Rum Jungle Pit Rim Investigations Factual Report

Prepared for

Northern Territory Department of Primary Industry and Resources

Prepared by

SRK Consulting (Canada) Inc.
1AR001.015
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Rum Jungle Main Pit Rim Investigations Factual Data Report

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Prepared for

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1 Introduction

The Northern Territory Department of Primary Industry and Resources (DPIR) is rehabilitating the former Rum Jungle mine site in Northern Territory, Australia (Figure 1-1). These efforts were initiated with a Conceptual Rehabilitation Plan and are advancing with detailed investigations and engineering design. The Conceptual Rehabilitation Plan includes backfilling the Main Pit with waste rock from the historical dumps on the site. Access would be via haul road established on the western half of the pit to be constructed by pushing back the pit wall.

SRK Consulting (Canada) Inc. (SRK) was subcontracted by Robertson GeoConsultants Inc. (RGC) to design and supervise geotechnical and hydrogeological investigations of the ground behind the pit walls on the western side of the Main Pit. The field program was successfully undertaken over the period January 10 to February 10, 2018. This factual report describes the field program design, investigation activities and presents the findings.

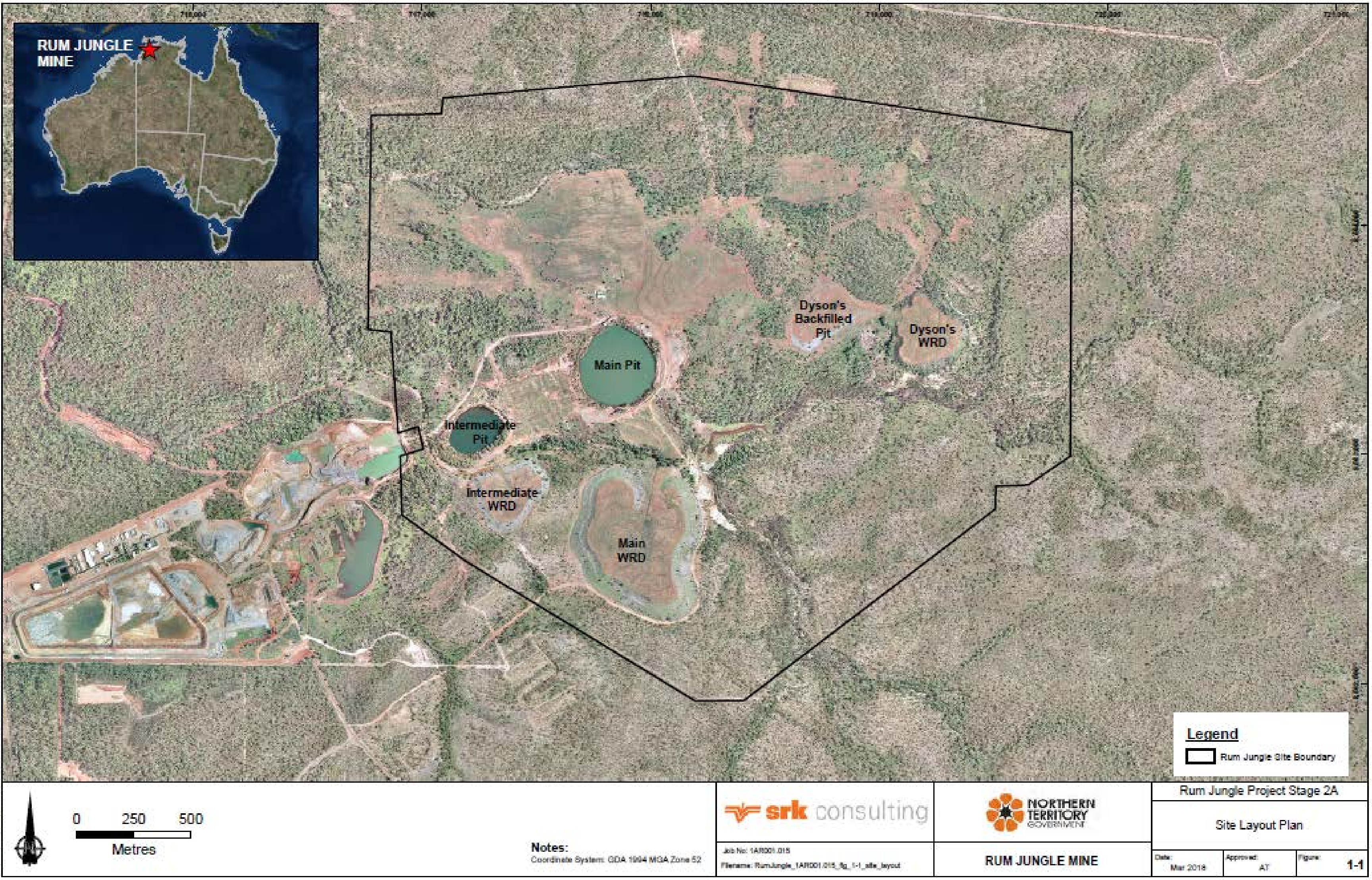

Figure 1-1 – site layout plan

2 Background

The Rum Jungle mine site is located 7 km north-northwest of the town of Batchelor in the Northern Territory, Australia. The climate at Rum Jungle is sub-tropical with wet and dry seasons. During the wet season from November to April, the site receives most of the approximately 1,500 mm rainfall. The mean monthly maximum temperatures at Rum Jungle range from 31°C in June to 37°C in October.

The orebody at Rum Jungle was discovered in 1949 and mining and processing operations were carried out from 1952 to 1971 (RGC, 2016). The main orebody was mined by underground methods from 1950 to 1953, and surface methods until 1958. About 700,000 tonnes of tailings slurry as well as waste rock and soil were deposited into the Main Pit from 1965 to 1971 (Department of Transport and Works, 1981). The Main Pit was flooded with groundwater and surface water from the East Branch of the Finniss River.

The mine was not rehabilitated at the end of operations in 1971. According to Verhoeven (1988), initial attempts had been made to clean up the treatment plant area from 1977 to 1978. Rehabilitation works were later funded by the Commonwealth of Australia from 1982 to 1986. Whilst the rehabilitation achieved the objectives at the time, subsequent monitoring indicated that further rehabilitation is needed to meet contemporary environmental performance standards and address concerns of the Aboriginal land owners.

The culmination of the early stages of rehabilitation planning was a Conceptual Rehabilitation Plan. The purpose of the plan was to have a framework of environmental and social outcomes that are consistent with the interests of the traditional owners. Subsequent stages include detailed engineering design, attaining approvals and stakeholder engagement (DPIR, 2013).

The intent of this report is to provide data on the Main Pit walls ground conditions as inputs to the design of the main ramp pit push back. Preliminary design was done by O’Kane Consultants Pty. Ltd. in 2016 and the main pit rim investigations were set-out based on the ramp access shown in the drawing titled ‘Main Pit Access and Pit Levee Layout Plan’ (Dwg. Number 871-6-063, Rev. 0, dated 10 May 2016). To capture the zone immediately behind the pit wall which is planned to be excavated in the push-back, drillholes would ideally have been drilled into the pit walls. However, because of the water cover and challenges with drilling over water, it was decided to instead collar the holes on land as close as practicable to the pit rim.

3 Scope of Work

The scope of work related to the Main Pit investigations, paraphrased from the DPIR tender document (RFQ Number Q17-0507, dated 11 October 2017), was to:

- design and supervise the field program and provide direction to the drilling contractor
- log, photograph and sample the recovered materials
- record groundwater intercepts and conduct hydraulic testing
- document details of the drilling and vibrating wire piezometer (VWP) installations
- collect groundwater samples during drilling for laboratory water chemistry testing
- process the data and conduct analyses to select pit wall design parameters

SRK understands that the primary objective of the VWP installations is not for current groundwater monitoring, but rather for monitoring groundwater drawdown rates and pit wall pore water pressures during future dewatering of the pit. Given their proximity to the flooded open pit, the current groundwater regime in the pit walls is likely to be highly influenced by, and reflective of, the equilibrated pit lake level.

The deliverables requested in the RFQ comprised a; i) factual report, and ii) summary report. Following the field program, SRK provided the DPIR with draft versions of project information, comprising; site and drillhole location plans, drillhole logs, and core photographs. SRK understands that this information was enough at that time for the design consultants. In SRK discussions with the DPIR, it was agreed that SRK's deliverables would be limited to a factual report (this document) to support and provide context to the information already provided.

4 Site Details

4.1 Regional Geology

The regional geology is described in detail in several documents, such as Berkman (1968). In brief, the site is situated in a triangular area of the Rum Jungle mineral field that is bounded by Giant's Reef Fault to the south and a series of east-trending ridges to the north. This triangular area is known as 'The Embayment' and it lies on the shallow-dipping limb of a north east trending, south west plunging asymmetric syncline that has been cut by northerly-dipping faults.

The main lithological units in The Embayment are the Rum Jungle Complex and meta-sedimentary and subordinate meta-volcanic rocks of the Mount Partridge Group. The Rum Jungle Complex consists mainly of granites and occurs primarily along the south eastern side of the Giant's Reef Fault, whereas the Mount Partridge Group occurs north of the fault and consists of Crater Formation, Geolsec Formation, Coomalie Dolostone, and Whites Formation.

4.2 Pit Geology and Details

This section summarizes the desk-top review and interpretation work done by SRK as background knowledge for the field program preparation and design.

According to Williams (1963), no detailed geological structural analysis was carried out in the Main Pit at the time of operations. The structure in the pit is complex, having been subjected to at least four generations of tectonics with brecciation in the later stages.

The ore body was located on the northern limb of a tightly folded syncline, on the contact between the Coomalie Dolostone and Golden Dyke Formation. It was hosted in the carbonaceous pyritic slate member of the Golden Dyke Formation which is a basal mudstone sequence comprising mudstone, schist, and slate. It is a quartz-sericite material with a strong foliation due to at least two generations of micro-folding.

The composite pit geology map (NT DTW, 1981) shows that the northern half of the pit consists mostly of mudstone, and the southern half is slate except for a significant zone of dolostone in the south south-east. An intensely sheared zone trending approximately east-west, called the 'main shear zone', bisects the pit. A north-south fault and east-west fault associated with tectonic shattering truncated the ore body at depth. A simplified version of this map for the Main Pit and the approximate lithology boundaries is shown in Figure 4-1.

Also shown on the map (stippled area) is the area of interest for the pit push back and the focus of this study. This zone is shown to intersect six geological units; Dolomite, Unaltered Talcose Slate, Main Shear Zone Schist, Banded Slate, Mudstone and Quartzite Breccia.

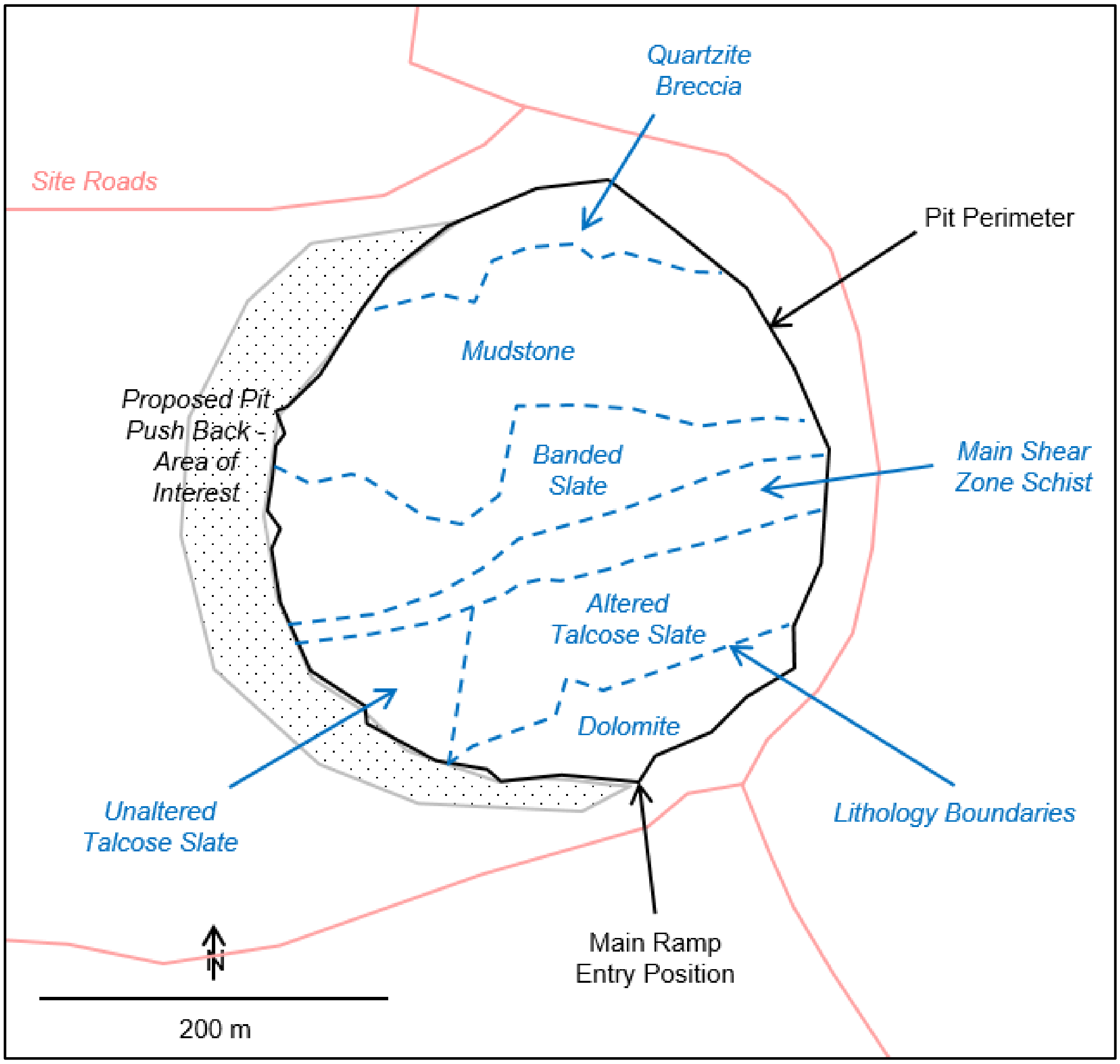

Figure 4-1 – approximate lithology and structural features exposed in the Main Pit (after NT DTW, 1981)

Historical photos of the Main Pit at the time of mining were reviewed and lithology boundaries and geological features exposed in the pit walls were interpreted and marked-up on the photos (Figure 4-2 and Figure 4-3).

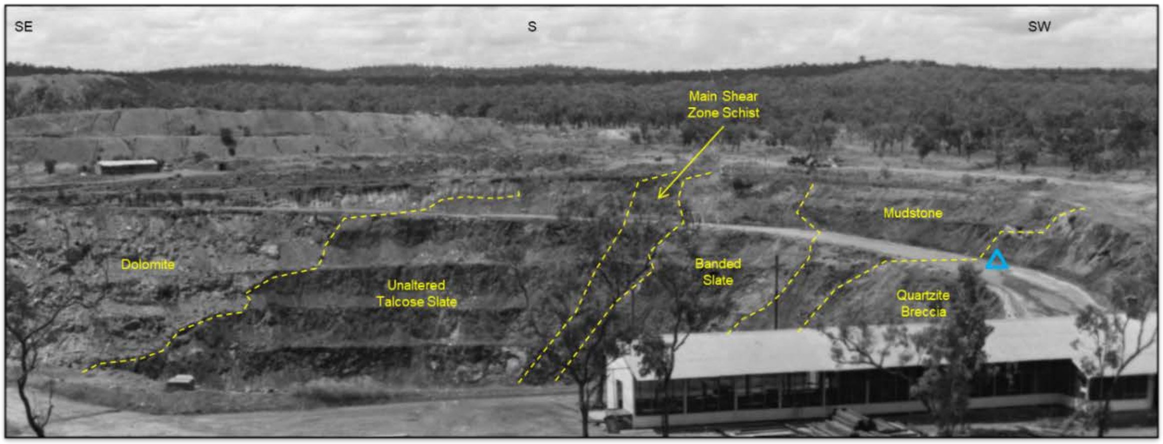

Figure 4-2 – photograph (circa 1958) view of the Main Pit taken from the mill, looking south, with marked-up interpretation of lithology boundaries and features

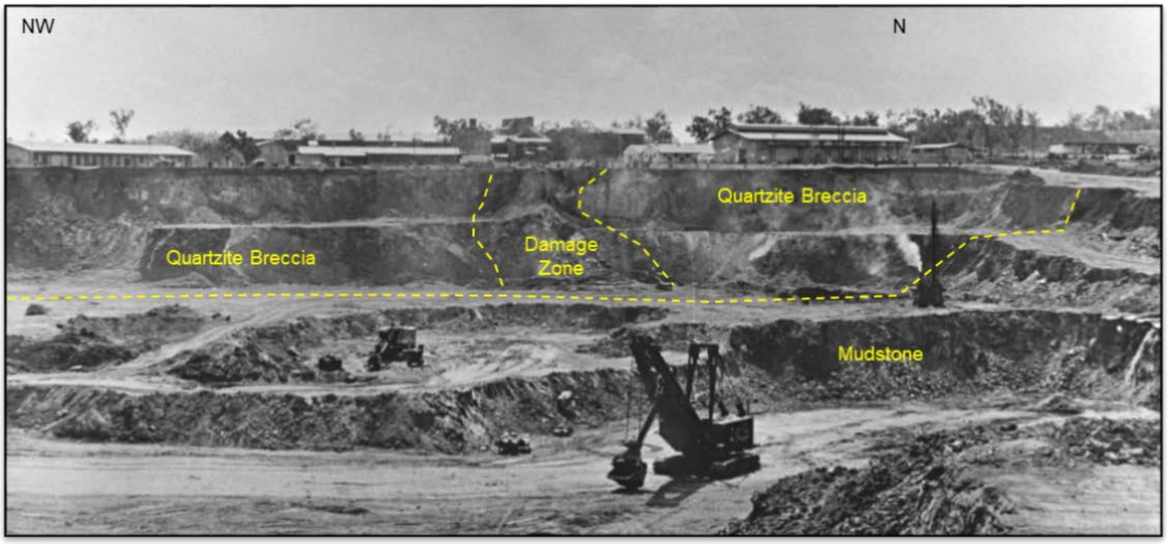

Figure 4-3 – photograph (circa 1953) view of the Main Pit taken from the main ramp, looking north, with marked-up interpretation of lithology boundaries and features

Based on review of these, and other historical photographs of the pit, SRK made these observations:

- the main ramp entry was from the south, descending clockwise, with a single switchback on the second turn at the main shear zone on the eastern side of the pit
- bench heights are estimated to have been approximately 8 m, composing single and double-benches, with a maximum stack height of around 40 m
- the main ramp running surfaces were approximately 20 m wide

- inter-ramp slope angles are estimated to have been around 40° [overall slope angles of between 25° and 30° in mudstone, and 28° to 38° in slate, are reported in RGC (2015)]

- little to no rock-fall catchment was achieved (or designed?) on the final walls for each bench

- the sequence of meta-sedimentary rocks exposed in the pit are highly anisotropic in the east-west orientation

- geological contacts appear to not be competent, and there are areas in which ‘lenses’ of mudstones and siltstones mingle within the main units

- fault-damaged rocks are present on all walls, especially the Main Shear Zone Schist (MSZS) and a brittle deformation zone which bisects the pit east-west

- the weakest rock masses during mining appear to have been the Altered Talcose Slate (ATS) and the MSZS;

- Banded Slate (BS), which is a marker horizon on the eastern wall, appears to have been relatively competent, and held bench-crests relatively well during mining

- Dolomite (D) exposed on the southern wall appears to be blocky and a relatively weak rock mass

- Unaltered Talcose Slate (UTS) on the south western flank of the pit held bench-crests well, and considering that blasting-practice was probably poor at the time, this is likely to be one of the better-quality rock masses

- areas of potential water-inflow, as noted by water channels in the photos, include the D, ATS, MSZS units, and the M-QB contact zone

These observations were considered in the design and optimization of the drillhole program and could also be valuable to future stage(s) of the push-back design.

5 Field Program

This section describes the work done by SRK in preparation and execution of the field program. The project was managed, and field work conducted, by Andy Thomas who is a senior geotechnical engineer with SRK and has experience on the Rum Jungle rehabilitation project since 2015.

5.1 Planning

SRK assisted the DPIR to design the field program to meet the objective of characterizing the geotechnical and hydrogeological conditions of the main lithological units behind the Main Pit walls in the proposed pit push-back area. This was done in late 2017, before the detailed design consultant had been engaged.

The content of the field program, comprising three drillholes, specified in the RFQ is reproduced in Table 5-1. SRK understands that this information was intended to be indicative only. DPIR's intent was that the project consultant would modify the drillhole details with the findings from the initial site walkover, and the VWP installation details with the drilling observations and findings from the core.

Table 5-1 – drilling and VWP installation details provided in the DPIR RFQ document

Drillhole ID	Drilling Method	Installation	Tentative Coordinates GDA1994 MGA z52		Total Depth (m bgs)	VWP Depth
			Easting (m)	Northing (m)		
BH17-1	HQ3	VWP	717975	8563235	100	50 m and 100 m
BH17-2	HQ3	VWP	717713	8563249	100	50 m and 100 m
BH17-3	HQ3	VWP	717725	8563495	100	50 m and 100 m

Prior to the field program, SRK collaborated with the DPIR and their selected drilling contractor to organize the field equipment and consumables. SRK provided the following documents;

- schedule of Vibrating Wire Piezometer (VWP) instrumentation and consumables
- schedule of field core processing facility tools and equipment
- geotechnical logging manual 'Atlas' for quality and consistency in the core logging
- standard operating procedure (SOP) for point load testing and core sampling
- spreadsheet templates for core logging testing, sampling

The Geotechnical Atlas which was tailored to be site-specific is provided in Appendix C.

5.2 Site Walkover

A pit rim site walkover was undertaken by Andy Thomas on 7 January 2018. Because the program was limited to three drillholes and there were six units to investigate, SRK approached the walkover with the primary objective of defining lithology contacts so that drillholes would intersect multiple units.

With SRK's knowledge of the pit geometry and geology (Section 4.2), observed contacts surface expressions were conceptually projected to depth. The drillhole collar locations, orientations and inclinations were selected with the intent of intersecting these contact surfaces. Details of the final design for the drillhole collars are in Table 5-2 and shown in Figure 5-1.

Table 5-2 – design drillhole collar details

Drillhole ID	Collar Coordinates GDA1994 MGA z52		Dip (°)	Azimuth (°)
	Easting (m)	Northing (m)		
18DH01	717769	8563224	-70	140
18DH02	717691	8563286	-60	300
18DH03	717709	8563463	-70	315

5.3 Drilling and Hydraulic Tests

The DPIR's drilling contractor for the field program was May Drilling Pty. Ltd. (May Drilling) who was responsible for supplying all materials and equipment for the drilling and hydraulic testing. The drilling method was HQ3 diamond drilling using a truck-mounted EDM Drill Master drill rig. Completed collar and drillhole details are in Table 5-3.

Table 5-3 – drillhole 'as drilled' details

Drillhole ID	Drilling Method	Date Started	Date Finished	Collar Coordinates GDA1994 MGA z52		Dip (°)	Azimuth (°)	Total Length (m)
				Easting (m)	Northing (m)			
18DH01	HQ3	10/01/18	13/01/18	717769	8563224	-70	143	50.7
18DH02	HQ3	17/01/18	22/01/18	717691	8563286	-60	303	51.2
18DH03	HQ3	25/01/18	02/02/18	717709	8563463	-69	315	86.7

The drilling meterage allowance for drillhole 18DH01 was reduced to 50 m, the rods jammed in drillhole 18DH02 and the hole had to be aborted at 51.2 m, and at the request of the DPIR drillhole 18DG03 was stopped before reaching target depth.

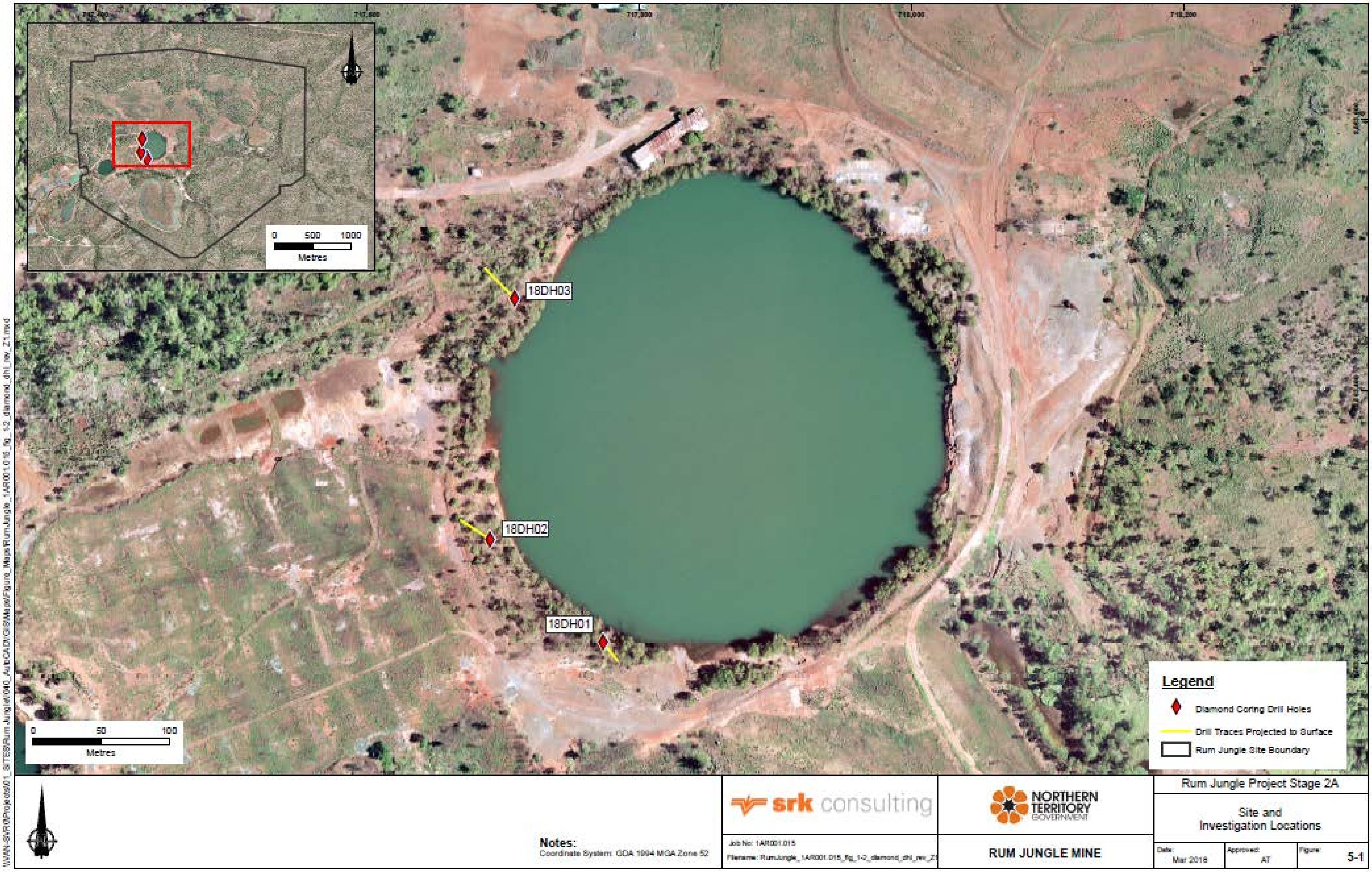

Figure 5-1 – site investigation locations

In preparation for the field program, SRK provided specifications for a pump for the program, but unfortunately such pump could not be sourced. Therefore, hydraulic testing was done using either May Drilling's Venturi-tube system (comprising an air line and water return discharge line), or the DPIR's 2-inch diameter electric submersible pump. The advantage of the pump was that the flow rate could be throttled to be compatible with the hydraulic response, but it had the drawback that the achievable lift capacity and flow rates were limited and lower than what could be achieved with the Venturi system. Although the Venturi system achieved higher pumping rates, the discharge was discontinuous as a function of the air injection rate, and the pumping depth was limited because the hoses could not be pushed deeper than about 50 m. With consideration of the limitations of each system and the expected formation yield, SRK selected whichever of the two hydraulic testing systems was better suited to each test.

Test intervals were selected to target specific geological features or lithology zones. Tests were conducted by raising the drill string to expose the test interval, then inserting the pump, or air line, to about 1 m above the drill bit (or as low as possible within in the drill string). Tests were single-stage and intended to be constant-rate. Unfortunately, the pumping equipment was unable to support constant flow on all occasions.

The drawdown response of the water column in the drillhole was measured manually using a hand-held dip meter through the drill string and via a transducer/thermistor (Solinst Levelogger Edge) attached to the hose. Flow rates and pumped volumes were measured using a bucket and stopwatch, and parameters (pH, electrical conductivity and temperature) were measured at selected volume intervals.

Samples of groundwater for possible laboratory water chemistry testing were taken at the end of testing when parameters had stabilized. Samples were preserved and stored in a refrigerator on site and collected by the DPIR on occasion to submit to the laboratory for testing. However, water chemistry results were not provided to SRK. Summary details of the testing and sampling are in Table 5-4.

Table 5-4 – hydraulic test and groundwater sample details

Drillhole ID	Test Number	Test Date	Test Interval (m)	Method	Lithology	Ground water Sample
18DH01	18DH01-01	27/01/18	11.4 – 17.4	Venturi	Shale (UTS)	Yes
	18DH01-02	03/02/18	21.5 – 50.3	Venturi	Dolomite (D)	Yes
18DH02	18DH02-01	18/01/18	15.1 – 20.6	Venturi	Schist (MSZS)	Yes
	18DH02-02	21/01/18	41.6 – 47.4	Submersible Pump	Meta-sandstone (MSZS?)	Yes
18DH03	18DH03-01	11/01/18	12.5 – 24.5	Venturi	Dolomitic Quartzite (DO?)	Yes
	18DH03-02	12/01/18	24.4 – 51.4	Venturi	Dolomitic Quartzite (DO)	Yes
	18DH03-03	13/01/18	53.5 – 80.5	Submersible Pump	Dolomitic Quartzite (DO?)	Yes

5.4 VWP and Data Logger Installations

Each drillhole was completed with two nested VWPs. SRK selected VWP installation depths to target specific geological features or representative lithology zones. VWPs were installed on a standpipe string constructed from 6 m lengths of PN18 PVC-U pipe. To the standpipe string was attached DN25mm PE100 PN12.5 polyethylene pipe which was used as a grout tremie pipe. The VWP installation details are in Table 5.5.

Table 5-5 – VWP installation details

Drillhole ID	Install Date	VWP	Location (m)	Depth (m)	Lithology/Target
18DH01	02-03/02/18	Upper	20.17	18.88	Shale (UTS)
		Lower	45.17	42.46	Dolomite (D)
18DH02	24-25/01/18	Upper	38.78	33.58	Shale/Meta-sandstone (MSZS?)
		Lower	50.73	43.93	Meta-sandstone (MSZS?)
18DH03	14-15/01/18	Upper	49.52	46.49	Dolomitic Quartzite (DO?)
		Lower	81.52	76.51	Dolomitic Quartzite (DO?)

Drillhole installations were grouted to surface using the bottom-up displacement technique. The installations were completed at surface by connecting the VWP wires to data loggers secured inside concreted standpipe enclosures. An example of the completed installation at the drillhole head is in Figure 5-2. The VWP calibration certificates are in Appendix E.

Figure 5-2 – completed VWP and data logger installation at drillhole 18DH02

5.5 Core Processing and Field Testing

The recovered core was retained and secured in the split inner tubes at the drilling rig and carefully transported to the core shed. The core was geotechnically logged in the split tubes before disturbance from point load testing, sampling and transfer to the core trays. A Reflex ACT electronic tool was used by May Drilling to mark core run orientation lines.

SRK carried out detailed geotechnical logging for rock mass characterization to the RMR_B89 system. The core was logged in accordance with the project Atlas and collected data included;

- **core recovery**; total core recovery (TCR), solid core recovery (SCR), rock quality designation (RQD)
- **intact rock strength**; based on empirical ISRM guidelines for testing the strength of strong and weak rock sections per drill run
- **fracture count by type**; natural, fabric-parallel natural, cemented, mechanical
- **intensity and strength of micro-defects**
- **discontinuity surface characterist**ics; depth and orientation (alpha and beta angles), roughness, alteration, aperture, and infilling
- **major structures**; depth, length and recovered material properties

Drillhole logs are in Appendix A. The core was photographed in the split tubes and the core trays. The core photos are in Appendix B.

ISRM strength testing and point load index tests (PLT) were performed in the field on every core run to enable correlation with laboratory test intact rock strengths (IRS). On average, more than one PLT was done per metre of core. For more reliable correlation with UCS values, additional PLTs were conducted around sample locations. Both diametral PLTs (across core axis) and axial tests (along core axis) were conducted. The number and type of PLTs by drillhole is in Table 5-6.

Table 5-6 – number and type of PLTs per drillhole

Drillhole ID	Point Load Tests	
	Axial	Diametral
18DH01	19	70
18DH02	31	46
18DH03	6	44
Total	**56**	**160**

Representative core intervals were sampled for possible laboratory strength testing. The sample geotechnical properties were recorded, and photographs taken before they were sealed in plastic film, protected with bubble wrap and labeled. The number of samples for possible UCS/triaxial test and direct shear tests is in Table 5-7.

Table 5-7 – number of samples and type per drillhole

Drillhole ID	UCS/Triaxial	Direct Shear
18DH01	9	-
18DH02	3	1
18DH03	12	3
Total	**24**	**4**

Following the field program, SRK provided to the DPIR a recommended two-stage schedule of laboratory testing. However, results were not provided to SRK.

6 Results

This section summarizes the rock geotechnical properties and hydraulic testing data.

6.1 Material Properties

The drillhole logs, drilling observations and field core strength test results were processed to summarize the intact and rock mass properties. The intent is that information will assist the designer in selecting design material properties.

6.1.1 Lithology

Without detailed working knowledge of, and experience with, the geological units and their subtleties e.g. inter-bedding, transitions, sub-units etc., it was challenging for SRK to be certain about lithological unit classification. In many cases the rock material that SRK identified aligned with the pit geology map (NT DTW, 1981), but question marks are added herein where there is uncertainty.

In 18DH01 the overburden was predominantly sandy clay of medium to high plasticity. Below this were interbedded layers of dolerite, schist and shale. Based on the historical lithology information, this area of the pit comprises Talcose Slate. Further detailed study would be required to understand the nature and sub-units of this unit. It is possible that these materials are bracketed within the Talcose Slate unit, or possibly represent a transition zone to the underlying Dolomite. The dolerite and schist layers were generally decomposed to highly weathered, with moderate to intense micro-defect content of lower strength than the intact rock.

In 18DH02 the overburden was sandy clay of medium to high plasticity. Below this were layers of meta-sediment materials; schist, shale, and shale interbedded with sandstone. Based on the historical lithology information, this area of the pit comprises the Main Shear Zone Schist unit with Banded Slate unit to the north and Unaltered Talcose Slate unit to the south. SRK did not identify slate rock type in the 18DH02 drillhole core, so has inferred that this drillhole was wholly within Main Shear Zone Schist unit. The rock was highly weathered to about 20 m depth and then moderately and slightly weathered. Over the interval 15 m to 25 m the core was mostly rubble with slight improvement to highly fractured below this.

In 18DH03 the overburden was clayey sand of fine to coarse grain size. Below this was a short interval of highly weathered and broken material. There was a sharp contact at about 17 m with the underlying dolomite material which was fresh and solid for the remainder. Based on the historical lithology information, this area of the pit comprises Quartz Breccia unit adjacent Mudstone unit to the south. SRK is uncertain if the upper rock layer was Quartz Breccia? or the weathered zone of the underlying dolomite. Mudstone material was not observed, and hence SRK infers that the Mudstone unit was not encountered.

Of the six reported main lithology units within the pit push-back area, three (four?) were interpreted to have been encountered in the drillholes; Dolomite, Talcose Slate, Main Shear Zone Schist, and Quartzite Breccia?. SRK considers that the main lithological unit contacts were intercepted in drillholes 18DH01 and 18DH02, and possibly in 18DH03. A summary of the units encountered in the drillholes is in Table 6-1.

Table 6-1– summary of units encountered in the drillholes

Drillhole ID	Unit Depth Intervals (m)			
	Overburden	**Talcose Slate**	**Dolomite**	**Main Shear Zone Schist**
18DH01	0 - 4.5	4.5 - 20.0	20.0 - 50.7 (EOH)	-
18DH02	0 - 3.0	-	-	3.0 - 51.2 (EOH)
18DH03	0 - 14.0	-	17.5 - 86.7 (EOH)	-

The lithology units Banded Slate, Mudstone, and Quartzite Breccia? were not encountered. Toward the end of the program SRK recommended to the DPIR that another drillhole be progressed on the west side of the pit targeting the Banded Slate and Mudstone units however this was not completed as part of SRK's program.

6.1.2 Structures

SRK took measurements of 117 structures in the core from the three drillholes. Beta angles were only able to be measured in the Dolomite unit, resulting in a data set of 42 joints with both dip and orientation angles. The measured alpha and beta angles are shown by lithology (Dolomite only) and by drillhole (18DH01 and 18DH03 only) in the stereonets in Figures 6-1 to 6-2 respectively. Due to the relatively small data sets for each unit the data may not be statistically reliable.

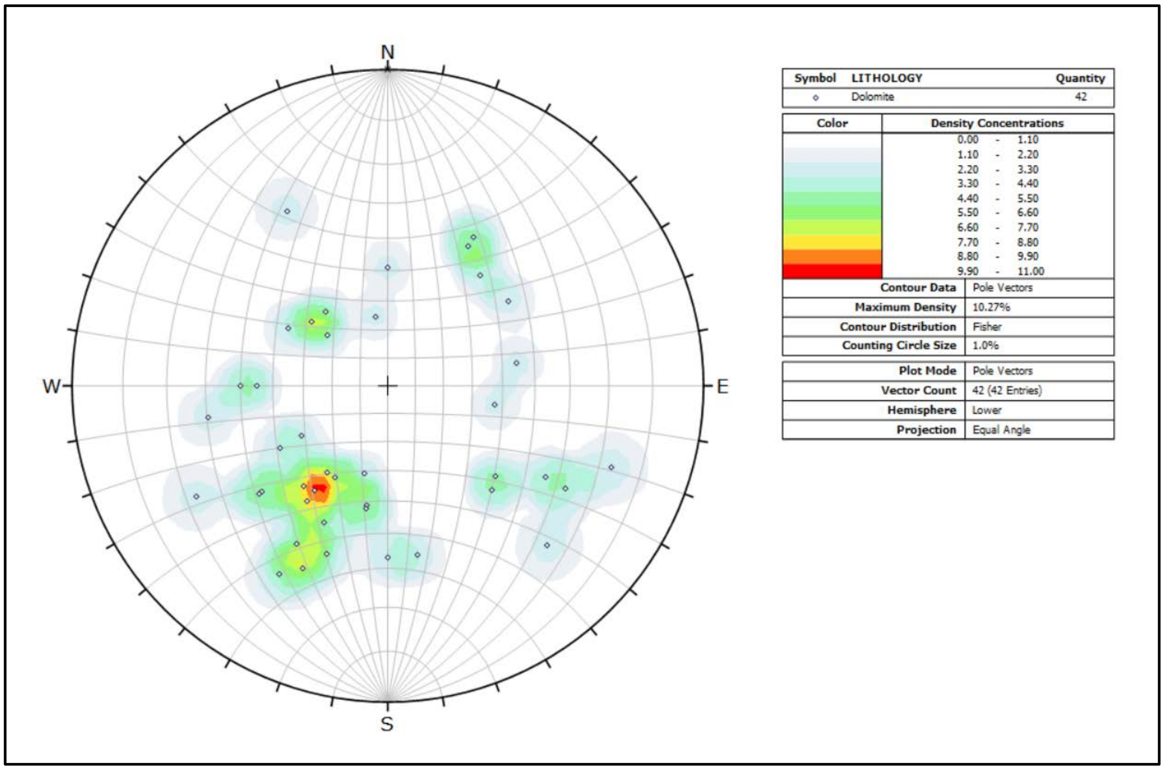

Figure 6-1 – stereonet of joints in the Dolomite unit

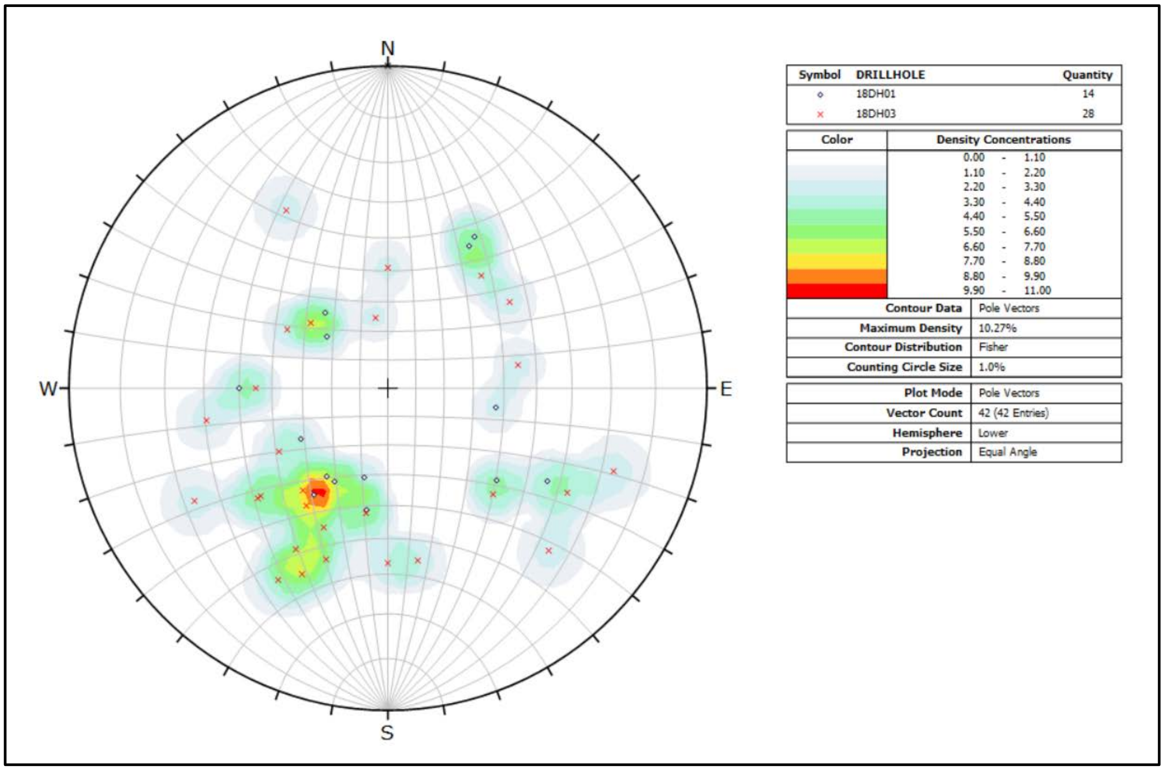

Figure 6-2 – stereonet of joints in drillholes 18DH01 and 18DH03

6.1.3 Point Load Tests

Statistics of point load index (Is(50) data results from the 143 valid axial and diametral point load tests are summarized in Table 6-2 and shown in the box plot in Figure 6-3.

Table 6-2 – summary statistics of point load index per lithology unit

PLT [Is(50)]			
	Talcose Slate	**Dolomite**	**Main Shear Zone Schist**
Min	0.46	0.06	0.03
Max	9.87	9.85	9.45
Average	3.70	6.00	1.21
StDev	3.38	2.21	1.57
25%	N/A	1.39	0.38
Median	N/A	5.16	0.75
75%	N/A	6.99	1.44
Total Valid Tests	**9**	**94**	**40**

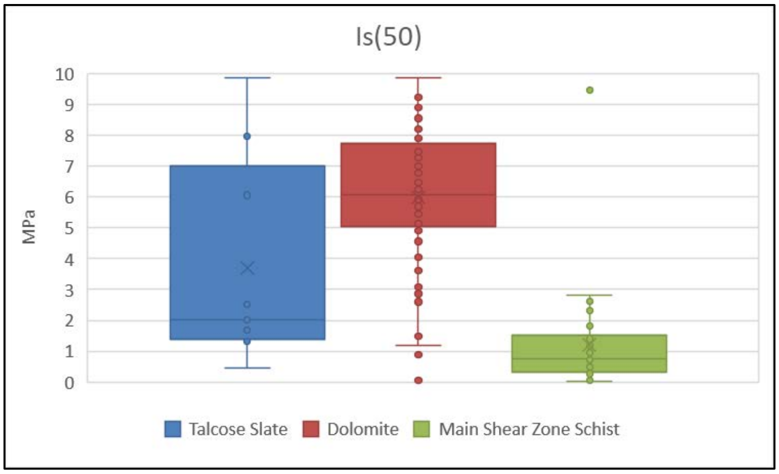

Figure 6-3 – plot of point load index per lithology unit

6.1.4 Rock Mass Rating

Statistics of key rock mass statistics are summarized in Table 6-3 and shown in the box plots in Figure 6-4.

Table 6-3 – summary statistics of key geotechnical properties per lithology unit

Talcose Slate				
	IRS (MPa)	**RQD (%)**	**FF/m**	**RMR89**
Min	1	0	14	29
Max	75	25	40	46
Average	25	1	33	37
StDev	24	5	9	4
25%	5	0	27	34
Median	15	0	40	37
75%	38	0	40	39
Total Length (m)	16			
Dolomite				
	IRS (MPa)	**RQD (%)**	**FF/m**	**RMR89**
Min	2	0	0	28
Max	250	100	37	91
Average	82	82	4	69
StDev	58	32	7	17
25%	9	0	1	35
Median	38	0	21	38
75%	75	63	37	56
Total Length (m)	103			
Main Shear Zone Schist				
	IRS (MPa)	**RQD (%)**	**FF/m**	**RMR89**
Min	1	0	0	28
Max	75	100	37	91
Average	31	82	4	69
StDev	22	32	7	17
25%	11	0	1	35
Median	38	0	21	38
75%	38	63	37	56
Total Length (m)	48			

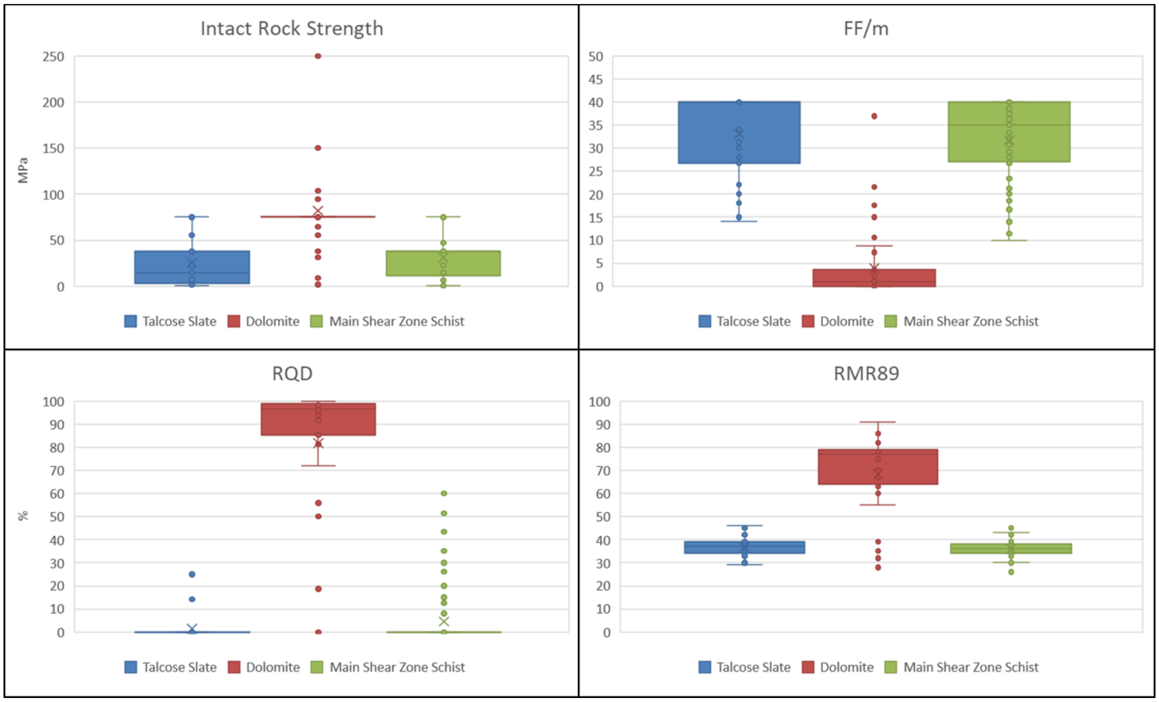

Figure 6-4 – plots of key geotechnical properties per lithology unit

6.2 Hydraulic Properties

Poor rock stability along the drill hole was encountered and hydrogeological testing was conducted as the drill hole was advanced without packer. Therefore, the hydraulic conductivity measured from the test conducted are an average over the entire open drill hole as there was hydraulic connection above and below the drill bit. A summary of the calculated hydraulic conductivities is in Table 6.4 and the data plots are in Appendix D.

Table 6-4 – pumping tests and calculated hydraulic conductivities

HoleID	Test Number	Date	From (m)	To (m)	Hydraulic Conductivity (m/s)	Logged Lithology
18DH01	1	1/27/2018	2.7	17.4	1 x 10^{-6}	Shale
18DH01	2	2/3/2018	1.3	50.3	1 x 10^{-6}	Shale and Dolomite
18DH02	1	1/18/2018	1.2	20.6	2 x 10^{-7}	Schist
18DH02	2	1/18/2018	3.5	47.7	7 x 10^{-7}	Schist and Meta-Sandstone
18DH03	1	1/11/2018	4.2	24.5	4 x 10^{-7}	Dolomitic Quartzite
18DH03	2	1/12/2018	11.0	51.4	7 x 10^{-8}	Dolomitic Quartzite
18DH03	3	1/13/2018	4.6	80.5	7 x 10^{-8}	Dolomitic Quartzite

a) Hydraulic conductivity estimated over the entire saturated open drill hole

b) Pressure response during the pumping was analyzed using Theis (1935) confined aquifers solution for most tests except for 18DH01 Test 2 where the pressure response during the recovery was used.

c) Borehole assumes HQ diameter.

Closing

This factual report presents the findings of the main pit rim geotechnical investigations supervised by SRK at the Rum Jungle site over the period of January 10 to February 10, 2018. It was prepared by;

Andy Thomas, M.Sc., P.Eng.
Senior Consultant (Geotechnical Engineering)

All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

8 References

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DPIR, 2013. Conceptual Rehabilitation Plan for the former Rum Jungle Mine Site. Northern Territory Government.

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Appendix A – Drillhole Logs

BOREHOLE LOG: 18DH01

PROJECT: Rum Jungle Mine Rehabilitation

LOCATION: Rum Jungle, NT

SITE & PROJECT No: 1AR001.015

SURVEY DATE:

DIP: -70 **AZIMUTH:** 143

COORDINATES: E: 717769, N: 8563224, Z(mAHD): 69

TOTAL DEPTH: 50.7 m

PAGE: 1 **OF** 3

DRILL TYPE: Diamond

CORE DIA.: HQ3

CASING DEPTH:

PLANNED HOLE ID:

DEFINTIONS

IRS: Intact Rock Strength (field est.)
PLT: Point Load Test (MPa)
TCR: Total Core Recovery
RMR_{89}: Rock Mass Rating
MW: Monitoring Well
UCS: Uniaxial Compressive Strength (MPa)
FF/m: Fracture Frequency per metre
RQD: Rock Quality Designation
VWP: Vibe Wire Piezometer

LEGEND OF MAJOR STRUCTURES

■ Gouge ▨ Broken
■ Sheared ▨ Solid
■ Rubble

LEGEND OF MD INTENSITY

🟩 0 - None 🟧 2 - Moderate
🟨 1 - Minor 🟥 3 - Intense

LEGEND OF WEATHERING

▨ 0 - Core Loss 🟨 3 - Moderate
🟥 1 - Decomposed 🟩 4 - Slight
🟧 2 - High 🟦 5 - None

LEGEND OF MD STRENGTH

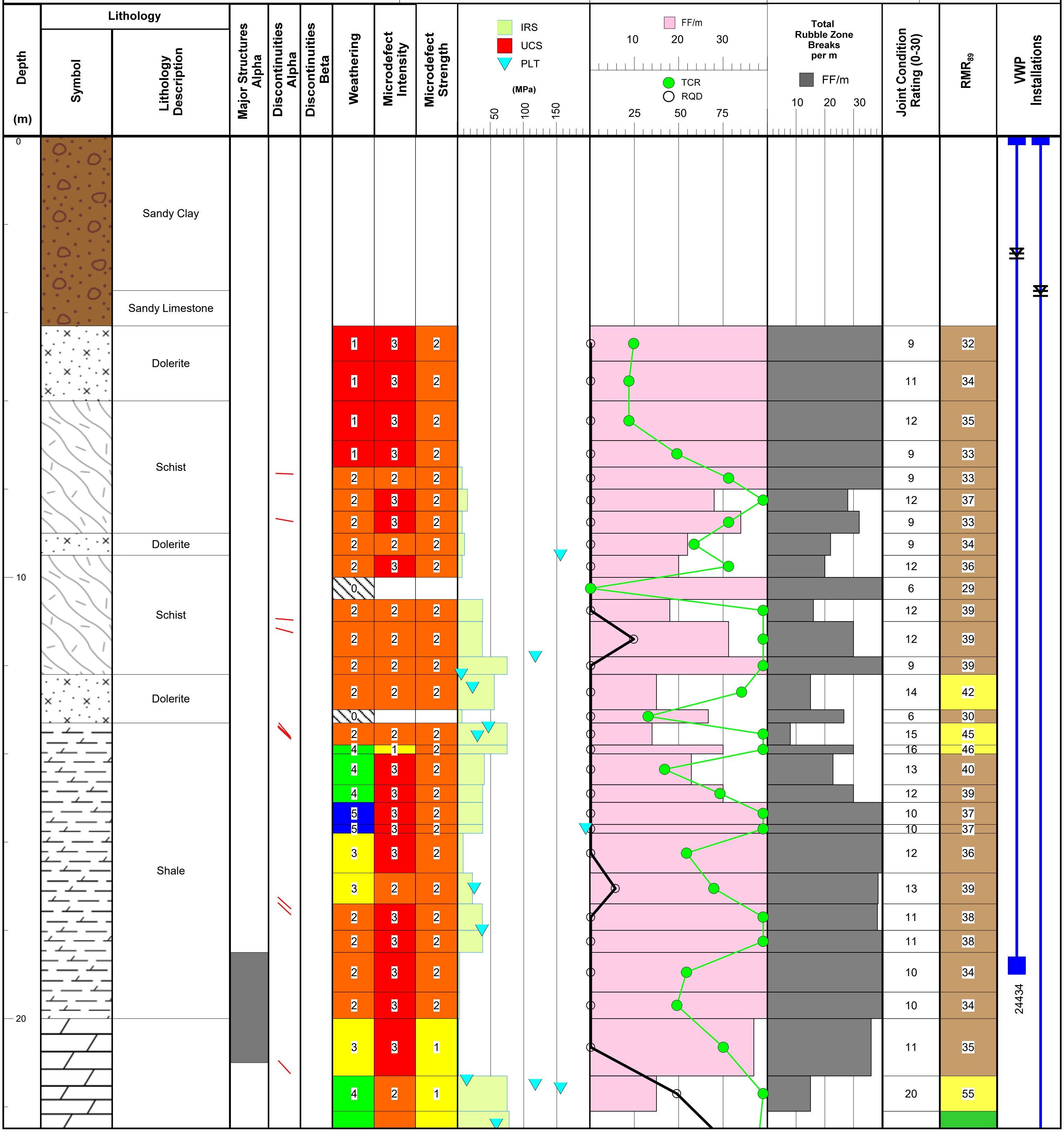
🟩 0 - Never Breaks 🟧 2 - Always Breaks
🟨 1 - Sometimes Breaks

LEGEND OF RMR89

🟥 0 - 20 🟩 61 - 80
🟫 21 - 40 🟦 81 - 100
🟨 41 - 60

HYDRO INSTALLATIONS

Water Level
🟦 VW Node
\# Screen



Weathering	Microdefect Intensity	Microdefect Strength	Joint Condition Rating (0-30)	RMR_{89}
1	3	2	9	32
1	3	2	11	34
1	3	2	12	35
1	3	2	9	33
2	2	2	9	33
2	3	2	12	37
2	3	2	9	33
2	2	2	9	34
2	3	2	12	36
0			6	29
2	2	2	12	39
2	2	2	12	39
2	2	2	9	39
2	2	2	14	42
0			6	30
2	2	2	15	45
4	1	2	16	46
4	3	2	13	40
4	3	2	12	39
5	3	2	10	37
5	3	2	10	37
3	3	2	12	36
3	2	2	13	39
2	3	2	11	38
2	3	2	11	38
2	3	2	10	34
2	3	2	10	34
3	3	1	11	35
4	2	1	20	55

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BOREHOLE LOG: 18DH01

PROJECT: Rum Jungle Mine Rehabilitation
LOCATION: Rum Jungle, NT
SITE & PROJECT No: 1AR001.015
SURVEY DATE:
DIP: -70 **AZIMUTH:** 143
COORDINATES: E: 717769, N: 8563224, Z(mAHD): 69

TOTAL DEPTH: 50.7 m
PAGE: 2 **OF** 3
DRILL TYPE: Diamond
CORE DIA.: HQ3
CASING DEPTH:
PLANNED HOLE ID:

DEFINTIONS
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PLT: Point Load Test (MPa)
TCR: Total Core Recovery
RMR$_{89}$: Rock Mass Rating
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UCS: Uniaxial Compressive Strength (MPa)
FF/m: Fracture Frequency per metre
RQD: Rock Quality Designation
VWP: Vibe Wire Piezometer

LEGEND OF MAJOR STRUCTURES
■ Gouge ▨ Broken
■ Sheared 🟨 Solid
🟦 Rubble

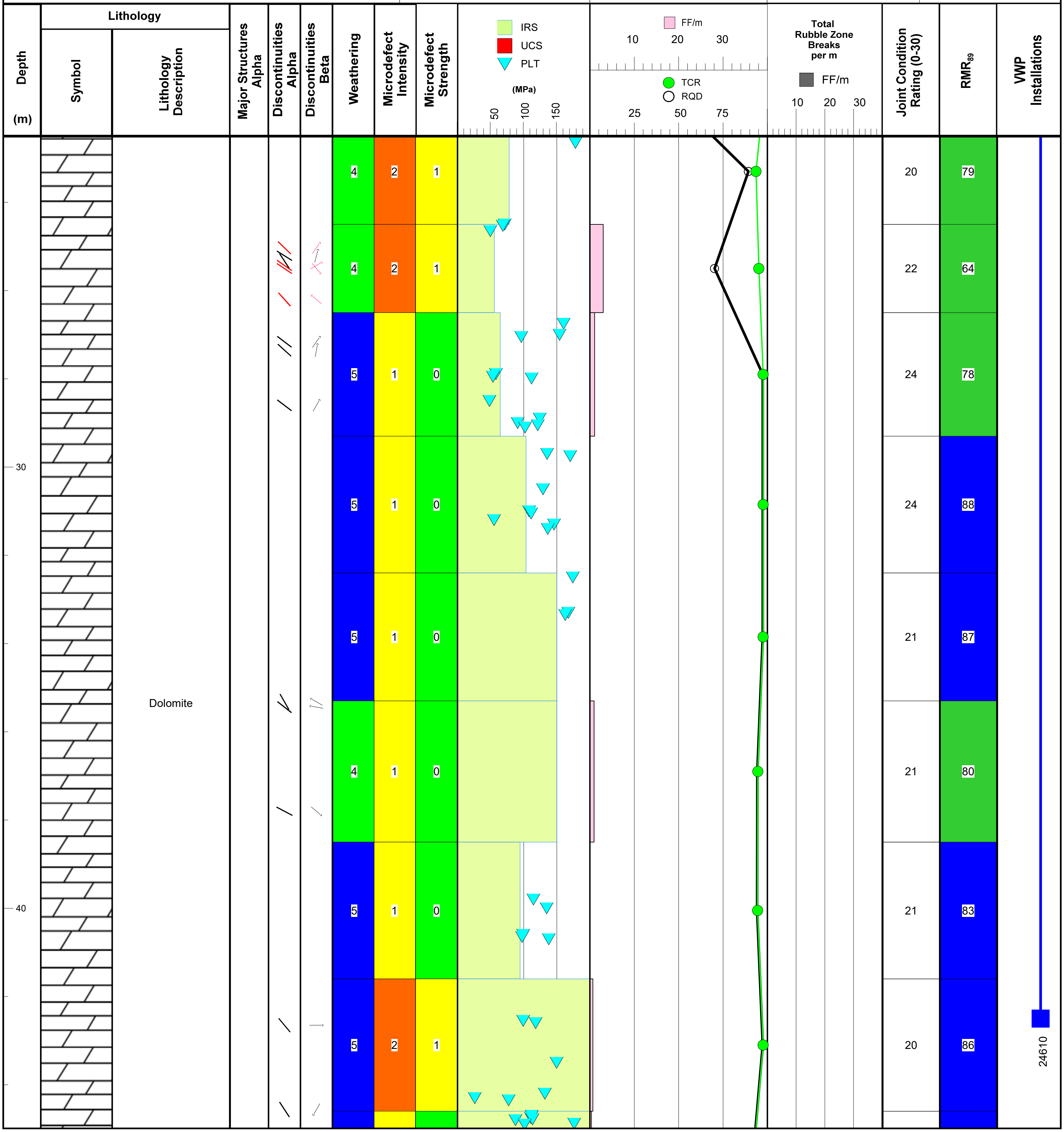
LEGEND OF WEATHERING
☐ 0 - Core Loss 🟨 3 - Moderate
🟥 1 - Decomposed 🟩 4 - Slight
🟧 2 - High 🟦 5 - None

LEGEND OF RMR89
🟥 0 - 20 🟩 61 - 80
🟫 21 - 40 🟦 81 - 100
🟨 41 - 60

HYDRO INSTALLATIONS
Water Level
🟦 VW Node
\# Screen

LEGEND OF MD INTENSITY
🟩 0 - None 🟧 2 - Moderate
🟨 1 - Minor 🟥 3 - Intense

LEGEND OF MD STRENGTH
🟩 0 - Never Breaks 🟧 2 - Always Breaks
🟨 1 - Sometimes Breaks



Weathering	Microdefect Intensity	Microdefect Strength	Joint Condition Rating (0-30)	RMR$_{89}$
4	2	1	20	79
4	2	1	22	64
5	1	0	24	78
5	1	0	24	88
5	1	0	21	87
4	1	0	21	80
5	1	0	21	83
5	2	1	20	86

BOREHOLE LOG: 18DH01

PROJECT: Rum Jungle Mine Rehabilitation

LOCATION: Rum Jungle, NT

SITE & PROJECT No: 1AR001.015

SURVEY DATE:

DIP: -70 **AZIMUTH:** 143

COORDINATES: E: 717769, N: 8563224, Z(mAHD): 69

TOTAL DEPTH: 50.7 m

PAGE: 3 **OF** 3

DRILL TYPE: Diamond

CORE DIA.: HQ3

CASING DEPTH:

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LEGEND OF WEATHERING

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- 🟨 3 - Moderate
- 🟥 1 - Decomposed
- 🟩 4 - Slight
- 🟧 2 - High
- 🟦 5 - None

LEGEND OF RMR89

- 🟥 0 - 20
- 🟩 61 - 80
- 🟫 21 - 40
- 🟦 81 - 100
- 🟨 41 - 60

HYDRO INSTALLATIONS

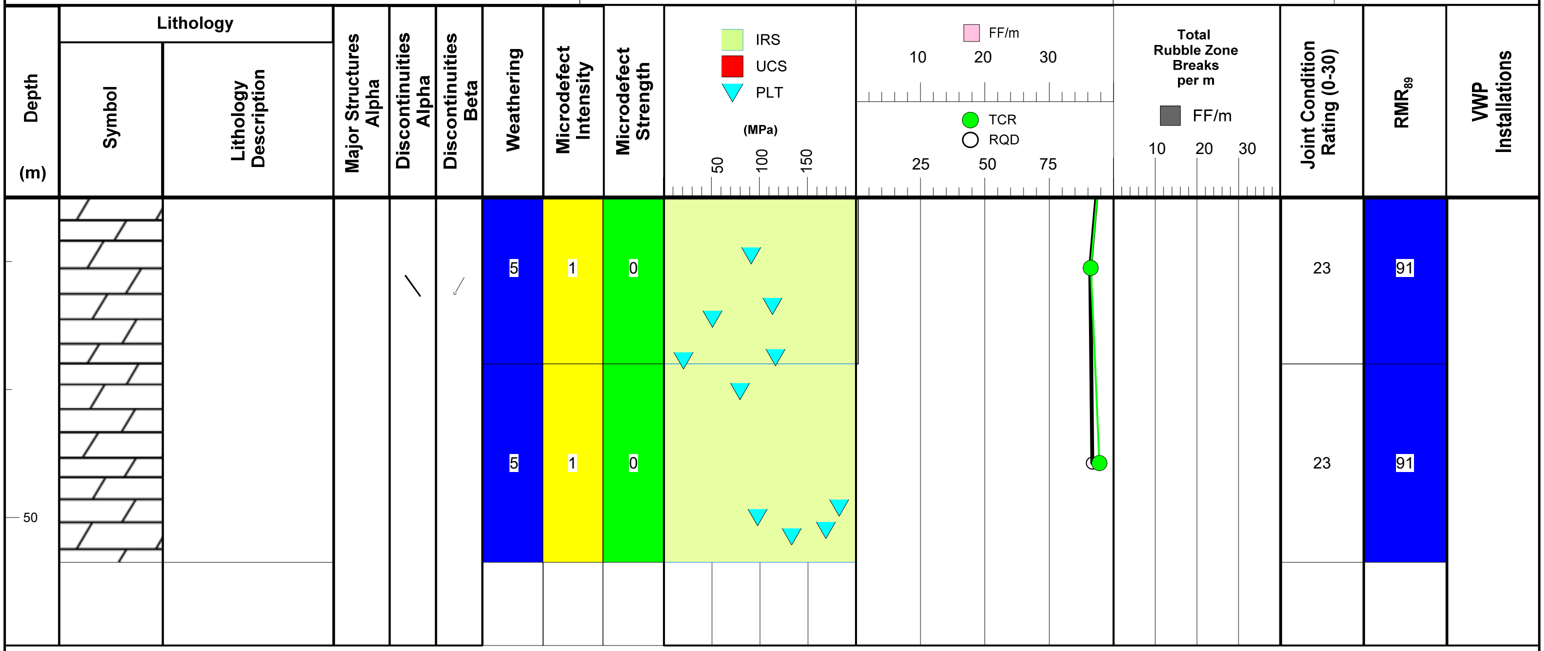
- Water Level
- 🟦 VW Node
- # Screen

LEGEND OF MD INTENSITY

- 🟩 0 - None
- 🟧 2 - Moderate
- 🟨 1 - Minor
- 🟥 3 - Intense

LEGEND OF MD STRENGTH

- 🟩 0 - Never Breaks
- 🟧 2 - Always Breaks
- 🟨 1 - Sometimes Breaks



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BOREHOLE LOG: 18DH02

PROJECT: Rum Jungle Mine Rehabilitation

LOCATION: Rum Jungle, NT

SITE & PROJECT No: 1AR001.015

SURVEY DATE:

DIP: -60 **AZIMUTH:** 303

COORDINATES: E: 717691, N: 8563286, Z(mAHD): 67

TOTAL DEPTH: 51.2 m

PAGE: 1 **OF** 3

DRILL TYPE: Diamond

CORE DIA.: HQ3

CASING DEPTH:

PLANNED HOLE ID:

DEFINTIONS

IRS: Intact Rock Strength (field est.)
PLT: Point Load Test (MPa)
TCR: Total Core Recovery
RMR_{89}: Rock Mass Rating
MW: Monitoring Well
UCS: Uniaxial Compressive Strength (MPa)
FF/m: Fracture Frequency per metre
RQD: Rock Quality Designation
VWP: Vibe Wire Piezometer

LEGEND OF MAJOR STRUCTURES
■ Gouge ▨ Broken
■ Sheared 🟨 Solid
■ Rubble

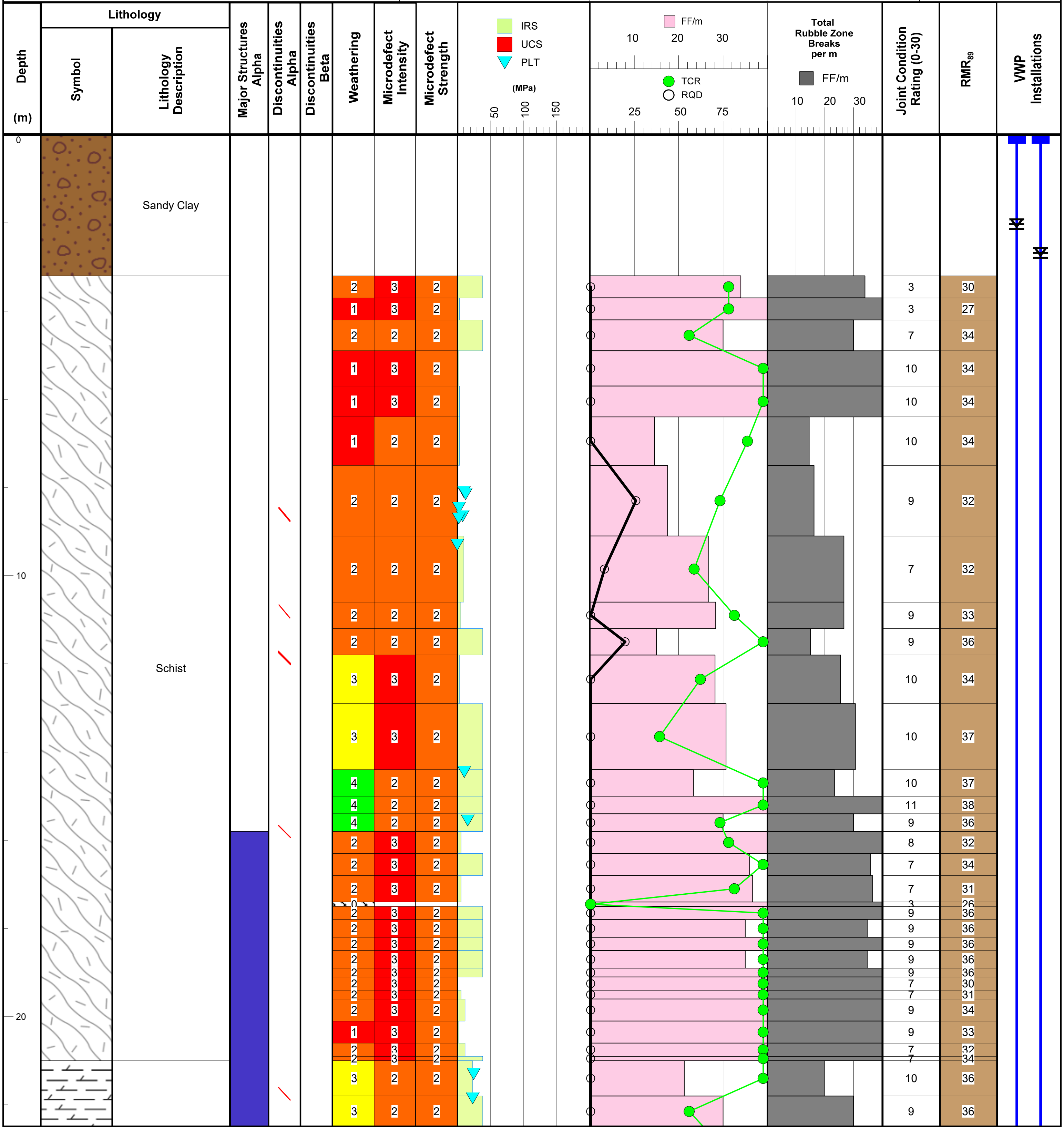
LEGEND OF MD INTENSITY
🟩 0 - None 🟧 2 - Moderate
🟨 1 - Minor 🟥 3 - Intense

LEGEND OF WEATHERING
▨ 0 - Core Loss 🟨 3 - Moderate
🟥 1 - Decomposed 🟩 4 - Slight
🟧 2 - High 🟦 5 - None

LEGEND OF MD STRENGTH
🟩 0 - Never Breaks 🟧 2 - Always Breaks
🟨 1 - Sometimes Breaks

LEGEND OF RMR89
🟥 0 - 20 🟩 61 - 80
🟫 21 - 40 🟦 81 - 100
🟨 41 - 60

HYDRO INSTALLATIONS
▽ Water Level
🟦 VW Node
\# Screen



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BOREHOLE LOG: 18DH02

PROJECT: Rum Jungle Mine Rehabilitation

LOCATION: Rum Jungle, NT

SITE & PROJECT No: 1AR001.015

SURVEY DATE:

DIP: -60 **AZIMUTH:** 303

COORDINATES: E: 717691, N: 8563286, Z(mAHD): 67

TOTAL DEPTH: 51.2 m

PAGE: 2 **OF** 3

DRILL TYPE: Diamond

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LEGEND OF MAJOR STRUCTURES
- ■ Gouge
- ▨ Broken
- ■ Sheared
- 🟨 Solid
- 🟦 Rubble

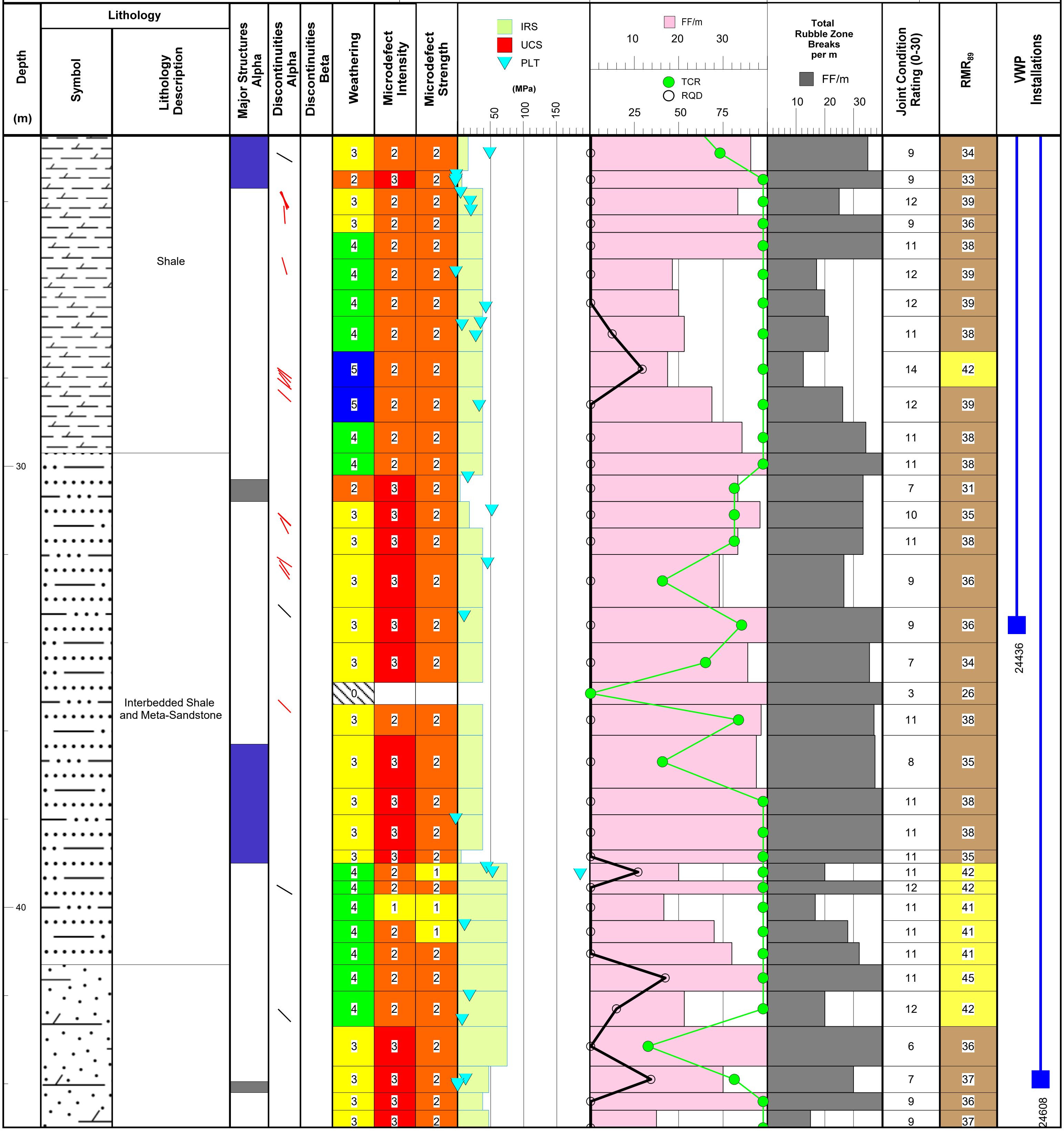
LEGEND OF WEATHERING
- ▨ 0 - Core Loss
- 🟥 1 - Decomposed
- 🟧 2 - High
- 🟨 3 - Moderate
- 🟩 4 - Slight
- 🟦 5 - None

LEGEND OF RMR89
- 🟥 0 - 20
- 🟫 21 - 40
- 🟨 41 - 60
- 🟩 61 - 80
- 🟦 81 - 100

HYDRO INSTALLATIONS
- Water Level
- 🟦 VW Node
- # Screen

LEGEND OF MD INTENSITY
- 🟩 0 - None
- 🟨 1 - Minor
- 🟧 2 - Moderate
- 🟥 3 - Intense

LEGEND OF MD STRENGTH
- 🟩 0 - Never Breaks
- 🟨 1 - Sometimes Breaks
- 🟧 2 - Always Breaks



Weathering	Microdefect Intensity	Microdefect Strength	Joint Condition Rating (0-30)	RMR$_{89}$
3	2	2	9	34
2	3	2	9	33
3	2	2	12	39
3	2	2	9	36
4	2	2	11	38
4	2	2	12	39
4	2	2	12	39
4	2	2	11	38
5	2	2	14	42
5	2	2	12	39
4	2	2	11	38
4	2	2	11	38
2	3	2	7	31
3	3	2	10	35
3	3	2	11	38
3	3	2	9	36
3	3	2	9	36
3	3	2	7	34
0			3	26
3	2	2	11	38
3	3	2	8	35
3	3	2	11	38
3	3	2	11	38
3	3	2	11	35
4	2	1	11	42
4	2	2	12	42
4	1	1	11	41
4	2	1	11	41
4	2	2	11	41
4	2	2	11	45
4	2	2	12	42
3	3	2	6	36
3	3	2	7	37
3	3	2	9	36
3	3	2	9	37

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BOREHOLE LOG: 18DH02

PROJECT: Rum Jungle Mine Rehabilitation

LOCATION: Rum Jungle, NT

SITE & PROJECT No: 1AR001.015

SURVEY DATE:

DIP: -60 **AZIMUTH:** 303

COORDINATES: E: 717691, N: 8563286, Z(mAHD): 67

TOTAL DEPTH: 51.2 m

PAGE: 3 **OF** 3

DRILL TYPE: Diamond

CORE DIA.: HQ3

CASING DEPTH:

PLANNED HOLE ID:

DEFINTIONS

IRS: Intact Rock Strength (field est.)
PLT: Point Load Test (MPa)
TCR: Total Core Recovery
RMR$_{89}$: Rock Mass Rating
MW: Monitoring Well
UCS: Uniaxial Compressive Strength (MPa)
FF/m: Fracture Frequency per metre
RQD: Rock Quality Designation
VWP: Vibe Wire Piezometer

LEGEND OF MAJOR STRUCTURES

■ Gouge
▨ Broken
■ Sheared
☐ Solid
■ Rubble

LEGEND OF WEATHERING

☐ 0 - Core Loss
🟨 3 - Moderate
🟥 1 - Decomposed
🟩 4 - Slight
🟧 2 - High
🟦 5 - None

LEGEND OF RMR89

🟥 0 - 20
🟩 61 - 80
🟫 21 - 40
🟦 81 - 100
🟨 41 - 60

HYDRO INSTALLATIONS

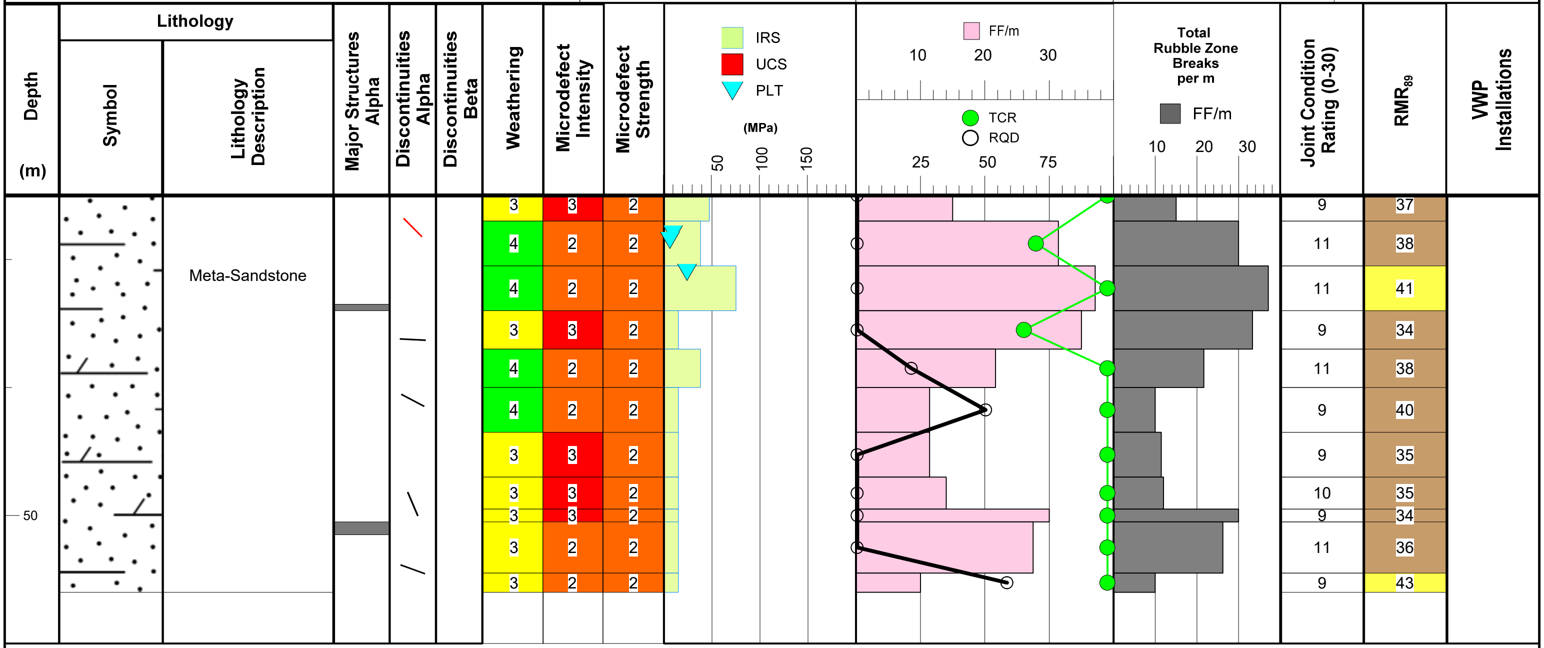
▽ Water Level
🟦 VW Node
Screen

LEGEND OF MD INTENSITY

🟩 0 - None
🟧 2 - Moderate
🟨 1 - Minor
🟥 3 - Intense

LEGEND OF MD STRENGTH

🟩 0 - Never Breaks
🟧 2 - Always Breaks
🟨 1 - Sometimes Breaks



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BOREHOLE LOG: 18DH03

PROJECT: Rum Jungle Mine Rehabilitation

LOCATION: Rum Jungle, NT

SITE & PROJECT No: 1AR001.015

SURVEY DATE:

DIP: -69 **AZIMUTH:** 315

COORDINATES: E: 717709, N: 8563463, Z(mAHD): 71

TOTAL DEPTH: 86.7 m

PAGE: 1 **OF** 4

DRILL TYPE: Diamond

CORE DIA.: HQ3

CASING DEPTH:

PLANNED HOLE ID:

DEFINTIONS

IRS: Intact Rock Strength (field est.)
PLT: Point Load Test (MPa)
TCR: Total Core Recovery
RMR$_{89}$: Rock Mass Rating
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LEGEND OF MAJOR STRUCTURES

■ Gouge
▨ Broken
■ Sheared
🟨 Solid
🟪 Rubble

LEGEND OF WEATHERING

☐ 0 - Core Loss
🟨 3 - Moderate
🟥 1 - Decomposed
🟩 4 - Slight
🟧 2 - High
🟦 5 - None

LEGEND OF RMR89

🟥 0 - 20
🟩 61 - 80
🟫 21 - 40
🟦 81 - 100
🟨 41 - 60

HYDRO INSTALLATIONS

Water Level
🟦 VW Node
\# Screen

LEGEND OF MD INTENSITY

🟩 0 - None
🟧 2 - Moderate
🟨 1 - Minor
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🟩 0 - Never Breaks
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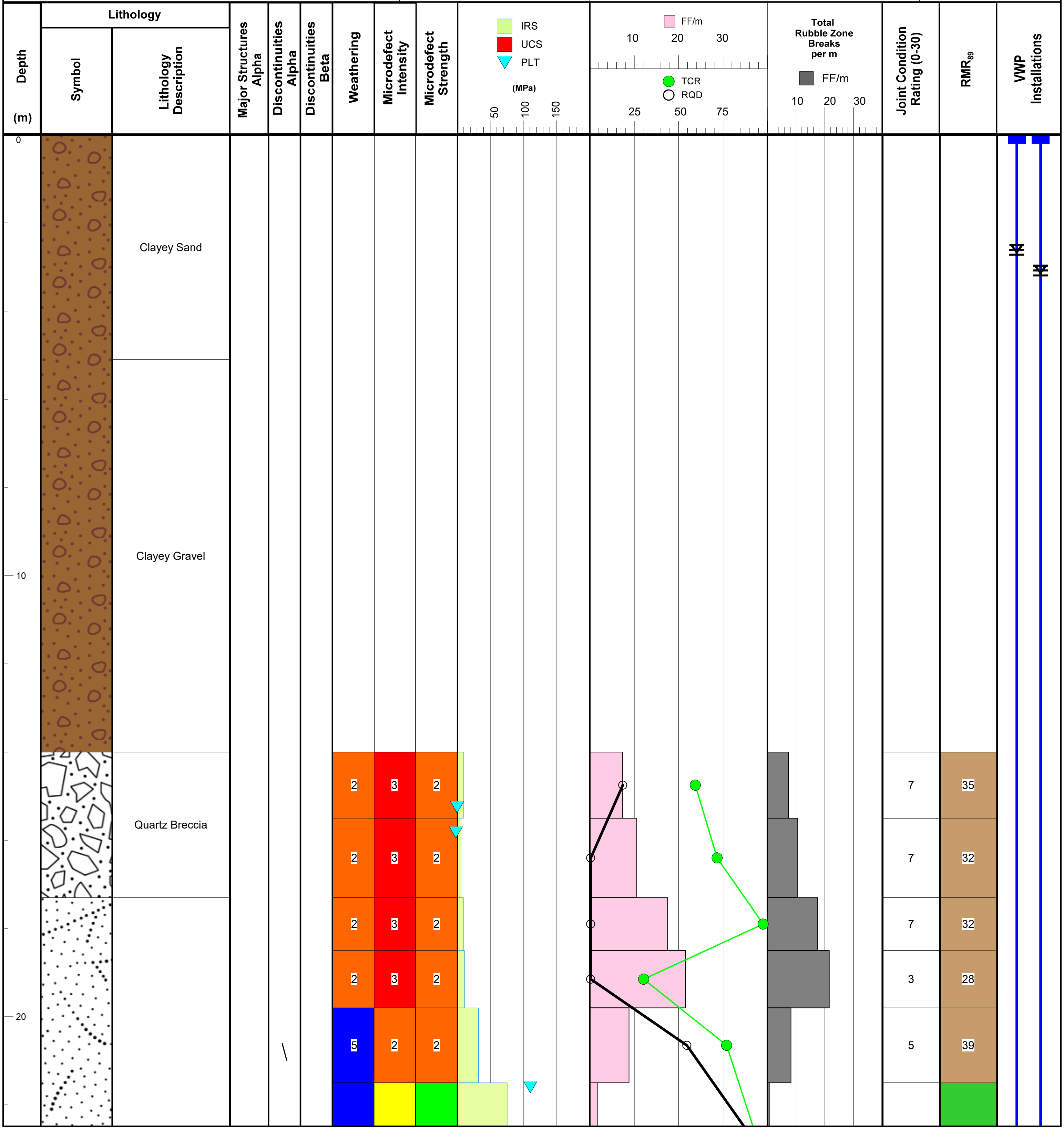

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BOREHOLE LOG: 18DH03

PROJECT: Rum Jungle Mine Rehabilitation

LOCATION: Rum Jungle, NT

SITE & PROJECT No: 1AR001.015

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DIP: -69 **AZIMUTH:** 315

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PAGE: 2 **OF** 4

DRILL TYPE: Diamond

CORE DIA.: HQ3

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🟫 21 - 40
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HYDRO INSTALLATIONS

Water Level
🟦 VW Node
\# Screen

LEGEND OF MD INTENSITY

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🟨 1 - Minor
🟧 2 - Moderate
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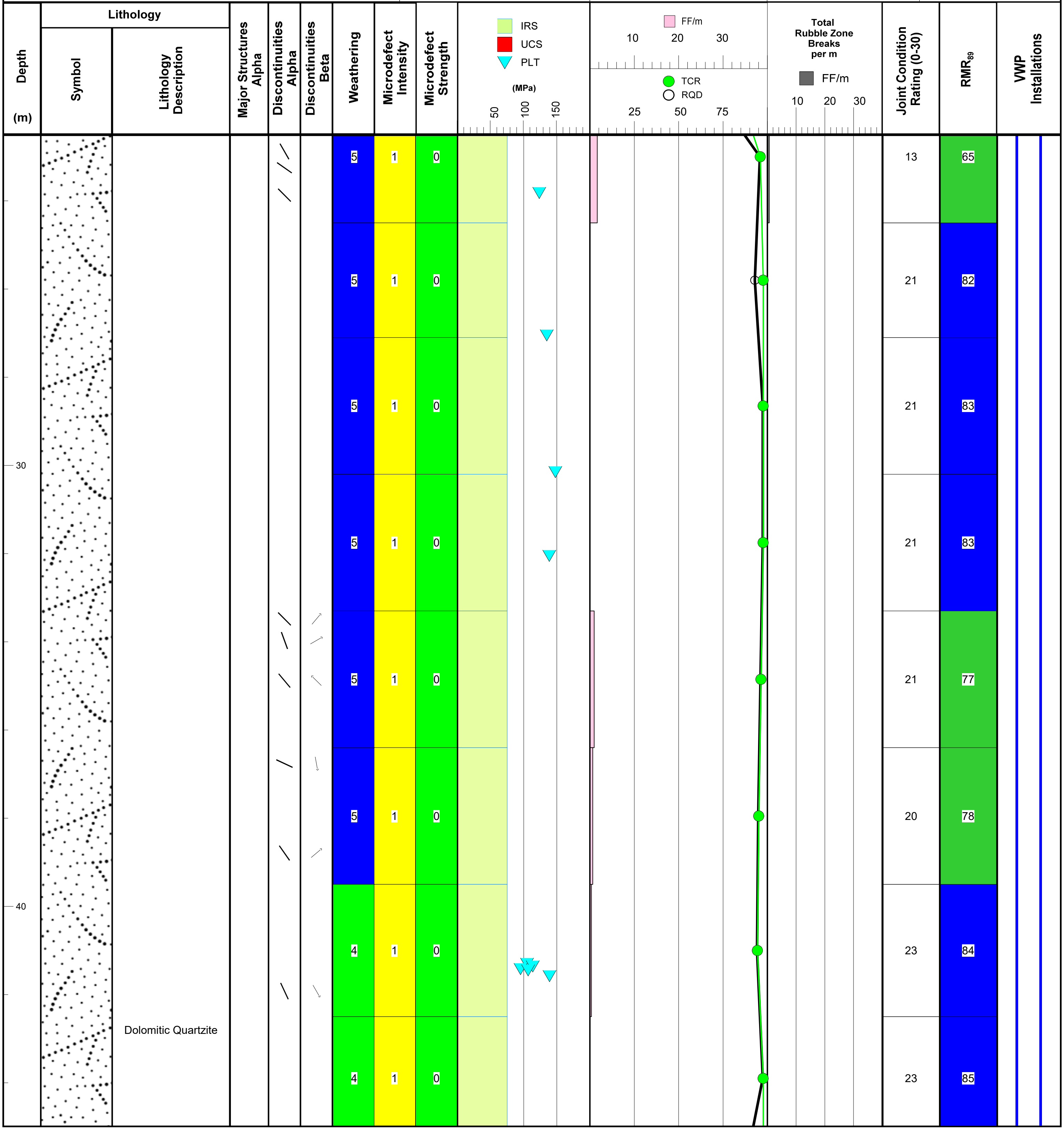

Weathering	Microdefect Intensity	Microdefect Strength	Joint Condition Rating (0-30)	RMR_{89}
5	1	0	13	65
5	1	0	21	82
5	1	0	21	83
5	1	0	21	83
5	1	0	21	77
5	1	0	20	78
4	1	0	23	84
4	1	0	23	85

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BOREHOLE LOG: 18DH03

PROJECT: Rum Jungle Mine Rehabilitation

LOCATION: Rum Jungle, NT

SITE & PROJECT No: 1AR001.015

SURVEY DATE:

DIP: -69 **AZIMUTH:** 315

COORDINATES: E: 717709, N: 8563463, Z(mAHD): 71

TOTAL DEPTH: 86.7 m

PAGE: 3 **OF** 4

DRILL TYPE: Diamond

CORE DIA.: HQ3

CASING DEPTH:

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RMR_{89}: Rock Mass Rating
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HYDRO INSTALLATIONS

Water Level
🟦 VW Node
Screen

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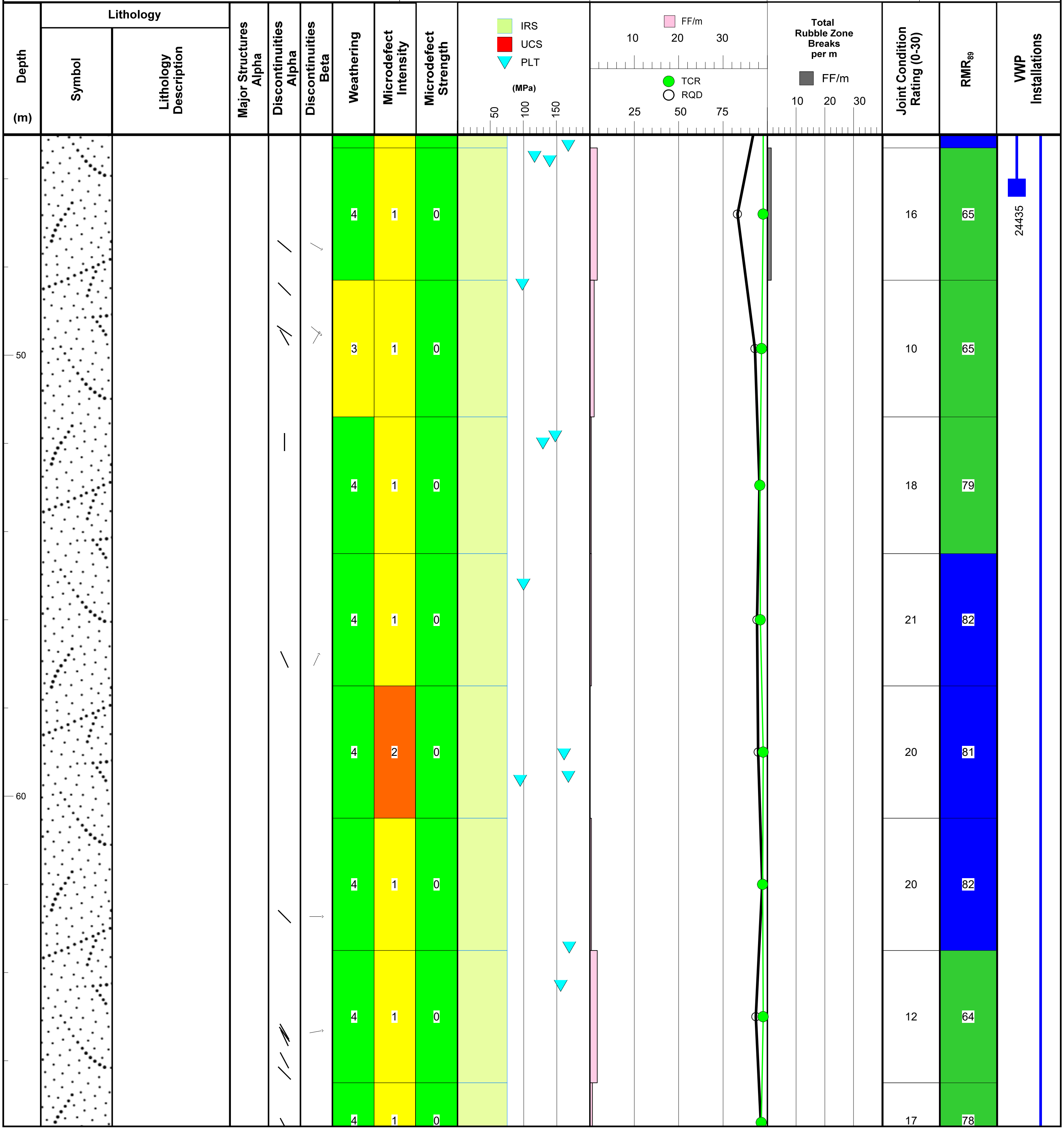

4	1	0	16	65
3	1	0	10	65
4	1	0	18	79
4	1	0	21	82
4	2	0	20	81
4	1	0	20	82
4	1	0	12	64
4	1	0	17	78

BOREHOLE LOG: 18DH03

PROJECT: Rum Jungle Mine Rehabilitation

LOCATION: Rum Jungle, NT

SITE & PROJECT No: 1AR001.015

SURVEY DATE:

DIP: -69 **AZIMUTH:** 315

COORDINATES: E: 717709, N: 8563463, Z(mAHD): 71

TOTAL DEPTH: 86.7 m

PAGE: 4 **OF** 4

DRILL TYPE: Diamond

CORE DIA.: HQ3

CASING DEPTH:

PLANNED HOLE ID:

DEFINTIONS

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MW: Monitoring Well
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FF/m: Fracture Frequency per metre
RQD: Rock Quality Designation
VWP: Vibe Wire Piezometer

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▨ Broken
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LEGEND OF WEATHERING

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🟥 1 - Decomposed
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🟨 3 - Moderate
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🟦 5 - None

LEGEND OF RMR89

🟥 0 - 20
🟫 21 - 40
🟨 41 - 60
🟩 61 - 80
🟦 81 - 100

HYDRO INSTALLATIONS

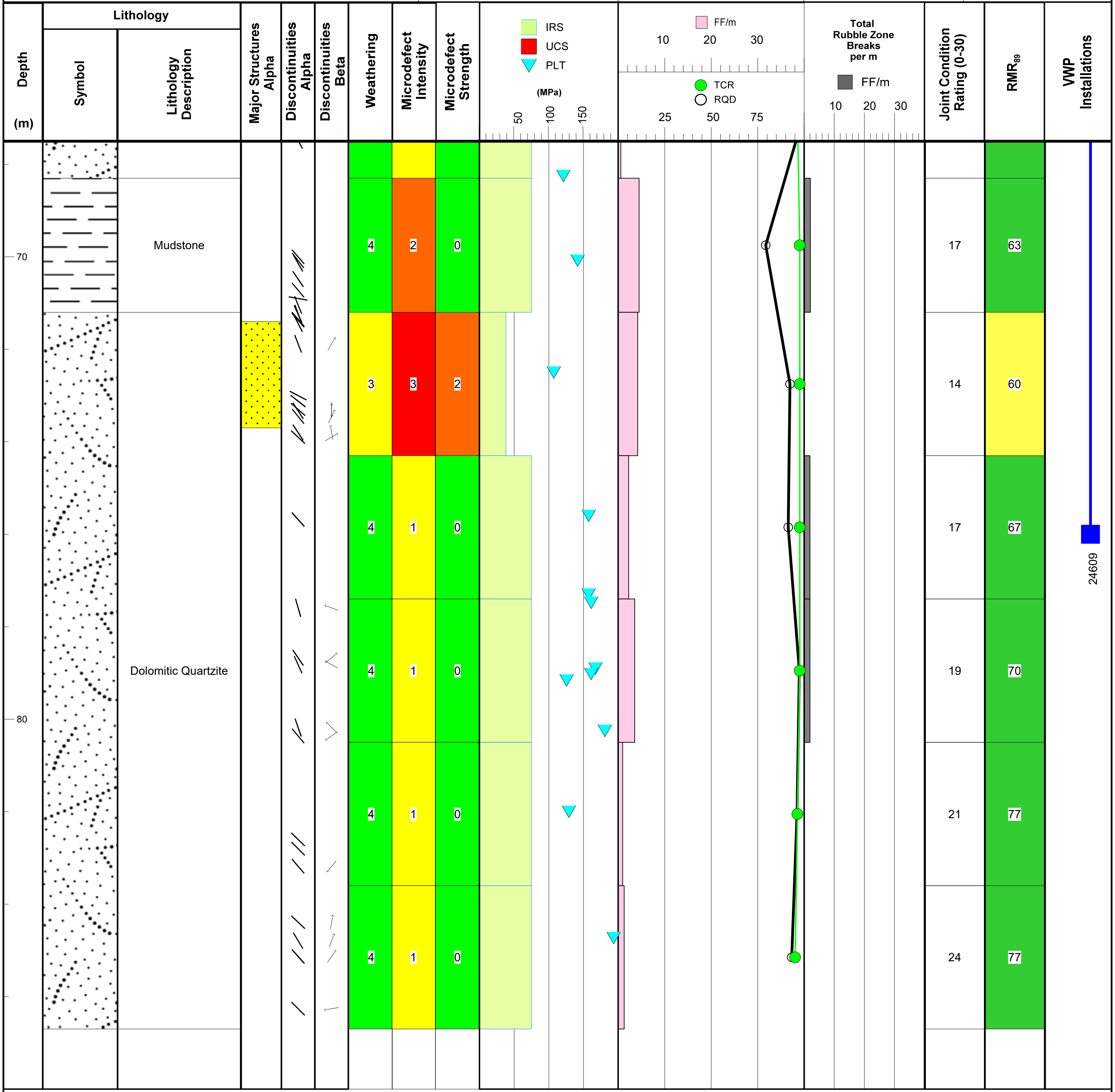
Water Level
🟦 VW Node
\# Screen

LEGEND OF MD INTENSITY

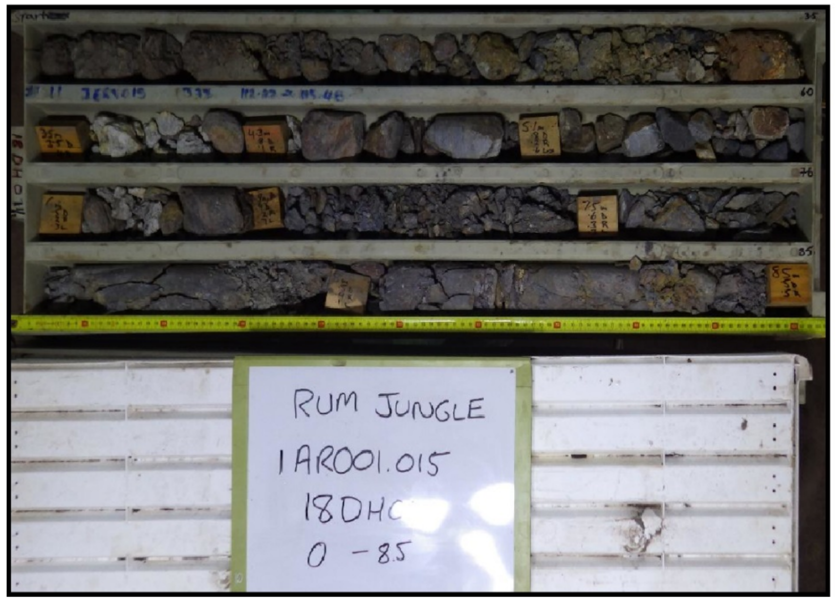
🟩 0 - None
🟨 1 - Minor
🟧 2 - Moderate
🟥 3 - Intense

LEGEND OF MD STRENGTH

🟩 0 - Never Breaks
🟨 1 - Sometimes Breaks
🟧 2 - Always Breaks



Appendix B – Core Photographs



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NORTHERN TERRITORY GOVERNMENT

Rum Jungle Mine

Core Photos
18DH01 0-15.80m

Job No: 1AR001.015
Filename: Rum Jungle Core Photos.pptx

Drilling Superintendent

Date: February 21, 2018
Approved:
Figure: 1

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NORTHERN TERRITORY GOVERNMENT

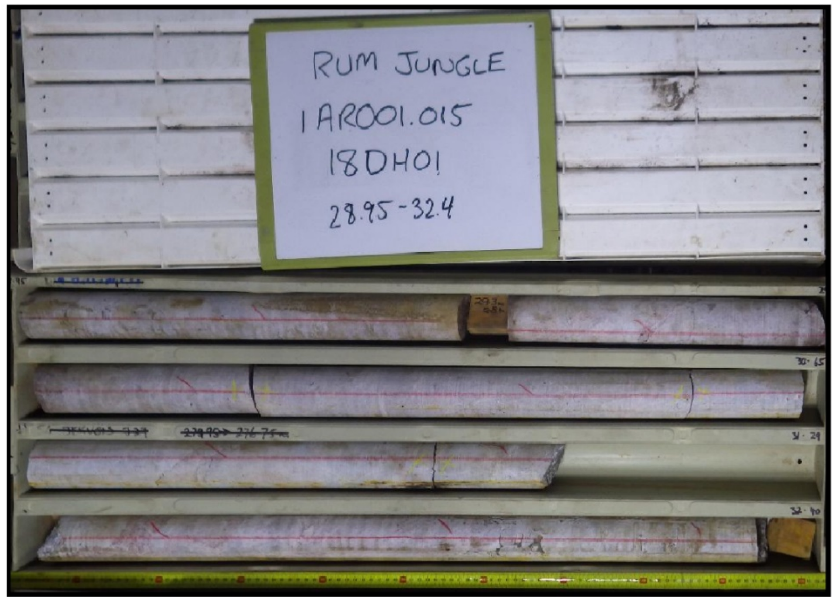
Rum Jungle Mine

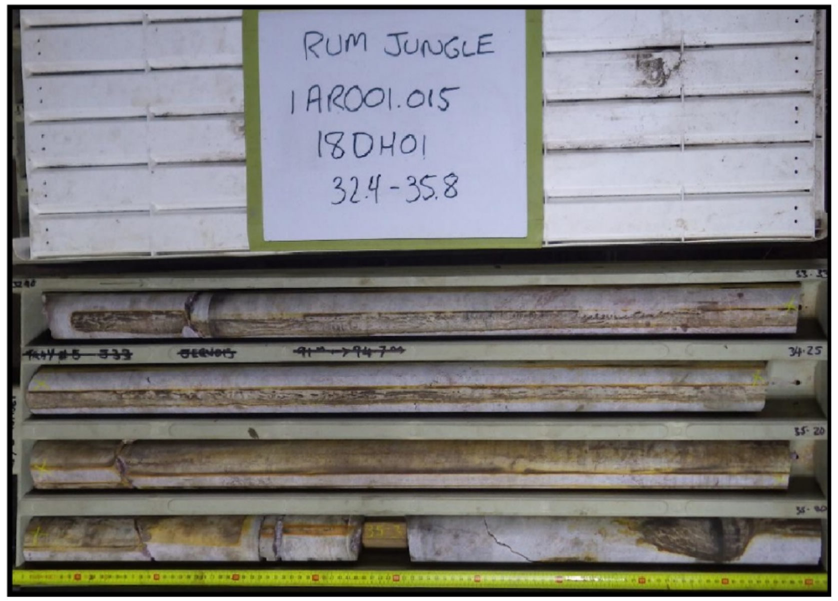
Core Photos
18DH01 15.80-25.43m

Job No: 1AR001.015
Filename: Rum Jungle Core Photos.pptx

Drilling Superintendent

Date:	Approved:	Figure:
February 21, 2018		1





		Rum Jungle Mine
		Core Photos **18DH01 25.50-35.80m**
Job No: 1AR001.015 Filename: Rum Jungle Core Photos.pptx	Drilling Superintendent	Date: February 21, 2018 Approved: Figure: 1

Rum Jungle Mine

Core Photos
18DH01 35.80-46.88m

Job No: 1AR001.015
Filename: Rum Jungle Core Photos.pptx

Drilling Superintendent

Date: February 21, 2018
Approved:
Figure: 1

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NORTHERN TERRITORY GOVERNMENT

Rum Jungle Mine

Core Photos
18DH01 46.9-50.7m

Job No: 1AR001.015
Filename: Rum Jungle Core Photos.pptx

Drilling Superintendent

Date: February 21, 2018
Approved:
Figure: 1

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NORTHERN TERRITORY GOVERNMENT

Rum Jungle Mine

Core Photos
18DH02 0-16.3m

Job No: 1AR001.015
Filename: Rum Jungle Core Photos.pptx

Drilling Superintendent

Date: February 21, 2018
Approved:
Figure: 1

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NORTHERN TERRITORY GOVERNMENT

Rum Jungle Mine

Core Photos
18DH02 16.3-24.3m

Job No: 1AR001.015
Filename: Rum Jungle Core Photos.pptx

Drilling Superintendent

Date: February 21, 2018
Approved:
Figure: 1

Rum Jungle Mine

Core Photos
18DH02 24.3-34.9m

Job No: 1AR001.015
Filename: Rum Jungle Core Photos.pptx

Drilling Superintendent

Date: February 21, 2018
Approved:
Figure: 1

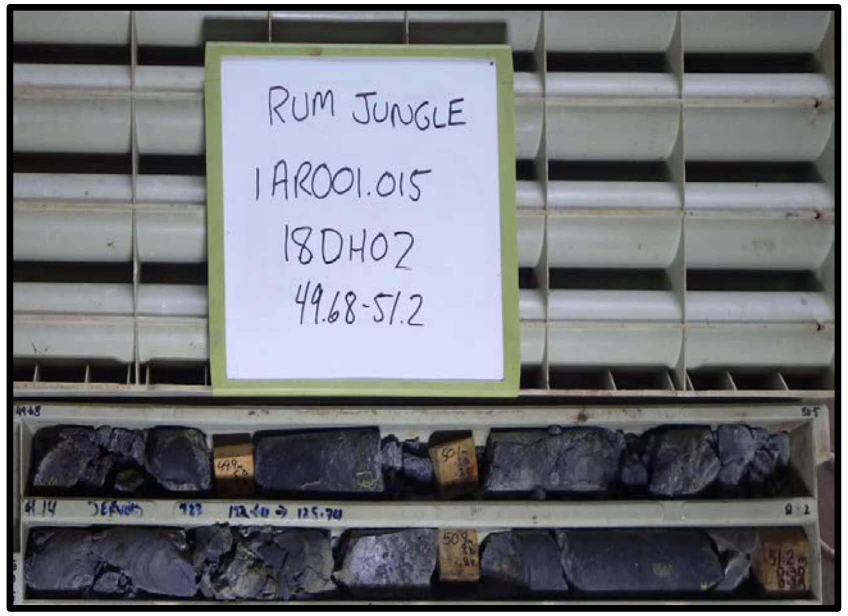
Job No: 1AR001.015
Filename: Rum Jungle Core Photos.pptx

Drilling Superintendent

Rum Jungle Mine

Core Photos
18DH02 34.9-46.35m

Date: February 21, 2018
Approved:
Figure: 1



Rum Jungle Mine

Core Photos
18DH02 46.35-51.2m

Job No: 1AR001.015
Filename: Rum Jungle Core Photos.pptx

Drilling Superintendent

Date: February 21, 2018
Approved:
Figure: 1

srk consulting	NORTHERN TERRITORY GOVERNMENT	Rum Jungle Mine
		Core Photos **18DH03 0-17.6m**
Job No: 1AR001.015 Filename: Rum Jungle Core Photos.pptx	Drilling Superintendent	Date: February 21, 2018 · Approved: · Figure: **1**

Rum Jungle Mine

Core Photos
18DH03 17.6-30.63m

Job No: 1AR001.015
Filename: Rum Jungle Core Photos.pptx

Drilling Superintendent

Date: February 21, 2018
Approved:
Figure: 1

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NORTHERN TERRITORY GOVERNMENT

Rum Jungle Mine

Core Photos
18DH03 30.63-44.34m

Job No:	1AR001.015	Drilling Superintendent	Date: February 21, 2018	Approved:	Figure: 1
Filename:	Rum Jungle Core Photos.pptx				

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NORTHERN TERRITORY GOVERNMENT

Rum Jungle Mine

Core Photos
18DH03 44.34-57.18m

Job No: 1AR001.015
Filename: Rum Jungle Core Photos.pptx

Drilling Superintendent

Date: February 21, 2018
Approved:
Figure: 1

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NORTHERN TERRITORY GOVERNMENT

Rum Jungle Mine

Core Photos
18DH03 57.18-69.78m

Job No: 1AR001.015
Filename: Rum Jungle Core Photos.pptx

Drilling Superintendent

Date: February 21, 2018
Approved:
Figure: 1

Rum Jungle Mine

Core Photos
18DH03 69.78-82.09m

Job No: 1AR001.015
Filename: Rum Jungle Core Photos.pptx

Drilling Superintendent

Date: February 21, 2018
Approved:
Figure: 1

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NORTHERN TERRITORY GOVERNMENT

Rum Jungle Mine

Core Photos
18DH03 82.09-86.7m

Job No: 1AR001.015
Filename: Rum Jungle Core Photos.pptx

Drilling Superintendent

Date: February 21, 2018
Approved:
Figure: 1

Appendix C – Geotechnical Atlas

Oriented Core, On-Rig Rock Logging Manual

National Archives of Australia: A1200, L26916

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NORTHERN TERRITORY GOVERNMENT

Overview of the On-Rig Logging Methodology

1. Receive split tube from drill;
2. Fit the core together if loose in split;
3. Clean core, carefully;
4. If core is oriented, continue the orientation line along the length of core;
5. Take a photo of the undisturbed core in the split tube;
6. Mark ‘hammer’ breaks, ‘drill’ breaks, foliation joints, and joints;
7. Review and comment on the drilling quality and notable features in the detailed log;
8. Conduct Scoping Level geotechnical logging, TCR, SCR, RQD, joint counts, joint condition summary;
9. Conduct orientation measurements and annotate on drillcore and record offsets;
10. Conduct detailed PFS/FS Level geotechnical logging;
11. Select one representative sample for the point load test (~10 cm);
12. Flag samples for laboratory test-work (> 20 cm) at specified depths and take point-load cluster of six tests around each sample position;
13. Take detailed photographs of specifics if required;
14. Edit photos taken of run (i.e. crop and rename). For example “SRK-GT-006_003.00-006.00m”;
15. At the end of shift, submit digital logs to the site senior for review;

Scoping-Level Geotechnical Logging

3) Total Core Recovery (TCR), Methodology;

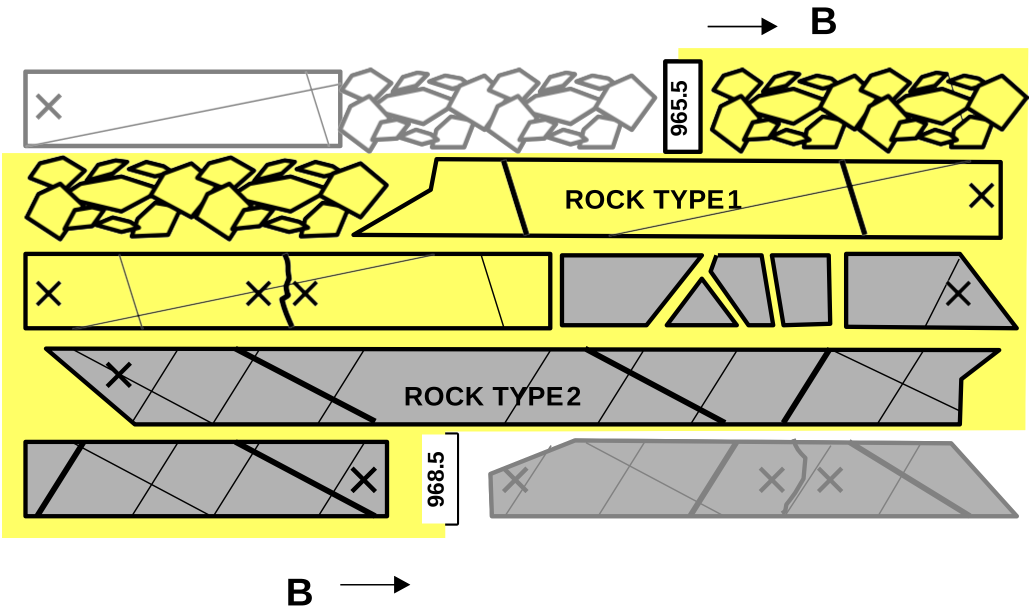
4) Solid Core Recovery (SCR), Methodology;

5) Rock Quality Designation (RQD), Methodology;

6) RQD Explained;

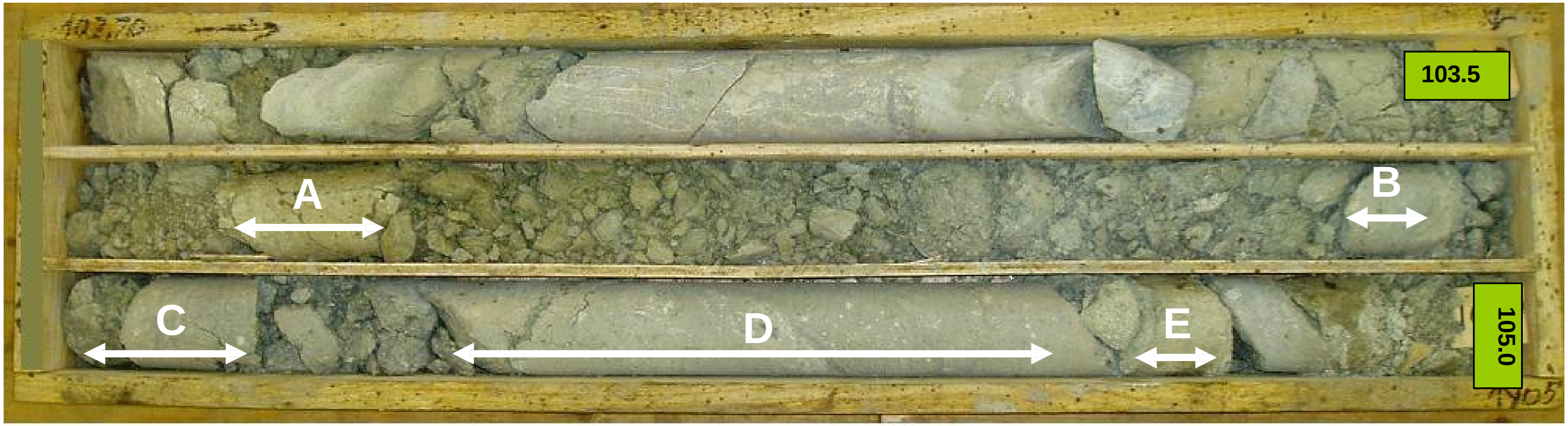
7) RQD Example;

TOTAL CORE RECOVERY (TCR), METHODOLOGY



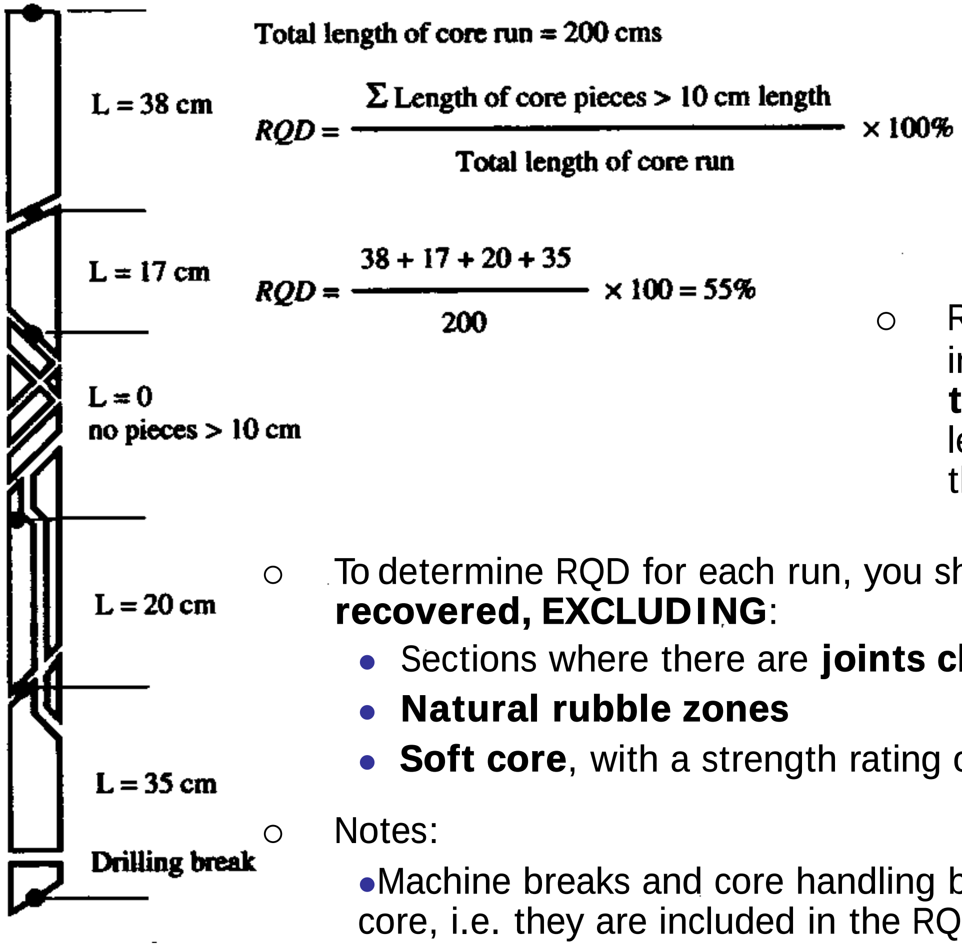
- TCR is defined as the sum of all measureable core recovered in one drill run;
- Fit the core together as best as possible to minimize measuring the gaps in with the core;
- For the broken zones, push the material together so that it approximately resembles a core volume;
- Measure the total length of core recovered, which includes the solid and broken zones, and;
- The **TCR** (yellow shaded area) of interval B is approximately 2.4 m (2.4 / 3.0 x 100 = 80%) while the indicated drill run is 3.0 m.

SOLID CORE RECOVERY (SCR), METHODOLOGY



- The SCR is defined as the sum of all sections of the core run that are greater than 1 core diameter;
  - For HQ/HQ3, this is 6 cm; and
  - For NQ/NQ3 this is 4.5 cm.
- This measurement is aimed at quantifying drilling-induced damage in weaker rocks in which no identifiable joints contribute to the breakage;
- In the above case, the SCR = A+B+C+D+E (between 103.50m to 105.00m).

ROCK QUALITY DESIGNATION (RQD), METHODOLOGY



Total length of core run = 200 cms

$$RQD = \frac{\Sigma \text{ Length of core pieces} > 10 \text{ cm length}}{\text{Total length of core run}} \times 100\%$$

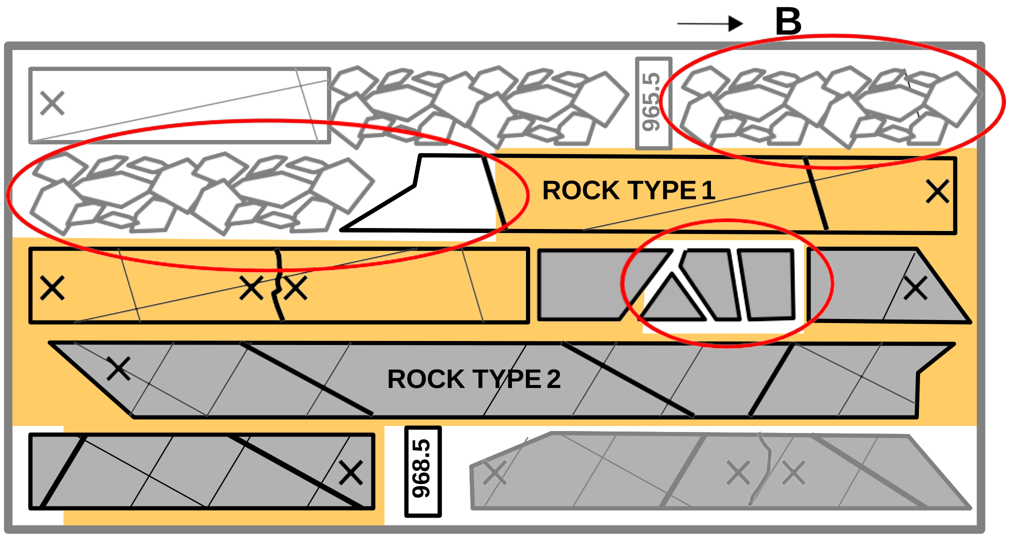
$$RQD = \frac{38 + 17 + 20 + 35}{200} \times 100 = 55\%$$

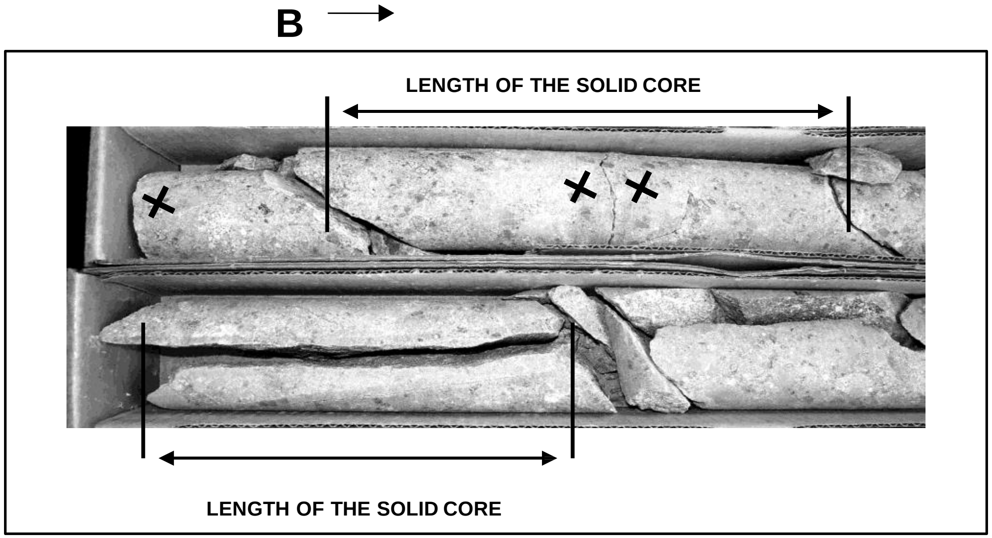
- Rock Quality Designation (RQD) is an indication of **how jointed and weak the rock is**, measured as the total length of core pieces that are longer than 10cm.

- To determine RQD for each run, you should measure the **length of core recovered, EXCLUDING**:
  - Sections where there are **joints closer than 10cm** together
  - **Natural rubble zones**
  - **Soft core**, with a strength rating of **R0-1** (discussed later)

- Notes:
  - Machine breaks and core handling breaks should be considered solid core, i.e. they are included in the RQD measurement
  - Joints along the core axis should be considered solid core, i.e. included in the RQD measurement.

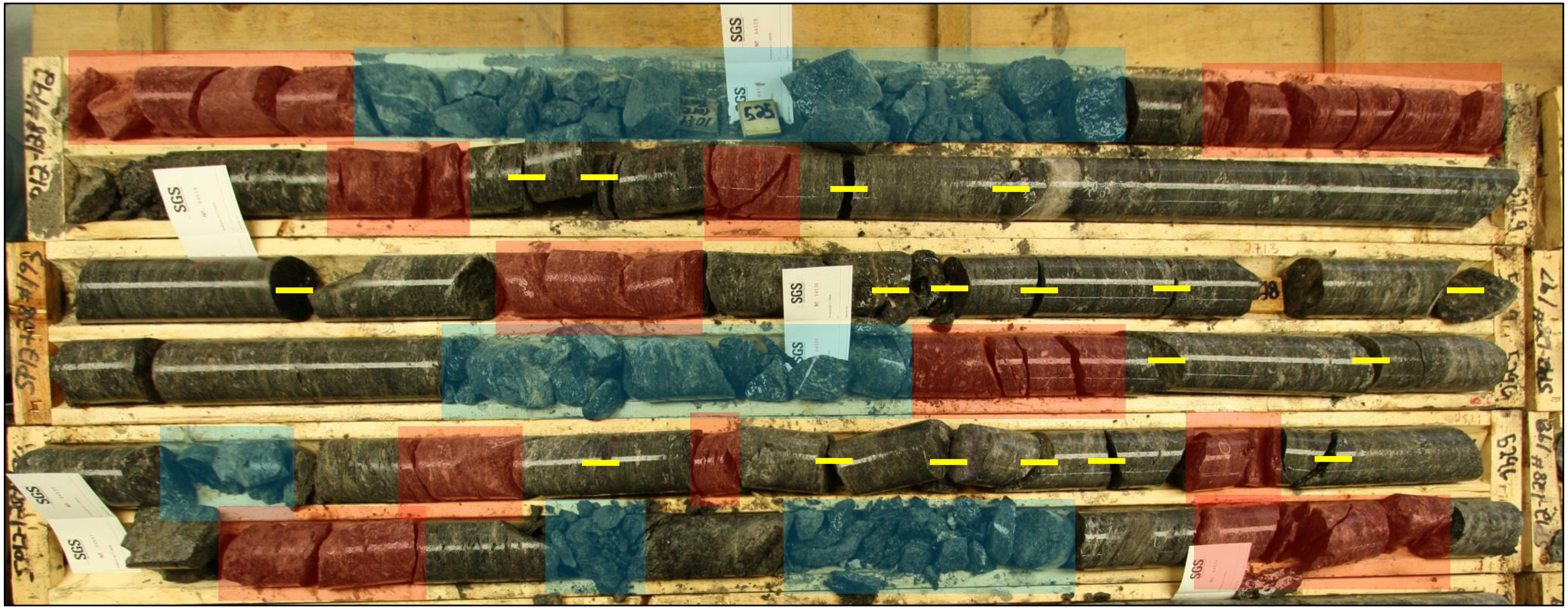
RQD EXPLAINED





- The RQD of interval B in the example illustrated is approximately 1.5 m (1.5 / 3.0 x 100 = 50%). Areas not counted are circled;
- Solid core is measured along the axis of the core, and;
- If a single joint runs parallel to the core axis but does not intersect it, then it is considered as a solid piece.

RQD EXAMPLE



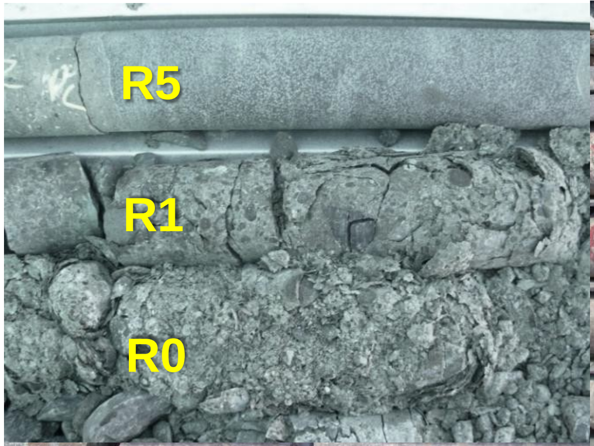
In the example provided above:

- Red-shaded areas are not considered ‘solid’ core (and are not included in the total length measured to determine the RQD) – these are areas of *in situ* jointing;
- Blue-shaded areas are rubble zones, not ‘solid’ core, and are counted at a rate of 4 joints per 10 cm and excluded from the ‘solid-core’ length for RQD, and;
- Yellow lines are considered ‘solid’ core (as they represent drill-breaks which do not affect RQD).

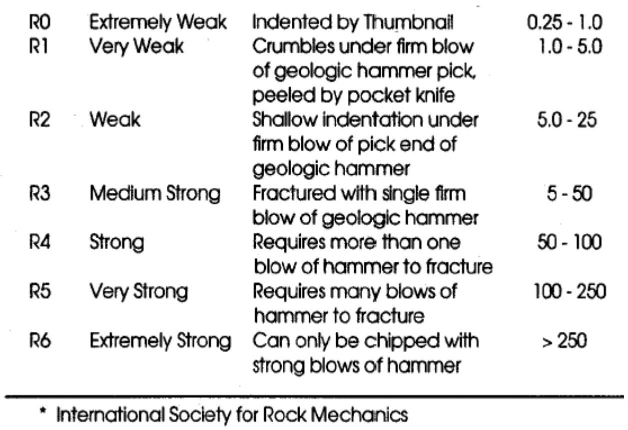
RMR$_{89}$ Logging

9) Intact Rock Strength (ISRM);
10) Weak Material Strength (ISRM);
11) Penetrometer Testing, Overview;
12) Rock Mass Weathering;
13) IRS Empirical Methods;
14) Fracture Assessment;
15) Joint Characteristics;
16) Drill-Break Characteristics;
17) Joints, Fabric and bedding Planes;
18) Joints or Partial Joints?
19) Joint Identification (1 of 2);
20) Joint Identification (2 of 2);
21) Drill-Breaks versus Joints;
22) Defects and Joint Conditions;
23) Joint Angle;
24) Joint Roughness Examples;
25) Joint Weathering Examples;
26) Joint Fill Type Examples;
27) Joint Aperture Examples;
28) Joint-Set Allocation Notes;
29) Zones of Broken Rock;
30) Micro Defect Notes;
31) Logging Examples;
32) Data-Entry Log for Geotech (1 of 2);
33) Data-Entry Log for Geotech (2 of 2).

INTACT ROCK STRENGTH (IRS) ESTIMATES




Technique to test core strength with a rock pick



R0	Extremely Weak	Indented by Thumbnail	0.25 - 1.0
R1	Very Weak	Crumbles under firm blow of geologic hammer pick, peeled by pocket knife	1.0 - 5.0
R2	Weak	Shallow indentation under firm blow of pick end of geologic hammer	5.0 - 25
R3	Medium Strong	Fractured with single firm blow of geologic hammer	5 - 50
R4	Strong	Requires more than one blow of hammer to fracture	50 - 100
R5	Very Strong	Requires many blows of hammer to fracture	100 - 250
R6	Extremely Strong	Can only be chipped with strong blows of hammer	> 250

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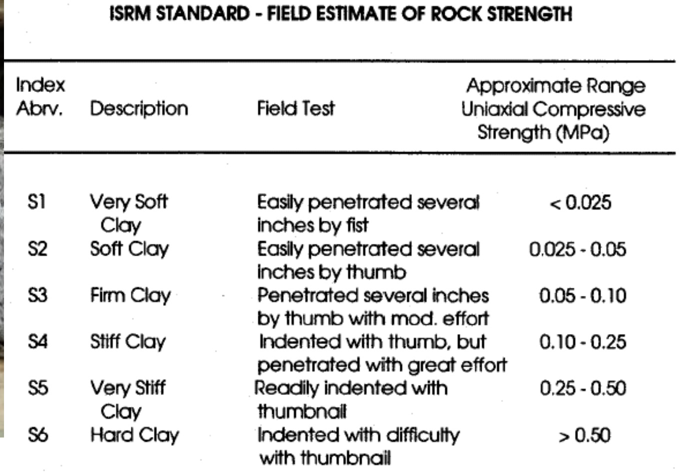
* International Society for Rock Mechanics

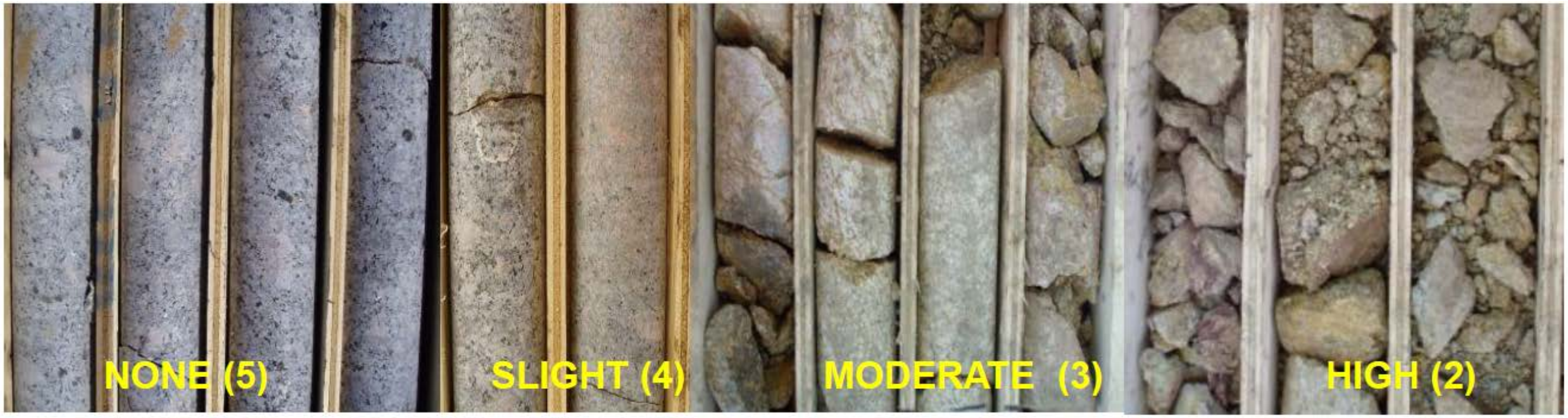
WEAK MATERIAL (CLAY, GRANULAR) STRENGTH ESTIMATES



ISRM STANDARD - FIELD ESTIMATE OF ROCK STRENGTH

Index Abrv.	Description	Field Test	Approximate Range Uniaxial Compressive Strength (MPa)
S1	Very Soft Clay	Easily penetrated several inches by fist	< 0.025
S2	Soft Clay	Easily penetrated several inches by thumb	0.025 - 0.05
S3	Firm Clay	Penetrated several inches by thumb with mod. effort	0.05 - 0.10
S4	Stiff Clay	Indented with thumb, but penetrated with great effort	0.10 - 0.25
S5	Very Stiff Clay	Readily indented with thumbnail	0.25 - 0.50
S6	Hard Clay	Indented with difficulty with thumbnail	> 0.50

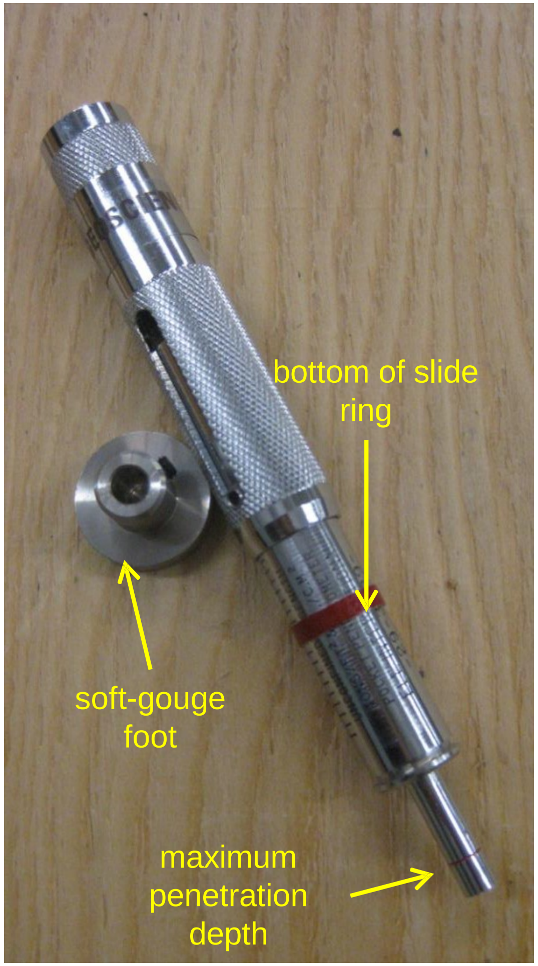
ROCK MASS WEATHERING



The “weathering” or degradation of the intact rock results from fluids moving along the joints and through permeable zones and altering the surrounding rock composition.

Rock Mass Weathering	
None	5
Slight	4
Moderate	3
High	2
Decomposed	1
Core-loss	0

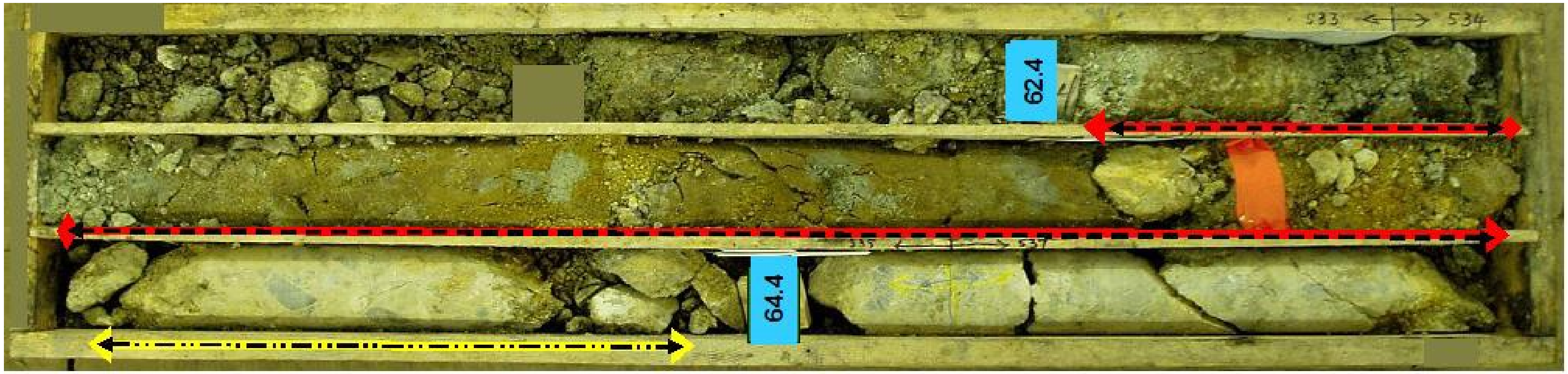
PENETROMETER TESTING, OVERVIEW



- The pocket penetrometer (PP) consists of a single unit ‘spring-compression’ style resistance probe, which comes with a 1” foot for very soft clays;
- Measurement range is 0 – 4.5 kg/cm^2 (0 – 490 KPa);
- It is typically used to measure the strength of intact soft gouge and weak/altered rock for which approximately 5 mm thick layer is needed;

1. Set the red ‘ring’ to base of unit by sliding towards the handle;
2. Push the tip gently into the material, to the depth of the red-scribed ring (or thickness of soft-gouge foot attachment if used);
3. Repeat three times, each time re-setting the indicator sleeve, within local area in the same material, and record the average resistance achieved from the scale on the barrel of the probe;
4. Measure to one decimal place and record value (kg/cm^2) in spreadsheet and specify if foot- attachment was used or not;
5. Provide brief comment about colour/type of material, and;
6. Clean unit by wiping and rinsing tip in water.

INTACT ROCK STRENGTH (IRS) EMPIRICAL METHODS



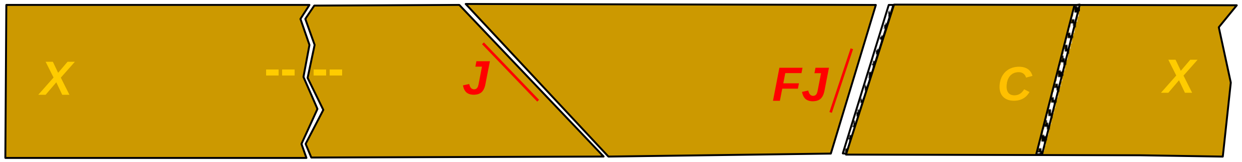
1. Start with the hammer test in what is likely to be the stronger rock, and then continue further intra-run tests to determine if ‘weaker-rock’ rock intervals exist;
2. Concentrate on only the strongest and weakest rock for which at least 0.1 m are represented in the interval being logged;
3. Assign the highest strength-index, for example R5, and then define the length of the run (or domain) which is represented by the weakest index, for example R0, and;
4. Record the IRS-strong = R5, and the IRS-weak = R0 metres and %weak will be calculated at a later stage (which in this example ≈ 80%).

FRACTURE ASSESSMENT

☐ It is important to realize that there are many reasons behind planar and irregular discontinuities in drilled rock core – it is the classification of these into the *in situ* and induced classes that is required; the most important being the joints (both J and CJ).

- All across-axis core breaks made post-drilling and arrival on-surface ("hammer" breaks) should be marked with a YELLOW (X);
- Core breaks which are opened during the drilling process at depth ("drill" breaks) should be marked with a YELLOW line across the break (--);
- Joints (*in situ*) that are present in the rock mass are marked with a RED (J);
- Rock fabric controls the orientation of several types of discontinuity, including joints which may parallel to foliation or bedding, and they are marked as a RED (FJ);
- Partially opened joints (on-axis appears freshly broken) are marked up as a broken cemented-discontinuity with a YELLOW (C) – this is considered as solid-core for RQD, but is included in the detailed discontinuity logs, and;
- Micro-defects can often be seen in the core, sometimes associated with breakage, and are evaluated using an estimate of abundance and strength.

IDEAL MARKING



JOINT CHARACTERISTICS

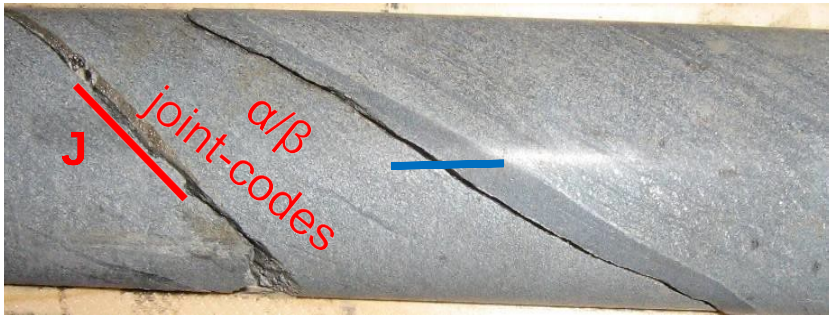
- A joint is a planar discontinuity within a rock-mass;
- Joints exhibit little or no tensile strength in tension**,** and separate solid (intact) core pieces for purposes of RQD calculation;
- Joints tend to have weathered faces and are sometimes stained and-or have some type of coating or fill which implies recent exposure to ground-water, and;
- Joints often occur as sets, recognized by multiple joints with a similar orientation.

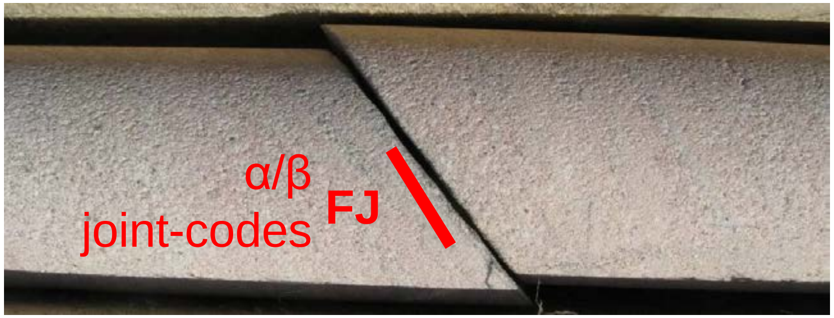
DRILL-BREAK CHARACTERISTICS

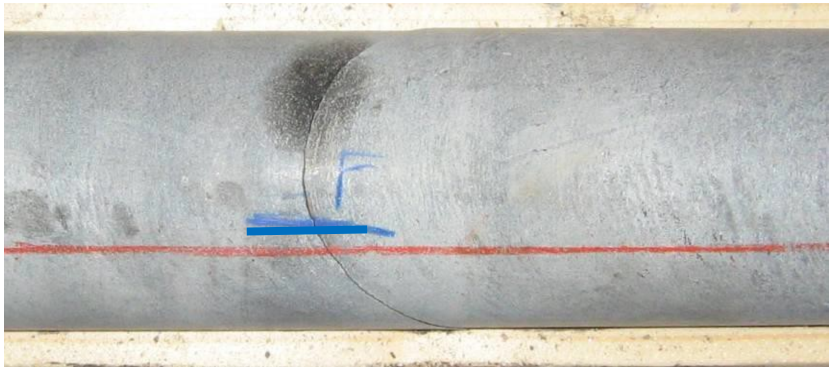
a. ‘Drill spin’ is an indication of either induced damage and/or a high-alpha joint;
b. A non-planar break in which individual recently broken mineral grains can be seen;
c. High angle ‘discing’ is considered to be drilling-induced damage, and;
d. Breaks may form clusters of sub-parallel breaks, sometimes rough and angular.

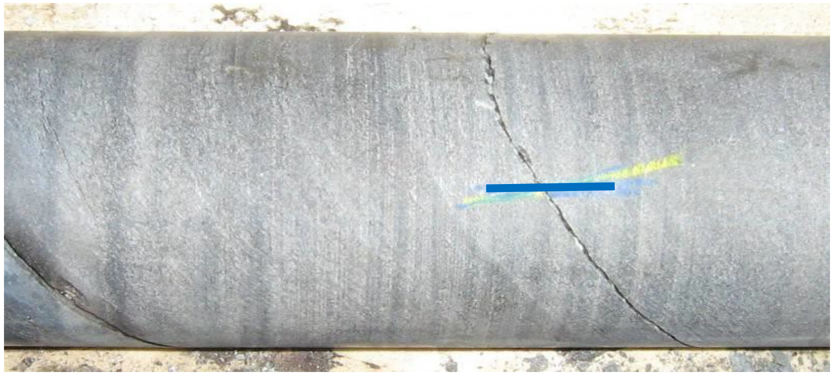
Note: Once the core has been snapped off-bottom, no more drill-breaks can be formed – they are then considered ‘hammer’ breaks.

JOINTS, FABRIC AND BEDDING PLANES





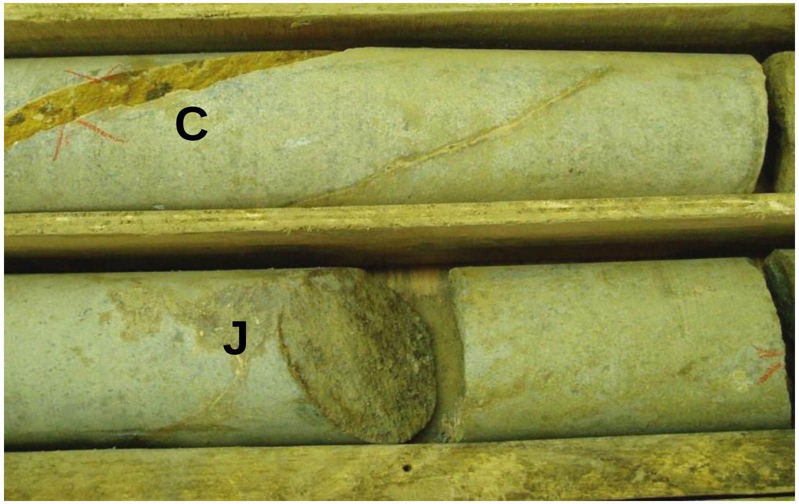




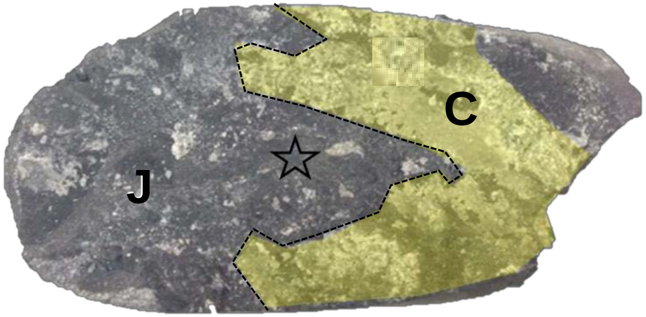
Example Procedure:

1. Look at surfaces for evidence of fluid movement or oxidation/precipitation from recent ground-water activity (for example; staining, coating of discontinuity surface, soft calcite fill, or 'dirty' appearance) – these are Js, and if parallel with the rock fabric or bedding planes then they are assigned to FJ;
2. Record the number of Js and FJs – remembering that only the Js and FJs are used for RQD and joint-set allocations;
3. Add the total joint-count to the count of drilling induced breaks (drill-breaks) along foliation/bedding which are annotated as YELLOW (----) in the Fractures-All column along with the joint-count.

JOINTS OR PARTIAL-JOINTS?



1. Evaluate the appearance of the surface of the discontinuity and determine if the centre of the face (which is along the axis) has the appearance of being a joint;
2. If (on the axis) it has joint-like properties, allocate it to Joints;
3. If (on the axis) is appears to be freshly broken during the drilling process, but it still has joint like properties elsewhere on the face, then assign it to the partial-joint category C;
4. If it is unclear as to whether or not it is a partial-joint or a joint, then err on the side of caution and classify it as a joint.



For a surface that looks like J and C, make the determination on the axis of the core. In the example above, half (or more) is a J while the rest is a C. The example provided is a J because on-axis it has J-properties.

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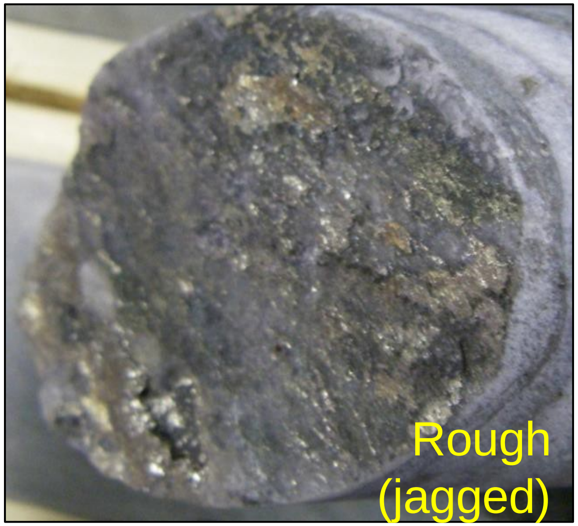
NORTHERN TERRITORY GOVERNMENT

JOINT IDENTIFICATION

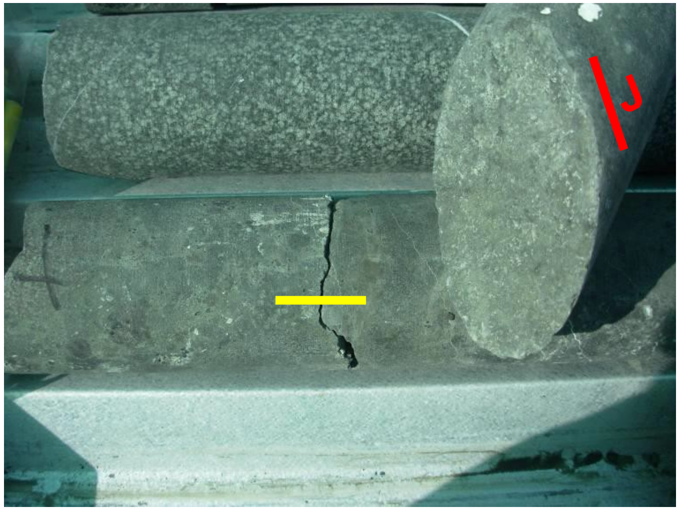
- No Tensile Strength – joints separate solid (intact) core pieces and exhibit no tensile strength, and;
- Freshness – Joints tend not to look fresh and often are stained or have some type of coating/fill.

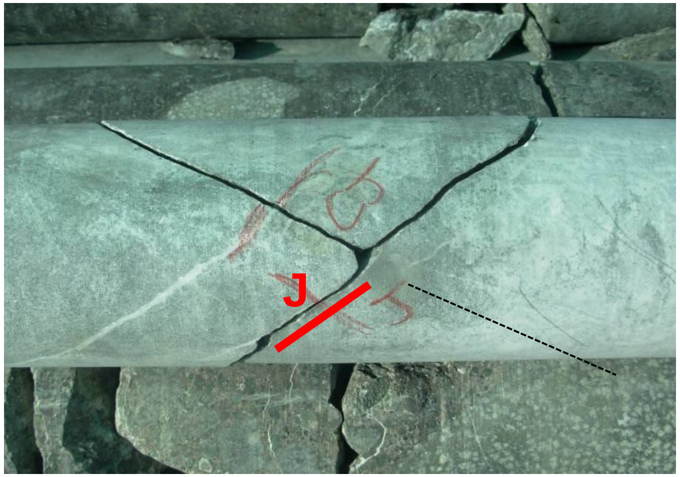
JOINT IDENTIFICATION (page 2 of 2)



- No Tensile Strength: Joints separate solid (intact) core pieces and exhibit no tensile strength, and;
- Freshness: Joints tend not to look fresh and often are stained or have some type of coating/fill.

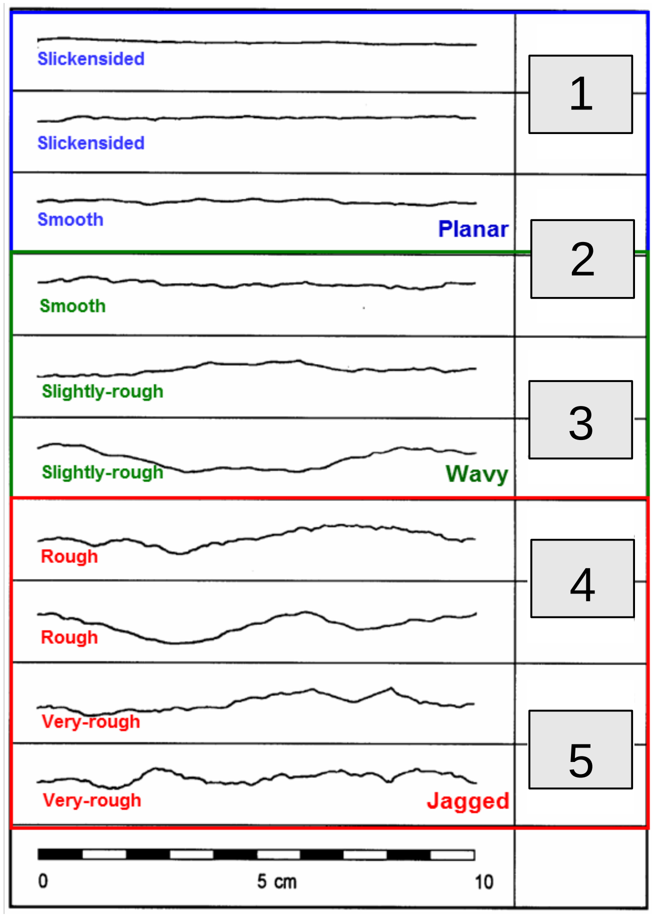
DRILL-BREAKS VERSUS JOINTS





- Heavy-handling after the drilling process can induce damage that looks like a joint, however it is unlikely to have drill-mud and/or rock flour on the joint-face;
- The differences in edge-sharpness, surface-fill, orientation, and staining can assist in differentiating these.

DEFECTS AND JOINT CONDITIONS



Roughness	
Very-rough	5
Rough	4
Slight-rough	3
Smooth	2
Slicken	1

Weathering	
None	5
Slight	4
Mod	3
High	2
Decomp	1

Fill Strength	
None	5
Hard < 5 mm	4
Hard > 5 mm	3
Soft < 5mm	2
Soft > 5 mm	1

Aperture (mm)	
None	5
< 0.1 mm	4
0.1 – 1 mm	3
1 – 5 mm	2
>5 mm	1

MD – Quantity	
None	0
Minor	1
Moderate	2
Intense	3

MD – Strength	
Never Breaks	0
Sometimes breaks	1
Always Breaks	2

JOINT ANGLE

- For detailed geotechnical logging, joint angle (alpha and beta-angles) and joint conditions need to be measured for each of the main discontinuity classes encountered;
- This angle is measured from the core-axis, looking down-hole. For example, 0° is parallel to the core axis;
- For geotechnical purposes, concentrate on the J and FJ classes. Remembering that only Js and FJs are considered when determining the length of solid core for RQD, and;
- Where core-orientation is not available, the alpha-angle and joint conditions still need to be evaluated.

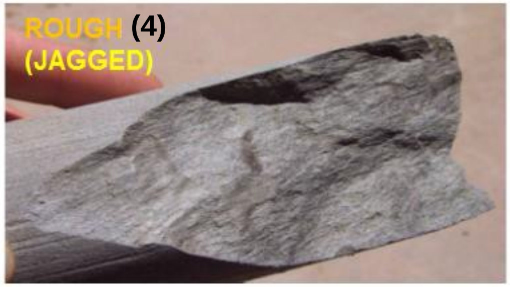
JOINT ROUGHNESS EXAMPLES


SLICKENSIDED (1)
(PLANAR)


SMOOTH (2)
(PLANAR)


SMOOTH (3)
(WAVY)


SLIGHLTY ROUGH (3)
(WAVY)


ROUGH (4)
(JAGGED)


VERY ROUGH (5)
(JAGGED)

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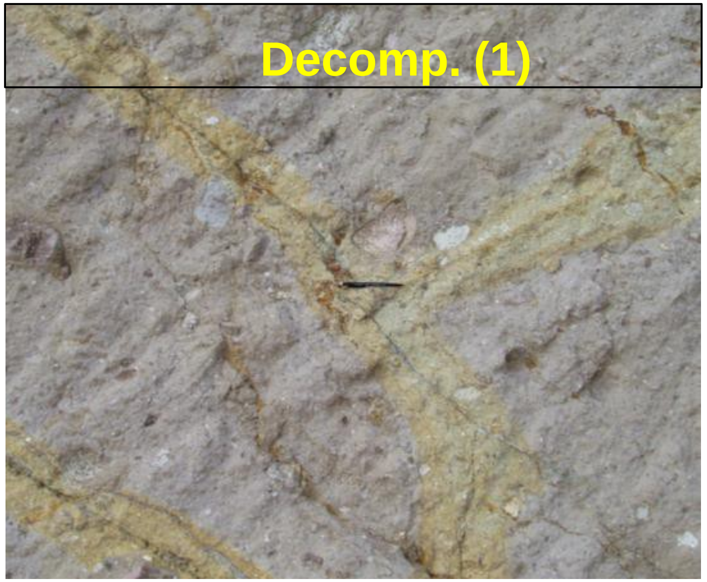
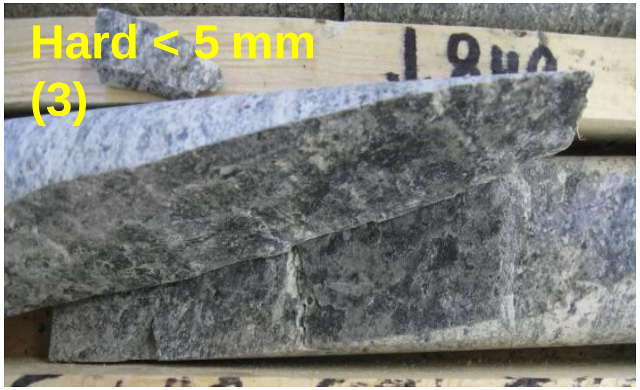
NORTHERN
TERRITORY
GOVERNMENT

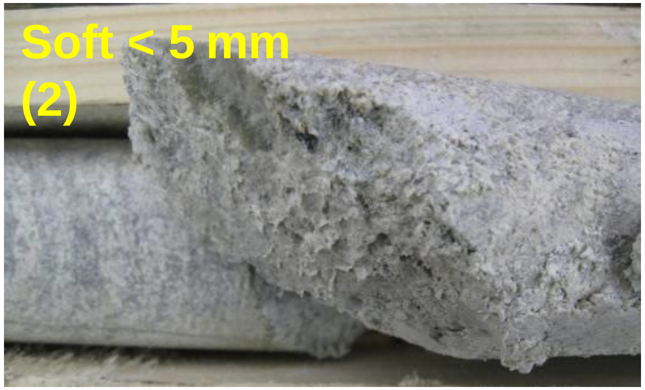
JOINT WEATHERING EXAMPLES



- Joint wall weathering results form fluids moving along the joint and altering the surrounding rock composition, and;
- It is the immediate back-wall of the joint that is considered for this parameter.

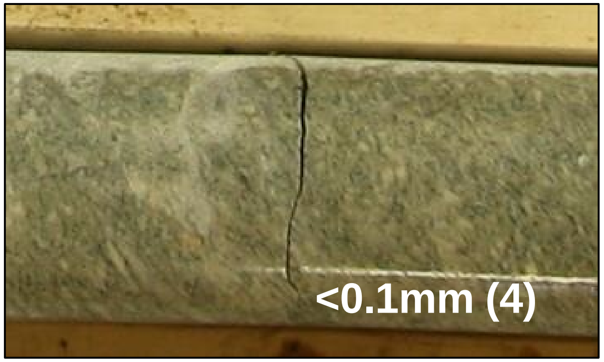
JOINT FILL TYPE EXAMPLES

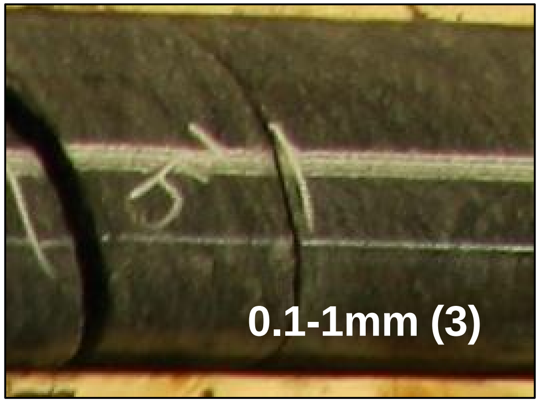


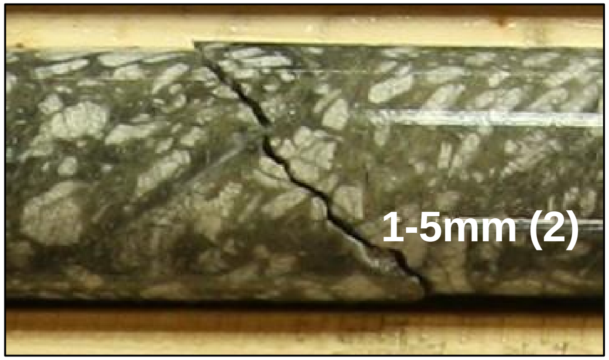


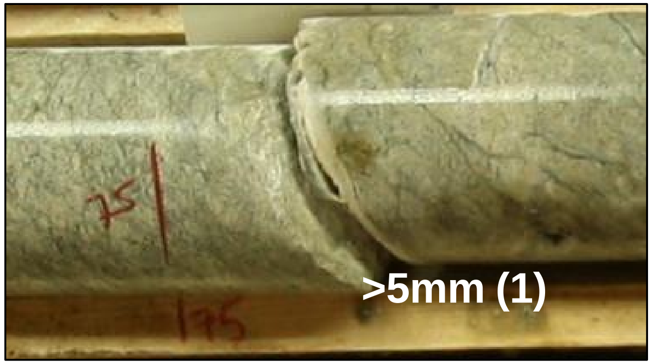
- Joint fill and type of fill needs to be recorded for each joint logged in the drill run, and;
- Fill strength is based on softening, or non-softening material types, gouge, staining, and by the width of the material. In essence; hard or soft, more or less than 5 mm.

JOINT APERTURE EXAMPLES



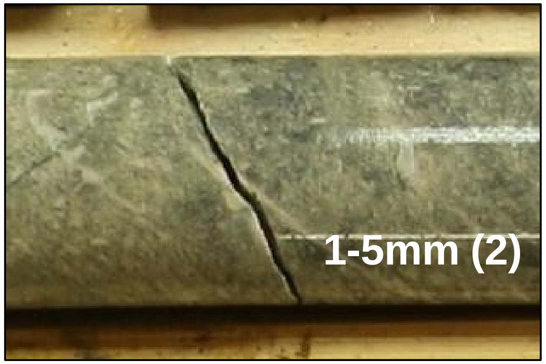






Joint aperture measures the openness of the joint.

Estimated based on how tight the joint fits back together



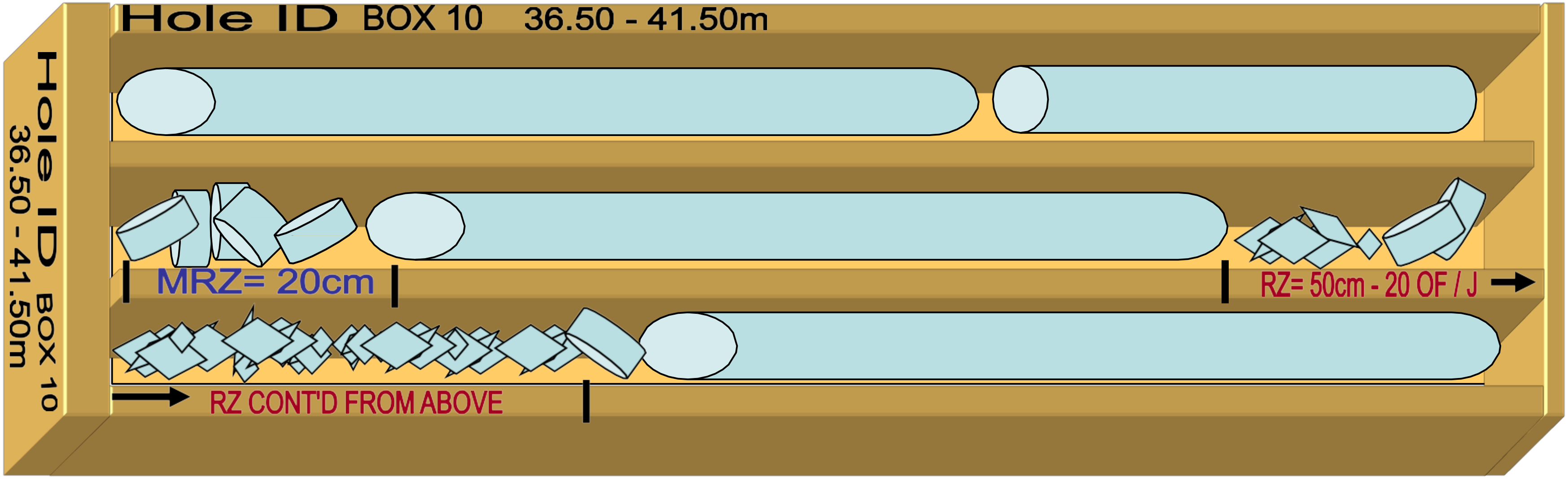
JOINT-SET ALLOCATION NOTES

1. All joints measured (J), measured fabric joints (FJ) and calculated joints (J's from rubble zones and weak rock) must be placed in the "Js" column;
2. Joint conditions should be estimated if measured joints do not exist within the interval;
3. The convention, when estimating is not possible, is to 'borrow' joint conditions from the overlying run or domain;
4. Joints (J) and fabric joints (FJ) should be split between J_1, J_2 and J_3 based on alpha angle (J_1 = 0-30, J_2 = 30-60, and J_3 = 60-90);
5. Calculated joints (e.g. fault related broken zones) must be placed in J_4 set.

Joint Parameters

- Use the mode (i.e. the most common value) for each of the four joint parameters (i.e. roughness, weathering, etc.)

ZONES OF BROKEN ROCK

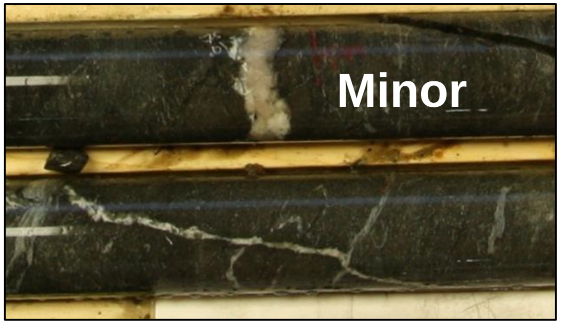


- Rubble zones (RZ) should include all natural damage (possibly around faults);
- If there is uncertainly as to whether it is a true rubble zone, or induced damage (MRZ), err on the side of caution and count it as a RZ;
- 3 Joints for each 10 cm of RZ is added to the joint-count;
- MRZ are caused by the drilling process, or induced during handling, look for signs of fresh breaks, and fresh surfaces of the pieces of core, and;
- Natural rubble zones are not considered ‘solid-core’ for the purposes of RQD measurements – MRZs are not.

MICRODEFECT NOTES

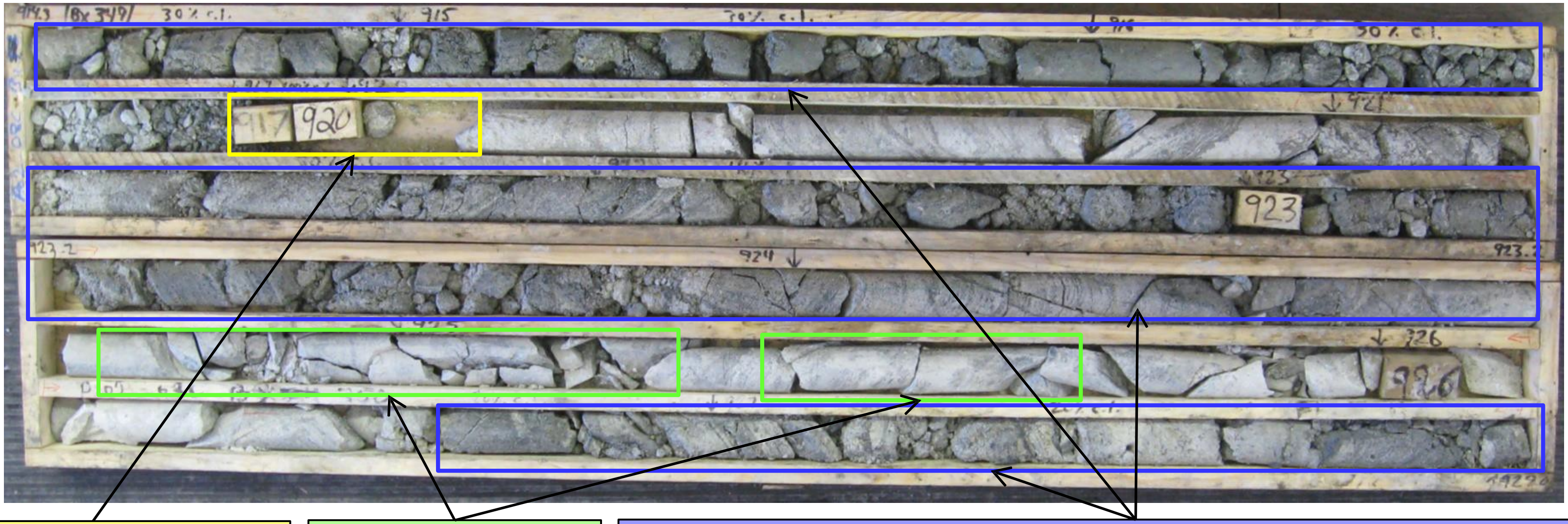
- As part of the detailed log, you need to rate the intensity of microdefects for run (if present). Microdefects include both veinlet/stringers (usually filled with carbonate or quartz), voids and/or very small (mm scale) fractures.

- The intensity of the microdefects in run is averaged over the run and rated as either:
  - 0 = **None**
  - 1 = **Minor**
  - 2 = **Moderate**
  - 3 = **Intense**



- The strength of the microdefects in run is averaged over the run and rated as either:
  - 0 = **Strong** (none of the MDs break)
  - 1 = **Moderate** (some of the MDs break)
  - 2 = **Weak** (all of the MDs break)

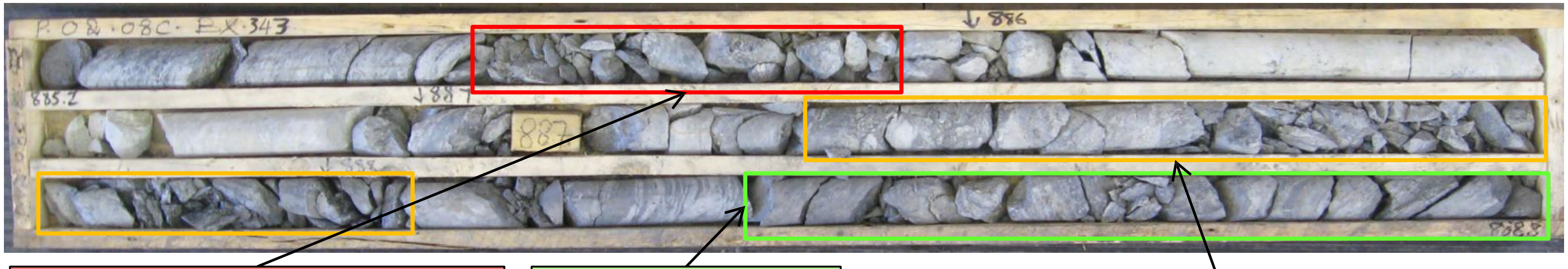
LOGGING EXAMPLES



Core Loss: Do not add joints for core loss. If an entire run has been lost, leave the parameters blank.

Drill-damage: Consider as intact core – check for indications of jointing.

R0 and R1 strength material: Add 4 joint per 10 cm to Joint Column and add calculated joints to a J-set. If no joints exist, estimate joint conditions. Use pocket penetrometer to record unconfined strength.



Natural rubble zone: Clayey gouge on fragments, shattered rock. Add 3 joints per 10 cm to Joint column and put calculated joints in a J-set.

Drill damage: Consider as intact core – check first for indications of jointing.

Breccia: Look for indications of weak matrix (if R0 or R1 add 4 joint per 10 cm to Joint column, estimate joint conditions and add to a J-set depending on the alpha angle); or if purely mechanical damage, consider as intact core.

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NORTHERN TERRITORY GOVERNMENT

DATA ENTRY FOR ROCK MASS LOG

HoleID	Run Number (n)	Logged by (Initials)	Date (YYYYMMDD)	from (m) run-length	to (m)	TCR (m)	SCR (m)	RQD (m)	IRSest-strong	Indentation Strong	Friability Strong	IRSest-weak (m)	Indentation Weak	Friability Weak	RM Weathering	MD Intensity	MD Strength	Litho-Code	F_All (n)	J-count (n)	FJ-count (n)	C-count (n)	Set-count (n)	Foliation Beta	Foliation Beta	OL Offset	OL Quality

Every drill-run (block to block) must be entered into the Rock Mass tab.

- **Hole** – Hole ID of current hole
- **Run No.** – Run number since the begging of the hole
- **Logger** – Initials of the Geotech(s)
- **Date** – Date of data collection (YYYYMMDD)
- **From (m)** – Start of the run
- **To (m)** – End of the run
- **TCR (m)** – Total core recovery in metres
- **SCR (m)** – Solid core recovery in metres
- **RQD (m)** – Rock Quality Designation "solid core" in metres
- o **IRSest Strong Code** – Strongest rock *(range: R0 to R6)*
- o **Strong Friability** – Friability Index for the IRS-strong.
- ▪ **IRSest Weak (m)** – Length of the IRS-weak zone;
- ▪ **IRSest Weak Code** – Descriptor for weak *(range: S0 to S6)*

- **MD Intensity** – Microdefect intensity *(range: 0-3)*
- **Litho-Code** – Lithology of the run (can be left for later)
- **F_All** – All open fractures in the core (except for handling {X} breaks). *Rubble zones (3 joins per 10 cm) are included here as well)*
- **J-count** – Total number of joints (including rubble zones)
- **FJ-count** – Total number of joints on fabric planes
- **C-count** – Total number of partial-joints
- **Foliation Alpha** – Average alpha angle of the foliation in the run (note: not just on breaks)
- **Foliation Beta** – Average Beta angle of the foliation in the run (note: not just on breaks)
- **OL Offset** – Offset of the OL to the previous run
- **OL Quality** – Assessment of the OL (good, fair, poor)
- **Comments** – If there is any additional information on the run

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NORTHERN TERRITORY GOVERNMENT

DATA ENTRY FOR ROCK MASS LOG CONT.

J-Sets (n)	J1 - count	J1 - Roughness	J1 - Weathering	J1 - Fill	J1 - Aperture	J2 - count	J2 - Roughness	J2 - Weathering	J2 - Fill	J2 - Aperture	J3 - count	J3 - Roughness	J3 - Weathering	J3 - Fill	J3 - Aperture	Comments

Every drill-run (block to block) must be entered into the Rock Mass tab.

- **J-Set** – This is a count of the number of joint sets which are present in the drill-run, and this is based on the alpha angle:
    - J1 – 1° to 30°
    - J2 – 31° to 60°
    - J3 – 61° to 90°
- **J* - count** – Total number of joints in a given set, and note that this also includes the rubble zone joints for J1
- **J* Roughness** – Typical roughness of the joint features in each set *(range: 1-5)*
- **J* Weathering** – Typical surface and back-wall weathering of the joints in each set *(range: 1-5)*
- **J* Fill** – Typical fill strength within the joint set (if any) *(range: 1-5)*
- **J* Aperture** – Estimated *in situ* aperture, between the upper and lower joint faces for each set *(range: 1-5)*

NOTE: The sum of J1..J3-count should be equal to the number entered in the “J-count” column.

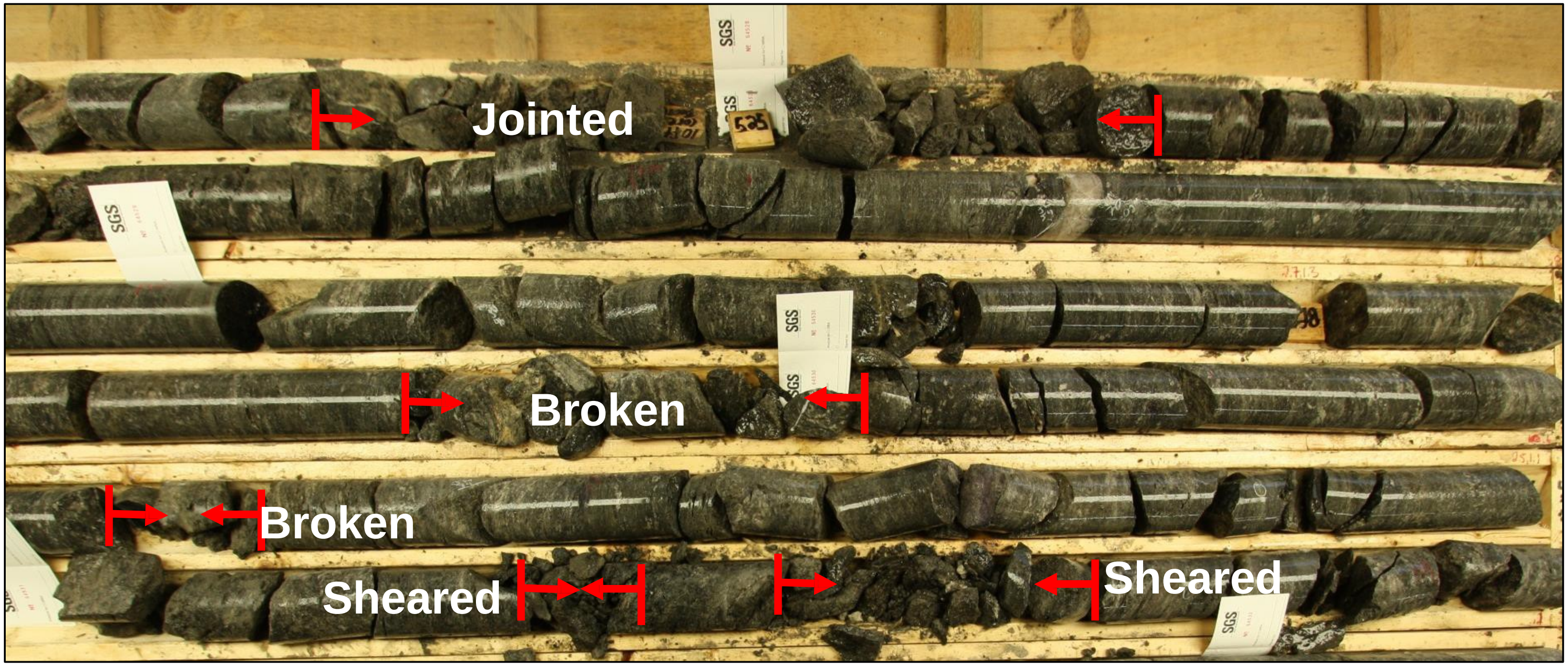
Detailed Oriented Core Logging

37) Rubble Zones (Possible Faults);
38) Rubble Zone Categories;
39) Data Entry for Rubble Zone Log;
40) Core Orientation;
41) Orientation Line Offset (1 of 2)
42) Orientation Line Offset (2 of 2);
43) Alpha and Beta Angles;
44) Measuring Alpha and Beta Angles (1 of 2)
45) Measuring Alpha and Beta Angles (2 of 2);
46) Data Entry for Oriented Log;

RUBBLE ZONES (POSSIBLE FAULTS)

- This log forms a summary of all rubble-zones (which are potentially brittle deformation structural features) along the length of the drill-hole;
- In some instances faults manifest themselves in rock core as rubble zones around faults or major structures, and this is what is being recorded;
- It should not be used to describe obvious mechanical damage or weaker rock – it is reserved for brittle deformation;
- It is used as a reference, or guide, during the detailed evaluation of the oriented core records to distinguish macro-structural features associated with faulting, and;
- This is not a substitute for, nor is it intended to be, a structural-geology log.

RUBBLE ZONE CATAGORIES



- Rubble zones are classified into four different categories:
  - **Gouge -** Containing mostly clay or very finely ground rock.
  - **Sheared -** Containing a mix of clay/finely ground rock with some larger core pieces.
  - **Jointed -** Core is fragmented but most of the core pieces are smaller than the core diameter.
  - **Broken -** Core is fragmented but most of the core pieces are larger than the core diameter.

DATA ENTRY FOR RUBBLE ZONE LOG

HoleID	Run No.	From (m)	To (m)	Alpha	Beta	J-count (n)	RZ Code	Roughness	Weathering	Fill Strength	Fill Type (mineral)	Aperture	Comment

- **Hole** – Hole ID of current hole
- **Run No.** – Run number since the begging of the hole (from the Rock Mass tab). *<u>Try to insure this is correct as it will save processing time during the QAQC process.</u>*
- **From (m)** – Start of the run
- **To (m)** – End of the run
- **Alpha** – Mode (most common) of the alpha angle of the features in the zone
- **Beta** – Mode (most common) of the beta angle of the features in the zone
- **Joint Count** – Total number of joint in this structure (3 joints per 10 cm)
- **RZ Code** – Description of the fragments making up the rubble (*options: FH, FG, FB, or FS*)
- **Roughness** – Mode of the Roughness of the joint feature *(range: 1-5)*
- **Weathering** – Mode of the Surface weathering of the joint feature *(range: 1-5)*
- **Fill** – Mode of the Fill strength of the fill in the joint (if any) *(range: 1-5)*
- **Fill Type** – Is the dominant mineral (if any) of the joint-fill material, for example CA (calcite)
- **Aperture** – Mode of the Size of the aperture between the two core pieces. This typically difficult to determine, so assume 5 when it is not possible to estimate *(range: 1-5)*
- **Comments** – Additional comments about the rubble zone

CORE ORIENTATION

- For angled holes, the drillers use a reflex product called an ACT or “Ace Tool” to determine the bottom of the hole for each run.
- They mark the bottom of the hole on the end of the core for that run.
- The geotech will use this mark to draw the bottom of hole orientation line on the core.
- From this information, we can measure the orientation of joint planes, called the ‘beta’ angles.

ORIENTATION LINE OFFSET

- If the orientation tool is being used correctly, and the logger ensures that the rock is matched together when the orientation line is drawn, the bottom-of-hole orientation lines marked on each run should correspond from one run to the next.

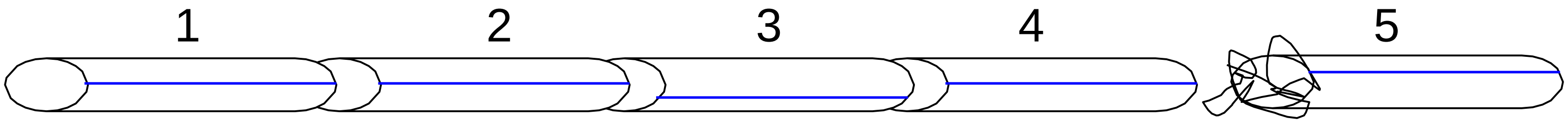
- If the lines do not match, there is an ‘offset’, which is measured in degrees around the core, from the current run’s line to the previous run’s line, in a clockwise direction looking down the hole.

- The offset is recorded as a number between zero and 360°:
  - Offset = 0 would indicate a perfect match between two orientation lines
  - Offset = 10 would indicate that the new run is rotated clockwise by 350 ° from the previous run (or that the previous run was 10° clockwise from the current run)
  - Offset = 350° would indicate that the new run is rotated clockwise by 10° from the previous run (or that the previous run was 350° clockwise from the current run)

ORIENTATION LINE OFFSET CONT.

- Please indicate if there is no OL available or the offset could not be determined because of the following reasons:
  - OL is marked on this run, but no offset could be measured because the run above did not have an orientation line. – NOS (no offset)
  - OL is marked on this run, but no offset could be measured because the core from the run above did not match well with this run. – NM (no match)
  - No OL for this run. – NA (not applicable)

- The logger should make a comment about the orientation line, including their confidence in the offset measured. For example, if a section of the run was broken and difficult to put together, the logger would indicate low confidence in the orientation for that run.



"0 offset"

"Offset 330. Correction of -330 needed. Operator error with tool?"

"Offset 30. Looks back on track again."

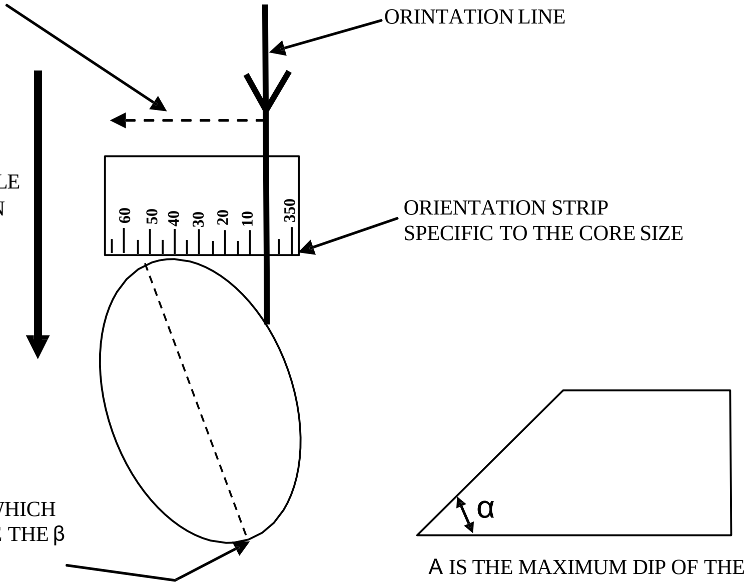
"OL but no match. Broken end."

Run No.	Ori. Offset
1	NA
2	0
3	330
4	30
5	NM

ALPHA AND BETA ANGLES

We measure two angles on each discontinuity:

- Alpha angles measure the joint dip, and are measured on every joint
- Beta angles measure orientation of the joint plane, and are only measured on joints with an orientation line



β IS MEASURED CLOCKWISE TO THE BOTTOM OF THE ELIPSE. IN THIS CASE IT IS ~232º

ORINTATION LINE

DOWN-HOLE DIRECTION

ORIENTATION STRIP SPECIFIC TO THE CORE SIZE

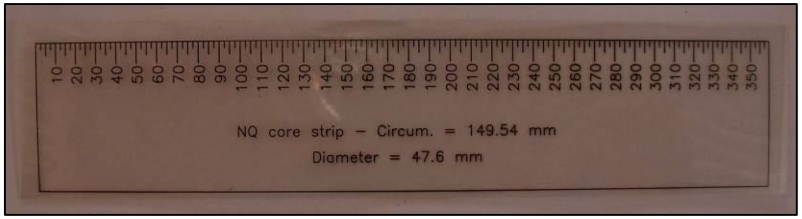
BOTTOM OF ELLIPSE TO WHICH WE MEASURE THE β ANGLE

Α IS THE MAXIMUM DIP OF THE JOINT/FEATURE, RELATIVE TO THE CORE AXIS

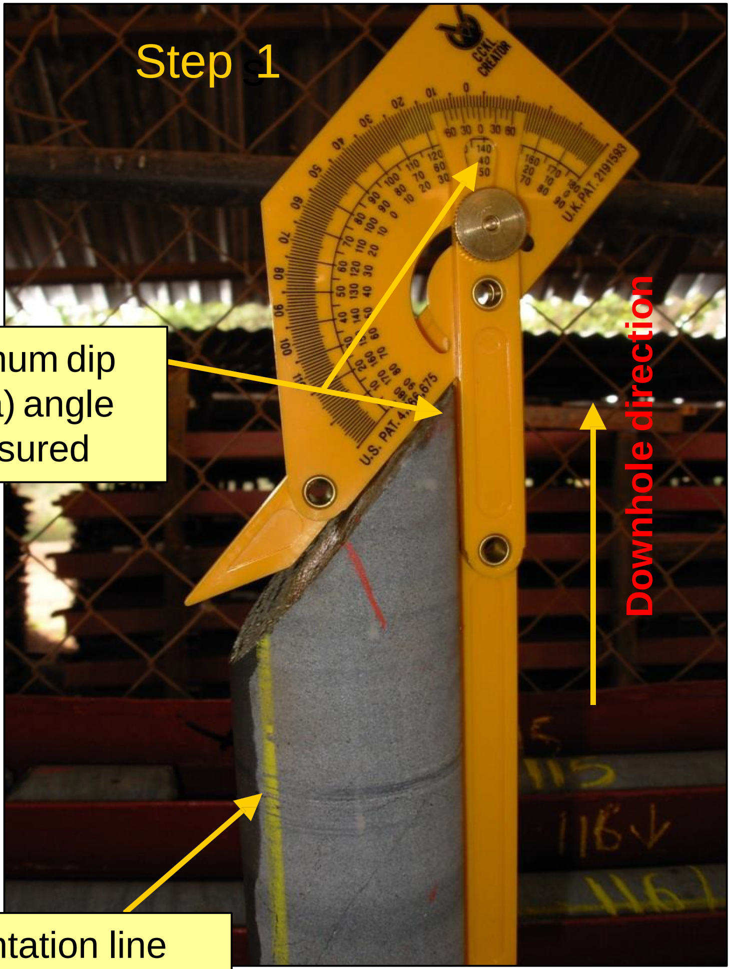
MEASURING ALPHA AND BETA ANGLES

○ Measuring the required orientation parameters is done using a graduated strip and a carpenters angle.

- **Alpha angle (α)**: the carpenter angle is used to measure the **maximum dip** (α) of the feature relative to the core axis.
- **Beta angle (β)**: The plastic calibrated strip is placed with the “0” on the orientation line of the same piece of core and the tape is wrapped clockwise around the core so that the 360º point returns to the orientation line. The angle (β) is then measured, **clockwise**, **from the orientation line to the most down hole part of the ellipse**.



MEASURING ALPHA AND BETA ANGLES



Maximum dip (alpha) angle measured

Orientation line (marked previously)

Beta angle is measured **clockwise** (in the **downhole direction**) around core from the orientation line

Alpha = 42° **Beta = 134°**

DATA ENTRY FOR ORIENTED LOG

HoleID	Run No.	Depth (m)	Alpha	Beta	Type (J, FJ, C)	Roughness	Weathering	Fill Strength	Fill Type (mineral)	Aperture	Comment

Every J, FJ, and C feature must be entered into the Oriented tab regardless of the orientation line presence/absence.

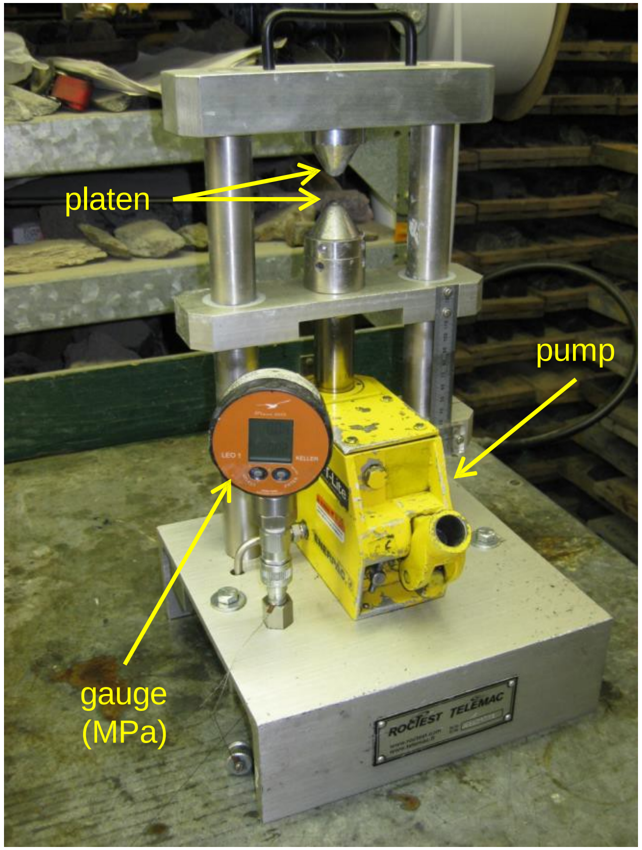
Data Fields

- **Hole** – Hole ID of current hole
- **Run No.** – Run number since the begging of the hole (from the Geotech tab)
- **Depth (m)** – Depth to the feature
- **Alpha** – Alpha angle of the feature
- **Beta** – Beta angle of the feature
- **Type** – J (joint), FJ (joint along fabric/foliation), or C (partial-joint)
- **Roughness** – Mode of the Roughness of the joint feature *(range: 1-5)*
- **Weathering** – Mode of the Surface weathering of the joint feature *(range: 1-5)*
- **Fill** – Mode of the Fill strength of the fill in the joint (if any) *(range: 1-5)*
- **Fill Type** – Is the dominant mineral (if any) of the joint-fill material, for example CA (calcite)
- **Aperture** – Mode of the Size of the aperture between the two core pieces. This typically difficult to determine, so assume 5 when it is not possible to estimate *(range: 1-5)*
- **Comments** – Additional comments about the rubble zone

ANCILLARY TESTING

48) Point Load Testing Overview;
49) Point Load Testing Procedure;
50) Point Load Testing, Test Types;
51) Point Load Testing, Platen Condition;
52) Point Load Testing, Foliation;
53) Point Load Testing, Test Result Reporting;
58) Data Entry for Point Load Testing;

POINT LOADING TESTING, OVERVIEW



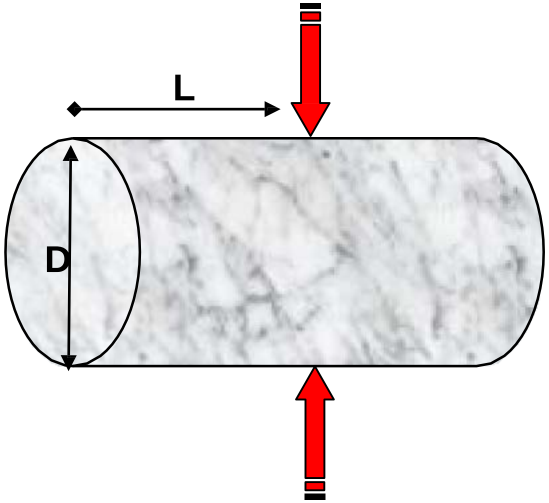
- The system consists of a point load testing unit connected to a hydraulic gauge reading unit or digital gauge;
- The point load tester consists of a hydraulic pump and a ram;
- The hydraulic ram can be adjusted to suit the size of core or grab sample being tested;
- The attached gauge is also for the evaluation of the loading rate. The failure load is also read from this unit – normally in MPa;
- Use 20 MPa on HQ-core as a maximum reference – at which stage the test should be abandoned, and;
- Record HoleID, depth (m), angle to foliation, diameter of core which is equal to the distance between platen (mm) for a diametral test, type of test, angle to foliation, maximum gauge pressure (MPa), and test failure-code.

POINT LOAD TESTING PROCEDURE

1. Always wear safety goggles;
2. Measure and mark the loading points on the core;
3. Open the relief valve and push down the platen to allow the core to be inserted;
4. Close the pump relief valve;
5. Press the **Select** and **Enter** buttons to turn the gauge system on;
6. Set the lower value close to zero by pushing **Enter**;
7. Place the core in the hydraulic ram and begin pumping;
8. Pump at a slow, even loading rate until the rock fails;
9. Note down the maximum load achieved, and;
10. Release the relief valve.

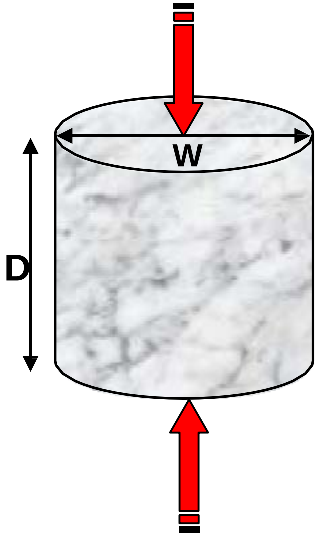
POINT LOADING TESTING, TEST TYPES

DIAMETRAL, TYPE-1



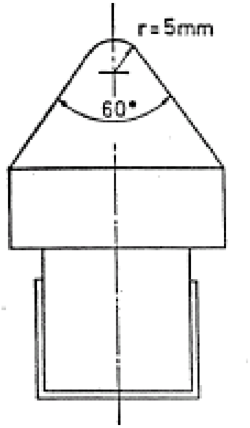
L > 0.6 D

AXIAL, TYPE-2



0.3W<D<W

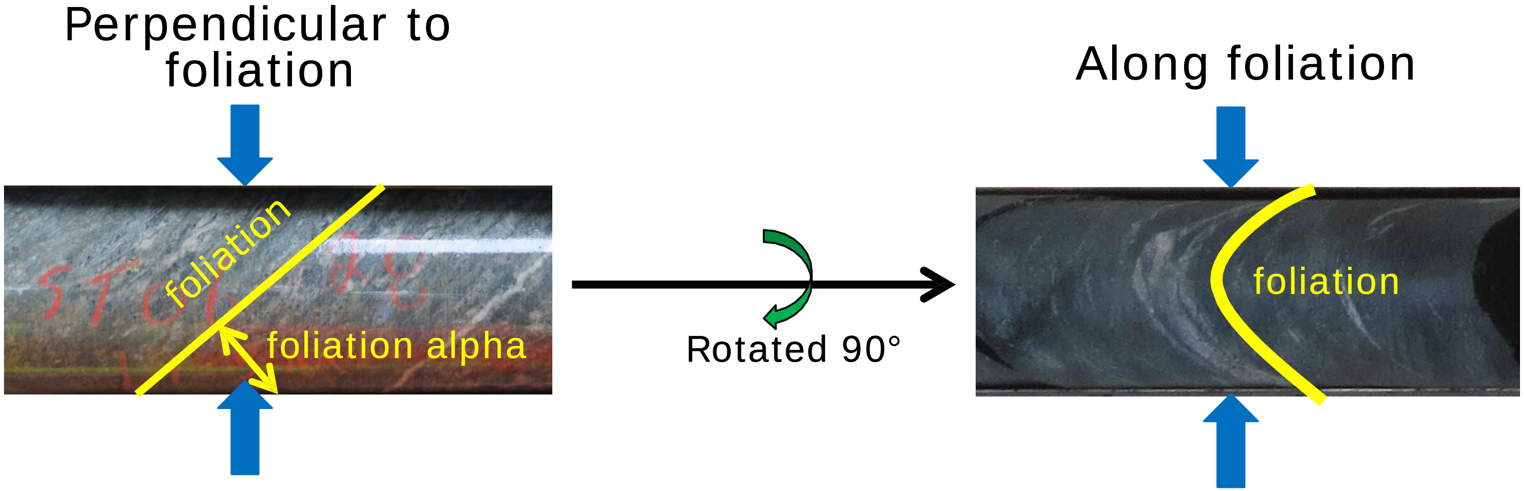
POINT LOADING TESTING, PLATEN CONDITION



- The points can be damaged by stronger rocks (> 200 MPa);
- Platen should be checked regularly for ‘flattening’ of the specified 5 mm radius;
- Flat platens generate excessively higher failure loads, and;
- Once these become too flattened (radius > 6 mm), the platens should be replaced.

POINT LOADING TESTING, FOLIATION

- When there is fabric in the rock, the point load test can be conducted parallel to the fabric (along foliation);
- The true material strength should be conducted to test the rock strength, not the fabric strength, thus a sample should be aligned so that the fabric is as perpendicular as possible to the platens. This is to be called perpendicular to foliation.



POINT LOADING TESTING, RESULT REPORTING

Test	Comment
T1	Good test (failed across diameter through intact rock)
T2	Failure along fabric (foliation/bedding; >50% along plane)
T3	Failure along CJ or vein (>50% along plane)
T4	Failed test; slipped, chipped or rock mass indent (soft)
T5	Refusal (>20MPa) for NQ and NQ3 core

DATA ENTRY FOR POINT LOAD TESTING

Hole_ID	Depth (m)	Penetrometer (kg/cm2)	PP Foot? (Y/N)	Core Diameter (mm)	TestType (1/2)	Foliation	Foliation Angle	Gauge Pressure (MPa)	Failure Code (T1..T5)	Test Quality	Laboratory Sample Match	TestBy (Initials)	Date (YYYYMMDD)	Comment

Data Fields

- **Hole** – Hole ID of current hole
- **Depth (m)** – Depth to the feature – no duplicates allowed (i.e. each test needs to have a unique depth in each hole)
- **Penetrometer** – If strength test is in weak material enter the maximum pressure attained for three independent ‘pushes’
- **PP Foot?** – If the pocket penetrometer ‘foot’ was added for very soft material, indicate this in this field **Y** or **N**
- **Core Diameter** – Diameter of the core measured in millimetres to one decimal place
- **Test Type** – Axial (along the core axis, 2) or diametral (across the core axis, 1)
- **Foliation** – Approximate direction of the foliation relative to the core axis (parallel or perpendicular)
- **Foliation Angle** – Alpha angle of the foliation relative to the core axis
- **Gauge Pressure** – Gauge reading of the point load test after failure (abort tests at 20 MPa)
- **Failure Mode** – Code of how the sample failed (T1, T2, T3, T4, T5)
- **Test Quality** – General description of the quality of the test (good, fair, poor).
- **Laboratory Sample Match** – Will be filled out by SRK site-senior
- **Test By**– Initials of the person doing the test
- **Date** – Date of data collection (YYYYMMDD)
- **Comment** – Additional information about the test if relevant

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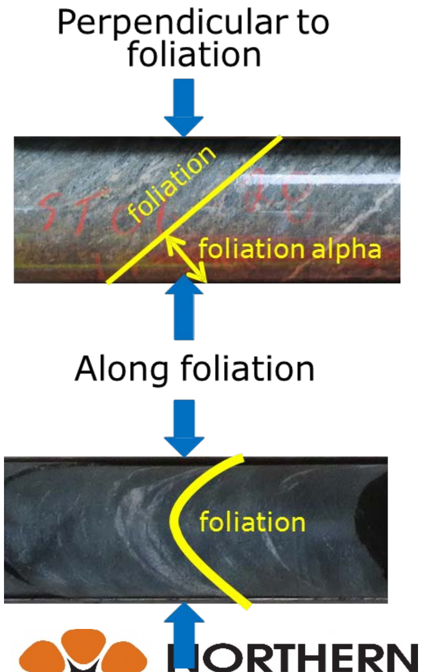
NORTHERN TERRITORY GOVERNMENT

REFERENCE CHEAT-SHEETS

56) Cheat Sheet for Point Load Tests;
57) Cheat Sheet for Joints and RM Descriptors;

Test Type	Veining/Defect Intensity	Failure Mode	Test Quality	PLT Failure Type
Diametral	None	Planar	Good	T1 = failed across intact rock, not along pre-existing feature or no break
Axial	Minor	Chipped	Fair	T2 = failed along fabric (foliation/bedding; >50% along plane)
	Moderate	Slipped	Poor	T3 = failed along existing weakness (microdefect, CJ)
	Intense	Dented		T4 = slipped during testing, chipped or rockmass at less than 5MPa
		No Break		T5 = Refusal (>20 MPa)
		Existing Plane		NA = no result provided, broke before testing etc



J Roughness	
Very-rough	5
Rough	4
Slight-rough	3
Smooth	2
Slicken	1

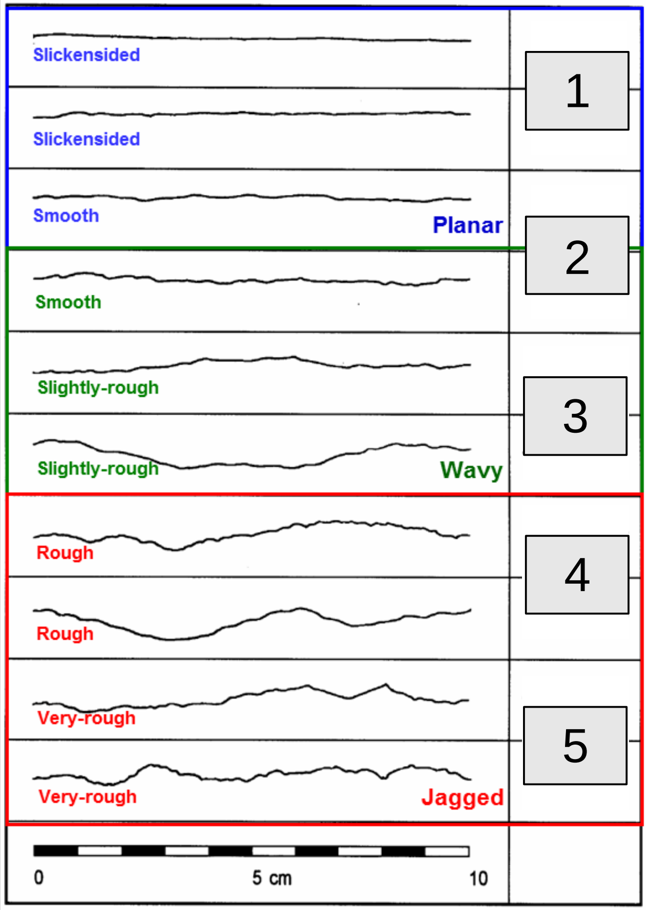
J Weathering	
None	5
Slight	4
Mod	3
High	2
Decomp	1

J Aperture (mm)	
None	5
< 0.1 mm	4
0.1 – 1 mm	3
1 – 5 mm	2
>5 mm	1

J Fill Strength	
None	5
Hard < 5 mm	4
Hard > 5 mm	3
Soft < 5mm	2
Soft > 5 mm	1

MD – Quantity	
None	0
Minor	1
Moderate	2
Intense	3

MD – Strength	
Never Breaks	0
Sometimes breaks	1
Always Breaks	2



Index Abrv.	Description	Field Test	Approximate Range Uniaxial Compressive Strength (MPa)
R0	Extremely Weak	Indented by Thumbnail	0.25 - 1.0
R1	Very Weak	Crumbles under firm blow of geologic hammer pick, peeled by pocket knife	1.0 - 5.0
R2	Weak	Shallow indentation under firm blow of pick end of geologic hammer	5.0 - 25
R3	Medium Strong	Fractured with single firm blow of geologic hammer	5 - 50
R4	Strong	Requires more than one blow of hammer to fracture	50 - 100
R5	Very Strong	Requires many blows of hammer to fracture	100 - 250

Reminders:

1) TCR – Sum of all measurable recovered core in one drill run or ‘domain-break’;
2) SCR – Length of all core pieces larger than one core diameter along axis;
3) RQD – Solid-core length for the run, which excludes pieces in which the joints are < 0.1 m apart, and/or are rubble zones;
4) Weak-R must have a lower rating than Strong-R;
5) If R0 or R1, then include 4 J per 10 cm of run-length into J4;
6) If R0, use pocket penetrometer to test strength, and;
7) The orientation line (OL) is always marked on the LOW-SIDE of the rock core.

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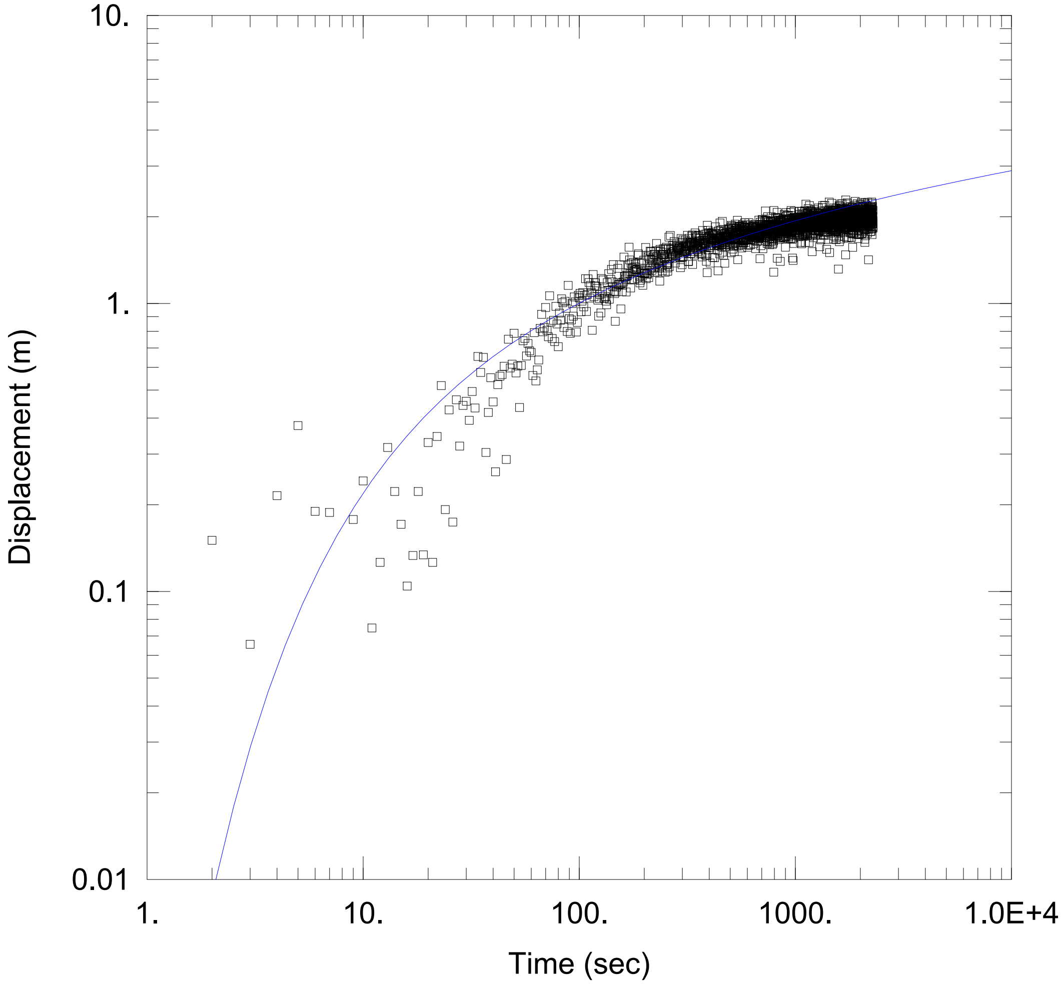
NORTHERN TERRITORY GOVERNMENT

Appendix D – Pumping Testing Field Sheets



TEST 1

Data Set: C:\Users\jcheang\Desktop\Working files\Rum Jungle\Rum_Jungle_18DH01-01_Rev01.aqt
Date: 05/17/19 Time: 16:13:54

PROJECT INFORMATION

Company: SRK Consulting
Location: Rum Jungle
Test Well: 18DH01

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
New Well	0	0

Observation Wells

Well Name	X (m)	Y (m)
□ New Well	0	0

SOLUTION

Aquifer Model: Confined

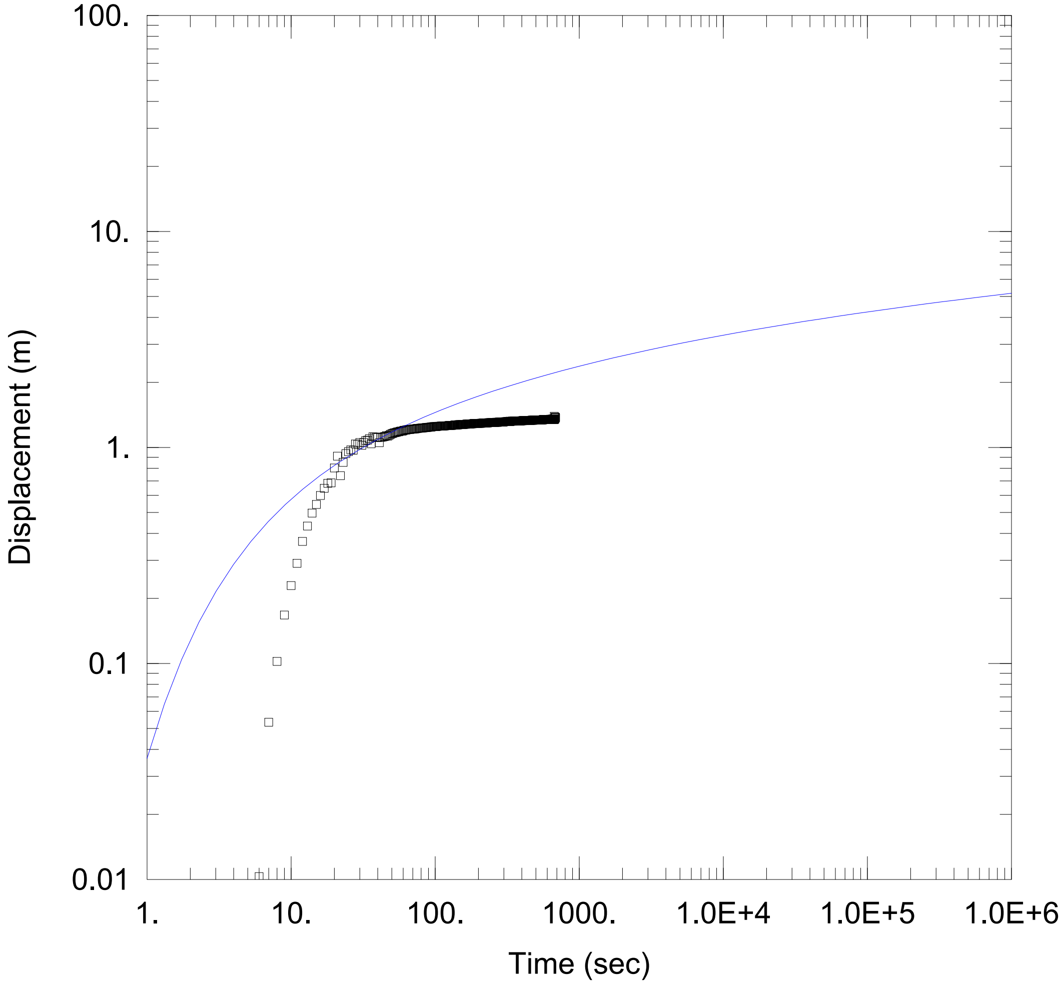
Solution Method: Theis

T = 1.922E-5 m^2/sec

S = 17.53

Kz/Kr = 1.

b = 14.72 m



WELL TEST ANALYSIS

Data Set: \...\Rum_Jungle_18DH01-02_dv.aqt
Date: 05/17/19 Time: 16:26:03

WELL DATA

Pumping Wells		
Well Name	X (m)	Y (m)
New Well	0	0

Observation Wells		
Well Name	X (m)	Y (m)
□ New Well	0	0

SOLUTION

Aquifer Model: Confined

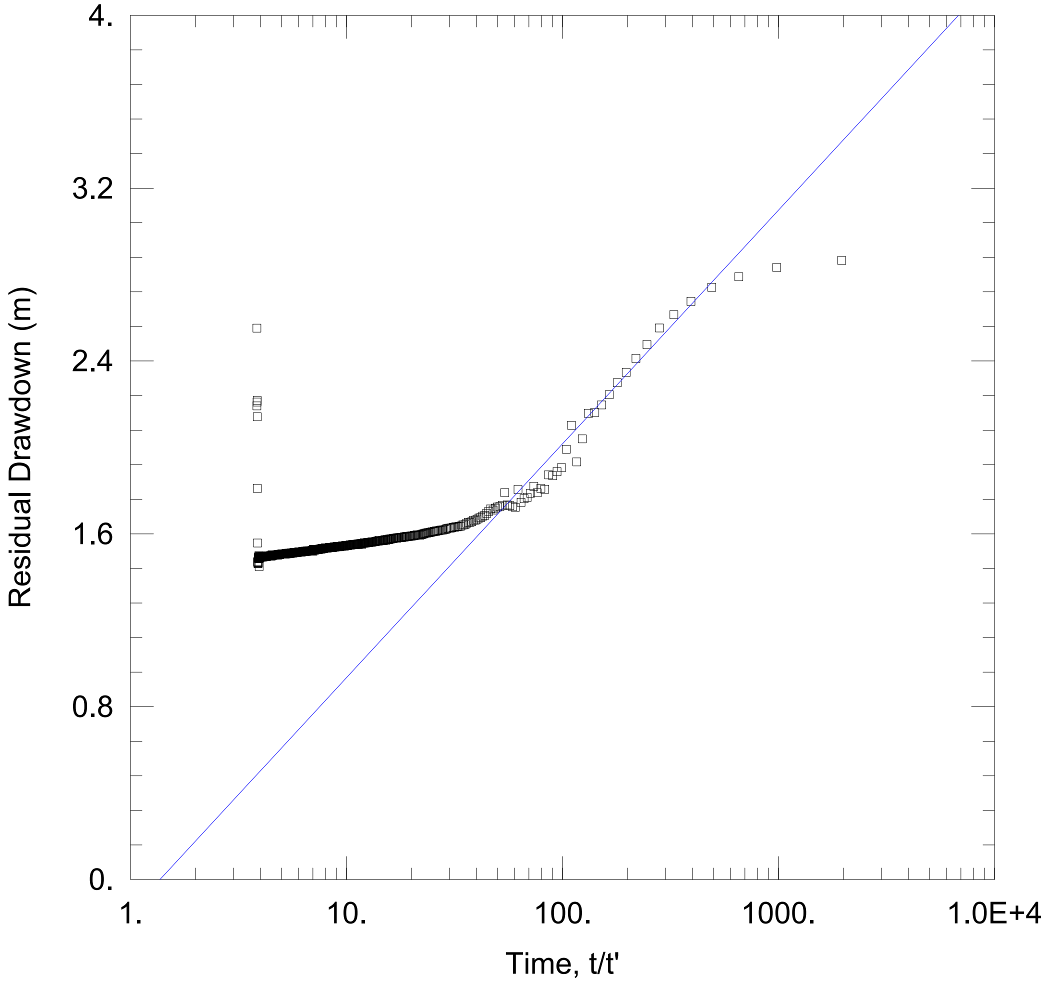
Solution Method: Theis

T = 5.314E-5 m^2/sec

S = 14.51

Kz/Kr = 1.

b = 49. m



WELL TEST ANALYSIS

Data Set: C:\Users\jcheang\Desktop\Working files\Rum Jungle\Rum_Jungle_18DH01-02_Rev01.aqt
Date: 05/21/19 Time: 11:50:39

AQUIFER DATA

Saturated Thickness: 49. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
New Well	0	0

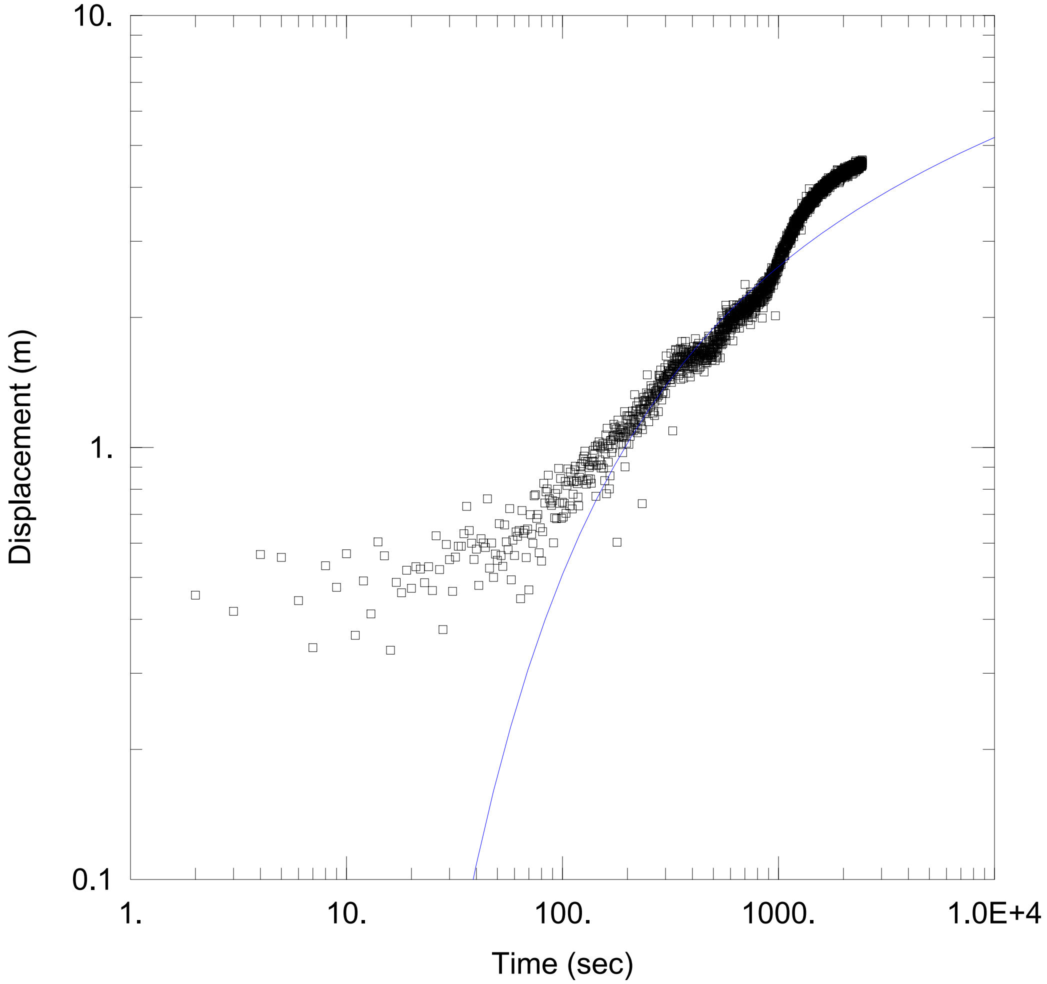
Observation Wells

Well Name	X (m)	Y (m)
□ New Well	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 4.911E-5 m^2/sec S/S' = 1.371



TEST 1

Data Set: C:\Users\jcheang\Desktop\Working files\Rum Jungle\Rum_Jungle_18DH02-01_Rev01.aqt
Date: 05/17/19 Time: 16:27:04

PROJECT INFORMATION

Company: SRK Consulting
Location: Rum Jungle
Test Well: 18DH02

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
New Well	0	0

Observation Wells

Well Name	X (m)	Y (m)
□ New Well	0	0

SOLUTION

Aquifer Model: Confined

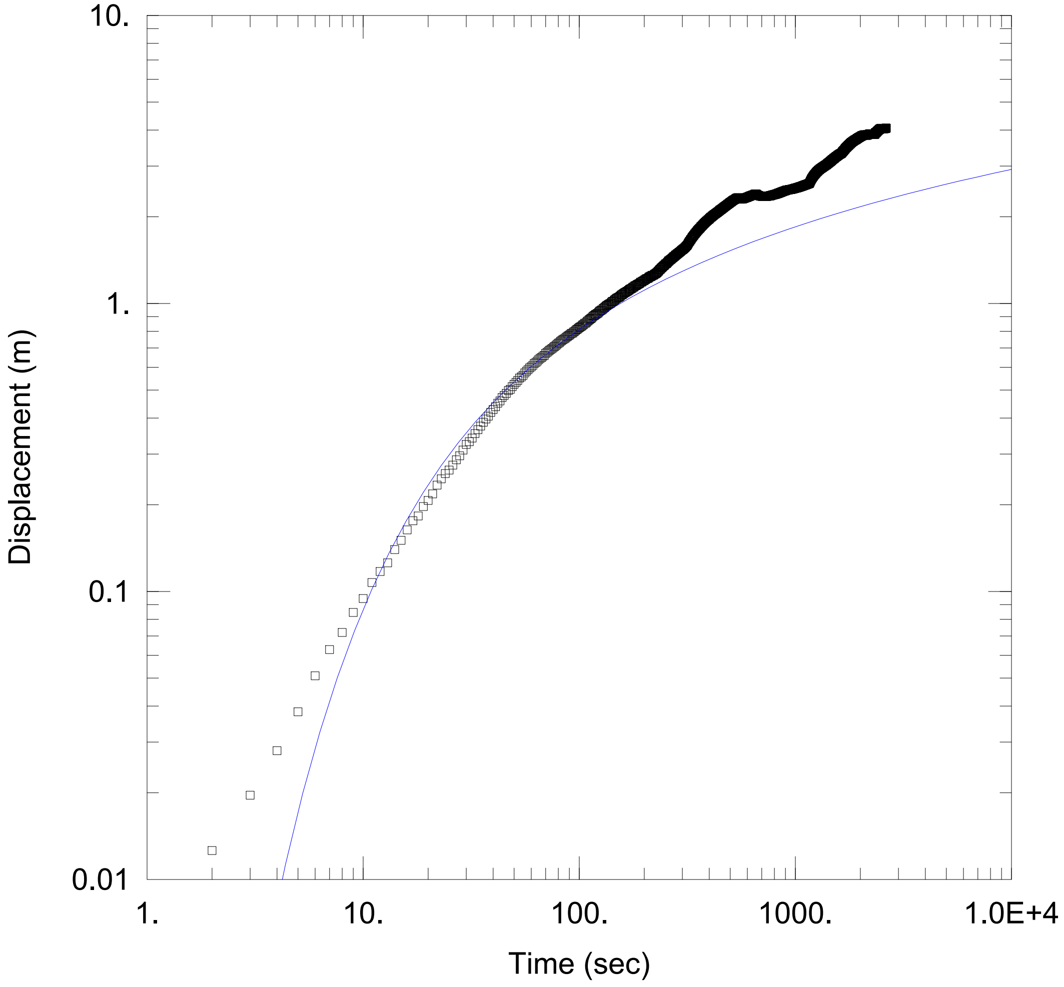
Solution Method: Theis

T = 4.481E-6 m^2/sec

S = 47.89

Kz/Kr = 1.

b = 19.4 m



WELL TEST ANALYSIS

Data Set: \...\Rum_Jungle_18DH02-02.aqt
Date: 05/21/19 Time: 11:10:47

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
New Well	0	0

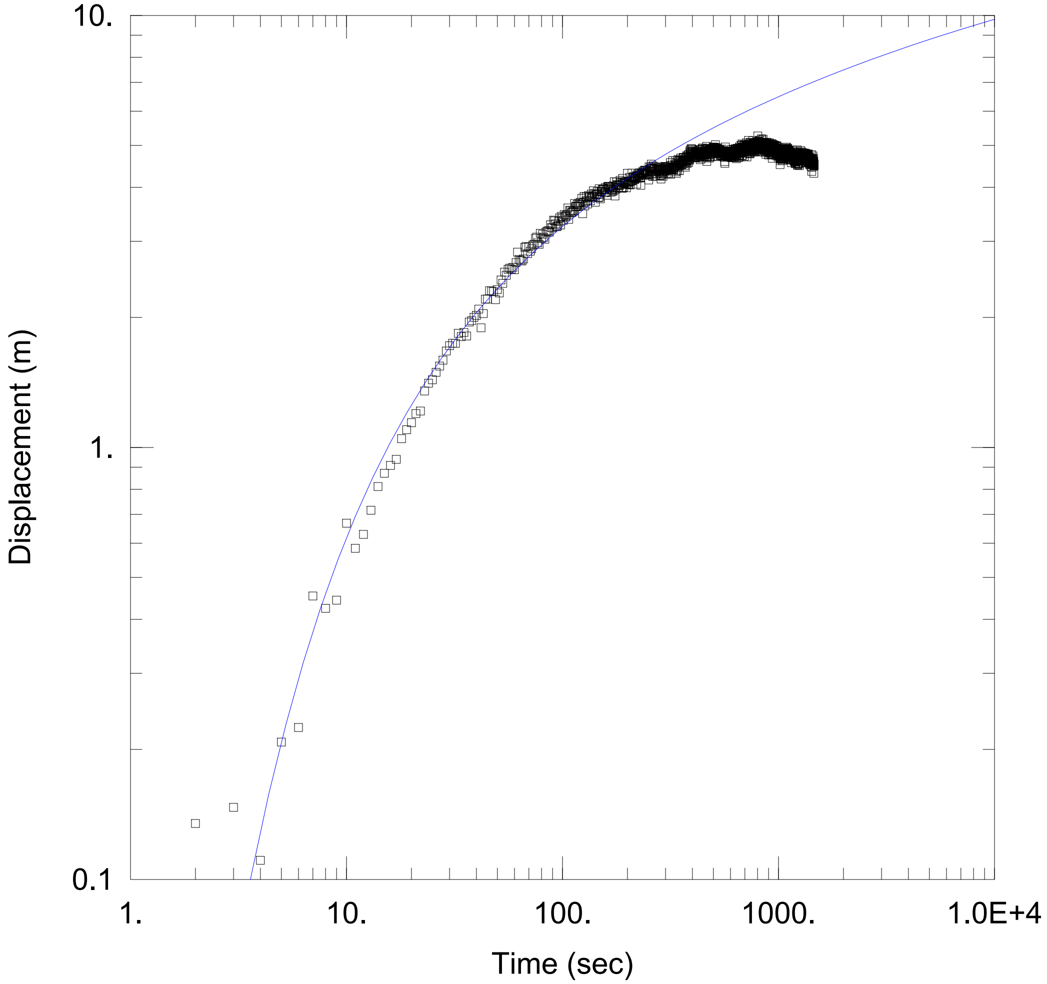
Observation Wells

Well Name	X (m)	Y (m)
□ New Well	0	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 2.888E-5 m^2/sec
S = 55.36
Kz/Kr = 1.
b = 44.23 m



WELL TEST ANALYSIS

Data Set: C:\Users\jcheang\Desktop\Working files\Rum Jungle\Rum_Jungle_18DH03-01.aqt
Date: 05/17/19 Time: 16:27:50

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
New Well	0	0

Observation Wells

Well Name	X (m)	Y (m)
□ New Well	0	0

SOLUTION

Aquifer Model: Confined

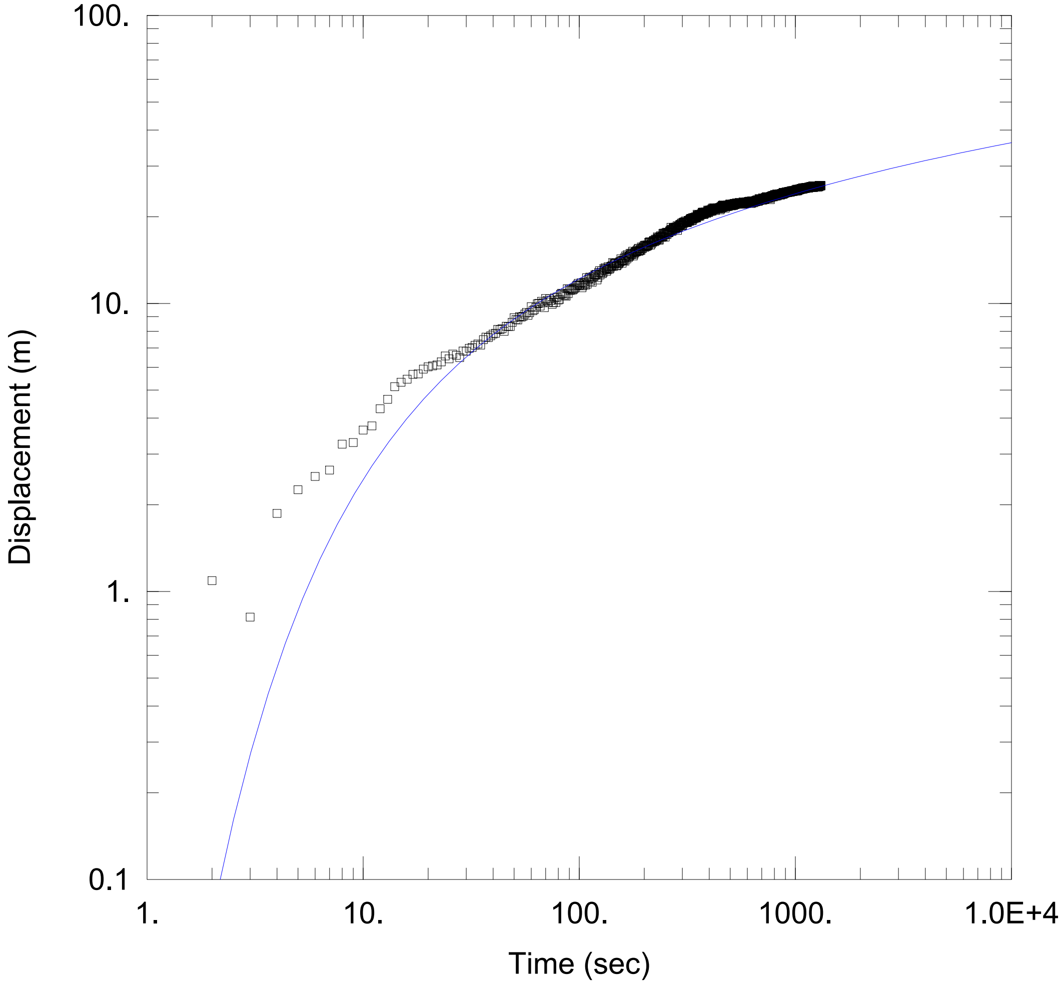
Solution Method: Theis

T = 8.832E-6 m^2/sec

S = 9.645

Kz/Kr = 1.

b = 20.3 m



WELL TEST ANALYSIS

Data Set: C:\Users\jcheang\Desktop\Working files\Rum Jungle\Rum_Jungle_18DH03-02.aqt
Date: 05/17/19 Time: 16:28:05

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
New Well	0	0

Observation Wells

Well Name	X (m)	Y (m)
□ New Well	0	0

SOLUTION

Aquifer Model: Confined

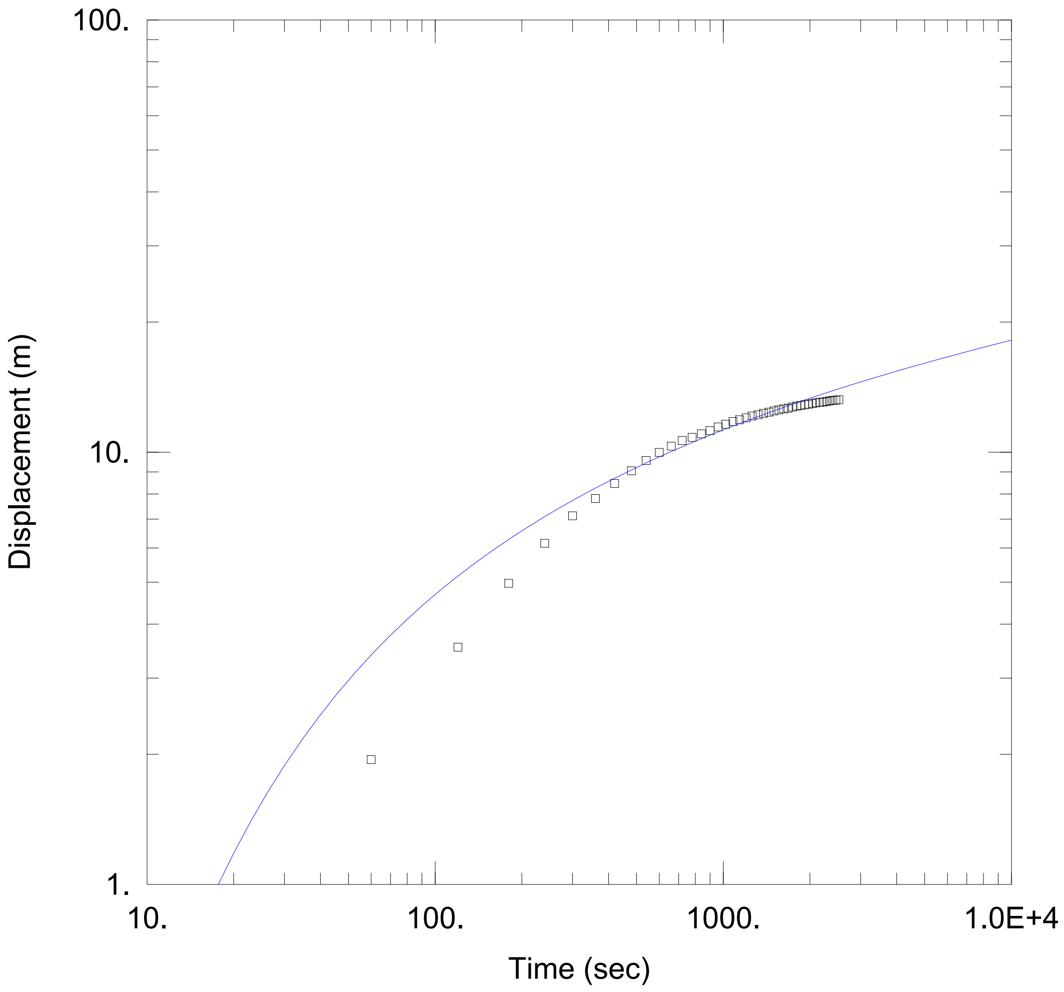
Solution Method: Theis

T = 2.869E-6 m^2/sec

S = 2.935

Kz/Kr = 1.

b = 40.36 m



WELL TEST ANALYSIS

Data Set: C:\Users\jcheang\Desktop\Working files\Rum Jungle\Rum_Jungle_18DH03-03.aqt
Date: 05/17/19 Time: 16:28:20

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
New Well	0	0

Observation Wells

Well Name	X (m)	Y (m)
□ New Well	0	0

SOLUTION

Aquifer Model: Confined

Solution Method: Theis

T = 5.29E-6 m^2/sec
S = 12.38
Kz/Kr = 1.
b = 75.9 m

Appendix E – VWP Calibration Certificates

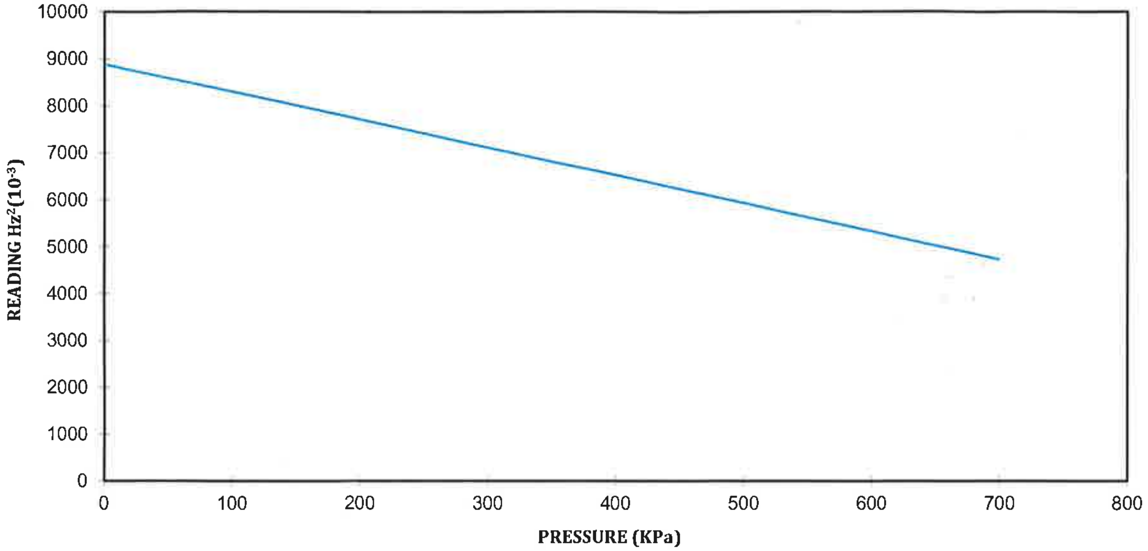
Calibration Sheet

HMA GEOTECHNICAL

CLIENT : DEP OF PRIMARY INDUSTRY & RESOURCES **JOB No:** GSA-62229
SERIAL : 24434
RATING : 700 KPa **DATE:** 20/12/2017

SHEET: 1

Vibrating Wire Piezometer Calibration Results



FACTORY ZERO READING :	8887	$Hz^2(10^{-3})$		
PRESSURE COEFFICIENT :	0.16800	$KPa/Hz^2(10^{-3})$	----------	(C_P)
AMBIENT TEMPERATURE :	24	°C		
THERMAL COEFFICIENT :	-0.02932	KPa/°C	----------	(C_T)

SEE INSTRUCTION MANUAL FOR STANDARD TEMPERATURE/THERMISTOR DATA

MAXIMUM PRESSURE :	1050	kPa
BAROMETRIC PRESSURE :	1008	hPa
OPERATING TEMPERATURE RANGE :		-30°C to +65°C

PORE PRESSURE = $(F_0-F_1)C_P + (T_1-T_0)C_T$

(F_0) & (T_0) TO BE ESTABLISHED DURING INSTALLATION

Calibration Sheet

HMA GEOTECHNICAL

CLIENT : DEP OF PRIMARY INDUSTRY & RESOURCES

JOB No: GSA-62229

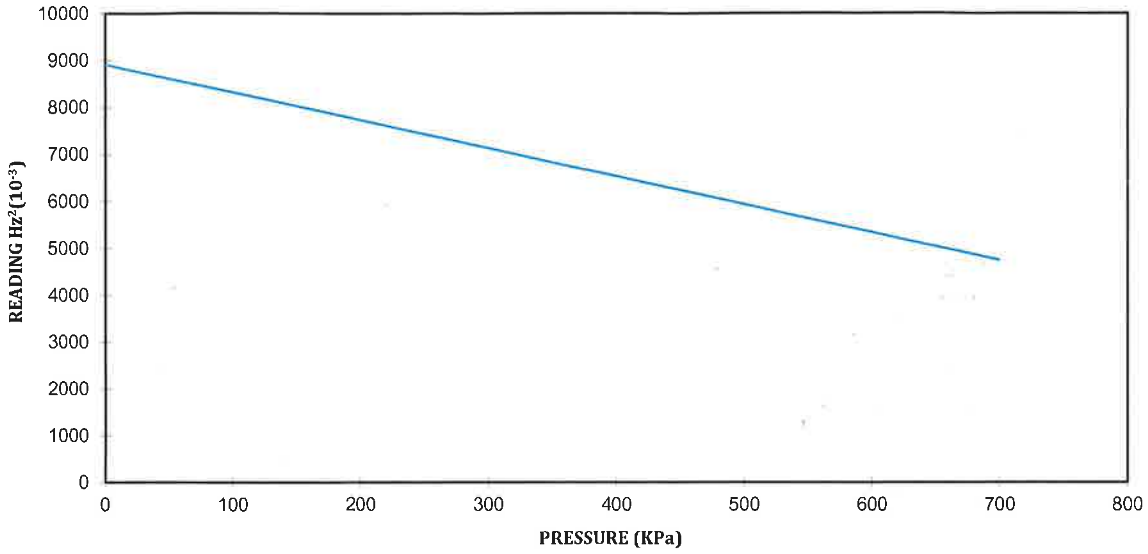
SERIAL : 24435

RATING : 700 KPa

DATE: 20/12/2017

SHEET: 2

Vibrating Wire Piezometer Calibration Results



FACTORY ZERO READING : 8919 $Hz^2(10^{-3})$

PRESSURE COEFFICIENT : 0.16740 $KPa/Hz^2(10^{-3})$ ---------- (C_P)

AMBIENT TEMPERATURE : 24 ^oC

THERMAL COEFFICIENT : -0.05707 $KPa/^oC$ ---------- (C_T)

SEE INSTRUCTION MANUAL FOR STANDARD TEMPERATURE/THERMISTOR DATA

MAXIMUM PRESSURE : 1050 kPa

BAROMETRIC PRESSURE : 1008 hPa

OPERATING TEMPERATURE RANGE : -30^oC to $+65^oC$

$$\textbf{PORE PRESSURE} = (F_0-F_1)C_P + (T_1-T_0)C_T$$

(F_0) & (T_0) TO BE ESTABLISHED DURING INSTALLATION

Calibration Sheet

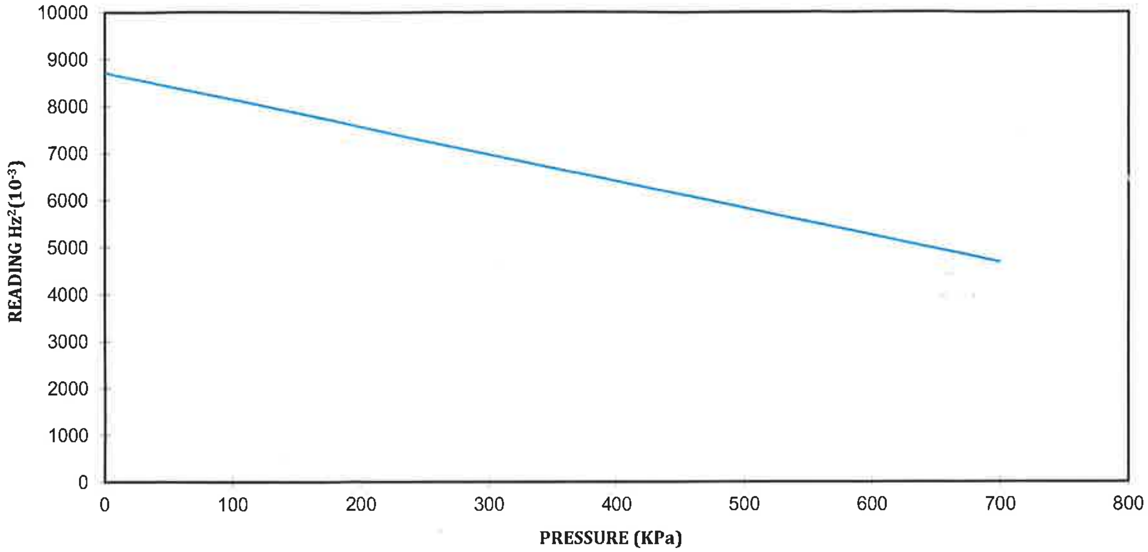
CLIENT : DEP OF PRIMARY INDUSTRY & RESOURCES
SERIAL : 24436
RATING : 700 KPa

JOB No: GSA-62229

DATE: 20/12/2017

SHEET: 3

Vibrating Wire Piezometer Calibration Results



FACTORY ZERO READING :	8718	Hz^2(10^{-3})	
PRESSURE COEFFICIENT :	0.17340	KPa/Hz^2(10^{-3}) ----------	(C_P)
AMBIENT TEMPERATURE :	24	°C	
THERMAL COEFFICIENT :	-0.07744	KPa/°C ----------	(C_T)

SEE INSTRUCTION MANUAL FOR STANDARD TEMPERATURE/THERMISTOR DATA

MAXIMUM PRESSURE :	1050	kPa
BAROMETRIC PRESSURE :	1008	hPa
OPERATING TEMPERATURE RANGE :		-30°C to +65°C

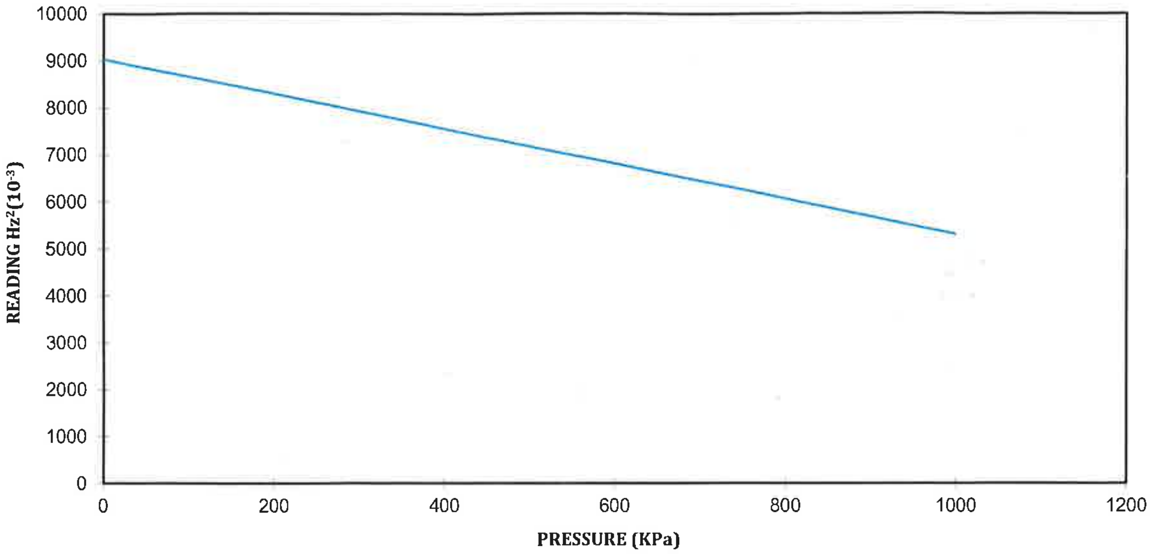
PORE PRESSURE = $(F_0-F_1)C_P + (T_1-T_0)C_T$

(F_0) & (T_0) TO BE ESTABLISHED DURING INSTALLATION

Calibration Sheet

CLIENT :	DEP OF PRIMARY INDUSTRY & RESOURCES	**JOB No:**	GSA-62229
SERIAL :	24608		
RATING :	1000 KPa	**DATE:**	20/12/2017
		SHEET:	4

Vibrating Wire Piezometer Calibration Results



FACTORY ZERO READING : 9015 $Hz^2(10^{-3})$

PRESSURE COEFFICIENT : 0.26810 $KPa/Hz^2(10^{-3})$ ---------- (C_P)

AMBIENT TEMPERATURE : 24 °C

THERMAL COEFFICIENT : 0.05803 KPa/°C ---------- (C_T)

SEE INSTRUCTION MANUAL FOR STANDARD TEMPERATURE/THERMISTOR DATA

MAXIMUM PRESSURE : 1500 kPa

BAROMETRIC PRESSURE : 1008 hPa

OPERATING TEMPERATURE RANGE : -30°C to +65°C

$$\textbf{PORE PRESSURE} = (F_0-F_1)C_P + (T_1-T_0)C_T$$

(F_0) & (T_0) TO BE ESTABLISHED DURING INSTALLATION

Calibration Sheet

HMA GEOTECHNICAL

CLIENT : DEP OF PRIMARY INDUSTRY & RESOURCES

SERIAL : 24609

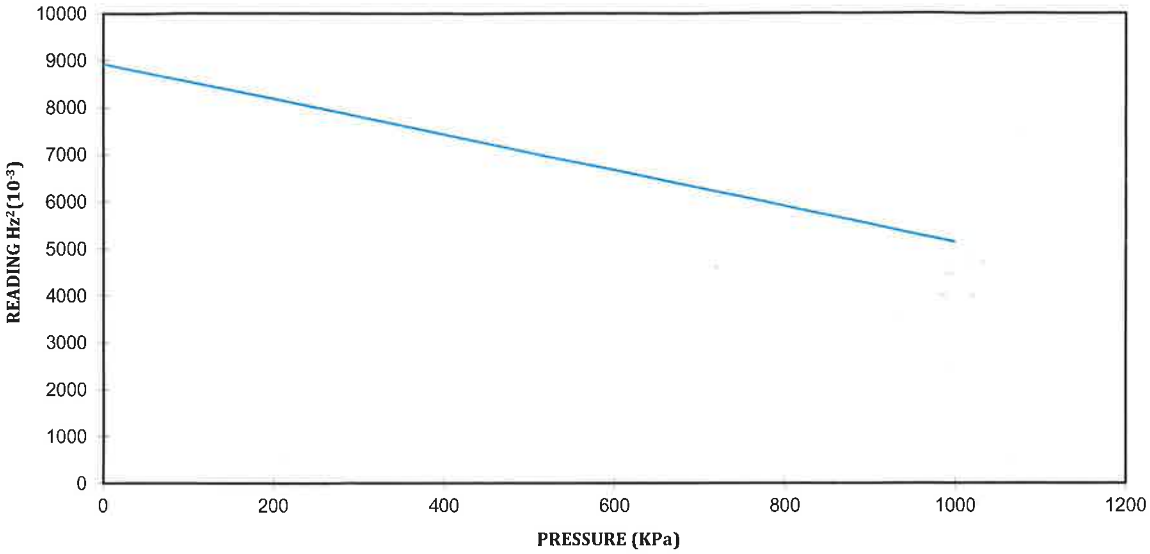
RATING : 1000 KPa

JOB No: GSA-62229

DATE: 20/12/2017

SHEET: 5

Vibrating Wire Piezometer Calibration Results



FACTORY ZERO READING :	8901	$Hz^2(10^{-3})$		
PRESSURE COEFFICIENT :	0.26280	$KPa/Hz^2(10^{-3})$	----------	(C_P)
AMBIENT TEMPERATURE :	24	°C		
THERMAL COEFFICIENT :	0.06663	KPa/°C	----------	(C_T)

SEE INSTRUCTION MANUAL FOR STANDARD TEMPERATURE/THERMISTOR DATA

MAXIMUM PRESSURE :	1500	kPa
BAROMETRIC PRESSURE :	1008	hPa
OPERATING TEMPERATURE RANGE :	-30°C to +65°C	

$$\textbf{PORE PRESSURE} = (F_0-F_1)C_P + (T_1-T_0)C_T$$

(F_0) & (T_0) TO BE ESTABLISHED DURING INSTALLATION

Calibration Sheet

HMA GEOTECHNICAL

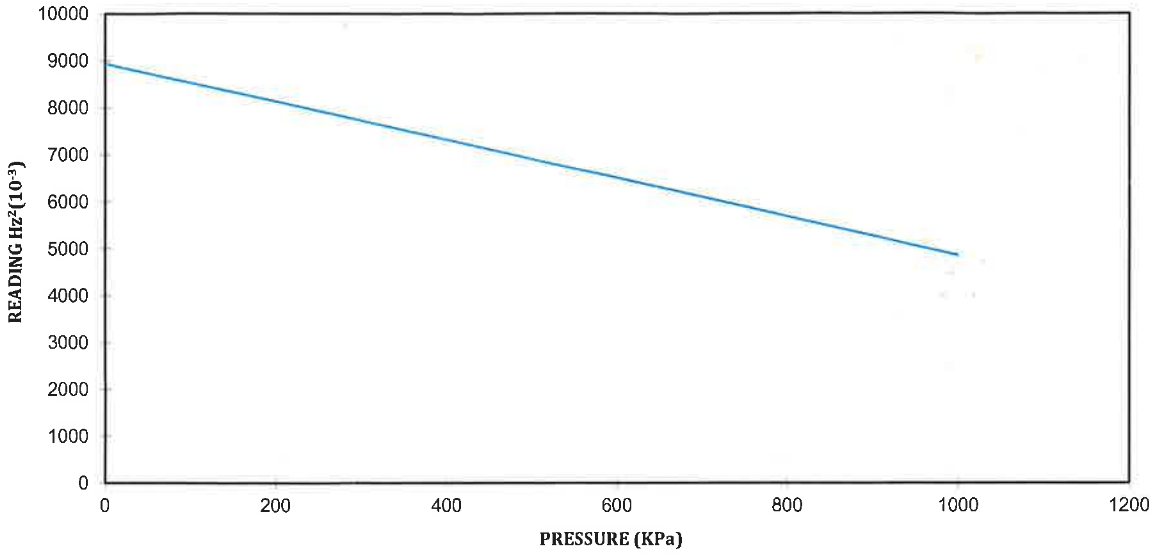
CLIENT : DEP OF PRIMARY INDUSTRY & RESOURCES
SERIAL : 24610
RATING : 1000 KPa

JOB No: GSA-62229

DATE: 20/12/2017

SHEET: 6

Vibrating Wire Piezometer Calibration Results



FACTORY ZERO READING :	8912	$Hz^2(10^{-3})$		
PRESSURE COEFFICIENT :	0.24470	$KPa/Hz^2(10^{-3})$	----------	(C_P)
AMBIENT TEMPERATURE :	24	°C		
THERMAL COEFFICIENT :	0.09930	KPa/°C	----------	(C_T)

SEE INSTRUCTION MANUAL FOR STANDARD TEMPERATURE/THERMISTOR DATA

MAXIMUM PRESSURE :	1500	kPa
BAROMETRIC PRESSURE :	1008	hPa
OPERATING TEMPERATURE RANGE :	-30°C to +65°C	

$$\textbf{PORE PRESSURE} = (F_0 - F_1)C_P + (T_1 - T_0)C_T$$

(F_0) & (T_0) TO BE ESTABLISHED DURING INSTALLATION