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Alaska Department of Transporation & Public Facilities

R&M Consultants, Inc.

Winter Reconnaissance - Preliminary Findings Report

Beach Road Landslide, Haines, Alaska

Professional Services Agreement No. 25213018
IRIS Program No. SDRER00317

LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS

WINTER RECONNISSANCE
PRELIMINARY FINDINGS REPORT

BEACH ROAD LANDSLIDE
HAINES, ALASKA

Professional Services Agreement No. 25213018
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Report To:

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LANDSLIDE TECHNOLOGY
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EXECUTIVE SUMMARY

The Beach Road Landslide in Haines, Alaska occurred on December 2, 2020 when regional weather produced an 'atmospheric river' that delivered historic precipitation and caused significant snowmelt. Several local, state, and national agencies along with local volunteers responded to the event conducting emergency evaluations of the landslide and adjacent terrain in early December. In February 2021, Landslide Technology (LT) along with prime consultant R&M Consultants, Inc. (R&M) were contracted by the State of Alaska Department of Transportation and Public Facilities (DOT&PF) to conduct a preliminary geotechnical investigation and analysis. This Preliminary Findings Report details work was completed during Phase 1 geotechnical investigations and analyses. Work was authorized under DOT&PF Agreement No. 25213018 (IRIS Program No. SDRER00317). A scope of work and details of the preliminary findings are provided in Section 1.

The preliminary findings provided herein are based on desktop studies of available information and observations gathered during a snow hindered winter reconnaissance. Until completion of a more detailed/unhampered surficial reconnaissance and subsurface investigation, these findings should be considered preliminary and incomplete.

Section 2 describes background information concerning the December 2020 atmospheric event and landslide occurrence, based on documentation from initial investigators and communications with residents. Regional and local geology is described in Section 3 of the report. Initial work included conducting a desktop geomorphic study of available information. This was followed by a winter reconnaissance and further geomorphic evaluations. Details of our reconnaissance and test pit observations are provided in Section 4 of the report.

Results of the geomorphic evaluations, summarized in Section 5.1, indicate there are consistent features across the site. The bedrock areas form the steep slopes near the top of Mt. Riley. The moderate to gentles slopes of the flanks of Mt. Riley are formed by colluvium at mid-slope elevations, and at lower elevations gentle slopes are formed by colluvium with contributions from alluvial and marine deposition processes. Lineaments, benches and swales are interpreted to be surficial expressions of the regional and local geologic structure. One feature only observed in the pre-slide LiDAR is a lobe of material near the headscarp area of the landslide. This lobe is interpreted to be an accumulation of colluvium that exhibited a relatively gentler slope angle than the surrounding bedrock areas. This lobe feature is interpreted to be a significant source area for the Beach Road Landslide.

While preliminary findings of the landslide mechanisms and conditions of the landslide body and adjacent slopes have been provided herein, there are several data gaps that require further investigation including: i) geomorphic features (ground surface geology), ii) subsurface geology, iii) stratigraphy in slopes on both sides of the landslide, iv) landslide geometry and thickness of slide debris deposits, v) source area of second flow slide, vi) composition of slide debris materials, vii) moisture content of slide debris, viii) groundwater pressure increase (trigger), ix) groundwater profile in the hillside, x) ground movement preceding catastrophic sliding, xi) ground movement following catastrophic sliding, xii) east tension crack conditions, xiii) condition of original roadbed beneath slide debris, xiv) hillside depression upslope of landslide headscarp, and xv) submarine slide debris runout. Approaches to address and better define these data gaps are provided in Section 5.2 of the report.

Section 5.3 describes interpretations of the landslide and causation. Groundwater and surficial runoff played a major role in landslide triggering. The unprecedented weather event produced historic precipitation and significant snowmelt that caused elevated groundwater pressures resulting in artesian flows. The high groundwater pressures at the toe of the colluvial lobe combined with surficial infiltration in the landslide area likely triggered movement of this thicker deposit.

Why did the catastrophic landslide occur where it did, in a limited 300- to 650-foot-wide swath, and not in the adjacent hillside slopes? The north-facing slope of Mt. Riley generally exhibits bedrock-controlled features (i.e., mapped bedrock areas). These features are not as evident in the landslide area as based on geomorphic evaluations of pre-slide LiDAR. Instead, slopes in the landslide area exhibited gentler angles than surrounding terrain in the pre-slide LiDAR. In addition, the western and eastern limits of the lobe-like shape of material present on the pre-slide LiDAR were wholly within the extents of the upper landslide area. Very likely, the area where the catastrophic landslide occurred was fractured and weathered with thicker accumulations of colluvium, which would create weaker shear strengths and permeable flow paths for surficial and groundwater to rapidly penetrate. The reason for the formation of these conditions is hypothesized to be related to regional structure or faulting due to tectonic activity in the past but is not clear at this time.

When the upper landslide failed, it left steep and tall sidescarps and a headscarp, which in turn reduced lateral support to the adjacent ground. The upper slide mass would also have caused friction (or drag) along its sides, imparting stresses to the ground immediately adjacent. The tension crack extending to the east of the headscarp is likely evidence of tension as the ground downslope slumped northwesterly towards the free face (sidescarp) created by the failure and down-dropping of the upper slide mass.

A subsequent lobe of liquefied slide debris reached the shore (second flow event), within the easterly half of the landslide area. This may have been precipitated by a collapse of weakened material, and possibly remnants of debris from the initial failure, near the wet midslope bench. Alternatively, high hydraulic gradients could have liquefied and rapidly displaced weak colluvium causing the very fluid material to flow over the easterly “midslope bedrock area”, carrying fallen trees and debris on its way to the shore.

The purpose of preparing a preliminary evaluation of the landslide is to develop realistic scenarios to guide planning a geotechnical investigation and to inform the community of potential and likely geologic hazards and risks. A qualitative assessment of geologic hazards was conducted to provide a sense of scale for potential failure scenarios along with discussions of factors that could trigger these events and conditions that may be needed for the scenario to occur, as described in Section 5.4.

Slope stability monitoring will be a key aspect to complete geotechnical investigations, as detailed in Section 5.5. Geotechnical instrumentation could include: i) groundwater piezometers, ii) slope movement inclinometers, iii) crack and surface extensometers, and iv) tell-tale stake locations. Survey monitoring methods that could be considered, include: i) robotic total stations combined with installation of reflector prisms at key locations, ii) GNSS units installed at critical locations, iii) periodic LiDAR surveys, and/or iv) satellite-based InSAR and land-based radar interferometry. An early warning system (EWS) may be desired; however, planning would be required to develop and understand conditions that are measurable and applicable. Those conditions known at this time include: i) precipitation, ii) snowpack depths, and iii) temperatures. Completion of the recommended spring reconnaissance and subsurface investigation would further inform evaluations of measurable conditions.

Several community concerns are addressed in Section 5.6. The hazards and risks associated with the community concerns were evaluated to provide the Haines Borough actionable information for their internal evaluation of allowable use of the area and temporary (interim) access road (Beach Road). Detailed descriptions of the community issues and the qualitative risk assessment is provided in Sections 5.6.2 through 5.6.10.

Preliminary mitigation concepts for landslide factors and slope mass wasting processes have been discussed in Section 5.7. Potential mitigation concepts for landslide factors may include: drainage measures, buttressing and filter berms, unloading of driving forces, surcharging to counteract groundwater pressures, and avoidance facilitated by signage and/or monitoring. Slope mass wasting mitigation concepts include: slope reinforcement, berms/walls/barriers, diversion berms, diversion channels, draped/pinned mesh, and drainage and/or rock inlays.

Recommendations provided in Section 6 include geotechnical items to investigate landslide and hillside slope stability conditions necessary for planning and designing restoration of infrastructure (i.e., interim and permanent roads, utilities, etc.). Once an understanding of slope stability conditions is gained, geotechnical models for analysis and design could be developed, and methods for interim and long-term monitoring could be evaluated. Recommendations for completing the geotechnical investigations include:

- Expand the Pre-slide (2014) LiDAR terrain model in the upper landslide area and upper hillside to complete the evaluation of site geomorphology.
- Conduct a spring reconnaissance to confirm geomorphic interpretations, implement initial instruments, and confirm subsurface exploration locations and logistics.
- Subsurface investigations and instrumentation are critical for understanding landslide geometry and stability factors in the landslide and adjacent slopes.
- Periodic LiDAR monitoring to monitor changes in ground surfaces, particularly in the area downslope of the east tension crack.
- Bathymetry of the offshore deposits could be beneficial should SAR be required in the submarine slide debris (optional task).
- Geotechnical assistance during possible SAR operations could be beneficial to the Haines EOC to provide daily landslide observations and evaluations.
- Geotechnical assistance regarding development of land use and community management of geologic hazards could be beneficial to the Haines Borough.
- Early warning systems should include a comprehensive weather station near the headscarp of the landslide. Camera(s) could also be installed to provide visual comparison capabilities.

This Preliminary Findings Report should be considered as an initial step towards investigating and analyzing the Beach Road Landslide and adjacent slopes. To develop an understanding of the landslide and adjacent slopes, additional work would be necessary, as recommended herein. The interpretations and evaluations should be considered preliminary until the recommended tasks can be completed.

1 INTRODUCTION

The Winter Reconnaissance Preliminary Findings Report for the Beach Road Landslide is the culmination of the initial Phase 1 of geotechnical study authorized by the state of Alaska Department of Transportation and Public Facilities (DOT&PF) as described in Agreement No. 25213018 (IRIS Program No. SDRER00317). The purpose of Phase 1 services is to provide an initial assessment of site conditions, geologic hazards, potential mitigation approach options, recommendations for Phase 2 investigations and monitoring, and preliminary guidance for emergency and community concerns.

1.1 Phase 1 Scope of Work

The geotechnical scope for Phase 1 includes:

1. Data collection and review of preliminary information prepared by others, including discussions with Haines representatives, local residents, initial emergency responders, and state agencies.
2. Winter reconnaissance of landslide and hillside within the Area of Concern (AOC), including helicopter fly-overs, traversing on foot, and accessing the headscarp area.
3. Preliminary Winter Reconnaissance Findings Report to summarize the data obtained and preliminary assessments of the landslide and potential geologic hazards of the subject area. In addition, recommendations will include supplemental geotechnical investigations to support Haines and its residents to improve understanding and interpretations of the geologic slope hazards and measures for use in managing and/or reducing risks. Identification of landslide hazard types associated with the site and landslide risks, including the likelihood and consequences of future landslides. Preliminary hazard and risk evaluations for use in strategizing options for emergency site management. Preliminary opinions and guidance to address community concerns, including the following:
    - Resumption of Search and Recovery (SAR) activities.
    - Temporary access precautions.
    - Reestablishing or reconstructing the roadway to residences and a State Park facility.
    - Reconnecting utilities.
    - Re-occupancy of homes.
    - Potential landslide and slope mitigation options.
    - Potential early warning systems.

1.2 Basis and Use of Report

This report is based on desktop geomorphic evaluations of pre- and post-slide LiDAR data, regional geologic mapping, information provided by the Haines Borough EOC, DGGS, DOT&PF, and local contributors along with a seven-day winter reconnaissance. During the reconnaissance, surficial observations were hampered by relatively heavy snow cover up to three feet thick in and adjacent to the landslide with more than six feet of drifted snow at higher elevations. Existing information and reconnaissance observations were used to develop a preliminary understanding of the landslide and adjacent hillside slopes. Gaps in understanding were identified, and approaches for characterizing the unknowns were evaluated. The information and interpretations provided in this report are based on readily available data and limited surficial observations. To develop an understanding of the landslide and adjacent slopes, additional work is necessary, as recommended herein. The interpretations and evaluations should be considered preliminary until the recommended tasks can be completed.

2 BACKGROUND INFORMATION

On December 2, 2020, damaging storms impacted several Southeast Alaska communities. The greater Haines Borough was impacted by flooding, landslides, and debris flows, causing widespread and severe infrastructure damage, mandatory and voluntary evacuations, and loss of life. Several local, state and federal agencies responded along with local contractors to assist the Haines Borough with the initial response. The state of Alaska Department of Natural Resources (DNR)-Division of Geological and Geophysical Surveys (DGGS) and DOT&PF, on behalf of the Haines Borough and Emergency Operations Center, deployed a team of geoscientists with different specialties to assist by collecting data to support decision making by the Local and State Emergency Operations Center (EOC) teams. The teams arrived in Haines between the 4th and 6th of December. The most severe impact was a large landslide event along Beach Road which completely destroyed two homes, significantly damaged another home, blocked road access and disrupted utilities to approximately 20 homes (refer to Location and Vicinity Map, Figure 1, and December 2020 Aerial Photo Map, Figure 2). Two residents of these homes are unaccounted for and presumed to have perished during the event. After ten days of on-site analysis, Search and Rescue (SAR) operations and re-occupancy of several homes were halted pending further evaluations of landslide stability and hazards.

The weather event was considered a very strong atmospheric river followed by a series of additional strong and moist weather fronts from December 1st through 8th. This weather event produced historic extreme precipitation along with significant snowmelt, as described by Jacobs (2021a & 2021b). The temperature in Haines at the time of the storm was above freezing and rose into the mid-40s °F. The downtown Haines COOP weather station reported 6.62 inches of precipitation which exceeded the previous historic daily record (2005) by 8:00 am December 2. The heavy rain continued and the snow level rose above 2500 feet elevation. The 48-hour precipitation recorded at the downtown Haines COOP weather station was 8.54 inches, and the weather station at the Haines airport recorded 10.26 inches in 48 hours. Jacobs performed an evaluation and estimated the storm recurrence return interval to be on the order of 200 to 500 years.

2.1 Landslide Description and Related Factors

The resulting rainfall and snowmelt produced a significant amount of runoff. Area residents were surprised by the unusually high amounts of stormwater and runoff water in their yards and along/across the roadway. Water discharge from a couple springs near the residences and road appeared to flow at rates far greater than previously observed. A water-supply well located on the Anderson residence located at the east end of Beach Road was overflowing from the top of the casing extending above the ground surface, indicating a rise in artesian groundwater pressures (domestic wells for several properties along Beach Road had previously been installed through shallow overburden and into deep bedrock over 200 feet deep to reach suitable groundwater, with prior flows typically of only a few gallons per minute). Residents observed excessive runoff, including unusual discharge of water appearing to flow from the roots of trees. Surface runoff water caused erosion of ditches and parts of the roadway, and residents attempted to regrade some ditches to divert flows from sheeting across the road. On the morning of and prior to the catastrophic landslide event, occupants at the Messano residence heard water flowing in the house, which was due to unexpected water discharging from a toilet.

In the early afternoon on December 2nd, shortly before 2 pm, residents in the Slate residence (located near the shore, immediately east of the landslide) heard a loud noise like a large slab of ice sliding off the roof. They stepped outside and saw the runout of the debris flow landslide moving with trees tilting in all directions, along with sounds of popping, breaking and snapping of trees, sounding like a train or big jet. They hurried inside the home for protection, then looked out the window to the west and saw the debris flow landslide extending downslope into the inlet water and realized homes had been washed away. This was followed within a few minutes by another phase of flow sliding, more fluid this time and the tree trunks were generally laying on the flow landslide as it flowed to the shoreline and further into the inlet water (which lasted possibly a minute or less). The Slates recorded a video of this second flow landslide. Electric power to the house was lost immediately concurrent with the first debris flow.

In the early afternoon on December 2nd, the occupants of the Messano house (located on the upslope side of Beach Road, immediately west of the landslide) had just driven back to the house from downtown, and had to find a location to park to avoid standing water and eroded areas. They were still in their car when they heard a loud rumbling noise which caused them to look up and then saw trees and boulders rapidly moving/flowing very close to their east, and saw the flowing debris push a parked car which impacted the Messano house. The landslide event lasted approximately a half minute, and then a few minutes later they heard a second debris flow event, but could not see it from their location due to the westerly pileup of debris from the first flow landslide.

The debris from the landslide covered a 650-foot portion of Beach Road, cutting off access to the residents to the east of the landslide on this dead-end road. After the landslide event, it was necessary to evacuate residents by boat as Beach Road had been rendered impassable.

2.2 Emergency Evaluations

Emergency evaluations of the debris landslide and hillside were subsequently performed by the DGGS, along with support from DOT&PF, Haines Borough and EOC, Haines Avalanche Center, National Weather Service (NWS, NOAA), and local geologists. Reconnaissances were performed of the landslide and adjacent terrain in early December, and a helicopter and drone were utilized to perform aerial evaluations and imaging. DNR staff accessed the headscarp area on December 11 and 12 and evaluated exposed rock conditions. Aerial photographs, LiDAR imaging and videos were obtained of the post-failure conditions. The reconnaissances documented the various materials and conditions comprising the slide debris, the relative geometry and topography of the ground surface of the landslide scarp and debris, surface water flows and springs, and identified a tension crack extending from the headscarp towards the east a reported distance of approximately 160 feet. This tension crack prompted further assessment of the hillside to the east of the landslide. Representative photographs taken in December 2020 are presented in Appendix A.

The reconnaissances verified that the slide debris consists of a heterogeneous mix of cobble and boulder-sized rocks, detached rock blocks, soil, vegetation and trees. Surface water flowed into the headscarp from upslope, apparently from a localized depression (hollow basin) that concentrated water from melting snow, creating a waterfall down the face of the headscarp. Springs were evident in the middle portion of the slide debris, which resulted in several streams coursing downslope. Some of the spring water appeared orange in color, possibly indicating iron staining in subsurface materials.

By December 9 the runoff from upslope of the headscarp had reduced significantly, and only a trickle was flowing by December 12 and no water or seepage was observed in the rock slopes comprising the headscarp. The headscarp was observed to consist of fractured and jointed bedrock, and no soil infilling or slickensides were evident.

An ortho-aerial photo was developed from the December post-slide photography to assess the landslide and adjacent hillside slopes. Figure 2 shows the aerial photo, which includes the approximate locations of private properties and roads. The extent of sliding and impacts to the terrain were visible. The length of the landslide was determined to be 2,300 feet from the headscarp to the shoreline. The width of the upper landslide area was approximately 300 to 400 feet, and the width along the road and shoreline was approximately 650 feet. Locations of large rock blocks and clusters of boulders on the surface of the slide debris were evident in the aerial photo. Drainage channels on the slide debris were also identified on the aerial photo. A "linear" feature was identified relatively parallel to the west flank of the landslide, comprised of a canopy of spruce trees.

The 2014 and 2020 LiDAR data were evaluated to identify apparent changes in the ground surface and to interpret geomorphology of the hillside. The images showed the irregular topography and areas incised by springs and streams. It became apparent that the 2014 LiDAR image did not extend all the way up to the headscarp, which limited the evaluations. Hillshade models were developed from the LiDAR terrain data, and 3-D images were created by the Haines Avalanche Center to discern geomorphic conditions. Representative oblique images captured from the LiDAR model are presented on Figure 3 to illustrate the terrain, apparent structural and drainage features, and landslide boundary and features.

Preliminary evaluations were performed to evaluate the hillside terrain east of the landslide for possible landslide features to identify geologic hazards. Of concern were drainage channel features that could possibly indicate the presence of historic landslide sidescarps, linear and arcuate changes in ground surface that could possibly indicate historic landslide scarps or jointing/weathering/erosion of bedrock, and mounds of bedrock separated by gently-sloped areas that could possibly indicate displaced bedrock blocks or weathering and erosion along faulted/jointed bedrock.

Haines Borough adopted a DGGS map delineating the AOC, which showed the properties included in the evacuated zone (December 18, 2020). The AOC was defined as an area that "could be impacted by a potential landslide originating at the fracture site" and that this area "remains an area of elevated concern with unknown stability." The approximate boundary of the AOC is shown on Figure 2.

2.3 Initial Landslide Monitoring

Survey monitoring was performed by local surveyor Dave Smith with Southeast Roadbuilders. Survey points were established above the landslide headscarp and close to the Messano house, including a boulder located in the slide debris east of the Messano house. Data through February 12 did not detect any movement of the survey points.

A series of "time lapse" photos of the upper landslide debris made by the Haines Avalanche Center from December 22, 2020 to February 5, 2021 did not discern any major movement of the slide debris. This matched observations by local residents that the slide debris began to get firmer, and that most of the slide debris did not appear to be noticeably moving.

2.4 Interim Temporary Access Road

After almost two months of apparently relatively minor to negligible ground movement, a local contractor constructed a temporary corduroy road across the landslide in late January, 2021. The temporary road was approved by Haines Borough to allow residents to retrieve belongings and to mitigate concerns at their properties. The surface of the slide debris appeared to be less saturated and was somewhat firmer to walk on. This construction effort took two and a half days to accomplish. Portions of the debris exhibited wet conditions, and the hydraulic Cat 335 excavator experienced localized buoyant conditions (like being on a waterbed). The western portion of the debris (the first 100 feet of the temporary road) was extremely soft and saturated. A "rocky" ridge was encountered between 100 and 150 feet from the western flank of the landslide). The middle and eastern area of slide debris contained more boulders and was relatively firmer. Many tree trunks were in the slide debris. The roadbed was developed by reinforcing the subgrade with logs and pushing boulders into muddy zones. One culvert was installed in a drainage area approximately 200 feet west of the eastern end of the temporary access road (reportedly a 30-inch diameter steel pipe).

3 REGIONAL AND LOCAL GEOLOGY

The landslide site is located on the east side of Haines, Alaska, which is approximately 75 miles northwest of Juneau, Alaska as shown on Figure 1. Haines lies at the northern end of the Alexander Archipelago on the Chilkat Peninsula. The Chilkat Peninsula is bounded on the northeast by the Chilkoot Inlet and on the southwest by the Chilkat Inlet. These two waterways form the northern extension of the Lynn Canal as shown on Figure 1.

The Chilkat Peninsula and the southeast region of Alaska has undergone numerous changes in geologic time. There has been accretion of terranes onto the western margin of the ancient North American tectonic plate, metamorphism of these terranes, igneous intrusions causing deformation, faulting and significant uplift, and most recently the advancement and retreat of continental glaciation. These processes have combined to form the complex geology and structural elements through the region. A regional geologic map is provided on Figure 4.

The Chilkat Peninsula is within the southwestern end of the Skagway Transect group of rock materials and the lithotectonic Wrangellia Terrane (Brew and Ford, 1994). The basal part of the Wrangellia terrane consists of Paleozoic-aged volcanic flows and breccias that are locally intruded by granitic rocks of the Skolai arc. The terrane is overlain by Gravina overlap assemblages and the post-amalgamation Wrangell Lava (Brew and Ford, 1994). These in turn have locally been intruded by extensive Cretaceous-aged ultramafic bodies.

The regional area and the Chilkat Peninsula have undergone faulting during the middle Tertiary era that controls much of the geologic structure currently present. The Chilkat River fault, which trends northwest to southeast is the main local segment of the Denali fault system in the area. The Denali system is a right-lateral feature with a number of splays. A major unnamed fault splay cuts across the Chilkat Peninsula south of Haines and connects with the Lutak Inlet-Chilkoot Inlet fault, which is north-northwest to south-southeast trending. This splay cuts through the Triassic basalts that make up the Chilkat Peninsula. As discussed above, these basalts (meta-basalt) are intruded by early- to mid-Cretaceous ultramafic rocks that are found at the site (Brew and Ford, 1994). These ultramafic rocks are intrusive bodies that consist of magnetite-bearing clinopyroxenite and usually contain hornblende and biotite (Gehrels and Berg, 1992). According to local geological experts who reside in Haines, visible plagioclase is rare to non-existent. In addition, exposed contacts between the ultramafics and the metabasalt are rare or non-existent. Dikes of diorite, granodiorite and tonalite are locally observed intruding the ultramafics.

In addition to faulting and intruded plutonic rock, the landscape and the topography at the site have been heavily influenced by glaciation. The area has been covered by glaciers likely several times during the Pleistocene Epoch (Lemke and Yehle, 1972). Marine deposits located several hundred feet above sea level indicate the land has been uplifted relative to sea level since the last major deglaciation of the region approximately 12,000 to 10,000 years ago. The rate of relative uplift due to deglaciation rebound in the Haines area has been estimated to be nearly an inch per year (Larson, et al., 2005).

Surficial deposits mapped in the area listed from oldest to youngest include the following Quaternary-aged units (Lemke and Yehle, 1972): 1) undifferentiated drift deposits, 2) outwash and ice-contact deposits, 3) elevated fine-grained marine deposits, 4) elevated shore and delta deposits, 5) alluvial fan deposits, 6) colluvial deposits, 7) modern beach deposits, 8) Chilkat River floodplain and delta deposits, 9) and fills. Surficial deposits observed during the winter reconnaissance at the site include till and/or glacial deposits, fine-grained marine sediments, delta deposits, colluvium, and fill. A discussion of observed units is provided in Section 4.

4 WINTER RECONNAISSANCE

Following a review of available information related to the landslide event (and the days preceding) and geomorphic interpretations of pre- and post-slide LiDAR images, a winter reconnaissance was performed at the project site. The goal of the reconnaissance was to: i) check observations obtained from the desktop review and map interpretations, ii) observe and document landslide features, iii) observe and document surficial and outcrop geology, iv) assess surficial hydraulic conditions, and v) estimate groundwater conditions.

Two geotechnical engineers and one engineering geologist from LT performed the winter reconnaissance between February 22 and March 1, 2021. The reconnaissance was performed via: i) helicopter over-flights, ii) traversing the landslide area and the slopes adjacent to and above the landslide within the Haines Borough EOC AOC as shown on Figure 2, iii) walking the limits of Beach Road and observing surficial conditions adjacent and behind local residences, and iv) conversations with local residents.

During the reconnaissance, surficial observations were hampered by relatively heavy snow cover. Up to three feet of snow was encountered in and adjacent to the landslide area and drifts thicker than six feet were encountered at higher elevations near and south of the headscarp of the landslide. Representative photos taken during the winter reconnaissance are provided in Appendix B.

4.1 Ground Observations

Aerial observation of the landslide and adjacent slopes was initially conducted on February 23, 2021. The goal of the initial helicopter work was to gain an understanding of potential outcrop locations, assess conditions in and around the headscrap and to deploy rope access gear to the communication tower located south of the landslide area. Observations were limited due to snow and vegetative cover. However, some rock outcrops and surficial slumps were observable and noted as targets for ground observation. A second flight was conducted on February 26, 2021 with the goal of confirming ground observations and to demobilize rope access gear.

When rock outcrops were observed a rock mass rating (RMR) was conducted (Kirkaldie, 1988). This included collection of geologic structural data and character, description of the rock type, weathering hardness, and jointing condition, estimating rock compressive strength, and observation of water/moisture conditions (i.e., seepage or groundwater). Geologic structure was measured with a Brunton Geostratum compass using a dip and dip direction nomenclature. Due to snow cover and colluvial deposits, bedrock outcrops were scattered and difficult to access due to the steepness of the slopes. Some outcrops were also seen to be highly magnetic affecting geologic structural measurements.

Reconnaissance of the headscarp was conducted by traversing onto the landslide body from the eastern tension crack area. The headscarp dip slope was covered by several feet of snow and was not directly observed by our reconnaissance team. However, some outcrops on the western sidescarps were accessible. Rock mass character was documented and geologic structure collected. The tension cracks east of the headscarp were not observable due to snow cover. The area of cracking appeared to be a depression in the snow cover.

A low area or hollow is located approximately 300 feet upslope from the headscarp. This area was accessed during the winter reconnaissance and was covered in approximately 3 feet of snow. The area appears to collect runoff from surrounding slopes. A swale was followed from the hollow that trending towards the landslide and ended at the headscarp of the landslide. It is our understanding a waterfall was observed subsequent to sliding near the location of the swale intersection with the headscarp.

The landslide materials were observed at two elevations near 290 and 180 feet, where traverses were conducted from west to east across the landslide. Slide debris was also observed in the vicinity of the headscarp, the lateral scarps, and at and below the current location of the temporary access road. In general, slide debris was covered with about one to three feet of snow. Slide debris was also encountered during the excavation of test pits on the down slope side of the temporary access road.

4.2 Residential Wells

Several residential wells were observed during the reconnaissance. One well at the residence at the east end of Beach Road was still producing artesian pressures at the time of our reconnaissance. Approximately one gallon per minute was still flowing from the well. All other residential wells observed along Beach Road were reported to not have artesian pressures. One springbox was observed at the Block 3 Lot 3 residence. Here water was flowing from the springbox towards Beach Road and under the road in a cross culvert. Discussions with residents indicated there are several areas on the east side of the landslide near elevation 300-350 feet that produce seepage and have been used as seasonal water sources. This includes areas upslope (south) of the residence on Block 3 Lot 6B. It is our understanding that the property at Block 4 Lot 1 obtains water from the drainage upslope of that property. A channel has been excavated just behind (south) of the facility to collect flow from the drainage and direct it to an onsite storage tank. Reportedly, the flow from the drainage can drop rapidly in the summer after just a few days without rainfall. Several flowing water conditions were also observed near elevation 300 feet on the west side of the landslide.

4.3 Survey Evaluations

A licensed surveyor from R&M was present to recover and verify previously established survey control at the site that was being used during mapping and monitoring of the landslide area and tie the survey control to the National Spatial Reference System (NSRS). Other survey tasks included evaluation of the existing monitoring points/prisms currently being utilized and to develop recommendations regarding an automated monitoring system. The results of this effort are provided in a separate report.

4.4 Account of Construction of Interim Temporary Access Road

On the 25th of February, a representative of LT met onsite with representatives from Southeast Roadbuilders, Inc. (a local contractor from Haines, Alaska) that were present in late January, 2021 during construction of a temporary road across the landslide to allow residents to retrieve belongings and mitigate concerns at their properties. During the onsite meeting, details of the work and the materials and conditions encountered during construction of the temporary road were discussed. This construction effort took two and a half days to accomplish. Portions of the debris exhibited wet conditions, and the hydraulic Cat 335 excavator experienced localized buoyant conditions (like being on a waterbed). The western portion of the debris (the first 100 feet of the temporary road) was extremely soft and saturated. The excavator had to tram (pull its body with the bucket and boom) across the first 100 feet. A "rocky" ridge was encountered between 100 and 150 feet from the western flank of the landslide). The middle and eastern area of slide debris was more boulder and relatively firmer. Many tree trunks were in the slide debris. This woody debris was used to construct the access road. The roadbed was developed by reinforcing the subgrade with logs and pushing boulders into muddy zones. One culvert was installed in a drainage area approximately 200 feet west of the eastern end of the temporary access road (reportedly a 30-inch diameter steel pipe). The inlet end of this pipe was blocked during the winter reconnaissance. A mound of slide debris was encountered on the eastern most end of the temporary access road. Within in this debris a very large rock block (larger than 10 feet in size) was encountered buried beneath the debris. A large hole was excavated on the downslope side of the rock block and the block was rolled into the hole to complete construction of the road. Reportedly, the hole that was excavated encountered fill that was either originally part of the Beach Road roadway embankment or fill used for the driveway to the Slate residence.

4.5 Test Pit Observations

During the winter reconnaissance, Southeast Roadbuilders, Inc. was subcontracted to perform a series of test pits along the recently established temporary access road across the landslide area. Four test pits were excavated on February 27, 2021 using a Cat 335 excavator. The test pits were excavated on the downslope side of the temporary access road across the landslide at select locations as shown in Appendix D. The test pit locations were excavated in areas that were reported to encounter more saturated conditions and soft/loose subsurface materials during its construction of the interim road earlier this year. The test pits were excavated to a depth between 14 feet and 18 feet below the ground surface. After excavation, each test pit was backfilled with excavated debris and compacted using the back of the excavator bucket. The materials encountered in the test pits are described on the test pit logs (Appendix D) and discussed below. Laboratory tests were performed on samples obtained from the test pits, including moisture contents, Atterberg limits, and gradation of matrix materials, which are presented in Appendix E.

4.6 Summary of Winter Reconnaissance Observations

The following is a summary of the various observations made during the winter reconnaissance.

4.6.1 Landslide Features

Few landslide features (i.e., headscarps, ground cracks, etc.) were observed during the winter reconnaissance due to the heavy snow cover. Within the footprint of the December 2, 2020 landslide, lateral scarps were observed on both sides of landslide area between approximate elevations 300 and 870 feet, from the middle of the landslide up to the crest of the headscarp. The tallest of these lateral scarps are along the upper east flank of the landslide where heights of approximately 40 vertical feet were observed. The inclinations of these slope were up to 55° above horizontal.

The headscarp area was mostly obscured by snow and ice; however, an approximately 8-foot near vertical section was observed. The ground cracks that propagate to the east from the eastern edge of the headscarp that were observed and photographed by others following the landslide event were not observable during the winter reconnaissance due to snow cover. Some faint shallow swales were observed in the snow that trended in an easterly direction from the eastern edge of the headscarp. In addition, one of the LT staff dropped through the snow into a pocket or void to a depth of roughly 5 feet in this area; however, it is unclear if this feature is associated with the previously observed ground cracks or drifted snow.

The only other landslide feature observed outside of the large landslide area was a relatively small slump/debris flow landslide observed on the far western edge of the EOC's AOC. The slump appears to have formed in a relatively steep ravine or drainage near approximate elevation 550 feet and it appears to be a local feature associated with shallow overburden and steep bedrock conditions.

4.6.2 Landslide Debris

Significant accumulations of landslide debris were observed within the limits of the slide mass. Although, mainly heavily covered by snow, some slide debris was observed during the reconnaissance and the test pit excavation work. The slide debris consists of varying percentages of silt, sand, gravel, cobbles, and boulders. Boulders up to 30 feet in maximum dimension were observed within the landslide debris. These large rock blocks were comprised of ultramafics with numerous dioritic materials, which was consistent with outcrop observations. The rock blocks were relatively fresh and were observed from within the upper third of the landslide to north of Beach Road. Several large blocks were also observed on the south side of the temporary access road as well. The inclination of the slide debris ranged from approximately 15° on the lower slopes near Beach Road to 40° above horizontal in the upper sections of the slide mass.

Significant accumulations of woody debris and downed trees were also observed throughout the surface of the slide mass. The only exception was in the area of the recently constructed temporary access road; however, it is our understanding that the contractor utilized most of the woody debris and logs as corduroy during construction of the interim road.

Up to 9 feet of landslide debris was encountered in the test pits (in TP-2 that was excavated approximately 75 feet west of the east flank of the landslide in the vicinity of Beach Road). In general, the landslide debris encountered in the test pits is medium dense to very dense, grey, moist, silty sand with angular rock fragments, gravel-sized to 2-foot boulders; scattered woody debris and roots.

4.6.3 Colluvial and Talus Deposits

Relatively thin layers of colluvium consisting of slightly silty sand with numerous gravel-sized angular rock fragments were observed in localized areas on the relatively moderately steep slopes (25° to 40°) below relatively steeper slope and bedrock outcrops. Based on winter reconnaissance observations, colluvial deposits do not appear to be thicker than 5 feet. On the west side of the landslide area, the relatively flat to moderately steep slopes between approximate elevations of 200 and 350 feet appear to be comprised of this material. Sporadic rock blocks and random talus was observed throughout the reconnaissance area, particularly near the slope break between the steeper rock slopes and the colluvial deposits. More rockfall blocks and talus were observed on the east side of the landslide area as compared to west of the landslide area.

4.6.4 Bedrock Outcrops

Bedrock exposures observed during the winter reconnaissance consisted of the ultramafic rock and granodiorite/diorite. In general, the ultramafic rock was dark grey, hard (R4), slightly weathered to fresh, and highly to slightly jointed (joint spacing between 6 inches to 5 feet). Jointing is relatively tight and joint surfaces range from smooth/planar to rough/undulating. Locally, very high to highly jointed zones were observed in the rock mass (less than 6-inch joint spacing).

Within the headscarp of the landslide area, localized areas of very soft (R1) to soft (R2), slightly to highly weathered ultramafic rock was observed. This material appeared to have an altered appearance and a diced/sheared texture. Biotite banding was also more apparent. A discussion of the structural data collected during the winter reconnaissance is provided in a subsequent section of this report. Stereonets illustrating collected discontinuity data are provided in Appendix C. The stereonets show a typical northeast dipping joint set consistently observed on both sides of the landslide and in the exposed rock at the headscarp.

Granodiorite/diorite dikes, typically ranging in width between 1 and 18 inches, was commonly observed in the ultramafic exposures. West of the landslide area below the eastern extent of Mt. Riley Road, a relatively large exposure of granodiorite (or possibly tonalite) was observed (approximate elevation of 300 feet). This rock is light grey, hard (R4), fresh, and moderately to slightly jointed (joint spacing between 2 to 6 feet).

4.6.5 Other Overburden Deposits

The following overburden materials (from oldest to youngest) were encountered in the test pit excavations performed along the temporary access road that crosses the landslide area: marine clay, elevated shore and delta deposits, and fill. The marine clay, locally referred to as the "blue clay layer" which overlies bedrock in a number of places around Haines according to local experts. This material was encountered in two of the test pit excavations (TP-2 and TP-4). Up to 9 feet of this material was encountered in the bottom of TP-4. The material consists of very stiff to stiff, grey, slightly sandy, very silty clay with scattered fine to coarse rounded gravel. The material was moist with no observable structure. No organics were observed but the material had a noticeable organic older. According to Lemke and Yehle, 1972, this deposit is a marine sediment that was deposited in the fiords by settling of fine-grained material derived from glaciers, rivers, and streams and subsequently these sediments have been elevated above sea level by rebound of the land due to deglaciation and possibly tectonic activity.

A loose to medium dense, brown, gravely sand with rounded cobbles and boulders (up to 3 feet in diameter) was encountered overlying the marine clay in three of the four test pit excavations (TP-1, TP-2, and TP-4). This material was moist with observable organic odor. This material was thought to be glacial outwash (till); however, according to Lemke and Yehle, 1972, the material is too young and likely stratigraphically out of place with the marine clay deposits. The material may be elevated shore and delta deposits, which are described as chiefly gravel, sand, and cobbles that are moderately well-sorted and stratified and are analogous to the partly contemporaneous elevated fine-grained marine sediments described above.

The third overburden material observed in the test pits is fill. Fill, consisting of brown, sand with gravel (described as a local source of fill material obtained from a pit near Haines) and grey, crushed rock were observed in at least three of the four test pits (TP-1, TP-2, and TP-4). This material is believed to be fill that was used to construct the original Beach Road. Approximately 1 foot of both the brown subgrade and grey road surfacing material were observed in each test pit.

On the east end of the temporary access road, the brown sandy material was observed in a hole that was reportedly excavated by Southeast Roadbuilders, Inc. during construction of the interim road. They indicated that it was likely originally part of the Beach Road roadway embankment or fill used for the driveway to the Slate residence.

4.6.6 Vegetation

The slopes on either side and above the landslide were heavily covered by conifer trees ranging in size up to over 3 feet in diameter. It appeared that the trees were larger in diameter generally on the west side of the landslide as compared to the eastern portion. This may be indicative of the presence of more near surface groundwater and thicker overburden soils, or it could be associated with the relatively flatter slope inclinations observed on the west side of the landslide. Tree growth appeared to be relatively normal, with some exhibiting slight curvature as might be expected in slopes experiencing surficial creep. More alders and devil's club were observed on the relatively flatter slope portions that were interpreted to be covered with relatively thicker deposits of colluvium. Based on discussions with a resident, trees on the landslide area were much younger (i.e., smaller in diameter) than those on the adjacent hillside slopes and there were more alders present. In addition, the slope was lacking the larger diameter trees (well over 3 feet diameter at breast height) that reportedly are over 300 years old.

4.6.7 Surficial Water and Groundwater

Surficial water was observed in localized areas in the broad, relatively low to moderately steep ground likely comprised of colluvial and "other overburden deposits." Surficial water was observed west of the landslide area between elevations 300 and 400 feet. Reportedly many residences on the south side of Beach Road in the vicinity of the landslide area currently (or had previously) obtain water from seep boxes or shallow stream feed cisterns. As previously discussed, local residents indicate that prior to the landslide event, significant amounts of surface water and erosion was observed throughout the landslide area.

According to local residents, there were no issues or unusual occurrences with the majority of residences' existing septic systems or groundwater supply wells. The exceptions are the Block 3 Lot 3 residence (adjacent to the west flank of the landslide) which reportedly experienced discharge from a toilet. It is our understanding that this residence has a septic tank and no septic field. The other exception is a well at the residence located on the south side of the road at the east end of Beach Road, experienced artesian flow from the top of the well prior to and after the landslide event. During the winter reconnaissance, artesian flow (approximately 1 gpm) was observed from the well casing, which extends 2.4 feet above the ground surface.

5 GEOTECHNICAL INTERPRETATIONS AND OPINIONS

Geotechnical interpretations are presented in the following subsections:

- Preliminary Geomorphology Assessment
- Data Gap Analysis
- Preliminary Evaluation of Landslide and Causation
- Preliminary Evaluation of Geologic Hazards
- Slope Stability Monitoring Methods
- Preliminary Evaluation of Community Concerns
- Preliminary Mitigation Concepts

5.1 Preliminary Geomorphology Assessment

Site geomorphology is a reflection of the geologic and environmental processes. The site geology is discussed in the previous section. The primary environmental processes at the site include continental glaciation, glacial rebound, stress relief and weathering. Glacier ice loading causes underlying materials to subside, and after glacial retreat the ground surface uplifts or rebounds. Glaciers also generate deposits of sediments (discussed in the previous section) and expose glacially carved landforms.

Glacial scouring of bedrock can vary from completely smooth to undulating surfaces that reflect different rock hardness and jointing/fracturing characteristics, both locally and broadly. The scouring may also broadly affect the bedrock surface depending on local variations in glacier burden/load, and rates of advancement/retreat. For instance, terraces could be scoured/carved in a waning stage of retreat. Terraces, benches and swales, lineaments, and colluvial aprons are several of the landforms that result from glaciation and weathering processes.

Stress relief and overly steep slopes result in marginally stable materials that can become destabilized, which reflects the inherent and variable nature of the rock mass character (i.e., strength, hardness, jointing, etc.). The predominant geologic structural conditions of the bedrock at the site promote rockfall, mass wasting and colluvial processes.

Site maps were developed to present LiDAR hillshade images of the terrain, topography contours derived from the LiDAR mapping, and geomorphic and geologic interpretations, as shown on Figures 5 through 8 for 2014 mapping and Figures 9 through 12 for December 2020 mapping. Representative cross sections were developed to show the slope changes before and after the catastrophic landslide, based on the topography derived from the 2014 and 2020 LiDAR mapping, as shown on Figures 13 through 17. The location of each cross section is shown on the site map in Figure 2. Cross Section 1 (Figure 13) extends along the length of landslide from shoreline to upslope of the headscarp. This cross section is a series of chords with angle changes at several pivot points to follow the interpreted main path of the landslide. Cross Section 1A (Figure 14) is similar to Cross Section 1, but is different in the upper area (headscarp) to illustrate the possible slump block between the headscarp and the east tension crack.

There are several dominant geomorphic features on the slopes overlying Beach Road that are observable in both the 2014 and 2020 LiDAR. These features have been illustrated on Figures 6 and 10, respectively for 2014 and 2020 mapping. Features beyond the upslope boundary of 2014 LiDAR mapping were interpreted from the larger dataset in the 2020 LiDAR mapping. Features similar to both 2014 and 2020 maps include:

- Colluvial Slopes: These slopes were seen at two elevation ranges. There are broad deposits that initiate within the base of the slopes directly adjacent to Beach Road ranging in elevation from approximately 200 to 300 feet. Additional colluvial deposits are at higher elevations ranging from approximately 300 to 450 feet. Generally, these colluvial deposits have slope grades ranging from 25° to 35°. Colluvium thickness in these areas is unknown, but is interpreted to be thicker than colluvium that is overlying Bedrock Areas (i.e., overburden).
- Bedrock Areas: Numerous rock outcrops were observed during the winter reconnaissance. These features were used to identify and map Bedrock Areas. Three elevation ranges were observed for Bedrock Areas, the lower of which is near the beaches from elevations ranging from approximately 0 to 80 feet, the middle range is from approximate elevations 170 to 420 feet, with the higher located above approximate elevations of 450 feet. The rock mass character and geologic structure of the Bedrock Areas was observed to be relatively consistent west and east of the landslide extents. A discussion of the structural data collected during the winter reconnaissance is provided in a subsequent section of this report and stereonets illustrating collected discontinuity data are provided in Appendix C. The stereonets show a typical northeast dipping joint set consistently observed on both sides of the landslide and in the exposed rock at the headscarp. Bedrock is interpreted to be covered with a thin veneer of overburden colluvial deposits likely less than five feet thick.
- Lineations: Numerous linear features can be seen in both the 2014 and 2020 LiDAR. Generally, these lineations trend west-northwest to east-southeast. The linear features are interpreted to be surficial expressions of the underlying bedrock geologic structure. The trends are in general accordance with several geological structural measurements collected during the winter reconnaissance. A rather prominent linear feature trending north to south is evident in the 2014 and 2020 LiDAR. This feature can be traced from just north of Beach Road to the low, depression area above the headscarp of the landslide. It appears to be a drainage area; however, it is not clear at this time if this feature is associated with faulting or regional structure due to tectonics.
- Benches and Swales: Several bench and swale features can be mapped on the west side of the landslide extents. As with the lineations, these features are interpreted to be surficial expressions of the underlying geologic structure and rock mass character.

Our interpretation of benches, swales and colluvial deposits on the slopes are that they are produced by weathering of the glacially carved landforms and underlying geologic structural conditions. Weathering has produced rock blocks and boulders that separate from in-place bedrock along two prominent sets of joints/fractures (i.e., plains of weakness). Based on preliminary rock structure analysis, the primary set trends northwest-southeast (with a dip direction to the northeast) and variable dips that are steeper and slightly oblique to the overall slope. The secondary set of joints/fractures trends northeast-southwest (with a dip direction of northwest) and dips very steeply and highly oblique to the overall slope. The intersections between these planes of weaknesses develop a series of rock blocks that appear to creep in a toppling mechanism over geologic time and ultimately fail through tertiary fractures or a local and shallow dipping primary joint/fracture that develops planar failure mechanism.

A feature only observed in the 2014 LiDAR includes a lobe-like shape of material downslope of the headscarp of the landslide from approximate elevations 380 to over 780 feet (see Figures 7 and 8). The upslope southern limit of the lobe feature is not known due to the limited coverage of the 2014 LiDAR data. The lobe feature may have extended upslope to the 2020 headscarp, or it may have extended to slope features that were removed by the 2020 mass wasting event. The western and eastern limits of the lobe feature are wholly within the extents of the upper landslide. Conditions outside of the landslide extents to the west and east of the landslide have been mapped as bedrock areas. In general, slopes of the upper hillside are relatively steep, almost 45° in inclination; whereas, the upper area of the landslide exhibits slopes of 35 to 38° inclination indicating weaker materials. These differing slope features appear to be a result of major contributors to rock slope weathering and the 2020 mass wasting event.

The steeper slopes east and west of the failure indicate the rock materials are more resistant, they hold a steeper angle. The benches and swales that occur on the slopes to the east and west are; therefore, a product of weathering of more resistant materials. Overall, the slopes have been subject to the same weathering conditions, it's the materials and how they weather that make the different landforms. The failed mass was lobate in shape, the shape of which occurs when a mass of material creeps downslope due to weathering and gravity. Somewhat like a slide mass, but also like a zone of rock that is experiencing a toppling rock failure mechanism that is faster than the toppling rock in the slopes to the east and west. Where the failure mechanism occurs at a faster rate, the rock becomes more fractured and colluvium becomes thicker than the slopes to the east and west.

Upslope of the failure area and observed in the 2020 data, is a hollow basin or low area approximately 300 feet upslope (south) of the headscarp. This likely was present in 2014 and before; however, the 2014 LiDAR data coverage does not extend far enough south to show the landform. The shape of the low area indicates it seasonally collects water from the surrounding slopes. There also appears to be a drainage path that leads from the low area to the north directing water towards the landslide area. During the winter reconnaissance this low area was covered in snow. A swale could be followed from the hollow towards the landslide to the headscarp. It is our understanding a 'waterfall' was observed near the point where the swale intersects the headscarp, indicating a significant amount of water flowed from the hollow basin and to the head of the landslide.

5.2 Data Gap Evaluations

The existing information was reviewed to determine a preliminary understanding of the landslide and adjacent hillside slopes. Gaps in understanding were identified, and approaches for characterizing the unknowns were evaluated.

5.2.1 Geomorphic Features (Ground Surface Geology)

Most of the ground was covered by snow during the Winter reconnaissance, and therefore most of the interpreted geomorphic ground features could not be verified. Pre-slide topography was found to be incomplete from 2014 LiDAR image/topo leading to the inability to determine change in ground surface in headscarp area. No report of additional flow slide lobes outside of the main landslide boundary was available and no report of tension cracks other than the one extending east from the headscarp was available.

5.2.1.1 Approach

Perform a Spring reconnaissance after snowmelt to observe and measure ground features and rock structure, scarp cracks, headscarp, and to verify interpreted features inferred from initial study, LiDAR images and topography. Check if slide flow materials entered other drainages. Map the location and extent of the east tension crack. Check the ground surface for signs of other tension cracks.

Obtain extended 2014 LiDAR coverage and process topography. Compare post-slide and pre-slide topography to identify areas of subsidence and deposition (change detection).

Compare observed ground conditions with pre-slide and post-slide topography.

5.2.2 Subsurface Geology

Condition of interpreted bedrock outcrops needs more detailed measurement, particularly joint structure to determine whether the bedrock is in-place or has been displaced.

5.2.2.1 Approach

Perform a Spring reconnaissance after snowmelt to measure joint orientations in bedrock outcrops.

Perform a subsurface investigation to measure joint structure in the subsurface by coring and using downhole imaging in geotechnical boreholes.

5.2.3 Stratigraphy in Slopes on Both Sides of Landslide, Suitable for Stability Analysis

No subsurface data exists for modeling the hillside stratigraphy.

5.2.3.1 Approach

Need geotechnical borings and instrumentation in representative areas, with a minimum 2 borings along each cross section for stability analysis (i.e., interpreted local slump block east of headscarp). Perform geotechnical investigation.

5.2.4 Landslide Geometry and Thickness of Slide Debris Deposits

No subsurface data exists for modeling the landslide.

5.2.4.1 Approach

Perform a Spring reconnaissance to develop interpretation of slide debris thickness based on surficial expressions.

Need geotechnical borings and instrumentation (minimum of 1 boring, and preferably 2 to develop cross section.

5.2.5 Source Area of Second Flow Slide

Source area of second flow slide was not observed and is currently inferred/assumed.

5.2.5.1 Approach

Perform Spring Reconnaissance in this area to verify extent and geometry of source area.

5.2.6 Composition of Slide Debris Materials

Composition of slide debris materials is not fully understood. It was reported that the slide debris in upper slide mass is generally rocky/bouldery, and slide debris in lower slide mass contains clayey silt with rocky/bouldery areas.

5.2.6.1 Approach

Perform Spring Reconnaissance to evaluate grain size distribution of slide debris material, including boulders and larger rock blocks. Predominantly granular or silty? Range of boulder and rock sizes (grain size distribution)?

Perform test pits to obtain visual estimates of exposed materials and on excavated slide debris materials.

5.2.7 Moisture Content of Slide Debris

Limited moisture content data currently from two test pits in landslide runout area next to Beach Road.

5.2.7.1 Approach

Need more moisture content data for representative areas of lands and runout zones. Spring Reconnaissance and Geotechnical Investigation. Test pits, borings, and surface samples.

5.2.8 Groundwater Pressure Increase - Catastrophic Landslide

Groundwater and pressure increase prior to initiation of catastrophic landslide, within upper slide mass, is not known.

5.2.8.1 Approach

Need to make a reasonable interpretation, based on Spring Reconnaissance of spring areas, geotechnical borings and piezometers.

Interpret main groundwater table within hillside bedrock.

Develop model of water infiltrating into overburden and jointed/fractured bedrock.

5.2.9 Groundwater Profile in Hillside

Groundwater level profile for slope stability analysis is not known.

5.2.9.1 Approach

Map springs and seepage/wet areas to aid in interpretation of groundwater profile (particularly midslope benched areas and drainage channels/swales). Check landslide sidescarps for possible springs.

Check areas of springs identified by local residents (i.e., Slate and Keller).

Install piezometers in borings during Geotechnical Investigation to measure hydrostatic pressures. Locations should include wet areas in midslope near east and west boundaries of landslide, in Beach Road in landslide area, and areas to be modeled for stability analyses.

5.2.10 Ground Movement Preceding Catastrophic Landslide

Ground movement prior to catastrophic landslide not known. Nobody saw or recorded any landslide displacement leading up failure. Maybe there was no ground displacement prior to initiation of this sudden, catastrophic landslide.

5.2.10.1 Approach

May need to assume the landslide occurred suddenly, without prior displacement.

5.2.11 Ground Movement Following Catastrophic Landslide

Ground movement following catastrophic landslide (and adjacent slopes) is currently based on limited survey monitoring of upper headscarp area and near Messano residence. The surveys have not detected any significant displacement since the landslide event; however, the prisms are not within the upper slide debris deposits.

5.2.11.1 Approach

Evaluate options for monitoring to detect potential ground displacement (including inclinometers, survey prisms, and GNSS GPS units).

5.2.12 East Tension Crack

Movement of ground downslope of tension crack to the east of the headscarp is not known.

5.2.12.1 Approach

Measure direction of movement along tension crack by examining remaining roots that connect both sides of the tension crack.

Crack meters should check both horizontal and vertical changes across the east tension crack in several representative locations.

Include wire extensometers across the east tension crack, in addition to crack meters, with sufficient length to check whether a slump exists and is moving.

5.2.13 Condition of Original Roadbed Beneath Slide Debris (Beach Road)

Condition of road buried by slide debris runout is mostly unknown. Four test pits were made during winter reconnaissance, with one test pit possibly indicating scour.

5.2.13.1 Approach

Perform additional test pits to determine if roadbed was locally scoured. Spring Reconnaissance and/or summer geotechnical subsurface investigations.

5.2.14 Hillside Depression Upslope of Landslide Headscarp

Duration of ponding condition in “depression” upslope of landslide headscarp is not verified. Suspect that this area becomes dry following snowmelt.

5.2.14.1 Approach

Check the condition of this depression during the Spring Reconnaissance.

5.2.15 Submarine Slide Debris Runout

Extent and thickness of slide runout debris underwater near the shoreline is not known.

5.2.15.1 Approach

Consider a bathymetric survey if this information is needed. Could be optional. Not necessary for developing models for stability analyses or for evaluations of geologic hazards.

5.3 Preliminary Evaluation of Landslide and Causation

The purpose of preparing a preliminary evaluation of the landslide is to develop realistic scenarios to guide planning a detailed geotechnical investigation and to inform the community of potential and likely geologic hazards and risks. This preliminary evaluation of the landslide is based on eyewitness accounts, images obtained and data gathered by state and local agencies, and our observations and interpretations made during the review of available information and the week-long February/March winter reconnaissance, as described in the preceding sections of this report. The preliminary evaluation includes a significant number of interpretations and assumptions due to gaps in factual knowledge, which were limited by the suddenness of the catastrophic landslide, snow cover obstructing evidence of landslide features during these winter months, and reliance on surficial information before a subsurface geotechnical investigation could be conducted. The following describes our preliminary opinions of the landslide and its causation.

In our opinion, the most likely landslide trigger scenario is the increase in hydrostatic pressures within overburden and fractured bedrock due to infiltration of runoff water from precipitation and snowmelt caused by the historic weather conditions (classified by NWS as an "atmospheric river"). The runoff caused area-wide erosion, flooding, surficial creep and sloughing, and debris flows. In addition, the historic storm likely caused very high groundwater pressures that destabilized materials within the subject landslide area, causing the upper slope to fail suddenly and initiate liquefied lobes that flowed long distances to the shore.

A change detection analysis was performed using the hillshade images from the 2014 and 2020 LiDAR mapping. The results are illustrated on Figure 18 to indicates zones of ground loss and slide debris accumulation, shown in blue and red, respectively. The analysis appears reasonable for the area of the landslide; however, areas outside the landslide may show apparent loss or accumulation which may be because of construction activities that occurred prior to the December 2020 landslide.

Why did the catastrophic landslide occur where it did, in a limited 300- to 650-foot-wide swath, and not in the adjacent hillside slopes?

The north-facing Mt Riley hillside exhibits bedrock-controlled features, with broad areas of mass wasting including rockfall and colluvium. The bedrock condition and stability are highly affected by its jointing structure and tectonic faulting. In general, slopes of the upper hillside area are relatively steep, almost 45° in inclination, are prominent and appear to be composed of bedrock. These same characteristics are observed on the slopes on either side of the landslide area; whereas, the upper area of the landslide exhibits slopes of 35 to 38° inclination and are less prominent in appearance, and do not appear to be bedrock outcrop. In addition, a lobe-like shape of material is present on the pre-slide LiDAR and the western and eastern limits of the lobe feature are wholly within the extents of the upper landslide area. Very likely, the area where the catastrophic landslide occurred was fractured and weathered, which would create weaker shear strengths and permeable flow paths for surficial and groundwater to rapidly penetrate. The reason for this is not clear at this time. The area may be associated with an existing shear zone/fault splay related to the north to south trending lineament observed within the landslide area. Other possible explanations could be associated with localized mineralogy/lithologic differences, pre-existing failure/mass movement events, stress relief due to deglaciation, or a combination of one or more of these factors. Another potential indicator that conditions were less stable in the subject landslide area compared to the adjacent hillside slopes could be the relative size and age of trees, where the vegetation in the landslide area was reportedly much younger indicative of greater changes in that area.

Wet areas on benches near the toe of the upper slide mass (approximately elevation 350 to 400 feet) appear to be evidence of groundwater discharge from the bedrock slope. Seepage and hydrostatic pressures in this area were very likely exacerbated during this historic storm event, reducing the stability of the upper fractured rock slope and causing it to fail rapidly. Surface water also entered the landslide area, including runoff from a hollow depression approximately 300 feet upslope of the headscarp. As the upper mass (lobe-like feature shown on pre-slide topography, Figure 8) collapsed towards the mid-slope colluvial bench, it displaced presumably saturated colluvial material comprising the bench. The release of pressurized groundwater (due to high hydraulic gradients) likely caused a mix of colluvium and water that created a liquefied condition resulting in debris flows to travel much further downslope (north), flowing into topographically low swales and possibly scouring new channels as gravity and fluidity forced the fluid material towards the ocean. Larger rock blocks and boulders were deposited along the flow path when the fluid mass could no longer transport them further (when the weight of the debris exceeded the buoyant water pressures in the fluidized mass) or when the rock blocks and large boulders were slowed or stopped by outcrops or other obstacles.

When the upper landslide failed and slumped dramatically, it left steep and tall sidescarps and a headscarp, which in turn reduced lateral support to the adjacent ground. The upper slide mass would also have caused friction (or drag) along its sides, imparting stresses to the ground immediately adjacent. The tension crack extending to the east of the headscarp is likely evidence of tension as the ground downslope slumped northwesterly towards the free face (sidescarp) created by the failure and down-dropping of the upper slide mass.

A subsequent lobe of liquefied slide debris reached the shore (second flow event), within the easterly half of the landslide area. This may have been precipitated by a collapse of weakened material, and possibly remnants of debris from the initial failure, just upslope of the wet midslope bench. Alternatively, high hydraulic gradients could have liquefied and rapidly displaced weak colluvium causing the very fluid material to flow over the easterly “midslope bedrock area” of bedrock, carrying fallen trees and debris on its way to the shore and inlet waters.

5.4 Preliminary Evaluation of Geologic Hazards (Qualitative Assessment)

The purpose of this preliminary evaluation is to inform the community of potential and likely geologic hazards associated with slope movements and what factors influence these hazards. This preliminary evaluation of the landslide and adjacent hillside slopes is based on images obtained and data gathered by state and local agencies, and our observations and measurements made during the week-long February/March winter reconnaissance. The preliminary evaluation includes significant interpretations and assumptions due to gaps in factual knowledge, which were limited by the suddenness of the catastrophic landslide, snow cover obstructing evidence of landslide features during these winter months, and reliance on surficial information before a subsurface geotechnical investigation could be conducted. The following describes our preliminary opinions of geologic hazards associated with slope movements.

The geologic hazards were evaluated qualitatively to provide a sense of scale for these potential hazards or failure scenarios along with a discussion of the factors that could possibly trigger these events and conditions that may be needed for the scenario to occur. Eight potential scenarios include:

1) Catastrophic reactivation of remnant slide debris in the recent landslide area (due to extreme rainstorms/weather/snow)
2) Localized reactivation of remnant slide debris in the recent landslide area (due to normal rainstorms/weather)
3) Boulders within the recent landslide mass rolling downslope
4) Retrogression of over-steepened slopes near headscarp of the recent landslide
5) Slump bounded by tension crack to east of headscarp of the recent landslide
6) Global failure of bedrock slopes east and west of recent landslide
7) Global failure of colluvial slopes east and west of recent landslide
8) Weathering and erosion of bedrock/colluvial slopes east and west of recent landslide

Evaluations are summarized in outline form. At this time, the evaluation is qualitative, based on limited landslide and hillside information and on engineering judgment, and therefore should be considered preliminary and subject to change as further reconnaissance and geotechnical investigations and analyses are performed. A discussion of how these events could impact the community, users of Beach Road, and local residents is provided in a subsequent section.

5.4.1 Catastrophic Reactivation of Remnant Slide Debris in Recent Landslide Area (due to extreme rainstorms/weather)

This scenario assumes a sudden release of fluid slide debris from the headscarp area, similar to the historic December 2, 2020 event, flowing all the way downslope to the road and into the ocean. This catastrophic scenario is thought to need a trigger mechanism similar to the historic precipitation/weather event (200+ year recurrence interval) that occurred leading up to the December 2, 2020 event. The size of this failure scenario would most likely be less (on the order of < 50% of original mass of the recent landslide) due to the fact that less mass, or volume of material to fail, is available due to the previous failure event. Other factors that could influence this failure scenario include:

- Size and geometry of remnant slide mass.

- Strength and moisture content of remnant slide debris.
- Effect of groundwater and surface water infiltration on remnant slide mass?
- Slope of ground surface along potential travel path includes a midslope bedrock area with gentle grades.
- Weather (extreme/sustained precipitation, snowpack/melt).
- Large, angular blocks add strength and roughness to the slide debris in drained condition. Numerous trees and woody debris also add short-term strength.

5.4.2 Localized Reactivation of Remnant Slide Debris in Recent Landslide Area (due to normal rainstorms/weather)

This scenario assumes the areas of remnant/deposited slide debris become saturated and portions slough and lobes flow downslope that occur during normal precipitation weather events. It is anticipated that the slide mass in this scenario would not travel as far down the slope due to the lack of water and saturated conditions that could cause as severe a liquefying event. Other factors that could influence this failure scenario include:

- Size and geometry of remnant slide mass is on the order of <25% of original mass.
- Strength and moisture content of remnant slide debris.
- Effect of groundwater and surface water infiltration on remnant slide mass?
- Slope of ground surface along potential travel path includes a midslope bedrock area with gentle grades.
- Weather (sustained precipitation, snowpack/melt).
- Ground motions and forces associated with significant seismic events.
- Large, angular blocks add strength and roughness to the slide debris in drained condition. Numerous trees and woody debris add short-term strength until they rot.

5.4.3 Boulders within Recent Landslide Mass Rolling Downslope

This scenario assumes that boulders detach from zones of slide debris (due to freeze/thaw, wetting/drying cycles, rainfall, ice-jacking, erosion, tree and woody debris rot, and other environmental factors) and roll or bounce downslope until coming to rest on a flatter slope or against an obstacle. The higher elevation on the landslide this occurs increases the likelihood one of these boulders can reach the roadway or beyond. Other factors that could influence this failure scenario include:

- Slope of ground surface along potential travel path includes a midslope bedrock area with gentle grades. Steep upper slope.
- Periods of sustained precipitation, resulting in increased hydrostatic pressures within slide debris.
- Wetting/drying and freezing/thawing cycles.
- Ground motions and forces associated with significant seismic events.
- Large, angular blocks add strength and roughness to the slide debris. Numerous trees and woody debris add short-term strength. Rotting of trees reduces strength and causes subsidence.

- Long-term consolidation/subsidence of slide debris.

5.4.4 Retrogression of Over-Steepened Slopes near Headscarp of Recent Landslide

This scenario assumes that portions of the headscarp of the landslide area to detach, topple or slump due to a variety of environmental factors, causing a mass of material to slide into the bowl of the headscarp and load the existing slide remnant. This process is quite common on over-steepened headscarps following a large failure event. In addition, this scenario assumes that groundwater pressures in and under the slide debris could be elevated. Other factors that could influence this failure scenario include:

- Retrogression would likely be limited to local areas, reaching equilibrium when the scarp slope angle is reduced to 1:1 or angle of repose. Therefore, volume of material detached during retrogression would be relatively small compared to volume of December 2 landslide mass.
- Structural and weathering condition of rock at headscarp (lower likelihood if scarp slopes are massive, fresh, competent rock).
- Weather (wetting/drying cycles, sustained precipitation, snowpack/melt, freeze/thaw).
- Ground motions and forces associated with significant seismic events could cause rockfall and displacement of over-steepened slopes such as the headscarp area.
- Erosion.
- Strength and moisture content of remnant slide debris.
- Effect of groundwater on headscarp and remnant slide mass?

5.4.5 Slump Bounded by Tension Crack to East of Headscarp of Recent Landslide

This scenario assumes that the ground between the east tension crack and the headscarp of the landslide develops into a slump and slides toward and into the bowl of the headscarp, adding load onto the existing remnant slide debris, possibly causing reactivation of the upper landslide. Other factors that could influence this failure scenario include:

- Weather (sustained precipitation, snowpack/melt, and increases in groundwater pressures).
- Springs indicative of high hydraulic gradient of groundwater? Is this area more drained due to tension crack and relief of main landslide sidescarp?
- Size, geometry and volume of slump mass.
- Constraint provided by bedrock downslope.
- Strength of material (does subsurface consist of rock? Weathered? Fractured? Decomposed? Displaced overburden?).
- Moisture content of slump material.
- Strength and moisture content of remnant slide debris.
- Groundwater conditions within slump and within remnant slide debris.
- Ground motions and forces associated with significant seismic events could cause displacement of the slump and over-steepened slopes such as the headscarp area.

5.4.6 Global Failure of Bedrock Slopes East and West of Recent Landslide

This scenario evaluates the potential for a large rockslide event occurring within the slopes above Beach Road. Preliminary kinematic analyses conducted considered slope angles from 35 to 52 degrees at slope dip directions from 008 to 024 degrees, depending on the locations data was collected. With the estimated slope geometry and friction, kinematics indicate direct toppling is the most prevalent potential failure mode within the slopes. Planar sliding, wedge sliding and flexural toppling were all shown to be a very low potential within the slopes due to the dip inclination of the primary joint sets present in the rock mass (between 54° and 88°) being steeper than the inclination or dip of the hillside slope (i.e., the failure planes do not daylight out of the slope face). Localized failures of this type are possible in segments of rock outcrop within the hillside that are steeper than the dip angles measured in the primary joint sets. A discussion for this analysis along with exhibits is provided in Appendix C. Factors that could influence this failure scenario include:

- Steepness/inclination of slopes.
- Weather (precipitation, snowpack/melt, runoff).
- Subsurface conditions (presence of altered/weakened bedrock, bedrock structure/faulting, discontinuity conditions, groundwater).
- Shear strength of bedrock and discontinuities.
- Ground motions and forces associated with significant seismic events could cause rockfall and displacement of over-steepened slopes.

5.4.7 Global Failure of Colluvial Slopes East and West of Recent Landslide

This scenario assumes a large landslide occurs within overburden materials on relatively steeper slopes (i.e., the colluvial slopes). In this scenario the overburden mantle experiences instability, creep and/or more deep-seated movement. Factors that could influence this failure scenario include:

- Weather (precipitation, snowpack/melt, runoff).
- Subsurface conditions (colluvium mantle thickness/conditions, groundwater).
- Shear strength of colluvium.
- Ground motions and forces associated with significant seismic events could cause rockfall and displacement of colluvial slopes.

5.4.8 Weathering and Erosion of Bedrock/Colluvial Slopes East of Recent Landslide

This scenario assumes environment processes that are common to the area, resulting in erosion, sloughing, creep, rockfall, and accumulation of colluvium. This scenario currently exists throughout much of the Haines area where moderate to steep slopes are present. Factors that influence this hazard scenario include:

- Weather (wetting/drying, freeze/thaw, snowpack/melt, wind, runoff).
- Subsurface conditions (bedrock, colluvium mantle, groundwater).
- Steepness of slopes.
- Ground motions and forces associated with significant seismic events.
- Shear strength of colluvium (angle of repose?).

5.5 Slope Stability Monitoring Methods

Various methods exist for measuring and monitoring landslides and slope stability. The methods are grouped as follows:

- Geotechnical Methods
- Survey Methods
- Early Warning Systems

5.5.1 Geotechnical Methods

Geotechnical instrumentation is often installed during subsurface investigation of landslides and slopes that experience creep or instability. Instruments for geotechnical evaluation of this landslide area could include the following:

5.5.1.1 Piezometers

Piezometers are used to detect groundwater pressures, possible artesian conditions, and changes in groundwater pressures due to weather events. Key locations for piezometers would include areas suspected to high hydrostatic pressures, such as: a) wet colluvial area midway between road and headscarp, b) within upper slide debris, c) within upper slope near east tension crack, and d) toe of slope near Beach Road. Vibrating wire piezometers are commonly used with automated data collection loggers (dataloggers) to store the measured groundwater pressures. Manual downloading from the dataloggers could be performed, but automated data acquisition systems would be preferential to minimize labor intensive site access.

5.5.1.2 Inclinometers

Inclinometers are used to detect subsurface displacements, such as slide shear zones and creep. Key locations for inclinometers would include slide areas and slopes in the AOC, such as: a) wet colluvial area midway between road and headscarp, b) within upper slide debris, and c) upslope and downslope of the east tension crack. Manual monitoring could be performed, but is labor intensive because of difficult site access. Therefore, automated data acquisition systems could be employed including MEMS (Micro Electrical Mechanical System) digital sensor strings. MEMS strings consist of a continuous string of sensors to detect deep ground movement at any depth. The direction of subsurface movement can also be measured.

5.5.1.3 Crack Meters

Crack meters could detect whether the east tension crack enlarges, indicative of possible slope movement or subsidence. Manual monitoring could be performed, but is labor intensive because of difficult site access. Therefore, digital crack meters and automated data acquisition systems would be preferred.

5.5.1.4 Surface Extensometers

Surface extensometers could be used to determine if the ground downslope of the east tension crack displaces. The surface extensometers consist of long-range displacement digital transducers with wire cables extending from fixed positions upslope of tension cracks to positions downslope areas within suspected slide blocks or marginally-stable slopes.

5.5.1.5 Tell-Tale Stakes

Tell-tale stakes could be established upslope of the headscarp along lines to roughly visualize and measure the amount of scarp calving over time (landslide retrogression). The stakes and distances of retrogression would be periodically monitored and measured manually.

5.5.1.6 Automated Data Acquisition

All digital instruments should utilize automated data acquisition methods, which would need power supplies and telemetry.

5.5.2 Survey Methods

Other ground surface movement detection and monitoring methods have also been evaluated for suitability at the site. R&M evaluated various survey methods for monitoring the landslide and hillside (R&M, 2021). Robotic total station surveying of prisms placed in critical locations throughout the landslide and adjacent hillsides rely on direct line of sight. Dense ground cover (trees) would present obstacles for prisms located in the adjacent forested hillside slopes, which could be resolved with removal of trees in the lines of sight. However, there may be limitations to how many trees would be allowed to be removed. Environmental conditions (such as snow, clouds, mist, rain and fog) could prevent accurate measurements of prisms. The robotic total station instrument will need to have a reliable power source.

GNSS units (stand-alone Global Navigation Satellite System) could be placed in critical locations to monitor displacements of the ground surface and would not be reliant on line of sight. However, the GNSS units are dependent on communicating with satellites, which on the north-facing slopes would require tree cover/foliage to be cleared and maintained in the vicinity of each instrument. Another complication would be to provide a power source to each GNSS unit.

Aerial methods that measure changes in the ground surface elevation, including aerial photogrammetry and LiDAR, would be limited by ground cover (dense trees), and would need significant tree removal to expose identifiable targets. LiDAR can be used to digitally remove vegetation through data processing, but extremely dense vegetation can limit the ability to survey ground with necessary precision.

Satellite-based InSAR and land-based radar interferometry are forms of active remote sensing that can identify the movement of ground in the direct line of sight to the radar detection instrument. Dense ground cover (trees) would present obstacles, which would need to be removed and maintained to allow use of this monitoring method.

5.5.3 Early Warning Systems

Monitoring methods for an early warning system will require further evaluation. Planning an early warning system would benefit from an understanding of factors that indicate impending slope instability and landsliding in sufficient time to allow people to react and avoid geologic hazards.

Measurable conditions preceding the December 2020 catastrophic landslide event include: a) precipitation, b) snowpack depths, and c) temperatures, particularly warming trends that cause snowmelt. Precipitation can be monitored with hourly measurements and further assess by analyzing various accumulation intervals. A prototype weather-related early warning system was developed in Sitka in response to landslide concerns following the destructive rainstorms in 2015. Because the main trigger factors were rainfall and infiltration, the Sitka early warning system consists of a tipping bucket rain gauge and soil moisture sensors embedded a few feet deep, with an automated data acquisition system to collect and display this data online and in real time. This system was developed with a focus on meteorology, geoscience, and social science to achieve a meaningful and practical approach.

Sudden occurrence and rapid movement experienced with the December 2, 2020 event indicates that there may not have been much time between initiation of ground displacement and debris flow runout reaching homes and the shoreline. There are no reports of ground movement preceding the catastrophic landslide. Therefore, there is insufficient information at this time to recommend ground movement detection instruments to provide early warning. Further investigation will be necessary.

Movement and groundwater pressure monitoring are recommended for geotechnical investigations to evaluate landslide mechanisms and slope stability. In addition, these monitoring methods can be evaluated to determine if they would be effective for use in an early warning system.

A "dashboard" website could be developed that would include trends being measured for key trigger factors. Threshold values/conditions would need to be estimated, which would need further evaluation to assign reasonable and effective values. The website could be accessible to Haines Borough and their technical team, and could also be made available to the general public.

5.6 Preliminary Evaluation of Community Concerns

The Haines community has expressed several concerns following the catastrophic landslide event. The concerns include: use of the interim access road, search and rescue precautions, re-establishment of the road across the landslide, re-establishment of power utility across landslide, and occupancy of residences.

The following evaluation of community concerns is based on a preliminary/partial understanding of geologic hazards (described in a preceding section of this report). The preliminary understanding of the hazards is based on interpretations and assumptions due to gaps in factual knowledge, and is limited by the suddenness of the catastrophic landslide, snow cover obstructing evidence of landslide features during these winter months, and reliance on surficial information and geotechnical investigation of shallow soil at the roadway. The following is a preliminary review of methods to address landslide and slope instability hazards, recognizing that additional or modified guidance will likely be needed.

5.6.1 Geologic Hazards

There are a variety of potential geologic hazards that may affect the AOC, as described in Section 5.4 Preliminary Evaluation of Geologic Hazards. The landslide and hillsides in the AOC have not been fully investigated at this time, and this assessment is preliminary. Geologic hazard scenarios were evaluated qualitatively to provide a sense of how different hazards have different factors and risks. Scenarios that were evaluated include:

5.6.1.1 Catastrophic Reactivation of Remnant Slide Debris in Recent Landslide Area (due to extreme rainstorms/weather)

This scenario assumes a sudden release of fluid slide debris from the headscarp area, similar to the historic December 2, 2020 event, flowing all the way downslope to Beach Road and into the ocean. This scenario would be considered a high-risk event with low likelihood of occurrence.

5.6.1.2 Localized Reactivation of Remnant Slide Debris in Recent Landslide Area (due to normal rainstorms/weather).

This scenario assumes the areas of remnant/deposited slide debris become saturated and portions slough and lobes flow downslope. This scenario would be considered a moderate-risk event with moderate likelihood of occurrence.

5.6.1.3 Boulders within Recent Slide Mass Rolling Downslope

This scenario assumes that boulders detach from zones of slide debris (due to freeze/thaw, wetting/drying cycles, rainfall, ice-jacking, erosion, tree and woody debris rot, and other environmental factors) and roll or bounce downslope until coming to rest on a flatter slope or against an obstacle. This scenario would be considered a moderate-risk event with low- to moderate likelihood of occurrence.

5.6.1.4 Retrogression of Over-Steepened Slopes near Headscarp of Recent Landslide

This scenario assumes that portions of the headscarp of the landslide area to detach, topple or slump due to a variety of environmental factors, causing a mass of material to slide into the bowl of the headscarp and load the existing slide remnant. In addition, this scenario assumes that groundwater pressures in and under the slide debris could be elevated. This scenario would be considered a low-risk event with moderate likelihood of occurrence.

5.6.1.5 Slump Bounded by Tension Crack East of Headscarp of Recent Landslide

This scenario assumes that the ground between the east tension crack and the headscarp of the landslide develops into a slump and slides toward and into the bowl of the headscarp, adding load onto the existing remnant slide debris, possibly causing reactivation of the upper landslide. This scenario would be considered a low- to moderate-risk event with moderate likelihood of occurrence.

5.6.1.6 Global Failure of Bedrock Slopes West and East of Recent Landslide

This scenario assumes that a landslide or slump forms in the bedrock hillside, which would be relatively shallow due to the assumed integrity and strength of the bedrock. This scenario would be considered a low-risk event with low likelihood of occurrence.

5.6.1.7 Global Failure of Colluvial Slopes West and East of Recent Landslide

This scenario assumes that a landslide or slump forms in the overburden mantle experiences creep and/or more deep-seated movement. This scenario would be considered a moderate- to high-risk event with low to moderate likelihood of occurrence.

5.6.1.8 Weathering and Erosion of Bedrock/Colluvial Slopes West and East of Recent Landslide

This scenario assumes environment processes that are common to the area, resulting in erosion, sloughing, creep, rockfall, and accumulation of colluvium. This scenario would be considered a low- to moderate-risk event with high likelihood of occurrence.

5.6.2 Community Issues

The following hazard and risk evaluations are provided for Haines Borough to evaluate allowable use of the area and temporary (interim) access road (Beach Road):

5.6.3 Accessing the Landslide Area

Haines Borough and EOC have governance regarding safety issues, including access and use of properties in the vicinity. Precautions when accessing landslide area could include the following:

1. Safety is the responsibility of each person accessing the landslide area.
2. Check weather conditions and forecasts, and avoid/minimize access near and on the landslide when risk factors increase (i.e., significant rainstorms, melt of deep snowpack, etc.).
3. Be aware of landslide changes and look for possible clues of new activity within the landslide and slope instability. Continually monitor and analyze landslide conditions and implement mitigation measures as necessary.
4. Prepare and follow safety plans, and include use of communication/location devices and backup/rescue personnel and equipment in event problems arise. Determine type of cellular or radio communication that is effective in this area (Verizon cell coverage was sporadic).
5. Preferable to be accompanied by at least one other person in the event problems arise.
6. Independent spotters could be used at various locations of the landslide to identify new and evolving landslide conditions to warn people in the landslide area.
7. Address other hazard and risk factors, such as snow/ice hazards, wind, temperatures, potential for avalanches, falling trees/limbs, voids and cracks in the ground, wildlife, etc.

5.6.4 Use of Interim Access Road

Haines Borough and EOC have governance regarding use of roads within the Borough. Policies and guidelines could include the following:

1. Users should be made aware of landslide movement risks and potential geologic hazards, which has moderate risk through the landslide area and low risk east and west of the landslide limits. Public notices could include a sign, possibly with partial barriers across half the road width, to inform users of potential hazards and guidelines for use of the road.
2. Precautions should be taken (see notes for "Accessing the Landslide Area" above).
3. Cross the landslide expeditiously, cautiously, and avoid lingering. If the interim access road becomes irregular, potholed, or damaged, maintenance personnel may need to also enter and work in the increased risk area.
4. Consider closing the road during significant storm events, which should include proactive communication with residents.
5. Anticipate that the road could degrade during spring thaw, possibly including subsidence, sinkholes, muddy conditions, uncontrolled runoff, sloughing, etc. Users should assess road conditions each time they plan to cross the landslide area.

5.6.5 Search and Rescue - Traversing Lower Slide Debris on Foot

1. When walking across the landslide, debris materials would likely be more stable during freezing ground conditions and/or dry conditions.
2. Personnel should be made aware of landslide movement risks and potential geologic hazards, and precautions should be taken.
3. Include spotters upslope for early warning to look for possible signs if the upper or middle zones of the landslide materials are active or if changes occur.
4. Probe ahead of walking using a long pole since slide debris may include soft/wet areas, voids and cracks/fissures.
5. Consider placing planking (such as plywood boards or similar) over soft/wet areas to improve bearing/support for walking across weak areas. Check the placed boards that intended stability is achieved.
6. Follow SAR protocols and procedures.

5.6.6 Search and Rescue - Probing Through Lower Slide Debris

1. SAR excavations in slide debris materials would likely be more stable during freezing ground conditions and/or dry conditions.
2. Personnel should be made aware of landslide movement risks and potential geologic hazards, and precautions should be taken.
3. Include spotters upslope for early warning to look for possible signs if the upper or middle zones of the landslide materials are active or if changes occur.
4. Equipment operated on the slide debris should preferably be track-mounted and have low-ground pressure (wide tracks or balloon tires). Traversing soft/wet areas may need use of ground stabilization measures such as corduroy logs, robust timber planking/beams, etc. Hydraulic excavators can use their bucket to probe ahead and pull the equipment along.
5. Plan potential excavations with stable side slopes and provisions to drain water.

6. When excavating, make trenches in the N-S direction to minimize disturbing slide debris upslope and to provide a path for water to flow out of the trench/downhill.
7. Have backup rescue equipment (i.e., tow trucks and heavy excavating equipment with cables) in the event primary equipment gets stuck in fluid/muddy conditions or are impacted by unstable ground.
8. Consider including geotechnical person onsite during SAR activities to provide consultation on landslide issues.
9. Follow SAR protocols and procedures.

5.6.7 Search and Rescue - Offshore

Guidance is provided in the event submarine search and rescue is planned.

1. Confirm that weather factors are mild and not conducive to causing slope or landslide movements.
2. Divers should be made aware of landslide movement risks and potential geologic hazards, and precautions should be taken.
3. Include spotters upslope for early warning to look for possible signs if the upper or middle zones of the landslide materials are active or if changes occur.
4. Submarine excavations can be risky due to the saturated and loose condition of the slide debris, and digging can cause instabilities, liquefaction, and/or reactivations of debris flow conditions.
5. Conditions of submarine slide debris are not known, have not been investigated, and a bathymetric survey has not been performed.
6. Follow SAR protocols and procedures.

5.6.8 Re-establishment of Road Across Landslide

Two options are described: one for the existing interim road on top of slide debris, and the other for restoring the original road by removing slide debris.

5.6.8.1 Use Interim Road Indefinitely

One option is to use the interim temporary corduroy road indefinitely. Preliminary comments follow:

1. Subsidence of the surfacing may occur as the ground thaws as the weather warms. In addition, a potential may exist for sinkholes, muddy conditions, uncontrolled runoff, sloughing, etc.
2. Possible lateral movement of slide debris as erosion undermines lower areas of the runout debris.
3. Repairs to the corduroy road may become necessary if logs and boulders experience shifting or subsidence.
4. Repairs could possibly include placing high-strength separation geotextile under base rock to improve integrity and longevity of pavement materials.
5. The vertical alignment is not as good as the original road (vertical rise to cross over the accumulated slide debris).
6. Will likely need to add culverts and effective ditches.

5.6.8.2 Restore Original Road Grade

Another option is to excavate slide debris to restore the original road grade. Preliminary comments follow:

1. Initial test pits indicate that most of original road subgrade is in-place, with the possible exception at test pit TP-3 where the slide runout debris may have scoured the roadbed. Further investigation is recommended to determine if original road was scoured and the extent of scouring.
2. Excavation of slide debris may need to be designed to achieve local stability. Excavate cuts upslope of road no steeper than 2H:1V (which may need to be flatter if soft/wet materials) and include transverse ditches and trench drains in wet areas to promote drainage of slide debris to reduce hydrostatic pressures in the cut slopes.
3. Create drainage channels towards shoreline in a North-South orientation to prevent ponding of water and to allow water pressures within slide debris to dissipate.
4. If original culverts cannot be restored/repaired, new culverts may be necessary.
5. May need to improve cut slope stability in loose/soft/wet soils with rock blankets (designed to resist instability and seepage piping).
6. May need geogrid-reinforced or geotextile-reinforced subbase to provide stability across loose/soft/wet soils.

5.6.9 Re-establishment of Power Utility Across Landslide

Preliminary options include:

1. Restore power poles across slide debris where the landslide width is approximately 600 to 650 feet. However, there is risk that future landslide movements and debris flow events could displace or damage the poles, potentially damaging the power line.
2. Place power line on ground surface (in conduit?) in curvy alignment to create slack to accommodate differential movements of the slide debris. However, there is risk that future landslide movements and debris flow events could be large and exceed the slack provided in the conduit, potentially damaging the power line.
3. Install conduit below original road grade in undisturbed ground to reduce risks due to future debris flow events. Prefer to install the conduit below the depth of possible landslide scour.
4. Place power line around perimeter of landslide, including a buffer zone from perimeter to reduce risks of landslide retrogression/widening. However, this would be a long route and more difficult to maintain.

5.6.10 Occupancy of Residences

There are a variety of geologic hazards affecting Beach Road residences, as described in the prior section on Preliminary Evaluation of Geologic Hazards. The hillsides upslope of residences west and east of the AOC have not been fully evaluated at this time. The following hazard and risk evaluations are provided for Haines Borough to evaluate allowable occupancy.

1. Low to moderate risk of rockfall, colluvial runout and hillside slumping to buildings located on the uphill side of Beach Road. This includes properties located downslope of steep slopes. In particular, the properties on Block 4 Lot 1 and Block 3 Lots 6B and 6C are located

at the base of a steep slope with possible geologic hazards. Rockfall, colluvial runout and hillside slumping are relatively common geologic hazards and risks for this area.

2. High risk of catastrophic landslide material moving/flowing on properties within the boundary of the December 2020 landslide. Includes the Block 3 Lot 3 residence since it has been impacted by the recent landslide and remains vulnerable to future landslides. Two other residences are no longer standing (located on Block 1, Lots 6 and 7). Undeveloped properties were also impacted by the recent landslide, including Block 3 Lots 4, 5, and 6A on the uphill side of Beach Road, and Block 1 Lots 4 and 5 and possibly Block 1 Lot 3 on the downhill side of Beach Road.
3. Moderate risk of catastrophic landslide material moving onto properties immediately next to the recent catastrophic landslide (i.e., Block 1 Lots 8 and 9, and Block 3 Lot 6B). The residence on Block 1 Lot 8 is founded on, or close to bedrock and was spared by the December 2020 landslide; however, approximately half the property has been eroded and a different means of access is needed to reach the residence. The Block 1 Lot 9 property adjoins the Block 1 Lot 8 property to the east and it appears only a small portion of the property next to Beach Road was affected by the recent landslide. The Block 3 Lot 6B residence appears to be slightly shielded from the recent landslide by a rock outcrop. At this time, it is uncertain whether future landslide events would impact the residences on Block 1 Lots 8 and 9 and Block 3 Lot 6B. Further evaluation is recommended.
4. Low to moderate risk of new catastrophic landslides occurring in bedrock hillside east and west of recent landslide. Low risk if geologic interpretation is correct that hillside is inplace bedrock, with risk related to potential for erosion, shallow/surficial sloughing, colluvial activity, and rockfall. Moderate to high risk might exist if pre-existing landslide conditions exist upslope of residences (unverified at this time). Further evaluation is recommended.

5.7 Preliminary Mitigation Concepts

It might be possible to construct mitigation measures to reduce the risks of geologic hazards. This is a preliminary evaluation based on limited data obtained in December 2020 and the winter reconnaissance when snow covered most of the ground surface and prior to performing geotechnical borings and instrumentation. Preliminary geologic interpretations of the landslide have identified possible trigger factors leading to slope instability and the rapid catastrophic debris flows. In addition, there are geotechnical factors that could be conducive to instability. Mitigation concepts have been identified for possible landslide factors.

Possible Landslide Factors	**Potential Mitigation Concepts**
Spiked groundwater pressures in midslope "wet areas"	• Horizontal drains, trench drains, relief wells • Reverse filter berms
Spiked groundwater pressures in headscarp area	• Trench drains • Interceptor ditches
Weight at head of landslide (& top of slope)	• Unload excavation
Weak support at toe of landslide/slope	• Buttress or Berm • Subsurface drainage system (trench drains)
Topographic depressions and swales that influence the paths of debris flows	• Berms, ditches, walls to limit the extent of debris flows
Liquefiable materials	• Drainage to reduce hydrostatic pressures and liquefaction potential • Surcharge weight to constrain hydraulic gradients
Extreme rainfall/snowmelt	• Posted signs explaining geo-hazards and risks to inform residents, users and visitors • Weather station data real-time for an early warning system (EWS) or online dashboard to inform residents, users and visitors of potential risks
Ground Movement (crackmeters, extensometers, inclinometers, prism surveys, LiDAR or InSAR change detection, etc.)	• Online Dashboard to inform residents, users and visitors of potential risks

Rockfall and colluvial mass wasting are normal geologic conditions occurring on these steep hillside areas. The following mitigation concepts could be considered:

Slope Mass Wasting Processes	**Potential Mitigation Concepts**
Rockfall (tilting, toppling, dislodging, weathering, erosion)	• Rockfall mitigation berms/walls • Rockfall catchment areas/ditches • Rock bolts • Rockfall draped mesh, pinned mesh, catchment barriers, and/or attenuator fences
Creep	• Vegetation (root reinforcement) • Pinned mesh
Sloughing	• Debris diversion/catchment berms • Diversion channels • Pinned mesh • Rock inlays • Drainage blankets

Further geotechnical investigation should be performed to provide data to evaluate potential mitigation options and for subsequent design if mitigation options are to be implemented.

6 RECOMMENDATIONS

We recommend the following geotechnical items to investigate landslide and hillside slope stability conditions, including development of geotechnical models and monitoring methods for improved geohazard assessments and evaluation of monitoring methods for possible integration with early warning systems.

6.1 Processing Additional 2014 LiDAR

Check with DGGS and their LiDAR vendor to extend the 2014 LiDAR image near the headscarp and further uphill and to the east, assuming the 2014 LiDAR flight has greater coverage than the area shown in the processed images. It is possible that some additional point data exists, but was out of scope for data delivery at that time. Evaluation of pre-existing ground surface conditions is critical for assessing the extent of slopes possibly impacted by the December extreme weather event.

6.2 Spring Reconnaissance

Supplemental geologic reconnaissance (Spring Reconnaissance) after snow melts to field-truth preliminary geomorphic interpretations pertaining to development of geologic models for the landslide and adjacent hillside slopes and to identify and locate landslide features and tension cracks, especially the terrain in the vicinity of the east tension crack. Details for a spring reconnaissance are provided in Appendix F.

6.3 Subsurface Investigations and Monitoring

A program of instrumented borings, test pits and analyses to evaluate critical slope geometry and stability factors in the landslide and adjacent slopes above homes and Beach Road, based on our geologic interpretations (preliminary geologic sections and geomorphic map), including the terrain in the vicinity of the east tension crack. Subsurface explorations are necessary for evaluating and managing geologic hazards while supporting initial community recovery efforts. Perform rock coring and downhole optical televiewing to determine rock quality and structure. Install geotechnical instrumentation, including vibrating wire piezometers and MEMS array inclinometers to measure groundwater pressures and subsurface deformations, respectively.

Supplemental test pits in slide runout deposits. Evaluate whether original road was scoured by landslide flow.

Stability analyses would be performed to evaluate various geologic hazard and landslide scenarios.

Details for the recommended geotechnical investigation are provided in Appendix F.

6.4 Periodic LiDAR Monitoring

LiDAR flight (orthorectified) performed periodically as a monitoring method to compare with prior LiDAR and hillshade images to detect changes in ground surface, particularly in the area downslope of the east tension crack (scarp).

6.5 Bathymetric Survey

Bathymetric survey could be performed if it is necessary to estimate the shape and volume of the submarine slide debris.

6.6 Geotechnical Assistance for On-site Activities

Geotechnical assistance during search and rescue operations could help EOC personnel with daily landslide observations and evaluations, and address EOC landslide concerns.

6.7 Site Access and Use Management

Geotechnical assistance to Haines Borough regarding development of land use and community management of geologic hazards.

6.8 Early Warning Systems

Evaluate potential methods for use in an early warning system. Geotechnical instrumentation installed in the investigation phase will provide data and understanding of landslide mechanism and could help to identify methods to use for early warning systems. Since the catastrophic December 2020 landslide was triggered by an extreme rainfall and snowmelt event, we recommend installing an automated weather station near the headscarp of the landslide or at the tower upslope this year. Camera(s) could also be installed for visual confirmation of potential triggering events.

7 CLOSING

We appreciate the opportunity to be of service to the Alaska Department of Transportation & Public Facilities on this important project. If you have any questions, please contact us at (503) 452-1100.

Sincerely,

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LIMITATIONS IN THE USE AND INTERPRETATIONS OF THIS REPORT

Our professional services were performed, our findings obtained, and our recommendations prepared in accordance with generally accepted engineering principles and practices. This warranty is in lieu of all other warranties, either expressed or implied.

The geotechnical report was prepared for the use of the Owner in the design of the subject facility and should be made available to potential contractors and/or the Contractor for information on factual data only. This report should not be used for contractual purposes as a warranty of interpreted subsurface conditions such as those indicated by the interpretive boring and test pit logs, cross-sections, or discussion of subsurface conditions contained herein.

The analyses, conclusions and recommendations contained in the report are based on site conditions as they presently exist and assume that the exploratory borings, test pits, and/or probes are representative of the subsurface conditions of the site. If, during construction, subsurface conditions are found which are significantly different from those observed in the exploratory borings and test pits, or assumed to exist in the excavations, we should be advised at once so that we can review these conditions and reconsider our recommendations where necessary. If there is a substantial lapse of time between the submission of this report and the start of work at the site, or if conditions have changed due to natural causes or construction operations at or adjacent to the site, this report should be reviewed to determine the applicability of the conclusions and recommendations considering the changed conditions and time lapse.

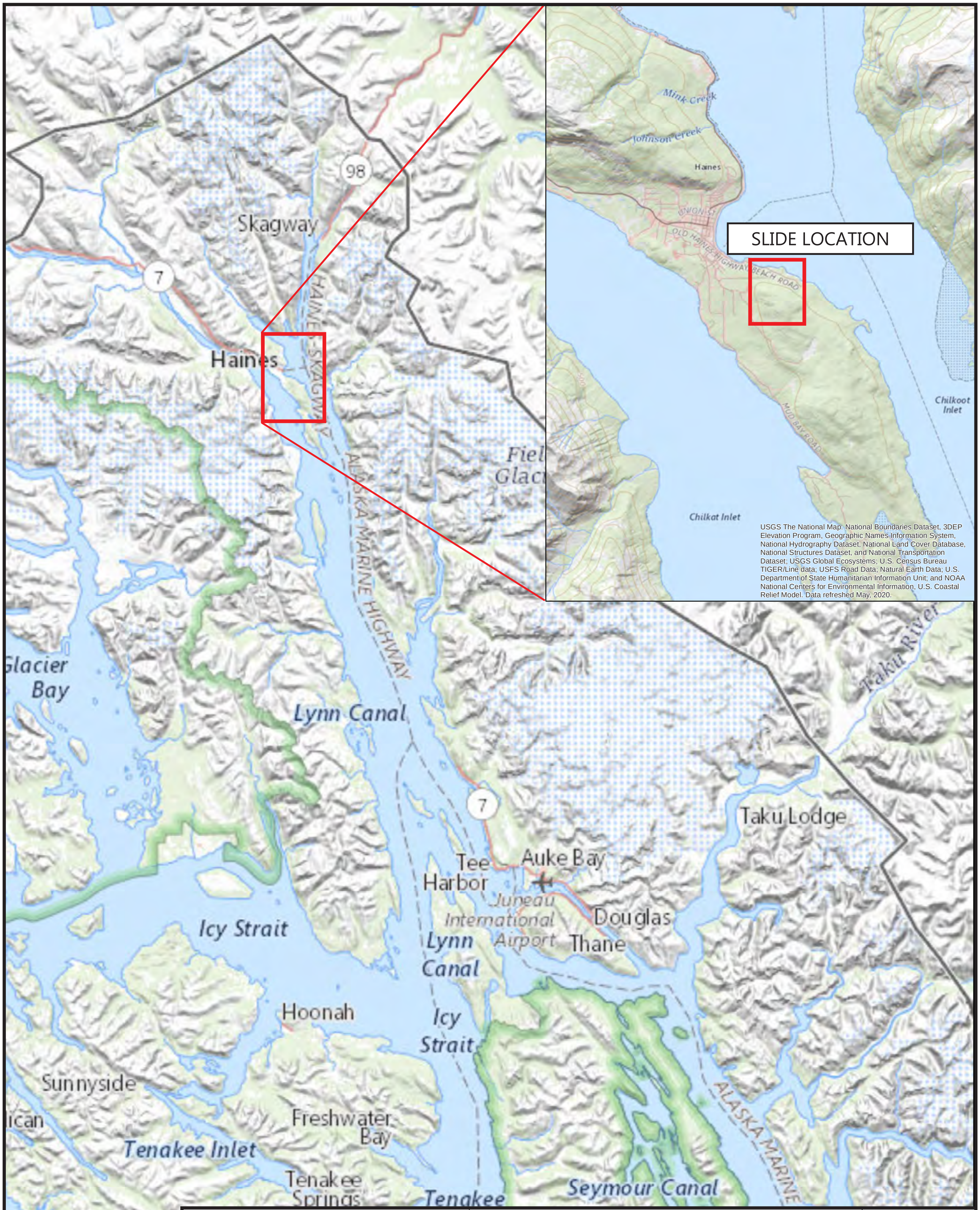
The Summary Boring Logs are our opinion of the subsurface conditions revealed by periodic sampling of the ground as the borings progressed. The soil descriptions and interfaces between strata are interpretive and actual changes may be gradual.

The boring logs and related information depict subsurface conditions only at these specific locations and at the particular time designated on the logs. Soil conditions at other locations may differ from conditions occurring at these boring locations. Also, the passage of time may result in a change in the soil conditions at these boring locations.

Groundwater levels often vary seasonally. Groundwater levels reported on the boring logs or in the body of the report are factual data only for the dates shown.

Unanticipated soil conditions are commonly encountered on construction sites and cannot be fully anticipated by merely taking soil samples, borings or test pits. Such unexpected conditions frequently require that additional expenditures be made to attain a properly constructed project. It is recommended that the Owner consider providing a contingency fund to accommodate such potential extra costs.

This firm cannot be responsible for any deviation from the intent of this report including, but not restricted to, any changes to the scheduled time of construction, the nature of the project or the specific construction methods or means indicated in this report; nor can our firm be responsible for any construction activity on sites other than the specific site referred to in this report.



USGS The National Map: National Boundaries Dataset, 3DEP Elevation Program, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; USGS Global Ecosystems; U.S. Census Bureau TIGER/Line data; USFS Road Data; Natural Earth Data; U.S. Department of State Humanitarian Information Unit; and NOAA National Centers for Environmental Information, U.S. Coastal Relief Model. Data refreshed May, 2020.

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LOCATION AND VICINITY MAP

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BEACH ROAD LANDSLIDE, HAINES ALASKA

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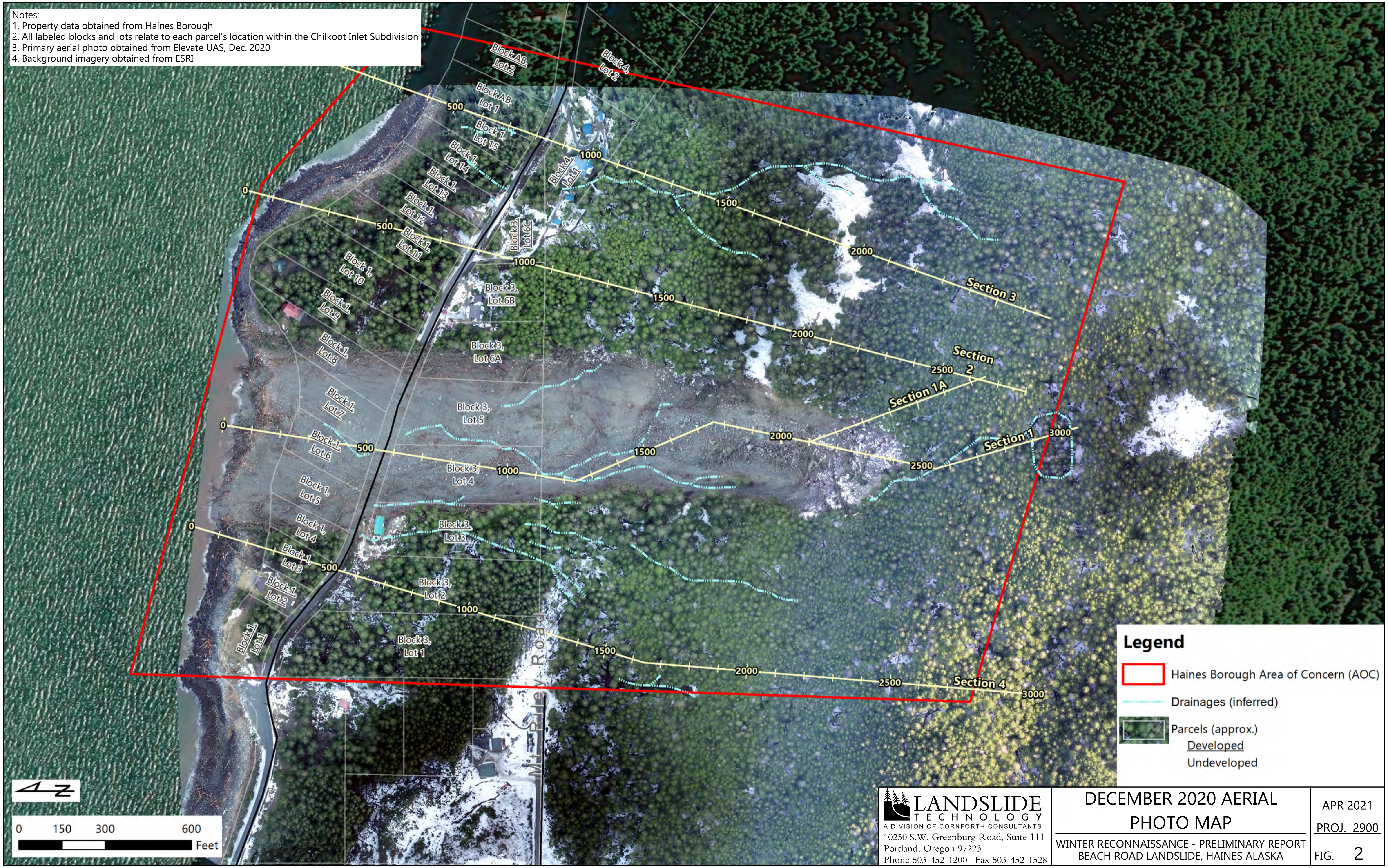
FIG. 1

Notes:
1. Property data obtained from Haines Borough
2. All labeled blocks and lots relate to each parcel's location within the Chilkoot Inlet Subdivision
3. Primary aerial photo obtained from Elevate UAS, Dec. 2020
4. Background imagery obtained from ESRI



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DECEMBER 2020 AERIAL PHOTO MAP

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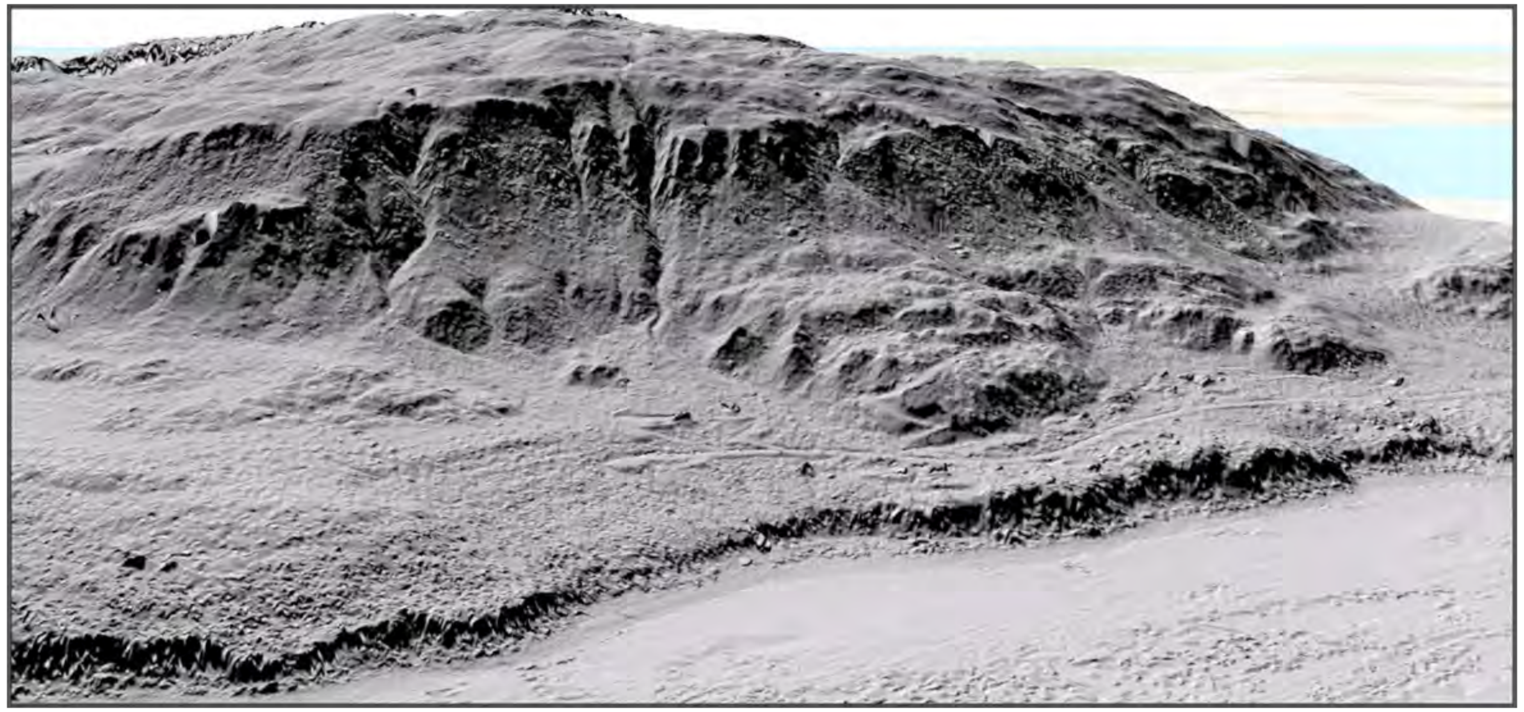
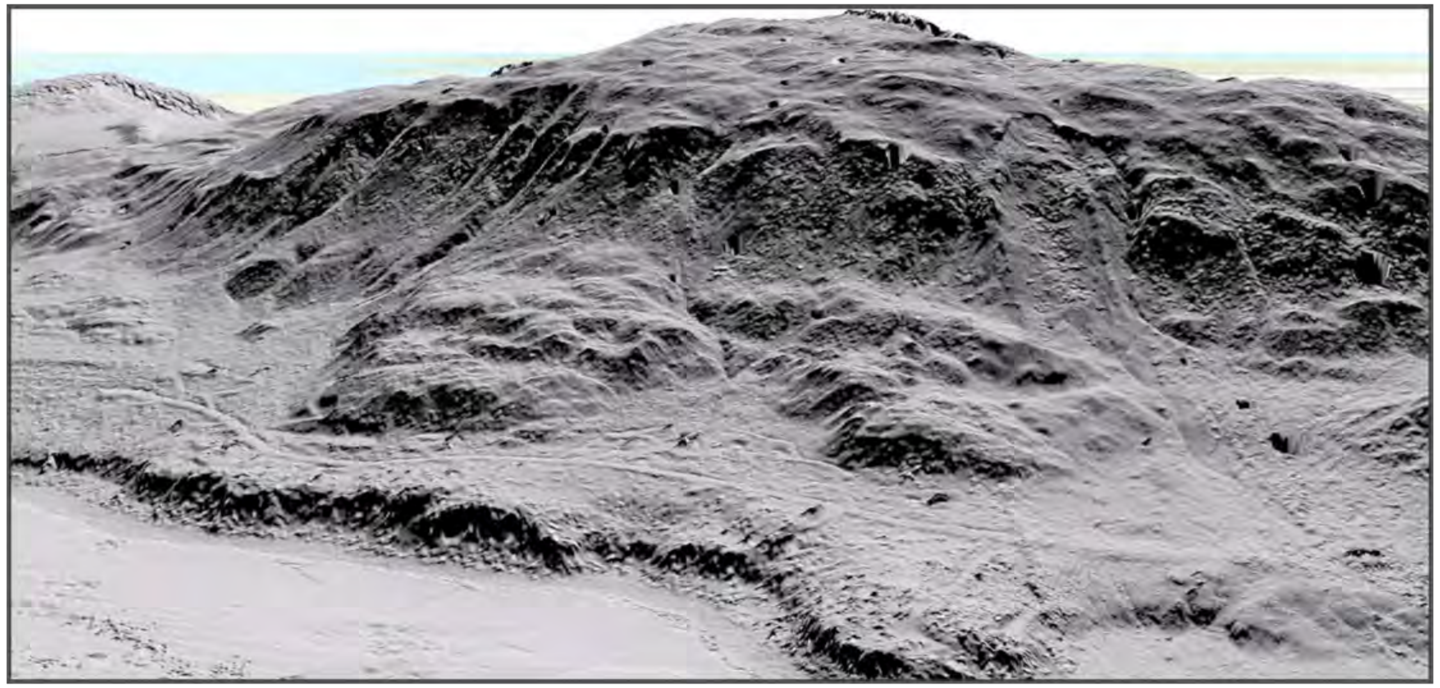
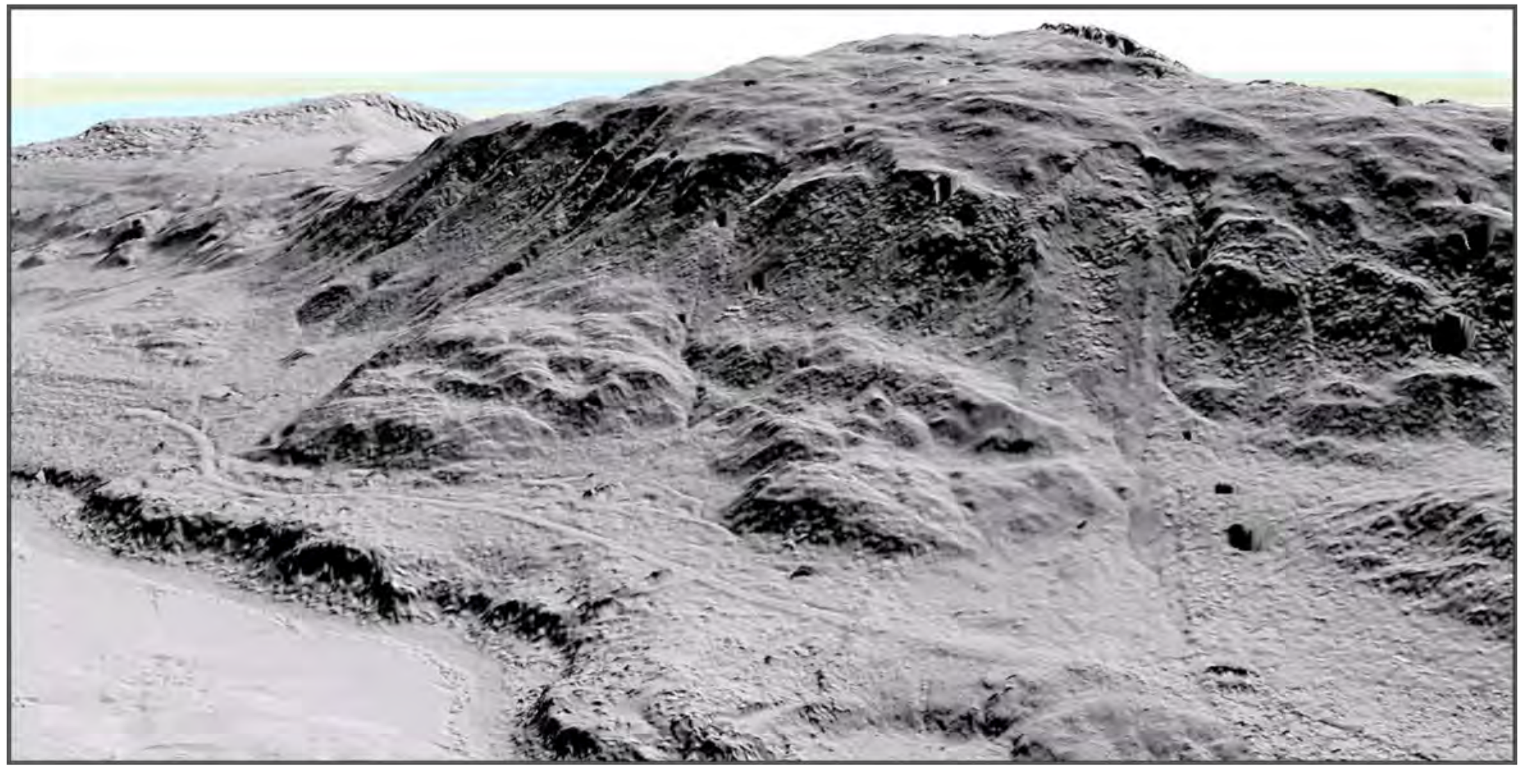
FIG. 2



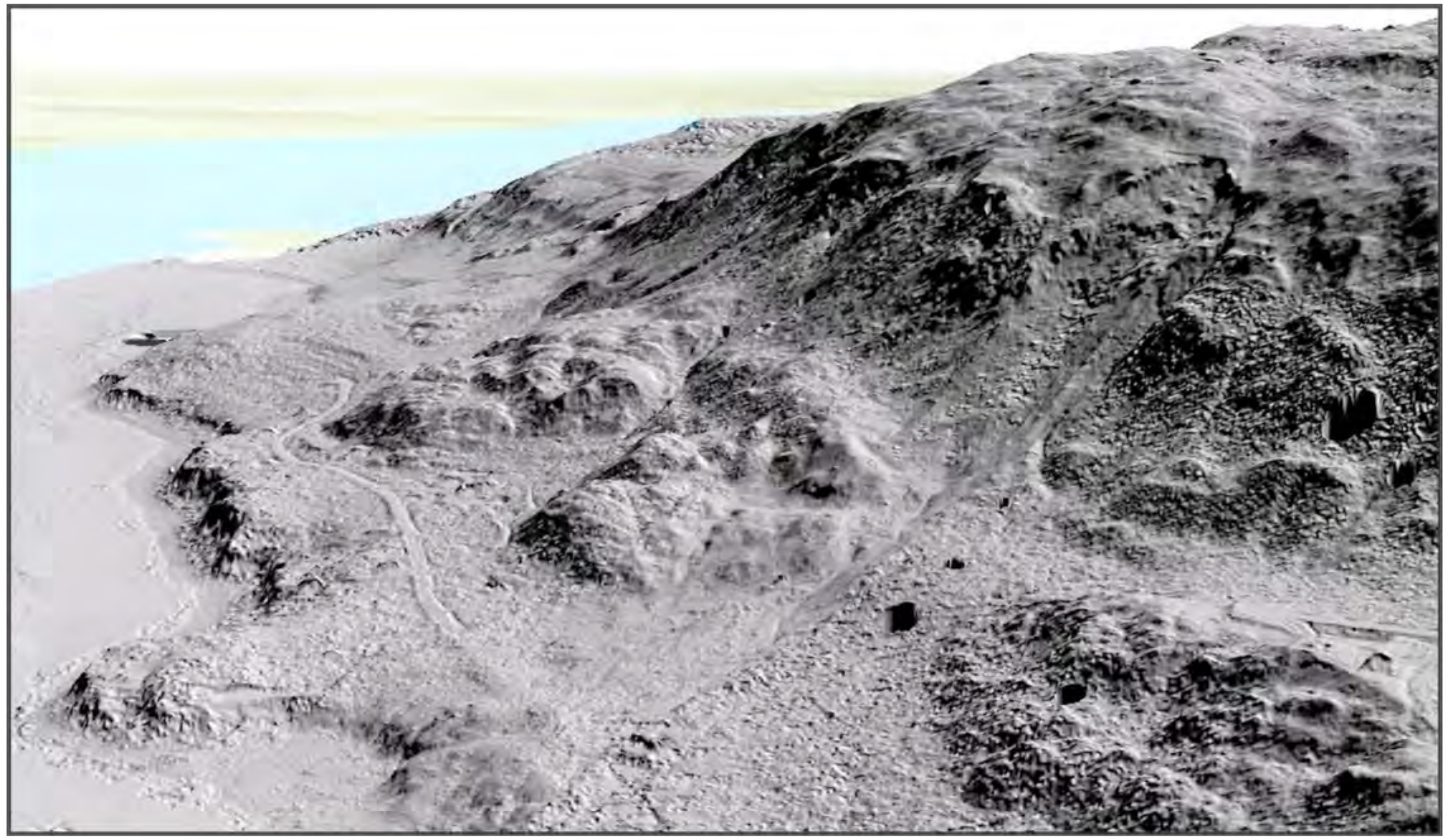
LOOKING WEST-SOUTHWEST



LOOKING SOUTH-SOUTHWEST



LOOKING SOUTH



LOOKING SOUTHEAST

Notes:
1. Images sampled from visualization provided by the Haines Avalanche Center
2. Three dimensional terrain derived from 2020 lidar data provided by DGGS, acquired Dec. 2020.

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OBLIQUE LiDAR IMAGES

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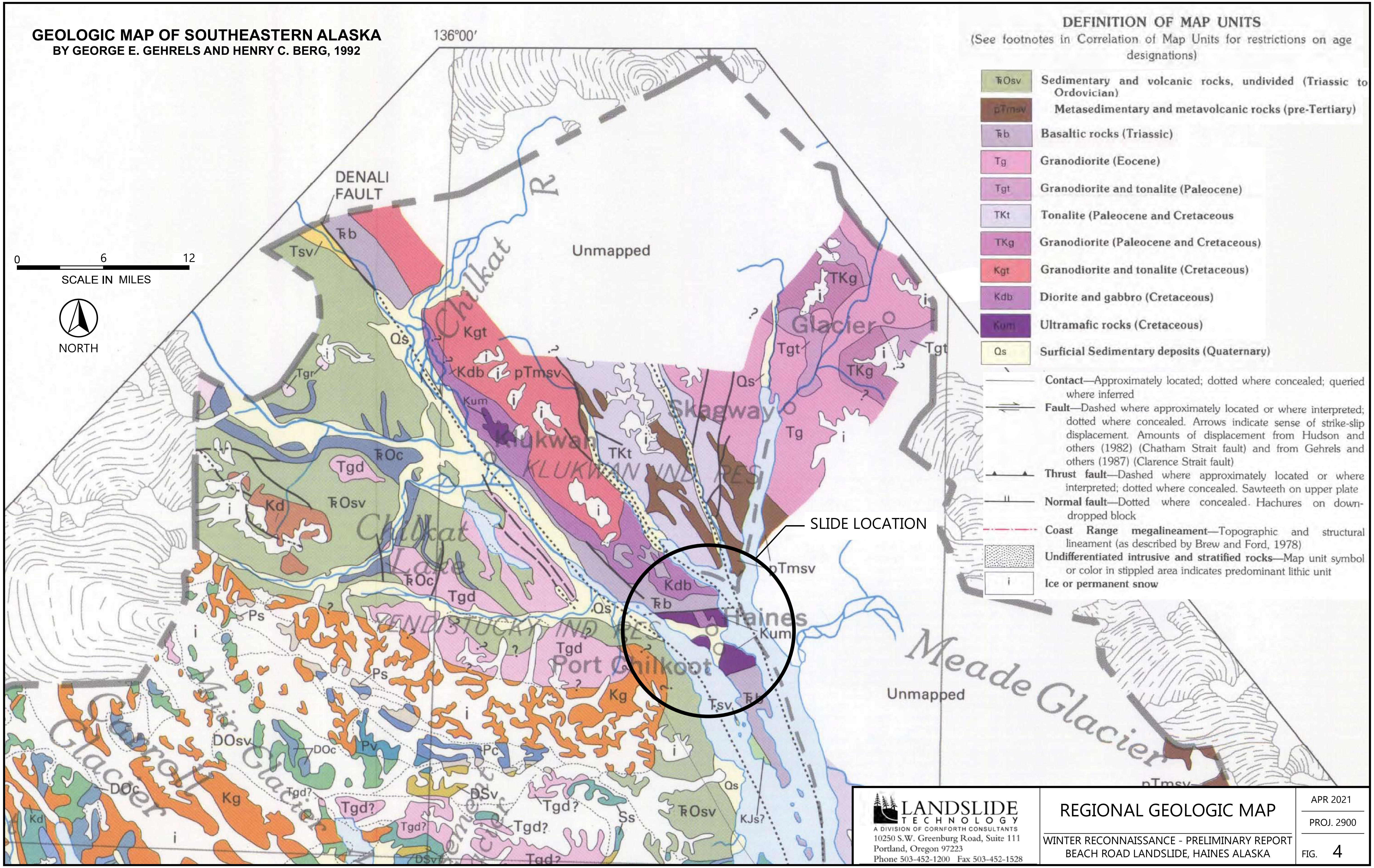
FIG. 3

GEOLOGIC MAP OF SOUTHEASTERN ALASKA
BY GEORGE E. GEHRELS AND HENRY C. BERG, 1992



DEFINITION OF MAP UNITS
(See footnotes in Correlation of Map Units for restrictions on age designations)

TROsv	Sedimentary and volcanic rocks, undivided (Triassic to Ordovician)
pTmsv	Metasedimentary and metavolcanic rocks (pre-Tertiary)
TRb	Basaltic rocks (Triassic)
Tg	Granodiorite (Eocene)
Tgt	Granodiorite and tonalite (Paleocene)
TKt	Tonalite (Paleocene and Cretaceous)
TKg	Granodiorite (Paleocene and Cretaceous)
Kgt	Granodiorite and tonalite (Cretaceous)
Kdb	Diorite and gabbro (Cretaceous)
Kum	Ultramafic rocks (Cretaceous)
Qs	Surficial Sedimentary deposits (Quaternary)

Contact—Approximately located; dotted where concealed; queried where inferred

Fault—Dashed where approximately located or where interpreted; dotted where concealed. Arrows indicate sense of strike-slip displacement. Amounts of displacement from Hudson and others (1982) (Chatham Strait fault) and from Gehrels and others (1987) (Clarence Strait fault)

Thrust fault—Dashed where approximately located or where interpreted; dotted where concealed. Sawteeth on upper plate

Normal fault—Dotted where concealed. Hachures on down-dropped block

Coast Range megalineament—Topographic and structural lineament (as described by Brew and Ford, 1978)

Undifferentiated intrusive and stratified rocks—Map unit symbol or color in stippled area indicates predominant lithic unit

i **Ice or permanent snow**

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REGIONAL GEOLOGIC MAP

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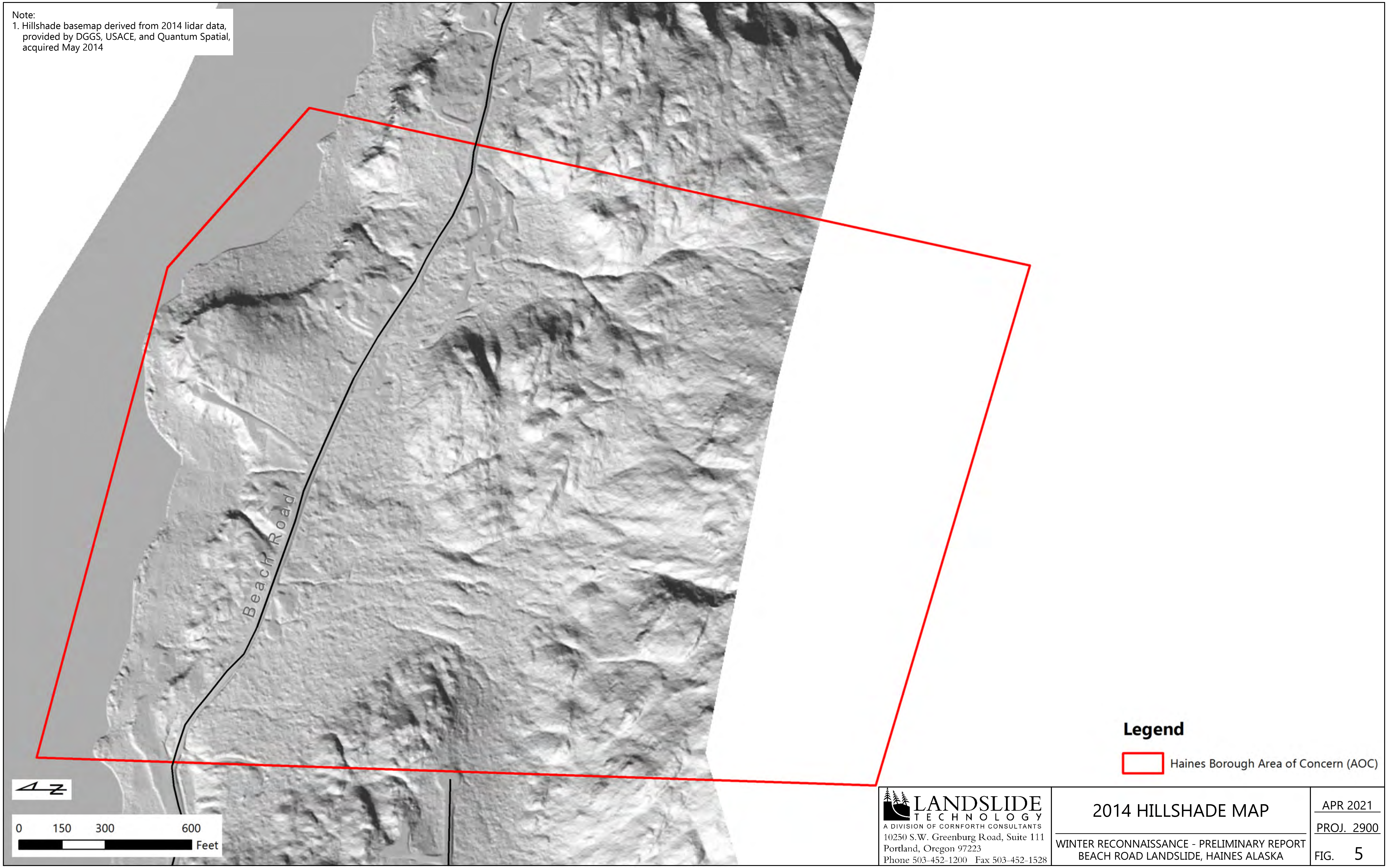
FIG. 4

Note:
1. Hillshade basemap derived from 2014 lidar data, provided by DGGS, USACE, and Quantum Spatial, acquired May 2014



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2014 HILLSHADE MAP

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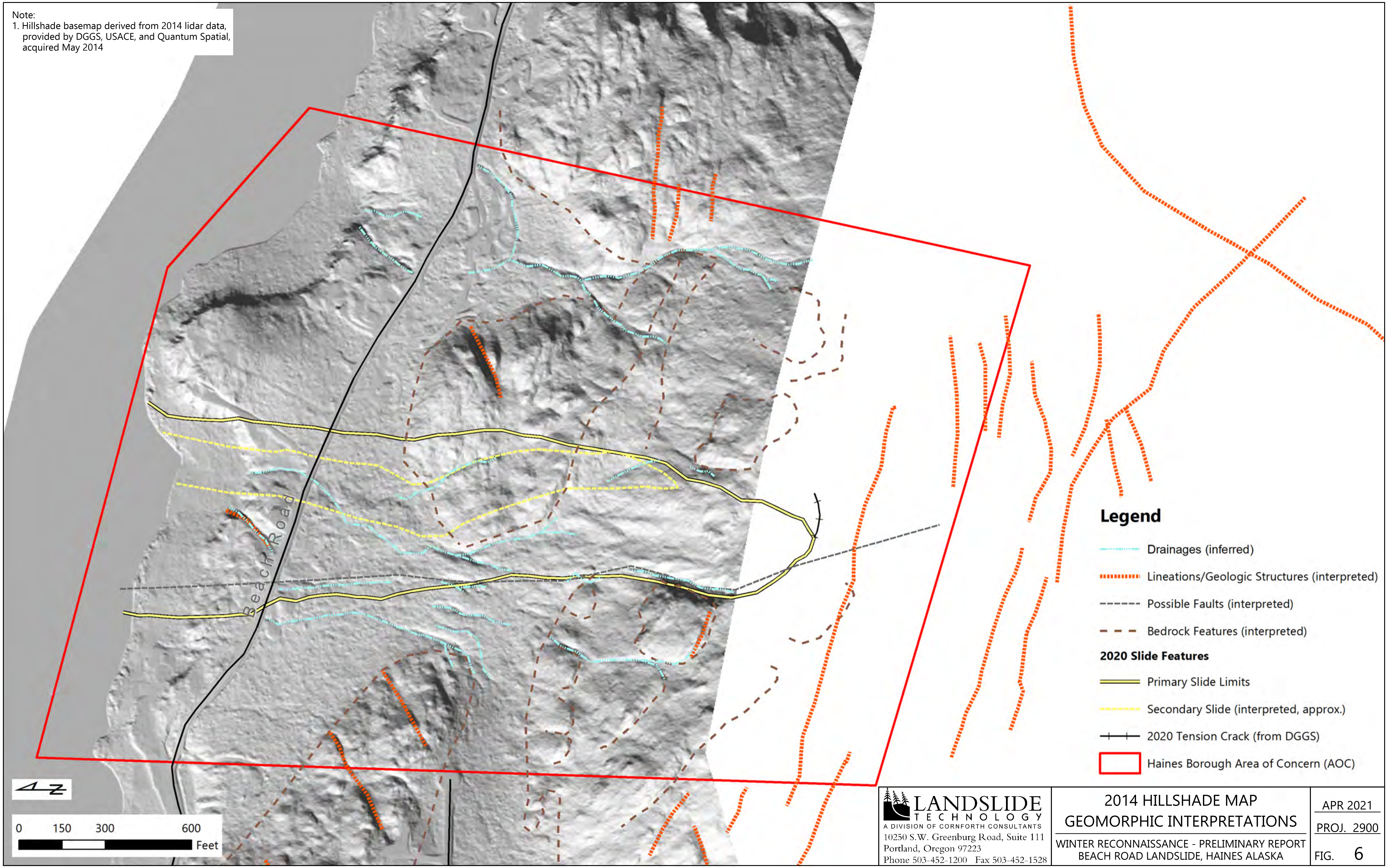
FIG. 5



Note:
1. Hillshade basemap derived from 2014 lidar data, provided by DGGS, USACE, and Quantum Spatial, acquired May 2014

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2014 HILLSHADE MAP
GEOMORPHIC INTERPRETATIONS

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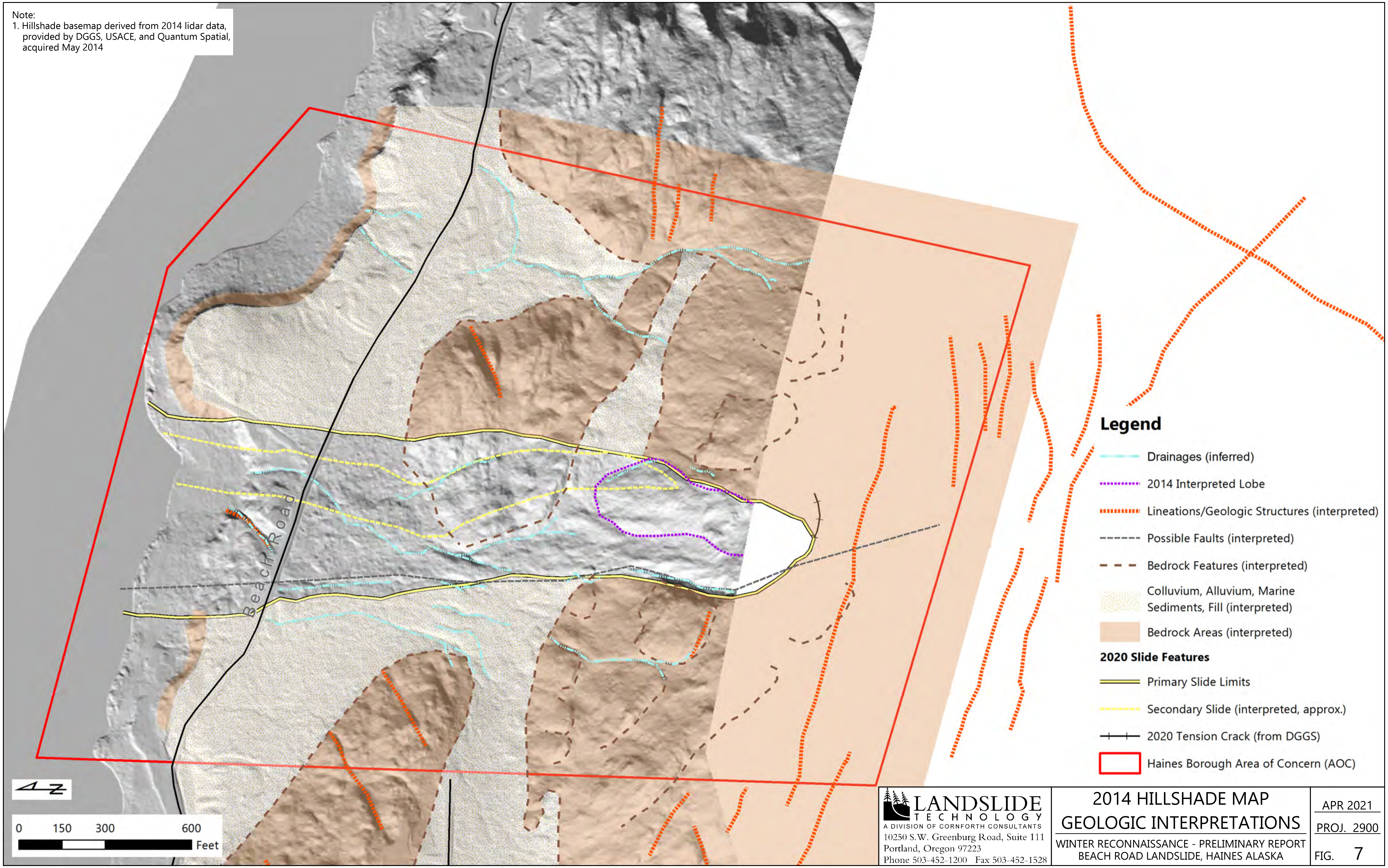
FIG. 6



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2014 HILLSHADE MAP GEOLOGIC INTERPRETATIONS

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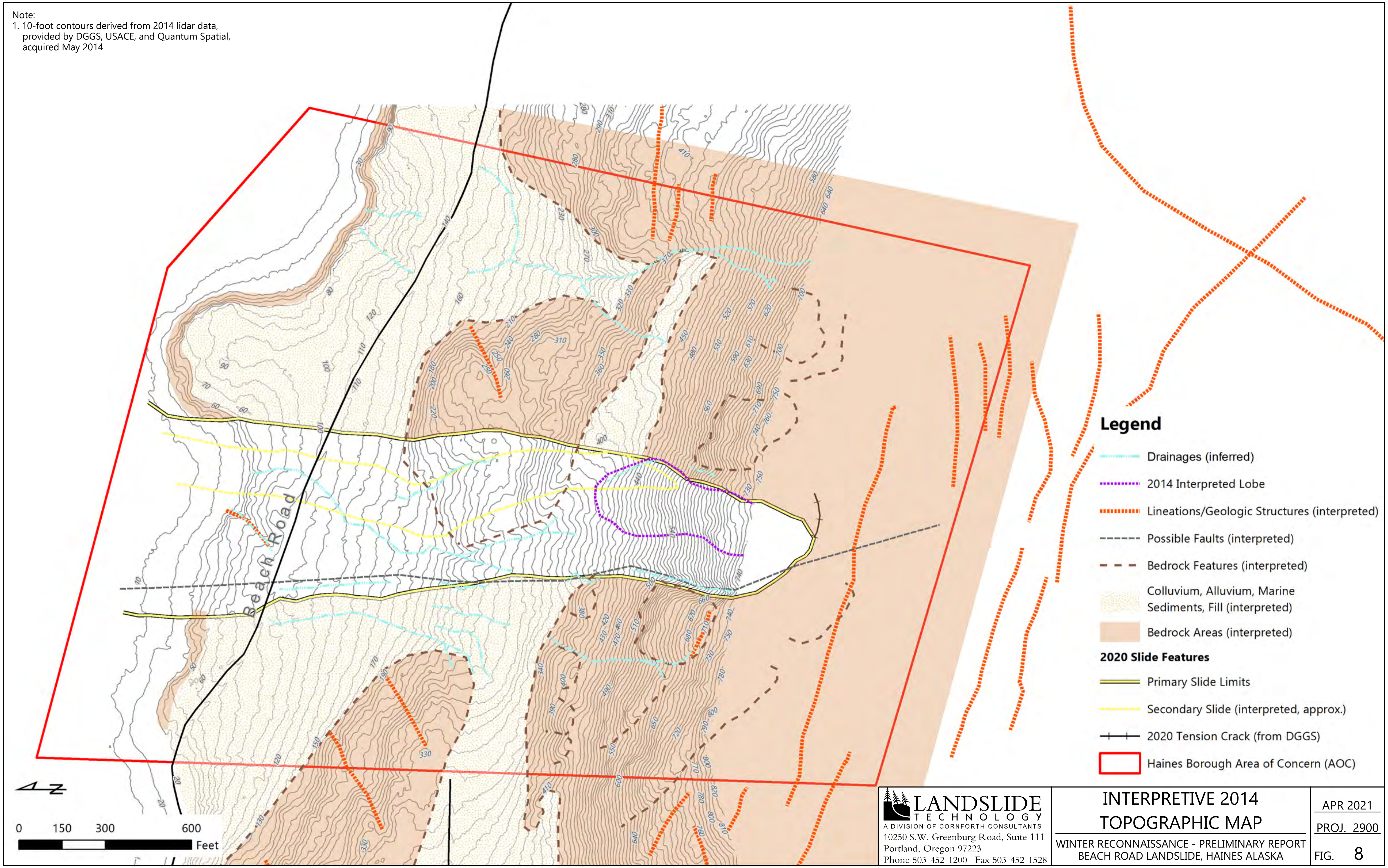
FIG. 7

Note:
1. 10-foot contours derived from 2014 lidar data, provided by DGGS, USACE, and Quantum Spatial, acquired May 2014



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INTERPRETIVE 2014 TOPOGRAPHIC MAP

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BEACH ROAD LANDSLIDE, HAINES ALASKA

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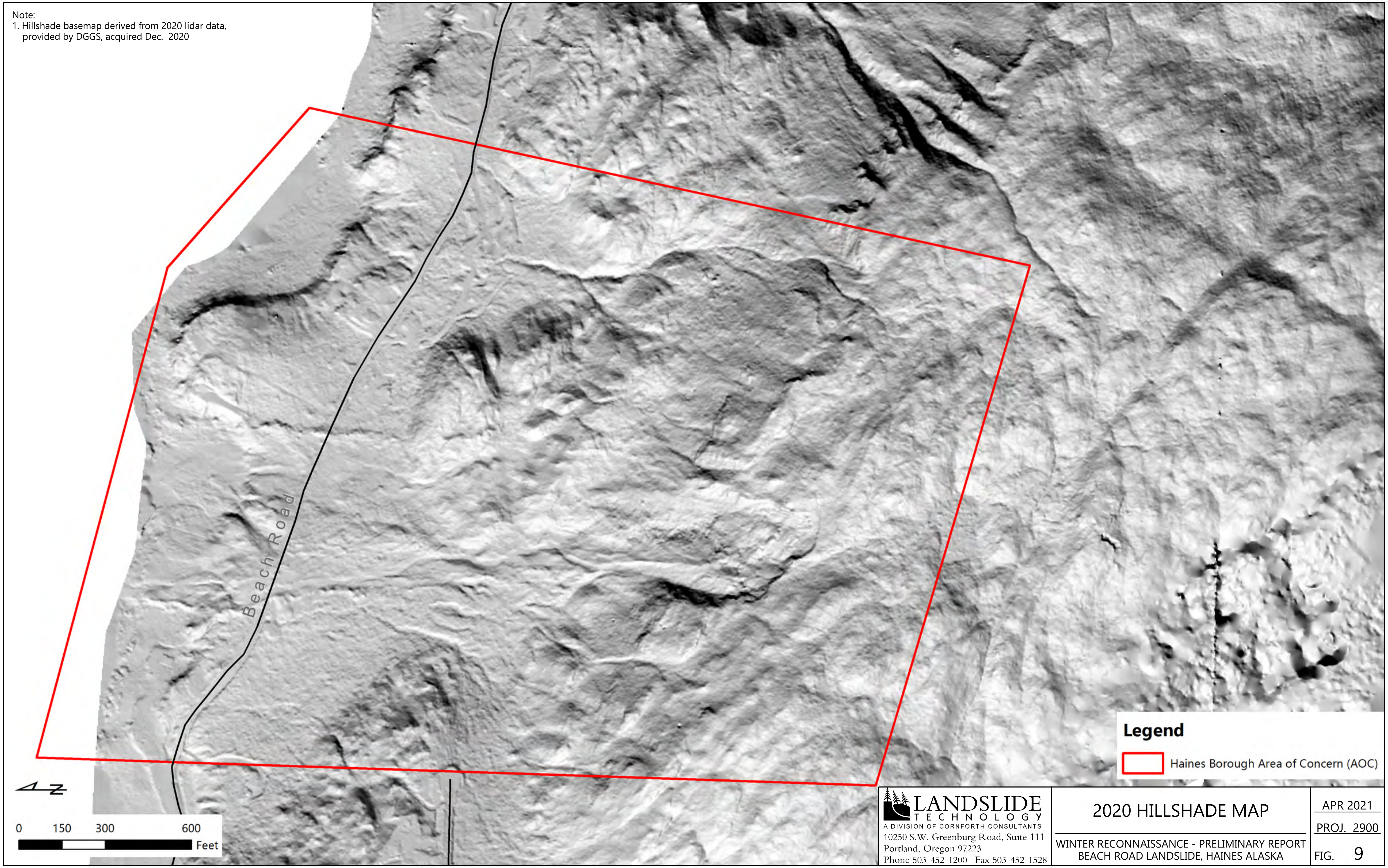
FIG. 8

Note:
1. Hillshade basemap derived from 2020 lidar data,
provided by DGGS, acquired Dec. 2020



Legend

🟥 Haines Borough Area of Concern (AOC)

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2020 HILLSHADE MAP

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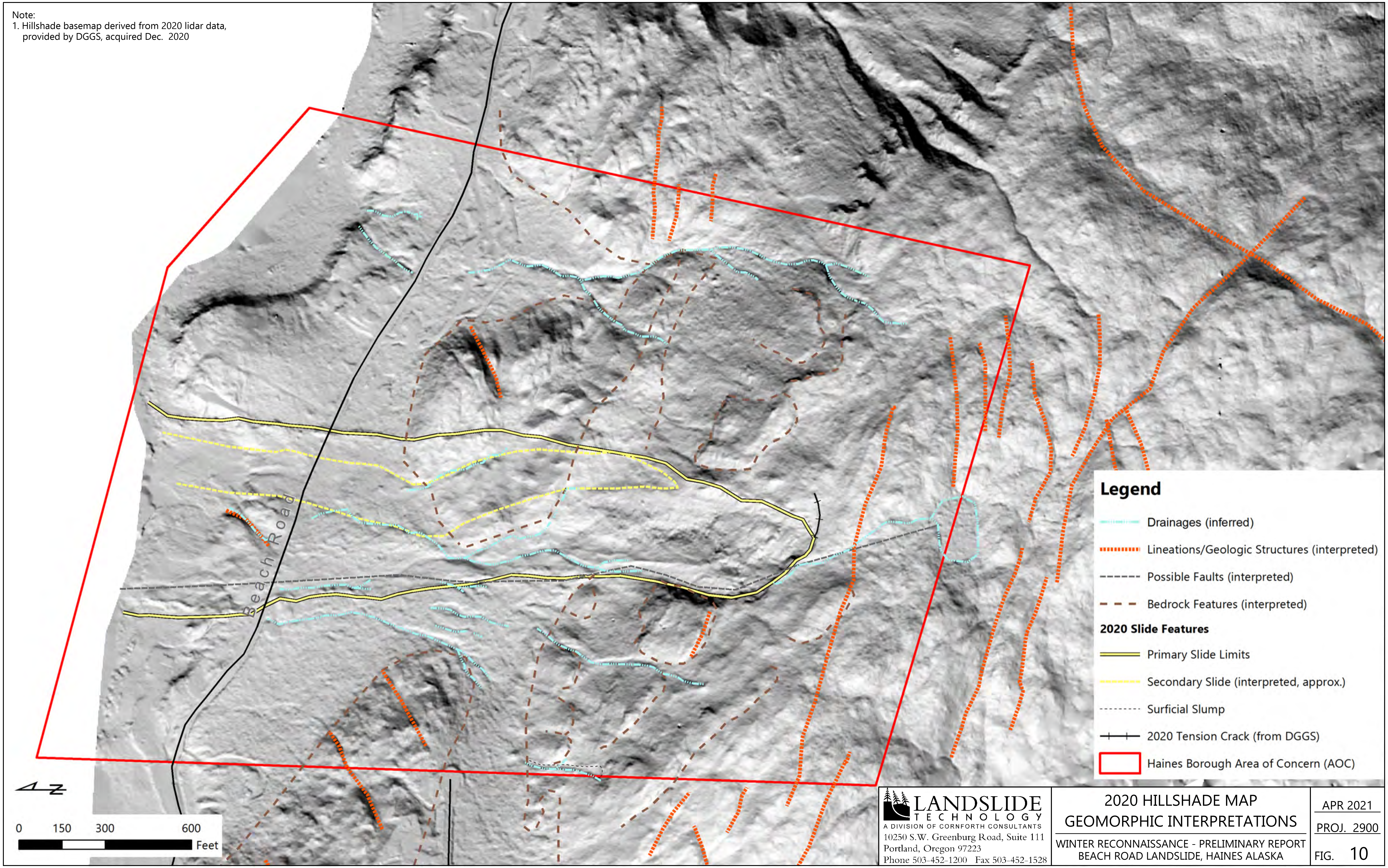
FIG. 9

Note:
1. Hillshade basemap derived from 2020 lidar data, provided by DGGS, acquired Dec. 2020



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2020 HILLSHADE MAP GEOMORPHIC INTERPRETATIONS

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BEACH ROAD LANDSLIDE, HAINES ALASKA

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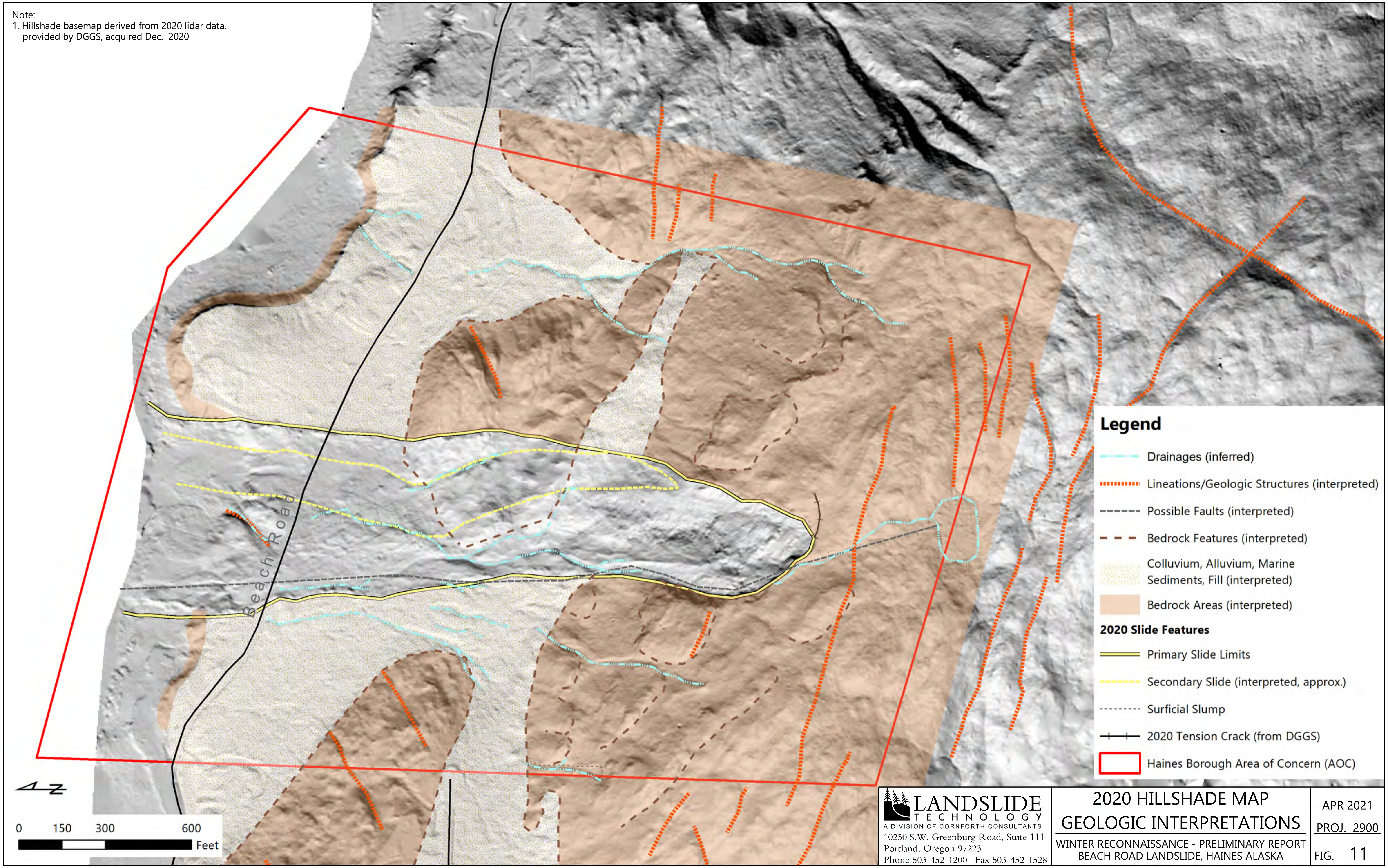
FIG. 10

Note:
1. Hillshade basemap derived from 2020 lidar data, provided by DGGS, acquired Dec. 2020



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2020 HILLSHADE MAP GEOLOGIC INTERPRETATIONS

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BEACH ROAD LANDSLIDE, HAINES ALASKA

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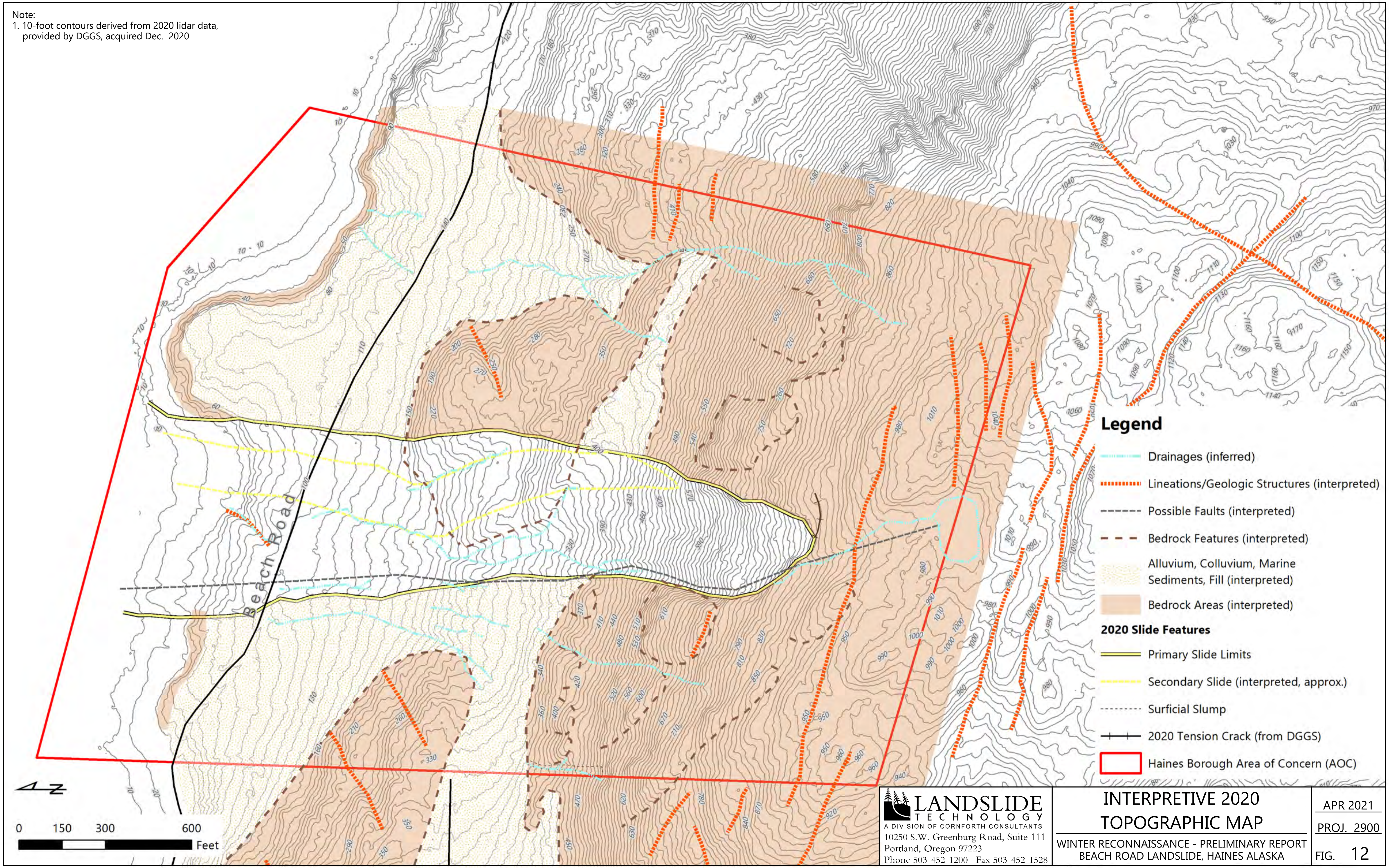
FIG. 11

Note:
1. 10-foot contours derived from 2020 lidar data, provided by DGGS, acquired Dec. 2020



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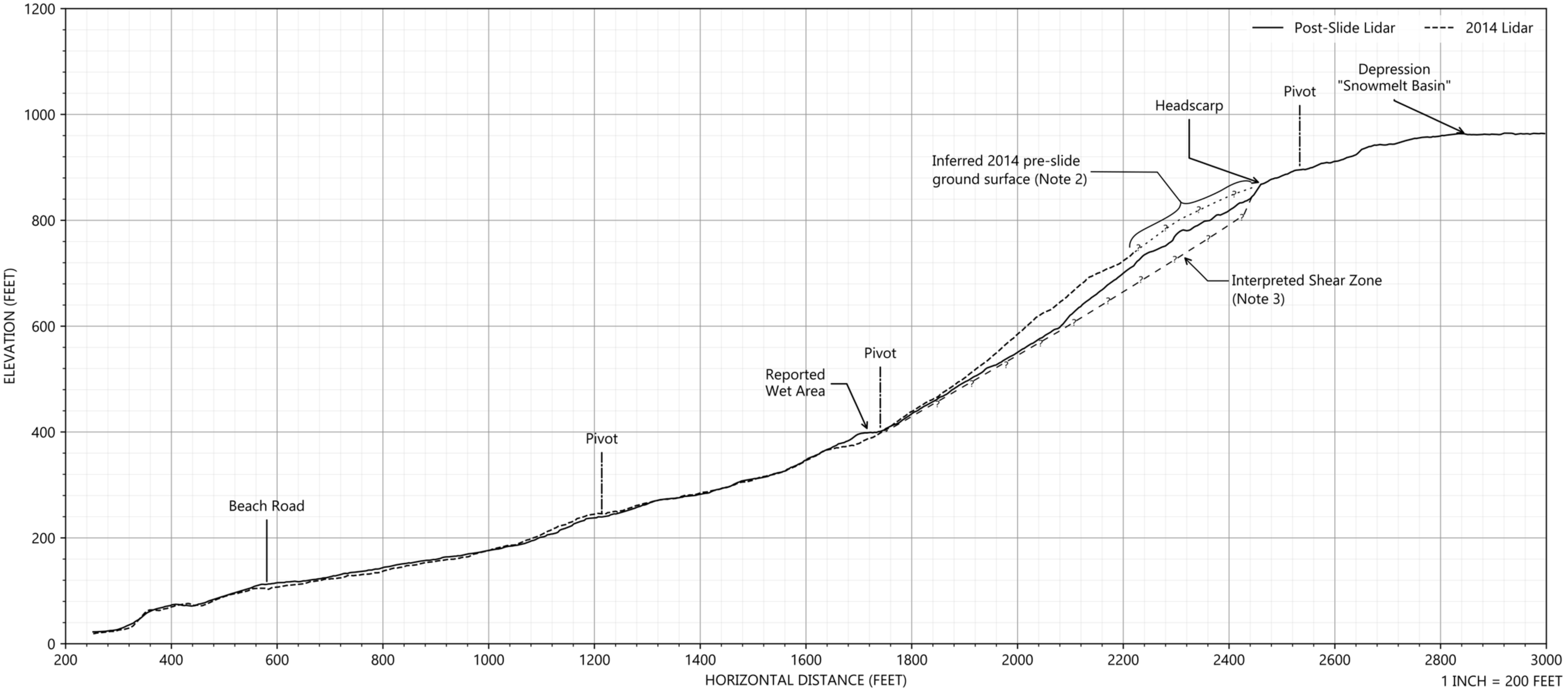
INTERPRETIVE 2020 TOPOGRAPHIC MAP

WINTER RECONNAISSANCE - PRELIMINARY REPORT
BEACH ROAD LANDSLIDE, HAINES ALASKA

APR 2021
PROJ. 2900
FIG. 12



Notes:
1.Cross section based on topography from 2014 and 2020 LiDAR data.
2. 2014 LiDAR dataset extended partway up slope. Ground surface in upper slide area was inferred.
3. Depth of slide debris is not known. Location of shear zone is interpreted/preliminary.
4. Location of cross section shown on Figure 2.

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INTERPRETIVE
CROSS SECTION 1
WINTER RECONNAISSANCE - PRELIMINARY REPORT
BEACH ROAD LANDSLIDE, HAINES ALASKA

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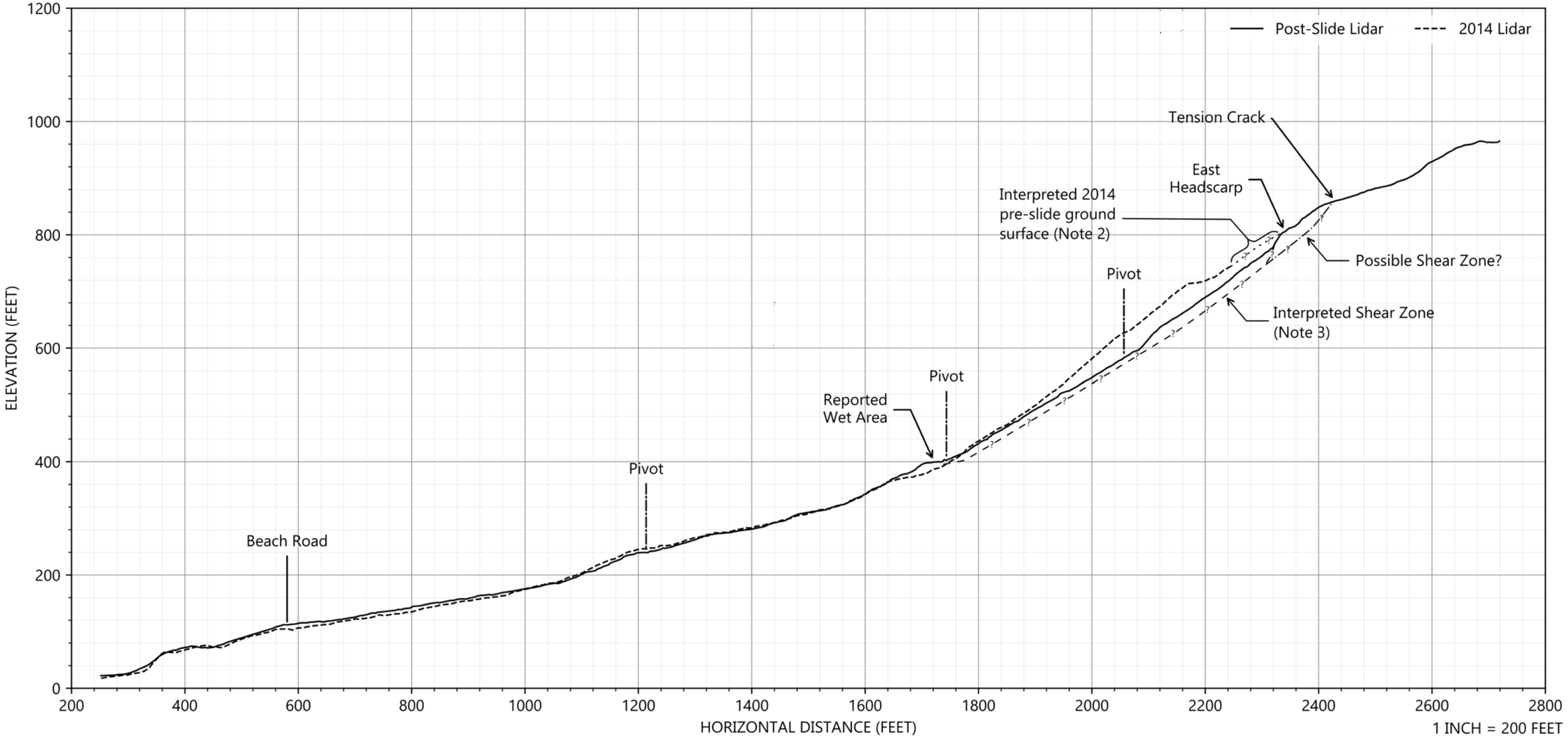
FIG. 13



Notes:
1.Cross section based on topography from 2014 and 2020 LiDAR data.
2. 2014 LiDAR dataset extended partway up slope. Ground surface in upper slide area was inferred.
3. Depth of slide debris is not known. Location of shear zone is interpreted/preliminary.
4. Location of cross section shown on Figure 2.

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INTERPRETIVE
CROSS SECTION 1A
WINTER RECONNAISSANCE - PRELIMINARY REPORT
BEACH ROAD LANDSLIDE, HAINES ALASKA

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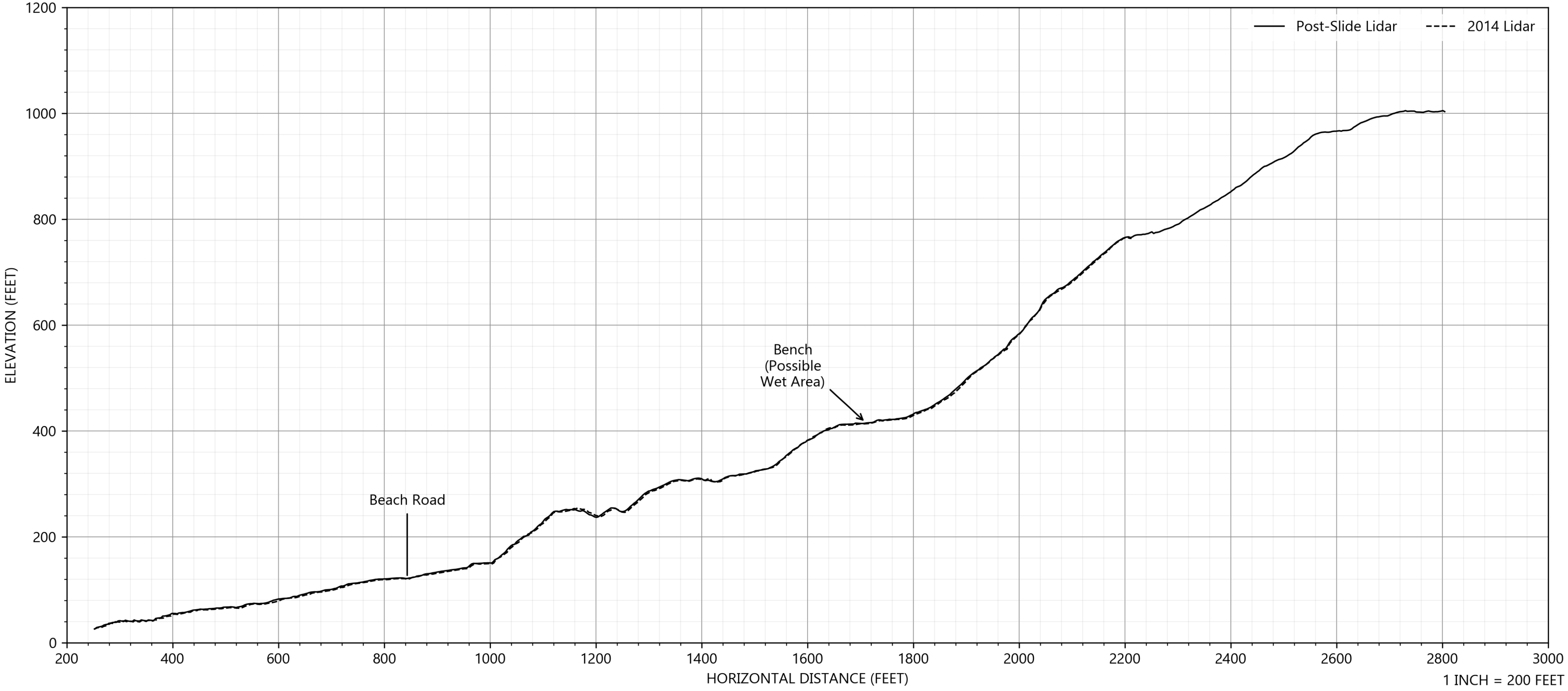
FIG. 14



Note:
1.Cross section based on topography from 2014 and 2020 LiDAR data.
2. Location of cross section shown on Figure 2.

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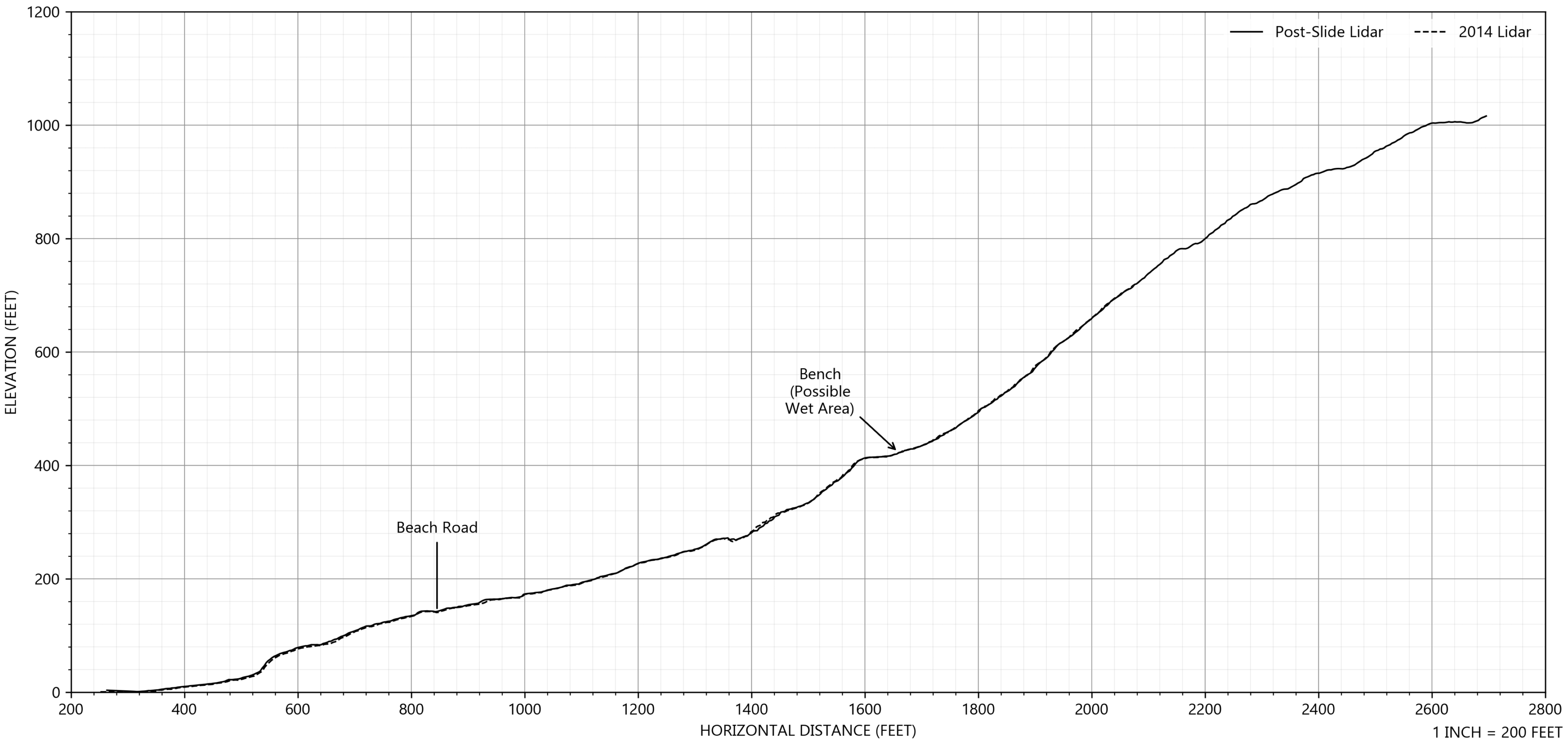
INTERPRETIVE
CROSS SECTION 2

WINTER RECONNAISSANCE - PRELIMINARY REPORT
BEACH ROAD LANDSLIDE, HAINES ALASKA

APR 2021
PROJ. 2900
FIG. 15



Note:
1.Cross section based on topography from 2014 and 2020 LiDAR data.
2. Location of cross section shown on Figure 2.

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INTERPRETIVE
CROSS SECTION 3

WINTER RECONNAISSANCE - PRELIMINARY REPORT
BEACH ROAD LANDSLIDE, HAINES ALASKA

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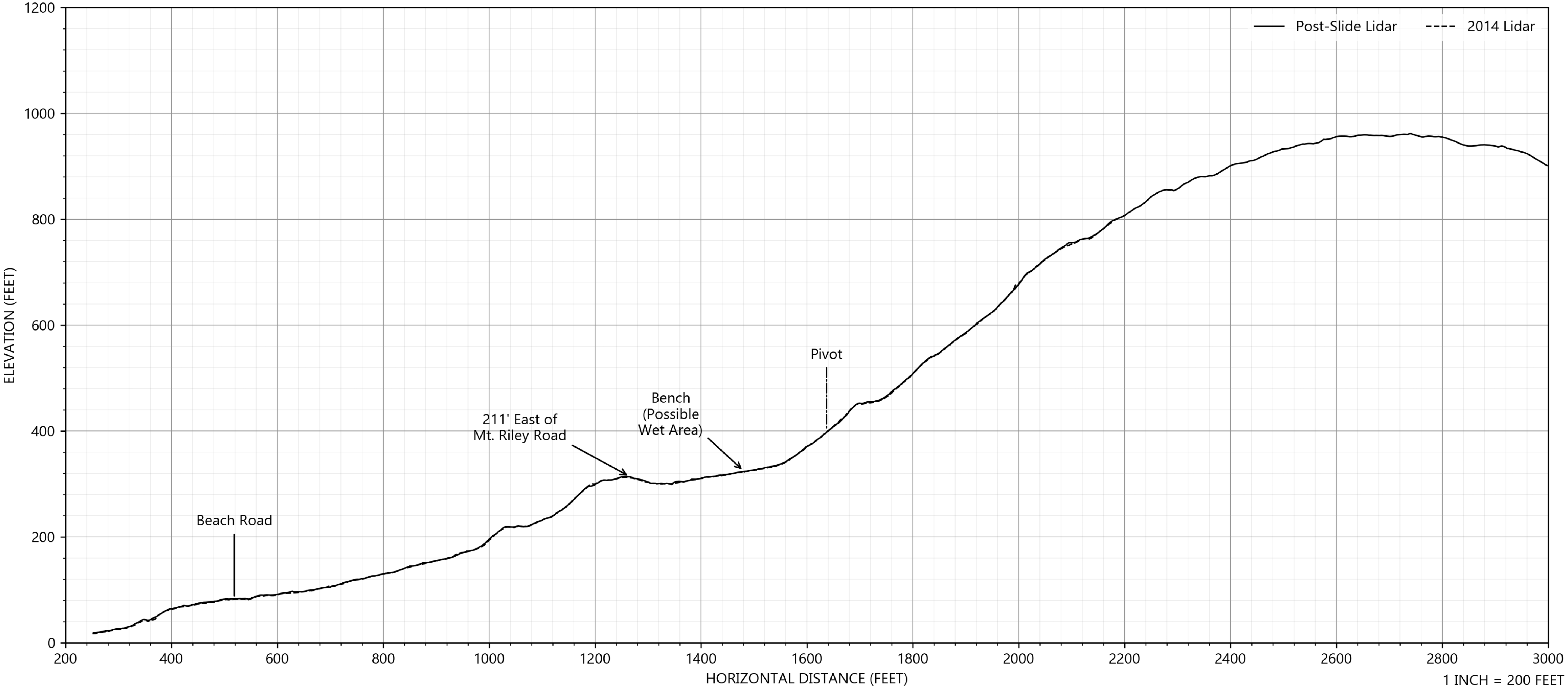
PROJ. 2900
FIG. 16



Note:
1.Cross section based on topography from 2014 and 2020 LiDAR data.
2. Location of cross section shown on Figure 2.

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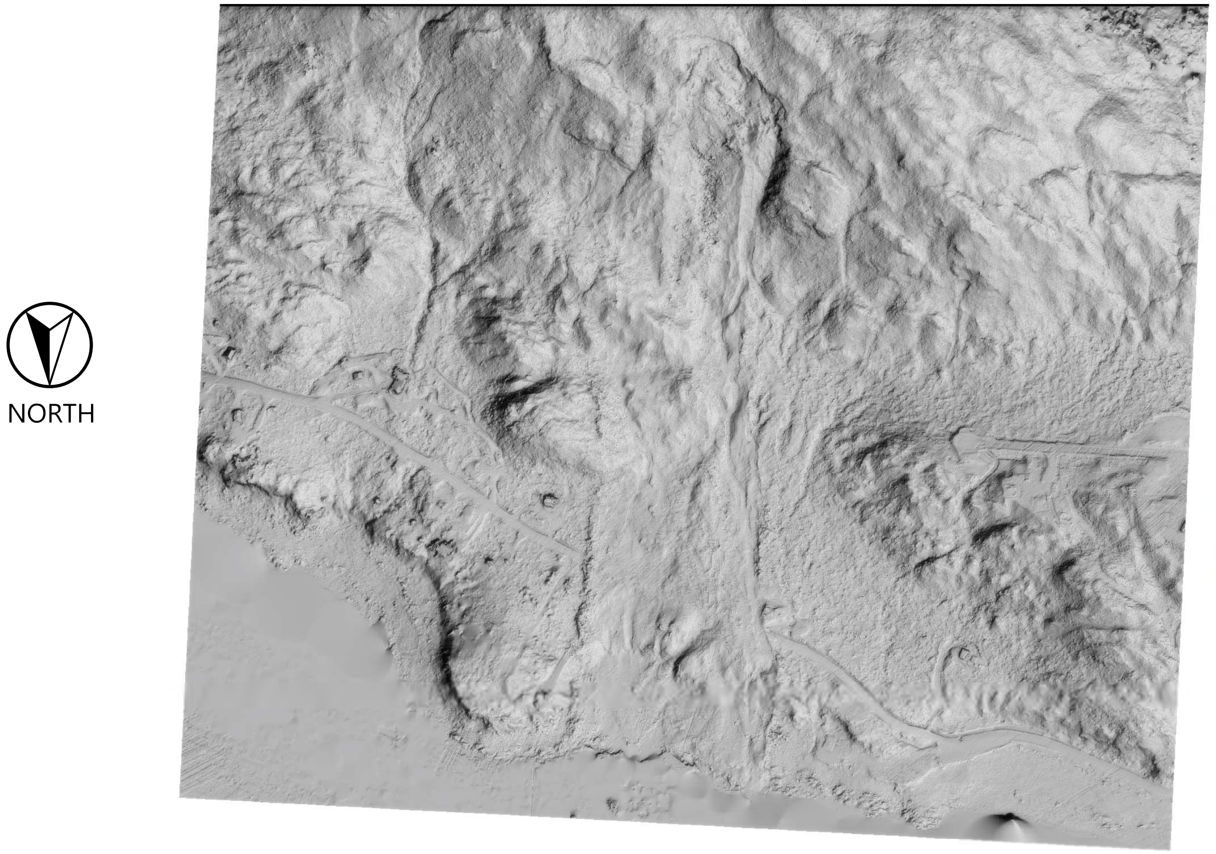
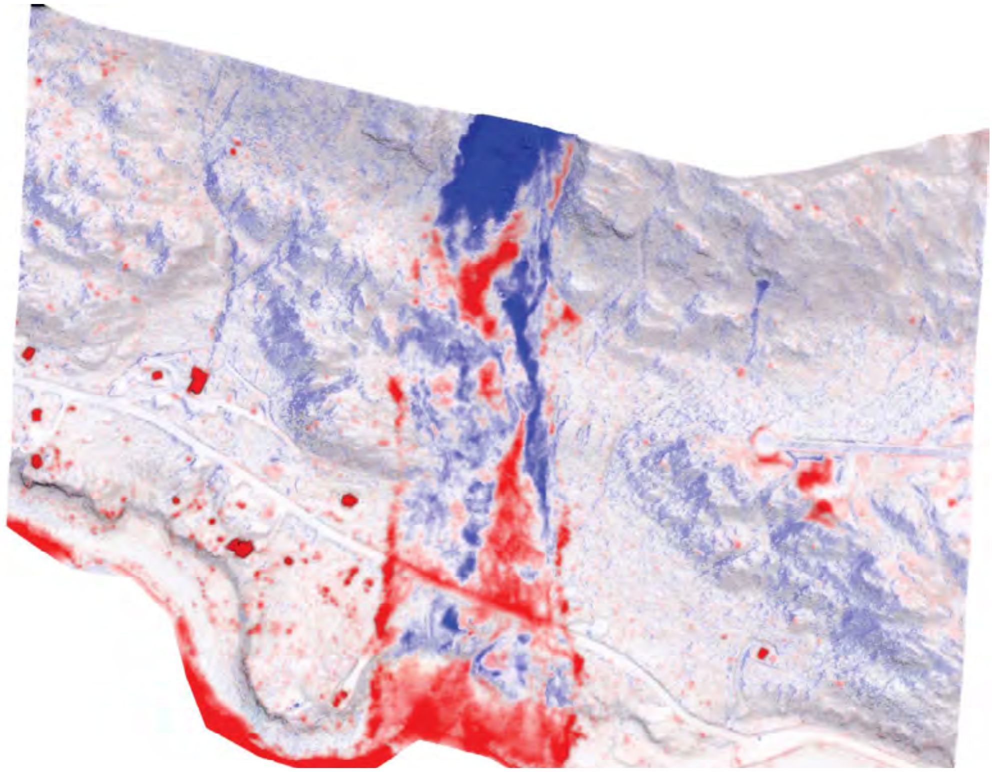
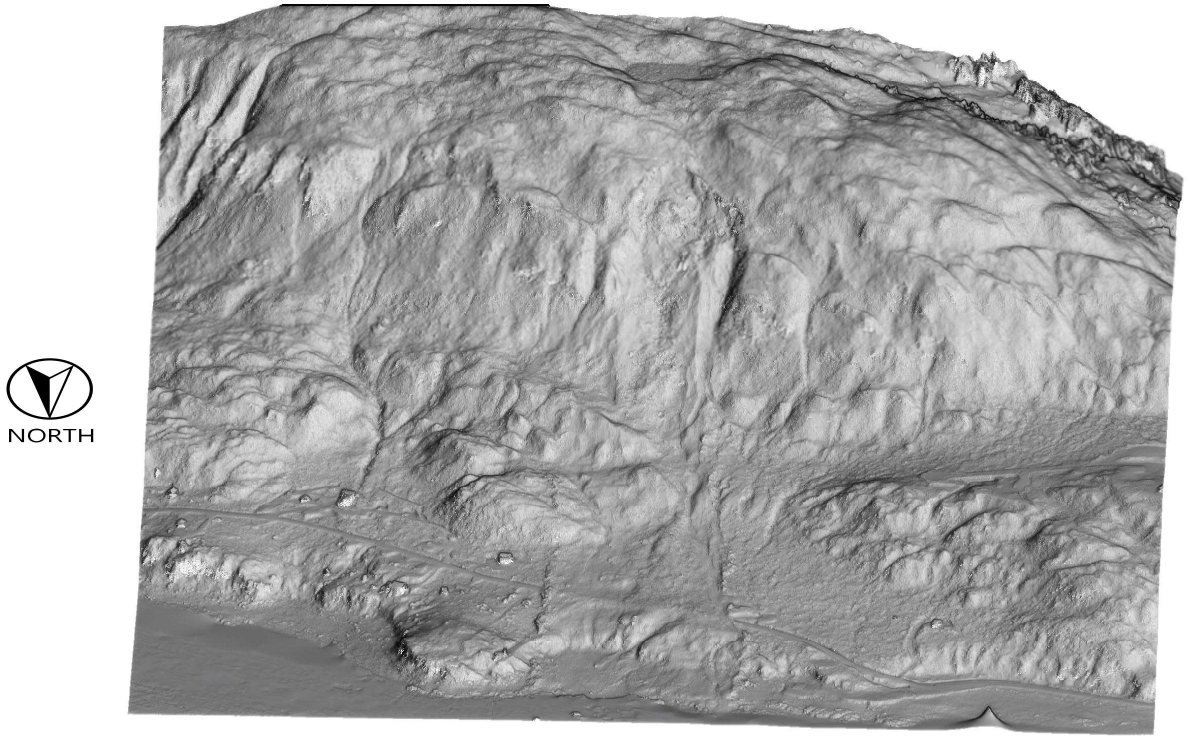
INTERPRETIVE
CROSS SECTION 4

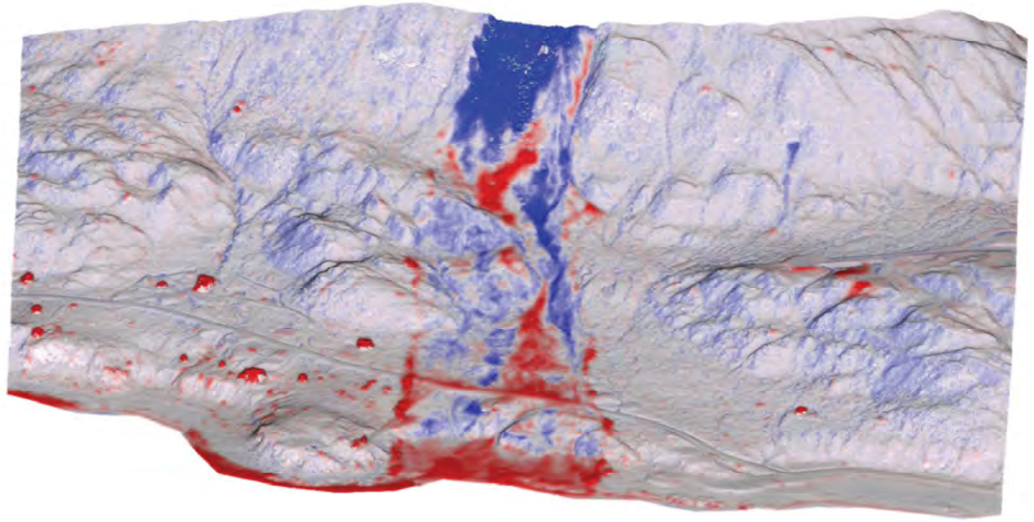
WINTER RECONNAISSANCE - PRELIMINARY REPORT
BEACH ROAD LANDSLIDE, HAINES ALASKA

APR 2021
PROJ. 2900
FIG. 17









LEGEND

🟥 ACCUMULATION

🟦 LOSS

NOTES:
1. Shading is the difference between 2014 and 2020 data in the vertical (z) directions.
2. Images are not to scale.

Hillshade images developed from DGGS 2014 and 2020 LiDAR.

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VERTICAL CHANGE DETECTION MAPS

WINTER RECONNAISSANCE - PRELIMINARY REPORT
BEACH ROAD LANDSLIDE, HAINES ALASKA

APR 2021

PROJ. 2900

FIG. 18

APPENDIX A: PHOTO EXHIBIT (DECEMBER 2020)

Aerial view looking southeast at landslide (from DGGS, taken 12/10/2020).

View looking approximately south at landslide from the inlet (from Haines Avalanche Center, taken 12/6/2020).

View looking southeast at upper portion of the landslide and the eastern lateral scarp (from Haines Avalanche Center, taken 12/9/2020).

Aerial view looking northeast at lower portion of the landslide (from DGGS, taken 12/10/2020).

Aerial view looking southwest at eastern portion of the landslide near the Keller property (from Haines Avalanche Center, taken 12/8/2020).

Aerial view southwest at western portion of the landslide on the Messano property (from Haines Avalanche Center, 12/8/2020).

View looking southeast at landslide debris and damage to the Messano property (from Haines Avalanche Center, taken 12/9/2020).

View looking at landslide debris near the western edge of the landslide (from Haines Avalanche Center, taken 12/9/2020).

View looking south at landslide debris in upper portion of landslide (from Haines Avalanche Center, taken 12/8/2020).

View looking north at landslide debris from the headscarp area (from DGGS, taken 12/11/2020).

Aerial view looking southeast at headscarp area and the upper eastern lateral scarp (from Haines Avalanche Center, taken 12/8/2020).

Aerial view looking south at the headscarp area (from Haines Avalanche Center, taken 12/9/2020). Note ground cracks extending east of the headscarp area.

View looking east at bedrock exposed in the headscarp (from DGGS, taken 12/12/2020).

View looking east at bedrock exposed in the upper eastern lateral scarp (from DGGS, taken 12/12/2020).

Aerial view looking south at crack extensions east of the headscarp area (from Haines Avalanche Center, taken 12/9/2020).

Close up view looking south at crack extensions east of the headscarp area (from Haines Avalanche Center, taken 12/9/2020).

View looking west at easternmost extension of ground cracks east of the headscarp (from DGGS, taken 12/11/2020).

View looking southwest at easternmost extension of ground cracks east of the headscarp (from DGGS, taken 12/11/2020).

Close up view of ground cracks east of the headscarp (from DGGS, taken 12/11/2020).

Close up view of ground cracks east of the headscarp (from DGGS, taken 12/11/2020).

View looking south at landslide from the inlet (from DGGS).

APPENDIX B: PHOTO EXHIBIT (WINTER RECONNAISSANCE)

Aerial view looking south-southwest at the slide area during the winter reconnaissance (taken 2/23/2021).

Aerial view looking south at a localized slide on the western edge of EOC "Area of Concern" (taken 2/23/2021).

View from temporary access road looking south at the headscarp of the slide.

View looking west across the middle of the slide near elevation 400 feet (taken 2/23/2021).

View looking west-northwest at debris in the upper slide mass near elevation 600 feet. Boulders up to 15 feet in height and 27 feet in width were observed (taken 2/24/2021).

View looking southeast at rock outcrop on the western flank of the slide near elevation 550 feet (taken 2/23/2021).

View looking east at the headscarp along the western flank of the slide near elevation 850 feet (taken 2/23/2021).

View of rock exposed in the western portion of the headscarp of the slide (taken 2/23/2021).

Close up view of the rock exposed in the western portion of the headscarp. Note altered nature of the rock surface (taken 2/23/2021).

View looking east at the headscarp area (taken 2/24/2021).

View looking west at the headscarp area (taken 2/24/2021).

Close up view of rock exposed in the eastern portion of the headscarp. Note altered nature of the rock surface (taken 2/24/2021).

Close up view of rock exposed in the eastern portion of the headscarp. Note altered nature of the rock surface (taken 2/24/2021).

View looking east in the area where DGGS observed ground cracks extending east of the main headscarp. The cracks could not be observed during the winter reconnaissance due to snow cover (taken 2/24/2021).

Photo of geotechnical engineer that fell into a possible void in the vicinity of the eastern ground crack extensions (taken 2/24/2021).

View looking north above the headscarp area. This area appears to be where concentrated surface water flowed into the headscarp area during the slide event (taken 2/24/2021).

View looking north further up the slope above the headscarp area. This area is the drainage path that channeled surface water flow toward the headscarp area during the slide event (taken 2/25/2021).

View looking southwest at rock outcrop above the prominent rock knob just east of the slide. The rock appears to be in place (taken 2/26/2021).

View looking southeast at rock outcrop at the base of the prominent rock knob just east of the slide. The rock appears to be in place (taken 2/26/2021).

View looking west at a bench feature above and further east the eastern most prominent rock knob (east of the slide area). The elevation of this feature is approximately 900 feet (taken 2/25/2021).

View looking southeast at a rock outcrop at the top eastern most prominent rock knob (east of the slide area; taken 2/26/2021).

View looking east at the base of the eastern most prominent rock knob (east of the slide area; taken 2/25/2021).

View looking north at the major drainage channel located on the eastern edge of the "Area of Concern" (taken 2/25/2021).

View of flowing artesian well at the Anderson Residence on east end of Beach Road (taken 2/26/2021).

View of excavator excavating a test pit (TP-2) on the east end of the temporary access road (taken 2/27/2021).

View of excavator excavating a test pit (TP-4) on the west end of the temporary access road (taken 2/27/2021).

APPENDIX C: ROCK OUTCROP STRUCTURAL ANALYSES

DISCONTINUITY ANALYSES

The presence, orientation and condition of discontinuities in a rock slope have a major influence on slope stability and rockfall potential. A thorough understanding of the structural character and potential rock mass characteristics, including block size, block shape, and the likely mode(s) of failure, provide input for effective and representative analysis. Several techniques were employed to define the geologic structural character, including discontinuity mapping, joint set analysis, and kinematic analysis.

Surficial discontinuity mapping was conducted at accessible rock outcrops across the AOC. Structural data were plotted on equal-area lower-half, equatorial stereonets using the RocScience computer program DIPS (version 8). Joint sets were estimated by contouring the data and visually identifying concentrations of similar discontinuities. The range of discontinuity orientations in the identified concentrations was averaged to represent a single geologic structure as a joint set.

Joint Set Analysis

A total of 205 discontinuity measurements were gathered during the winter reconnaissance, which includes 16 orientations collected by DGGS. Four major joint sets were identified as summarized on Table 1 and shown on a stereonet in this Appendix C. These joints were seen consistently across the site on both sides of the slide at various elevations and in the headscarp.

Table 1: Summary of Joint Set Analysis (All Data)

Joint Set Number	Dip Range (°)	Ave Dip (°)	Dip Direction Range (°)	Ave Dip Direction (°)
Set 1	54-88	71	033-068	047
Set 2	65-85	77	319-341	331
Set 3	69-87	75	129-151	144
Set 4	60-81	70	188-219	205

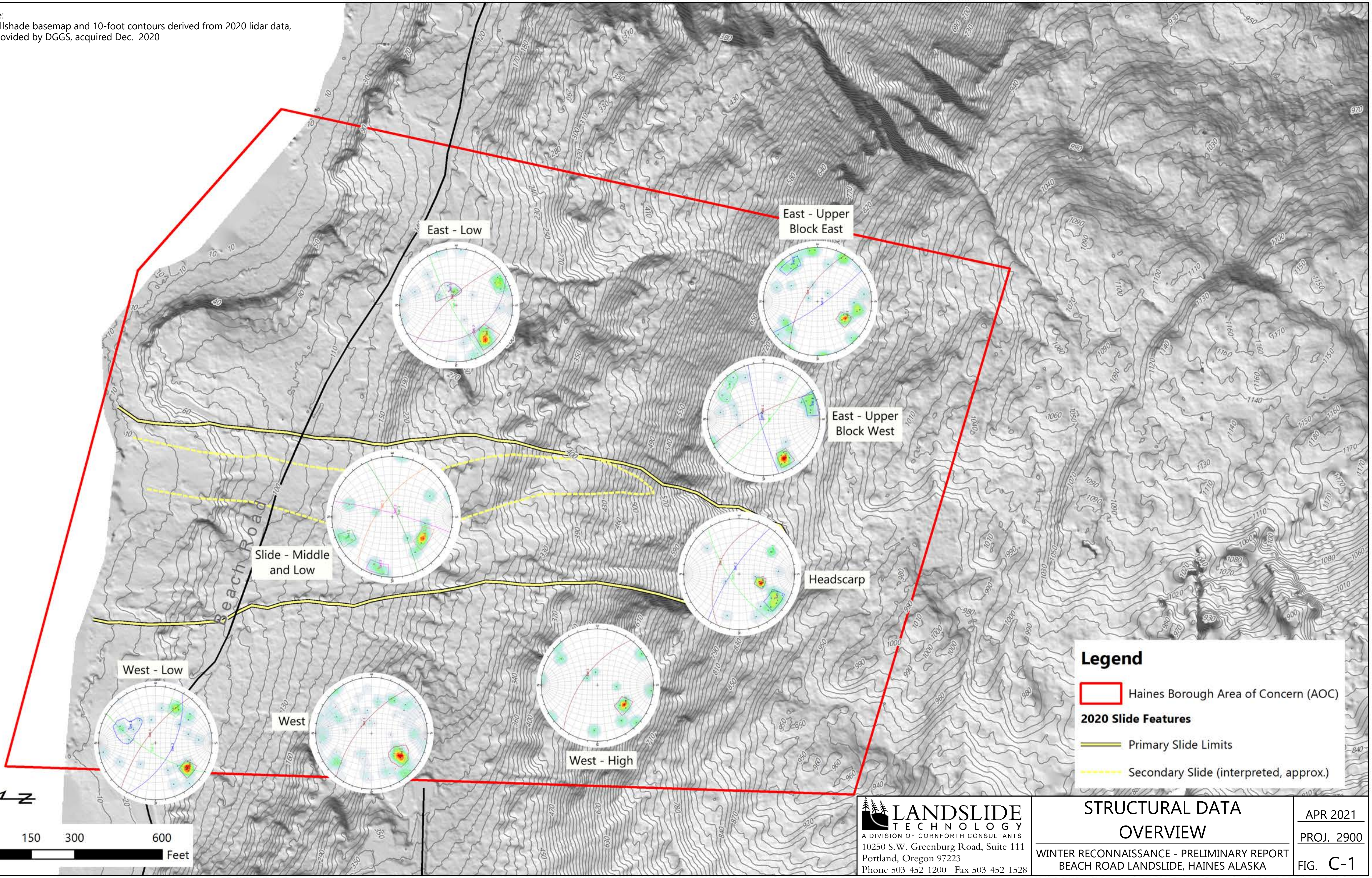
The spatial distribution of the geologic conditions across the site are illustrated on a Figure found in this Appendix C. Joint Set 1 can be seen in all of the stereonets across the site. Sets 2, 3, and 4 were not seen as consistently as Set 1. However, at least one of these sets were present at all of the data collection locations.

Kinematic Analysis

Kinematic analyses were performed using DIPS (v8) to form an understanding of the potential for various modes of rock slope failure. Modes of failure considered were planar sliding, wedge sliding, direct toppling, and flexural toppling. This analysis compared the orientations of each joint set with other joint sets, the cut slope or natural slope orientation (i.e. inclination angle and direction), and estimated friction angle. If the joint set orientations and/or intersections of joint set orientations fell within specified critical zones, the failure modes were then deemed kinematically possible. These analyses provided an indication of the types of failures that may be possible, but did not give a Factor-of-Safety (FS) for failures, nor did they take observed slope performance into consideration. The slope orientation used in the analyses was based on site topographic maps prepared from the 2020 lidar data collected by DGGS. The friction angle of joint surfaces was estimated based on published literature and our professional experience.

The kinematic analyses considered slope angles from 35 to 52 degrees at slope dip directions from 008 to 024 degrees, depending on the locations data was collected (see attached Figure C-1). A friction angle of 40 degrees was used for all analyses. With the estimated slope geometry and friction, the kinematic analyses suggested that direct toppling would be the most prevalent potential failure mode. Planar sliding, wedge sliding and flexural toppling were all shown to have a very low potential. Stereonets showing the kinematic analyses are provided in this Appendix C.

Note:
1. Hillshade basemap and 10-foot contours derived from 2020 lidar data, provided by DGGS, acquired Dec. 2020



Legend

🟥 Haines Borough Area of Concern (AOC)

2020 Slide Features

Primary Slide Limits

Secondary Slide (interpreted, approx.)

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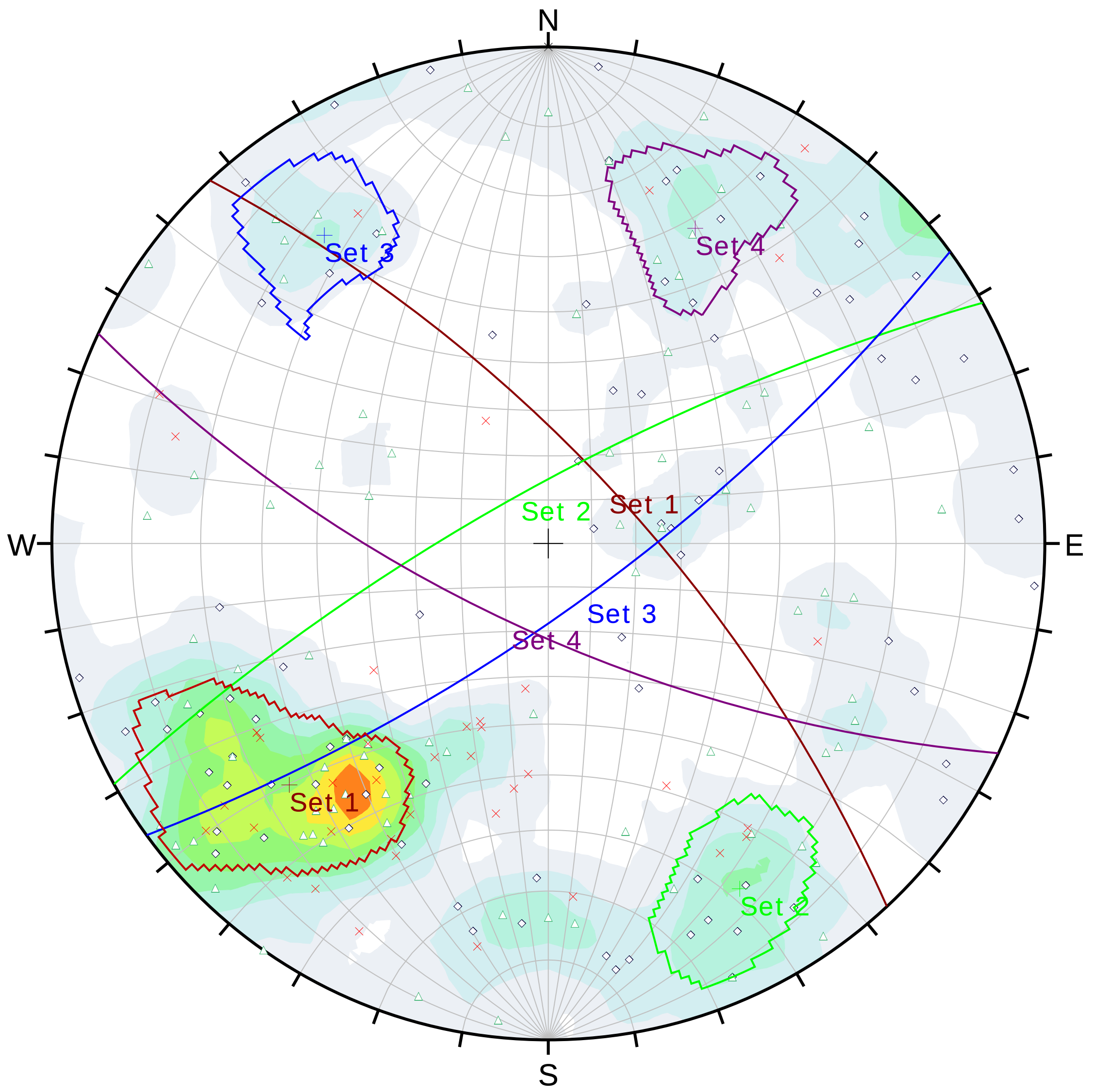
STRUCTURAL DATA OVERVIEW

WINTER RECONNAISSANCE - PRELIMINARY REPORT
BEACH ROAD LANDSLIDE, HAINES ALASKA

APR 2021
PROJ. 2900
FIG. C-1



Symbol	LOCATION	Quantity
◇	EAST	82
×	SLIDE	41
△	WEST	82

Color	Density Concentrations
⬜	0.00 - 0.80
⬜	0.80 - 1.60
⬜	1.60 - 2.40
🟩	2.40 - 3.20
🟩	3.20 - 4.00
🟩	4.00 - 4.80
🟩	4.80 - 5.60
🟨	5.60 - 6.40
🟧	6.40 - 7.20
🟥	7.20 - 8.00

Contour Data	Pole Vectors
Maximum Density	7.19%
Contour Distribution	Fisher
Counting Circle Size	1.0%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m	🟥	71	47	Set 1
2m	🟩	77	331	Set 2
3m	🟦	75	144	Set 3
4m	🟪	70	205	Set 4

Plot Mode	Pole Vectors
Vector Count	205 (205 Entries)
Hemisphere	Lower
Projection	Equal Angle

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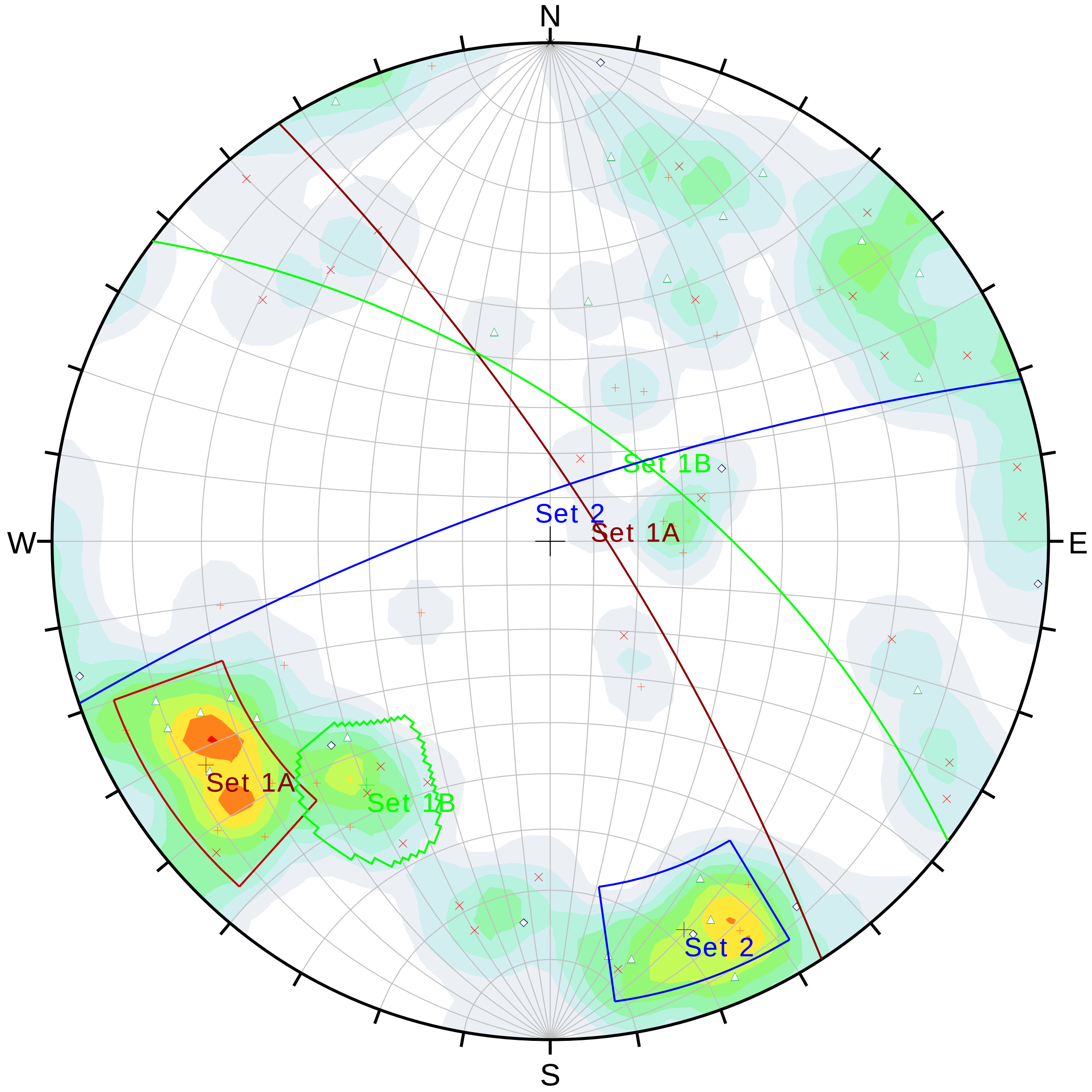
DIPS 8.009

Project	Haines Slide Emergency Response		
Analysis Description	All Data		
Drawn By	NK	*Company*	LT
Date	2/12/2021, 9:01:54 AM	*File Name*	2900-PreliminaryData.dips8



Symbol	LOCATION	Quantity
◇	BEACH	8
×	EAST UPPER BLOCKS - CENTER	27
△	EAST UPPER BLOCKS - WEST	24
+	LOW	23

Color	Density Concentrations
⬜	0.00 - 0.80
⬜	0.80 - 1.60
🟦	1.60 - 2.40
🟦	2.40 - 3.20
🟩	3.20 - 4.00
🟩	4.00 - 4.80
🟩	4.80 - 5.60
🟨	5.60 - 6.40
🟧	6.40 - 7.20
🟥	7.20 - 8.00
Contour Data	Pole Vectors
Maximum Density	7.30%
Contour Distribution	Fisher
Counting Circle Size	1.0%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m	🟥	79	57	Set 1A
2m	🟩	63	37	Set 1B
3m	🟦	79	341	Set 2

Plot Mode	Pole Vectors
Vector Count	82 (82 Entries)
Hemisphere	Lower
Projection	Equal Angle

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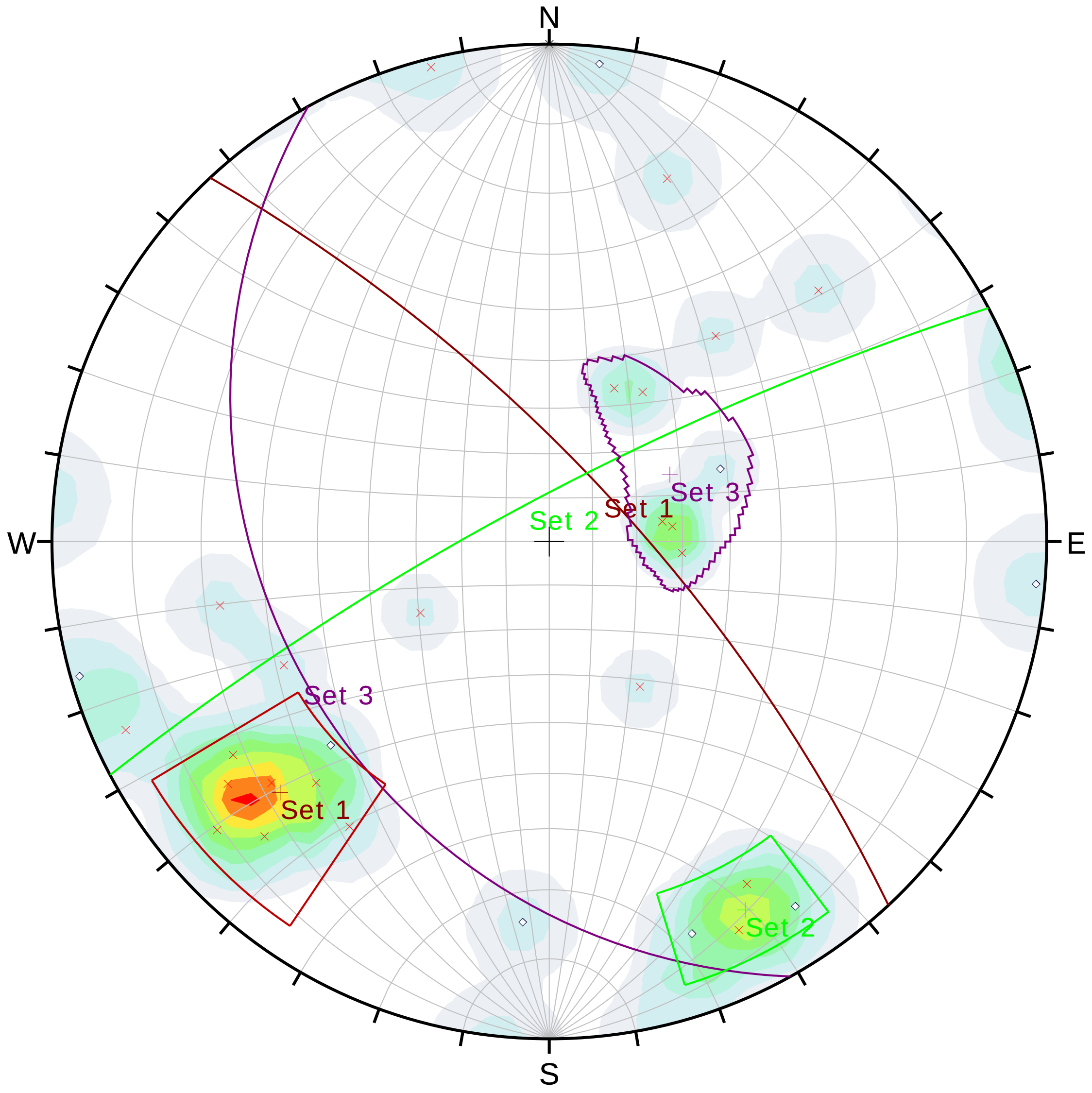
DIPS 8.009

Project	Haines Slide Emergency Response
Analysis Description	East

Drawn By	NK	*Company*	LT
Date	2/27/2021, 3:16:08 PM	*File Name*	2900-EAST.dips8



Symbol	LOCATION	Quantity
◇	BEACH	8
×	LOW	23

Color	Density Concentrations
⬜	0.00 - 1.50
⬜	1.50 - 3.00
🟦	3.00 - 4.50
🟦	4.50 - 6.00
🟩	6.00 - 7.50
🟩	7.50 - 9.00
🟩	9.00 - 10.50
🟨	10.50 - 12.00
🟧	12.00 - 13.50
🟥	13.50 - 15.00

Contour Data	Pole Vectors
Maximum Density	14.07%
Contour Distribution	Fisher
Counting Circle Size	1.0%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m	🟥	73	47	Set 1
2m	🟩	80	332	Set 2
3m	🟪	31	241	Set 3

Plot Mode	Pole Vectors
Vector Count	31 (31 Entries)
Hemisphere	Lower
Projection	Equal Angle

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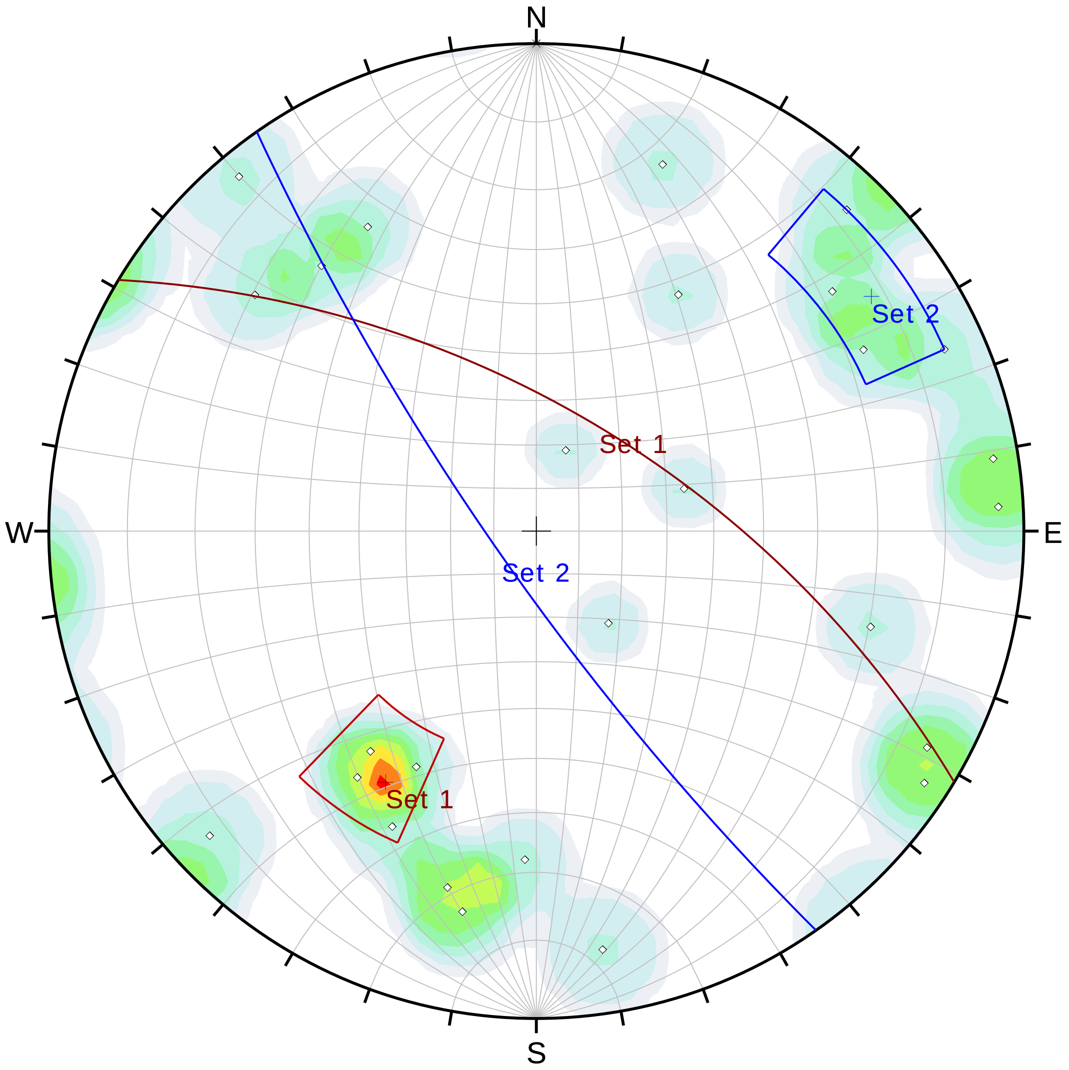
DIPS 8.009

Project	Haines Slide Emergency Response
Analysis Description	East - Low
Drawn By	NK
Company	LT
Date	2/27/2021, 3:16:08 PM
File Name	East_Low.dips8



Symbol	Feature
◇	Pole Vectors

Color	Density Concentrations
⬜	0.00 - 1.20
⬜	1.20 - 2.40
🟦	2.40 - 3.60
🟩	3.60 - 4.80
🟩	4.80 - 6.00
🟩	6.00 - 7.20
🟨	7.20 - 8.40
🟨	8.40 - 9.60
🟧	9.60 - 10.80
🟥	10.80 - 12.00

Contour Data	Pole Vectors
Maximum Density	11.38%
Contour Distribution	Fisher
Counting Circle Size	1.0%

	Color	Dip	Dip Direction	Label
		Mean Set Planes		
1m	🟥	62	31	Set 1
2m	🟦	80	235	Set 2

Plot Mode	Pole Vectors
Vector Count	27 (27 Entries)
Hemisphere	Lower
Projection	Equal Angle

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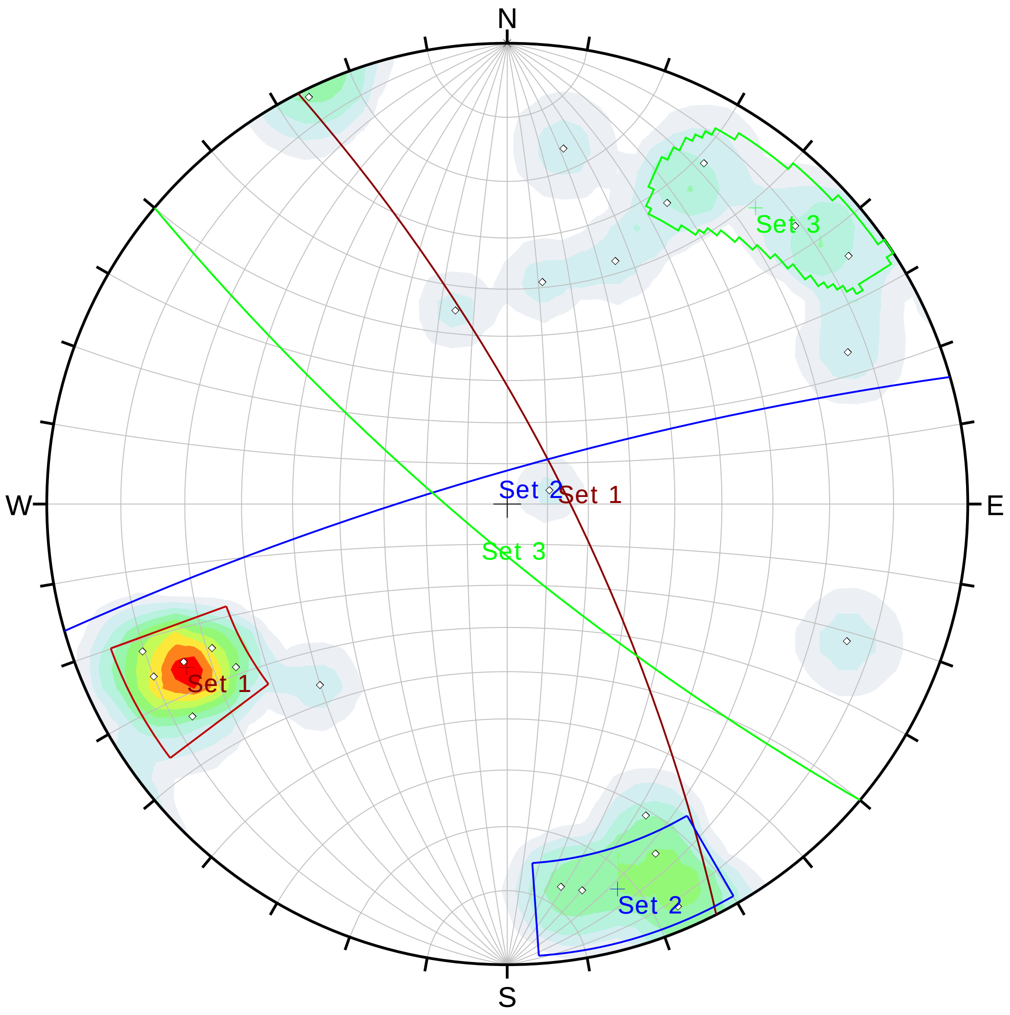
DIPS 8.010

Project	Haines Slide Emergency Response		
Analysis Description	East - Upper East Block		
Drawn By	NK	*Company*	LT
Date	2/12/2021, 9:01:54 AM	*File Name*	East_UpperBlock_East.dips8



Symbol	Feature
◇	Pole Vectors

Color	Density Concentrations
⬜	0.00 - 1.90
⬜	1.90 - 3.80
🟦	3.80 - 5.70
🟦	5.70 - 7.60
🟩	7.60 - 9.50
🟩	9.50 - 11.40
🟩	11.40 - 13.30
🟨	13.30 - 15.20
🟧	15.20 - 17.10
🟥	17.10 - 19.00

Contour Data	Pole Vectors
Maximum Density	18.79%
Contour Distribution	Fisher
Counting Circle Size	1.0%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m	🟥	76	63	Set 1
2m	🟦	82	344	Set 2
3m	🟩	80	220	Set 3

Plot Mode	Pole Vectors
Vector Count	24 (24 Entries)
Hemisphere	Lower
Projection	Equal Angle

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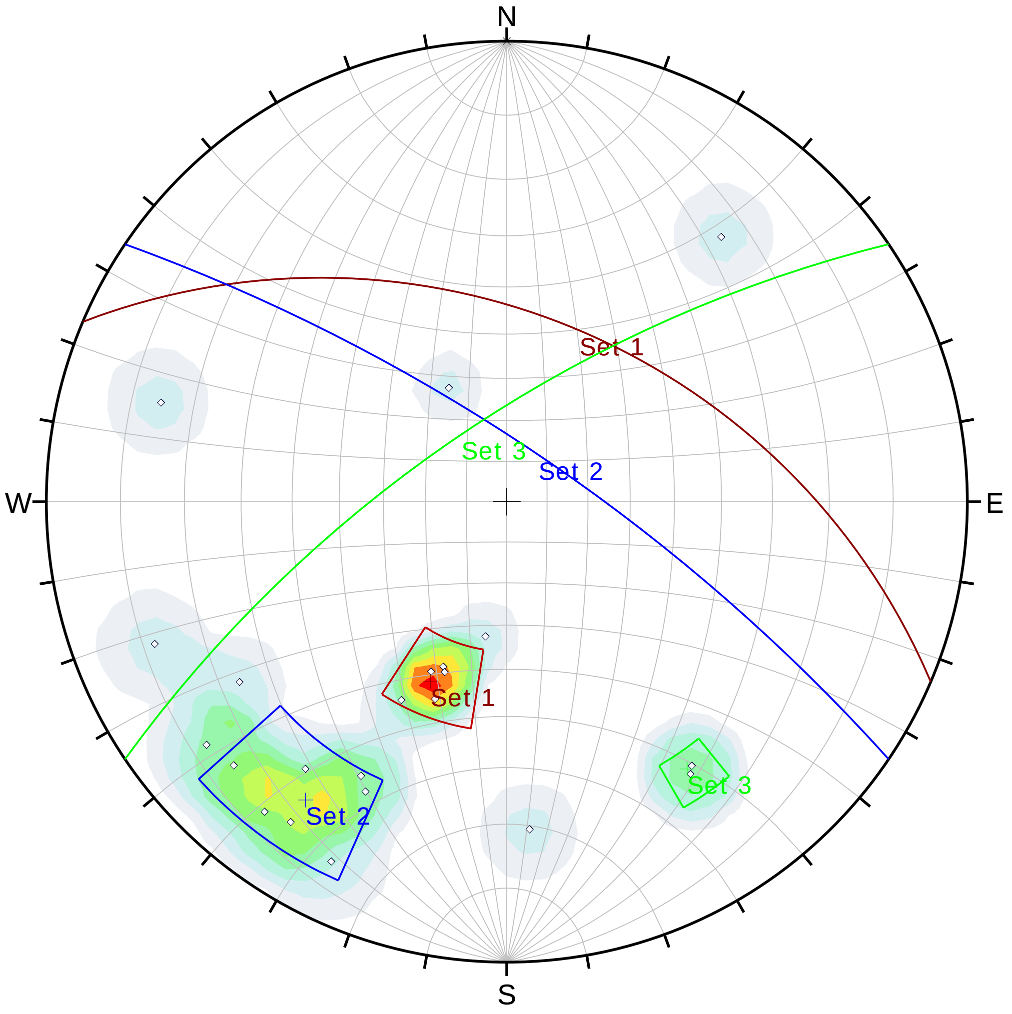
DIPS 8.009

Project	Haines Slide Emergency Response
Analysis Description	East - Upper West Block

Drawn By	NK	*Company*	LT
Date	2/12/2021, 9:01:54 AM	*File Name*	East_UpperBlock_West.dips8



Symbol	LOCATION	Quantity
◇	HEADSCARP	22

Color	Density Concentrations
	0.00 - 2.10
⬜	2.10 - 4.20
⬜	4.20 - 6.30
🟦	6.30 - 8.40
🟩	8.40 - 10.50
🟩	10.50 - 12.60
🟩	12.60 - 14.70
🟨	14.70 - 16.80
🟧	16.80 - 18.90
🟥	18.90 - 21.00

Contour Data	Pole Vectors
Maximum Density	20.26%
Contour Distribution	Fisher
Counting Circle Size	1.0%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m	🟥	46	23	Set 1
2m	🟦	76	34	Set 2
3m	🟩	70	326	Set 3

Plot Mode	Pole Vectors
Vector Count	22 (22 Entries)
Hemisphere	Lower
Projection	Equal Angle

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DIPS 8.009

Project Haines Slide Emergency Response

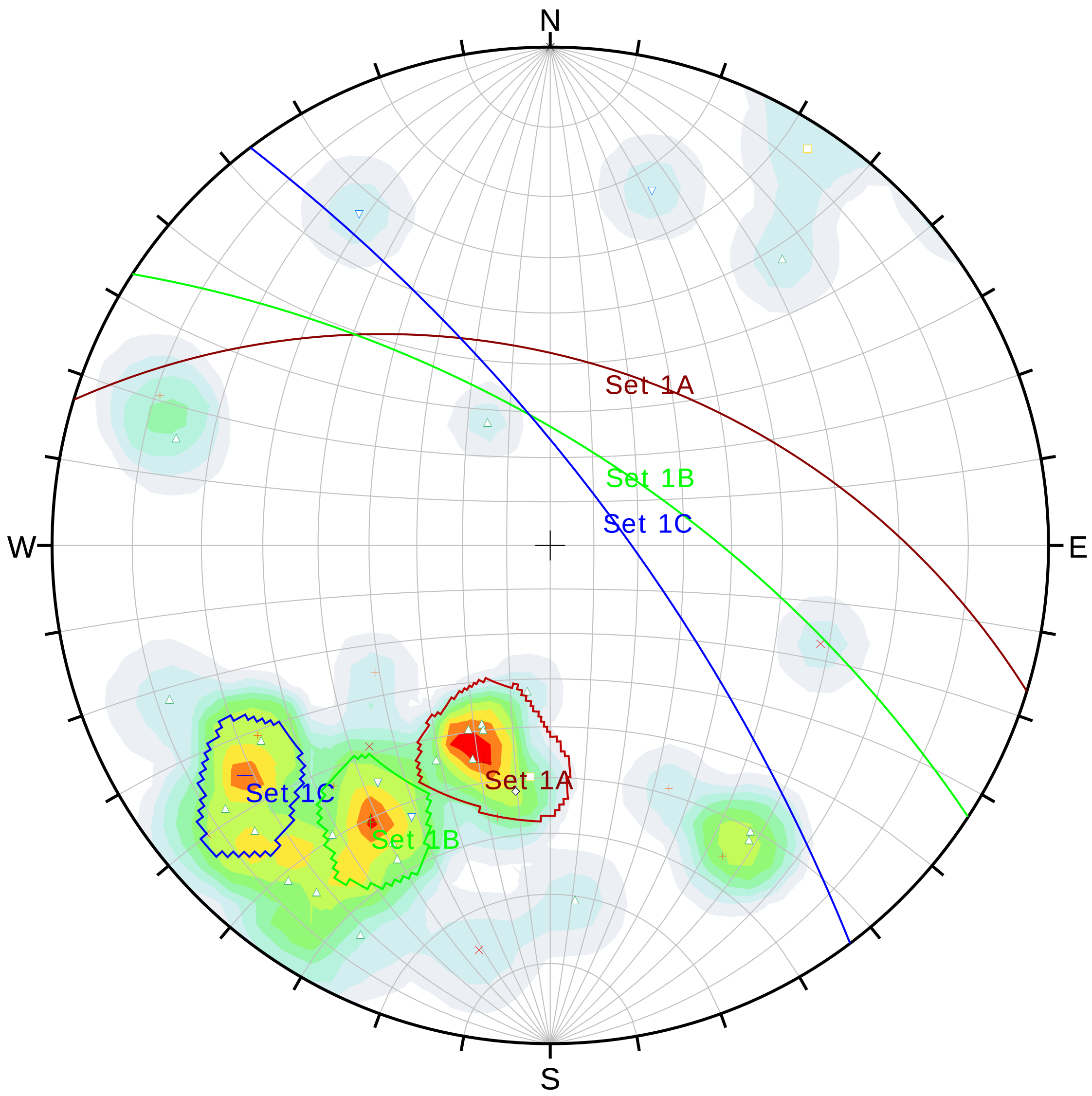
Analysis Description Headscarp

Drawn By NK

Company LT

Date 2/12/2021, 9:01:54 AM

File Name Headscarp.dips8



Symbol	LOCATION	Quantity
◇	Compositional fracture	1
×	EAST LATERAL SCARP	4
△	HEADSCARP	22
+	LOW	8
▽	MIDDLE	4
□	Subordante fracture	2

Color	Density Concentrations
⬜	0.00 - 1.10
⬜	1.10 - 2.20
🟦	2.20 - 3.30
🟦	3.30 - 4.40
🟩	4.40 - 5.50
🟩	5.50 - 6.60
🟩	6.60 - 7.70
🟨	7.70 - 8.80
🟧	8.80 - 9.90
🟥	9.90 - 11.00

Contour Data	Pole Vectors
Maximum Density	11.00%
Contour Distribution	Fisher
Counting Circle Size	1.0%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m	🟥	49	17	Set 1A
2m	🟩	67	33	Set 1B
3m	🟦	75	53	Set 1C

Plot Mode	Pole Vectors
Vector Count	41 (41 Entries)
Hemisphere	Lower
Projection	Equal Angle

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Project

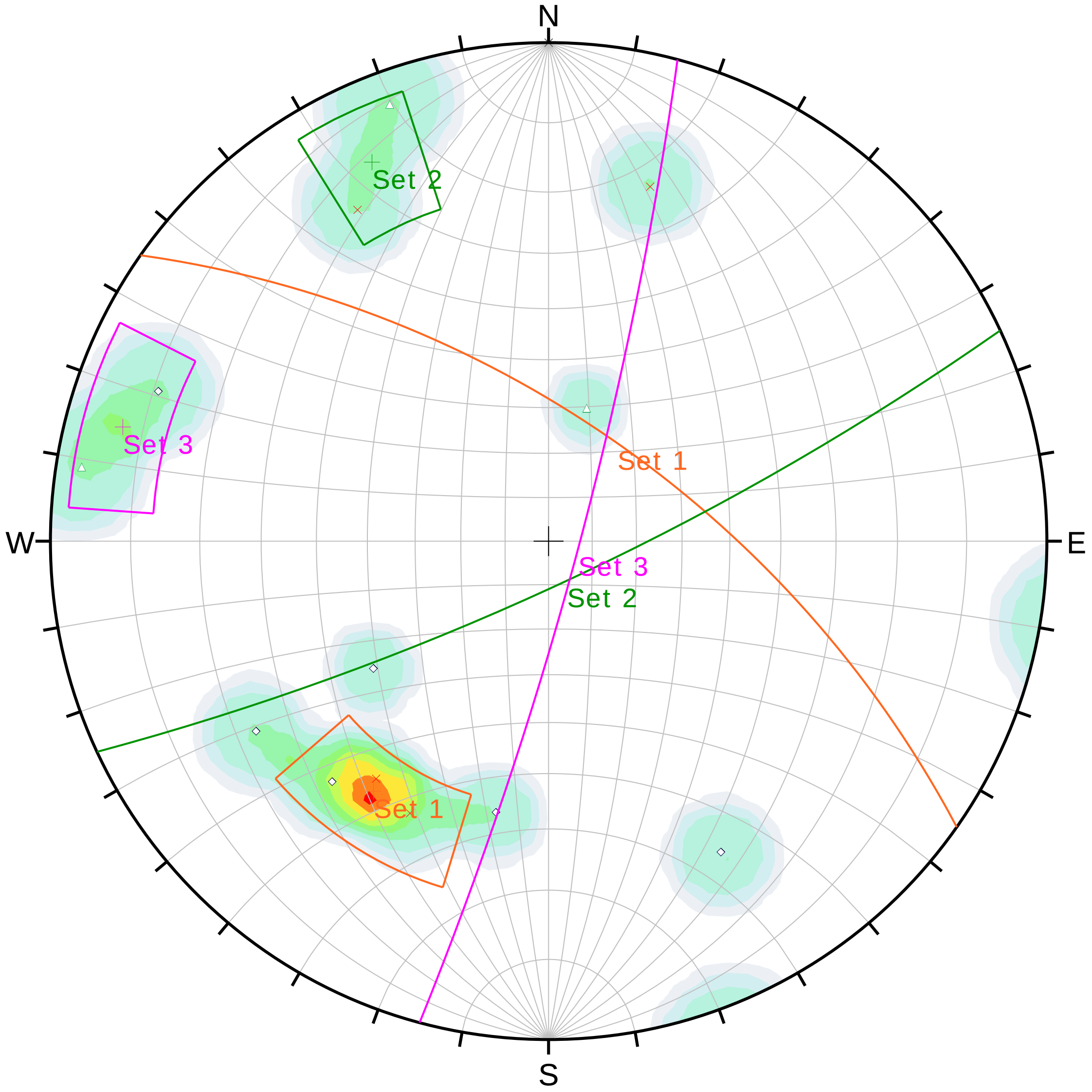
Analysis Description

Drawn By

Company

Date 2/12/2021, 9:01:54 AM

File Name 2900-SLIDE.dips8



Symbol	LOCATION	Quantity
◇	LOW	6
×	MIDDLE	4
△	MIDDLE - LAT SCARP	3

Color	Density Concentrations
⬜	0.00 - 1.90
⬜	1.90 - 3.80
🟦	3.80 - 5.70
🟦	5.70 - 7.60
🟩	7.60 - 9.50
🟩	9.50 - 11.40
🟩	11.40 - 13.30
🟨	13.30 - 15.20
🟧	15.20 - 17.10
🟥	17.10 - 19.00
Contour Data	Pole Vectors
Maximum Density	18.05%
Contour Distribution	Fisher
Counting Circle Size	1.0%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m	🟧	63	35	Set 1
2m	🟩	80	155	Set 2
3m	🟪	83	105	Set 3

Plot Mode	Pole Vectors
Vector Count	13 (13 Entries)
Hemisphere	Lower
Projection	Equal Angle

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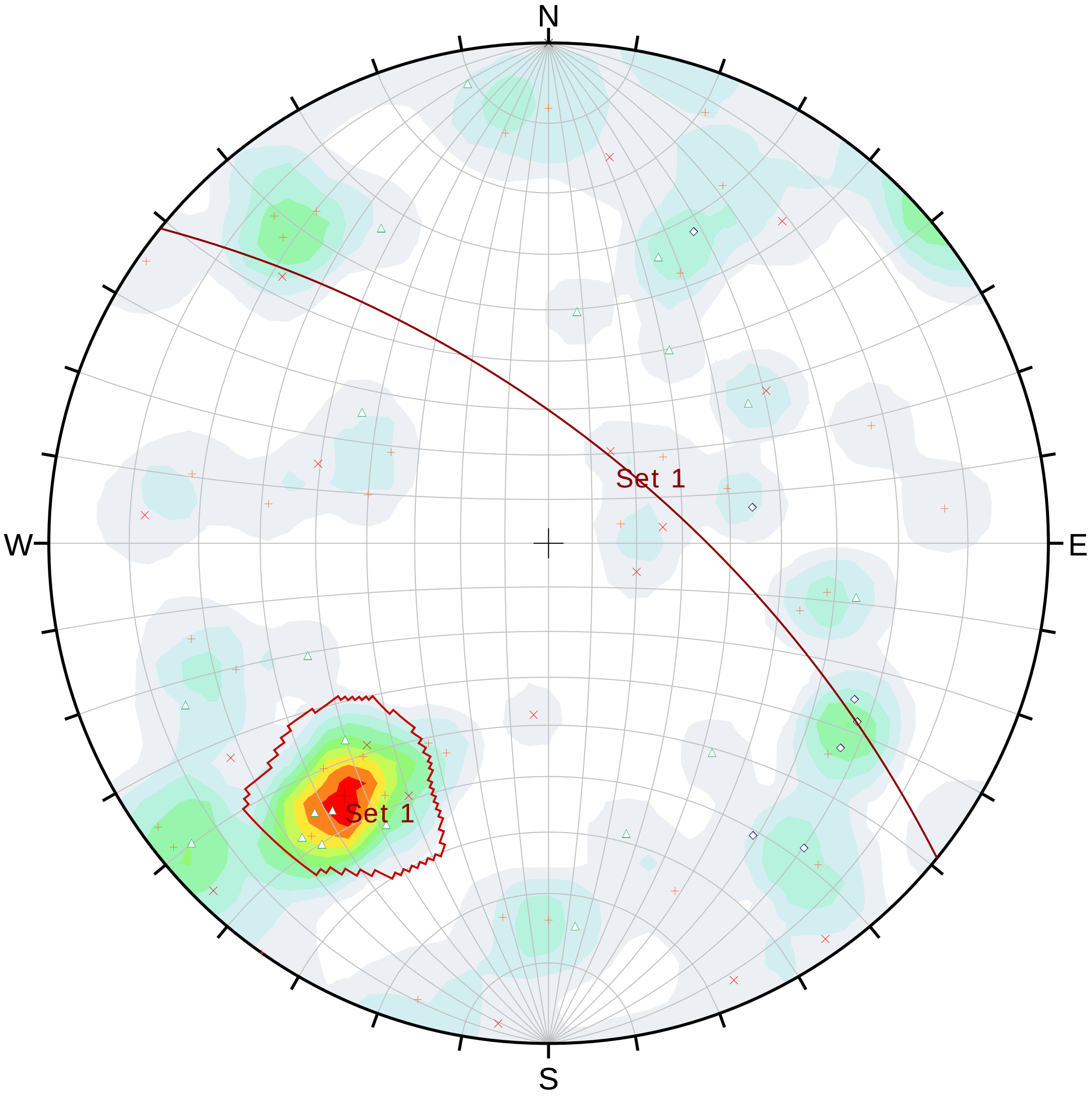
Project	Haines Slide Emergency Response
Analysis Description	Slide - Middle and Low
Drawn By	NK
Company	LT
Date	2/12/2021, 9:01:54 AM
File Name	Slide_MidAndLow.dips8



Symbol	LOCATION	Quantity
◇	BEACH	7
×	HIGH	18
△	LOW	20
+	MIDDLE	37

Color	Density Concentrations
⬜	0.00 - 0.90
⬜	0.90 - 1.80
🟦	1.80 - 2.70
🟦	2.70 - 3.60
🟩	3.60 - 4.50
🟩	4.50 - 5.40
🟩	5.40 - 6.30
🟨	6.30 - 7.20
🟧	7.20 - 8.10
🟥	8.10 - 9.00

Contour Data	Pole Vectors
Maximum Density	8.89%
Contour Distribution	Fisher
Counting Circle Size	1.0%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m	🟥	66	39	Set 1

Plot Mode	Pole Vectors
Vector Count	82 (82 Entries)
Hemisphere	Lower
Projection	Equal Angle

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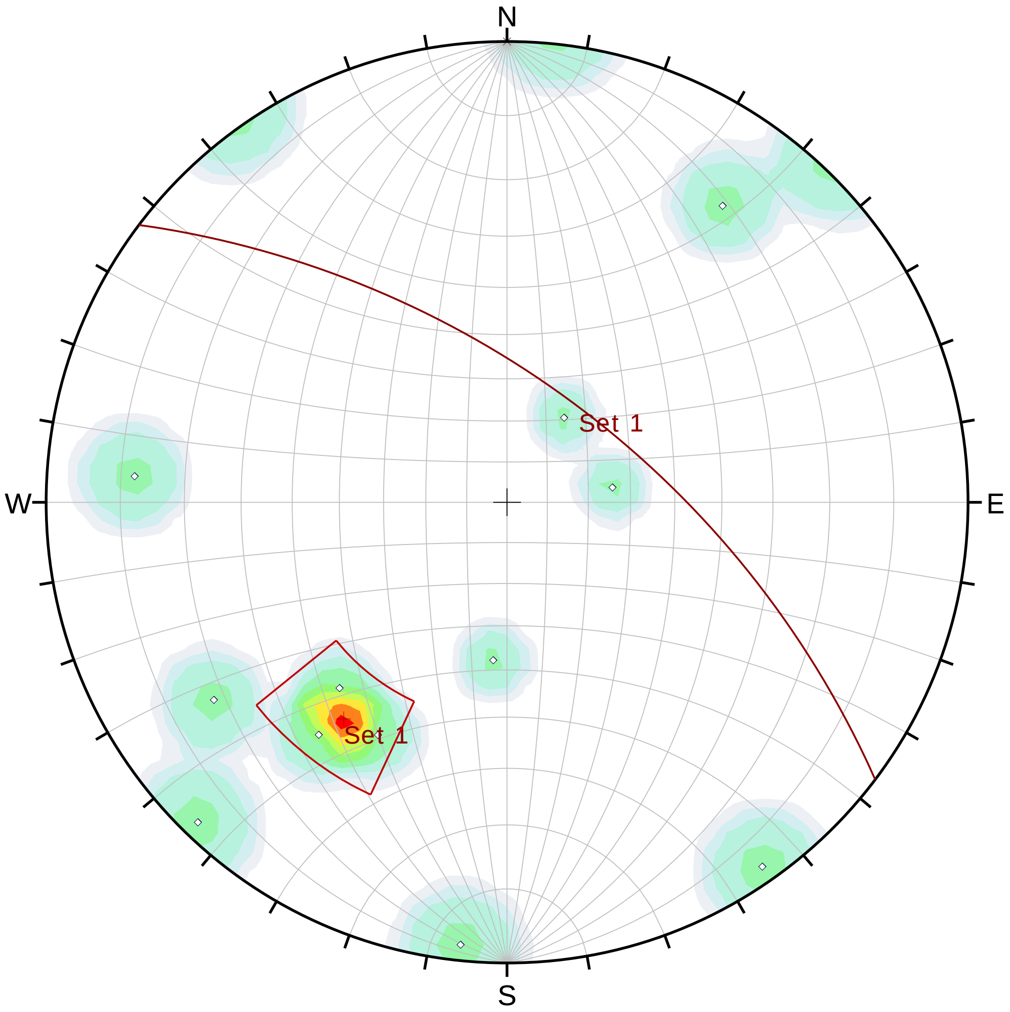
Project
Haines Slide Emergency Response

Analysis Description
West

Drawn By NK
Company LT

Date 2/27/2021, 3:16:08 PM
File Name 2900-WEST.dips8



Symbol	LOCATION	Quantity
◇	HIGH	12

Color	Density Concentrations
⬜	0.00 - 2.00
⬜	2.00 - 4.00
🟦	4.00 - 6.00
🟦	6.00 - 8.00
🟩	8.00 - 10.00
🟩	10.00 - 12.00
🟩	12.00 - 14.00
🟨	14.00 - 16.00
🟧	16.00 - 18.00
🟥	18.00 - 20.00

Contour Data	Pole Vectors
Maximum Density	19.41%
Contour Distribution	Fisher
Counting Circle Size	1.0%

	Color	Dip	Dip Direction	Label
		Mean Set Planes		
1m	🟥	61	37	Set 1

Plot Mode	Pole Vectors
Vector Count	12 (12 Entries)
Hemisphere	Lower
Projection	Equal Angle

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Project
Haines Slide Emergency Response

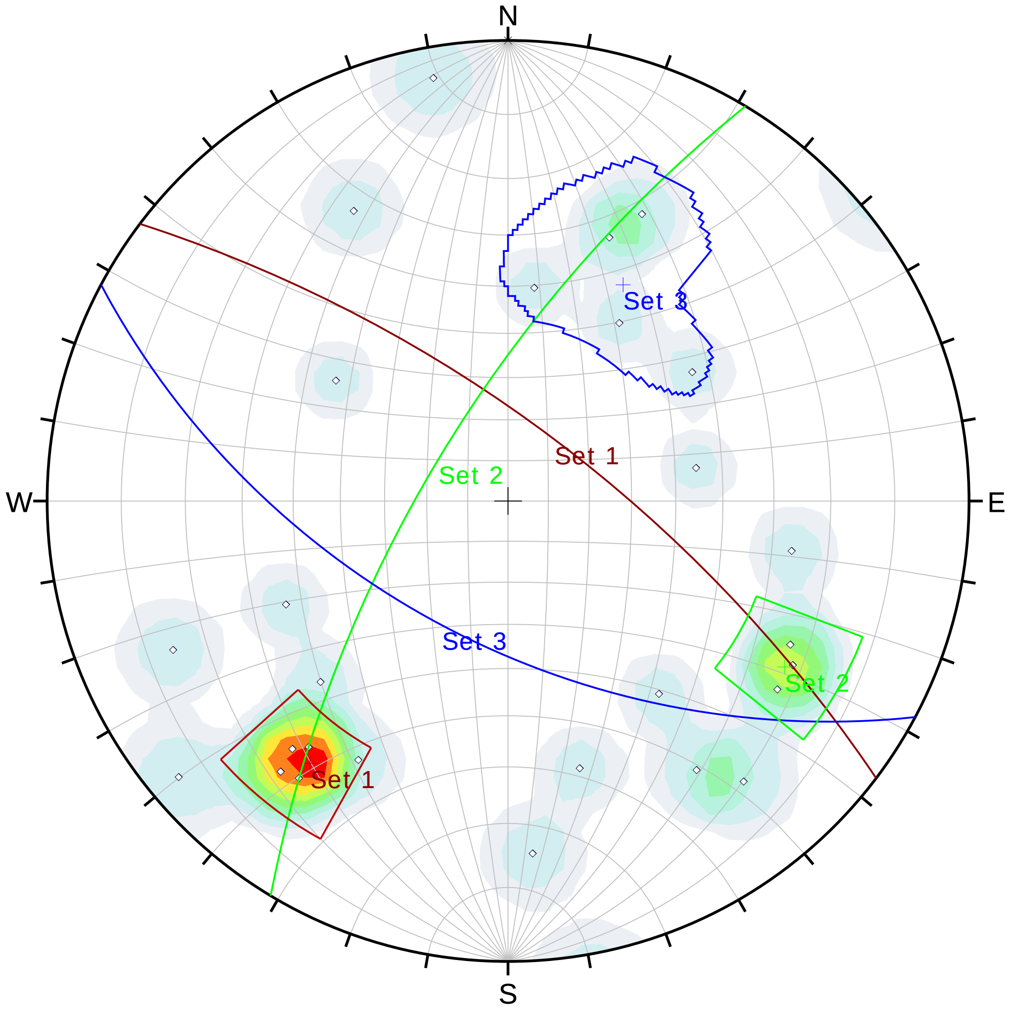
Analysis Description
West - High

Drawn By
NK

Company

Date
2/27/2021, 3:16:08 PM

File Name
West_High.dips8



Symbol	LOCATION	Quantity
◇	BEACH	27

Color	Density Concentrations
⬜	0.00 - 1.60
⬜	1.60 - 3.20
⬜	3.20 - 4.80
🟩	4.80 - 6.40
🟩	6.40 - 8.00
🟩	8.00 - 9.60
🟩	9.60 - 11.20
🟨	11.20 - 12.80
🟧	12.80 - 14.40
🟥	14.40 - 16.00
Contour Data	Pole Vectors
Maximum Density	15.41%
Contour Distribution	Fisher
Counting Circle Size	1.0%

	Color	Dip	Dip Direction	Label
		Mean Set Planes		
1m	🟥	71	37	Set 1
2m	🟩	70	301	Set 2
3m	🟦	56	208	Set 3

Plot Mode	Pole Vectors
Vector Count	27 (27 Entries)
Hemisphere	Lower
Projection	Equal Angle

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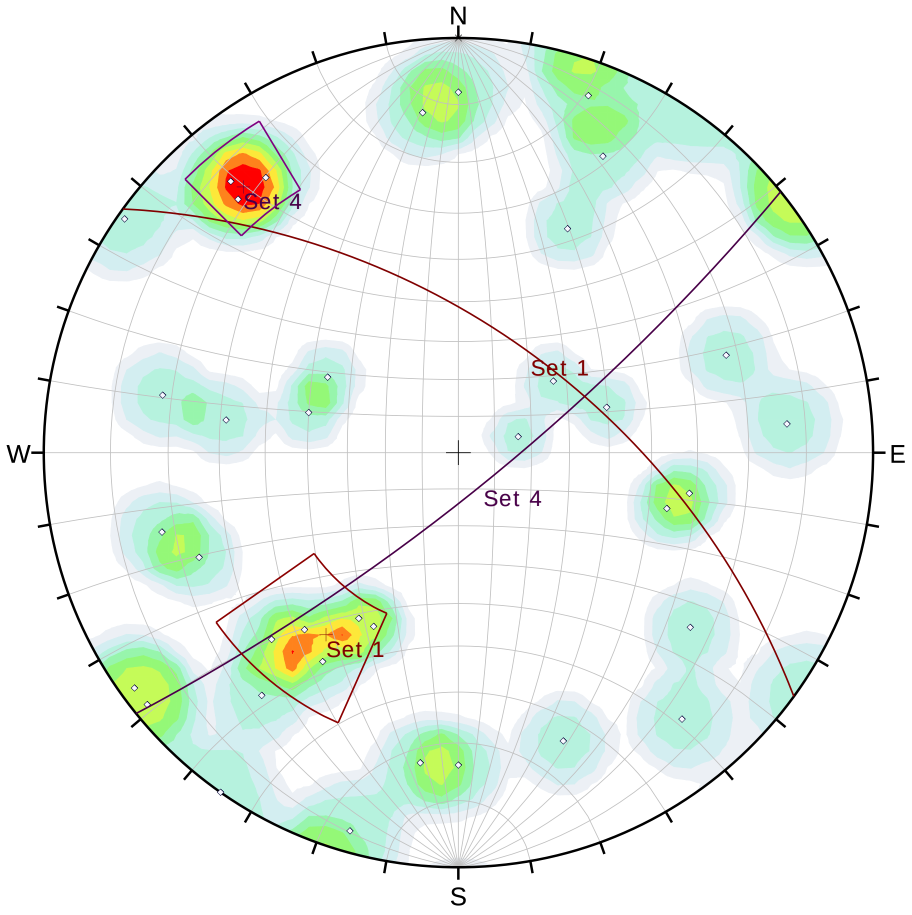
Project	Haines Slide Emergency Response		
Analysis Description	West - Low		
Drawn By	NK	*Company*	LT
Date	2/27/2021, 3:16:08 PM	*File Name*	West_Low.dips8



Symbol	LOCATION	Quantity
◇	MIDDLE	37

Color	Density Concentrations
⬜	0.00 - 0.80
⬜	0.80 - 1.60
🟦	1.60 - 2.40
🟩	2.40 - 3.20
🟩	3.20 - 4.00
🟩	4.00 - 4.80
🟩	4.80 - 5.60
🟨	5.60 - 6.40
🟧	6.40 - 7.20
🟥	7.20 - 8.00

Contour Data	Pole Vectors
Maximum Density	7.82%
Contour Distribution	Fisher
Counting Circle Size	1.0%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m	🟪	79	141	Set 4
2m	🟥	57	36	Set 1

Plot Mode	Pole Vectors
Vector Count	37 (37 Entries)
Hemisphere	Lower
Projection	Equal Angle

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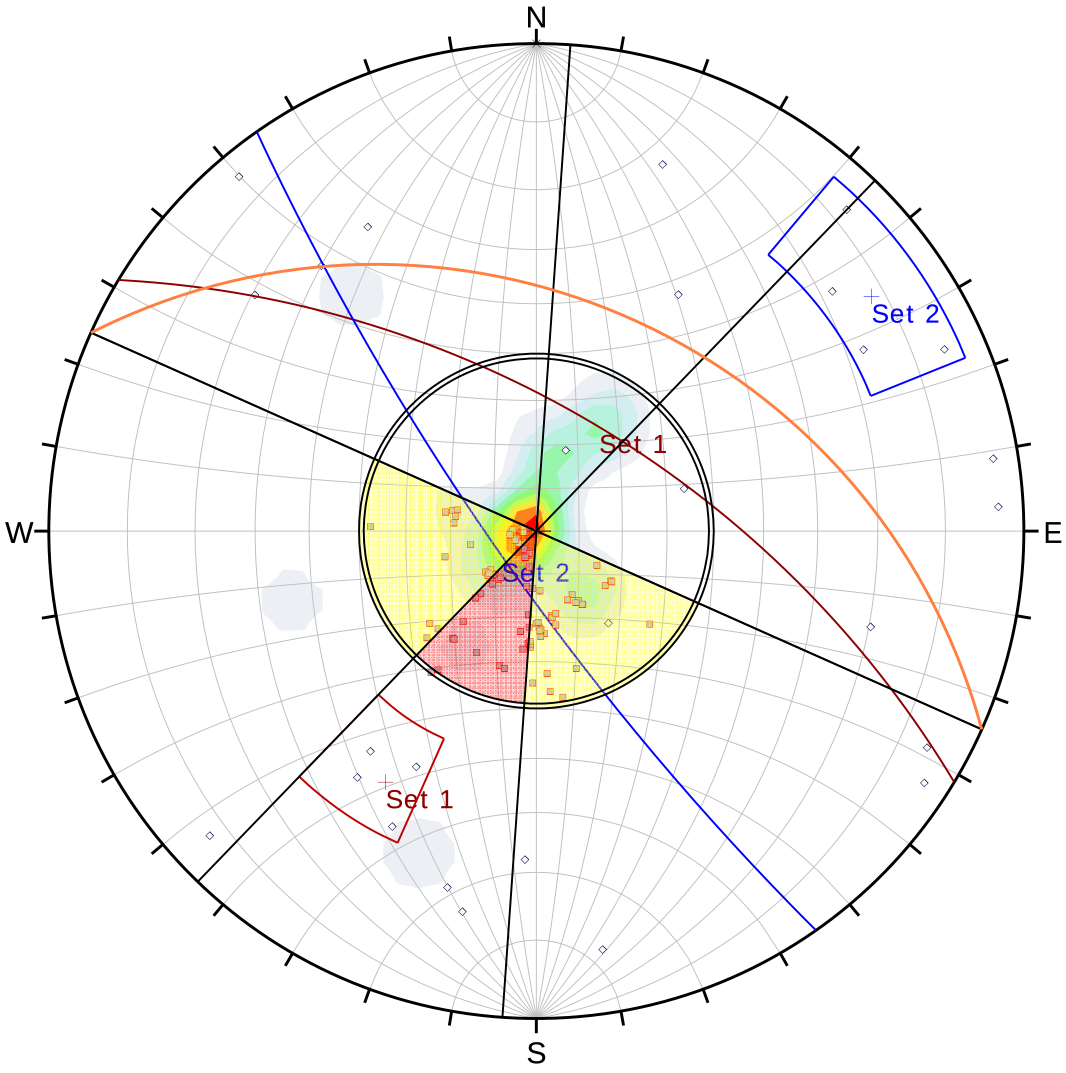
Project	Haines Slide Emergency Response		
Analysis Description	West - Middle		
Drawn By	NK	*Company*	LT
Date	2/27/2021, 3:16:08 PM	*File Name*	West_Middle.dips8



Symbol	LOCATION	Quantity
◇	EAST UPPER BLOCKS - EAST	27
Symbol	**Feature**	
▫	Critical Intersection	

Color	Density Concentrations
⬜	0.00 - 3.00
⬜	3.00 - 6.00
🟦	6.00 - 9.00
🟩	9.00 - 12.00
🟩	12.00 - 15.00
🟩	15.00 - 18.00
🟩	18.00 - 21.00
🟨	21.00 - 24.00
🟧	24.00 - 27.00
🟥	27.00 - 30.00

Contour Data	Pole Vectors
Maximum Density	29.39%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Direct Toppling
Slope Dip	39
Slope Dip Direction	24
Friction Angle	40°
Lateral Limits	20°

	Critical	Total	%
Direct Toppling (Intersection)	28	351	7.98%
Oblique Toppling (Intersection)	60	351	17.09%
Base Plane (All)	1	27	3.70%

	Color	Dip	Dip Direction	Label
		Mean Set Planes		
1m	🟥	62	31	Set 1
2m	🟦	80	235	Set 2

Plot Mode	Pole Vectors
Vector Count	27 (27 Entries)
Intersection Mode	Grid Data Planes
Intersections Count	351
Hemisphere	Lower
Projection	Equal Angle

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Project
Haines Slide Emergency Response

Analysis Description
East - Upper East Block - Direct Toppling Analysis

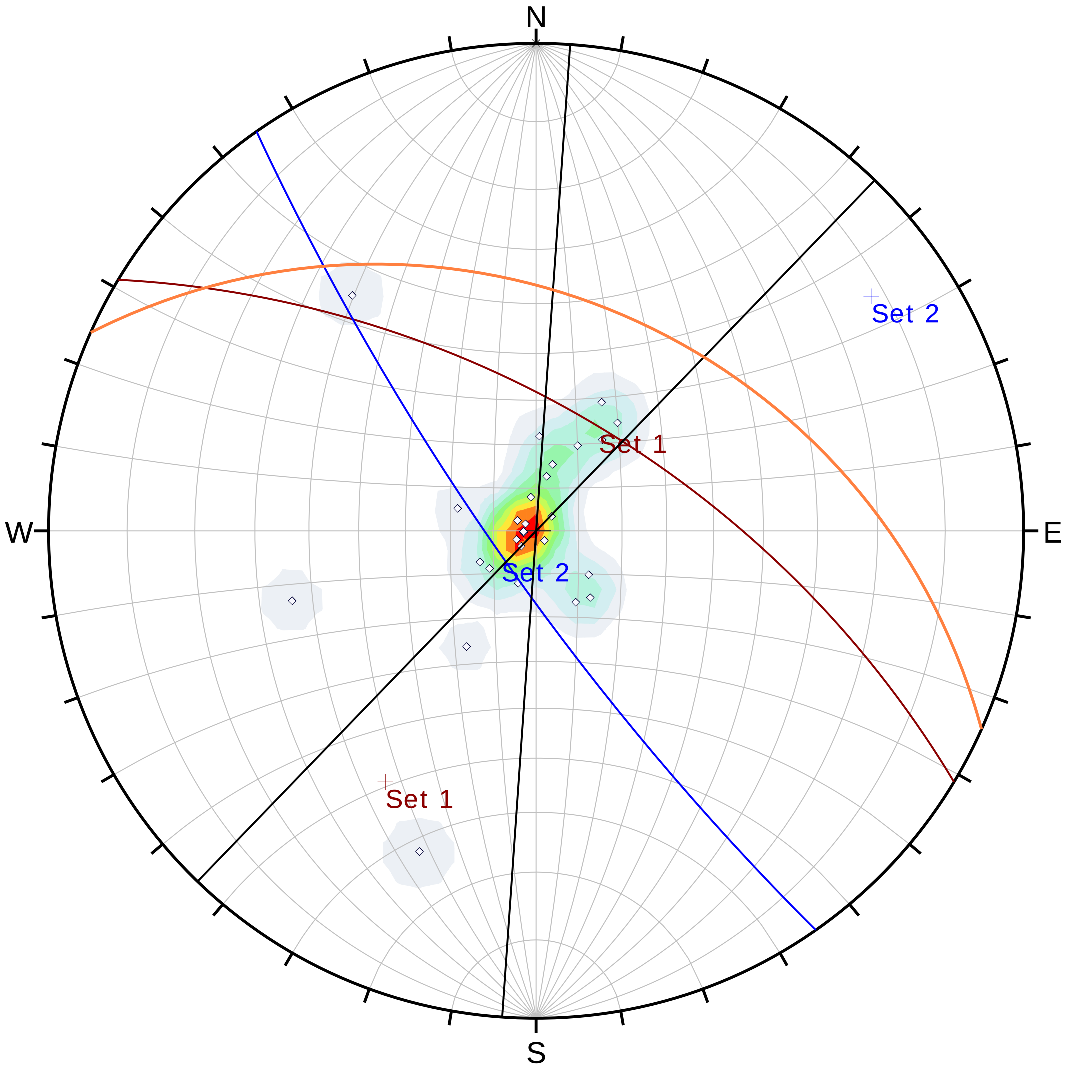
Drawn By SWD

Company LT

Date 3/16/2021

File Name East_UpperBlock_East_DirectToppling.dips8

DIPS 8.010



Symbol	LOCATION	Quantity
◇	EAST UPPER BLOCKS - EAST	27

Color	Density Concentrations
⬜	0.00 - 3.00
⬜	3.00 - 6.00
🟦	6.00 - 9.00
🟦	9.00 - 12.00
🟩	12.00 - 15.00
🟩	15.00 - 18.00
🟨	18.00 - 21.00
🟨	21.00 - 24.00
🟧	24.00 - 27.00
🟥	27.00 - 30.00
Contour Data	Dip Vectors
Maximum Density	29.39%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Flexural Toppling		
Slope Dip	39		
Slope Dip Direction	24		
Friction Angle	40°		
Lateral Limits	20°		
	Critical	Total	%
Flexural Toppling (All)	0	27	0.00%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m	🟥	62	31	Set 1
2m	🟦	80	235	Set 2

Plot Mode	Dip Vectors
Vector Count	27 (27 Entries)
Hemisphere	Lower
Projection	Equal Angle

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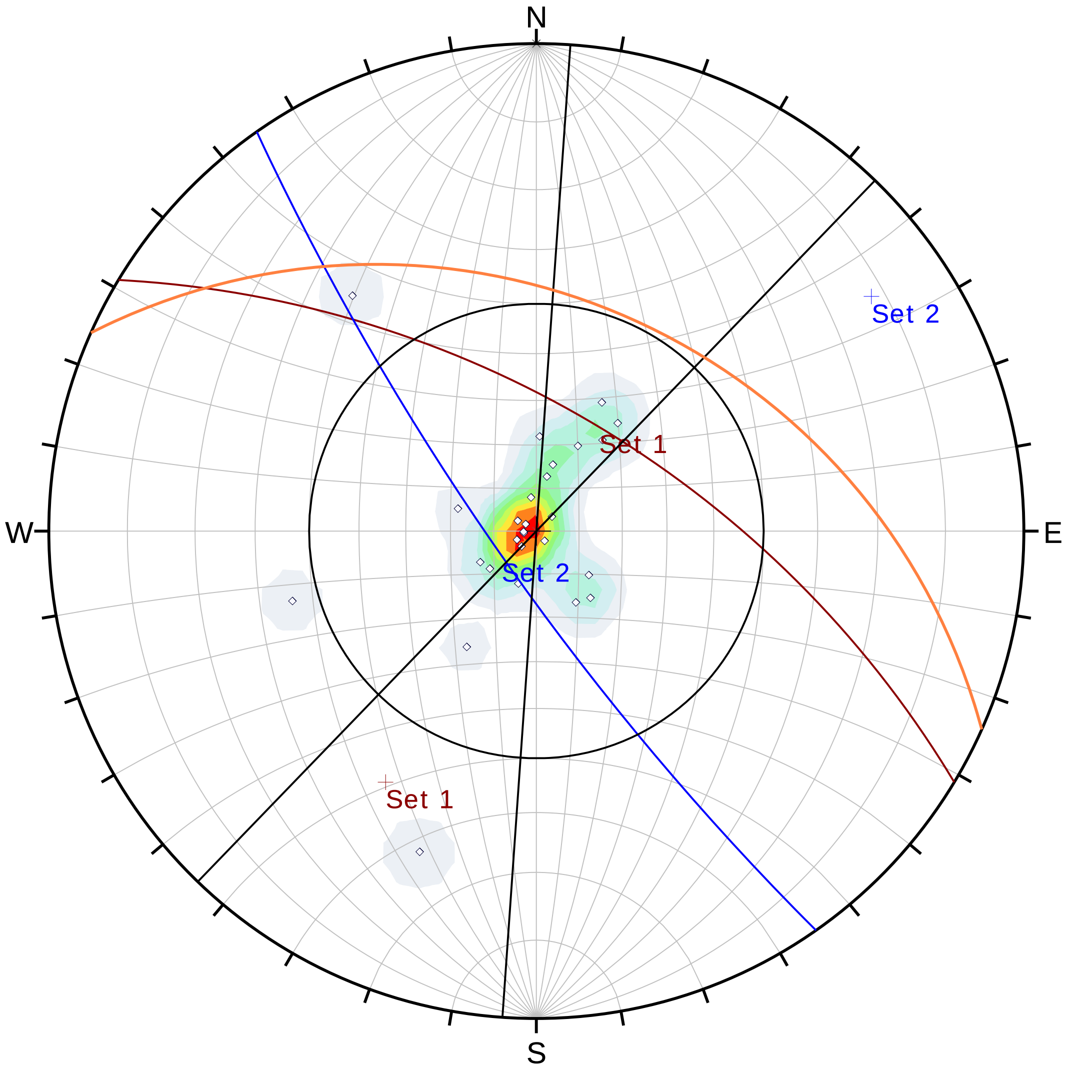
Analysis Description East - Upper East Block - Flexural Toppling Analysis

Drawn By SWD

Company LT

Date 3/16/2021

File Name East_UpperBlock_East_FlexuralToppling.dips8



Symbol	LOCATION	Quantity
◇	EAST UPPER BLOCKS - EAST	27

Color	Density Concentrations
⬜	0.00 - 3.00
⬜	3.00 - 6.00
🟦	6.00 - 9.00
🟩	9.00 - 12.00
🟩	12.00 - 15.00
🟩	15.00 - 18.00
🟨	18.00 - 21.00
🟨	21.00 - 24.00
🟧	24.00 - 27.00
🟥	27.00 - 30.00

Contour Data	Dip Vectors
Maximum Density	29.39%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Planar Sliding
Slope Dip	39
Slope Dip Direction	24
Friction Angle	40°
Lateral Limits	20°

	Critical	Total	%
Planar Sliding (All)	0	27	0.00%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m	🟥	62	31	Set 1
2m	🟦	80	235	Set 2

Plot Mode	Dip Vectors
Vector Count	27 (27 Entries)
Hemisphere	Lower
Projection	Equal Angle

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Project
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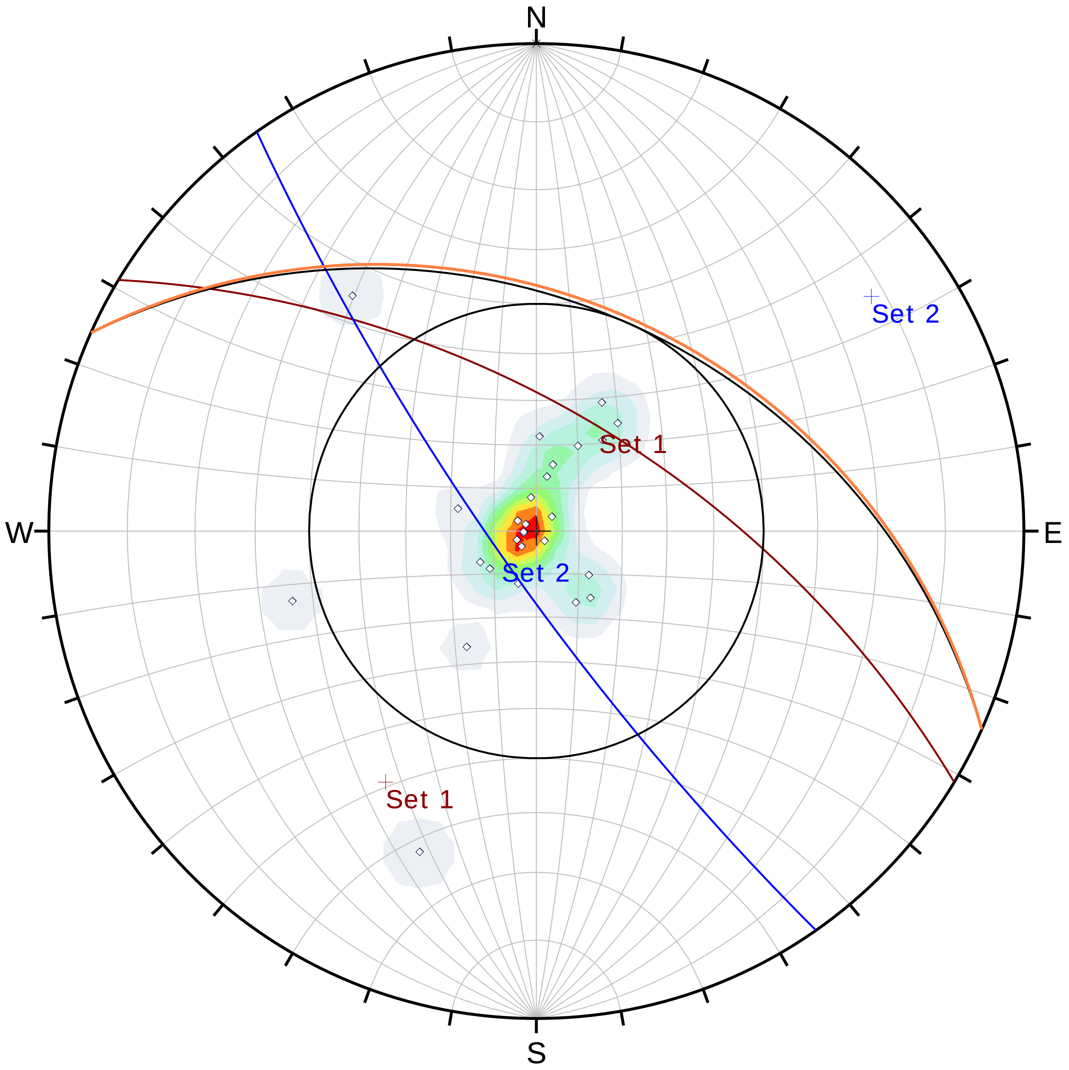
Analysis Description
East - Upper East Block - Planar Analysis

Drawn By BAG

Company LT

Date 3/16/2021

File Name East_UpperBlock_East_planar.dips8



Symbol	LOCATION	Quantity
◇	EAST UPPER BLOCKS - EAST	27
Symbol	**Feature**	
▫	Critical Intersection	

Color	Density Concentrations
⬜	0.00 - 3.00
⬜	3.00 - 6.00
🟦	6.00 - 9.00
🟦	9.00 - 12.00
🟩	12.00 - 15.00
🟩	15.00 - 18.00
🟩	18.00 - 21.00
🟨	21.00 - 24.00
🟧	24.00 - 27.00
🟥	27.00 - 30.00
Contour Data	Dip Vectors
Maximum Density	29.39%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Wedge Sliding		
Slope Dip	39		
Slope Dip Direction	24		
Friction Angle	40°		
	Critical	**Total**	**%**
Wedge Sliding	0	351	0.00%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m	🟥	62	31	Set 1
2m	🟦	80	235	Set 2

Plot Mode	Dip Vectors
Vector Count	27 (27 Entries)
Intersection Mode	Grid Data Planes
Intersections Count	351
Hemisphere	Lower
Projection	Equal Angle

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Project
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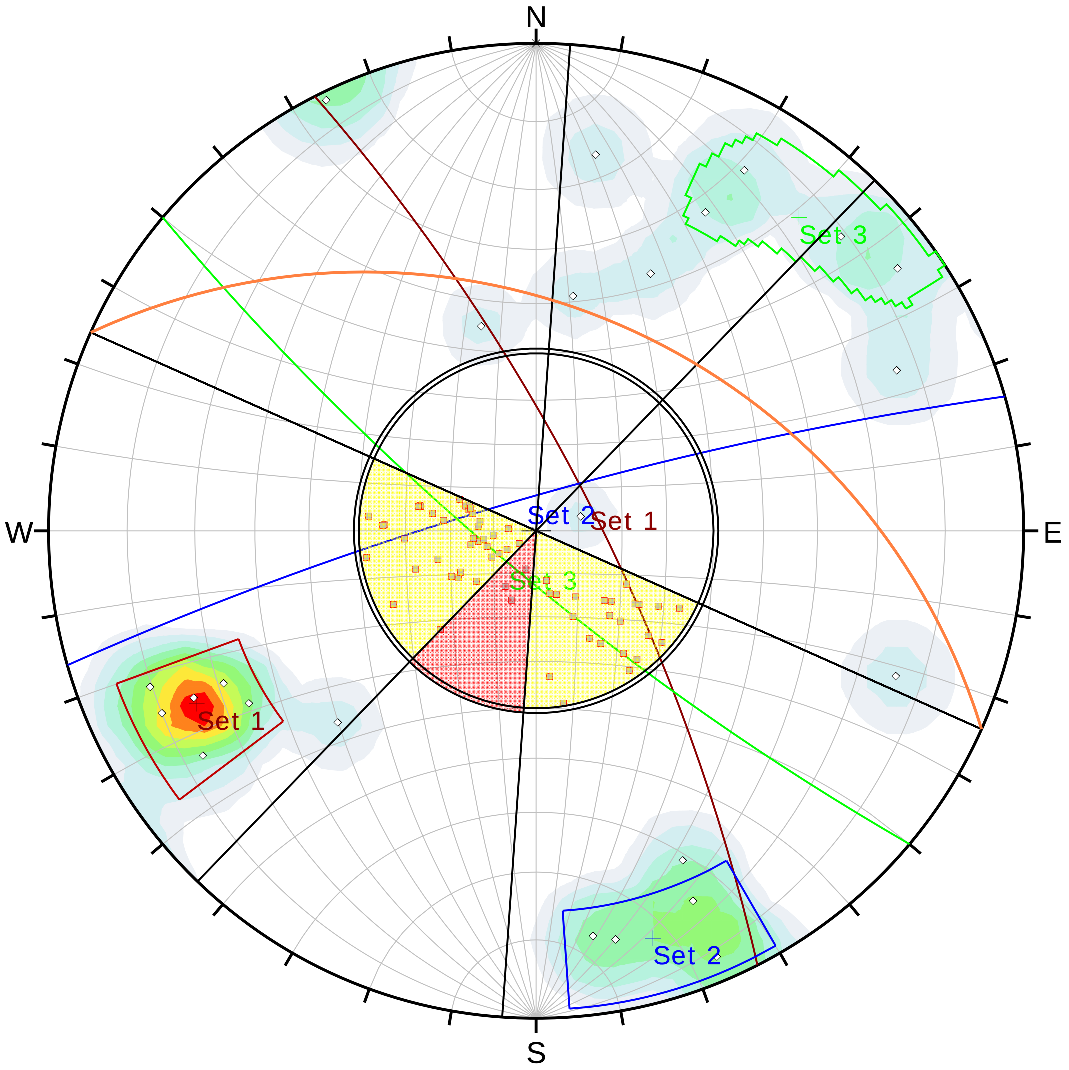
Analysis Description
East - Upper East Block - Wedge Analysis

Drawn By SWD

Company LT

Date 3/16/2021

File Name East_UpperBlock_East_Wedge.dips8



Symbol	Feature
◇	Pole Vectors
▪	Critical Intersection

Color	Density Concentrations
⬜	0.00 - 1.90
⬜	1.90 - 3.80
🟦	3.80 - 5.70
🟦	5.70 - 7.60
🟩	7.60 - 9.50
🟩	9.50 - 11.40
🟩	11.40 - 13.30
🟨	13.30 - 15.20
🟧	15.20 - 17.10
🟥	17.10 - 19.00

Contour Data	Pole Vectors
Maximum Density	18.79%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Direct Toppling
Slope Dip	41
Slope Dip Direction	24
Friction Angle	40°
Lateral Limits	20°

	Critical	Total	%
Direct Toppling (Intersection)	3	276	1.09%
Oblique Toppling (Intersection)	63	276	22.83%
Base Plane (All)	0	24	0.00%

	Color	Dip	Dip Direction	Label
		Mean Set Planes		
1m	🟥	76	63	Set 1
2m	🟦	82	344	Set 2
3m	🟩	80	220	Set 3

Plot Mode	Pole Vectors
Vector Count	24 (24 Entries)
Intersection Mode	Grid Data Planes
Intersections Count	276
Hemisphere	Lower
Projection	Equal Angle

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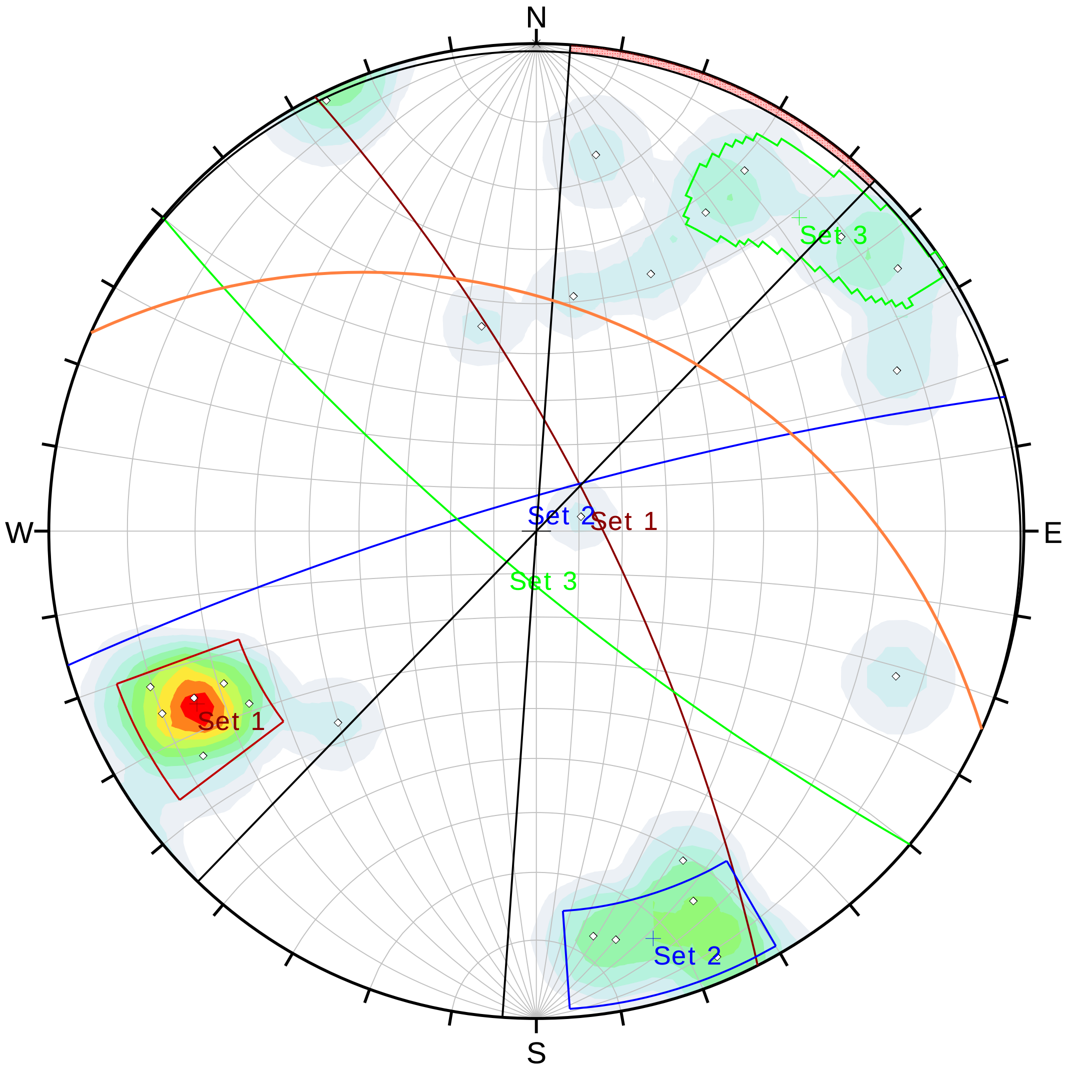
Project	Haines Slide Emergency Response		
Analysis Description	East - Upper West Block - Direct Toppling Analysis		
Drawn By	SWD	*Company*	LT
Date	3/16/2021	*File Name*	East_UpperBlock_West.dips8



Symbol	Feature
◇	Pole Vectors

Color	Density Concentrations
⬜	0.00 - 1.90
⬜	1.90 - 3.80
🟦	3.80 - 5.70
🟩	5.70 - 7.60
🟩	7.60 - 9.50
🟩	9.50 - 11.40
🟨	11.40 - 13.30
🟨	13.30 - 15.20
🟧	15.20 - 17.10
🟥	17.10 - 19.00

Contour Data	Pole Vectors
Maximum Density	18.79%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Flexural Toppling
Slope Dip	41
Slope Dip Direction	24
Friction Angle	40°
Lateral Limits	20°

	Critical	Total	%
Flexural Toppling (All)	0	24	0.00%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m	🟥	76	63	Set 1
2m	🟦	82	344	Set 2
3m	🟩	80	220	Set 3

Plot Mode	Pole Vectors
Vector Count	24 (24 Entries)
Hemisphere	Lower
Projection	Equal Angle

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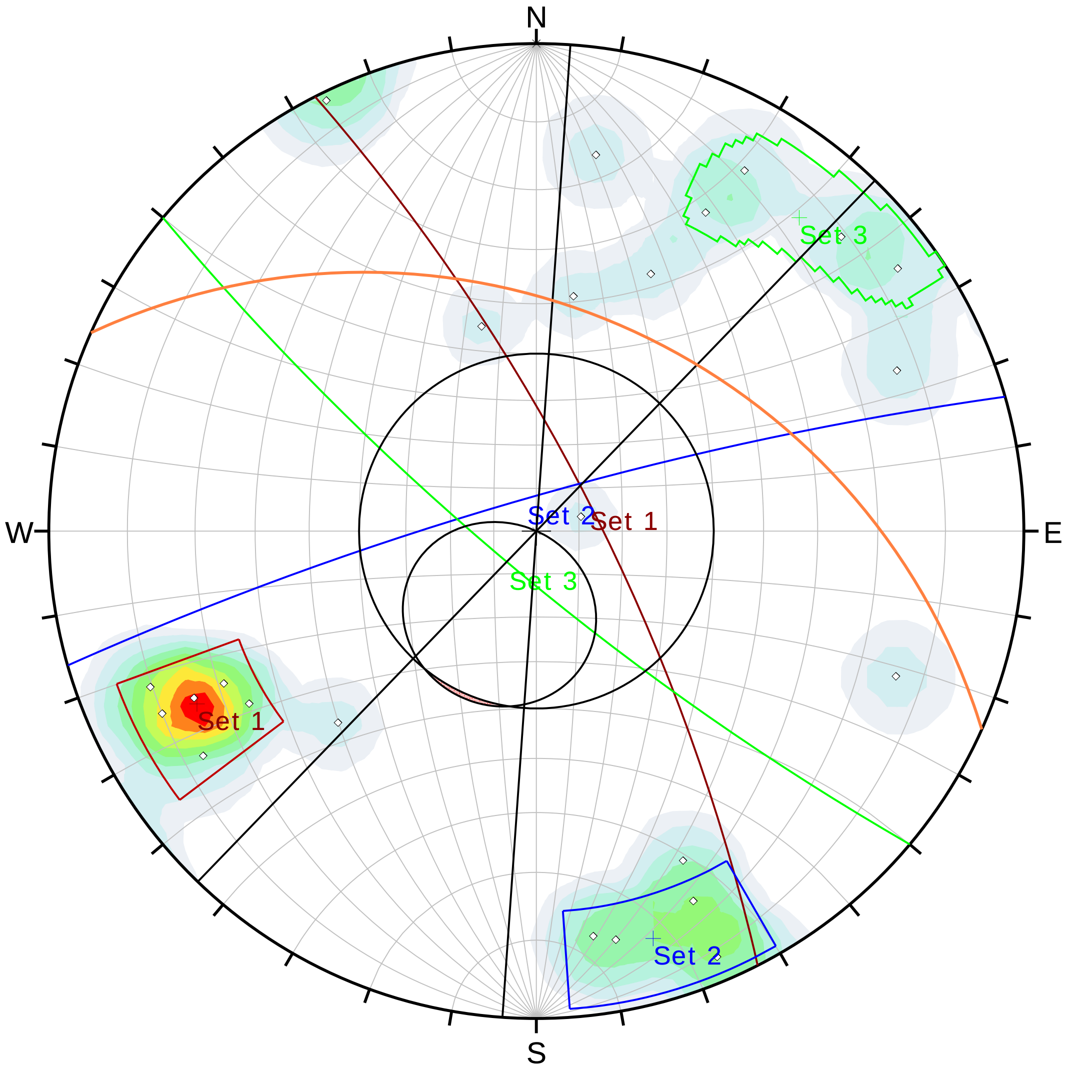
Project	Haines Slide Emergency Response		
Analysis Description	East - Upper West Block - Flexural Toppling Analysis		
Drawn By	SWD	*Company*	LT
Date	3/16/2021	*File Name*	East_UpperBlock_West_FlexuralToppling.dips8



Symbol	Feature
◇	Pole Vectors

Color	Density Concentrations
⬜	0.00 - 1.90
⬜	1.90 - 3.80
🟦	3.80 - 5.70
🟩	5.70 - 7.60
🟩	7.60 - 9.50
🟩	9.50 - 11.40
🟨	11.40 - 13.30
🟨	13.30 - 15.20
🟧	15.20 - 17.10
🟥	17.10 - 19.00

Contour Data	Pole Vectors
Maximum Density	18.79%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Planar Sliding
Slope Dip	41
Slope Dip Direction	24
Friction Angle	40°
Lateral Limits	20°

	Critical	**Total**	**%**
Planar Sliding (All)	0	24	0.00%

	Color	**Dip**	**Dip Direction**	**Label**
Mean Set Planes				
1m	🟥	76	63	Set 1
2m	🟦	82	344	Set 2
3m	🟩	80	220	Set 3

Plot Mode	Pole Vectors
Vector Count	24 (24 Entries)
Hemisphere	Lower
Projection	Equal Angle

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Project	Haines Slide Emergency Response		
Analysis Description	East - Upper West Block - Planar Analysis		
Drawn By	SWD	*Company*	LT
Date	3/16/2021	*File Name*	East_UpperBlock_West_Planar.dips8

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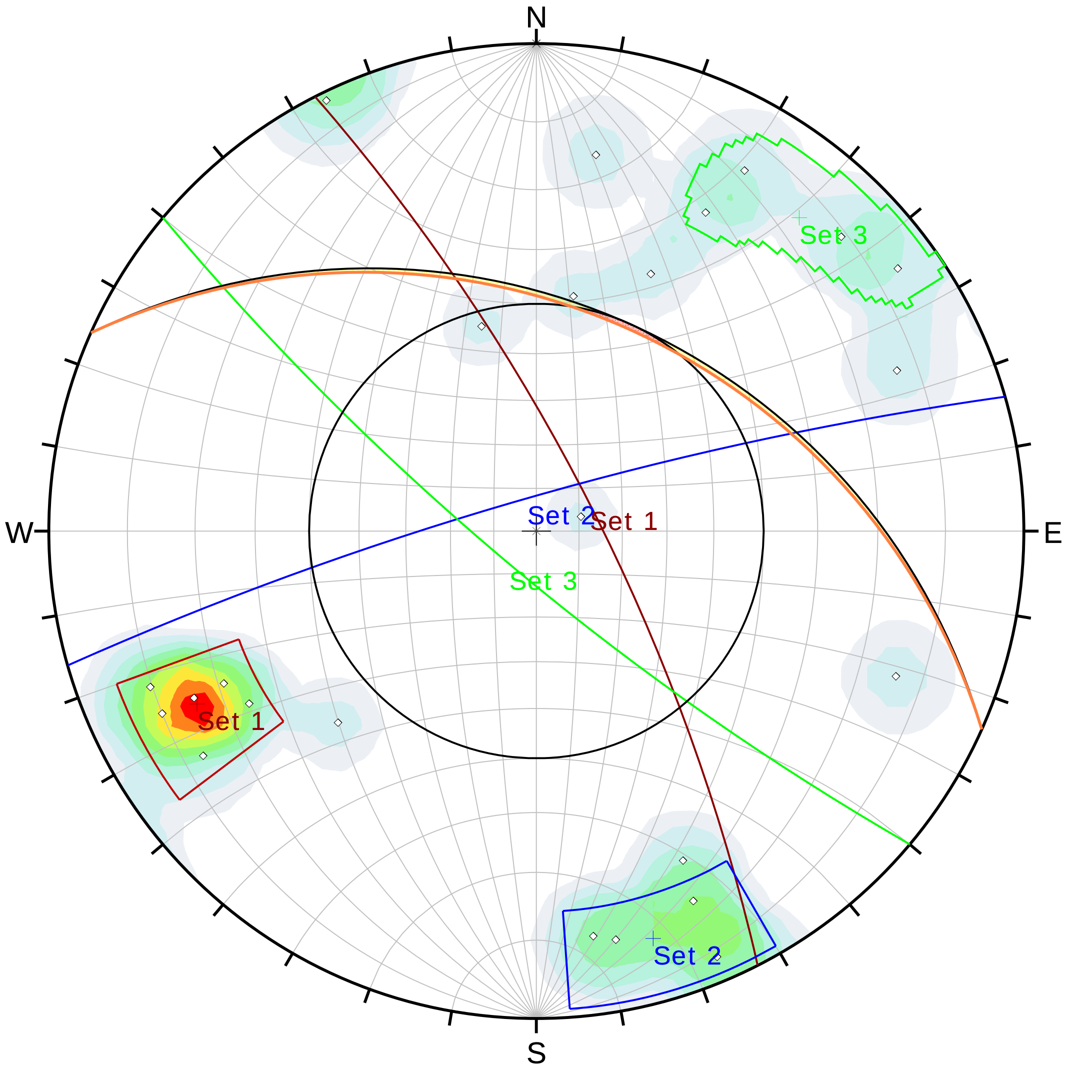

Symbol	Feature
◇	Pole Vectors
▪	Critical Intersection

Color	Density Concentrations
⬜	0.00 - 1.90
⬜	1.90 - 3.80
🟦	3.80 - 5.70
🟦	5.70 - 7.60
🟩	7.60 - 9.50
🟩	9.50 - 11.40
🟩	11.40 - 13.30
🟨	13.30 - 15.20
🟧	15.20 - 17.10
🟥	17.10 - 19.00

Contour Data	Pole Vectors
Maximum Density	18.79%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Wedge Sliding
Slope Dip	41
Slope Dip Direction	24
Friction Angle	40°

	Critical	Total	%
Wedge Sliding	0	276	0.00%

	Color	Dip	Dip Direction	Label
		Mean Set Planes		
1m	🟥	76	63	Set 1
2m	🟦	82	344	Set 2
3m	🟩	80	220	Set 3

Plot Mode	Pole Vectors
Vector Count	24 (24 Entries)
Intersection Mode	Grid Data Planes
Intersections Count	276
Hemisphere	Lower
Projection	Equal Angle

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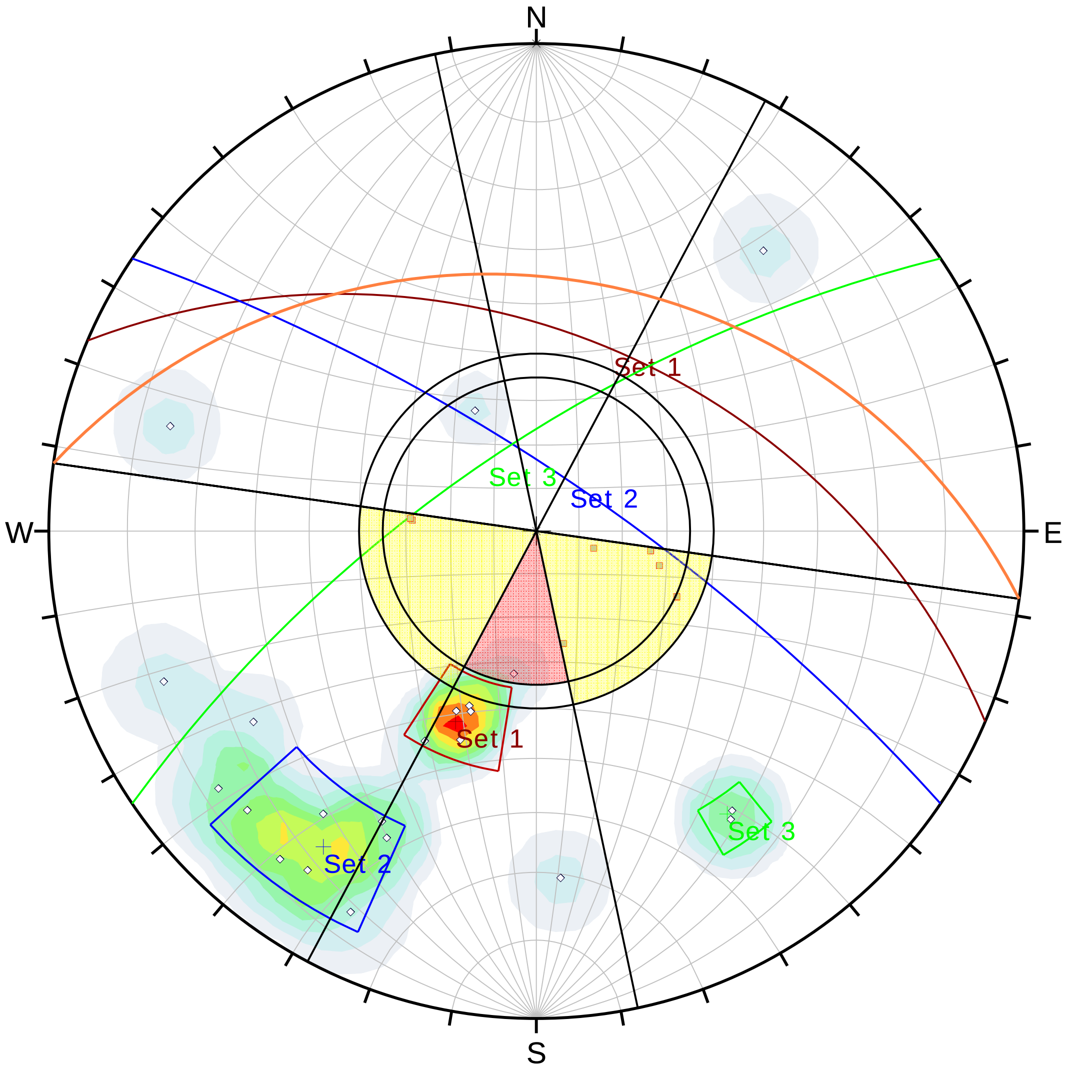
DIPS 8.010

Project	Haines Slide Emergency Response		
Analysis Description	East - Upper West Block - Wedge Analysis		
Drawn By	SWD	*Company*	LT
Date	3/16/2021	*File Name*	East_UpperBlock_West_Wedge.dips8



Symbol	LOCATION	Quantity
◇	HEADSCARP	22
Symbol	**Feature**	
□	Critical Intersection	

Color	Density Concentrations
⬜	0.00 - 2.10
⬜	2.10 - 4.20
🟦	4.20 - 6.30
🟦	6.30 - 8.40
🟩	8.40 - 10.50
🟩	10.50 - 12.60
🟩	12.60 - 14.70
🟨	14.70 - 16.80
🟧	16.80 - 18.90
🟥	18.90 - 21.00

Contour Data	Pole Vectors
Maximum Density	20.26%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Direct Toppling
Slope Dip	35
Slope Dip Direction	8
Friction Angle	40°
Lateral Limits	20°

	Critical	Total	%
Direct Toppling (Intersection)	0	231	0.00%
Oblique Toppling (Intersection)	7	231	3.03%
Base Plane (All)	1	22	4.55%

	Color	Dip	Dip Direction	Label
		Mean Set Planes		
1m	🟥	46	23	Set 1
2m	🟦	76	34	Set 2
3m	🟩	70	326	Set 3

Plot Mode	Pole Vectors
Vector Count	22 (22 Entries)
Intersection Mode	Grid Data Planes
Intersections Count	231
Hemisphere	Lower
Projection	Equal Angle

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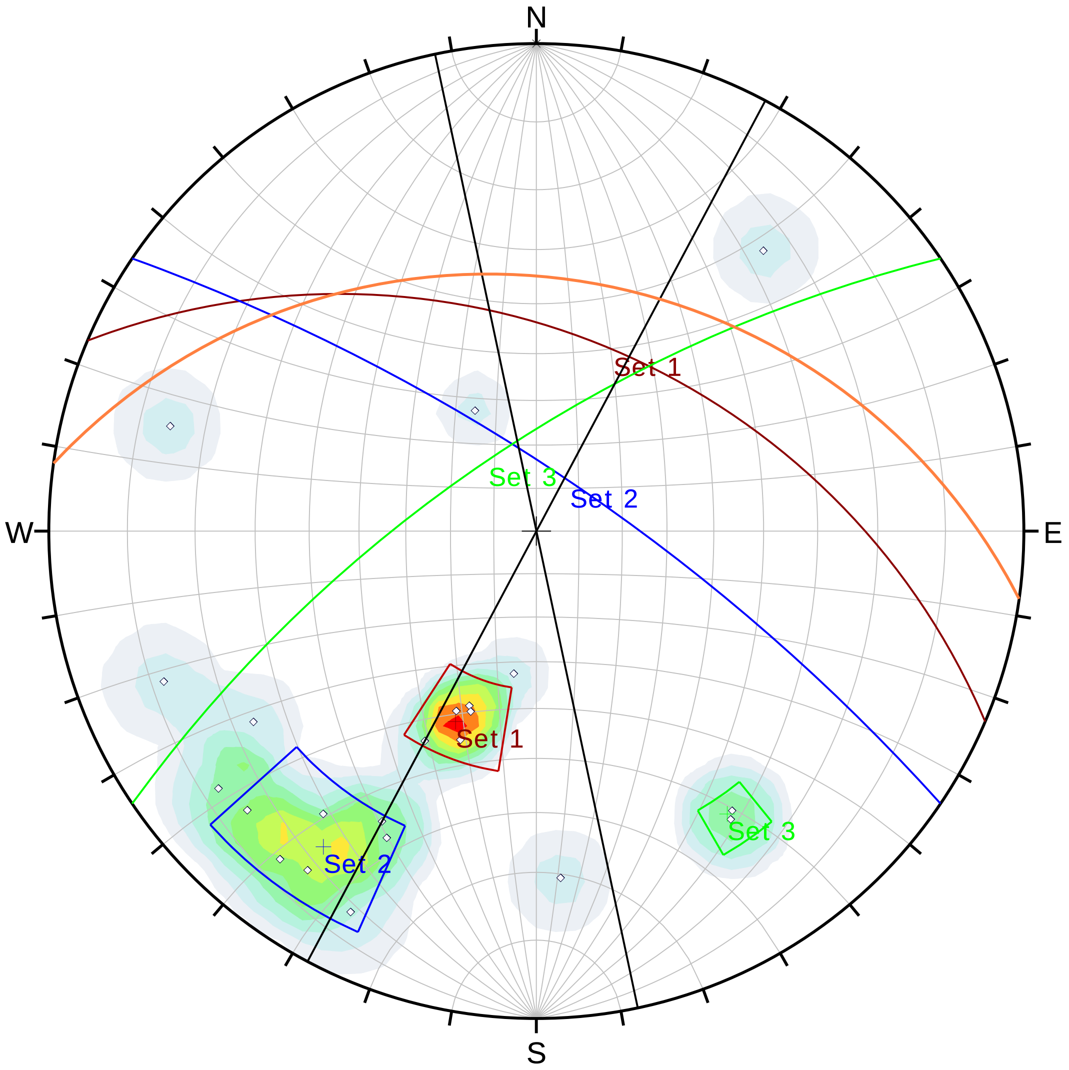
DIPS 8.010

Project	Haines Slide Emergency Response
Analysis Description	Headscarp - Direct Toppling Analysis
Drawn By	SWD
Company	LT
Date	3/16/2021
File Name	Headscarp_DirectToppling.dips8



Symbol	LOCATION	Quantity
◇	HEADSCARP	22

Color	Density Concentrations
⬜	0.00 - 2.10
⬜	2.10 - 4.20
🟦	4.20 - 6.30
🟦	6.30 - 8.40
🟩	8.40 - 10.50
🟩	10.50 - 12.60
🟩	12.60 - 14.70
🟨	14.70 - 16.80
🟧	16.80 - 18.90
🟥	18.90 - 21.00
Contour Data	Pole Vectors
Maximum Density	20.26%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Flexural Toppling		
Slope Dip	35		
Slope Dip Direction	8		
Friction Angle	40°		
Lateral Limits	20°		
	Critical	Total	%
Flexural Toppling (All)	0	22	0.00%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m	🟥	46	23	Set 1
2m	🟦	76	34	Set 2
3m	🟩	70	326	Set 3

Plot Mode	Pole Vectors
Vector Count	22 (22 Entries)
Hemisphere	Lower
Projection	Equal Angle

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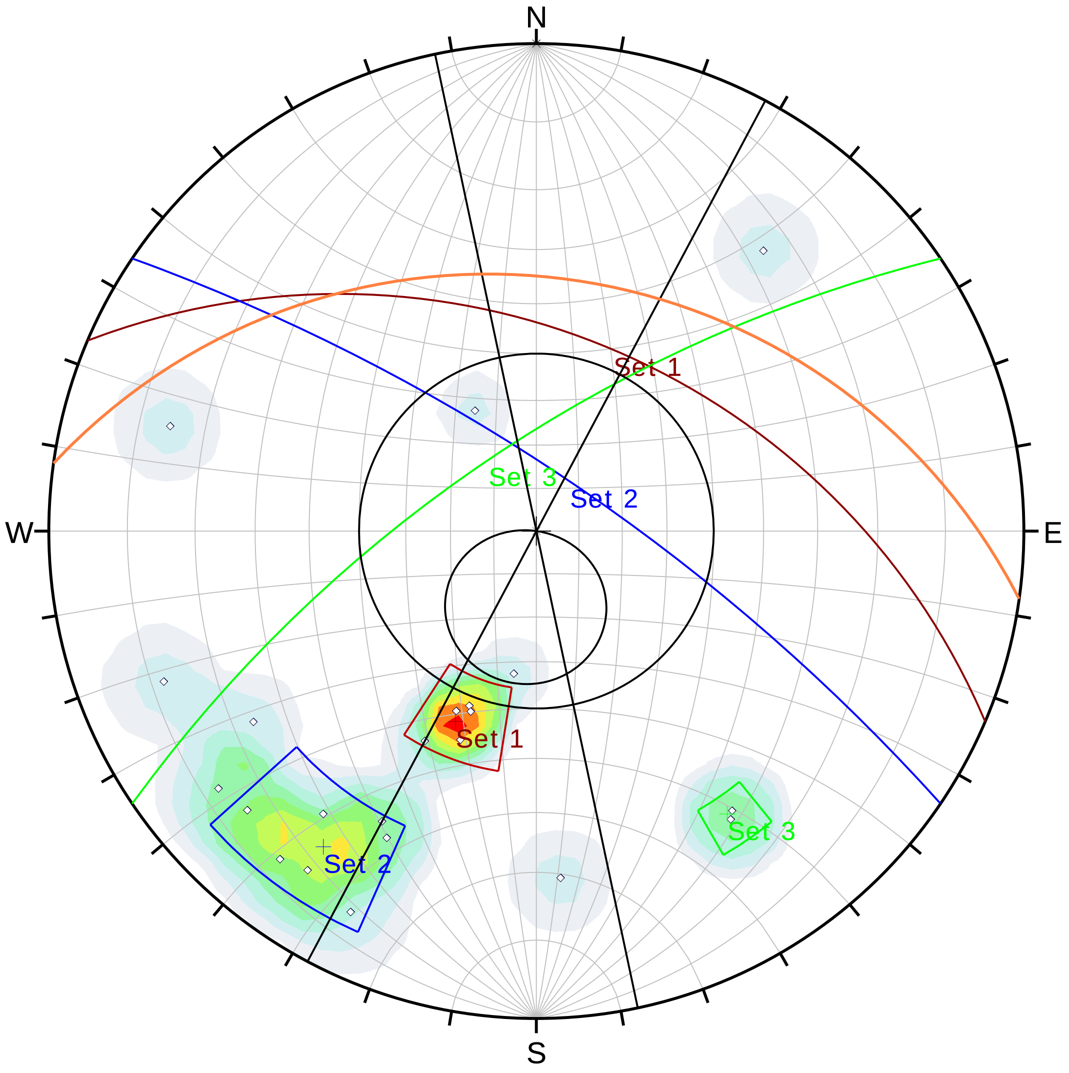
DIPS 8.010

Project	Haines Slide Emergency Response		
Analysis Description	Headscarp - Flexural Toppling Analysis		
Drawn By	SWD	*Company*	LT
Date	3/16/2021	*File Name*	Headscarp_FlexuralToppling.dips8



Symbol	LOCATION	Quantity
◇	HEADSCARP	22

Color	Density Concentrations
⬜	0.00 - 2.10
⬜	2.10 - 4.20
🟦	4.20 - 6.30
🟦	6.30 - 8.40
🟩	8.40 - 10.50
🟩	10.50 - 12.60
🟩	12.60 - 14.70
🟨	14.70 - 16.80
🟧	16.80 - 18.90
🟥	18.90 - 21.00

Contour Data	Pole Vectors
Maximum Density	20.26%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Planar Sliding
Slope Dip	35
Slope Dip Direction	8
Friction Angle	40°
Lateral Limits	20°

	Critical	Total	%
Planar Sliding (All)	0	22	0.00%

	Color	Dip	Dip Direction	Label
		Mean Set Planes		
1m	🟥	46	23	Set 1
2m	🟦	76	34	Set 2
3m	🟩	70	326	Set 3

Plot Mode	Pole Vectors
Vector Count	22 (22 Entries)
Hemisphere	Lower
Projection	Equal Angle

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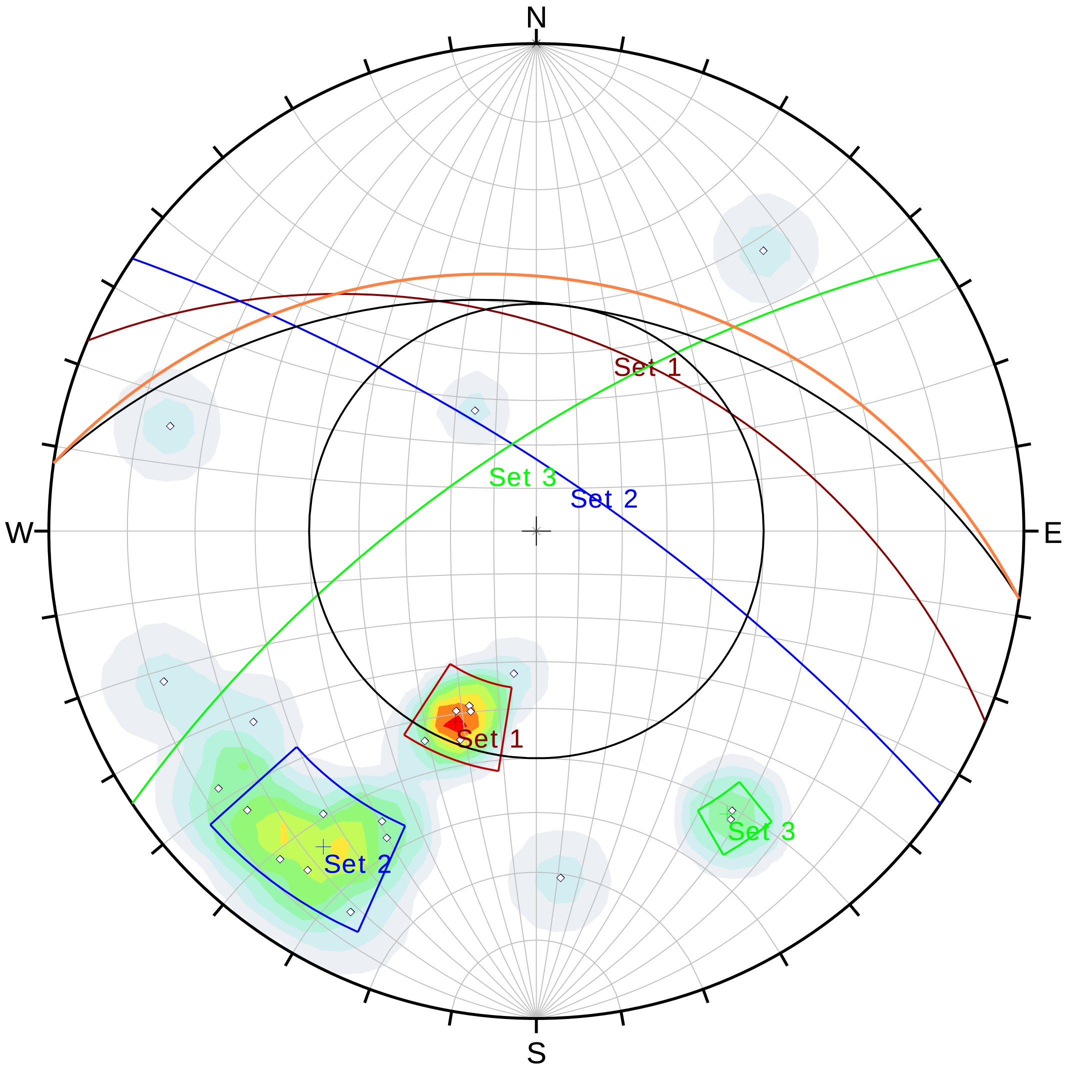
Project	Haines Slide Emergency Response
Analysis Description	Headscarp - Planar Analysis
Drawn By	SWD
Company	LT
Date	3/16/2021
File Name	Headscarp_Planar.dips8

DIPS 8.010



Symbol	LOCATION	Quantity
◇	HEADSCARP	22
Symbol	**Feature**	
▫	Critical Intersection	

Color	Density Concentrations
⬜	0.00 - 2.10
⬜	2.10 - 4.20
🟦	4.20 - 6.30
🟦	6.30 - 8.40
🟩	8.40 - 10.50
🟩	10.50 - 12.60
🟩	12.60 - 14.70
🟨	14.70 - 16.80
🟧	16.80 - 18.90
🟥	18.90 - 21.00
Contour Data	Pole Vectors
Maximum Density	20.26%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Wedge Sliding		
Slope Dip	35		
Slope Dip Direction	8		
Friction Angle	40°		
	Critical	**Total**	**%**
Wedge Sliding	0	231	0.00%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m	🟥	46	23	Set 1
2m	🟦	76	34	Set 2
3m	🟩	70	326	Set 3

Plot Mode	Pole Vectors
Vector Count	22 (22 Entries)
Intersection Mode	Grid Data Planes
Intersections Count	231
Hemisphere	Lower
Projection	Equal Angle

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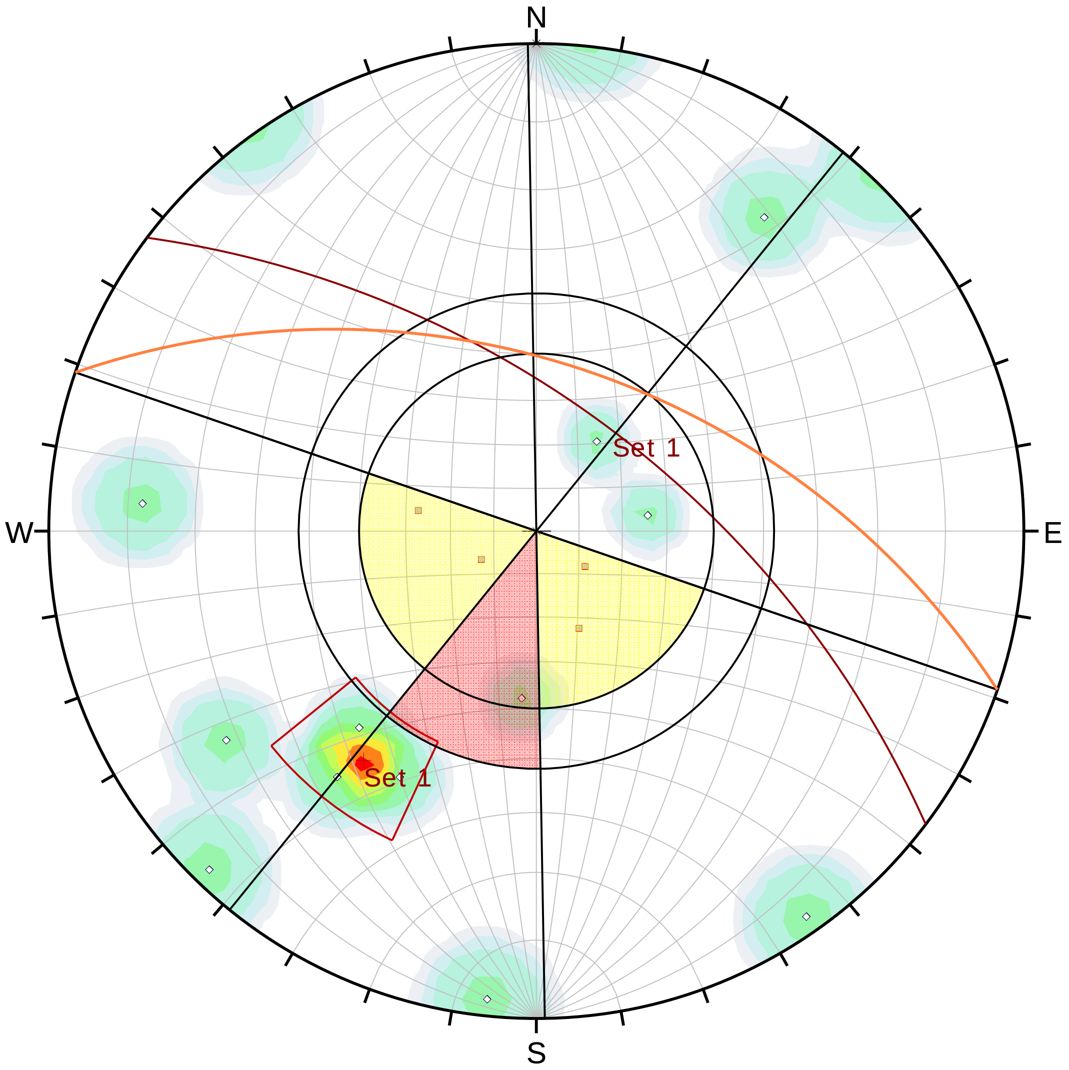
DIPS 8.010

Project	Haines Slide Emergency Response
Analysis Description	Headscarp - Wedge Analysis
Drawn By	SWD
Company	LT
Date	3/16/2021
File Name	Headscarp_Wedge.dips8



Symbol	LOCATION	Quantity
◇	HIGH	12
Symbol	**Feature**	
▫	Critical Intersection	

Color	Density Concentrations
⬜	0.00 - 2.00
⬜	2.00 - 4.00
🟦	4.00 - 6.00
🟩	6.00 - 8.00
🟩	8.00 - 10.00
🟩	10.00 - 12.00
🟩	12.00 - 14.00
🟨	14.00 - 16.00
🟧	16.00 - 18.00
🟥	18.00 - 20.00
Contour Data	Pole Vectors
Maximum Density	19.41%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Direct Toppling
Slope Dip	52
Slope Dip Direction	19
Friction Angle	40°
Lateral Limits	20°

	Critical	Total	%
Direct Toppling (Intersection)	0	66	0.00%
Oblique Toppling (Intersection)	4	66	6.06%
Base Plane (All)	1	12	8.33%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m	🟥	61	37	Set 1

Plot Mode	Pole Vectors
Vector Count	12 (12 Entries)
Intersection Mode	Grid Data Planes
Intersections Count	66
Hemisphere	Lower
Projection	Equal Angle

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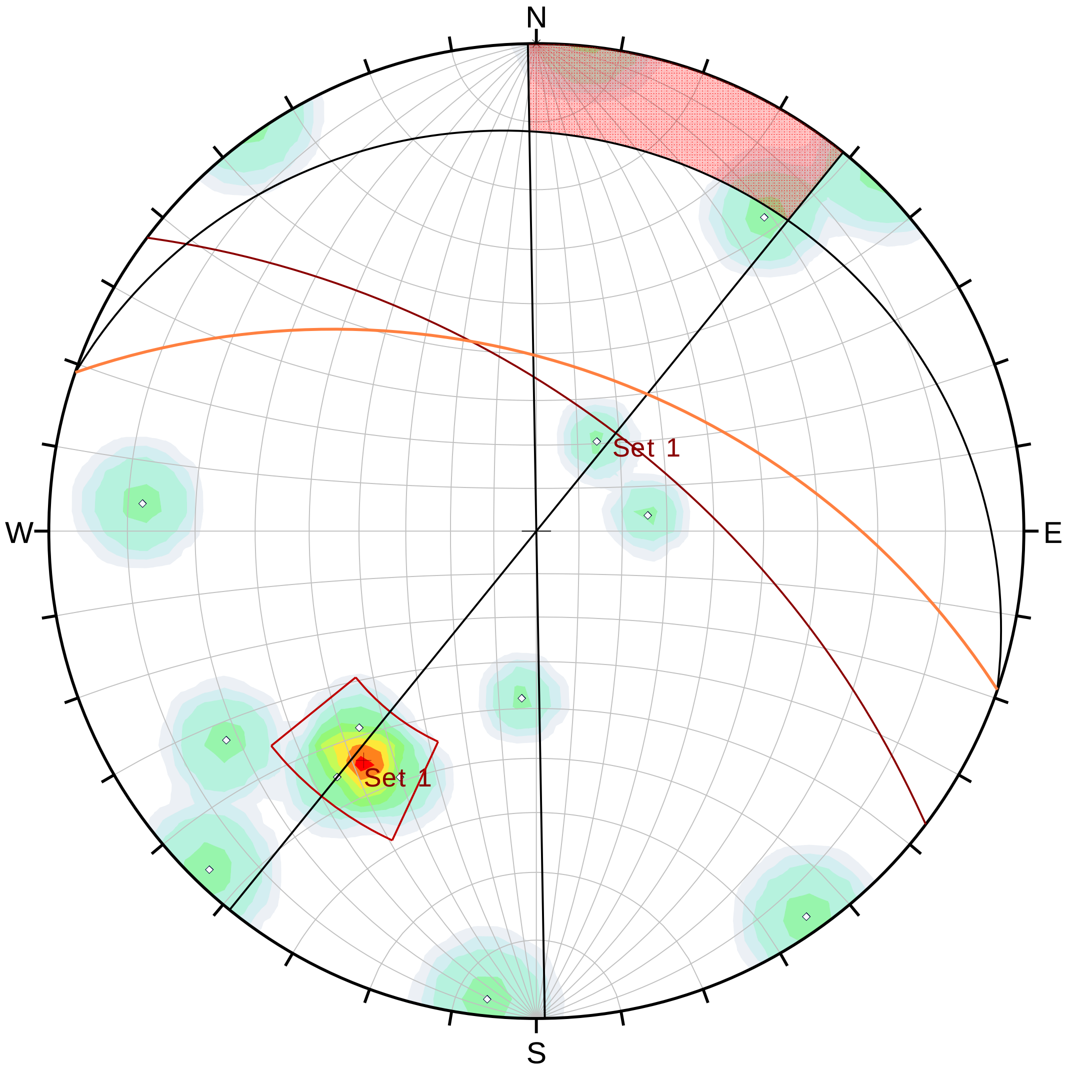
DIPS 8.010

Project	Haines Slide Emergency Response		
Analysis Description	West - High - Direct Toppling Analysis		
Drawn By	SWD	*Company*	LT
Date	3/16/2021	*File Name*	West_High_DirectToppling.dips8



Symbol	LOCATION	Quantity
◇	HIGH	12

Color	Density Concentrations
⬜	0.00 - 2.00
⬜	2.00 - 4.00
🟦	4.00 - 6.00
🟩	6.00 - 8.00
🟩	8.00 - 10.00
🟩	10.00 - 12.00
🟨	12.00 - 14.00
🟨	14.00 - 16.00
🟧	16.00 - 18.00
🟥	18.00 - 20.00

Contour Data	Pole Vectors
Maximum Density	19.41%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Flexural Toppling
Slope Dip	52
Slope Dip Direction	19
Friction Angle	40°
Lateral Limits	20°

	Critical	Total	%
Flexural Toppling (All)	0	12	0.00%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m	🟥	61	37	Set 1

Plot Mode	Pole Vectors
Vector Count	12 (12 Entries)
Hemisphere	Lower
Projection	Equal Angle

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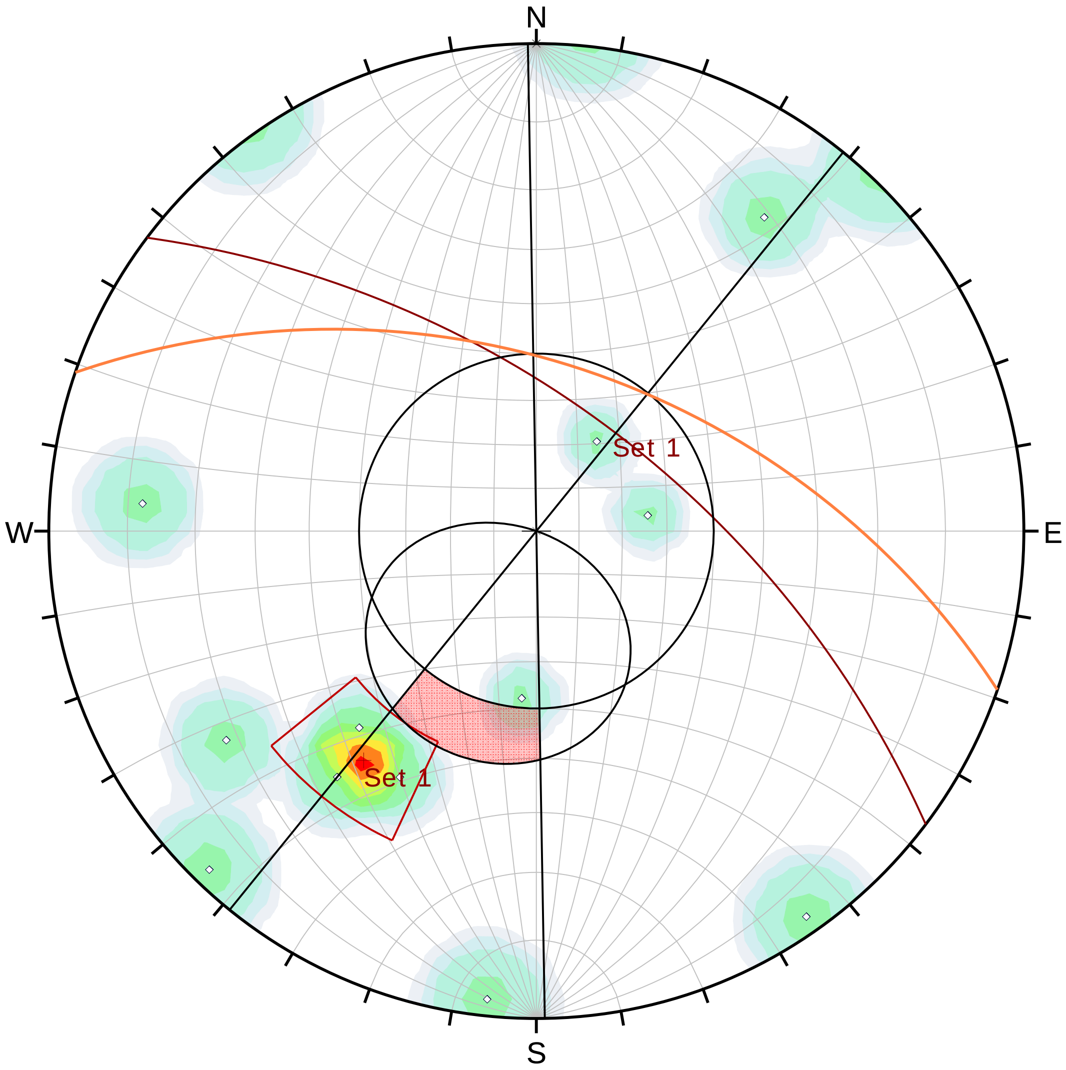
DIPS 8.010

Project	Haines Slide Emergency Response
Analysis Description	West - High - Flexural Toppling Analysis

Drawn By	SWD	*Company*	LT
Date	3/16/2021	*File Name*	West_High_FlexuralToppling.dips8



Symbol	LOCATION	Quantity
◇	HIGH	12

Color	Density Concentrations
⬜	0.00 - 2.00
⬜	2.00 - 4.00
🟦	4.00 - 6.00
🟦	6.00 - 8.00
🟩	8.00 - 10.00
🟩	10.00 - 12.00
🟨	12.00 - 14.00
🟨	14.00 - 16.00
🟧	16.00 - 18.00
🟥	18.00 - 20.00

Contour Data	Pole Vectors
Maximum Density	19.41%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Planar Sliding
Slope Dip	52
Slope Dip Direction	19
Friction Angle	40°
Lateral Limits	20°

	Critical	Total	%
Planar Sliding (All)	0	12	0.00%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m	🟥	61	37	Set 1

Plot Mode	Pole Vectors
Vector Count	12 (12 Entries)
Hemisphere	Lower
Projection	Equal Angle

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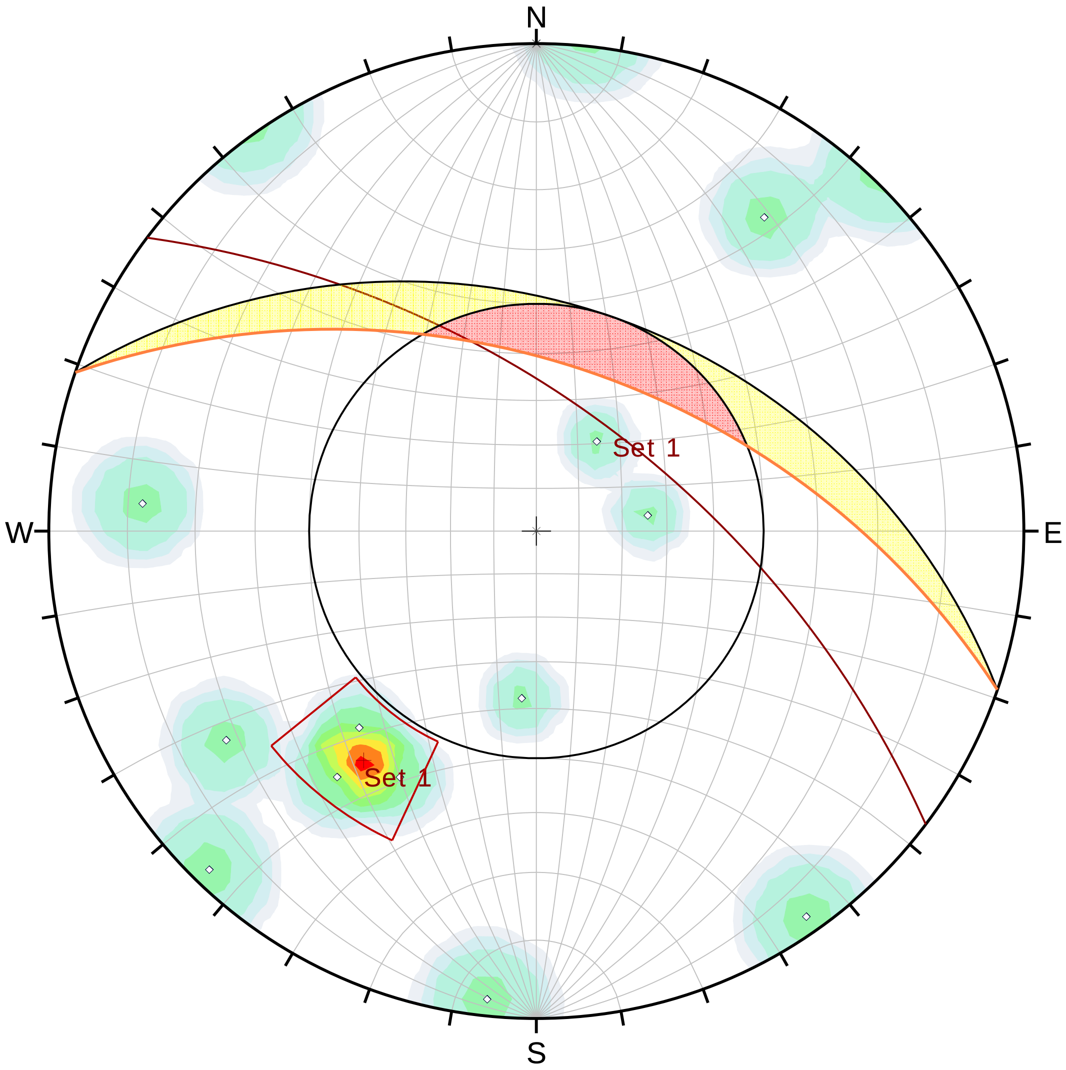
DIPS 8.010

Project	Haines Slide Emergency Response		
Analysis Description	West - High - Planar Analysis		
Drawn By	SWD	*Company*	LT
Date	3/16/2021	*File Name*	West_High_Planar.dips8



Symbol	LOCATION	Quantity
◇	HIGH	12
Symbol	**Feature**	
▫	Critical Intersection	

Color	Density Concentrations
⬜	0.00 - 2.00
🟦	2.00 - 4.00
🟦	4.00 - 6.00
🟩	6.00 - 8.00
🟩	8.00 - 10.00
🟩	10.00 - 12.00
🟩	12.00 - 14.00
🟨	14.00 - 16.00
🟧	16.00 - 18.00
🟥	18.00 - 20.00

Contour Data	Pole Vectors
Maximum Density	19.41%
Contour Distribution	Fisher
Counting Circle Size	1.0%

Kinematic Analysis	Wedge Sliding		
Slope Dip	52		
Slope Dip Direction	19		
Friction Angle	40°		
	Critical	**Total**	**%**
Wedge Sliding	0	66	0.00%

	Color	Dip	Dip Direction	Label
		Mean Set Planes		
1m	🟥	61	37	Set 1

Plot Mode	Pole Vectors
Vector Count	12 (12 Entries)
Intersection Mode	Grid Data Planes
Intersections Count	66
Hemisphere	Lower
Projection	Equal Angle

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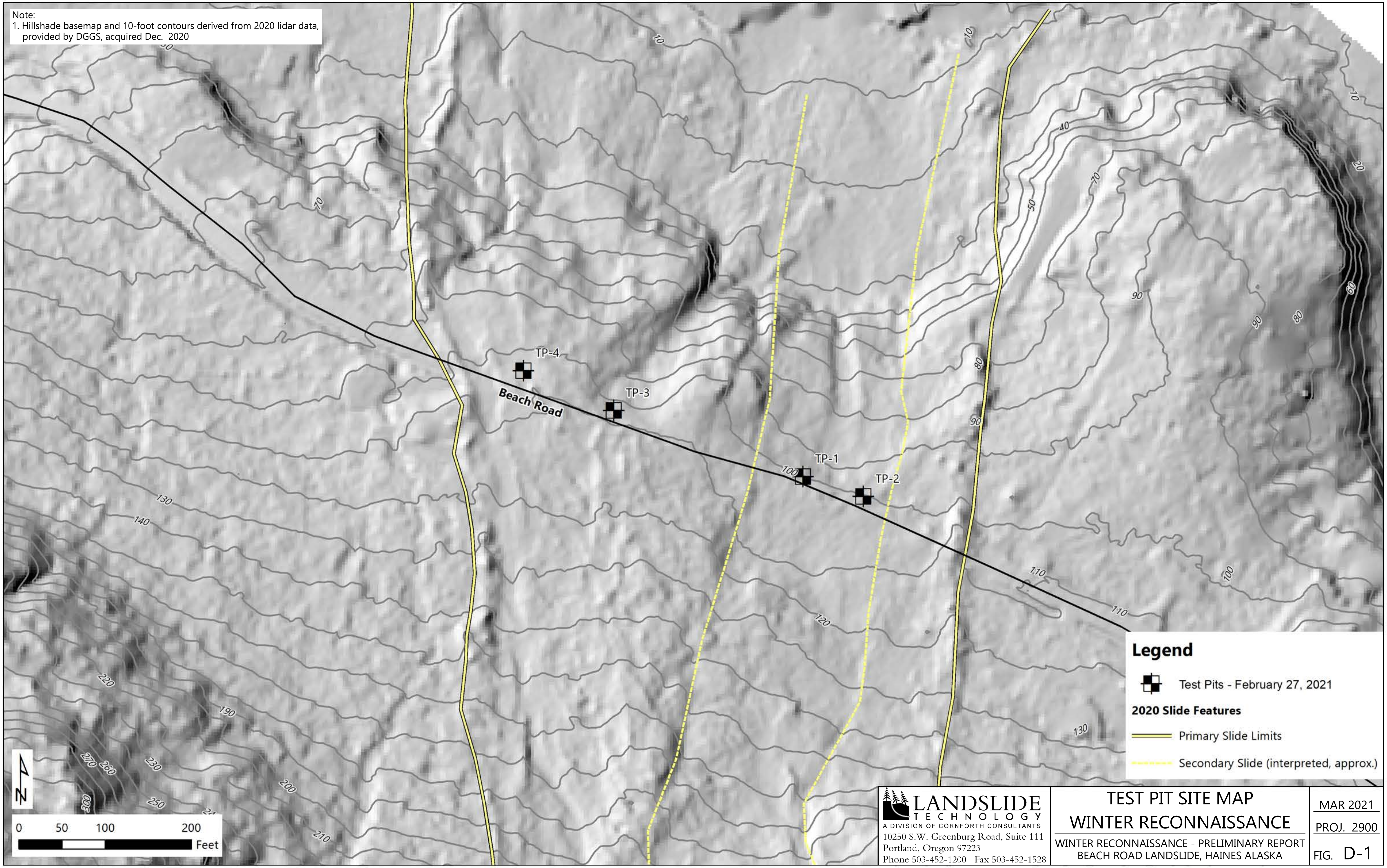
DIPS 8.010

Project	Haines Slide Emergency Response		
Analysis Description	West - High - Wedge Analysis		
Drawn By	SWD	*Company*	LT
Date	3/16/2021	*File Name*	West_High_Wedge.dips8

APPENDIX D: TEST PIT LOGS

Note:
1. Hillshade basemap and 10-foot contours derived from 2020 lidar data, provided by DGGS, acquired Dec. 2020



Legend

- ▣ Test Pits - February 27, 2021

2020 Slide Features

- ═ Primary Slide Limits
- ┄ Secondary Slide (interpreted, approx.)

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TEST PIT SITE MAP
WINTER RECONNAISSANCE

WINTER RECONNAISSANCE - PRELIMINARY REPORT
BEACH ROAD LANDSLIDE, HAINES ALASKA

MAR 2021
PROJ. 2900
FIG. D-1

LANDSLIDE
TECHNOLOGY
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Portland, Oregon 97223
Phone 503-452-1200 Fax 503-452-1528

LOCATION OF TEST PIT: Beach Road, Haines, AK
DATUM: Interim Road Elevation
ELEVATION: ~110 Feet
BY: BAB DATE: 2/27/2021
CK: BAG DATE: 3/25/2021
EQUIPMENT & CONTRACTOR: Cat 335, SE Road Builders
WEATHER: 28F, Clear
JOB NO.: 2900
LOCATION: ~460 ft. East of West Lateral
SAMPLING METHODS: Grab Samples
WATER LEVEL: Dry

TEST PIT NO.: TP-1

START	FINISH
TIME:	TIME:
DATE: 2/27/2021	DATE: 2/27/2021

PHOTO OF TEST PIT

☐ GRAB SAMPLE
▯ THIN WALL SAMPLE
▽ POCKET PENETROMETER
⊕ TORVANE

Photo not to scale

DEPTH IN FEET	ELEV. IN FEET	SURFACE CONDITIONS:
		~2 ft snow (pit dug on down slope side of interim road).
0		Top of TP is 2 ft below interim road grade elevation.
		~1 ft frozen ground.
2		Difficult excavation due to rocky conditions.
		0 - 9 ft Very dense, grey, silty sand with angular rock fragments,
4		gravel-sized to 2.5 ft boulders; scattered woody debris and roots,
		moist (Landslide Debris).
6		
8		
10		9 ft (6 to 9 in) Grey, crushed rock, 1-in minus (Original Road Surface)
		Underlain by (9 in to 1 ft) brown, sl. silty sand with scattered rounded
12		gravels (Road Base - Fill). This material is underlain by 1 to 1.5 ft
		of woody debris (Corduroy Road)
14		11.5 to 14 ft Loose to medium dense, brown, gravely sand, with
		round cobbles and boulders up to 3 ft in size, moist
16		(Delta Deposits/Till?)
		Refusal at 14 ft (Rock/Boulder?)
18		
20		
22		
24		
26		
28		

FIG. D-2

LANDSLIDE
TECHNOLOGY
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Portland, Oregon 97223
Phone 503-452-1200 Fax 503-452-1528

LOCATION OF TEST PIT: Beach Road, Haines, AK
DATUM: Interim Road Elevation
ELEVATION: ~110 feet

BY: BAB DATE: 2/27/2021
CK: BAG DATE: 3/25/2021
EQUIPMENT & CONTRACTOR: Cat 335, SE Road Builders
WEATHER: 28F, Clear

JOB NO.: 2900
LOCATION: ~140 ft. West of East Lateral
SAMPLING METHODS: Grab Samples
WATER LEVEL: Dry

TEST PIT NO.: TP-2

START	FINISH
TIME:	TIME:
DATE: 2/27/2021	DATE: 2/27/2021

PHOTO OF TEST PIT

☐ GRAB SAMPLE
▯ THIN WALL SAMPLE
▽ POCKET PENETROMETER
⊕ TORVANE

Photo not to scale

FIG. D-3

DEPTH IN FEET	ELEV. IN FEET
0	
2	
4	
6	
8	
10	
12	
14	
16	
18	
20	
22	
24	
26	
28	

SURFACE CONDITIONS:
~2 ft snow (pit dug on down slope side of interim road).

Top of TP is 3 ft below interim road grade elevation.
~2 ft frozen ground.
~Easy excavation.

0 - 9 ft Medium dense, grey, silty sand with angular rock fragments, gravel-sized up to 2 ft boulders; scattered woody debris and roots, moist (Landslide Debris).

9 ft (6 to 9 in) Grey, crushed rock, 1-in minus (Original Road Surface) Underlain by (9 to 12 in) brown, sl. silty sand with scattered rounded gravels (Road Base - Fill). This material is underlain by 1 to 1.5 ft. of woody debris (Corduroy Road)

11.5 to 14 ft Loose to medium dense, brown, gravely sand, with round cobbles and boulders up to 3 ft in size, moist (Delta Deposits/Till?)

14 to 17 ft Very stiff, grey, slightly sandy, slightly clayey to clayey silt; scattered rounded gravel up to 3", moist, slight lenses to no observable structure, no observable organics but organic smell (Glacial Lacustrine/marine clay?)

17 to 18 ft Hard excavation. Gravel- to cobble-sized angular rock fragments. Refusal on rock and out of reach at 18 feet.

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Portland, Oregon 97223
Phone 503-452-1200 Fax 503-452-1528

LOCATION OF TEST PIT: Beach Road, Haines, AK
DATUM: Interim Road Elevation
ELEVATION: ~110 feet

BY: BAB DATE: 2/27/2021
CK: BAG DATE: 3/25/2021
EQUIPMENT & CONTRACTOR: Cat 335, SE Road Builders
WEATHER: 28F, Clear

JOB NO.: 2900
LOCATION: ~250 ft. East of West Lateral
SAMPLING METHODS: Grab Samples
WATER LEVEL: 5 feet seeping water

TEST PIT NO.: TP-3

START	FINISH
TIME:	TIME:
DATE: 2/27/2021	DATE: 2/27/2021

PHOTO OF TEST PIT

☐ GRAB SAMPLE
THIN WALL SAMPLE
▽ POCKET PENETROMETER
⊕ TORVANE

DEPTH IN FEET
ELEV. IN FEET

Photo not to scale

DEPTH IN FEET
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28

SURFACE CONDITIONS:

~2 ft snow (pit dug on down slope side of interim road).

Top of TP is 3 ft below interim road grade elevation.

~1 ft frozen ground.

~Difficult excavation due to rocky matertial

0 - 5 ft Dense to very dense, grey, silty sand with angular rock fragments gravel-sized up to 3 ft boulders; scattered woody debris and roots, saturated (Landslide Debris).

At 5 ft seeping water into south side of the test pit. Believe water source was from ponding water in ditch on uphill side of interim road. Observed level of water in ditch drop.

A grey and brown layer underlain by woody debris was observed in the pit below 5 ft. It is unclear if this the original road surfacing.

Pit was saturated and caving due to inflow of surface or near surface water. Pit was excavated to a depth of 18 ft. Due to caving conditions, it is unclear what material was encountered at depth.

Most of the material appeared grey, silty sand with angular and sub-rounded rock fragments (Landslide Debris or Delta Deposits/Till?)

Terminated pit due to lack of reach and caving conditions.

FIG. D-4

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TECHNOLOGY
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Portland, Oregon 97223
Phone 503-452-1200 Fax 503-452-1528

LOCATION OF TEST PIT: Beach Road, Haines, AK
DATUM: Interim Road Elevation
ELEVATION: ~110 feet

BY: BAB DATE: 2/27/2021
CK: BAG DATE: 3/25/2021
EQUIPMENT & CONTRACTOR: Cat 335, SE Road Builders
WEATHER: 28F, Clear

JOB NO.: 2900
LOCATION: ~75 ft. West of East Lateral
SAMPLING METHODS: Grab Samples
WATER LEVEL: Dry

TEST PIT NO.: TP-4

START TIME:
DATE: 2/27/2021
FINISH TIME:
DATE: 2/27/2021

PHOTO OF TEST PIT

☐ GRAB SAMPLE
▯ THIN WALL SAMPLE
▽ POCKET PENETROMETER
⊕ TORVANE

DEPTH IN FEET	ELEV. IN FEET
0	
2	
4	
6	
8	
10	
12	
14	
16	
18	
20	
22	
24	
26	
28	

SURFACE CONDITIONS:
~2 ft snow (pit dug on down slope side of interim road).

Top of TP is 1 ft below interim road grade elevation.

~2 ft frozen ground.

~Hard excavation.

0 - 4.5 ft Very dense, grey, silty sand with angular rock fragments, gravel-sized up to 2 ft boulders; scattered woody debris and roots, moist (Lanslide Debris).

5 - 5.5 ft. Grey, crushed rock, 1-in minus (Original Road Surface)

5.5 - 6 ft. Brown, sl. silty sand with scattered rounded gravels (Road Base - Fill). This material is underlain by 1 ft of grey, angular gravel (appears like road surfacing material).

7 - 8 ft Woody debris and roots inter-mixed with dark grey organic silt and sand (possible corduroy road?).

8 - 9 ft Loose to medium dense, brown, gravely sand, with round cobbles, moist. Rounded boulders up to 3 ft in size inter-mixed with these materials and overlying woody debris (Delta Deposits/Till?)

9 - 18 ft Very stiff to Hard, grey, slightly sandy, v. silty clay; scattered rounded fine gravel, moist, slight lenses to no observable structure, no observable organics but organic smell (Glacial Lacustrine/Marine Sediments?)

Becomes more difficult to excavate. Clay becomes "harder" with depth. Refusal and out of reach at 18 ft.

FIG. D-5

APPENDIX E: LABORATORY TESTS

State of Alaska
Department of Transportation & Public Facilities
Central Materials Lab
5750 East Tudor Road
Anchorage, AK 99507
Phone (907) 269-6200 FAX (907) 269-6201

Laboratory Report

Information

Laboratory No.: **2021A-0628**

Name: **HNS Beach Road Slide**
Project No.: **00317**
Sample: **Soil**
Item/Spec No.:
Field No.: **I-21C-0016**
Sampled From: **Test Pit No. 2**
Submitted By: **W. Coleman**
Date Sampled: **03/12/2021**
Source: **HNS Beach road slide**
Sampled By: **W. Coleman**
Date Received: **03/15/2021**
Location: **Haines**
Quantity Represented: **As Required**
Date Completed: **03/22/2021**
Examined For: **Atterburg**
Date Reported: **03/22/2021**

Sample Preparation by: AASHTO R58 & T248

Sieve Analysis	Lab	Field	Specs
4"			
3"			
2"			
1 1/2"			
1"			
3/4"			
1/2"			
3/8"			
1/4"			
#4			
#8			
#10			
#16			
#30			
#40			
#50			
#80			
#100			
#200			
.02 mm			
.002 mm			
Fineness Modulus			

	Lab	Specs
% Organic		
% Natural Moisture		
pH of Soil		
% Sticks & Roots		
Dry Unit Weight, pcf		
% Lightweight Particles		
Uncompacted Voids of FA		
Specific Gravity of Soil		
Sand Equivalent		
Expansion Breakdown		

	Coarse		Fine	
	Lab	Specs	Lab	Specs
Friable Particles				
Sulfate Soundness, % Loss				
Agg. Specific Gravity, Bulk				
Agg. Specific Gravity, SSD				
Agg. Specific Gravity, App.				
% Absorption				
LA Abrasion, Total % Loss				
@ 100 revs % Loss				
Degradation				
Nordic Abrasion				
California Bearing Ratio				
Organic Impurities				

% Fracture	Lab	Field	Specs
Single Face			
Double Face			

Mortar Making Properties of Sand - Compressive Strength

Unwashed	Washed	Ratio	Spec
			95 min

Atterberg Limits	Dry Prep	AASHTO T89 & T90	
Liquid Limit	**18**		
Plastic Limit	**13**		
Plastic Index	**5**		

Soil Classification

% +3"
FSV
AASHTO
Unified
% Gravel
% Sand
% Silt/Clay
% Clay

Flat / Elongated			
1:3			
1:5			

Remarks:

Signature: DRAFT

Mike Yerkes, P.E.
Regional Materials Engineer

D5 The Material as Submitted Conforms to Specifications
Yes [ ] No [ ] NA [ ]

THE TEST RESULTS ARE ONLY REPRESENTATIVE OF THE MATERIAL AS SUBMITTED

State of Alaska
Department of Transportation & Public Facilities
Central Materials Lab
5750 East Tudor Road
Anchorage, AK 99507
Phone (907) 269-6200 FAX (907) 269-6201

Laboratory Report

Information
Laboratory No.: **2021A-0627**

Name: **HNS Beach Road Slide**
Project No.: **00317**
Sample: **Soil**
Item/Spec No.:
Field No.: **I-21C-0017**
Sampled From: **Test Pit No. 4, Depth 9-14'**
Submitted By: **W. Coleman**
Date Sampled: **03/12/2021**
Source: **HNS Beach road slide**
Sampled By: **W. Coleman**
Date Received: **03/15/2021**
Location: **Haines**
Quantity Represented: **As Required**
Date Completed: **03/22/2021**
Examined For: **Atterburg**
Date Reported: **03/22/2021**

Sample Preparation by: AASHTO R58 & T248

Sieve Analysis	Lab	Field	Specs
4"			
3"			
2"			
1 1/2"			
1"			
3/4"			
1/2"			
3/8"			
1/4"			
#4			
#8			
#10			
#16			
#30			
#40			
#50			
#80			
#100			
#200			
.02 mm			
.002 mm			
Fineness Modulus			

% Fracture			
Single Face			
Double Face			

Atterberg Limits	Dry Prep	AASHTO T89 & T90	
Liquid Limit	**26**		
Plastic Limit	**17**		
Plastic Index	**9**		

Flat / Elongated			
1:3			
1:5			

	Lab	Specs
% Organic		
% Natural Moisture		
pH of Soil		
% Sticks & Roots		
Dry Unit Weight, pcf		
% Lightweight Particles		
Uncompacted Voids of FA		
Specific Gravity of Soil		
Sand Equivalent		
Expansion Breakdown		

	Coarse		Fine	
	Lab	Specs	Lab	Specs
Friable Particles				
Sulfate Soundness, % Loss				
Agg. Specific Gravity, Bulk				
Agg. Specific Gravity, SSD				
Agg. Specific Gravity, App.				
% Absorption				
LA Abrasion, Total % Loss				
@ 100 revs % Loss				
Degradation				
Nordic Abrasion				
California Bearing Ratio				
Organic Impurities				

Mortar Making Properties of Sand - Compressive Strength

Unwashed	Washed	Ratio	Spec
			95 min

Soil Classification

% +3"	FSV	
	AASHTO	
% Gravel	Unified	
% Sand		
% Silt/Clay		
% Clay		

Remarks:

Signature: DRAFT

Mike Yerkes, P.E.
Regional Materials Engineer

D5 The Material as Submitted Conforms to Specifications
Yes [ ] No [ ] NA [X]

THE TEST RESULTS ARE ONLY REPRESENTATIVE OF THE MATERIAL AS SUBMITTED

State of Alaska DOT&PF
Central Materials Laboratory
SOILS & AGGREGATE WORKCARD

Information

Laboratory No.: 2021A-0627
Field No.: I-21C-0017
Date Received: 03/15/2021
State Project No. 99910

Project Name: **UNASSIGNED: METRIC**

SIEVE ANALYSIS

Sieve	Individual	Cumulative	% Ret	% Pass	Specs
100.0					
75.0				t=	
50.0					
37.5					
25.0					
19.0					
12.5					
9.5					
6.3					
4.75		=D			
Pan E		=(A-D)=M1			

Total Mass After D+E ____ =G
Total Mass Before ____ =A

Gilson # ________

Gradation Check <=0.3
(A-G)/Ax100 =

Test by:

Sieve	Cumulative -#4 B	Tot Cumulative D+(M1/M2)xB C	% Ret C/A	% Pass	Specs
2.36					
2.0					
1.18					
.600					
.425					
.300					
0.210					
.150					
.075				s=	
Pan					

% pass #200 on 3" = s/ t x 100

R ____ = After Wash
M2 ____ = Fines Total

Sieve Stack #______

Gradation Check <=0.3
(R-Pan)/Rx100 = ______

Test by:

Sample Preparation Method

AASHTO R58 & T248

pH of SOIL

Test by:

Result, to .5 ____
Spec ____

ORGANIC CONTENT

Test by:

A. Wt Before + Tare ____
B. Wt After + Tare ____
C. Tare ____
% Organic (A-B)/(A-C)x100 ____
Specification ____

MOISTURE CONTENT

Test by:

A. Wet Wt + Tare ____
B. Dry Wt + Tare ____
C. Tare ____
D. Correction ____
% Moisture (A-B)/(B-C)x100+D ____
Specification ____

ATTERBERG LIMITS

AASHTO T89 & T90

Test by: PK

	Liquid Limit DRY		Liquid Limit WET		Plastic Limit DRY		Plastic Limit WET		Oven Dry LL 1		Oven Dry LL 2	
Blow Count LL	22											
A. Wet Wt + Tare	38.52				37,95							
B. Dry Wt + Tare	36.44				36.63							
C. Tare Wt + Num	28.50	AD			28.70	77						
% Moisture (A-B)/(B-C)x100	26				17							
	26				17							
									Avg LL			

PI Dry
9

PI Spec ____ LL Spec ____

FRACTURE

Test by:

Face	Single	Double
A. Fracture Weight		
B. Questionable Weigh		
C. Unfractured Weig		
% Fracture (B/2+A)/(A+B+C)x100		
Specification		

Comments: Save material if PI found

Checked by
Date Completed 3/22/21

Page 1 of 1

State of Alaska DOT&PF
Central Materials Laboratory
SOILS & AGGREGATE WORKCARD

Information

Laboratory No.: 2021A-0628
Field No.: I-21C-0016
Date Received: 03/15/2021
State Project No. 99910

Project Name: UNASSIGNED: METRIC

SIEVE ANALYSIS

Sieve	Individual	Cumulative	% Ret	% Pass	Specs
100.0					
75.0				t=	
50.0					
37.5					
25.0					
19.0					
12.5					
9.5					
6.3					
4.75		=D			
Pan E		=(A-D)=M1			

Gilson # ______

Total Mass After D+E ____ =G
Total Mass Before ____ =A

Gradation Check <=0.3
(A-G)/Ax100 =

Test by:

Sieve	Cumulative -#4 B	Tot Cumulative D+(M1/M2)xB C	% Ret C/A	% Pass	Specs
2.36					
2.0					
1.18					
.600					
.425					
.300					
0.210					
.150					
.075				s=	
Pan					

% pass #200 on 3" = s / t x 100

Sieve Stack # ______

R ____ = After Wash
M2 ____ = Fines Total

Gradation Check <=0.3
(R-Pan)/Rx100 = ____

Test by:

Sample Preparation Method

AASHTO R58 & T248

pH of SOIL

Test by:

Result, to .5
Spec

ORGANIC CONTENT

Test by:

A. Wt Before + Tare
B. Wt After + Tare
C. Tare
% Organic (A-B)/(A-C)x100
Specification

MOISTURE CONTENT

Test by:

A. Wet Wt + Tare
B. Dry Wt + Tare
C. Tare
D. Correction
% Moisture (A-B)/(B-C)x100+D
Specification

ATTERBERG LIMITS

AASHTO T89 & T90

Test by: PK

	Liquid Limit DRY		Liquid Limit WET		Plastic Limit DRY		Plastic Limit WET		Oven Dry LL 1	Oven Dry LL 2
Blow Count LL	27									
A. Wet Wt + Tare	40.54				39.36					
B. Dry Wt + Tare	38.73				38.09					
C. Tare Wt + Num	2868	22			28.59	L				
% Moisture (A-B)/(B-C)x100	18				13					
	18				13					
PI Dry									Avg LL	

PI Dry: 5

PI Spec ____ LL Spec ____

FRACTURE

Test by:

Face	Single	Double
A. Fracture Weight		
B. Questionable Weigh		
C. Unfractured Weig		
% Fracture (B/2+A)/(A+B+C)x100		
Specification		

Save material if PI is found.
PK

Checked by PK
Date Completed 3/22/21

Page 1 of 1

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES
SOUTHCOAST REGION

PRE-CONSTRUCTION SAMPLE REPORT

PROJECT NAME: **HNS Beach Rd Slide**
PROJECT NO.: **SDRER00317**
DATE RECEIVED: **3/5/2021**
LAB NO: **21C-0012**
FIELD NO: **TP-1 (3')**
HOLE / PIT NO: **TP-1**
DEPTH (FT / IN): **3'**
DATE REPORTED: **3/8/2021**

NATURAL MOISTURE CONTENT

TARE WT	540.9
WET WT & TARE	855.6
DRY WT & TARE	794.9
WET WT OF SOIL	314.7
DRY WT OF SOIL	254.0
PERCENT MOISTURE	**23.9**

ORGANIC CONTENT

TARE WT	
WT & TARE BEFORE	
WT & TARE AFTER	
WT OF MATERIAL BEFORE	
WT OF MATERIAL AFTER	
% ORGANIC CONTENT	

ATTERBURG LIMITS (LL)

	1	2	3			
	L.L.	L.L.	L.L.	1	2	3
NO. BLOWS				P.L.	P.L.	P.L.
WET WT. & TARE						
DRY WT. & TARE						
TARE WT.						
WT. OF MOIST.	0.00	0.00	0.00	0.00	0.00	0.00
DRY WT. OF SOIL	0.00	0.00	0.00	0.00	0.00	0.00
PERCENT MOIST.	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

REMARKS:

GRADATION (METHOD A-AASHTO T11/T27)

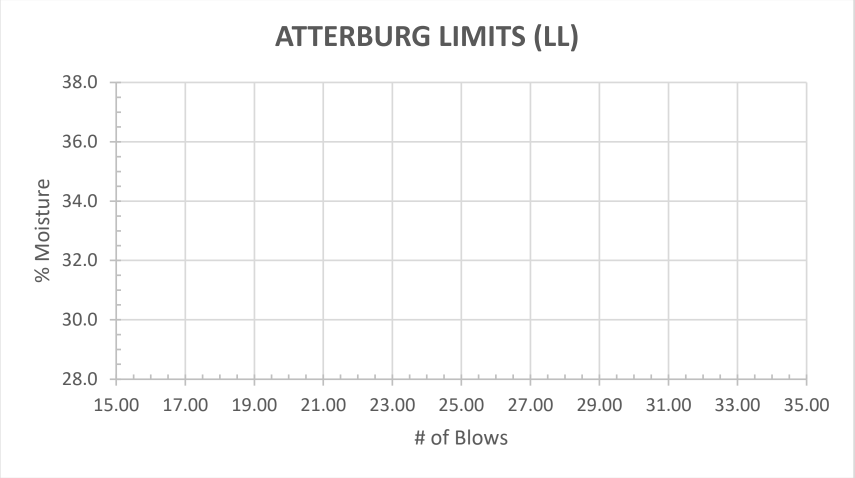
COARSE PORTION

Sieve Size mm (in.)	Cum. Mass Retained **R**	Cum. % Retained (R/M)*100	% Passing (100- Cum. % Retained)
100mm (4")			
75mm (3")			
50mm (2")			
37.5mm (1 1/2")			
25mm (1")	0	0	**100**
19mm (3/4")	11.2	4.4	**96**
12.5mm (1/2")	28.7	11.3	**89**
9.5mm (3/8")	35.4	13.9	**86**
4.75mm (#4)	56.9	22.4	**78**
Dry Mass After Wash before sieving (H)	233.1		
Original Dry Mass (M)	254.0		

FINE PORTION

Sieve Size mm (in)	Cum. Mass Retained **R**	Cum % Retained (R/M)*100	% Passing (100- Cum % Retained)
2.36mm (#8)	86.6	34.1	**66**
1.18mm (#16)	115.8	45.6	**54**
0.600mm (#30)	145.8	57.4	**43**
0.300mm (#50)	178.1	70.1	**30**
0.150mm (#100)	204.8	80.6	**19**
0.075mm (#200)	223.5	88	**12.0**
PAN **P**	233.0		
Total Check Sum < 0.3% [(H-P)/H] x 100		**0.0**	

AASHTO CLASS.	**UNIFIED CLASS.**



OTHER REMARKS:

CHECKED BY:	**WILLIAM COLEMAN, P.E.**	**DATE:**	**3/12/2021**
TESTED BY:	**RICHARD EUBANK**		

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES
SOUTHCOAST REGION

PRE-CONSTRUCTION SAMPLE REPORT

PROJECT NAME: **HNS Beach Rd Slide**
PROJECT NO.:
DATE RECEIVED: **3/5/2021**

LAB NO: **21C-0013**
FIELD NO: **TP-1 (6')**
HOLE / PIT NO: **TP-1**
DEPTH (FT / IN): **6'**
DATE REPORTED: **3/12/2021**

NATURAL MOISTURE CONTENT

TARE WT	549.2
WET WT & TARE	1046.2
DRY WT & TARE	965.9
WET WT OF SOIL	497.0
DRY WT OF SOIL	416.7
PERCENT MOISTURE	**19.3**

ORGANIC CONTENT

TARE WT	
WT & TARE BEFORE	
WT & TARE AFTER	
WT OF MATERIAL BEFORE	
WT OF MATERIAL AFTER	
% ORGANIC CONTENT	

ATTERBURG LIMITS (LL)

	1	2	3			
	L.L.	L.L.	L.L.	1	2	3
NO. BLOWS				P.L.	P.L.	P.L.
WET WT. & TARE						
DRY WT. & TARE						
TARE WT.						
WT. OF MOIST.	0.00	0.00	0.00	0.00	0.00	0.00
DRY WT. OF SOIL	0.00	0.00	0.00	0.00	0.00	0.00
PERCENT MOIST.	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

REMARKS: **Sticks mass=9.0 grams, gradation original dry mass does not include sticks.**

GRADATION (METHOD A-AASHTO T11/T27)

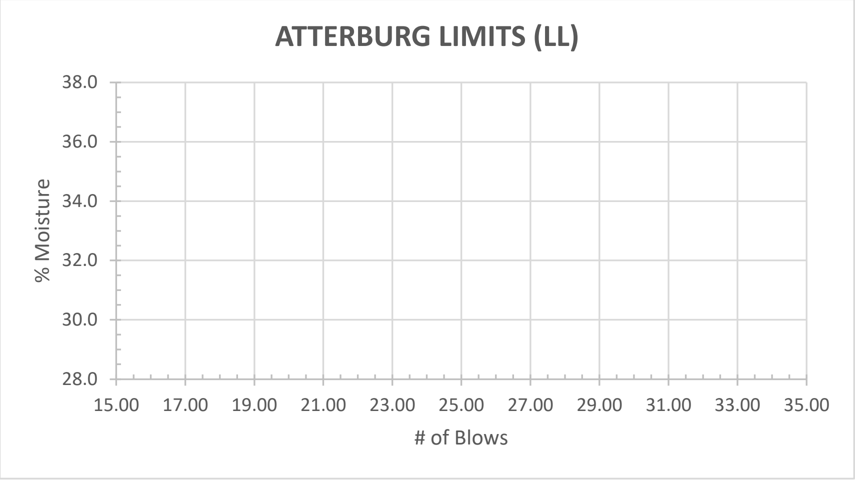
COARSE PORTION

Sieve Size mm (in.)	Cum. Mass Retained **R**	Cum. % Retained (R/M)*100	% Passing (100- Cum. % Retained)
100mm (4")			
75mm (3")			
50mm (2")			
37.5mm (1 1/2")	0	0	**100**
25mm (1")	29.9	7.3	**93**
19mm (3/4")	29.9	7.3	**93**
12.5mm (1/2")	44.1	10.8	**89**
9.5mm (3/8")	66.6	16.3	**84**
4.75mm (#4)	123.9	30.4	**70**
Dry Mass After Wash before sieving (H)	386.4		
Original Dry Mass (M)	407.7		

FINE PORTION

Sieve Size mm (in)	Cum. Mass Retained **R**	Cum % Retained (R/M)*100	% Passing (100- Cum % Retained)
2.36mm (#8)	168.3	41.3	**59**
1.18mm (#16)	210.5	51.6	**48**
0.600mm (#30)	255	62.5	**38**
0.300mm (#50)	302.5	74.2	**26**
0.150mm (#100)	343.6	84.3	**16**
0.075mm (#200)	372.2	91.3	**8.7**
PAN **P**	386.3		
Total Check Sum < 0.3% [(H-P)/H] x 100		**0.0**	

AASHTO CLASS.	UNIFIED CLASS.



OTHER REMARKS:

CHECKED BY:	**WILLIAM COLEMAN, P.E.**	**DATE:**	**3/12/2021**
TESTED BY:	**RICHARD EUBANK**		

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES
SOUTHCOAST REGION

PRE-CONSTRUCTION SAMPLE REPORT

PROJECT NAME: **HNS Beach Rd Slide**
PROJECT NO.:
DATE RECEIVED: **3/5/2021**

LAB NO: **21C-0014**
FIELD NO: **TP-1 (9')**
HOLE / PIT NO: **TP-1 (9')**
DEPTH (FT / IN): **9'**
DATE REPORTED: **3/12/2021**

NATURAL MOISTURE CONTENT

TARE WT	568.2
WET WT & TARE	1306.4
DRY WT & TARE	1286.3
WET WT OF SOIL	738.2
DRY WT OF SOIL	718.1
PERCENT MOISTURE	**2.8**

ORGANIC CONTENT

TARE WT	
WT & TARE BEFORE	
WT & TARE AFTER	
WT OF MATERIAL BEFORE	
WT OF MATERIAL AFTER	
% ORGANIC CONTENT	

ATTERBURG LIMITS (LL)

	1	2	3			
	L.L.	L.L.	L.L.	1	2	3
NO. BLOWS				P.L.	P.L.	P.L.
WET WT. & TARE						
DRY WT. & TARE						
TARE WT.						
WT. OF MOIST.	0.00	0.00	0.00	0.00	0.00	0.00
DRY WT. OF SOIL	0.00	0.00	0.00	0.00	0.00	0.00
PERCENT MOIST.	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

REMARKS:

GRADATION (METHOD A-AASHTO T11/T27)

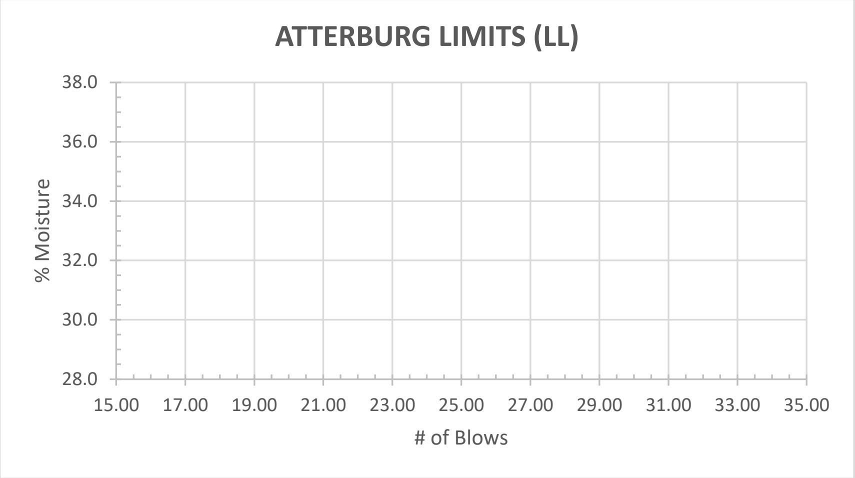
COARSE PORTION

Sieve Size mm (in.)	Cum. Mass Retained **R**	Cum. % Retained (R/M)*100	% Passing (100- Cum. % Retained)
100mm (4")			
75mm (3")			
50mm (2")			
37.5mm (1 1/2")			
25mm (1")			
19mm (3/4")			
12.5mm (1/2")			
9.5mm (3/8")			
4.75mm (#4)			
Dry Mass After Wash before sieving (H)			
Original Dry Mass (M)			

FINE PORTION

Sieve Size mm (in)	Cum. Mass Retained **R**	Cum % Retained (R/M)*100	% Passing (100- Cum % Retained)
2.36mm (#8)			
1.18mm (#16)			
0.600mm (#30)			
0.300mm (#50)			
0.150mm (#100)			
0.075mm (#200)			
PAN **P**			
Total Check Sum < 0.3% [(H-P)/H] x 100			

AASHTO CLASS.	**UNIFIED CLASS.**



OTHER REMARKS:

CHECKED BY:	**WILLIAM COLEMAN, P.E.**	**DATE:**	**3/12/2021**
TESTED BY:	**RICHARD EUBANK**		

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES
SOUTHCOAST REGION

PRE-CONSTRUCTION SAMPLE REPORT

PROJECT NAME: **HNS Beach Rd Slide**
PROJECT NO.:
DATE RECEIVED: **3/5/2021**

LAB NO: **21C-0014 + 21C-0015**
FIELD NO: **TP-1 (9-14')**
HOLE / PIT NO: **TP-1 (9-14')**
DEPTH (FT / IN): **9-14'**
DATE REPORTED: **3/15/2021**

NATURAL MOISTURE CONTENT

TARE WT	
WET WT & TARE	
DRY WT & TARE	
WET WT OF SOIL	
DRY WT OF SOIL	
PERCENT MOISTURE	

ORGANIC CONTENT

TARE WT	
WT & TARE BEFORE	
WT & TARE AFTER	
WT OF MATERIAL BEFORE	
WT OF MATERIAL AFTER	
% ORGANIC CONTENT	

ATTERBURG LIMITS (LL)

	1	2	3			
	L.L.	L.L.	L.L.	1	2	3
NO. BLOWS				P.L.	P.L.	P.L.
WET WT. & TARE						
DRY WT. & TARE						
TARE WT.						
WT. OF MOIST.	0.00	0.00	0.00	0.00	0.00	0.00
DRY WT. OF SOIL	0.00	0.00	0.00	0.00	0.00	0.00
PERCENT MOIST.	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

REMARKS: **Gradation is samples 21C-0014 & 21C-0015 (9-14' depth) combined after moisture was run.**

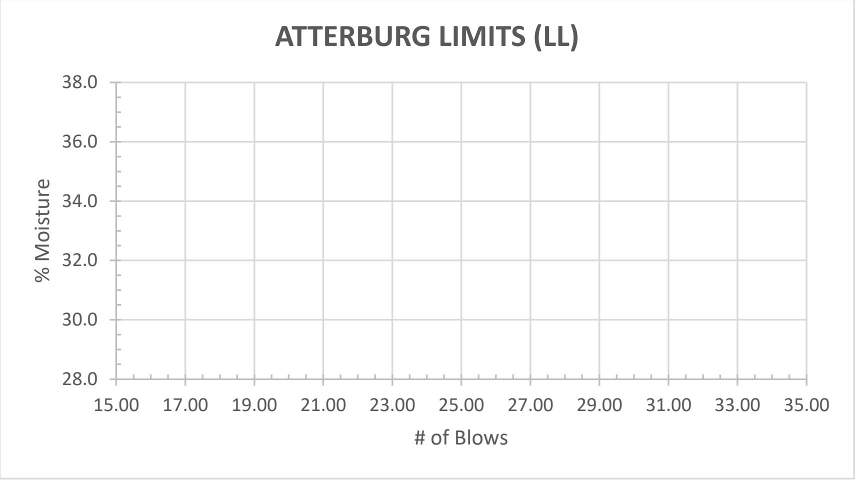
GRADATION (METHOD A-AASHTO T11/T27)

COARSE PORTION

Sieve Size mm (in.)	Cum. Mass Retained **R**	Cum. % Retained (R/M)*100	% Passing (100- Cum. % Retained)
100mm (4")			
75mm (3")	0	0	**100**
50mm (2")	360	17.5	**83**
37.5mm (1 1/2")	360	17.5	**83**
25mm (1")	554.3	26.9	**73**
19mm (3/4")	711.7	34.5	**66**
12.5mm (1/2")	820	39.7	**60**
9.5mm (3/8")	860.8	41.7	**58**
4.75mm (#4)	988.2	47.9	**52**
Dry Mass After Wash before sieving (H)	1988		
Original Dry Mass (M)	2062.9		

FINE PORTION

Sieve Size mm (in)	Cum. Mass Retained **R**	Cum % Retained (R/M)*100	% Passing (100- Cum % Retained)
2.36mm (#8)	1118.0	54.2	**46**
1.18mm (#16)	1281.9	62.1	**38**
0.600mm (#30)	1467.6	71.1	**29**
0.300mm (#50)	1680.6	81.5	**19**
0.150mm (#100)	1844.3	89.4	**11**
0.075mm (#200)	1937.2	93.9	**6.1**
PAN **P**	1986.1		
Total Check Sum < 0.3% [(H-P)/H] x 100		**0.1**	



AASHTO CLASS.	UNIFIED CLASS.

OTHER REMARKS:

CHECKED BY:	**WILLIAM COLEMAN, P.E.**	**DATE:**	**3/15/2021**
TESTED BY:	**RICHARD EUBANK**		

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES
SOUTHCOAST REGION

PRE-CONSTRUCTION SAMPLE REPORT

PROJECT NAME: **HNS Beach Rd Slide**
PROJECT NO.:
DATE RECEIVED: **3/5/2021**

LAB NO: **21C-0015**
FIELD NO: **TP-1 (14')**
HOLE / PIT NO: **TP-1 (14')**
DEPTH (FT / IN): **14'**
DATE REPORTED: **3/15/2021**

NATURAL MOISTURE CONTENT

TARE WT	533.2
WET WT & TARE	2021.2
DRY WT & TARE	1878.0
WET WT OF SOIL	1488.0
DRY WT OF SOIL	1344.8
PERCENT MOISTURE	**10.6**

ORGANIC CONTENT

TARE WT	
WT & TARE BEFORE	
WT & TARE AFTER	
WT OF MATERIAL BEFORE	
WT OF MATERIAL AFTER	
% ORGANIC CONTENT	

ATTERBURG LIMITS (LL)

	1	2	3			
	L.L.	L.L.	L.L.	1	2	3
NO. BLOWS				P.L.	P.L.	P.L.
WET WT. & TARE						
DRY WT. & TARE						
TARE WT.						
WT. OF MOIST.	0.00	0.00	0.00	0.00	0.00	0.00
DRY WT. OF SOIL	0.00	0.00	0.00	0.00	0.00	0.00
PERCENT MOIST.	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

REMARKS:

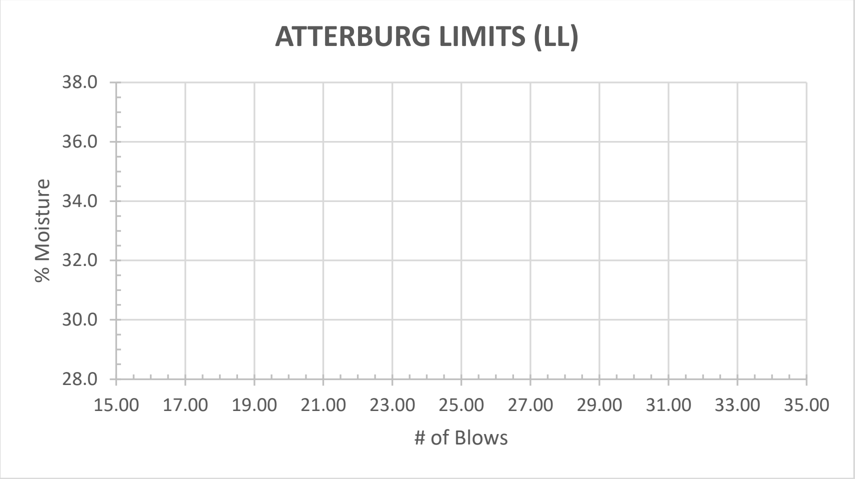
GRADATION (METHOD A-AASHTO T11/T27)

COARSE PORTION

Sieve Size mm (in.)	Cum. Mass Retained **R**	Cum. % Retained (R/M)*100	% Passing (100- Cum. % Retained)
100mm (4")			
75mm (3")			
50mm (2")			
37.5mm (1 1/2")			
25mm (1")			
19mm (3/4")			
12.5mm (1/2")			
9.5mm (3/8")			
4.75mm (#4)			
Dry Mass After Wash before sieving (H)			
Original Dry Mass (M)			

FINE PORTION

Sieve Size mm (in)	Cum. Mass Retained **R**	Cum % Retained (R/M)*100	% Passing (100- Cum % Retained)
2.36mm (#8)			
1.18mm (#16)			
0.600mm (#30)			
0.300mm (#50)			
0.150mm (#100)			
0.075mm (#200)			
PAN **P**			
Total Check Sum < 0.3% [(H-P)/H] x 100			



AASHTO CLASS.	UNIFIED CLASS.

OTHER REMARKS:

CHECKED BY:	WILLIAM COLEMAN, P.E.	DATE:	3/15/2021
TESTED BY:	RICHARD EUBANK		

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES
SOUTHCOAST REGION

PRE-CONSTRUCTION SAMPLE REPORT

PROJECT NAME: **HNS Beach Rd Slide**
PROJECT NO.:
DATE RECEIVED: **3/5/2021**

LAB NO: **21C-0016**
FIELD NO: **TP-2 (11')**
HOLE / PIT NO: **TP-2 (11')**
DEPTH (FT / IN): **11'**
DATE REPORTED: **3/15/2021**

NATURAL MOISTURE CONTENT

TARE WT	537.5
WET WT & TARE	1219.5
DRY WT & TARE	1138.4
WET WT OF SOIL	682.0
DRY WT OF SOIL	600.9
PERCENT MOISTURE	**13.5**

ORGANIC CONTENT

TARE WT	
WT & TARE BEFORE	
WT & TARE AFTER	
WT OF MATERIAL BEFORE	
WT OF MATERIAL AFTER	
% ORGANIC CONTENT	

ATTERBURG LIMITS (LL)

	1	2	3			
	L.L.	L.L.	L.L.	1	2	3
NO. BLOWS				P.L.	P.L.	P.L.
WET WT. & TARE						
DRY WT. & TARE						
TARE WT.						
WT. OF MOIST.	0.00	0.00	0.00	0.00	0.00	0.00
DRY WT. OF SOIL	0.00	0.00	0.00	0.00	0.00	0.00
PERCENT MOIST.	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

REMARKS: **LL/PI (Atterberg Limits) sent to Anchorage for testing on 3/12/21**

GRADATION (METHOD A-AASHTO T11/T27)

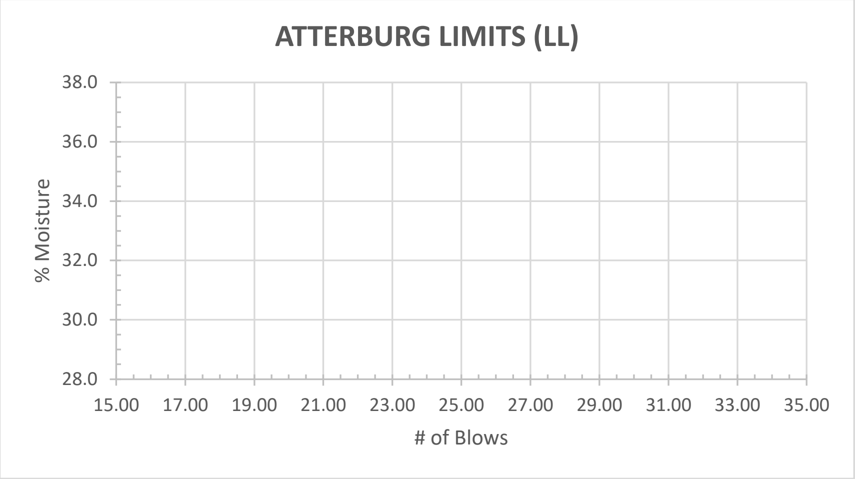
COARSE PORTION

Sieve Size mm (in.)	Cum. Mass Retained **R**	Cum. % Retained (R/M)*100	% Passing (100- Cum. % Retained)
100mm (4")			
75mm (3")			
50mm (2")			
37.5mm (1 1/2")			
25mm (1")			
19mm (3/4")			
12.5mm (1/2")			
9.5mm (3/8")			
4.75mm (#4)			
Dry Mass After Wash before sieving (H)			
Original Dry Mass (M)			

FINE PORTION

Sieve Size mm (in)	Cum. Mass Retained **R**	Cum % Retained (R/M)*100	% Passing (100- Cum % Retained)
2.36mm (#8)			
1.18mm (#16)			
0.600mm (#30)			
0.300mm (#50)			
0.150mm (#100)			
0.075mm (#200)			
PAN **P**			
Total Check Sum < 0.3% [(H-P)/H] x 100			

AASHTO CLASS.	**UNIFIED CLASS.**



OTHER REMARKS:

CHECKED BY:	**WILLIAM COLEMAN, P.E.**	**DATE:**	**3/15/2021**
TESTED BY:	**RICHARD EUBANK**		

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES
SOUTHCOAST REGION

PRE-CONSTRUCTION SAMPLE REPORT

PROJECT NAME: **HNS Beach Rd Slide**
PROJECT NO.:
DATE RECEIVED: **3/5/2021**

LAB NO: **21C-0017**
FIELD NO: **TP-4 (9-14')**
HOLE / PIT NO: **TP-4 (9-14')**
DEPTH (FT / IN): **9-14'**
DATE REPORTED: **3/15/2021**

NATURAL MOISTURE CONTENT

TARE WT	537.1
WET WT & TARE	1475.7
DRY WT & TARE	1344.0
WET WT OF SOIL	938.6
DRY WT OF SOIL	806.9
PERCENT MOISTURE	**16.3**

ORGANIC CONTENT

TARE WT	
WT & TARE BEFORE	
WT & TARE AFTER	
WT OF MATERIAL BEFORE	
WT OF MATERIAL AFTER	
% ORGANIC CONTENT	

ATTERBURG LIMITS (LL)

	1	2	3			
	L.L.	L.L.	L.L.	1	2	3
NO. BLOWS				P.L.	P.L.	P.L.
WET WT. & TARE						
DRY WT. & TARE						
TARE WT.						
WT. OF MOIST.	0.00	0.00	0.00	0.00	0.00	0.00
DRY WT. OF SOIL	0.00	0.00	0.00	0.00	0.00	0.00
PERCENT MOIST.	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

REMARKS: **LL/PI (Atterberg Limits) sent to Anchorage for testing on 3/12/21**

GRADATION (METHOD A-AASHTO T11/T27)

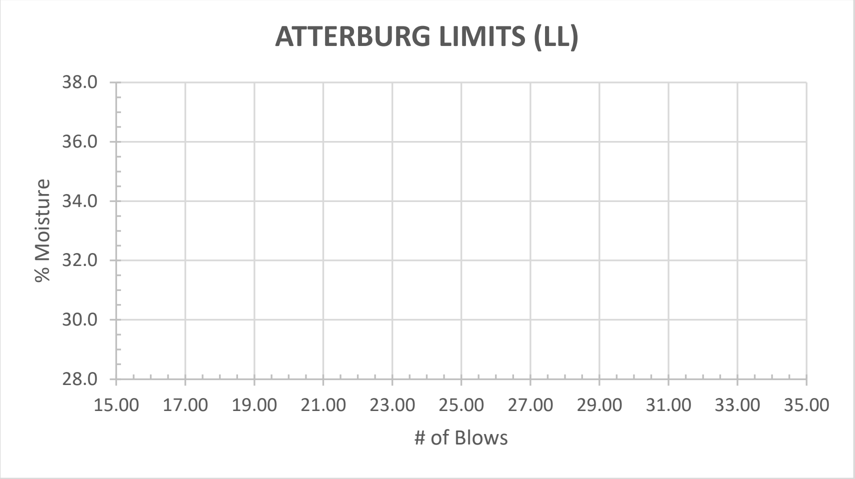
COARSE PORTION

Sieve Size mm (in.)	Cum. Mass Retained **R**	Cum. % Retained (R/M)*100	% Passing (100- Cum. % Retained)
100mm (4")			
75mm (3")			
50mm (2")			
37.5mm (1 1/2")			
25mm (1")			
19mm (3/4")			
12.5mm (1/2")			
9.5mm (3/8")			
4.75mm (#4)			
Dry Mass After Wash before sieving (H)			
Original Dry Mass (M)			

FINE PORTION

Sieve Size mm (in)	Cum. Mass Retained **R**	Cum % Retained (R/M)*100	% Passing (100- Cum % Retained)
2.36mm (#8)			
1.18mm (#16)			
0.600mm (#30)			
0.300mm (#50)			
0.150mm (#100)			
0.075mm (#200)			
PAN **P**			
Total Check Sum < 0.3% [(H-P)/H] x 100			

AASHTO CLASS.	UNIFIED CLASS.



OTHER REMARKS:

CHECKED BY:	**WILLIAM COLEMAN, P.E.**	**DATE:**	**3/15/2021**
TESTED BY:	**RICHARD EUBANK**		

APPENDIX F: SPRING RECONNAISSANCE AND GEOTECHNICAL INVESTIGATION RECOMMENDATIONS

SPRING RECONNAISSANCE AND GEOTECNICAL INVESTIGATION RECOMMENDATIONS

The following are preliminary recommendations (provided in outline form) for tasks that could be performed at the site to advance the understanding of the slide and the surrounding slopes within the AOC, specifically for the purpose of evaluating and managing geologic hazards while supporting initial community recovery efforts. The recommendations include: i) obtaining extended 2014 LiDAR imagery near and above the headscarp of the slide and to the east of the slide, ii) a supplemental geologic reconnaissance (Spring Reconnaissance) to field-truth preliminary geomorphic interpretations obtained during the winter reconnaissance, and iii) a program of exploratory borings with instrumentation to provide and monitor subsurface data, potential slide movement(s), and groundwater data.

Spring Reconnaissance

The spring reconnaissance should be done after snow has melted at the site and ideally, prior to the arrival of spring foliage.

1. Map drainages and locations of springs
2. Evaluate wet areas on topographic benches/troughs
3. Map drainages and springs along margins of slide and within the slide debris.
4. Evaluate depression/hollow basin upslope of headscarp (ponded or dry? Storage capacity?).
5. Evaluate springs and residential springwater systems
6. Bedrock outcrop mapping, with structure measurements
7. Map possible evidence of faulting (fault-displaced blocks, fault gouge, etc.).
8. Evaluate material exposed in headscarp (east, south and west portions)
9. Collect rock samples for mineralogy evaluations (to determine if weak zones exist within bedrock).
10. Map east tension crack limits. Measure direction of displacement (based on connecting pints on both sides of the tension crack, such as extended roots, fractured ground, matching elements) and measure horizontal and vertical displacements.
11. Look for possible additional tension cracks and map their locations
12. Evaluate and classify debris materials within various zones of the landslide. Estimate gradations. Obtain samples for lab testing (moisture content, Atterberg limits). Interpret depths of slide debris along length of slide, based on surficial expressions.
13. Test pits (or defer to geotechnical investigations).
    a. Along road to fill-in gaps between first 4 test pits (TP-1 through TP-4).
    b. At midslope west area bench, if accessible for trackhoe (access from Mt Riley Road?).
14. Evaluate source of 2nd flow slide. Map the source area.
15. Evaluate if lobes of the debris slide flowed towards other drainages or topographic lows.
16. Evaluate if adjacent wet area benches liquefied or were disturbed.
17. Install X-Y crack meters at 3 locations. Install cable extensometers at 3 locations. Install ADAS or defer until geotechnical investigation?
18. Consider establishing survey prisms at 6 to 10 locations within slide debris areas.

Evaluations/Studies

1. Update geology interpretations maps
2. Update cross sections
3. Summarize bedrock conditions, including rock structures and mineralogy tests
4. Prepare profile of slide debris scouring and deposition along Beach Road
5. Update evaluation of landslide and causation
6. Update recommendations for geotechnical investigation and instrumentation
7. Preliminary debris flow slide runout modeling analyses
8. If instrumentation was installed, establish online portal and develop data plotting formats. Provide troubleshooting and management for X months.
9. Spring Reconnaissance Findings Report (update the Winter Recon report?).

Subsurface Investigations and Instrumentation

This work should be performed following the spring reconnaissance effort and consists of the following:

1. Borings to evaluate hillside overburden and bedrock conditions and stratigraphy, and landslide thickness and conditions. This information will provide data for developing geotechnical models for analyzing geologic hazards and slope stability.
   a. Most borings would be located on the steep hillside, which will necessitate use of lightweight/mobile drill rigs, mobilized by helicopter. Locations of potential borings are shown on Figure F-1. Tree clearing will be necessary where helicopter drops and boring locations are planned. It might be possible to move drills to several locations from one helicopter drop point, using cables, winches, etc. Delivering water to the drill will be challenging, probably by helicopter to onsite portable water storage tanks (flexible, collapsible).
   b. Each boring should be drilled a minimum 40 feet into rock to verify inplace bedrock conditions, terminating in at least 20 feet of fresh unweathered bedrock. Oriented core (if feasible) would be desirable to measure joint structure. In addition, downhole camera would be used to record the rock structure.
   c. Piezometers are planned to measure water pressures at various depths (in overburden, fractured upper zones of bedrock, and deep bedrock) to quantify groundwater pressures and distribution with depth. Vibrating wire piezometers will be installed to enable digital readout and data acquisition.
   d. Inclinometers would likely consist of MEMS string arrays (Measurand) to detect possible displacements at any depth penetrated by the borings.
   e. Instruments will be automated with dataloggers and remotely accessed using an ADAS system consisting of local radio transmitters and telemetry to export the data.
2. Test pits (potential TP locations are shown on Figure F-1).
   a. Along road to fill-in gaps between first 4 test pits (TP-1 through TP-4).
   b. At midslope west area bench, if accessible for trackhoe (access from Mt Riley Road?).
3. Laboratory Tests (DOT or R&M labs)

4. Install (or check condition of previously-installed) X-Y crack meters at multiple locations. Install cable extensometers at approximately 3 locations. Install ADAS.
5. Consider establishing survey prisms at 6 to 10 locations within slide debris areas (or this may have been previously implemented).

Evaluations/Studies

1. Boring and test pit logs.
2. Update geology interpretations maps
3. Update cross sections, and include borings and interpreted stratigraphy
4. Summarize bedrock conditions, including rock structures and mineralogy tests
5. Prepare profile of slide debris scouring and deposition along Beach Road
6. Update evaluation of landslide and causation
7. Geotechnical Data Report
8. Recommendations for geotechnical instrumentation monitoring and evaluation
9. Preliminary slope stability analyses
10. Preliminary debris flow slide runout modeling analyses
11. Establish online portal and develop data plotting formats. Provide troubleshooting and management for several months at a minimum.
12. Geotechnical Instrument Monitoring update memos.
13. Geotechnical Evaluations Report to summarize analyses, interpretations, conclusions, and recommendations.

Instrumentation

1. Piezometers are used to detect groundwater pressures, possible artesian conditions, and changes in groundwater pressures due to weather events. Key locations for piezometers would include areas suspected to high hydrostatic pressures, such as: a) wet colluvial area midway between road and headscarp, b) within upper slide debris, c) within upper slope near east tension crack, and d) toe of slope near Beach Road. Vibrating wire piezometers are commonly used with automated data collection loggers (dataloggers) to store the measured groundwater pressures. Manual downloading from the dataloggers could be performed, but automated data acquisition systems would be preferential to minimize labor intensive site access.

2. Inclinometers are used to detect subsurface displacements, such as slide shear zones and creep. Key locations for inclinometers would include slide areas and slopes in the Area of Concern (AOC), such as: a) wet colluvial area midway between road and headscarp, b) within upper slide debris, and c) upslope and downslope of the east tension crack. Manual monitoring could be performed, but is labor intensive because of difficult site access. Therefore, automated data acquisition systems could be employed including MEMS (Micro Electrical Mechanical System) digital sensor strings. MEMS strings consist of a continuous string of sensors to detect deep ground movement at any depth. The direction of subsurface movement can also be measured.

3. Crack meters could detect whether the east tension crack enlarges, indicative of possible slope movement or subsidence. Manual monitoring could be performed, but is labor

intensive because of difficult site access. Therefore, digital crack meters and automated data acquisition systems would be preferred.

4. Surface extensometers could be used to determine if the ground downslope of the east tension crack displaces. The surface extensometers consist of long-range displacement digital transducers with wire cables extending from fixed positions upslope of tension cracks to positions downslope areas within suspected slide blocks or marginally-stable slopes.
5. Tell-tale stakes could be established upslope of the headscarp along lines to roughly visualize and measure the amount of scarp calving over time (landslide retrogression). The stakes and distances of retrogression would be periodically monitored and measured manually.
6. All digital instruments should utilize automated data acquisition methods, which would need power supplies and telemetry.

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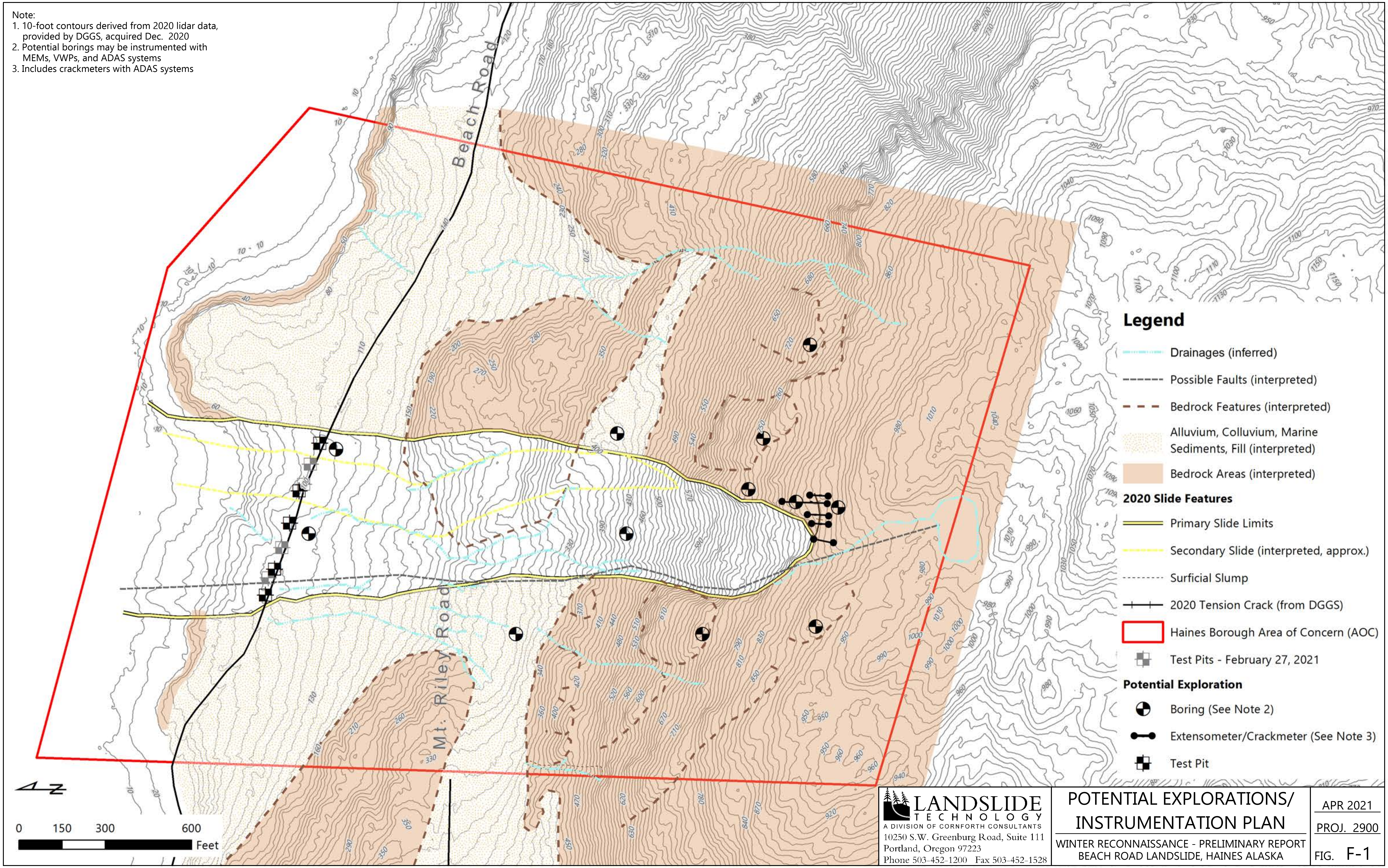
Note:
1. 10-foot contours derived from 2020 lidar data, provided by DGGS, acquired Dec. 2020
2. Potential borings may be instrumented with MEMs, VWPs, and ADAS systems
3. Includes crackmeters with ADAS systems



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POTENTIAL EXPLORATIONS/ INSTRUMENTATION PLAN

WINTER RECONNAISSANCE - PRELIMINARY REPORT
BEACH ROAD LANDSLIDE, HAINES ALASKA

APR 2021
PROJ. 2900
FIG. F-1