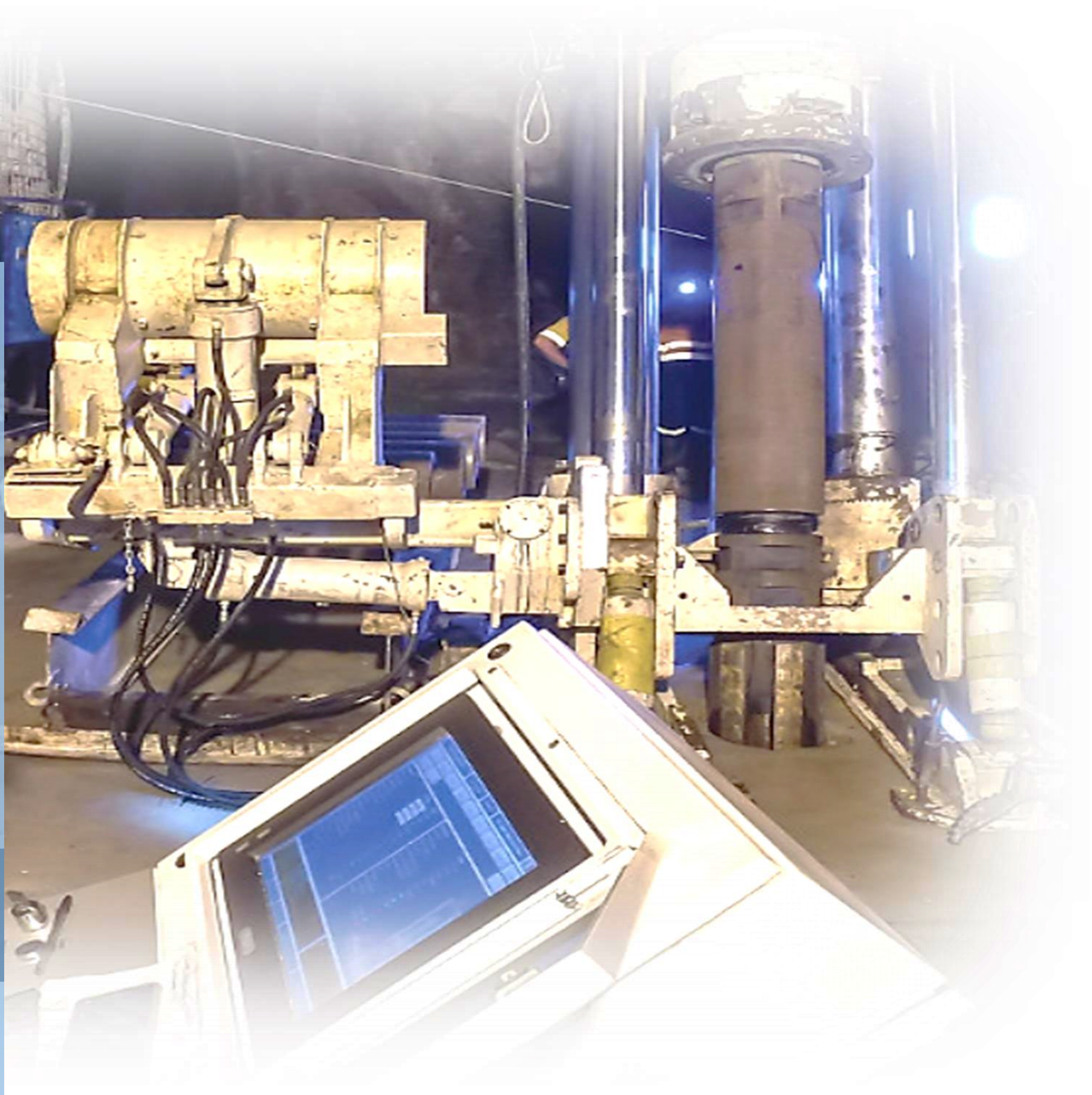
Raisebore Stability Assessment of an upcast ventilation shaft

Case study of an underground mine



I. Introduction

I.I Outline, methodology and objective

- An exhaust vent raise will be a raise bored with a final diameter of 4.5m and a length of 201m.

- A geotechnical investigation for the proposed 4.5m diameter raise bore has been completed. The investigation incorporated the 201m long dedicated geotechnical drill hole. However, it was found that there was hole deviation from a down hole depth 80m to 201m (EOH) which resulted in the hole being offset by 13m away from the planned bottom of the raise bore, (this is equivalent to less than 3m raise bore diameters away)

- As a result of this, it was decided that the geotechnical investigation would incorporate geotechnical data collected from multiple drill holes that were identified as additional and relevant sources of data to supplement the data from the geotechnical drill hole.

- The objective of this report is to provide a geotechnical stability assessment for raise boring based on the industry standard practice methods established by McCracken & Stacey (1989).

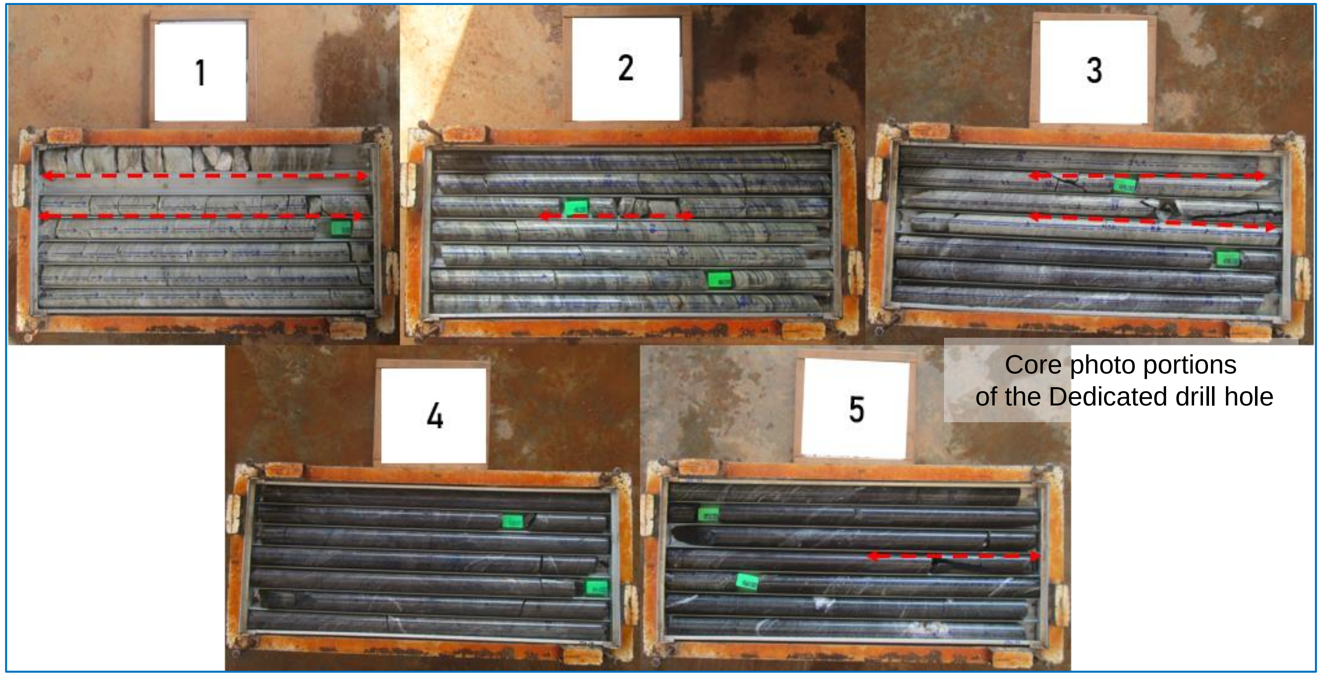
II. KUG001 Geotechnical Logging

Table 1: Summary results of the geotechnical logging of 1 hole

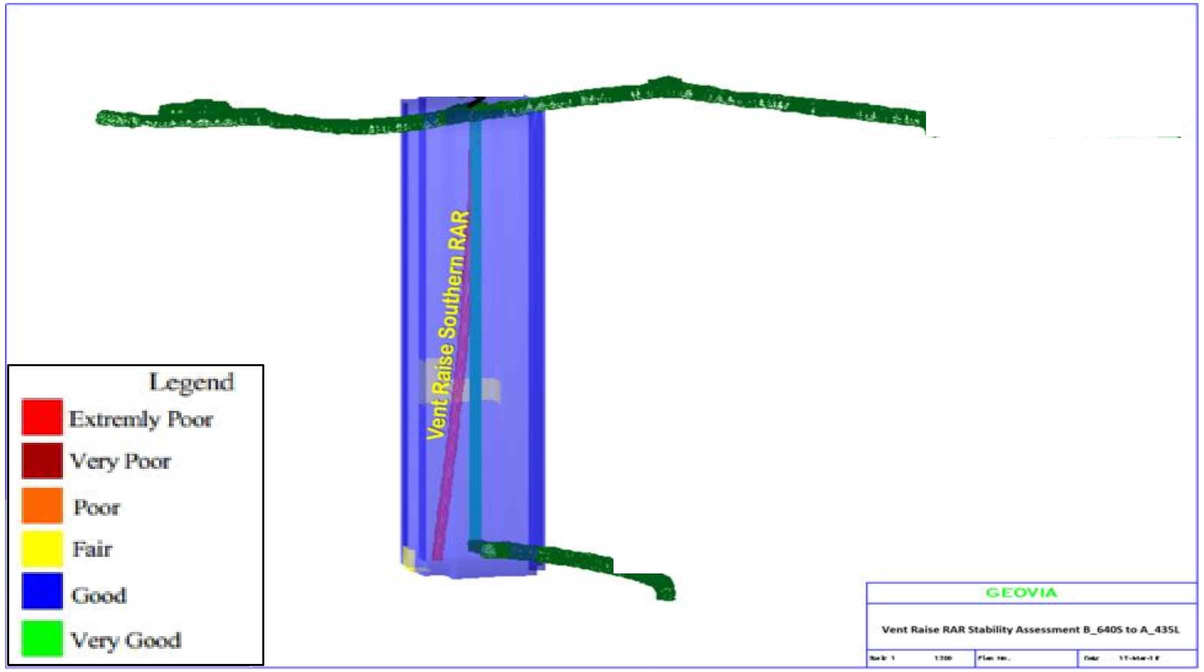
From	To	RQD	RQD_Jn	Jr_Ja	Jw_SRF	Q	Qr	Span_max
0	89.4	98.5	10.9	1.5	0.4	6.6	11.1	5.5
89.4	93	100.0	16.7	1.5	0.4	10.0	16.9	6.5
93	122	98.6	16.4	1.0	0.4	6.6	11.1	5.5
122	130	95.6	15.9	3.0	0.4	19.1	32.3	8.5
130	151	98.6	16.4	1.0	0.4	6.6	11.1	5.5
151	179.6	98.9	16.5	1.5	0.4	9.9	16.7	6.5
179.6	192.4	98.4	16.4	1.5	0.4	9.8	16.6	6.5
192.4	196.4	100.0	16.7	3.0	0.4	20.0	33.8	8.6
196.4	201.2	95.8	16.0	1.5	0.4	9.6	16.2	6.4

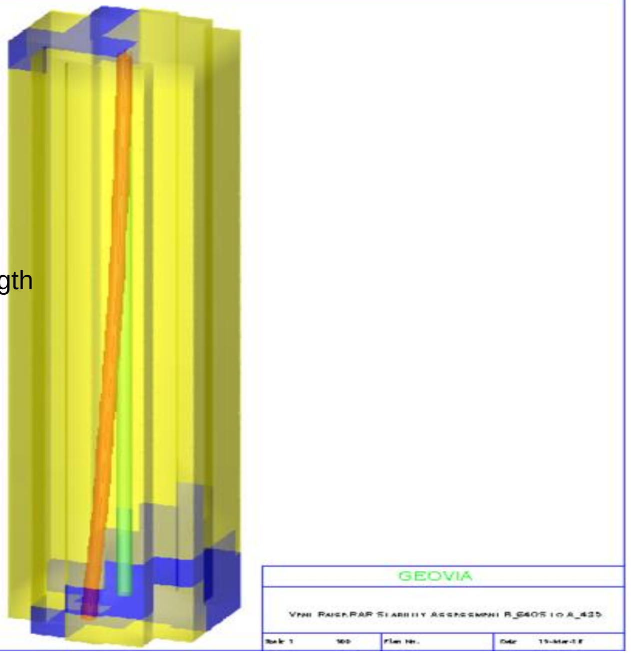
Remarks:

- The geotech hole intersected many (Seven) portions of FAIR to GOOD ground from 0m to 89.4m, from 89.4m to 93m, from 93m to 122m, from 130m to 151m, from 151m to 179.6m from 179.6m to 192.4m and 196.4m to 201.2m (Highlighted in red Table 1). All of the remaining portions of cores were classified as GOOD.



Core photo portions of the Dedicated drill hole

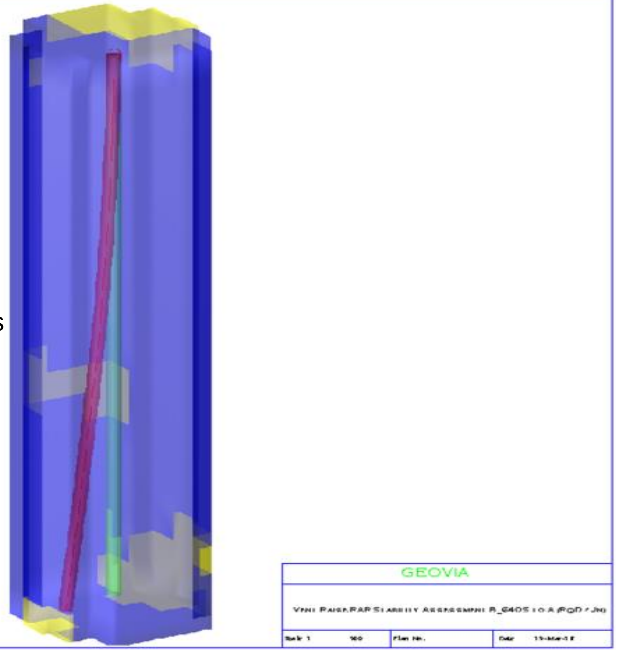




MRMM section showing the resultant Defect Shear Strength (Jr/Ja) condition surrounding the drill hole

Jr/Ja

0 - 0.5		Very Poor
0.5 - 0.75		Poor
0.75 - 2		Fair
2 - 3		Good



MRMM section showing the resultant Rock Mass Blockiness(RQD/Jn) surrounding the drill hole

RQD/Jn

0 - 4		Very Poor
4 - 8		Poor
8 - 15		Fair
15 - 25		Good
25 - 50		Very Good

III.1 Geotechnical Rock Mass Assessment

The logged data was subsequently processed for the raise bore assessment by employing the method established by McCracken & Stacey (1989). This method derives a Q-index and Raisebore Quality Index (Q_R). Using this approach, a Q value has been calculated for the geotechnical domains identified in the rock mass logs. To account for the difference in orientation and purpose between a vertical raisebore and a horizontal development drive, various adjustment factors are applied to the calculated Q values to derive Q_R:

$$Q_R = A_s \times A_o \times A_w \times Q$$

With:

- **As = Sidewall adjustment factor accounting for the greater stability of a raisebore sidewall, when compared to the back of an excavation.**
- **Ao = Joint orientation factor**
- **Aw = Weathering adjustment factor that accounts for the potential of a rock mass to deteriorate over long term exposure.**

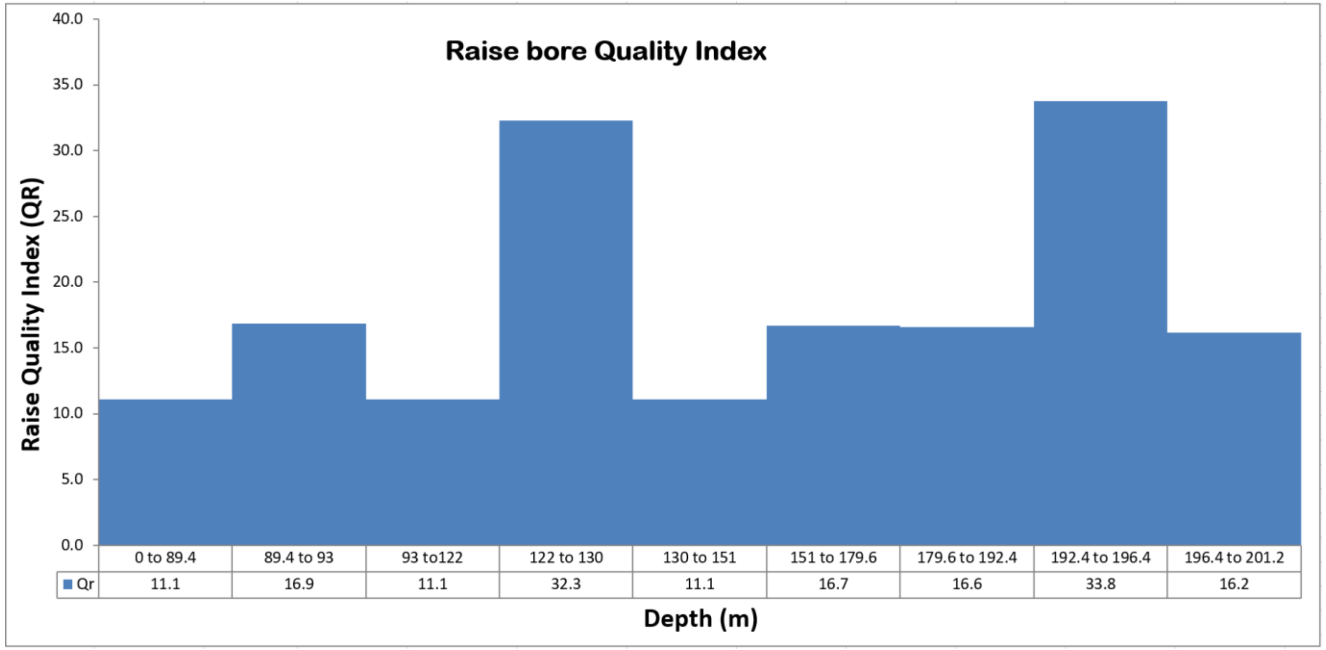
III.2 Raise bore Assessment –Stable Dimensions

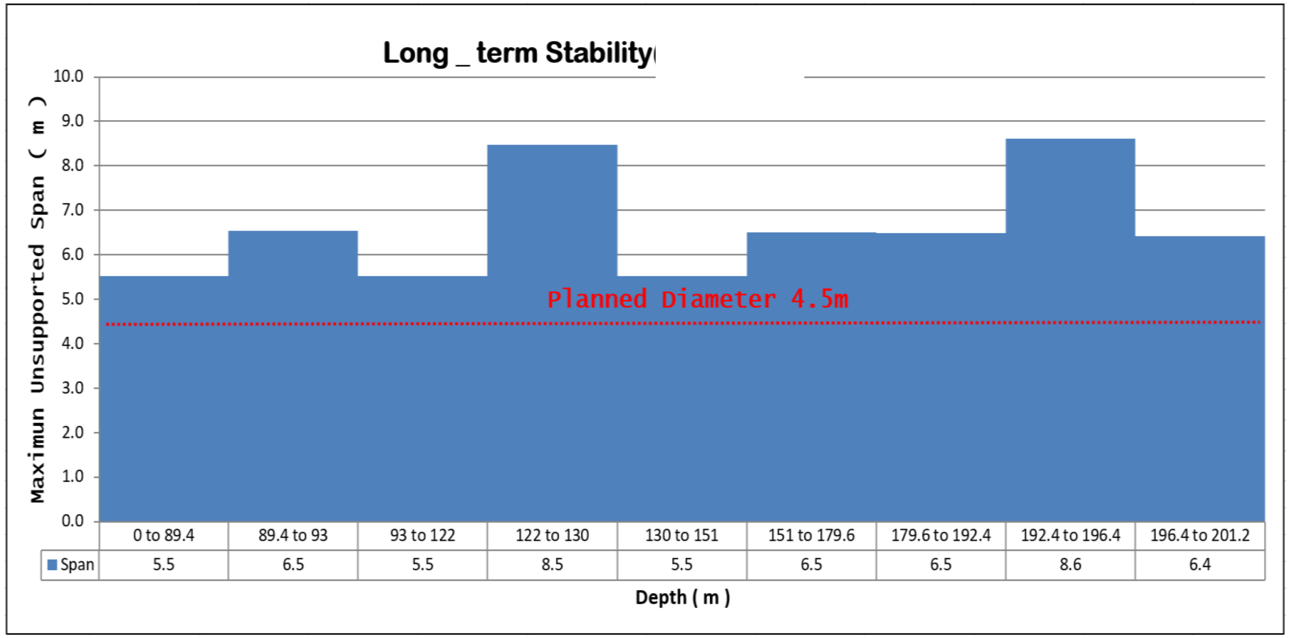
A relationship between the maximum unsupported raise diameter and QR has been determined using McCracken & Stacey's Raise Stability Ratio (RSR), in a similar way to which the Excavation Support Ratio is used in assessing development drives. This enables calculation of the maximum unsupported span for the long term sidewall stability of the raise bore – an RSR value of 1.3 is used for the long term stability of the sidewalls. Maximum unsupported spans are given by:

$$Span_{max} = 2 \times RSR \times {Q_R}^{0.4}$$

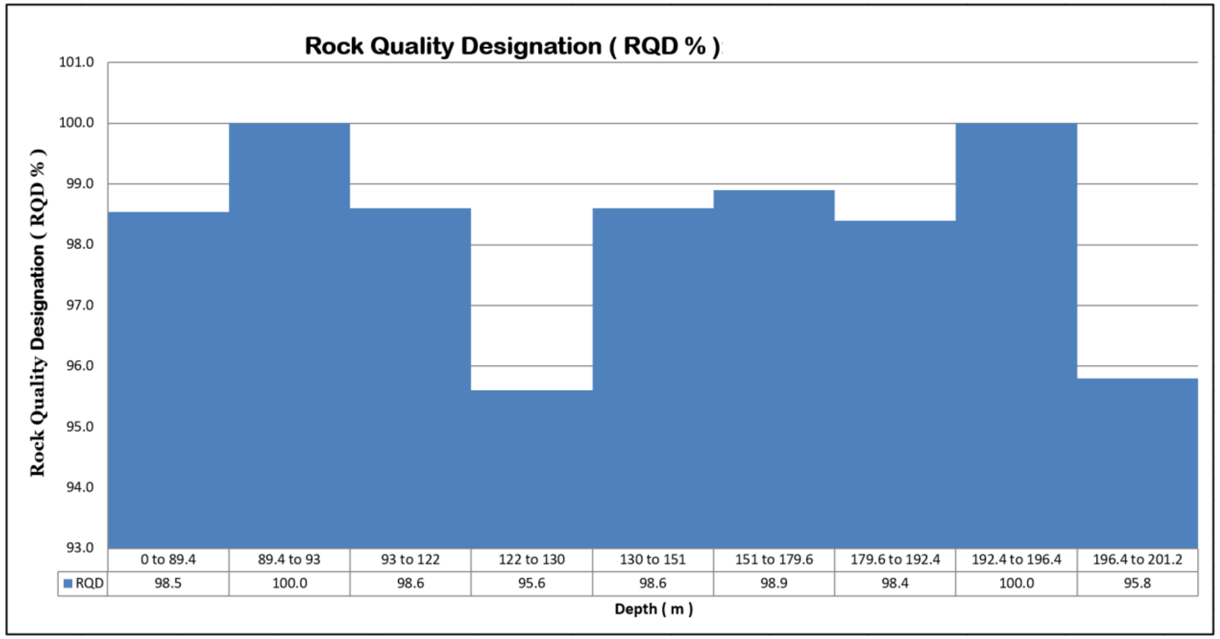
RSR values of 3.2 and 1.3 are used respectively for the immediate stability of the crown during the raise boring, the short and subsequent long term stability of the sidewalls.

Raise bore Quality Index (QR)
At different depths through the drillhole



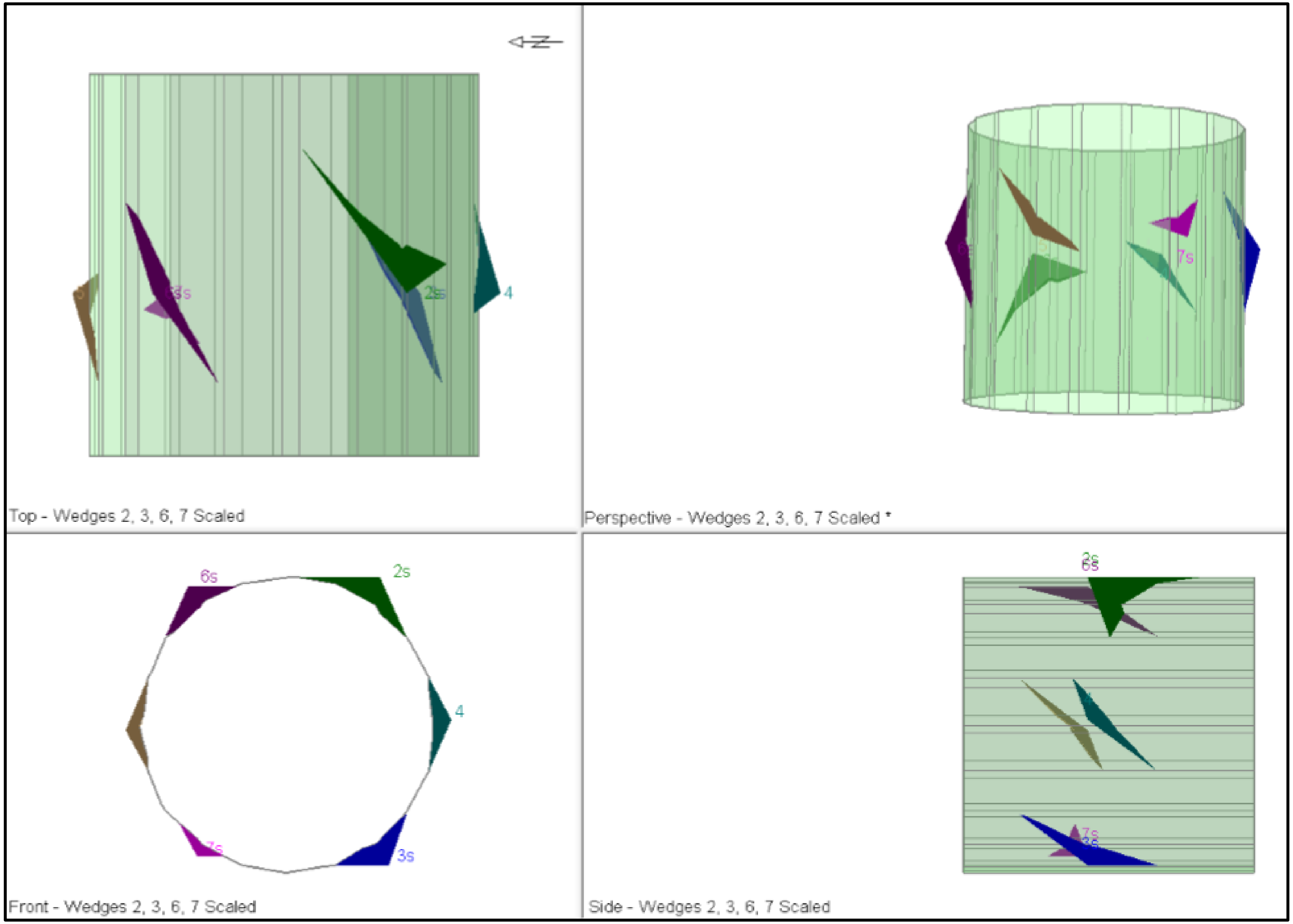


Max unsupported span for long-term stability along the raise (note the inclusion of the 4.5m diameter marker)



Rock Quality Designation (%)

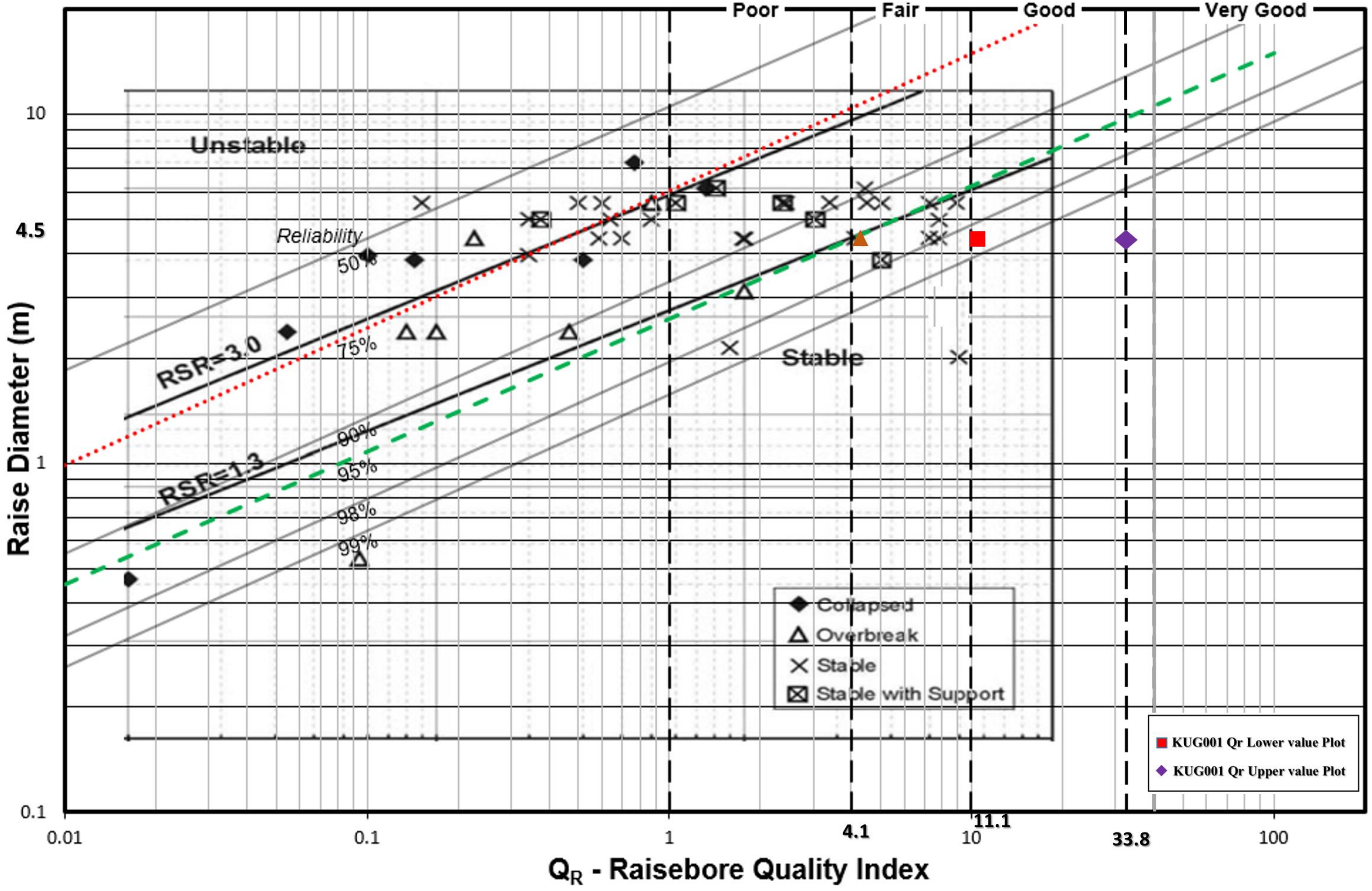
IV. Structural Assessment and Wedge Analysis



- With an assumed 32° angle of friction and 5kPa cohesion with no ground support, the UNWEDGE analysis predicted the potential for the unstable wedges to be formed. Potential unstable wedges are defined as those with a FOS≤0.0. The unstable wedges had resultant FOS of 0.0 for the domain from 15.2m to 17.1m due to the inter block shear strength and only one single joint has been identified into the domain from 95.5m to 96m and no potential unstable wedge forming. It should also be appreciated that UNWEDGE looks at the worst case scenario of the dominant joint sets which introduces a level of conservatism into the analysis. It should also be appreciated that the analysis also included blast fracture and stress fracture orientations in order to create the wedges (this introduces another level of conservatism) – there will however be no blast induced effects from raise boring.

- While the UNWEDGE analysis predicts there is a potential for wedge formation within the raise bore shaft, the risk is considered low. Long term stability of the raise bored vent shaft is unlikely to be affected by the potential formation of wedges. Any wedge failure if it occurs can be appropriately managed at the bottom of the vent raise.

V. Raisebore Assessment – Reliability Graphs



- The long term reliability of a raise bore is a function of the Raisebore Quality Index (QR) and the diameter of the Raisebore.
- The reliability can be expressed in terms of a nominal percentage (from McCracken & Stacey, 1989), the equivalent RSR value, or conversely the probability of failure.
- An RSR of 1.3 (used for the long term stability of the sidewalls) has a 95% reliability, or 5% probability of failure.
- As shown from the Reliability Graph (beside), with a planned raise bore diameter of 4.5m, the corresponding Raisebore Quality Index is 4.1(Orange triangle). From the distribution of QR values along the drill hole as presented above, the minimum value was 11.1 (red square). This infers a reliability of 98% or a probability of failure of 2%.

VI. Conclusion

The proposed diameter for the ventilation raise bored is 4.5m.

- A geotechnical stability assessment for raiseboring based on the industry standard practice (McCracken&Stacey,1989) has been completed.

- The geotechnical evaluation incorporated the relationship between the Raisebore Quality Index, Raisebore diameter and Reliability/Probability Failure.

- With an RSR of 1.3(used for the long term stability of the sidewalls), for a raisebore diameter of 4.5m the corresponding QR value must be greater than 4.1. From the recovered core, the minimum QR was11.1. This infers a reliability of 98% or a probability of failure of 2% for the unsupported span of 4.5m.

- From the geotechnical drill hole, the geotechnical evaluation has shown that the long term stability for the Raisebore will be achieved.

- While the risk of any failure is considered to be low (and localized), the consequence of any failure in the rock mass within the raise is considered to be manageable (bogging away any fall-off material from the level) and will not impact on the long term stability of the upcast ventilation raise.

VII. References and Bibliography

McCracken, A. & Stacey, T.R., 1989, Geotechnical risk assessment of large-diameter raise-bored shafts, IMM, Proceedings Shaft Engineering Conference, pp 309-316.

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