LANDSLIDE TECHNOLOGY
A DIVISION OF CORNFORTH CONSULTANTS

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Subject:	**Spring Surface Reconnaissance Memo** **Haines Beach Road Landslide – NTP2 Task 5.1** **PSA Agreement No. 25213018, IRIS No. SDRER00317**	

This memo is a deliverable for the Task 5.1 Spring Reconnaissance work conducted for the Haines Beach Road Landslide. It includes a brief summary of the field results and opinions on risk associated with the geohazards within the Haines Borough Area of Concern (AOC). Further evaluation and assessment of this data will be performed as the project progresses, additional data is collected and summarized, and the Findings Report is updated.

BACKGROUND INFORMATION

Three personnel from Landslide Technology (LT) were on site from July 5 through July 12, 2021, to collect field reconnaissance information to supplement that which was provided in the *Winter Reconnaissance – Preliminary Findings Report* dated April 8, 2021. The landslide and surrounding slopes west and east of the upper slopes were traversed to observe and map the site geology, prominent landslide features, landslide debris, and surface water within the landslide. A reconnaissance interpretation map is provided as Figure 1. A summary of the information collected is provided below.

This *Spring Surface Reconnaissance Memo* is an interim report, similar to the *Winter Reconnaissance - Preliminary Findings Report*. Data and opinions provided herein will be incorporated and updated as necessary within a *Final Findings Report*. The *Final Findings Report* is planned following completion of the subsurface drilling investigation, instrumentation installation, and finalization of the geophysics surveys.

SITE GEOLOGY

Geologic materials observed during the spring reconnaissance include in-place rock (often referred to as "bedrock") and overburden sediments. The sediments are presented below in three groups: marine and glacial, colluvium, and debris flow deposits.

In-Place Rock (Bedrock)

In-place rock at the Beach Road Landslide is comprised predominantly of an ultramafic rock formation, along with relatively small, localized felsic intrusions. The ultramafic rock is banded, with layers that appear to be defined primarily by rock hardness and the grain size of the mineral's biotite and pyroxene. Thicknesses of the layers range from 6 inches or less to a maximum observed 8 feet, as observed in rock exposed in the landslide's upper scarps. The thickness of individual rock layers varies considerably, often pinching to half the thickness over distances of 30 to 40 feet.

Felsic intrusions are a minimal component of the bedrock, estimated less than 5%. The intrusions appear to be primarily planar/tabular shaped, and range in thickness from less than 1 inch to 5 feet. Multiple episodes of intrusion have occurred. The initial intrusion appears to be parallel to the layering in the ultramafic rock, while later intrusions crisscross the ultramafic layering. Felsic intrusions do not appear to associate with differences in the rock mass characteristics and weathering.

Rock hardness appears to vary by layer. The layers containing medium- to coarse-grained biotite are typically soft rock (rock hardness R2), while the layers of fine-grained ultramafic rock are typically medium hard to hard (R3-R4). Felsic intrusions are typically medium hard to hard rock (R3-R4). Some layers of the mafic rock exhibit decomposed or saprolitic character with extremely soft rock hardness (R0). For reference, rock hardness is a descriptor of geologic materials used in classifying rock for engineering purposes. The Rock Hardness descriptors include: R0 (estimated range of unconfined compressive strength <100 psi), R1 (100-100 psi), R2 (1,000-4,000 psi), R3 (4,000-8,000 psi), R4 (8,000-16,000 psi) and R5 (>16,000 psi). Other descriptors used in rock and soil classification will be referenced in a *Final Findings Report*. The color of the rock layers varies from gray to black. The rock layers that are decomposed are brown-gray to gray-brown.

The rock contains structures including joints and fractures as well as the layers. A summary of the rock structure data is provided in Appendix A. In general, a primary set of relatively continuous joints is parallel to the layering in the ultramafics. This jointing (and layering) dips approximately 70° to the northeast (azimuth 047°). A secondary set of joints/fractures cuts across the layering, is less continuous than the primary joints, and dips approximately 80° to the northwest (azimuth 330°). A set of tertiary joints are not continuous across multiple layers and they dip between 60 and 85° to the east-southeast (or west-southwest). An additional tertiary joint set dips shallowly (between 12 and 30°) to the west-southwest.

Occasionally, the ultramafic rock is sheared, often parallel to the layering, but shears also cut across the rock layers. The sheared zones exhibit a high degree of fracturing and weathering with some zones that are decomposed. The sheared zones often contain micro and macro textures that include striations and fractures with asymmetric kinematic indicators of fault displacement with lateral/sideways movement. Vertically oriented striations (kinematic indicators of up/down movement), were also observed on one shear zone that cuts across rock layers. In general, other vertically oriented kinematic indicators include tension cracks within slide debris, settlement within the layered ultramafic rock and in-place colluvium, and pressure ridges in lobate-shaped debris flow deposits.

Occasionally, layers of ultramafic rock are also highly fractured, significantly more fractured than the joint and fracture sets described above. The layers of highly fractured rock occur in zones that appear to be associated with open fracture zones between tilted blocks. The highly fractured rock also appears to be the harder, medium-grained ultramafic.

Overburden Sediments

Overburden materials/deposits that are encountered in the Beach Road Landslide area include, from oldest to youngest, marine sediments, glacial (till?), colluvium (both weathered in place and transported), and debris flow fans. Overburden was encountered everywhere except for steep, rock slopes. Small areas of alluvium were also encountered, but are limited in extent and often associated with narrow ravines and local debris flow fans

Marine and Glacial Sediment

Near the headscarp, a layer of medium dense to dense, gray, silty sandy gravel to gravelly sand with silt and traces of clay was observed underlying topsoil and overlying the in-place rock. The material contained subrounded to rounded gravel to cobbles of ultramafics and granodiorite that are decomposed to moderately weathered. This gray layer of soil is relatively thin (estimated less than 5 feet) and likely discontinuous, and appears to be glacial in origin, possibly a till or lodgment till, with remnants of outwash. In addition, it may be contemporaneous with the gray marine sediment observed in test pits at lower elevations.

Colluvium and Talus

Colluvium varies from thin deposits (typically 5 feet or less), which overlies relatively shallow bedrock, to greater than 30-foot-thick deposits of weathered in-place colluvium, which is well exposed in a portion of the upper east lateral scarp. Thickness of talus deposits was not directly observable during the site reconnaissance.

Colluvium on 35-40° slopes appears to be primarily weathered in-place and consists of rotated and tilted rock blocks with fractured rock and soil-filled graben features in between. The ground surface on these slopes is comprised of sloping benches that trend from obliquely up, to across the slope (southeast-northwest to east-west, respectively). The size of the sloping benches varies and is described in two groups: large and small. The larger benches tend to be 20 to 50 feet wide and 100 to 250 feet long, and well pronounced on the ground surface as large mounds or block terrain. The small sloping benches are typically 5 to 20 feet wide and 50 to 100 feet long, and less pronounced on the ground surface. Color of the fine-grained sandy soil in this colluvium is variable and includes red-brown, brown-gray, gray-brown, shades of gray, and black.

Colluvium on slopes that range from 25-35° consists primarily of boulder- to gravel-sized rock fragments and sand. These slopes are typically downslope of the rotated and tilted block colluvium and its "benched" terrain, but also occur upslope and laterally adjacent to steeper terrain. These gentler slope colluvium deposits appear to contain materials that are more weathered than the in-place colluvium, and transported downslope, resulting in a higher degree of grain size breakdown and reduction in material strength, thus the flatter slopes formed by these materials. Distribution of these materials and downslope migration was observed both on the western and eastern sides of the landslide. In addition, in the east lateral flank, the transition from tilted rock blocks (upslope) to greater percentage of soil colluvium (downslope) is enhanced at rock layer-parallel shears/faults, similar to those that are exposed in the headscarp. The color of this colluvium is primarily brown and gray-brown.

In local areas, some of the colluvium appears to consist of coarse-grained (gravel-to boulder-sized) rock fragments, with few fine-grained materials (sand and silt), and appear to be talus deposits downslope of cliffs overgrown by the forest. The talus slopes range from 33 to 38°, and have a consistent slope grade without sloped benches.

In addition to the sandy gravel and boulder talus, colluvium that contained larger boulders and rock blocks were observed within the upper landslide area and along the eastern side of the AOC. These areas were observed to include accumulations of boulders to blocks larger than 20 feet in maximum dimension. Singular blocks larger than 20 feet were also observed; however, the origin of these singular blocks is uncertain and could be transported by a debris flow, rolled from a cliff failure, or deposited from glacial ice.

Debris Flow Deposits

Within the scoured west flank of the lower area of the landslide, near elevation 170 feet, pre-existing old debris flow deposits were observed consisting of gravelly sand, with gravel- to cobble-sized, rounded to sub-angular rock clasts. Buried root horizons revealed at least two event deposits, plus the December 2020 event that scoured the flank and deposited new debris flow materials over the flank, within the relatively gentle slopes that occur at the lower elevations of the area.

Local debris flow fans also occur where drainage swales transition to gentler slopes, such as the upslope side of topographic benches. Local drainages within the upper, steeper slopes are the sources of the debris flow deposits that fan out where the drainages encounter gentler grades/slopes.

LANDSLIDE FEATURES

For discussion purposes, the landslide is described in general as a slump and debris flow. The slump portion includes an Upper Rock Slump and a Middle Boulder Field on the steep slopes of Mt. Riley. The slump is the source of the landslide debris. The toe of the upper slump transitions to a Lower Debris Flow where the steep slopes become gentler, primarily at a sloped bench elevation that is approximately halfway down the slide.

A gently inclined and somewhat discontinuous series of benches occur mid-slope, at the toe of the steep upper slopes. These benches are identified as the Mt. Riley Road "benches". Downslope of the benches the landslide was a debris flow on gentler slopes that include Beach Road, and ends with a step down to a shoreline bench. The discontinuous nature and local slope orientation of the benches also created a low area within the west side of the landslide that landslide debris flowed through.

Features observed on the landslide during the spring reconnaissance include the headscarp, lateral rock scarps and lateral soil scarps, tension cracks, landslide debris and lateral extents, flowing surface water, and seepage points. Mapping of these features has been refined based on spring reconnaissance observations. Updated geologic and topographic interpretation maps are provided as Figure 1. Photographs taken during the spring reconnaissance are attached as Appendix B Photo Exhibits.

Headscarp

The landslide's headscarp is, in general, oblique to the main body of the slide and the lateral scarps. The headscarp trends approximately northwest-southeast between approximate elevation 800 feet on the west and 860 feet on the east. The height of the headscarp varies from 15 to 25 feet, and the headscarp slope angle varies from 25 to 80°. Photos showing the headscarp are provided as Photo Exhibit 1 through 8.

The headscarp is irregular and appears to be comprised of two scarps (west and east), which together face generally toward azimuth 045° (northeast). Between the two scarps, the headscarp steps upslope and across slabs of layered ultramafic rock between elevation 830 and 840 feet (Photo Exhibits 2 and 3). In-place rock materials that are the surface of the headscarp are comprised of extremely soft (R0) to very soft (R1) decomposed and sheared ultramafic rock, except where the headscarp steps across medium hard (R3) to hard (R4) layers. The headscarp appears to be formed by release along geologic structures (i.e., shears and joints).

Lateral Scarps

Lateral scarps include upper rock scarps, mid-slope soil (colluvium) scarps, and lower debris flow scarps. The headscarp transitions into the upper lateral rock scarps that form the sides of the Upper Rock Slump. The upper rock scarps are exposing in-place rock, while the middle debris field scarps are a combination of colluvium and scour, and the lower debris flow scarps include scour but also debris deposits.

Upper Lateral Rock Scarps

On the upper eastern flank between approximate elevation 800 and 860 feet, and on the western flank between approximate elevation 690 and 800 feet, the lateral scarps are 20 to 30 feet in height and have slope angles that vary between 45 and 80 degrees. These upper lateral scarps appear to be formed by release along geologic structures (i.e., shears, joints). Rock exposed in these scarps ranges from extremely soft (R0) decomposed ultramafics up to hard (R4) layers of fine to medium grained ultramafics. Photos showing the eastern and western lateral scarps of the upper rock slump are shown on Photo Exhibits 9, 10 and 12, respectively. There are many exposures of structures within the lateral scarps with a dip direction to the north-northeast (040-050°) that have both high angle dips of 70-85° and lower to moderate angle dips of 40-60°. The lower angle dips are similar to the headscarp. An example of the high angle dipping layers is shown on Photo Exhibits 3, 9 and 10. However, the lateral scarps around the upper slump blocks appear to be comprised primarily of a set of orthogonal jointing that dips 70-80° in the north-northwest direction (320-340°).

Sheared and faulted rock was observed at two locations on the eastern lateral scarp at approximate elevations 810 and 830 feet. Photo Exhibit 11 shows two areas of fractured and sheared rock that are approximately parallel to the layered ultramafics. The shear at elevation 810 feet is approximately 4 feet wide and the shear at elevation 830 feet is approximately 10 inches wide.

The rock layers are generally dipping steeply to the northeast; however, based on openness and occasional displacement along joints and fractures, the rock layers also appear to be slightly rotated or tilted in-place, both upslope and downslope. Occasionally, joints and fractures in the upper rock scarps are sufficiently open and fractured rock has fallen into the spaces, forming a graben feature. Based on infill, soil overburden and vegetation, the tilting and rotation appears to have occurred primarily before the recent slide/slump movement; however, some occurred at the same time as the recent landslide movements.

Mid-Slope Lateral Soil (Colluvium) Scarps

Lower on the mid-slope the lateral scarps transition into soil conditions and the scarps are 40 to 50 feet in height on the east and 5 to 10 feet in height on the west. Materials exposed in the eastern lateral scarp between approximate elevations 860 and 560 feet are typically colluvial, unconsolidated materials comprised of silty sand with numerous cobble-sized blocks and scattered boulders up to 6-foot in maximum dimension. Remnants of ultramafic rock layers and felsic intrusions also occur within the colluvium, which indicates the colluvium developed in-place. Photo Exhibits 13 through 15 illustrates conditions in the eastern lateral soil scarp. These scarp slope angles of 50 to 70 degrees are steep and actively raveling.

The eastern lateral scarp widens the middle portion of the slide downslope of approximate elevation 560 feet. This eastern "middle" area of the slide is an area of slumped colluvium soil, and based on overlapping soil and tree debris, appears to have occurred before the middle boulder field was deposited. This area is identified as the "east middle" area in the following discussion of landslide debris and lateral limits and is labeled as East and West Side of Middle Boulder Field on Figure 1. The conditions of the "east middle" area are shown on Photo Exhibit 16. This "east middle" area transitions downslope into debris/slump deposits below elevation 490 feet, which is the upper Mt. Riley Road bench.

The western lateral scarp between approximate elevations 690 and 410 feet is comprised of scoured slopes of a ravine that existed before the landslide event. In-place rock (bedrock) is exposed between elevation 690 and 530 feet, while colluvium is exposed between elevations 530 and 410 feet. Photo Exhibit 17 illustrates conditions in the western lateral scarp. The scoured materials were likely comprised of relatively shallow soil (less than approximately 10 feet thick) on both slopes of the ravine and a linear ridge that formed the east side of the ravine. Subsequent to being scoured the ravine was buried as some of the slide debris remains within the ravine. The ravine transitions downslope, or empties onto a debris fan as it approaches the upper Mt. Riley Road bench and the mapped contact between the West Side of Middle Boulder Field and Lower Debris Flow areas on Figure 1.

Lower Lateral Debris Flow Scarps

Downslope of the bench, the western and eastern scarps of the debris flow range in height from 5 to 10 feet. The lateral debris flow scarps are comprised of scoured old debris flow deposits, and recent deposits of the lower debris flow as the landslide flowed downslope to the Chilkoot Inlet.

Tension Cracks

Several tension cracks are present near the eastern flank of the upper rock slump (Photo Exhibits 18 through 23). The main, upper tension crack initially extends eastward (away from the headscarp) at an approximate azimuth of 110°. The tension crack then curves to an azimuth of 045° where the crack becomes obscured or is no longer present, which is approximately 200 feet from the headscarp. Approximately 10 feet from the headscarp, the main eastern tension crack had 3.4 feet of horizontal and 4.1 feet of vertical displacement. Approximately 30 feet from the headscarp, the displacement was 3.0 feet horizontal and 3.7 feet vertical. Approximately 80 feet from the headscarp, the displacement was 1.2 feet horizontal and 1.7 feet vertical. Greater than 130 feet from the headscarp, the vertical displacement varied from 1-foot until it disappeared.

Roots stretched across the tension crack had a range of orientation with those closest to the landslide headscarp showing a relative direction of movement of azimuth 005° and those at the distal (eastern) end of the crack oriented approximately 315°. This trend of root stretch movements is generally perpendicular to the tension crack, which indicates the approximate orientation of movement toward the center of the area defined/outlined by the eastern tension crack. The horizontal and vertical movements appear to be settlement within a steep-sided slump block trending toward the slumped landslide.

Additional tension cracking was observed adjacent to the upper eastern lateral scarp. One tension crack has azimuth orientation of 035 to 040°, and extends from elevation 840 to 875 feet where it terminates within 20 feet of the east tension crack (Photo Exhibit 21). A second crack at approximate elevation 745 to 760 feet is approximately 45 feet long (Photo Exhibit 22). These north-south trending cracks appear to be a result of relaxation of materials exposed in the eastern lateral scarp into the main body of the slide due to the loss of lateral confinement or support from materials that slid.

An arcuate tension crack was also observed on the western side of the upper rock slump, extending from approximate elevation 735 to 810 feet (Photo Exhibit 23). At the headscarp the western tension crack had 3 to 4 feet of vertical displacement and 1 to 2 feet of horizontal displacement, and the displacement decreased along the length of the crack as it extended to the northwest and rotated around a rock slump. This ground cracking appears to be a similar process as the tension cracking on the eastern flank, in that the materials at this location along the western flank are part of a local, steep-sided, slump block.

Landslide Debris and Extents

The horizontal length of the Beach Road Landslide is over 2,300 feet from the headscarp to the shoreline of Chilkoot Inlet. The width ranges from approximately 300 feet at the upper slump, to 440 feet across the middle part of the slide near the upper Mt. Riley Road bench, to 600 feet at Beach Road, and 660 feet at the shoreline. The area of the landslide is approximately 27 acres.

As described in the *Winter Reconnaissance – Preliminary Findings Report*, the debris in the Beach Road Landslide consists of a range of grain sizes from silt to 30-foot boulders. In general, there is a gradation of the debris with large dimensioned boulders (i.e., 20-30 foot in size), slumped rock blocks, and downed timber near the head of the slide, to a boulder field comprised of boulders to large blocks (i.e. 10-20 foot sized boulders) mid-slope on the slide, to a deposit of smaller dimensioned rocks (i.e. 2-5 foot boulders and cobbles) in a matrix of micaceous silty sands with occasional 8-10 foot boulders at the lower elevations that include Beach Road. An overview photograph of the landslide is provided as Photo Exhibit 24.

Upper Rock Slump

At the headscarp, the landslide debris includes a mixture of rock block slabs, boulder- to gravel-sized rock fragments and sandy soil. Within the upper portion of the slide mass, bounded by the headscarp and lateral scarps that cut in-place rock, are remnants of rock slumps. An example of the rock slumps is shown on Photo Exhibit 25. Several rock blocks are within the slump including, near elevation 670 feet adjacent to the western lateral scarp, a dilated and fractured rock block consisting of an assemblage of smaller blocks on the order of 5 to 8 feet in dimension that are partially separated from a much larger rock block (Photo Exhibit 26). In addition, another 30- to 40-foot block is centrally located in the slide mass at approximate elevation 730 feet (Photo Exhibit 27).

Middle Boulder Field

The Upper Slump Block transitions downslope into the Middle Boulder Field with large rock blocks/"mega-talus" within the middle of the slide area. A central portion of the middle debris field, from approximate elevations 400 to 670 feet, is a "mega-talus" deposit with boulders typically on the order of 5 to 10 feet in dimension and large blocks up to 30-foot in maximum dimension. Photo Exhibits 28 and 29 illustrate the range of boulders that have accumulated. The bottom or toe of the boulder field is at a change to a gentler slope at the upper Mt. Riley Road bench.

To the east of the Middle Boulder Field, debris in the "east middle" portion of the landslide is comprised of silty sand with cobble- to boulder-size rock fragments (Photo Exhibit 16). To the west of the Middle Boulder Field, a narrow lobe of bouldery debris buries the center of the ravine that was scoured on the west side of the upper slide (Photo Exhibit 17).

Lower Debris Flow

The lower portion of the landslide is a debris flow that deposited materials and scoured pre-existing materials. Deposits occur over broad areas, but the majority appears to be within the western side of the lower debris flow, and on the beach at the shoreline. The lower lateral extents (below elevation 360 feet on the east and west, and 320 feet at the toe of the Middle Boulder Field), are dominated by a matrix of silty sand with numerous cobble- and boulder-sized material and scattered boulders up to 15 feet in maximum dimension. The debris is generally loose, and the color is typically dark-brown with grays and black. Scattered amongst the boulders between elevations 280 and 130 feet are pockets of red-brown and brown, silty sand soil, occasionally containing remnants of topsoil with vegetation and roots. An overview of the Lower Debris Flow is shown in Photo Exhibit 30.

Scouring of the pre-existing soil and rock materials also occurred within the lower debris flow, primarily in four areas. One scour is where the slide debris flowed down a primary drainage within the west side of the slide (Photo Exhibits 30, 31 and 32), and a second scour is in a smaller drainage within the east side of the slide (Photo Exhibits 30 and 33). There is also scour within the central area of the lower debris flow, and where the debris flowed over the Mt. Riley Road benches (Photo Exhibit 34), and through ravines that are in the bluff north of Beach Road that steps down to the adjacent shoreline.

Pressure ridges observed within the lower debris flow deposits are convex downslope or lobate-shaped (Photo Exhibit 35). The pressure ridges range in height from less than 1-foot and up to approximately 10 feet, and are distributed between approximate elevation 110 and 200 feet. The pressure ridges indicate that in the late stage of the flowing debris, it encountered increasing resistance as it moved downslope (and eventually stopped), or there was a limit to materials that could maintain the load and movement.

Downed Timber

The lateral extents have numerous, large diameter, downed trees along the delineation of disturbed and undisturbed ground (Photo Exhibits 16, 24 and 30). There is an accumulation of somewhat haphazardly oriented trees within the Upper Rock Slump. Numerous trees are also within the Middle Boulder Field, albeit oriented primarily up and down the slope, and along the sides of the boulder field. The "east middle" area includes another accumulation of downed trees. Bunches of downed trees are deposited on the upper and lower Mt. Riley Road benches, and on the western and eastern deposits of the Lower Debris Flow, and also on the sides of the debris flow that outline the extent of the slide.

Surficial Water and Groundwater

The landslide has several locations where water is flowing on the surface along with numerous seepage points. The observed flow paths and seepage points are shown on Figure 1. The largest flow is following the western lateral extent of the slide (Photo Exhibit 31 and 32). This flow gains volume as it runs to the north, collecting water from at least five seepage points with the highest observed near elevation 630 feet and the lowest near 350 feet. At the time of observation in July 2021, the flow rate was estimated to be approximately 10-15 gpm at the Beach Road grade.

It is our understanding water was observed in December 2020 to be cascading over the headscarp at about elevation 820 feet, which appears to be seasonally flowing from a drainage fed by the low area (a.k.a. glacial pond area) near elevation 980 south/uphill of the slide. A dry flow path was observed leading from the low area to the headscarp, as mapped on Figure 1. The low area had several locations of standing water along with significant skunk cabbage growth, which is indicative of saturated ground conditions.

A smaller surface flow was observed on the eastern side of the slide (Photo Exhibit 30, 33 and 36). This flow appears to be capturing water from two or more seepage points and was less than 5 gpm near their source at the time of our site visit in July 2021 (Photo Exhibit 36). This flow also gains volume as it proceeds toward Beach Road.

While only one other seepage point was observed west of the landslide near elevation 620 feet, there is evidence in the vegetation for shallow groundwater. Devil's club and scrub alders are thick on both the west and east sides of the landslide. This is especially true on the slopes above elevation 460 feet on the east. The relatively flat area between approximate elevations 270 and 350 feet on the west side of the slide is a marshy bog area with significant skunk cabbage growth and several locations with standing water.

GEOTECHNICAL INTERPRETATIONS AND OPINIONS

Preliminary interpretations presented in the *Winter Reconnaissance – Preliminary Findings Report* have been revisited and updated based on initial re-evaluation, as described below.

Geomorphology Assessment

The geomorphic features recognized during desktop studies of the 2014 and 2020 LiDAR data included: colluvial slopes, bedrock areas, lineations, and benches and swales. These features were obscured during the winter recon due to snow cover and to a certain extent during the spring recon due to vegetation and overburden cover. However, additional interpretations were made based on the more detailed observations of site materials and colluvial processes occurring at the site. A description of the interpreted processes forming the terrain surrounding the landslide is offered below.

As stated in the Transportation Research Board (TRB) *Special Report 247 – Landslides: Investigation and Mitigation* (1996):

> "Physical and chemical weathering of bedrock produce disaggregated particles that accumulate on the land surface in the absence of erosional processes adequate to remove them. In locations with sufficient topographic relief, gravitational forces acting on these disaggregated particles cause them to move down the slopes and accumulate as distinctive deposits along the lower portions of slopes, in topographic depressions, and especially at the base of cliffs. The terms *colluvium* or *colluvial materials* are used to refer to deposits that have been transported by gravitational forces."

The development of colluvium is prevalent on both the east and west sides of the slide. There are varying levels of disaggregation of the bedrock with coarser (i.e., large diameter blocks on the order of 10-15 feet in maximum dimension or larger) materials located at higher elevations near the upper outcrops and finer (i.e., silty sand matrices with 3-5 foot boulders) materials at lower elevations. The thickness of these deposits varies as a result of several factors such as: condition of the paleo topography the colluvium is deposited on, the mechanisms of material transport, and obstacles on the slopes.

After the glaciers retreated, the in-place rock would have been scoured clean or covered with a thin veneer of glacial till, outwash and marine sediment. This thickness of overburden was likely variable, with some areas of rock scoured clean and no overburden, to other areas of softer rock that could have been scoured deeper and also buried with glacial till. With reported glacial rebound that has been nearly 1 inch per year, the elevation of the landslide headscarp (currently 800 to 860 feet) would have been near sea level 10,000 to 11,000 years ago.

The ground surface in the upper elevations of Mt. Riley, generally above elevation 950 feet, away from the steeper, north facing slopes, are likely to be what the ground surface would have appeared like at the end of glacial time: other than topsoil and forest vegetation, a series of rounded and elongate mounds and depressions. The mounds are likely the hard rock and the depressions are likely the soft rock, including the soft rock ultramafics as well as faulted and sheared rock. Therefore, the shapes of the mounds and depressions likely reflect the pattern of hard and soft rock and the rock structures. In addition to the glacial and marine sediments, local deposits of colluvium and talus likely began accumulating immediately after the glaciers retreated.

On the steeper slopes, the stress release following retreat of glacier burden, along with the different rock mass characteristics of the rock layers and gravitational forces, likely resulted in the rock structures becoming more open. As the joints and fractures open, the rock layers fracture, rotate and tilt, generally remaining somewhat in-place. Local grabens developed, eventually filling in with fractured rock and soil while maintaining pressure (vertical and lateral) on the slow, creep movement of the weathering rock. The occurrence and orientation of the sloping benches within the upper slopes are likely a result of the intersection of rock layers and rock structures, glacial scouring, and differential weathering (local block rotation and tilt along with graben features).

Since the glaciation, the slopes of Mt. Riley have been weathering and creeping downslope, and the occurrence of in-place rock, which is relatively close to the ground surface in the upper slope, transitions downslope into thicker, deeper deposits of colluvium. In addition, the colluvium tends to become finer-grained in a downslope direction. This is a general observation, since coarse-grained colluvium and "mega-talus" deposits also occur in the area and low on the slopes.

Evaluation of Landslide and Causation

Observations from the Spring Reconnaissance have not changed interpretations of the landslide causation provided in the *Winter Reconnaissance – Preliminary Findings Report*. The slide area appeared to have a lobe of colluvium in the pre-slide topography (see Figure 8 in the *Preliminary Findings Report*). Mobilization of the pre-slide lobe was likely due to a concentration of surface water runoff and extreme groundwater pressures from the historic storm event.

Concentrated surface water and high groundwater pressures caused unconsolidated materials to liquefy and slough resulting in debris flows that traveled downslope. The sloughing and loss of confinement, in combination with geologic structures within the in-place rock materials at higher elevation, resulted in rock slump failure. The rock failure moved downslope, likely adding load to the soil slide debris. The lower portion of the slide material continued to flow downslope, carrying portions of the rock failure with it. This is observed in the lobes of slide debris that are within the central area of the lower debris flow, downslope of the drainage constriction through the Mt. Riley Road benches, while the significant portion of the rock debris stopped within the middle slopes above the Mt. Riley Road bench.

The gradation of landslide debris from coarser rock materials near the top of the slide to finer materials (i.e., small boulders, cobbles, gravels, and silty sand) near Beach Road and down to Chilkoot Inlet, along with the form of the landslide features, is an indicator of the failure mechanics of the landslide. Within the upper landslide, large sized material (i.e., rock slump blocks over 20 feet in maximum dimension) slumped and the resulting boulder debris largely stopped at a change from steeper to gentler slope. However, the lower debris flow was comprised of finer-grained materials with entrained boulders that were water-saturated and transported a greater distance downslope.

Updated Evaluation of Geologic Hazards (Qualitative Assessment) and Community Concerns

Evaluations of the eight potential scenarios presented in the *Winter Reconnaissance – Preliminary Findings Report*, along with Occupancy of Residences have been revisited below. This updated assessment is qualitative and based on preliminary winter and spring reconnaissance surface observations. The assessment will be updated as surface instrumentation data is gathered and analyzed, geophysical data is interpreted, and the subsurface explorations and instruments are completed and installed, and data is analyzed.

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

The factors that affect the potential for this scenario to occur are interpreted to remain the same as presented in the *Preliminary Findings Report*. The landslide body has significantly less volume of unconsolidated materials, slope angles are flatter than those adjacent to the slide and that were present pre-slide, and it appears the materials have a higher propensity to be free draining (i.e., buildup of pore pressures may be less prevalent). This scenario is considered a high-risk event with a low likelihood of occurrence.

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

The likely trigger for the December 2, 2020 event was the high groundwater pressures and surficial water runoff produced as a result of the historic storm event. This scenario considers normal weather patterns, which, as interpreted in the *Preliminary Findings Report*, would likely not produce a debris flow event on the same scale as the December 2020 event. If remnant slide materials were to mobilize under normal weather/precipitation, the mobilized material likely would not travel as far downslope due to the lack of water and saturated conditions that would be needed to liquefy materials. This scenario is considered a moderate-risk event with a moderate likelihood of occurrence.

3. Boulders within Landslide Mass Rolling Downslope

As stated above, there is a gradation of the remnant slide materials with large dilated rock blocks in the higher elevations, a boulder field in the midslope areas of the slide, and matrix-supported boulders and cobbles in the lower portions of the slide. Mobilization of the large dilated rock blocks and boulders from the midslope elevations could occur if there is loss of support, due to freeze/thaw processes, an increase in groundwater pressures or several other factors as described in the *Preliminary Findings Report*. However, it is our interpretation that these materials would not travel significant distances due to the loose nature of the slide debris and relative shallow slopes that are present near

Beach Road. This scenario is considered a moderate-risk event with a low- to moderate-likelihood of occurrence.

4. Retrogression of Over-Steepened Slopes near Headscarp of Landslide

This scenario is a common process of over-steepened headscarps, as indicated in the *Preliminary Findings Report*. There are several blocks on the headscarp that are dislodged and will likely fall into the headscarp bowl. These appear to be localized and will likely have minimal effect on the remnant slide materials in the headscarp bowl and lower portions of the slide body. This scenario is considered a low-risk event with a moderate-likelihood of occurring.

5. Slump Bounded by Tension Crack to East and West of Landslide Headscarp

Observations of tension cracking on both the east and west side of the slide indicate slumping of material from the lateral scarps is occurring. This process will continue to occur until the lateral scarps have reached an equilibrium with the new terrain formed by the slide. It appears likely that slumped material will be localized with minimal effect on the remnant slide materials in the headscarp bowl and lower portions of the slide body. This scenario is considered a low- to moderate-risk event with a moderate-likelihood of occurring.

6. Global Failure of Bedrock Slopes East and West of Landslide

As indicated in the *Preliminary Findings Report,* the primary mode of failure identified in the kinematic analyses was toppling failure. However, based on surface observations, the bedrock outcrops on the east and west side of the slide do not show evidence for on-going global failures. There is evidence of relaxation of bedrock blocks due to deglaciation and colluvial development processes that could be interpreted as toppling movement. Evidence includes the benches and swales mapped as part of the geomorphic assessment and as observed during reconnaissance. Additional interpretations are necessary to identify structure that may further promote global failures either in a toppling mode or other. The subsurface explorations and instrumentation may provide information to make these additional interpretations. With what we have observed during the surface reconnaissance, this scenario is considered high-risk on the eastern slopes and low-risk on the western slopes, both with low-likelihood of occurrence.

7. Global Failure of Colluvial Slopes East and West of Landslide

The accumulation of colluvial materials east and west of the slide appear to be less significant than the lobe deposit that was present in the slide area pre-slide. Mobilization of the relatively thinner deposits of colluvium could occur, but it is likely any movement would not be on the order of what was experienced in December 2020 without the mass available. This scenario is considered a moderate- to high-risk event (especially east of the slide) with a moderate-likelihood of occurrence.

8. Weathering and Erosion of Bedrock/Colluvial Slopes East of Landslide

Development of colluvium due to weathering and erosional processes will continue at the site until the slopes are flattened and at an equilibrium with the surrounding terrain. This is common through southeast Alaska and could be considered the baseline hazard for mountainous terrain. This scenario is considered a low- to moderate-risk event with a high-likelihood of occurrence.

9. Occupancy of Residences

The risks associated with occupancy of residences presented in the *Preliminary Findings Report* are considered with the following additional surficial observations. This evaluation is preliminary, while awaiting the results of geophysical investigations, and subsurface borings and instrumentation. The scenarios discussed in the *Preliminary Findings Report* are revisited below.

1. Rockfall, colluvial runout, and hillside slumping is considered a low- to moderate-risk with a moderate- to high-likelihood of occurrence for those properties on the south (uphill) side of Beach Road.
2. Catastrophic landslide material moving/flowing on properties within the landslide boundary is considered a high-risk with a low-likelihood of occurrence without a major storm similar to the December 2020 event. There remains one residence (Block 3 Lot 3) with a dwelling, all other properties with dwellings no longer have structures or were undeveloped.
3. Catastrophic landslide material moving onto properties immediately next to the recent catastrophic landslide is considered a moderate-risk with a low- to moderate-likelihood of occurrence.
4. New catastrophic landslides occurring in the bedrock hillside east and west of the recent catastrophic landslide is considered a low- to moderate-risk with a low- to moderate-likelihood of occurrence. Surficial observations were consistent between the winter and spring reconnaissance. Outcrops on the east and west appear to be in-place material without signs of active movement. The geophysical interpretations and subsurface explorations are necessary and may affect preliminary interpretation and opinions.

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.

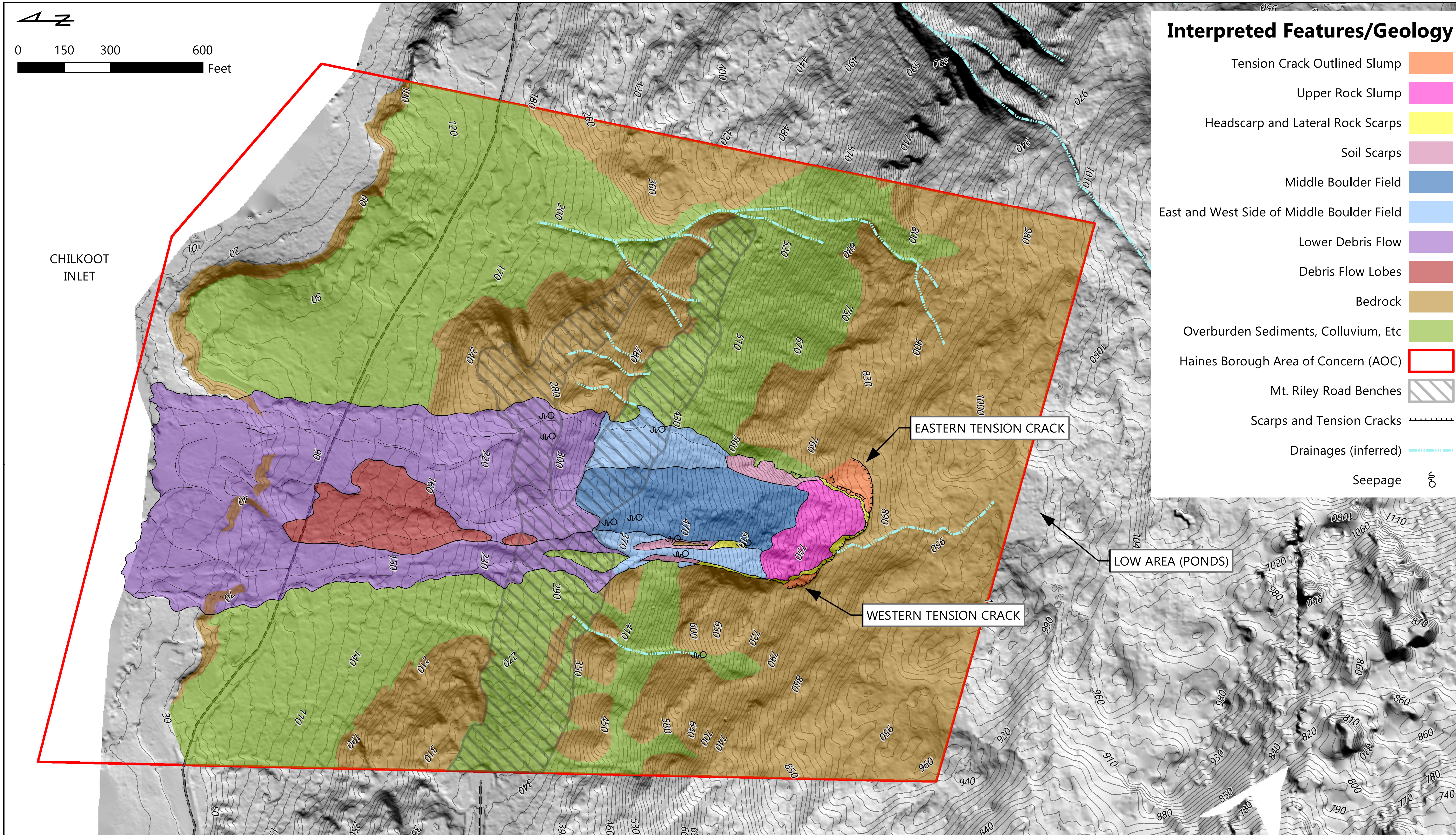
The Summary Boring Logs are our opinion of the subsurface conditions revealed by periodic sampling of the ground as the borings progressed. The soil descriptions and interfaces between strata are interpretive and actual changes may be gradual.

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.



NOTES: 1. Map is based on Spring reconnaissance performed July 2021.
2. Basemap is derived from 2020 lidar data provided by DGGS, acquired Dec. 2020.

LANDSLIDE TECHNOLOGY
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SPRING RECONNAISSANCE INTERPRETATION MAP

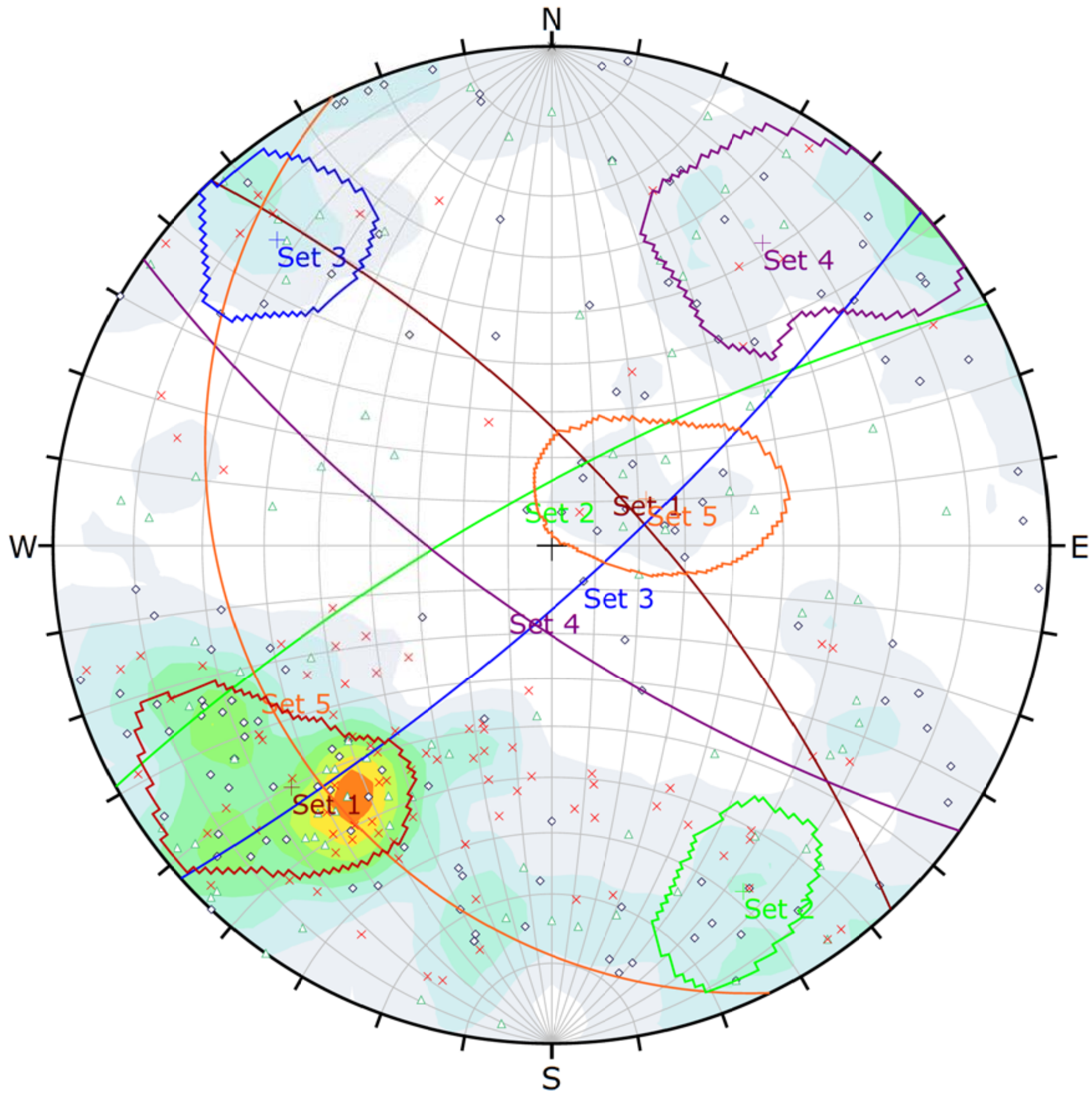
BEACH ROAD LANDSLIDE
HAINES, ALASKA

SEP 2021

PROJ. 2925

FIG. 1

APPENDIX A: ROCK STRUCTURE DATA SUMMARY STEREONETS



Symbol	LOCATION	Quantity
◇	EAST	129
×	SLIDE	100
△	WEST	91

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	7.10%
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		79	138	Set 3
4m		73	215	Set 4
5m		24	244	Set 5

Plot Mode	Pole Vectors
Vector Count	320 (320 Entries)
Hemisphere	Lower
Projection	Equal Angle

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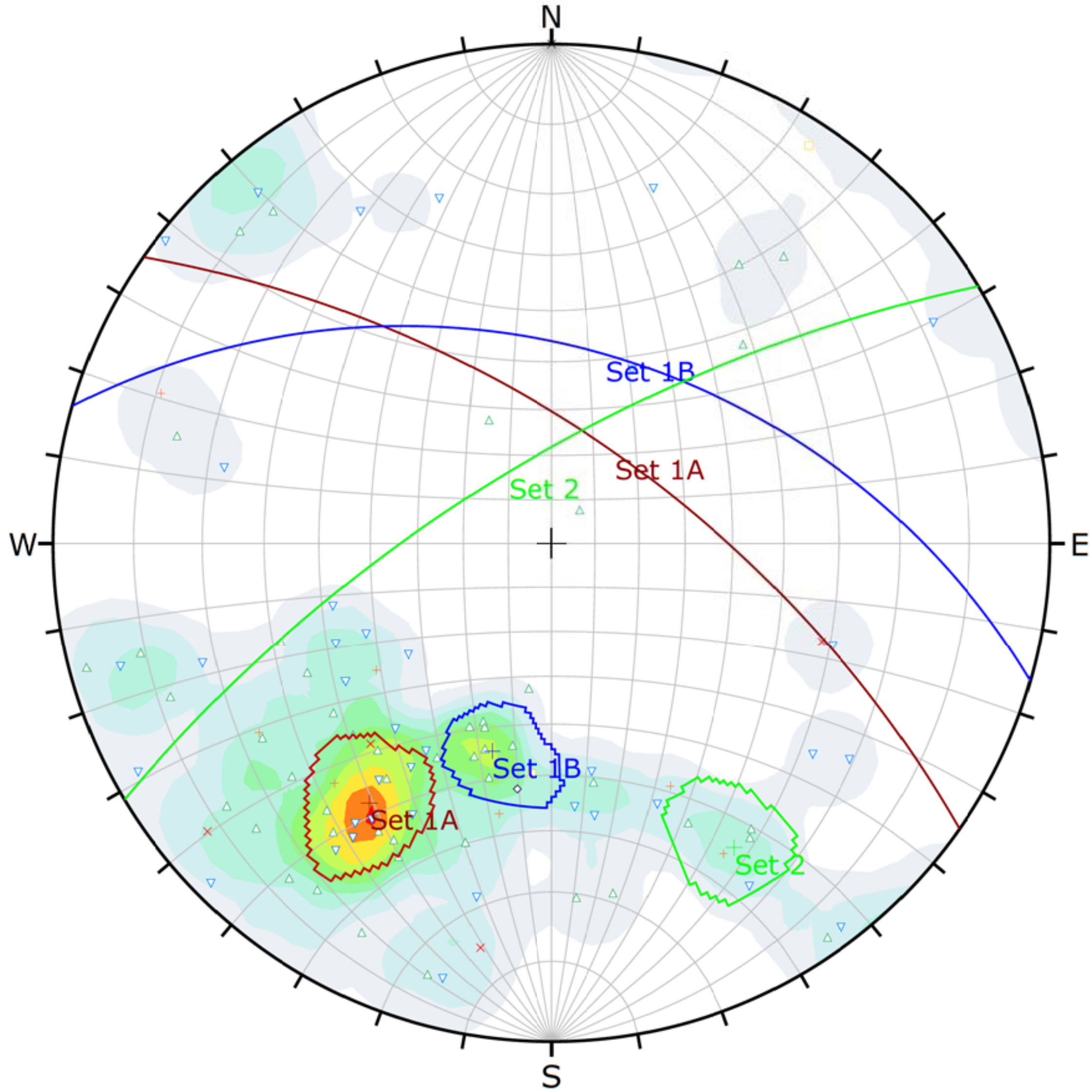
DIPS 8.015

Project	Beach Road Landslide Reconnaissance		
Analysis Description	All Data		
Drawn By	NK	*Company*	LT
Date	8/12/2021	*File Name*	SpringAndWinterCombined.dips8



Symbol	ELEVATION	Quantity
◇	Compositional fracture	1
×	EAST LATERAL SCARP	4
△	HEADSCARP/UPPER	48
+	LOW	8
▽	MIDDLE	37
□	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	10.14%
Contour Distribution	Fisher
Counting Circle Size	1.0%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		65	35	Set 1A
2m		47	16	Set 1B
3m		71	329	Set 2

Plot Mode	Pole Vectors
Vector Count	100 (100 Entries)
Hemisphere	Lower
Projection	Equal Angle

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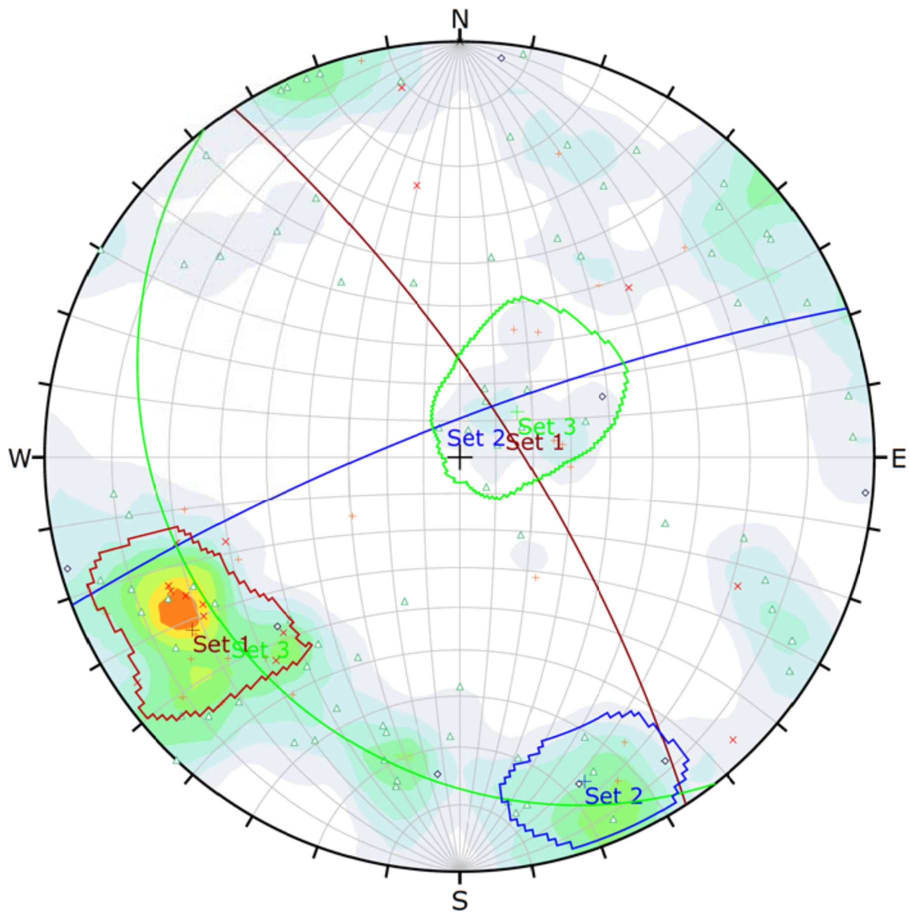
DIPS 8.016

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



Symbol	ELEVATION - SIMPLE	Quantity
◇	BEACH	8
×	EAST LINEATIONS	15
△	EAST UPPER BLOCKS	83
+	LOW	23

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

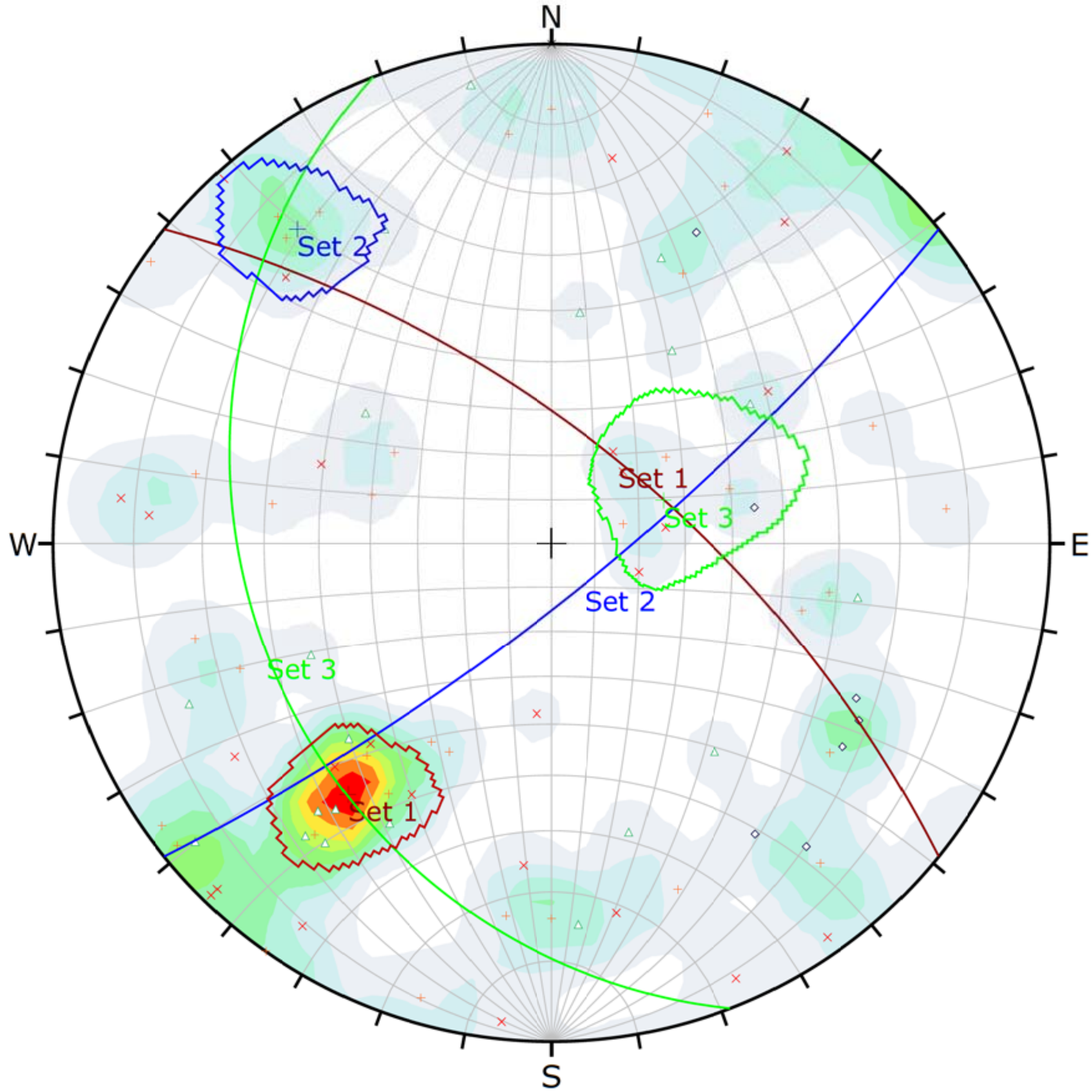
Contour Data	Pole Vectors
Maximum Density	8.05%
Contour Distribution	Fisher
Counting Circle Size	1.0%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		75	57	Set 1
2m		80	339	Set 2
3m		20	232	Set 3

Plot Mode	Pole Vectors
Vector Count	129 (129 Entries)
Hemisphere	Lower
Projection	Equal Angle

LANDSLIDE TECHNOLOGY A DIVISION OF CORNFORTH CONSULTANTS 10250 S.W. Greenburg Road, Suite 111 Portland, Oregon 97223 Phone 503-452-1200 Fax 503-452-1528	*Project* Beach Road Landslide Reconnaissance		
	Analysis Description East		
	Drawn By NK	*Company* LT	
	Date 8/12/2021	*File Name* SpringAndWinterCombined_East.dips8	

DIPS 8.018



Symbol	ELEVATION	Quantity
◇	BEACH	7
×	HIGH	27
△	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	8.86%
Contour Distribution	Fisher
Counting Circle Size	1.0%

	Color	Dip	Dip Direction	Label
Mean Set Planes				
1m		66	39	Set 1
2m		78	141	Set 2
3m		27	249	Set 3

Plot Mode	Pole Vectors
Vector Count	91 (91 Entries)
Hemisphere	Lower
Projection	Equal Angle

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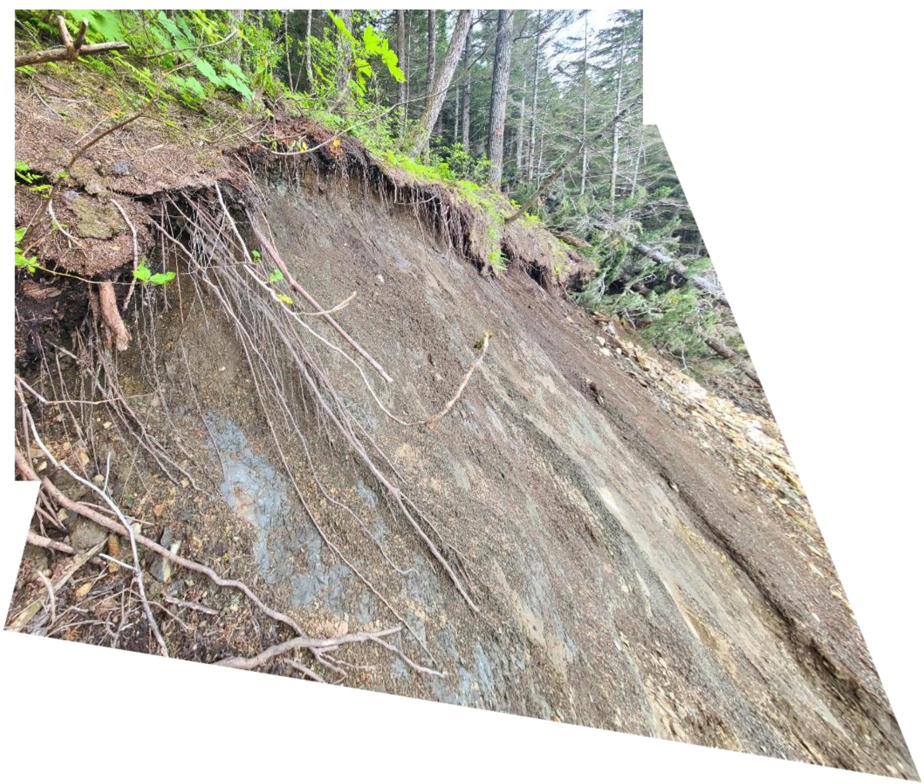
DIPS 8.015

Project	Haines Slide Emergency Response
Analysis Description	West
Drawn By	NK
Company	LT
Date	8/12/2021
File Name	SpringAndWinterCombined_West.dips8

APPENDIX B: RECONNAISSANCE PHOTOGRAPHS JULY 2021

A: Looking southeast at the eastern extent of the headscarp (at the highest elevation).



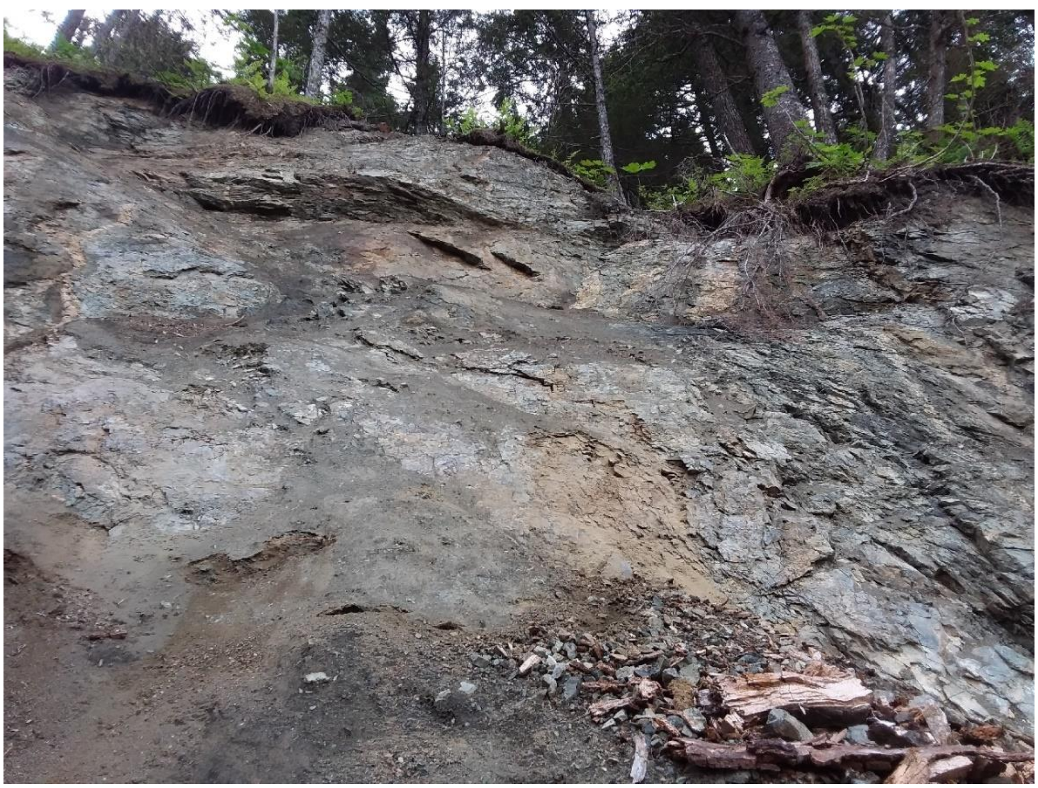
B: Looking west at the eastern extent of the headscarp.

Looking west across the eastern extent to the western extent of the headscarp.

Looking west at the central portion of the headscarp with layered ultramafic rock exposures.

Looking southwest at the central portion of the headscarp with exposure of decomposed layers of ultramafic rock.

A: Looking east at the central portion of the headscarp with exposure of decomposed rock.



B: Looking south at the rock exposures in the central portion of the headscarp.

Looking east at rock exposures in the central portion of the headscarp, with eastern lateral scarp in the background.


A: Looking southeast along the west central headscarp.

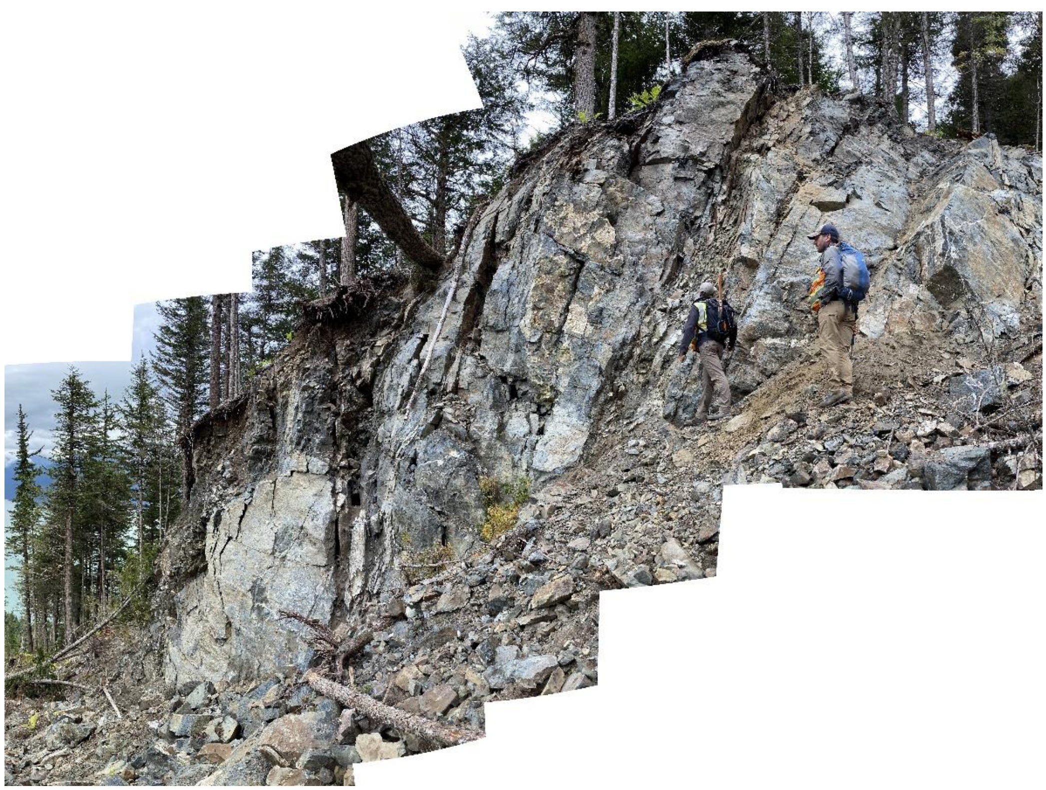

B: Looking south at the rock exposures in the west central portion of the headscarp.

Looking south at rock conditions in the west central portion of the headscarp.

A: Looking east at the extents of rock exposures in the eastern lateral scarp.

B: Looking northeast at the eastern lateral scarp rock exposures.

A: Looking northeast at the eastern lateral scarp rock exposures.



B: Looking northeast at the eastern lateral scarp rock exposures.

A: 10-inch wide shear/fault near parallel to layered rock at elev. ~830 ft in eastern lateral scarp.

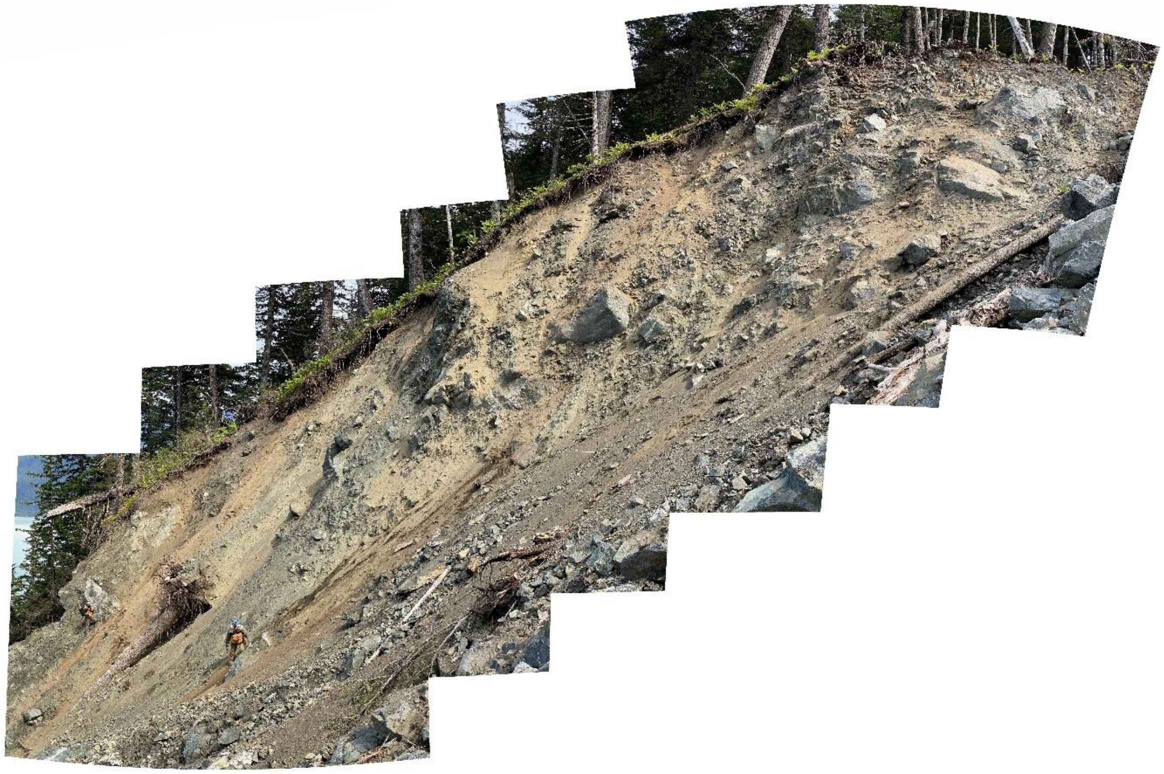
B: 4-foot wide fault near parallel to layered rock at elev. ~810 ft in eastern lateral scarp.

A: Looking southwest at the western lateral scarp near elevation 730-800 feet (below the west tension crack).

B: Looking west at the western lateral scarp rock exposures.

A: Looking east at the eastern lateral soil scarp below elevation 800 feet.

B: Looking northeast at the eastern lateral soil scarp below elevation 800 feet.



A: Panorama looking east at the eastern lateral soil scarp below elevation 800 feet.

B: Looking southeast at the eastern lateral scarp, including a transition from rock (lateral rock scrap) to soil (lateral soil scarp).

Looking southeast at the eastern lateral soil scarp.

A: Looking south at the eastern middle portion of the landslide.

B: Overview looking south at the middle boulder field and eastern middle portion of the landslide.

A: Looking southeast at colluvial materials near the western lateral scarp.

B: Looking southwest at rock and colluvial materials exposed in the western lateral scarp.

A: Looking west along the eastern tension crack.

B: Eastern tension crack with roots pulled in direction of movement.

A: Tension, down drop and cavities along the eastern tension crack.

B: Looking southwest at an eastern tension crack cavity, approximately 150 feet from the headscarp.

A: Cavities developed along the eastern tension crack.

B: Looking southwest along the eastern tension crack, approximately 160 feet from the headscarp.

A: Looking southwest along a tension crack that parallels the eastern lateral scarp (i.e. 035-040° azimuth).

B: Looking southwest along a tension crack that parallels the eastern lateral scarp (i.e. 035-040° azimuth).

A: Looking south at a tension crack adjacent to the eastern lateral scarp near elevation 745 feet.

B: Looking south at a tension crack adjacent to the eastern lateral scarp near elevation 745 feet.

A: Looking east along the west tension crack adjacent to the western lateral scarp.

B: Looking northeast along the west tension crack.

Looking south at the Beach Road Slide at the upper portion of the lower debris flow, with the middle and upper portions in the background.

Looking south at a dilated slump block adjacent to the western lateral scarp near elevation 670 feet.

A: Looking east at a dilated rock block in the central portion of the slide near elevation 730 feet.

B: Looking northeast at a dilated rock block in the central portion of the slide near elevation 730 feet.

Looking west at a dilated rock block in the central portion of the slide near elevation 730 feet.

A: Looking southwest at the boulder field in the main body of the slide.

B: Looking northwest at the boulder field in the main body of the slide.

A: Looking north at the boulder field in the main body of the slide.

B: Looking south at the boulder field in the main body of the slide.

Overview from the middle boulder field down the lower debris flow.

A: Looking west at exposed slide debris and pre-existing ground in the western lateral extents on the lower portion of the slide.

B: Looking north at the western lateral extents of the slide on the lower portion of the slide.

Looking south along the path of surface runoff along the western side of the slide.

A: Looking north at the lower bench and eastern lateral extends of the lower debris flow.

B: Panorama looking northeast from a high groundwater area on the lower bench.

Looking west at scoured soil (middle ground center and left) between gravel and boulder debris deposits on the slope above the lower Mt. Riley Road extension bench.

Lobe in lower debris flow, and low-height pressure ridge in the foreground left.

A: Looking south at a seepage point above flow near the eastern side of the slide near elevation 280 feet.

B: Looking north at a seepage point above flow near the eastern side of the slide near elevation 280 feet.