

ITA - AITES WORLD TUNNEL CONGRESS 2007 PRAGUE



The 3<sup>rd</sup> Training course  
**TUNNELLING IN URBAN AREA**  
Prague, 4-5<sup>th</sup> May 2007

# **Mechanized Tunnelling in Urban Areas – Case History**

TRAINING MATERIAL PREPARED BY

Dr.-Ing. E.h. Martin Herrenknecht  
(Herrenknecht AG, Germany)



ASSOCIATION  
INTERNATIONALE DES TRAVAUX  
EN SOUTERRAIN  
**AITES**



**ITA**  
INTERNATIONAL  
TUNNELLING  
ASSOCIATION



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**Soft Ground and Hard Rock TBMs. Overview.**

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2

**Mixshields: Hamburg, Cologne, Leipzig, Kuala Lumpur, Shanghai, Paris**

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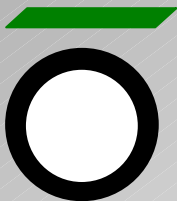
**EPB Shields: Botlekspoor, Los Angeles, Madrid**

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**Hard Rock TBMs: Islisberg, Zurich, Atlanta, Lötschberg, Gotthard**

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# Soft Ground and Hard Rock TBMs. Overview.

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## Soft Ground TBMs

- Slurry supported tunnel face (Slurry Shield, Hydroshield, Mixshields).
- Convertible TBMs.
- Earth Pressure Balance Shields.

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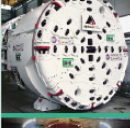

4

## Hard Rock TBMs

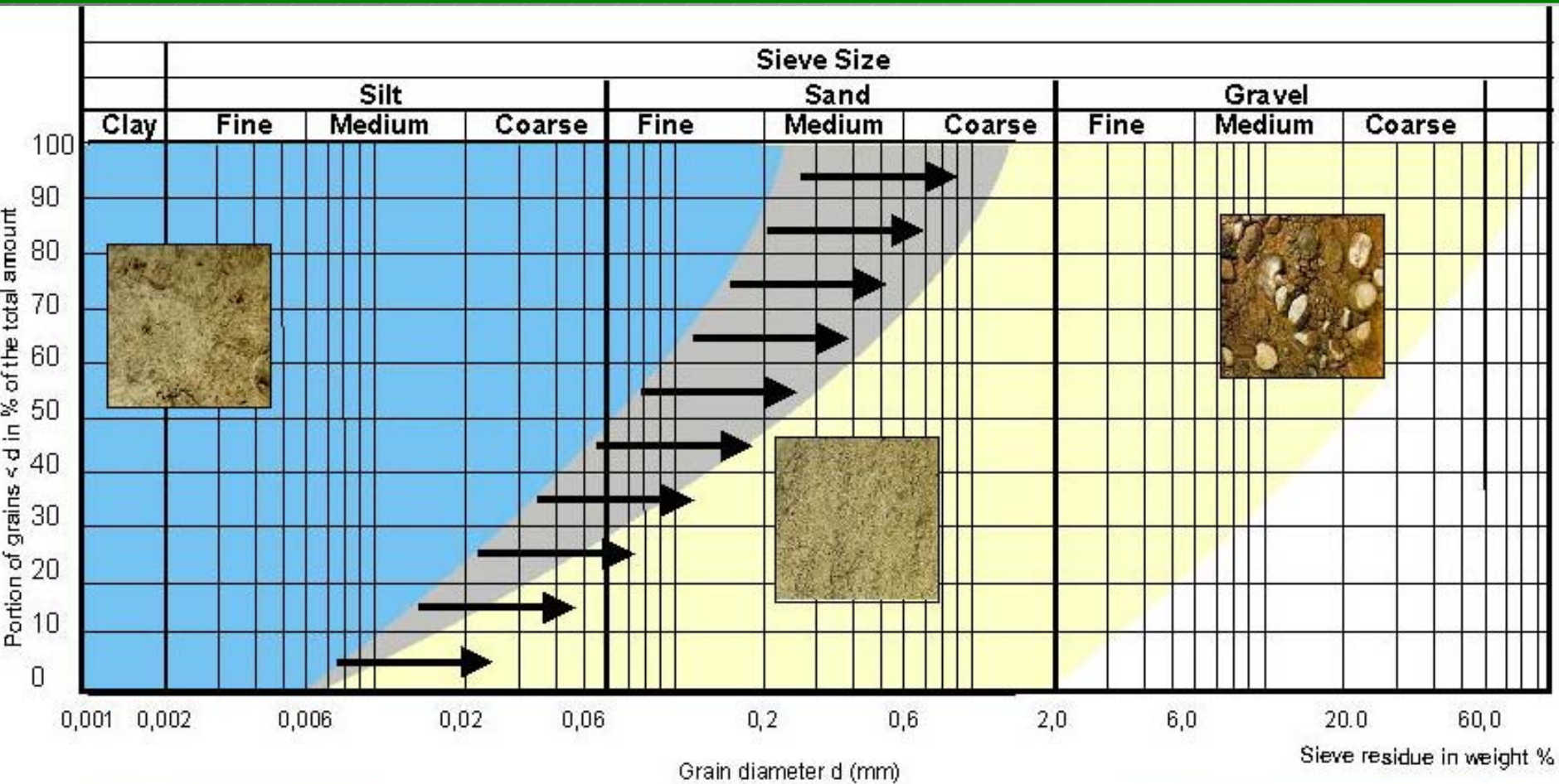
- Shielded Hard Rock TBMs (Single Shield TBMs, Double Shield TBMs).
- Gripper TBMs.



# Herrenknecht AG. Range of Products.

Diameter		0mm ->	1,000mm	-> 2,000mm	-> 16,000mm
	Auger Drilling Machines		DN 150 – DN800		
	AVN Micromachines		DN 250 – DN 2000		
	Pipe Jacking			DN 1200 – DN 3500	
	Segmental Lining			DN 1800 – DA 12000	
	Pipe Jacking			DN 1200 – DN 3000	
	Segmental Lining			DN 1800 – DA 16000	
	Pipe Jacking			DN 1600 – DN 3000	
	Segmental Lining			DN 1800 – DA 15060	
	Hard Rock-TBM			DN 1200 – DA 12500	
	Hard Rock Gripper-TBM				DN 2200 – DN 10000
	Vertical Shaft Sinking Machines				DN 5500 – DN 11000

# Soft Ground TBMs (EPBs and Mixshields).



**EPB Methods**

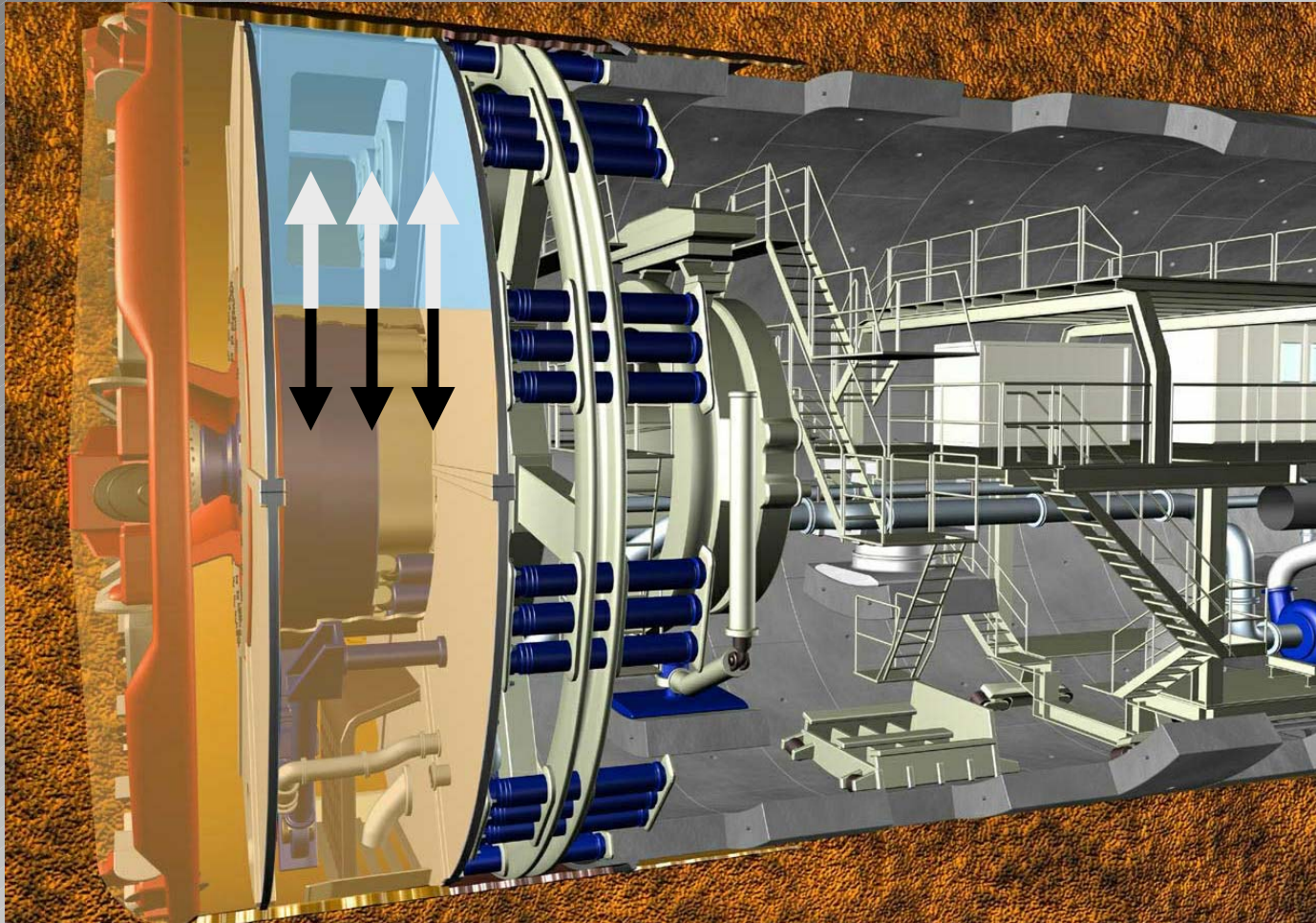
**Mixshield Methods**

# Mixshield. Safe Tunnelling in Varying Ground Conditions.



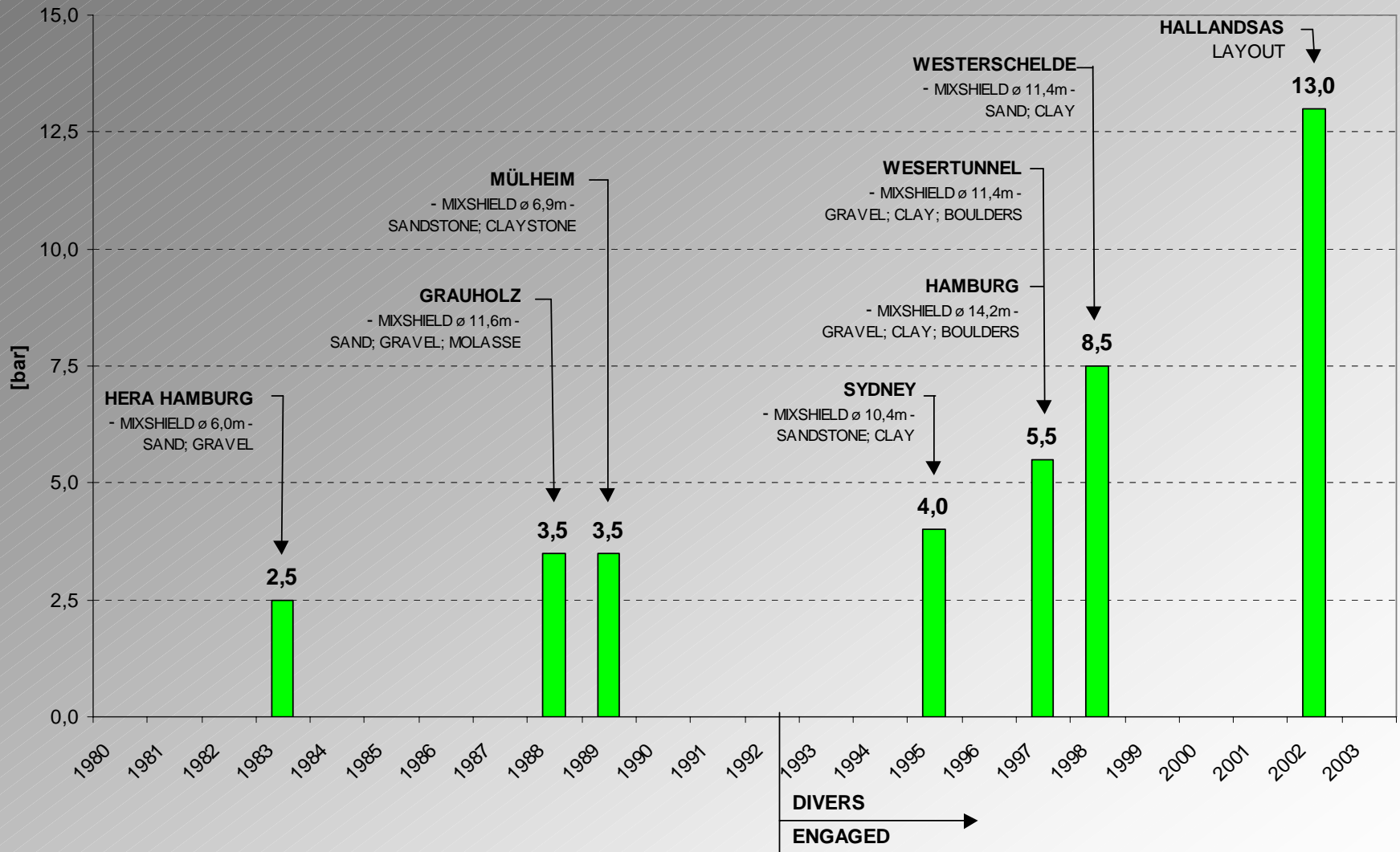
***Soft ground TBMs***

# Mixshield.General Layout.



***Soft ground TBMs***

# Real Performed Operational Pressure During Excavation.



***Soft ground TBMs***



# Mixshield: Hamburg, Germany. 4<sup>th</sup> Elbe River Tunnel.

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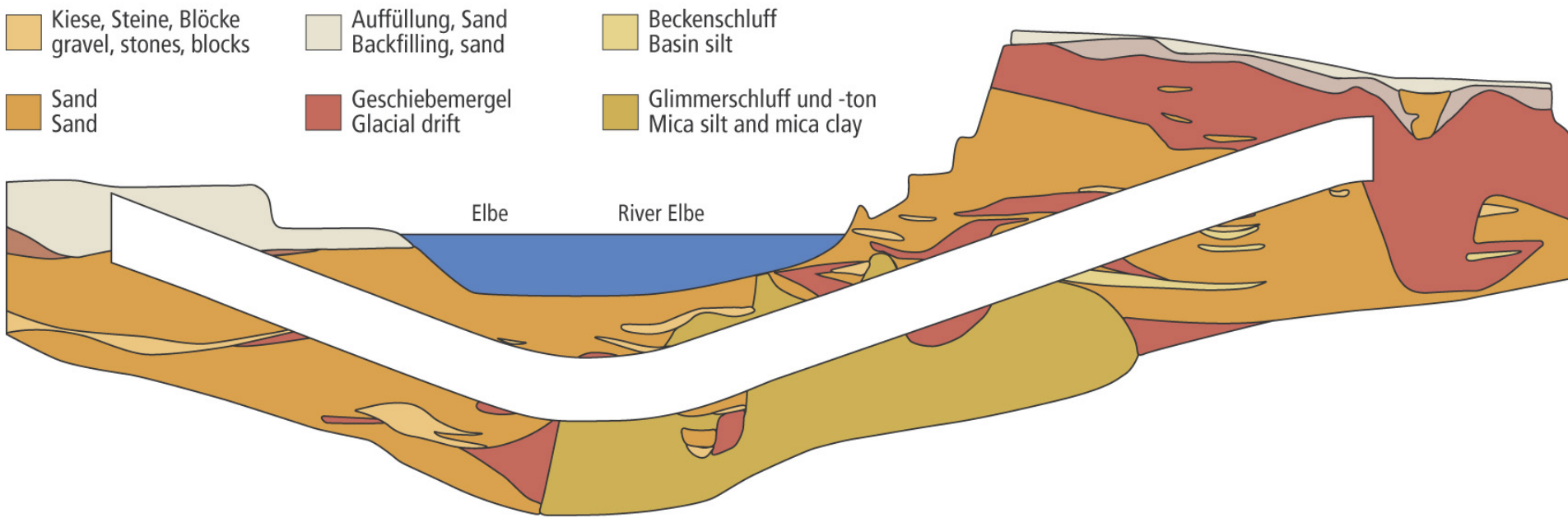
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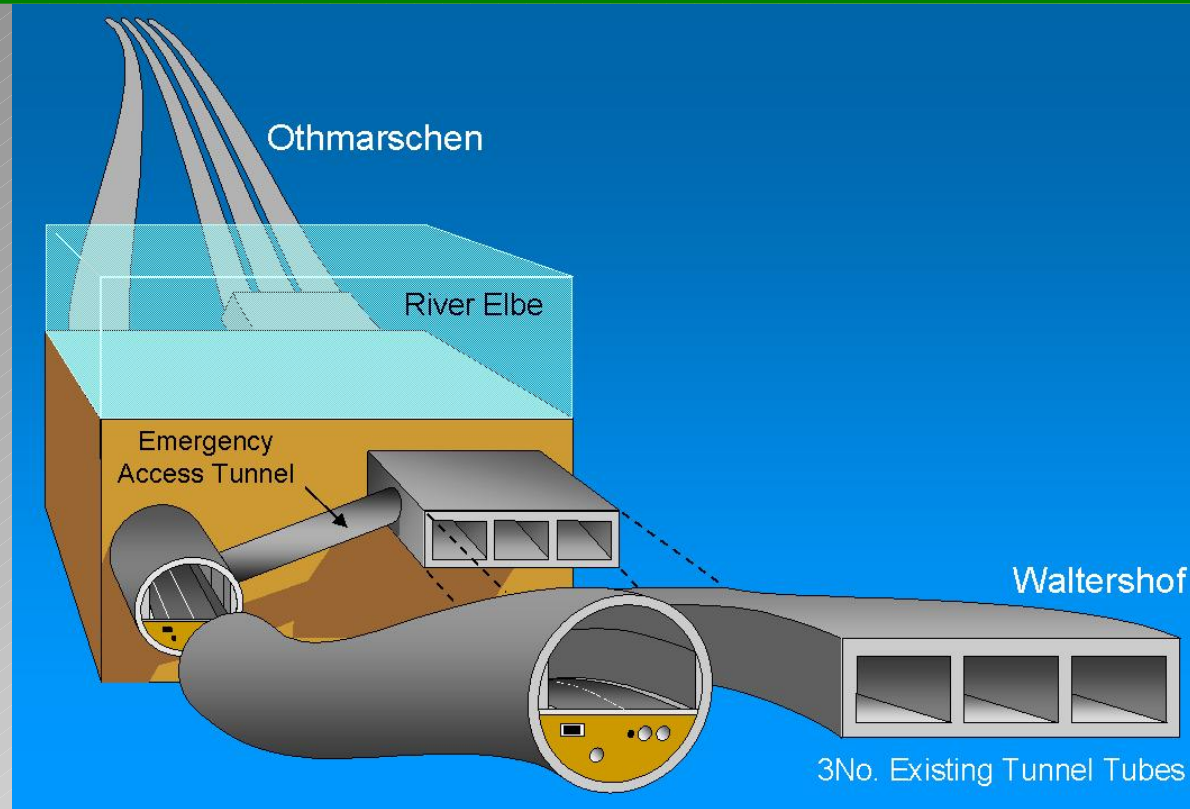


- S-108 Mixshield
- Diameter: 14,200mm
- Cutterhead power: 3,400kW
- Tunnel length: 2,560m
- Geology: Gravel, silt, sand, boulders
- Contractor: Bilfinger Berger AG  
Dyckerhoff & Widman AG  
Heitkamp GmbH  
HOCHTIEF AG  
Philipp Holzmann AG  
Wayss & Freytag AG  
Ed. Züblin AG

# Demanding Geology under the Elbe River.



# Connection to the Existing Tunnel Tubes.



# Jaw Crusher. Capable of Handling Boulders up to $\varnothing$ 1,200 mm.



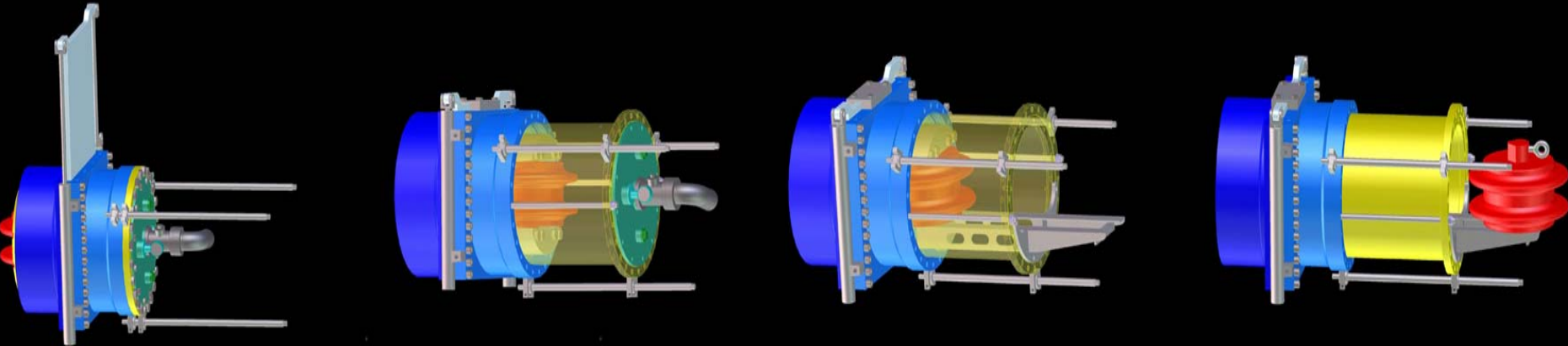
- Crusher jaws can apply force 900kN.
- Replaceable jaws.
- Crusher grill size 200mm.

# Cutting Tool Change under Atmospheric Pressure.



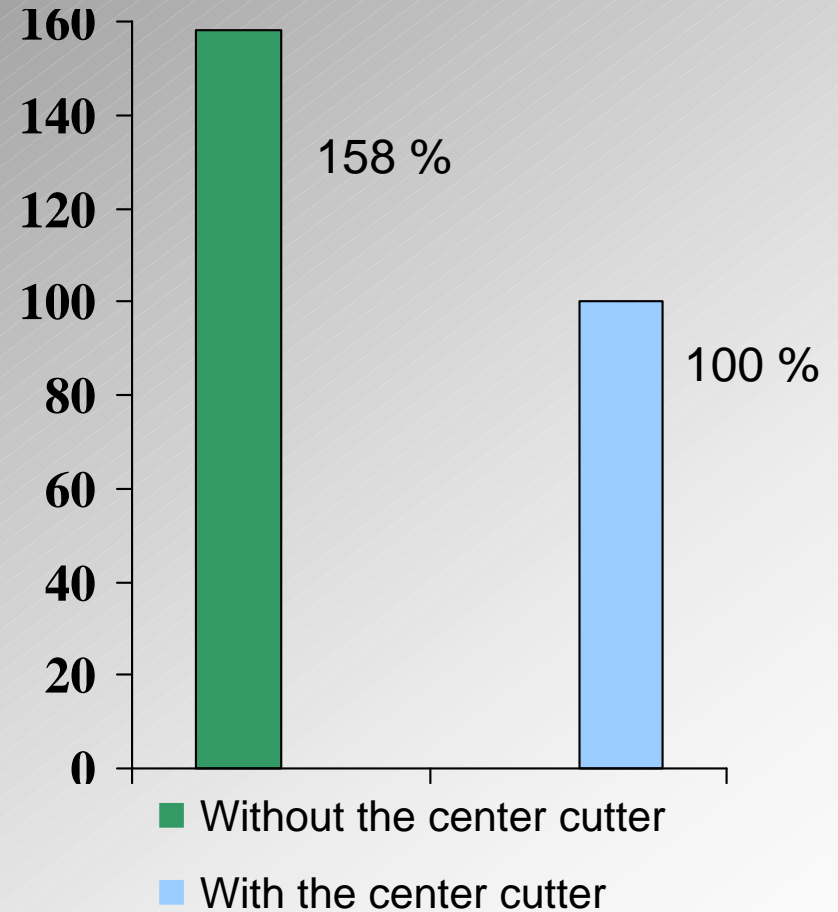
- Access to the main arm of the cutting wheel under atmospheric pressure.
- Operator undertakes maintenance procedure's without the risk of having to work at the tunnel face.
- Back loading cutting tools.

# Procedure Cutting Tool Change.



- Each disc cutter is mounted in a pressurized housing with a hydraulically operated gate valve.
- Removing of mounting bolts.
- Withdrawal of disc cutter.
- Closing of gate valve to seal the housing off from the face.
- Disc cutter removal with a crane attachment.

# Torque Reduction with Active Center Cutter.



# Mixshields: Three TBMs for North-South City Railroad Cologne.

1



- S-320 and S-321 Mixshields
- Diameter: 8,400 mm
- Cutterhead power: 1,100 kW
- Tunnel length: 2,700 m
- Contractor: ARGE Nord-Süd  
Stadtbahn Köln Los Süd

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- S-314 Mixshield
- Diameter: 6,800 mm
- Cutterhead power: 630 kW
- Tunnel length: 2 x 260 m
- Contractor: ARGE Ingenieurbau  
Nord-Süd Stadtbahn Köln Los Nord

***Cologne/ Germany***



# Three TBMs for North-South City Railroad Cologne



*Cologne/ Germany*

# Mixshield: City-Tunnel Leipzig, Germany.

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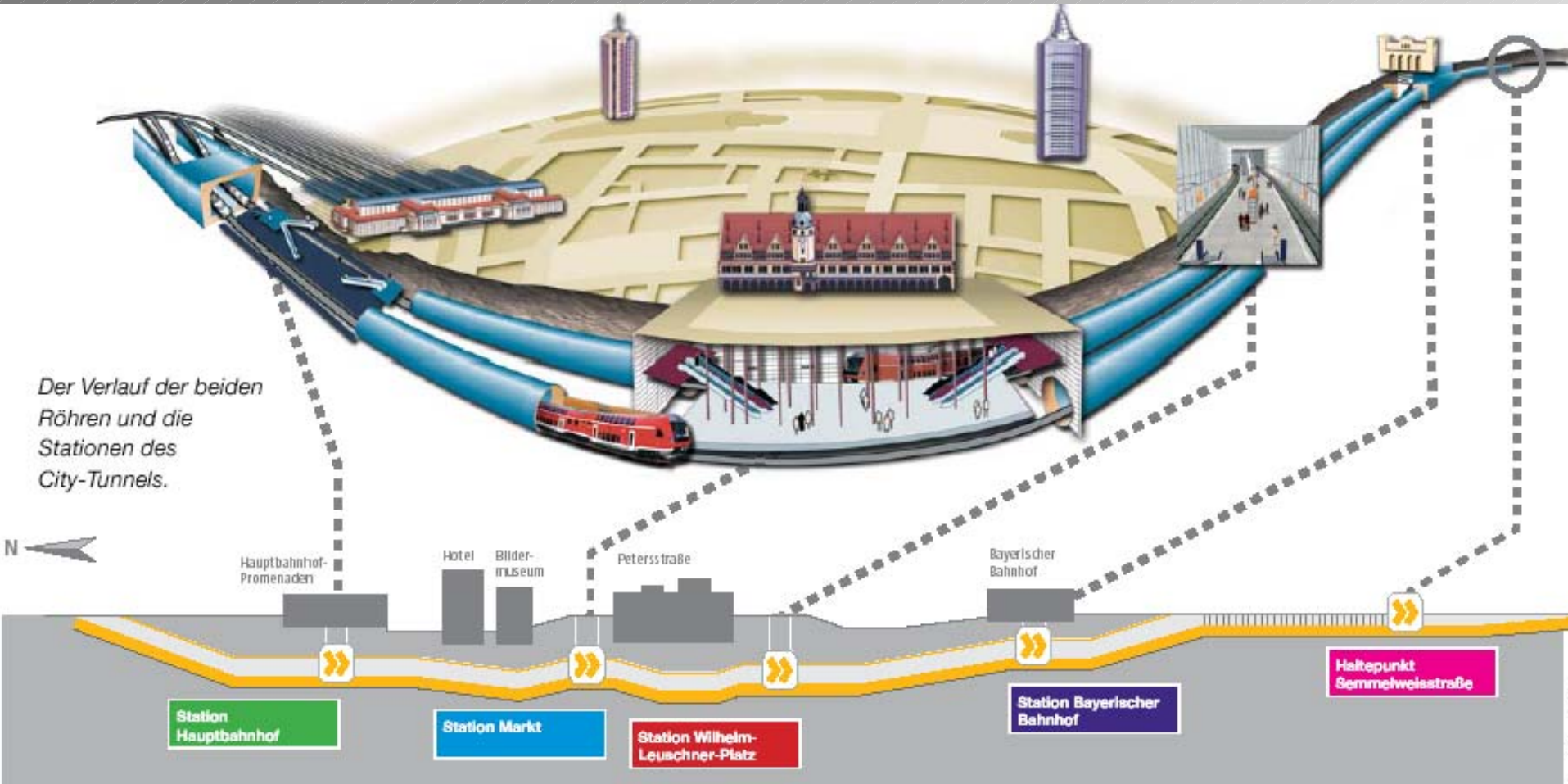
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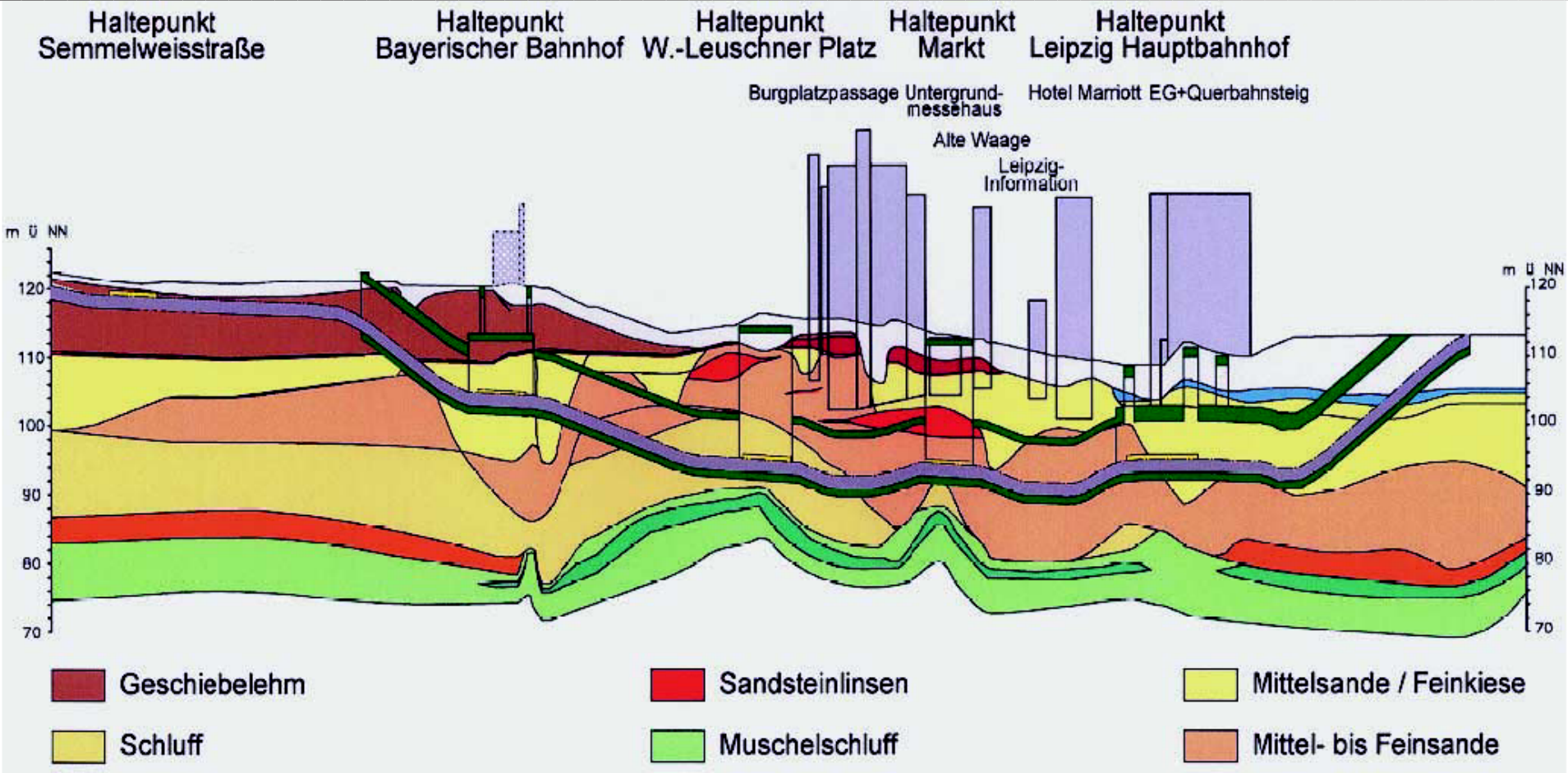


- S-326 Mixshield
- Exc. Diameter: 9,010 mm
- Cutterhead power: 880 kW
- Tunnel length: 2 x 1,782 m
- Geology: sand, silt, gravel, lenses of sandstone
- Contractor: ARGE Tunnel- und Ingenieurbau Leipzig  
Los B (Dywidag Bau GmbH, Alpine Bau Deutschland GmbH, Oevermann GmbH & Co. KG, Strabag AG)

# City-Tunnel Leipzig. Tunnel Route.

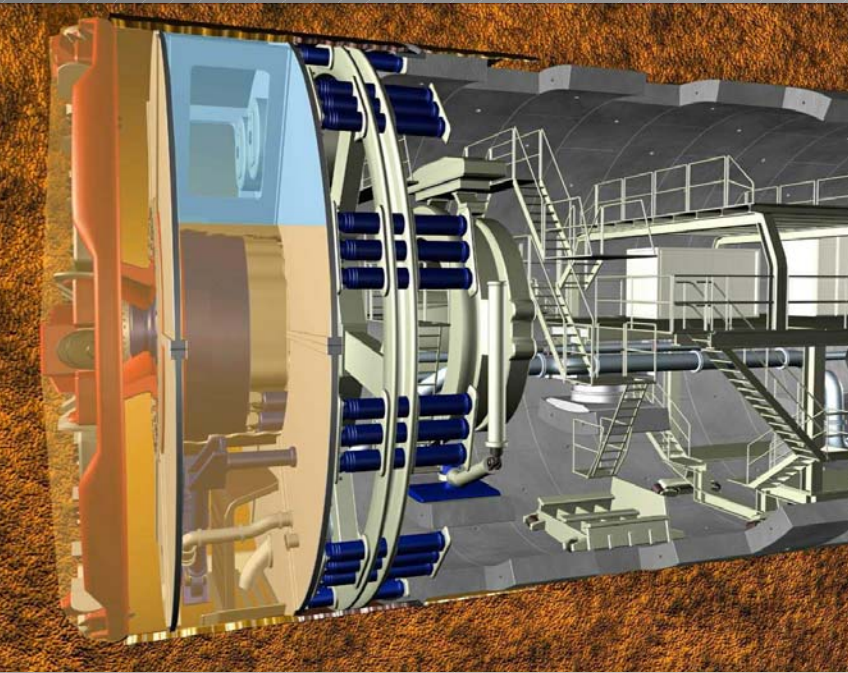


# City-Tunnel Leipzig.Geology.



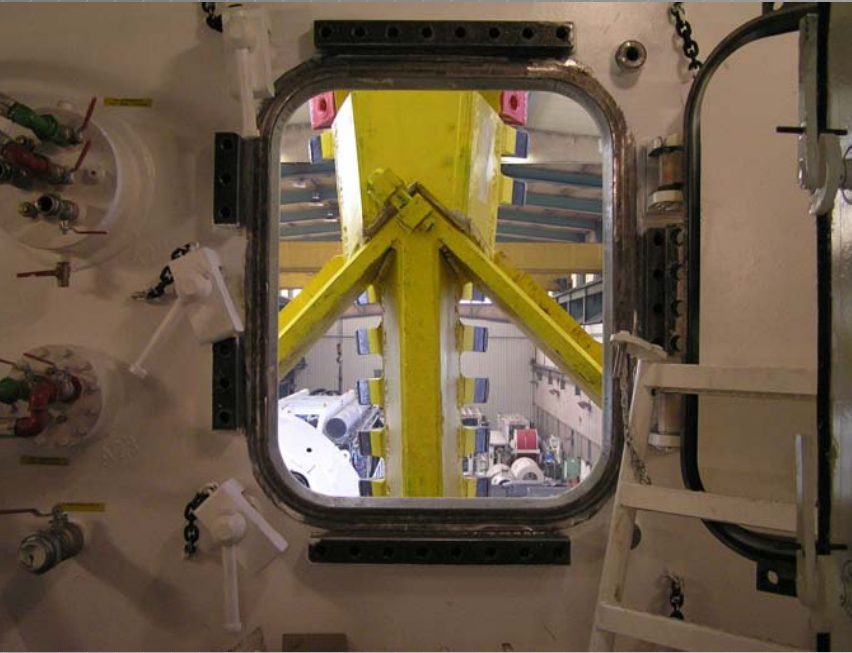
Max. Grundwasserhöhe über Tunnelsohle beträgt ca. 18 m.

# City-Tunnel Leipzig. Demands on TBM Technology.



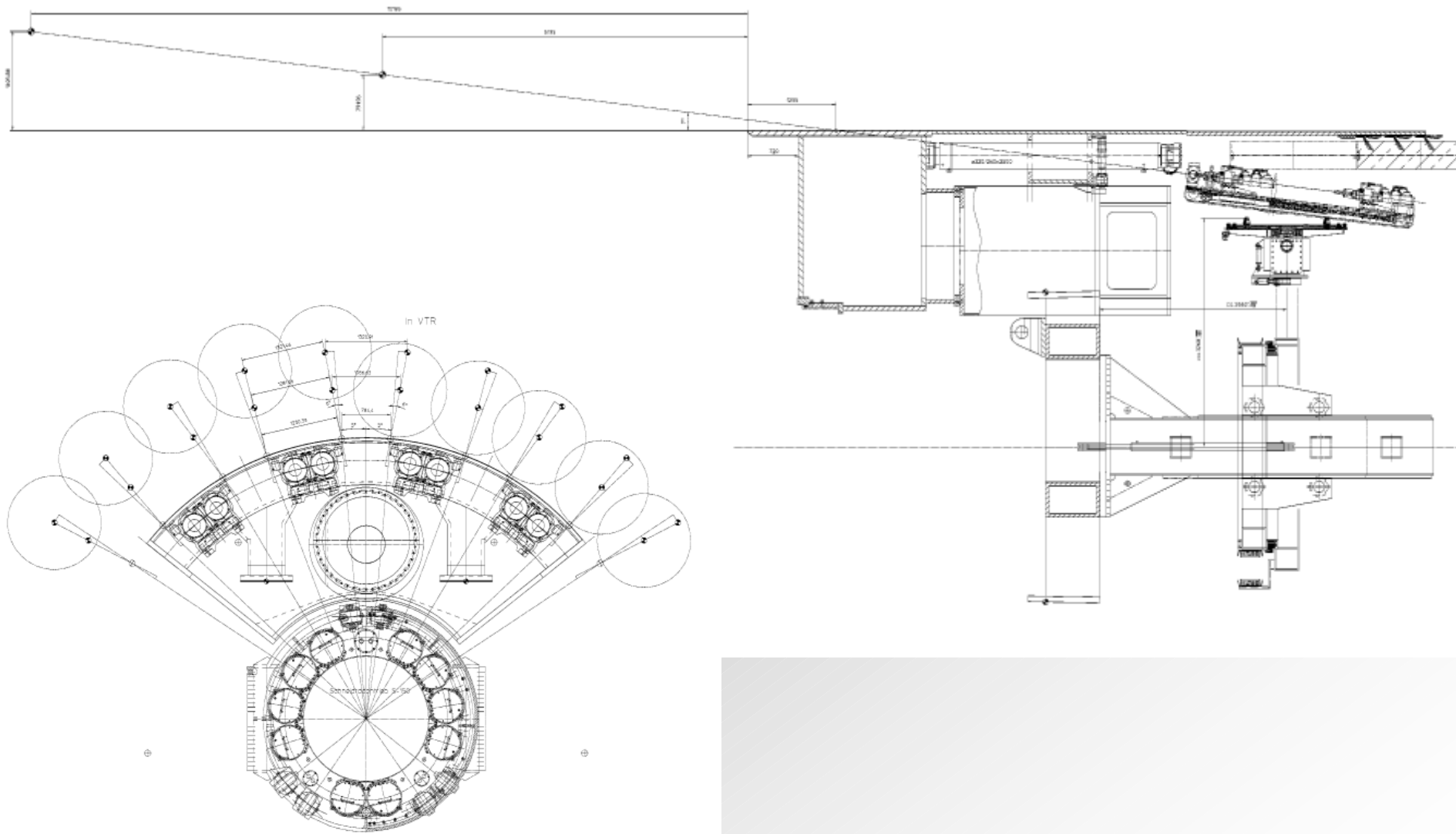
- Settlement controlled TBM process with liquid supported tunnel face (alternatively EPB-Shield).
- Heterogeneous geological conditions.
- SSP (System for seismic probing ahead which allows “insights into unknown” ahead of the cutting wheel).
- Equipment and installations for chamber access and tool change procedure under pressurized conditions according to the latest state of the art.

# Cutting Wheel Design. Main Characteristics.



- Safe tool change from the backside of the cutting wheel.
- Tools for both soft and hard rock conditions.
- Intensive wear protection.
- Access to the tunnel face possible through openings in the cutting wheel structure.
- Cutting wheel design optimized regarding material flow.

# Possibility of Injection Umbrella. 10 Injection Openings.



**Leipzig/ Germany**

# Installation for Ground Stabilization Measures.

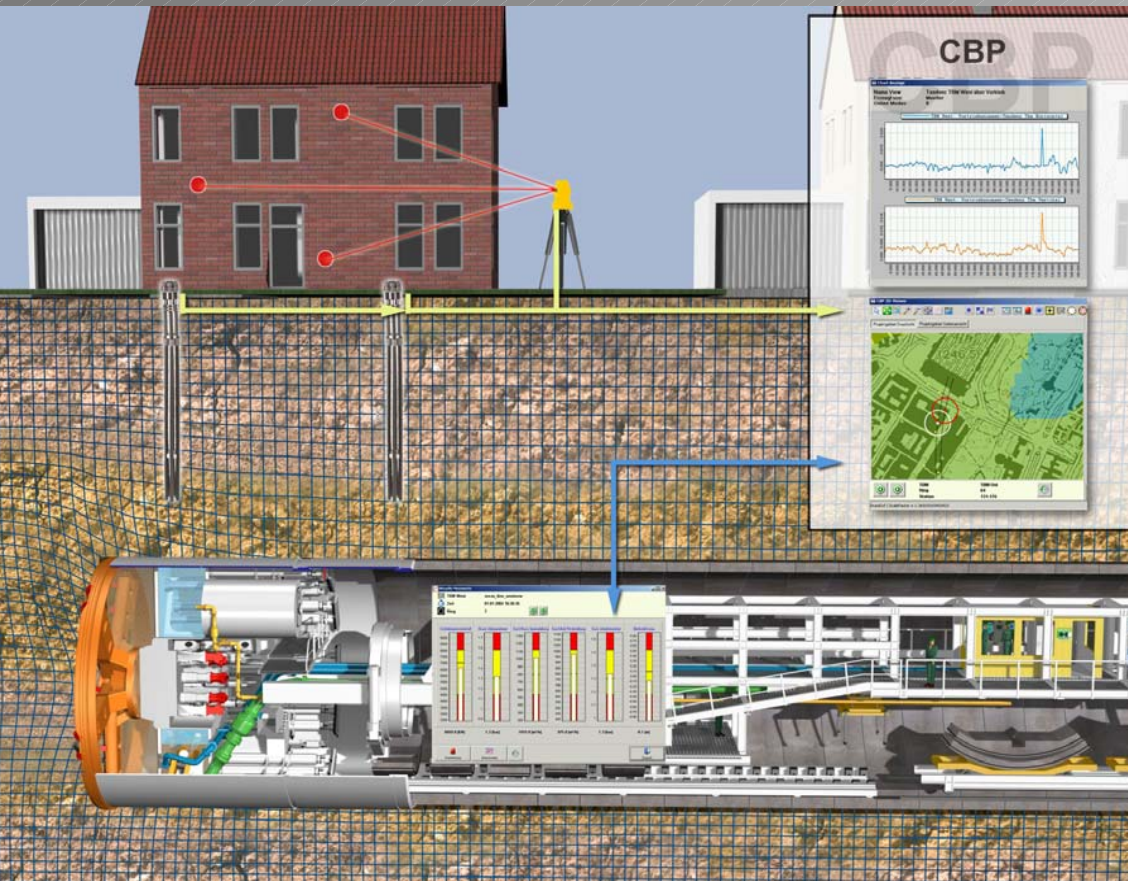


*Leipzig/ Germany*

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# Warning in Case of Difficult Tunnel Face Conditions.



- Controlled boring process.
- Online visualization of the TBM advance.

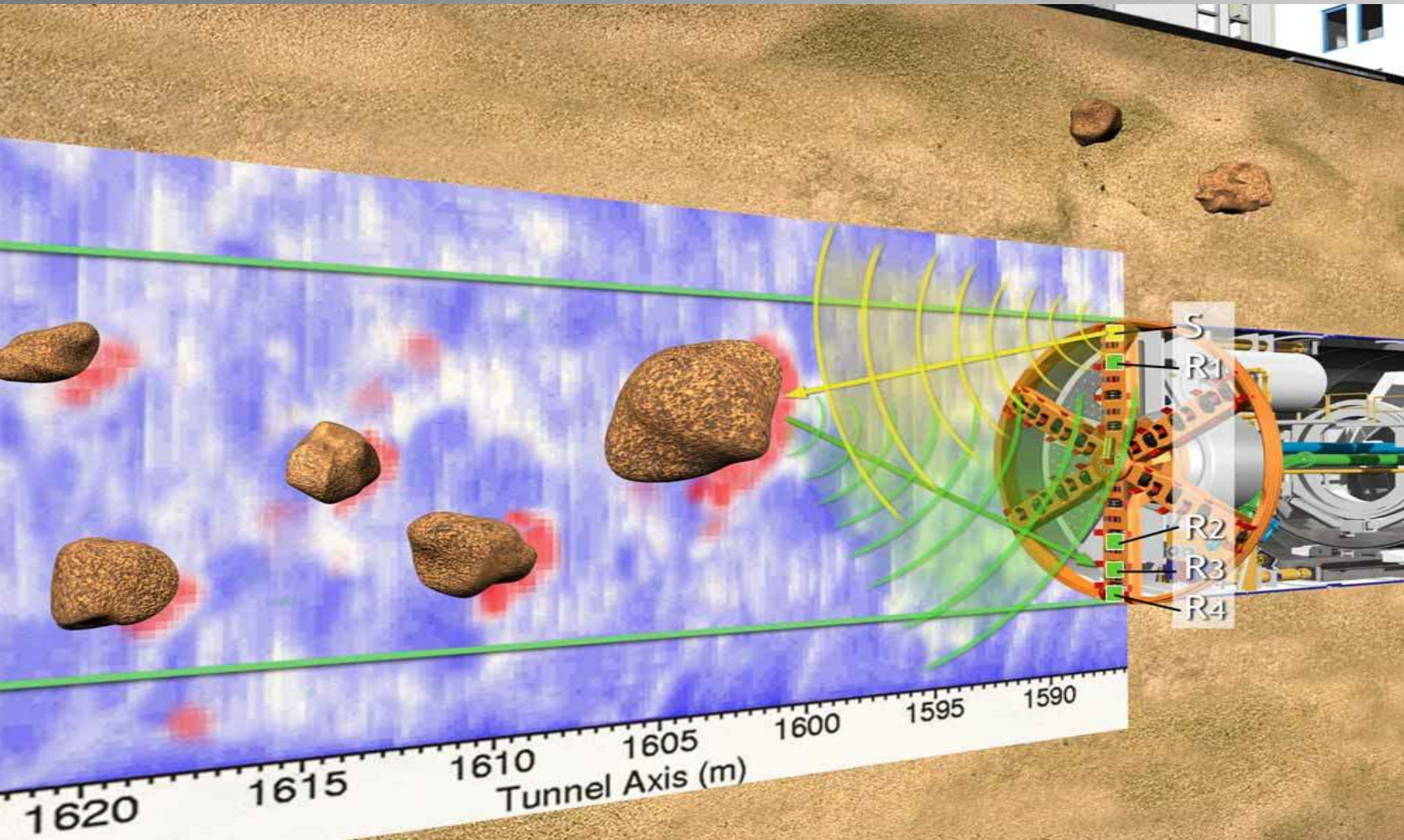
# Muck Control.



*Leipzig/ Germany*

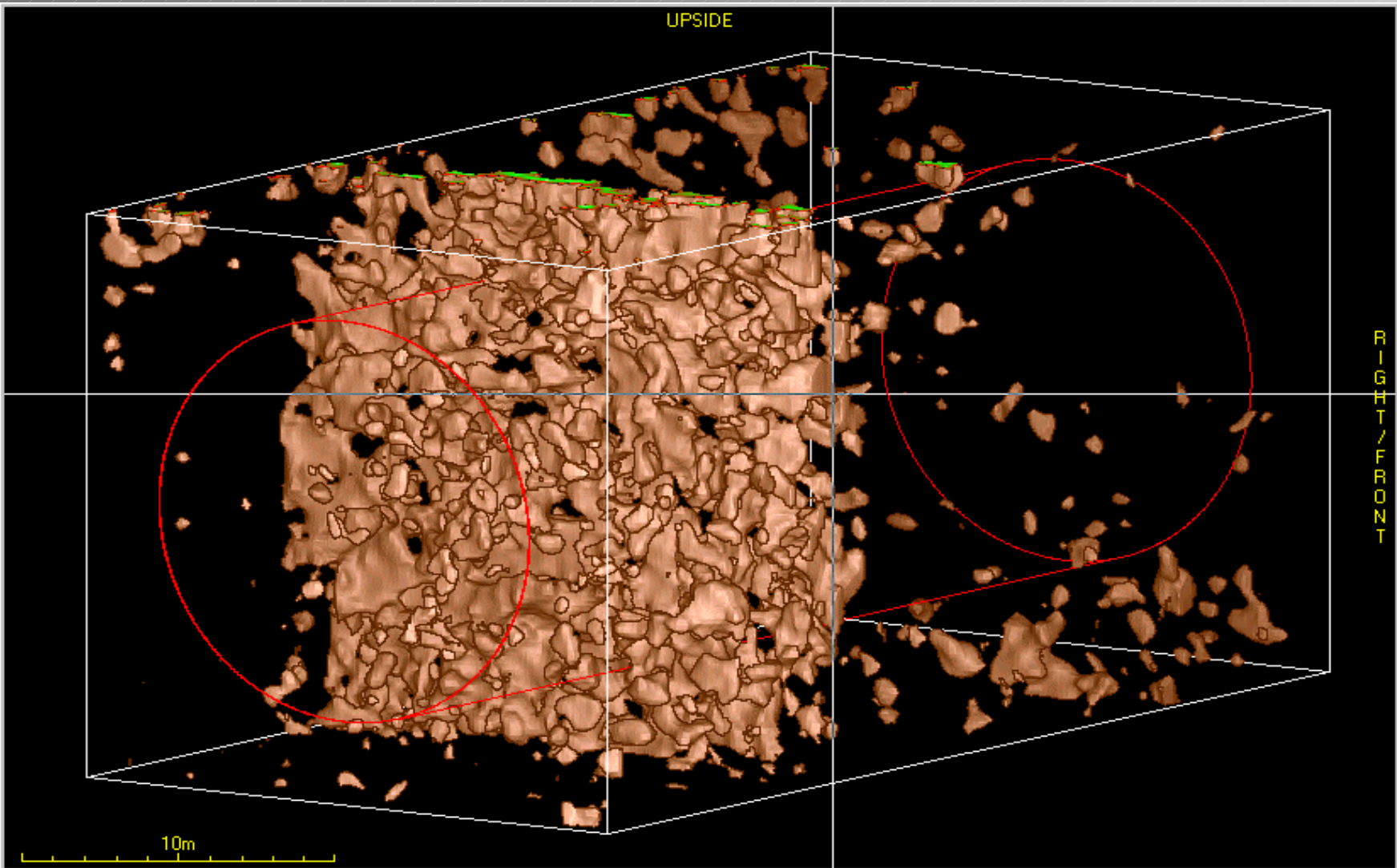
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# SSP: Discovering Obstacles in Good Time.



*Leipzig/ Germany*

# 3-D-Visualization. Injection Block Discovered by SSP.



*Leipzig/ Germany*

# Two Mixshields for SMART Tunnel Project in Kuala Lumpur, Malaysia.

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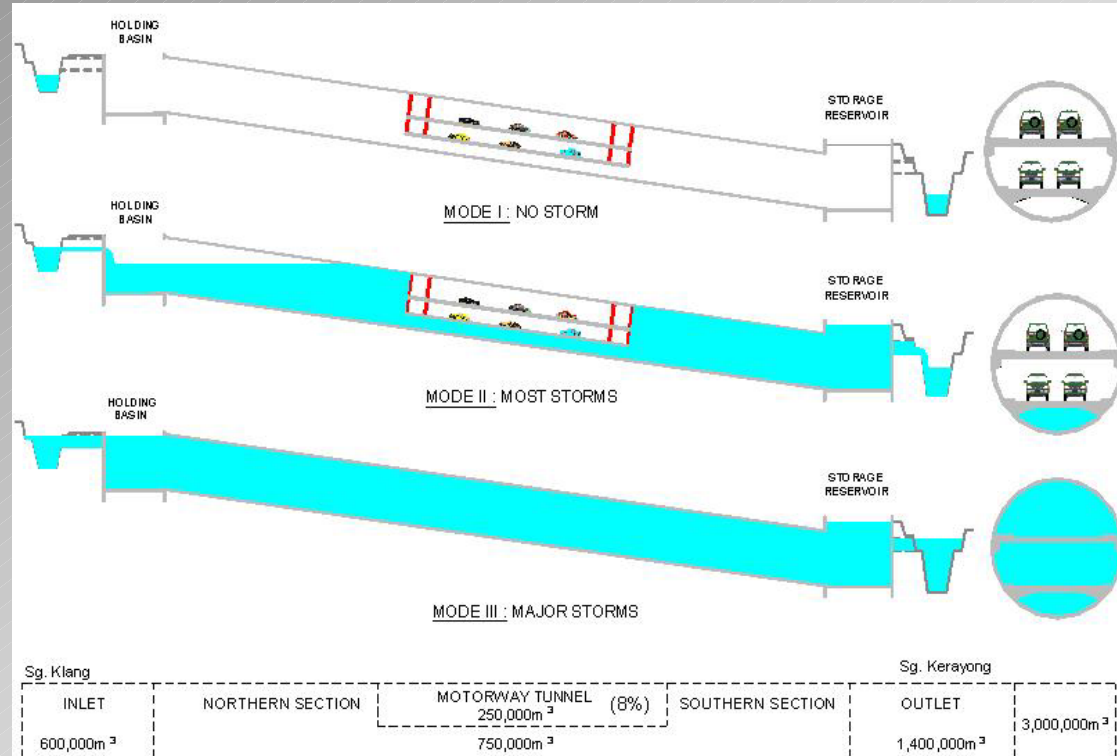
4



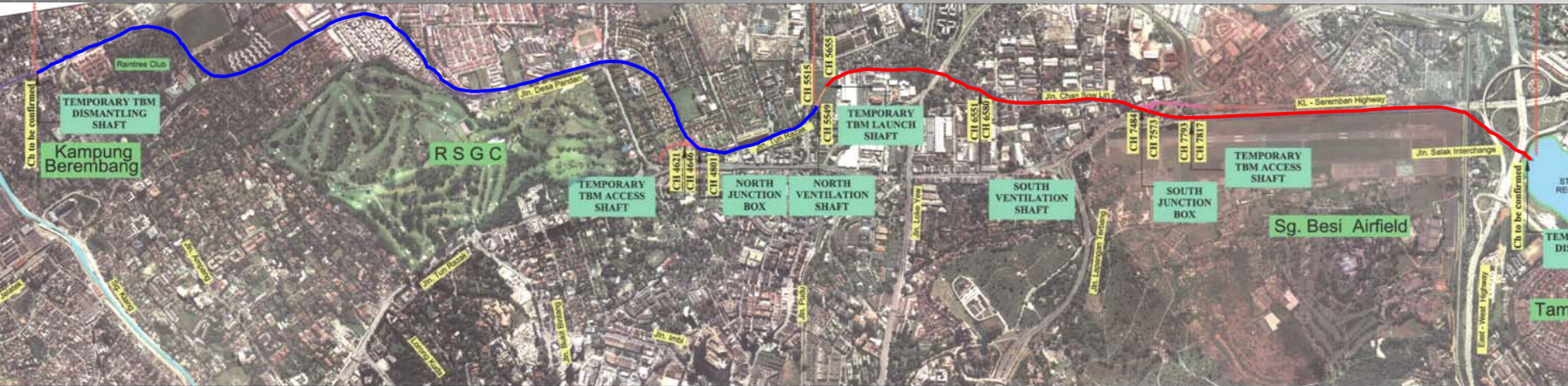
- S-252 and S-253 Mixshields
- Tunnel length: 5,400 m (W&F); 4,059 m (MCC-Gamuda)
- Cutterhead power: 4,000 kW
- Geology: Limestone, sand, marble
- Contractors: S-252: Wayss & Freytag AG, S-253: MMC-Gamuda

***Kuala Lumpur/ Malaysia***

# An Innovative Idea. Multi-function Tunnel in Kuala Lumpur.



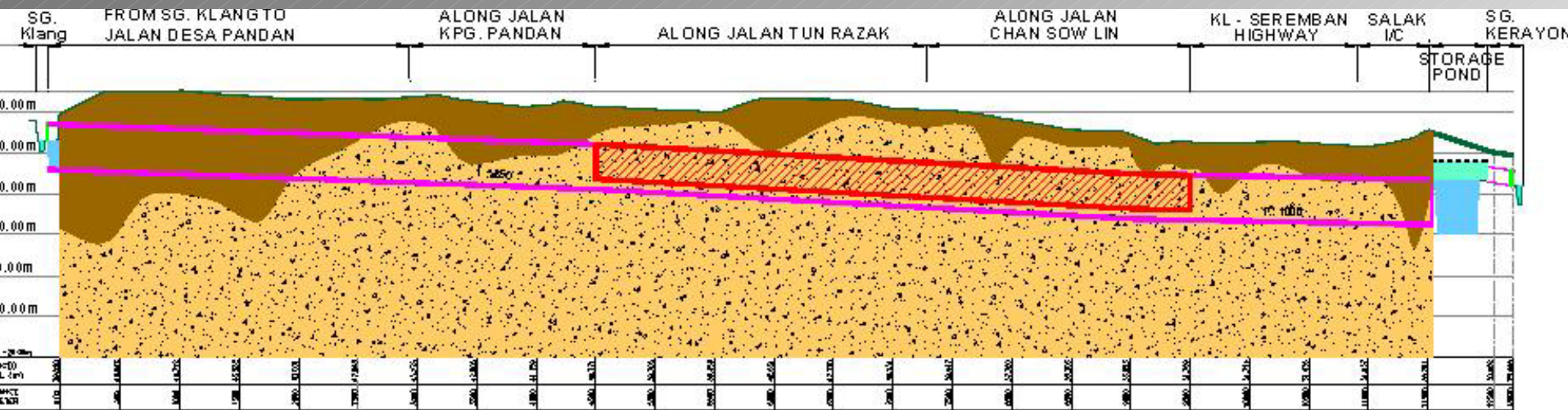
# The SMART Tunnel Route, Kuala Lumpur.



- North TBM Drive, S-252
- Tunnel length: 5,400 m

- South TBM Drive, S-253
- Tunnel length: 4,050 m

# SMART Tunnel. Geology.



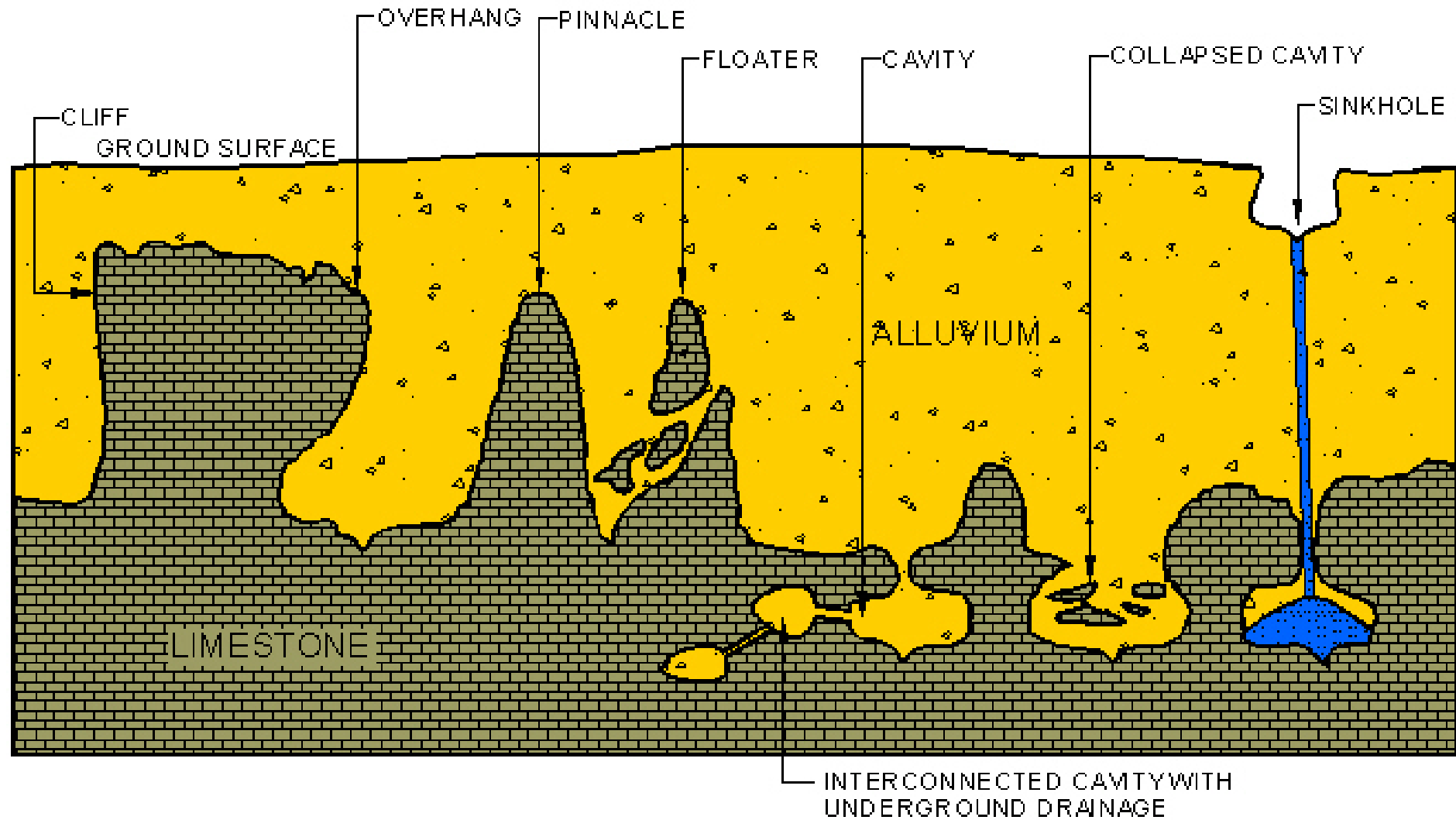
## LEGEND:-

- OVER BURDEN
- BED ROCK

- 70 % traverses karstic limestone and sections in compact and fresh marble.
- 30 % traverses quarternary alluvial deposits (silty, gravely sand) and mine tailings.
- Road tunnel section is marked red



# Feature of Karstic Limestone Bedrock.

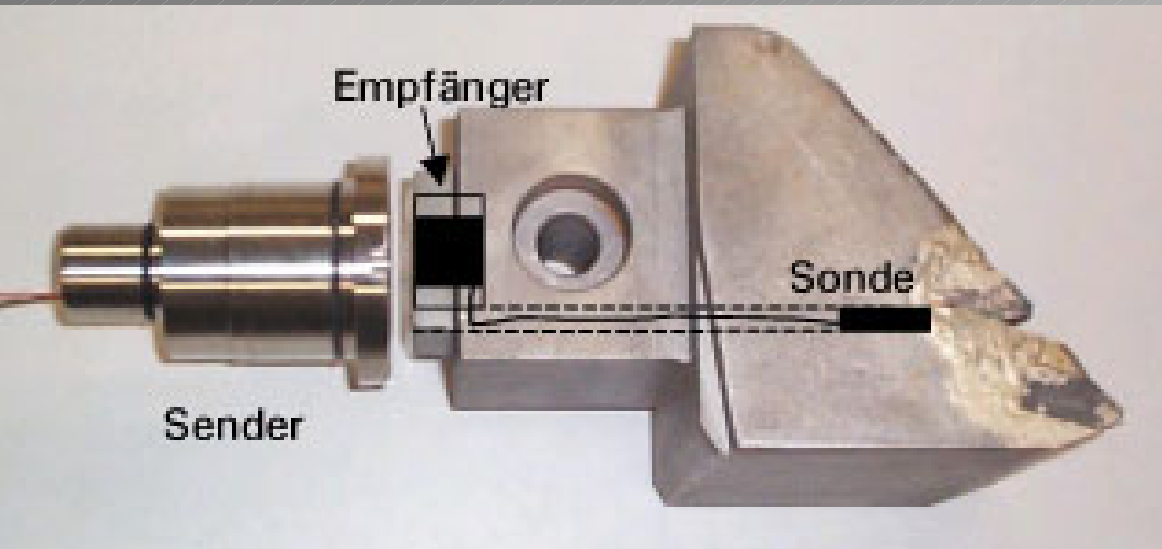


# Exposed Karstic Rockhead During Tin Mining.



*Kuala Lumpur/ Malaysia*

# Efficient mining in soft ground. Soft ground tools with wear detection system.



- Enables current information about cutting tool wear.
- Economical tool change.
- Damage limitation on steel structure.



# Mixshield: Shanghai, China. The World's Largest Cutting Wheel.

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- S-317 and S-318 Mixshields
- Diameter: 15,430mm each
- Power: 3,500kW each
- Tunnel length: 7,170m each
- Geology: Sand, clay and rubble
- End user: Shanghai Metro Shield Machine Equipment and Engineering Co., Ltd.

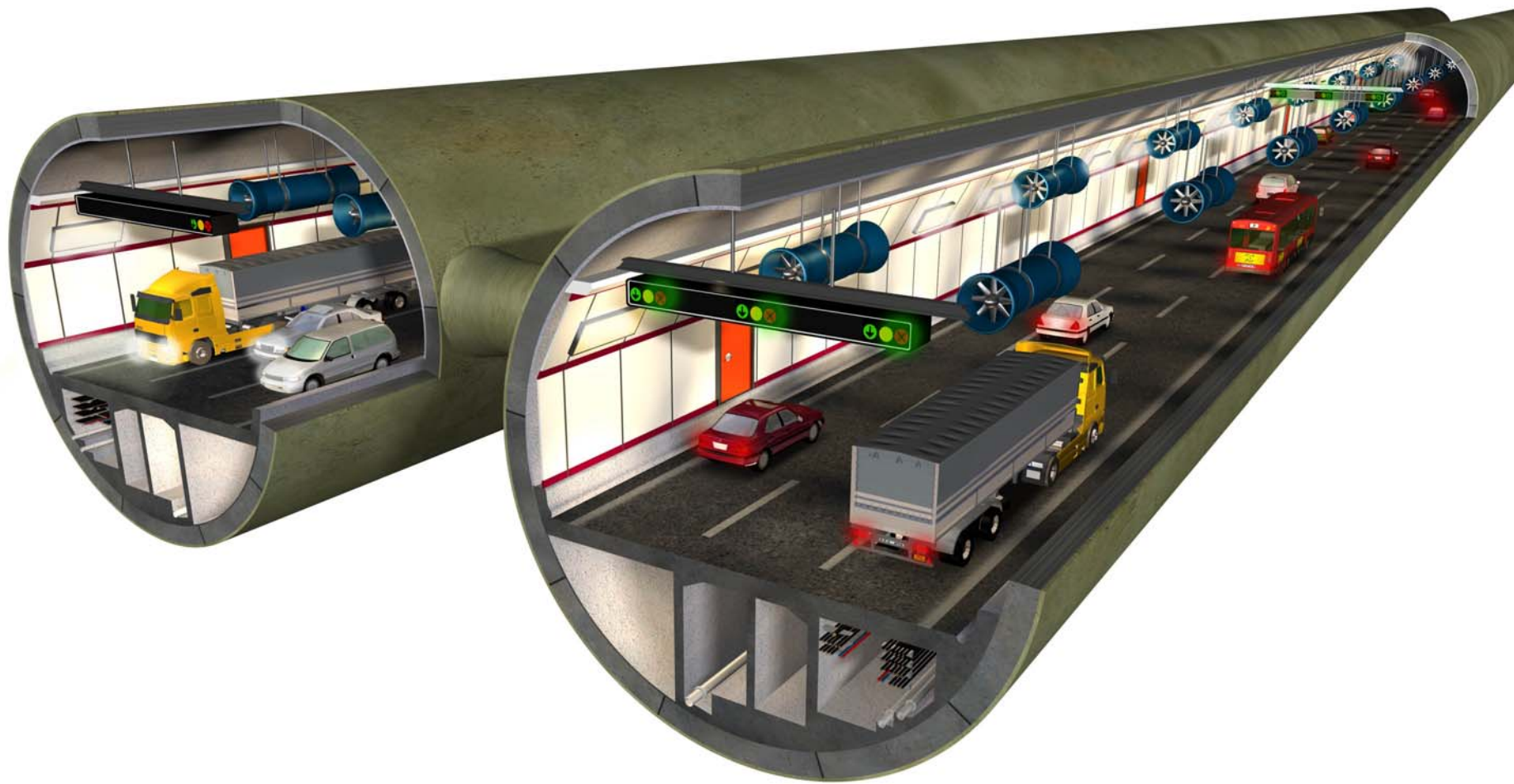
*Shanghai / China*



# Changjian Under River Tunnels, Shanghai.



# Changjian Under River Tunnels, Shanghai. Tunnel Cross Section.



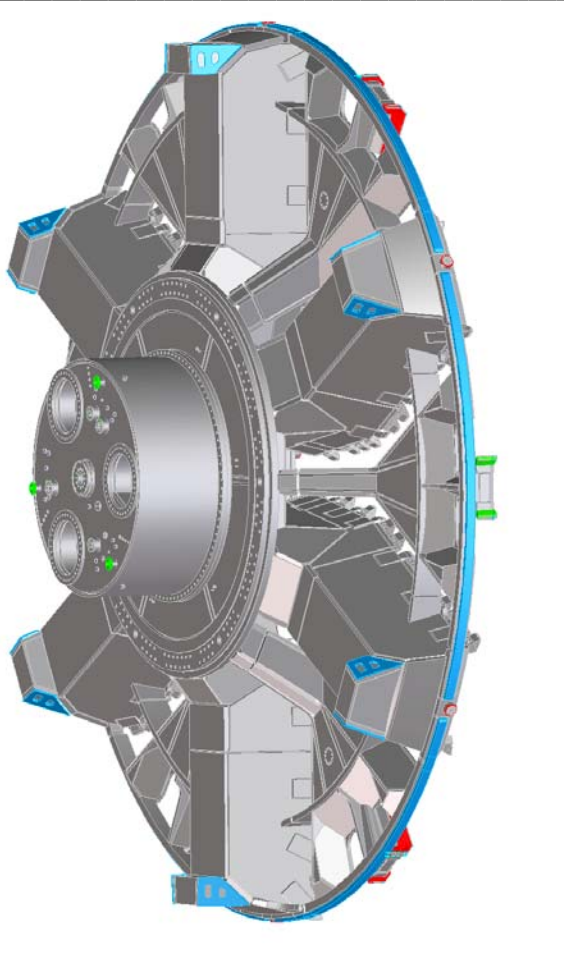
# Changjian Under River Tunnels, Shanghai.

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**Risk control with large diameter TBMs, long tunnel drive, high pressures.**

- Double-deck road tunnel:
  - Upper level: 2 lanes + rescue lane.
  - Lower level: Service- and safety tunnel.
- Two tunnel pipes with 7.2 km each underpassing the river Yangtze in depths of up to 60 m and with pressures of up to 6 bar.

# Changjian Under River Tunnels, Shanghai.



*Shanghai/ China*



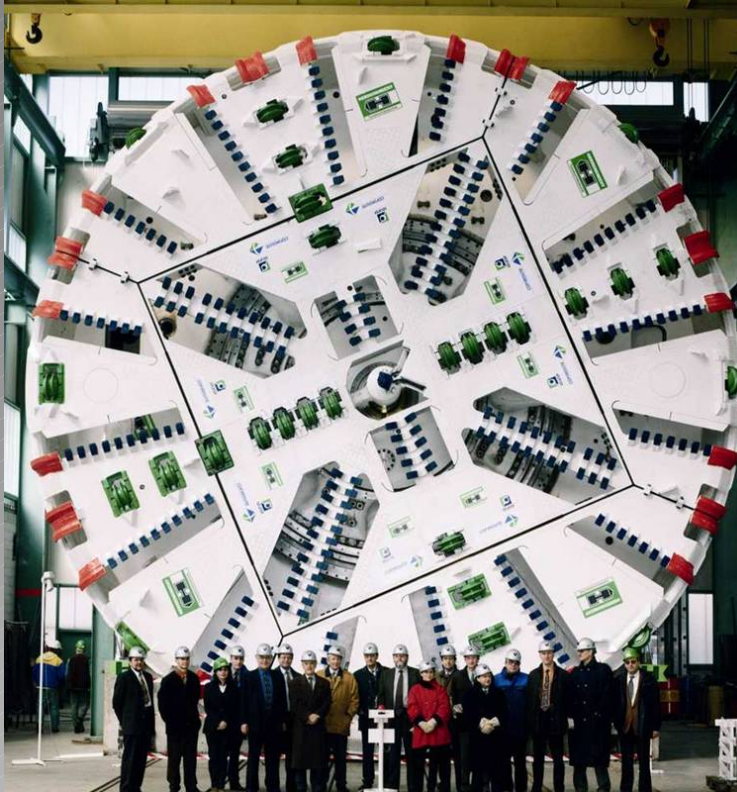
# Mixshield: Socatop, Paris.

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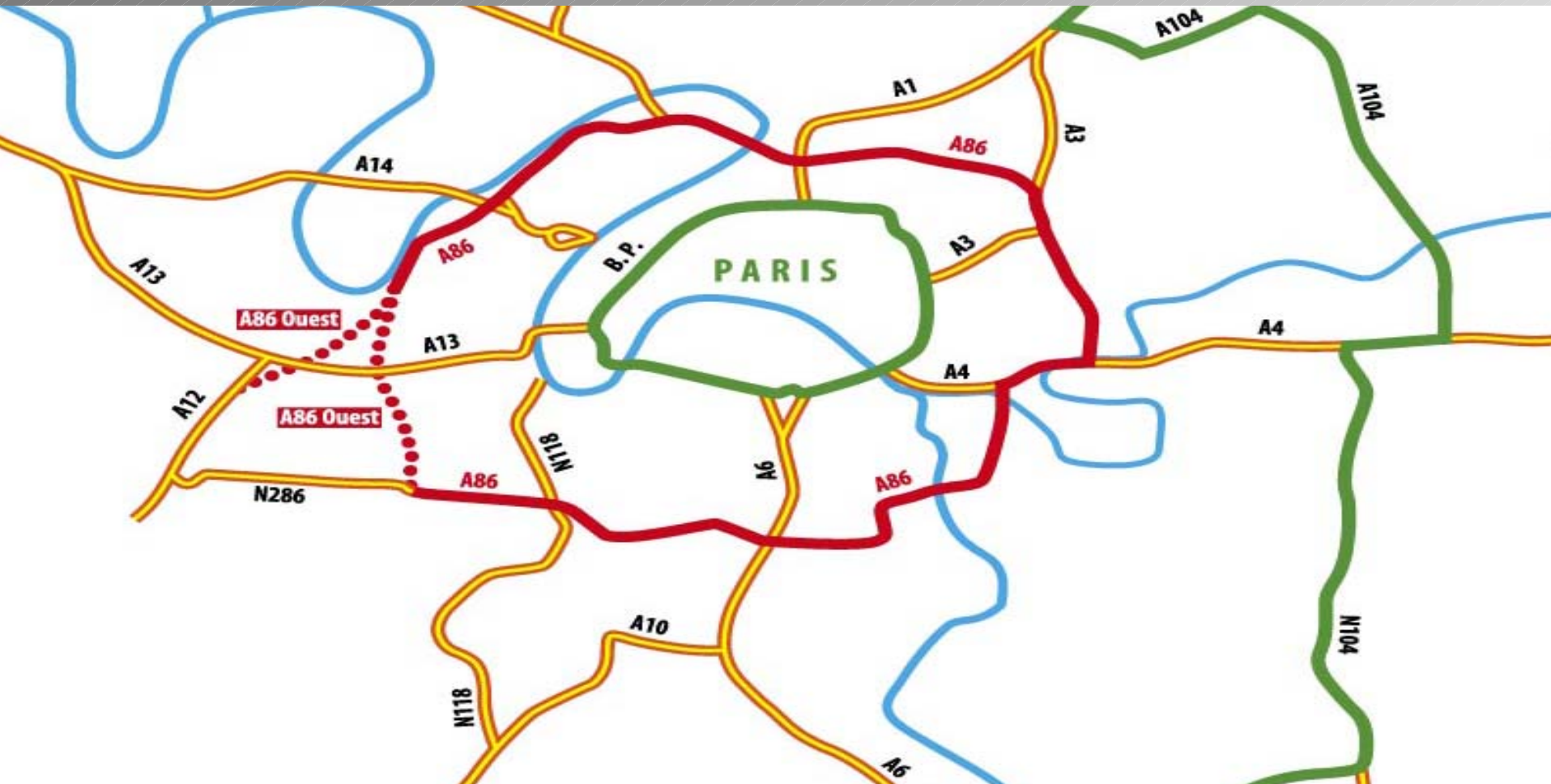
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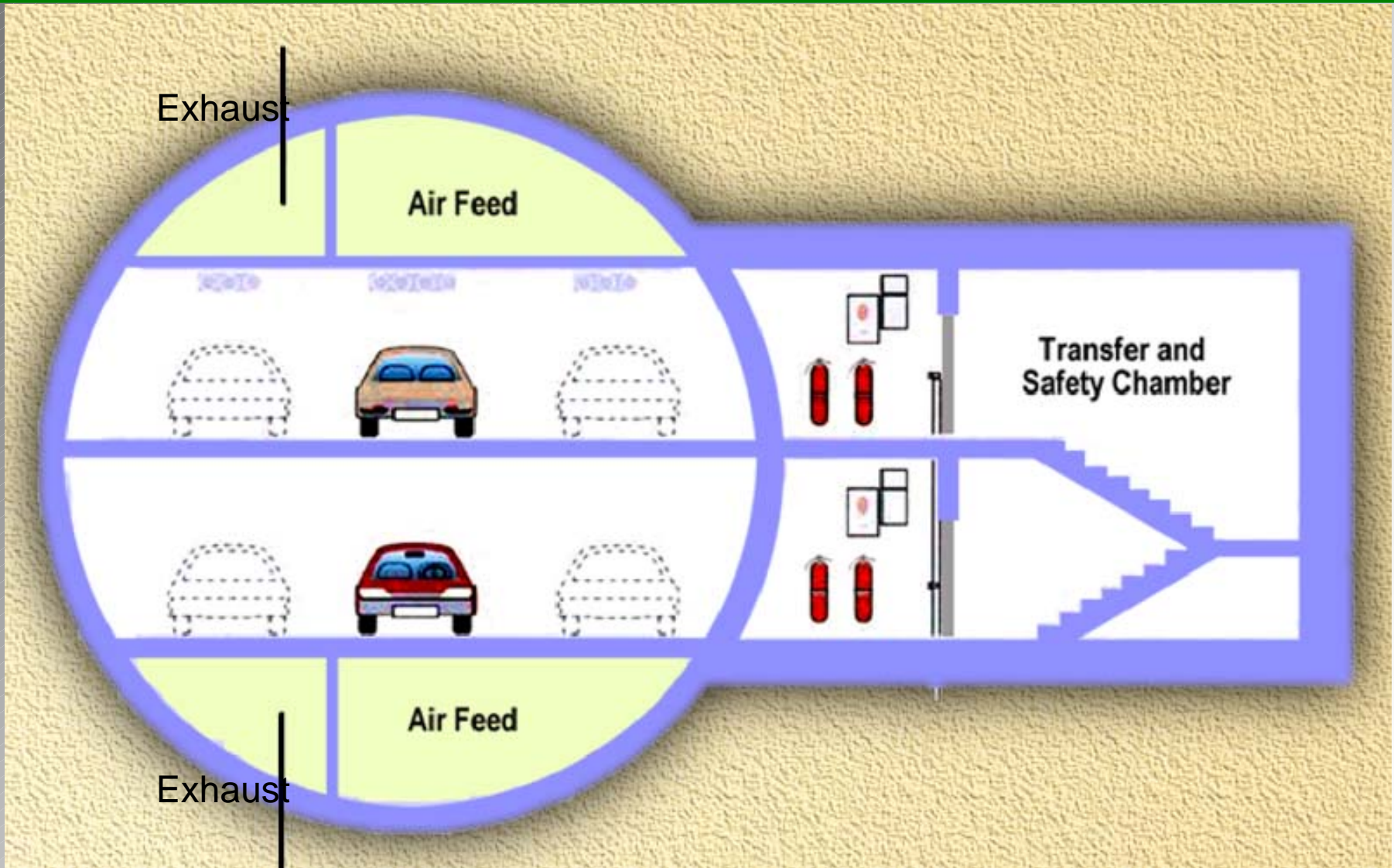
- S-127 Mixshield
- Diameter: 11,565 mm
- Tunnel length: 10,500 m
- Geology: Sand, lime, clay, marl, chalk
- Contractor: Campenon Bernard TP; Colas; GTM Construction; Dumez GTM; Fougerolle Ballot

*Socatop, Paris/ France*

# Socatop. Road Tunnel for the A86.

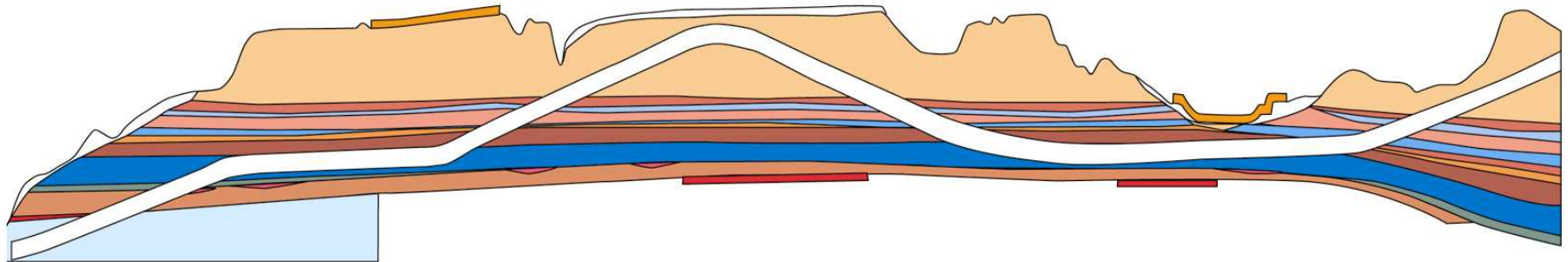


# Socatop. Tunnel Cross Section.

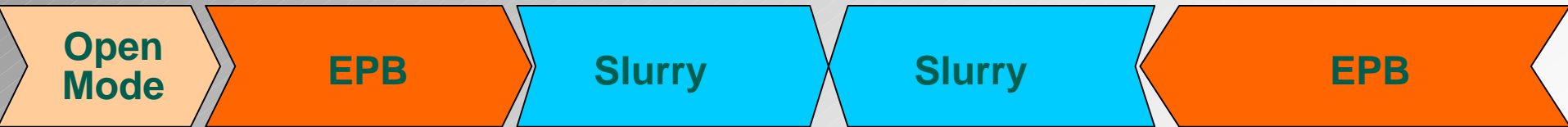


*Socatop, Paris/ France*

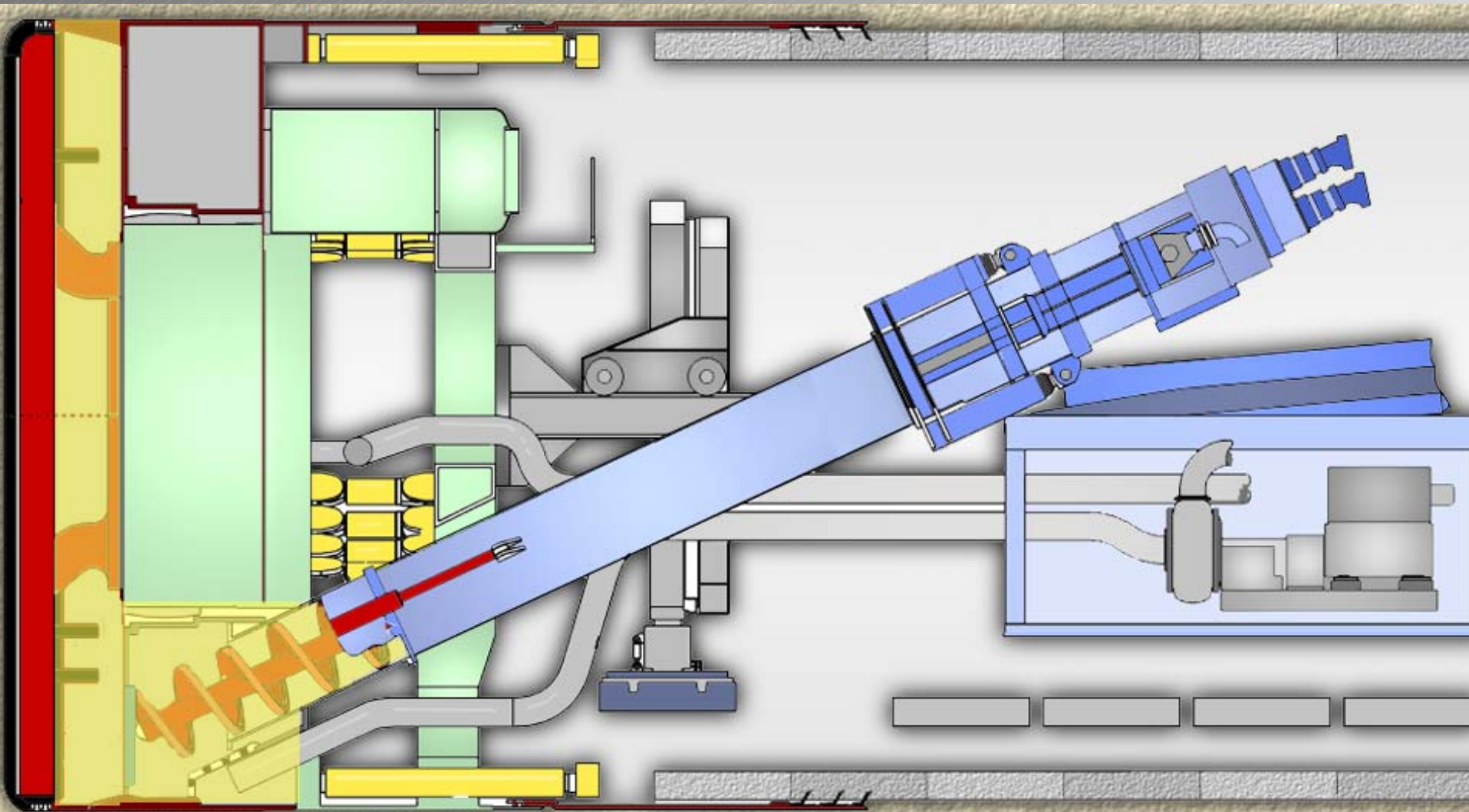
# Socatop. Geology.



- |   |  |  |   |                                    |
|---|--|--|---|------------------------------------|
| Sandböden in Fontainebleau<br>Sandy ground in fontainebleau | Plastische Tonböden<br>Plastic clay                      | Kalkstein in Champigny<br>Limestone in champigny | Mergel und Schotter<br>Marl and crushed stone   | Kreide<br>Chalk                    |
| Sandböden in Beauchamp<br>Sandy ground in beauchamp         | Falsche Letten<br>False poller's clay                    | Massenkalkstein<br>mass limestone                | Sandböden in Auteuil<br>Sandy ground in auteuil | Mergel in Meudon<br>marl in meudon |
| Austermergel<br>Oyster marl                                 | Kalkstein und grüne Tonböden<br>Limestone and green clay | Supragipsmergel<br>Supra gypsum marl             |   |                                    |

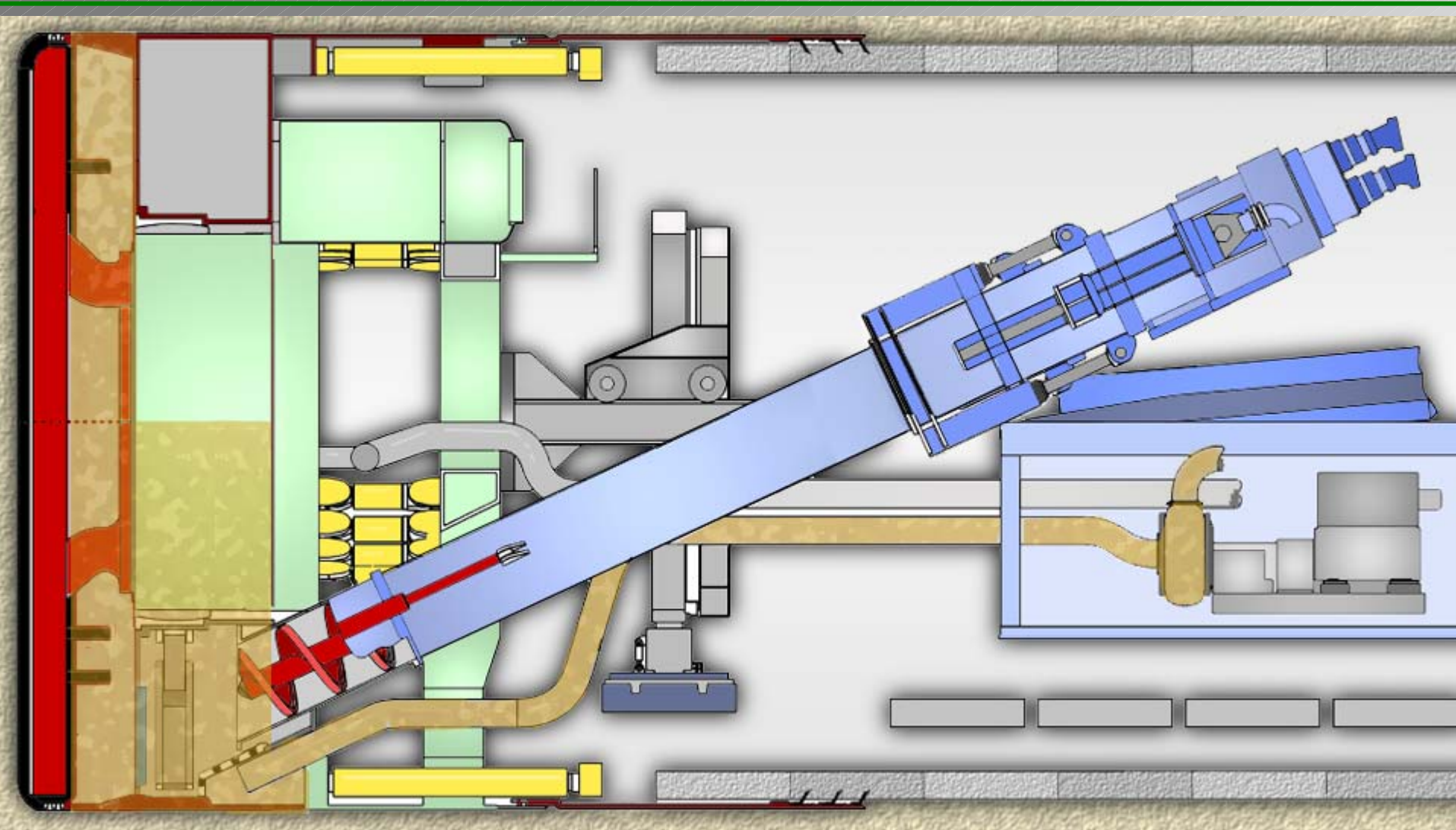


# Socatop. Gate Open. EPB-Mode.



*Socatop, Paris/ France*

# Socatop. Mixshield Mode.



*Socatop, Paris/ France*

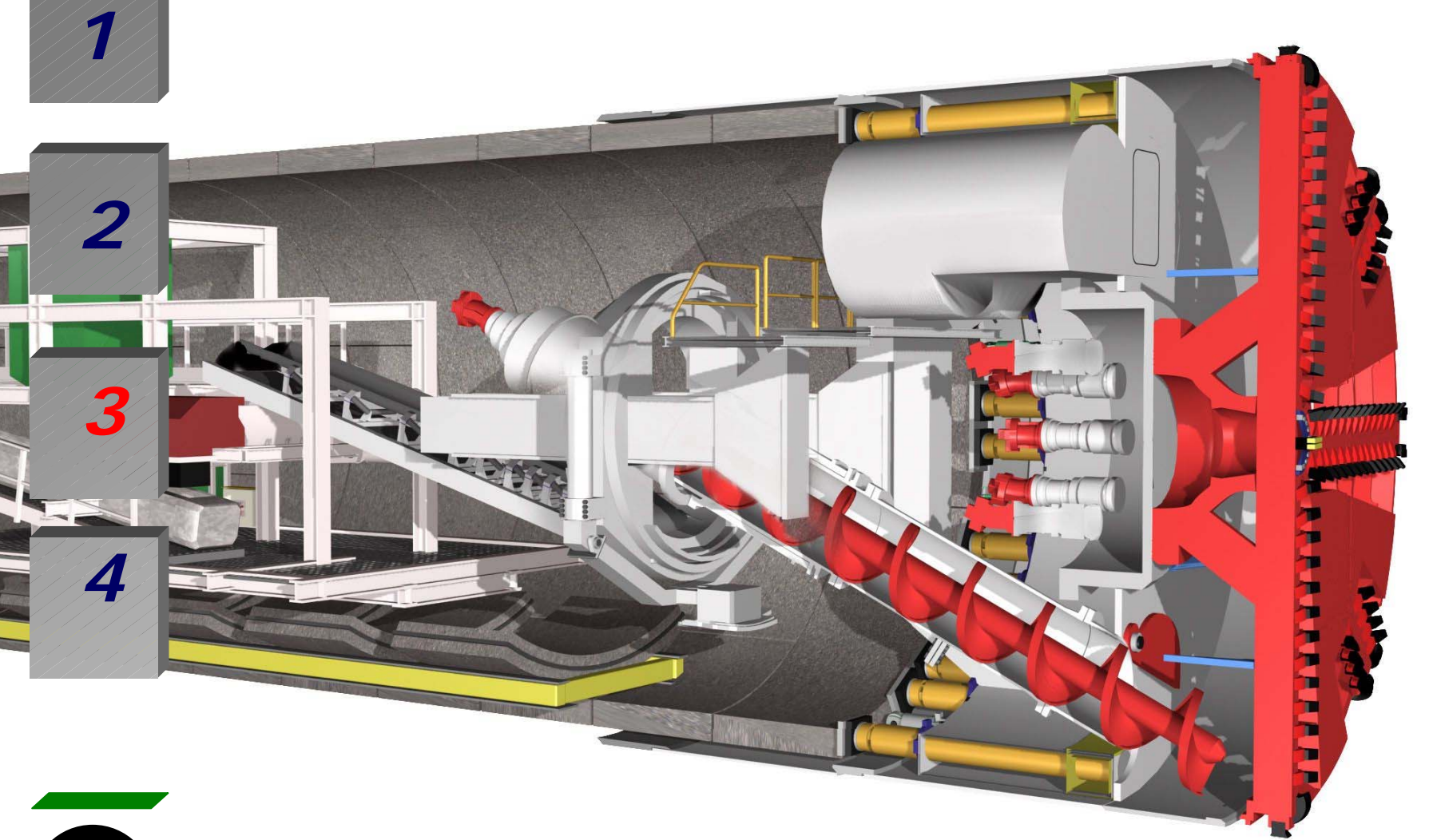
# EPB Shields.

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# EPB Shield: Botlekspoortunnel Railway Tunnel, The Netherlands.

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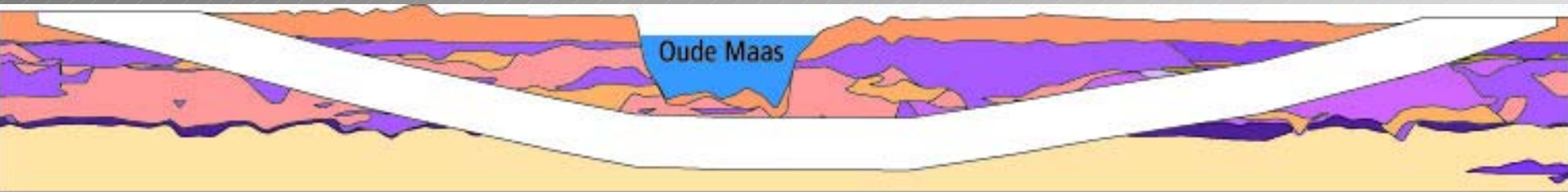
- S-144 EPB Shield
- Diameter: 9,755 mm
- Tunnel length: 2 x 1,835 m
- Segmental lining
- Geology: Clay, coarse sand, gravel
- Contractor: Ballast Nedam Beton en Waterbouw BV  
Hollandsche Beton-en Waterbouw BV  
Strukton Betonbouw BV  
Van Hattum en Blankevoort BV  
Wayss & Freytag AG



# Botlekspoortunnel. Two Tubes Under the River “Oude Maas”.

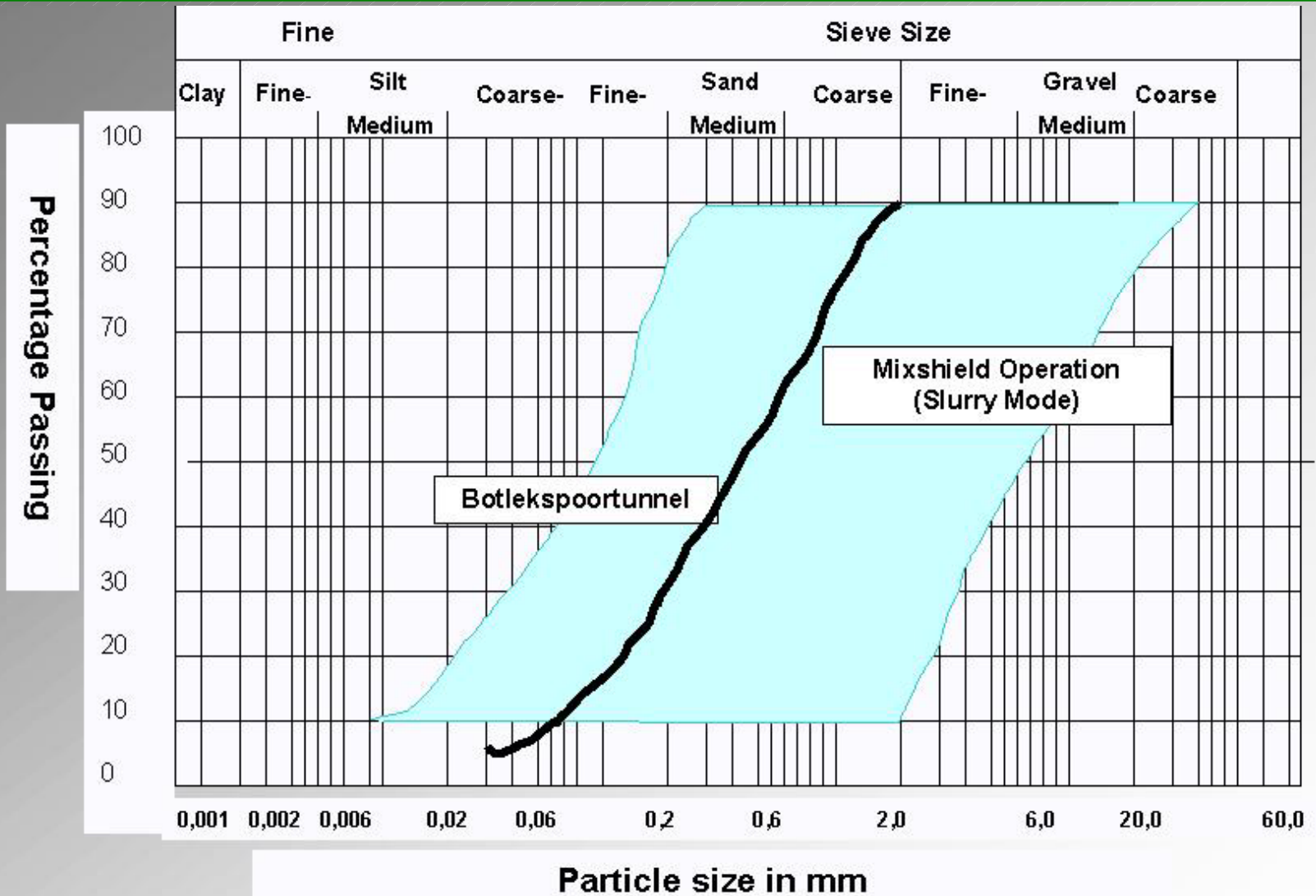


# Botlekspoortunnel. Geology.



- |   |  |   |
|---|--|---|
| Sand schluffig mit dünnen Tonschichten<br>Sand silty with thin layers of clay | Hauptsächlich Sand<br>Mainly sand  | Sand, mittel-grob, oft kiesig<br>Sand, middle to coarse, mainly gravel                    |
| Sand fein<br>Fine sand  | Sand, fein mit dünnen Tonschichten<br>Sand fine with thin layers of clay | Torf<br>Peat  |
| Torf / Ton, schluffig und/oder sandig<br>Peat / clay, silty and/or sandy      | Ton schluffig mit Sandschichten<br>Clay silty with layers of sand        | Ton, örtlich Schluff, sandig bis Sand, tonig<br>Clay, locally silt, sandy to sand, clayey |
| Ton, sandig und schluffig<br>Clay, sandy and silty                            | Ton mit dünnen Sandschichten<br>Clay with thin layers of sand            | Ton, mit Humus und/oder Torfstücken<br>Clay, with humus and/or peat                       |

# Grain Size Distribution Curve Botlek.



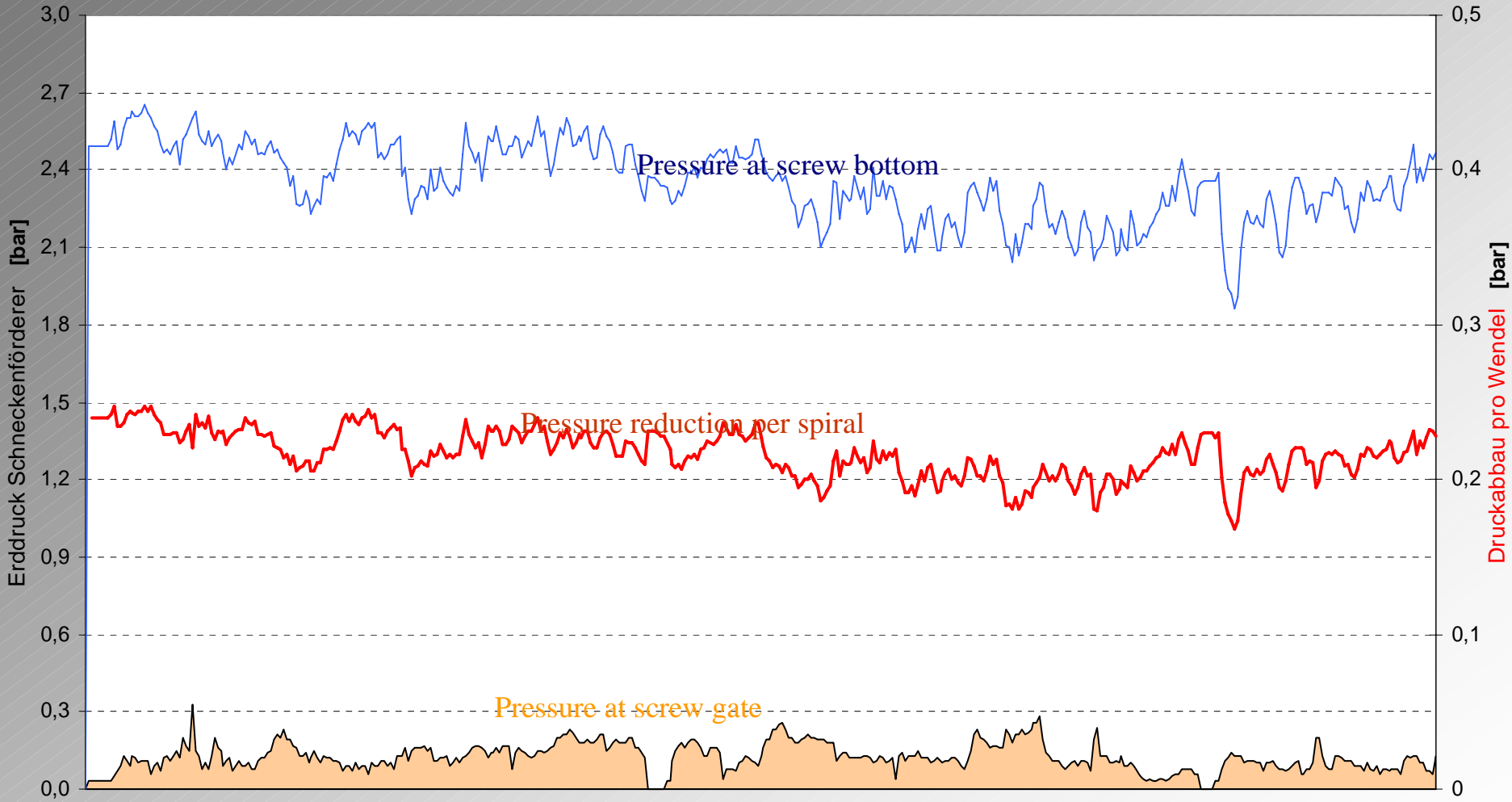
***Botlek/ Netherlands***

# Piston Pump for Pressure Control.

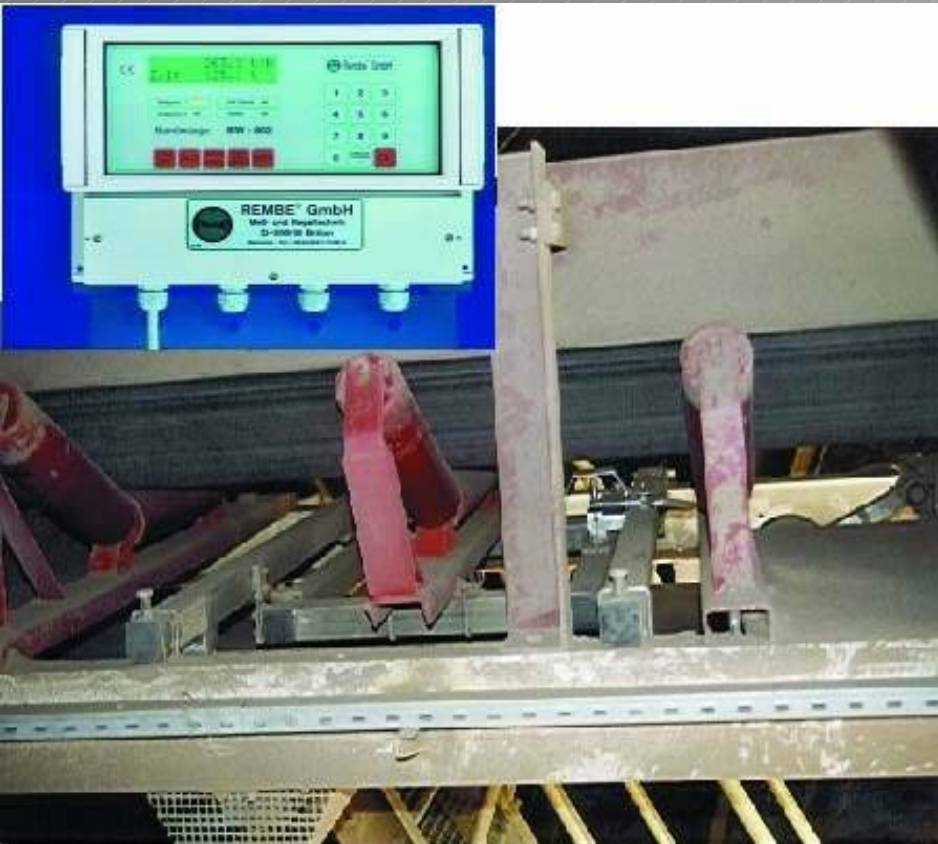


***Botlek/ Netherlands***

# Pressure Reduction Along the Screw.



# Belt Weighing System.



**Oporto Subway Line S -PT-**

11:45:53 19.07.2002	Roda de corte	Avanco F7	Argam. Strg+F7	Temp F9	Avanco	parar	parar
		M. cons. F8	M. cons. Strg+F8	Temp Strg+F9			

**Accionamento roda de corte**

Nº de rotacoes Pressao de trabalho Binário

0.0 rpm      0 Bar      0.000 MNm

**à esquerda à direita**

0.0 Bar      0.0 Bar

0.0 Bar      0.0 Bar

0.0 Bar      0.0 Bar

0.0 Bar      0.0 Bar

**Pressao de sin-fin**

trente      atras

0.0 Bar      0.0 Bar

Velocidade reale

0 mm/min

Forca de avanco

0 kN

Deslocamento

0 kN

Densidade ●

**Accionamento sem - fin**

Nº de rotacoes Pressao de trabalho Binário

0 rpm      0 Bar      0.000 kNm

**Tonelagem 1      Tonelagem 2**

0 t      0 t

0.0 t/h      0.0 t/h

Calculated material

0.000 t

Cinta 1 ●

Cinta 2 ●

**Corrente eléctrica**      Corrente roda de corte

<p>sem - fin</p> <p>convey material</p>	<p>Cinta Transport. 1</p> <p>Inst. espuma F6</p>	<p>Cinta Transport. 2</p> <p>Bentonit</p>
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à direita      à esquerda

fechado

aberto

Telescópio

trente

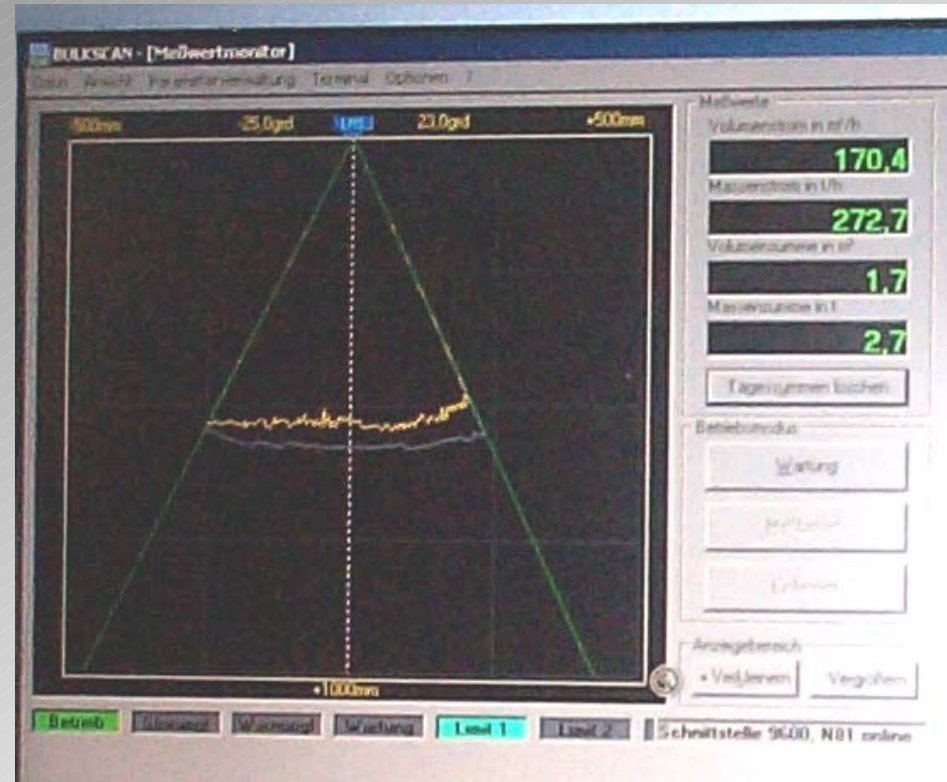
atras

Válvula corredeira

0 mm

fechado       aberto

# Laser Scanner for Muck Control.



# EPB Shields: Eastside LRT Los Angeles, USA

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- S-297 and S-298 EPB Shields
- Diameter: 6,514 mm each
- Cutterhead power: 945 kW each
- Tunnel length: 870m + 1,257m each

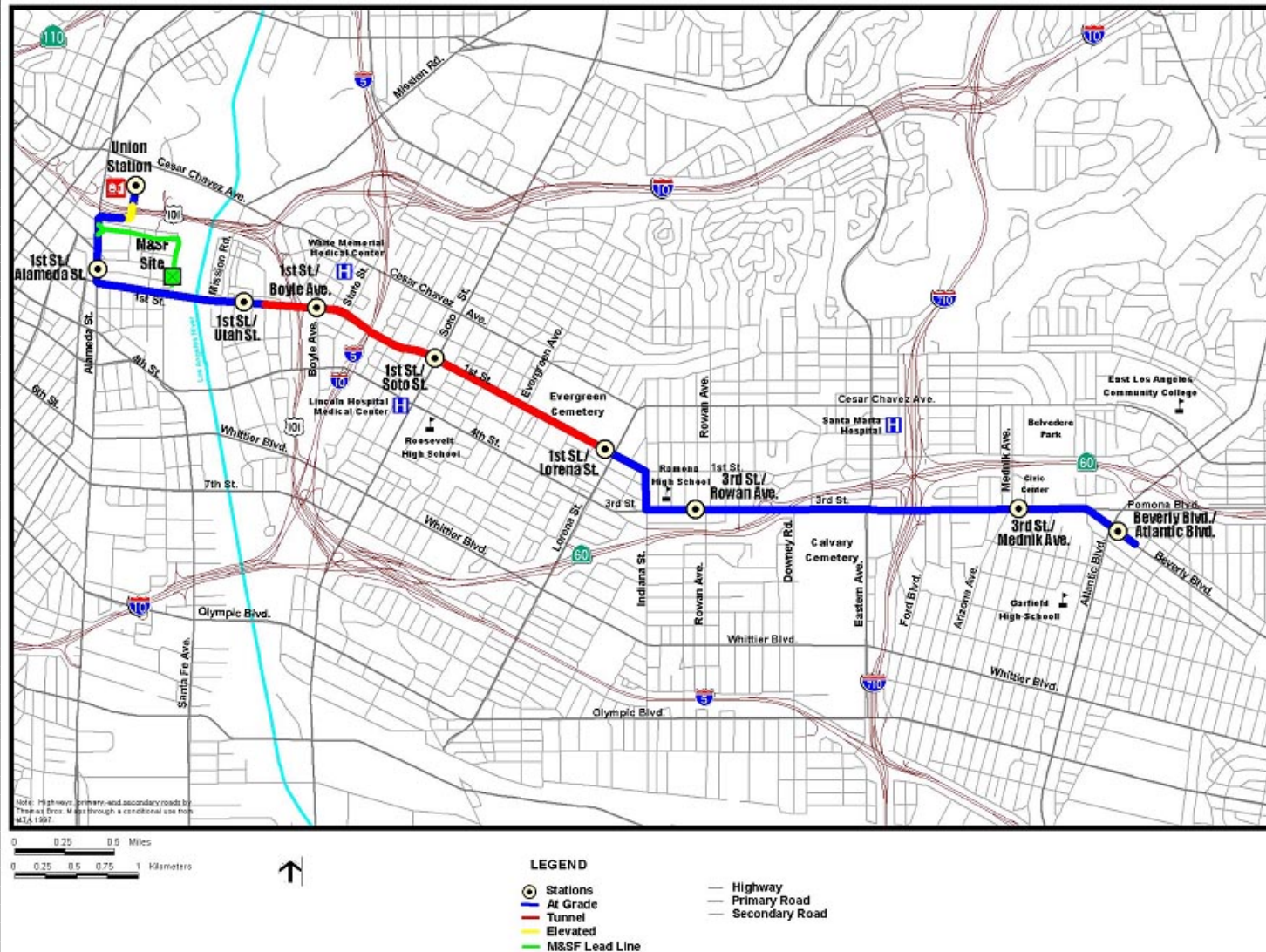
- Geology: Alluvium
- Contractor: Traylor - Frontier  
Kemper JV

***Los Angeles / U.S.***



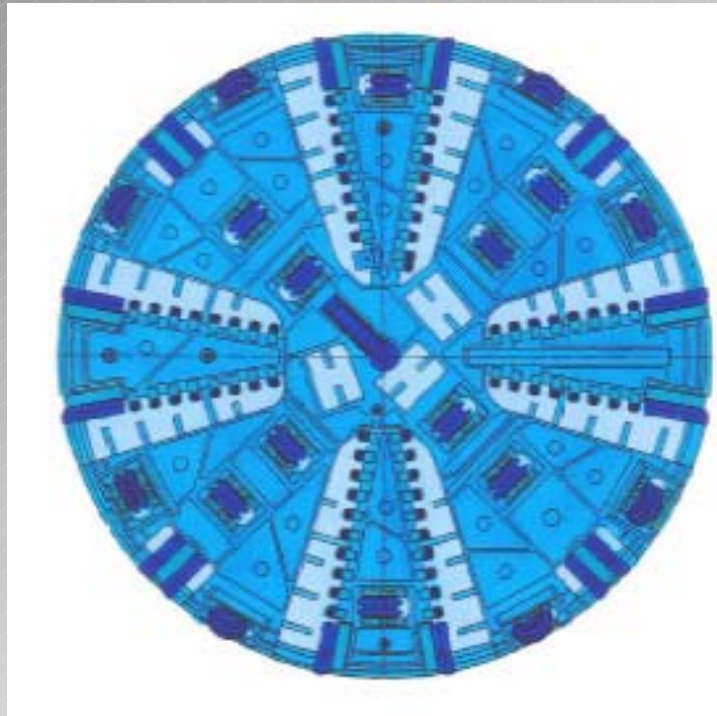


# Eastside LRT Los Angeles. Tunnel Route.



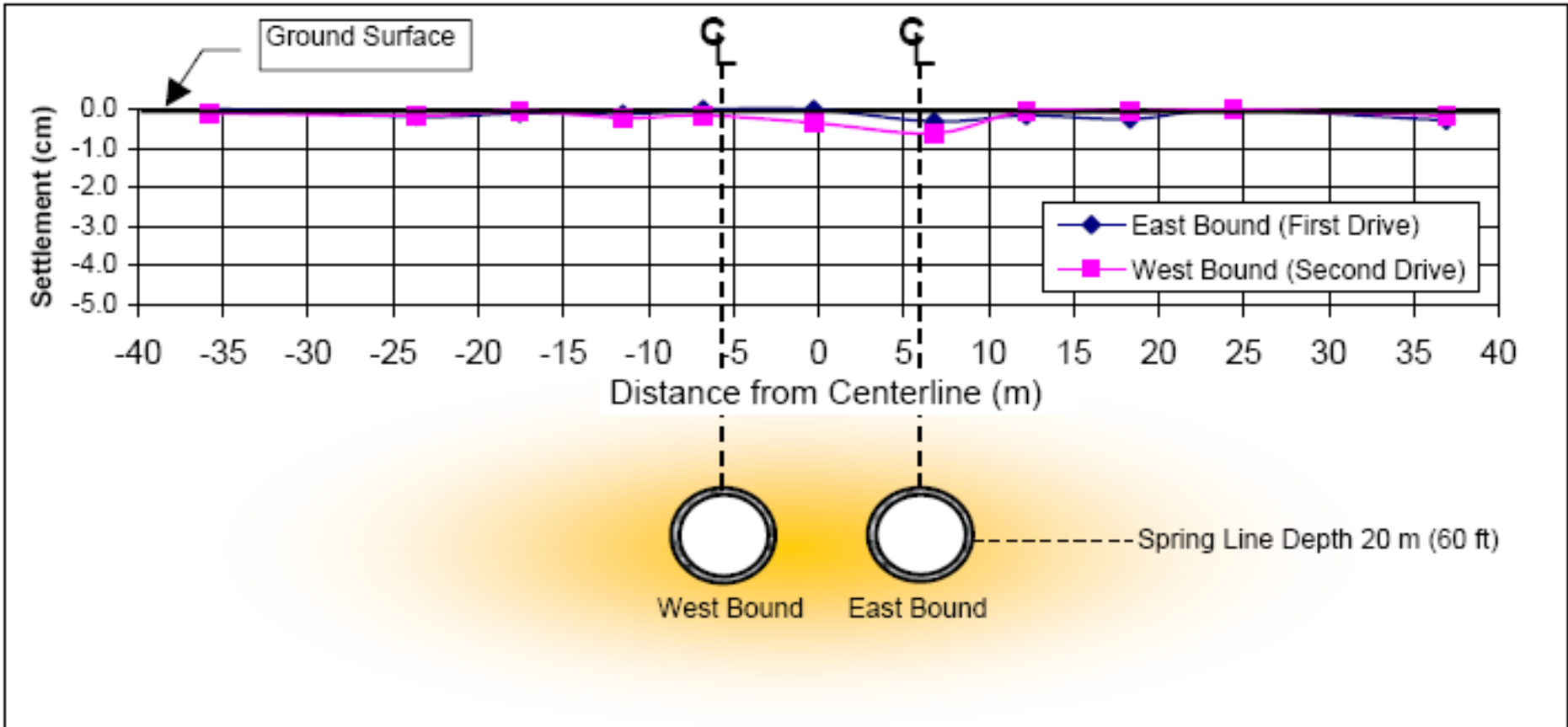
**Los Angeles / U.S.**

# Eastside LRT Los Angeles.



*Los Angeles / U.S.*

# Eastside LRT Los Angeles. Zero Ground Loss.



# EPB Shield: M30 Madrid, Spain.

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- S-300 EPB Shield
- Diameter: 15,200 mm
- Cutterhead power: 12,000 kW
- Tunnel length: 3,500 m
- Geology: Clay, sandy clay, gypsum
- Contractor: Necso/ Ferrovial Agroman

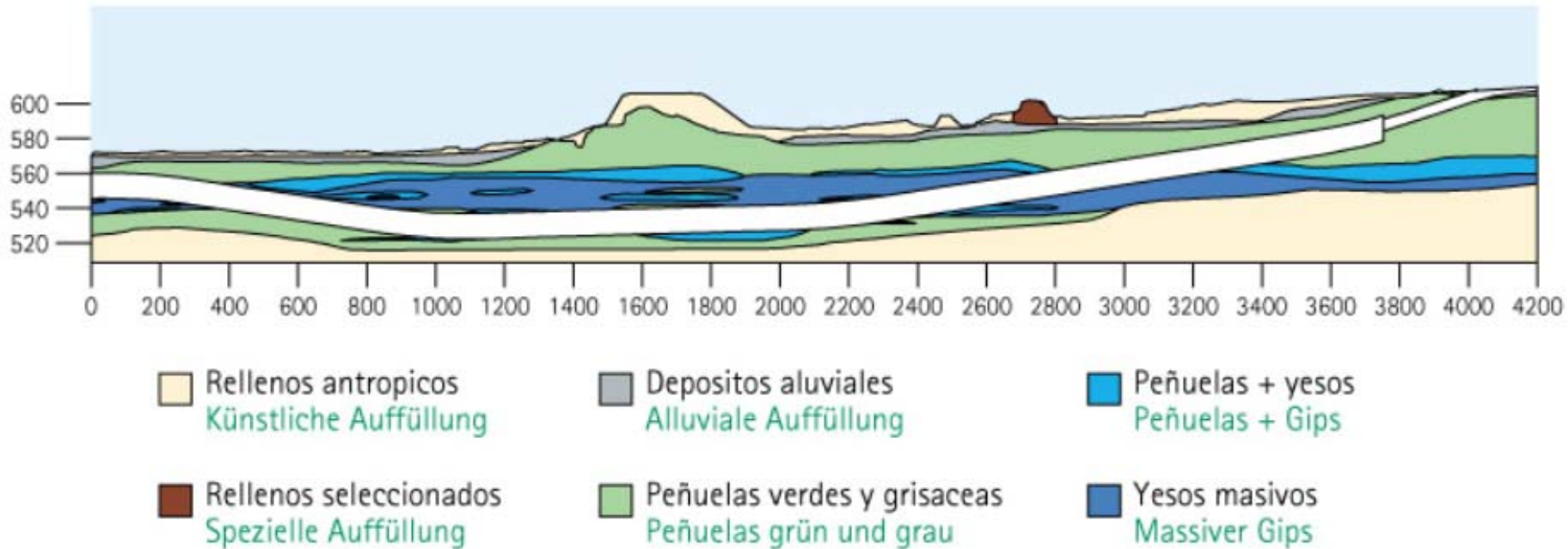


# M30 Madrid. Tunnel Route.



**Madrid / Spain**

# M30 Madrid. Geology.



# Highest Torque Ever Installed in a TBM: 125,268kNm.



*Madrid / Spain*

# Gigantic Performance in Madrid.



- Tunnel length: 3,650 m
- Start November: 2006
- Completion: June 2007
- Completed tunnel: in 8 months
- Best daily performance: 34 m (17 rings)



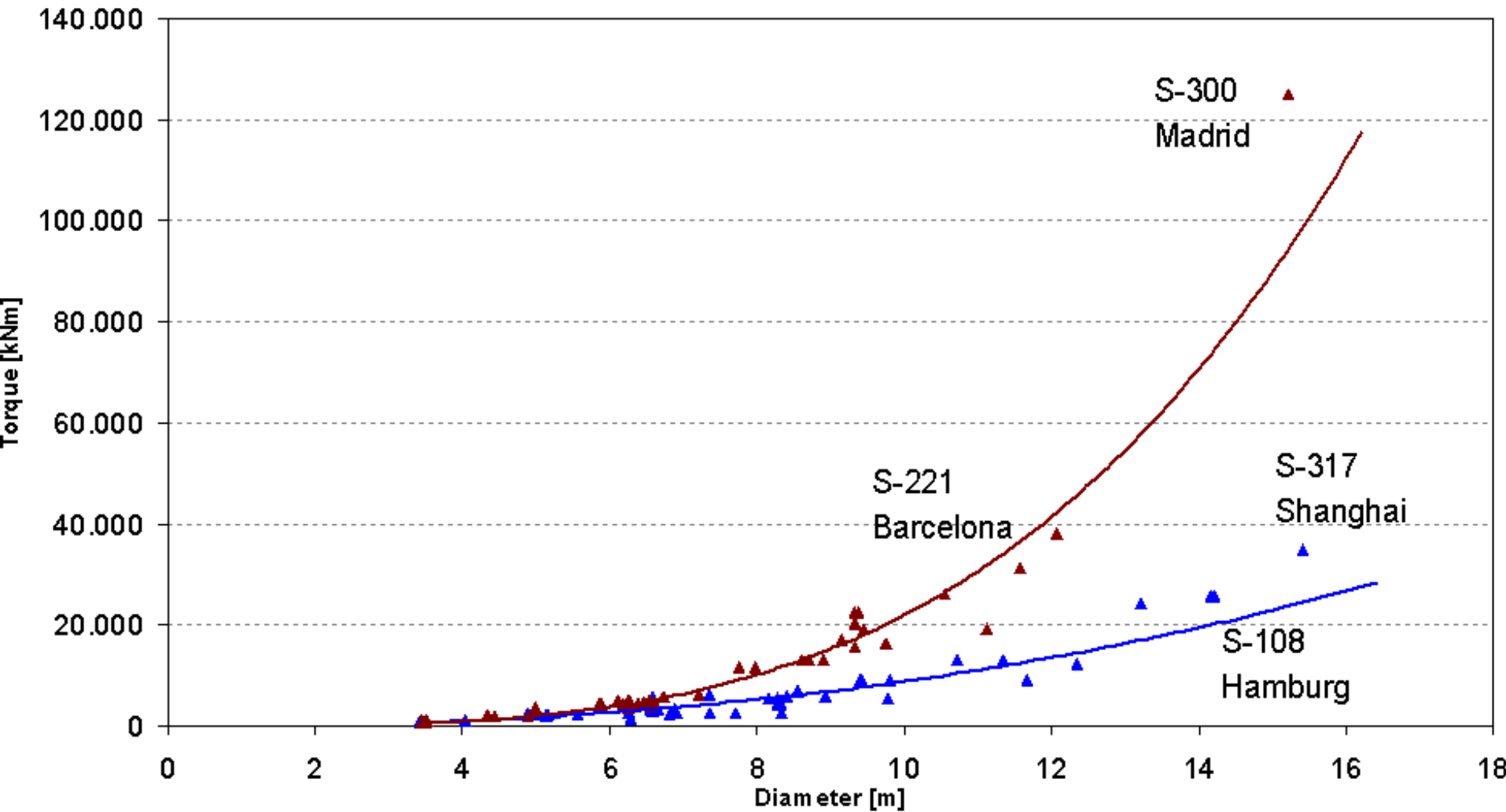
3,600m in 8 months. Max. Performance of 758m per Month.



*Madrid / Spain*

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# Torque Development EPB / Mix.



*Madrid / Spain*

# Hard Rock TBMs.

1



**Single Gripper-TBM:**  
S-155 Tschärner,  $\varnothing$  9.53 m

2



**Double Gripper-TBM:**  
S-96 TBM 3000,  $\varnothing$  3.00 m

3

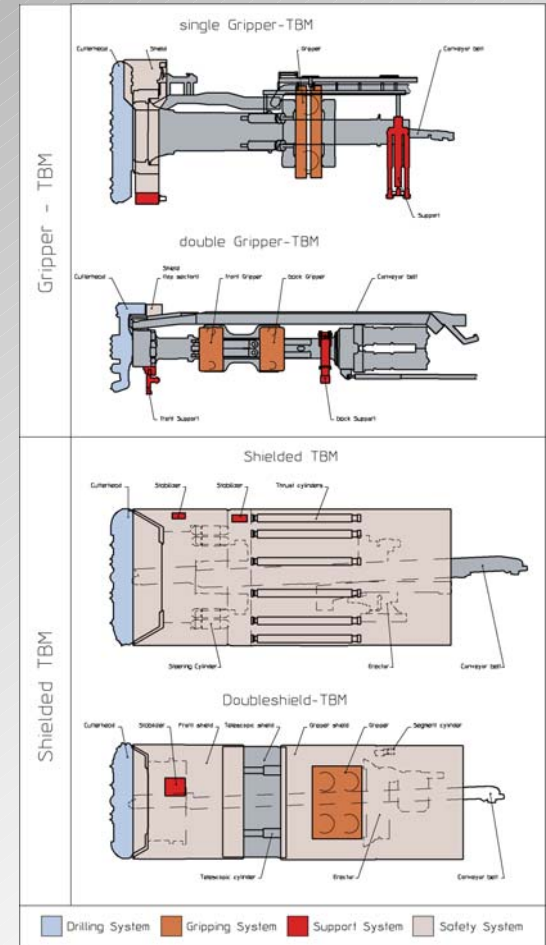


**Shielded-TBM with articulation joint:**  
S-163 Sörenberg,  $\varnothing$  4.56 m

4



**Double Shield-TBM:**  
S-153 La Réunion,  $\varnothing$  3.80m



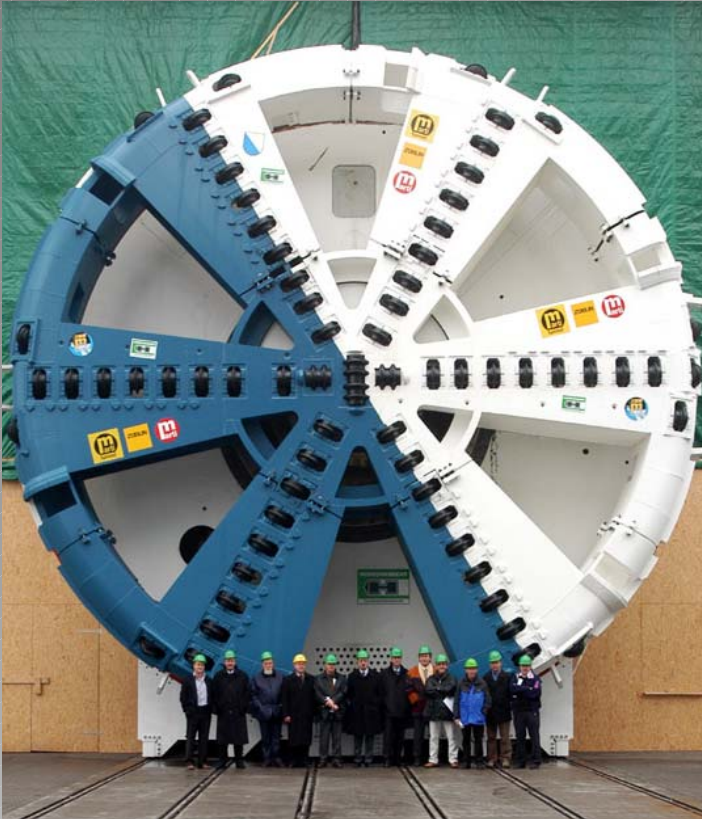
# Single Shield TBM: Islisberg, Switzerland.

1

2

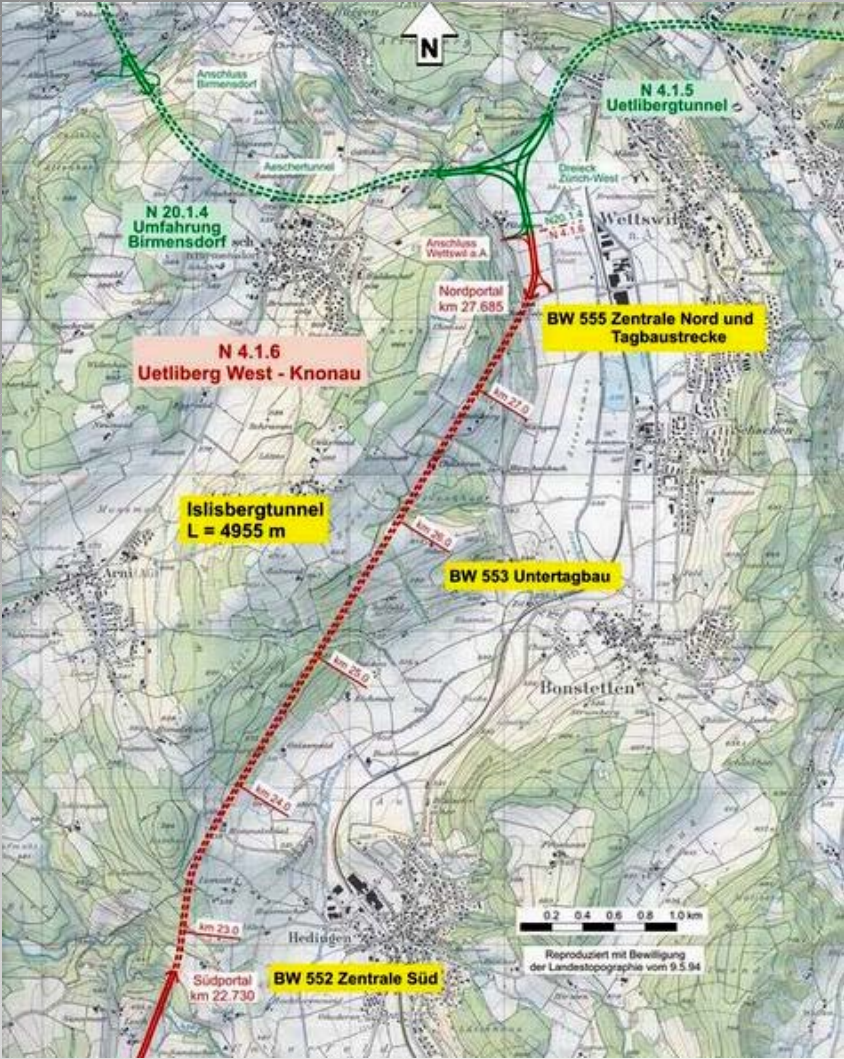
3

4

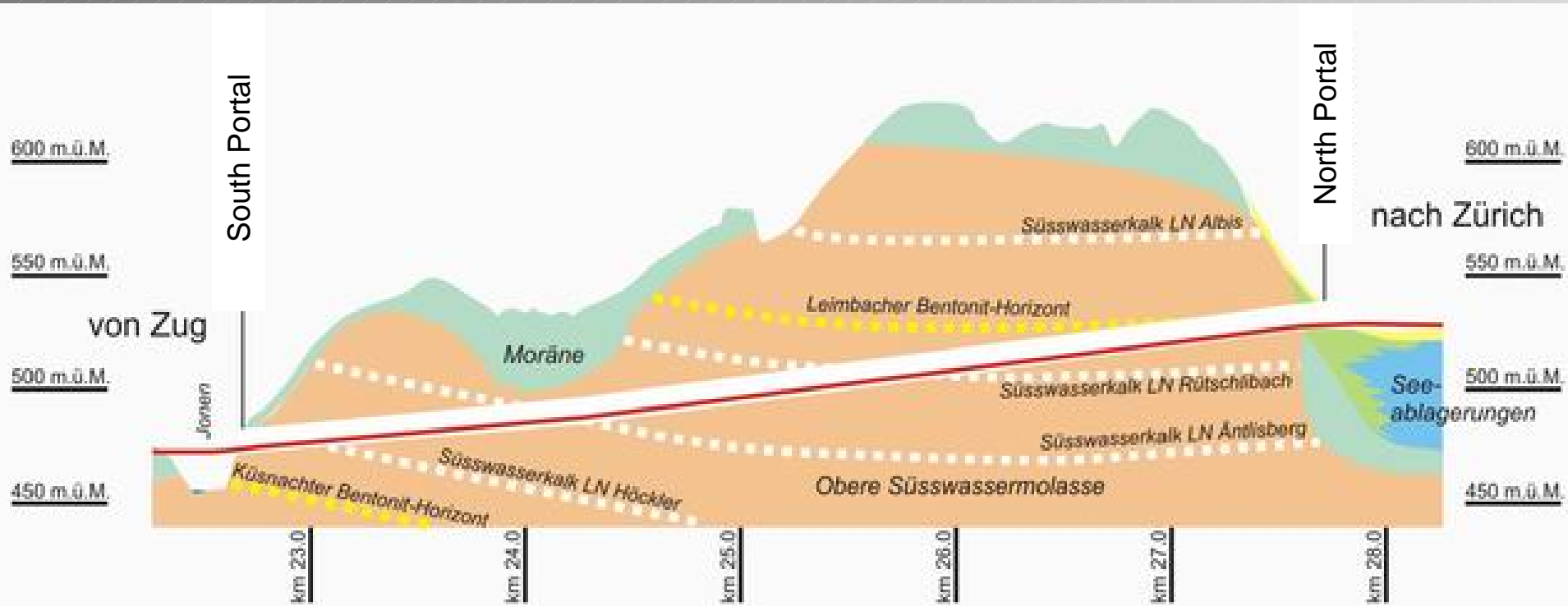


- Diameter: 11,805 mm
- Tunnel length: 1 x 4,680 m, 1 x 4,645 m  
Segmental lining
- Geology: Molasse (Limy siltstone with varying clay and sand content and sandstone)
- Contractor: Marti Tunnelbau AG, Ed. Züblin AG, Marti AG Bauunternehmung

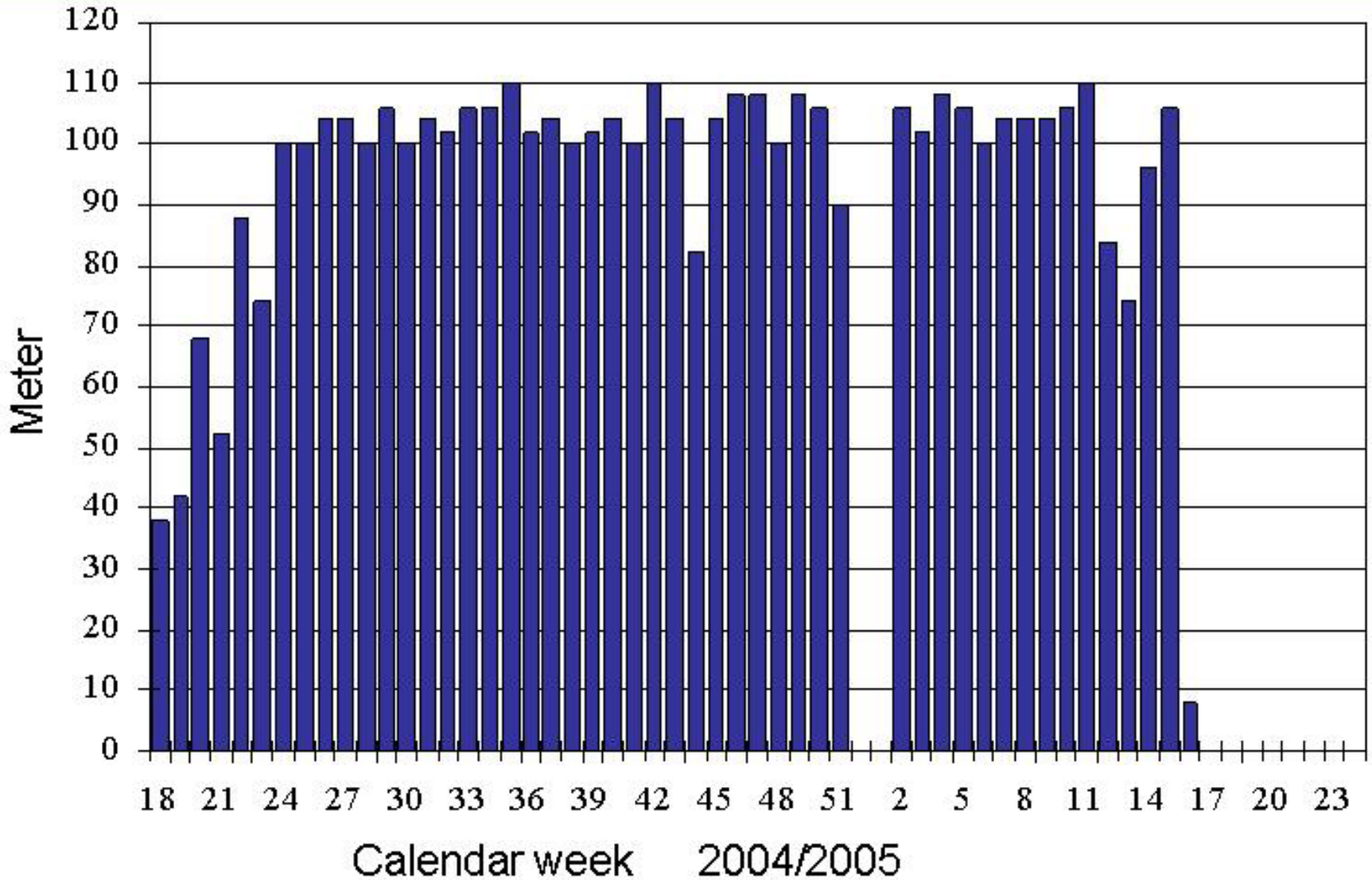
# Islisberg Road Tunnel. Tunnel Route.



# Islisberg Road Tunnel. Geological Profile.



# Tunnelling Rates, Islisberg. First Drive (Tunnel 1, West).



# Breakthrough West Tunnel Islisberg: 4,680m in 54 Weeks, Single-shift Operation.



***Islisberg / Switzerland***



# Single Shield TBM: Zürich-Thalwil, Switzerland.

1

2

3

4

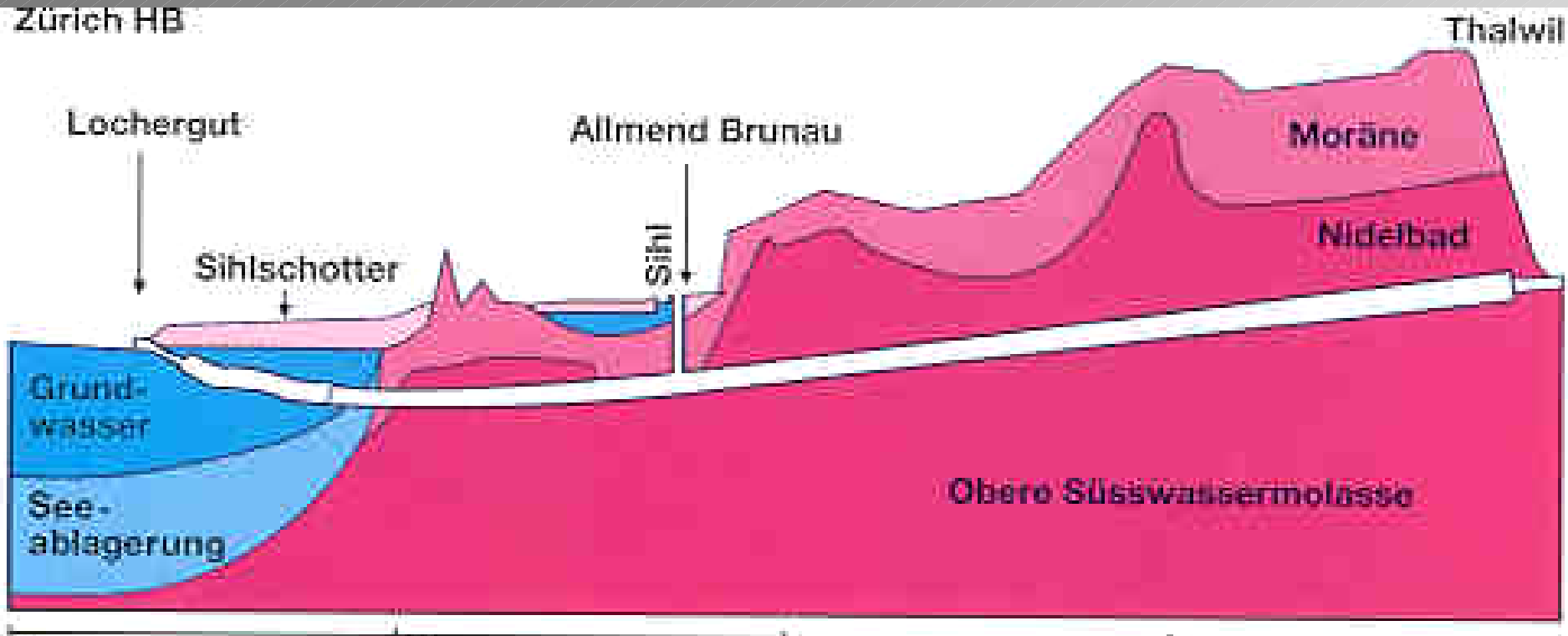


- Diameter: 12,280mm
- Cutterhead power: 1,540kW
- Tunnel length: 5,570m
- Geology: Molasse
- Contractor: Zschokke Locher AG  
Murer AG  
Prader AG  
Wayss&Freytag AG  
CSC  
J. Scheifele AG  
Specogna & Co.

# Zürch-Thalwil, Switzerland. Railway 2000. The Tunnel Route.



# Zürch-Thalwil, Switzerland. Geological Profile.



# Zürch-Thalwil, Switzerland. Breakthrough of the Mixshield (Convertible TBM).



**Zürich-Talwil / Switzerland**

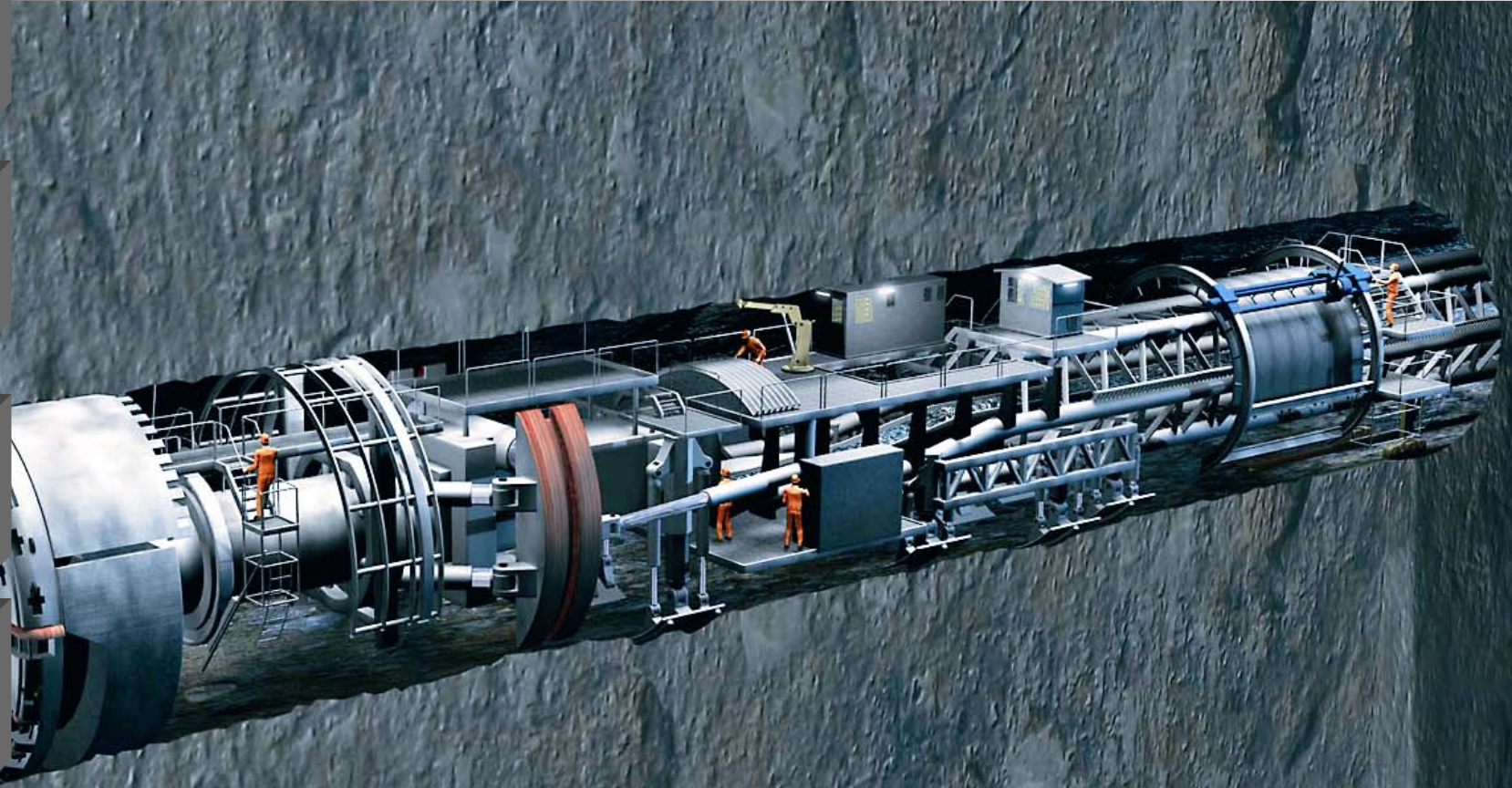
# Gripper TBMs.

1

2

3

4



*Islisberg / Switzerland*



# Gripper TBM: West Area CSO Tunnel, Atlanta, USA.

1

2

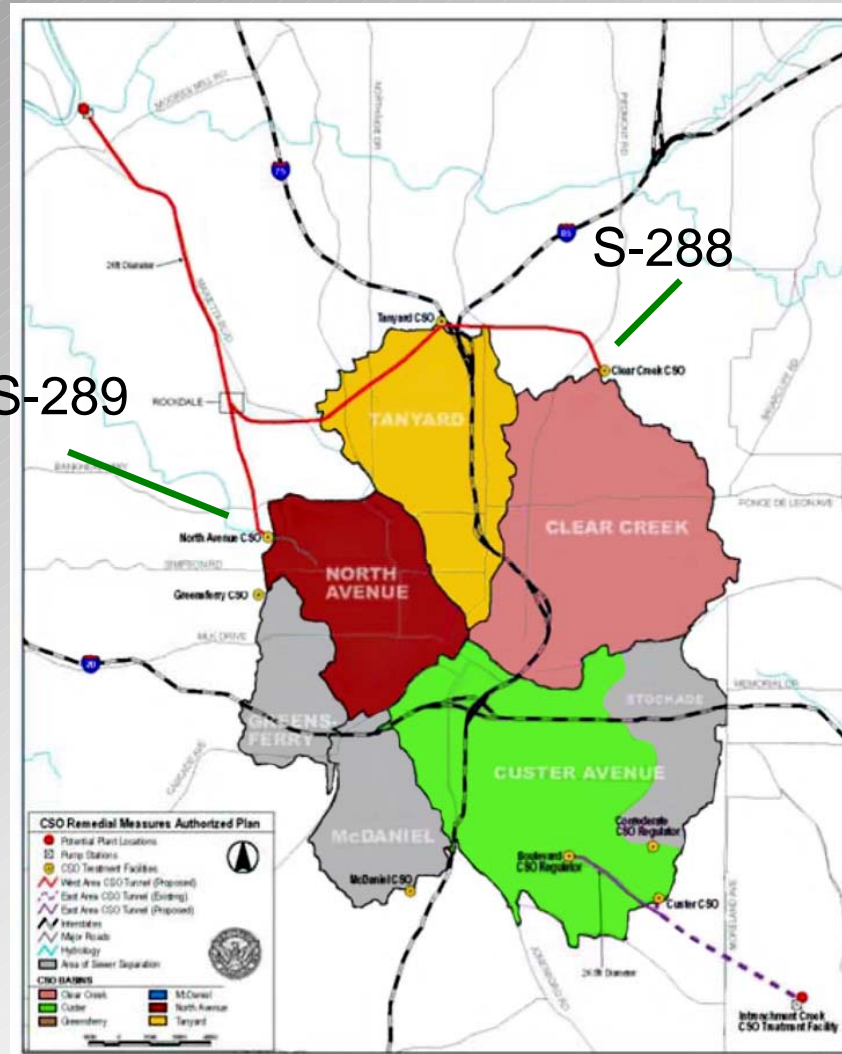
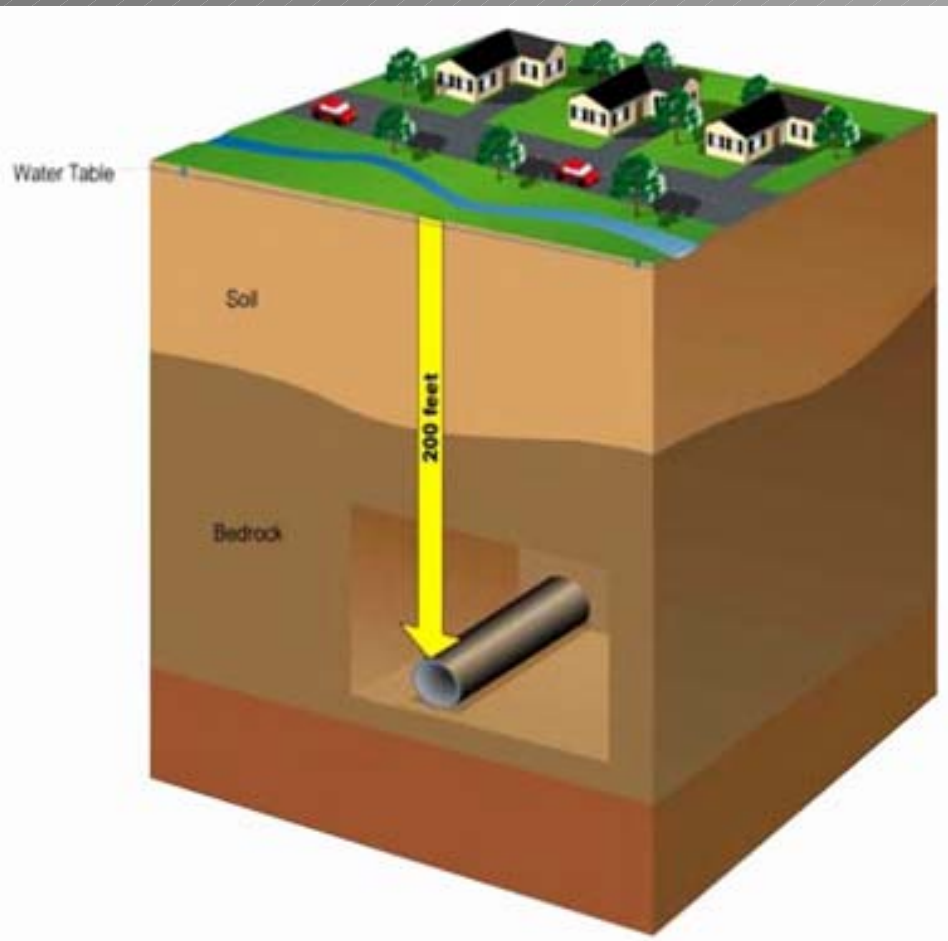
3

4



- S-288 and S-289 Gripper
- Diameter: 8,230 mm each
- Cutterhead power: 3,150 kW each
- Tunnel length: 1 x 6,600 m  
1 x 6,800 m
- Geology: Gneiss, Granite
- Contractors: Obayashi  
Massana JV

# West Area CSO Tunnel, Atlanta.



# West Area CSO Tunnel, Atlanta.



*Atlanta/ USA*



# Gripper TBM: Lötschberg.

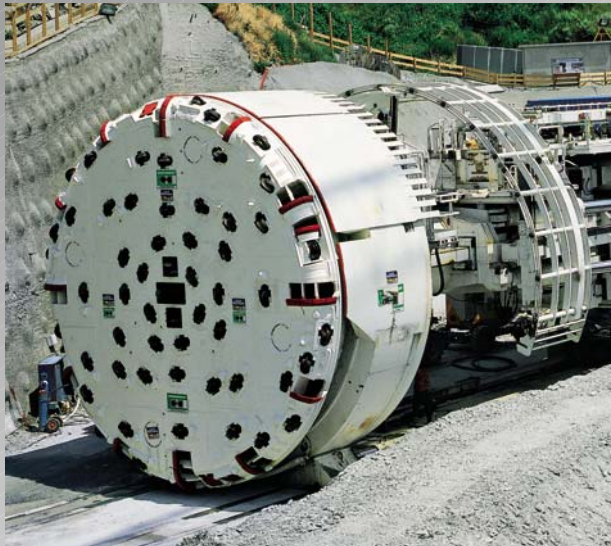
1



2

3

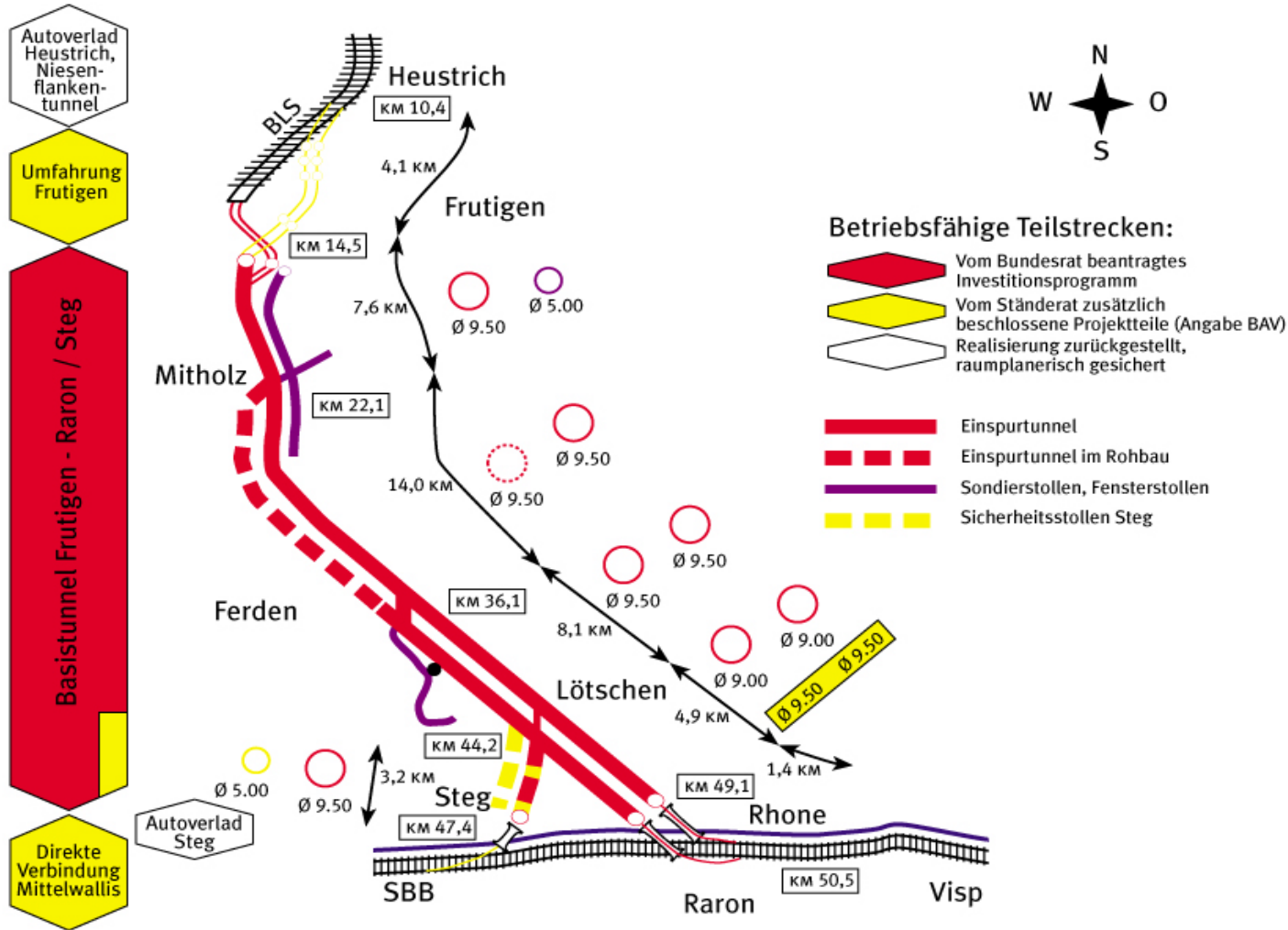
4



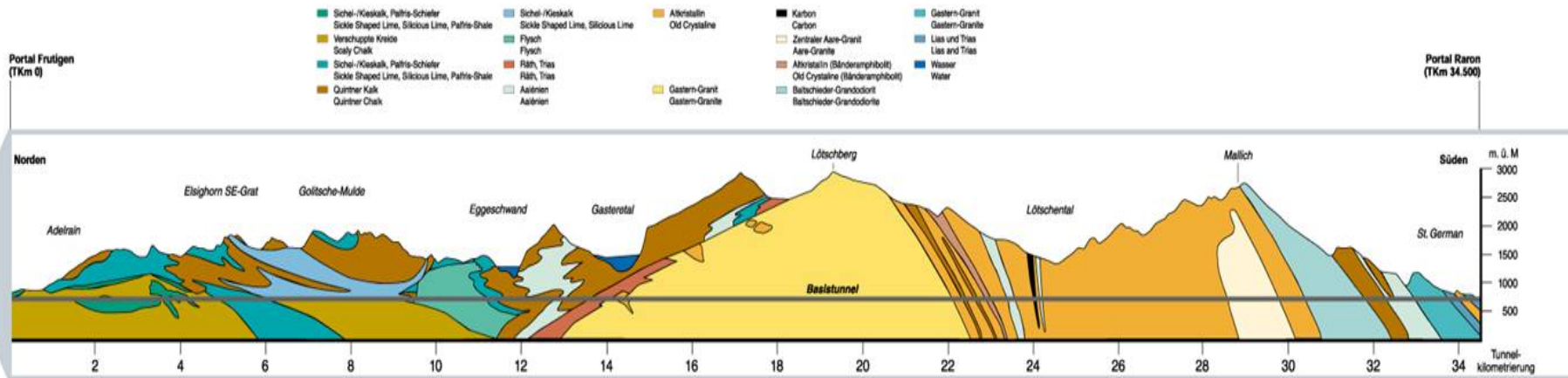
- S-167 and S-174 Gripper TBM
- Diameter: 9,430mm each
- Cutterhead power: 3,500kW each
- Tunnel length: S-167: 8,848m  
S-174: 9,200m
- Geology: Od crystalline gneiss, granite, granodiorite
- Contractor: Marti Tunnelbau AG, A. Porr AG, Balfour Beatty Group Ltd., Walter Gruppe

***Lötschberg / Switzerland***

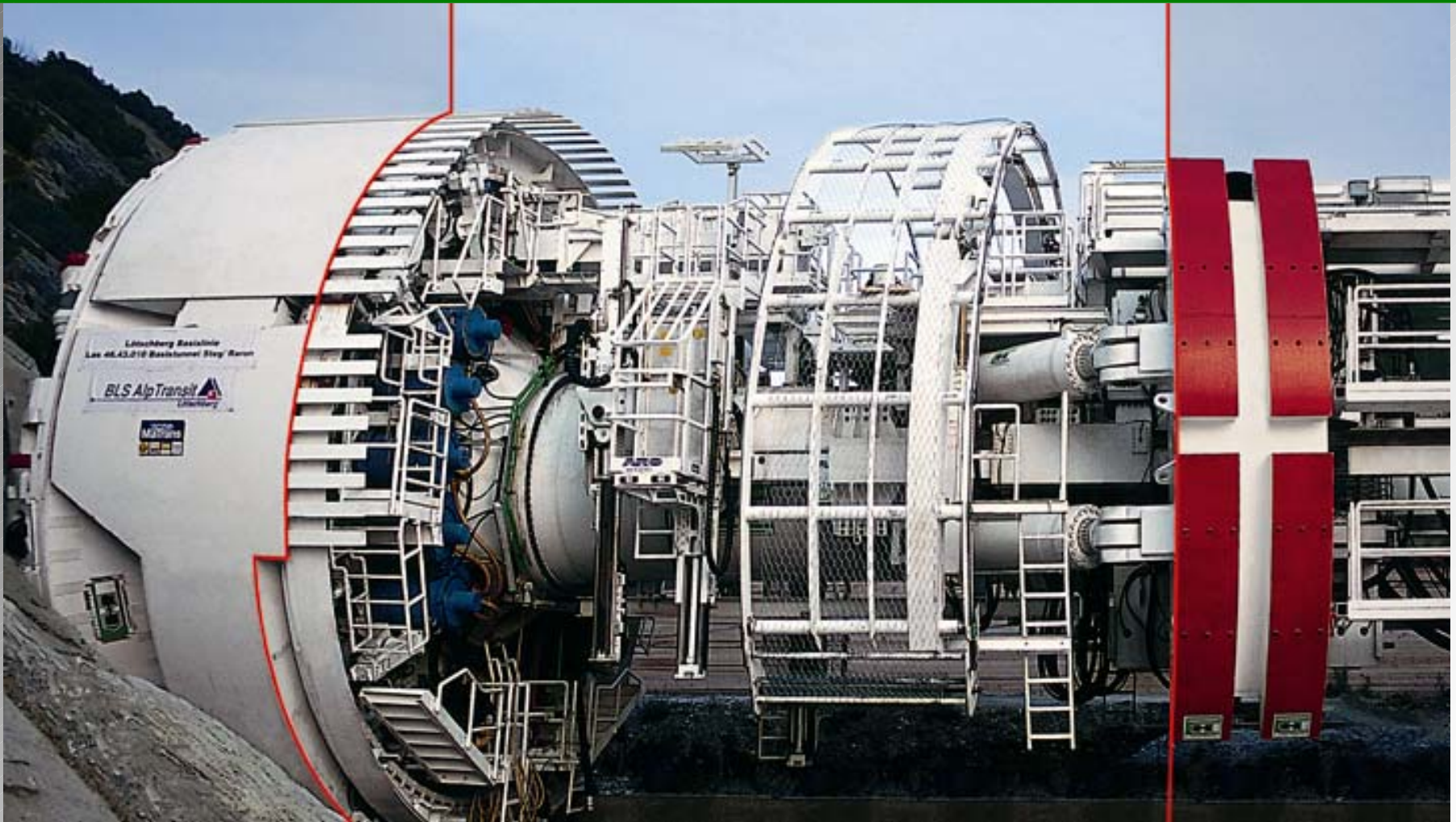
# Lötschberg. Tunnel Route.



# Lötschberg. Geology.

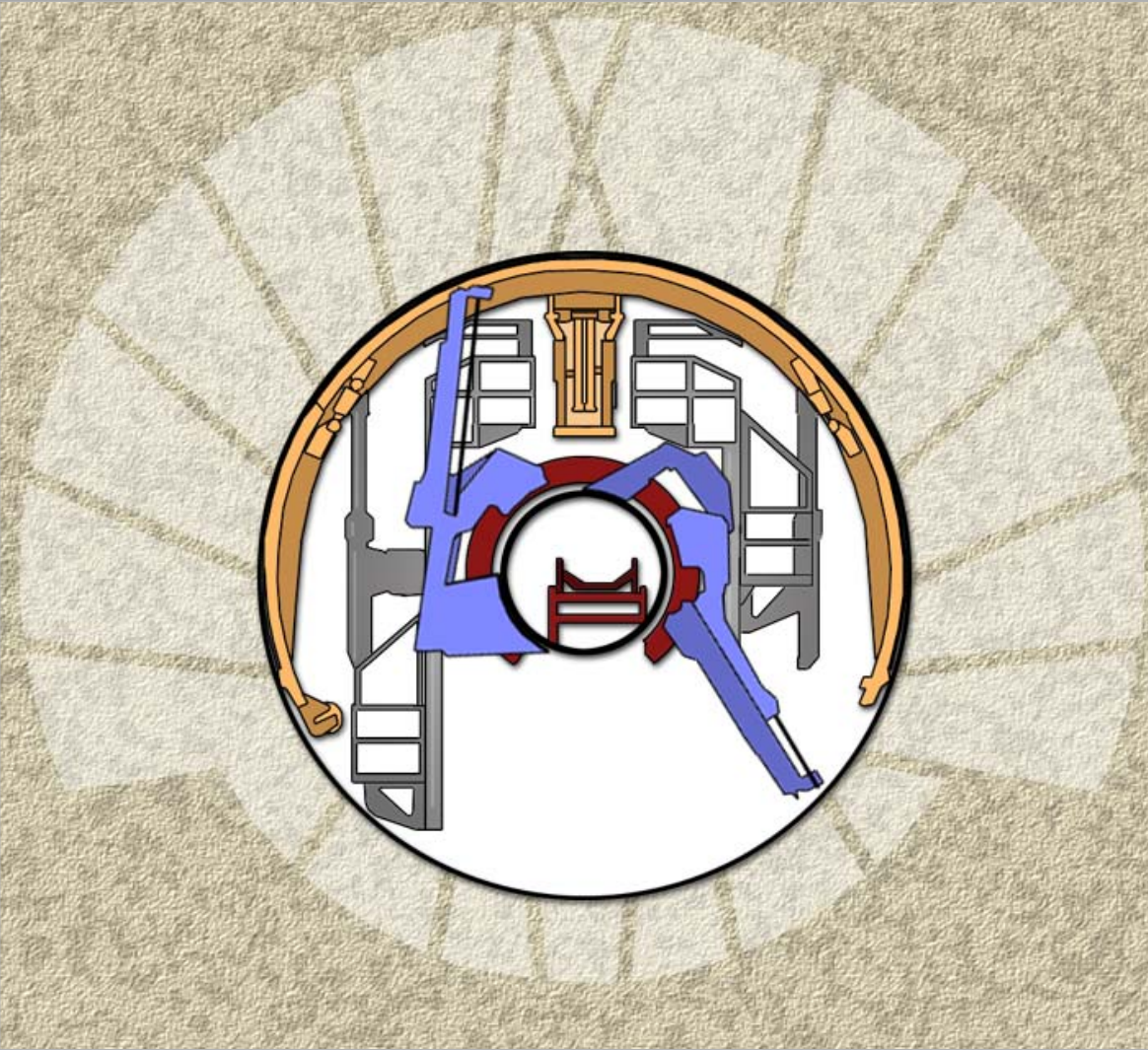


# Gripper TBM. Features.



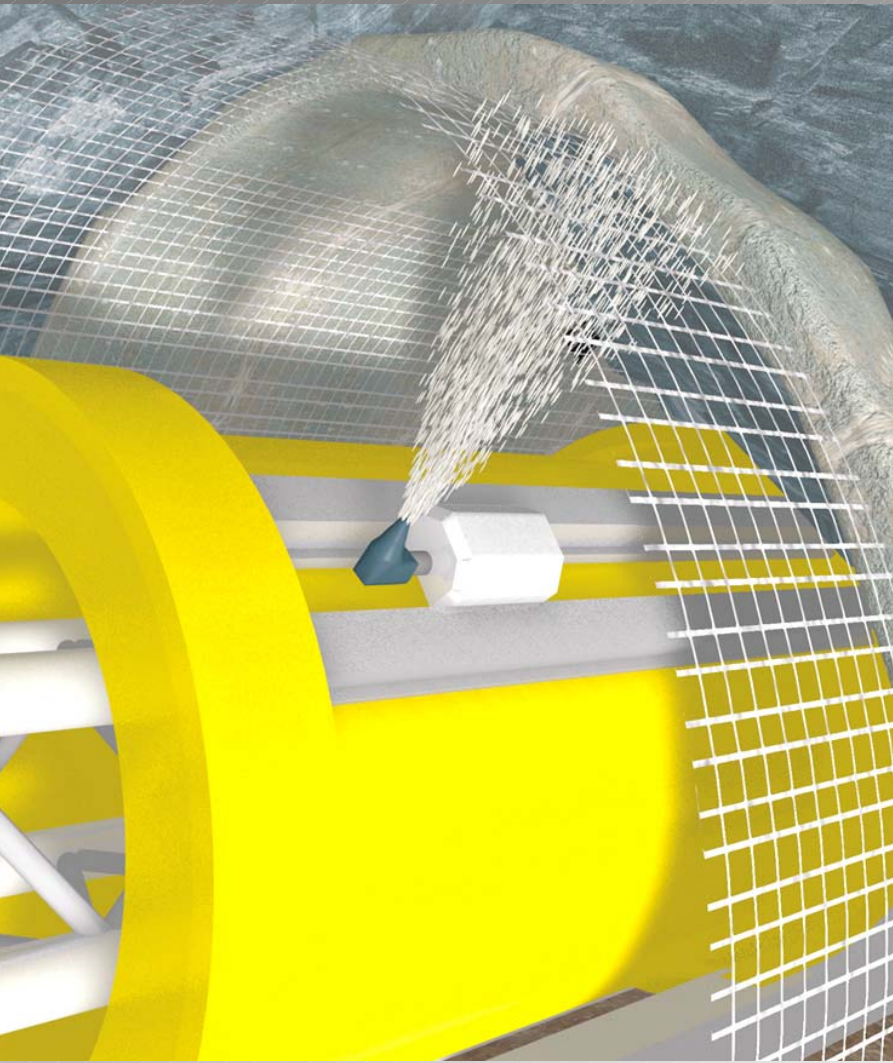
***Lötschberg / Switzerland***

# Tunnel Protection Anchors.



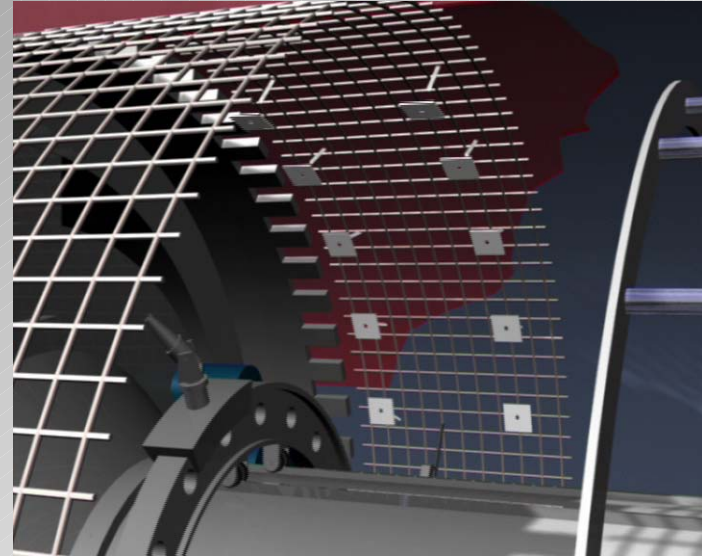
***Lötschberg / Switzerland***

# Shotcrete Robot. L2.



***Lötschberg / Switzerland***

# Wire Mesh Erector.



***Lötschberg / Switzerland***

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# 4 Gripper TBM: Gotthard Base Tunnel, Switzerland.

1

2

3

4

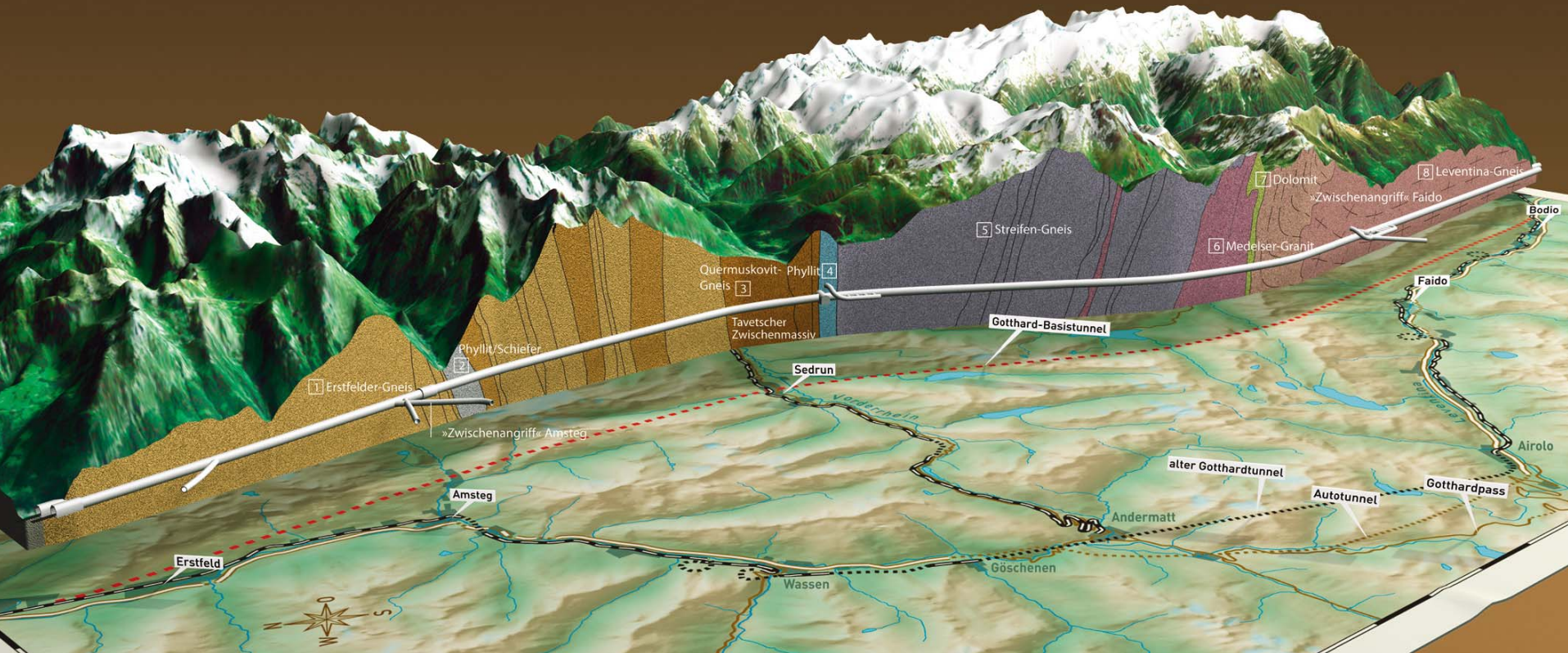


- Diameter: 8.89m/ 9.33m/ 9.58m.
- Cutterhead power: 3,500kW each
- Weight: 3,200t each
- TBM length: 410m each
- Tunnel length: Bodio-Faido: 28.75km  
Faido-Sedrun: 23.80km  
Amsteg-Sedrun: 22.70km
- Geology: Granite, gneiss, schist
- Contractor:  
Bodio-Sedrun: Implen Bau AG,  
HOCHTIEF AG, Alpine  
Mayreder Bau GmbH,  
CSC Impresa  
Costruzioni SA,  
Impregilo S.p.A.  
Amsteg-Sedrun: Murer AG, Strabag AG

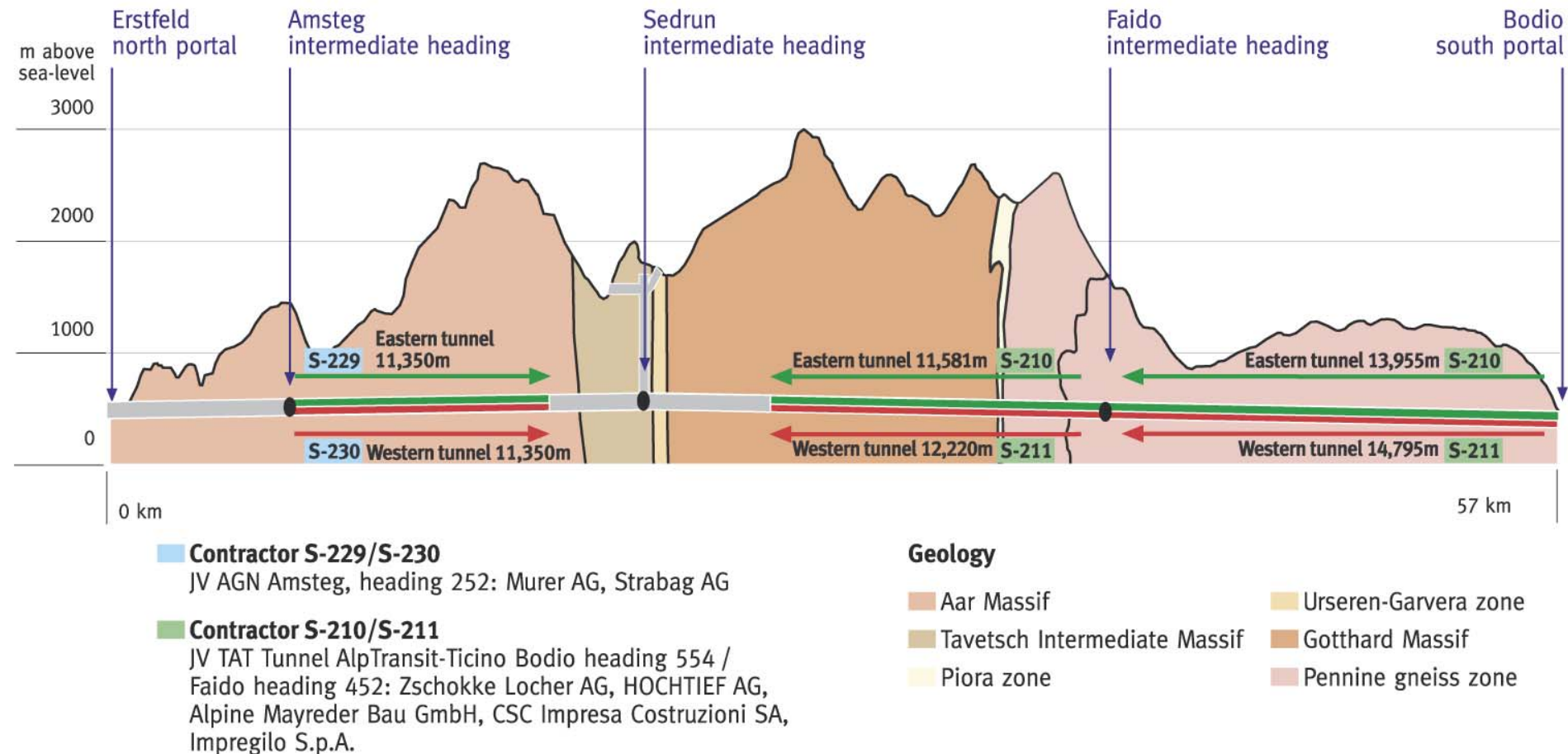




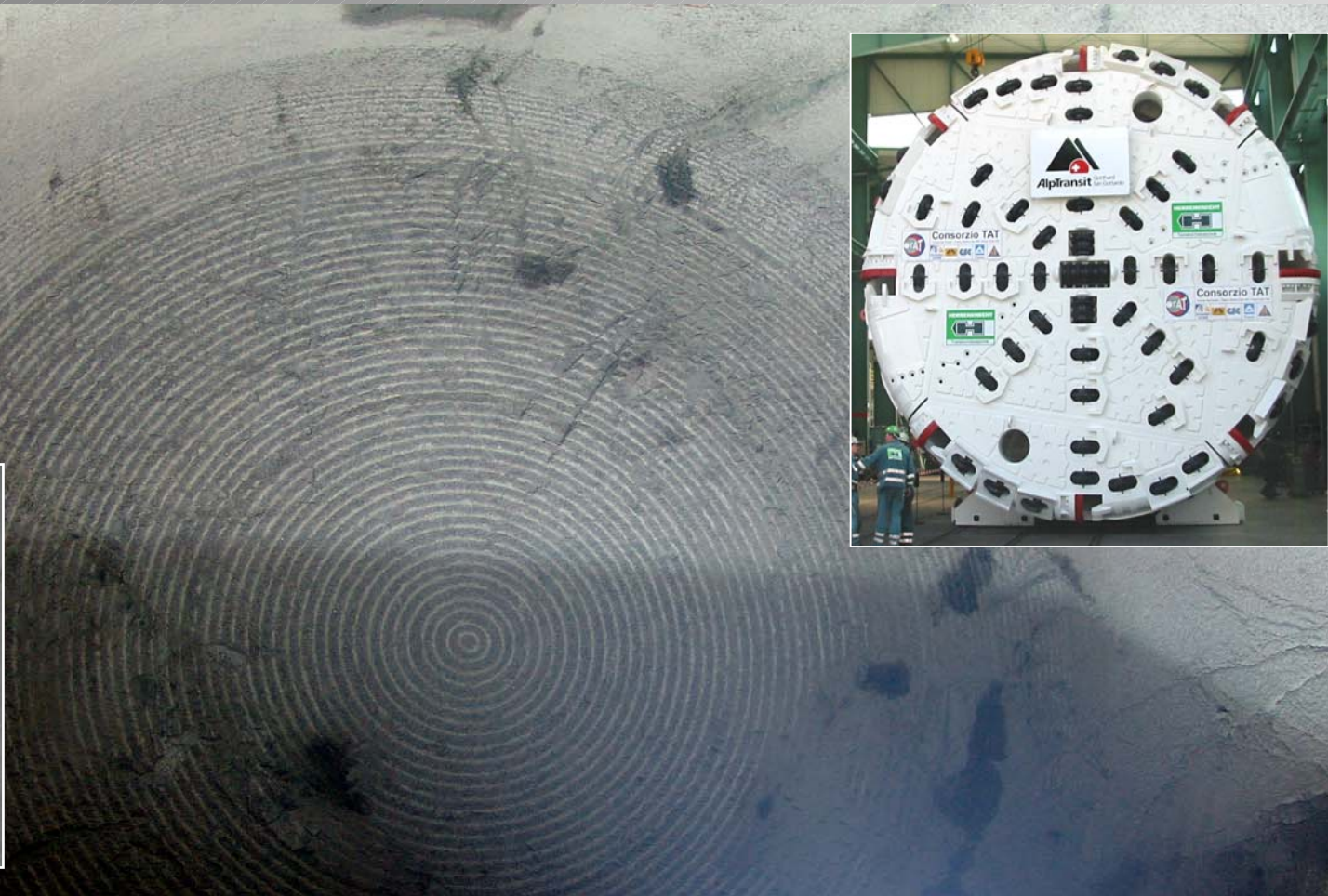
# Crossing of the Alps. 4 Gripper TBMs for a Total of 75km of Tunnel.



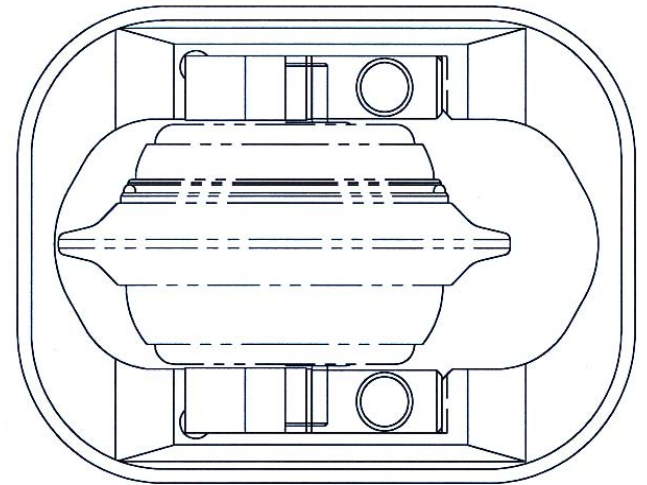
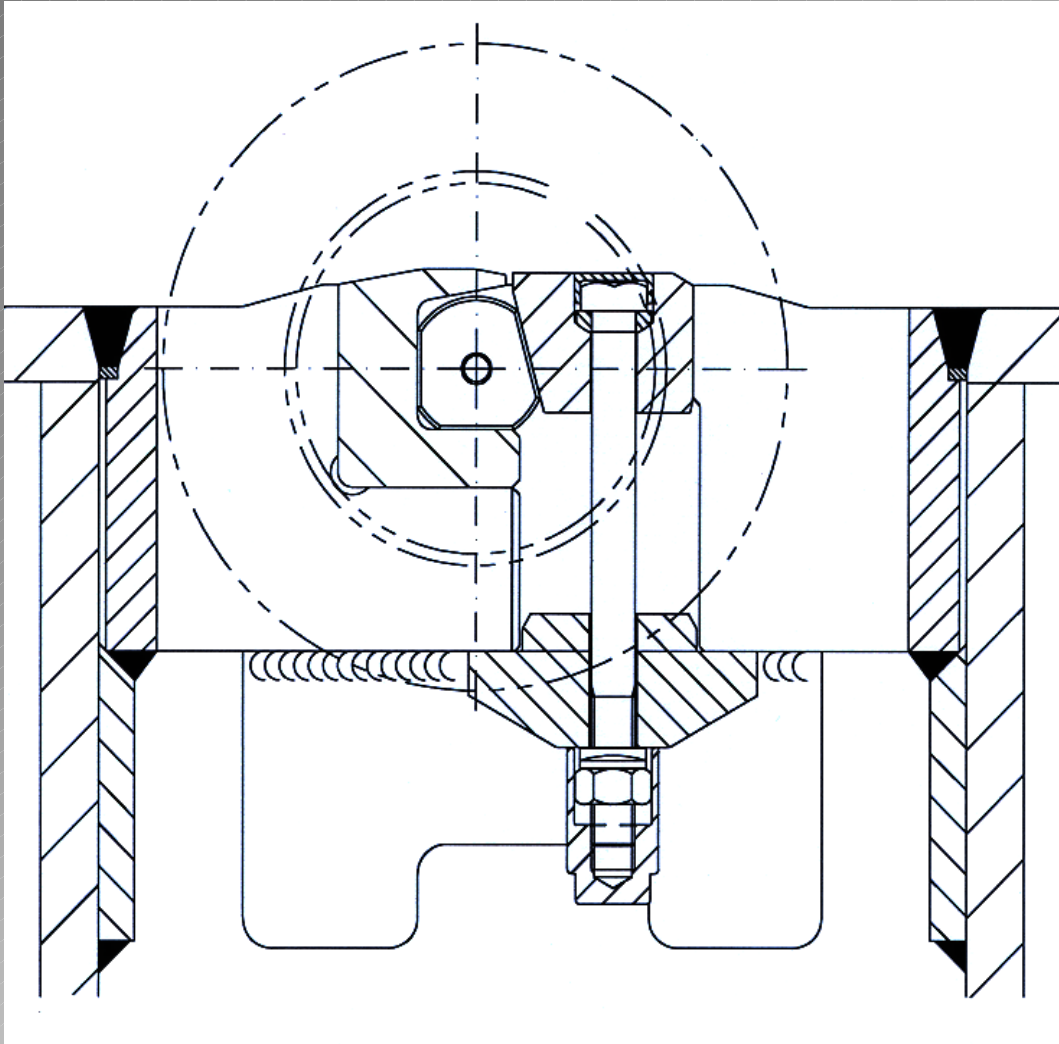
# TBM-Advance with Herrenknecht Machines through the Gotthard Massif.



# The Cutterhead.



# New Housing Design.



***Gotthard / Switzerland***

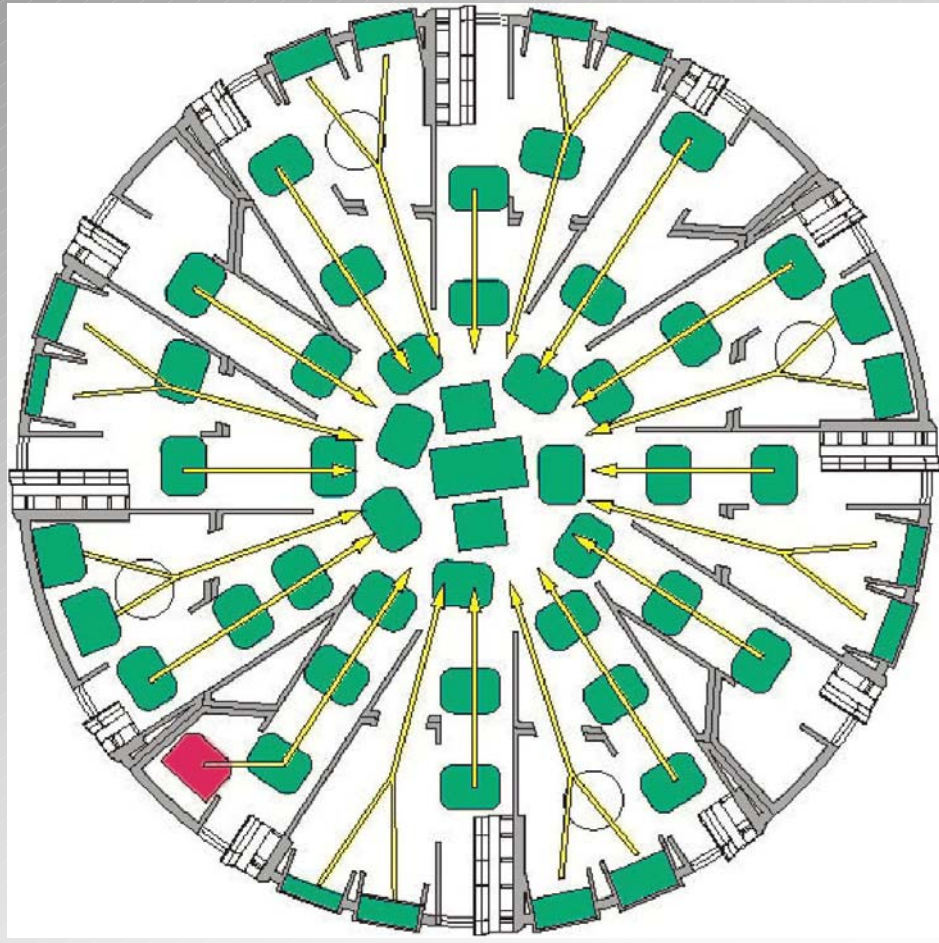
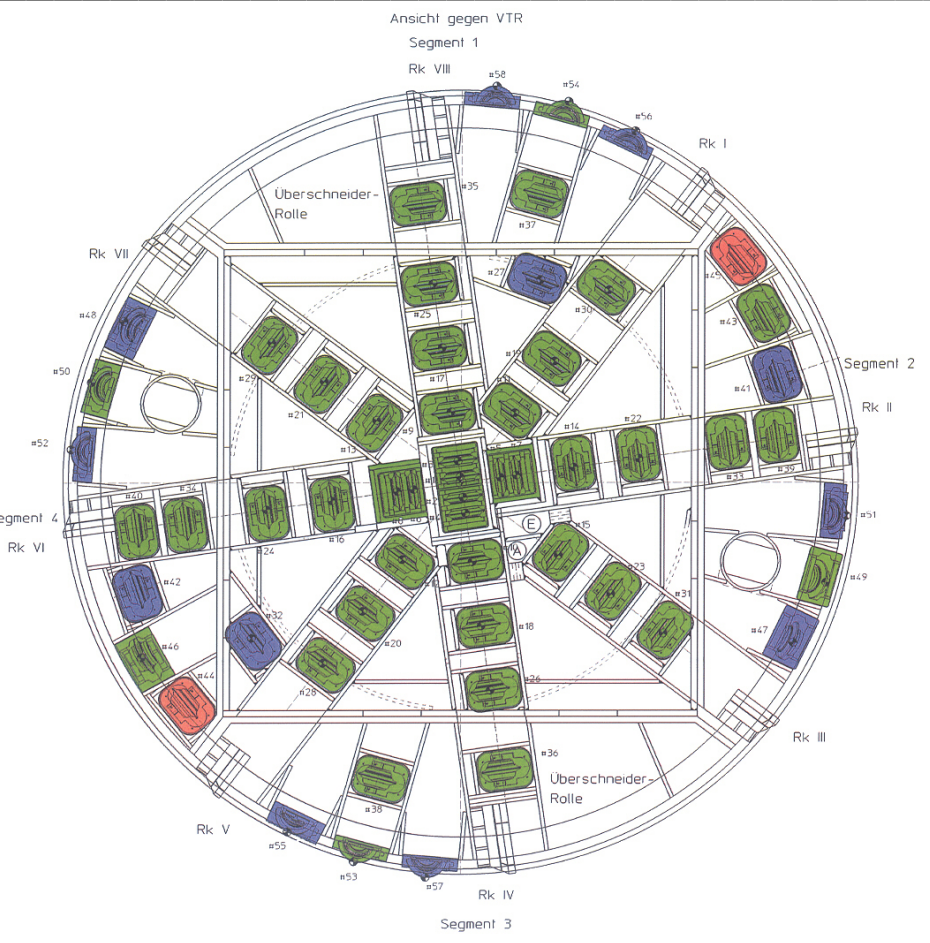
# Safe Tool Change. Back Loading Cutters.



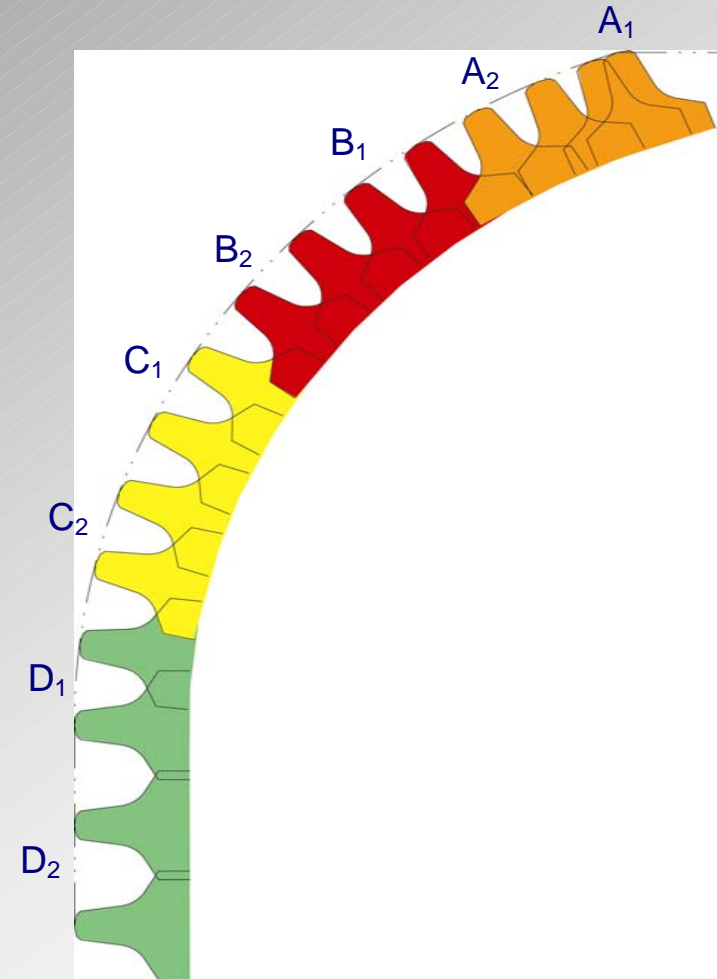
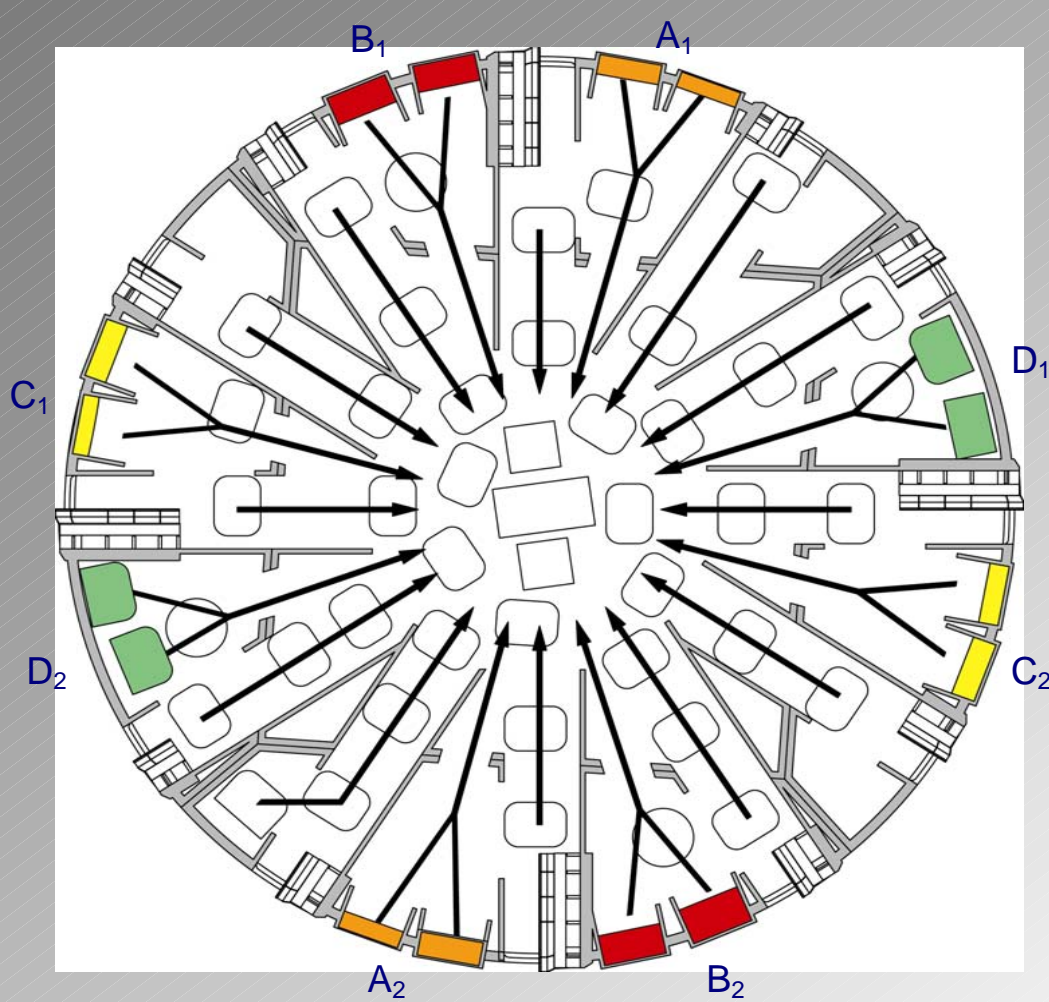
***Gotthard / Switzerland***

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# Accessibility of Cutterhead.



# Cutter Group Arrangement.



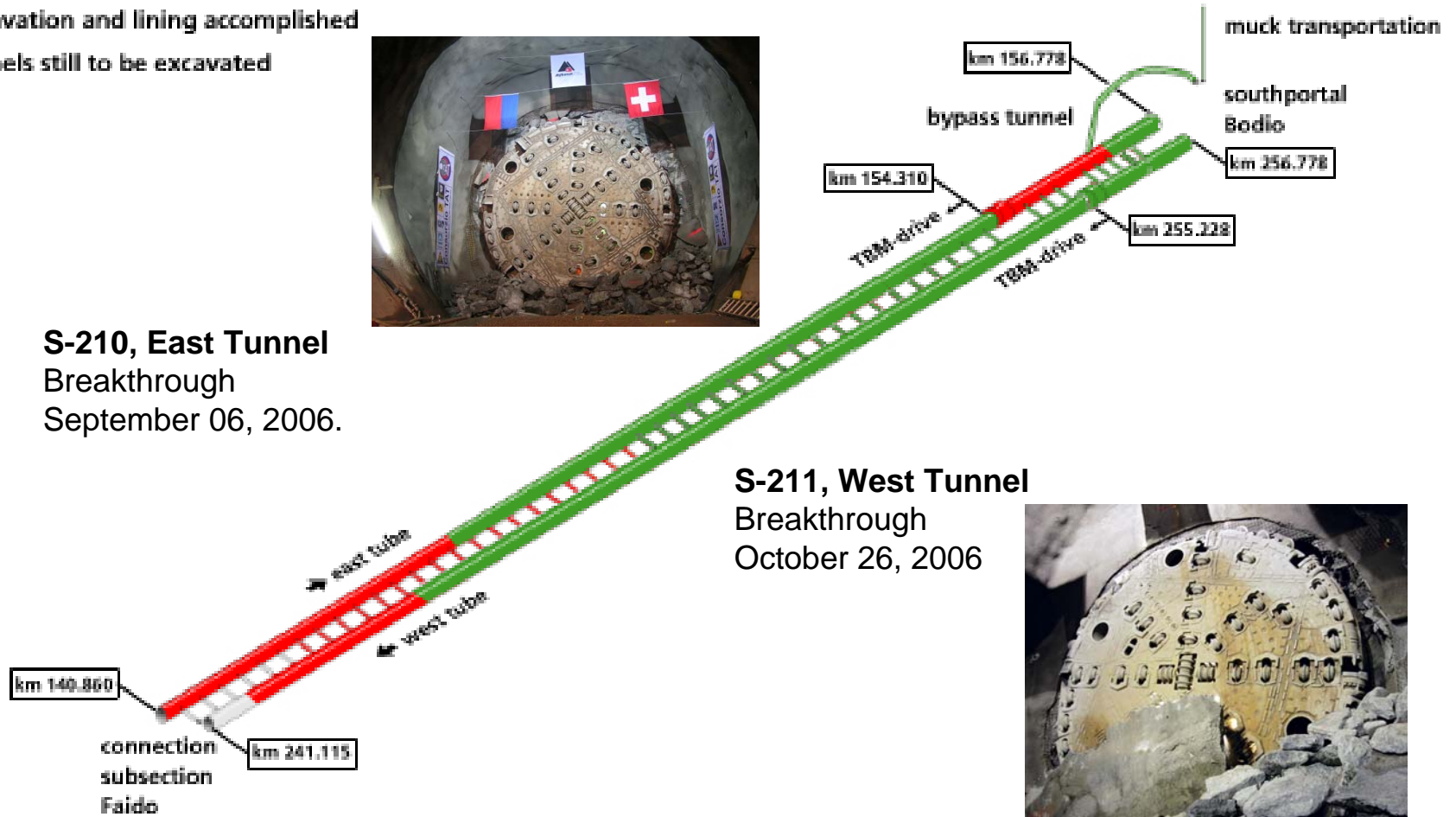
***Gotthard / Switzerland***

# Current Situation Bodio.

- already excavated tunnels
- excavation and lining accomplished
- tunnels still to be excavated



**S-210, East Tunnel**  
Breakthrough  
September 06, 2006.



**S-211, West Tunnel**  
Breakthrough  
October 26, 2006



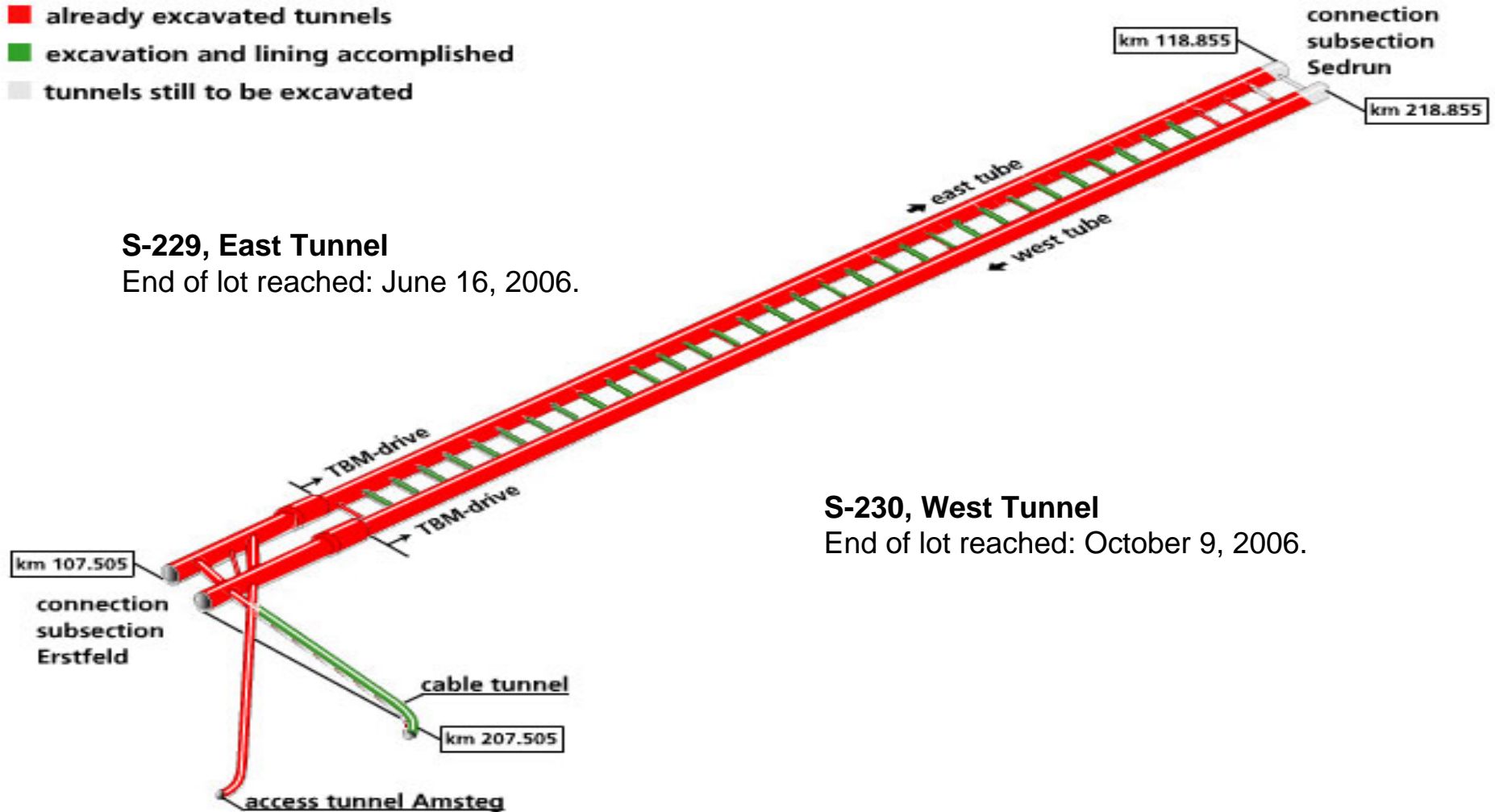


# Current Situation Amsteg.

- already excavated tunnels
- excavation and lining accomplished
- tunnels still to be excavated

**S-229, East Tunnel**  
End of lot reached: June 16, 2006.

**S-230, West Tunnel**  
End of lot reached: October 9, 2006.





Thank you very much for your attention.