



Polski Kongres Drogowy

VI INTERNATIONAL TUNNELLING FORUM

Bielsko-Biala, 13-15.05.2024



The Follo Line Project (Oslo, Norway): 40 km of Tunnels in Hard Rock Executed by 4 TBM Machines with Preliminary Grouting

Fernando Vara

ACCIONA Global Specialized Business Unit Director



- The Follo Line project



- Pregrouting from a TBM

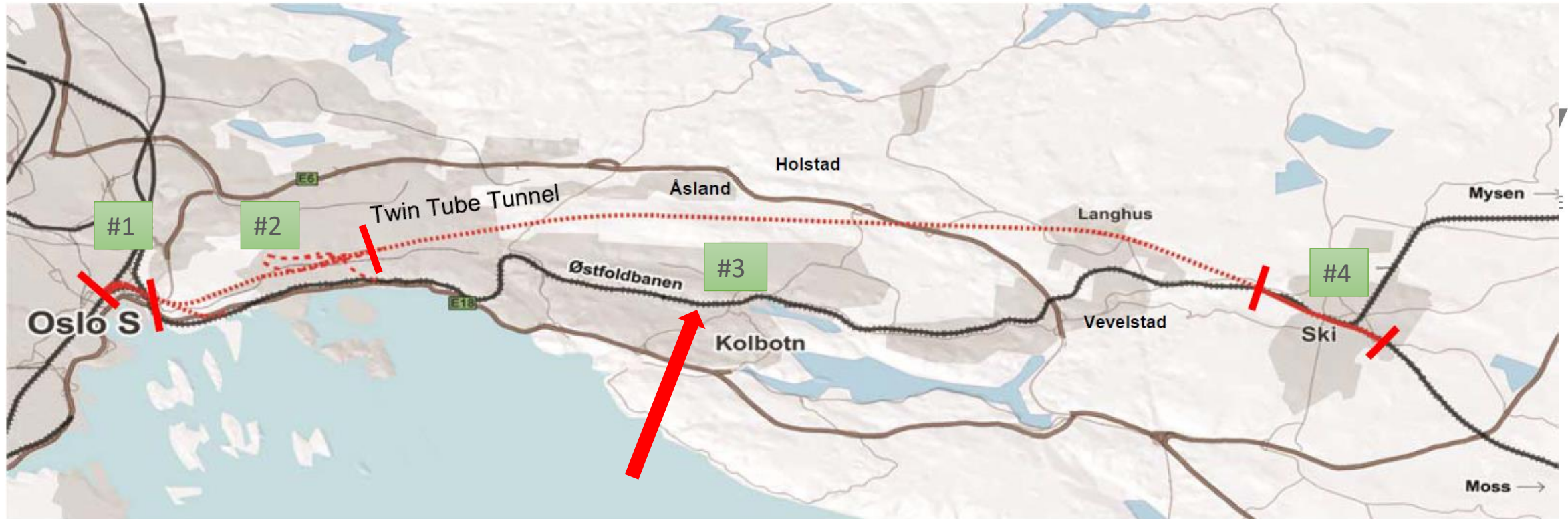


1.- Follo Line





EPC TBM CONTRACT



Follo Line EPC Civil Works Contracts



JV COMPOSITION



CONSTRUCTION COMPANIES:



INDEPENDENT



VERYFIERS



RAMS

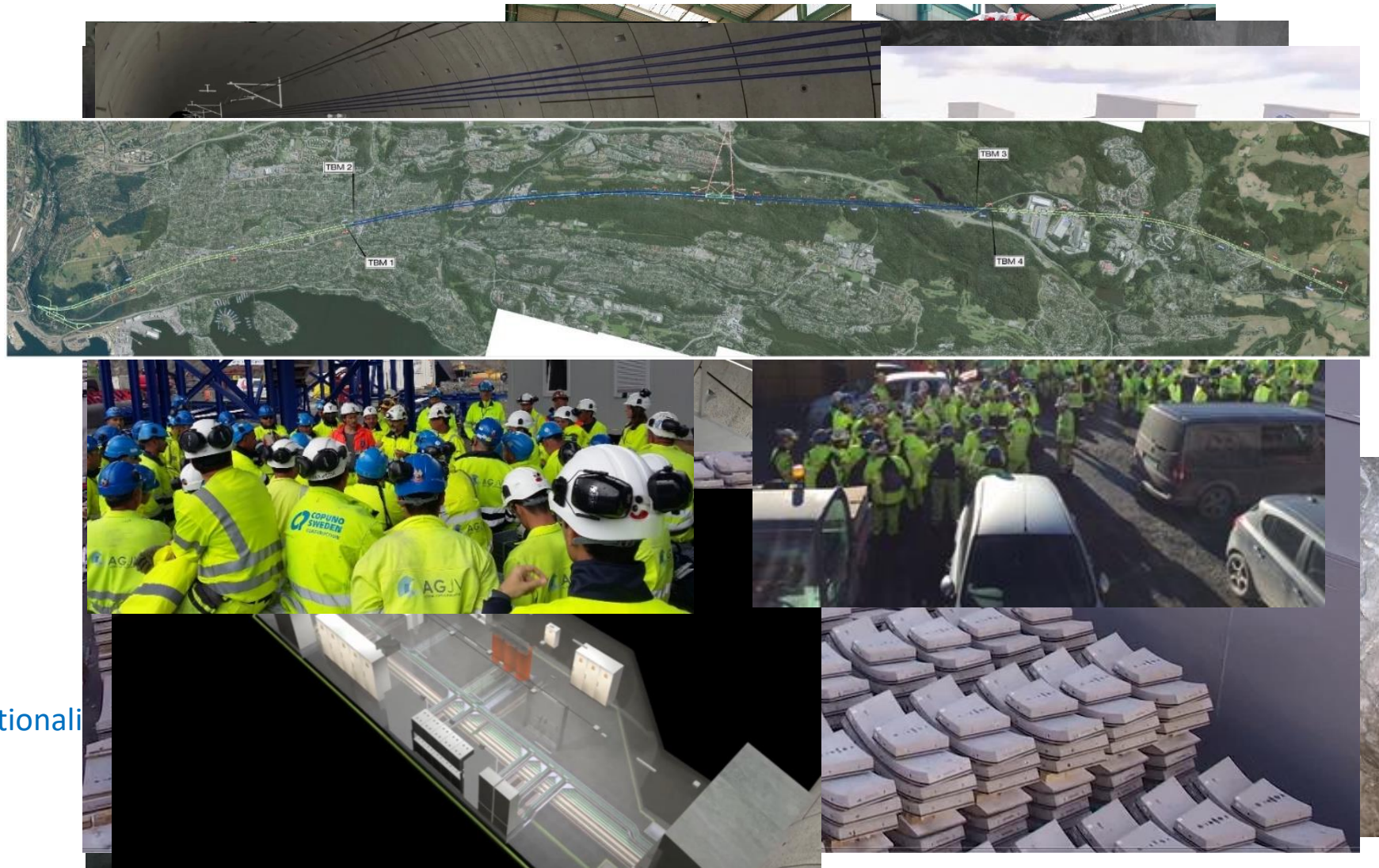


MAIN LOCAL SUBCONTRACTORS



SCOPE OF WORKS

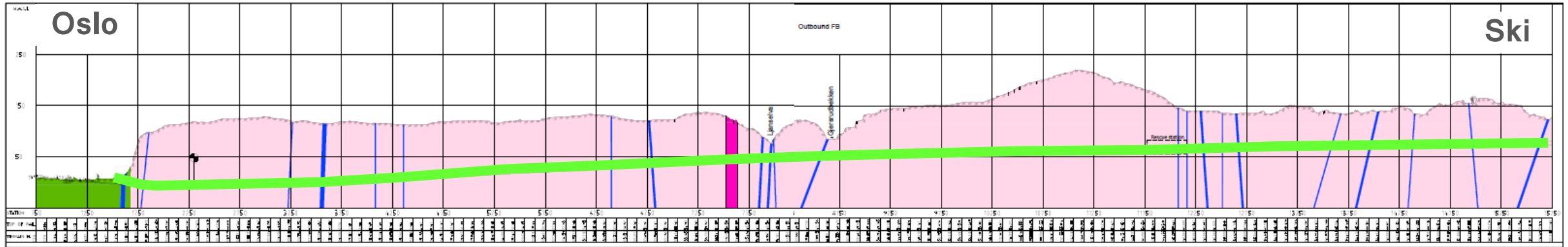
- 4 Double Shield Hard Rock TBMs
- 37.000 ml TBM tunnel
- 40 Cross Passages
- 9 M tons of rock
- 140.000 concrete segments
- Fit Out & Railway Systems
- 1,200 workers peak, more than 25 nationalities





GEOLOGY

Follo Line Geological Profile

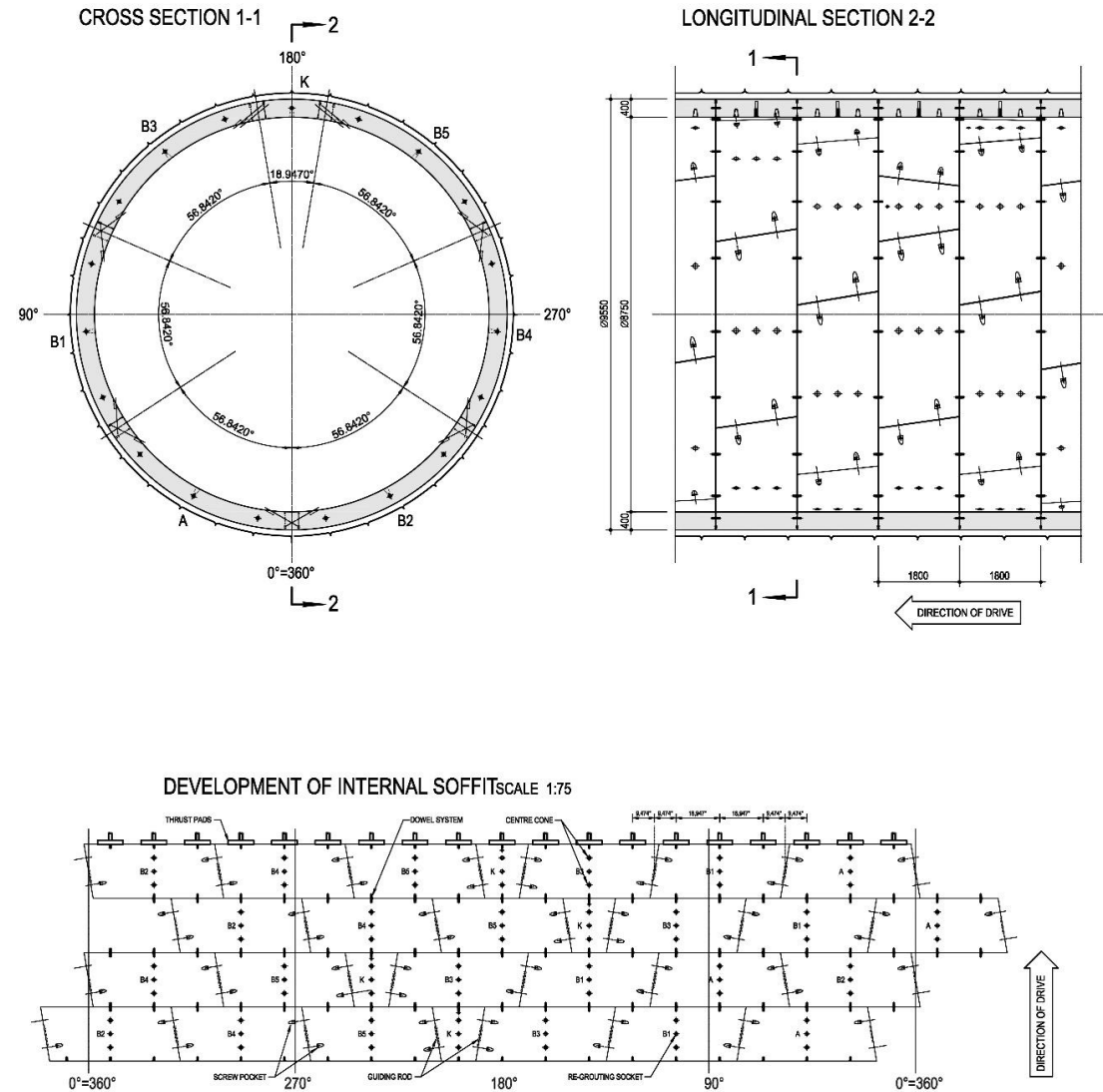


- Largely tonalitic to granitic gneiss
- Average compressive strength: 142 MPa - peak above 300 MPa
- Mixed Face conditions: 15% of alignment amphibolite 250 MPa & gneiss UCS 100 MPa
- Average quartz content: 28% - peak above 50%
- Maximum overburden: 150m
- Groundwater level is generally 2 - 3 m below terrain



Segment Design

- Outer Diameter 9,55 m
- Inner Diameter 8,75 m
- Thickness 400 mm
- Segment Length 1,8 m
- Segments + Key 6 + 1
- Total Concrete 500.000m³
- Backfilling two component grout





Segment Supply with MSVs

- Load capacity 125 t
- Length 45 m
- Turning radius 15 m
- Engine 405 kW, Euro IV
- Operational grade +/- 10 %
- Retarder system
- Winter provisions
- Suitable for two complete rings with invert segments





VENTILATION DUCT

CONVEYOR BELT

PIPES NETWORK

- 2" Grout "B"
- 4" Cooling in
- 6" Cooling out
- 6" Industrial water
- 8" Dewatering
- 3" Grout "A"
- 12" Emergency dewatering

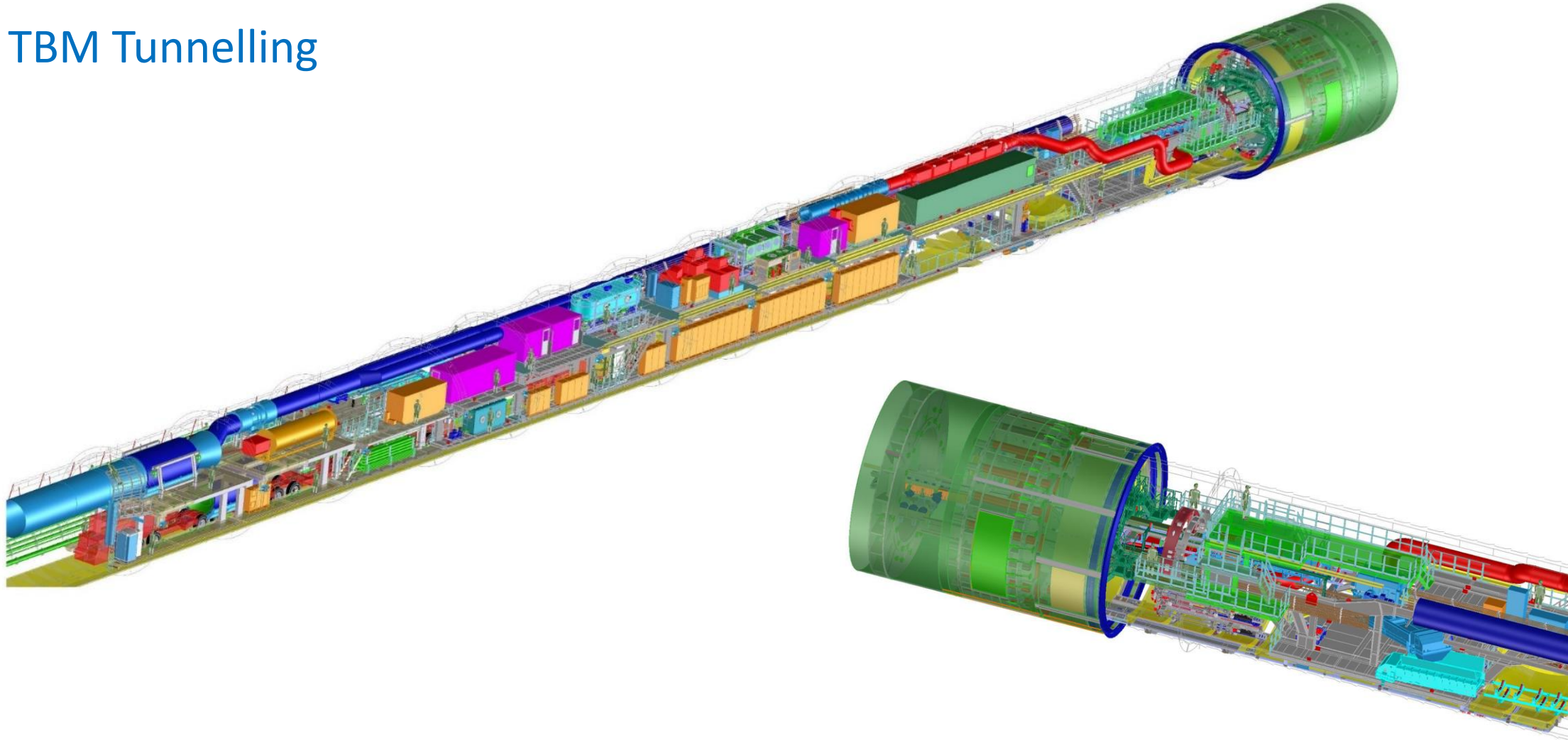


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- TBM Tunnelling



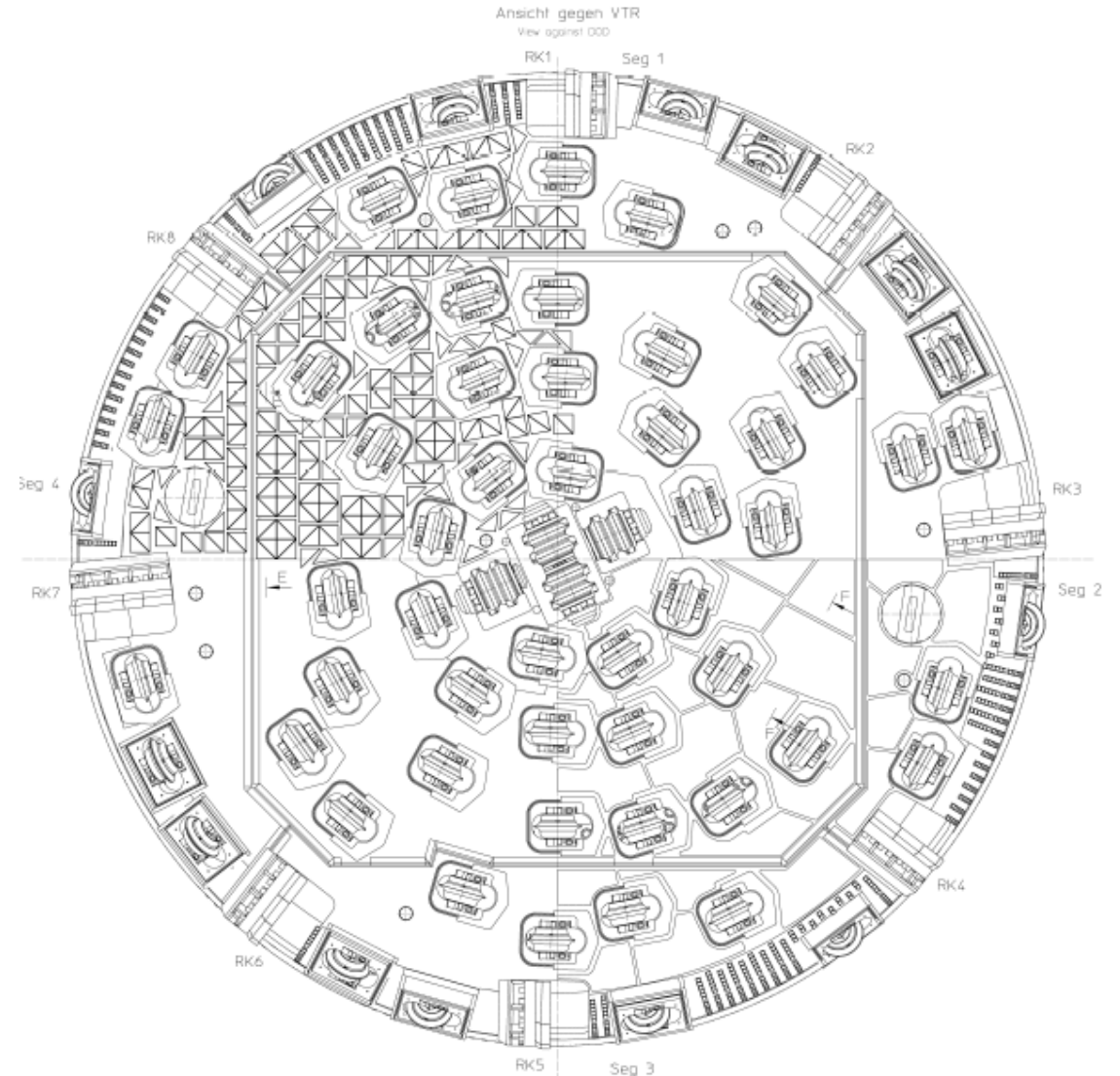


TBM CONFIGURATION

TBM's fit for purpose

TBM Cutterhead Design

- Adapted to high rock strength
- Bane Nor input based on Norwegian experience
- 71 Cutter rings 19" on 70 tracks
- Heavy structure, stiff support
- Diameter machine/tunnel: 9,96 m/8,75m
- Length of machines: 150 m
- Weight: 2400 tons
- Installed Power: 6200 kW
- No of Cutters: 71
- Main bearing size increased to \varnothing 6.6 m



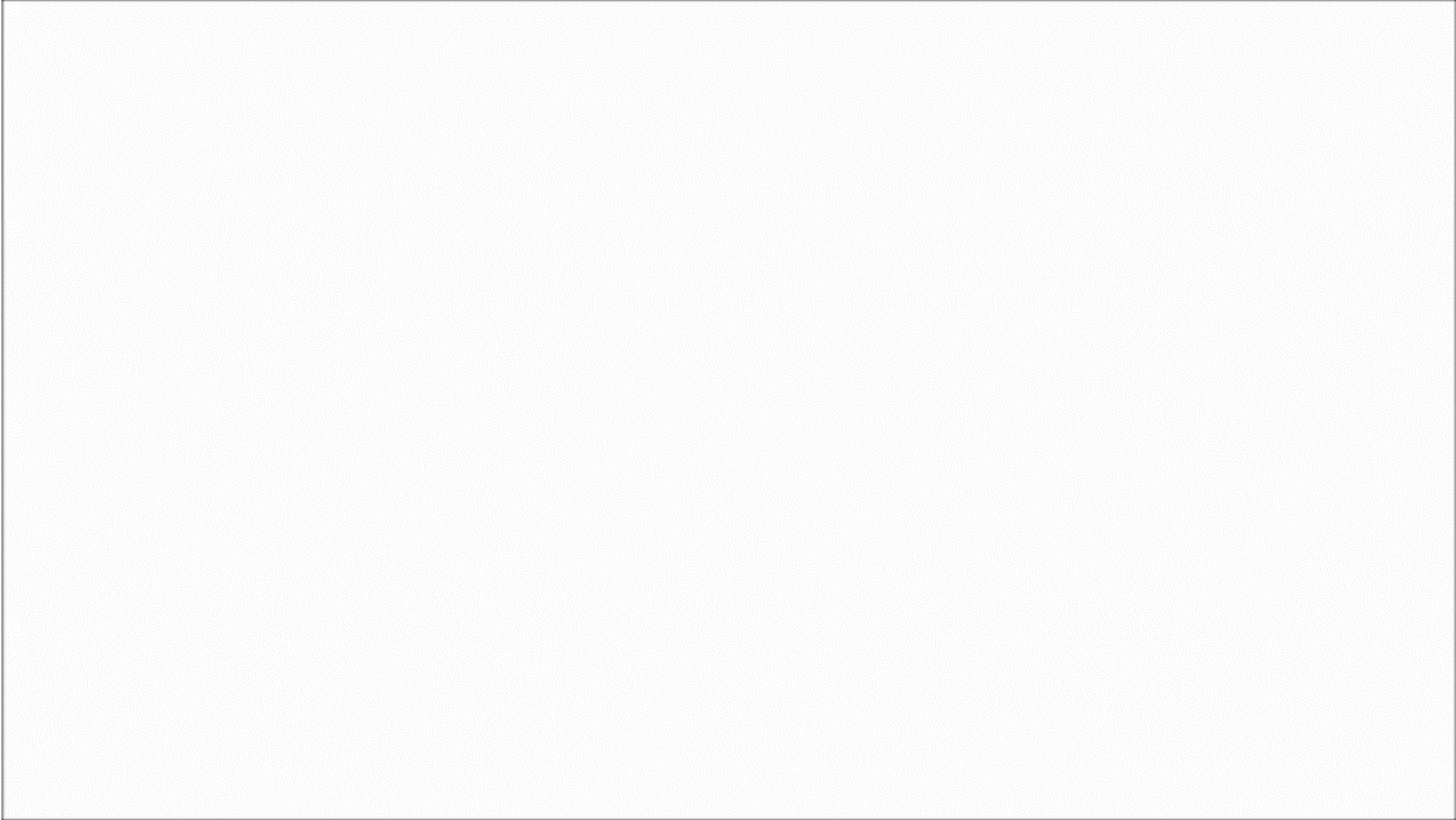


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2.- Pregrouting from a TBM

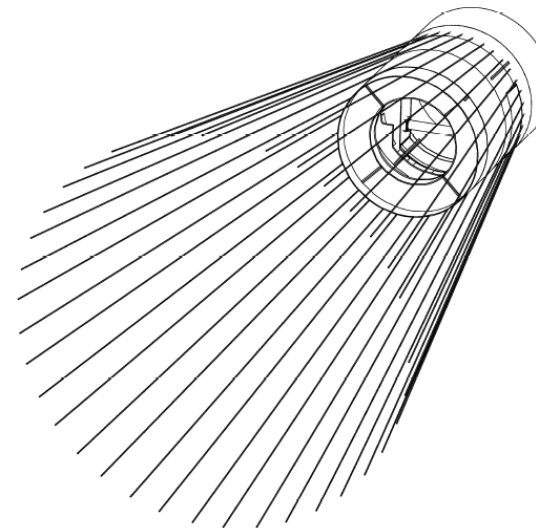
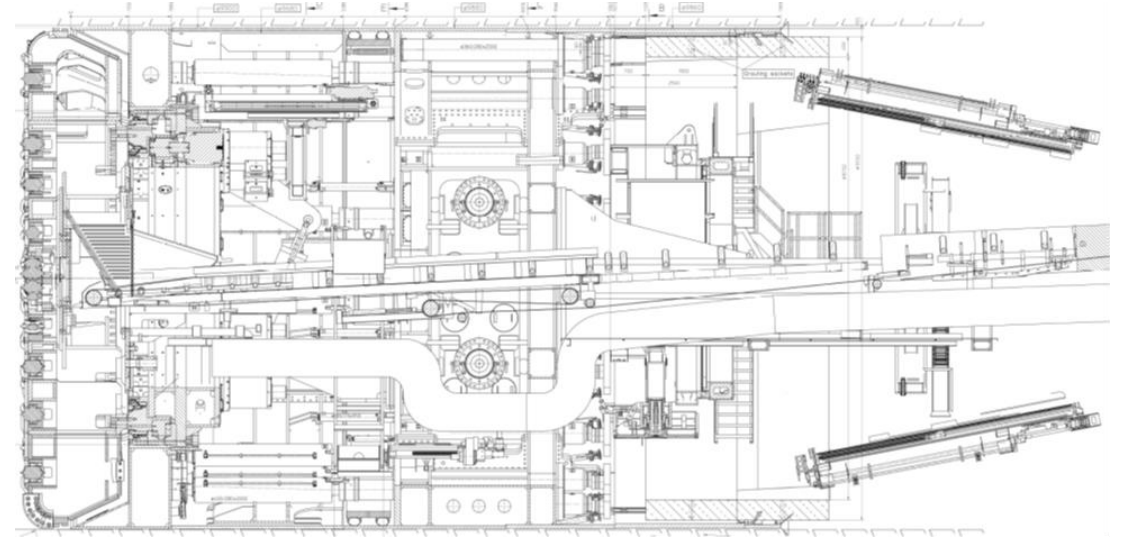




• Pregrouting

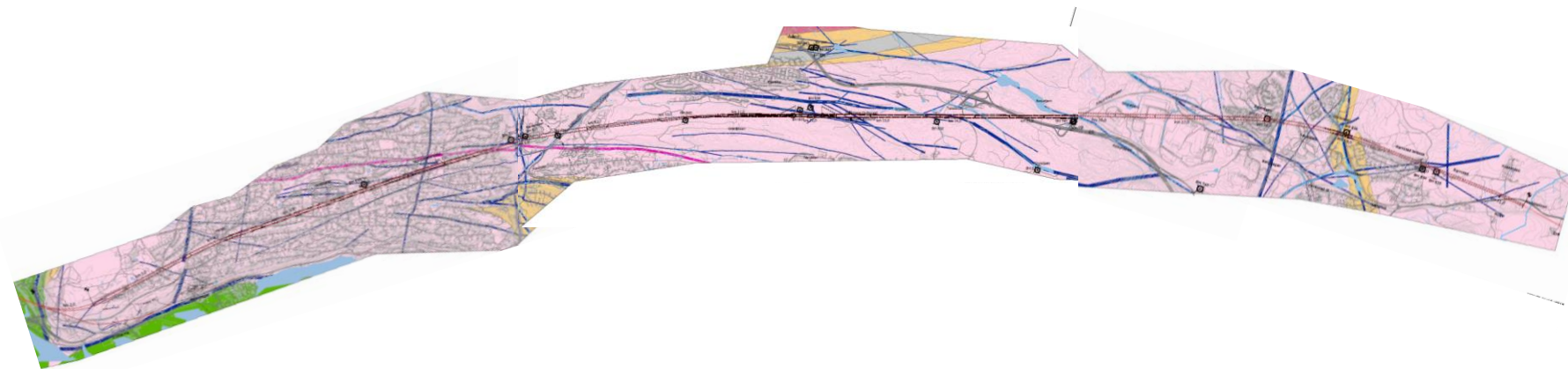
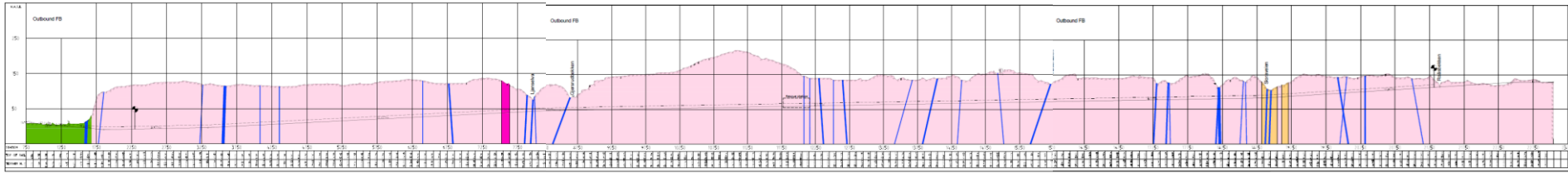
Basic concept

- Maximum 35m probing distance
- TBM to remain no less than 5m behind probing
- Probe drilling advance interval every 30m.
- Through shield as primary probing system
- 38 no. probe hole can be drilled and grouted
- 4 no., 6no, 8 no. probe hole depend on the sensitivity category
- Televiewing for every meter of tunnel length to check joint condition





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- Tonalitic to granitic gneiss with inclusions of amphibolite and pegmatite
- Some sub-vertical weakness zones, variable width between 1 and 10 m and some with width > 10 m



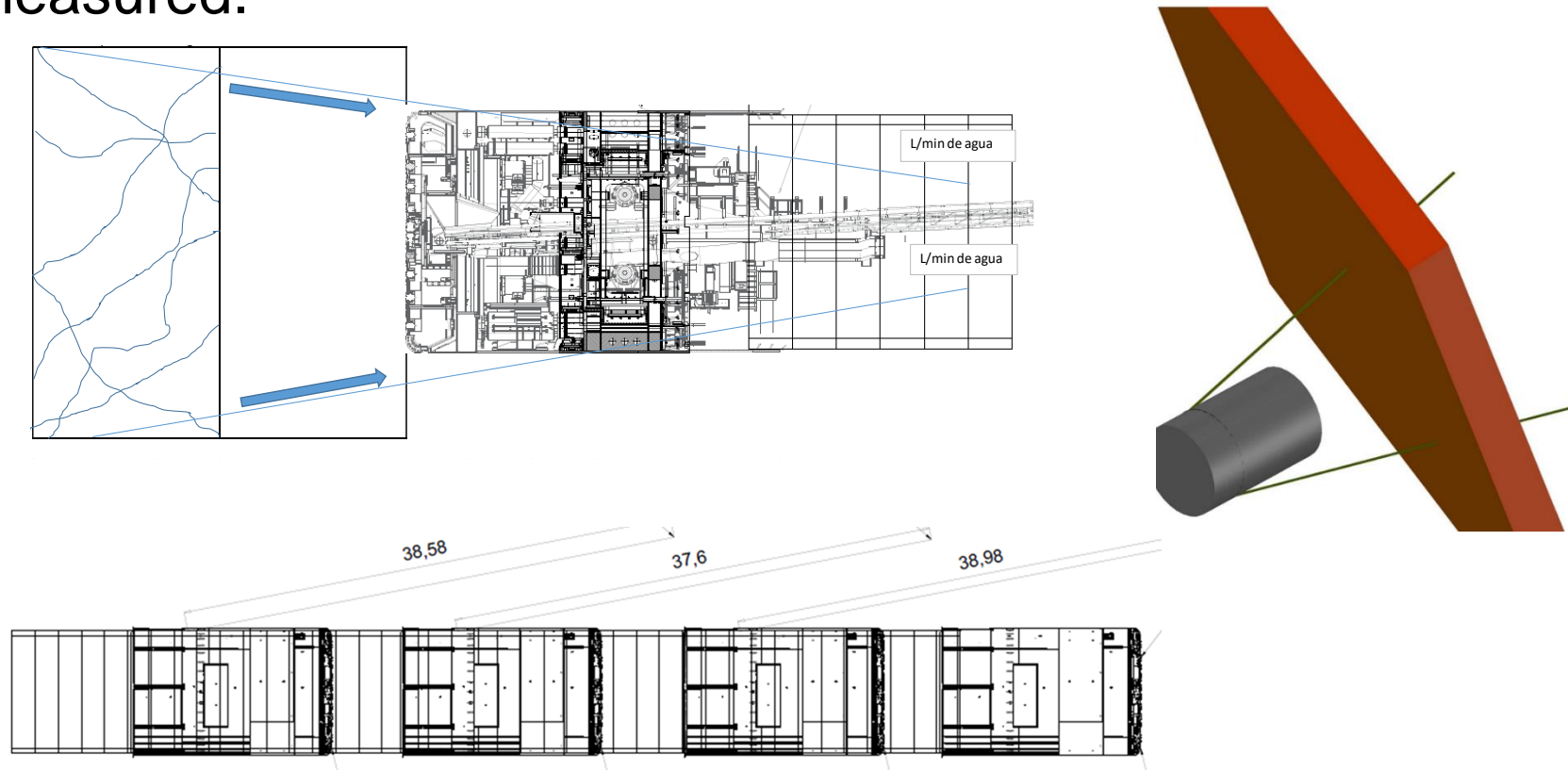
Ground Water

| Km | Location | Area classification of pore pressure sensitivity |
|-------------|---------------------------|--|
| 2.3 – 4.0 | Below Ekeberg (to Holtet) | Small sensitivity |
| 4.0 - 5.0 | Holtet -Lambertseter | Moderate sensitivity |
| 5.0 – 7.8 | Nordstrandsplatået | Sensitive |
| 7.8 – 8.5 | Ljanselva -Gjersrudbekken | Small sensitivity |
| 8.5 – 9.0 | Bjørnerud | Moderate sensitivity |
| 9.0 – 11.2 | Grønliåsen north | Small sensitivity |
| 11.2 – 12.0 | Grønliåsen | Moderate sensitivity |
| 12.0 – 15.7 | Snipetjern -Assurdalen | Sensitive |
| 15.7 – 18.9 | Assurdalen - Sloraveien | Moderate sensitivity |
| 18.9 – 20.6 | Sloraveien – Ramstad S | Very sensitive |
| 20.6 – 21.3 | Ramstad – Portal Langhus | Moderate sensitivity |

- Impact on ground water levels is main concern
- Sensitivity classification
- 4 classes



To control the water entrance into the TBMs face: through the probe drill methodology. Around 40 m probe had to be performed from the TBMs, and the rock quality and water ingress could be measured.

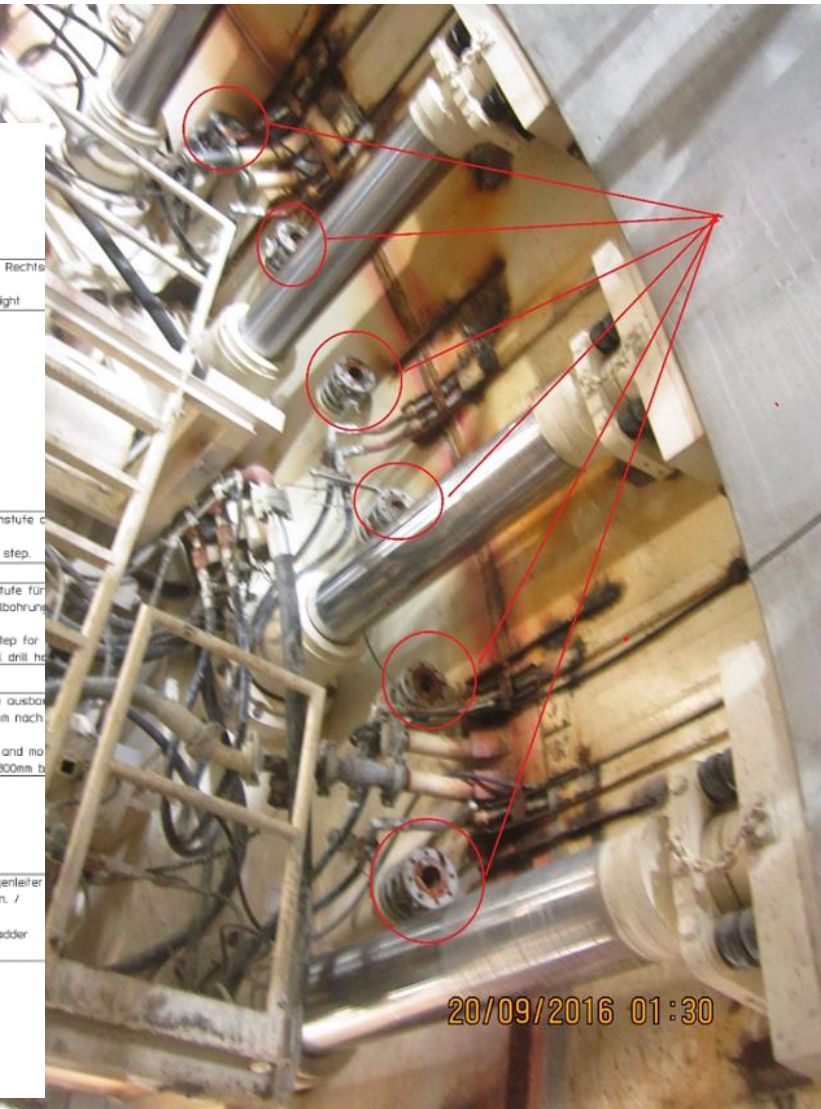
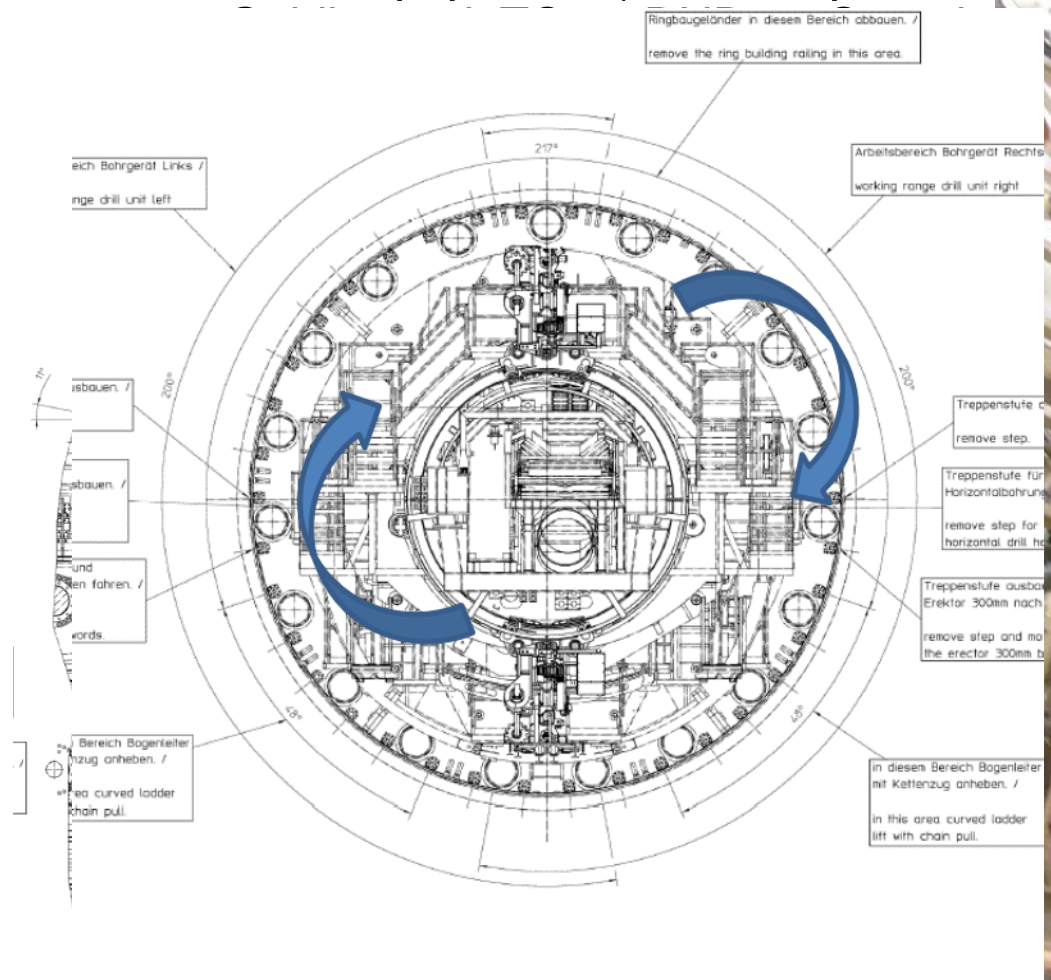




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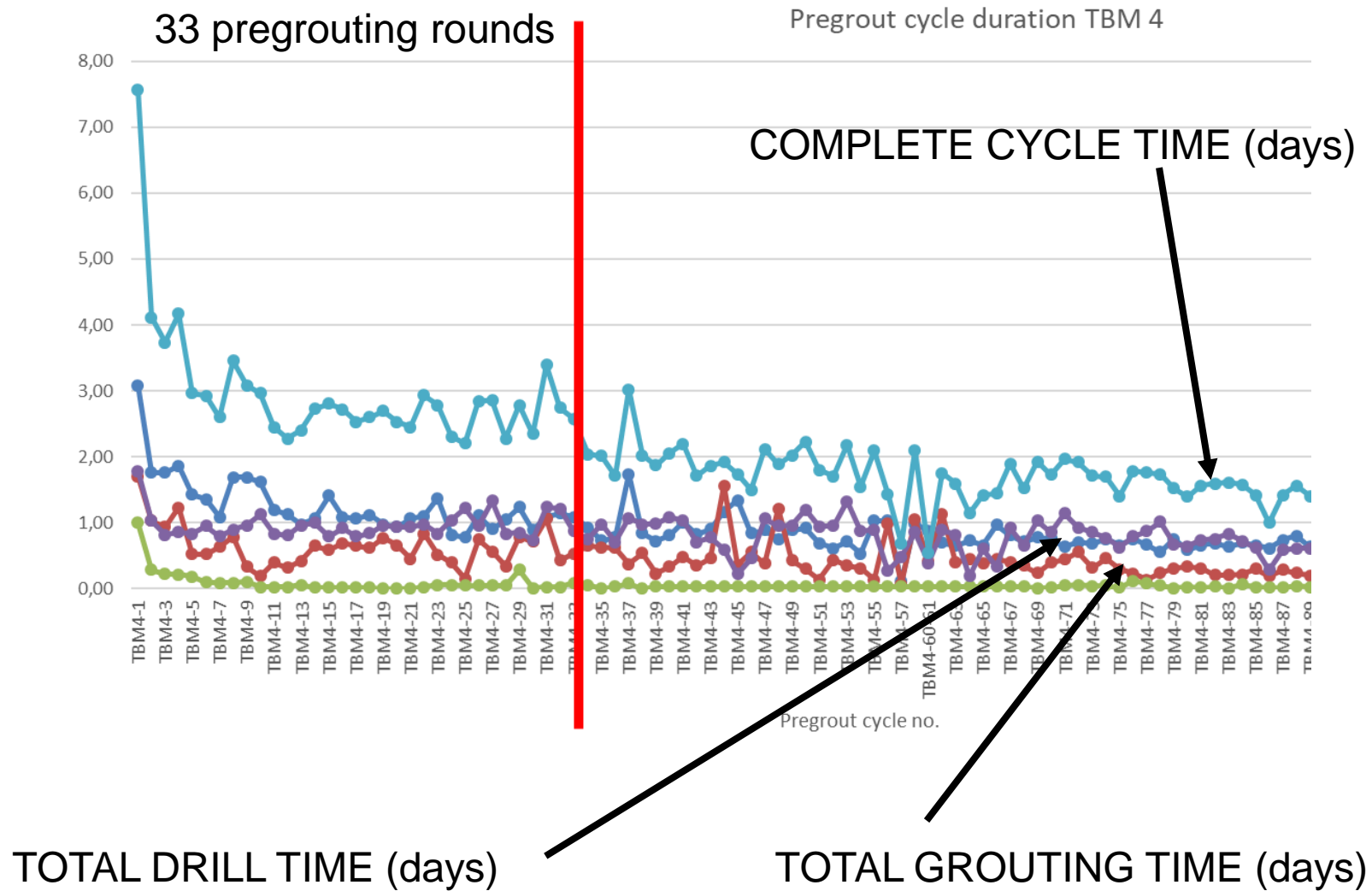


- Shank adapter: TG 42 short twisted steel
- 38 drilled shield positions.
- Two extra equipment (Atlas Copco)





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- 36,000 metres bored !!

| | EUPHEMIA | | | |
|----------------------------|----------|-------|-------|-------|
| PRODUCTION TO DATE (M) | 8,900 | 8,900 | 9,100 | 9,100 |
| MAX DAILY PRODUCTION (M) | 28.8 | 28.8 | 30.6 | 32.4 |
| MAX WEEKLY PRODUCTION (M) | 144 | 136 | 141 | 145 |
| MAX MONTHLY PRODUCTION (M) | 523 | 583 | 491 | 520 |



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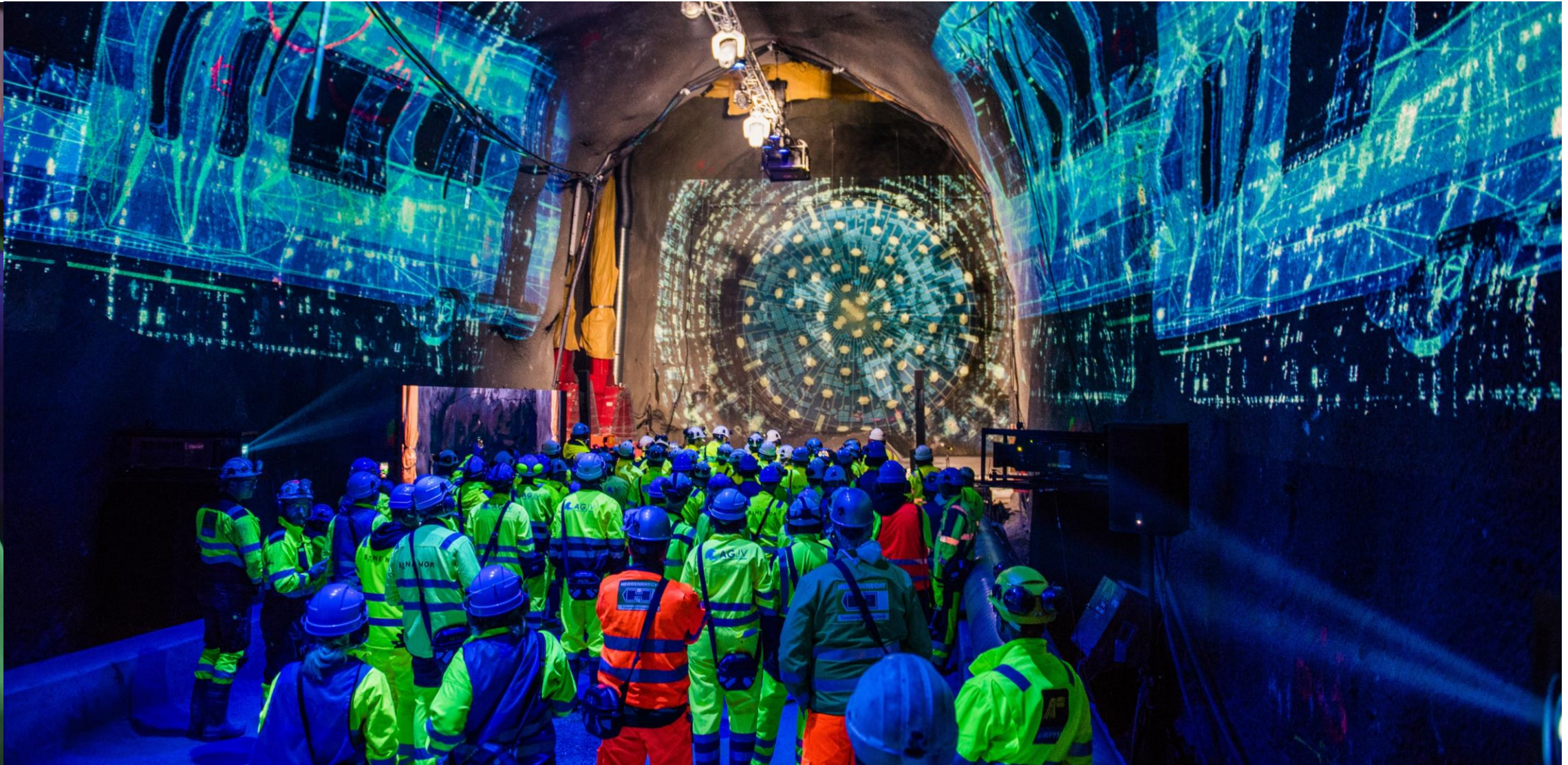
Two successful real double breakthroughs

- Each TBM has excavated 9 km of tunnel
- Ahead of schedule:
 - 11. September 2018
 - 26. February 2019





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THANK YOU !!