February 13, 2023 Ecora File No.: 220805-05

Ministry of Forests
Engineering Branch, Southern Engineering Group
441 Columbia Street
Kamloops, BC V2C 2T3

Attention: **Mr. Alex Soukup, RFT, Engineering Officer, Rail Corridors**

Reference: **Preliminary ARD/ML Assessment for Proposed KV-005 Rock Source**

1. Introduction

1.1 General

The British Columbia Ministry of Forests (MoF) has retained Ecora Engineering & Resource Group Ltd. (Ecora) to carry out Acid Rock Drainage and Metal Leaching (ARD/ML) assessments for individual rock sources identified for potential use in the construction of erosion protection measures for a local bridge site. The volume of material used for the project is expected to be less than 1,000 m^3 and will be placed in or about the West Kettle River.

This preliminary ARD/ML assessment has been conducted as per MoF guidelines and includes visual examination of samples provided by MoF from surface collection of two weathered bedrock outcrop locations along the Rich Forest Service Road (FSR). This report summarizes our observations of the provided samples and opinion on the ARD/ML potential and suitability of the weathered bedrock for use as riprap.

The results and recommendations with respect to the ARD/ML potential and riprap suitability contained within this technical memorandum have been developed specifically for the proposed KV-005 rock source site and are not considered applicable elsewhere.

1.2 Site Description

The proposed KV-005 rock source site is located along the Rich Forest Service Road, approximately 22 km south of Beaverdell, BC, as shown in Figure 1.0. The proposed rock source site consists of bedrock outcrops and road cuts along the existing Forest Service Road. The site is situated approximately 250 m west of the West Kettle River and is accessible via the Rich FSR.

2. The Acid Rock Drainage/Metal Leachate Process

Acid Rock Drainage (ARD) occurs as a result of natural oxidation of sulphide minerals contained in rock which is exposed to air and water. Although the phenomenon is usually associated with mining activity, it can happen wherever naturally occurring sulphide minerals contained within a rock mass, are exposed to natural weathering.

The exposure of sulphide minerals such as pyrite and pyrrhotite, and the absence of significant acid neutralizing capacity in the form of rock constituents such as limestone and dolomite, can result in the generation of acidic drainage from a number of different sources such as:

- Surface runoff from natural rock outcrops, rock cuts or waste rock piles;
- Subsurface seepage through fissured rock mass or underground workings, and;
- Quarried rock used as rip rap or in aggregate production.

Metal Leachate (ML) typically occurs when acidic drainage causes leaching of metallic minerals from the rock mass and/or ore bodies, and if uncontrolled, can cause a significant environmental impact due to metal toxicity to fauna and flora. It is important to note that while ML usually occurs in acidic conditions, it can also occur in neutral or alkaline pH conditions.

3. Rock Type Susceptibility to ARD/ML Formation

Certain rock types are more susceptible to ARD/ML formation due to the presence, abundance and nature of sulphide minerals, and the absence of potentially acid-neutralizing minerals within the rock mass, or the presence of hydrothermal alteration zones where sulphide and metallic minerals are deposited in concentration within the rock mass.

Sedimentary and volcanic rock types are more likely to have the presence of sulphides and an absence of acid-neutralizing minerals within the rock mass and therefore have a higher susceptibility to developing ARD/ML.

Susceptibility of hydrothermally altered rock mass to developing ARD/ML, is a function of the type of alteration and the alteration pattern that can range from broad to concentrated zones of alteration.

4. Preliminary ARD/ML Assessment

Ecora's preliminary ARD/ML assessment included examination of a total of 2 sets of hand samples obtained from the proposed rock source site provided by BC MoF and consisted of the following:

- Background review; and
- Visual inspection and field testing of the samples.

The results are explained in Sections 5 to 9 below.

5. Background Review

5.1 Regulatory Framework

The following regulatory framework and guidelines were used for the ARD/ML assessment:

- Guidance for Evaluation of the Potential for Acid Rock Drainage and Metal Leaching For Use in the South Area. MoF Southern Engineering Group, April 2022;
- Technical Circular T-04/13, BC MoTI, Evaluating the Potential for Acid Rock Drainage and Metal Leaching at Quarries, Rock Cuts and from Stockpiled Rock or Talus Materials used by the MOTI. September 15, 2013;

- Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials, MEND Report 1.20.1, December 2009;
- Acid Rock Drainage Prediction Manual, MEND Project 1.16.1b, March 1991; and
- List of Potential Information Requirements in Metal Leaching/Acid Rock Drainage Assessment and Mitigation, MEND Report 5.10E, January 2005.

5.2 Bedrock Geology

Reference to iMapBC and the bedrock geology map “Kettle River, West Half, Similkameen and Osoyoos Districts, British Columbia” indicates the bedrock geology consists of porphyritic granite, granodiorite and monzonite of the Nelson intrusion. Figure 5.2 below contains an excerpt of the referenced map indicating the proposed rock source site location.

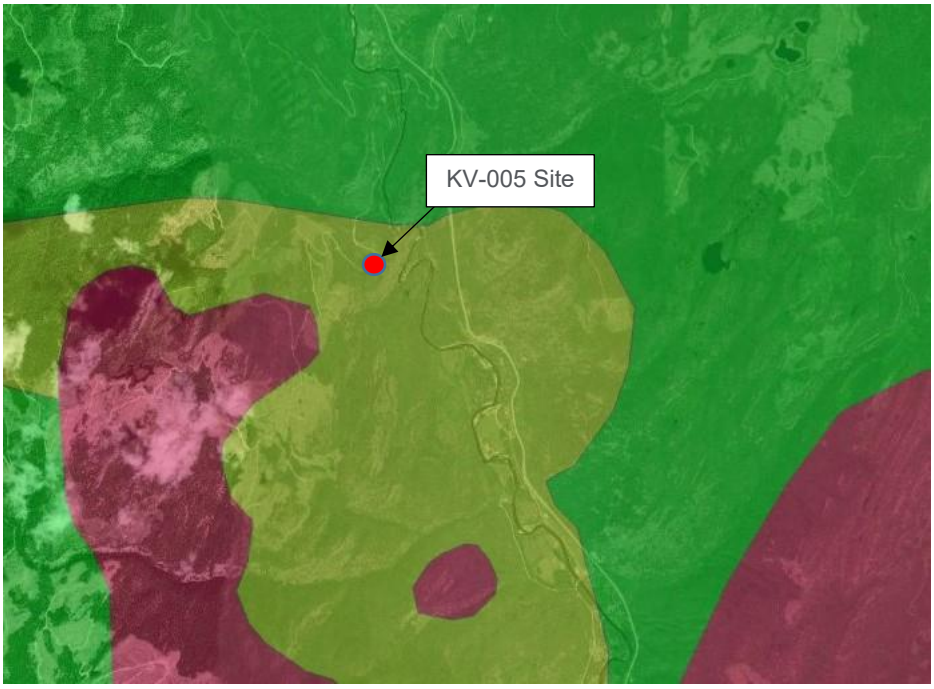

Figure 5.2: Bedrock geology of the proposed KV-005 rock source site.

5.3 Mineral Occurrences

According to BC MINFILE, the nearby recorded mineral occurrences to the proposed KV-005 rock source site within the same rock type as the subject site (Ohio, Monte Christo, Enterprise, Boomerang) contain localized deposits of Gold, Silver, Lead, Copper, Zinc and Tellurium. These occurrences contain sulphur bearing mineralogy in the form of Pyrite, Chalcopyrite, Bornite, and Galena. According to the BC MINFILE reports, the nearby occurrences of sulphide mineralogy are associated with quartz veins within shear zones and not the host rock.

The Chenier 5 and RCJV 7-10 mineral occurrences are located west and east of the KV-005 site, respectively, in granitic intrusion of the Okanagan Batholith. Mineral occurrences include Gold, Silver, Lead, Zinc and Molybdenum, with sulphur-bearing mineralogy in the form of Pyrite, Pyrrhotite, Galena, Sphalerite, and Molybdenite recorded at the Chenier 5 and RCJV 7-10 mineral occurrences.

The Colby 1 mineral occurrence is located west of the KV-005 site, in metasedimentary and metavolcanic rocks of the Anarchist Group. Mineral occurrences include Gold, Silver, Lean and Zinc, with sulphur bearing mineralogy in the form of Pyrite recorded at the Colby 1 mineral occurrence.

A summary of the nearby mineral occurrences is provided in Table 1 with the source locations shown on Figure 5.3 below.

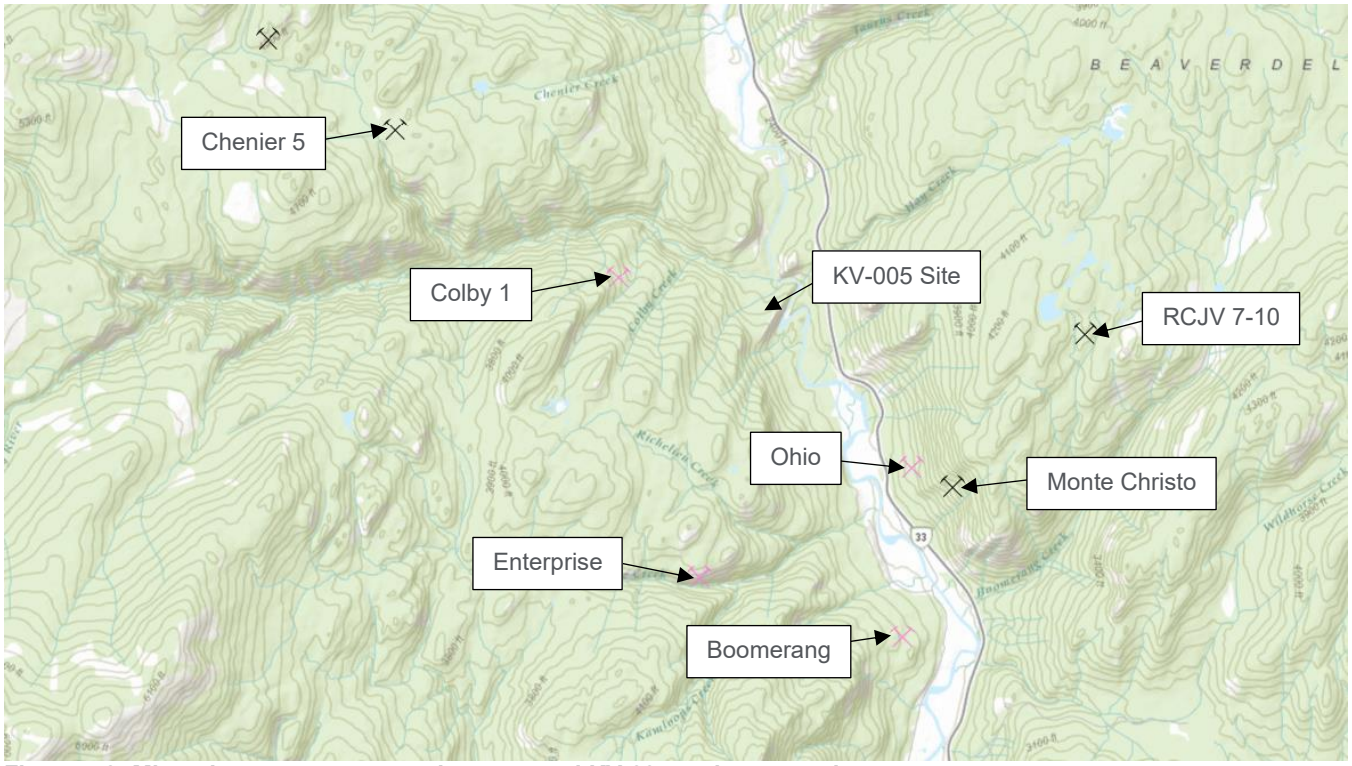

Figure 5.3: Mineral occurrences near the proposed KV-005 rock source site.

Table 1 Mineral Occurrences Near the Proposed KV-005 Rock Source Site

Occurrence Name	BC Minfile Number	Distance from Subject Site (km)	Significant Mineralogy
Colby 1	082ESW062	1.5	Gold, Silver, Lead, Zinc, Pyrite
Ohio	082ESW234	2.4	Gold, Silver, Copper, Lead, Pyrite, Chalcopyrite, Galena
Monte Christo	082ESW233	2.8	Gold, Silver, Copper, Lead, Zinc, Pyrite, Chalcopyrite, Bornite, Galena
Enterprise	082ESW061	2.9	Gold, Silver, Tellurium, Copper, Lead, Zinc, Pyrite, Chalcopyrite, Telluride, Galena
RCJV 7-10	082ESE304	3.6	Gold, Molybdenum, Silver, Lead, Zinc, Pyrite, Pyrrhotite, Galena, Sphalerite
Boomerang	082ESW063	3.8	Gold, Silver, Lead, Zinc, Copper, Pyrite, Galena, Chalcopyrite

Chenier 5	082ESW270	4.4	Molybdenum, Zinc, Lead, Molybdenite

6. Site Reconnaissance and Sample Inspection

A site reconnaissance to inspect the subject site was undertaken by staff from the Ministry of Forests on July 7, 2022. The reconnaissance included inspection of the existing bedrock outcrops and surface collection of weathered rock samples. Location coordinates for the two sample sites are found in Table 2 below.

Table 2 KV-005 Rock Source Sample Location Coordinates

Name	Easting (m)	Northing (m)	UTM Zone
KV-005 Rock Source Site 1A	351824	5460917	11U
KV-005 Rock Source Site 1B	351850	5460943	11U

Based on review of the photos provided by MoF and visual inspection of the grab samples, the outcrops at the KV-005 rock source site 1A were generally described as slightly weathered (W2), white to dark grey, small to large (B4-B2) rhombohedral blocks, medium grained (G3), Granodiorite, strong to very strong (R4-R5), with three to four dominant joint sets.

Visual inspection utilizing a 14x hand lens indicated a minor amount of discrete and clustered sulphide mineralogy (i.e. pyrite, galena?, arsenopyrite?) within the provided samples. The samples had no reaction when exposed to 10% HCl solution. Testing with a geological hammer indicated the samples were durable, angular and typically took multiple blows with the hammer to break. The rock did not have an earthly odour nor appear to contain significant amounts of clay.

Based on review of the photos provided by MoF and visual inspection of the grab samples, the outcrops at the KV-005 rock source site 1B were generally described as slightly weathered (W2), white to dark grey, small to large (B4-B2) rhombohedral blocks, medium to coarse grained (G3-G2), Granodiorite and Monzonite, strong to very strong (R4-R5), with three to four dominant joint sets.

Visual inspection utilizing a 14x hand lens indicated that no sulphide mineralogy or signs of sulphide oxidation was observed within the provided samples. The samples had no reaction when exposed to 10% HCl solution. Testing with a geological hammer indicated the samples were durable, angular and typically took multiple blows with the hammer to break. The rock did not have an earthly odour nor appear to contain significant amounts of clay.

Photos provided to Ecora from the site reconnaissance and sample photos are attached at the end of this report.

7. Sulphur Speciation and Acid Potential

Determining the types of sulphur species and their concentration in the samples is an important aspect of an ARD/ML assessment. Sulphide minerals are particularly important since they determine the potential for ARD/ML. The oxidation of sulphide-sulphur is the predominant chemical process responsible for the acid generation potential of a rock sample (MEND 2009).

Examination of the collected samples with a 14x hand lens noted that the visible mineralogy of the rock comprised Quartz [SiO_2], Plagioclase Feldspar [$NaAlSi_3O_8$ – $CaAl_2Si_2O_8$], Alkali Feldspar [$KAlSi_3O_8$ – $NaAlSi_3O_8$] and Biotite [$K(Mg,Fe)_3(Al,Fe)Si_3O_{10}(OH,F)_2$]. It is noteworthy that a minor amount of sulphur bearing mineralogy was identified in the inspected samples from sample location #1. This potentially acid generating minerology could

include iron bearing sulphide such as pyrite [FeS_2], and possibly galena [PbS], and arsenopyrite [FeAsS] These observations indicate the acid generation potential of the inspected material as **UNCERTAIN**.

8. Carbonate Content and Neutralization Potential

Carbonate minerals, such as calcite, are the most effective in counteracting acid generation due to their short reaction time. Secondary mineral sources such as silicates (i.e. feldspars), aluminum, iron hydroxides and oxides contribute to acid neutralization but at a slower rate.

A 10% HCl solution was applied to the samples as a field test for the presence of calcium carbonate. No reaction to 10% HCl solution was observed on the provided samples. This result indicates a low amount of primary neutralization mineralogy in the samples.

9. Conclusions

Based on our background review, review of site reconnaissance photos, examination of the collected samples and Ecora's previous experience with similar rock types, the material sampled from the proposed KV-005 rock source is considered **UNCERTAIN** for acid generation due to the presence of visible sulphide mineralogy within the inspected rock samples for sample location #1 and the absence of primary neutralization minerology. We recommend that a detailed ARD/ML assessment including ABA testing for the rock source is undertaken to determine the acid and metal leaching potential of the material and to confirm whether it is suitable for use in and about a waterway.

The material sampled from the proposed KV-005 rock source appears strong and durable, and therefore suitable for use as riprap however, laboratory testing, such as that found in Section 205 of the 2020 BC MoTI Standard Specifications, would be required to quantitatively confirm the suitability of the proposed rock source for use as riprap.

10. Limitations of Report

This report and its contents are intended for the sole use of the BC Ministry of Forests, their agents and the applicable regulatory authorities. Ecora Engineering & Resource Group Ltd. (Ecora) does not accept any responsibility for the accuracy of any data, analyses, or recommendations contained or referenced in the report when the report is used or relied upon by any Party other than the BC Ministry of Forests, their agents, the applicable regulatory authorities or for any Project other than that described in this report. Any such unauthorized use of this report is at the sole risk of the user.

Where Ecora submits both electronic file and hard copy versions of reports, drawings, and other project-related documents, only the signed and/or sealed versions shall be considered final and legally binding. The original signed and/or sealed version archived by Ecora shall be deemed to be the original for the Project. Both electronic file and hard copy versions of Ecora's deliverables shall not, under any circumstances, no matter who owns or uses them, be altered by any party except Ecora.

11. Closure

We trust this report meets your requirements. If you have any questions or comments, please contact the undersigned.

Sincerely
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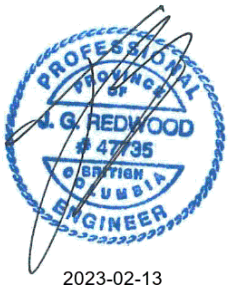

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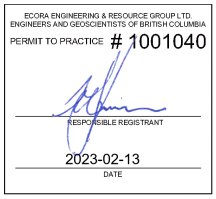

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Version Control and Revision History

Version	Date	Prepared By	Reviewed By	Approved By	Notes/Revisions
0	2023-02-13	MS/JR	MJL	MJL	Issued for Use

Attachments: Figures
Photos
Appendix A – Ecora Field Key Sheet - Rock

References

BC Ministry of Forests (BC MoF). Guidance for Evaluation of the Potential for Acid Rock Drainage and Metal Leaching For Use in the South Area. MoF Southern Engineering Group, April 2022.

BC Ministry of Transportation and Infrastructure (BC MoTI), 2013. Technical Circular T-04/13. Evaluating the Potential for Acid Rock Drainage and Metal Leaching at Quarries, Rock Cuts and from Stockpiled Rock or Talus Materials used by the MOTI. September 15, 2013.

BC Ministry of Transportation and Infrastructure (BC MoTI), 2020. “2020 Standard Specifications for Highway Construction”.

Cairnes, C.E., “Kettle River, West Half, Similkameen and Osoyoos Districts, British Columbia”, Geological Survey of Canada, “A” Series Map 538A, 1940.

Government of British Columbia. iMapBC, https://www2.gov.bc.ca/gov/content/data/geographic-data-services/web-based-mapping/imapbc.

Mine Environment Neutral Drainage (MEND). 2009. Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials, MEND Report 1.20.1, December 2009.

Mine Environment Neutral Drainage (MEND). 2005. List of Potential Information Requirements in Metal Leaching/Acid Rock Drainage Assessment and Mitigation, MEND Report 5.10E, January 2005.

Mine Environment Neutral Drainage (MEND). 1991. Acid Rock Drainage Prediction Manual, MEND Project 1.16.1b, March 1991.

Figures

Figure 1.0 Site Plan Map

SITE PLAN

PRELIMINARY ARD/ML ASSESSMENT FOR PROPOSED KV-005 ROCK SOURCE HIGHWAY 33, BC

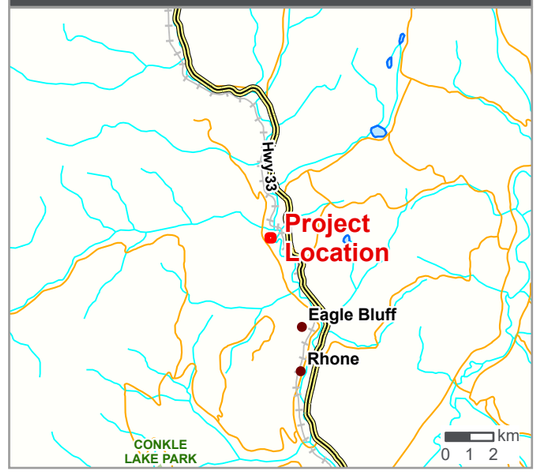
Legend

- Sample Locations
- 100m TRIM Contour Lines
- Digital Atlas Roads
- Fresh Water Atlas Streams
- PMBC Legal Parcels

References

Aerial Imagery: *Maxar, 5/31/2019*

LOCATION MAP



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Client: Ministry of Forests
NAD 1983 UTM Zone 11N

Date: 2023/01/18
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Figure 1.0

Photographs

Photo 1 View of outcrops at sample location 1A at the proposed KV-005 rock source site, received from MoF on January 5, 2023.

Photo 2 View of outcrops at sample location 1A at the proposed KV-005 rock source site, received from MoF on January 5, 2023.

Photo 3 View of outcrops at sample location 1A at the proposed KV-005 rock source site, received from MoF on January 5, 2023.

Photo 4 View of outcrops at sample location 1B at the proposed KV-005 rock source site, received from MoF on January 5, 2023.

Photo 5 View of outcrops at sample location 1B at the proposed KV-005 rock source site, received from MoF on January 5, 2023.

Photo 6 View of outcrops at sample location 1B at the proposed KV-005 rock source site, received from MoF on January 5, 2023.

Photo 7 Samples collected from sample location 1A at the proposed KV-005 rock source site.

Photo 8 Samples collected from sample location 1B at the proposed KV-005 rock source site.

Appendix A

Ecora Field Key Sheet - Rock

TERMS, SYMBOLS AND ABBREVIATIONS USED IN FIELD MAPPING OF ROCK

ROCK DESCRIPTION SEQUENCE OF TERMS - weathering - colour - block shape - block size - grain size - rock name - strength - discontinuities

The visual field description and classification of rocks is made in accordance with the International Society of Rock Mechanics Bulletin, Basic Geological Description of Rock Masses (1981b) and the International Association of Engineering Bulletin, Rock and Soil Description and Classification for Engineering Geological Mapping (1981).

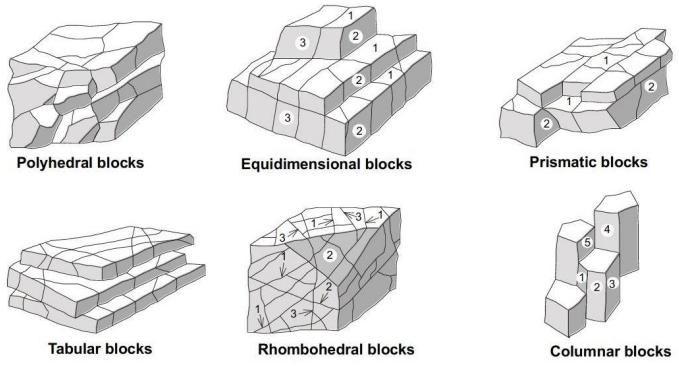
WEATHERING

TERM	DESCRIPTION	CODE
Fresh	No visible sign of rock material weathering; perhaps slight discoloration on major discontinuity surfaces.	W1
Slightly weathered	Discolouration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discoloured by weathering and may be somewhat weaker externally than in its fresh condition.	W2
Moderately weathered	Less than half the rock material is decomposed and/or disintergrated to a soil. Fresh or discoloured rock is present either as a continuous framework or as corestones.	W3
Highly weathered	Discolouration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discoloured by weathering and may be somewhat weaker externally than in its fresh condition.	W4
Completely weathered	All rock material is decomposed and/or disintegrated to a soil. The original mass structure is still largely intact.	W5
Residual soil	All rock material is converted to a soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the spoil has not been significantly transported.	W6

BLOCK SHAPE

SHAPE TERM	DESCRIPTION	CODE
Massive	Few joints or very wide spacing.	MA
Polyhedral	Irregular discontinuities without arrangement into distinct sets, and of small persistence.	PO
Tabular	One dominant set of parallel discontinuities (eg bedding planes), with other non-continuous discontinuities.	TA
Prismatic	Two dominant set of discontinuities orthogonal and parallel, with a third irregular set.	PR
Equidimensional	Three dominant orthogonal sets of discontinuities, with some other irregular discontinuities.	EQ
Rhomboidal	Three or more dominant, mutually oblique sets of discontinuities.	RH
Columnar	Several (usually more than three) sets of continuous, parallel discontinuities crossed by irregular discoutinuities.	CO
Disintegrated	Poorly interlocked, heavily broken rock mass.	DI

VISUAL EXAMPLES



BLOCK SIZE

SIZE TERM	AVERAGE DIMENSION	CODE
Very Large	> 2 m	B1
Large	0.6 - 2 m	B2
Medium	200 - 600 mm	B3
Small	60 - 200 mm	B4
Very Small	< 60 mm	B5

GRAIN SIZE

SIZE TERM	GRAIN SIZE	CODE
Very Coarse	> 60 mm	G1
Coarse	60 - 2 mm	G2
Medium	2 - 0.060 mm	G3
Fine	0.06 - 0.002 mm	G4
Very Fine	< 0.002 mm	G5

STRENGTH

TERM	FIELD DIAGNOSTIC CHARACTERISTICS	UCS (MPa)	$I_{s(50)}$ (MPa)	CODE
Extremely Strong	Rock can only be chipped with geological hammer.	> 250	>10	R6
Very Strong	Rock requires many blows of geological hammer to break it.	100-250	5-10	R5
Strong	Rock requires more than one blow with geological hammer to fracture it.	50-100	2-5	R4
Moderately Strong	Rock cannot be scraped or peeled with a pocket knife. Can be fractured with a single firm blow by a geological hammer.	25-50	1-2	R3
Weak	Rock can be peeled by a pocket knife with difficulty. Shallow indentations are made by firm blow with the point of a geological hammer.	5-25	-	R2
Very Weak	Rock can be peeled by a pocket and a crumbles under firm blows with the point of a geological hammer.	1-5	-	R1
Extremely Weak	Can be indented by thumb nail or other lesser terms used for soils.	<1	-	R0
Hard	Difficult to indent by thumb nail.	0.4-1	-	S6
Very Stiff	Can be indented by thumb nail.	0.2-0.4	-	S5
Stiff	Cannot be indented by thumb pressure.	0.1-0.2	-	S4
Firm	Can be indented by strong finger or thumb pressure.	0.05-0.1	-	S3
Soft	Easily indented by fingers.	0.025-0.05	-	S2
Very Soft	Easily exudes between fingers when squeezed.	<0.025	-	S1

UCS = Unconfined Compressive Strength

$I_{s(50)}$ = Point Load Strength