Geotechnical Assessment of the Icicle Creek Boulder Field Study Reach

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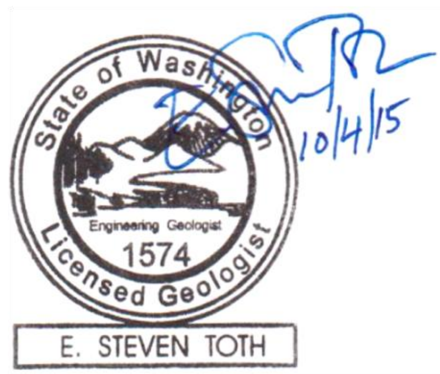

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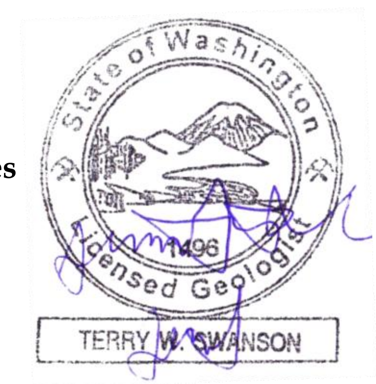

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1.0 Introduction

Trout Unlimited is sponsoring the development of fish passage designs for the Icicle Creek Boulder Field located approximately five miles upstream from the City of Leavenworth. The project site is situated on the north bank of Icicle Creek on Icicle Creek Irrigation District (IID) property. Mr. Patrick Powers, P.E. of Waterfall Engineering is developing preliminary designs for a step-pool fishway on the north bank of Icicle Creek just upstream of the Snow Creek trailhead parking lot. The site is accessed by the IID road, a portion of which would be abandoned as part of the proposed project. The City of Leavenworth has a water supply pipeline located within the road prism that conveys water to their water treatment plant adjacent to the Snow Creek parking lot. The water supply pipeline would likely need to be relocated, at least in part, to construct the proposed fishway.

Toth (2013) previously prepared a geologic assessment of the boulder field for Trout Unlimited. The purpose of this report is to provide a more detailed geologic and geotechnical assessment of the rock and sub-surface conditions in specific portions of the Boulder Field project area. The IID access road was constructed in 1934 as part of the original Icicle Creek Road (Rieman 2001). The current road that accesses upper Icicle Creek, the U.S. Forest Service 7600 Road, was constructed upslope of the original road during the 1960s. In both cases, rock was blasted along the north bank of Icicle Creek when the road grades were constructed. The scope of work for this assessment focused on characterizing rock and sub-surface conditions below the IID access road on the north bank of Icicle Creek.

We had initially planned to excavate temporary test pits along the Irrigation District access road. The purpose of the test pits was to characterize the variability of rocks and overburden under the access road, ascertain the presence of bedrock, and gain insight into potential challenges of excavation for the step-pool fishway. All of the necessary permits were secured to start working, but unfortunately, the location of the City of Leavenworth's water supply line on the inboard side of the road precluded any excavation into the road prism material. The potentially fragile nature of the old pipeline did not allow for any disturbance of the road prism area.

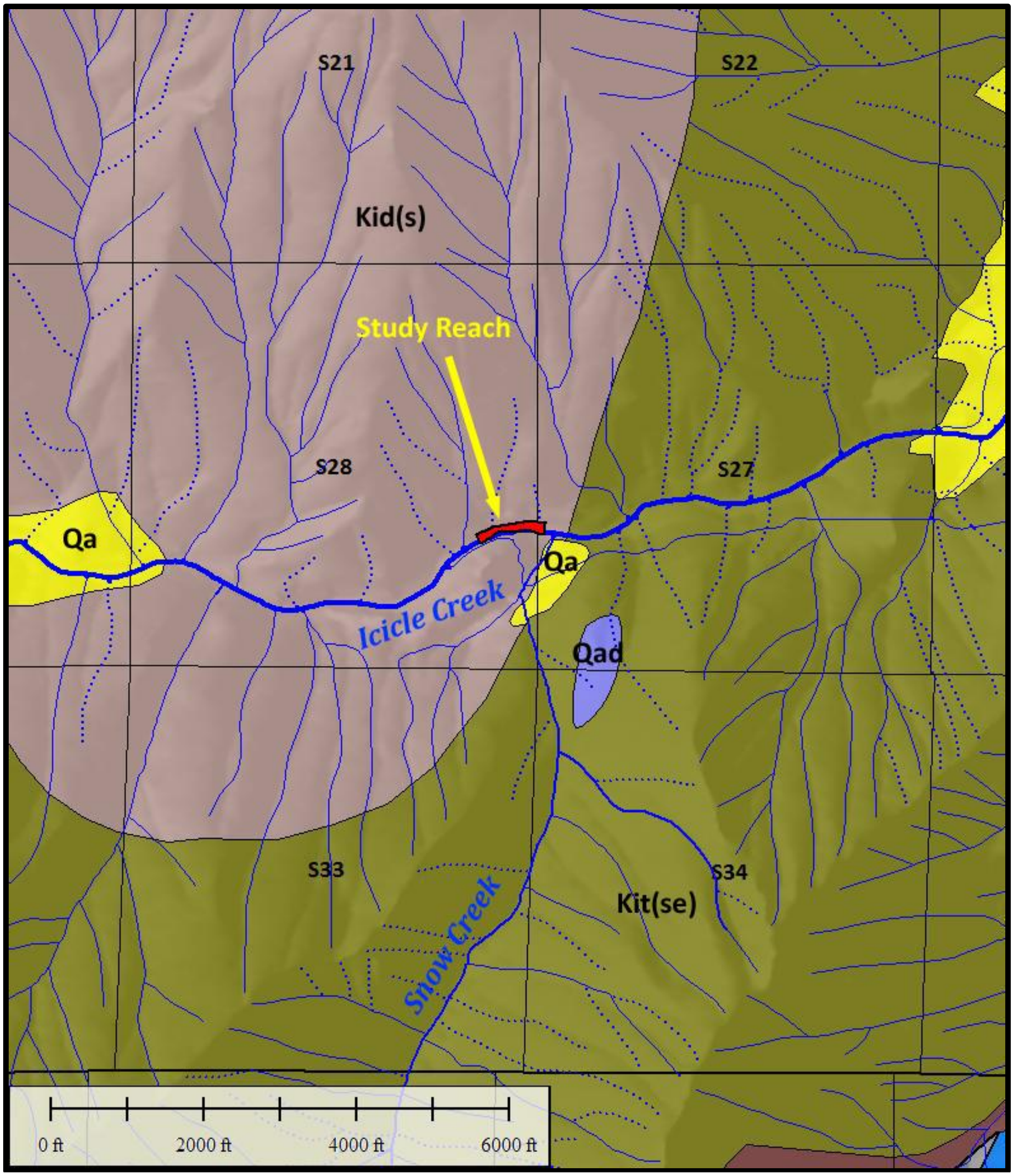
The assessment, therefore, utilized a more detailed geologic and geotechnical investigation of the boulder field area to determine rock characteristics and the likelihood of bedrock outcropping along the proposed route of the step-pool fishway. Field investigations included climbing between large boulders along the road prism and the Icicle Creek channel to assess sub-surface conditions. Rock samples were collected and brought back to the office for further testing of engineering properties. Rock hardness was also evaluated in the field using a Schmidt hammer to estimate the compressive strength of selected boulders. Finally, various rock-breaking methods were tested on sample boulders to identify the most effective procedures.

2.0 Icicle Creek Basin Geology

Most of the Icicle Creek basin is located within the Mount Stuart granitic batholith. The Mount Stuart batholith is a granodiorite pluton that intruded the local metamorphic rocks approximately 60 million years ago (Tabor et al. 1987). The Mount Stuart Batholith consists predominantly of medium-grained, granular hornblende-biotite tonalite or quartz diorite, with a considerable amount of granodiorite east of the project reach along Icicle Ridge. Isotopic tests of Mount Stuart Batholith rocks indicate the age of the eastern pluton at about 93 million years ago and the western pluton at about 85 million years ago (Tabor et al., 1987; Dragovich et al. 2002). The bedrock in the project reach has been mapped by Tabor et al. (1987) and Dragovich et al. (2002) as pre-Tertiary diorite and gabbro and is near the contact with pre-Tertiary tonalite (Figure 1). The rocks are medium-grained hornblende diorite and gabbro, with the hornblende filling in and around plagioclase crystals. The contact with the tonalite is gradational and locally irregular (Tabor et al. 1987). The tonalite is differentiated by quartz crystals in addition to the plagioclase. The diorite, granodiorite, and tonalite of the project area are highly resistant to weathering. Long-term average weathering rates of granitic rock surfaces in the Icicle Creek area have been estimated at about 2 mm per 1,000 years (Porter and Swanson 2008).

Porter and Swanson (2008) did an extensive investigation of the advance and retreat of alpine glaciers in the Icicle Creek valley during the late Pleistocene (between 12,000 and 120,000 years ago). A sequence of five glacial moraines near the junction of the Wenatchee River and Icicle Creek provides evidence of multiple advances of a large east-flowing Cascade Range glacier system (Figure 2, Porter and Swanson 2008). A dozen steep northern tributary ice streams also flowed from an ice cap on the crest of Icicle Ridge. An equal number of southern tributary glaciers, including the Snow Creek drainage, flowed from cirques along the crest of the Stuart Range (Figure 2). At the time of the Last Glacial Maximum (Leavenworth Glaciation I), the ice is estimated to have been over 1,200 feet (380 m) thick in the main valley (Figure 2). Sub-rounded granitic boulders up to 25 feet (8 meters) or more in diameter are present in lateral moraines along the Icicle Creek valley.

During Late Glacial time (12,000 to 14,000 years ago) glaciers re-advanced into the southerly tributary drainages and terminated near their junction with Icicle Creek (Porter and Swanson 2008). Rat Creek, the drainage located directly west of Snow Creek, is the type location for moraines deposited during Late Glacial time (Figure 2). Similar to the Rat Creek drainage, the Snow Creek glacier deposited small loop moraines across Icicle Creek that have since been truncated by fluvial erosion following original deposition (Figure 3). The Snow Creek trailhead parking lot and colluvium observed on the lower, southerly valley sidewall is comprised of matrix-supported till deposited within the original moraines (Figure 4). Post-glacial fluvial erosion removed the fine till matrix within the Icicle Creek channel leaving the large remnant boulders comprising the boulder field within the study area. Similar boulders fields (e.g., Rat Creek and Eight Mile Creeks) are observed along the reaches of the Icicle Creek where Late Glacial moraines were deposited within the main channel and subsequently eroded by glaciofluvial and/or fluvial processes.



ALL BOUNDARIES ARE APPROXIMATE AND MAY NOT BE TO SCALE.

Key: *Kid(s)* – Diorite; Kit(se) – Tonalite; Qad – Alpine glacial drift*;* Qa –Alluvium

Figure 1. Geology map of the Icicle Creek Boulder Field project area (Dragovich 2002).

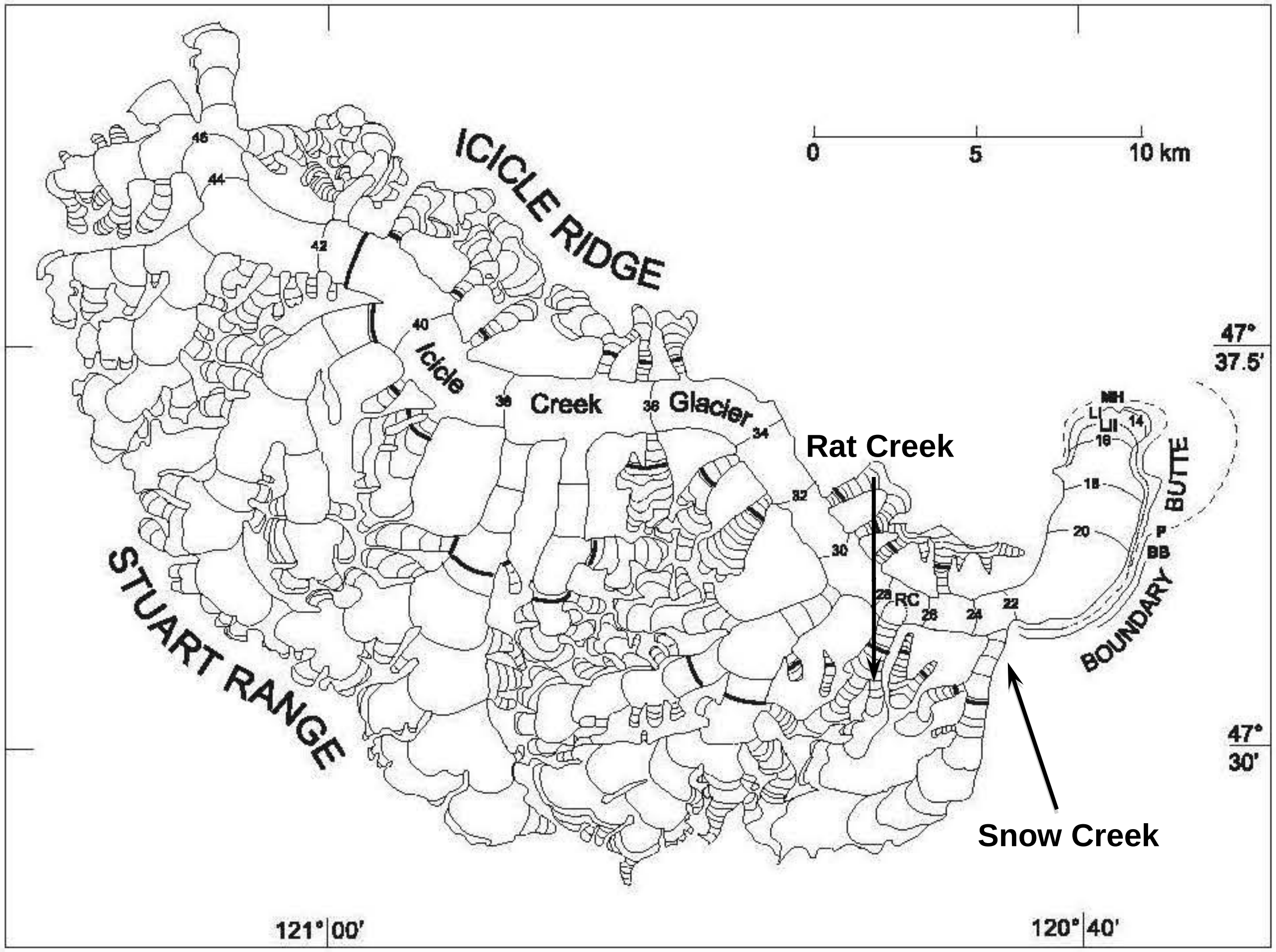


Figure 2: Topographic reconstruction of the Icicle Creek glacier during the Last Glacial Maximum (Leavenworth Glaciation I) 20,000-23,000 years ago. Snow Creek (drainage denoted with black arrow) was one of the southerly tributary glaciers that coalesced with main Icicle Creek glacier during its maximum extent. Crests of major moraines mapped in the lower reaches of the valley include (from oldest to youngest glacial moraine): Boundary Butte (BB), Peshastin (P), Mountain Home (MH), Leavenworth I and II (LI and LII). The type location, Rat Creek (RC), for the Late Glacial advance (12,000 – 14,000 years ago), is the adjacent drainage west of Snow Creek. The reconstructed glacier contour interval is 200 feet (61 meters). Figure 2 adapted from Porter and Swanson (2008).

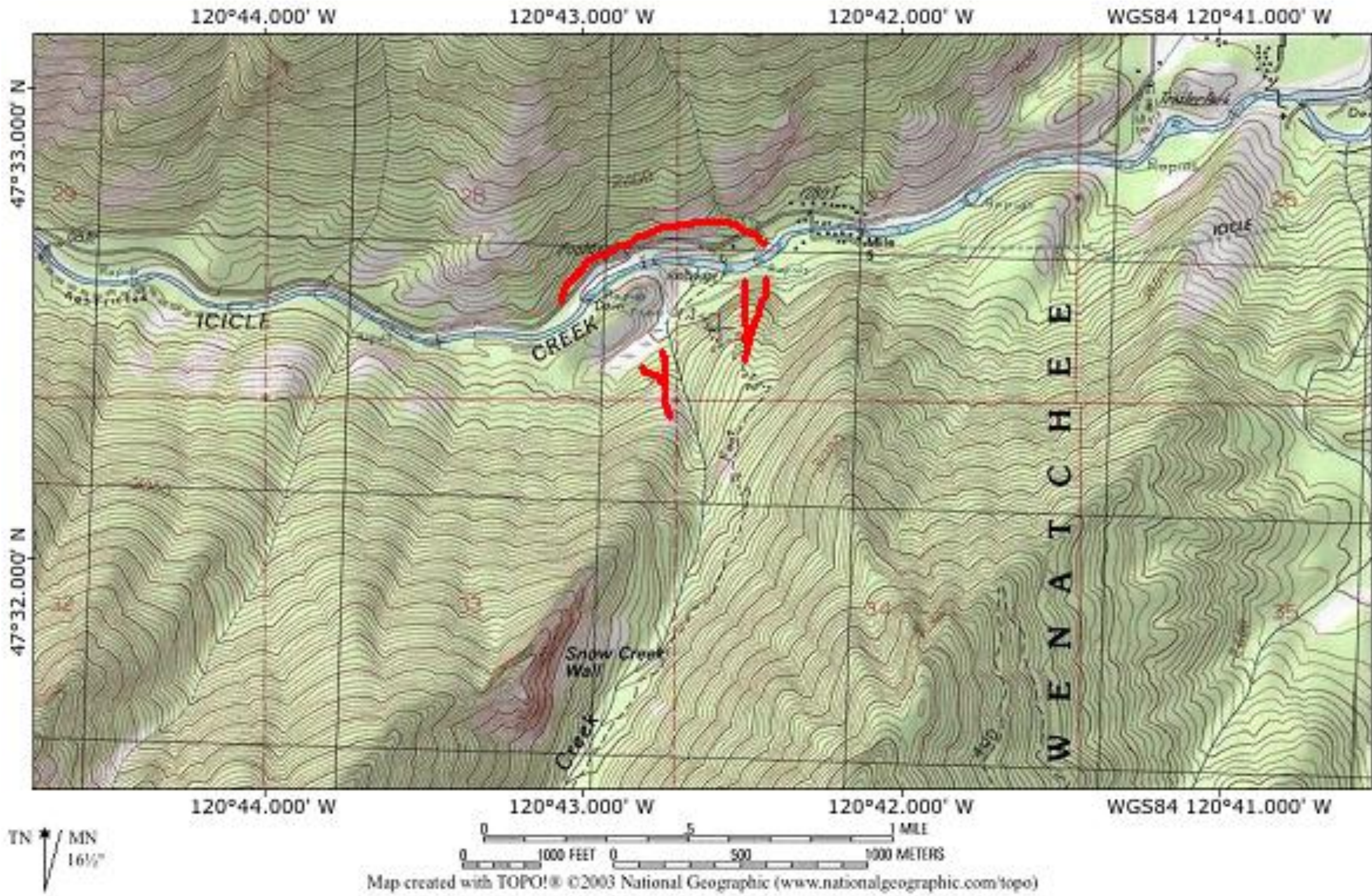


Figure 3. During Late Glacial time (12,000 – 14,000 years ago) the Snow Creek glacier deposited small loop moraines across Icicle Creek that have since been truncated by fluvial erosion following original deposition. Remnant morainal deposits are outlined in red. The boulder field within the study area is comprised of remnant morainal till boulders that were too large to be transported by post-glacial fluvial erosion processes.

Figure 4: The Snow Creek trailhead parking lot and colluvium observed on the lower, southerly valley sidewall is comprised of matrix-supported till deposited within the original Late Glacial moraines. The crest of the oldest Late Glacial moraine is shown by a solid white line and inferred (shown by white dashed line) where it was eroded by post-glacial fluvial processes or the topography is too steep to support unconsolidated till.

To better characterize the potential for encountering bedrock at the Boulder Field site, a cross-sectional slope profile was derived from 2007 bare-earth LiDAR digital elevation models (Puget Sound LiDAR Consortium 2007). The cross-section includes the steep bedrock face and wedge of colluvium and glacial sediments on the north side of Icicle Creek (Figure 5). The cross-section also goes through both roads and the Anchor Rock situated in the channel. A projection of the bedrock below the colluvial wedge and the U.S. Forest Service 7600 Road suggests that the depth to bedrock exceeds excavation depths for the proposed fishway. The construction of the proposed fishway will likely encounter large native boulders derived from the Snow Creek glacial moraine deposits. A matrix of finer sediments from glacial and colluvial sources may also be present between the boulders.

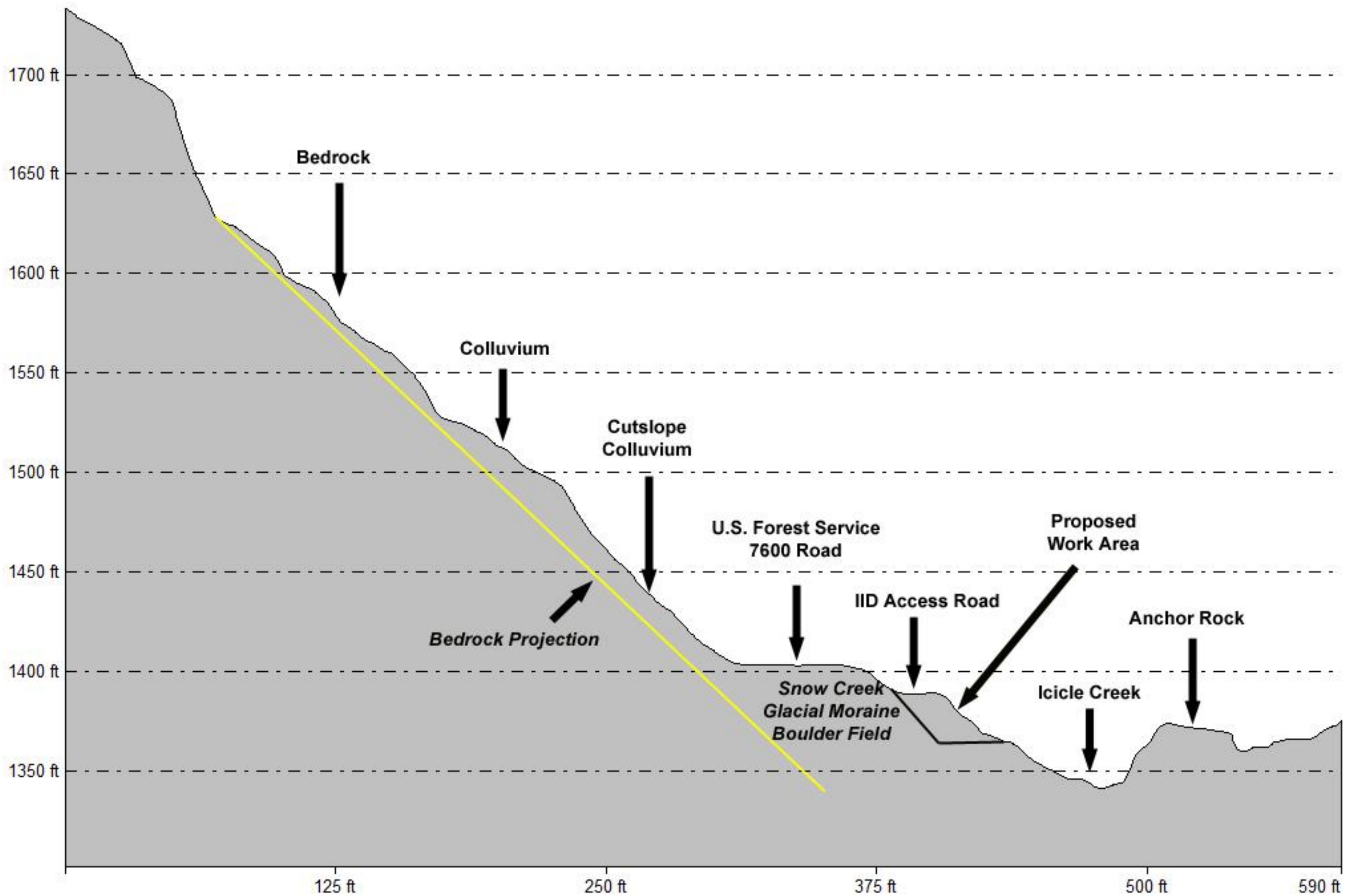


Figure 5. Bedrock projection for a typical cross-section of the project area from bare-earth LiDAR digital elevation models.

3.0 Boulder Characteristics

The proposed step-pool fishway will require the breaking of at least 20 to 30 large boulders greater than 500 cubic feet in volume. Based on the size, angularity, weathering, and coloration of the rock, almost all of the boulders being removed are of native origin. Several feet of overburden exists on the IID access road upslope from most of the large boulders. During construction, smaller rocks were manually stacked along the fillslope and finer, rocky material was likely dumped between and on top of existing large boulders to create a stable road prism at the proper grade. A few hundred feet of the road will likely need to be removed in order to accommodate the step-pool fishway.

Table 1 summarizes the size and placement of various boulders around the potential step-pool fishway. Figures 6 through 9 shows four different perspectives of the boulders located within the proposed fishway.

At the start of the fishway, Boulder 43/45 will need to be removed to allow more flow through the primary channel area (Figure 9). The fishway will then begin to gain elevation, requiring the removal of most of the boulders along the north side of the Icicle Creek channel (Figure 7). The IID access road will also need to be removed to access the boulders and allow for construction of the fishway. Excavation depths will vary from 15 to 24 feet. The fishway will reconnect with the primary channel at about the location of Boulder 18 (Figures 6 and 7). The reconstructed slope below the U.S. Forest Service 7600 Road will be at a 1.4:1 angle and is based on adjacent stable reference slopes constructed from similar rock. The reconstructed slope should be able to utilize existing native boulders in the road prism and strategic placement of large rock from the fishway construction activities.

One design feature worth noting in the proposed fishway is that a line of boulders will be maintained between the roughened channel and the primary channel area. The lineup of boulders can be best viewed in Figure 6, where Boulders 19, 21, and likely Boulder 25 will be retained in the channel to help direct flows and protect the fishway from hydraulic forces. In addition, Boulders 14 and 17 will be retained to preserve the large pool that has formed below them (Figures 6 and 7).

Boulder	Estimated Width (ft)	Estimated Length (ft)	Estimated Height (ft)	Estimated Volume (cu ft)	Remove	Notes
14	20	30	20	12,000	N	Blocks flow, creates small falls, try to keep in place or shave/step upper part of boulder
15-16					N	Keep in place
17	15	20	20	6,000	N	Perched on rounded large boulder and Boulder 22; forms cave pool under Boulder 14
18	8	30	15	3,600	Y	Comes out entirely for new side channel, helps keep up road fill
19	10	20	12	2,400	N	Might be propped up by Boulder 39; resting on smaller boulders and Boulder 20; try to keep in place
20					N	Keep in place
21	10	15	20	3,000	N	Propped up by Boulder 25; likely to stay
22	10	30	12	3,600	Y	Holding Boulder 17 and Boulder 38; comes out for new side channel
23	10	12	5	600	Y	Resting on Boulder 22, 34, and 40; comes out for new channel
24	15	15	10	2,250	Y	On top of Boulder 30; comes out for new channel
25	15	20	10	3,000	Y?	Propped up on in-channel boulder; not clear if planned for removal
26-29					N	Keep in place

Table 1. Summary of boulder characteristics in the proposed step-pool fishway.

Boulder	Estimated Width (ft)	Estimated Length (ft)	Estimated Height (ft)	Estimated Volume (cu ft)	Remove	Notes
30	10	15	4	600	Y	On top of Boulder 25 and 26; Boulder 24 rests on it; comes out for new channel
32	5	20	5	500	Y	Could be holding Boulder 33
33	15	25	20	7,500	Y	Appears to end at edge of road fill
34	20	20	20	8,000	Y	Large boulder that props up Boulder 23 and holds up Boulder 35 and road fill
35	15	20	20	6,000	Y	Propped up on 34; part of road fill; unclear how far extends into road prism
36	10	20	10	2,000	Y	Unclear how far rock extends into road prism
37	10	15	5	750	Y	Holding up road fill
38	10	20	8	1,600	Y	Located behind Boulder 22 and below Boulder 37, holding smaller boulders in place upslope
39	15	20	20	6,000	Y	Resting on Boulder 19 and located below Boulder 22; Boulder 40 rests on it, comes out for new channel
40	6	15	5	450	Y	Resting on Boulder 39 and 44; Boulder 23 rests on top; comes out for new channel
44	15	20	10	3,000	Y	Props up Boulder 40; comes out for new channel
43/45	15	25	15	5,625	Y	Double numbered rock in channel will be removed
46	10	10	5	500	Y	Comes out for new channel

Table 1 (continued). Summary of boulder characteristics in the proposed step-pool fishway.

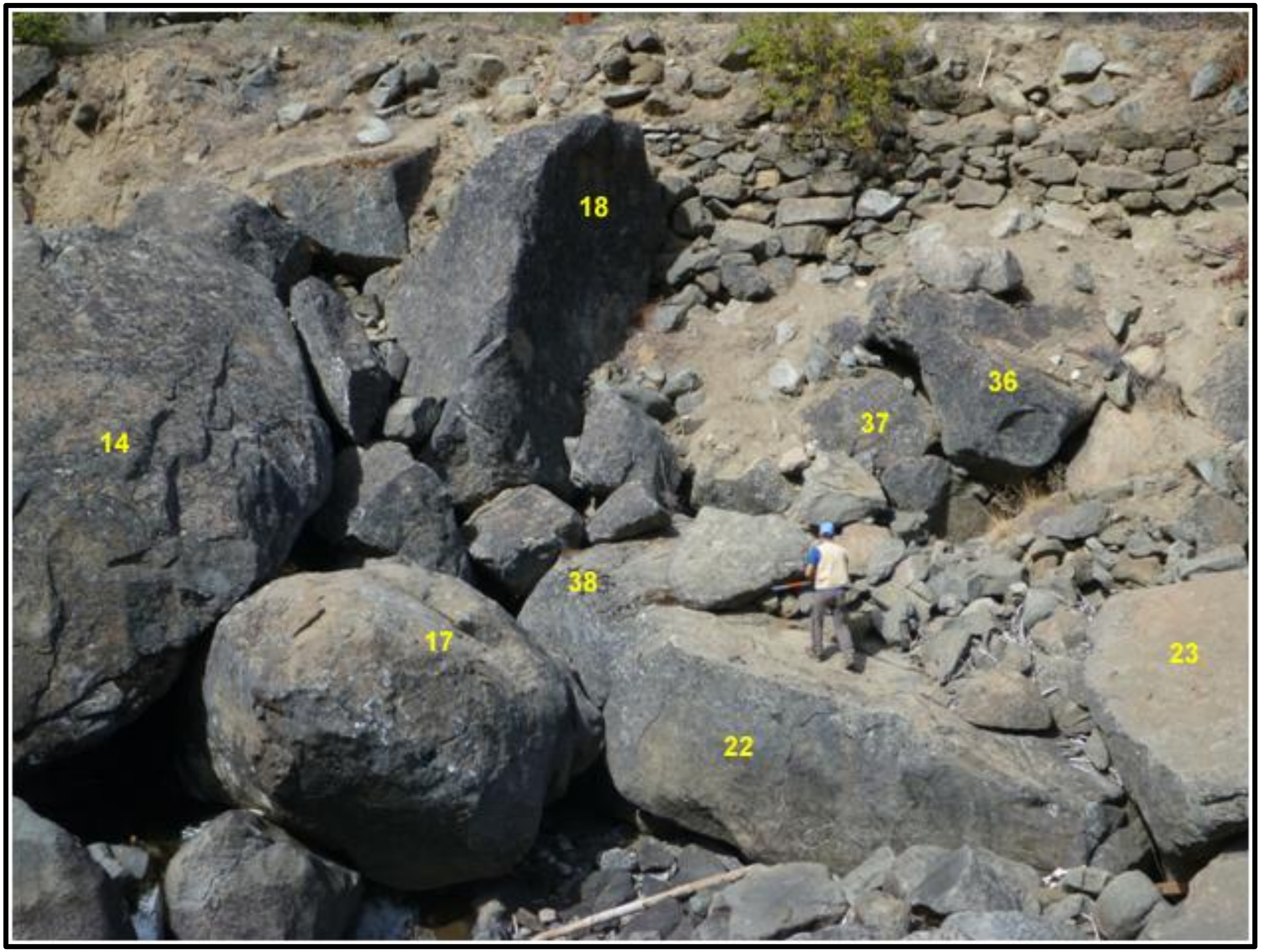


Figure 6. View from the Anchor Rock of the boulders located in the upper portion of the proposed step-pool fishway.

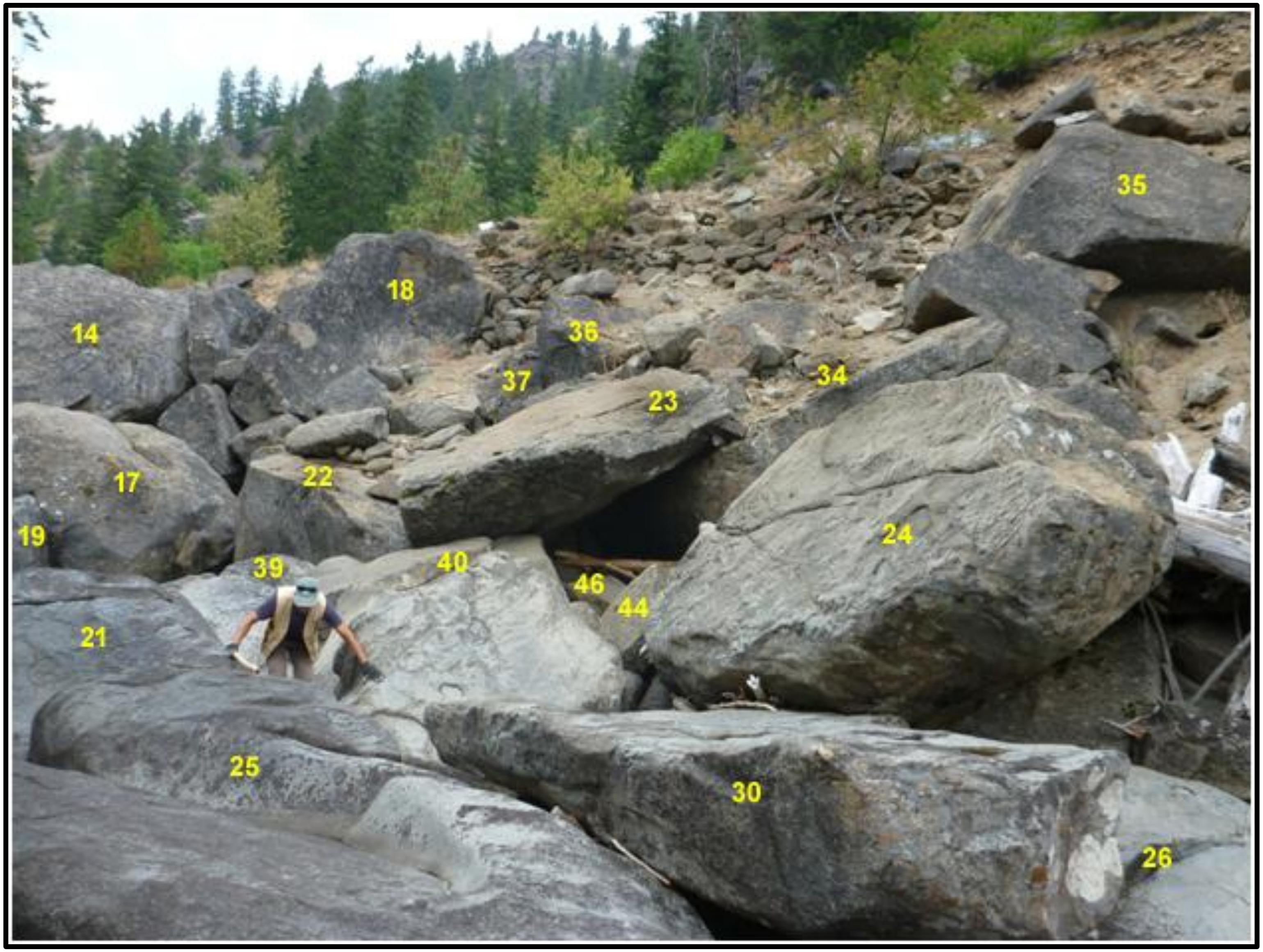


Figure 7. Upstream view of the boulders located in the proposed step-pool fishway area.

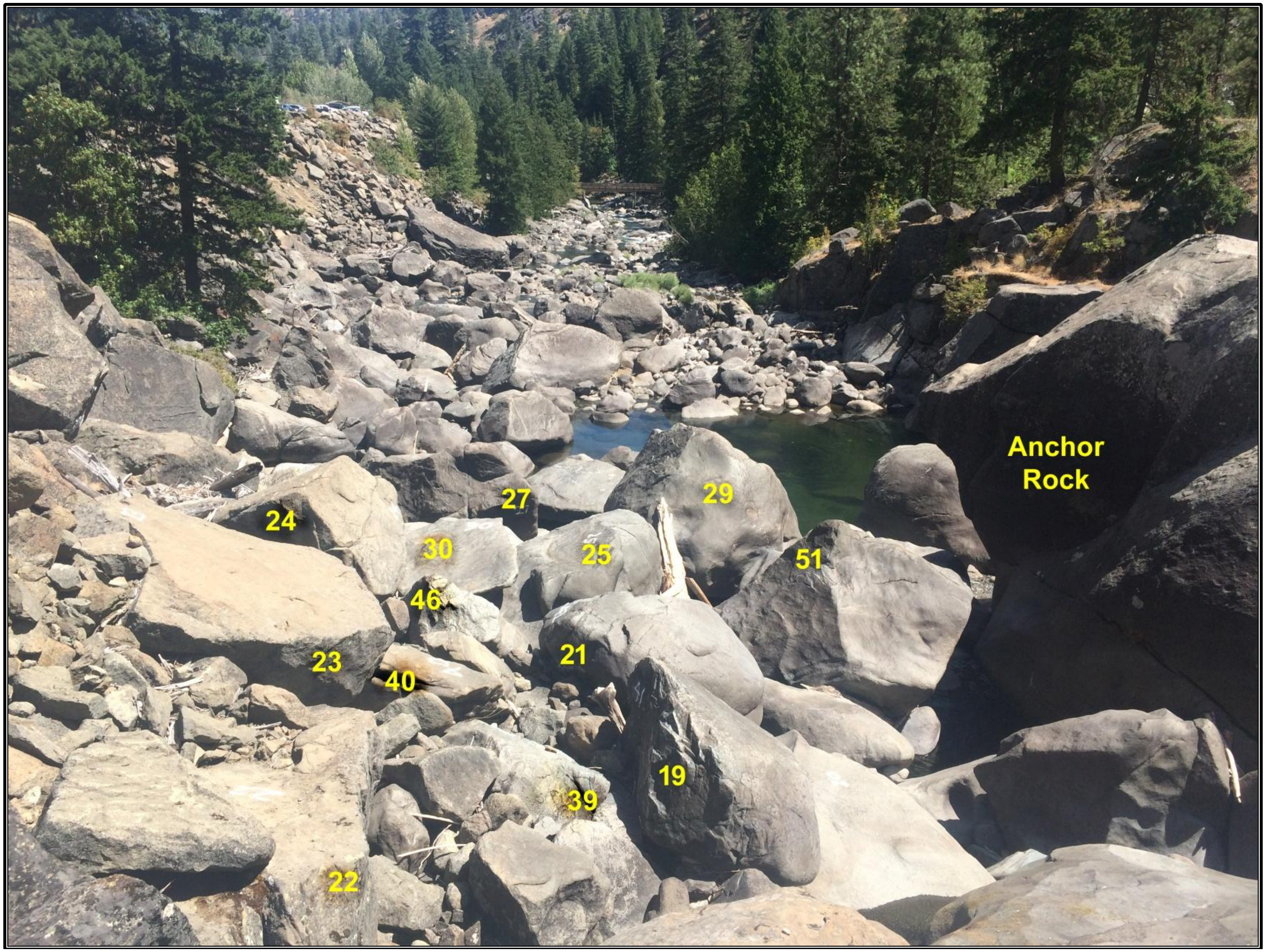


Figure 8. Downstream view of the boulders located in the proposed step-pool fishway area.

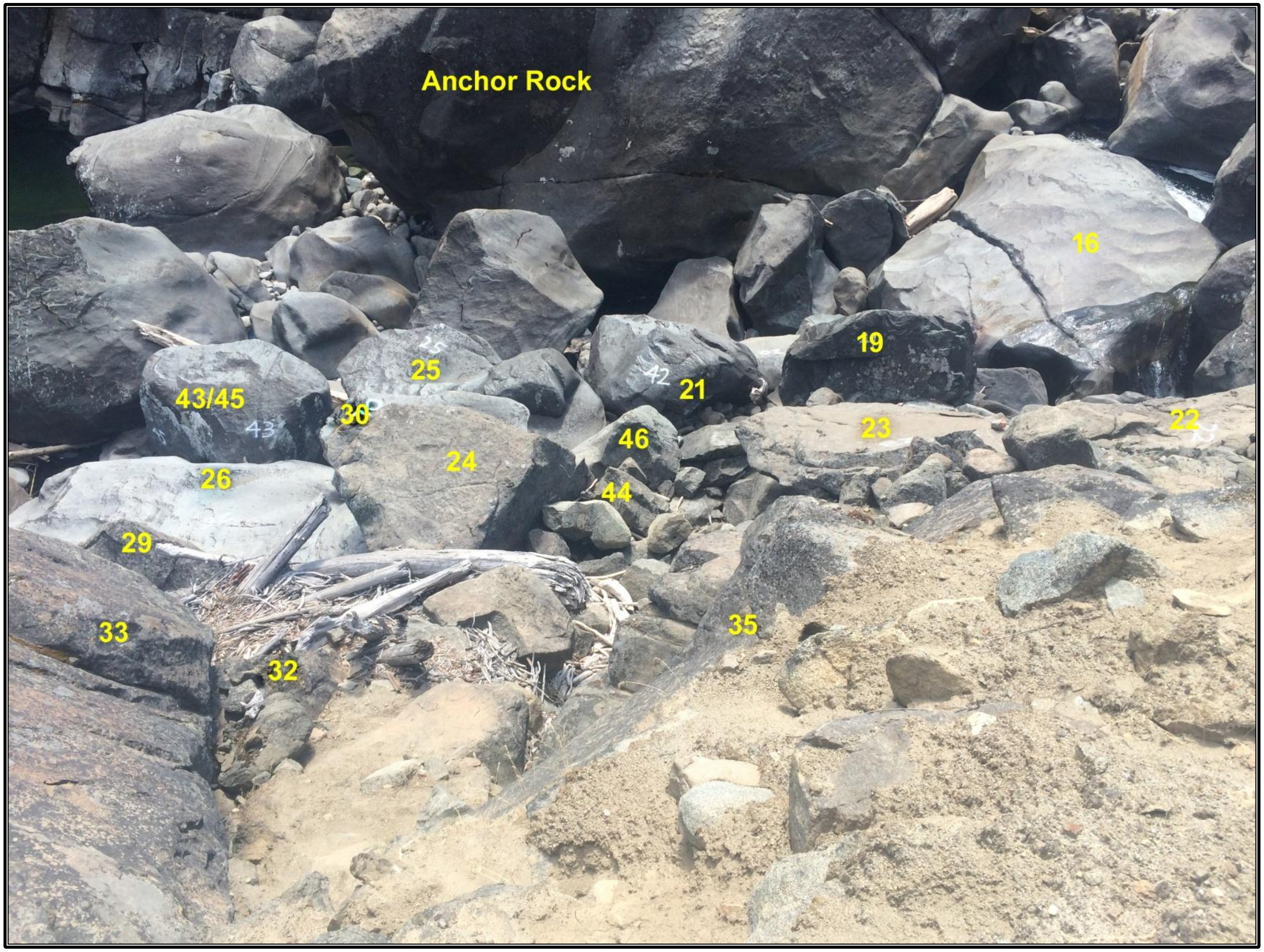


Figure 9. View from the Icicle Creek Irrigation District access road of the boulders located in the proposed step-pool fishway area.

4.0 Rock Engineering Properties

Several methods were used to assess the engineering properties of the boulders in the project area. Rock samples were collected and measured to determine hardness and density. A Schmidt hammer was used to assess the *in situ* unconfined compressive strength of several boulders. Finally, various rock-breaking methods were tested to evaluate their effectiveness in fracturing the granitic boulders.

4.1 Rock Density

Rock samples were collected during field work and brought back to the office for further testing. Tests were conducted to calculate the unit weight of the samples and density of the rock. Test samples averaged about 2 inches by 1-inches (6 cm by 3 cm) in size. The samples were weighed after drying for at least 48 hours and then submerged in water. The difference in weight is used to calculate the volume and density of the sample. Table 2 shows the unit weight data for all of the measured samples. The average density of the weathered tonalite samples was 2.76 g/cm^3 or 172.07 lbs/ft^3. The tonalite sample densities are similar to the 2.73 g/cm^3 value for granodiorite samples that were collected further upstream on Icicle Creek (Shannon and Wilson 2004).

Boulder No.	Rock Type	Weight in Air (g)	Weight in Water (g)	Density (g/cm^3)	Density (lb /ft^3)
14	Tonalite	32.38	20.54	2.73	170.73
20	Tonalite	115.27	74.42	2.82	176.16
22	Tonalite	22.40	13.96	2.65	165.69
26	Tonalite	226.59	146.09	2.81	175.72
Average Density				**2.76**	**172.07**

Table 2. Summary of unit weight and density data for measured samples.

4.2 Compressive Strength

During field work, a Schmidt hammer was used to estimate the compressive strength of various boulders in their natural state. The Schmidt hammer applies a calibrated impact to a rock surface and the rebound value is measured after each blow. The rebound value can be correlated to a compressive strength based on rock type and empirical laboratory measurements.

Slight weathering of the rock surface was observed across most of the boulders, unless the boulder surface has been regularly in contact with flowing water. Minor exfoliation of the rock surface layer was also noted on many of the rocks. Exfoliation involves thin sheeting joints that are generally flat, somewhat curved and parallel to the rock surface. The areas of the boulders with a noticeable weathered surface layer were prepped with carborundum abrasive. Carborundum treatment removes a thin, weaker surface layer allowing the device to record harder, less weathered rock below. Treatment with carborundum abrasives allows for more consistent measurements of rock hardness (Viles et al. 2011).

Table 3 shows the field rebound readings and the estimated unconfined compressive strength (UCS). Aydin and Basu (2005) provide a regression correlation between Schmidt hammer rebound values and unconfined compressive strength for granite rock. The average compressive strength of the boulders is estimated to be 152 MPa or 21,980 psi. The range of values, however, is significant and largely reflects differential weathering of the boulder surface. More detailed data from the Schmidt hammer tests are available in Appendix A.

Boulder	Average Rebound Value	Standard Deviation	Estimated Compressive Strength (MPa)	Estimated Compressive Strength (psi)
17	59	8.2	90	13,053
18	51	9.8	51	7,397
22	59	8.9	90	13,053
24	72	10.2	224	32,488
30	70	6.6	195	28,282
34	54.5	9.9	66	9,573
39	77	4.0	318	46,122
40	59	12.4	90	13,053
43	66.5	13.1	152	22,046
44	69	9.3	182	26,397
46	71	7.0	209	30,313

Table 3. Summary of Schmidt hammer data and estimated compressive strengths.

The unconfined compressive strength of the boulders ranges from medium strength to very high strength rock. Unconfined compressive strength values of less than 50 MPa or 8,000 psi would be considered medium strength rock, while values greater than 100 MPa or 16,000 psi are considered very high strength rock. Boulders with more exfoliated and weathered tonalite have relatively low strength values compared to unweathered intact granitic rock, but the specific gravity of 2.76 suggests a generally high interior strength. The weathering of these rocks over several thousand years, however, does reduce their overall compressive strength.

4.3 Rock Breaking Methods

Waterfall Engineering contracted with Maple Leaf Powder Company to evaluate the boulders at the site and to provide an assessment of potential rock-breaking methods for the proposed step-pool fishway. The assessment identified several potential methods for breaking rocks including the use of a hydraulic hammer, low-impact deflagrating explosives, and high explosives. The conclusions suggested that a hydraulic hammer or deflagrating explosives would likely be the most effective methods. Both methods would result in very little ground vibration. Rock drilling could be accomplished by an excavator-mounted hydraulic drill or hand drilled using a portable air compressor. The complete report can be found in Appendix B.

To increase our understanding of the best methods for breaking rock at the site, five boulders were removed from along the IID access road and taken to a construction yard for rock drilling and breaking tests. Rock sizes ranged from 5 to 6 feet in diameter. Three methods were tested for breaking up the boulders in the project area:

1) A hydraulic rock-breaking hammer mounted on an excavator,
2) Boulder Buster™ non-detonating rock-breaking propellant, and
3) Expansive demolition grout.

A Caterpillar 320E hydraulic excavator was mounted with a Caterpillar H115ES hammer. The tool was jack-hammered into the boulder to break the rock into smaller pieces. The hammer was used on two of the boulders and took 10 to 15 minutes to break each of the boulders into manageable pieces. Rocks with existing cracks or fractures typically can be broken into smaller pieces within just a few minutes.

The Boulder Buster™ is a non-detonating rock-breaking tool that utilizes propellant technology. A pressure impulse is generated in the tool by a cartridge filled with propellant. The pressure impulse is directed via a barrel into a pre-drilled hole in the rock filled with water. The rapidly developing pressure wave transmitted by the fluid column creates fractures in the rock. The static pressure causes further mechanical stress and tensile fracturing of the rock. The propellant is low concussion with little flying rock and scatter. Blasting mats can be used to prevent even small amounts of flying rock. Two boulders were used to test the effectiveness of the Boulder Buster™ tool. A pneumatic rock drill with an approximately 1½-inch diameter bit was used to drill to approximately 80 percent of the boulder's depth. Drilling of each boulder took about 10 minutes. Another 5 minutes was needed to insert the water and cartridge and to fire the tool. The two boulders broke into manageable pieces almost instantly with only minor amounts of flying rock.

The expansive demolition grout is available to the general public and does not require any special licenses. Using the expansive grout required the drilling of three 1½-inch diameter holes in the boulder, which took approximately 20 minutes. The hole spacing generally needs to be on one-foot centers. Dexpan™ non-explosive controlled demolition agent was mixed with water to the proper proportions and poured into the three holes. The Dexpan™ grout has 19,000 psi expansive strength when mixed with water, but generally takes at least 24 hours to be completely effective. The results of the tests suggest that cracking of the large granitic boulders may require from 36 to 48 hours to achieve best results.

Appendix C includes photographs of the boulder transport and the three methods used for breaking the rock.

5.0 Construction Considerations

Based on the valley wall bedrock slope angles and the size of the glacial moraine boulder field in the surrounding area, we do not believe that excavation depths of up to 25 feet will encounter bedrock. Excavations below the road prism will likely encounter large native boulders, as well as fill material from the original construction. These native boulders may need to be excavated to a degree before boulder cracking can commence. All of the rock-cracking methods require that boulders not be buried to allow for expansion of the rock. Following excavation activities, a few of the large boulders under the road fill may need to be partially cracked or shaped in order to reconstruct a stable slope.

We believe that a combination of the hydraulic rock hammer and the Boulder Buster™ non-detonating rock-breaking tool would be optimal for constructing the step-pool fishway. Both methods require a similar amount of time to break up boulders, but the Boulder Buster™ would likely be a more efficient and effective tool on larger, intact boulders. The hydraulic hammer could be used to break up larger pieces or fractured rocks to allow for easier excavation. The hydraulic rock hammer may also be a good tool for shaping boulders.

Removal of talus rock carries a risk of slope instability whenever slopes are oversteepened or key buttressing rocks are removed. The stability of talus slopes depends upon the interlocking of the larger rock fragments. Rock-supported talus is often inherently unstable because the weight of the deposit is transmitted as point loads among the fragments. Particular care must be taken in constructing access points and reconstructing the slope face. Rocks should be removed progressing in a downhill direction to reduce the potential for initiating upslope rock movement and threatening operator safety.

6.0 References

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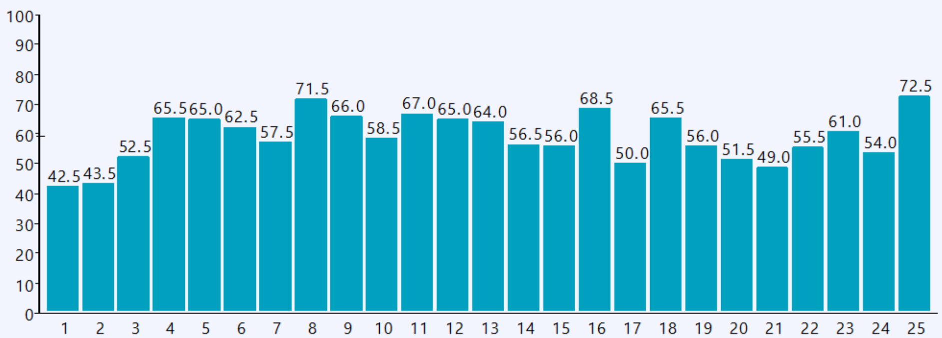
Appendix A

Schmidt Hammer Results

Boulder Number 17

Impact counter	Name	Date & Time	Mean value
Σ 341		08/04/2015 3:31 PM	59.0 R

R-Values diagram [measurement order]



R-Values

42.5	65.5
43.5	56.0
52.5	51.5
65.5	49.0
65.0	55.5
62.5	61.0
57.5	54.0
71.5	72.5
66.0	
58.5	
67.0	
65.0	
64.0	
56.5	
56.0	
68.5	
50.0	

Statistics

Measurements	N = 25
Invalid measurements	Ni = 0 (0%)
Mean value	f = 59.0 R
Range	R = 30.0 R
Standard deviation	s = 8.2 R

Settings

Averaging mode	Mean
Conversion curve	---
Correction factor	1.00
Unit	R
Serial number	SH01-007-0842
Spring type	RockSchmidt N

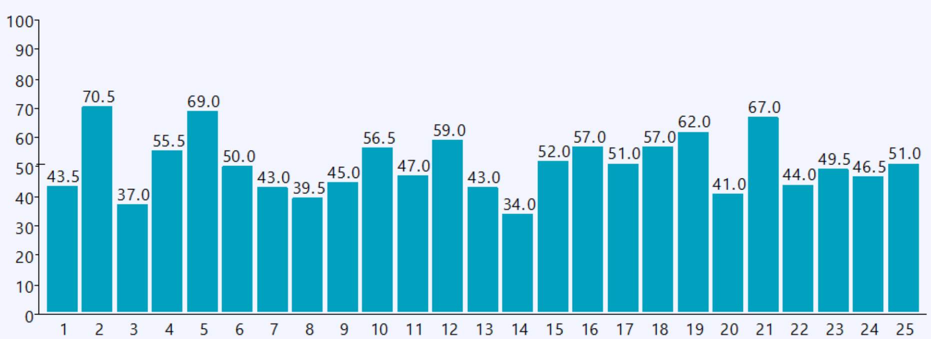
Comment

[Add]

Boulder Number 18

Impact counter	Name	Date & Time	Mean value
Σ 392		08/04/2015 3:48 PM	51.0 R

R-Values diagram [measurement order]



R-Values

43.5	57.0
70.5	62.0
37.0	41.0
55.5	67.0
69.0	44.0
50.0	49.5
43.0	46.5
39.5	51.0
45.0	
56.5	
47.0	
59.0	
43.0	
34.0	
52.0	
57.0	
51.0	

Statistics

Measurements	N = 25
Invalid measurements	Ni = 0 (0%)
Mean value	f = 51.0 R
Range	R = 36.5 R
Standard deviation	s = 9.8 R

Settings

Averaging mode	Mean
Conversion curve	---
Correction factor	1.00
Unit	R
Serial number	SH01-007-0842
Spring type	RockSchmidt N

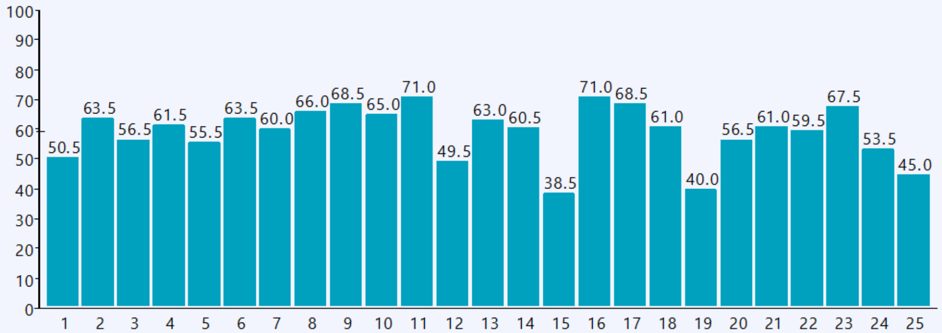
Comment

[Add]

Boulder Number 22

Impact counter	Name	Date & Time	Mean value
Σ 366		08/04/2015 3:36 PM	59.0 R

R-Values diagram [measurement order]



R-Values

50.5	61.0
63.5	40.0
56.5	56.5
61.5	61.0
55.5	59.5
63.5	67.5
60.0	53.5
66.0	45.0
68.5	
65.0	
71.0	
49.5	
63.0	
60.5	
38.5	
71.0	
68.5	

Statistics

Measurements	N = 25
Invalid measurements	Ni = 0 (0%)
Mean value	f = 59.0 R
Range	R = 32.5 R
Standard deviation	s = 8.9 R

Settings

Averaging mode	Mean
Conversion curve	---
Correction factor	1.00
Unit	R
Serial number	SH01-007-0842
Spring type	RockSchmidt N

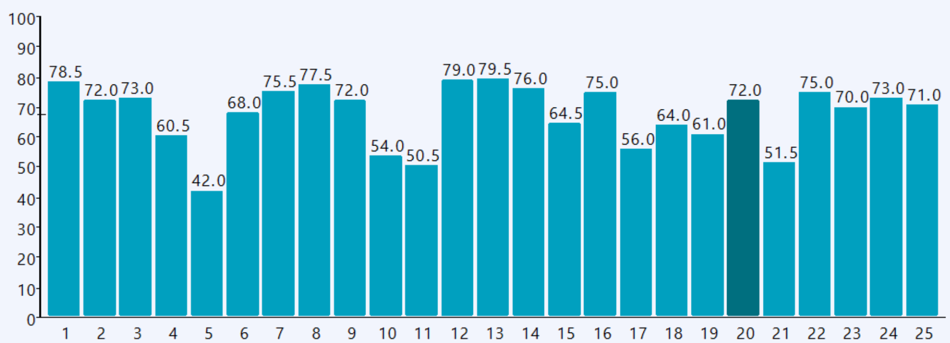
Comment

[Add]

Boulder Number 24

Impact counter	Name	Date & Time	Mean value
Σ 153		08/04/2015 2:47 PM	72.0 R

R-Values diagram [measurement order]



R-Values

78.5	64.0
72.0	61.0
73.0	72.0
60.5	51.5
42.0	75.0
68.0	70.0
75.5	73.0
77.5	71.0
72.0	
54.0	
50.5	
79.0	
79.5	
76.0	
64.5	
75.0	
56.0	

Statistics

Measurements	N = 25
Invalid measurements	Ni = 0 (0%)
Median	f = 72.0 R
Range	R = 37.5 R
Standard deviation	s = 10.2 R

Settings

Averaging mode	Median
Conversion curve	---
Correction factor	1.00
Unit	R
Serial number	SH01-007-0842
Spring type	RockSchmidt N

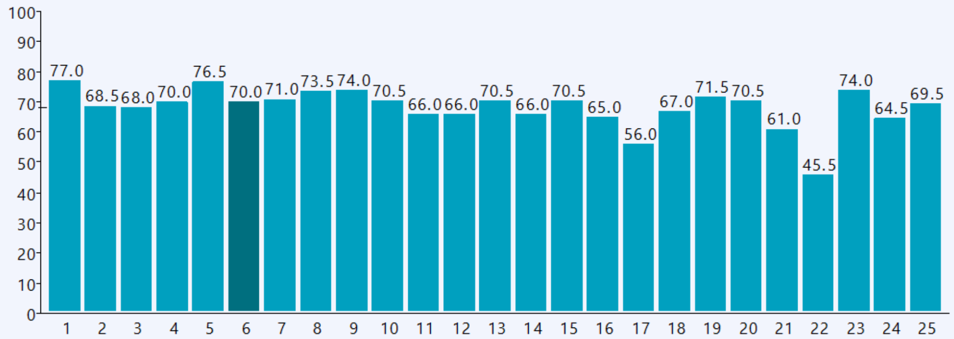
Comment

[Add]

Boulder Number 30

Impact counter	Name	Date & Time	Mean value
Σ 178		08/04/2015 2:57 PM	70.0 R

R-Values diagram [measurement order]



R-Values

77.0	67.0
68.5	71.5
68.0	70.5
70.0	61.0
76.5	45.5
70.0	74.0
71.0	64.5
73.5	69.5
74.0	
70.5	
66.0	
66.0	
70.5	
66.0	
70.5	
65.0	
56.0	

Statistics

Measurements	N = 25
Invalid measurements	Ni = 0 (0%)
Median	f = 70.0 R
Range	R = 31.5 R
Standard deviation	s = 6.6 R

Settings

Averaging mode	Median
Conversion curve	---
Correction factor	1.00
Unit	R
Serial number	SH01-007-0842
Spring type	RockSchmidt N

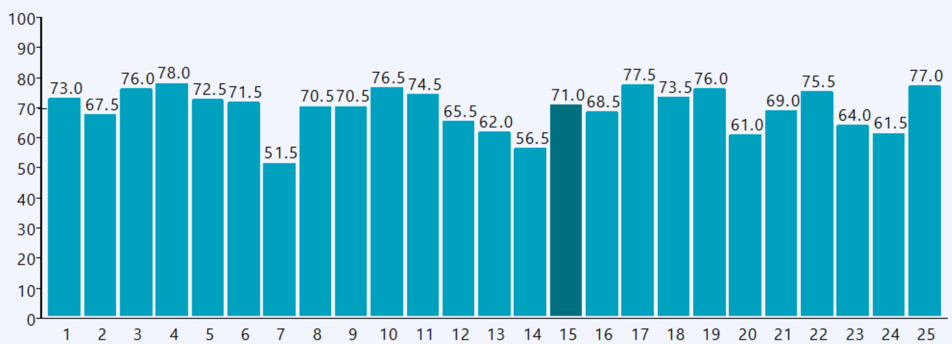
Comment

[Add]

Boulder Number 46

Impact counter	Name	Date & Time	Mean value
Σ 203		08/04/2015 2:59 PM	71.0 R

R-Values diagram [measurement order]



R-Values

73.0	73.5
67.5	76.0
76.0	61.0
78.0	69.0
72.5	75.5
71.5	64.0
51.5	61.5
70.5	77.0
70.5	
76.5	
74.5	
65.5	
62.0	
56.5	
71.0	
68.5	
77.5	

Statistics

Measurements	N = 25
Invalid measurements	Ni = 0 (0%)
Median	f = 71.0 R
Range	R = 26.5 R
Standard deviation	s = 7.0 R

Settings

Averaging mode	Median
Conversion curve	---
Correction factor	1.00
Unit	R
Serial number	SH01-007-0842
Spring type	RockSchmidt N

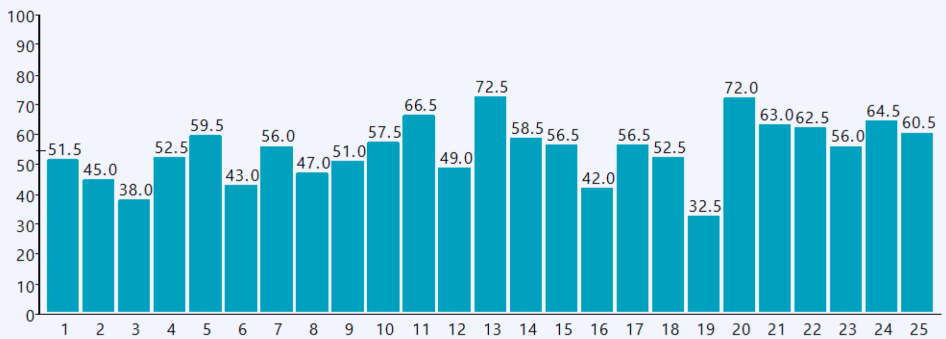
Comment

[Add]

Boulder Number 34

Impact counter	Name	Date & Time	Mean value
Σ 290		08/04/2015 3:15 PM	54.5 R

R-Values diagram [measurement order]



R-Values

51.5	52.5
45.0	32.5
38.0	72.0
52.5	63.0
59.5	62.5
43.0	56.0
56.0	64.5
47.0	60.5
51.0	
57.5	
66.5	
49.0	
72.5	
58.5	
56.5	
42.0	
56.5	

Statistics

Measurements	N = 25
Invalid measurements	Ni = 0 (0%)
Mean value	f = 54.5 R
Range	R = 40.0 R
Standard deviation	s = 9.9 R

Settings

Averaging mode	Mean
Conversion curve	---
Correction factor	1.00
Unit	R
Serial number	SH01-007-0842
Spring type	RockSchmidt N

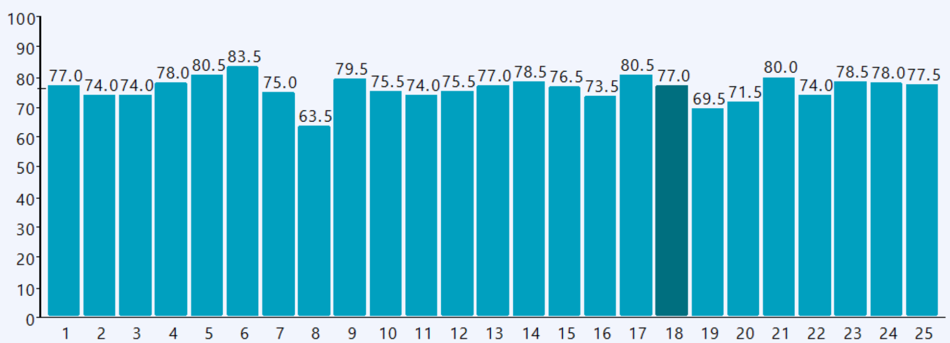
Comment

[Add]

Boulder Number 39

Impact counter	Name	Date & Time	Mean value
Σ 253		08/04/2015 3:06 PM	77.0 R

R-Values diagram [measurement order]



R-Values

77.0	77.0
74.0	69.5
74.0	71.5
78.0	80.0
80.5	74.0
83.5	78.5
75.0	78.0
63.5	77.5
79.5	
75.5	
74.0	
75.5	
77.0	
78.5	
76.5	
73.5	
80.5	

Statistics

Measurements	N = 25
Invalid measurements	Ni = 0 (0%)
Median	f = 77.0 R
Range	R = 20.0 R
Standard deviation	s = 4.0 R

Settings

Averaging mode	Median
Conversion curve	---
Correction factor	1.00
Unit	R
Serial number	SH01-007-0842
Spring type	RockSchmidt N

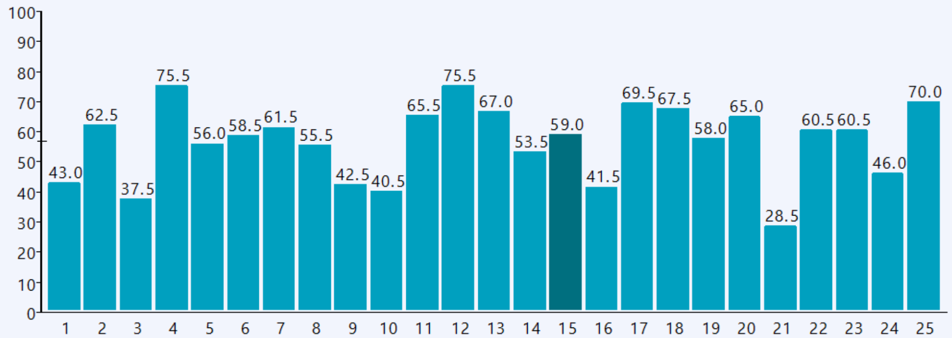
Comment

[Add]

Boulder Number 40

Impact counter	Name	Date & Time	Mean value
Σ 228		08/04/2015 3:03 PM	59.0 R

R-Values diagram [measurement order]



R-Values

43.0	67.5
62.5	58.0
37.5	65.0
75.5	28.5
56.0	60.5
58.5	60.5
61.5	46.0
55.5	70.0
42.5	
40.5	
65.5	
75.5	
67.0	
53.5	
59.0	
41.5	
69.5	

Statistics

Measurements	N = 25
Invalid measurements	Ni = 0 (0%)
Median	f = 59.0 R
Range	R = 47.0 R
Standard deviation	s = 12.4 R

Settings

Averaging mode	Median
Conversion curve	---
Correction factor	1.00
Unit	R
Serial number	SH01-007-0842
Spring type	RockSchmidt N

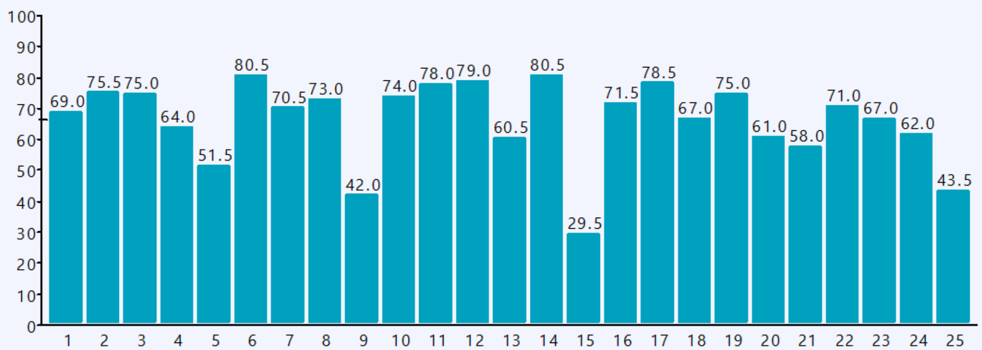
Comment

[Add]

Boulder Number 43

Impact counter	Name	Date & Time	Mean value
Σ 115		08/04/2015 2:39 PM	66.5 R

R-Values diagram [measurement order]



R-Values

69.0	67.0
75.5	75.0
75.0	61.0
64.0	58.0
51.5	71.0
80.5	67.0
70.5	62.0
73.0	43.5
42.0	
74.0	
78.0	
79.0	
60.5	
80.5	
29.5	
71.5	
78.5	

Statistics

Measurements	N = 25
Invalid measurements	Ni = 0 (0%)
Mean value	f = 66.5 R
Range	R = 51.0 R
Standard deviation	s = 13.1 R

Settings

Averaging mode	Mean
Conversion curve	---
Correction factor	1.00
Unit	R
Serial number	SH01-007-0842
Spring type	RockSchmidt N

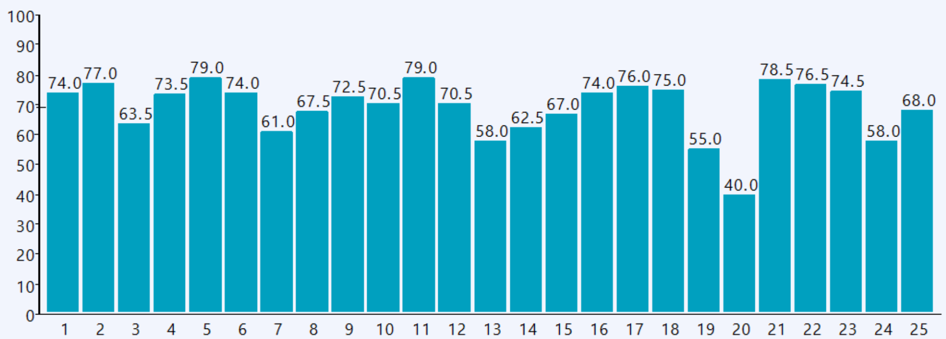
Comment

[Add]

Boulder Number 44

Impact counter	Name	Date & Time	Mean value
Σ 316		08/04/2015 3:20 PM	69.0 R

R-Values diagram [measurement order]



R-Values

74.0	75.0
77.0	55.0
63.5	40.0
73.5	78.5
79.0	76.5
74.0	74.5
61.0	58.0
67.5	68.0
72.5	
70.5	
79.0	
70.5	
58.0	
62.5	
67.0	
74.0	
76.0	

Statistics

Measurements	N = 25
Invalid measurements	Ni = 0 (0%)
Mean value	f = 69.0 R
Range	R = 39.0 R
Standard deviation	s = 9.3 R

Settings

Averaging mode	Mean
Conversion curve	---
Correction factor	1.00
Unit	R
Serial number	SH01-007-0842
Spring type	RockSchmidt N

Comment

[Add]

Appendix B

Maple Leaf Powder Company Report

Maple Leaf Powder Company

2025 Allenby St.
Victoria B.C. V8R 3B9
Canada
(250) 744-8765
www.mapleleafpowder.com

October 25 2014

Icicle Creek Boulder Field Passage
Leavenworth Washington USA
Project # 13-1342

To Waterfall Engineering LLC
9427 Delphi Road
Olympia WA
98512 USA
Patrick Powers, P.E. 360 352 5773 office, 360 701 8433 cell

A site visit to Icicle creek was conducted on October 22 2014. The purpose of the site visit was to view the project and establish effective, safe, legal and environmentally responsible methods of removing the fill and boulders and constructing a fish channel.

In attendance
Patrick Powers -Waterfall Engineering LLC
Aaron Penvose -Project Director, Trout Unlimited, Washington Water Project 509 881 7689
Dan Jaspers- Construction Manager, Trout Unlimited, Washington Water Project 509 881 669 0028
Rod Shearer -Contractor, RM Shearer Inc. 509 430 9144
Aaron Jones -Contractor POW Contracting 509 366 6050

General

Icicle Creek in the Cascade mountain range flows into the Wenatchie River on the west side of the town of Leavenworth WA. Many years ago a mining road was built along side the creek. A 16 inch steel waterline was installed along side the creek and buried in the road. A walking bridge was built over the creek and a number of recreational services were put in.

All this activity caused a stretch where the water in the creek falls at approximately a 20 percent incline, to get narrowed, confined and potentially clogged up with large boulders that where placed there during the road and waterline constructions. There was likely some of these boulders that fell into the creek from natural occurrences tumbling down from the top of the steep banks above the creek.

Generally speaking the rocks in the creek appear to be very hard granite.

This boulder field has caused a situation where the fish passage is partially

1

The purpose of this project is to design and build a passage around and /or through this boulder field to allow the various fish species to get up stream into the natural habitat.

The main fish species are Steelhead and Bull trout with the potential for Chinook and Spring Salmon

Patrick Powers identified three different construction options. All three options involve breaking up the boulders in the creek. Each option would involve different amounts of boulder breaking depending on how wide the channel is built and exactly where the channel is installed along the side of the creek.

This report focuses on different methods of breaking the boulders and moving them safely effectively and economically. Bearing in mind trying to minimize the impact on the surrounding environment and fish and wildlife in the creek.

Hydraulic Rock Breaking Hammers

This method of breaking rock can be very effective. It eliminates the need for a certified blaster on the project. It eliminates the need for legal ATF storage of either high explosives or deflagrating explosives.

Rock hammers come in a variety of sizes. This report feels that a large size would be required here to break these large, tough, dense, granite boulders.

These rock hammers operate on the end of the exactor arm. So it eliminates the need for a rock drill.

If the boulders can be successfully broken down in this fashion, in a reasonable time frame, it would certainly reduce costs and speed up the entire project.

This would be the lowest impact on the surrounding environment and the safest method.

This report recommends a trial of breaking some of these boulders with a rock hammer to establish the effectiveness of this method.

Deflagrating Low Impact Explosives

Technology today has developed a new generation of deflagrating explosives. These types of explosives are designed to minimize the impact on the surrounding environment while still carrying out the job of breaking rocks.

The product formulation inside the waterproof cartridges is a mixture of ammonium nitrates blended with black powders.

These blends when primed and confined properly, create a very low velocity deflagration rather than a detonation. The speed at which the gases created move is very low velocity in the range of 600 meters per second. This would compare to a detonation of high explosives, which move at velocities of 18000 feet per second.

These blends also create a lot of this slow moving gas. Therefore when confined properly, the gases expand slowly and enable the rocks to break without throwing rock particles through the air.

It is the recommendation of this report that this generation of low impact explosives should certainly be tried for effectiveness on these boulders.

If they can successfully break the boulders it would be a far safer method than using conventional high explosives.

This method would eliminate the need for covering each boulder with expensive and very heavy blasting mats.

These explosives would only crack the boulders into smaller sizes that can be handled by an excavator bucket. No flyrock would be created.

There are a number of different brand names of these type of explosives and they are all equally effective. These products are readily available throughout the USA.

The brand name that this report is familiar with is Nxburst explosives. Just google this name for product information

High Explosives

If the above two methods are proven to be too cumbersome, slow or ineffective, high explosives can certainly be used to break these boulders. There is no question this method will work.

But when using high explosives, a number of new issues arise.

Good quality, heavy rubber tired blasting mats would need to be used.
This hard granite rock will certainly fly a long ways when broken with high velocity explosives. Therefore flyrock created from this method is a very real and definite concern for public and wildlife safety.

Each boulder would have to be completely covered with these blasting mats.

The area would have to be completely evacuated of all people and wild life when blasting.

Blasting would cause higher ground vibrations than the above two methods.
Any wildlife living in the immediate area of the creek where the boulders are blasted would certainly be concussed to various degrees.

A proper rock drill would have to be employed to drill holes deep enough and large enough diameter.
A licensed blaster would need to carry out the blasting.

Legal ATF storage of the explosives would have to be confirmed. Legal transportation of the explosives to and from the project would have to be confirmed

High explosives are readily available throughout the USA. There are a number of legal explosive suppliers in Washington State who would have all the products required to carry out this method of blasting

This report recommends not to use high explosives on this project until the rock hammer and/or deflagrating explosives methods are proven to be ineffective, too cumbersome or too expensive.

If high explosives are to be used, this report recommends priming the explosives with high strength, shock tube detonators. **Do not prime the explosives with detonating cord.**

Detonating cord will cause very high decibel noise levels and could effect the overhanging rocks on the cliffs above the creek. As well these high noise levels will alarm the public and area wildlife.

Shock tube detonators are very effective primers and are almost noiseless if the explosives in the boreholes are confined properly and the blasting mats are applied properly.

If the project gets to the point of using high explosives please contact the writer for more detailed procedural information.

Drilling

If drilling is needed to be done there would be a few options here.
This report would first recommend finding a company that would have a hydraulic excavator mounted rock drill available.

This method of drilling would have some clear advantages on this project. These drills mount on the arm of the excavator. They therefore have a very wide-ranging area they can drill at. As long as the arm of the excavator can reach the boulder the drill can drill it. Some of these boulders are going to be difficult to reach and this method would assist greatly to reach the target boulder.

The drill connects to the excavator arm with a quick connect set up. This set up doesn't take very long to complete. It therefore enables one machine to do the excavating work and the drilling work. When not needed, the drill can be laid on its side near where the excavator is working. When a boulder is encountered the drill can easily and quickly be attached to the excavator arm to commence drilling.

A number of brand names of these drills are made. They are readily available throughout the USA.
The brand name this report is familiar with is Traxxon excavator mounted hydraulic drills.

Tamrock small hole hydraulic commando drills.

These drills are very good at drilling small diameter holes quickly in all rock conditions. They are very agile and easily picked up with an exactor and placed in an appropriate position to drill. The drill is self-contained and no other equipment is needed at the boulder location.

If the excavator mount drill was not available this style drill may be a good fit.

Hand Drilling

Hand drilling for loading of either deflagrating explosives or high explosives with a jack hammer is certainly an option on this project.

This method would give good access to each boulder. It would only require a driller to stand on each boulder to carry out the drilling.

A compressor could be located above the creek with an air hose attached to the drill down on the boulder location.

The problem with this method is these granite boulders are very dense, very large and hard. It would require a very long difficult drilling schedule.

Care would have to be taken to ensure the driller is safe while out in the creek drilling. This would have to be done during low water flow levels.

Vibration Analysis

Questions arose during the site meeting about ground vibration from blasting. There are precarious looking boulders perched high on the cliffs above the creek. Concern was raised about ground vibration jarring these boulders free causing them to tumble down the banks into the creek.

All methods of breaking the boulders will create some ground vibrations.
The most severe ground vibrations will be caused when using the high explosives methods described above.
But because the blasting or boulder breaking will be carried out in boulders and not in any bedrock. Ground vibrations of all methods will be very low.

The only concern this report would have with ground vibration is for the fish and any other wildlife in the immediate area of the creek when using high explosives.

This report would not be concerned about ground vibrations disturbing ground above the creek from any of the boulder breaking methods.

To confirm this fact, below is a spread sheet of a typical explosion that would result from a high explosives blast.

The bottom of the sheet has a PPV (Peak Particle velocity) prediction of how intense the ground vibrations would be at 50 feet from a blast that would occur in bed rock. Above ground boulders would create even less ground vibrations.

The spreadsheet uses the high explosives method of blasting for all values inputted into the blast program. Therefore this would be the worst-case scenario.

A PPV vibration level of 7mm per second as predicted, is very low and is close to being an undetectable amount of ground vibration. The further away you get from the blast the lower the ground vibration becomes.
Hydraulic hammers and low impact explosives would cause even less ground vibratuons.

Heavy equipment working on the road above the creek would cause equally or even high ground vibrations than 7 mm per second.

This report therefore is not concerned about ground vibrations from any method of boulder breaking.

Conclusions

Initially try breaking the boulders with a large excavator mounted hydraulic hammer.

If this proves in-effective for various reasons try breaking the boulders with low impact deflagrating explosives.

Only use high explosives if the above two methods prove in-effective

Try to have your rock breaking and or drilling equipment capable of working from the end of an excavator arm. This will reduce the congestion of multiple pieces of equipment working in these tight ground conditions.

Try to find a contractor with a large size excavator and a large size hydraulic hammer. A 245 caterpillar size excavator or larger would be appropriate.

If it is decided that high explosives need to be used, please use extreme caution and make sure all ATF and State regulations are followed.

It is the opinion of this report that if the correct size equipment is used, this project will not take more than two months to complete.

Maple Leaf Powder Company		
Initial Blast Design Guide		
Icicle Creek Vibration Prediction		
Enter units 1=BCM, 2=Tonnes	1	
1 for kg/bcm, 2 for bcm/kg, 3 kj/t	1	
Explosive Name	Dynamite	
Explosive Diameter	25	millimetres
Explosive Density	1.43	grams per cubic centimetre
Explosive Energy	1105	calories per gram
Rock Density	2.4	grams per cubic centimetre
Bench Height	1.5	metres
Hole Angle (0 = vertical)	0	degrees
Desired Powder Factor	0.75	kilograms of explosive per bcm
Suggested Burden	***0.6***	***metres***
Actual Burden	0.6	metres
Stiffness Ratio	2.5	*favorably flexible*
Suggested Spacing	***0.7***	***metres***
Actual Spacing	0.6	metres
Suggested Stemming	***1.1***	***metres***
Actual Stemming	1.0	***Use With Caution!***
Vertical Energy Distribution	33%	
Confinement Factor	1.35	*fair energy confinement*
Suggested Subdrill	***0.2***	***metres***
Actual Subdrill	0.0	metres
Blasthole Length	1.5	metres
Explosive Length	0.5	metres
Loading Density	0.7	kilograms per metre of blasthole
Explosive Weight	0	kilograms per blasthole

6

Explosive Energy	0	megajoules per blasthole
Volume Shot	1	bank cubic metres per blasthole
Mass Shot	1	tonnes per blasthole
Powder Factor	0.65	kilograms per bank cubic metre
Powder Factor	1.54	bank cubic metres per kilogram
Energy Factor	298	kilocalories per tonne
Distance Away	15	metres
Blastholes Per 8ms Delay	1	
Est. Peak Part. Velocity	***7***	***millimetres per second***

Sincerely

Maple Leaf Powder Company
David Sly
President

7

Disclaimer

Maple Leaf Powder Company shall not be responsible for the use of any product, service or information referred to herein. Any users of information contained in this report assume the risk of relying on such information. Maple Leaf Powder Company makes no representations or warranties as to the information provided herein or with respect to products or services referred to in this report. The information contained herein may contain inaccuracies and is subject to change without notice. Maple Leaf Powder Company shall not be responsible for any damages caused by blasting or as a result of blasting on this project. Maple Leaf Powder Company will not be responsible for any injuries caused by or as a result of blasting on this project.

Appendix C

Rock Breaking Photographs

Figure C-1. Boulder collection along the Icicle Irrigation District access road.

Figure C-2. Boulder transport on trailer to construction yard.

Figure C-3. Rock drilling of boulders.

Figure C-4. Boulder Blaster™ rock-breaking propellant tool.

Figure C-5. Results from the use of Boulder Blaster™ rock-breaking propellant tool.

Figure C-6. Hydraulic rock-breaking hammer mounted on excavator.

Figure C-7. Preparation for expansive demolition grout.

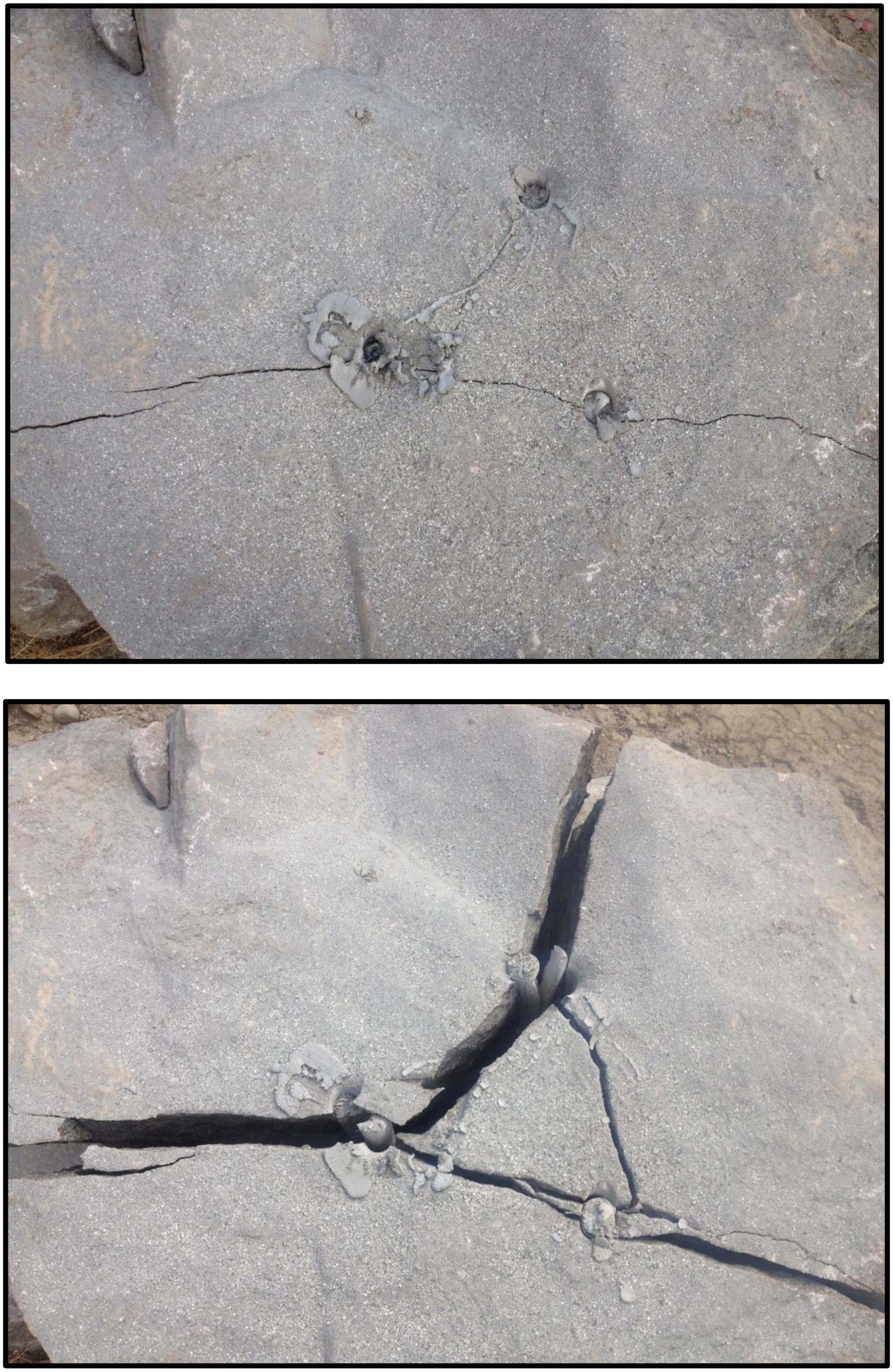


Figure C-8. Results of expansive demolition grout 18 hours and 36 hours after application.