Open Rock Socket Stability Assessment

Risk of Open-Hole Instability — RS Insert Pile Locations

Shinan-Ui Offshore Wind Farm
19 RS Insert Pile locations + OSS

10 independent stability methods (RMR-weighted composite)
Bieniawski 89 | Barton 74 | Hoek-Brown 02 | Kirsch / Mogi-Coulomb
Mathews-Potvin | Palmstrom 96 | Hutchinson-Diederichs 96 | Panet 95 | Sakurai 97

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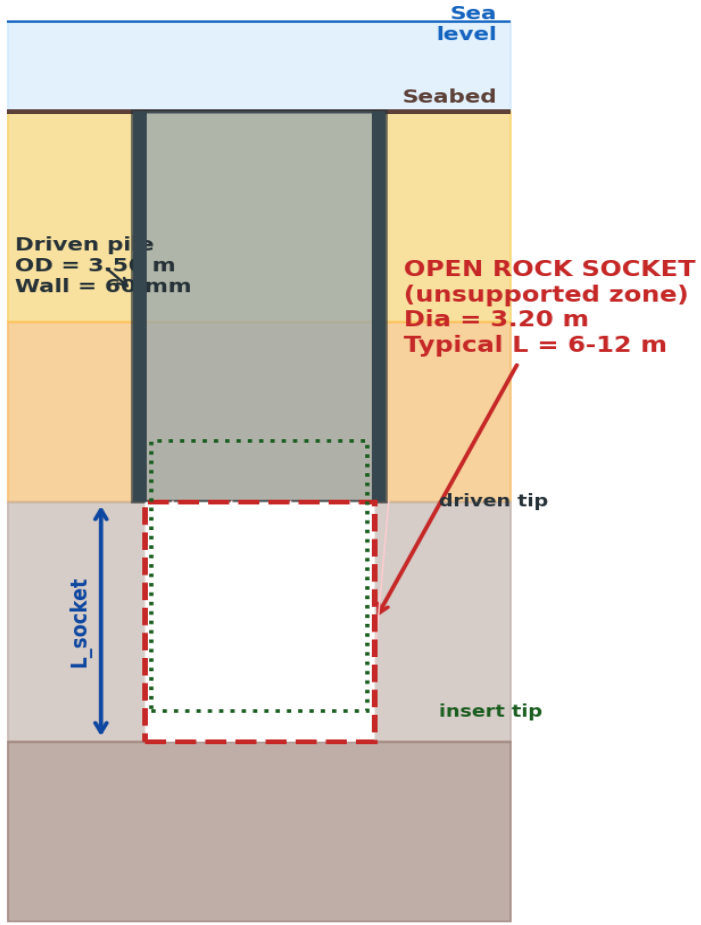
DRAFT — Calculations Under Check

Open Rock Socket Stability Assessment

Context, Geometry and Failure Mechanisms

Cross-section of the open socket (between driven pile tip and insert pile tip)



PROBLEM STATEMENT

After the driven pile is installed, a rock socket of diameter 3.2 m is drilled below the driven pile tip down to the planned insert pile tip elevation. During this operation the socket remains UNSUPPORTED for the time required to drill, clean, lower the insert pile and grout the annulus.

This study assesses the risk of OPEN-SOCKET INSTABILITY (caving, block fall, time-dependent breakouts) over the entire set of RS Insert Pile locations of the Shinan-Ui OWF.

GEOMETRY

- Driven pile OD = 3.50 m (60 mm wall, ID = 3.38 m)
- Insert pile OD = 3.00 m
- Rock socket diameter = 3.20 m
- Annulus = 100 mm radial (for grout)
- 19 RS Insert Pile locations analysed

POTENTIAL FAILURE MECHANISMS

1. Stress-induced shear failure (Kirsch / Mogi-Coulomb)
2. Time-dependent caving (Bieniawski stand-up time)
3. Joint-controlled block fall (Q / RMR / RMi)
4. Plastic yielding around opening (Panet 1995)
5. Slaking / weathering of weak zones
6. Excessive convergence (Sakurai critical strain)

Methodology - 10 Independent Methods Applied

RMR-weighted composite risk score (RMR carries 3x weight as primary method)

1 RMR

Rock Mass Rating

Bieniawski 1989

* Primary method - 3x weight
* Direct stand-up time prediction
* 100-year case history calibration

2 Q-system

Tunneling Quality Index

Barton et al. 1974

Q = (RQD/Jn)*(Jr/Ja)*(Jw/SRF)
ESR = 5.0 (temporary opening)

3 GSI / Hoek-Brown

Rock mass strength

Hoek et al. 2002

sigma_cm = sigma_ci * s^a
mi = 20 (andesite)

4 Kirsch + Mogi-C

Cavity stress at wall

Kirsch 1898 / Bradley 79

Vertical borehole - HORIZONTAL stresses only:
sigma_theta_max = 3*sigma_H - sigma_h

5 Stability Number N'

Empirical stability graph

Mathews 81 / Potvin 88

N' = Q' * A * B * C
C = 3 (vertical wall)

6 Stability Index SI

Simplified ratio

(simplified)

SI = (UCS * RQD) / (gamma * D)

7 Palmstrom RMi

Rock Mass Index

Palmstrom 1996

RMi = sigma_c * JP
JP from block volume

8 Critical Span Curve

CS vs Q'

Hutchinson-Diederichs 96

CS = 3.3 * Q'^0.43 * 1.25
(circular cylinder factor)

9 Plastic Zone Radius

Convergence-confinement

Panet 1995

rp/r0 from Mohr-Coulomb elasto-plastic solution

10 Sakurai Strain

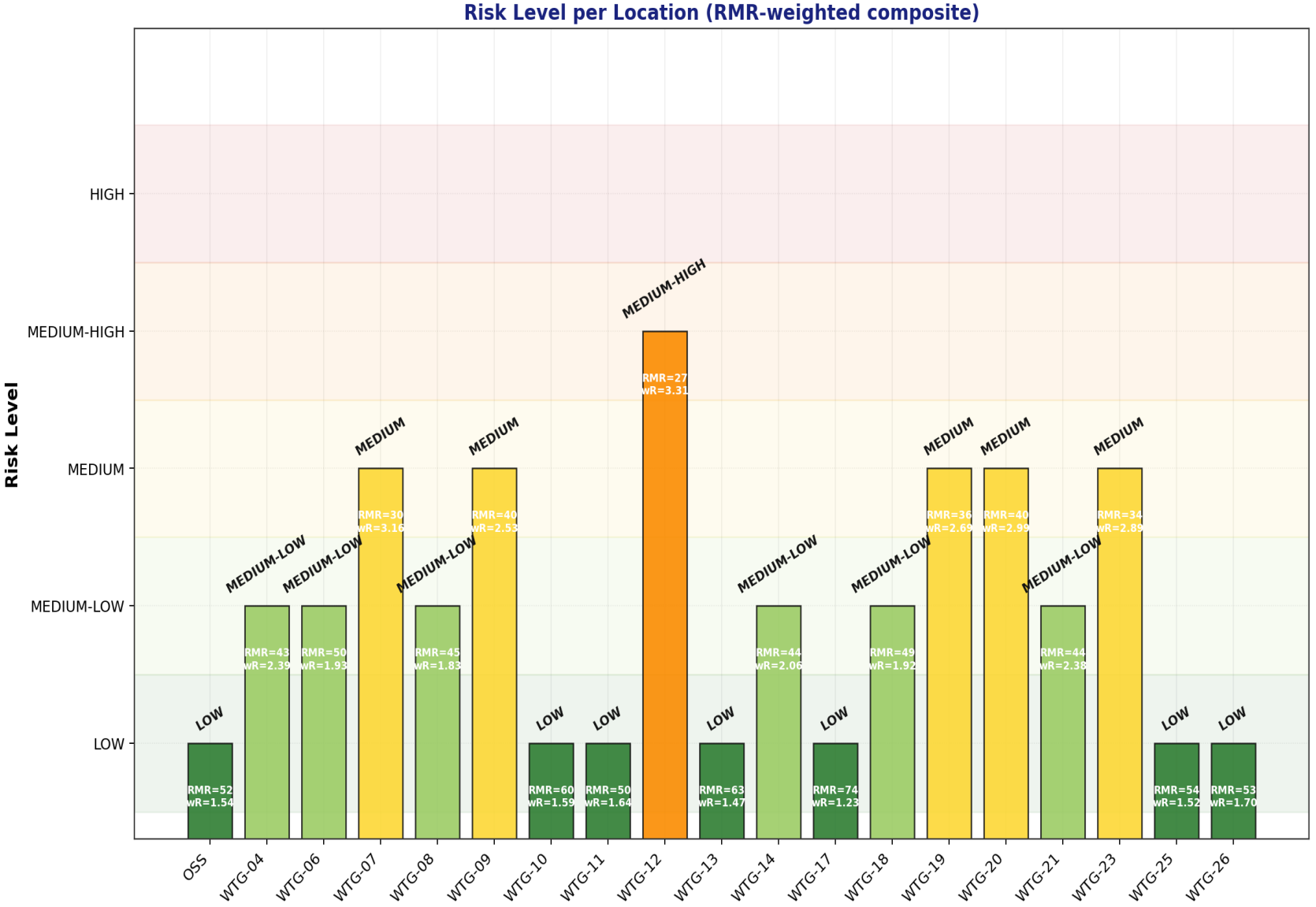
Critical strain

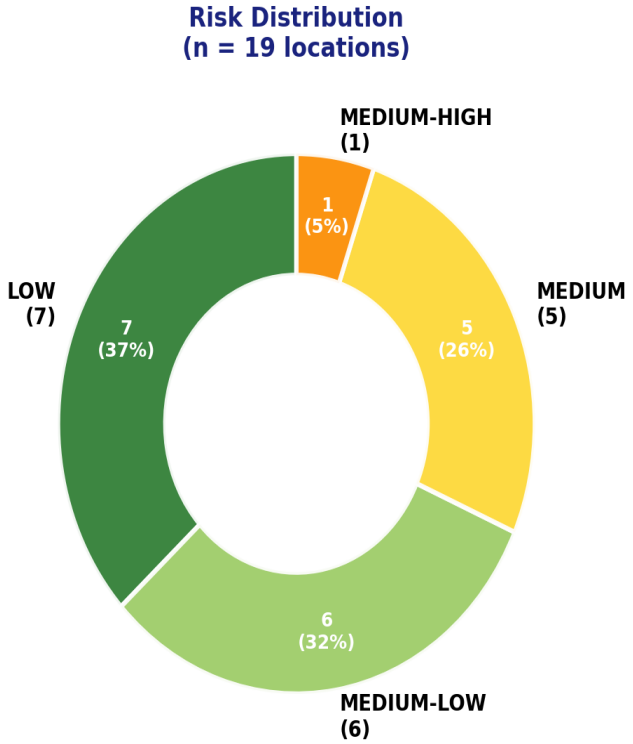
Sakurai 1997

log(eps_c%) = -0.25*log(UCS) - 0.85
Warning levels

Risk components are combined as a thickness-weighted composite. Worst-layer fraction influences blending (25-60%).

Open Socket Stability - Shinan-Ui OWF - Risk Overview





Method Comparison — 12 metrics across all locations

Summary Table — Risk classification per location

Open Socket Stability Risk Assessment - Shinan-Ui Offshore Wind Farm

RS Insert Pile Locations | Socket diameter = 3.2 m | Required stand-up = 24 h

Methods: RMR (Bieniawski 89) | Q-system (Barton 74) | GSI/Rock-brown 92 | Mean stress | Hoek-Brown Failure | Simplified SI | Palmström RMi 95 | Modified Span (Hatzesfeld-Diederichs 96) | Plastic Zone (Panet 95) | Sakurai Strain 97*

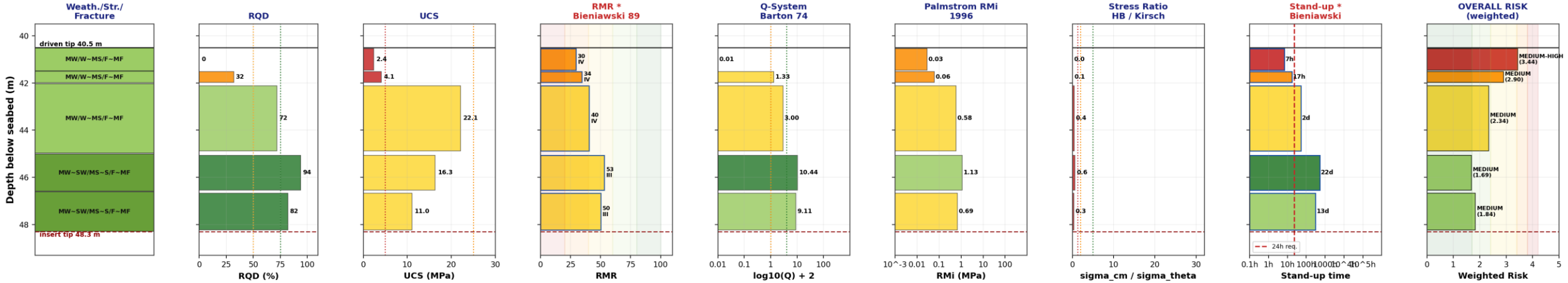
** RMR components weighted 3x in composite risk score*

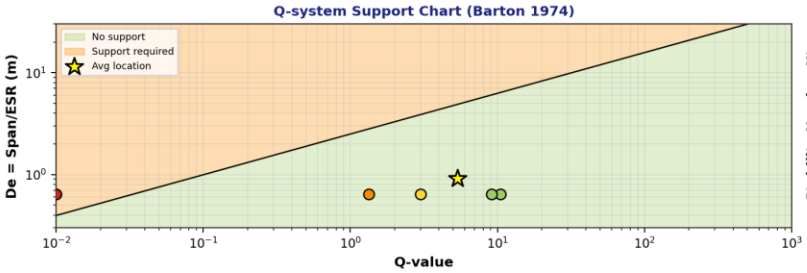
Location	Socket Depth (m)	Socket Length (m)	Avg RQD (%)	Avg UCS (MPa)	Avg RMR *	RMR Class	Avg Q	Avg RMi	GSI	sigma_cm (MPa)	Min Stress Ratio	Min Stand-up (hrs) *	Avg N'	Max rp/r0	Min CS/D	RISK
OSS	37.5-46.5	8.9	61	47.7	52	Fair	12.28	3.86	48	2.53	1.0	132	18.43	1.00	2.31	LOW
WTG-04	40.5-48.3	7.7	67	14.8	43	Fair	5.37	0.61	38	0.51	0.0	7	7.17	1.00	0.16	MEDIUM-LOW
WTG-06	34.9-40.9	5.9	51	105.7	50	Fair	4.32	4.62	45	5.19	0.5	9	6.47	1.00	0.16	MEDIUM-LOW
WTG-07	37.9-45.7	7.7	12	49.5	30	Poor	0.38	0.11	25	0.68	0.2	6	0.56	1.00	0.85	MEDIUM
WTG-08	36.0-43.3	7.2	56	90.0	45	Fair	3.65	3.02	40	3.74	1.3	69	5.47	1.00	1.80	MEDIUM-LOW
WTG-09	38.0-45.6	7.5	38	83.0	40	Poor	1.67	1.12	35	2.45	0.4	16	2.50	1.00	0.74	MEDIUM
WTG-10	38.1-43.5	5.3	55	103.8	60	Fair	19.21	16.53	55	8.88	0.5	5	28.81	1.00	0.16	LOW
WTG-11	25.2-33.0	7.7	65	122.1	50	Fair	3.61	3.75	45	5.39	5.9	290	5.42	1.00	2.24	LOW
WTG-12	36.4-44.5	8.0	13	34.1	27	Poor	0.43	0.11	22	0.47	0.1	1	0.64	1.00	0.16	MEDIUM-HIGH
WTG-13	17.1-28.2	11.0	95	141.2	63	Good	17.78	20.88	58	17.33	1.2	4	26.67	1.00	0.16	LOW
WTG-14	20.2-31.2	10.9	65	79.1	44	Fair	3.61	2.43	39	2.65	0.8	46	5.42	1.00	2.24	MEDIUM-LOW
WTG-17	16.2-30.5	14.2	58	141.7	74	Good	69.62	73.08	69	30.28	6.5	1486	104.44	1.00	5.85	LOW
WTG-18	23.8-33.1	9.2	37	98.0	49	Fair	8.72	10.27	44	5.65	0.1	2	13.09	1.00	0.69	MEDIUM-LOW
WTG-19	40.5-47.1	6.5	46	31.0	36	Poor	2.34	0.49	31	0.60	0.2	2	3.51	1.00	0.67	MEDIUM
WTG-20	40.7-47.0	6.2	30	165.4	40	Poor	1.69	3.63	35	8.01	0.1	2	2.54	1.00	0.16	MEDIUM
WTG-21	47.7-53.5	5.7	49	16.9	44	Fair	5.35	0.66	39	0.58	0.0	1	8.01	1.00	0.16	MEDIUM-LOW
WTG-23	38.7-45.2	6.4	40	8.3	34	Poor	1.57	0.15	29	0.16	0.0	1	1.69	1.00	0.16	MEDIUM
WTG-25	33.6-39.6	5.9	82	56.6	54	Fair	9.14	3.55	49	3.34	1.7	481	13.71	1.00	3.32	LOW
WTG-26	13.2-26.0	12.7	57	132.5	53	Fair	6.26	6.39	48	7.38	2.1	6	9.39	1.00	0.55	LOW

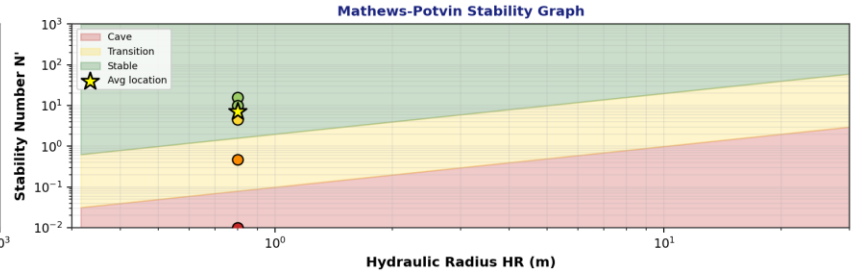
Colour code: GREEN = Favourable | YELLOW = Marginal | ORANGE = Unfavourable | RED = Critical

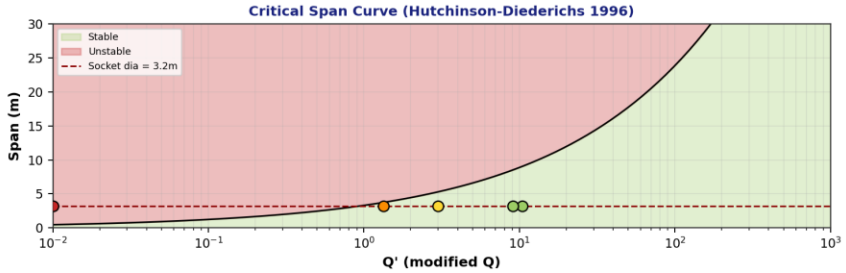
WTG-04 - Open Rock Socket Stability Assessment

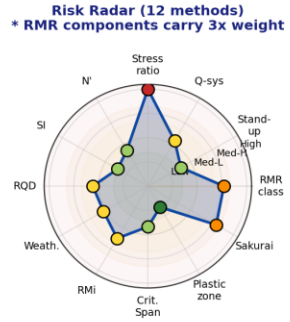
Socket: 40.5 - 48.3 m b.s.b. | Length = 7.7 m | Diameter = 3.2 m | Required stand-up: 24 h

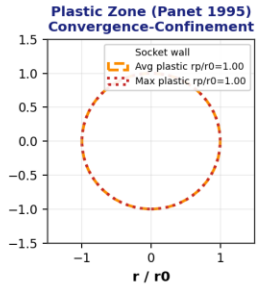










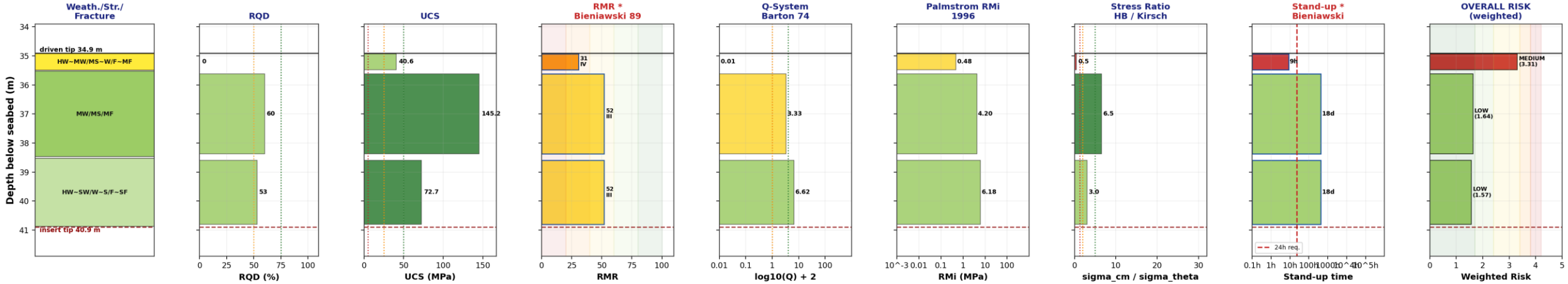


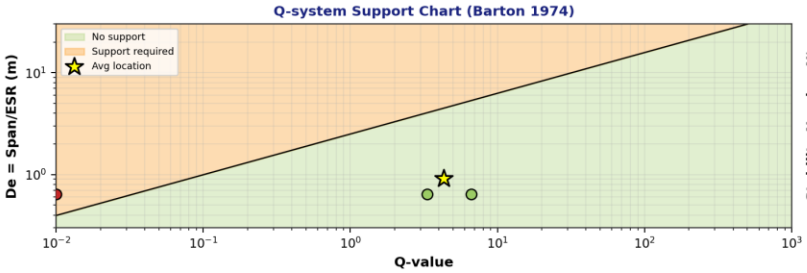
Parameter	Value	Parameter	Value
Socket length	7.7 m	Avg RMR	43 [Fair]
Socket diameter	3.2 m	Avg Q-value	5.37 [Fair]
Avg UCS	14.8 MPa	Avg GSI	38
Avg RQD	67 %	Avg N'	7.17
Avg sigma_cm	0.51 MPa	Avg Em	1.0 GPa
Min stress ratio	0.0	Min CS / span	0.16
Avg RMi	0.51	Avg RMR	1.00
Min stand-up	7 h (0.3 d)	Worst layer	MEDIUM-HIGH

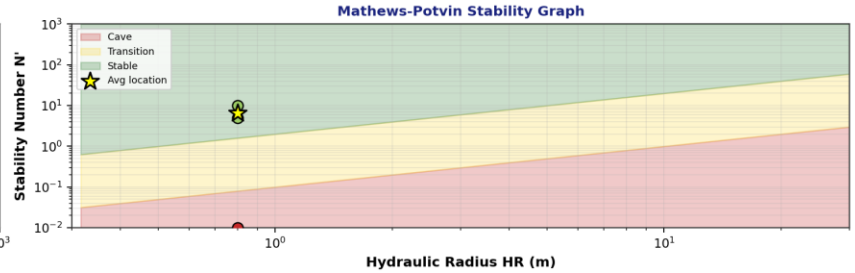
OVERALL SOCKET STABILITY RISK: MEDIUM-LOW

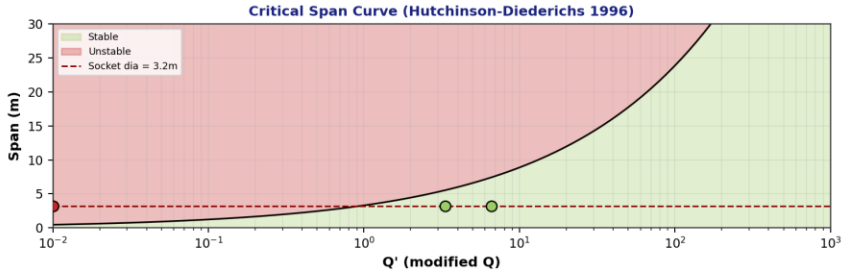
WTG-06 - Open Rock Socket Stability Assessment

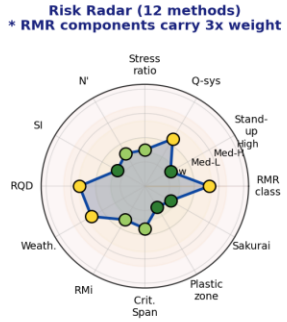
Socket: 34.9 - 40.9 m b.s.b. | Length = 5.9 m | Diameter = 3.2 m | Required stand-up: 24 h

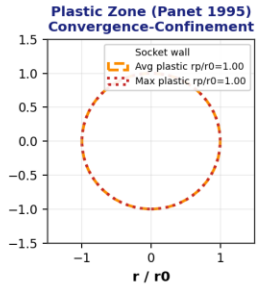








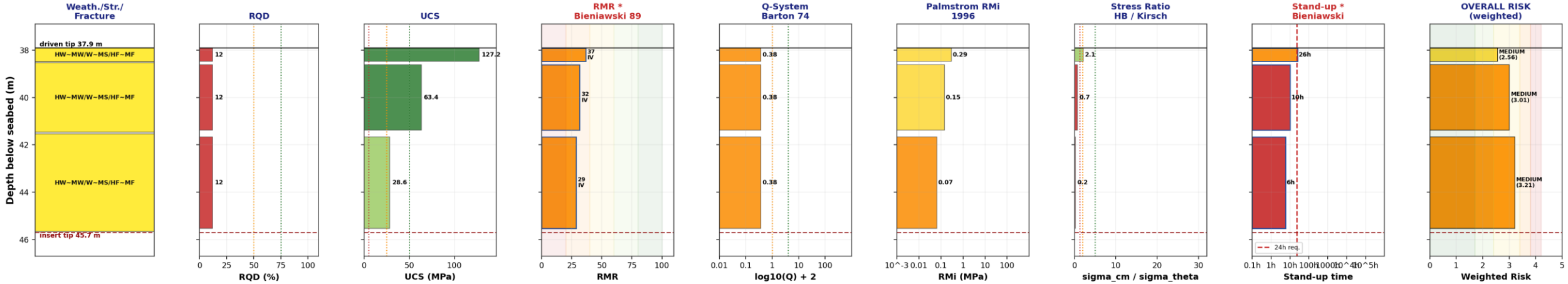


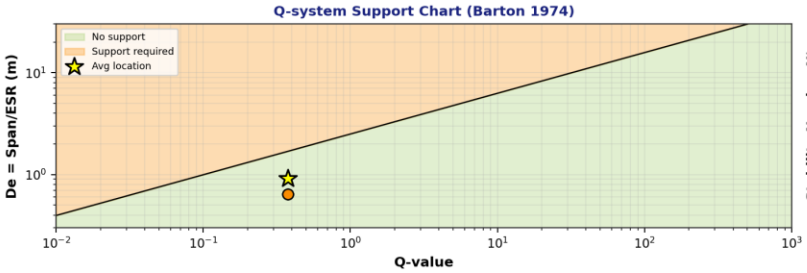


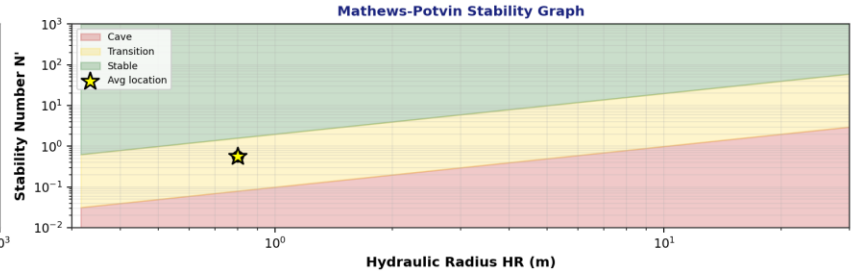
Parameter	Value	Parameter	Value
Socket length	5.9 m	Avg RMR	50 [Fair]
Socket diameter	3.2 m	Avg Q-value	4.32 [Fair]
Avg UCS	105.7 MPa	Avg GSI	45
Avg RQD	51 %	Avg N'	6.47
Avg sigma_cm	5.19 MPa	Avg Em	10.5 GPa
Min stress ratio	0.5	Min CS / span	0.16
Avg RMi	4.62	Min RMR	1.00
OVERALL SOCKET STABILITY RISK: MEDIUM-LOW			
Min stand-up	9 h (0.4 d)	Worst layer	MEDIUM

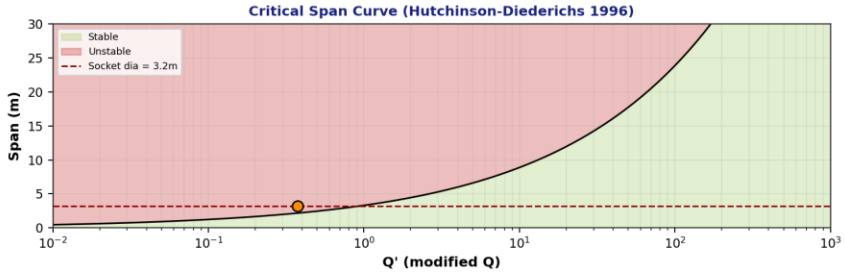
WTG-07 - Open Rock Socket Stability Assessment

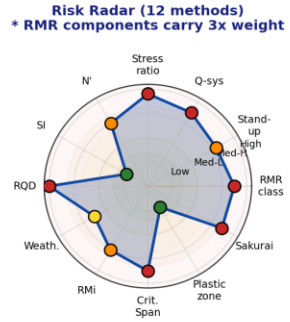
Socket: 37.9 - 45.7 m b.s.b. | Length = 7.7 m | Diameter = 3.2 m | Required stand-up: 24 h

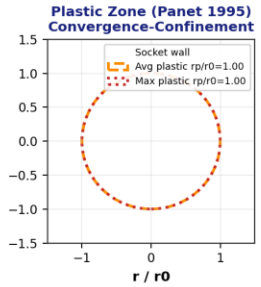








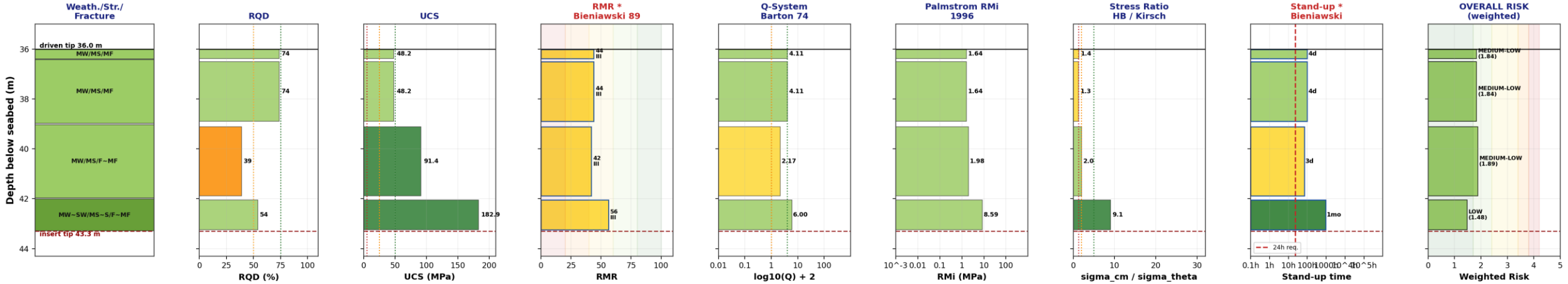


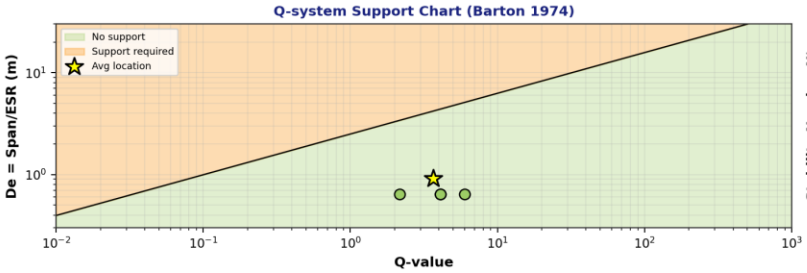


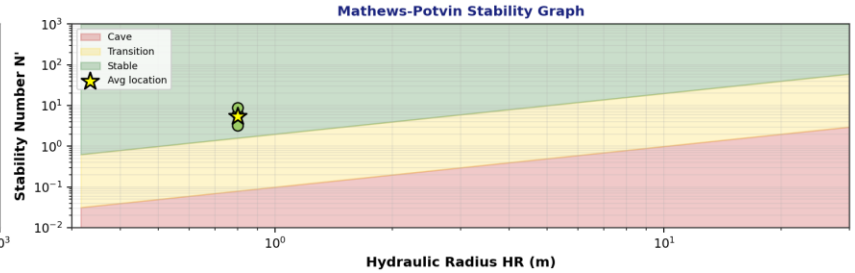
Parameter	Value	Parameter	Value
Socket length	7.7 m	Avg RMR	30 [Poor]
Socket diameter	3.2 m	Avg Q-value	0.38 [Very Poor]
Avg UCS	49.5 MPa	Avg GSI	25
Avg RQD	12 %	Avg N'	0.56
Avg sigma_cm	0.68 MPa	Avg Em	1.3 GPa
Min stress ratio	0.2	Min CS / span	0.85
Avg RMi	0.11	Avg Q' (mod.)	1.00
OVERALL SOCKET STABILITY RISK: MEDIUM			
Min stand-up	6 h (0.2 d)	Worst layer	MEDIUM

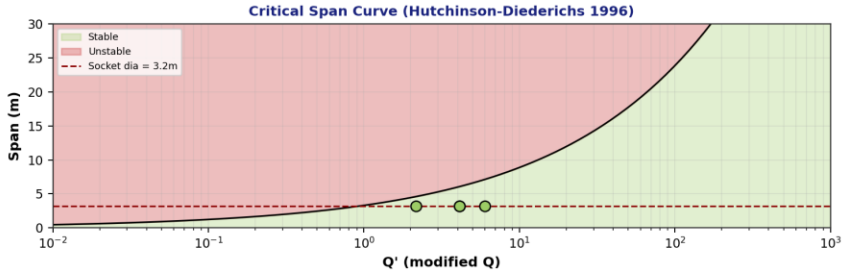
WTG-08 - Open Rock Socket Stability Assessment

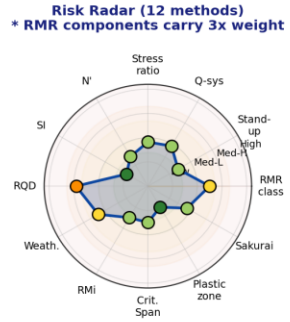
Socket: 36.0 - 43.3 m b.s.b. | Length = 7.2 m | Diameter = 3.2 m | Required stand-up: 24 h

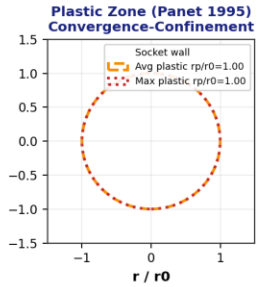








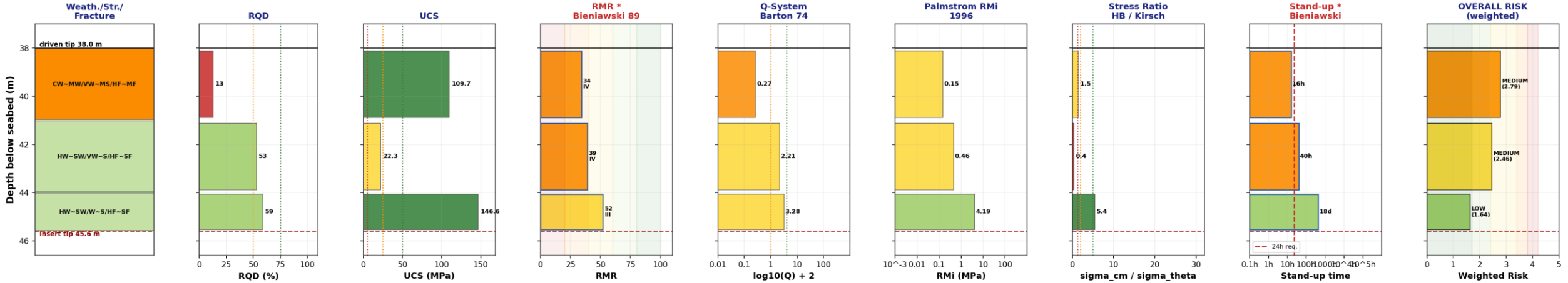


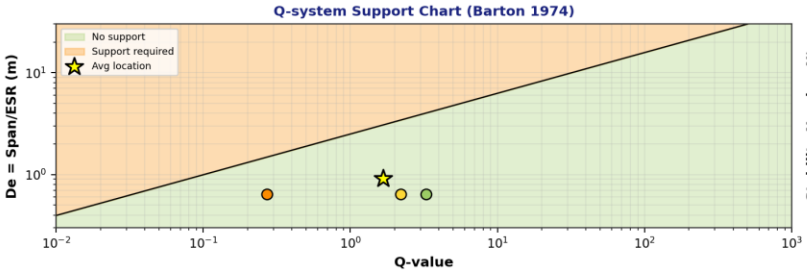


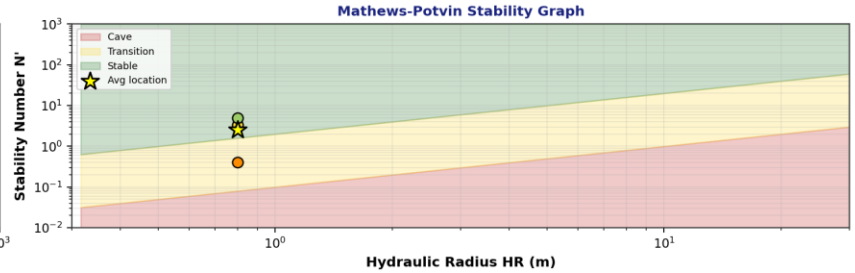
Parameter	Value	Parameter	Value
Socket length	7.2 m	Avg RMR	45 [Fair]
Socket diameter	3.2 m	Avg Q-value	3.65 [Poor]
Avg UCS	90.0 MPa	Avg GSI	40
Avg RQD	56 %	Avg N'	5.47
Avg sigma_cm	3.74 MPa	Avg Em	7.4 GPa
Min stress ratio	1.3	Min CS / span	1.80
Avg RMi	3.02	Min RMR	1.00
OVERALL SOCKET STABILITY RISK: MEDIUM-LOW			
Min stand-up	69 h (2.9 d)	Worst layer	MEDIUM-LOW

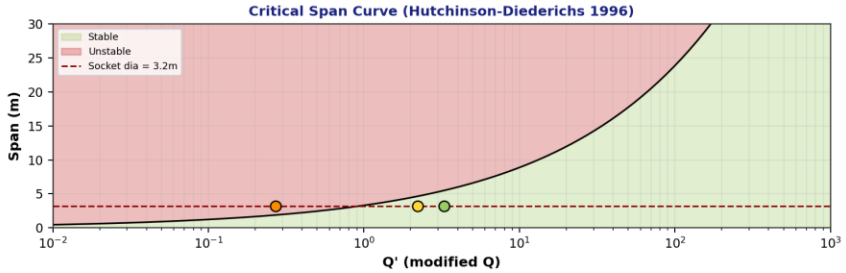
WTG-09 - Open Rock Socket Stability Assessment

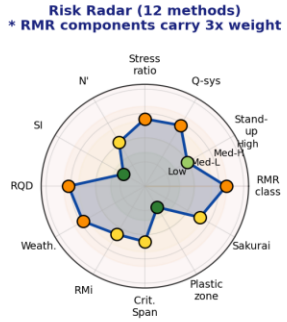
Socket: 38.0 - 45.6 m b.s.b. | Length = 7.5 m | Diameter = 3.2 m | Required stand-up: 24 h

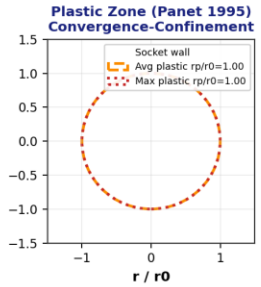








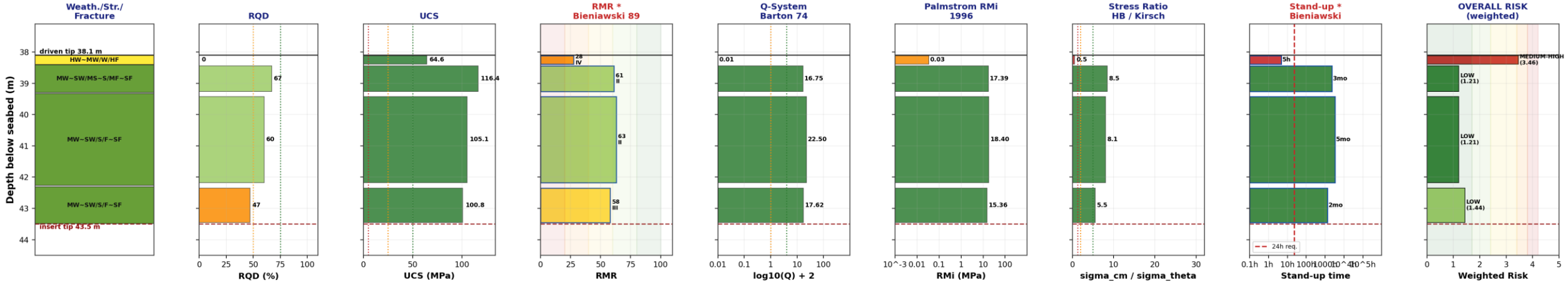


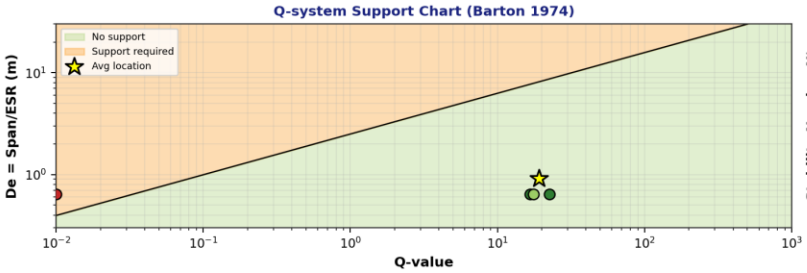


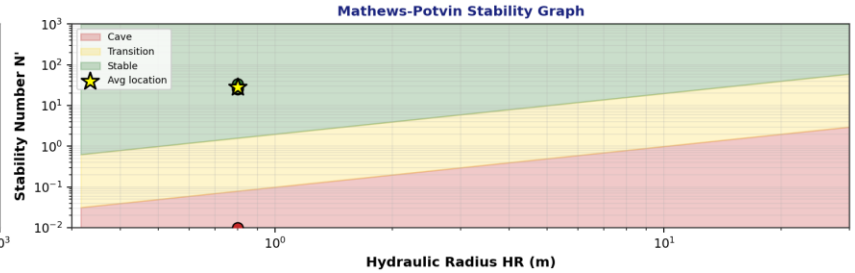
Parameter	Value	Parameter	Value
Socket length	7.5 m	Avg RMR	40 [Poor]
Socket diameter	3.2 m	Avg Q-value	1.67 [Poor]
Avg UCS	83.0 MPa	Avg GSI	35
Avg RQD	38 %	Avg N'	2.50
Avg sigma_cm	2.45 MPa	Avg Em	4.8 GPa
Min stress ratio	0.4	Min CS / span	0.74
Avg RMi	1.12	Avg RMR	1.00
OVERALL SOCKET STABILITY RISK: MEDIUM			
Min stand-up	16 h (0.7 d)	Worst layer	MEDIUM

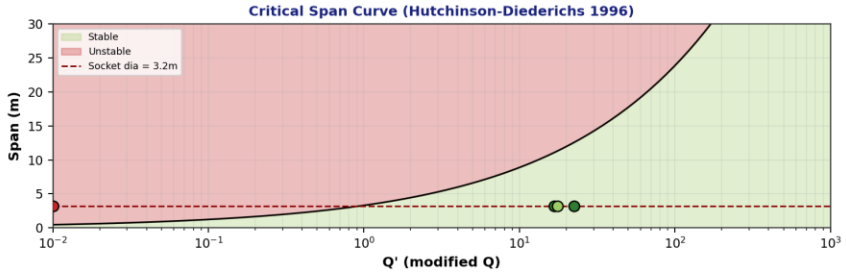
WTG-10 - Open Rock Socket Stability Assessment

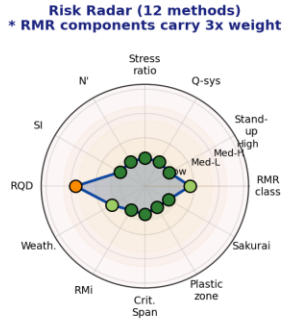
Socket: 38.1 - 43.5 m b.s.b. | Length = 5.3 m | Diameter = 3.2 m | Required stand-up: 24 h

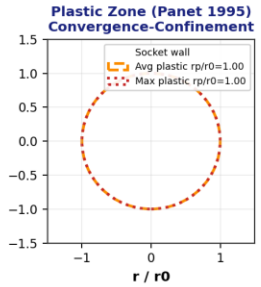










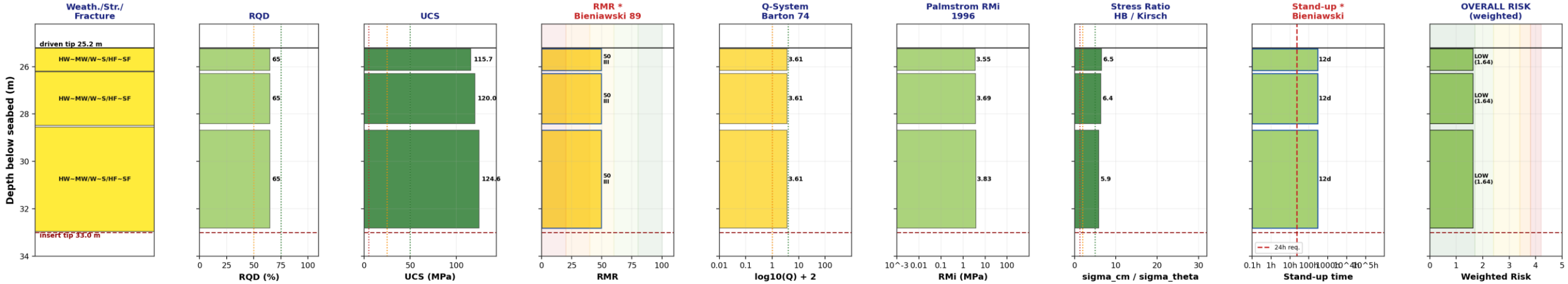


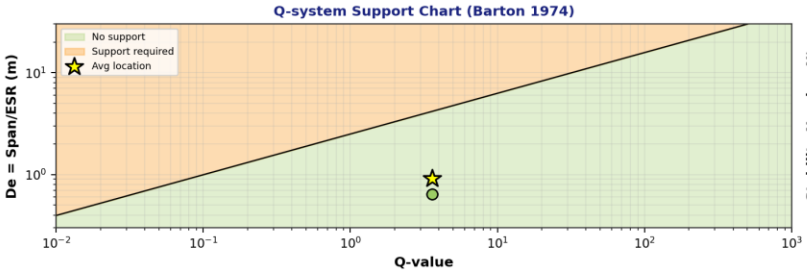
Parameter	Value	Parameter	Value
Socket length	5.3 m	Avg RMR	60 [Fair]
Socket diameter	3.2 m	Avg Q-value	19.21 [Good]
Avg UCS	103.8 MPa	Avg GSI	55
Avg RQD	55 %	Avg N'	28.81
Avg sigma_cm	8.88 MPa	Avg Em	17.8 GPa
Min stress ratio	0.5	Min CS / span	0.16
Avg RMi	16.53	Avg RMR/Q	1.00
Min stand-up	5 h (0.2 d)	Worst layer	MEDIUM-HIGH

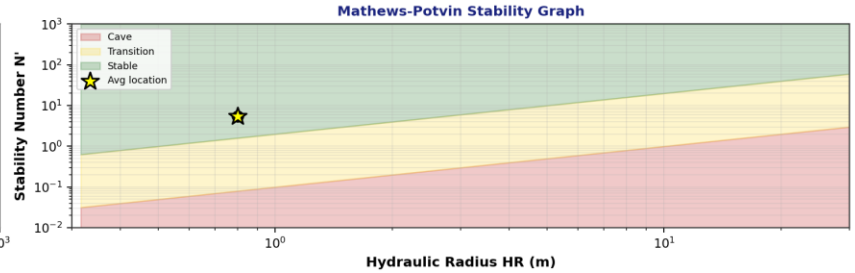
OVERALL SOCKET STABILITY RISK: LOW

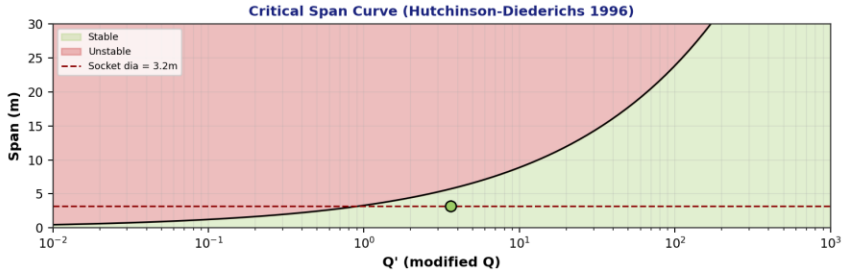
WTG-11 - Open Rock Socket Stability Assessment

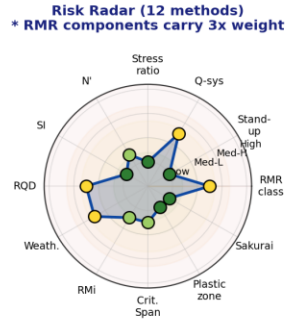
Socket: 25.2 - 33.0 m b.s.b. | Length = 7.7 m | Diameter = 3.2 m | Required stand-up: 24 h

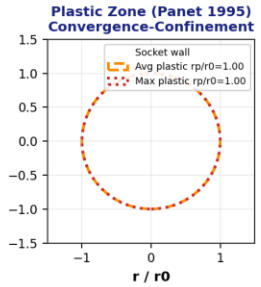










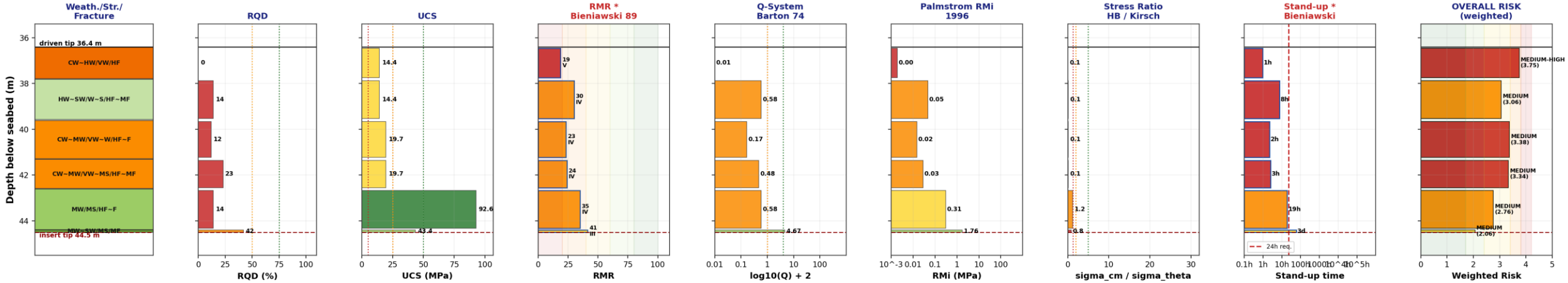


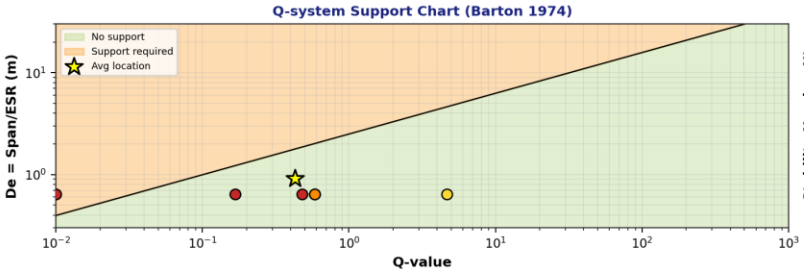
Parameter	Value	Parameter	Value
Socket length	7.7 m	Avg RMR	50 [Fair]
Socket diameter	3.2 m	Avg Q-value	3.61 [Poor]
Avg UCS	122.1 MPa	Avg GSI	45
Avg RQD	65 %	Avg N'	5.42
Avg sigma_cm	5.39 MPa	Avg Em	10.7 GPa
Min stress ratio	5.9	Min CS / span	2.24
Avg RMi	3.75	Min ESR	1.00
Min stand-up	290 h (12.1 d)	Worst layer	LOW

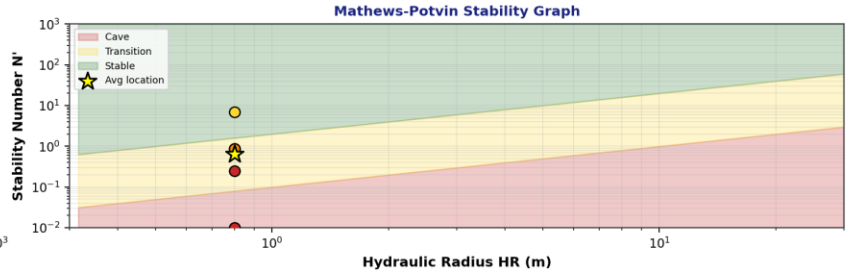
OVERALL SOCKET STABILITY RISK: LOW

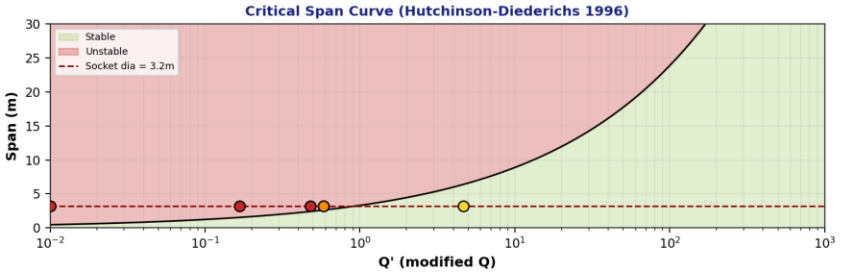
WTG-12 - Open Rock Socket Stability Assessment

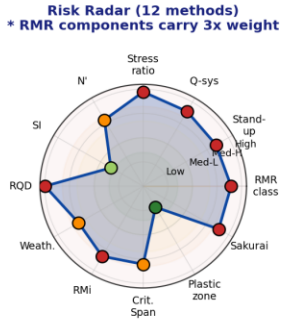
Socket: 36.4 - 44.5 m b.s.b. | Length = 8.0 m | Diameter = 3.2 m | Required stand-up: 24 h

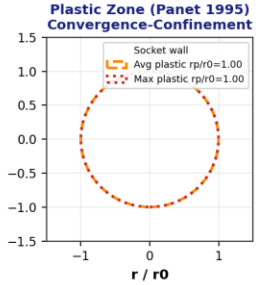








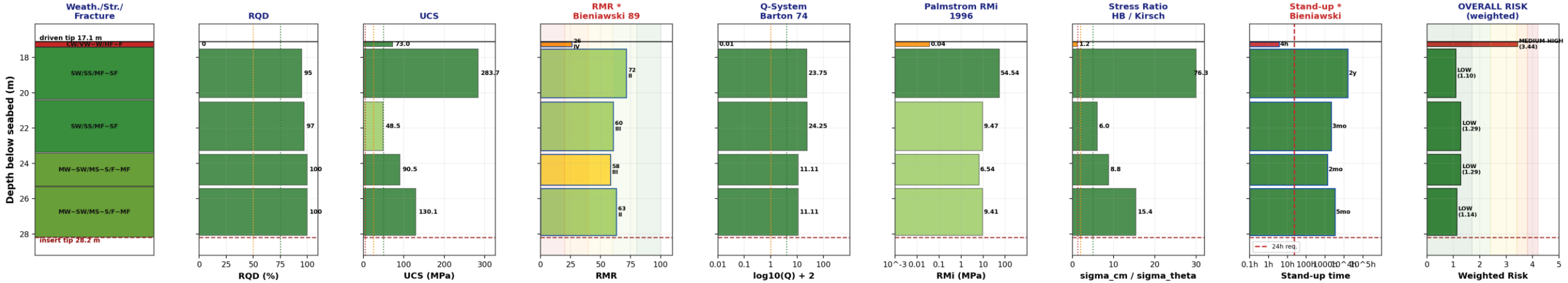


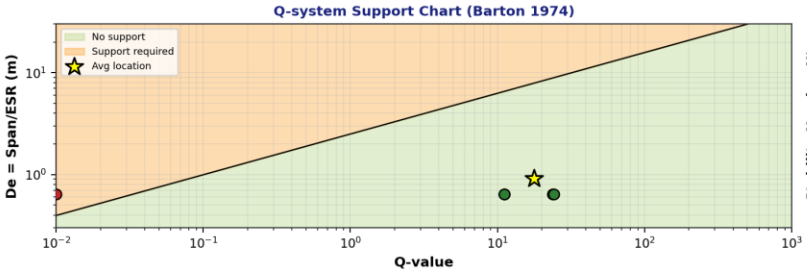


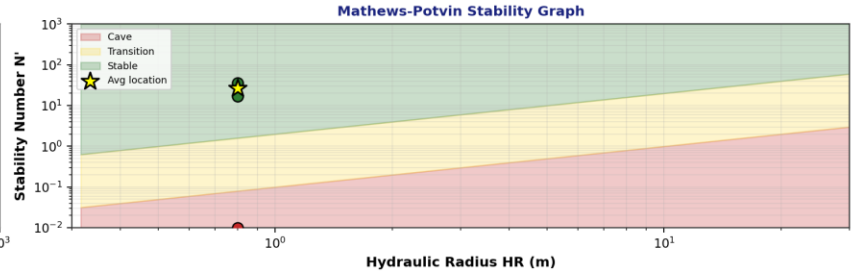
Parameter	Value	Parameter	Value
Socket length	8.0 m	Avg RMR	27 [Poor]
Socket diameter	3.2 m	Avg Q-value	0.43 [Very Poor]
Avg UCS	34.1 MPa	Avg GSI	22
Avg RQD	13 %	Avg N'	0.64
Avg sigma_cm	0.47 MPa	Avg Em	0.9 GPa
Min stress ratio	0.1	Min CS / span	0.16
Avg RMi	0.16	Max RMR	1.00
OVERALL SOCKET STABILITY RISK: MEDIUM-HIGH			
Min stand-up	1 h (0.0 d)	Worst layer	MEDIUM-HIGH

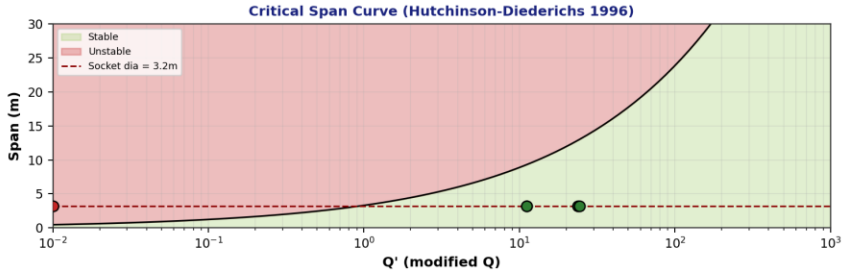
WTG-13 - Open Rock Socket Stability Assessment

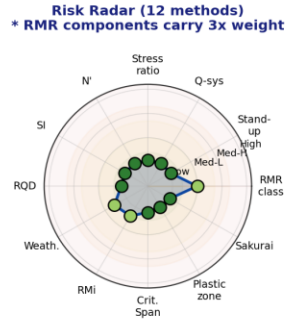
Socket: 17.1 - 28.2 m b.s.b. | Length = 11.0 m | Diameter = 3.2 m | Required stand-up: 24 h

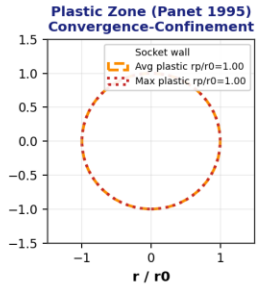










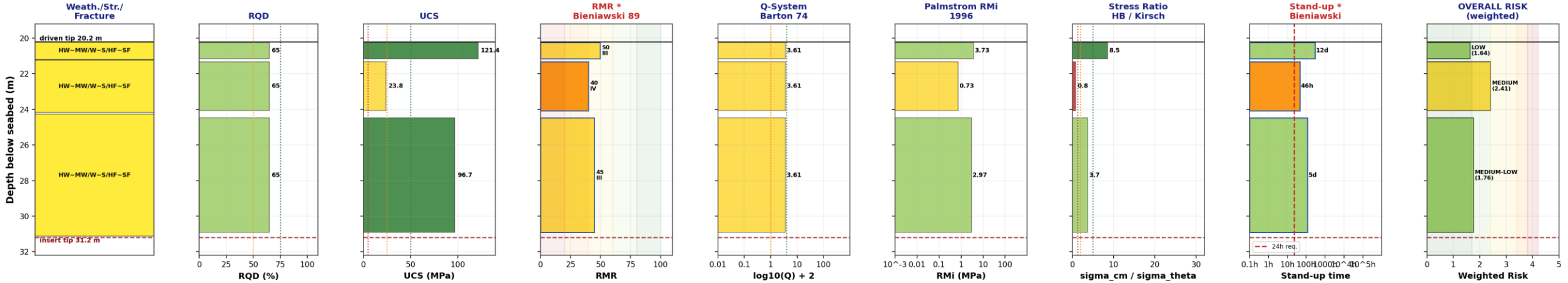


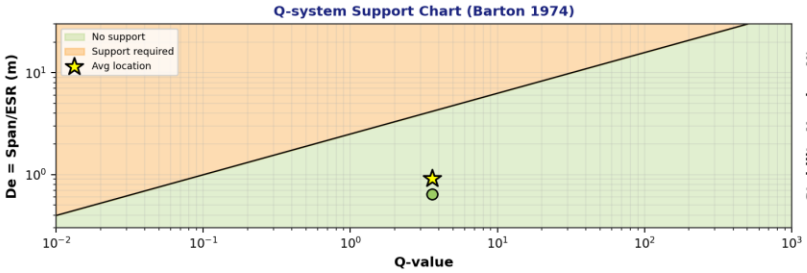
Parameter	Value	Parameter	Value
Socket length	11.0 m	Avg RMR	63 [Good]
Socket diameter	3.2 m	Avg Q-value	17.78 [Good]
Avg UCS	141.2 MPa	Avg GSI	58
Avg RQD	95 %	Avg N'	26.67
Avg sigma_cm	17.33 MPa	Avg Em	31.4 GPa
Min stress ratio	1.2	Min CS / span	0.16
Avg RMi	20.86	Min RMR	1.00
Min stand-up	4 h (0.2 d)	Worst layer	MEDIUM-HIGH

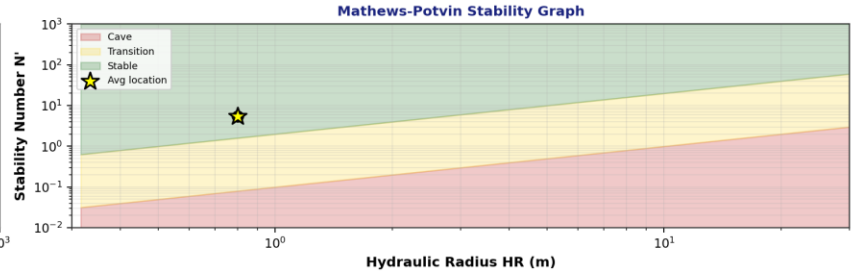
OVERALL SOCKET STABILITY RISK: LOW

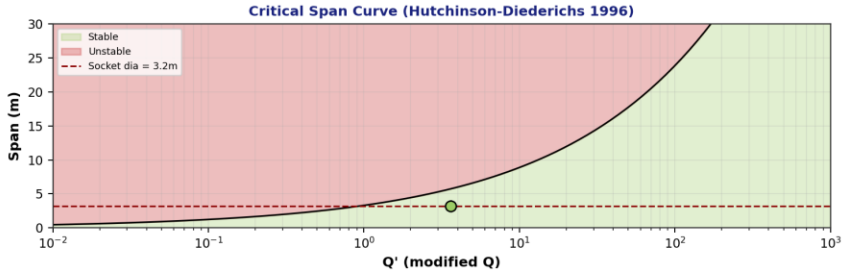
WTG-14 - Open Rock Socket Stability Assessment

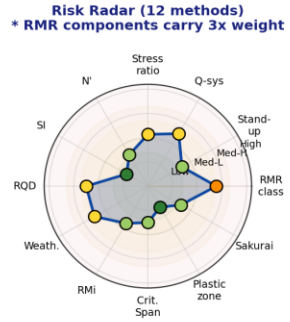
Socket: 20.2 - 31.2 m b.s.b. | Length = 10.9 m | Diameter = 3.2 m | Required stand-up: 24 h

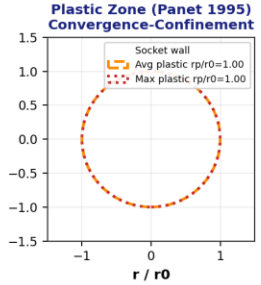








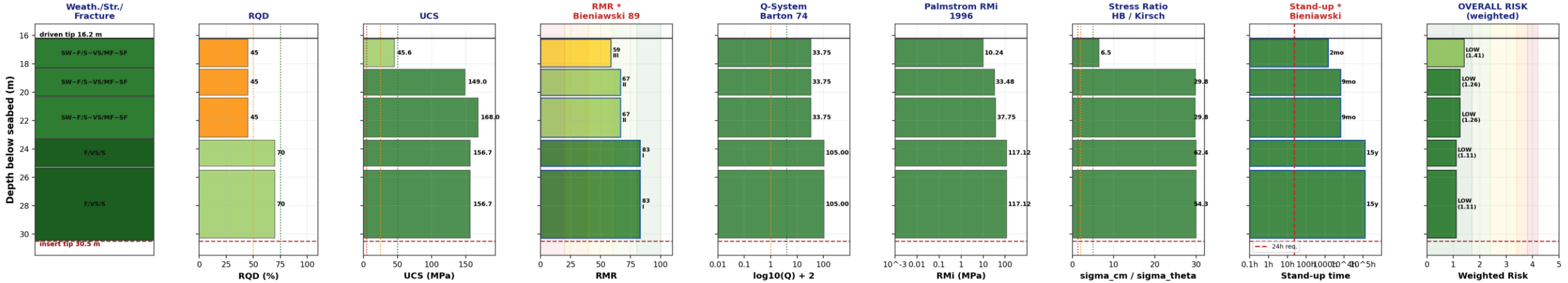


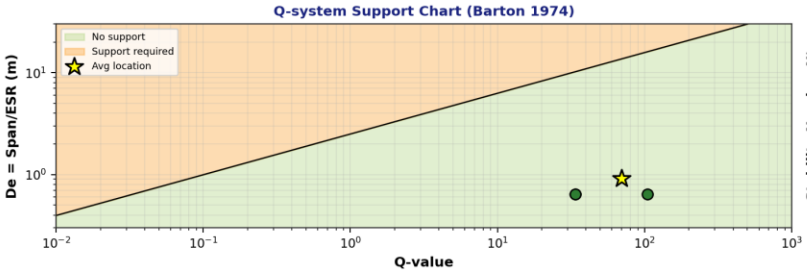


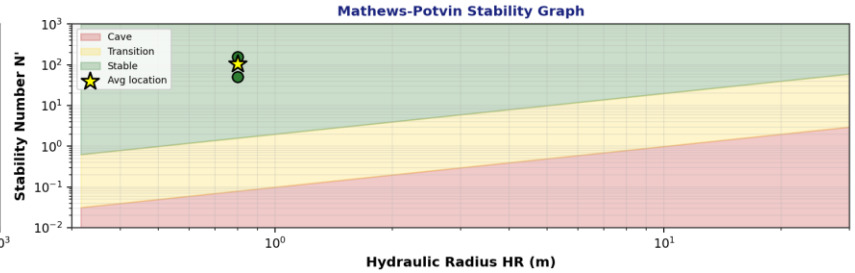
Parameter	Value	Parameter	Value
Socket length	10.9 m	Avg RMR	44 [Fair]
Socket diameter	3.2 m	Avg Q-value	3.61 [Poor]
Avg UCS	79.1 MPa	Avg GSI	39
Avg RQD	65 %	Avg N'	5.42
Avg sigma_cm	2.65 MPa	Avg Em	5.1 GPa
Min stress ratio	0.8	Min CS / span	2.24
Avg RMi	2.43	Min RMR	1.00
OVERALL SOCKET STABILITY RISK: MEDIUM-LOW			
Min stand-up	46 h (1.9 d)	Worst layer	MEDIUM

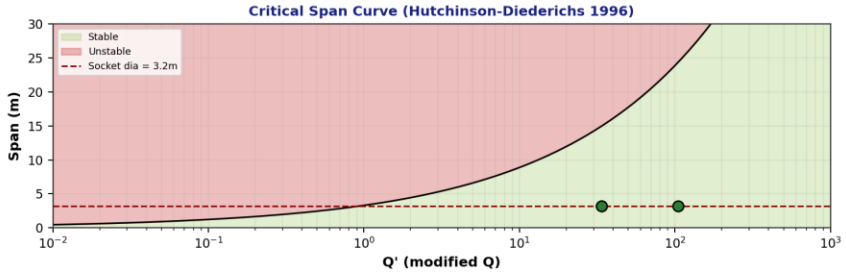
WTG-17 - Open Rock Socket Stability Assessment

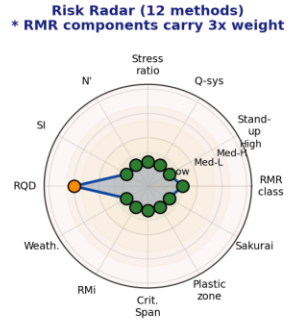
Socket: 16.2 - 30.5 m b.s.b. | Length = 14.2 m | Diameter = 3.2 m | Required stand-up: 24 h

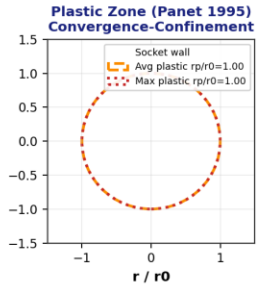










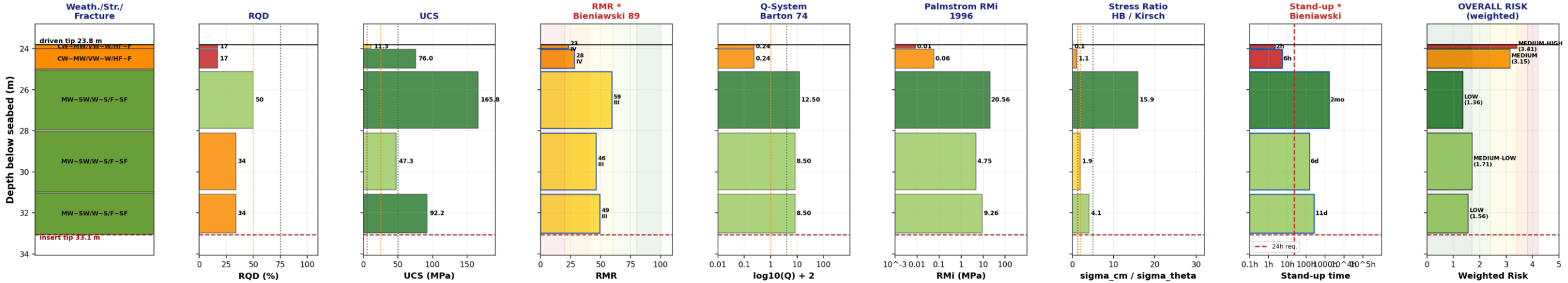


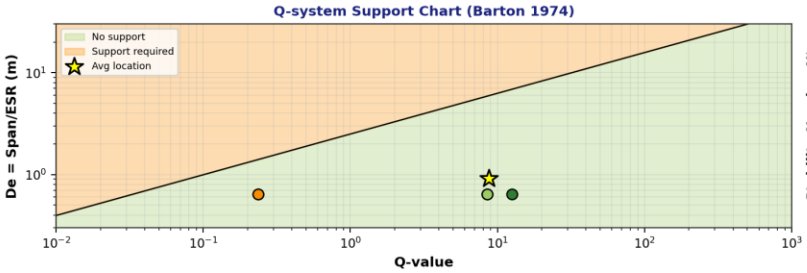
Parameter	Value	Parameter	Value
Socket length	14.2 m	Avg RMR	74 [Good]
Socket diameter	3.2 m	Avg Q-value	69.62 [Very Good]
Avg UCS	141.7 MPa	Avg GSI	69
Avg RQD	58 %	Avg N'	104.44
Avg sigma_cm	30.28 MPa	Avg Em	40.6 GPa
Min stress ratio	6.5	Min CS / span	5.85
Avg RMi	73.06	Min RMR	1.00
Min stand-up	1486 h (61.9 d)	Worst layer	LOW

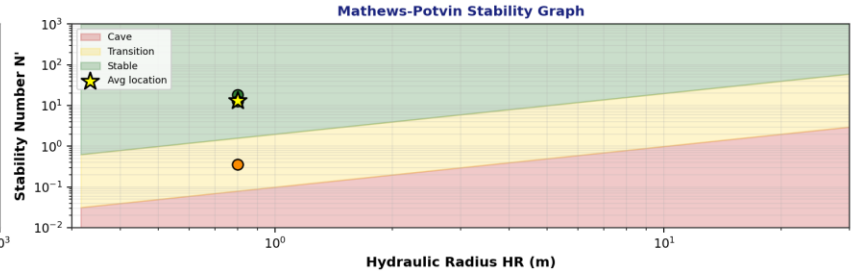
OVERALL SOCKET STABILITY RISK: LOW

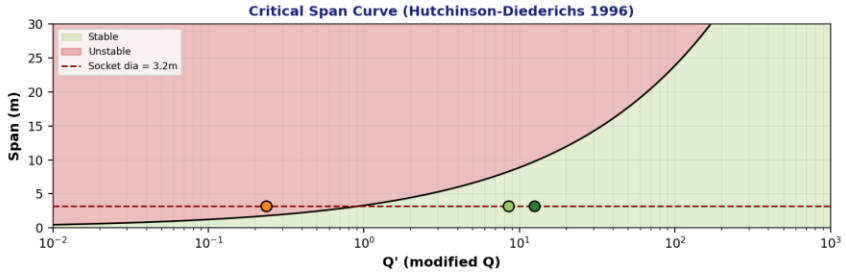
WTG-18 - Open Rock Socket Stability Assessment

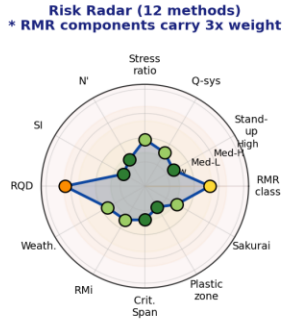
Socket: 23.8 - 33.1 m b.s.b. | Length = 9.2 m | Diameter = 3.2 m | Required stand-up: 24 h

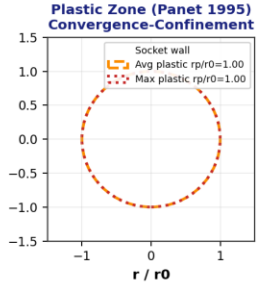








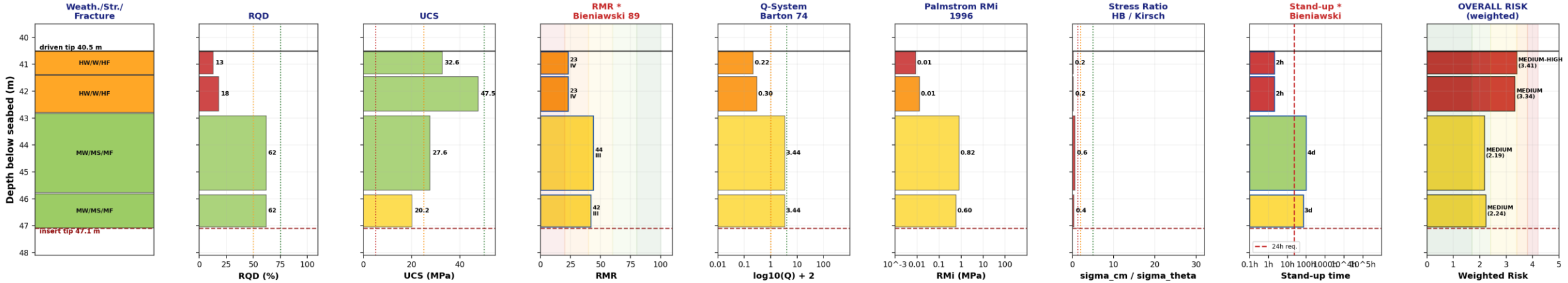


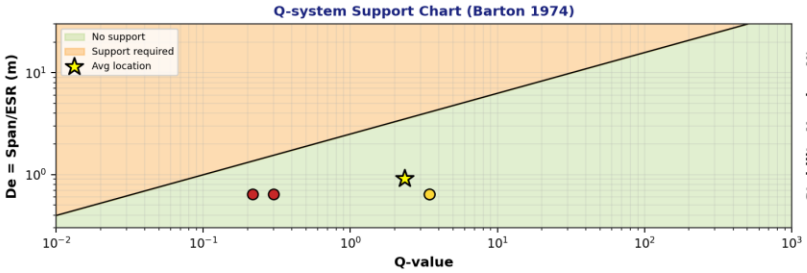


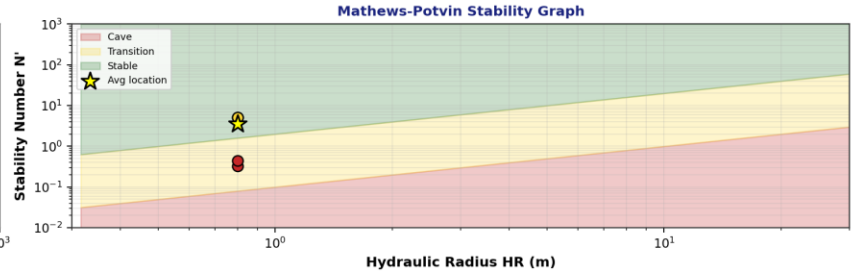
Parameter	Value	Parameter	Value
Socket length	9.2 m	Avg RMR	49 [Fair]
Socket diameter	3.2 m	Avg Q-value	8.72 [Fair]
Avg UCS	98.0 MPa	Avg GSI	44
Avg RQD	37 %	Avg N'	13.09
Avg sigma_cm	5.65 MPa	Avg Em	11.4 GPa
Min stress ratio	0.1	Min CS / span	0.69
Avg RMi	10.7	Avg RMR	1.00
OVERALL SOCKET STABILITY RISK: MEDIUM-LOW			
Min stand-up	2 h (0.1 d)	Worst layer	MEDIUM-HIGH

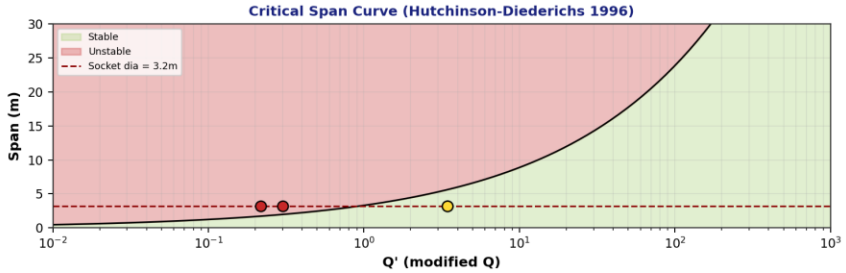
WTG-19 - Open Rock Socket Stability Assessment

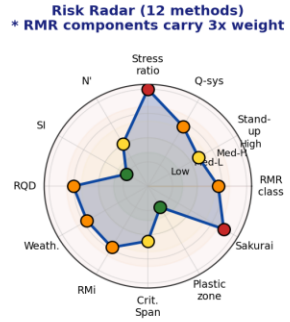
Socket: 40.5 - 47.1 m b.s.b. | Length = 6.5 m | Diameter = 3.2 m | Required stand-up: 24 h

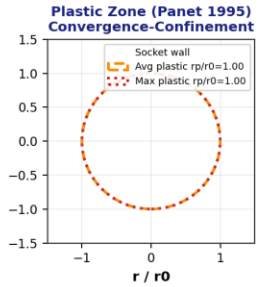










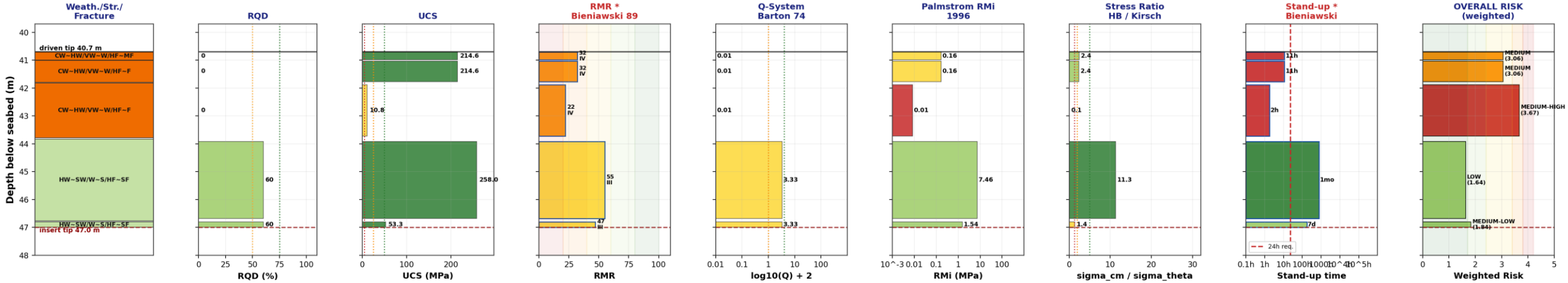


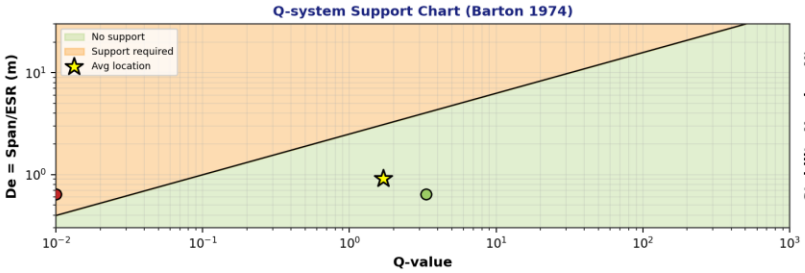
Parameter	Value	Parameter	Value
Socket length	6.5 m	Avg RMR	36 [Poor]
Socket diameter	3.2 m	Avg Q-value	2.34 [Poor]
Avg UCS	31.0 MPa	Avg GSI	31
Avg RQD	46 %	Avg N'	3.51
Avg sigma_cm	0.60 MPa	Avg Em	1.2 GPa
Min stress ratio	0.2	Min CS / span	0.67
Avg RMi	0.49	Avg RMR	1.00
Min stand-up	2 h (0.1 d)	Worst layer	MEDIUM-HIGH

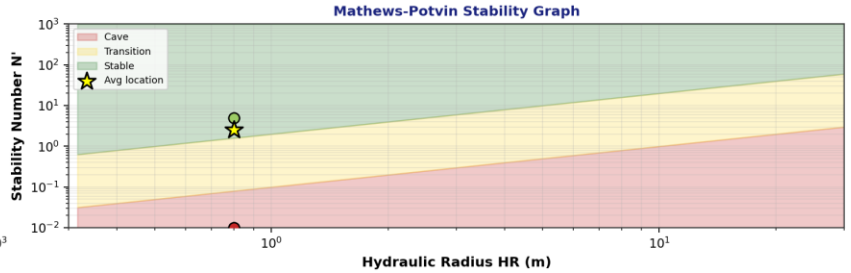
OVERALL SOCKET STABILITY RISK: MEDIUM

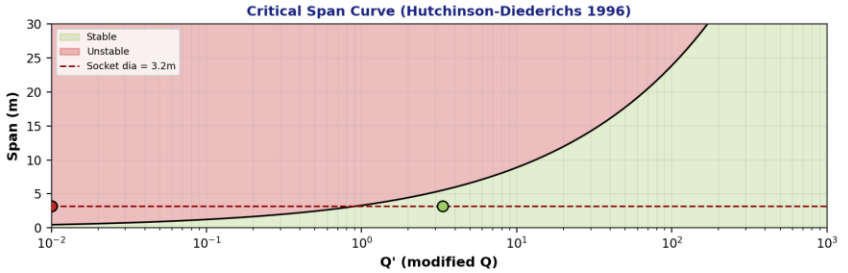
WTG-20 - Open Rock Socket Stability Assessment

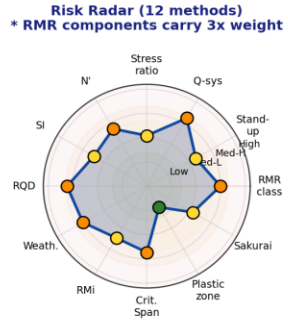
Socket: 40.7 - 47.0 m b.s.b. | Length = 6.2 m | Diameter = 3.2 m | Required stand-up: 24 h

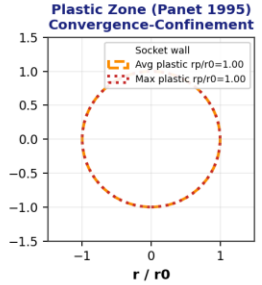










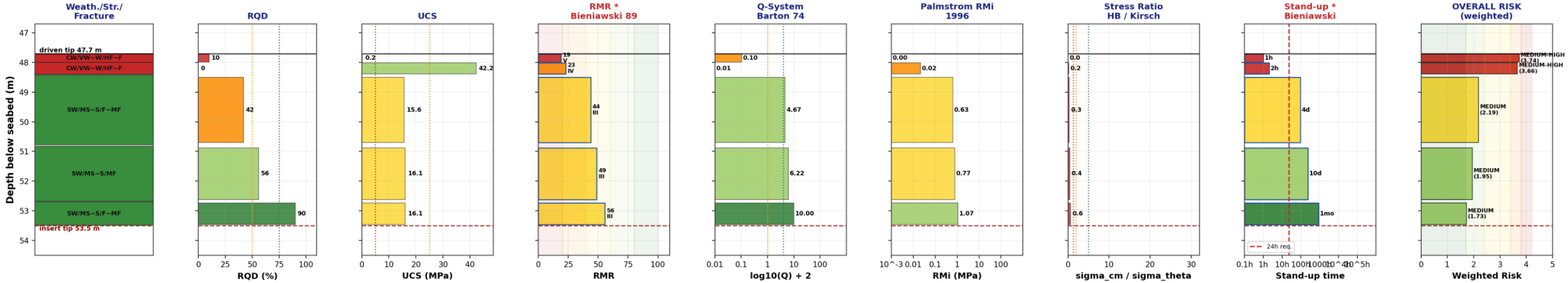


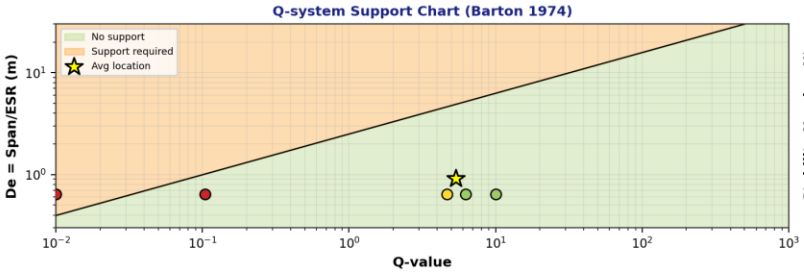
Parameter	Value	Parameter	Value
Socket length	6.2 m	Avg RMR	40 [Poor]
Socket diameter	3.2 m	Avg Q-value	1.69 [Poor]
Avg UCS	165.4 MPa	Avg GSI	35
Avg RQD	30 %	Avg N'	2.54
Avg sigma_cm	8.01 MPa	Avg Em	16.3 GPa
Min stress ratio	0.1	Min CS / span	0.16
Avg RMi	3.83	Max rp/r0	1.00
Min stand-up	2 h (0.1 d)	Worst layer	MEDIUM-HIGH

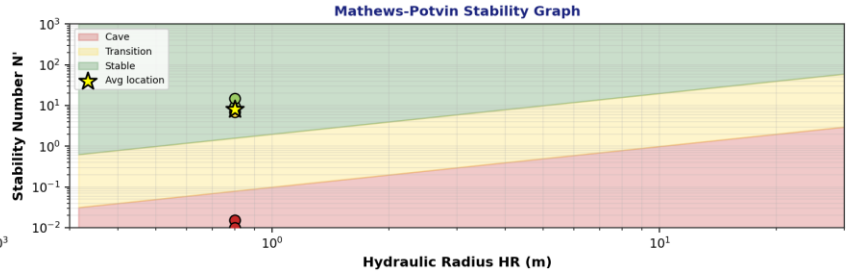
OVERALL SOCKET STABILITY RISK: MEDIUM

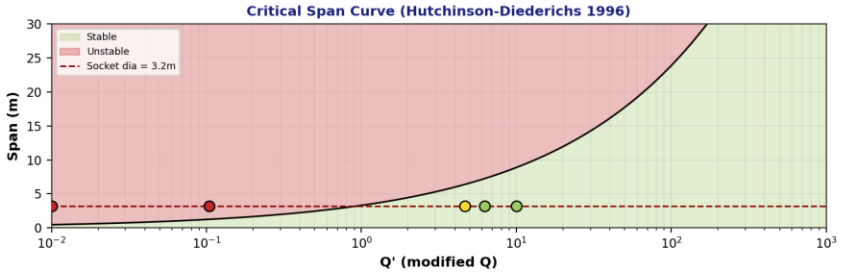
WTG-21 - Open Rock Socket Stability Assessment

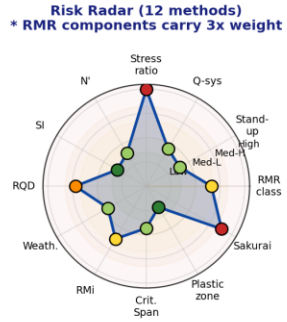
Socket: 47.7 - 53.5 m b.s.b. | Length = 5.7 m | Diameter = 3.2 m | Required stand-up: 24 h

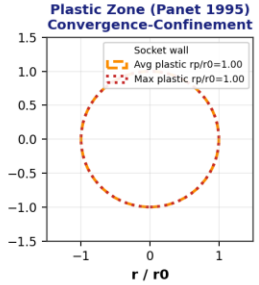










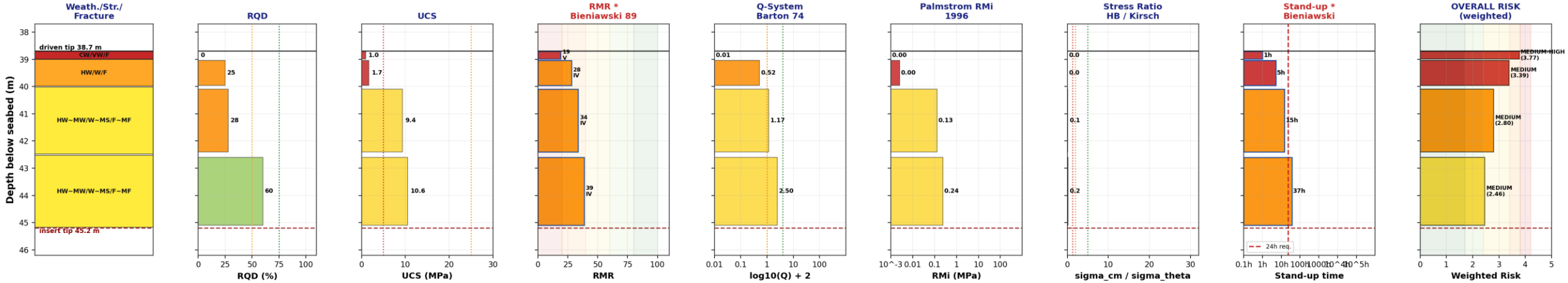


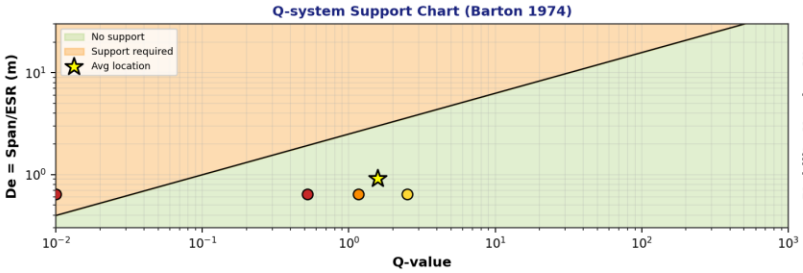
Parameter	Value	Parameter	Value
Socket length	5.7 m	Avg RMR	44 [Fair]
Socket diameter	3.2 m	Avg Q-value	5.35 [Fair]
Avg UCS	16.9 MPa	Avg GSI	39
Avg RQD	49 %	Avg N'	8.01
Avg sigma_cm	0.58 MPa	Avg Em	1.1 GPa
Min stress ratio	0.0	Min CS / span	0.16
Avg RMi	0.65	Max RMR	1.00
Min stand-up	1 h (0.0 d)	Worst layer	MEDIUM-HIGH

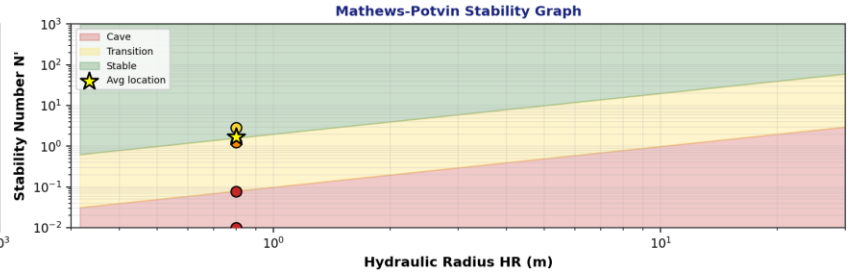
OVERALL SOCKET STABILITY RISK: MEDIUM-LOW

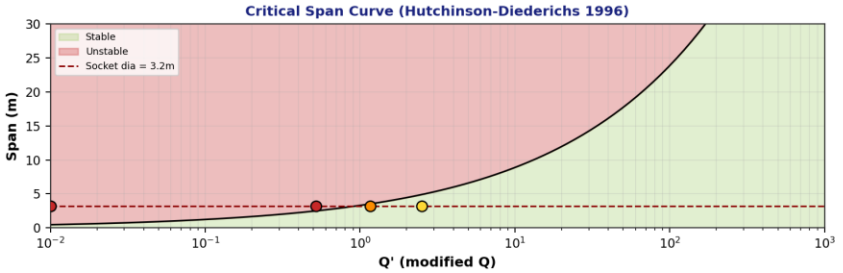
WTG-23 - Open Rock Socket Stability Assessment

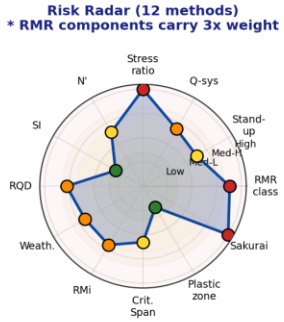
Socket: 38.7 - 45.2 m b.s.b. | Length = 6.4 m | Diameter = 3.2 m | Required stand-up: 24 h

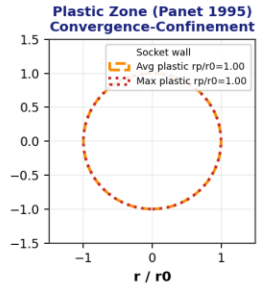










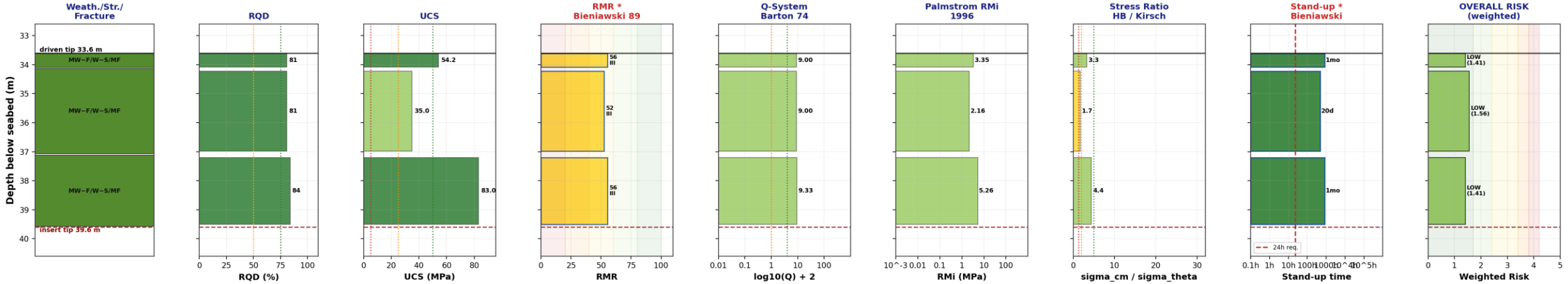


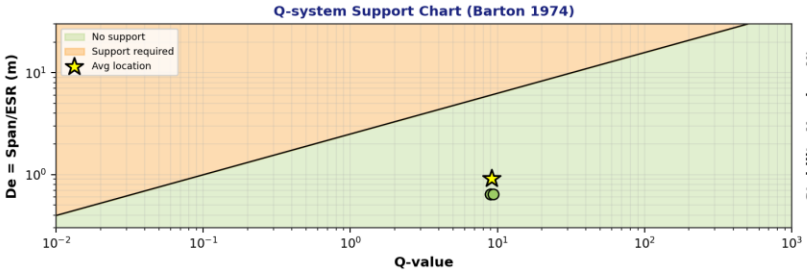
Parameter	Value	Parameter	Value
Socket length	6.4 m	Avg RMR	34 [Poor]
Socket diameter	3.2 m	Avg Q-value	1.57 [Poor]
Avg UCS	8.3 MPa	Avg GSI	29
Avg RQD	40 %	Avg N'	1.69
Avg sigma_cm	0.16 MPa	Avg Em	0.3 GPa
Min stress ratio	0.0	Min CS / span	0.16
Avg RMi	0.17	Max RMR	100
Min stand-up	1 h (0.0 d)	Worst layer	MEDIUM-HIGH

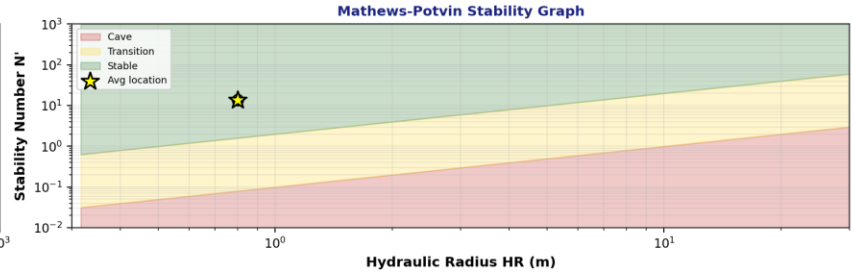
OVERALL SOCKET STABILITY RISK: MEDIUM

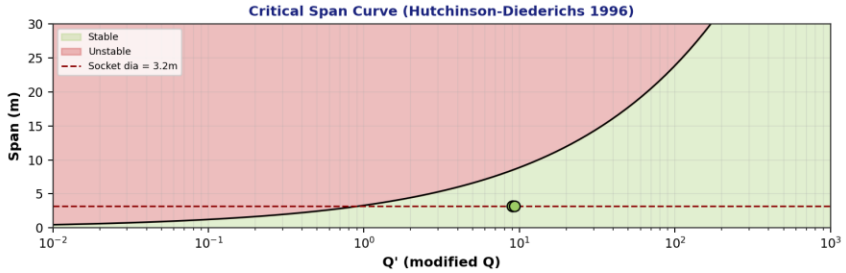
WTG-25 - Open Rock Socket Stability Assessment

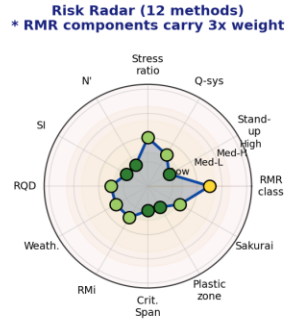
Socket: 33.6 - 39.6 m b.s.b. | Length = 5.9 m | Diameter = 3.2 m | Required stand-up: 24 h

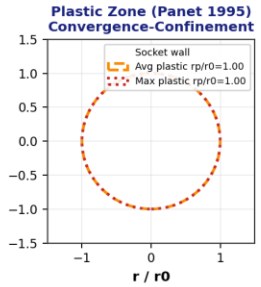










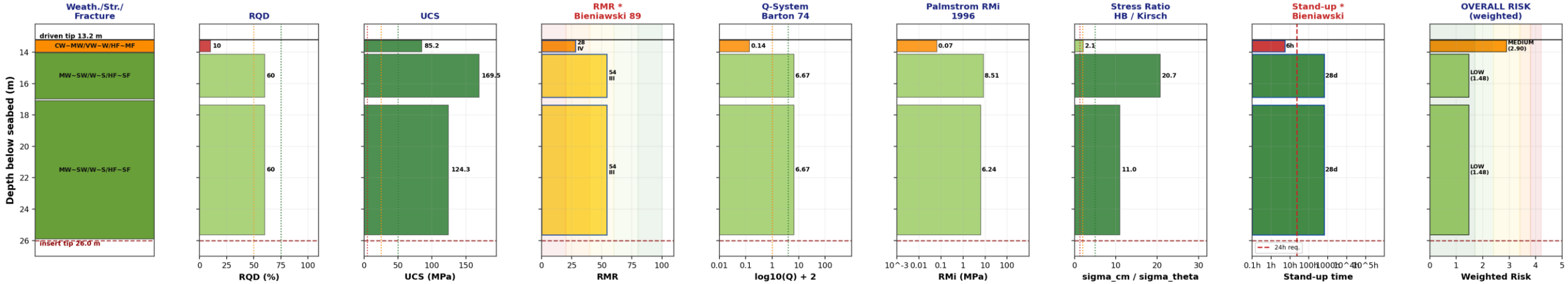


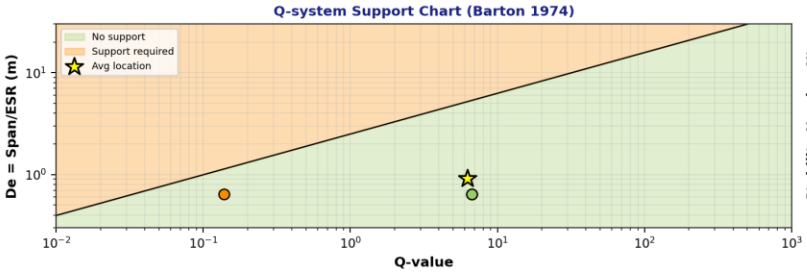
Parameter	Value	Parameter	Value
Socket length	5.9 m	Avg RMR	54 [Fair]
Socket diameter	3.2 m	Avg Q-value	9.14 [Fair]
Avg UCS	56.6 MPa	Avg GSI	49
Avg RQD	82 %	Avg N'	13.71
Avg sigma_cm	3.34 MPa	Avg Em	6.8 GPa
Min stress ratio	1.7	Min CS / span	3.32
Avg RMi	3.35	Min RMR	1.00
Min stand-up	481 h (20.0 d)	Worst layer	LOW

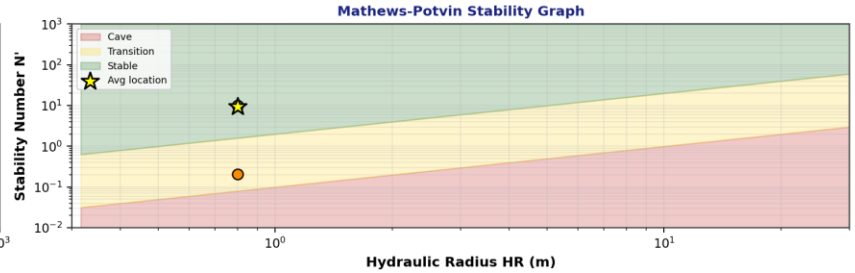
OVERALL SOCKET STABILITY RISK: LOW

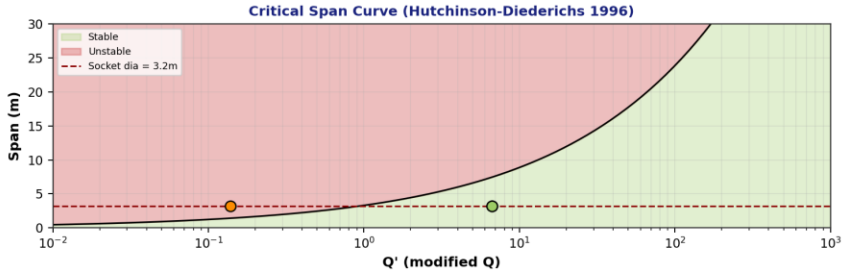
WTG-26 - Open Rock Socket Stability Assessment

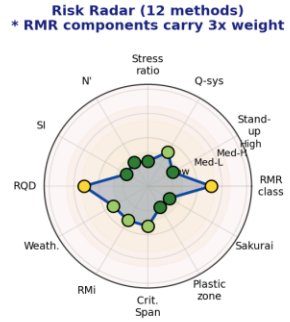
Socket: 13.2 - 26.0 m b.s.b. | Length = 12.7 m | Diameter = 3.2 m | Required stand-up: 24 h

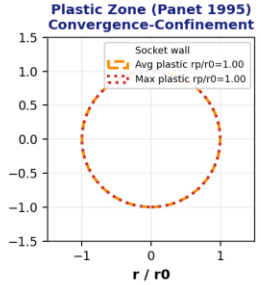










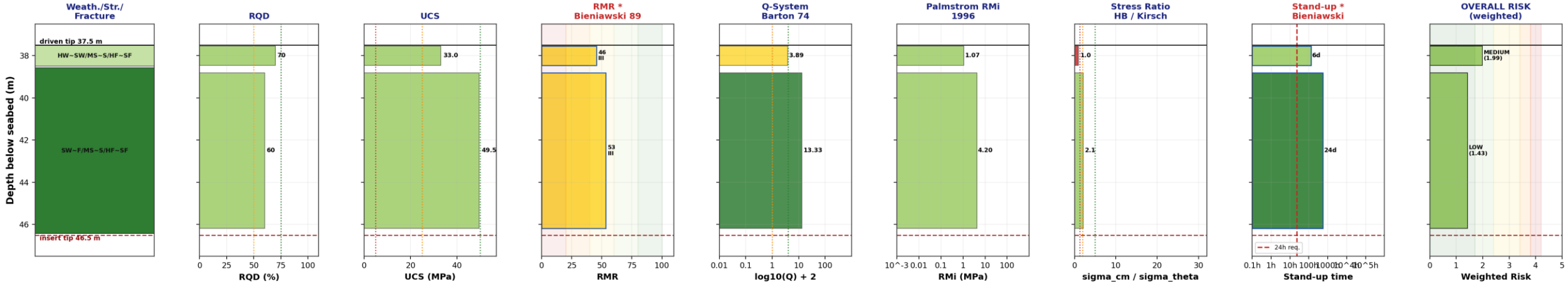


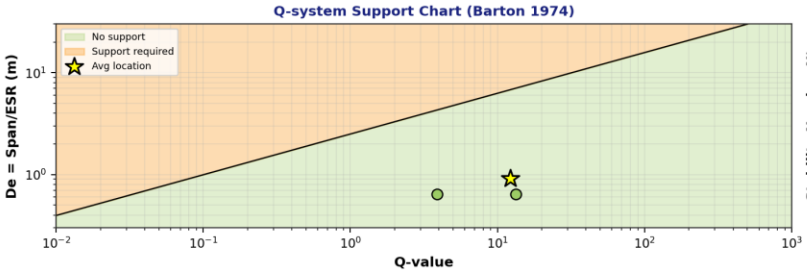
Parameter	Value	Parameter	Value
Socket length	12.7 m	Avg RMR	53 [Fair]
Socket diameter	3.2 m	Avg Q-value	6.26 [Fair]
Avg UCS	132.5 MPa	Avg GSI	48
Avg RQD	57 %	Avg N'	9.39
Avg sigma_cm	7.38 MPa	Avg Em	15.0 GPa
Min stress ratio	2.1	Min CS / span	0.55
Avg RMi	6.39	Min RMR	1.00
Min stand-up	6 h (0.2 d)	Worst layer	MEDIUM

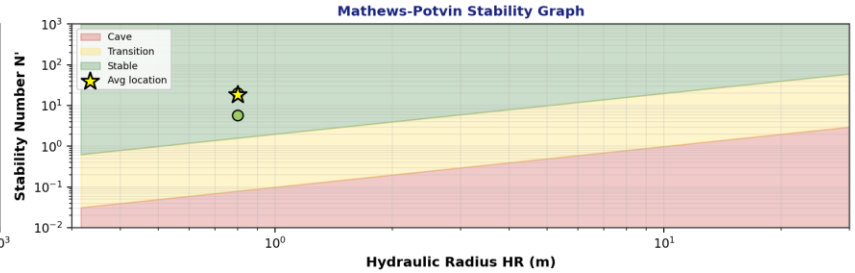
OVERALL SOCKET STABILITY RISK: LOW

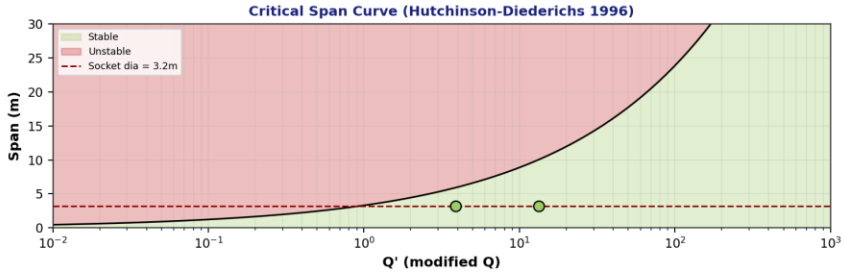
OSS - Open Rock Socket Stability Assessment

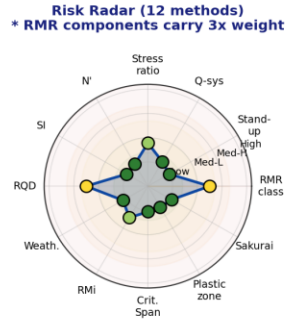
Socket: 37.5 - 46.5 m b.s.b. | Length = 8.9 m | Diameter = 3.2 m | Required stand-up: 24 h

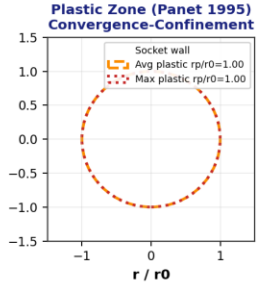












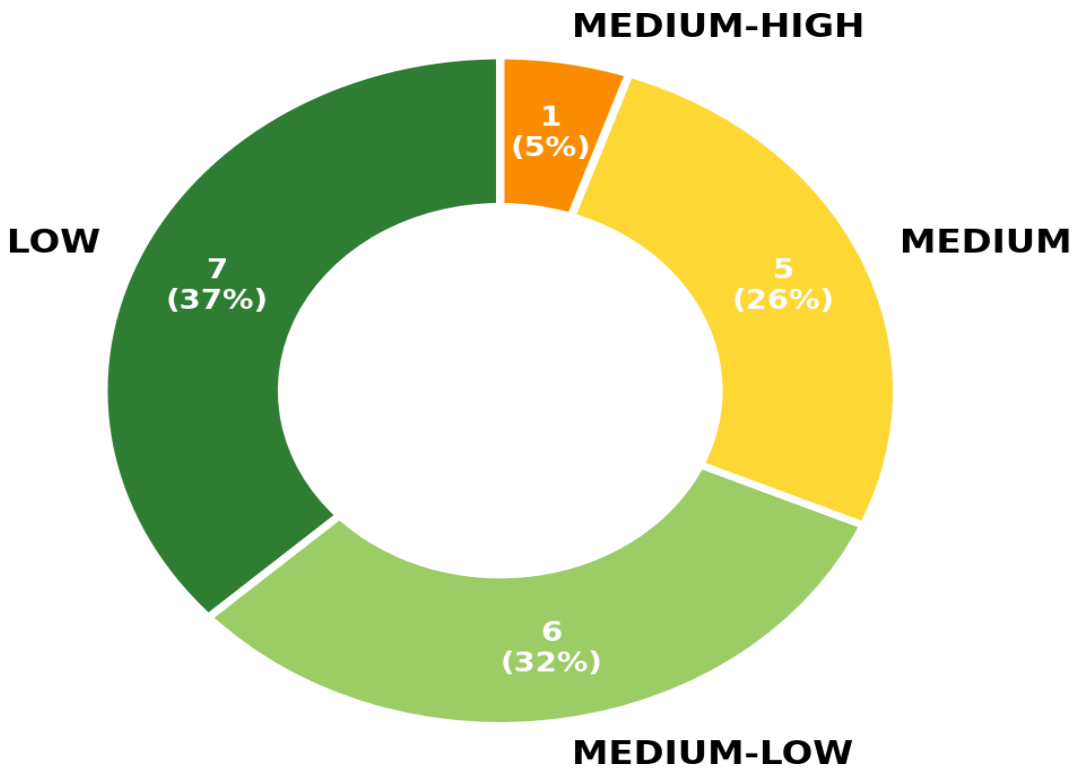
Parameter	Value	Parameter	Value
Socket length	8.9 m	Avg RMR	52 [Fair]
Socket diameter	3.2 m	Avg Q-value	12.28 [Good]
Avg UCS	47.7 MPa	Avg GSI	48
Avg RQD	61 %	Avg N'	18.43
Avg sigma_cm	2.53 MPa	Avg Em	5.1 GPa
Min stress ratio	1.0	Min CS / span	2.31
Avg RMi	3.86	Min RMi	1.00
Min stand-up	132 h (5.5 d)	Worst layer	MEDIUM

OVERALL SOCKET STABILITY RISK: LOW

Conclusions

Open Rock Socket Stability - Shinan-Ui OWF

Risk Distribution (19 locations)



KEY FINDINGS

- 13 of 19 locations are LOW or MEDIUM-LOW risk
- 5 locations are MEDIUM risk
- 1 locations are MEDIUM-HIGH risk: WTG-12
- 0 locations are HIGH risk

PHYSICAL MECHANISM:

- Stress-induced collapse is NOT the controlling mechanism:
  sigma_theta_max ~ 1.0-1.5 MPa vs sigma_cm ~ 0.3-2 MPa
  Mogi-Coulomb factor of safety = 24 to 1700+

- The real concern is TIME-DEPENDENT CAVING in poor or fractured rock zones

- RMR-based stand-up time is the controlling indicator (RMR weighted 3x in the composite risk score)

- Across the 19 RS Insert Pile locations, the rock mass varies from Very Good (RMR 74) to Poor (RMR 27), with stand-up times from a few hours to >1000 hours

All numerical results in Socket_Stability_Results.xlsx | Per-location plots in Plots/<LOC>_Socket_Stability.png