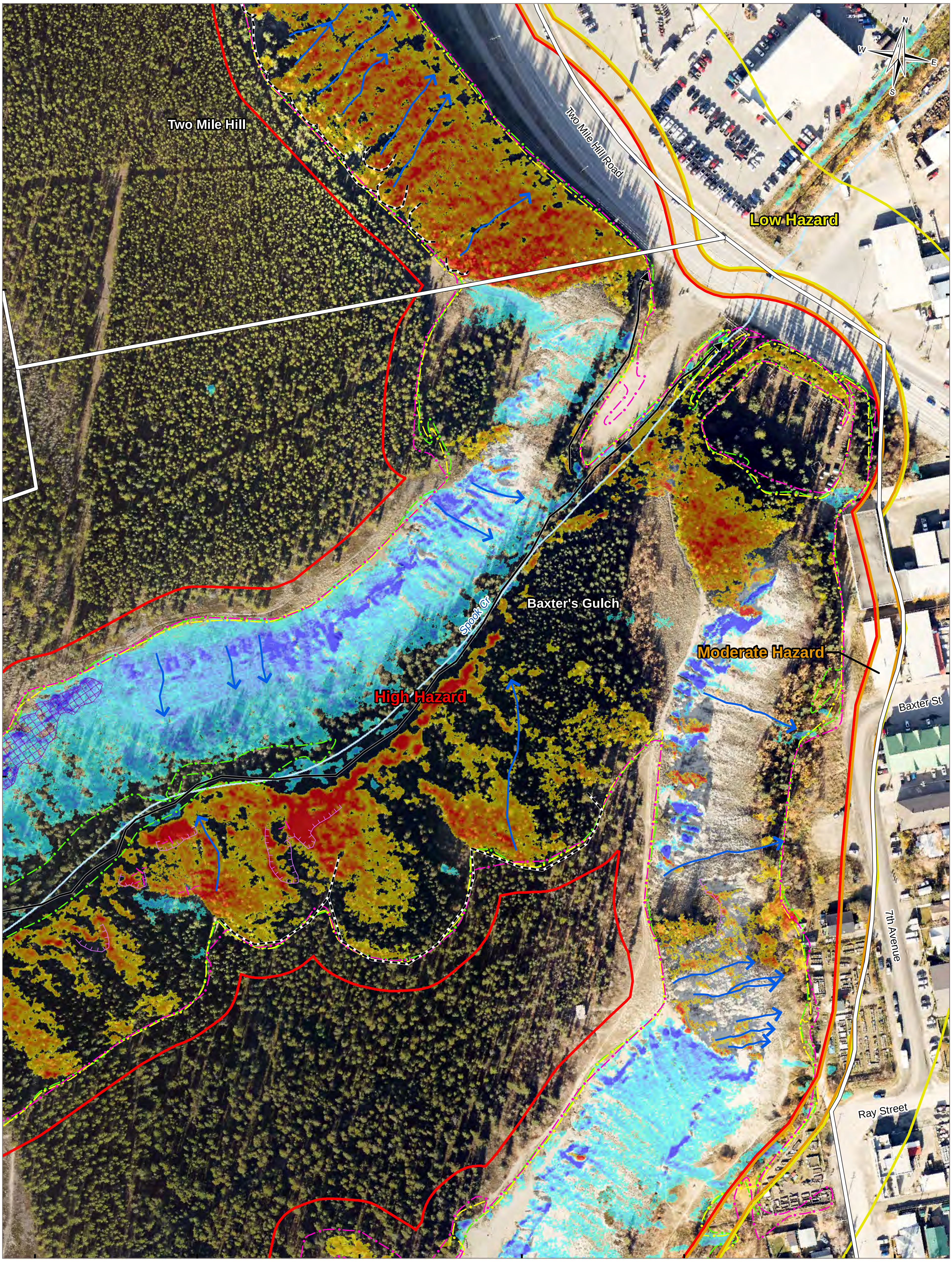


LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Base Data

- Watercourse

2013 to 2019 Surface Elevation Change (m)

> 1

< -1

STATUS
ISSUED FOR USE

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2019 Imagery 2013-2019 Surface Elevation Change Detection Analysis

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse THE WILDERNESS CITY

Scale: 1:1,750

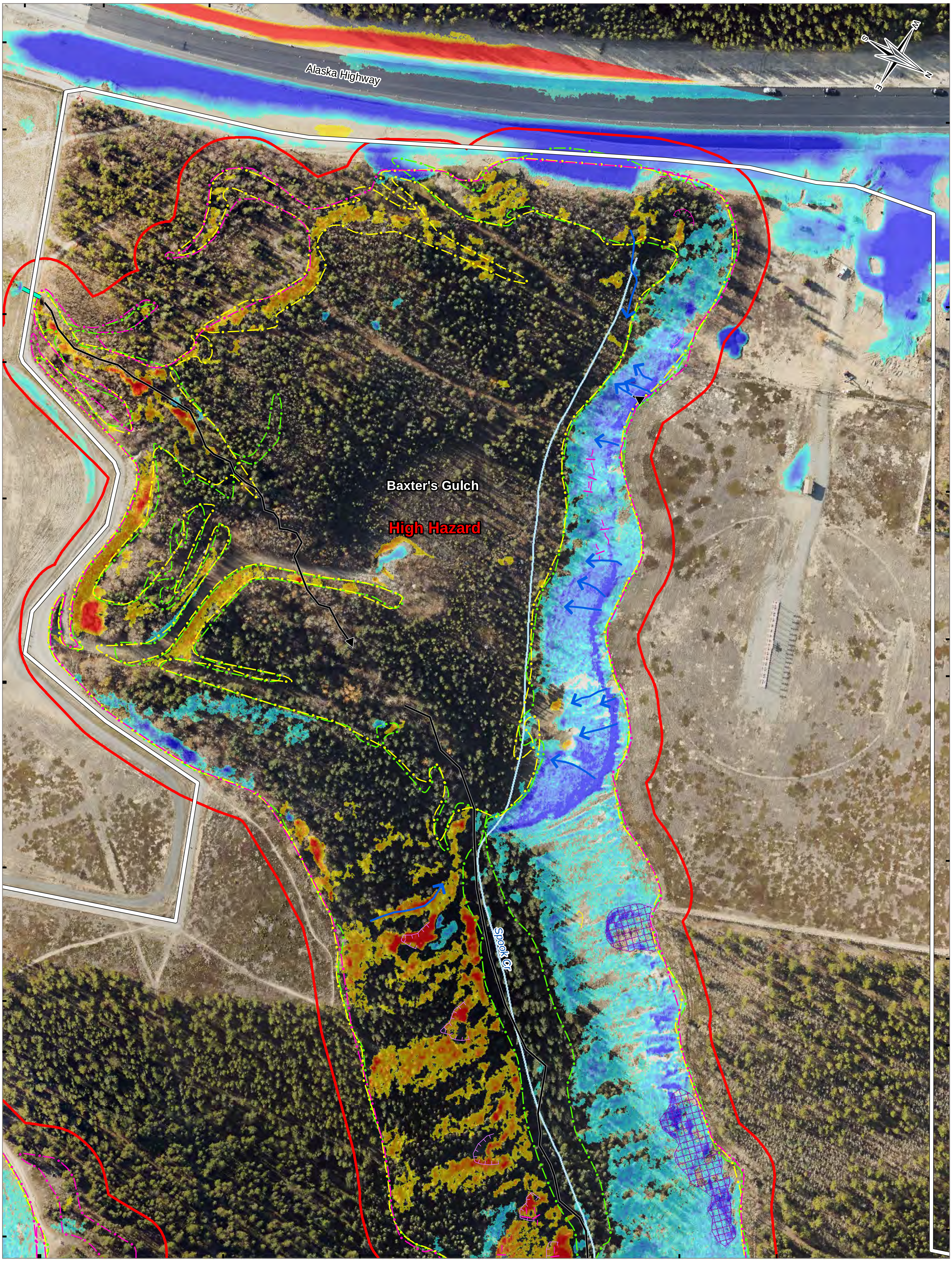
25 12.5 0 25

Metres

TETRA TECH

FILE NO.				
WARC04258-01_Figure04_ChgDet2019.mxd				
OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1
DATE	PROJECT NO.			
June 26, 2023	ENG.WARC04258-01			

Figure 4g



LEGEND

Existing Berm
Gully
Seepage
Toe/Crest of Slope

Mass Movement Features

Debris Flow Headscarp
Landslide Scar - Active
Headscarp - Historical
Tension Crack
Debris Flow Scar
Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

2022
2021
2019
2016
2013
Pre 2013
Pre 2002
Not Dated

Flow Direction
Culvert
Slope Monitoring Zone

Landslide Hazard Rating

High

Base Data

Watercourse

STATUS
ISSUED FOR USE

2013 to 2019 Surface Elevation Change (m)

> 1
< -1

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2019 Imagery 2013-2019 Surface Elevation Change Detection Analysis

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse THE WILDERNESS CITY

Scale: 1:1,750
25 12.5 0 25
Metres

TETRA TECH

FILE NO.				
WARC04258-01_Figure04_ChgDet2019.mxd				
OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1
DATE	PROJECT NO.			
June 26, 2023	ENG.WARC04258-01			

Figure 4h

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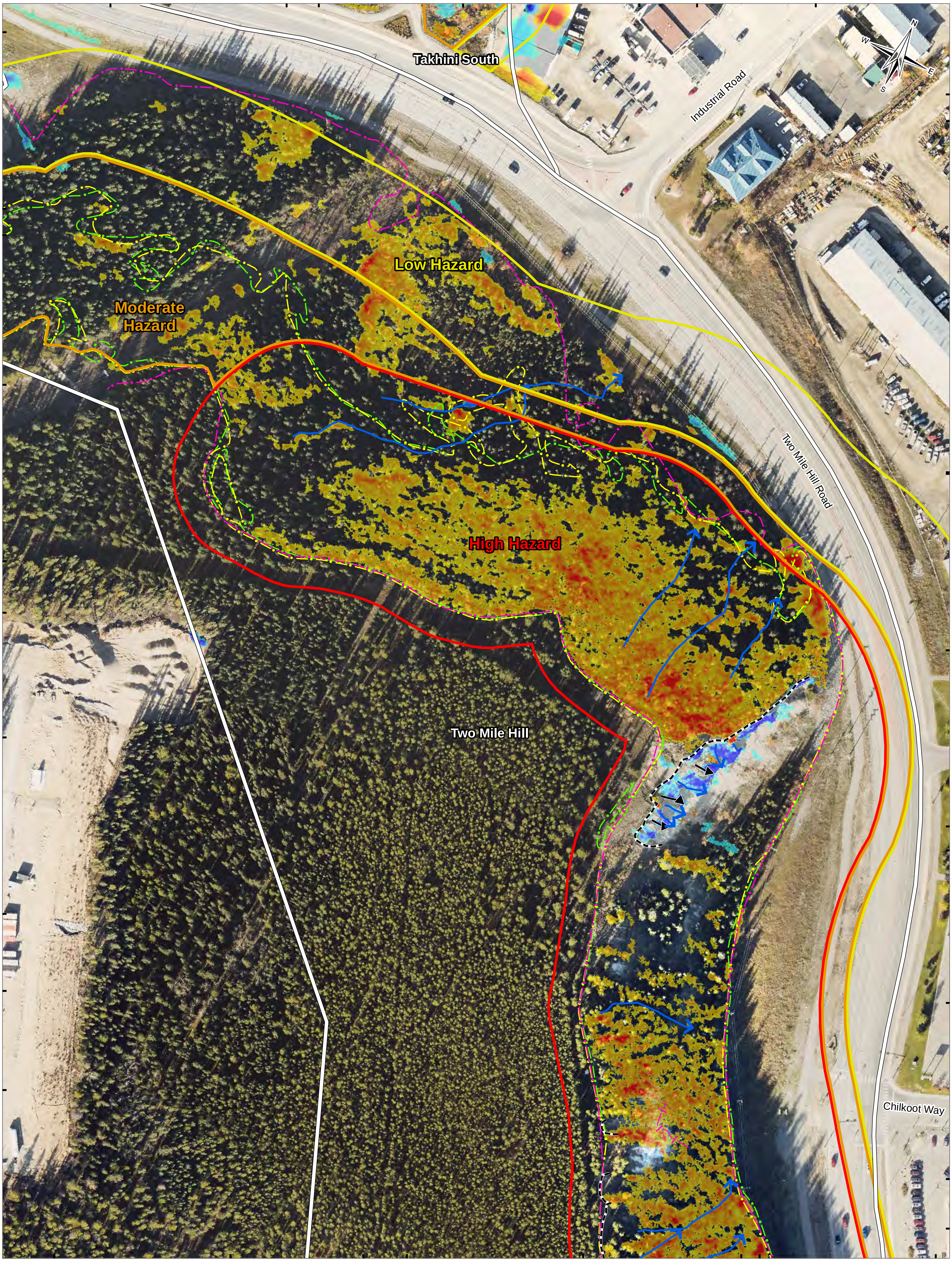

LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Base Data

- Watercourse

STATUS
ISSUED FOR USE

2013 to 2019 Surface Elevation Change (m)

> 1

< -1

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2019 Imagery 2013-2019 Surface Elevation Change Detection Analysis

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750

25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure04_ChgDet2019.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

TETRA TECH

Figure 4i

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LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Base Data

- Watercourse

STATUS
ISSUED FOR USE

2013 to 2019 Surface Elevation Change (m)

> 1

< -1

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2019 Imagery 2013-2019 Surface Elevation Change Detection Analysis

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure04_ChgDet2019.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 4j

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LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Base Data

- Watercourse

2013 to 2019 Surface Elevation Change (m)

> 1

< -1

STATUS
ISSUED FOR USE

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

OVERVIEW

m l k j i h g f e d c b a

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2019 Imagery 2013-2019 Surface Elevation Change Detection Analysis

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

TETRA TECH

FILE NO.				
WARC04258-01_Figure04_ChgDet2019.mxd				
OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1
DATE	PROJECT NO.			
June 26, 2023	ENG.WARC04258-01			

Figure 4k

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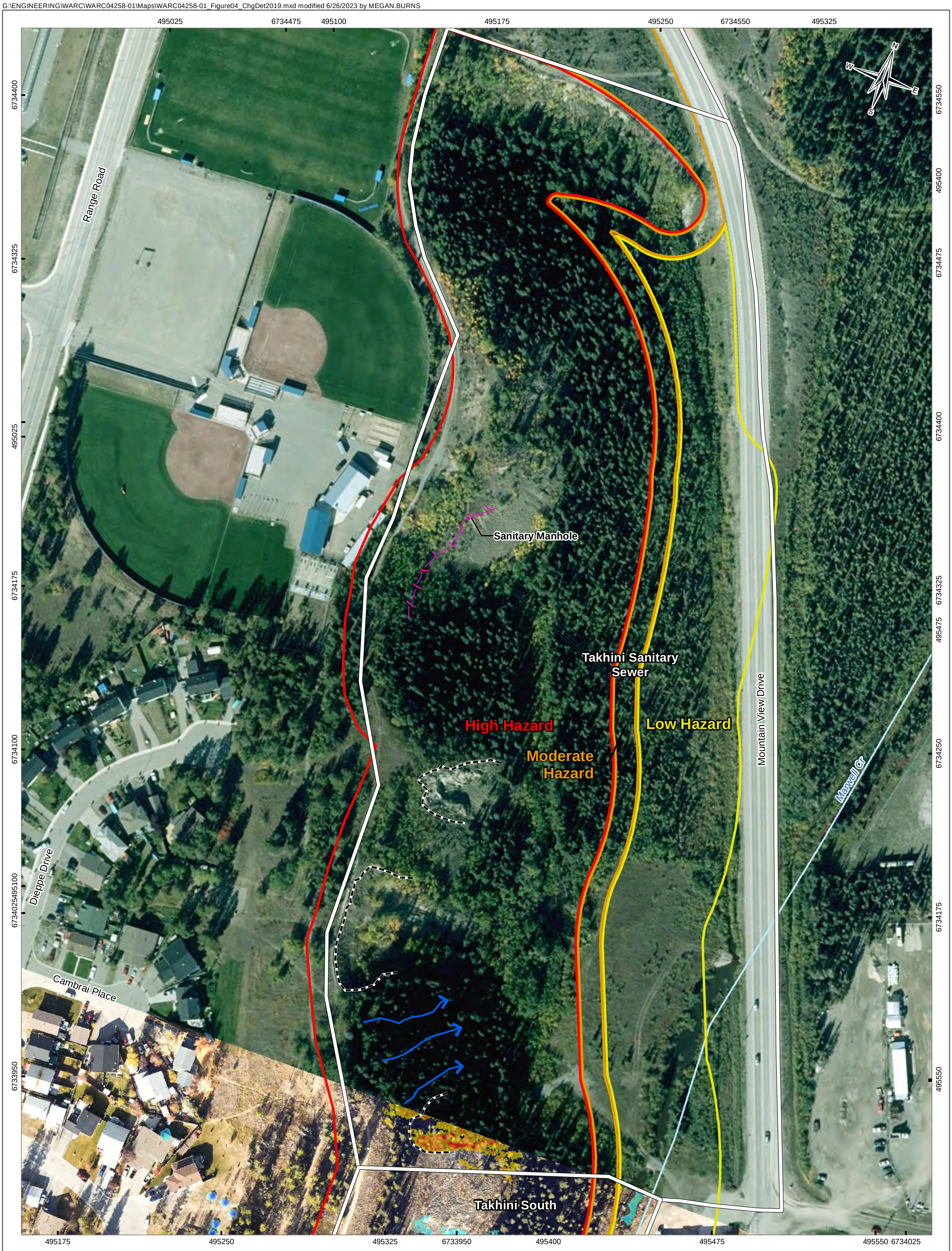

LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Base Data

- Watercourse

STATUS
ISSUED FOR USE

2013 to 2019 Surface Elevation Change (m)

> 1

< -1

OVERVIEW

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2019 Imagery 2013-2019 Surface Elevation Change Detection Analysis

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse THE WILDERNESS CITY

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure04_ChgDet2019.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 4l

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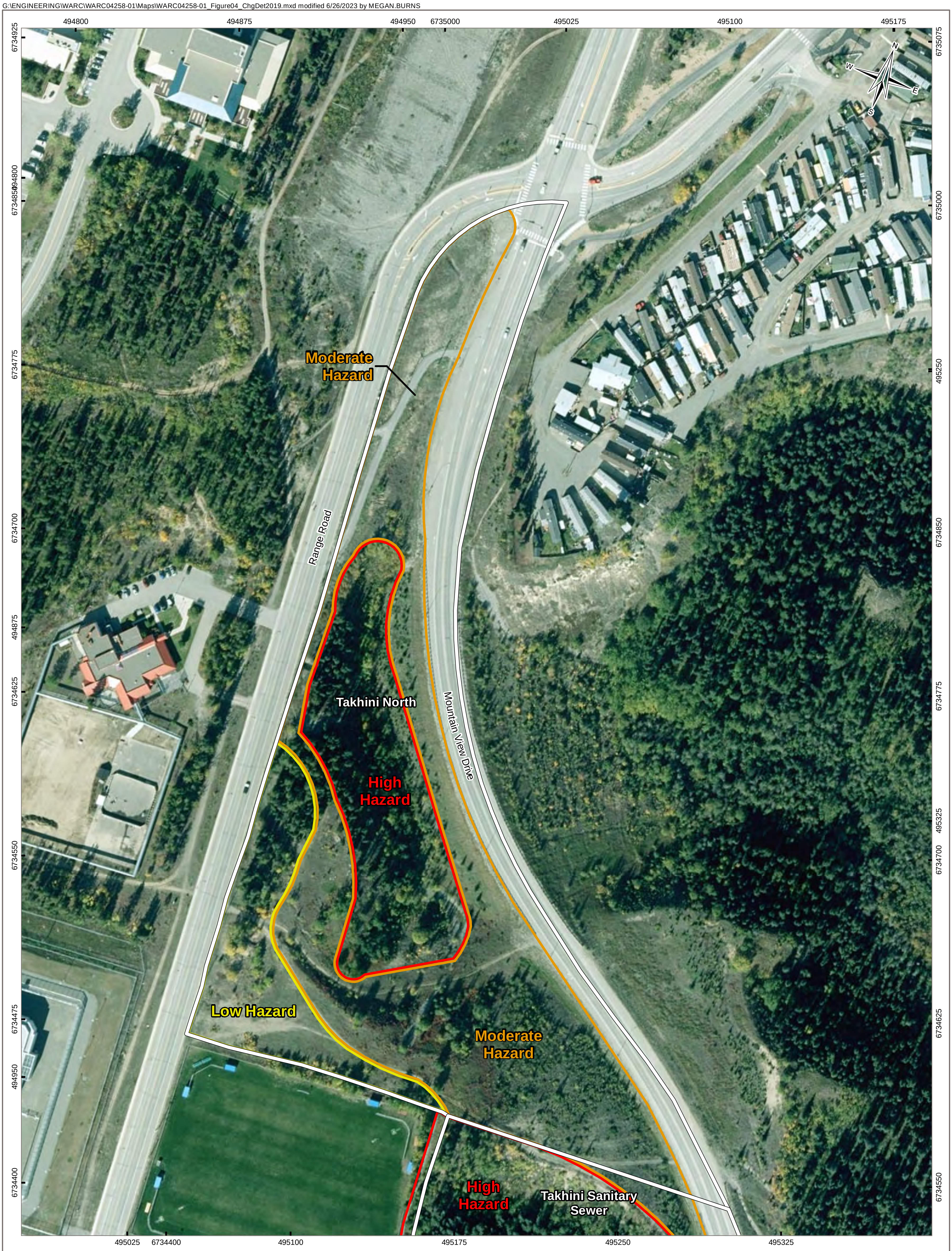

LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

STATUS
ISSUED FOR USE

2013 to 2019 Surface Elevation Change (m)

> 1

< -1

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2019 Imagery 2013-2019 Surface Elevation Change Detection Analysis

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure04_ChgDet2019.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 4m

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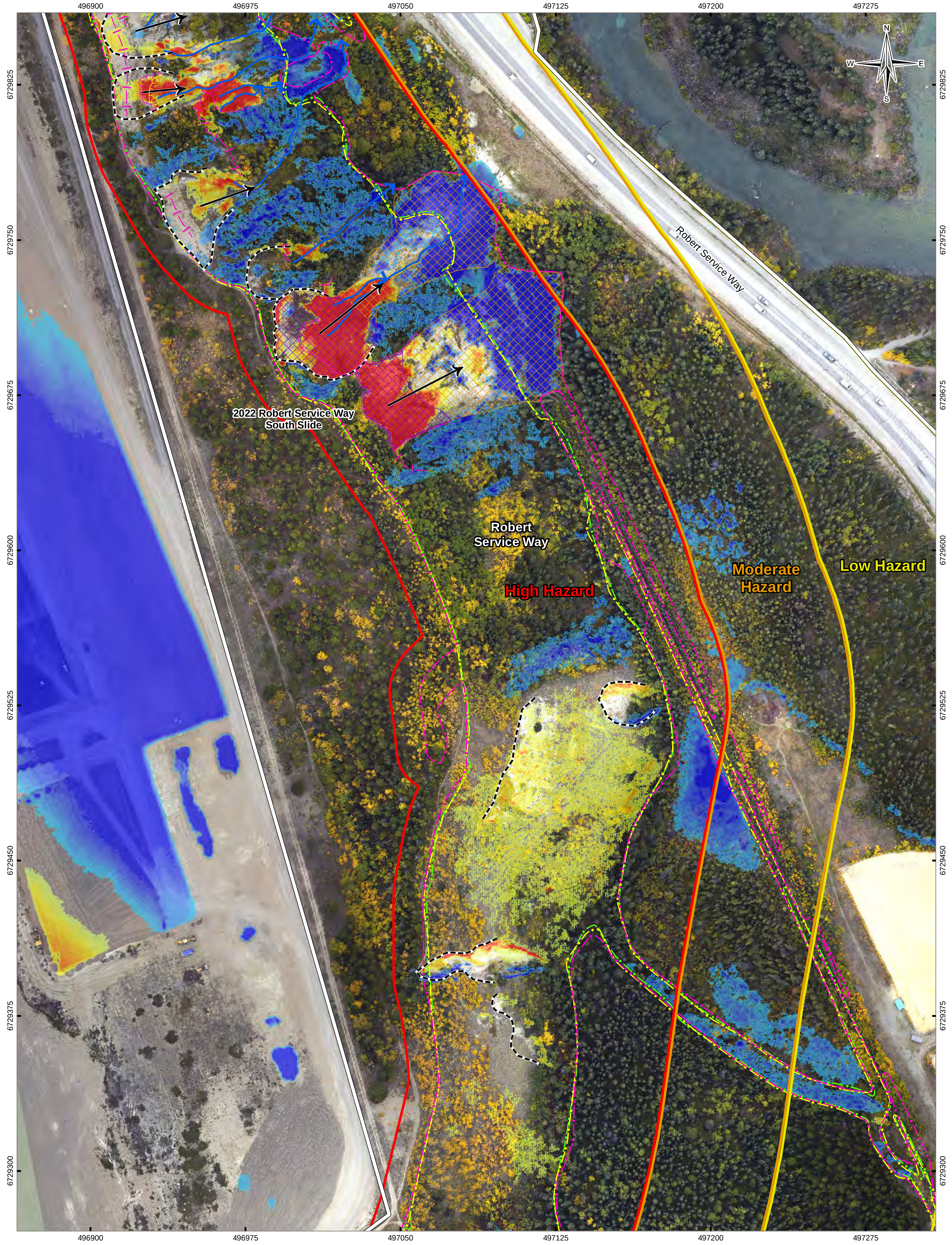


LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

STATUS
ISSUED FOR USE

2019 to 2022
Surface Elevation Change (m)

> 1

< -1

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 Imagery 2019-2022 Surface Elevation Change Detection Analysis

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse – The Wilderness City

Scale: 1:1,750
25 12.5 0 25
Metres

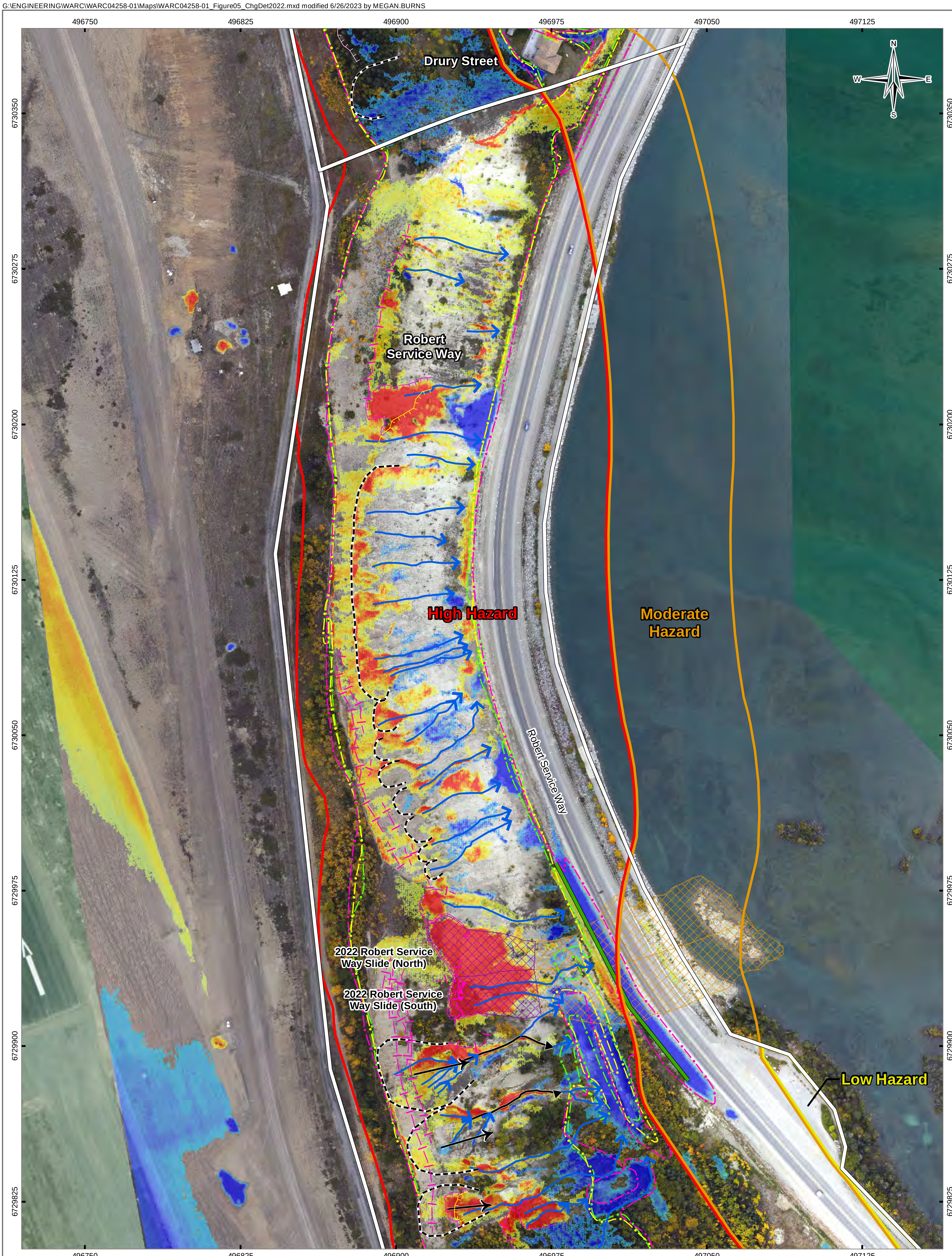
FILE NO.
WARC04258-01_Figure05_ChgDet2022.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 5a



LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Sheet-Pile Wall
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

STATUS
ISSUED FOR USE

2019 to 2022 Surface Elevation Change (m)

> 1

< -1

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 Imagery 2019-2022 Surface Elevation Change Detection Analysis

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse THE WILDERNESS CITY

Scale: 1:1,750
25 12.5 0 25
Metres

TETRA TECH

FILE NO.				
WARC04258-01_Figure05_ChgDet2022.mxd				
OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1
DATE	PROJECT NO.			
June 26, 2023	ENG.WARC04258-01			

Figure 5b

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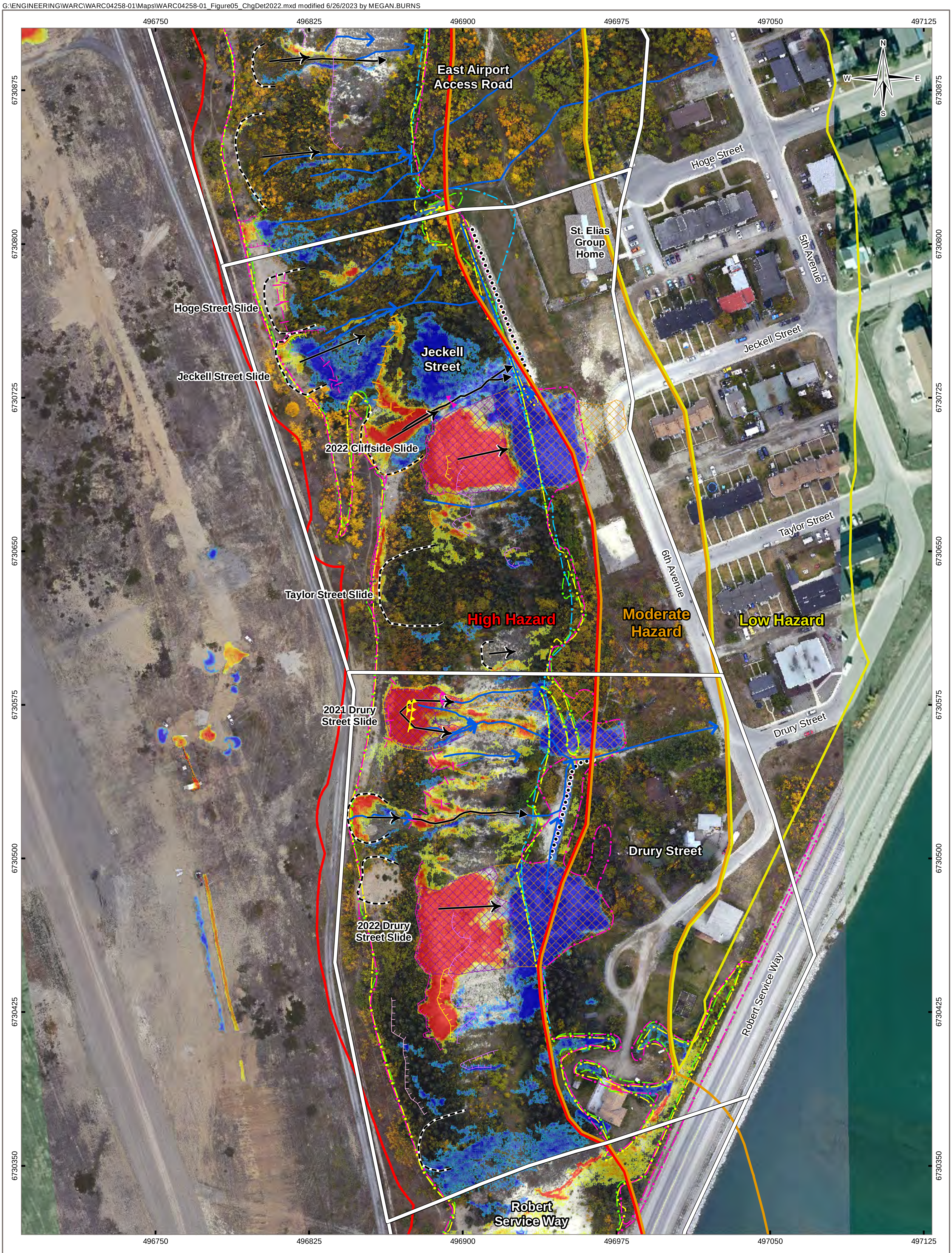

LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scarp - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

2019 to 2022 Surface Elevation Change (m)

- > 1
- < -1

STATUS
ISSUED FOR USE

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 Imagery 2019-2022 Surface Elevation Change Detection Analysis

PROJECTION: UTM Zone 8	DATUM: NAD83	CLIENT: Whitehorse THE WILDERNESS CITY
Scale: 1:1,750 (25 12.5 0 25 Metres)		TETRA TECH
FILE NO.: WARC04258-01_Figure05_ChgDet2022.mxd		
OFFICE: Tt-VANC	DWN: MRB; CKD: SL; APVD: EP; REV: 1	Figure 5c
DATE: June 26, 2023	PROJECT NO.: ENG.WARC04258-01	

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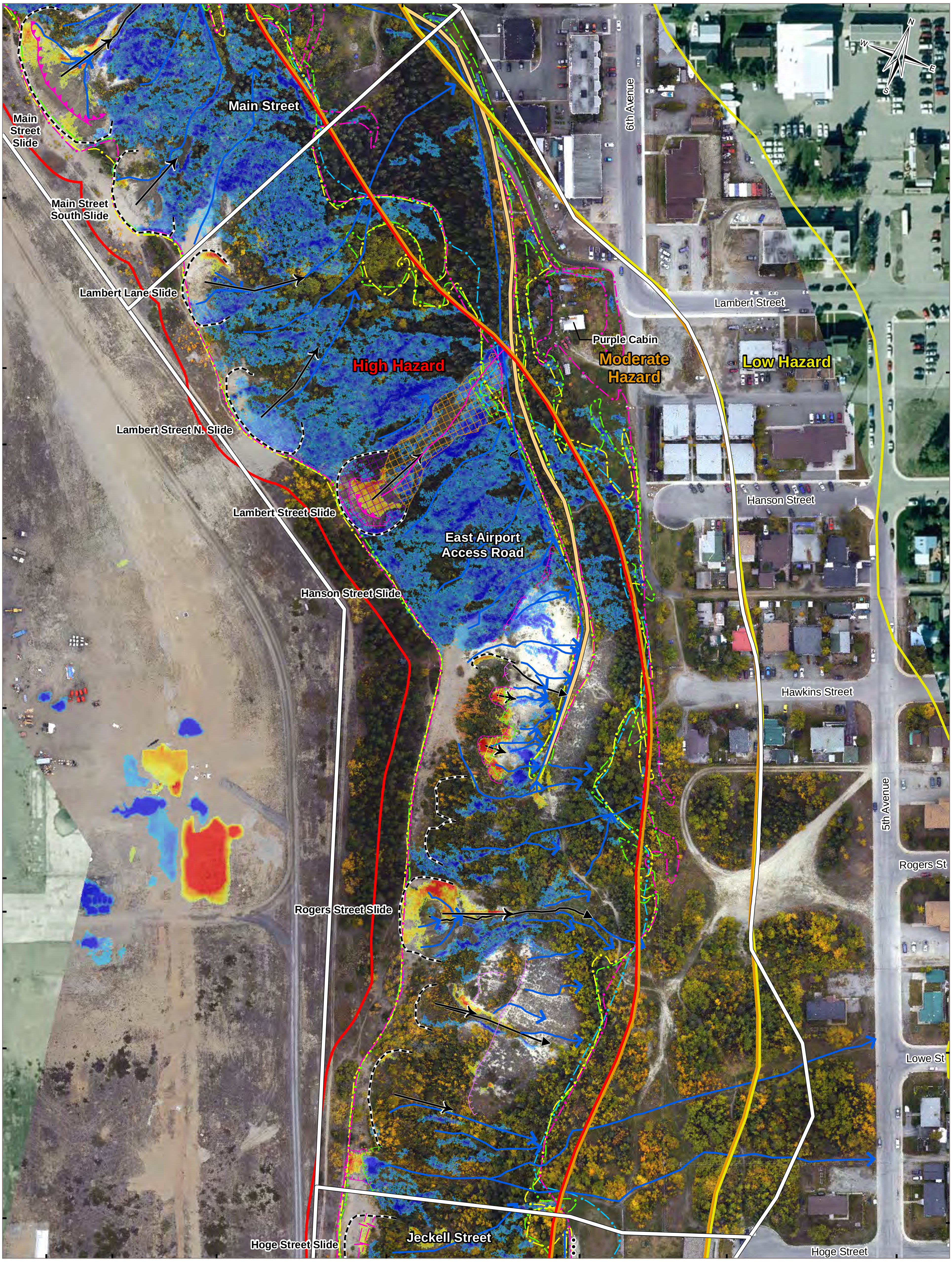

LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- East Airport Access
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

2019 to 2022 Surface Elevation Change (m)

> 1

< -1

STATUS
ISSUED FOR USE

OVERVIEW

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 Imagery 2019-2022 Surface Elevation Change Detection Analysis

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure05_ChgDet2022.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 5d

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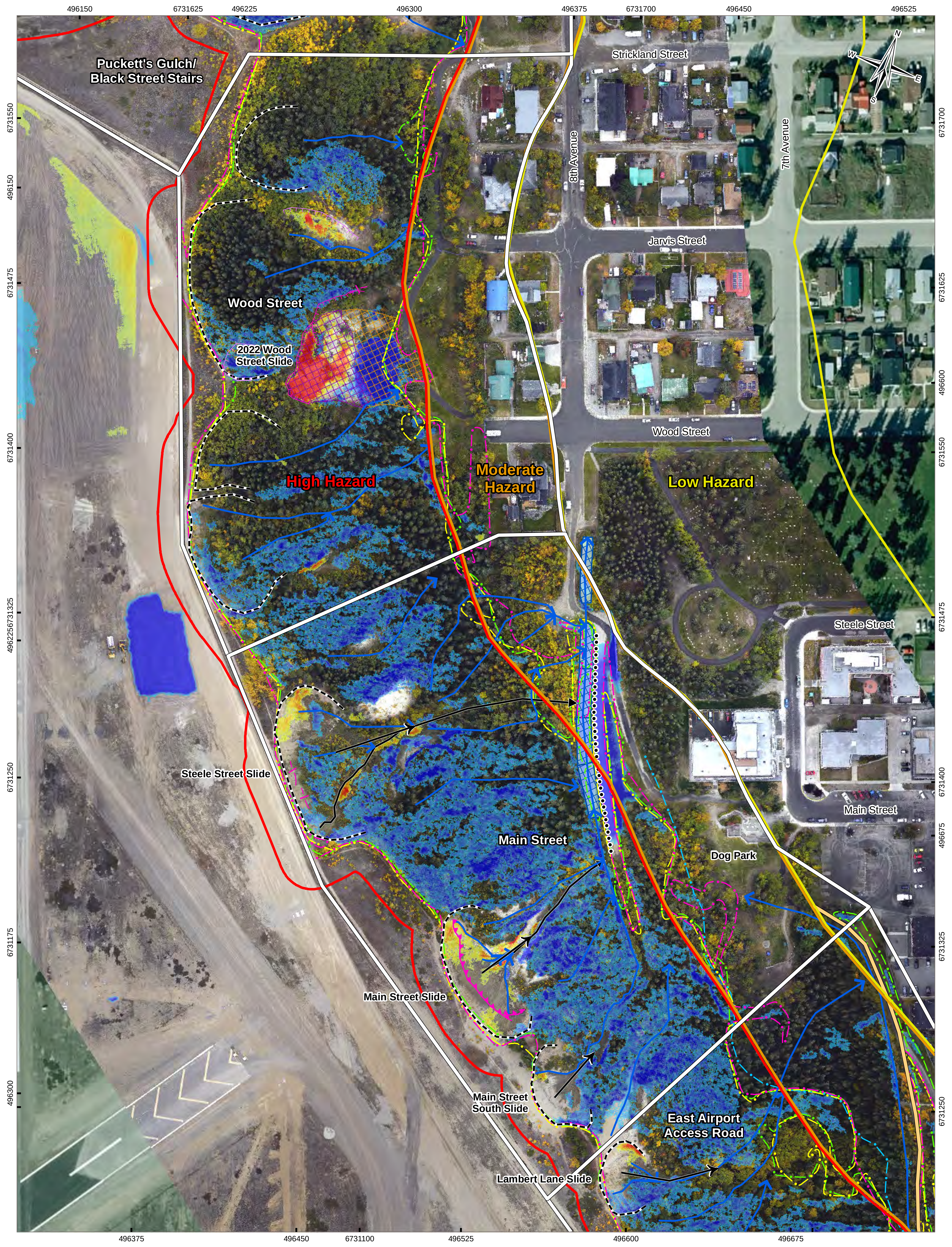

LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- East Airport Access
- Settling Pond
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

STATUS
ISSUED FOR USE

2019 to 2022 Surface Elevation Change (m)

> 1

< -1

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 Imagery 2019-2022 Surface Elevation Change Detection Analysis

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure05_ChgDet2022.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

TETRA TECH

Figure 5e

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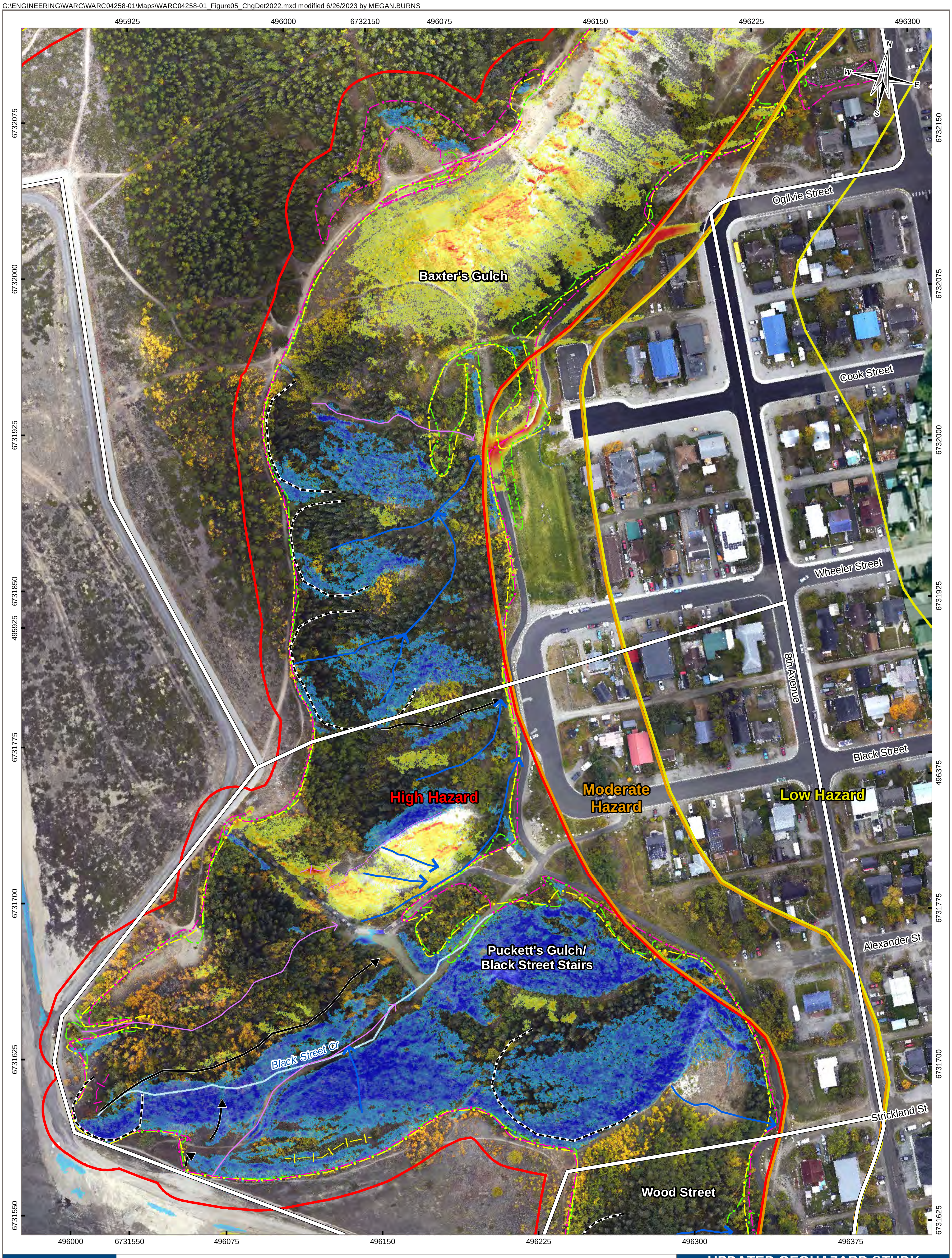


LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Base Data

- Watercourse

STATUS
ISSUED FOR USE

2019 to 2022 Surface Elevation Change (m)

- > 1
- < -1

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 Imagery 2019-2022 Surface Elevation Change Detection Analysis

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse THE WILDERNESS CITY

Scale: 1:1,750

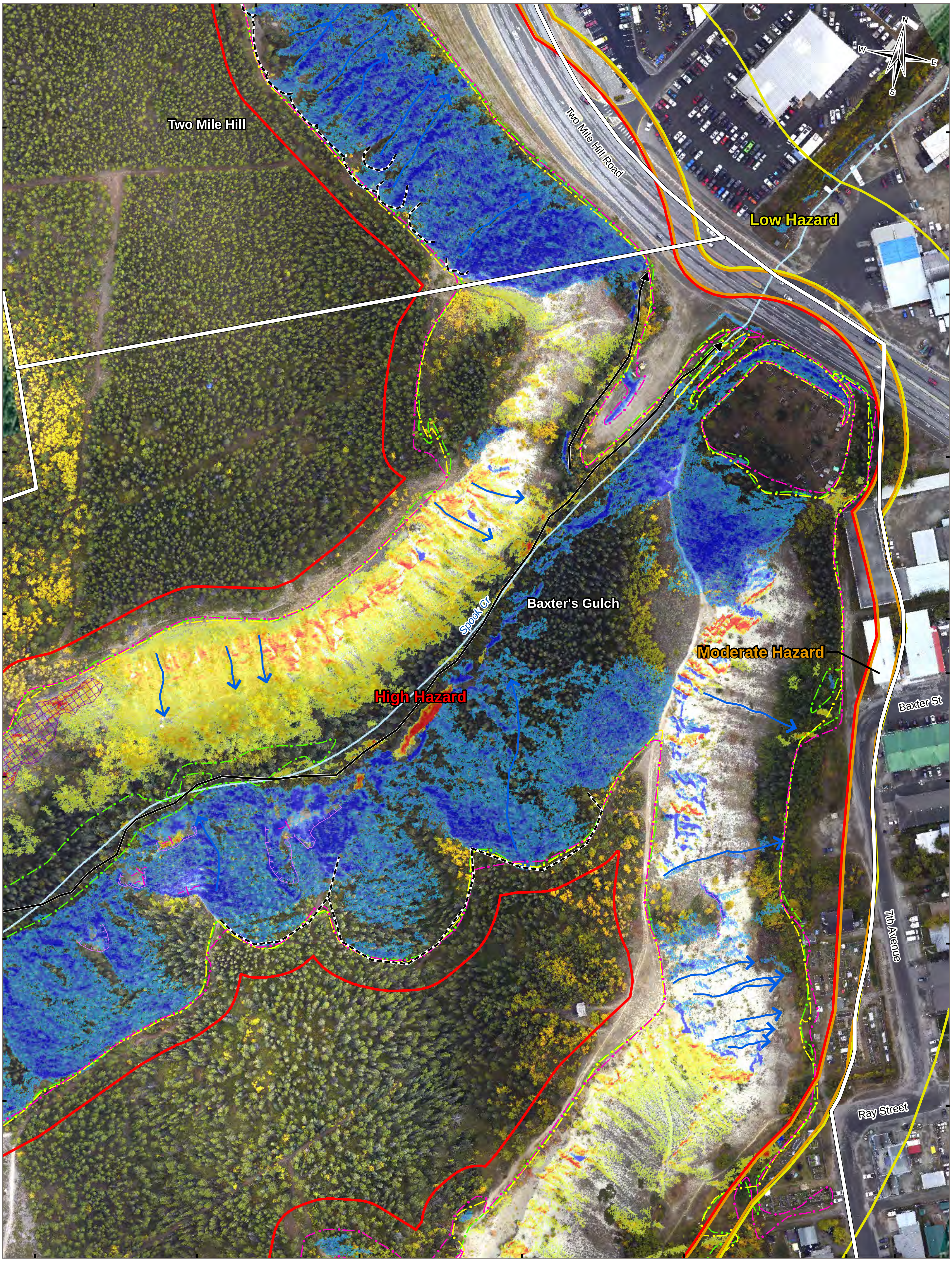
25 12.5 0 25
Metres

FILE NO.				
WARC04258-01_Figure05_ChgDet2022.mxd				
OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1
DATE	PROJECT NO.			
June 26, 2023	ENG.WARC04258-01			

TETRA TECH

Figure 5f

G:\ENGINEERING\WARC\WARC04258-01\Maps\WARC04258-01_Figure05_ChgDet2022.mxd modified 6/26/2023 by MEGAN.BURNS



LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Base Data

- Watercourse

2019 to 2022 Surface Elevation Change (m)

- > 1
- < -1

STATUS
ISSUED FOR USE

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 Imagery 2019-2022 Surface Elevation Change Detection Analysis

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse THE WILDERNESS CITY

Scale: 1:1,750
25 12.5 0 25
Metres

TETRA TECH

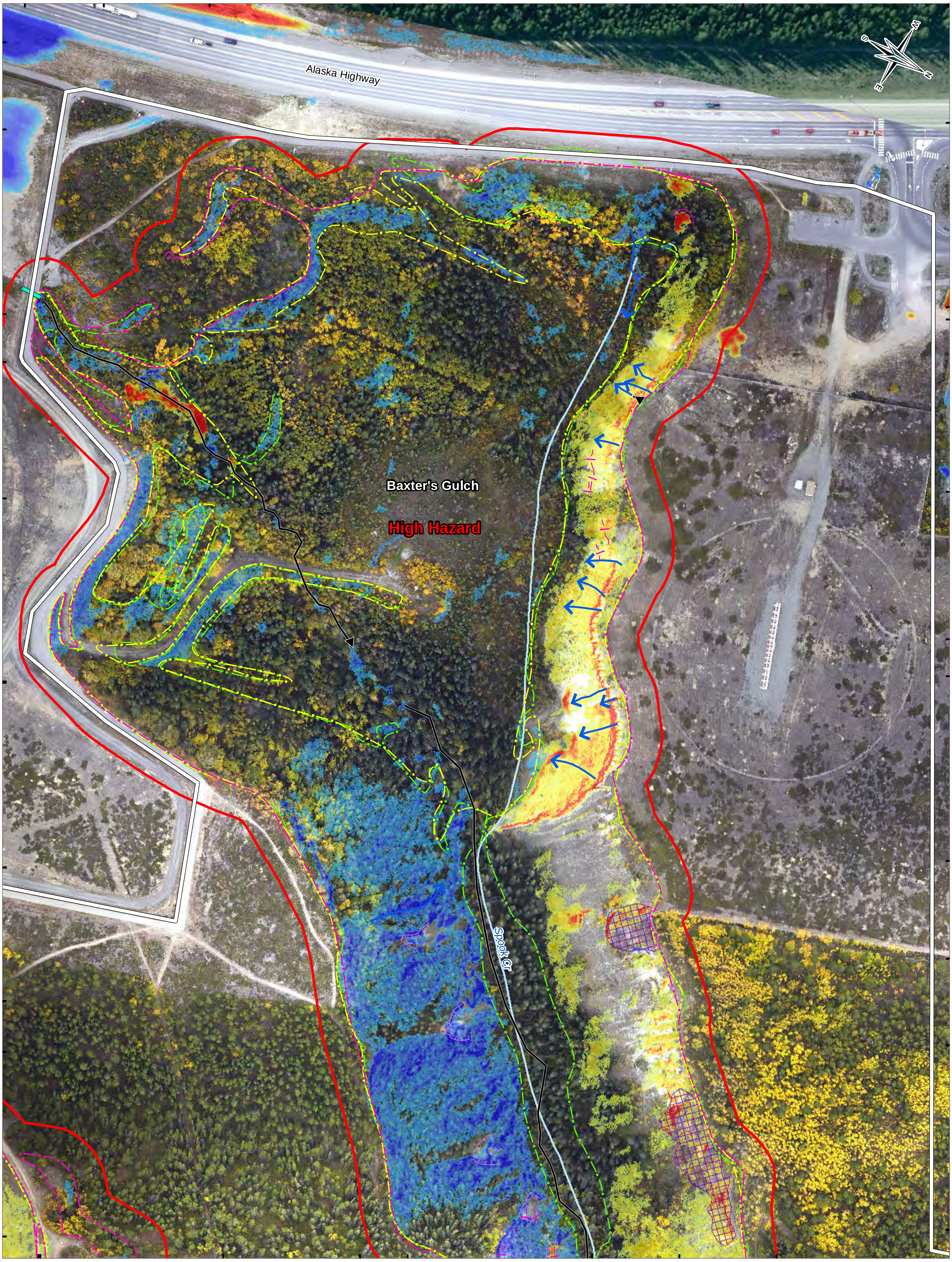
FILE NO.
WARC04258-01_Figure05_ChgDet2022.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 5g

G:\ENGINEERING\WARC\WARC04258-01\Maps\WARC04258-01_Figure05_ChgDet2022.mxd modified 6/26/2023 by MEGAN.BURNS



LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Culvert
- Slope Monitoring Zone

Landslide Hazard Rating

- High

Base Data

- Watercourse

STATUS
ISSUED FOR USE

2019 to 2022 Surface Elevation Change (m)

> 1

< -1

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 Imagery 2019-2022 Surface Elevation Change Detection Analysis

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure05_ChgDet2022.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 5h

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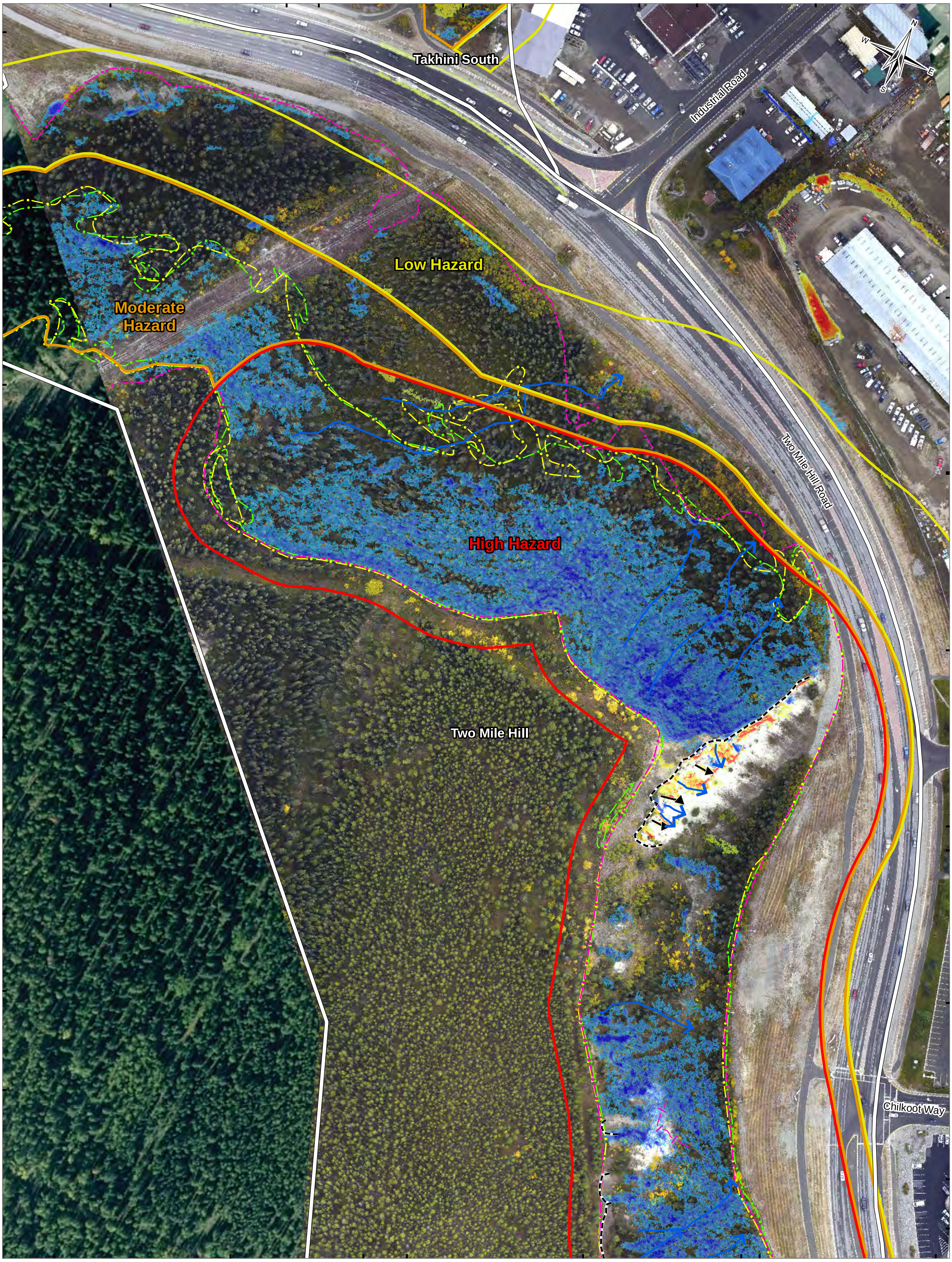

LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Base Data

- Watercourse

STATUS
ISSUED FOR USE

2019 to 2022 Surface Elevation Change (m)

> 1

< -1

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 Imagery 2019-2022 Surface Elevation Change Detection Analysis

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

TETRA TECH

FILE NO.
WARC04258-01_Figure05_ChgDet2022.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 5i

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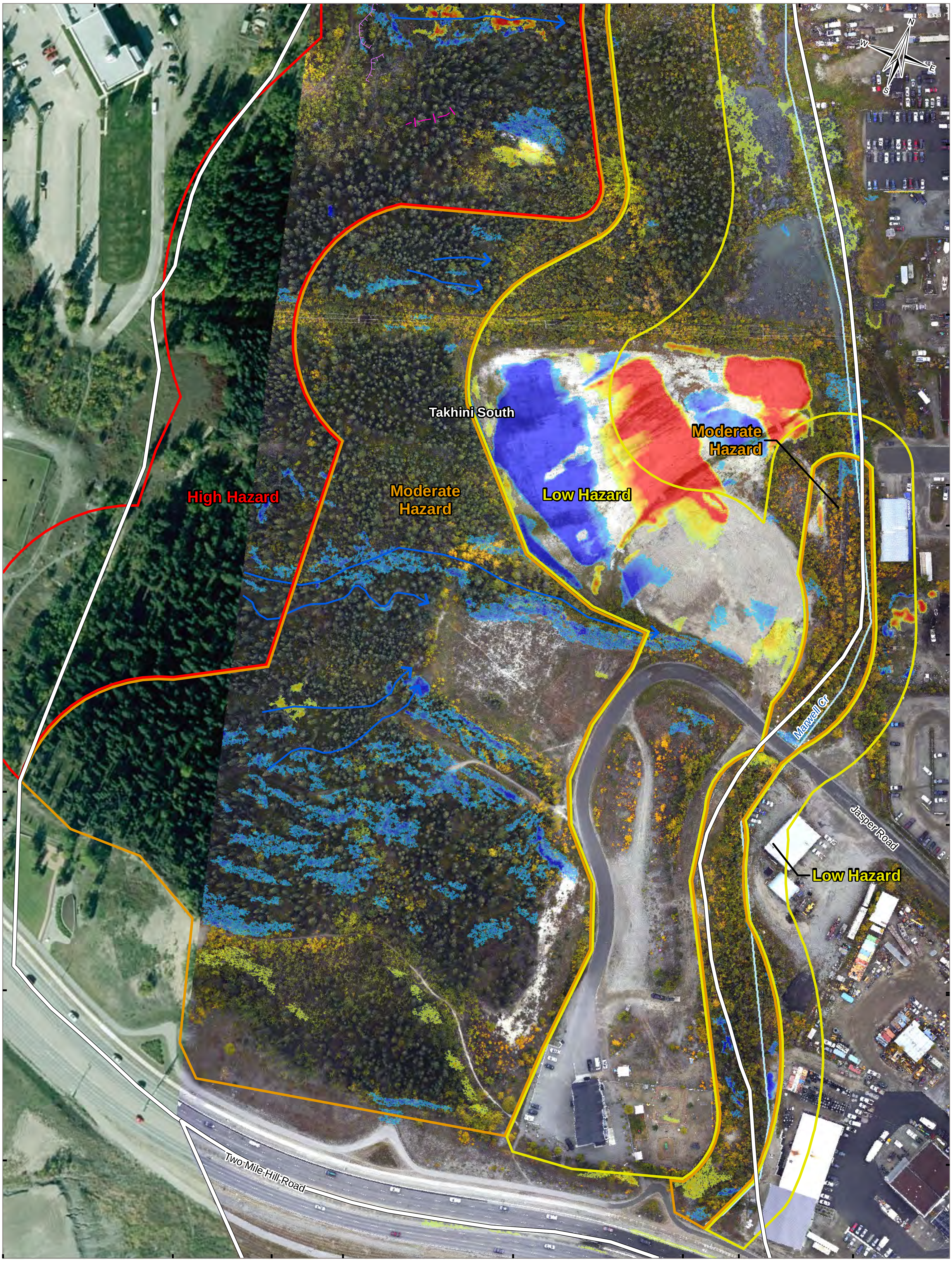

LEGEND

Existing Berm	**Year Feature Observed**	Flow Direction
Gully	2022	Slope Monitoring Zone
Seepage	2021	**Landslide Hazard Rating**
Toe/Crest of Slope	2019	High
Mass Movement Features	2016	Moderate
Debris Flow Headscarp	2013	Low
Landslide Scar - Active	Pre 2013	**Base Data**
Headscarp - Historical	Pre 2002	Watercourse
Tension Crack	Not Dated	
Debris Flow Scar		
Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)		

2019 to 2022 Surface Elevation Change (m)

> 1

< -1

STATUS
ISSUED FOR USE

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 Imagery 2019-2022 Surface Elevation Change Detection Analysis

PROJECTION UTM Zone 8				**DATUM** NAD83	**CLIENT** Whitehorse
Scale: 1:1,750 (25 12.5 0 25 Metres)					TETRA TECH
FILE NO. WARC04258-01_Figure05_ChgDet2022.mxd					
OFFICE Tt-VANC	**DWN** MRB	**CKD** SL	**APVD** EP	**REV** 1	**Figure 5j**
DATE June 26, 2023	**PROJECT NO.** ENG.WARC04258-01				

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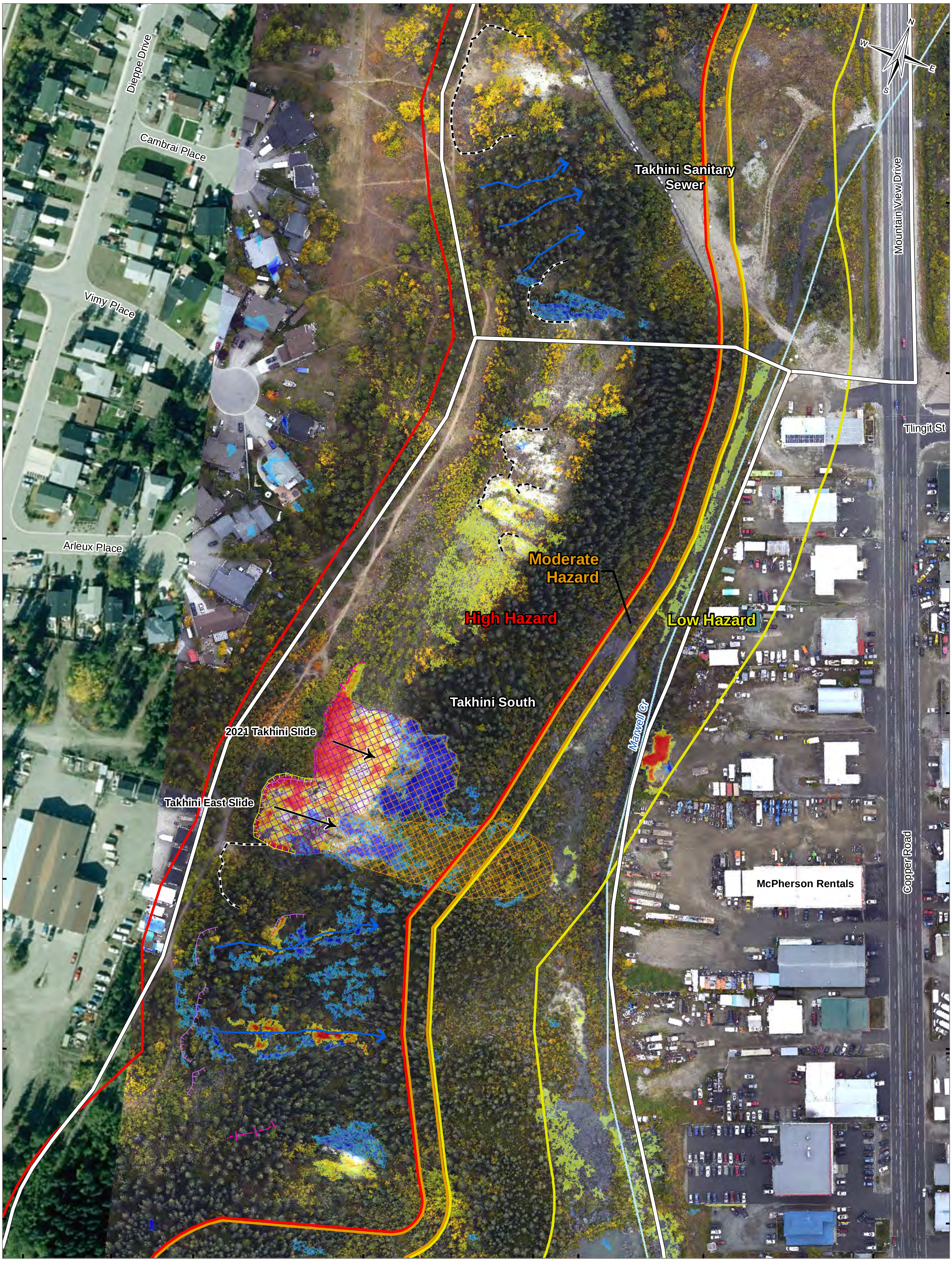

LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Base Data

- Watercourse

STATUS
ISSUED FOR USE

2019 to 2022 Surface Elevation Change (m)

> 1

< -1

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 Imagery 2019-2022 Surface Elevation Change Detection Analysis

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750

25 12.5 0 25

Metres

FILE NO.
WARC04258-01_Figure05_ChgDet2022.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 5k

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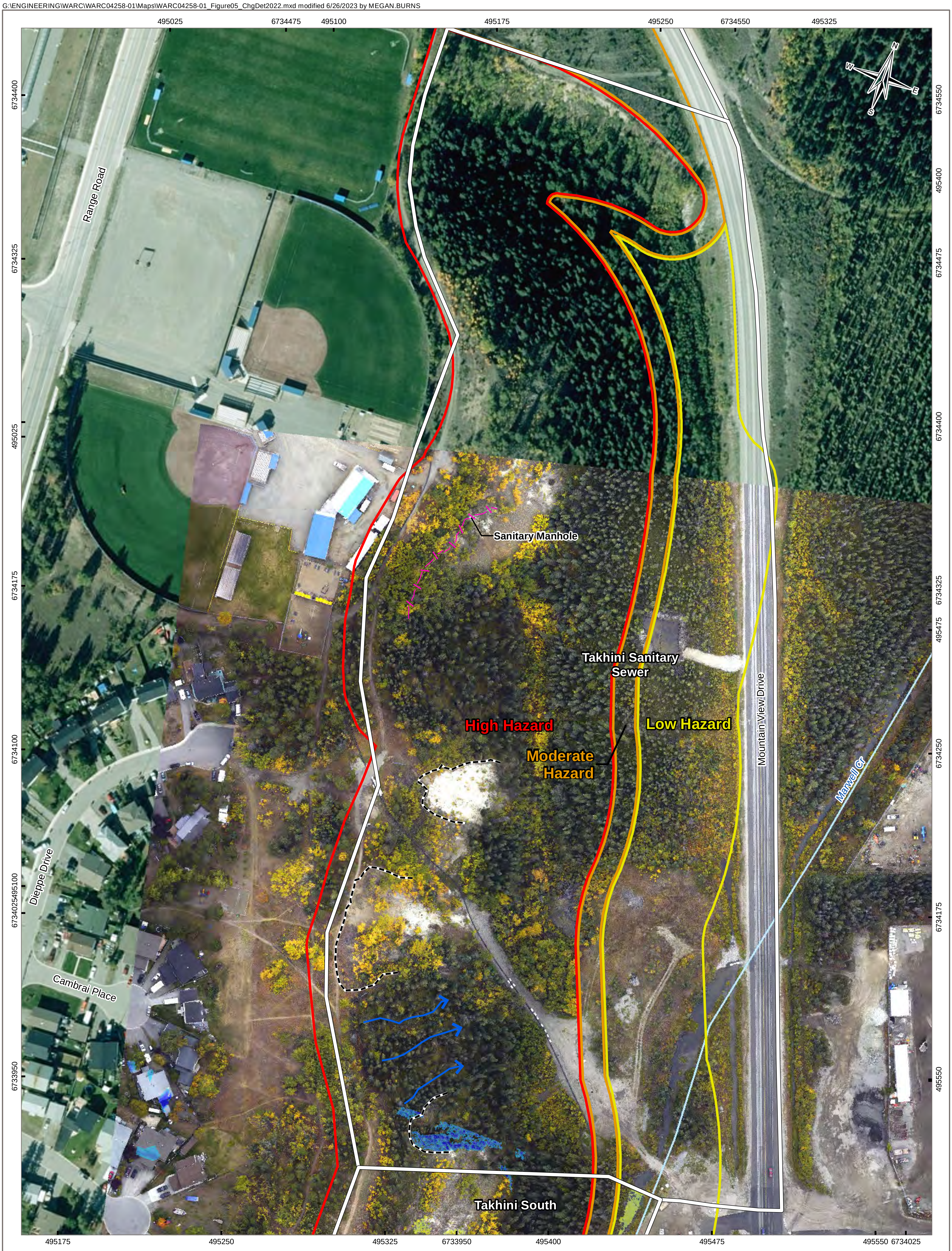

LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Base Data

- Watercourse

STATUS
ISSUED FOR USE

2019 to 2022
Surface Elevation Change (m)

> 1

< -1

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 Imagery 2019-2022 Surface Elevation Change Detection Analysis

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure05_ChgDet2022.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 5l

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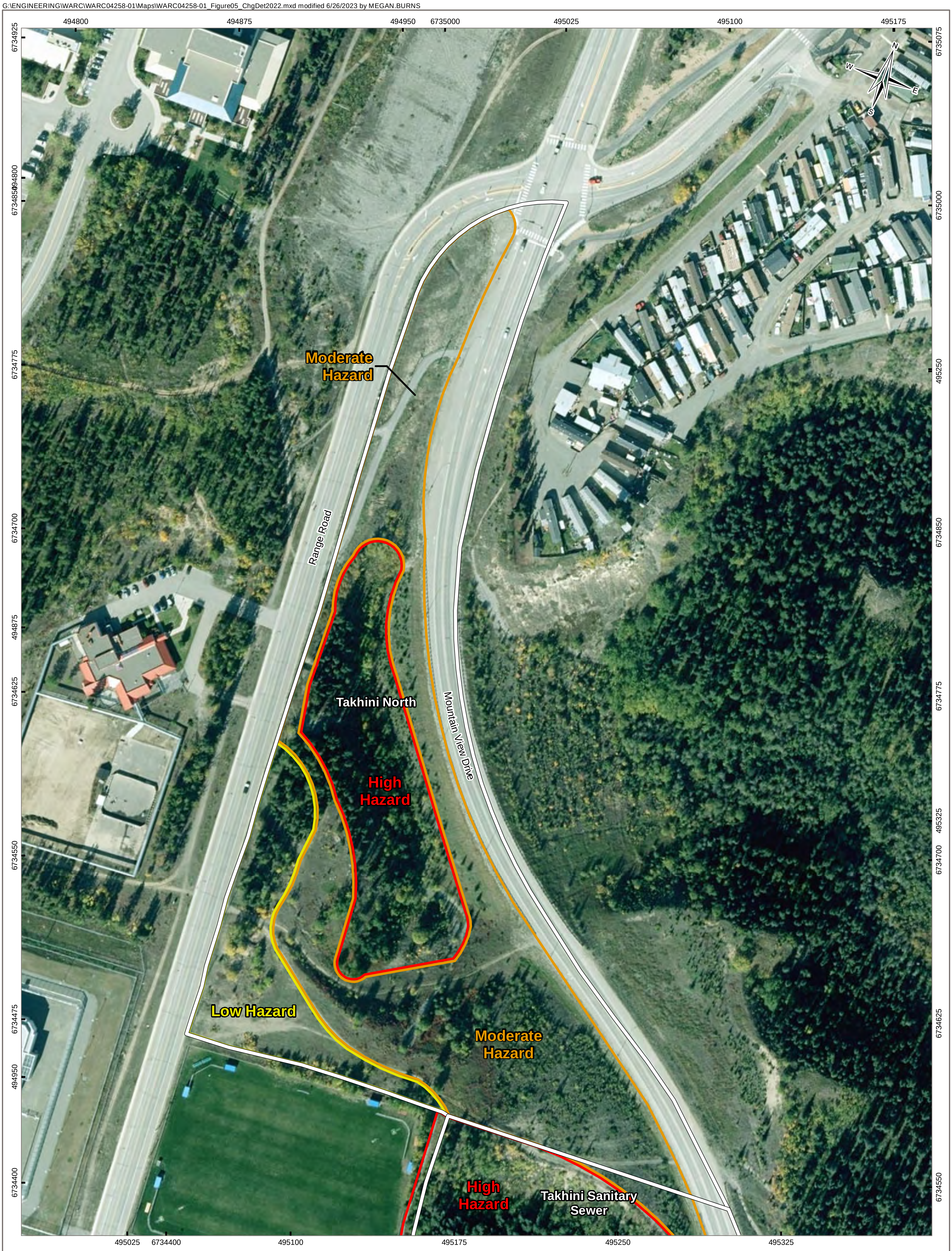

LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

2019 to 2022 Surface Elevation Change (m)

> 1

< -1

STATUS
ISSUED FOR USE

OVERVIEW

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

2022 Imagery 2019-2022 Surface Elevation Change Detection Analysis

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure05_ChgDet2022.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	MRB	SL	EP	1

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 5m

LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

STATUS
ISSUED FOR USE

Frequency Ratio Slope Susceptibility Model

Hazard Index

- No (< 300)
- Low (300 - 400)
- Moderate (400 - 450)
- High (>450)

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

Frequency Ratio Landslide Susceptibility Model

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse THE WILDERNESS CITY

Scale: 1:1,750
25 12.5 0 25
Metres

TETRA TECH

FILE NO.
WARC04258-01_Figure06_FR_Model.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	JI	SL	EP	0

DATE
June 26, 2023

PROJECT NO.
ENG.WARC04258-01

Figure 6a

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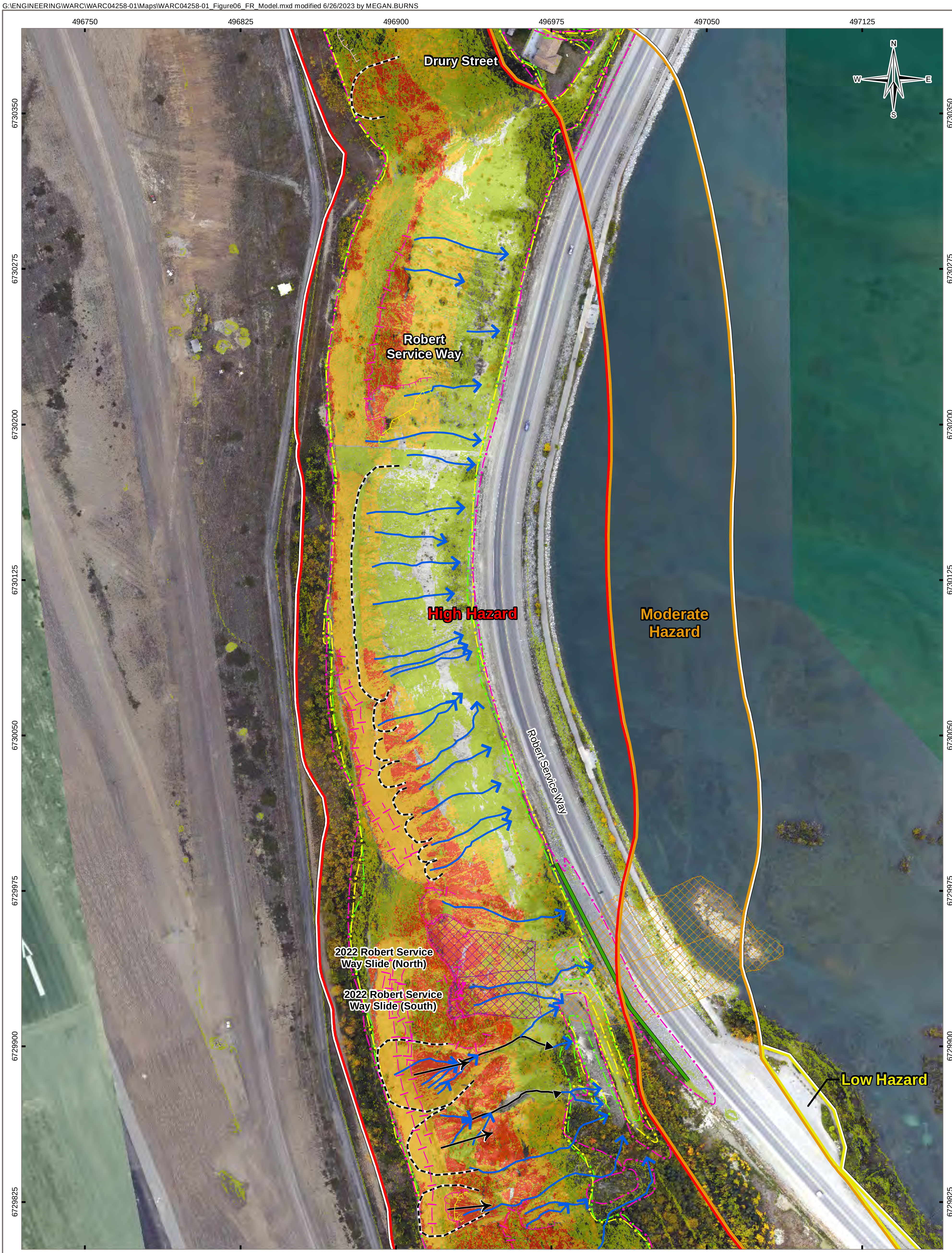

LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Sheet-Pile Wall
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

STATUS
ISSUED FOR USE

Frequency Ratio Slope Susceptibility Model

Hazard Index

- No (< 300)
- Low (300 - 400)
- Moderate (400 - 450)
- High (>450)

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

Frequency Ratio Landslide Susceptibility Model

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse THE WILDERNESS CITY

Scale: 1:1,750

25 12.5 0 25

Metres

FILE NO.
WARC04258-01_Figure06_FR_Model.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	JI	SL	EP	0

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 6b

LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

STATUS
ISSUED FOR USE

Frequency Ratio Slope Susceptibility Model

Hazard Index

- No (< 300)
- Low (300 - 400)
- Moderate (400 - 450)
- High (>450)

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

Frequency Ratio Landslide Susceptibility Model

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse THE WILDERNESS CITY

Scale: 1:1,750
25 12.5 0 25
Metres

TETRA TECH

FILE NO.				
WARC04258-01_Figure06_FR_Model.mxd				
OFFICE	DWN	CKD	APVD	REV
Tt-VANC	JI	SL	EP	0
DATE	PROJECT NO.			
June 26, 2023	ENG.WARC04258-01			

Figure 6c

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LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- East Airport Access
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Frequency Ratio Slope Susceptibility Model

Hazard Index

- No (< 300)
- Low (300 - 400)
- Moderate (400 - 450)
- High (>450)

STATUS
ISSUED FOR USE

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

Frequency Ratio Landslide Susceptibility Model

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure06_FR_Model.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	JI	SL	EP	0

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

TETRA TECH

Figure 6d

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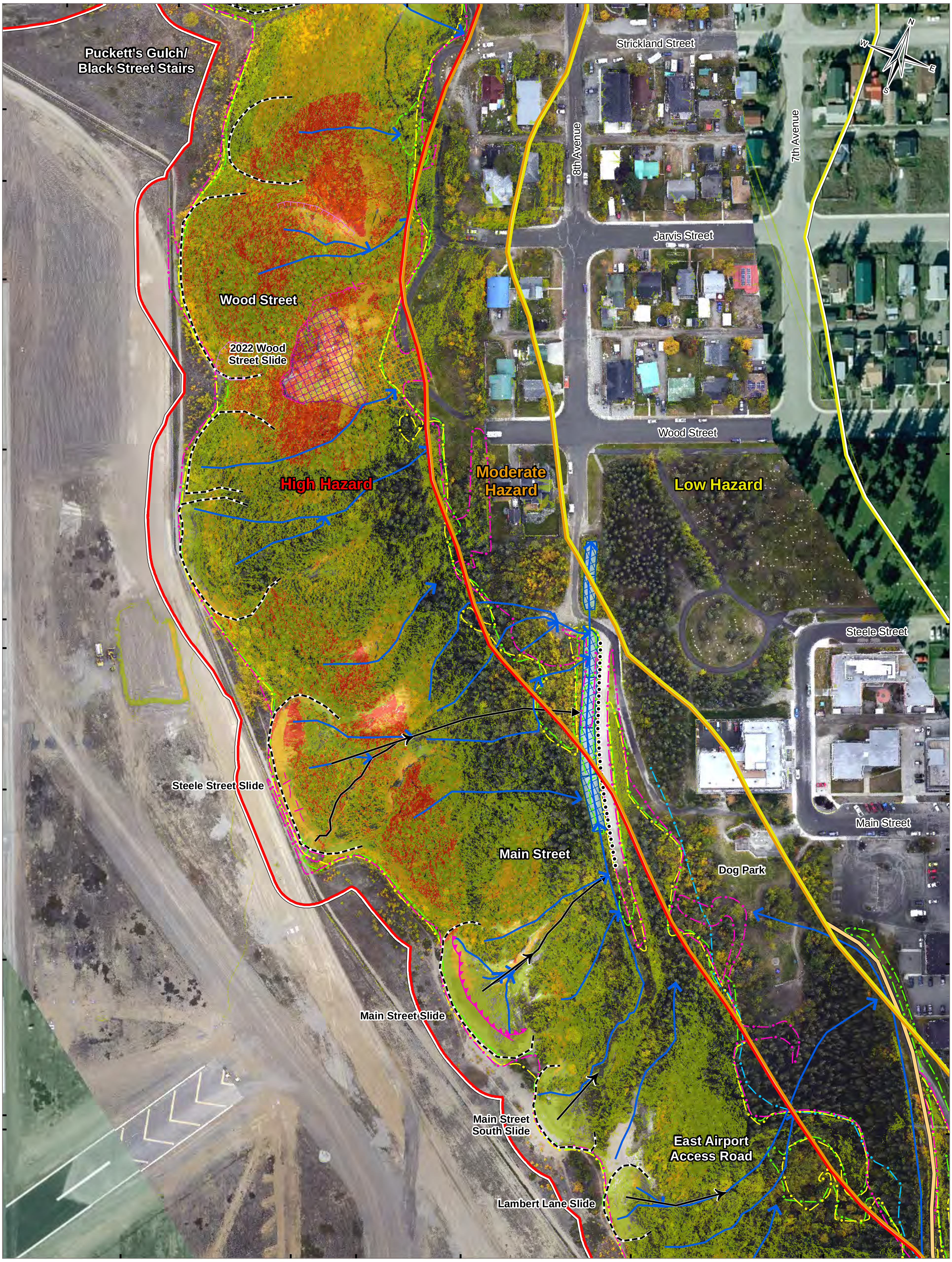

LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scarp - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- East Airport Access
- Settling Pond
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

STATUS
ISSUED FOR USE

Frequency Ratio Slope Susceptibility Model

Hazard Index

- No (< 300)
- Low (300 - 400)
- Moderate (400 - 450)
- High (>450)

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

Frequency Ratio Landslide Susceptibility Model

PROJECTION: UTM Zone 8			DATUM: NAD83		CLIENT: Whitehorse
Scale: 1:1,750 (25 12.5 0 25 Metres)					TETRA TECH
FILE NO.: WARC04258-01_Figure06_FR_Model.mxd					
OFFICE: Tt-VANC	DWN: JI	CKD: SL	APVD: EP	REV: 0	Figure 6e
DATE: June 26, 2023		PROJECT NO.: ENG.WARC04258-01			

LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Base Data

- Watercourse

STATUS
ISSUED FOR USE

Frequency Ratio Slope Susceptibility Model

Hazard Index

- No (< 300)
- Low (300 - 400)
- Moderate (400 - 450)
- High (>450)

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

Frequency Ratio Landslide Susceptibility Model

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse THE WILDERNESS CITY

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure06_FR_Model.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	JI	SL	EP	0

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 6f

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LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Base Data

- Watercourse

STATUS
ISSUED FOR USE

Frequency Ratio Slope Susceptibility Model

Hazard Index

- No (< 300)
- Low (300 - 400)
- Moderate (400 - 450)
- High (>450)

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

Frequency Ratio Landslide Susceptibility Model

PROJECTION	DATUM
UTM Zone 8	NAD83

Scale: 1:1,750
25 12.5 0 25
Metres

CLIENT Whitehorse THE WILDERNESS CITY

TETRA TECH

FILE NO.
WARC04258-01_Figure06_FR_Model.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	JI	SL	EP	0

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 6g

LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Culvert
- Slope Monitoring Zone

Landslide Hazard Rating

- High

Base Data

- Watercourse

STATUS
ISSUED FOR USE

Frequency Ratio Slope Susceptibility Model

Hazard Index

- No (< 300)
- Low (300 - 400)
- Moderate (400 - 450)
- High (>450)

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

Frequency Ratio Landslide Susceptibility Model

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse (THE WILDERNESS CITY)

Scale: 1:1,750
25 12.5 0 25
Metres

TETRA TECH

FILE NO.
WARC04258-01_Figure06_FR_Model.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	JI	SL	EP	0

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 6h

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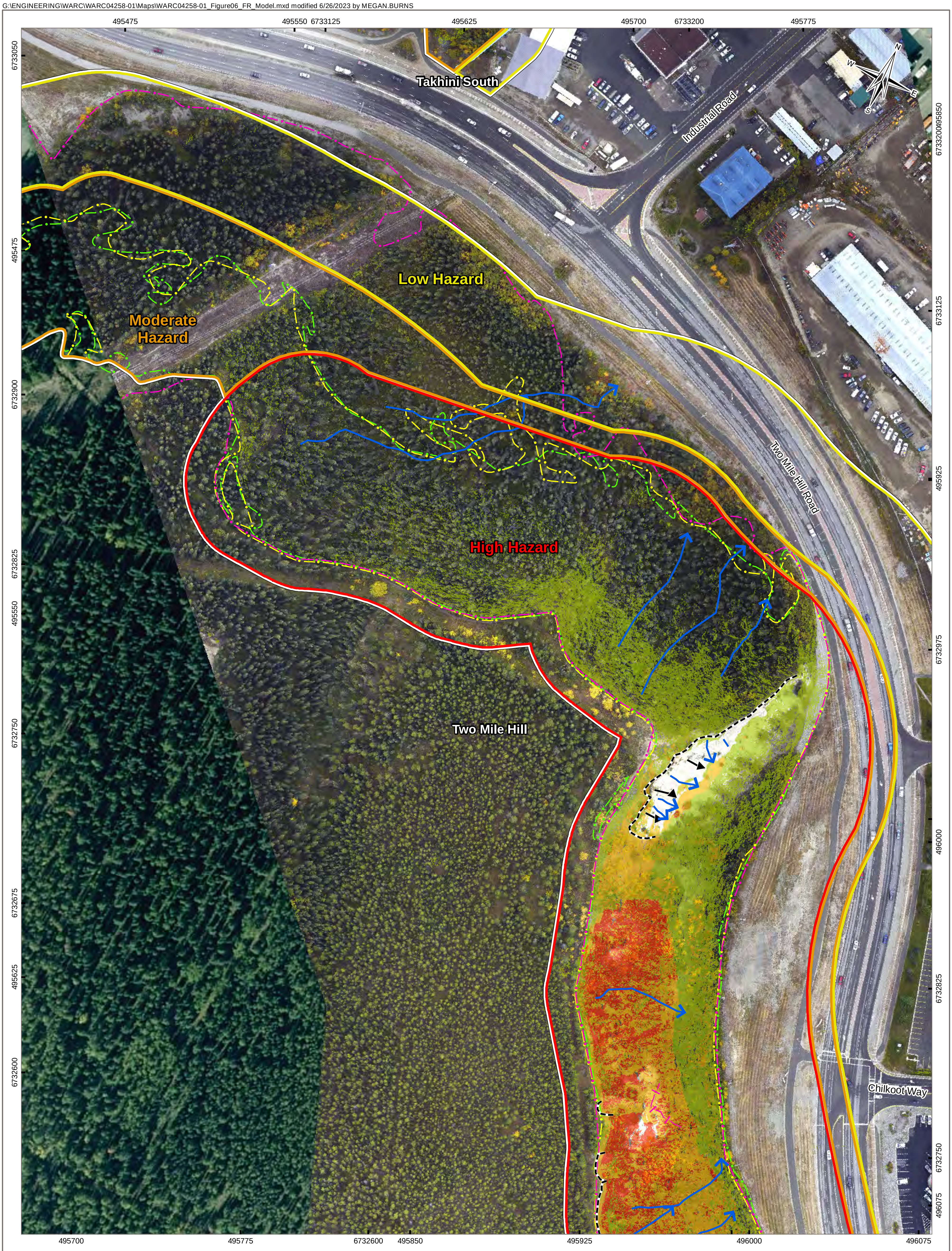

LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Base Data

- Watercourse

STATUS
ISSUED FOR USE

Frequency Ratio Slope Susceptibility Model

Hazard Index

- No (< 300)
- Low (300 - 400)
- Moderate (400 - 450)
- High (>450)

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

Frequency Ratio Landslide Susceptibility Model

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse THE WILDERNESS CITY

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure06_FR_Model.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	JI	SL	EP	0

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 6i

G:\ENGINEERING\WARC\WARC04258-01\Maps\WARC04258-01_Figure06_FR_Model.mxd modified 6/26/2023 by MEGAN.BURNS

LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Base Data

- Watercourse

STATUS
ISSUED FOR USE

Frequency Ratio Slope Susceptibility Model

Hazard Index

- No (< 300)
- Low (300 - 400)
- Moderate (400 - 450)
- High (>450)

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

Frequency Ratio Landslide Susceptibility Model

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

TETRA TECH

FILE NO.
WARC04258-01_Figure06_FR_Model.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	JI	SL	EP	0

DATE
June 26, 2023

PROJECT NO.
ENG.WARC04258-01

Figure 6j

G:\ENGINEERING\WARC\WARC04258-01\Maps\WARC04258-01_Figure06_FR_Model.mxd modified 6/26/2023 by MEGAN.BURNS

LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Base Data

- Watercourse

STATUS
ISSUED FOR USE

Frequency Ratio Slope Susceptibility Model

Hazard Index

- No (< 300)
- Low (300 - 400)
- Moderate (400 - 450)
- High (>450)

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

Frequency Ratio Landslide Susceptibility Model

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750 (25 – 12.5 – 0 – 25 Metres)

FILE NO.
WARC04258-01_Figure06_FR_Model.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	JI	SL	EP	0

DATE: June 26, 2023
PROJECT NO.: ENG.WARC04258-01

Figure 6k

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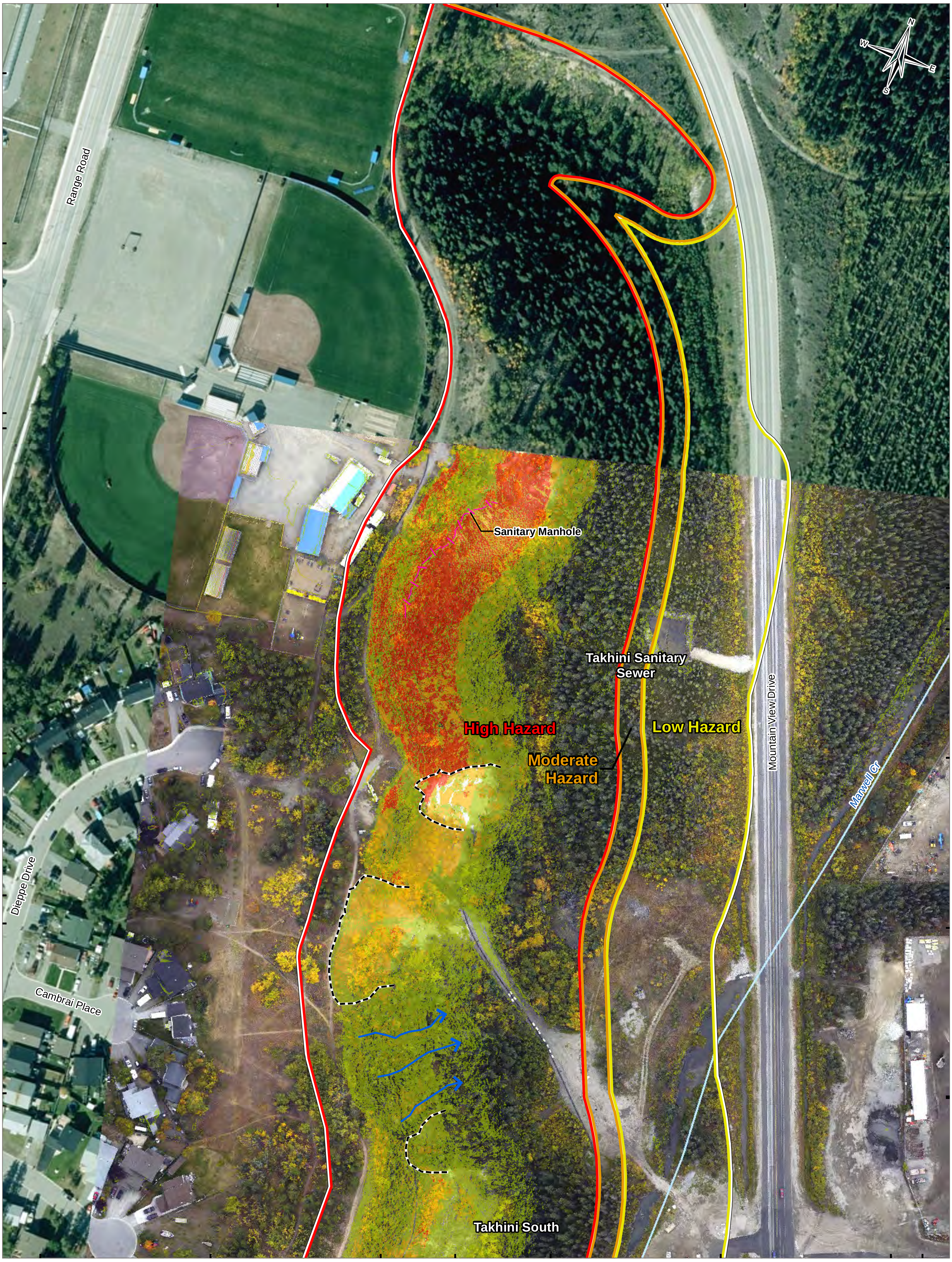

LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Base Data

- Watercourse

STATUS
ISSUED FOR USE

Frequency Ratio Slope Susceptibility Model

Hazard Index

- No (< 300)
- Low (300 - 400)
- Moderate (400 - 450)
- High (>450)

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

Frequency Ratio Landslide Susceptibility Model

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure06_FR_Model.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	JI	SL	EP	0

DATE: June 26, 2023
PROJECT NO.: ENG.WARC04258-01

Figure 6l

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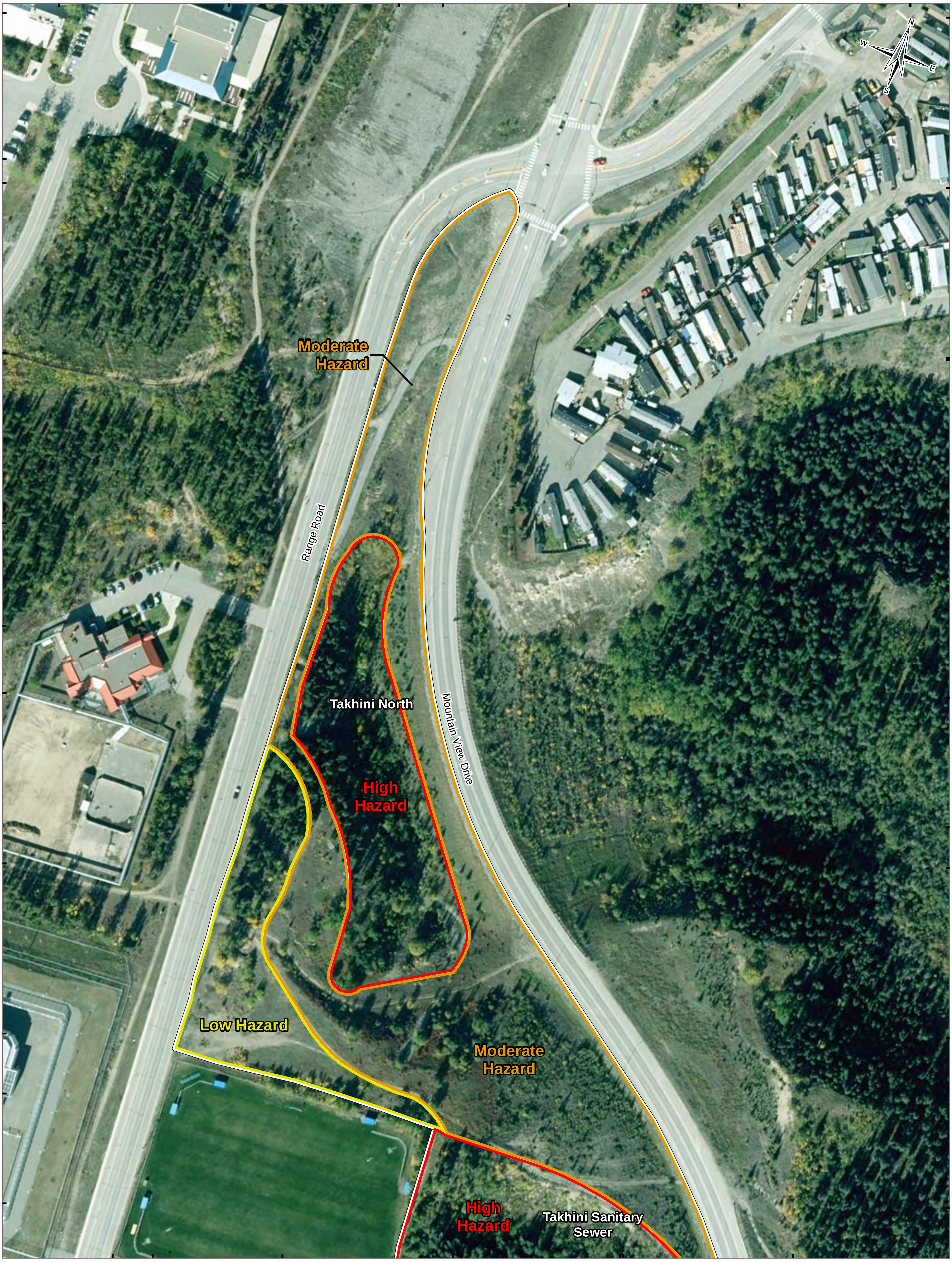


LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

STATUS
ISSUED FOR USE

Frequency Ratio Slope Susceptibility Model

Hazard Index

- No (< 300)
- Low (300 - 400)
- Moderate (400 - 450)
- High (>450)

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

Frequency Ratio Landslide Susceptibility Model

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure06_FR_Model.mxd

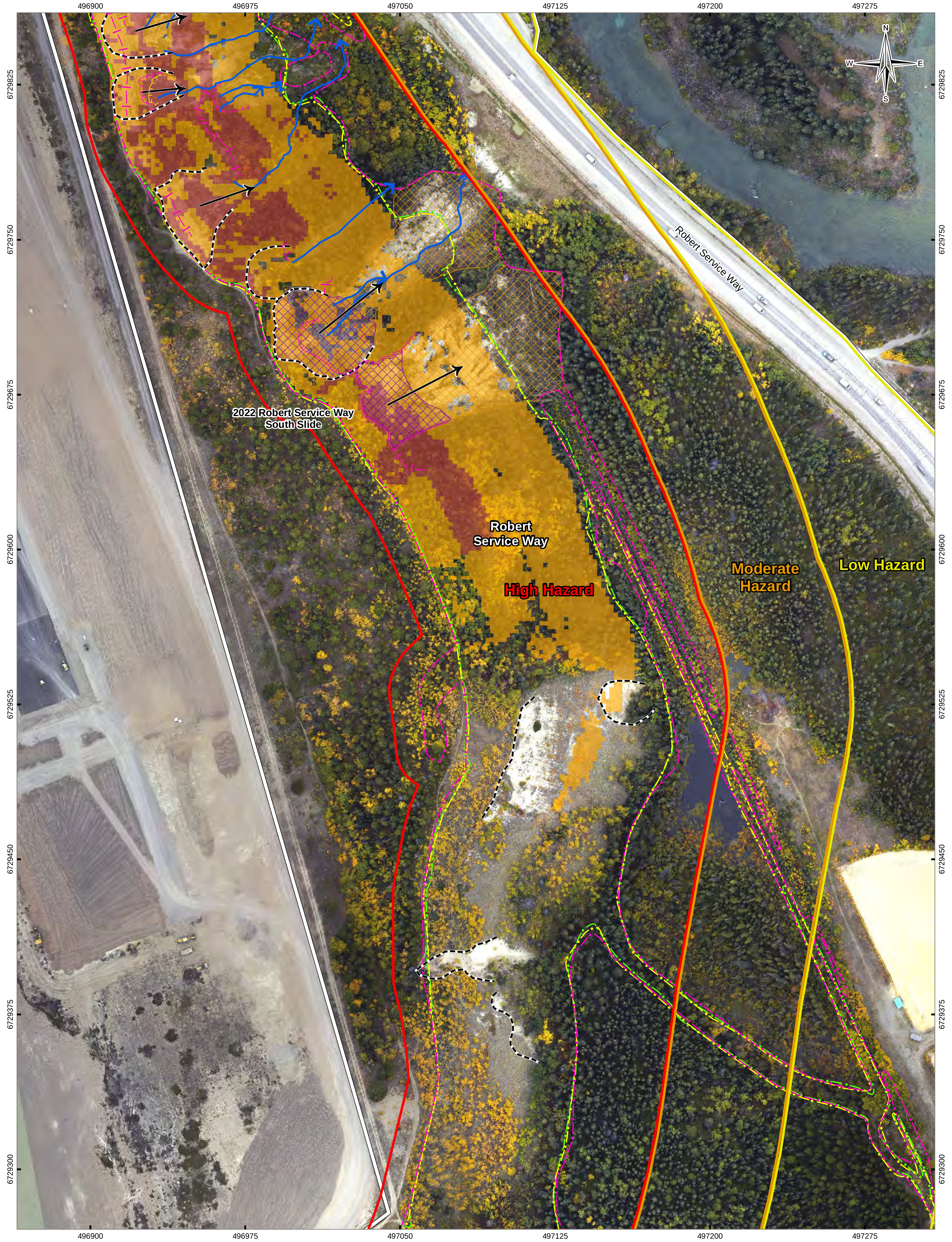
OFFICE	DWN	CKD	APVD	REV
Tt-VANC	JI	SL	EP	0

DATE
June 26, 2023

PROJECT NO.
ENG.WARC04258-01

TETRA TECH

Figure 6m



LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

STATUS
ISSUED FOR USE

Machine Learning Model

Hazard Index

- High (<2)
- Moderate (2 - 2.5)
- Low (> 2.5)

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

Machine Learning (GLM) Landslide Susceptibility Model

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure07_ML_GLM.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	JI	SL	EP	0

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

TETRA TECH

Figure 7a

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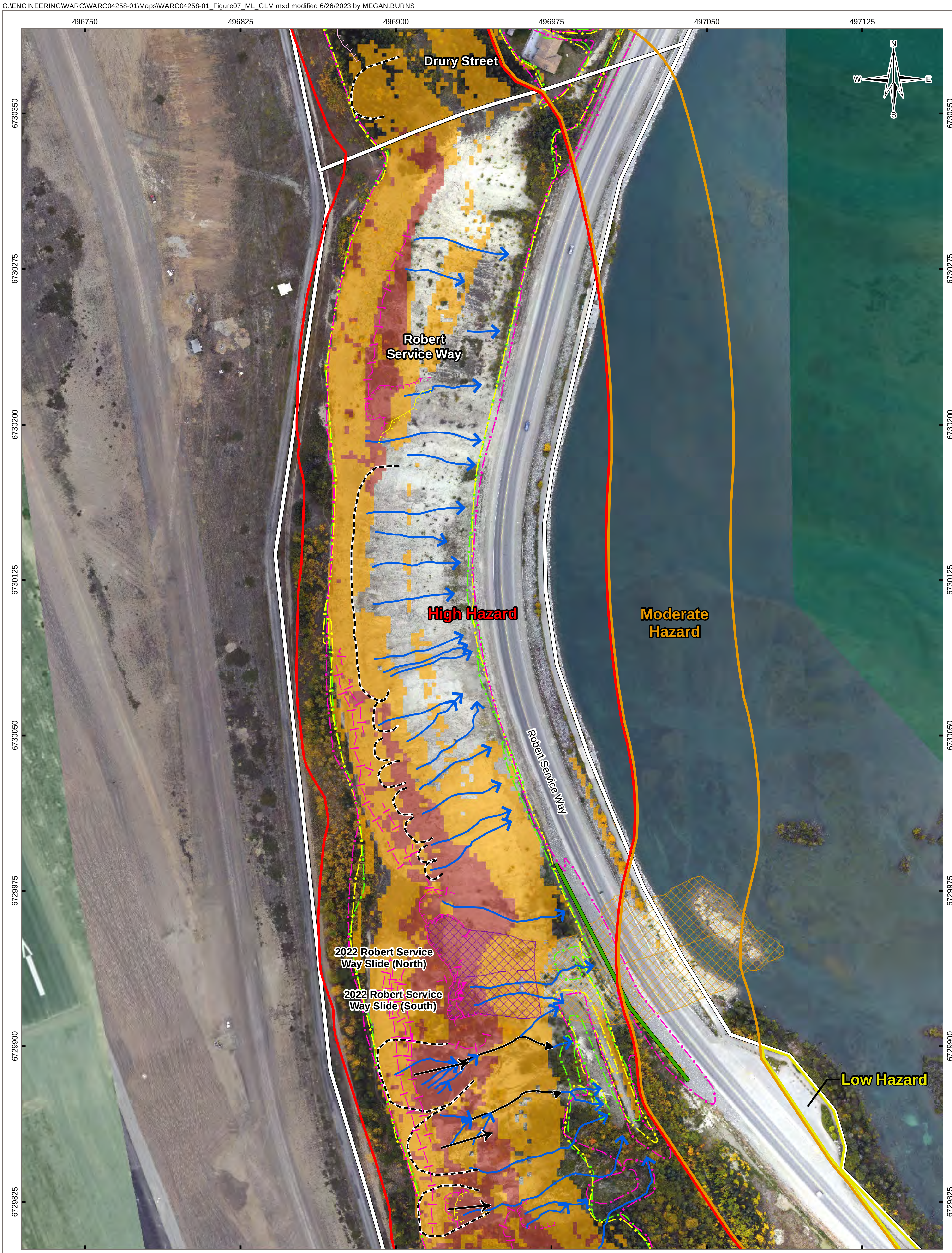

LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Sheet-Pile Wall
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

STATUS
ISSUED FOR USE

Machine Learning Model

Hazard Index

- High (<2)
- Moderate (2 - 2.5)
- Low (> 2.5)

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

Machine Learning (GLM) Landslide Susceptibility Model

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

TETRA TECH

FILE NO.				
WARC04258-01_Figure07_ML_GLM.mxd				
OFFICE	DWN	CKD	APVD	REV
Tt-VANC	JI	SL	EP	0
DATE	PROJECT NO.			
June 26, 2023	ENG.WARC04258-01			

Figure 7b

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LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

STATUS
ISSUED FOR USE

Machine Learning Model

Hazard Index

- High (<2)
- Moderate (2 - 2.5)
- Low (> 2.5)

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

Machine Learning (GLM) Landslide Susceptibility Model

PROJECTION UTM Zone 8	DATUM NAD83	CLIENT Whitehorse
Scale: 1:1,750 25 12.5 0 25 Metres		TETRA TECH
FILE NO. WARC04258-01_Figure07_ML_GLM.mxd		
OFFICE Tt-VANC	DWN JI / CKD SL / APVD EP / REV 0	Figure 7c
DATE June 26, 2023	PROJECT NO. ENG.WARC04258-01	

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LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- East Airport Access
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

STATUS
ISSUED FOR USE

Machine Learning Model

Hazard Index

- High (<2)
- Moderate (2 - 2.5)
- Low (> 2.5)

OVERVIEW

m, l, k, j, i, h, g, f, e, d, c, b, a

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

Machine Learning (GLM) Landslide Susceptibility Model

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

TETRA TECH

FILE NO.				
WARC04258-01_Figure07_ML_GLM.mxd				
OFFICE	DWN	CKD	APVD	REV
Tt-VANC	JI	SL	EP	0
DATE	PROJECT NO.			
June 26, 2023	ENG.WARC04258-01			

Figure 7d

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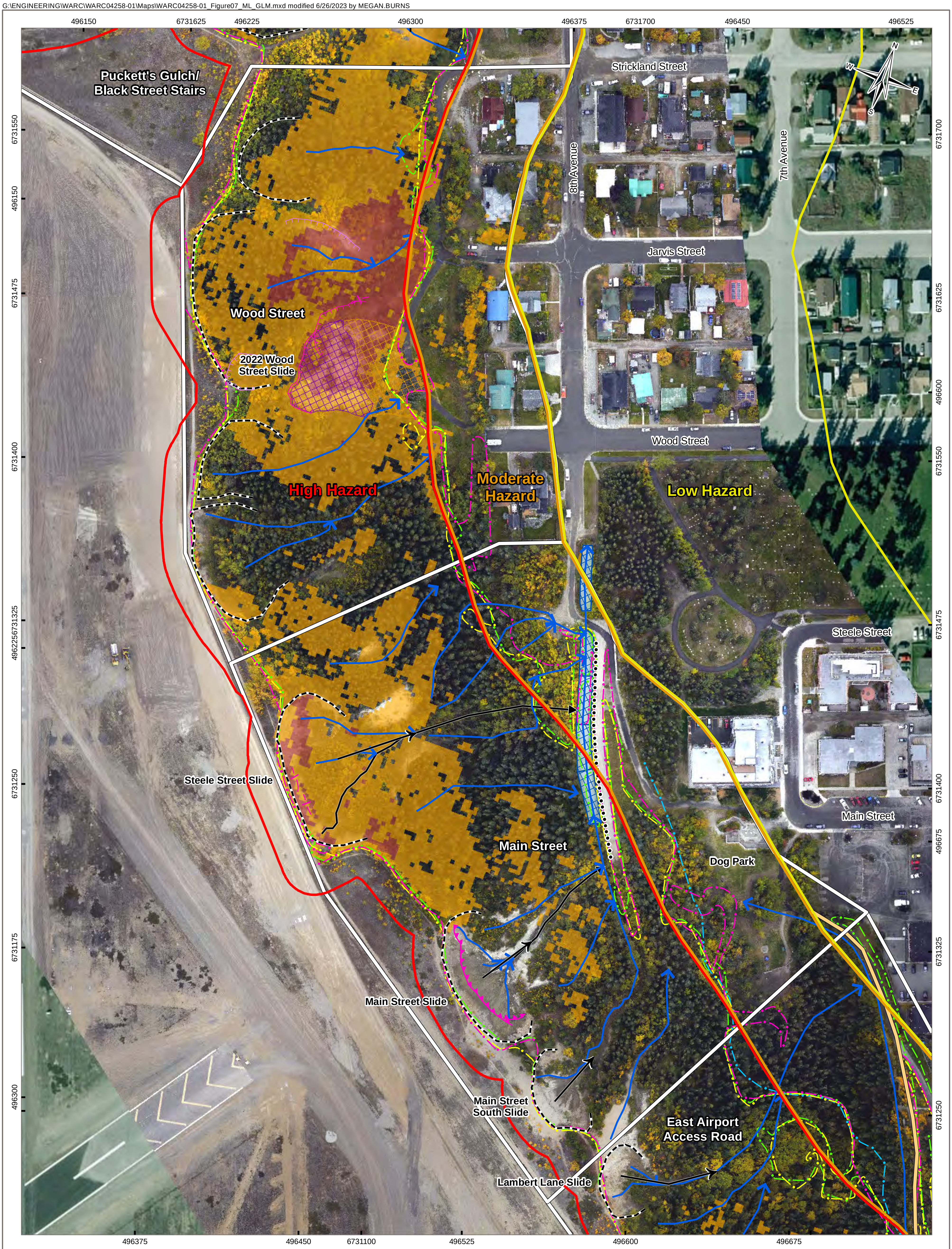

LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- East Airport Access
- Settling Pond
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

STATUS
ISSUED FOR USE

Machine Learning Model

Hazard Index

- High (<2)
- Moderate (2 - 2.5)
- Low (> 2.5)

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

Machine Learning (GLM) Landslide Susceptibility Model

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse THE WILDERNESS CITY

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure07_ML_GLM.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	JI	SL	EP	0

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 7e

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LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Base Data

- Watercourse

STATUS
ISSUED FOR USE

Machine Learning Model

Hazard Index

- High (<2)
- Moderate (2 - 2.5)
- Low (> 2.5)

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

Machine Learning (GLM) Landslide Susceptibility Model

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse THE WILDERNESS CITY

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure07_ML_GLM.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	JI	SL	EP	0

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 7f

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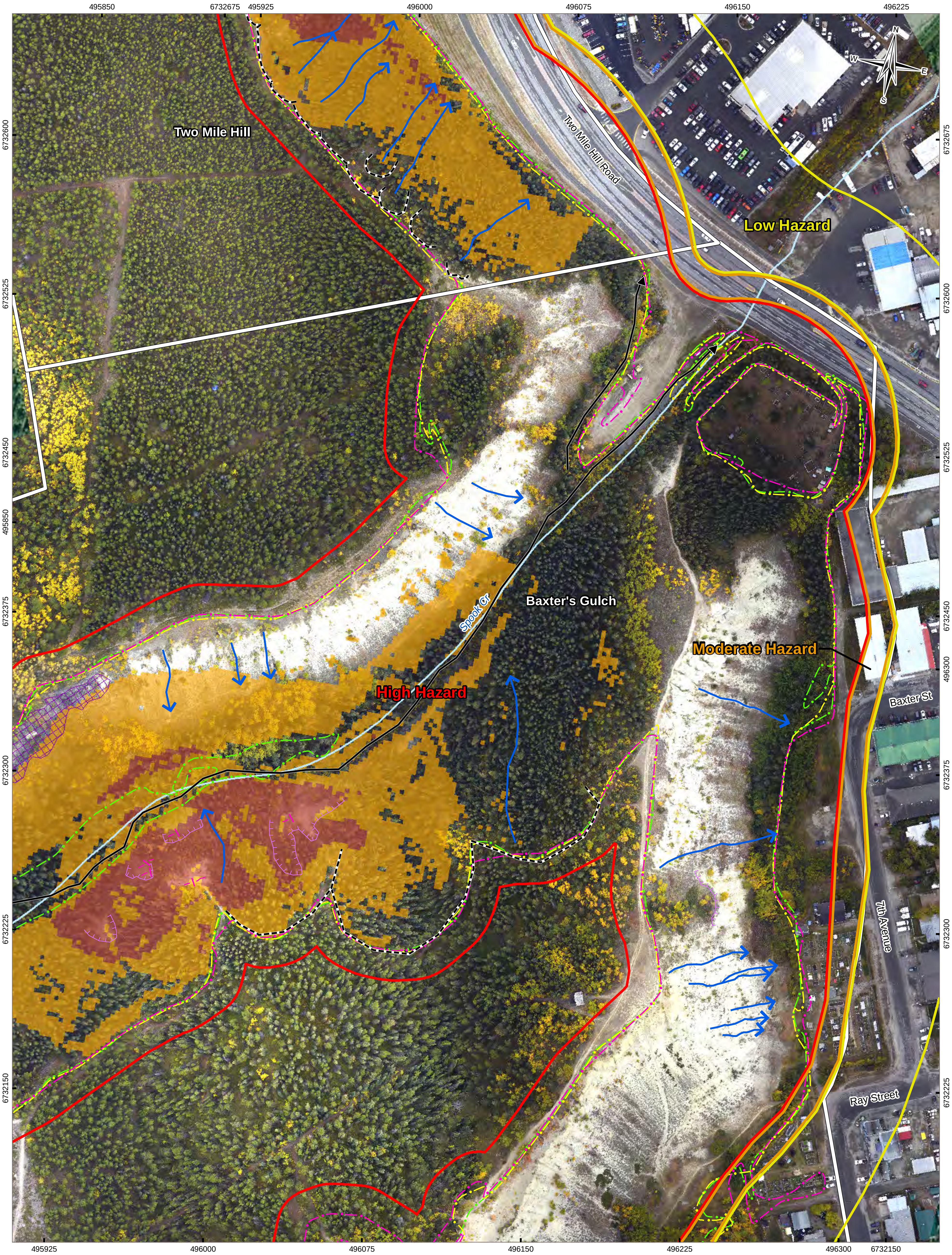

LEGEND

Existing Berm
Gully
Seepage
Toe/Crest of Slope

Mass Movement Features

Debris Flow Headscarp
Landslide Scar - Active
Headscarp - Historical
Tension Crack
Debris Flow Scar
Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

2022
2021
2019
2016
2013
Pre 2013
Pre 2002
Not Dated

Flow Direction
Slope Monitoring Zone

Landslide Hazard Rating

High
Moderate
Low

Base Data

Watercourse

STATUS
ISSUED FOR USE

Machine Learning Model

Hazard Index

High (<2)
Moderate (2 - 2.5)
Low (> 2.5)

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

Machine Learning (GLM) Landslide Susceptibility Model

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

TETRA TECH

FILE NO.
WARC04258-01_Figure07_ML_GLM.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	JI	SL	EP	0

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 7g

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LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Culvert
- Slope Monitoring Zone

Landslide Hazard Rating

- High

Base Data

- Watercourse

STATUS
ISSUED FOR USE

Machine Learning Model

Hazard Index

- High (<2)
- Moderate (2 - 2.5)
- Low (> 2.5)

OVERVIEW

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

Machine Learning (GLM) Landslide Susceptibility Model

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure07_ML_GLM.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	JI	SL	EP	0

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 7h

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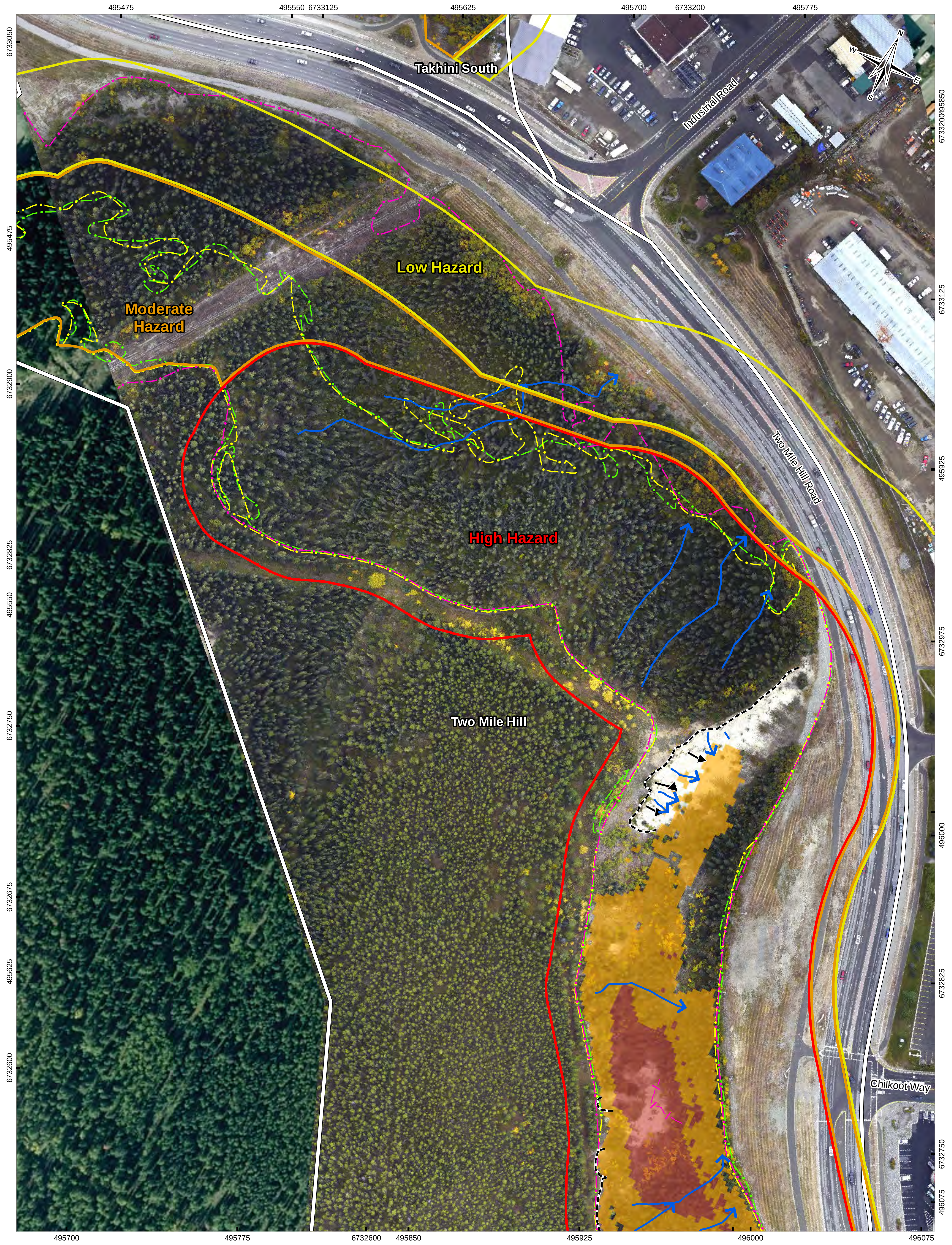

LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Base Data

- Watercourse

STATUS
ISSUED FOR USE

Machine Learning Model

Hazard Index

- High (<2)
- Moderate (2 - 2.5)
- Low (> 2.5)

OVERVIEW

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

Machine Learning (GLM) Landslide Susceptibility Model

PROJECTION: UTM Zone 8	DATUM: NAD83			CLIENT: Whitehorse THE WILDERNESS CITY
Scale: 1:1,750 (25 12.5 0 25 Metres)				TETRA TECH
FILE NO.: WARC04258-01_Figure07_ML_GLM.mxd				
OFFICE: Tt-VANC	DWN: JI	CKD: SL	APVD: EP	REV: 0
DATE: June 26, 2023	PROJECT NO.: ENG.WARC04258-01			Figure 7i

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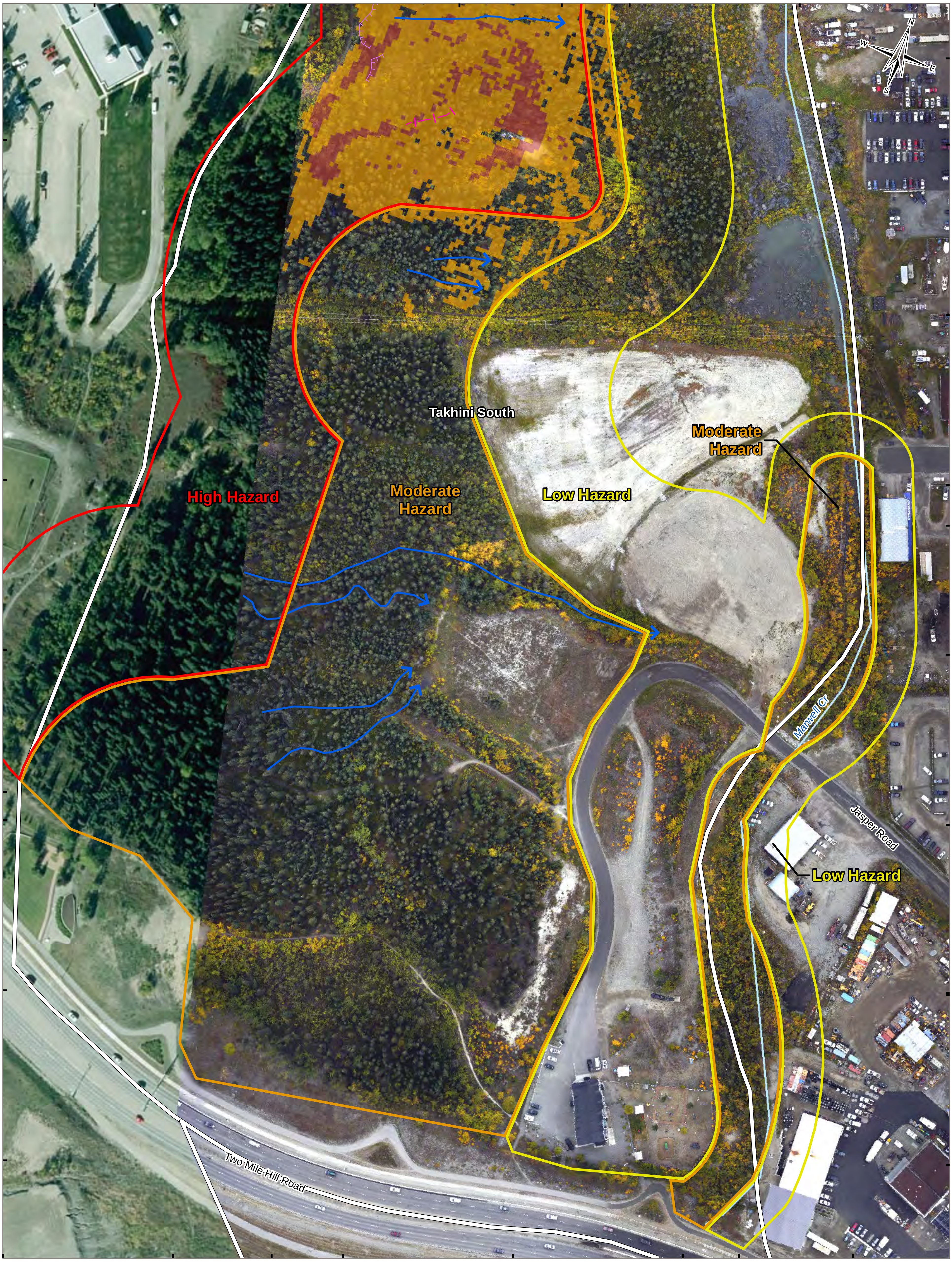


LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Base Data

- Watercourse

Machine Learning Model

Hazard Index

- High (<2)
- Moderate (2 - 2.5)
- Low (> 2.5)

STATUS
ISSUED FOR USE

OVERVIEW

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

**UPDATED GEOHAZARD STUDY
WHITEHORSE ESCARPMENT
WHITEHORSE, YUKON**

**Machine Learning (GLM)
Landslide Susceptibility Model**

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

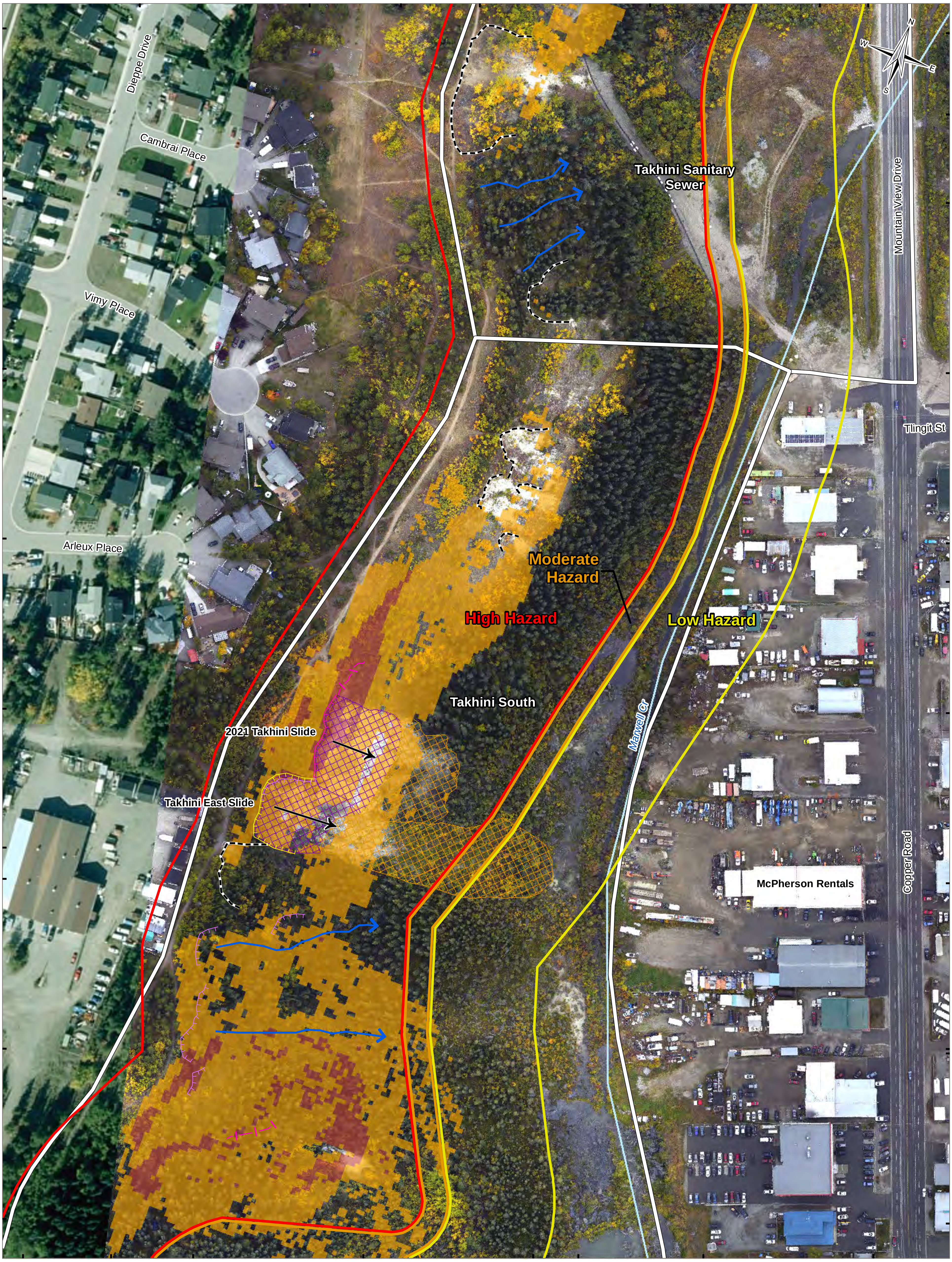
FILE NO.
WARC04258-01_Figure07_ML_GLM.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	JI	SL	EP	0

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 7j



LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Base Data

- Watercourse

STATUS
ISSUED FOR USE

Machine Learning Model

Hazard Index

- High (<2)
- Moderate (2 - 2.5)
- Low (> 2.5)

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

OVERVIEW

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

Machine Learning (GLM) Landslide Susceptibility Model

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750

25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure07_ML_GLM.mxd

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	JI	SL	EP	0

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

TETRA TECH

Figure 7k

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LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

Year Feature Observed

- 2022
- 2021
- 2019
- 2016
- 2013
- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Base Data

- Watercourse

STATUS
ISSUED FOR USE

Machine Learning Model

Hazard Index

- High (<2)
- Moderate (2 - 2.5)
- Low (> 2.5)

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd.
2019 LiDAR and imagery from GeoYukon
Supplemental imagery from ESRI; Maxar (2022)
City of Whitehorse Open Data

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

Machine Learning (GLM) Landslide Susceptibility Model

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse THE WILDERNESS CITY

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure07_ML_GLM.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	JI	SL	EP	0

DATE	PROJECT NO.
June 26, 2023	ENG.WARC04258-01

Figure 7l

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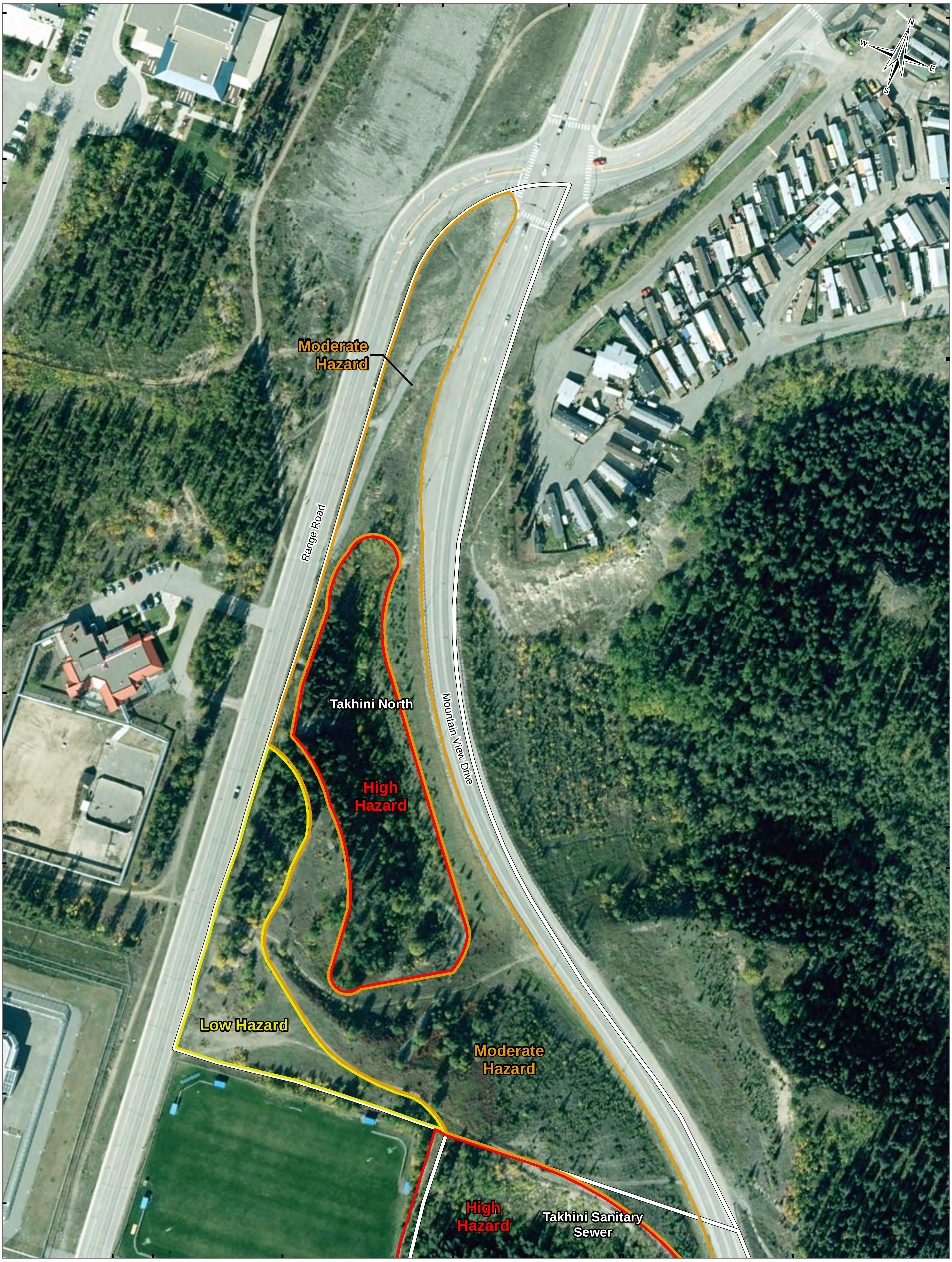

LEGEND

- Existing Berm
- Gully
- Seepage
- Toe/Crest of Slope

Mass Movement Features

- Debris Flow Headscarp
- Landslide Scar - Active
- Headscarp - Historical
- Tension Crack
- Debris Flow Scar
- Landslide (Purple is Initiation/Transition Zone and Orange is Runout Zone)

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- Pre 2013
- Pre 2002
- Not Dated

- Flow Direction
- Slope Monitoring Zone

Landslide Hazard Rating

- High
- Moderate
- Low

Machine Learning Model

Hazard Index

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- Moderate (2 - 2.5)
- Low (> 2.5)

STATUS
ISSUED FOR USE

OVERVIEW

NOTES
Base data source: 2022 LiDAR and orthoimagery collected by Pioneer Exploration Consultants Ltd. 2019 LiDAR and imagery from GeoYukon Supplemental imagery from ESRI; Maxar (2022) City of Whitehorse Open Data

UPDATED GEOHAZARD STUDY WHITEHORSE ESCARPMENT WHITEHORSE, YUKON

Machine Learning (GLM) Landslide Susceptibility Model

PROJECTION	DATUM	CLIENT
UTM Zone 8	NAD83	Whitehorse

Scale: 1:1,750
25 12.5 0 25
Metres

FILE NO.
WARC04258-01_Figure07_ML_GLM.mxd

TETRA TECH

OFFICE	DWN	CKD	APVD	REV
Tt-VANC	JI	SL	EP	0

DATE
June 26, 2023

PROJECT NO.
ENG.WARC04258-01

Figure 7m

APPENDIX A

TETRA TECH'S LIMITATIONS ON THE USE OF THIS DOCUMENT

LIMITATIONS ON USE OF THIS DOCUMENT

GEOTECHNICAL

1.1 USE OF DOCUMENT AND OWNERSHIP

This document pertains to a specific site, a specific development, and a specific scope of work. The document may include plans, drawings, profiles and other supporting documents that collectively constitute the document (the "Professional Document").

The Professional Document is intended for the sole use of TETRA TECH's Client (the "Client") as specifically identified in the TETRA TECH Services Agreement or other Contractual Agreement entered into with the Client (either of which is termed the "Contract" herein). TETRA TECH does not accept any responsibility for the accuracy of any of the data, analyses, recommendations or other contents of the Professional Document when it is used or relied upon by any party other than the Client, unless authorized in writing by TETRA TECH.

Any unauthorized use of the Professional Document is at the sole risk of the user. TETRA TECH accepts no responsibility whatsoever for any loss or damage where such loss or damage is alleged to be or, is in fact, caused by the unauthorized use of the Professional Document.

Where TETRA TECH has expressly authorized the use of the Professional Document by a third party (an "Authorized Party"), consideration for such authorization is the Authorized Party's acceptance of these Limitations on Use of this Document as well as any limitations on liability contained in the Contract with the Client (all of which is collectively termed the "Limitations on Liability"). The Authorized Party should carefully review both these Limitations on Use of this Document and the Contract prior to making any use of the Professional Document. Any use made of the Professional Document by an Authorized Party constitutes the Authorized Party's express acceptance of, and agreement to, the Limitations on Liability.

The Professional Document and any other form or type of data or documents generated by TETRA TECH during the performance of the work are TETRA TECH's professional work product and shall remain the copyright property of TETRA TECH.

The Professional Document is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of TETRA TECH. Additional copies of the Document, if required, may be obtained upon request.

1.2 ALTERNATIVE DOCUMENT FORMAT

Where TETRA TECH submits electronic file and/or hard copy versions of the Professional Document or any drawings or other project-related documents and deliverables (collectively termed TETRA TECH's "Instruments of Professional Service"), only the signed and/or sealed versions shall be considered final. The original signed and/or sealed electronic file and/or hard copy version archived by TETRA TECH shall be deemed to be the original. TETRA TECH will archive a protected digital copy of the original signed and/or sealed version for a period of 10 years.

Both electronic file and/or hard copy versions of TETRA TECH's Instruments of Professional Service shall not, under any circumstances, be altered by any party except TETRA TECH. TETRA TECH's Instruments of Professional Service will be used only and exactly as submitted by TETRA TECH.

Electronic files submitted by TETRA TECH have been prepared and submitted using specific software and hardware systems. TETRA TECH makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

1.3 STANDARD OF CARE

Services performed by TETRA TECH for the Professional Document have been conducted in accordance with the Contract, in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Professional judgment has been applied in developing the conclusions and/or recommendations provided in this Professional Document. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of the Professional Document.

If any error or omission is detected by the Client or an Authorized Party, the error or omission must be immediately brought to the attention of TETRA TECH.

1.4 DISCLOSURE OF INFORMATION BY CLIENT

The Client acknowledges that it has fully cooperated with TETRA TECH with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The Client further acknowledges that in order for TETRA TECH to properly provide the services contracted for in the Contract, TETRA TECH has relied upon the Client with respect to both the full disclosure and accuracy of any such information.

1.5 INFORMATION PROVIDED TO TETRA TECH BY OTHERS

During the performance of the work and the preparation of this Professional Document, TETRA TECH may have relied on information provided by persons other than the Client.

While TETRA TECH endeavours to verify the accuracy of such information, TETRA TECH accepts no responsibility for the accuracy or the reliability of such information even where inaccurate or unreliable information impacts any recommendations, design or other deliverables and causes the Client or an Authorized Party loss or damage.

1.6 GENERAL LIMITATIONS OF DOCUMENT

This Professional Document is based solely on the conditions presented and the data available to TETRA TECH at the time the data were collected in the field or gathered from available databases.

The Client, and any Authorized Party, acknowledges that the Professional Document is based on limited data and that the conclusions, opinions, and recommendations contained in the Professional Document are the result of the application of professional judgment to such limited data.

The Professional Document is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site conditions present, or variation in assumed conditions which might form the basis of design or recommendations as outlined in this report, at or on the development proposed as of the date of the Professional Document requires a supplementary investigation and assessment.

TETRA TECH is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the Client.

1.7 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, TETRA TECH has not been retained to investigate, address or consider and has not investigated, addressed or considered any environmental or regulatory issues associated with development on the subject site.

1.8 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems and methods employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system or method prevail, they are specifically mentioned.

Classification and identification of geological units are judgmental in nature as to both type and condition. TETRA TECH does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

Where subsurface conditions encountered during development are different from those described in this report, qualified geotechnical personnel should revisit the site and review recommendations in light of the actual conditions encountered.

1.9 LOGS OF TESTHOLES

The testhole logs are a compilation of conditions and classification of soils and rocks as obtained from field observations and laboratory testing of selected samples. Soil and rock zones have been interpreted. Change from one geological zone to the other, indicated on the logs as a distinct line, can be, in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil or rock zone transition elevations may require further investigation and review.

1.10 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of test holes and/or soil/rock exposures. Stratigraphy is known only at the locations of the test hole or exposure. Actual geology and stratigraphy between test holes and/or exposures may vary from that shown on these drawings. Natural variations in geological conditions are inherent and are a function of the historic environment. TETRA TECH does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional investigation and review may be necessary.

1.11 PROTECTION OF EXPOSED GROUND

Excavation and construction operations expose geological materials to climatic elements (freeze/thaw, wet/dry) and/or mechanical disturbance which can cause severe deterioration. Unless otherwise specifically indicated in this report, the walls and floors of excavations must be protected from the elements, particularly moisture, desiccation, frost action and construction traffic.

1.12 SUPPORT OF ADJACENT GROUND AND STRUCTURES

Unless otherwise specifically advised, support of ground and structures adjacent to the anticipated construction and preservation of adjacent ground and structures from the adverse impact of construction activity is required.

1.13 INFLUENCE OF CONSTRUCTION ACTIVITY

There is a direct correlation between construction activity and structural performance of adjacent buildings and other installations. The influence of all anticipated construction activities should be considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques are known.

1.14 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, as well as the potential of adverse circumstances arising from construction activity, observations during site preparation, excavation and construction should be carried out by a geotechnical engineer. These observations may then serve as the basis for confirmation and/or alteration of geotechnical recommendations or design guidelines presented herein.

1.15 DRAINAGE SYSTEMS

Where temporary or permanent drainage systems are installed within or around a structure, the systems which will be installed must protect the structure from loss of ground due to internal erosion and must be designed so as to assure continued performance of the drains. Specific design detail of such systems should be developed or reviewed by the geotechnical engineer. Unless otherwise specified, it is a condition of this report that effective temporary and permanent drainage systems are required and that they must be considered in relation to project purpose and function.

1.16 BEARING CAPACITY

Design bearing capacities, loads and allowable stresses quoted in this report relate to a specific soil or rock type and condition. Construction activity and environmental circumstances can materially change the condition of soil or rock. The elevation at which a soil or rock type occurs is variable. It is a requirement of this report that structural elements be founded in and/or upon geological materials of the type and in the condition assumed. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions assumed in this report in fact exist at the site.

1.17 SAMPLES

TETRA TECH will retain all soil and rock samples for 30 days after this report is issued. Further storage or transfer of samples can be made at the Client's expense upon written request, otherwise samples will be discarded.