SKAGIT COUNTY CRITICAL AREAS REPORT
GEOLOGICALLY HAZARDOUS AREAS (SCC 14.24.400)
MARBLEMOUNT QUARRY

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1. INTRODUCTION

1.1 Purpose

Element Solutions (Element) was retained by the client to provide professional consulting services to identify the potential occurrence of regulated environmental areas and evaluate any potential impacts from the proposed project action to comply with environmental regulatory code. The proposed project action is the development of a rock quarry, as described in detail in **Section 1.2**. The subject property is located near Marblemount in Skagit County, Washington (**Figure 1**) and includes Tax Parcels P45543, P45550, P120304, P128574, and parts of P45548 and P45541 as detailed in **Section 1.3**. The subject property was identified by Skagit County as potentially containing regulated environmental areas as defined under Skagit County Critical Areas Ordinance (SCC 14.24) as detailed in **Section 1.4**. Pursuant to the review and reporting requirements specified in this code, the objectives of the assessment were to evaluate and describe, to the extent feasible, the 1) existing site conditions, 2) occurrence, functions, and processes of regulated areas, and 3) potential impact from the proposed project action on regulated areas. Recommendations for avoiding, minimizing and/or mitigating potential impacts as relevant are provided in accordance with the assessment and reporting requirements specified in the regulatory code.

1.2 Proposed Project Action

Brief Description

The Proposed Project includes boundary line adjustments, site clearing, site grading, road building, quarry operations, and reclamation of a bedrock quarry on Rockport Cascade Road approximately one mile south of Marblemount, WA (**Figure 1**). The Proposed Project will involve development activities on parcels P45543, P128574, P120304, P45550, and parts of P45548 and P45541 (**Figure 2**). A majority of the mining would take place on P45543, which has been used as a small-scale quarry (under 3 acres) over the past several decades. The overall project limit footprint at full buildout is approximately 120 acres. At full buildout, the proposed mining footprint would encompass approximately 30 acres (20 acres proposed for Phase I); quarry operations—including roads, stockpile areas, stormwater management, and operations areas—would encompass approximately 60 acres; and approximately 30 acres would be retained vegetation areas.

Currently, stands of second-growth timber cover a majority of the site and an approximately 800-foot-high rock face dominates P45543. This rock face consists of Shuksan greenschist, which is the desired quarry stone source.

The proposed project would occur in four steps:

1. Boundary Line Adjustment, Site Clearing, Preparation, and Building Access Road for Forest Practice Conversion;
2. Mining within the MRO Overlay Area;
3. Possible Quarry Expansion, Contingent on MRO Boundary Change, and;
4. Quarry Reclamation.

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Step 1 – Boundary Line Adjustment, Site Clearing, Preparation, and Building Access Road for Forest Practice Conversion would include acquiring and performing boundary line adjustments on P128574. The property line would be adjusted to encompass approximately 10.2 acres of P45541. Additionally, an approximately 20.2-acre portion of P45548 would also be boundary line adjusted to P128574. Step 1 also includes clearing, removing stumps, site grading, and road construction on Parcels P45543, P45550, P120304, P128574, and parts of P45548 and P45541. Marketable timber will be removed from the site. An approximately 6,700-foot gravel access road would be built to access the top and eastern portions of the project site. Wood mulch and top soil would be stockpiled on site for future reclamation. Access to the site would include building two new access driveways on Rockport Cascade Road and decommissioning the two existing access points. Grading and roadways for quarry operations and stormwater management will be constructed on the western portion of the project limits. The road providing access to the eastern portion of the site would be designed to meet or exceed Skagit County standards, Washington Department of Natural Resources (DNR) Forest Practice and Mining standards, and any other standards appropriate for its use. Following site clearing and preparation, the road would be used to access the top of the quarry and for hauling rocks to the bottom for processing.

Step 2 – Mining within the MRO Overlay Area would include establishing the quarry on P45543 within the current MRO boundary per the Mining Site Plan. Step 2 would also include the construction of mining operation areas and support facilities, including an armor stone staging area in the western portion of P45543. This step would also involve constructing portable offices/storage structures, a truck loadout scale, a heavy equipment and employee parking area, a fueling station, maintenance shops, and storage facilities for blasting equipment. An undersized rock stockpile area would be established within the existing MRO area on P128574 and a potential future phase undersized rock stockpile area has been designated if the MRO boundary is successfully expanded (see Step 3). Rock mining would be conducted using a “top down” approach, such that rock would be transported to the stockpile or staging areas by truck, instead of being cast off the cliff face. The land use to the south, east, and west is secondary and industrial forestry and the land use to the north is rural residential. A minimum 100-foot setback would be maintained along adjacent property lines or bordering quarry activities. A 50-foot vegetative buffer would be maintained on Rockport Cascade Road.

Step 3 – Possible Quarry Expansion, Contingent on MRO Boundary Change, would include quarry and undersized rock stockpile area expansions. Step 3 is dependent upon an expansion of the MRO through the Skagit County Comprehensive Plan Amendment process. Once the MRO overlay is expanded, the quarry area would expand approximately 10 acres into P45541, and the undersized rock stockpile area described in Step 2 would expand to the south (approximately 20 acres) onto P45548 to accommodate the additional undersized rocks from the expanded quarry. The mining activities of Step 3 would be the same as those in Step 2.

Step 4 – ***Quarry Reclamation*** would include full reclamation of all the affected parcels following decommissioning of the quarry, roads, and supporting mining operations. The full lifespan of the quarry would be up to 100 years or whenever the source of rock is exhausted. The Mining Reclamation Plan is consistent with DNR surface quarry reclamation regulations. The land will be restored to forestry land use following reclamation.

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1.3 Location and Physiography

The study area is located in unincorporated Skagit County in the NE ¼ of the NW ¼ of Section 24 and the SW ¼ of Section 13, Township 35 North, and Range 10 East of the Willamette Meridian. The subject parcel is approximately 1.25 miles south of Marblemount and 0.5 miles east of the Skagit River (**Figure 1**). Existing access to the site is possible from Rockport Cascade Road via a short gravel driveway and turnaround. Ground surface elevations in the study area vicinity range from approximately 300 feet along the western parcel boundary to approximately 1,200 feet at the crest of the rock outcrop (all elevations NAVD 88). The presumed hydrologic gradient is roughly easterly to westerly; no wetlands are mapped in or adjacent to the study area nor were any observed on site. Two small watercourses were identified in the southern portion of the site during the field reconnaissance (**Figure 2**).

1.4 Geologically Hazardous Areas Designation and Applicable Code

SCC regulates Geologically Hazardous Areas through Title 14, Chapter 14.24, and Article 4 – Geologically Hazardous Areas. General "Geologically Hazardous Areas" as defined in Section 14.24.400 of the SCC are described in the following statement:

"Geologically hazardous areas shall be designated consistent with the definitions provided in WAC 365-190-080(4). These include areas susceptible to the effects of erosion, sliding, earthquake, or other geologic events. They pose a threat to the health and safety of citizens when incompatible residential, commercial, industrial, or infrastructure development is sited in areas of a hazard. Geologic hazards pose a risk to life, property, and resources when steep slopes are destabilized by inappropriate activities and development or when structures or facilities are sited in areas susceptible to natural or human-caused geologic events. Some geologic hazards can be reduced or mitigated by engineering, design, or modified construction practices so that risks to health and safety are acceptable. When technology cannot reduce risks to acceptable levels, building and other construction in, above and below geologically hazardous areas should be avoided."

More specifically, hazard classes are defined by the criteria listed below:

Erosion Hazard Areas

SCC 14.24.410(1) states that Erosion Hazard Areas specifically include:

a) Areas with gradients greater than or equal to 30%.
b) Areas located within the following map units: No. 1 Andic Cryochrepts, Nos. 3 and 4 Andic Xerocrepts, No. 13 Birdsview, Nos. 47 and 48 Dystric Xerochrepts, Nos. 50 and 51 Dystic Xerorthents, Nos. 63 and 65 Guemes, No. 69 Hoogdal, No. 90 Lithic Haploxerolls, No. 91 Marblemount, No. 99 Mundt and Nos. 150 and 151 Typic Croyorthods or mapped severe erosion hazard, as identified in the U.S. Department of Agriculture Natural Resources Conservation Service Soil Survey of Skagit County Area, WA (1989).
c) Coastal beaches or bluffs.
d) Areas designated in the Department of Ecology, Coastal Zone Atlas, Washington, Volume Two Skagit County (1978) as U (Unstable), UB (Unstable Bluff), URS (Unstable Recent Slide), or UOS (Unstable Old Slide).
e) Areas susceptible to rapid stream incision and stream bank erosion.

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Landslide Hazard Areas

In regard to Landslide Hazards, SCC 14.24.410(2) states that "landslide hazards are areas potentially subject to landslides based on a combination of geologic, topographic and hydrologic factors."

These areas may include:

a) Areas designated in the Department of Ecology, Coastal Zone Atlas, Washington, Volume Two, Skagit County (1978) as U (Unstable), UB (Unstable Bluff), URS (Unstable Recent Slide), or UOS (Unstable Old Slide).

b) Slopes having gradients of 15% or greater:

   (i) That intersect geologic contacts with permeable sediments overlying low-permeability sediment or bedrock and springs or groundwater seepage are present; or

   (ii) That are parallel or subparallel to planes of weakness (such as bedding planes, joint systems, and fault planes) in subsurface materials.

c) Slopes of 40% or steeper and with a vertical relief of 10 feet or more.

d) Areas of previous failure such as earth slumps, earthflows, mudflows, lahars, debris flows, rock slides, landslides or other failures as observed in the field or as indicated on maps or in technical reports published by the U.S. Geological Survey, the Geology and Earth Resources Division of DNR, or other documents authorized by government agencies.

e) Potentially unstable areas resulting from rapid stream incision, stream bank erosion, and undercutting by wave action.

f) Coastal bluffs.

g) Slopes with a gradient greater than 80% and subject to rock fall.

h) Areas that are at risk from snow avalanches.

i) Areas designated on the Skagit County Alluvial Fan Study Orthophoto Maps as alluvial fans or as identified by the Administrative Official during site inspection.

j) Areas located in a narrow canyon potentially subject to inundation by debris flows or catastrophic flooding.

k) Those areas delineated by the U.S. Department of Agriculture's Natural Resources Conservation Service Soil Survey of Skagit County as "severe" (Table 9) limitation for building development.

Seismic Hazard Areas

SCC 14.24.410(3) states that Seismic Hazard areas specifically include "areas (that) are subject to severe risk of damage as a result of earthquake-induced ground shaking, slope failure, settlement, soil liquefaction or surface faulting." These Seismic Hazard Areas include:

a) Areas located within a high liquefaction susceptibility area as indicated on the Liquefaction Susceptibility Map of Skagit County issued by Washington Department of Natural Resources dated September 3, 2004, or as amended thereafter. A site assessment is not required for high liquefaction hazard areas for single-family residence proposals unless other criteria provided in this Section apply.

b) Areas located within 1/4 mile of an active fault as indicated on investigative maps or described in studies by the United States Geologic Survey (USGS), Geology and Earth Resources Division of the Washington Department of Natural Resources, or other documents authorized by government agencies, or as identified during site inspection.

c) Those known or suspected erosion and landslide hazards referenced in Subsections (1) and (2) of this Section.

d) Tsunami and seiche hazard areas include coastal areas and lake shoreline areas susceptible to flooding, inundation, debris impact, and/or mass wasting as the result of coastal or inland wave action generated by seismic events or other geologic events.

Skagit County does not require a site assessment for tsunami and seiche hazard areas.

Volcanic Hazard Areas

SCC 14.24.410(4) states that Volcanic Hazard Areas are areas that "are subject to pyroclastic flows, lava flows, debris avalanche, and inundation by debris flows, mudflows, lahars or related flooding resulting from volcanic activity. Suspect volcanic hazards include those areas indicated in the USGS Open-File Report 95-499 as the volcanic hazard zone for Glacier Peak, Washington; or in the USGS Open-File Report 95-498 as the volcanic hazard area of Mount Baker, Washington."

Skagit County does not require a site assessment for Volcanic Hazard Areas unless other Critical Areas designations also apply to the subject site.

Mine Hazard Areas

SCC 14.24.410(5) states that Mine Hazard Areas are "as designated on the Department of Natural Resources Map: Coal Measures of Skagit County (1924) or within 200 feet of any other current or historic mine operations determined to be a suspect or known geologically hazardous area by the Administrative Official."

In SCC 14.24.430, Skagit County has defined a series of requirements which apply to all development activities occurring within Geologically Hazardous Areas. The requirements include a mitigation plan prepared by an environmental professional describing the proposed project and discussing the design measures being utilized to avoid and minimize impacts to the Critical Areas described above. Mitigation plans must include "the location and methods of drainage, locations and methods of erosion control, a vegetation management and/or restoration plan and/or other means for maintaining long-term stability of geologic hazards."

In addition, the plan should also address "the potential impact of mitigation on the hazard area, the subject property and affected adjacent properties." Mitigation plans must be approved by the Administrative Official, and must be implemented as a condition of project approval.

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1.5 Mitigation Standards

As described in SCC 14.24.430(1), Mitigation Standards may include:

a) A temporary erosion and sedimentation control plan prepared in accordance with the requirements of Chapter 14.32 SCC (Drainage Ordinance), as amended.

b) A drainage plan for the collection, transport, treatment, discharge and/or recycling of water in accordance with the requirements of Chapter 14.32 SCC, as amended. Surface drainage shall not be directed across the face of a landslide hazard (including marine bluffs or ravines). If drainage must be discharged from the hazard area into adjacent waters, it shall be collected above the hazard and directed to the water by tight line drain and provided with an energy dissipating device at the point of discharge.

c) All proposals involving excavation and/or placement of fill shall be subject to structural review under the appropriate provisions of the International Building Code (IBC) as amended by Skagit County.

d) Critical facilities as defined under Chapter 14.04 SCC shall not be sited within designated geologically hazardous areas with the exception of volcanic hazard areas. No critical facilities shall be located within 1/4 mile of an active fault.

e) All infiltration systems, such as stormwater detention and retention facilities and curtain drains utilizing buried pipe or French drains, are prohibited in geologically hazardous areas and their buffers unless the mitigation plan indicates such facilities or systems will not affect slope stability.

f) Existing vegetation shall be maintained in landslide and erosion hazard areas and associated buffers. Any replanting that occurs shall consist of native trees, shrubs, and ground cover that is compatible with the existing surrounding native vegetation, meets the objectives of erosion prevention and site stabilization, and does not require permanent irrigation for long-term survival. Normal nondestructive pruning and trimming of vegetation for maintenance purposes; or thinning of limbs of individual trees to provide a view corridor, shall not be subject to these requirements.

g) A minimum buffer width of 30 feet shall be established from the top, toe and all edges of all landslide and erosion hazard areas. For landslide and erosion hazard areas with a vertical relief greater than 50 feet, the minimum buffer shall be 50 feet. The buffer may be increased by the Administrative Official for development adjacent to a marine bluff or ravine which is designated as Unstable in the Coastal Zone Atlas, Washington, Volume Two, Skagit County (1978) or where the Administrative Official determines a larger buffer is necessary to prevent risk of damage to existing and proposed development.

h) Structural development proposals within seismic hazard areas shall meet all applicable provisions of the IBC as amended by Skagit County. The Administrative Official shall evaluate documentation submitted pursuant to SCC 14.24.420(2) and condition permit approvals to minimize the risk on both the subject property and affected adjacent properties. All conditions shall be based on known, available, and reasonable methods of prevention, control and treatment. Evaluation of geotechnical reports may also constitute grounds for denial of the proposal.

i) No residential structures shall be located in geologic hazard areas or their buffers if that hazard cannot be fully mitigated.

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Landslide or Erosion Hazard Buffer Reduction

As described in SCC 14.24.430 (2), buffers of landslide or erosion hazard areas may be reduced to a minimum of 10 feet for development meeting all of the following criteria:

a) No reasonable alternative to buffer reduction exists; and

b) A site assessment is submitted and certifies that:

  (i) There is a minimal hazard in the vicinity of the proposed development as proven by evidence of no landslide activity in the past; and

  (ii) A quantitative slope stability analysis indicates no significant risk to the development proposal and adjacent properties; or the geologically hazardous area can be modified; or the development proposal can be designed so that the hazard is eliminated. The quantitative analysis shall include the minimum setback allowed for development as indicated by a slope stability model with respect to a minimum factor of safety of 1.5 for static conditions, 1.25 for seismic conditions, or 10 feet, whichever results in the greater setback. The elements of the quantitative site assessment shall be determined by the Administrative Official and may include 1 or more of the following:

    A. Subsurface exploration, to include at least 1 boring with sample collection for laboratory analysis.

    B. Laboratory analysis shall assess the soil characteristics and include sieve analysis, moisture, angle of internal friction, and cohesion.

    C. Utilizing the information from the subsurface exploration and laboratory analysis, the quantitative site assessment shall include slope stability modeling with factor of safety analysis. The analysis shall indicate the factor of safety within 50 feet of the top and toe of geologic hazards; and

  (iii) The development will not significantly increase surface water discharge or sedimentation to adjacent properties beyond pre-development conditions; and

  (iv) The development will not decrease slope stability on adjacent properties; and

  (v) Such alterations will not adversely impact other critical areas.

2. Geologically Hazardous Areas Assessment

2.1 Methods

The following assessment integrates the best available science to characterize the existing conditions at the subject site and utilizes both desktop and field assessment methods. Analyses were conducted by a qualified professional and include previous studies and information as well as new interpretations based on professional judgment and experience. Evaluation of impacts uses industry and regulatory standards. Assessment methods integrated both desktop and field assessment methods as described below.

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2.2 Existing Conditions Characterization - Desktop Analysis

2.2.1 Spatial Data

The desktop analysis utilized in this assessment was conducted by licensed geologist and is built on previous studies and information performed by others; however, it includes new interpretations based on professional judgment and experience. The desktop data is inventoried below in Table 1.

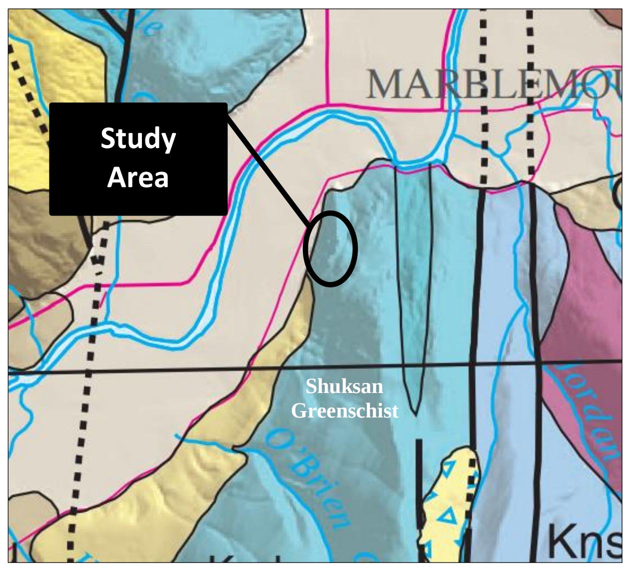
Table 1: Data Used for Desktop Analysis

Data	Format	Date	Source
Aerial photography (NAIP Orthophoto)	SID	2011 - 2017	USDA and Skagit County
LiDAR	Bare earth grid	2006 and 2016	PSLC and WADNR
Geology	Shapefile	2006	DNR 1:100,000 Digital Geology
Soils	Accessed online	Current	USDA/NRCS Web Soil Survey
Topographic Contour Map	Shapefile	2016	Generated from LiDAR

2.2.2 Previous Studies and Information

Geologic Mapping and Literature Review

The study area occurs within a tectonically active, accretionary terrane. The Shuksan Greenschist is a member of the Easton Metamorphic suite, which also includes Darrington Phyllite, a metasedimentary unit which stratigraphically overlies the Shuksan Greenschist (see illustration at right adapted from Dragovich et. al., 2003). The oceanic shale and sandstone protolith of the Darrington Phyllite was deposited on top of the oceanic basalt protolith of the Shuksan Greenschist, which originally formed in the Middle and Late Jurassic and was metamorphosed in the Early Cretaceous (Brown, 1987). The Shuksan Greenschist is described as follows:



"The Shuksan Greenschist is a fine-grained but well-recrystallized metamorphic rock, commonly containing sodic amphiboles." - Tabor et. al, 2003

"Predominantly fine grained greenschist and (or) blueschist derived mostly from probable Jurassic ocean-floor basalt. Blueschist contains an unusual dark-blue amphibole. The crystals are typically very small and, even with a hand lens, are not easily distinguished." - Tabor and Haugerud, 2009

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“*Mostly well-recrystallized and strongly S1-foliated metabasaltic greenschist or blueschist; greenschist is shades of greenish gray and weathered to light olive gray; blueschist is bluish gray to bluish green; locally includes quartzite (metachert) and graphitic phyllite interlayers; commonly layered on a centimeter scale and contains conspicuous epidote and (or) quartz segregations; S1 foliation and layering are commonly folded on an outcrop scale.*” - Dragovich at. al., 2003

Bedrock Structure

The Shuksan Greenschist outcrops along the western flank of the North Cascades in Washington State in a fragmented, north-south trending belt roughly 111 miles long. The metamorphic facies (blueschist and/or greenschist) are consistent with low temperature, high-pressure subduction zone metamorphism (estimated 330 – 400°C and 7 – 9 kilobars) which began roughly 144 – 164 million years ago (Ma) (Brown, 1986). Emplacement occurred with uplift and imbrication due to thrust faulting and displacement along high-angle north-south trending strike-slip faults; the time of emplacement has been roughly constrained to between 75 Ma and 105 Ma. As described in Brown, 1986, fault zones in the Shuksan Greenschist are “characterized by the development of mylonite, typically 1 to 2 m thick, and showing minor new crystallization of quartz, chlorite, muscovite, stilpnomelane, and calcite.”

2.3 Existing Condition Characterization - Field Assessment

A field visit of the subject property was conducted by a qualified Element environmental professional on October 22, 2018. The investigation consisted of walking the site focusing on the areas identified in the desktop analysis. The following subsections describe conditions that were observed while in the field.

In summary, the site consists of two distinct geomorphic conditions: natural, steep bedrock foothill topography, including cliffs with talus, and a low gradient Holocene alluvial terrace (**Figure 2**). The site ranges from sparsely vegetated to densely vegetated. A forest fire in ~1998 burnt most of the timber on the foothills in the project vicinity and young timber stands are reestablishing in the burnt areas. The alluvial terrace has been historically logged and cleared and is sparsely vegetated. Two small watercourses flow down the steep topographic areas and infiltrate into the alluvial terrace east of the proposed quarry. A proposed access road will cross these watercourses. No seeps or flowing streams were observed in the area where quarrying is proposed. The proposed mining will take place within the steep bedrock while the quarry operations will primarily take place within the alluvial terrace. The access road will cross steep slopes to access the east, upper portions of the subject site. The steep slopes were generally found to be bedrock with shallow soils, colluvium, and talus. The steep bedrock cliffs and slopes create the potential for geologically hazardous areas. The presence of talus indicates that rockfall processes occur intermittently at this site. Talus ranges in size from small particulate to boulders in excess of 10-foot in diameter. No evidence in the field or in the desktop analysis revealed any historic deep-seated landslide occurrence within the subject site.

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2.4 Assessment of Critical Areas

Table 3 summarizes the geologic hazards as defined by SCC 14.24 that were identified as potentially occurring at this site:

Table 3: Geological Hazard Summary for Subject Area

Critical Area	Present on Subject Property?
Landslide Hazard Critical Area	Yes
Seismic Hazard Critical Area	Yes
Alluvial Fan Hazard Critical Area	No
Volcanic Hazard Critical Area	No
Erosion Hazard Critical Area	Yes
Tsunami and Seiche Hazard Critical Area	No
Mine Hazard Critical Area	No

2.4.1 Rockfall Geologic Hazards

A primary focus for this project site was determined to be the potential for rockfall occurrence. A rockfall hazard study was completed by Shannon and Wilson, Inc. on December 26, 2018 for the purposes of evaluating potential rockfall impacts to the Cascade Rockport Road (Appendix A). The analysis utilized RocFall™ version 6.011 to predict probable rockfall runout potential for a range of potential rockfall scenarios. Rockfall hazards are possible from slopes 40% or greater as identified in SCC 14.24 (**Figure 3**). Rockfall hazards could be encountered during the road building and quarrying activities as well as potentially occurring intermittently without obvious triggers.

2.4.2 Seismic Hazards

Seismic activity is likely to occur in the vicinity of the subject area in the future. The magnitude of seismicity may range for small, imperceptible events to significant ground motion for larger magnitude events. During significant ground motion, rockfall and other landsliding may result as well as potential liquefaction of saturated soils.

2.4.3 Erosion Hazards

Erosion hazards can occur on steeper slopes comprised of erodible soils. Channeling or rilling can result and sediment can be transported downgradient. Slopes that are disturbed, regraded, cleared, or otherwise modified are more susceptible to erosion processes.

2.5 Risk Analysis

To understand the risk of geologic hazards at the subject site, it is necessary to first define *hazard* and *risk*. *Hazards* are defined as sources of danger. In this analysis, relevant geologic hazards as defined in SCC 14.24.410 include the following:

- **Landslide Hazards**, which involve the mass movement of earth, rock, and/or debris downslope;
- **Seismic Hazards**, which involve ground motions and earth processes either directly or indirectly caused by an earthquake;

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- **Erosion Hazards**, which involve the removal and transport of soil or sediment by mechanical or chemical means.

Risk is defined as an integration of the probability of an occurrence of a hazard combined with the potential effects, or consequences, if the hazard does occur. Therefore, frequency and effect are captured by discussions of risk rather than hazard. The effects of erosion are that ecological systems and infrastructure/private property management costs can be impacted. The effects of earthquakes and landslides are that the built environment could be damaged and the result may adversely impact human safety and/or ecological systems. Table 4 is a sample chart illustrating different levels of relative risk:

Table 4: Relative Risk Table

Probability	Low	Medium	High
Consequence	RELATIVE RISK		
Minor	Low	Moderate	Moderately High
Moderate	Moderate	Moderately High	High
Severe	Moderately High	High	Very High

The geologic risk that exists at the site is divided between risk to the public and occupational risk. For this analysis, the public risk is the subject of focus for analysis. Occupational risk will be evaluated through a separate geotechnical analysis being conducted in coordination with the DNR surface mining review process. The DNR geotechnical analysis will look at geologic risks related to the mining operations following state and federal code requirements for occupational safety. The geotechnical analysis cannot be completed until the access road is complete to allow for the investigation.

Potential risk to the public may exist from rockfall hazard occurrence. Rockfall occurrence will be greatest during the road construction. The road will be constructed as a full or partial bench and will utilize embankment fill. During the benching and grading process, rockfalls may be triggered. While rockfalls are a natural process that occur intermittently on steep bedrock landforms, the temporary disturbance during road building will increase the rockfall occurrence in the areas at and immediately adjacent to the road construction. The analysis conducted by Shannon and Wilson (2018) concluded that rockfall is unlikely to travel as far as the Rockport Cascade Road, the closest point that the public can get to the quarrying and road building activities. Therefore, the change in relative risk to the public as a result of this proposed project is low. The residential property to the north of the quarry site is currently within a potential rockfall hazard area as evidenced by the talus present at that site; however, the property it is not within the footprint of rockfall that is anticipated to be potentially dislodged by the road construction or quarrying activities. The change to risk resulting from the proposed project, therefore, is low.

The project occurs within a seismically-active area. During seismic events, the potential for rockfall is increased. This project will not increase the likelihood of potential seismicity occurrences; therefore, the existing geological risk associated with seismicity is considered existing background risk and will be unaffected by the proposed project activities. All structures being used for this project are modular, transportable and temporary structures occupied only during business hours. No permanent dwellings are proposed; therefore, the risk to structural damage from seismic shaking is low.

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Potential risk from erosion of disturbed and altererd slopes is probable, particularly during construction. Risk can be mitigated with construction techniques and materials. There is no significant threat to public safety or other critical areas anticipated if the potential for erosion is adequately mitigated; therefore, the risk is low.

2.6 Changes in Conditions

Certain changes to the site conditions, anthropogenic or natural, can change the probability of hazard occurrence or consequence. Potential changes may include (but are not limited to) slope loading, grading, subsurface or surface hydrologic alterations, seismic deformation, soil disturbance, and de-vegetation. In the event that such changes significantly alter the site conditions in ways other than those explicitly described in this report, the findings presented in this analysis should be considered obsolete until a reassessment of site conditions and relative risk is performed.

2.7 Limitations

No subsurface evaluation or bedrock mechanics analyses were performed in this assessment, and as such all conditions below grade are inferred from surficial topographic indicators, exposed geology, and visual observation of several shallow hand dug test pits and soil probing (≤ 24 inches below ground surface). The bedrock cliffs could not be visually inspected at the time of the site assessment due to physical access limitations; the cliffs are too steep to ascend/descend from the subject parcel without technical rigging. In recognition of the reasonable feasibility constraints of this assessment, no warrantee regarding the competency, composition, or quality of any geologic site characteristic that was not directly evaluated is expressed or implied by this communication.

3. SUMMARY OF FINDINGS AND RECOMMENDATIONS

3.1 Summary of Findings

The subject parcel contains slopes that are regulated Critical Areas due to the presence of Landslide, Erosion, and Seismic Geologically Hazardous Areas as defined in SCC 14.24.410, and as such is subject to the Mitigation Standards and Critical Area buffers described in SCC 14.24.430. This includes the establishment of setbacks from the top, toe, and edge of all landslide hazard areas. Pursuant to SCC 14.24.430.1(h), structural development in the subject parcel area must be constructed in conformance with IBC standards as amended by Skagit County. Talus deposition at the base of the steep slopes in the subject area indicates that rockfall has occurred in the area historically and may continue to occur periodically in the future, with or without parcel development. Isolated rockfall is a natural geologic process and should be expected as a background condition. Modeling determined that rockfall runout is unlikely to propogate as far as the public road either as a natural occurrence or because of the proposed development, therefore the risk for public impacts is low. No indicators of historic landslides were observed during the field and desktop assessment of the Project Limits, and the presence of shallow, competent bedrock across the site suggests a low probability for significant landslides. Steep areas that are developed, modified, or disturbed during quarry or road development and operations are susceptible to erosion hazard occurrence in the future.

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3.2 Recommendations

The following recommendations were developed to further reduce the risk associated with landslide, erosion, and/or seismic hazards in the study area:

1) **A minimum 200-foot setback from the toe of slopes exceeding 40 percent grade is recommended for any structures that are to be occupied regularly by employees**, with the exception of the access road, as shown in Figure 3.
    a. If a reduction to the recommended setback is desired, more detailed geotechnical evaluation is recommended.
    b. During times of blasting, rock moving, or if rockfall activity is observed, the 200-foot setback area should be avoided until conditions stabilize.
    c. The 200-foot setback area should be signed and notice of rockfall hazards identified.

2) Signage at the top of steep slopes would be utilized to warn employees or site users of the hazardous steep slope conditions.

3) A geotechnical engineer would be available for site inspection during the construction of the road to help determine suitability of cuts and fills and to identify potential geologically hazardous conditions that may be encountered.

4) A site-specific construction stormwater pollution prevention plan would be developed in conformance with the requirements of SCC 14.32 and other applicable stormwater regulatory code. At a minimum, the plan should include the following Best Management Practices (BMPs) for Temporary Erosion and Sediment Control (TESC):
    a. Native vegetation would be left in place wherever possible, while restoration of native vegetation and appropriate landscaping techniques may be implemented to enhance soil stability and reduce erosion in impacted areas.
    b. Clearing limits would be clearly demarcated with flagging, lathe, and/or high visibility construction fencing prior to the onset of construction activities and would be visible to equipment operators in the proposed development area.
    c. BMPs would be established if erosion is anticipated or occurring such that it may cause erosion and mobilization of sediments that could potentially leave the site or enter areas where they could pose a risk to other critical areas.

5) Pursuant to SCC 14.24.430.1(b), a site-specific plan for the collection, transport, treatment, discharge and/or recycling of stormwater would be developed in conformance with the requirements of SCC 14.32.

In the event that *any* of the following conditions are encountered during excavation or grading activities, contact Element or a similarly qualified geotechnical professional for additional site evaluation:

- Highly fractured bedrock, fault breccia, large cracks or voids.
- Groundwater springs, seepage, or saturation.
- Fine-grained (silt or clay dominant) sediment.

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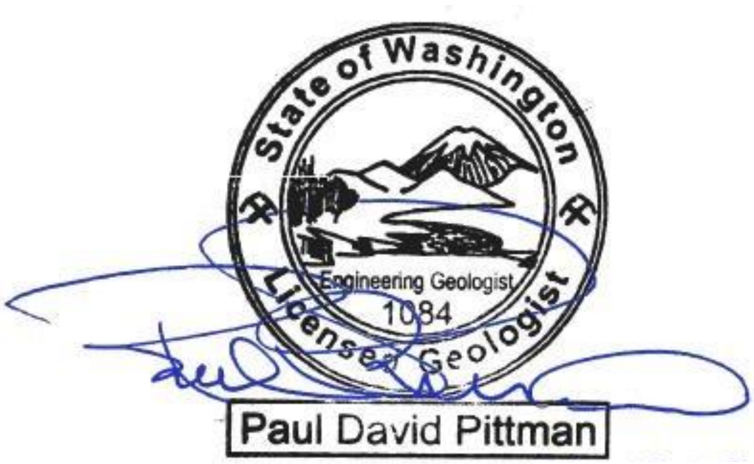
4. CLOSURE

This report was prepared and submitted by:



Exp. 05/21/2019

Paul Pittman, MS, LEG
Earth & Environmental Sciences Manager,
Principal

Statement of Limitations

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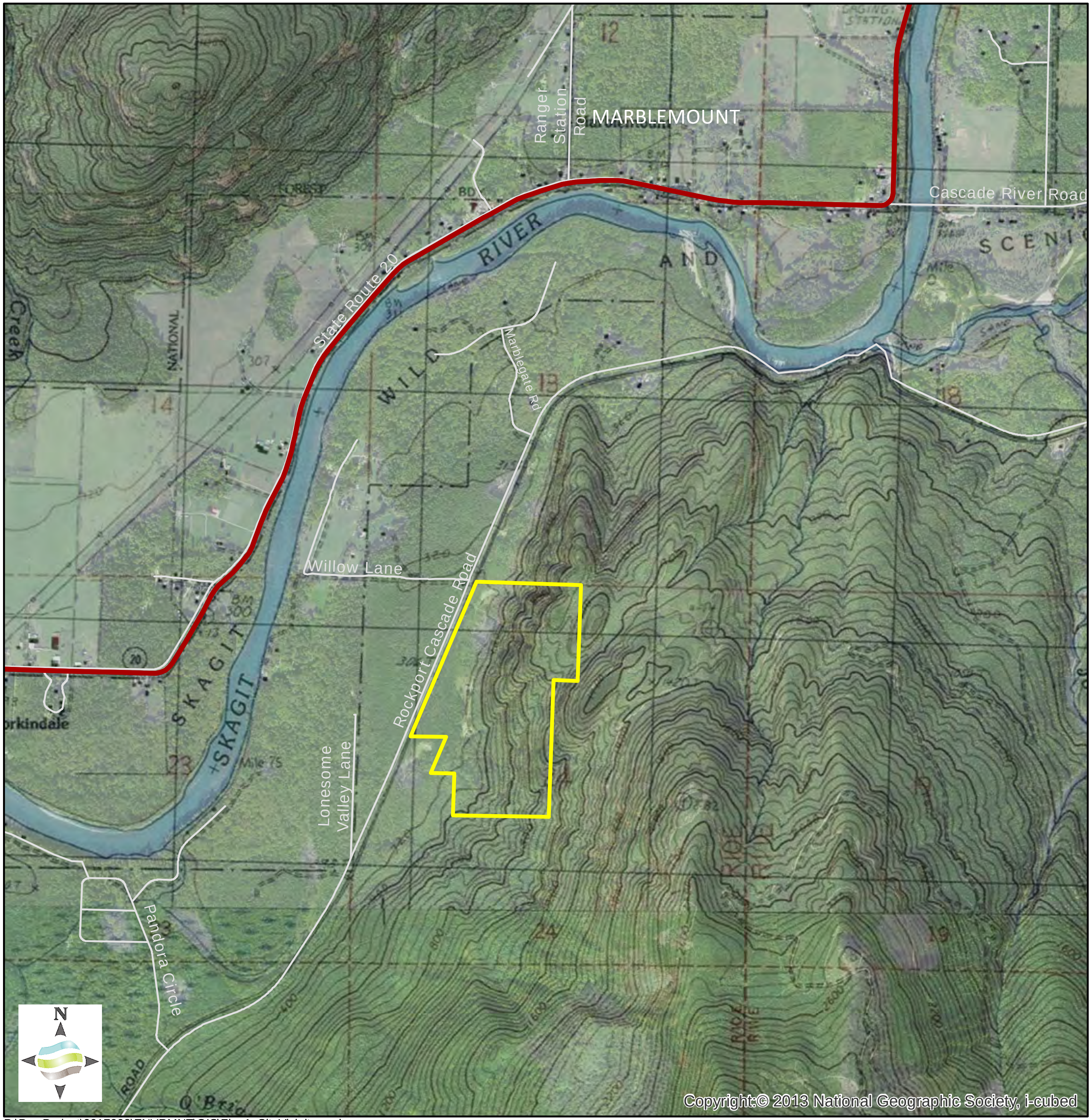
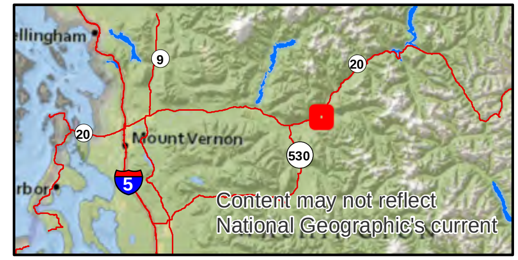
Figures

1) Figure 1 – 1:24,00-Scale USGS Topographic Contour Site Vicinity Map for Project Vicinity
2) Figure 2 – Critical Areas Identified on Subject Property and Study Area
3) Figure 3 – Critical Area Buffers





Data Credits:
USDA NAIP 2015
WSDOT 2018
Skagit County 2018

Project Limits
Rural Roads
State Highways

Feet
0 1,000 2,000 4,000
1:24,000
1 inch = 2,000 feet

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Figure 1

Marblemount Quarry
Site Vicinity Map

Date: 1/9/2019

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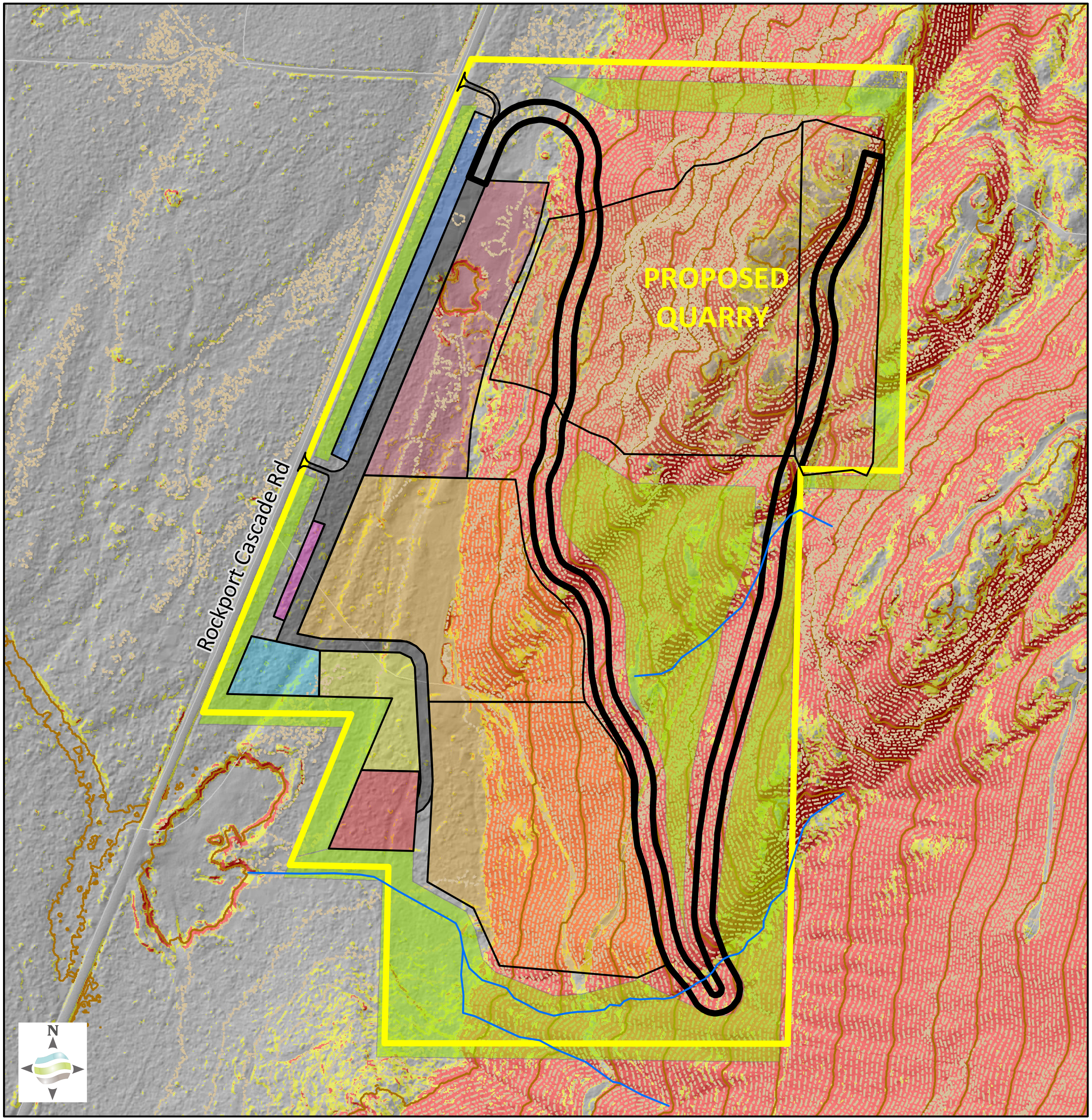

Observed Surfacewater Flow (Watercourse)
ProjectBoundary
Proposed Access Road
Clearing Limits (Trees Retained)
Armor Stone Stockpile
Access/Scale Roads
Explosives Storage Exclusion Area
Undersized Stockpile Area
Misc. Structures Footprint
Quarry Footprint
Soil Stockpile
Stormwater Facility B
Stormwater Facility A

Contour

10 Foot Contours
100 Foot Contours

Geohazard Areas

Percent Slopes

<20%
20-40%
>40%

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FIGURE 2

Marblemount Quarry
Geologically Hazardous Areas

Date: 2/8/2019

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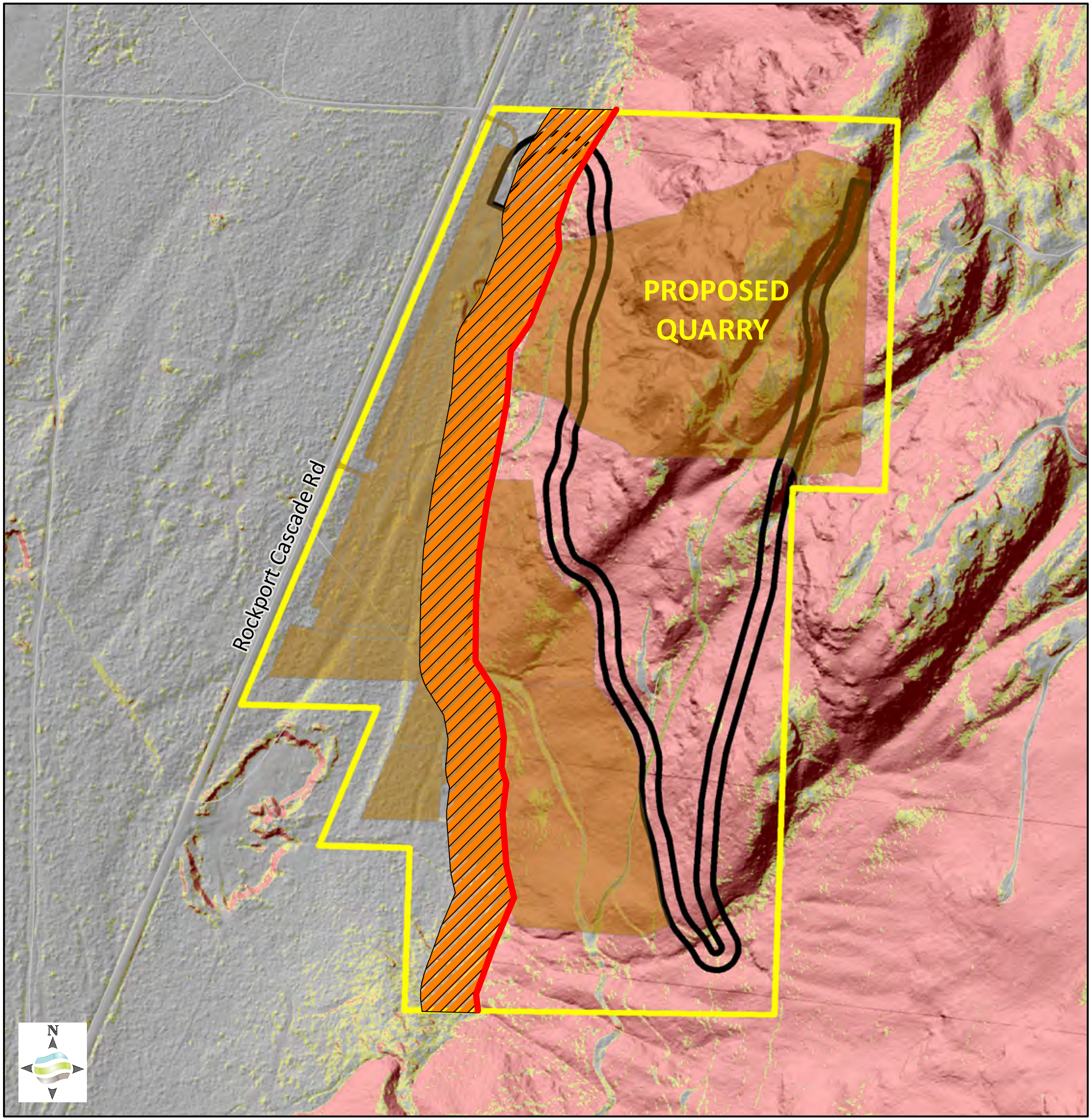

- Toe Of Slope
- Rock Fall Hazard Area (200 Feet)
- Proposed Quarry Activies (Maximum Buildout Potential)
- Project Limits
- Proposed Access Road

Geohazard Areas

Percent Slopes

- <20%
- 20-40%
- >40%

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FIGURE 3

Marblemount Quarry
Rock Fall Hazard Setback Area

Date: 1/10/2019

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Appendix A – Shannon and Wilson Rockfall Hazard Study, December 26, 2018

December 26, 2018

Kiewit Infrastructure West Company
2200 Columbia House Boulevard
Vancouver, Washington 98661

Attn: Mr. Chuck Nylund

RE: ROCKFALL HAZARD STUDY, PROPOSED MARBLEMOUNT QUARRY, SKAGIT COUNTY, WASHINGTON

We understand that Kiewit Infrastructure West Companies (Kiewit) is proposing to expand an existing quarry near Marblemount, Washington. In accordance with our proposal dated November 27, 2018, this letter report presents the results of a limited rockfall hazard evaluation to support the Washington State Environmental Policy Act (SEPA) permitting review process. Our scope of services for this project included the following tasks:

- Completing a brief site reconnaissance on December 12, 2018;
- Reviewing available site data and developing topographic cross sections;
- Performing rockfall modeling simulations to evaluate potential hazards to nearby public roadways and structures; and
- Writing this letter report.

This study is limited to evaluating rockfall hazards along the nearby Cascade Rockport Road (the Road) and residential structures near the base of the slope.

Our services were conducted in general accordance with our approved proposal dated November 27, 2018, approved by Kiewit on December 3, 2018, and our Master Services Agreement with Kiewit dated September 4, 2018.

PROJECT UNDERSTANDING

The project site is located along the left bank of the Skagit River about 1 mile south of Marblemount, Washington (see Figure 1). We understand that Kiewit is studying development of the Marblemount Quarry as a source of rock for jetty construction and similar future projects.

We understand that Kiewit chose the Marblemount site for further study due to the presence of metabasalt bedrock (greenstone and greenschist), which exhibits a relatively high unit weight appropriate for use as armor stone. We understand a small existing quarry operation is present at the site.

Preliminary plans provided by Pacific Survey & Engineering, Inc. (PSE) dated November 14, 2018 (PSE, 2018), show the development would include constructing a new, approximately 6,700-foot-long haul road with 12 percent grade to access the top of the quarry excavation at approximate elevation 1085 feet (see Figure 2). The haul road would be approximately 45 feet wide with excavation slopes of ¼ horizontal to 1 vertical (¼H:1V). At build-out, the quarry would consist of an approximately 765-foot-high and 1,000-foot-wide excavation involving approximately 9.5 million cubic yards of excavation. Preliminary plans indicate that quarry slopes will consist of a benched configuration with 40-foot-high ¼H:1V cut slopes and 20-foot-wide horizontal benches.

We understand that the proposed quarry development sequence would consist of constructing the quarry haul road, followed by sequential quarry excavations in “lifts” proceeding from the top down. Each lift would be excavated horizontally to the proposed quarry extent before advancing the next lift. The haul road would be used to transport the rock to the base of the slope.

SITE GEOLOGIC CONDITIONS

We reviewed the published geologic map (Misch, 1979) for the site, which shows bedrock consists of Early Cretaceous age (approximately 100 to 145 million-year-old) metabasaltic greenschist and blueschist of the Shuksan Metamorphic Suite. Misch (1979) indicates that Shuksan Metamorphic Suite rocks at the site dip to the east, or into the proposed quarry and haul road slopes. Misch (1979) maps undifferentiated Quaternary (less than about 1.2-million-year-old) soil deposits in the low-relief Skagit River valley to the west of the proposed quarry slopes. These deposits are likely alluvium (river-deposited soils).

SITE RECONNAISSANCE

On December 12, 2018, a Shannon & Wilson, Inc. geotechnical engineer made a limited geotechnical reconnaissance visit to evaluate conditions pertinent to rockfall analysis. Our reconnaissance included:

- Observing and photographing existing slope conditions and ground cover at the proposed quarry and haul road;
- Observing potential rockfall sources; and
- Observing typical size and shape of individual rockfall boulders and typical rockfall runout extents at and beyond the toe of slope.

The reconnaissance visit did not include geologic mapping, evaluation of rock mass structural conditions, or slope stability evaluations. Our observations are summarized below.

Existing Slope Conditions and Cover

Overall slopes at the proposed quarry site are about 800 feet high. The natural slopes average about 45 degrees (1H:1V). The upper face of the existing slopes at the proposed quarry consist of sparsely forested slopes underlain by rock, with cliff bands more than about 100 feet high that slope in excess 70 degrees (about 1/3H:1V). Locally, the cliff bands overhang. A talus apron is present below the cliff bands that is about 300 feet high at the base of the proposed quarry slope. The talus slopes about 35 to 40 degrees and includes boulders up to about 40 feet in diameter. The current quarry operator has mined aggregate from this talus slope.

The existing slopes along the haul road alignment are up to about 900 feet high and stand at an overall angle of about 35 degrees (about 1.3H:1V). These slopes are vegetated with sparse to immature forest cover and are underlain by boulder colluvium (slope-derived soil) deposits and intermittent bedrock exposures. The forest covering these slopes burned in the late 1990s; therefore, the most trees are about 20 years old.

The Skagit River floodplain extends beyond the base of the slope. The floodplain consists of low-relief, approximately level ground underlain by alluvial (river-deposited) soil. The area between the Road and the toe of slope is underlain by river terraces that were deposited when the river level was higher than its current level. The soil visible in pits excavated in the terrace deposits typically consist of silty sand with gravelly interbeds and lenses. This area is covered by forest vegetation with clearings around residential structures and the quarry operation.

Potential Rockfall Sources

During the reconnaissance we observed few obvious indications of recent rockfall sources. We anticipate that rockfall on existing slopes likely originates from many locations, primarily steep cliff bands. Rockfall may also originate from boulder colluvium soils.

Observed Rockfall Debris Characteristics

As indicated by the presence of talus deposits and a relative lack of large vegetation, the base of the proposed quarry slope appears to be the most active area of existing rockfall. The talus apron consists of a bouldery deposit with a visually estimated median boulder dimension of about 5 feet. Boulders were typically subangular and roughly equidimensional to slightly elongate in shape.

In the talus aprons below the proposed quarry slope, we noted about 10 individual boulders with a maximum dimension greater than 20 feet, and about 30 individual boulders with maximum dimension between 10 and 20 feet. Most exposed boulders larger than about 10 feet in maximum dimension occurred in the lower half of the talus apron slopes.

We made a reconnaissance of the floodplain near the toe of the slope. We observed that most boulders were located within about 10 feet of the slope toe. The maximum observed runout (most distant boulder) was about 90 feet from the talus slope toe.

We noted relatively few boulders beyond the toe of slope below the base of the proposed haul road slope. In this area, we noted several large boulders had fallen to at or near the base of slope, with no evidence of boulder runout beyond the base of slope. The residents reported that a rockfall occurred between their primary residence and the barn. They reported that a car-size boulder came to a rest near the slope toe. We observed a boulder in the area that had little moss on it. The boulder was about 15 feet vertically above the toe of slope and was about 5 feet in diameter.

ROCKFALL HAZARD EVALUATION

The purpose of rockfall modeling is to evaluate the probable range of trajectory, velocity, energy, bounce height, and runout distance of rocks traveling down a slope. Because the project design is preliminary, we limited our rockfall analysis study to evaluate whether the proposed quarry and haul road may change the probable range of rockfall runout distances relative to the Road and residential structures at the base of the slope. The limited study did not include efforts to evaluate operational rockfall hazards along the proposed haul road and quarry excavation.

Model Setup

We utilized the program RocFall™ version 6.011 (RocScience, Inc., 2018) for our study. We considered two ground surface topographic profiles, one along the proposed quarry excavation

(Profile A), and the other along the proposed haul road above an existing residential structure (Profile B). For each profile, we considered existing conditions and estimated final conditions based on preliminary survey and design (PSE, 2018). Plan locations of the profiles are shown on Figure 2. Topographic profiles are shown in Figures 3 through 7.

For each analysis case, we defined ground cover conditions and estimated accompanying physical parameters for the rockfall model (coefficients of normal and tangential restitution and surface friction) based on published values tabulated in Turner and Duffy (2012). We then assigned rockfall origination points ("seeders") on each model to simulate randomly distributed rockfall sources on the slope face (for back-analysis), point sources for likely locations of future rockfall sources (edges of cuts), or point sources for conservative forward analysis (assuming top-of slope). We then assigned mass and unit weight of rocks to approximate "small" and "large" metabasalt boulders with mean mass of 50 and 10,000 kips to generally approximate the range of boulder sizes observed during reconnaissance.

We utilized "lump mass" analysis procedure that considers falling rocks to be point masses with an infinitesimal area. In our opinion, a more involved effort to utilize "rigid body" modeling techniques that estimate the size and shape of boulders is not warranted given:

- The additional variables and associated uncertainty involved (rock shape, dynamic and rolling friction parameters);
- The preliminary nature of the current quarry and haul road design; and
- The limited goals of the study, namely to estimate changes in the distribution of rockfall runout distances following construction of the haul road and quarry.

Profile A Methodology and Results

- **Case 1 -** *A conservative back-analysis case to determine parameters required for runout to reach the Road.* This case considered a point seeder at the top of the existing slope to simulate fugitive rocks issuing from the edge of the initial, highest quarry excavation lift. Starting with published rebound parameters and a rolling friction angle of 30 degrees, we noted that the runout distribution did not extend more than about 100 feet beyond the base of slope (similar to field observations). We then incrementally reduced the rolling friction for slope materials to allow rocks to runout nearer to the Road, which is located about 450 feet beyond the slope toe. As shown on Figure 3, a friction parameter of 10 degrees (an unrealistically low value) still did not allow runout within about 200 feet of the Road. This case is summarized on Figure 3.

- **Case 2 –** *A conservative case to evaluate rockfall runout distribution at quarry build-out.* This case considered a point seeder at the top of the slope to result in the highest likely rockfall energies. This case also assumed clean bedrock benches and erosion of the downhill edges of each bench ("crest loss"). Even with conservative parameters, most rockfall is arrested on benches. Our analyses indicated about 1 percent of total rocks reach the bottom of the pit. Of those, the analysis indicated no rocks would roll out beyond about 200 feet from base of slope. This case is summarized on Figure 4.

Profile B Methodology and Results

- **Case 3 –** *A back-analysis case to calibrate parameters to approximate observed boulder runout conditions on existing slope.* Because rockfall sources are not obvious in this area, we considered a line seeder from the top to the base of the slope to simulate random rockfall origin. To allow some rocks to roll to the base of the hill, we used rebound parameters approximating bedrock and reduced the rolling friction angle to 25 degrees. These surface parameters were used on the slope for forward analysis cases as described below. This case is summarized on Figure 5.
- **Case 4 –** *Forward analysis to evaluate effect of haul road cuts on runout.* This case considered construction of 45-foot-wide haul road cuts with ¼H:1V slopes and same parameters as described above, notably use of a line seeder from top to base of slope and the same rebound parameters approximating a bedrock surface. As shown on Figure 6, the section includes two intercepts of the proposed haul road at approximate Stations 25+50 and 46+25, or elevations 616 and 887 feet, respectively. The results of this case suggest that the proposed haul road will overall act as catchment when considering rocks originating from random locations on the slope. This case is summarized on Figure 6.
- **Case 5 –** *Forward analysis to evaluate effect of point rockfall sources from cuts on runout.* This case considers the same geometry and slope parameters as Case 4 but includes two point rockfall seeders instead of a random line seeder, each located at the downhill edge of the haul road cut. To simulate rocks loosened by mechanical excavation activities or haul road traffic, we assigned an initial, nominal horizontal velocity of 1 foot per second away from the cut. This case suggests that rocks falling from the edges of cuts have a higher probability of rolling to the base of slope than randomly seeded rocks. This case also indicates that rocks originating at the edge of cut will not be more likely to run out farther than randomly seeded rocks. This case is summarized on Figure 7.

CONCLUSIONS

Based on the results of our study, it is our opinion that quarry and haul road construction should not significantly increase the likelihood that rockfall will impact Rockport Cascade Road.

Further, we believe natural and mining or construction related rockfall is unlikely to run out more than 100 feet from the existing toe of the slope.

In our opinion, existing rockfall runout observed during the December 2018 reconnaissance suggests that residential structures at the base of the slope are subject to infrequent rockfall impacts under current conditions. Our modeling suggests that rockfall runouts may increase near residential structures due to construction of the haul road. We also anticipate that construction activities will greatly increase the number of rockfall events capable of impacting the residential structures.

LIMITATIONS

While rockfall simulations are useful to evaluate potential distributions of rockfall, they have several important limitations. Rockfall simulations can only model the behavior of individual, intact rocks. Large-scale rock instabilities could potentially form due to excavation of the haul road and quarry. Such large-scale rock failures can result in debris avalanches capable of running out over distances much longer than individual rockfalls due to complex interactions beyond the capability of currently available analysis tools. Evaluation of rock slope stability during haul road and quarry construction is beyond the scope of this limited study.

Similarly, rockfall modeling software cannot evaluate the *amount* or number of rocks that may fall from a slope. However, we anticipate that construction activities and associated disturbances may cause more frequent rockfall events on the slopes in question as compared to current frequency of rockfalls originating from native slopes. Depending on construction techniques used and efforts to contain rockfall during excavation, denudation of slopes due to repeated rockfall may change ground conditions and allow for longer runouts over time. If significant denudation or accumulations of rockfall debris occur during construction, we recommend additional study to reevaluate potential impacts to the traveling public along Rockport Cascade Road.

This modeling effort was limited to evaluation of two cross-sections considering the preliminary quarry and haul road design as indicated on plans provided by PSE in November 2018 (PSE, 2018). If the design is changed before or during construction, additional analysis may be necessary to evaluate potential impacts to Rockport Cascade Road.

CLOSURE

We appreciate the opportunity to be of service to Kiewit. If you have questions or comments regarding this report, please contact me at 720-258-4129 or mtg@shanwil.com.

Sincerely,

SHANNON & WILSON, INC.

CHRISTOPHER A. ROBERTSON
STATE OF WASHINGTON
30636
REGISTERED
PROFESSIONAL ENGINEER

12/26/2018

Christopher A. Robertson, PE
Vice President

MTG:KDD:CAR/mtg

Enc: Figure 1 – Vicinity Map
Figure 2 – Site Plan
Figure 3 – Case 1, Profile A, Existing Conditions with Conservative Parameters
Figure 4 – Case 2, Profile A, Final Conditions
Figure 5 – Case 3, Profile B, Existing Conditions
Figure 6 – Case 4, Profile B, Final Conditions with Dispersed Rockfall Source
Figure 7 – Case 5, Profile B, Final Conditions with Point Rockfall Sources at Cuts

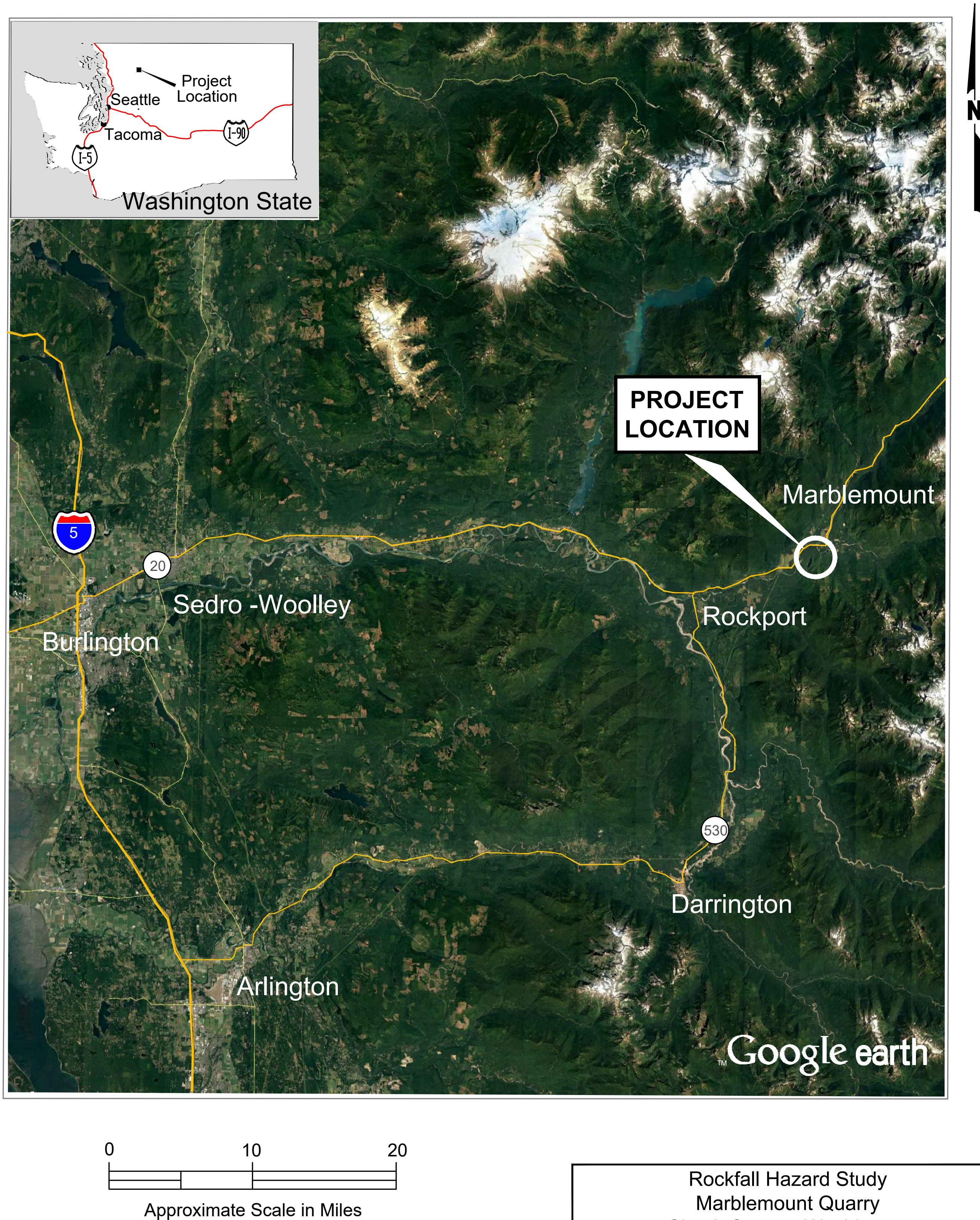
REFERENCES

Misch, Peter, 1979, Geologic map of the Marblemount quadrangle, Washington: Washington Division of Geology and Earth Resources, Geologic Map GM-23, scale 1:48,000

Pacific Survey & Engineering, Inc., 2018, Jetty Stone Quarry Reclamation Plan: Pacific Survey & Engineering plan set, November 21, 12 p.

Rocscience, Inc., 2018, RocFall (v. 6.011): Toronto, Ontario, Rocscience, Inc.

Turner, A.K. and Duffy, J.D., 2012, Evaluation of Rockfall Mechanics, *in* A.K. Turner and R.L. Schuster, eds., Rockfall Characterization and Control: Washington, D.C., Transportation Research Board of the National Academies, p. 333.

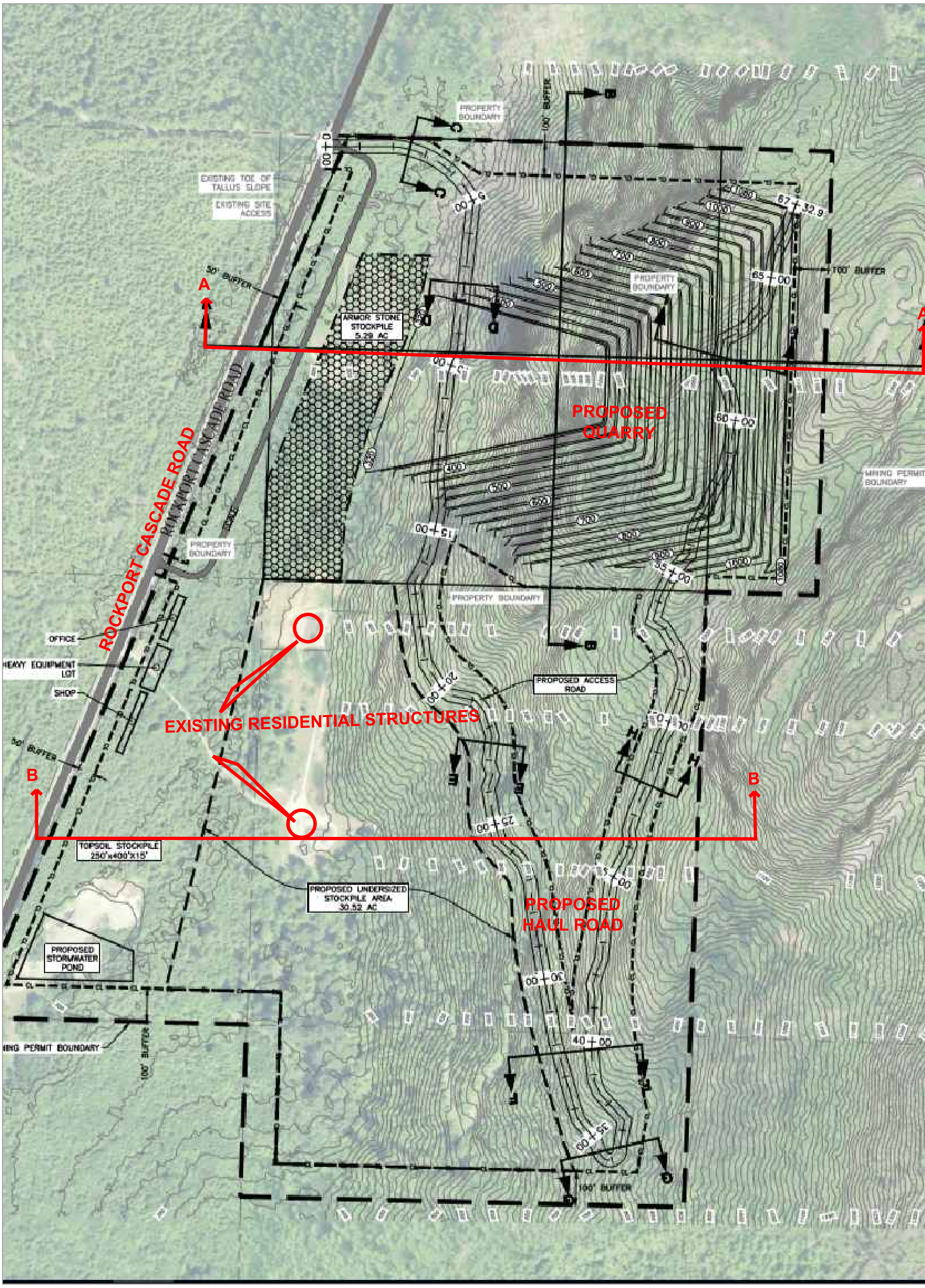


NOTE

Map adapted from aerial imagery provided by Google Earth Pro, reproduced by permission granted by Google Earth ™ Mapping Service.

Rockfall Hazard Study Marblemount Quarry Skagit County, Washington	
VICINITY MAP	
December 2018	102282-001
SHANNON & WILSON, INC. Geotechnical and Environmental Consultants	**FIG. 1**

Filename: I:\EF\DEN\102000s\102282 Marblemount Qua\001 Phase 1 - Rock\Drafting\Fig.1 Vicinity Map.dwg Date: 12-26-2018 Login: mtg



LEGEND

Topographic Profile Used for Rockfall Hazard Analysis

SCALE

0 300 600

Approximate Scale in Feet

NOTE

Drawing adapted from plan set provided by Pacific Engineering & Survey titled "Marblemount_Prelim_2018.11.27_Reduced_.pdf" dated November 21, 2018.

Rockfall Hazard Study
Proposed Marblemount Quarry
Skagit County, Washington

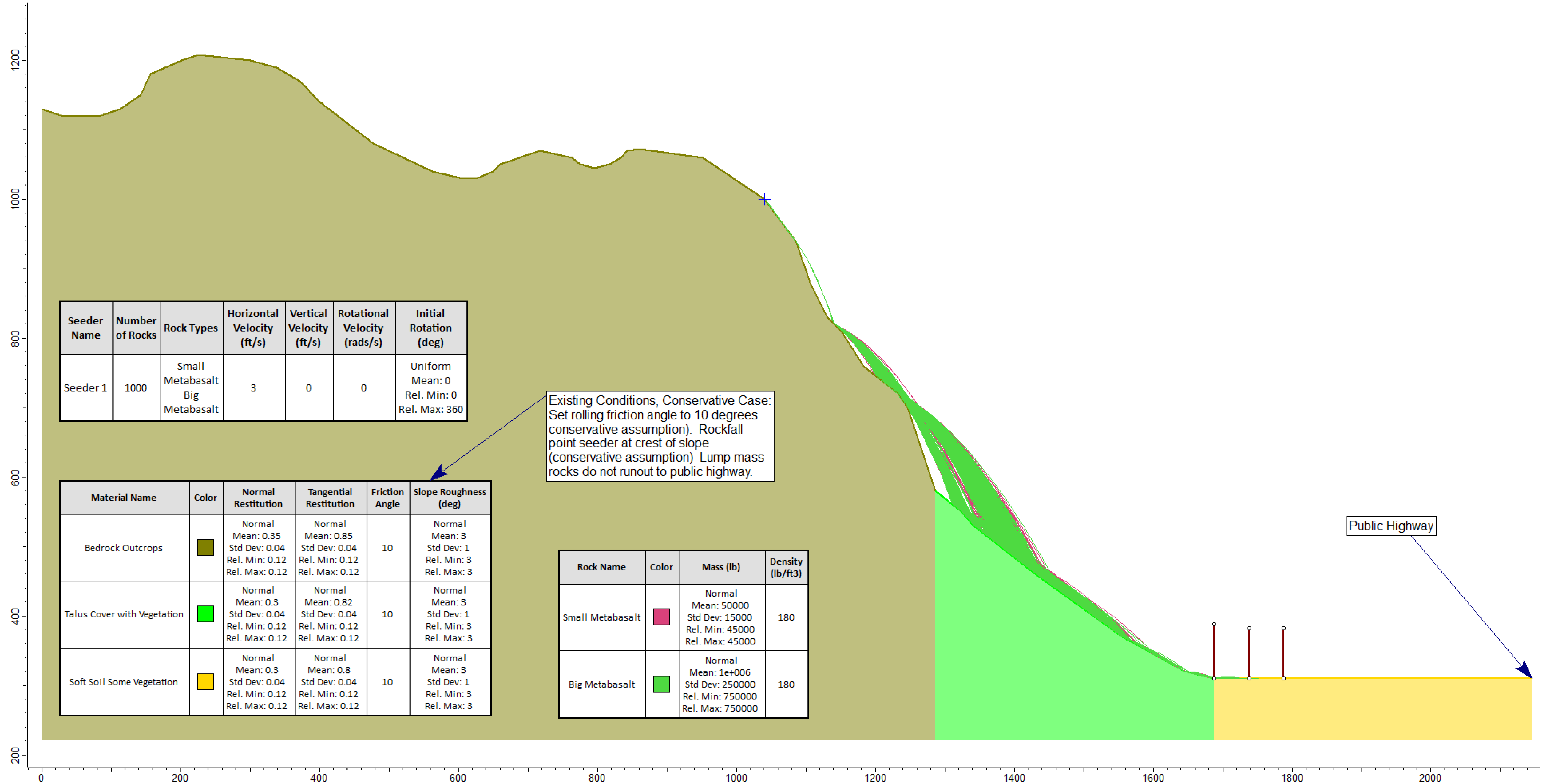
SITE PLAN

December 2018 102282-001

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. 2

FIG. 2



Seeder Name	Number of Rocks	Rock Types	Horizontal Velocity (ft/s)	Vertical Velocity (ft/s)	Rotational Velocity (rads/s)	Initial Rotation (deg)
Seeder 1	1000	Small Metabasalt Big Metabasalt	3	0	0	Uniform Mean: 0 Rel. Min: 0 Rel. Max: 360

Material Name	Color	Normal Restitution	Tangential Restitution	Friction Angle	Slope Roughness (deg)
Bedrock Outcrops		Normal Mean: 0.35 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.85 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	10	Normal Mean: 3 Std Dev: 1 Rel. Min: 3 Rel. Max: 3
Talus Cover with Vegetation		Normal Mean: 0.3 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.82 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	10	Normal Mean: 3 Std Dev: 1 Rel. Min: 3 Rel. Max: 3
Soft Soil Some Vegetation		Normal Mean: 0.3 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.8 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	10	Normal Mean: 3 Std Dev: 1 Rel. Min: 3 Rel. Max: 3

Rock Name	Color	Mass (lb)	Density (lb/ft3)
Small Metabasalt		Normal Mean: 50000 Std Dev: 15000 Rel. Min: 45000 Rel. Max: 45000	180
Big Metabasalt		Normal Mean: 1e+006 Std Dev: 250000 Rel. Min: 750000 Rel. Max: 750000	180

NOTES:

1. Figure not to scale.
2. Surface topography developed from AutoCAD file titled "ACAD-2017008_ecP_RP_2018.12.10.dwg" provided by Pacific Survey & Engineering on December 10, 2018.
3. Rockfall trajectories and display obtained with RocScience RocFall™ version 6.011 software.

Rockfall Hazard Study
Proposed Marblemount Quarry
Skagit County, Washington

CASE 1 - PROFILE A EXISTING CONDITIONS WITH CONSERVATIVE PARAMETERS

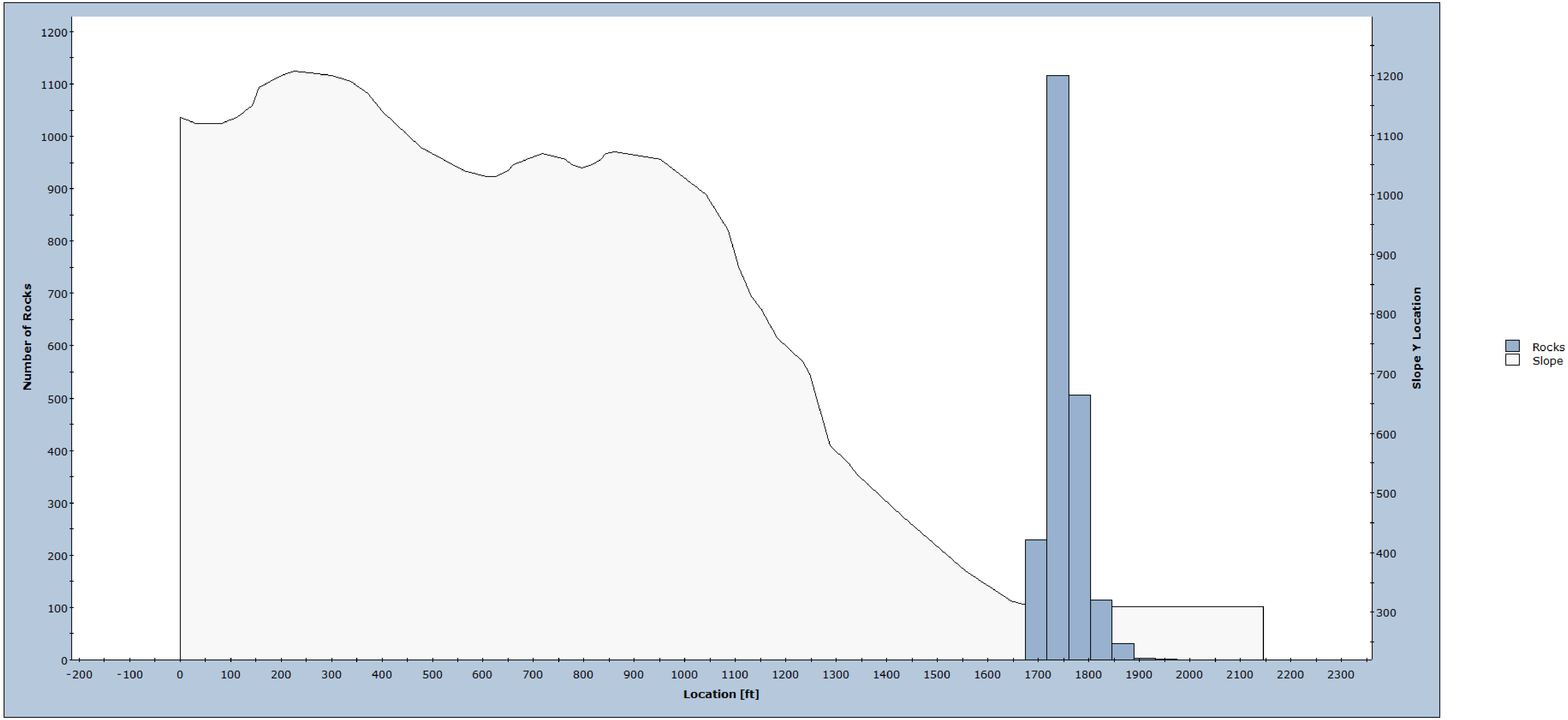
December 2018 102282-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. 3
Sheet 1 of 2

FIG. 3
Sheet 1 of 2

Distribution of Rock Path End Locations



Total number of rock paths: 2000

NOTES:

1. Figure not to scale.
2. Surface topography developed from AutoCAD file titled "ACAD-2017008_ecP_RP_2018.12.10.dwg" provided by Pacific Survey & Engineering on December 10, 2018.
3. Rockfall trajectories and display obtained with RocScience RocFall™ version 6.011 software.

Rockfall Hazard Study
Proposed Marblemount Quarry
Skagit County, Washington

CASE 1 - PROFILE A
EXISTING CONDITIONS WITH CONSERVATIVE PARAMETERS

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FIG. 3
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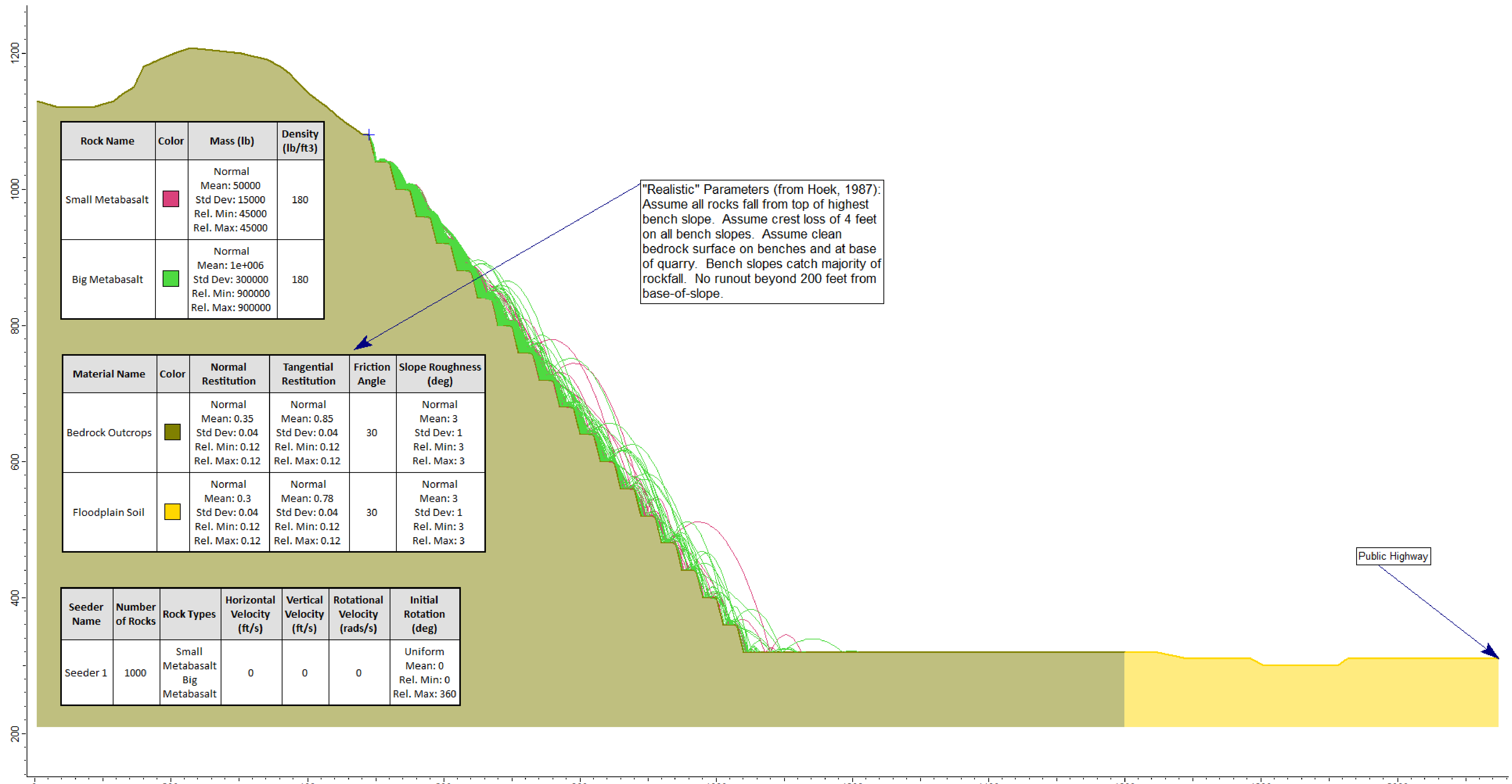

Rock Name	Color	Mass (lb)	Density (lb/ft3)
Small Metabasalt	(pink)	Normal Mean: 50000 Std Dev: 15000 Rel. Min: 45000 Rel. Max: 45000	180
Big Metabasalt	(green)	Normal Mean: 1e+006 Std Dev: 300000 Rel. Min: 900000 Rel. Max: 900000	180

Material Name	Color	Normal Restitution	Tangential Restitution	Friction Angle	Slope Roughness (deg)
Bedrock Outcrops	(olive)	Normal Mean: 0.35 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.85 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	30	Normal Mean: 3 Std Dev: 1 Rel. Min: 3 Rel. Max: 3
Floodplain Soil	(yellow)	Normal Mean: 0.3 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.78 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	30	Normal Mean: 3 Std Dev: 1 Rel. Min: 3 Rel. Max: 3

Seeder Name	Number of Rocks	Rock Types	Horizontal Velocity (ft/s)	Vertical Velocity (ft/s)	Rotational Velocity (rads/s)	Initial Rotation (deg)
Seeder 1	1000	Small Metabasalt Big Metabasalt	0	0	0	Uniform Mean: 0 Rel. Min: 0 Rel. Max: 360

NOTES:

1. Figure not to scale.
2. Surface topography developed from AutoCAD file titled "ACAD-2017008_ecP_RP_2018.12.10.dwg" provided by Pacific Survey & Engineering on December 10, 2018.
3. Rockfall trajectories and display obtained with RocScience RocFall™ version 6.011 software.

Rockfall Hazard Study
Proposed Marblemount Quarry
Skagit County, Washington

CASE 2 - PROFILE A FINAL CONDITIONS

December 2018 102282-001

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FIG. 4
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FIG. 4
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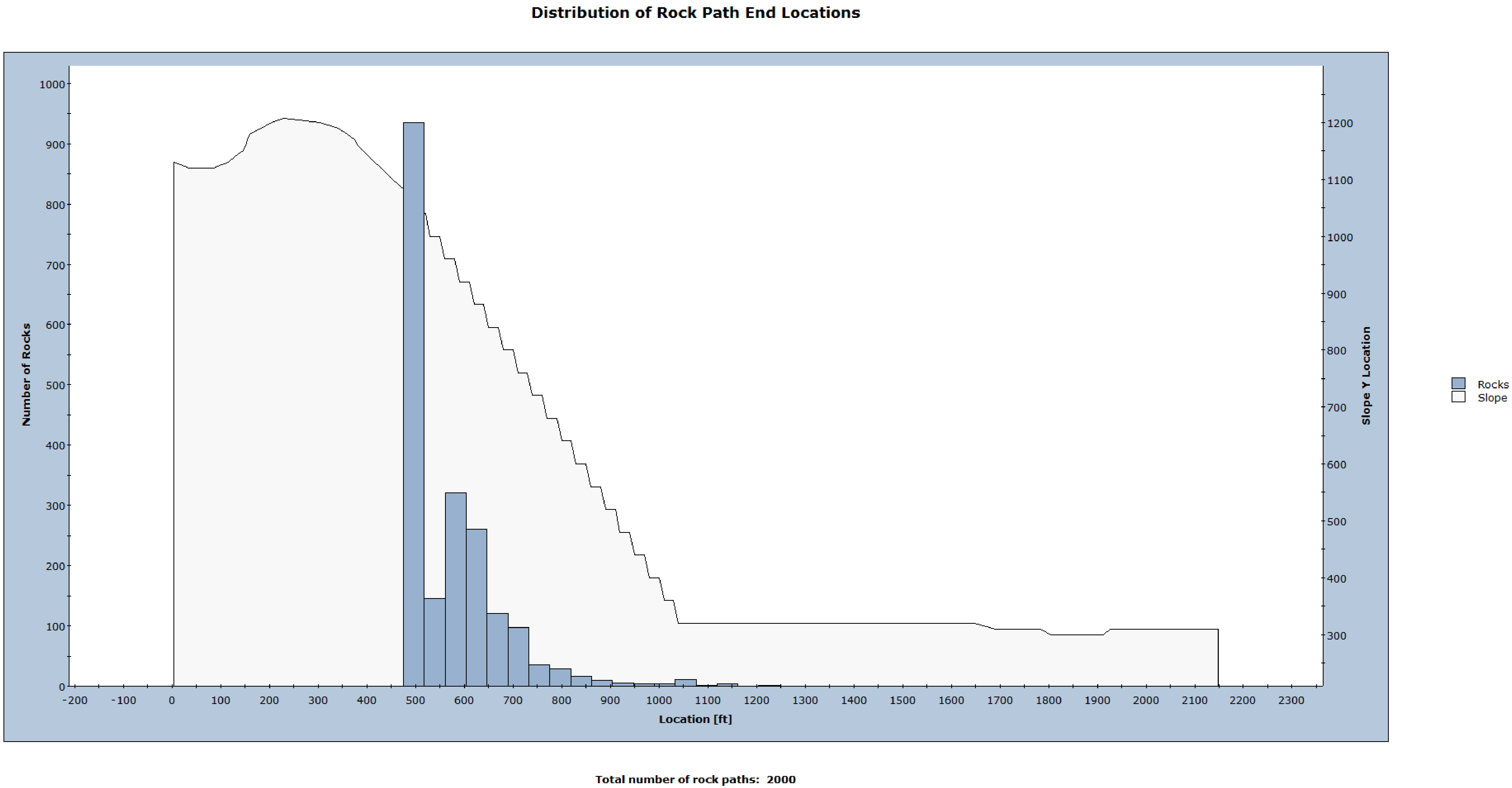

NOTES:

1. Figure not to scale.
2. Surface topography developed from AutoCAD file titled "ACAD-2017008_ecP_RP_2018.12.10.dwg" provided by Pacific Survey & Engineering on December 10, 2018.
3. Rockfall trajectories and display obtained with RocScience RocFall™ version 6.011 software.

Rockfall Hazard Study
Proposed Marblemount Quarry
Skagit County, Washington

CASE 2 - PROFILE A
FINAL CONDITIONS

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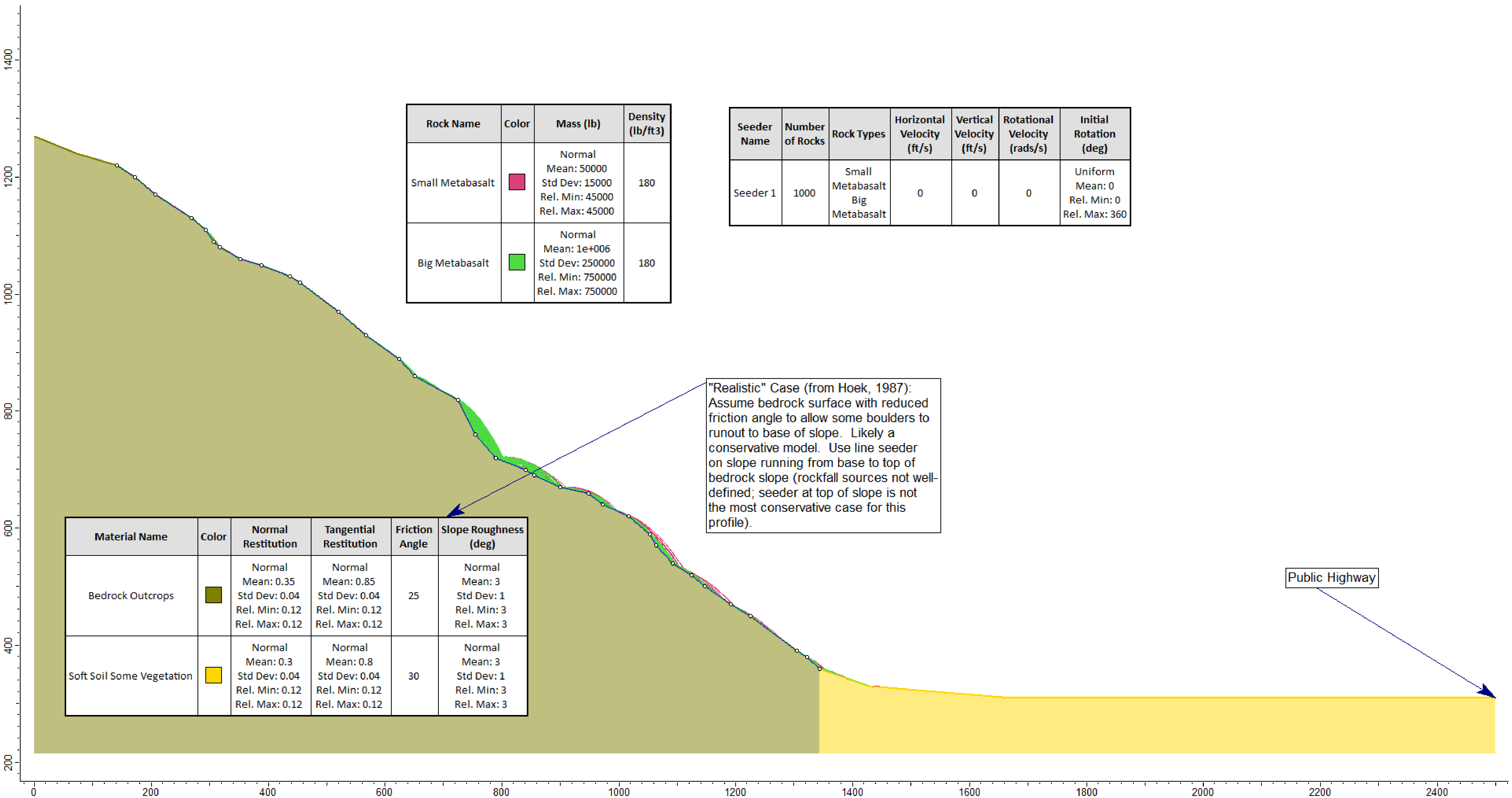

Rock Name	Color	Mass (lb)	Density (lb/ft3)
Small Metabasalt		Normal Mean: 50000 Std Dev: 15000 Rel. Min: 45000 Rel. Max: 45000	180
Big Metabasalt		Normal Mean: 1e+006 Std Dev: 250000 Rel. Min: 750000 Rel. Max: 750000	180

Seeder Name	Number of Rocks	Rock Types	Horizontal Velocity (ft/s)	Vertical Velocity (ft/s)	Rotational Velocity (rads/s)	Initial Rotation (deg)
Seeder 1	1000	Small Metabasalt Big Metabasalt	0	0	0	Uniform Mean: 0 Rel. Min: 0 Rel. Max: 360

Material Name	Color	Normal Restitution	Tangential Restitution	Friction Angle	Slope Roughness (deg)
Bedrock Outcrops		Normal Mean: 0.35 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.85 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	25	Normal Mean: 3 Std Dev: 1 Rel. Min: 3 Rel. Max: 3
Soft Soil Some Vegetation		Normal Mean: 0.3 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.8 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	30	Normal Mean: 3 Std Dev: 1 Rel. Min: 3 Rel. Max: 3

NOTES:

1. Figure not to scale.
2. Surface topography developed from AutoCAD file titled "ACAD-2017008_ecP_RP_2018.12.10.dwg" provided by Pacific Survey & Engineering on December 10, 2018.
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Proposed Marblemount Quarry
Skagit County, Washington

CASE 3 - PROFILE B
EXISTING CONDITIONS

December 2018 102282-001

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FIG. 5
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FIG. 5
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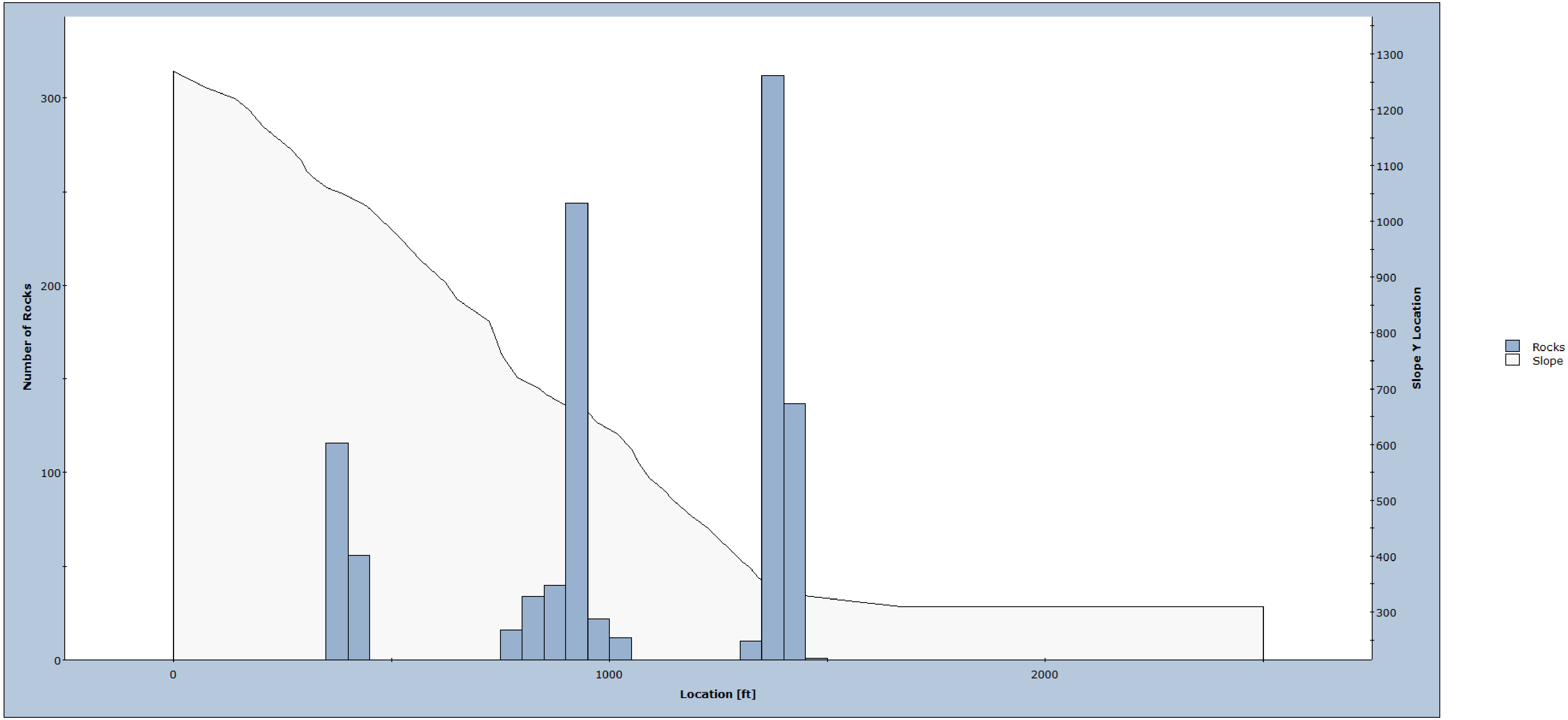
Distribution of Rock Path End Locations



Total number of rock paths: 1000

NOTES:

1. Figure not to scale.
2. Surface topography developed from AutoCAD file titled "ACAD-2017008_ecP_RP_2018.12.10.dwg" provided by Pacific Survey & Engineering on December 10, 2018.
3. Rockfall trajectories and display obtained with RocScience RocFall™ version 6.011 software.

Rockfall Hazard Study
Proposed Marblemount Quarry
Skagit County, Washington

CASE 3 - PROFILE B
EXISTING CONDITIONS

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FIG. 5
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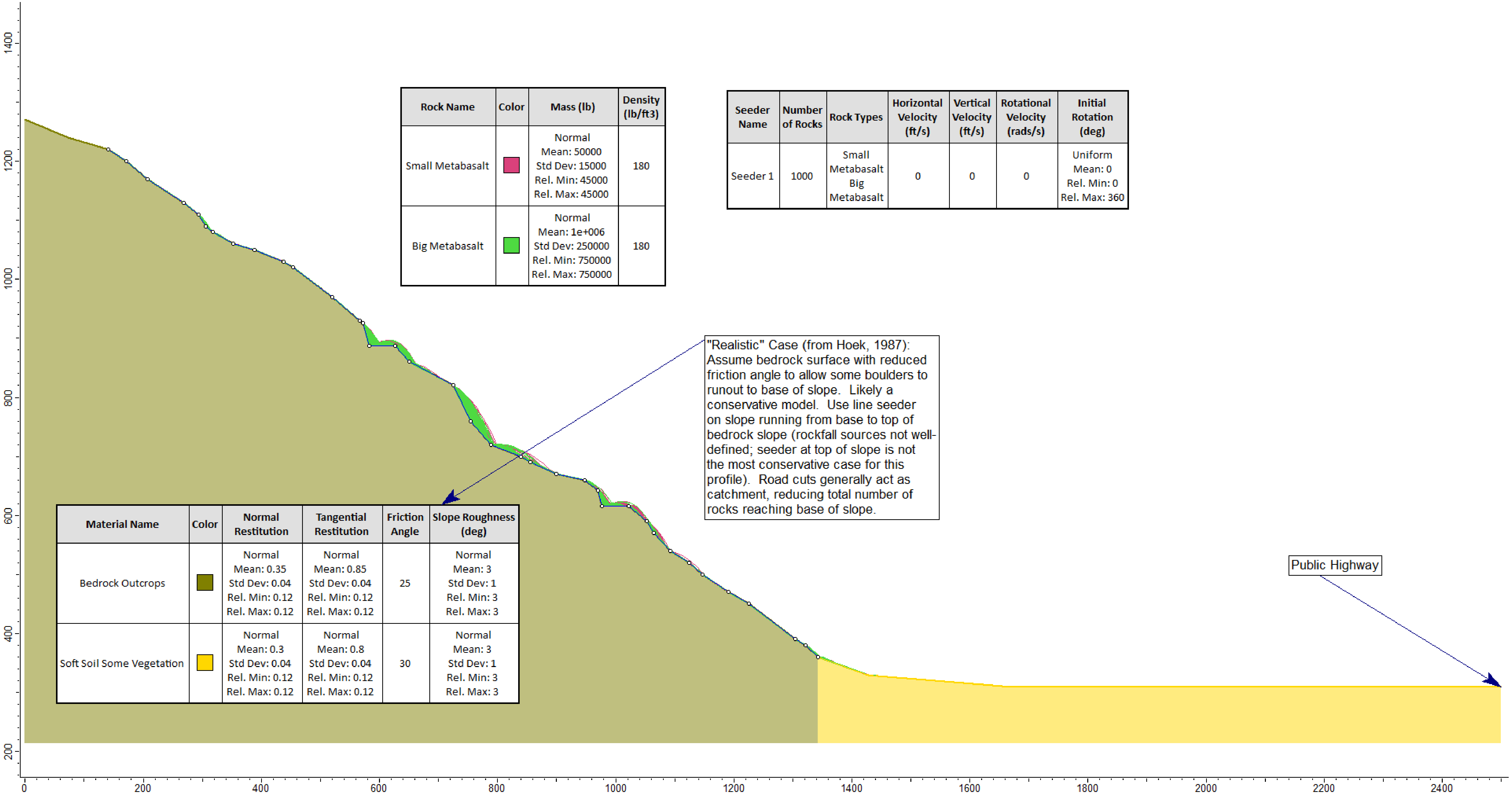

Rock Name	Color	Mass (lb)	Density (lb/ft3)
Small Metabasalt		Normal Mean: 50000 Std Dev: 15000 Rel. Min: 45000 Rel. Max: 45000	180
Big Metabasalt		Normal Mean: 1e+006 Std Dev: 250000 Rel. Min: 750000 Rel. Max: 750000	180

Seeder Name	Number of Rocks	Rock Types	Horizontal Velocity (ft/s)	Vertical Velocity (ft/s)	Rotational Velocity (rads/s)	Initial Rotation (deg)
Seeder 1	1000	Small Metabasalt Big Metabasalt	0	0	0	Uniform Mean: 0 Rel. Min: 0 Rel. Max: 360

Material Name	Color	Normal Restitution	Tangential Restitution	Friction Angle	Slope Roughness (deg)
Bedrock Outcrops		Normal Mean: 0.35 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.85 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	25	Normal Mean: 3 Std Dev: 1 Rel. Min: 3 Rel. Max: 3
Soft Soil Some Vegetation		Normal Mean: 0.3 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.8 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	30	Normal Mean: 3 Std Dev: 1 Rel. Min: 3 Rel. Max: 3

NOTES:

1. Figure not to scale.
2. Surface topography developed from AutoCAD file titled "ACAD-2017008_ecP_RP_2018.12.10.dwg" provided by Pacific Survey & Engineering on December 10, 2018.
3. Rockfall trajectories and display obtained with RocScience RocFall™ version 6.011 software.

Rockfall Hazard Study
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CASE 4 - PROFILE B
FINAL CONDITIONS WITH DISPERSED ROCKFALL SOURCE

December 2018 102282-001

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FIG. 6
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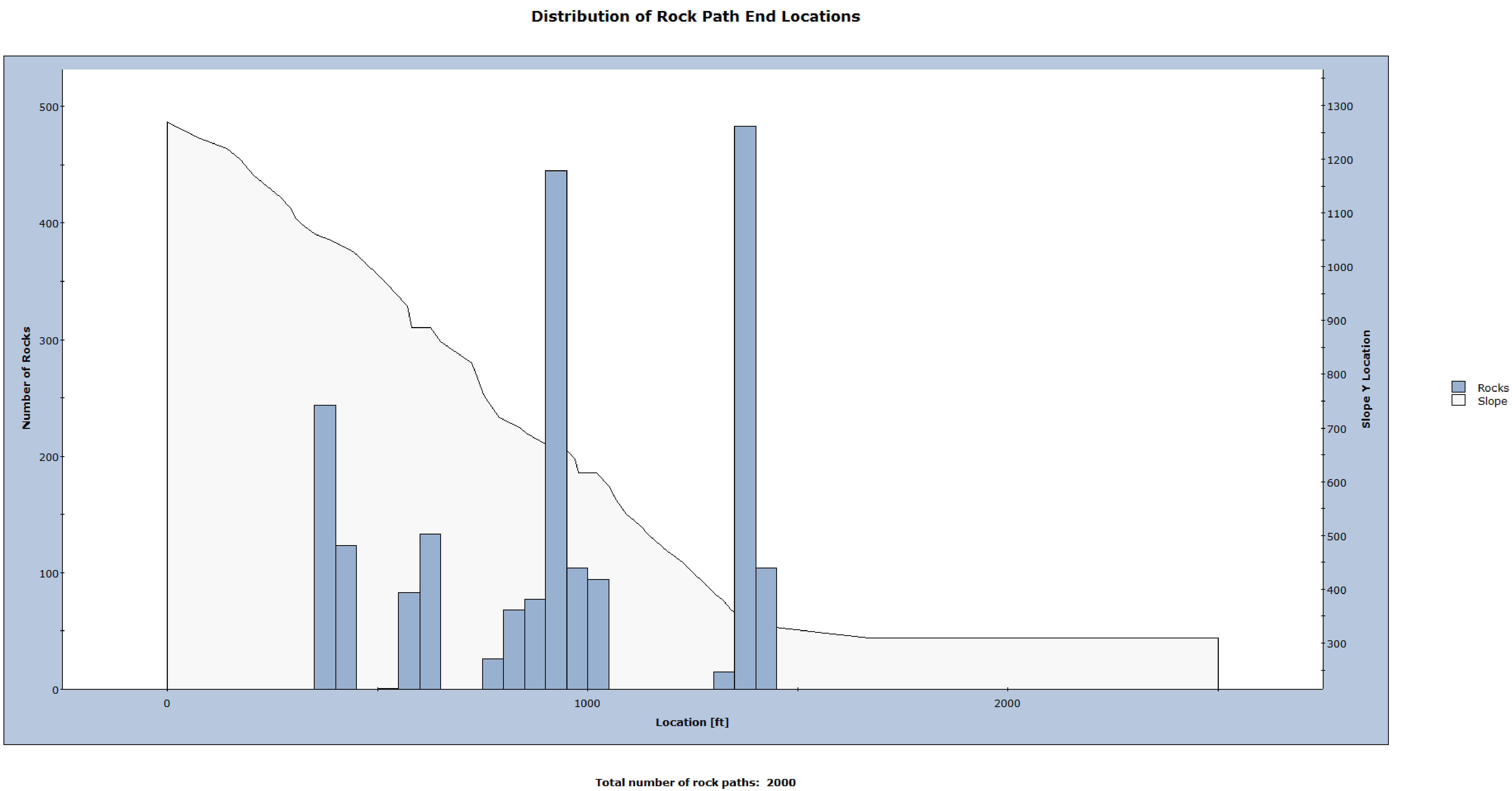

NOTES:

1. Figure not to scale.
2. Surface topography developed from AutoCAD file titled "ACAD-2017008_ecP_RP_2018.12.10.dwg" provided by Pacific Survey & Engineering on December 10, 2018.
3. Rockfall trajectories and display obtained with RocScience RocFall™ version 6.011 software.

Rockfall Hazard Study
Proposed Marblemount Quarry
Skagit County, Washington

CASE 4 - PROFILE B FINAL CONDITIONS WITH DISPERSED ROCKFALL SOURCE

December 2018 102282-001

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FIG. 6
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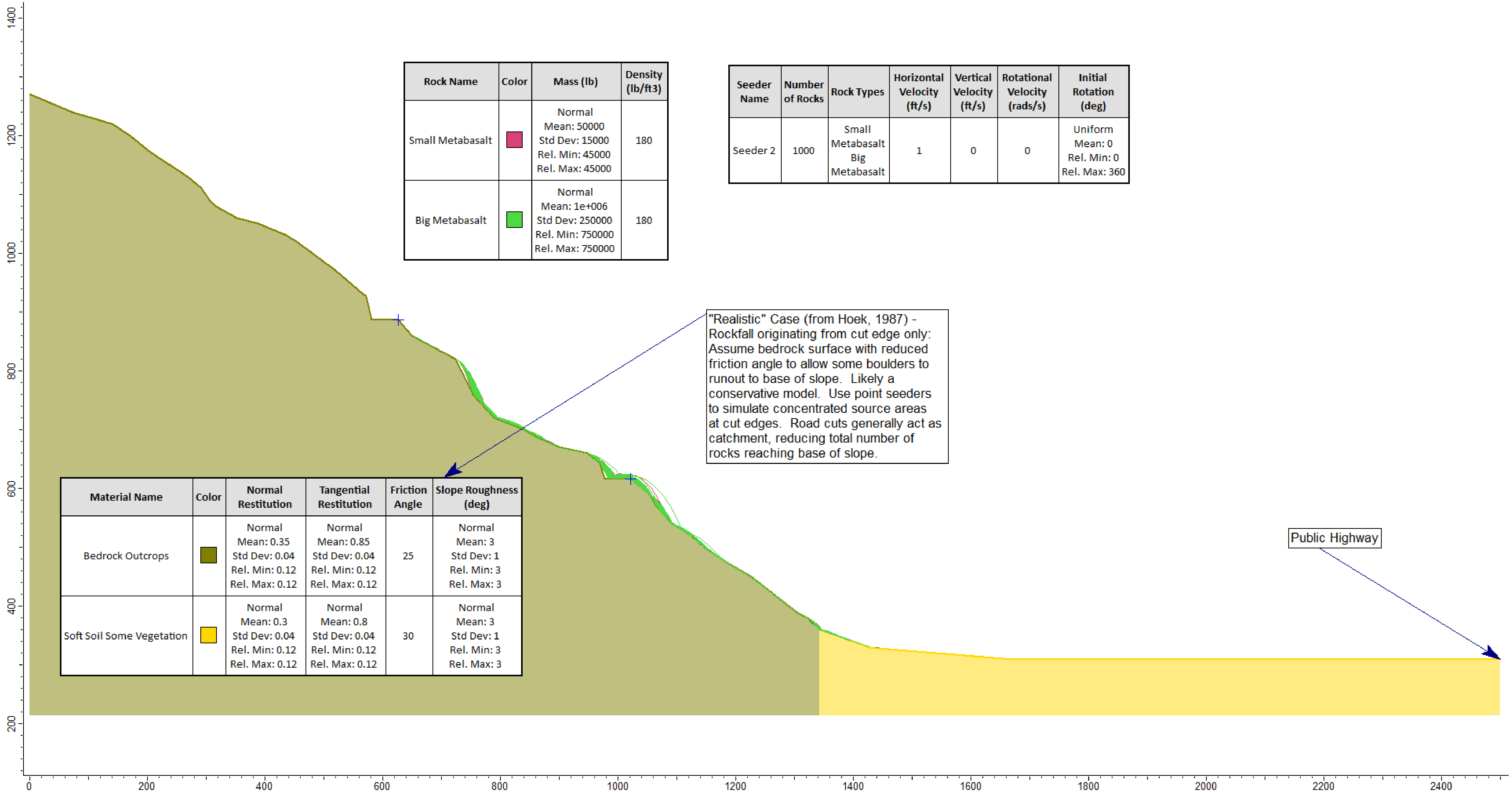

Rock Name	Color	Mass (lb)	Density (lb/ft3)
Small Metabasalt		Normal Mean: 50000 Std Dev: 15000 Rel. Min: 45000 Rel. Max: 45000	180
Big Metabasalt		Normal Mean: 1e+006 Std Dev: 250000 Rel. Min: 750000 Rel. Max: 750000	180

Seeder Name	Number of Rocks	Rock Types	Horizontal Velocity (ft/s)	Vertical Velocity (ft/s)	Rotational Velocity (rads/s)	Initial Rotation (deg)
Seeder 2	1000	Small Metabasalt Big Metabasalt	1	0	0	Uniform Mean: 0 Rel. Min: 0 Rel. Max: 360

Material Name	Color	Normal Restitution	Tangential Restitution	Friction Angle	Slope Roughness (deg)
Bedrock Outcrops		Normal Mean: 0.35 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.85 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	25	Normal Mean: 3 Std Dev: 1 Rel. Min: 3 Rel. Max: 3
Soft Soil Some Vegetation		Normal Mean: 0.3 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	Normal Mean: 0.8 Std Dev: 0.04 Rel. Min: 0.12 Rel. Max: 0.12	30	Normal Mean: 3 Std Dev: 1 Rel. Min: 3 Rel. Max: 3

NOTES:

1. Figure not to scale.
2. Surface topography developed from AutoCAD file titled "ACAD-2017008_ecP_RP_2018.12.10.dwg" provided by Pacific Survey & Engineering on December 10, 2018.
3. Rockfall trajectories and display obtained with RocScience RocFall™ version 6.011 software.

Rockfall Hazard Study
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Skagit County, Washington

CASE 5 - PROFILE B
FINAL CONDITIONS WITH POINT ROCKFALL SOURCES AT CUTS

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FIG. 7
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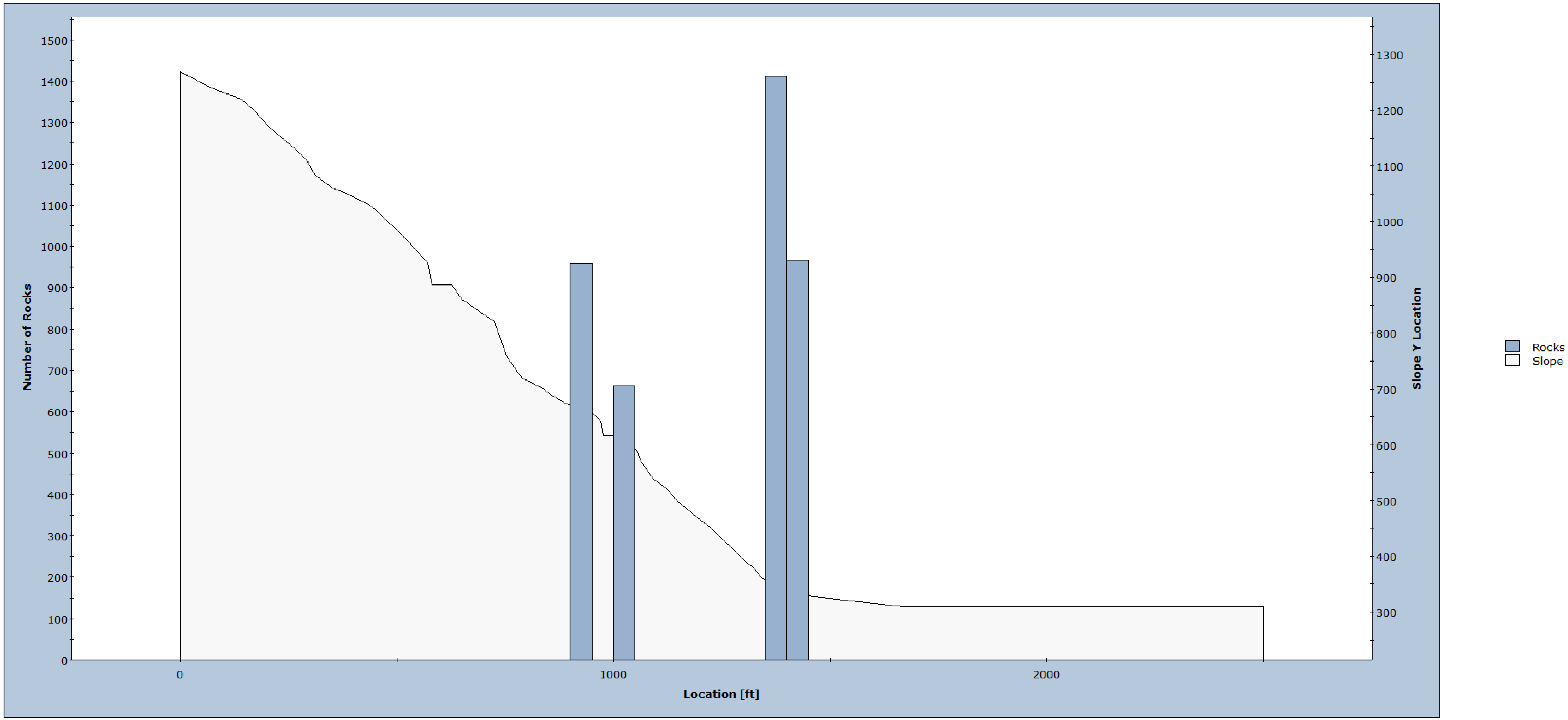
Distribution of Rock Path End Locations



Total number of rock paths: 4000

NOTES:

1. Figure not to scale.
2. Surface topography developed from AutoCAD file titled "ACAD-2017008_ecP_RP_2018.12.10.dwg" provided by Pacific Survey & Engineering on December 10, 2018.
3. Rockfall trajectories and display obtained with RocScience RocFall™ version 6.011 software.

Rockfall Hazard Study
Proposed Marblemount Quarry
Skagit County, Washington

CASE 5 - PROFILE B
FINAL CONDITIONS WITH POINT ROCKFALL SOURCES AT CUTS

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