

Grout Volume Loss into Rock Fractures

Rock Socket Grouting — RS Insert Pile Locations

Shinan-Ui Offshore Wind Farm

Based on Rock Characterization Data: TCR, RQD, Fracture, Weathering, Strength

Methods: Lombardi (1985), Priest & Hudson (1976), Houlsby (1990)

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Grout Loss into Rock Fractures — Geometry

1. ROCK SOCKET ZONE — Where Grout Contacts Rock

Grout is exposed to rock ONLY below the driven pile tip:

- **TOP:** Driven Pile Tip (bottom of driven pile)
- **BOTTOM:** Insert Pile Tip (bottom of insert pile)

Above this zone, grout is contained between two steel pipes — no rock contact.

KEY DIMENSIONS

Rock Socket Diameter	$D = 3.2 \text{ m}$
Insert Pile Outside Dia.	$d = 3.0 \text{ m}$
Socket Wall Perimeter	$P = \pi \times 3.2 = 10.05 \text{ m}$
Annular Area (socket)	$A = \pi/4 \times (3.2^2 - 3.0^2) = 0.974 \text{ m}^2$

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Method A — Joint Geometry (Lombardi 1985, Priest & Hudson 1976)

STEP 1: Fracture Frequency λ from RQD

Priest & Hudson (1976): $RQD = 100 \times e^{(-0.1\lambda)} \times (0.1\lambda + 1)$

RQD (%)	λ (frac/m)	Quality
90 – 100	1 – 3	Excellent
75 – 90	4 – 6	Good
50 – 75	6 – 10	Fair
25 – 50	10 – 15	Poor
0 – 25	15 – 25	Very Poor

STEP 2: Base Joint Aperture from Fracture Class

S = 0.3 mm **SF = 0.75 mm** **MF = 2.0 mm**
F = 3.5 mm **HF = 7.0 mm**

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Method A (cont.) — Effective Aperture & Volume Formula

STEP 3: Effective Aperture

$$e_{eff} = e_{base} \times W_{mult} \times S_{factor}$$

Weathering Multiplier (W_mult):

$$F = 1.0 \quad SW = 1.1 \quad MW = 1.75 \quad HW = 3.0 \quad CW = 4.5$$

Strength Factor (S_factor):

$$VS = 1.0 \quad S = 1.0 \quad MS = 1.1 \quad W = 1.25 \quad VW = 1.5$$

STEP 4: Grout Loss Volume per Layer

$$V_A = 2 \times \pi \times r_{socket} \times R_{pen} \times \lambda \times e_{eff} \times L$$

where:

r_{socket} = 1.6 m (rock socket radius)

R_{pen} = 0.75 m (grout penetration radius into rock)

L = layer thickness (m)

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Method B — TCR Void Fraction Method

CONCEPT: Core Loss = Rock Mass Voids

Core loss (100 – TCR) represents voids, cavities, and fractured zones that can accept grout from the rock socket wall.

Void Fraction:

$$V_f = \alpha \times (100 - \text{TCR}) / 100$$

where $\alpha = 0.5$ (effectiveness factor — not all voids accept grout)

Grout Loss Volume:

$$V_B = \pi \times [(r + R_{\text{pen}})^2 - r^2] \times V_f \times L$$
$$= \pi \times [(1.6 + 0.75)^2 - 1.6^2] \times V_f \times L = 13.22 \times V_f \times L \quad (\text{m}^3)$$

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Method C — RQD Empirical Multiplier (Houlsby 1990)

EMPIRICAL MULTIPLIER FROM DAM GROUTING EXPERIENCE

$$V_C = (\text{Multiplier} - 1) \times V_{\text{annular_per_layer}}$$

RQD (%)	Rock Quality	Multiplier
> 90	Excellent	1.10
75 – 90	Good	1.22
50 – 75	Fair	1.55
25 – 50	Poor	2.40
< 25	Very Poor	4.00

Reference: Houlsby, A.C. (1990) — "Construction and Design of Cement Grouting" — Wiley

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Combined Estimate & Grout Loss Percentage

COMBINED ESTIMATE

Mean Estimate = average of Method A, B, and C

(combines joint geometry + void fraction + empirical dam grouting data)

All values capped at maximum 50%

GROUT LOSS PERCENTAGE

$\% \text{ Loss} = \text{Grout Loss} / (\text{Overlap Annulus} + \text{Socket Annulus}) \times 100$

$\text{Total Grout per Pile} = \text{Net Annular Volume} + \text{Mean Grout Loss}$

KEY REFERENCES

- Priest & Hudson (1976) — RQD to fracture frequency
- Lombardi (1985) — Joint penetration model for grout flow
- Houlsby (1990) — Empirical grout take from dam grouting
- Ewert (1985) — Rock grouting & Lugeon correlations

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Summary Table — Grout Loss per Location (% of Annulus Volume)

Grout Loss into Rock Fractures — Summary per Location Shinan-Ui Offshore Wind Farm — RS Insert Pile Locations

% Loss = Grout Loss / (Overlap + Socket Annulus) * 100 | Cap Loss = 5% Max
Green <15% | Yellow 15-30% | Orange 30-60% | Red >60%

Location	Overlap Annulus (m³)	Socket Annulus (m³)	Total Annulus (m³)	Method A Joints (m³)	% A	Method B TCR (m³)	% B	Method C RQD (m³)	% C	Mean Loss (m³)	% Mean	Total Grout (net+mean) (m³)
WTG-04	9.33	7.50	16.83	3.11	18%	1.35	8%	5.73	34%	3.40	20%	20.23
WTG-06	9.33	5.75	15.08	2.47	16%	2.12	14%	4.65	31%	3.08	20%	18.16
WTG-07	9.33	7.50	16.83	5.20	31%	2.65	16%	8.41	50%	5.42	32%	22.25
WTG-08	9.33	7.01	16.34	3.03	19%	1.13	7%	6.18	38%	3.45	21%	19.79
WTG-09	9.33	7.30	16.63	8.32	50%	3.21	19%	8.32	50%	6.61	40%	23.25
WTG-10	9.33	5.16	14.49	2.23	15%	2.00	14%	4.60	32%	2.94	20%	17.44
WTG-11	13.14	7.50	20.64	1.14	6%	0.96	5%	1.23	6%	1.11	5%	21.75
WTG-12	9.33	7.79	17.12	8.56	50%	8.56	50%	8.56	50%	8.56	50%	25.68
WTG-13	13.90	10.71	24.61	1.95	8%	0.77	3%	1.65	7%	1.46	6%	26.07
WTG-14	13.90	10.62	24.52	1.49	6%	0.28	1%	1.61	7%	1.13	5%	25.64
WTG-17	13.14	13.83	26.97	0.31	1%	2.79	10%	3.80	14%	2.30	9%	29.27
WTG-18	13.90	8.96	22.86	5.43	24%	7.21	32%	8.62	38%	7.09	31%	29.95
WTG-19	9.33	6.33	15.66	7.83	50%	1.87	12%	7.83	50%	5.84	37%	21.50
WTG-20	9.33	6.04	15.37	6.49	42%	0.00	0%	4.82	31%	3.77	25%	19.14
WTG-21	9.33	5.55	14.88	4.81	32%	1.41	9%	6.41	43%	4.21	28%	19.09
WTG-23	9.33	6.23	15.56	5.33	34%	4.57	29%	6.22	40%	5.37	35%	20.94
WTG-25	9.33	5.75	15.08	0.68	5%	0.00	0%	1.18	8%	0.62	4%	15.70
WTG-26	13.33	12.37	25.70	3.18	12%	2.68	10%	3.94	15%	3.27	13%	28.96
OSS	9.52	8.67	18.19	1.90	10%	0.47	3%	4.82	27%	2.40	13%	20.58

Proposed values

NOTE: All % loss values are capped at maximum 50%

DRAFT — Calculations in Progress

Rock Characterization & Grout Volume — WTG-04

Rock Characterization — WTG-04 (RS Insert Pile) Shinan-Ui Offshore Wind Farm

GROUT VOLUME (per pile)
 Driven OD=3.5m, ID=3.38m
 Insert OD=3.0m
 Rock Socket=3.2m

Plug (0.1m): 0.80 m³
 Overlap zone: 4.9m → 9.33 m³
 Socket zone: 7.7m → 7.50 m³

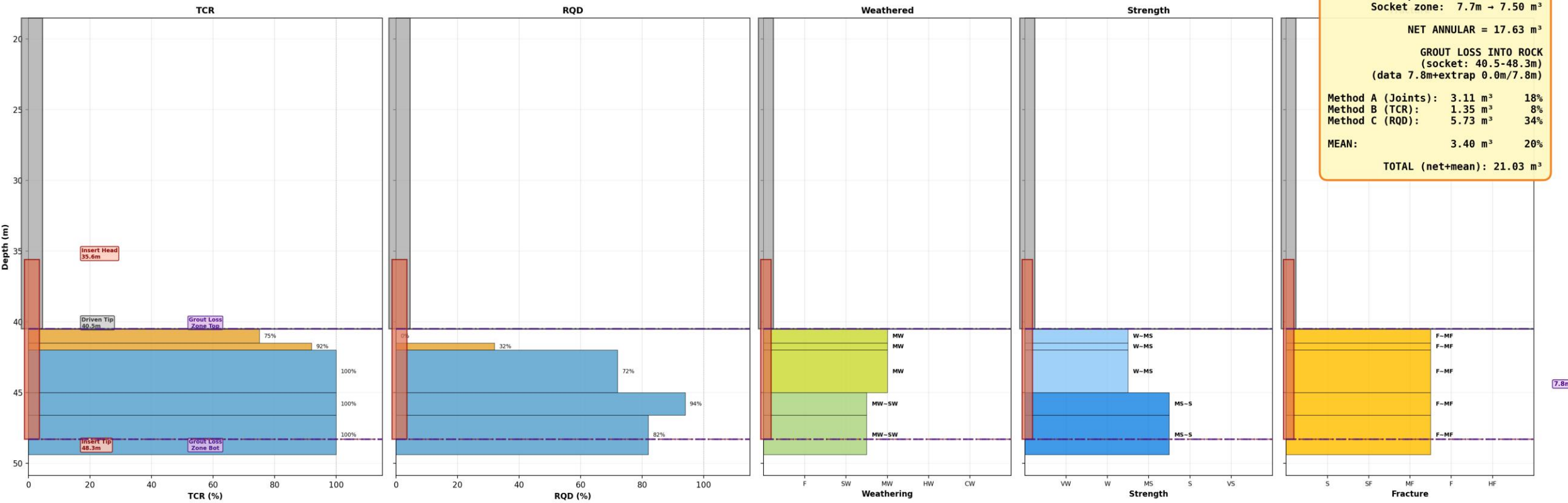
NET ANNULAR = 17.63 m³

**GROUT LOSS INTO ROCK
(socket: 40.5-48.3m)
(data 7.8m+extrap 0.0m/7.8m)**

Method A (Joints): 3.11 m³ 18%
 Method B (TCR): 1.35 m³ 8%
 Method C (RQD): 5.73 m³ 34%

MEAN: 3.40 m³ 20%

TOTAL (net+mean): 21.03 m³



- TCR/RQD Legend:**
 - Weathered Rock (Orange)
 - Soft Rock (Blue)
 - Driven Pile (Grey)
 - Insert Pile (Red)
- Weathered Legend:**
 - F - Fresh (Dark Green)
 - SW - Slightly Weath. (Light Green)
 - MW - Moderately Weath. (Yellow-Green)
 - HW - Highly Weath. (Yellow)
 - CW - Completely Weath. (Orange)
- Strength Legend:**
 - VS - Very Strong (Dark Blue)
 - S - Strong (Blue)
 - MS - Moderately Strong (Light Blue)
 - W - Weak (Yellow)
 - VW - Very Weak (Orange)
- Fracture Legend:**
 - S - Solid (Dark Green)
 - SF - Slightly Fract. (Light Green)
 - MF - Moderately Fract. (Yellow-Green)
 - F - Fractured (Yellow)
 - HF - Highly Fract. (Orange)

DRAFT — Calculations in Progress | Values capped at 50% max

Rock Characterization & Grout Volume — WTG-06

Rock Characterization — WTG-06 (RS Insert Pile) Shinan-Ui Offshore Wind Farm

GROUT VOLUME (per pile)
 Driven OD=3.5m, ID=3.38m
 Insert OD=3.0m
 Rock Socket=3.2m

Plug (0.1m): 0.80 m³
 Overlap zone: 4.9m → 9.33 m³
 Socket zone: 5.9m → 5.75 m³

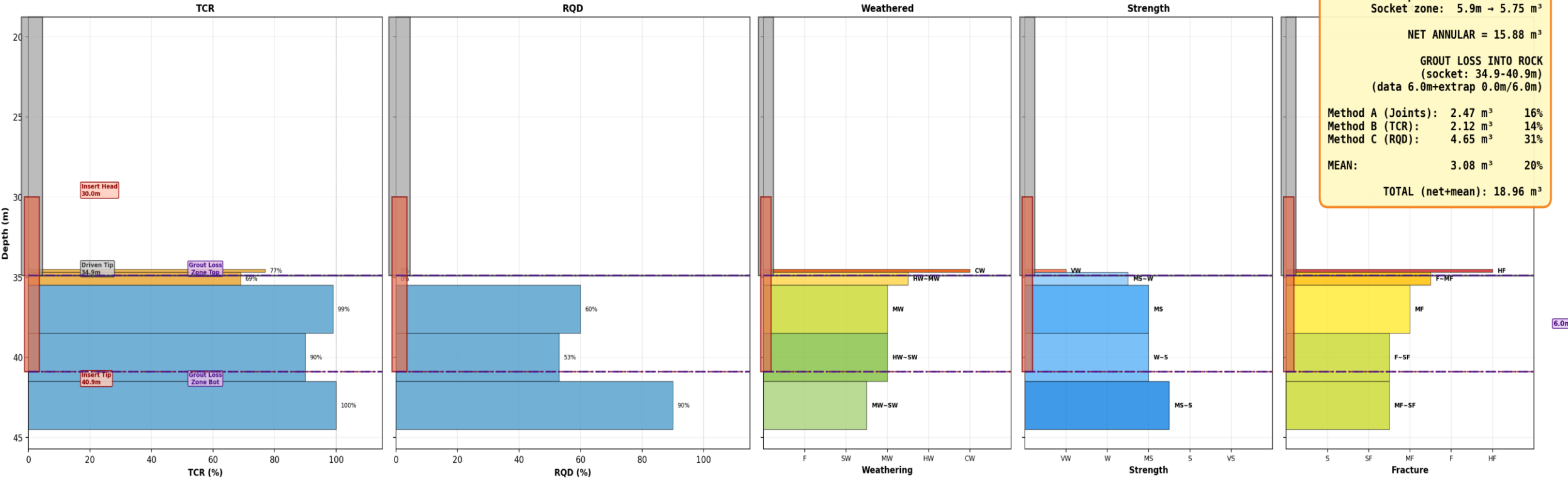
NET ANNULAR = 15.88 m³

GROUT LOSS INTO ROCK (socket: 34.9-40.9m)
 (data 6.0m+extrap 0.0m/6.0m)

Method A (Joints): 2.47 m³ 16%
 Method B (TCR): 2.12 m³ 14%
 Method C (RQD): 4.65 m³ 31%

MEAN: 3.08 m³ 20%

TOTAL (net+mean): 18.96 m³



DRAFT — Calculations in Progress | Values capped at 50% max

Rock Characterization & Grout Volume — WTG-07

Rock Characterization — WTG-07 (RS Insert Pile) Shinan-Ui Offshore Wind Farm

GROUT VOLUME (per pile)
 Driven OD=3.5m, ID=3.38m
 Insert OD=3.0m
 Rock Socket=3.2m

Plug (0.1m): 0.80 m³
 Overlap zone: 4.9m → 9.33 m³
 Socket zone: 7.7m → 7.50 m³

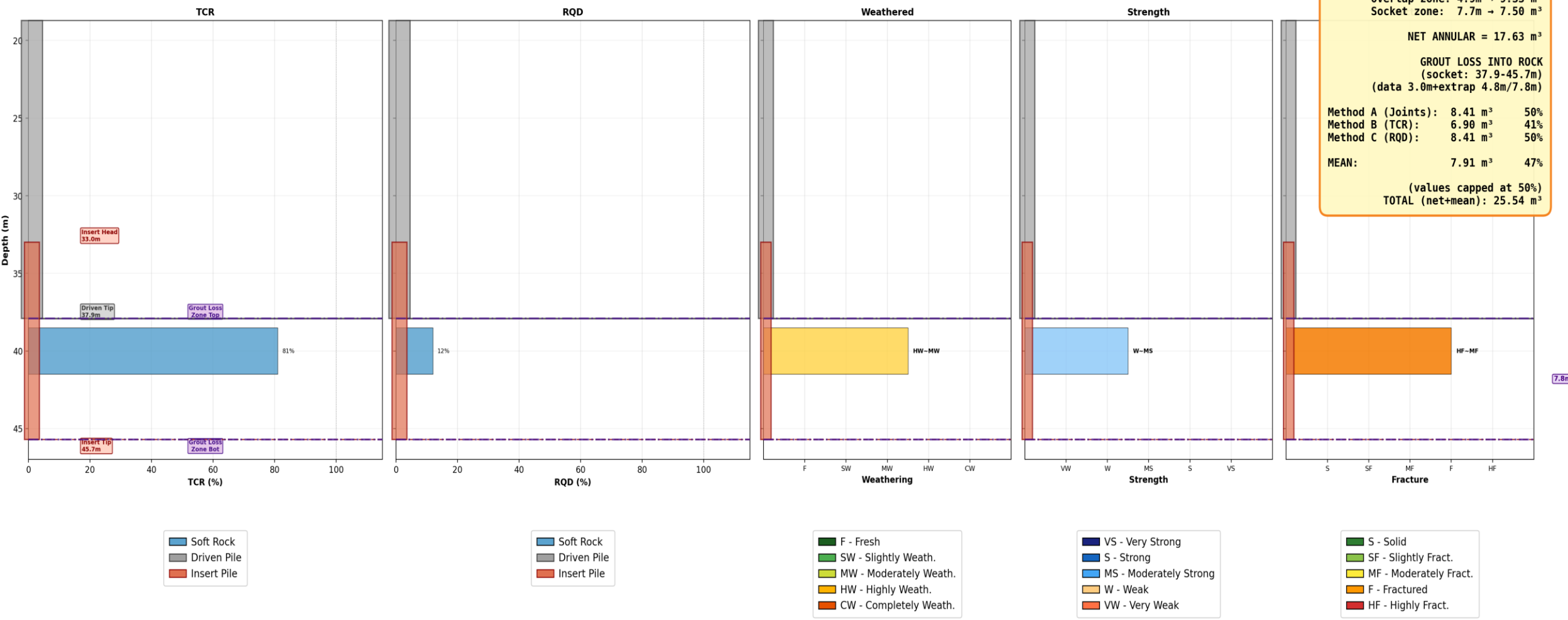
NET ANNULAR = 17.63 m³

GROUT LOSS INTO ROCK
 (socket: 37.9-45.7m)
 (data 3.0m+extrap 4.8m/7.8m)

Method A (Joints): 8.41 m³ 50%
 Method B (TCR): 6.90 m³ 41%
 Method C (RQD): 8.41 m³ 50%

MEAN: 7.91 m³ 47%

(values capped at 50%)
TOTAL (net+mean): 25.54 m³



DRAFT — Calculations in Progress | Values capped at 50% max

Rock Characterization & Grout Volume — WTG-08

Rock Characterization — WTG-08 (RS Insert Pile) Shinan-Ui Offshore Wind Farm

GROUT VOLUME (per pile)
 Driven OD=3.5m, ID=3.38m
 Insert OD=3.0m
 Rock Socket=3.2m

Plug (0.1m): 0.80 m³
 Overlap zone: 4.9m → 9.33 m³
 Socket zone: 7.2m → 7.01 m³

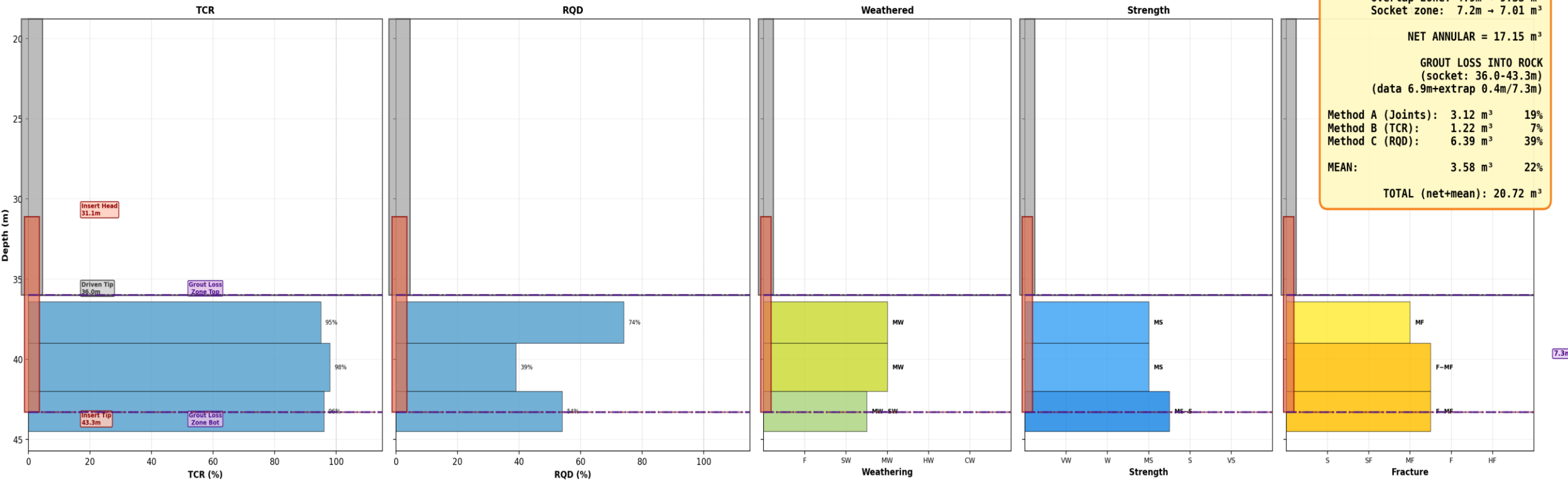
NET ANNULAR = 17.15 m³

GROUT LOSS INTO ROCK
 (socket: 36.0-43.3m)
 (data 6.9m+extrap 0.4m/7.3m)

Method A (Joints): 3.12 m³ 19%
 Method B (TCR): 1.22 m³ 7%
 Method C (RQD): 6.39 m³ 39%

MEAN: 3.58 m³ 22%

TOTAL (net+mean): 20.72 m³



- Soft Rock
 - Driven Pile
 - Insert Pile
- Soft Rock
 - Driven Pile
 - Insert Pile
- F - Fresh
 - SW - Slightly Weath.
 - MW - Moderately Weath.
 - HW - Highly Weath.
 - CW - Completely Weath.
- VS - Very Strong
 - S - Strong
 - MS - Moderately Strong
 - W - Weak
 - VW - Very Weak
- S - Solid
 - SF - Slightly Fract.
 - MF - Moderately Fract.
 - F - Fractured
 - HF - Highly Fract.

DRAFT — Calculations in Progress | Values capped at 50% max

Rock Characterization & Grout Volume — WTG-09

Rock Characterization — WTG-09 (RS Insert Pile) Shinan-Ui Offshore Wind Farm

GROUT VOLUME (per pile)
 Driven OD=3.5m, ID=3.38m
 Insert OD=3.0m
 Rock Socket=3.2m

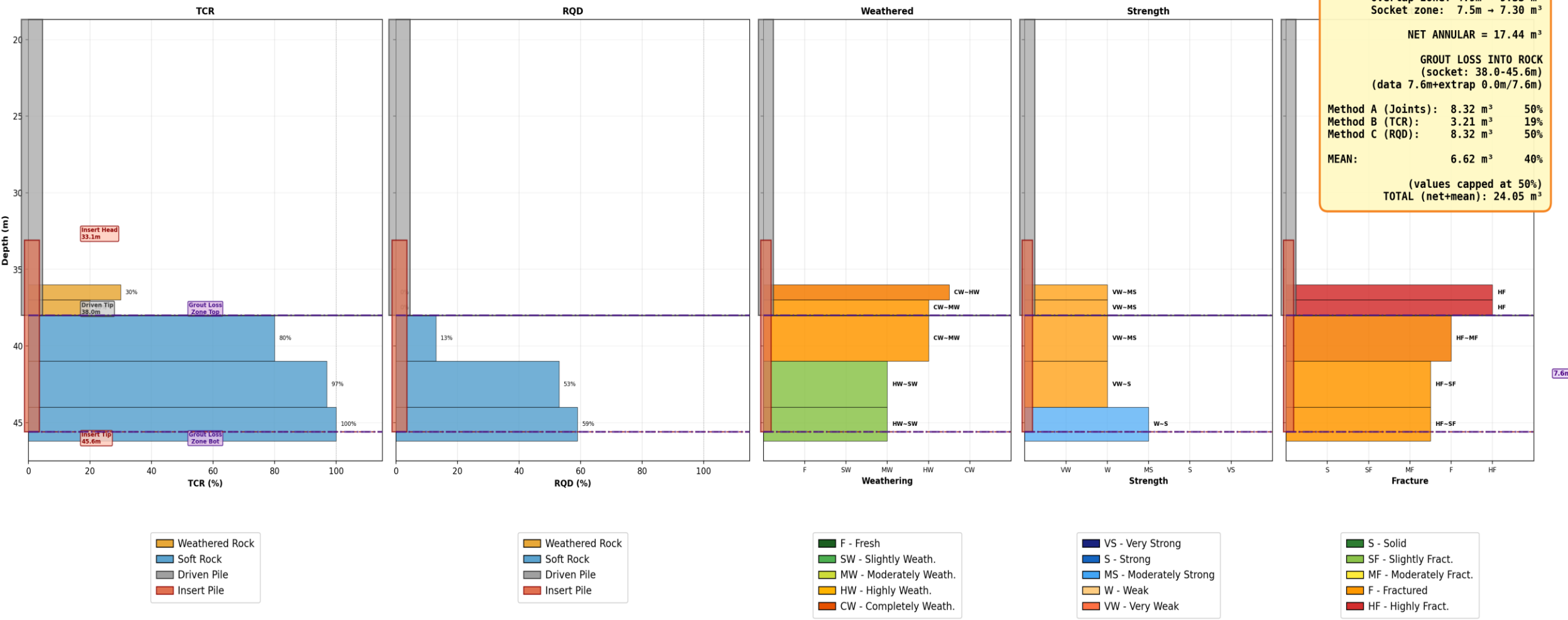
Plug (0.1m): 0.80 m³
 Overlap zone: 4.9m → 9.33 m³
 Socket zone: 7.5m → 7.30 m³

NET ANNULAR = 17.44 m³

GROUT LOSS INTO ROCK (socket: 38.0-45.6m)
 (data 7.6m+extrap 0.0m/7.6m)

Method A (Joints): 8.32 m³ 50%
 Method B (TCR): 3.21 m³ 19%
 Method C (RQD): 8.32 m³ 50%

MEAN: 6.62 m³ 40%
 (values capped at 50%)
TOTAL (net+mean): 24.05 m³



DRAFT — Calculations in Progress | Values capped at 50% max

Rock Characterization & Grout Volume — WTG-10

Rock Characterization — WTG-10 (RS Insert Pile) Shinan-Ui Offshore Wind Farm

GROUT VOLUME (per pile)
 Driven OD=3.5m, ID=3.38m
 Insert OD=3.0m
 Rock Socket=3.2m

Plug (0.1m): 0.80 m³
 Overlap zone: 4.9m → 9.33 m³
 Socket zone: 5.3m → 5.16 m³

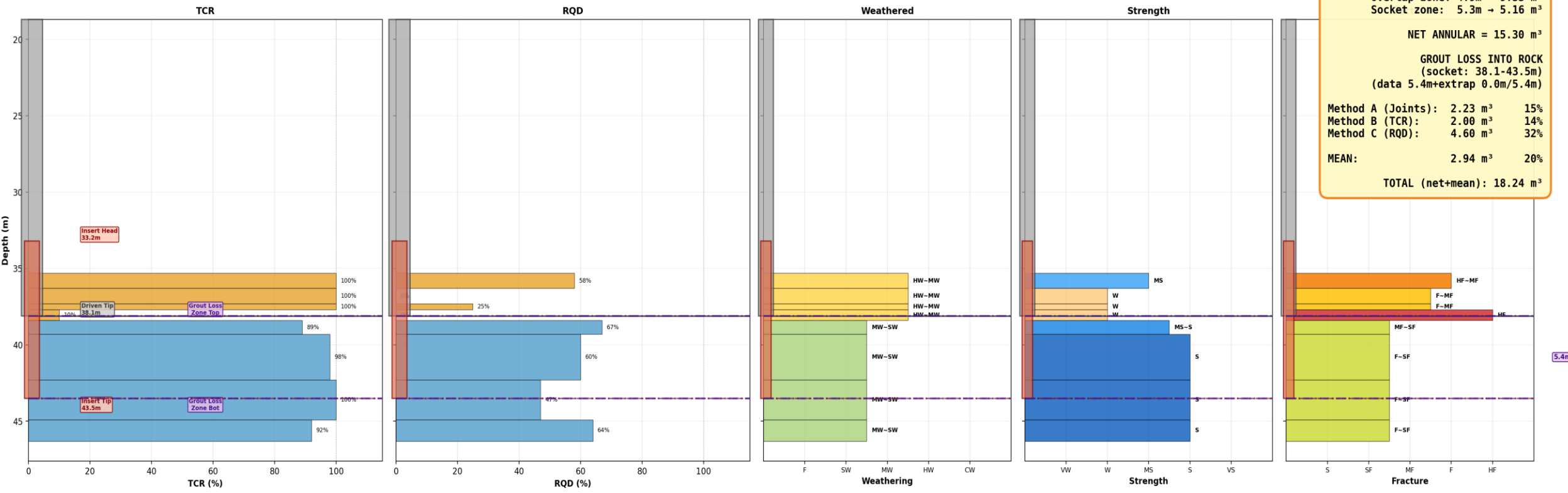
NET ANNULAR = 15.30 m³

**GROUT LOSS INTO ROCK
(socket: 38.1-43.5m)
(data 5.4m+extrap 0.0m/5.4m)**

Method A (Joints): 2.23 m³ 15%
 Method B (TCR): 2.00 m³ 14%
 Method C (RQD): 4.60 m³ 32%

MEAN: 2.94 m³ 20%

TOTAL (net+mean): 18.24 m³



Weathered Rock
 Soft Rock
 Driven Pile
 Insert Pile

Weathered Rock
 Soft Rock
 Driven Pile
 Insert Pile

F - Fresh
 SW - Slightly Weath.
 MW - Moderately Weath.
 HW - Highly Weath.
 CW - Completely Weath.

VS - Very Strong
 S - Strong
 MS - Moderately Strong
 W - Weak
 VW - Very Weak

S - Solid
 SF - Slightly Fract.
 MF - Moderately Fract.
 F - Fractured
 HF - Highly Fract.

DRAFT — Calculations in Progress | Values capped at 50% max

Rock Characterization & Grout Volume — WTG-11

Rock Characterization — WTG-11 (RS Insert Pile) Shinan-Ui Offshore Wind Farm

GROUT VOLUME (per pile)
 Driven OD=3.5m, ID=3.38m
 Insert OD=3.0m
 Rock Socket=3.2m

Plug (0.1m): 0.80 m³
 Overlap zone: 6.9m → 13.14 m³
 Socket zone: 7.7m → 7.50 m³

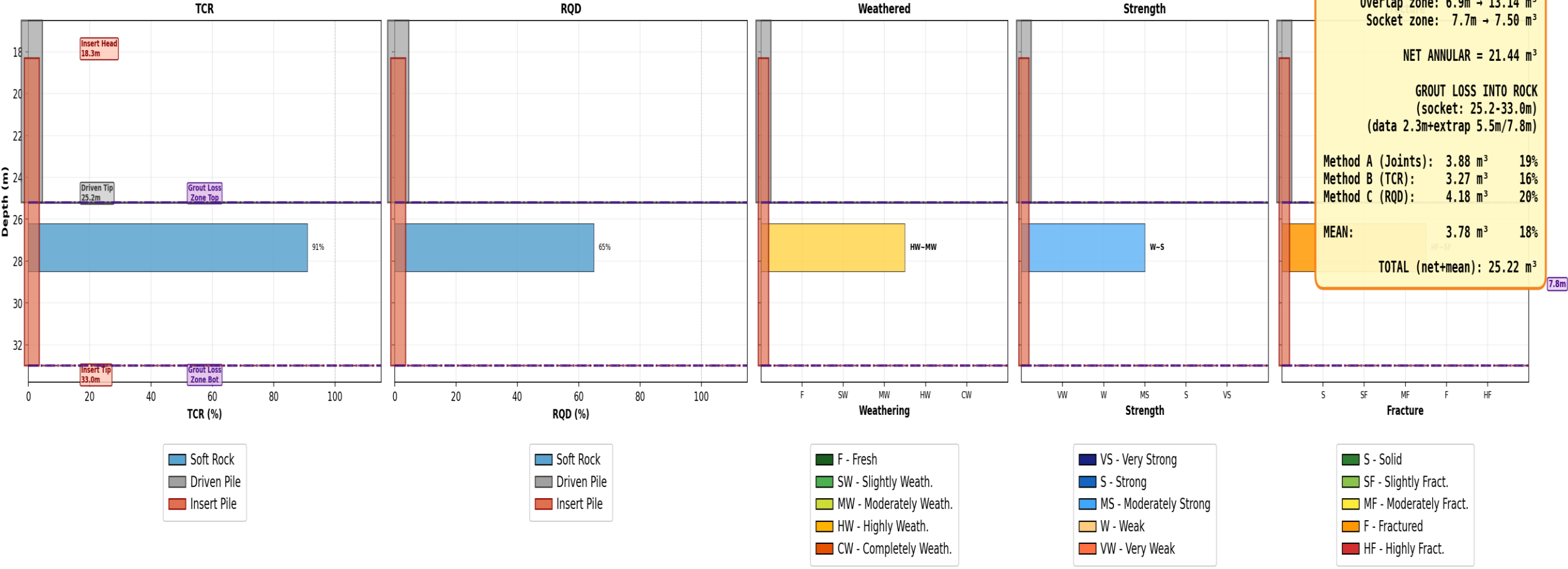
NET ANNULAR = 21.44 m³

GROUT LOSS INTO ROCK
 (socket: 25.2-33.0m)
 (data 2.3m+extrap 5.5m/7.8m)

Method A (Joints): 3.88 m³ 19%
 Method B (TCR): 3.27 m³ 16%
 Method C (RQD): 4.18 m³ 20%

MEAN: 3.78 m³ 18%

TOTAL (net+mean): 25.22 m³



DRAFT – Calculations in Progress | Values capped at 50% max

Rock Characterization & Grout Volume — WTG-12

Rock Characterization — WTG-12 (RS Insert Pile) Shinan-Ui Offshore Wind Farm

GROUT VOLUME (per pile)
 Driven OD=3.5m, ID=3.38m
 Insert OD=3.0m
 Rock Socket=3.2m

Plug (0.1m): 0.80 m³
 Overlap zone: 4.9m → 9.33 m³
 Socket zone: 8.0m → 7.79 m³

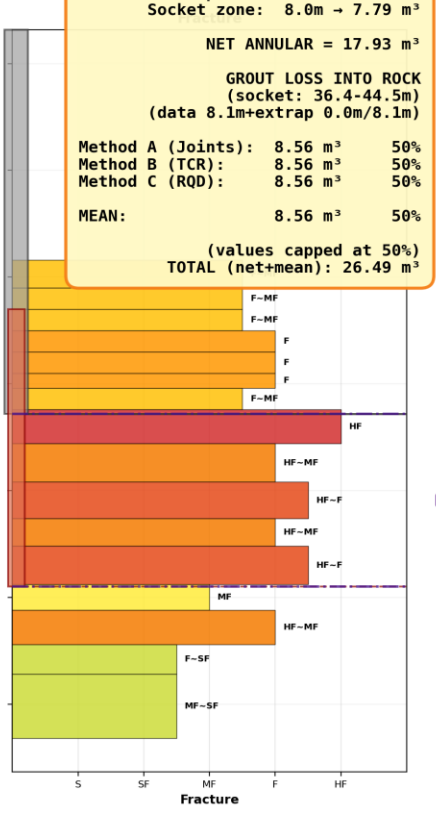
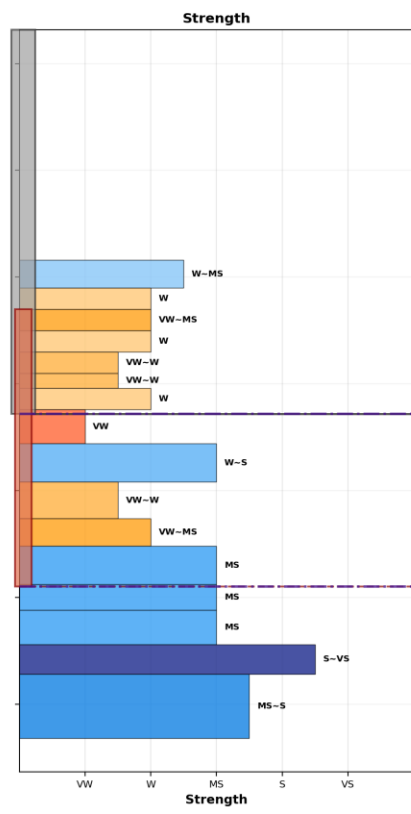
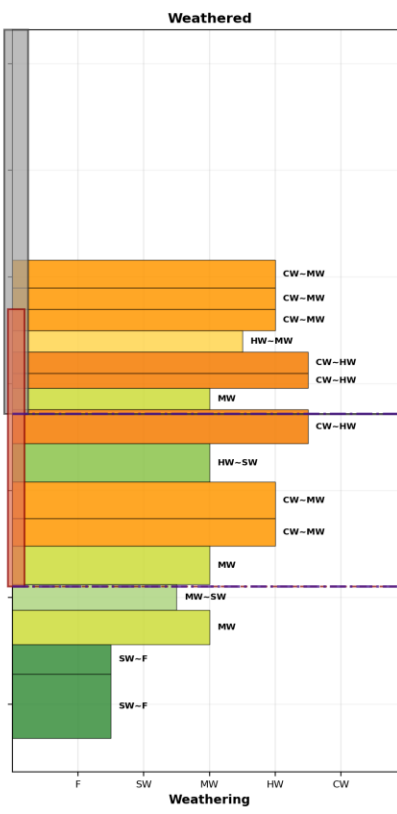
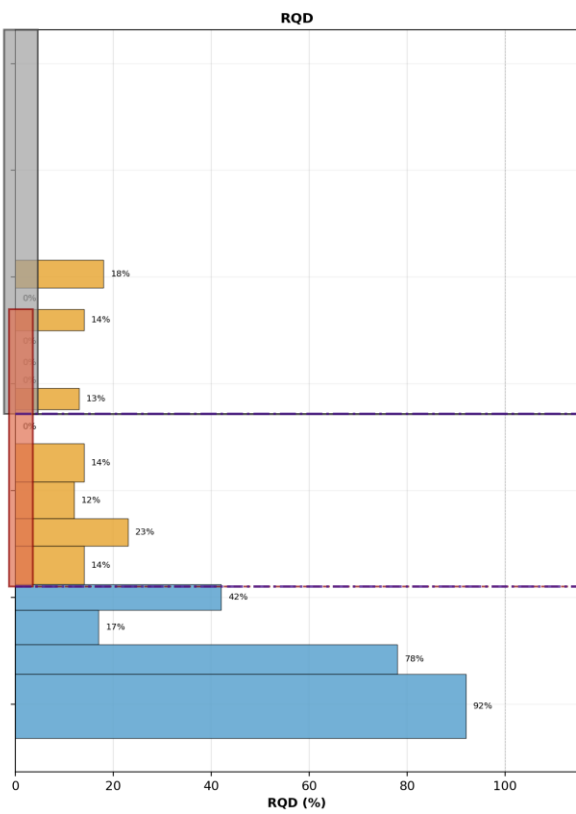
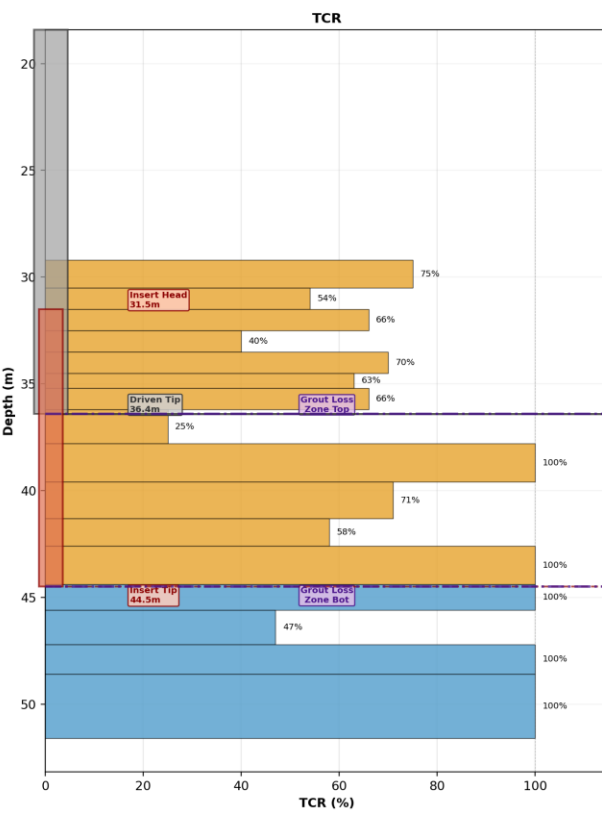
NET ANNULAR = 17.93 m³

GROUT LOSS INTO ROCK
 (socket: 36.4-44.5m)
 (data 8.1m+extrap 0.0m/8.1m)

Method A (Joints): 8.56 m³ 50%
 Method B (TCR): 8.56 m³ 50%
 Method C (RQD): 8.56 m³ 50%

MEAN: 8.56 m³ 50%

(values capped at 50%)
TOTAL (net+mean): 26.49 m³



Weathered Rock
 Soft Rock
 Driven Pile
 Insert Pile

Weathered Rock
 Soft Rock
 Driven Pile
 Insert Pile

F - Fresh
 SW - Slightly Weath.
 MW - Moderately Weath.
 HW - Highly Weath.
 CW - Completely Weath.

VS - Very Strong
 S - Strong
 MS - Moderately Strong
 W - Weak
 VW - Very Weak

S - Solid
 SF - Slightly Fract.
 MF - Moderately Fract.
 F - Fractured
 HF - Highly Fract.

DRAFT — Calculations in Progress | Values capped at 50% max

Rock Characterization & Grout Volume — WTG-13

Rock Characterization — WTG-13 (RS Insert Pile) Shinan-Ui Offshore Wind Farm

GROUT VOLUME (per pile)
 Driven OD=3.5m, ID=3.38m
 Insert OD=3.0m
 Rock Socket=3.2m

Plug (0.1m): 0.80 m³
 Overlap zone: 7.3m → 13.90 m³
 Socket zone: 11.0m → 10.71 m³

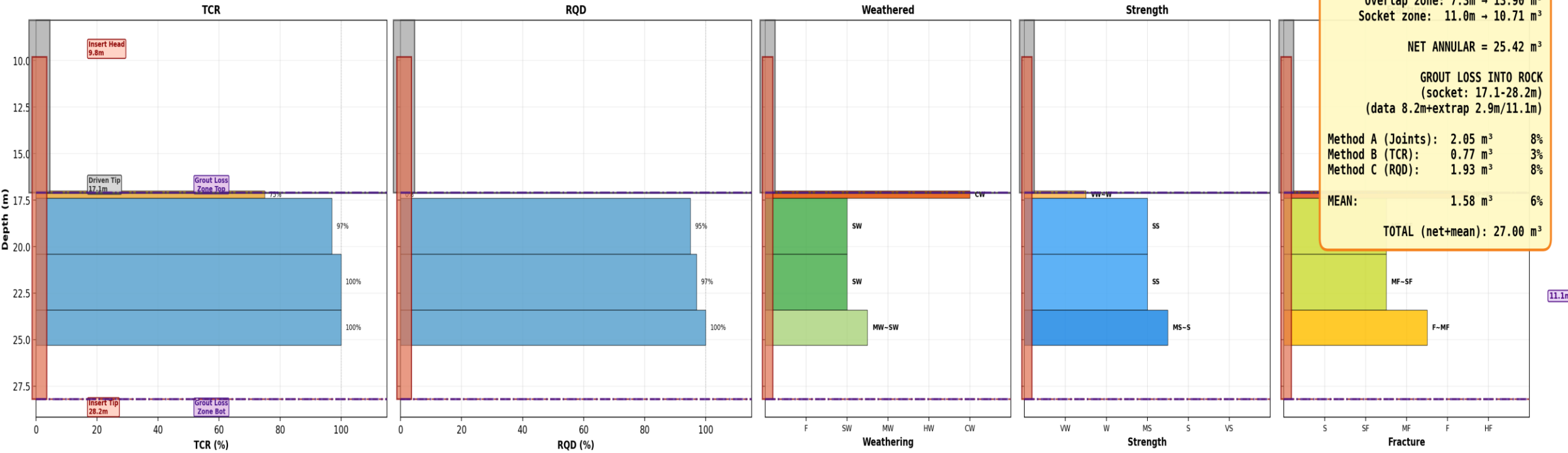
NET ANNULAR = 25.42 m³

GROUT LOSS INTO ROCK
 (socket: 17.1-28.2m)
 (data 8.2m+extrap 2.9m/11.1m)

Method A (Joints): 2.05 m³ 8%
 Method B (TCR): 0.77 m³ 3%
 Method C (RQD): 1.93 m³ 8%

MEAN: 1.58 m³ 6%

TOTAL (net+mean): 27.00 m³



Weathered Rock
 Soft Rock
 Driven Pile
 Insert Pile

Weathered Rock
 Soft Rock
 Driven Pile
 Insert Pile

F - Fresh
 SW - Slightly Weath.
 MW - Moderately Weath.
 HW - Highly Weath.
 CW - Completely Weath.

VS - Very Strong
 S - Strong
 MS - Moderately Strong
 W - Weak
 VW - Very Weak

S - Solid
 SF - Slightly Fract.
 MF - Moderately Fract.
 F - Fractured
 HF - Highly Fract.

DRAFT — Calculations in Progress | Values capped at 50% max

Rock Characterization & Grout Volume — WTG-14

Rock Characterization — WTG-14 (RS Insert Pile) Shinan-Ui Offshore Wind Farm

GROUT VOLUME (per pile)
 Driven OD=3.5m, ID=3.38m
 Insert OD=3.0m
 Rock Socket=3.2m

Plug (0.1m): 0.80 m³
 Overlap zone: 7.3m → 13.90 m³
 Socket zone: 10.9m → 10.62 m³

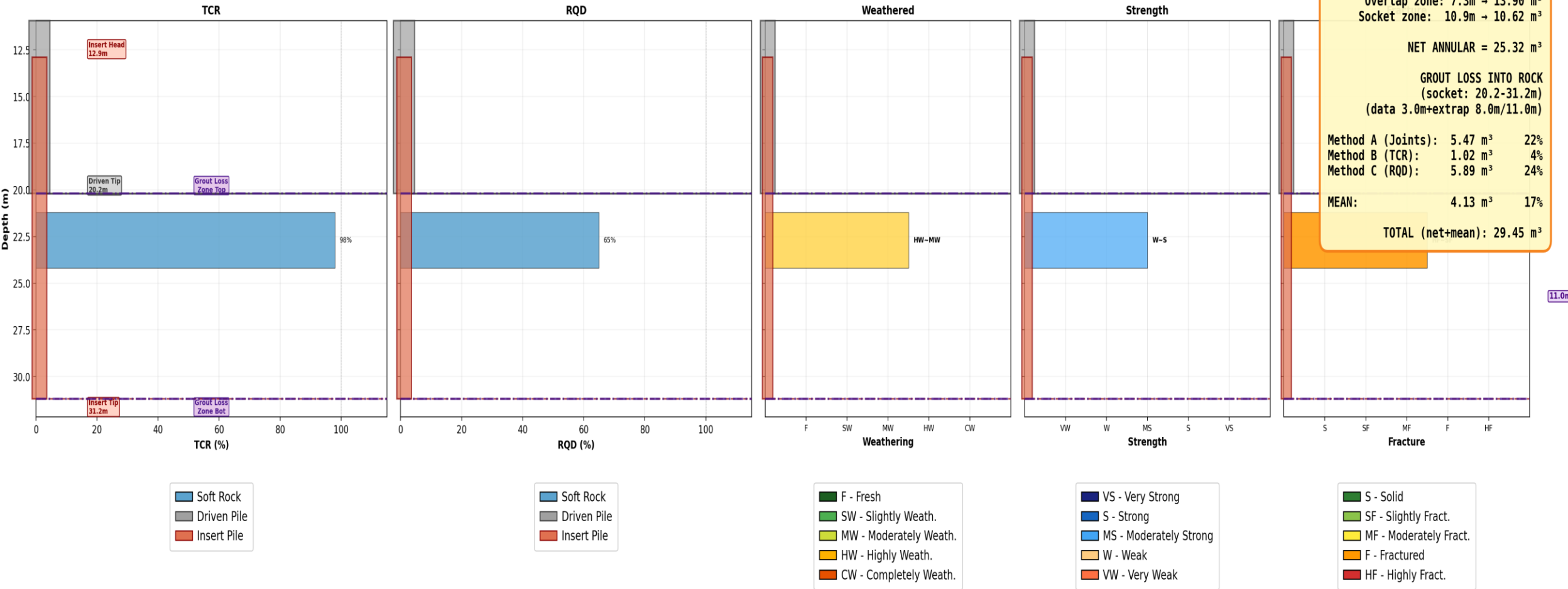
NET ANNULAR = 25.32 m³

**GROUT LOSS INTO ROCK
(socket: 20.2-31.2m)
(data 3.0m+extrap 8.0m/11.0m)**

Method A (Joints): 5.47 m³ 22%
 Method B (TCR): 1.02 m³ 4%
 Method C (RQD): 5.89 m³ 24%

MEAN: 4.13 m³ 17%

TOTAL (net+mean): 29.45 m³



DRAFT — Calculations in Progress | Values capped at 50% max

Rock Characterization & Grout Volume — WTG-17

Rock Characterization — WTG-17 (RS Insert Pile) Shinan-Ui Offshore Wind Farm

GROUT VOLUME (per pile)
 Driven OD=3.5m, ID=3.38m
 Insert OD=3.0m
 Rock Socket=3.2m

Plug (0.1m): 0.80 m³
 Overlap zone: 6.9m → 13.14 m³
 Socket zone: 14.2m → 13.83 m³

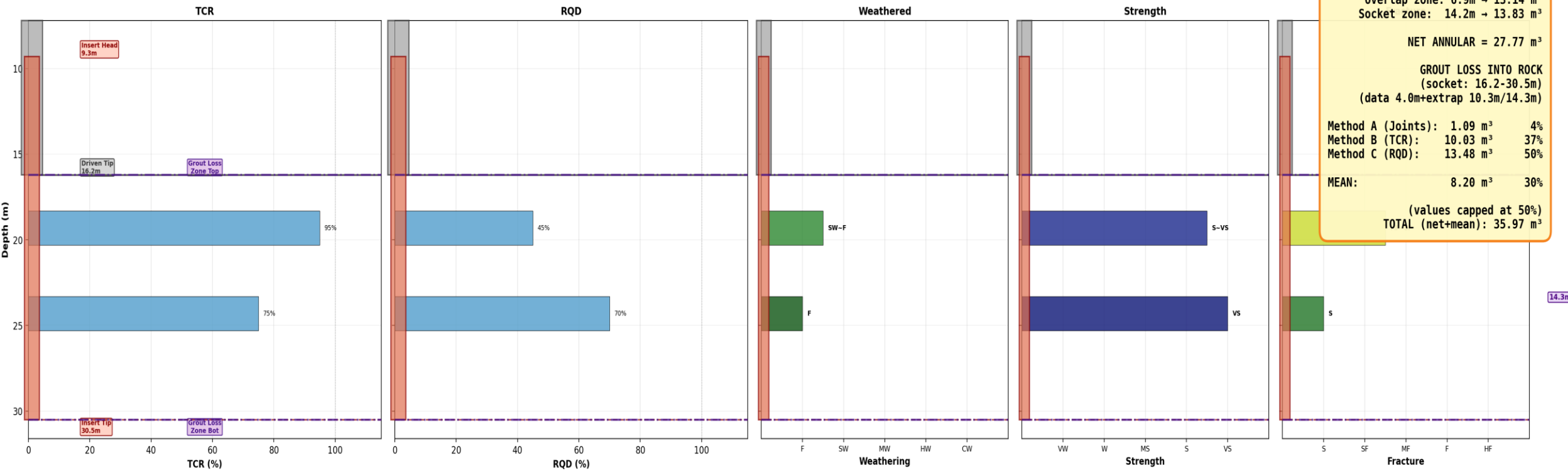
NET ANNULAR = 27.77 m³

GROUT LOSS INTO ROCK
 (socket: 16.2-30.5m)
 (data 4.0m+extrap 10.3m/14.3m)

Method A (Joints): 1.09 m³ 4%
 Method B (TCR): 10.03 m³ 37%
 Method C (RQD): 13.48 m³ 50%

MEAN: 8.20 m³ 30%

(values capped at 50%)
TOTAL (net+mean) = 35.97 m³



- Soft Rock
 - Driven Pile
 - Insert Pile
- Soft Rock
 - Driven Pile
 - Insert Pile
- F - Fresh
 - SW - Slightly Weath.
 - MW - Moderately Weath.
 - HW - Highly Weath.
 - CW - Completely Weath.
- VS - Very Strong
 - S - Strong
 - MS - Moderately Strong
 - W - Weak
 - VW - Very Weak
- S - Solid
 - SF - Slightly Fract.
 - MF - Moderately Fract.
 - F - Fractured
 - HF - Highly Fract.

DRAFT — Calculations in Progress | Values capped at 50% max

Rock Characterization & Grout Volume — WTG-18

Rock Characterization — WTG-18 (RS Insert Pile) Shinan-Ui Offshore Wind Farm

GROUT VOLUME (per pile)
 Driven OD=3.5m, ID=3.38m
 Insert OD=3.0m
 Rock Socket=3.2m

Plug (0.1m): 0.80 m³
 Overlap zone: 7.3m → 13.90 m³
 Socket zone: 9.2m → 8.92 m³

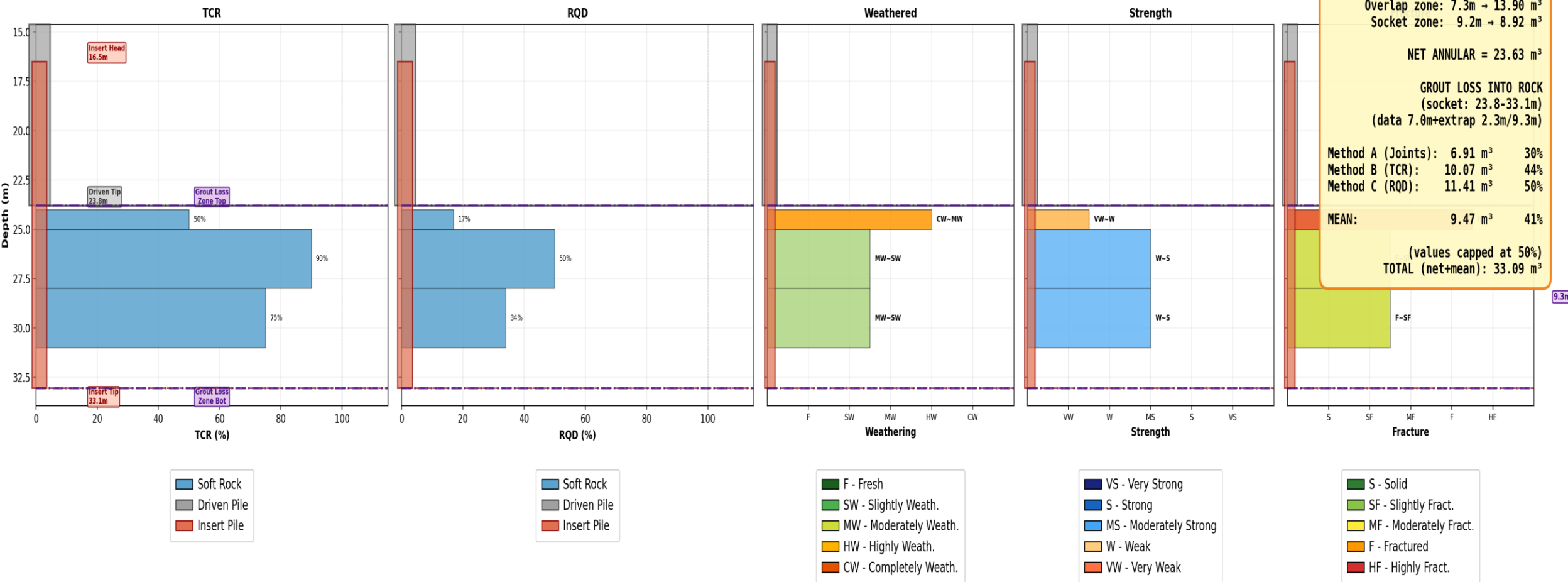
NET ANNULAR = 23.63 m³

GROUT LOSS INTO ROCK
 (socket: 23.8-33.1m)
 (data 7.0m+extrap 2.3m/9.3m)

Method A (Joints): 6.91 m³ 30%
 Method B (TCR): 10.07 m³ 44%
 Method C (RQD): 11.41 m³ 50%

MEAN: 9.47 m³ 41%

(values capped at 50%)
TOTAL (net+mean): 33.09 m³



DRAFT — Calculations in Progress | Values capped at 50% max

Rock Characterization & Grout Volume — WTG-19

Rock Characterization — WTG-19 (RS Insert Pile) Shinan-Ui Offshore Wind Farm

GROUT VOLUME (per pile)
 Driven OD=3.5m, ID=3.38m
 Insert OD=3.0m
 Rock Socket=3.2m

Plug (0.1m): 0.80 m³
 Overlap zone: 4.9m → 9.33 m³
 Socket zone: 6.5m → 6.33 m³

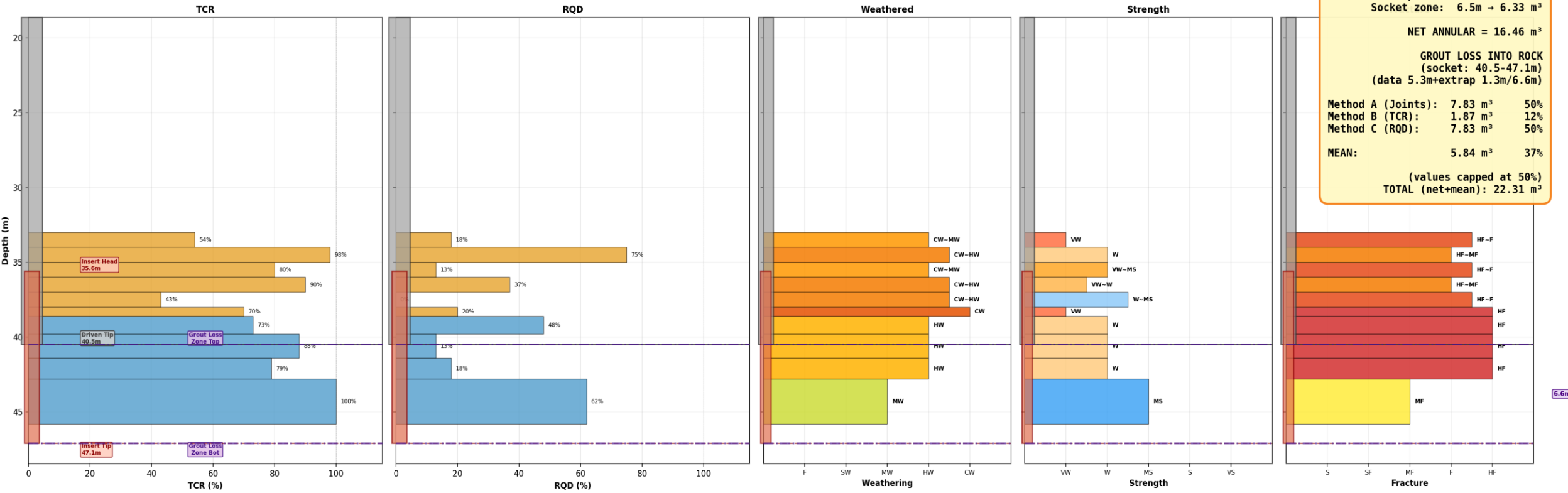
NET ANNULAR = 16.46 m³

**GROUT LOSS INTO ROCK
(socket: 40.5-47.1m)
(data 5.3m+extrap 1.3m/6.6m)**

Method A (Joints): 7.83 m³ 50%
 Method B (TCR): 1.87 m³ 12%
 Method C (RQD): 7.83 m³ 50%

MEAN: 5.84 m³ 37%

(values capped at 50%)
TOTAL (net+mean): 22.31 m³



Weathered Rock
 Soft Rock
 Driven Pile
 Insert Pile

Weathered Rock
 Soft Rock
 Driven Pile
 Insert Pile

F - Fresh
 SW - Slightly Weath.
 MW - Moderately Weath.
 HW - Highly Weath.
 CW - Completely Weath.

VS - Very Strong
 S - Strong
 MS - Moderately Strong
 W - Weak
 VW - Very Weak

S - Solid
 SF - Slightly Fract.
 MF - Moderately Fract.
 F - Fractured
 HF - Highly Fract.

DRAFT — Calculations in Progress | Values capped at 50% max

Rock Characterization & Grout Volume — WTG-20

Rock Characterization — WTG-20 (RS Insert Pile) Shinan-Ui Offshore Wind Farm

GROUT VOLUME (per pile)
 Driven OD=3.5m, ID=3.38m
 Insert OD=3.0m
 Rock Socket=3.2m

Plug (0.1m): 0.80 m³
 Overlap zone: 4.9m → 9.33 m³
 Socket zone: 6.2m → 6.04 m³

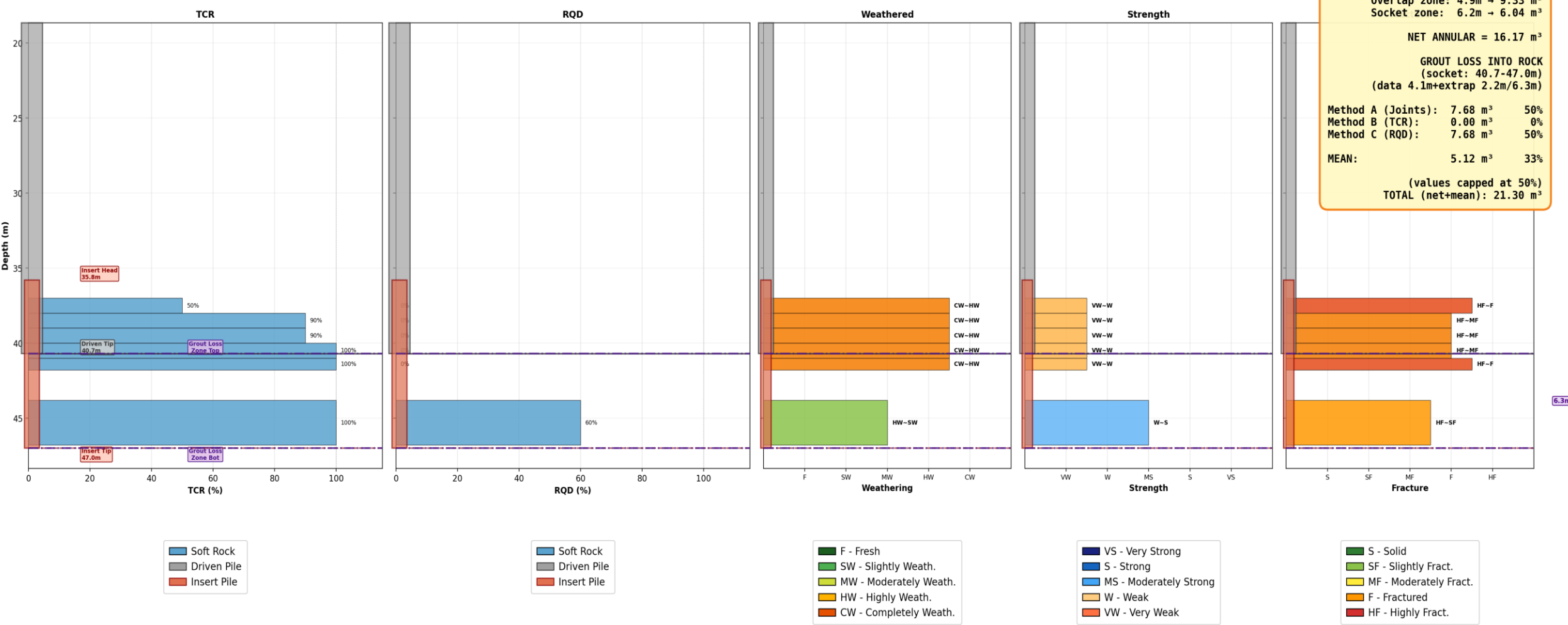
NET ANNULAR = 16.17 m³

**GROUT LOSS INTO ROCK
(socket: 40.7-47.0m)
(data 4.1m+extrap 2.2m/6.3m)**

Method A (Joints): 7.68 m³ 50%
 Method B (TCR): 0.00 m³ 0%
 Method C (RQD): 7.68 m³ 50%

MEAN: 5.12 m³ 33%

(values capped at 50%)
TOTAL (net+mean): 21.30 m³



DRAFT — Calculations in Progress | Values capped at 50% max

Rock Characterization & Grout Volume — WTG-21

Rock Characterization — WTG-21 (RS Insert Pile) Shinan-Ui Offshore Wind Farm

GROUT VOLUME (per pile)
 Driven OD=3.5m, ID=3.38m
 Insert OD=3.0m
 Rock Socket=3.2m

Plug (0.1m): 0.80 m³
 Overlap zone: 4.9m → 9.33 m³
 Socket zone: 5.7m → 5.55 m³

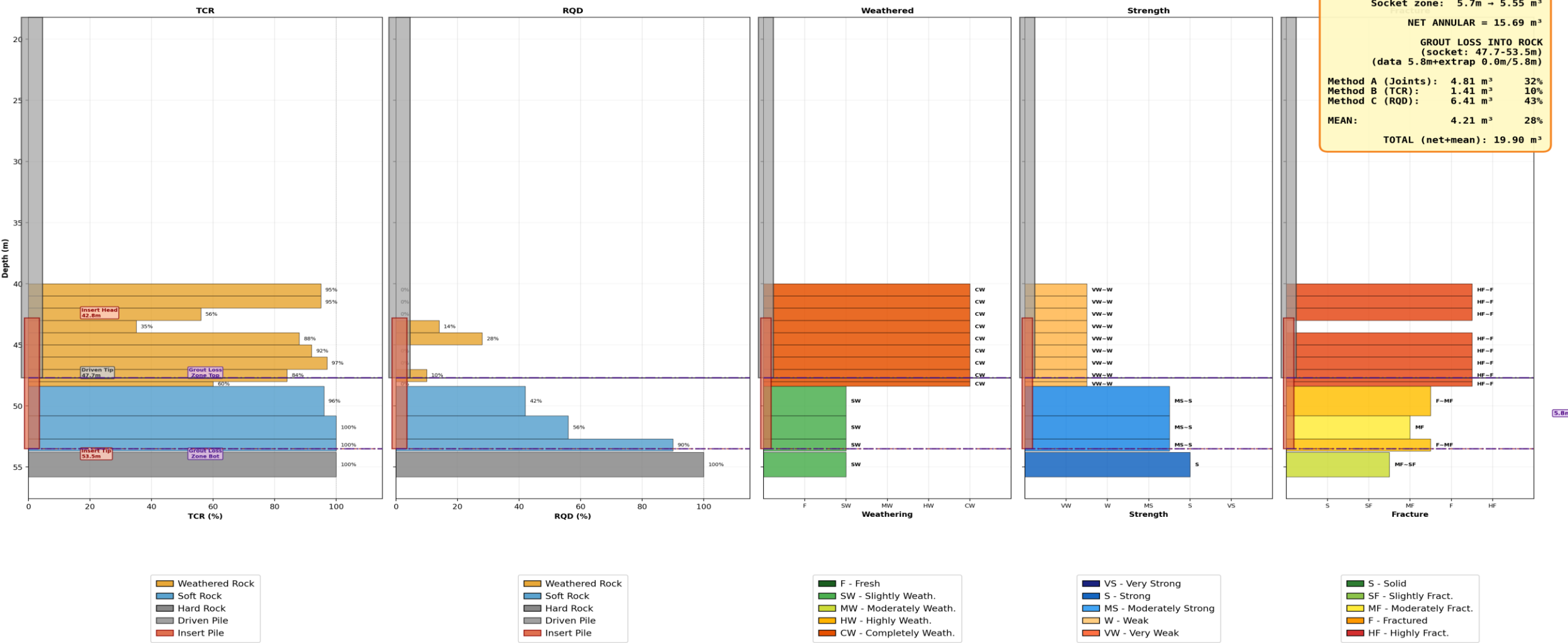
NET ANNULAR = 15.69 m³

**GROUT LOSS INTO ROCK
(socket: 47.7-53.5m)
(data 5.8m+extrap 0.0m/5.8m)**

Method A (Joints): 4.81 m³ 32%
 Method B (TCR): 1.41 m³ 10%
 Method C (RQD): 6.41 m³ 43%

MEAN: 4.21 m³ 28%

TOTAL (net+mean): 19.90 m³



DRAFT — Calculations in Progress | Values capped at 50% max

Rock Characterization & Grout Volume — WTG-23

Rock Characterization — WTG-23 (RS Insert Pile) Shinan-Ui Offshore Wind Farm

GROUT VOLUME (per pile)
 Driven OD=3.5m, ID=3.38m
 Insert OD=3.0m
 Rock Socket=3.2m

Plug (0.1m): 0.80 m³
 Overlap zone: 4.9m → 9.33 m³
 Socket zone: 6.4m → 6.23 m³

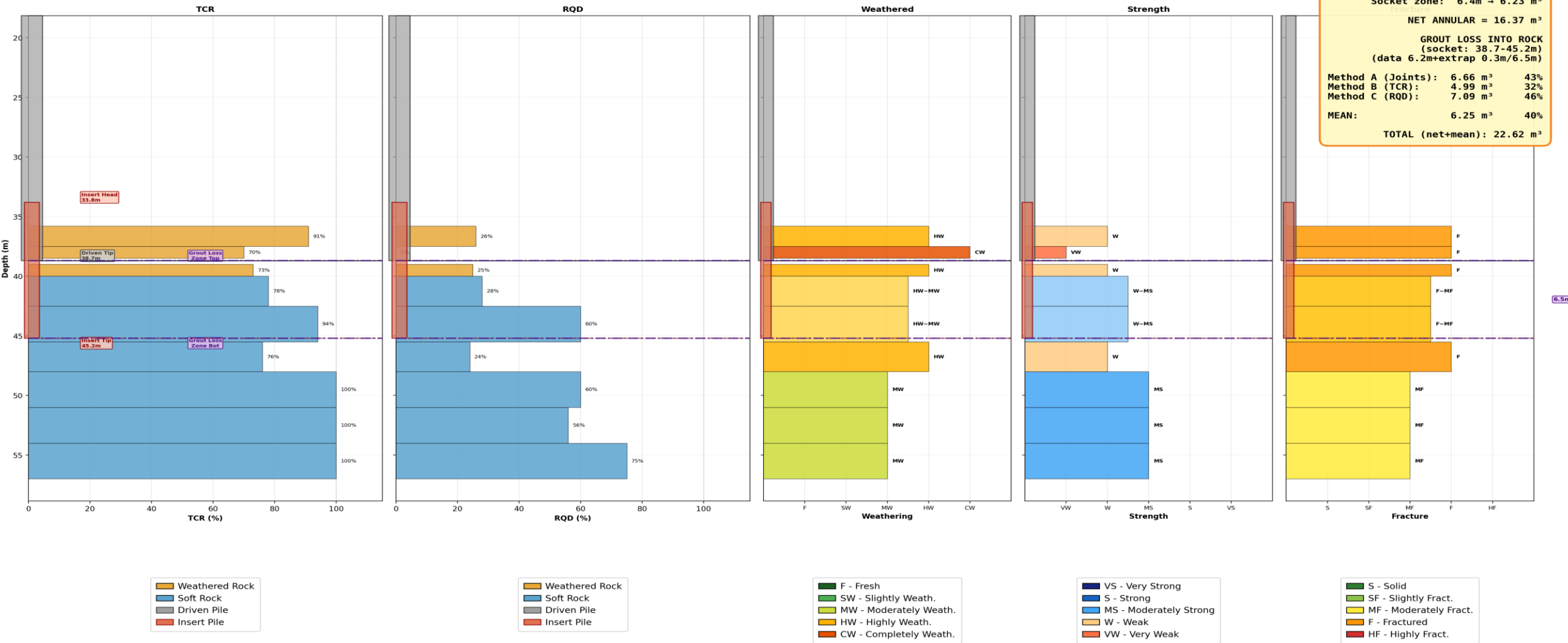
NET ANNULAR = 16.37 m³

GROUT LOSS INTO ROCK
 (data 6.2m+extrap 0.3m/6.5m)

Method A (Joints): 6.66 m³ 43%
 Method B (TCR): 4.99 m³ 32%
 Method C (RQD): 7.09 m³ 46%

MEAN: 6.25 m³ 40%

TOTAL (net+mean): 22.62 m³



DRAFT — Calculations in Progress | Values capped at 50% max

Rock Characterization & Grout Volume — WTG-25

Rock Characterization — WTG-25 (RS Insert Pile) Shinan-Ui Offshore Wind Farm

GROUT VOLUME (per pile)
 Driven OD=3.5m, ID=3.38m
 Insert OD=3.0m
 Rock Socket=3.2m

Plug (0.1m): 0.80 m³
 Overlap zone: 4.9m → 9.33 m³
 Socket zone: 5.9m → 5.75 m³

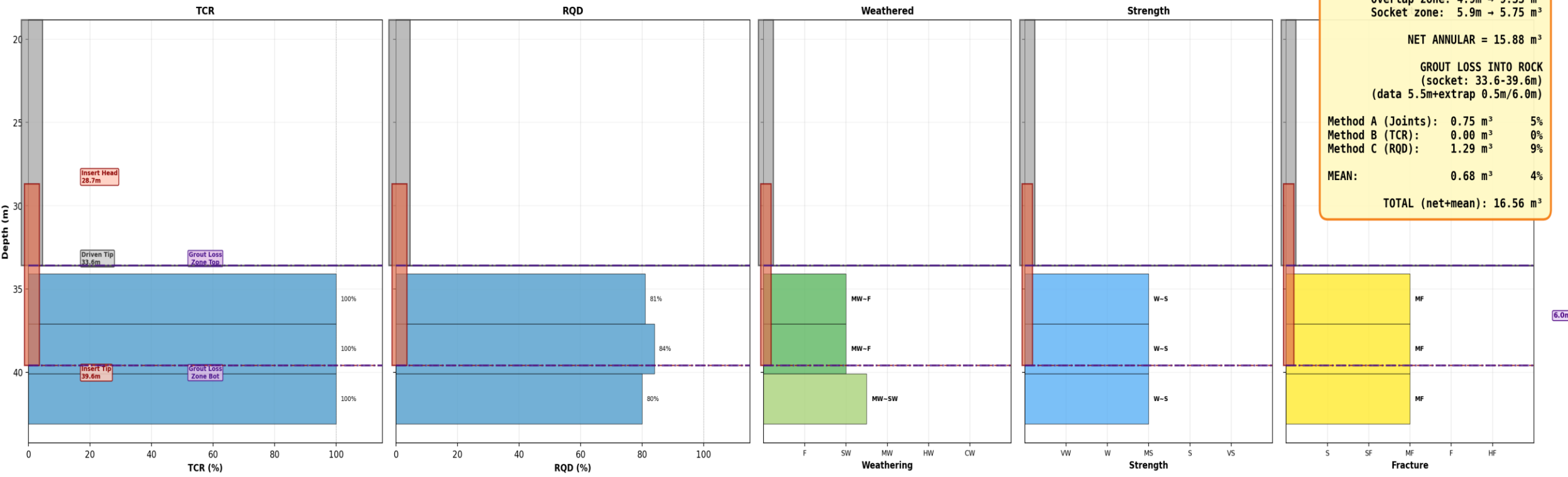
NET ANNULAR = 15.88 m³

GROUT LOSS INTO ROCK
 (socket: 33.6-39.6m)
 (data 5.5m+extrap 0.5m/6.0m)

Method A (Joints): 0.75 m³ 5%
 Method B (TCR): 0.00 m³ 0%
 Method C (RQD): 1.29 m³ 9%

MEAN: 0.68 m³ 4%

TOTAL (net+mean): 16.56 m³



Soft Rock
 Driven Pile
 Insert Pile

Soft Rock
 Driven Pile
 Insert Pile

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DRAFT — Calculations in Progress | Values capped at 50% max

Rock Characterization & Grout Volume — WTG-26

Rock Characterization — WTG-26 (RS Insert Pile) Shinan-Ui Offshore Wind Farm

GROUT VOLUME (per pile)
 Driven OD=3.5m, ID=3.38m
 Insert OD=3.0m
 Rock Socket=3.2m

Plug (0.1m): 0.80 m³
 Overlap zone: 7.0m → 13.33 m³
 Socket zone: 12.7m → 12.37 m³

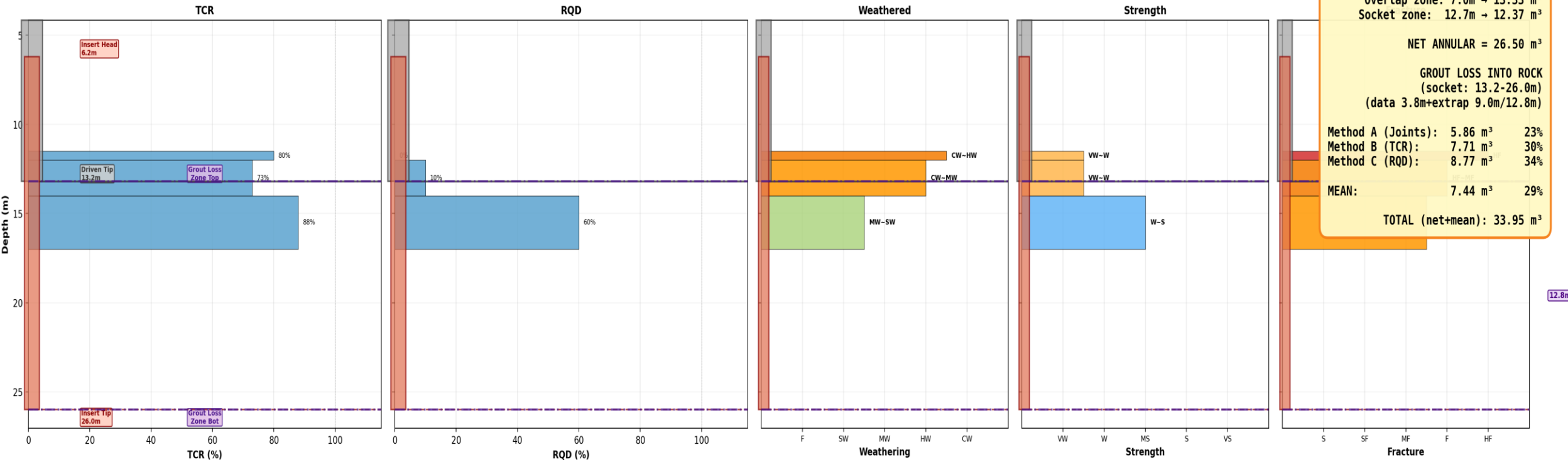
NET ANNULAR = 26.50 m³

**GROUT LOSS INTO ROCK
(socket: 13.2-26.0m)
(data 3.8m+extrap 9.0m/12.8m)**

Method A (Joints): 5.86 m³ 23%
 Method B (TCR): 7.71 m³ 30%
 Method C (RQD): 8.77 m³ 34%

MEAN: 7.44 m³ 29%

TOTAL (net+mean): 33.95 m³



DRAFT — Calculations in Progress | Values capped at 50% max

Rock Characterization & Grout Volume — OSS

Rock Characterization — OSS (RS Insert Pile) Shinan-Ui Offshore Wind Farm

GROUT VOLUME (per pile)
 Driven OD=3.5m, ID=3.38m
 Insert OD=3.0m
 Rock Socket=3.2m

Plug (0.1m): 0.80 m³
 Overlap zone: 5.0m → 9.52 m³
 Socket zone: 8.9m → 8.67 m³

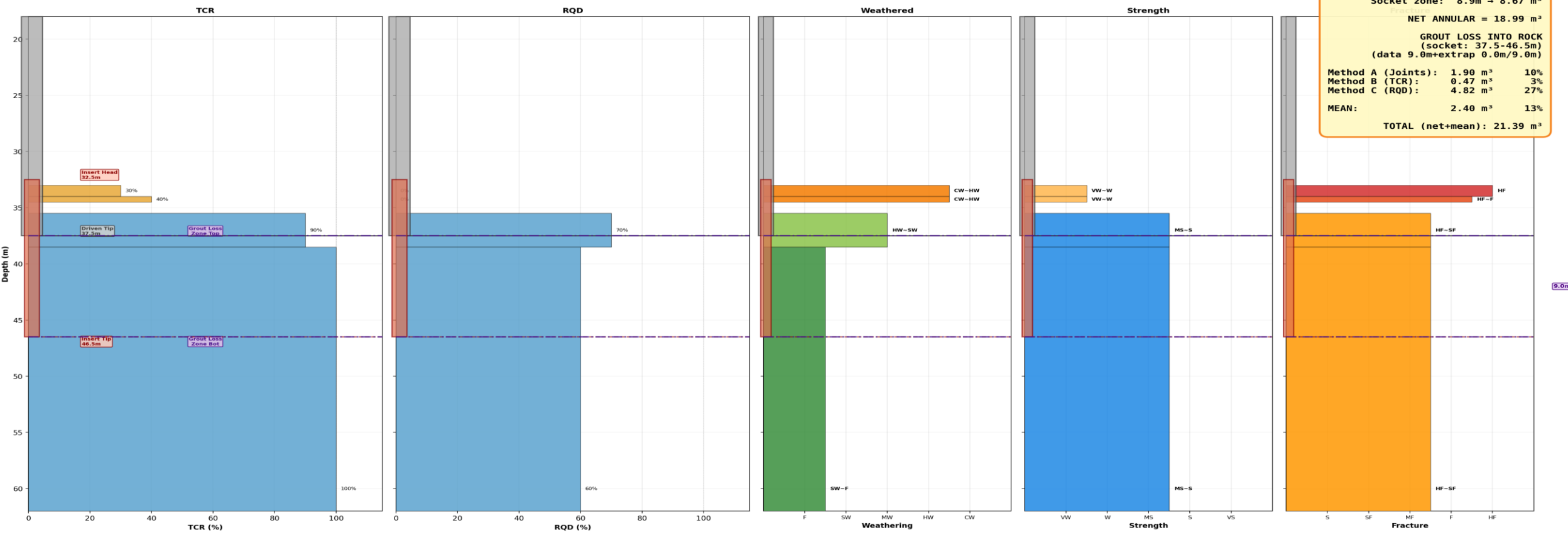
NET ANNULAR = 18.99 m³

**GROUT LOSS INTO ROCK
(socket: 37.5-46.5m)
(data 9.0m+extrap 0.0m/9.0m)**

Method A (Joints): 1.90 m³ 10%
 Method B (TCR): 0.47 m³ 3%
 Method C (RQD): 4.82 m³ 27%

MEAN: 2.40 m³ 13%

TOTAL (net+mean): 21.39 m³



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 Soft Rock
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 Insert Pile

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 Soft Rock
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 Insert Pile

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DRAFT — Calculations in Progress | Values capped at 50% max