SHANNON & WILSON
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

July 13, 2022

Mr. Brad Ryan
Municipality of Skagway
PO Box 415
700 Spring Street
Skagway, Alaska 99840

RE: RAILROAD DOCK LANDSLIDE, INITIAL SITE VISIT TRIP REPORT, SKAGWAY, ALASKA

Dear Mr. Ryan:

At the request of the Municipality of Skagway (MOS), Shannon & Wilson conducted a site visit to observe slope conditions along the White Pass & Yukon Route Railway (WPYR) Dock in Skagway, Alaska. Shannon & Wilson mobilized an experienced geotechnical engineer (Kyle Brennan) from our Anchorage, Alaska office and our rock mechanics and rock slope expert (Rex Whistler) from our Portland, Oregon office to conduct the site visit. The purpose of the site visit was to observe surface conditions and conduct a rapid assessment of overall slope stability and potential hazards in response to the recent isolated slope failure that impacted the dock. While at the site we observed surface conditions on foot and aerially (in a helicopter) and we also met with you, Cody Jennings (MOS Port Director), the WPYR General Manager (Tyler Rose), and the consulting engineer hired by WPYR for slope evaluation (Tim Blackwood, Haley & Aldrich).

SITE HISTORY AND CONDITIONS

The information on this section is intended to relay our current understanding of the slope conditions and history of the site and conditions. Note that this understanding is based on observations during our site visit and conversations with you, the WPYR and, and Tim Blackwood. At the time of this letter, we have not been presented with existing data, reports, or data collected from onsite instrumentation on the slope.

General Geologic Setting

The topography of the region was formed by past glacial processes and shows typical U-shaped valleys with flat/wide bottoms and slopes of increasing steepness with elevation. The railroad dock is situated along the toe of a natural slope on the east side of the Port of

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Skagway, near the head of Taiya Inlet. The slope above railroad dock is approximately 600 to 700 feet tall with an average slope angle of approximately 40 to 50 degrees, with isolated cliff bands throughout. With the exception of cliff zones and areas of past slope failures, the ground surface is covered with well-established tree and brush vegetation.

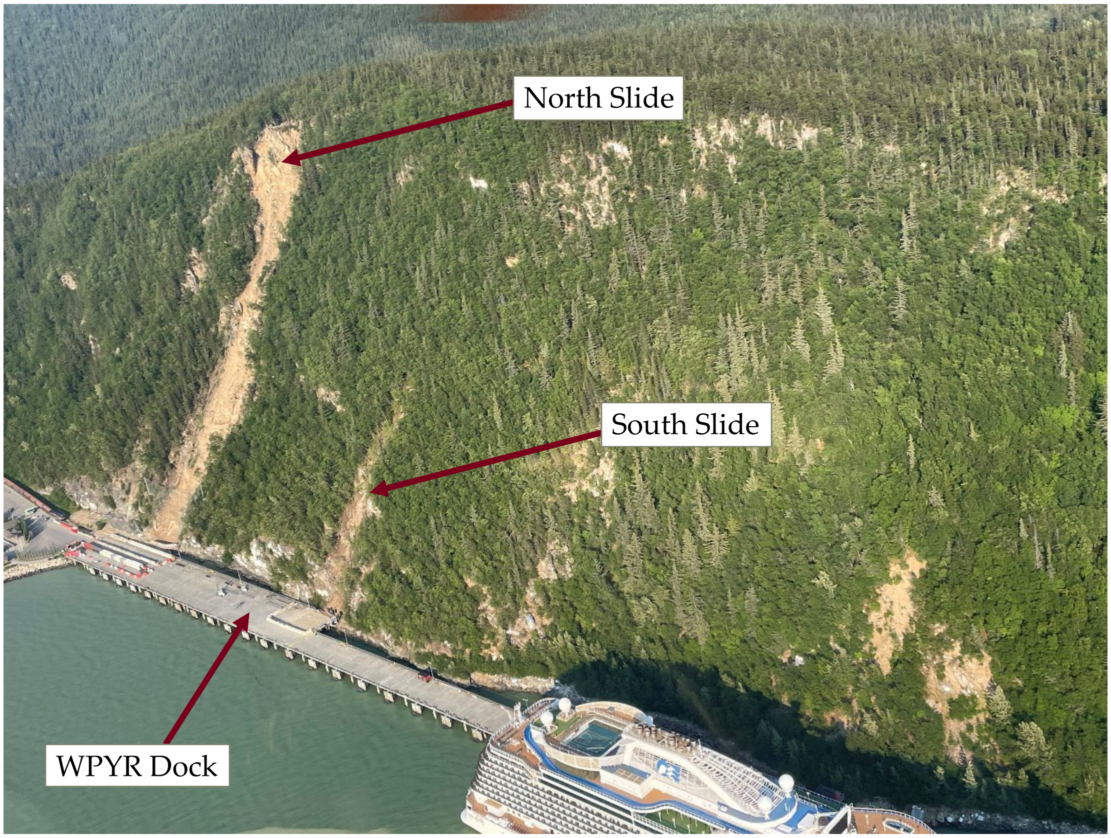

Photo 1: Oblique aerial view of the WPYR Dock and slope to the east of the dock showing site layout, slope, and ground topography/vegetative cover. Note the location of the two slide features referenced below in this letter.

On average, soil overburden in this region is relatively thick at the valley bottoms but very thin in upslope areas. Based on visual observations on the slope above the railroad dock, soil overburden consists of thin surface deposits of organic and fine grained soils, typically less than about 5 feet thick. Isolated areas of thicker talus and colluvial deposits may be present on the slope. Bedrock geology consists of relatively monotonous granite with isolated intrusive sills, one of which appears to be exposed nearly horizontally mid-slope above the dock. With the exception of occasional zones of highly fractured rock, the granitic parent rock appears to be relatively massive with widely spaced and persistent orthogonal joint sets. Based on limited structural review, it appears that the jointing in the rock mass observed in the slopes above the dock is favorable for developing toppling failures with limited potential for planar shear.

Past Slope Instability

While observing the slope conditions from the air, it was clear that in addition to the two active failures above the dock, many other failure events have occurred, both historically and at present, on the slope above the railroad dock. The two most recent and prominent failures exhibited active material release, runout zones, and debris piles at the base of the slope. Older features were evident based on debris piles that were obscured by ground cover and vegetative growth. It appeared that the instabilities on the slope were associated with cliff bands where toppling had occurred. The following discussion will focus on the two active instabilities at the dock, the locations of which are indicated above in Photo 1.

North Slide

The North Slide is located near the north end of the railroad dock and has been active for at least seven to ten years and currently generates rockfall throughout the year. There have been multiple, significant slide events associated with this feature, the most recent are two slides within two weeks of each other in the fall of 2017. The initiation zone of this slide appears to be a large rock mass near the top of the natural slope with bifurcated rockfall slide paths on the north and south side of the mass. The primary rockfall slide path is to the south of the mass, but both have been treated with attenuators and other catchment remediation in an effort to reduce the risk of rockfall impacting the dock. We understand that this feature receives nearly annual scaling maintenance and debris cleanout coordinated by the WPYR. The WPYR has also installed instrumentation at the top of the slide mass in the form of survey prisms, tilt meters, and extensometers. The instrumentation is automatically logged and collected data can be read and downloaded remotely. We understand that since the fall of 2017 when the instrumentation was installed, the instrumentation has indicated approximately 1.5 inches per year of movement in the slide mass, but that recently the rate of movement has increased to approximately 2.5 inches per year.

Photo 2: View of the North Slide from the YPWR Dock. Rockfall attenuator is shown at the base of the slope and connex box in foreground is the southernmost in a series of connected connexes that are used as covered/protective walkways by pedestrians and users of the dock.

Based on our observations, it appears that this slide feature is a progressive toppling failure with a stair-stepped basal feature. It is difficult to determine how much material is in the slide mass at the top of the slope, but we observed rocks in excess of 20 feet in diameter within the mass. The surface expression of the mass at the top of the slope is at least 130 feet long (parallel to the ridgeline) and 160 feet wide (from the outermost expression of the mass back into the slope to apparently stable material). The toe of the slide mass exposed in the south slide path is at least 80 feet below the top of the slide mass. We believe that the consequences of full failure of this feature could be catastrophic and would cause significant damage to the railroad dock, upland civil works at the base of the slope, and collateral damage to the small boat harbor and other waterfront developments in the Port of Skagway.

Photo 3: View of the top of the North Slide standing on the slide mass, looking back at the slope, additional slide mass, and head scarp on the ridge. Extensometer instrumentation is visible on the slide mass and significant fracturing and dilated joints are visible and typical of that observed in the slide mass.

South Slide

The South Slide is located roughly 600 feet south of the North Slide at the point where the dock transitions from its full approximately 80-foot width on the north end to a narrower approximately 50-foot width to the south. This slide consisted of an isolated failure that initiated approximately midway up the slope. The event released several large rocks estimated to be in excess of 5 to 6 feet in diameter, which landed on the dock surface adjacent to the slope. One of the larger rocks penetrated the dock surface and smaller rocks broke apart upon hitting the dock and shattered, spreading debris across the full width of the dock, some of which impacted a moored cruise ship adjacent to the place of impact. The event occurred at approximately 6:00 AM and no people were within the vicinity of the impacts. While no human injuries resulted from the event, the impact zone on the dock is in an area where pedestrians congregate at different times of the day. Eco Blocks are stacked three high around the impact zone to block off the area from pedestrian traffic and isolate the site for scaling activities.

Photo 4: View of the South Slide from the WPYR Dock. Photo was taken after scaling activities.

We did not observe the surface conditions directly on the ground, but according to Tim Blackwood the failure appeared to be caused by toppling of an isolated block with a relatively clean break. According to the railroad, mechanical and hydraulic scaling activities were conducted at the slide area in the week preceding our site visit. The scaling removed an additional 4- to 5-foot-deep block behind at the initiation point and additional rock along the slide path. Tim Blackwood suggested that an additional 10 to 20 cubic yards of material is still on the slope that will eventually need to come down with additional scaling. He estimates that remaining rock on the slope is less than 3 feet in diameter with most material being approximately 18 inches in diameter or smaller.

The toppling failure mechanism that caused this slide is consistent with our rock structure observations on other parts of the slope. Persistent, high angle jointing, which forms overhanging rockmasses, was observed along the crest of the slope, indicating that similar failures are possible along the entirety of the slope where cliff bands are exposed. The presence of this ubiquitous hazard was confirmed by Tim Blackwood during conversations with him on-site. In addition to the toppling failures, lower persistence but ubiquitous discontinuities were observed that form kinematically admissible plane shear failures were observed within the rockmass. These additional structures contribute to the hazard as smaller rock fall events may occur sporadically along the length of the dock and likely are involved in the basal shearing of larger toppling failures. The timing and frequency of similar future events is difficult to predict, but there is little question that similar events could occur in the future along the entire length of the dock with little to no warning.

CONCLUSIONS

The information below presents our preliminary assessment of the future risks associated with instabilities in the slope adjacent to the dock. Note that additional information is needed to refine this assessment and our recommendations may change with further review of existing information, instrumentation data, and site observations that are forthcoming.

North Slide

Given our onsite observations, reported historic movement of the slide mass, and the apparent increase in movement rates measured by the instrumentation, we believe that there is a significant risk associated with complete failure of this feature. It is our opinion that the slide mass will eventually fail and the consequences of such failure will be catastrophic in nature with significant risks to life and property. The timing of such a failure is difficult to predict but accelerating movement rates suggest that the failure event is approaching.

Based on our observations, the only reasonable option for mitigating the risk of full failure of the north slide is a controlled excavation to re-shape the slope. The amount of debris is too great to control using debris arrestors or rockfall protection, and too much movement has occurred in the slide mass to allow for stabilization with pattern rock anchors or dowels. If it is the desire of the MOS and the railroad to keep the dock and adjacent upland areas open, we recommend installing real-time monitoring tied to an alarm system so that if movement rates exceed a certain threshold, the dock and area below the slope can be evacuated and closed to access until the risk is removed. In the mean-time, we recommend that mitigation measures consisting of reshaping the slope and controlled excavation of the slide mass be designed and implemented as soon as possible. The excavation would have two major phases. First, the stable rockmass upslope of the existing slide would be removed to prevent progression of this failure mode upslope and to provide a safe bench to perform slide removal. Second, the active rockslide would be removed in lifts until a stable slope configuration is achieved that removes the failure mode. There should be some urgency in developing a solution to this issue because there will come a time when the slide mass movement rates will be too great to perform any mitigation in a controlled and safe manner and limit downslope impacts.

South Slide

Based on our observations and the information provided by Tim Blackwood, we believe that the recent south slide is an isolated event and the risk of further, progressive failures from that isolated area is low. However, we believe that the slide highlights an unpredictable rockfall hazard that exists along the entire length of the dock. We recommend that mitigation measures be taken immediately to reduce exposure to these risks in the short term while long-term, permanent rockfall mitigation can be designed and constructed. We recommend that operations on the dock be evaluated to determine how much of the east side of the dock (up against the slope) can be blocked off to allow for a catchment zone and still maintain dock operations. Moving

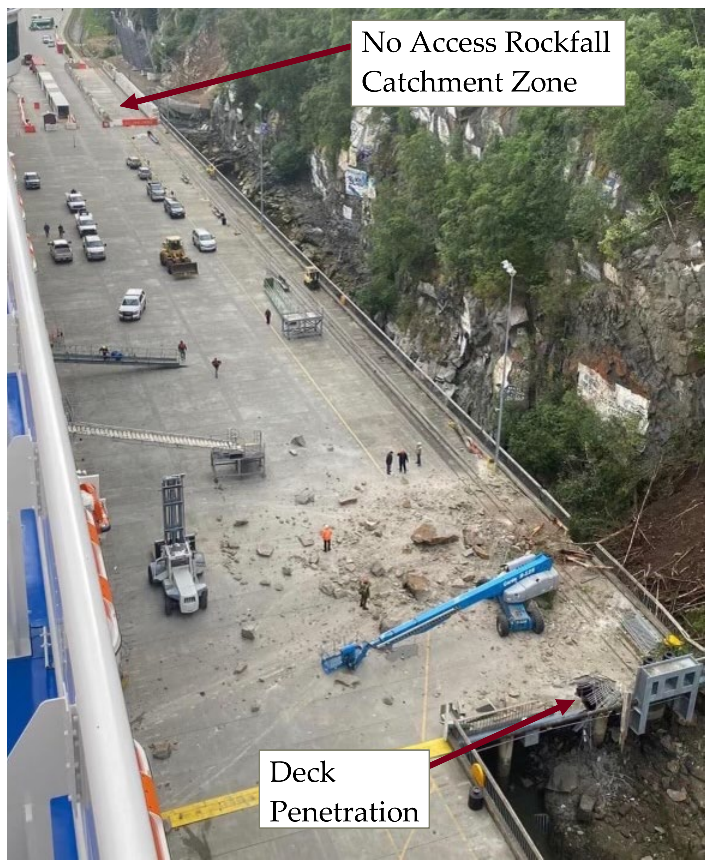

Photo 5: View of South Slide debris immediately after the event. Note the spread of the debris across the deck and the full penetration of the dock surface. Also note blocked access zone on north end of dock under the North Slide. Photo courtesy Cody Jennings.

pedestrian and vehicle traffic as much as possible to the west (water) side of the dock will also reduce the amount of risk exposure and thereby reduce the exposure to risk of injury or damages.

In addition to limiting access to the east side of the dock, temporary mitigation measures that can be taken immediately include the installation of temporary barriers such as Eco Blocks, rockfall fences, or other similar barriers. The rockfall barriers should protect users from falling rocks as well as rocks that shatter upon impacting the dock surface in the catchment zone. Permanent solutions would include more permanent versions of the temporary measures but should be based on rockfall modelling, taking into account actual slope geometry, various initiation zones, debris sizes, and trajectories. We recommend that the rockfall mitigation be designed to retain a percentage of the modelled rockfall that is consistent with Alaska DOT&PF standards or other recognized standard for protection for similar intermodal/transportation facilities.

CLOSURE AND LIMITATIONS

This letter was prepared for the exclusive use of our client and their representatives for evaluating the site as it relates to the geotechnical aspects discussed herein. The conclusions contained in this report are based on site conditions as they were observed during our field visit and through information gained through discussions with the MOS and the WPYR personnel and their geotechnical consultant. Additional work will be needed to refine our conclusions and recommendations. Regardless, it is our opinion that the slope conditions observed during our site visit display significant hazards to people and structures below the slope and mitigation of these hazards should be undertaken immediately to reduce the risk of injury and damage. We are unable to predict timing of full failure of the north slide, nor are we able to predict the timing or location of additional slides similar to that of the south slide. However, we are confident that these events will occur in the future and cannot guarantee that there will be enough time to adequately address these hazards through mitigation before they occur.

Unanticipated conditions are commonly encountered. Such unexpected conditions frequently require that additional expenditures be made to attain a properly constructed project. Therefore, some contingency fund is recommended to accommodate such potential extra costs. Shannon & Wilson has prepared the attachment *Important Information About Your Geotechnical*/Environmental *Report* to assist you and others in understanding the use and limitations of the reports.

Copies of documents that may be relied upon by our client are limited to the printed copies (also known as hard copies) that are signed or sealed by Shannon & Wilson with a wet, blue ink signature. Files provided in electronic media format are furnished solely for the convenience of the client. Any conclusion or information obtained or derived from such electronic files shall be at the user's sole risk. If there is a discrepancy between the electronic files and the hard copies, or you question the authenticity of the report please contact the undersigned. We appreciate this opportunity to be of service. Please contact the undersigned at (907) 561-2120 with questions or comments concerning the contents of this report.

Should you have questions or comments regarding the information contained herein, please contact the undersigned. We look forward to continue working with you on this project and appreciate the opportunity to be of service to you.

Sincerely,

SHANNON & WILSON

Kyle Brennan, PE
Vice President

Rex Whistler, PE

Enc. Important Information about your Geotechnical/Environmental Report

Attachment to 109508-001

Date: March 2021
To: Municipality of Skagway
Re: Railroad Dock Slide Assessment

Important Information About Your Geotechnical/Environmental Report

CONSULTING SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES AND FOR SPECIFIC CLIENTS.

Consultants prepare reports to meet the specific needs of specific individuals. A report prepared for a civil engineer may not be adequate for a construction contractor or even another civil engineer. Unless indicated otherwise, your consultant prepared your report expressly for you and expressly for the purposes you indicated. No one other than you should apply this report for its intended purpose without first conferring with the consultant. No party should apply this report for any purpose other than that originally contemplated without first conferring with the consultant.

THE CONSULTANT'S REPORT IS BASED ON PROJECT-SPECIFIC FACTORS.

A geotechnical/environmental report is based on a subsurface exploration plan designed to consider a unique set of project-specific factors. Depending on the project, these may include: the general nature of the structure and property involved; its size and configuration; its historical use and practice; the location of the structure on the site and its orientation; other improvements such as access roads, parking lots, and underground utilities; and the additional risk created by scope-of-service limitations imposed by the client. To help avoid costly problems, ask the consultant to evaluate how any factors that change subsequent to the date of the report may affect the recommendations. Unless your consultant indicates otherwise, your report should not be used: (1) when the nature of the proposed project is changed (for example, if an office building will be erected instead of a parking garage, or if a refrigerated warehouse will be built instead of an unrefrigerated one, or chemicals are discovered on or near the site); (2) when the size, elevation, or configuration of the proposed project is altered; (3) when the location or orientation of the proposed project is modified; (4) when there is a change of ownership; or (5) for application to an adjacent site. Consultants cannot accept responsibility for problems that may occur if they are not consulted after factors, which were considered in the development of the report, have changed.

SUBSURFACE CONDITIONS CAN CHANGE.

Subsurface conditions may be affected as a result of natural processes or human activity. Because a geotechnical/environmental report is based on conditions that existed at the time of subsurface exploration, construction decisions should not be based on a report whose adequacy may have been affected by time. Ask the consultant to advise if additional tests are desirable before construction starts; for example, groundwater conditions commonly vary seasonally.

Construction operations at or adjacent to the site and natural events such as floods, earthquakes, or groundwater fluctuations may also affect subsurface conditions and, thus, the continuing adequacy of a geotechnical/environmental report. The consultant should be kept apprised of any such events, and should be consulted to determine if additional tests are necessary.

MOST RECOMMENDATIONS ARE PROFESSIONAL JUDGMENTS.

Site exploration and testing identifies actual surface and subsurface conditions only at those points where samples are taken. The data were extrapolated by your consultant, who then applied judgment to render an opinion about overall subsurface conditions. The actual interface between materials may be far more gradual or abrupt than your report indicates. Actual conditions in areas not sampled may differ from those predicted in your report. While nothing can be done to prevent such situations, you and your consultant can work together to help reduce their impacts. Retaining your consultant to observe subsurface construction operations can be particularly beneficial in this respect.

A REPORT'S CONCLUSIONS ARE PRELIMINARY.

The conclusions contained in your consultant's report are preliminary because they must be based on the assumption that conditions revealed through selective exploratory sampling are indicative of actual conditions throughout a site. Actual subsurface conditions can be discerned only during earthwork; therefore, you should retain your consultant to observe actual conditions and to provide conclusions. Only the consultant who prepared the report is fully familiar with the background information needed to determine whether or not the report's recommendations based on those conclusions are valid and whether or not the contractor is abiding by applicable recommendations. The consultant who developed your report cannot assume responsibility or liability for the adequacy of the report's recommendations if another party is retained to observe construction.

THE CONSULTANT'S REPORT IS SUBJECT TO MISINTERPRETATION.

Costly problems can occur when other design professionals develop their plans based on misinterpretation of a geotechnical/environmental report. To help avoid these problems, the consultant should be retained to work with other project design professionals to explain relevant geotechnical, geological, hydrogeological, and environmental findings, and to review the adequacy of their plans and specifications relative to these issues.

BORING LOGS AND/OR MONITORING WELL DATA SHOULD NOT BE SEPARATED FROM THE REPORT.

Final boring logs developed by the consultant are based upon interpretation of field logs (assembled by site personnel), field test results, and laboratory and/or office evaluation of field samples and data. Only final boring logs and data are customarily included in geotechnical/environmental reports. These final logs should not, under any circumstances, be redrawn for inclusion in architectural or other design drawings, because drafters may commit errors or omissions in the transfer process.

To reduce the likelihood of boring log or monitoring well misinterpretation, contractors should be given ready access to the complete geotechnical engineering/environmental report prepared or authorized for their use. If access is provided only to the report prepared for you, you should advise contractors of the report's limitations, assuming that a contractor was not one of the specific persons for whom the report was prepared, and that developing construction cost estimates was not one of the specific purposes for which it was prepared. While a contractor may gain important knowledge from a report prepared for another party, the contractor should discuss the report with your consultant and perform the additional or alternative work believed necessary to obtain the data specifically appropriate for construction cost estimating purposes. Some clients hold the mistaken impression that simply disclaiming responsibility for the accuracy of subsurface information always insulates them from attendant liability. Providing the best available information to contractors helps prevent costly construction problems and the adversarial attitudes that aggravate them to a disproportionate scale.

READ RESPONSIBILITY CLAUSES CLOSELY.

Because geotechnical/environmental engineering is based extensively on judgment and opinion, it is far less exact than other design disciplines. This situation has resulted in wholly unwarranted claims being lodged against consultants. To help prevent this problem, consultants have developed a number of clauses for use in their contracts, reports and other documents. These responsibility clauses are not exculpatory clauses designed to transfer the consultant's liabilities to other parties; rather, they are definitive clauses that identify where the consultant's responsibilities begin and end. Their use helps all parties involved recognize their individual responsibilities and take appropriate action. Some of these definitive clauses are likely to appear in your report, and you are encouraged to read them closely. Your consultant will be pleased to give full and frank answers to your questions.

The preceding paragraphs are based on information provided by the
ASFE/Association of Engineering Firms Practicing in the Geosciences, Silver Spring, Maryland

Kyle Brennan, PE

Digitally signed by Kyle Brennan, PE
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