SMART

Stormwater Management and Road Tunnel

Construction of the SMART Project in MALAYSIA

Presentation for the

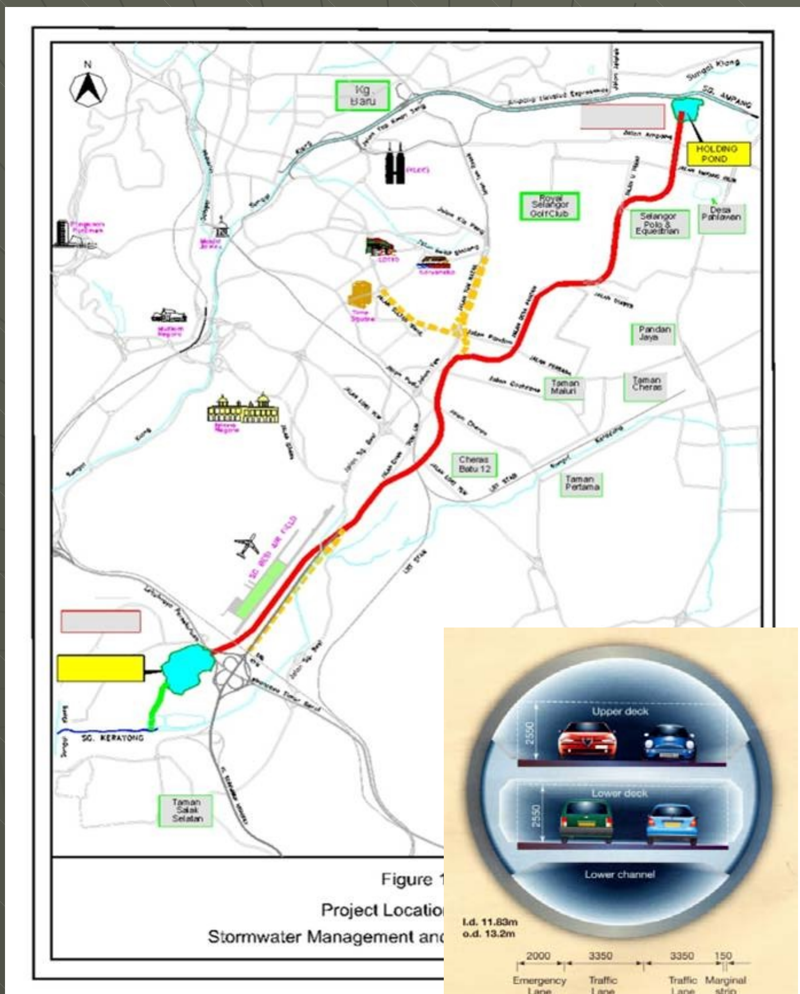
ITA-AITES WTC 2009 BUDAPEST

23d- 28th May 2009

FLOODED AREAS IN KUALA LUMPUR

TUN PERAK BRIDGE
Flow Capacity: 180 m³/s only

THE **SMART** IDEA



PROVIDE FLOOD RELIEF BY:

BORING A **13.26/11.83m** DIAMETRE 9KM LONG TUNNEL TO PROVIDE FLOW OF **291m3/sec**

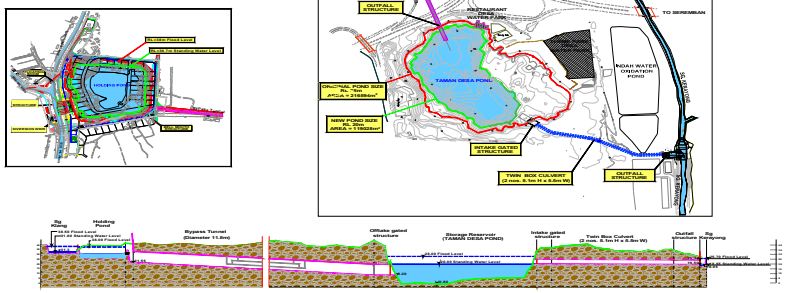
MAKE IT CHEAPER TO THE PUBLIC BY:

BUILDING A TWIN LEVEL 2 LANE MOTORWAY IN THE CENTRAL 3KM TO RELIVE TRAFFIC CONGESTION AVAILABLE MOST OF THE TIME TO THE PUBLIC

MAIN ELEMENTS:

- PONDS
- INTAKE & OUTLET STRUCTURE
- GATE STRUCTURES
- VENTILATION SHAFTS
- TUNNEL
- ROAD DECKS & ESCAPE PASSAGES

THE FLOOD DIVERSION SYSTEM



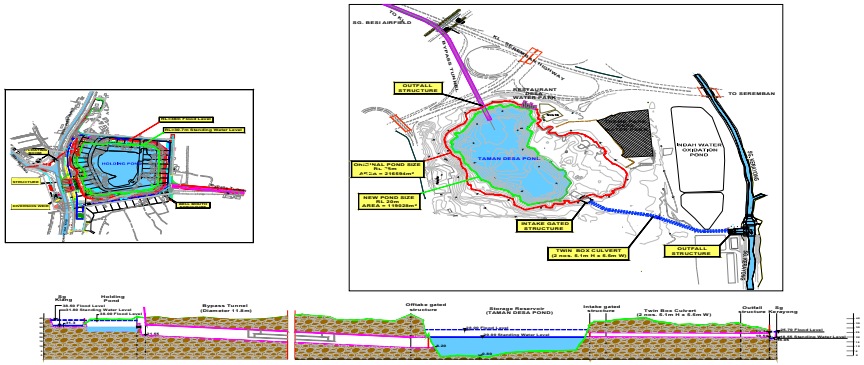
Floodgates divert storm-water from Klang river to Holding Pond

Water flows through Intake Tower and tunnel gravitationally to Storage Reservoir at Taman Desa

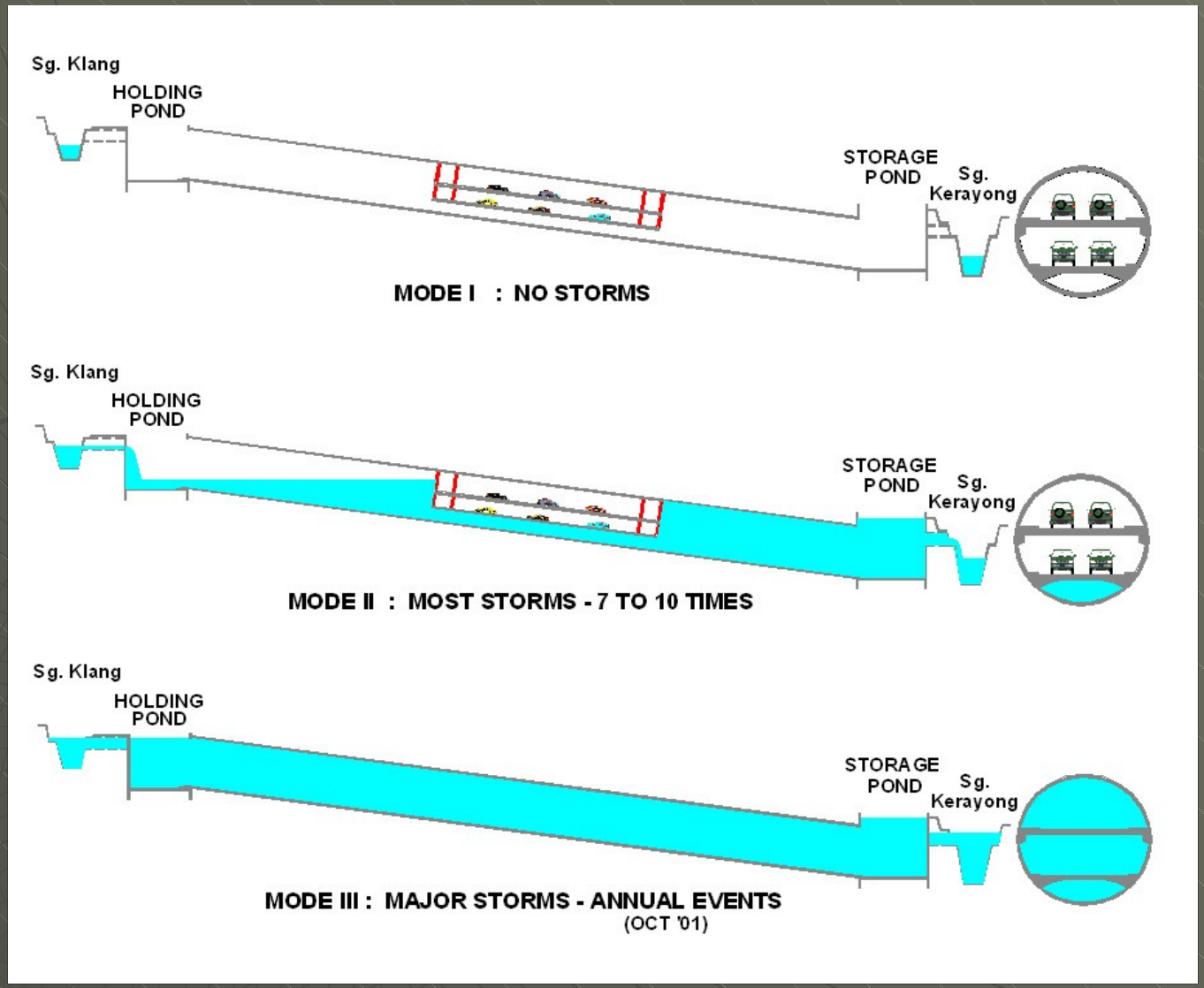
Max. flow: 280m³/sec

Water flows through Twin Box Culvert to the Kerayong river

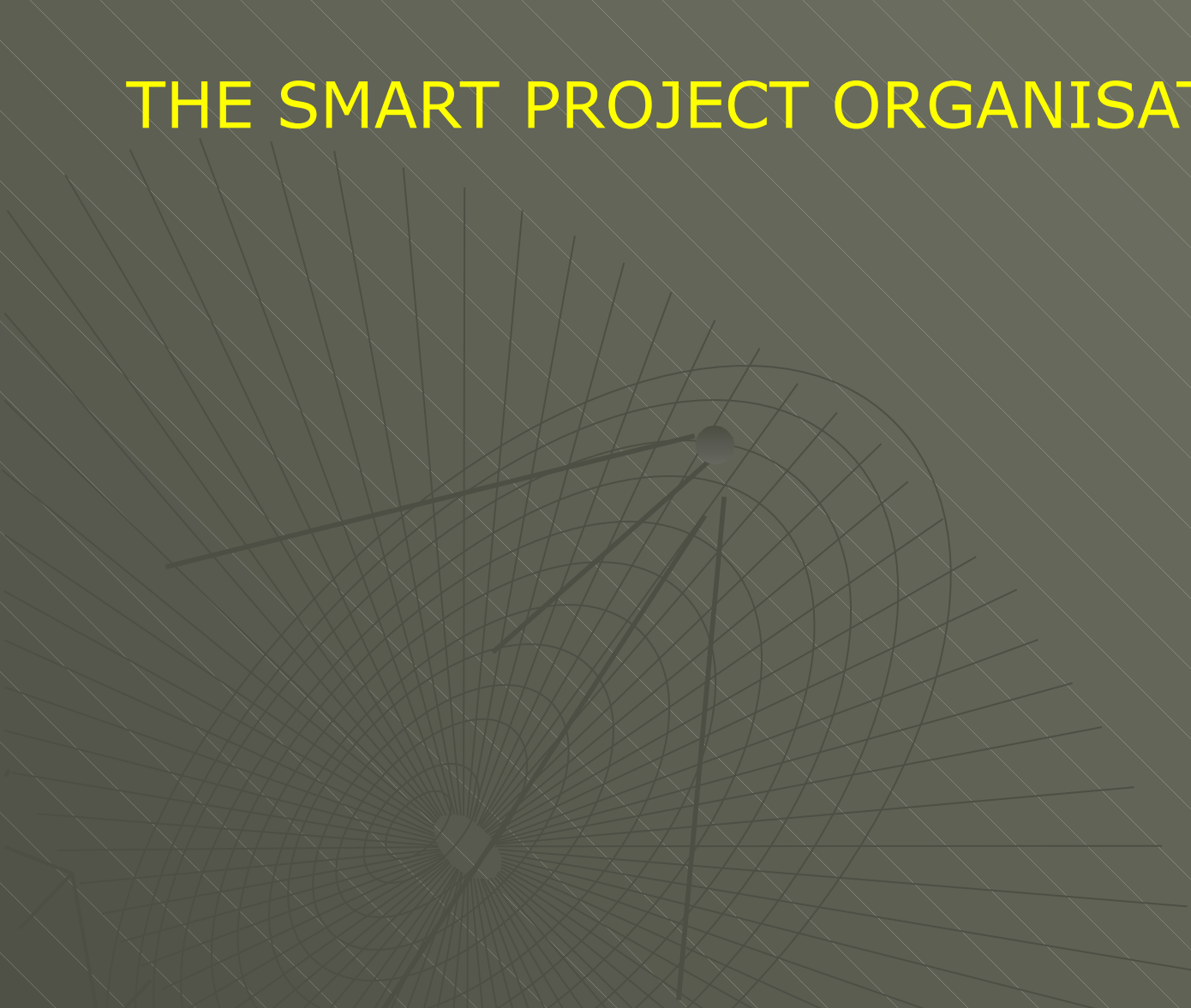
Low section of tunnel pumped dry



THREE MODES OF OPERATION

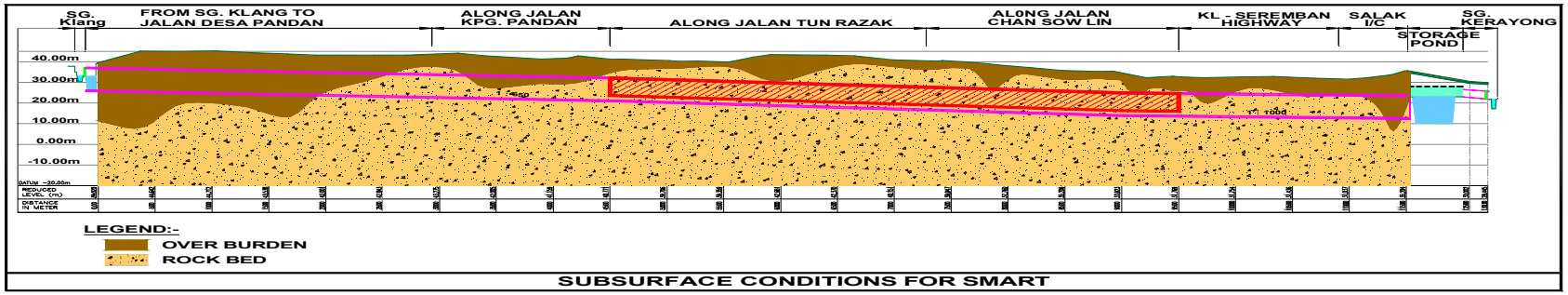


THE SMART PROJECT ORGANISATION



After 2,2km the North Drive contract was terminated, the remaining 2.8km was completed by MMC-GAMUDA JV in 11 months.

GROUND CONDITIONS



OVERBURDEN

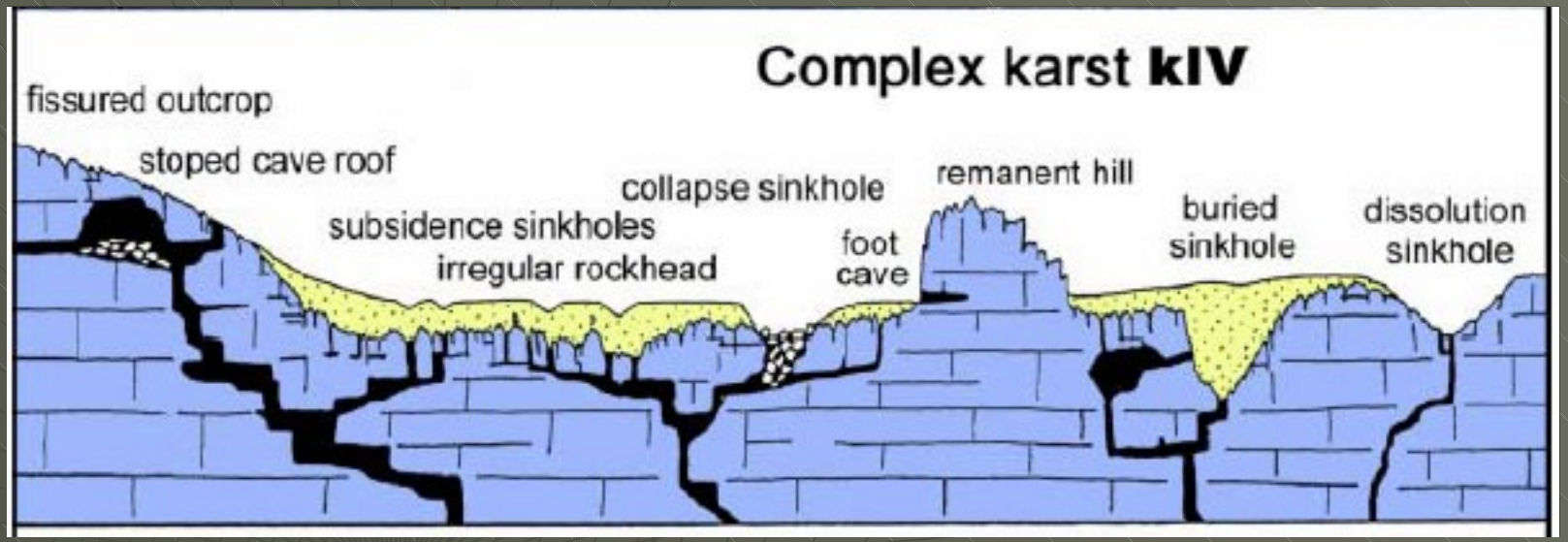
- SILTS & SANDS
- ALLUVIAL TIN DEPOSITS
- MINE TAILINGS
- SLUMP ZONES OVER THE KARSTIC ROCKHEAD

KUALA LUMPUR LIMESTONE FORMATION

- DEEPLY FISSURED
- ERRATIC ROCKHEAD WITH RELIEF OF >30M
- SINK HOLES
- KARST SOLUTION CHANNELS, MOSTLY FILLED SOMETIMES OPEN

KARSTIC ROCKHEAD
EXPOSED DURING TIN MINING

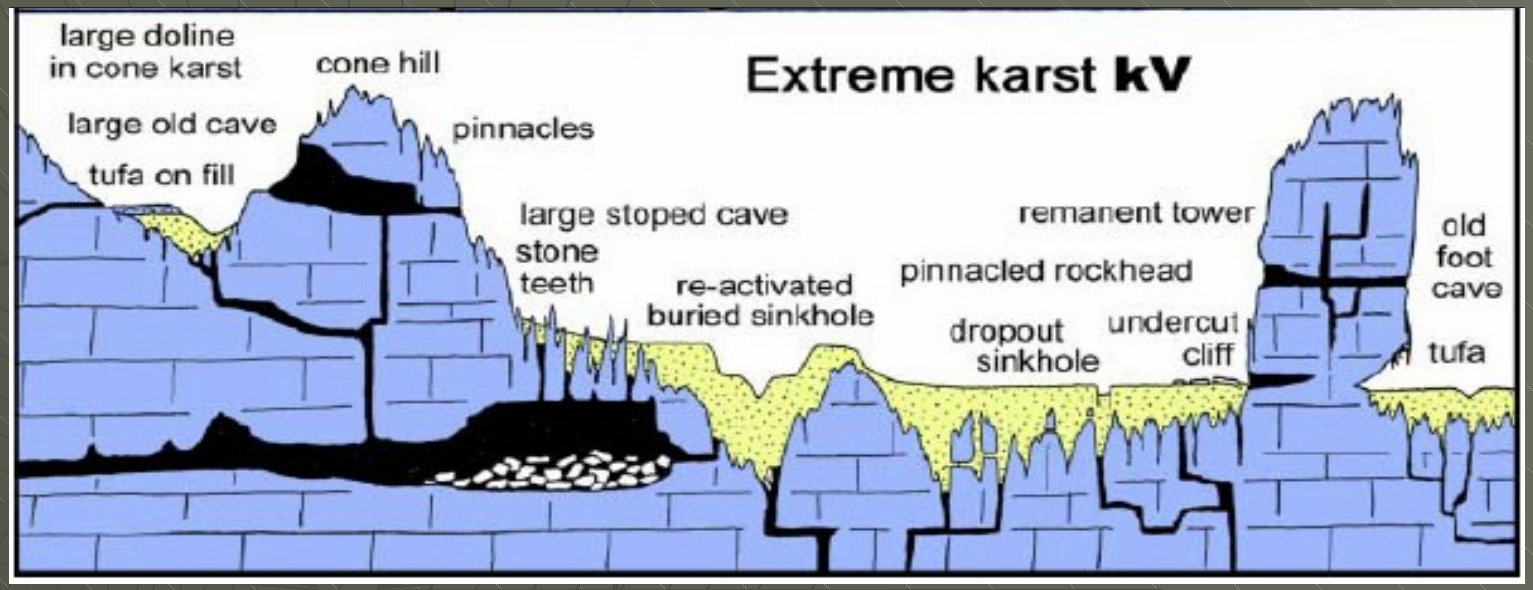
KARST MORPHOLOGY
kIV - KOMPLEX KARST



K IV is typical in tropical climate, rare in temperate climate.

(from Waltham és Fookes)

KARST MORPHOLOGY
k V - EXTREME, COVERED KARST

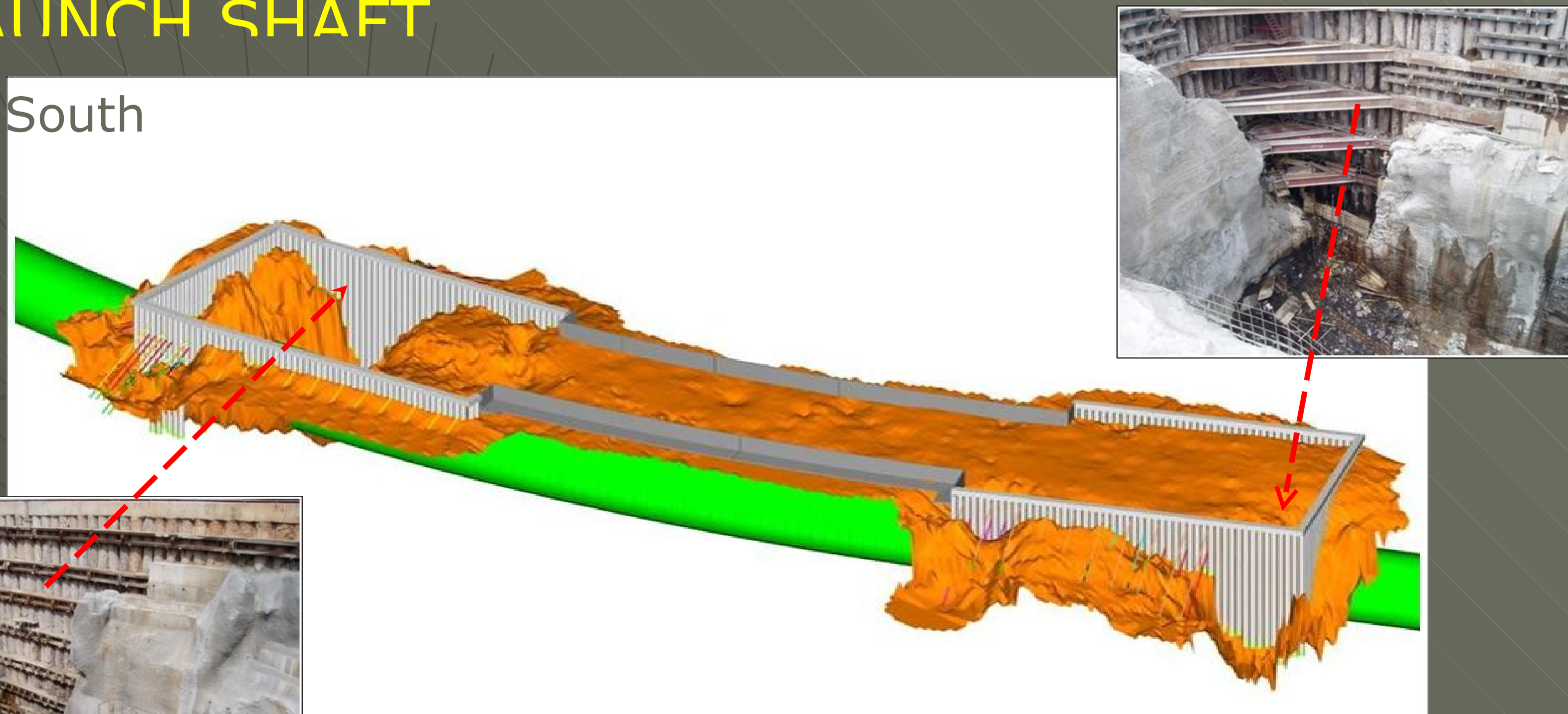


k V is typical in Peninsular Malaysia. Climatic conditions accelerate solution.

(from Waltham és Fookes)

KARST FEATURES

3D IMAGE OF THE NORTH VENTILATION & TBM'S LAUNCH SHAFT



The widening at the ends are the two TBM launch areas.

'L' shaped walls used at 'normal depth' rockhead tied back secant pile walls keyed into the rock at karstic features.

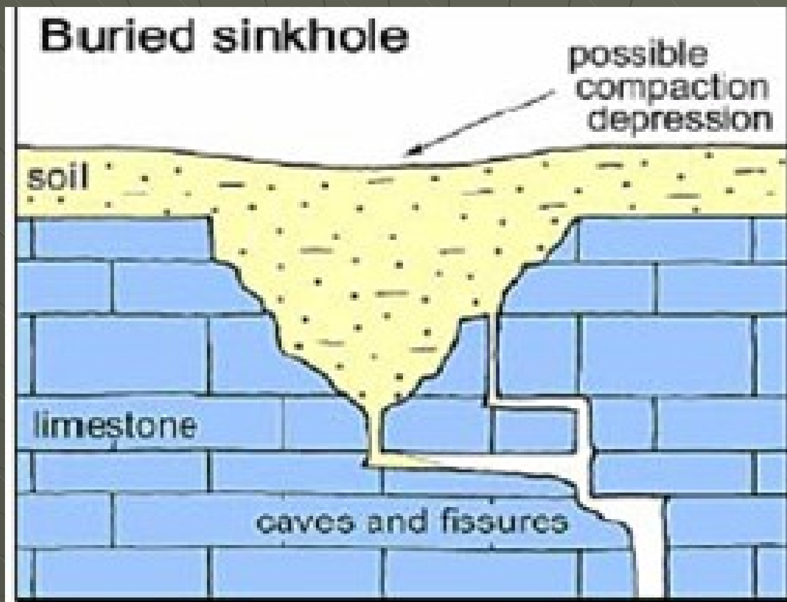
300m³ of grout was used to stem 4000l/min water inflow at the south end (LHS).

KARST FEATURES
SUDDEN DROP OF ROCKHEAD

Tied back bored pile wall temporary support next to the generally used 'L' shaped walls

KARST FEATURES

POTHOLE or BURIED SINKHOLE



AS SHOWN BY WALTHAM & FOOKES

AS FOUND ON SITE

KARST FEATURES
POTHOLE AT THE NORTH JUNCTION BOX

RESISTIVITY TOMOGRAPHY

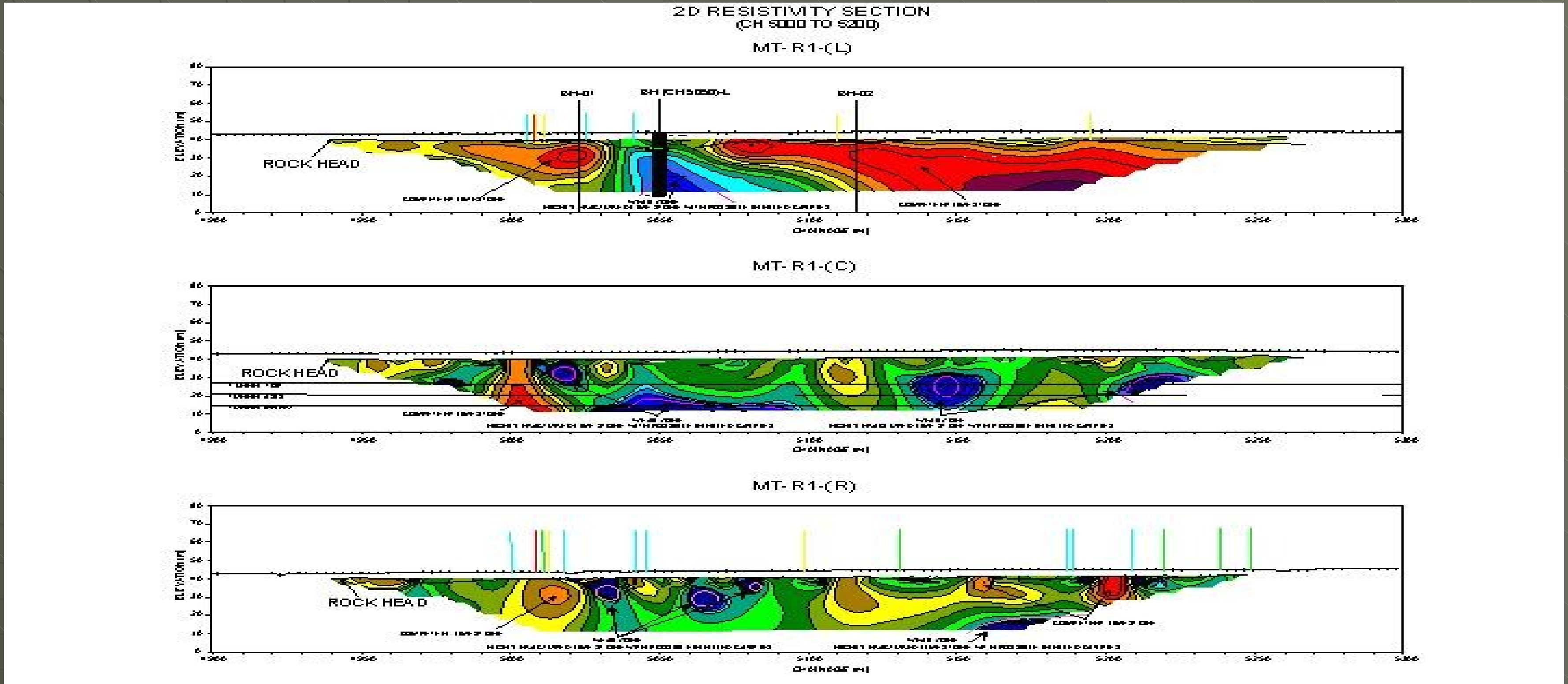
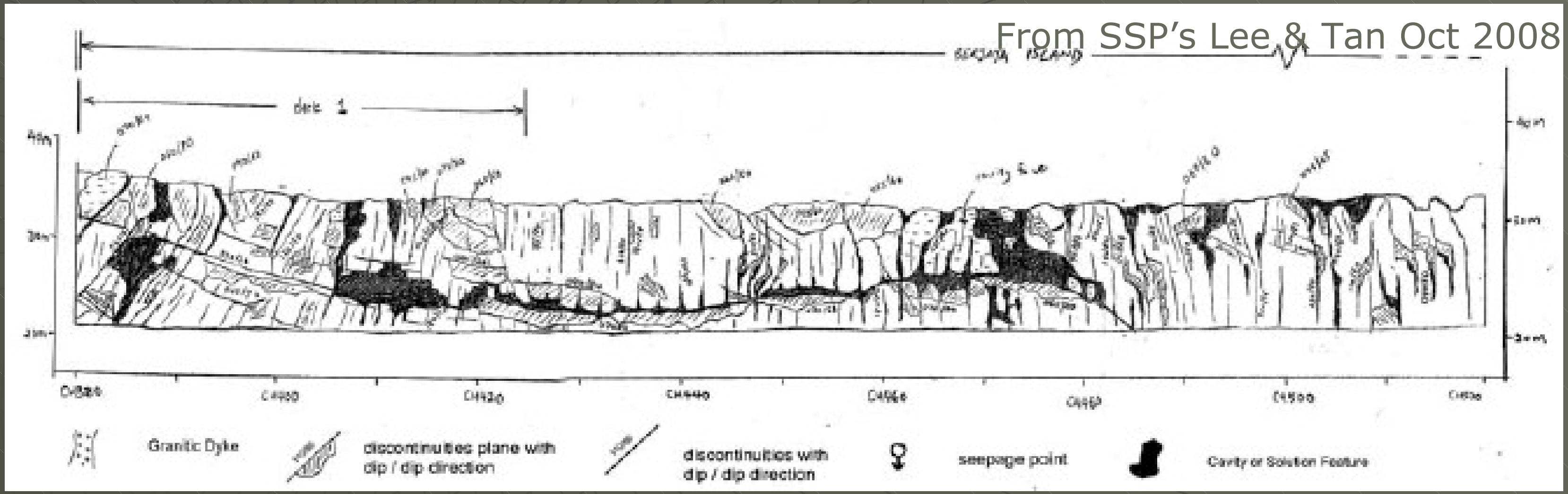


Figure 15: 2D Resistivity Imanage Between Ch5000 and Ch5200

Successfully used in the South Drive to detect anomalies in the karst well ahead of the TBM. The suspect areas were investigated by drilling from the surface and treteated if necessary. Probing from the machine was abandoned.

KARST FEATURES
AS MAPPED AT AN EGRESS RAMP

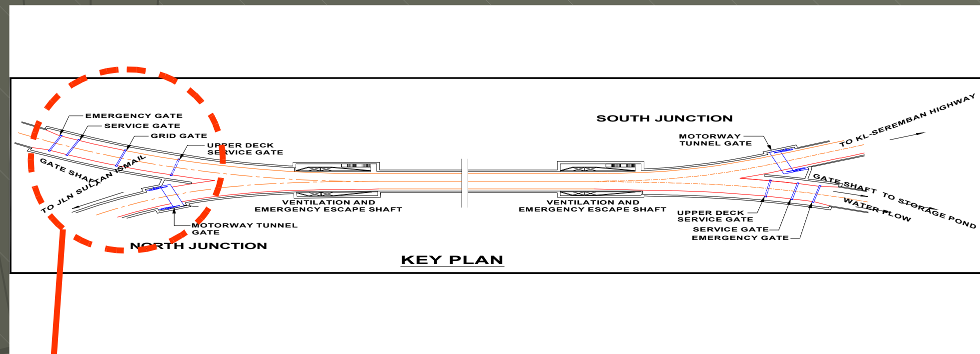


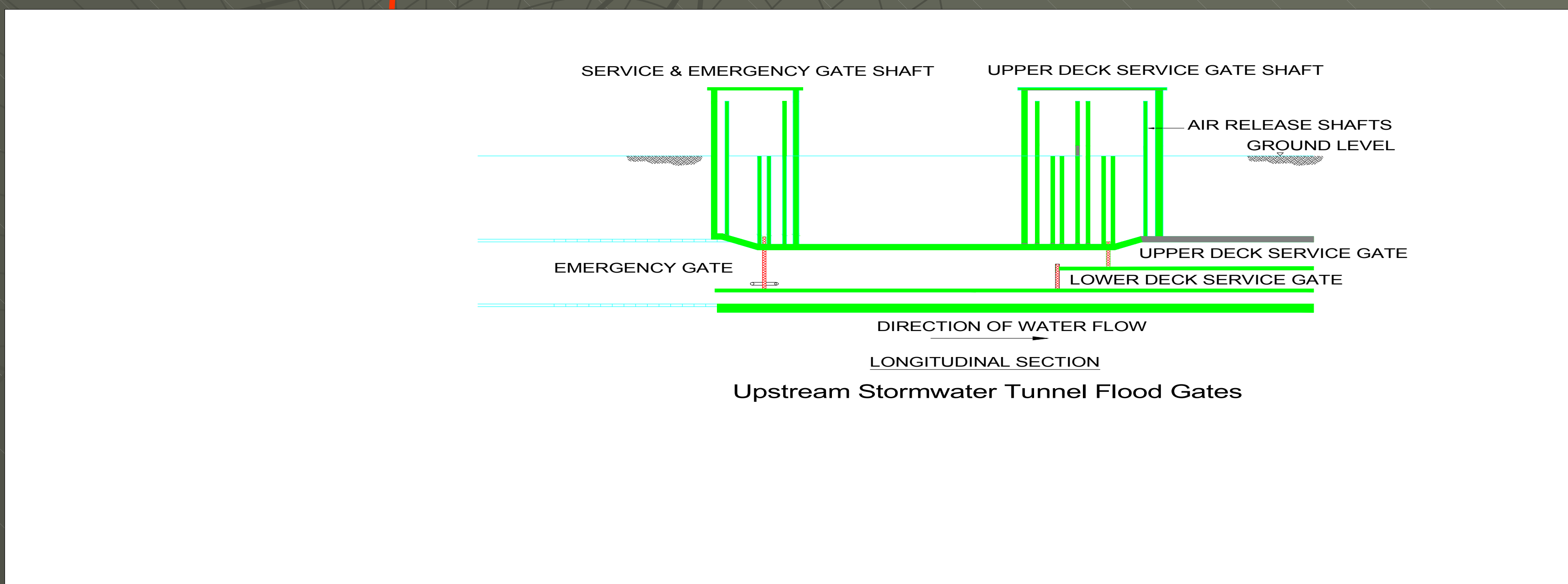
From SSP's Lee & Tan Oct 2008

RCC LINING

External diametre: 12,83m
Internal diametre: 11,83m
Ring length: 1,70m
Ring split: 8 + 1
Ring weight: 82t
Normal segment weight: 10t
Reinforcement ratio: 82kg/m3
Concrete: Grade 50

GATES AT THE NORTH JUNCTION BOX

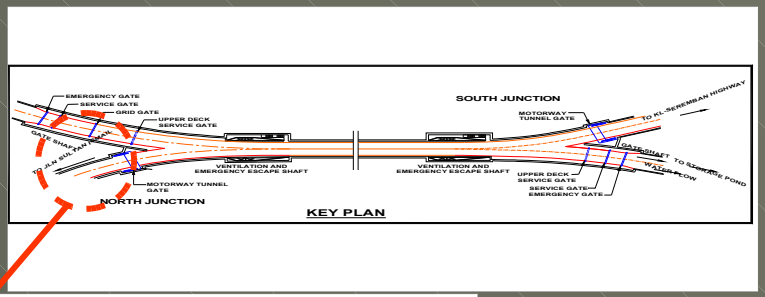


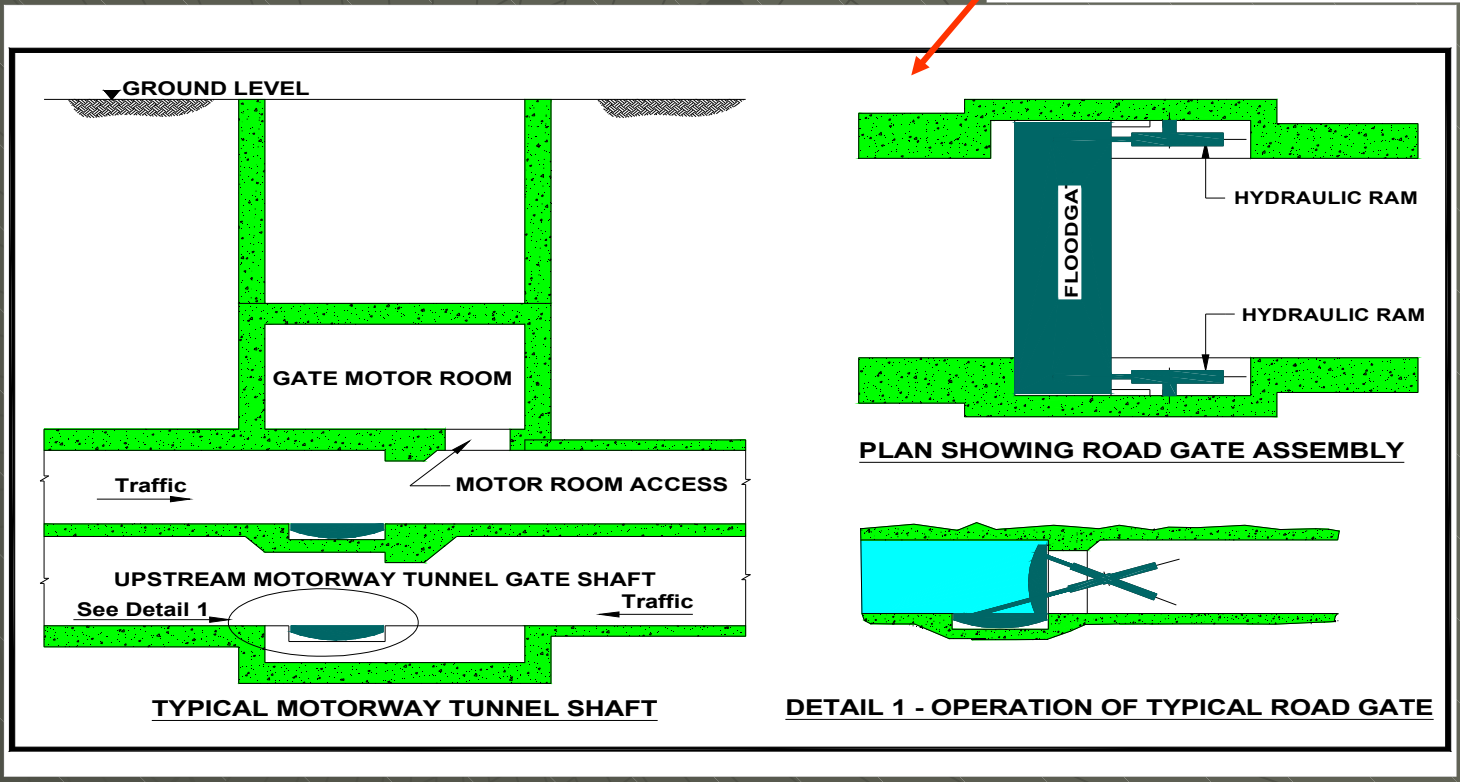


ROAD CLOSURE/FLOOD GATES

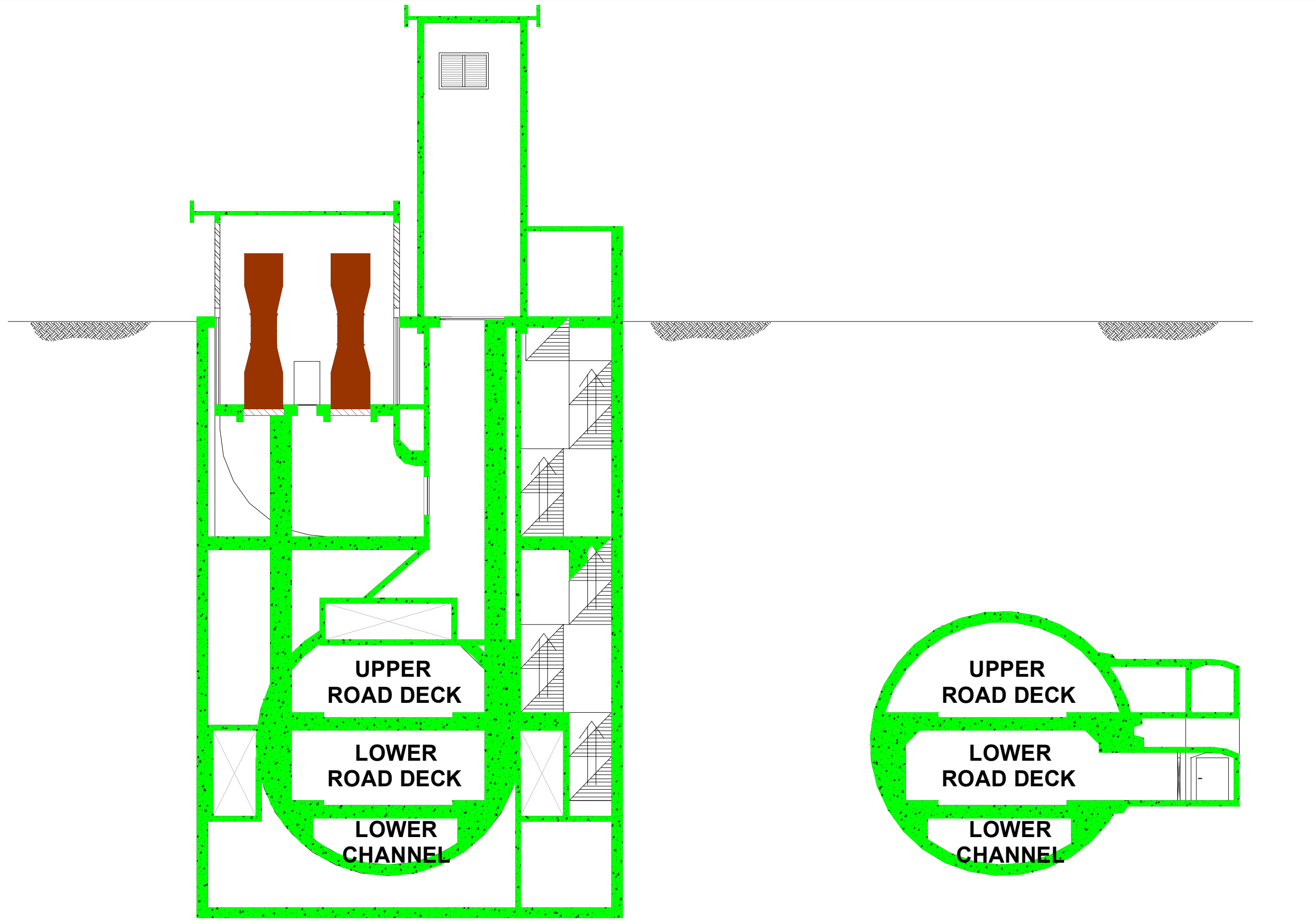
Prevents vehicle acces during flood diversion

Prevents flooding of ramps and reduces cleaning time





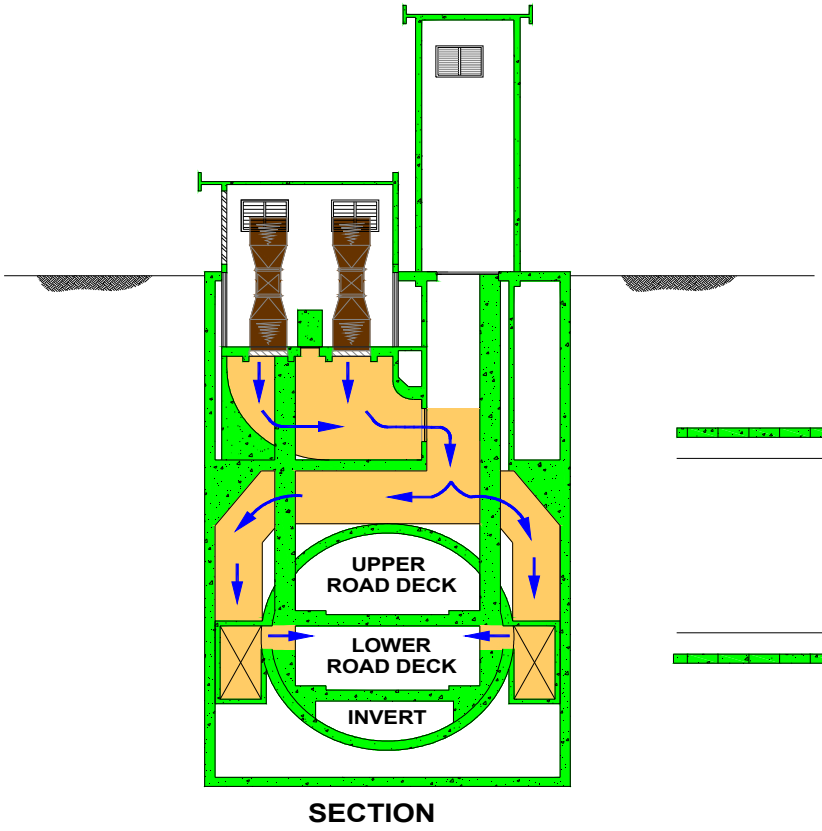
ESCAPE ARRANGEMENTS



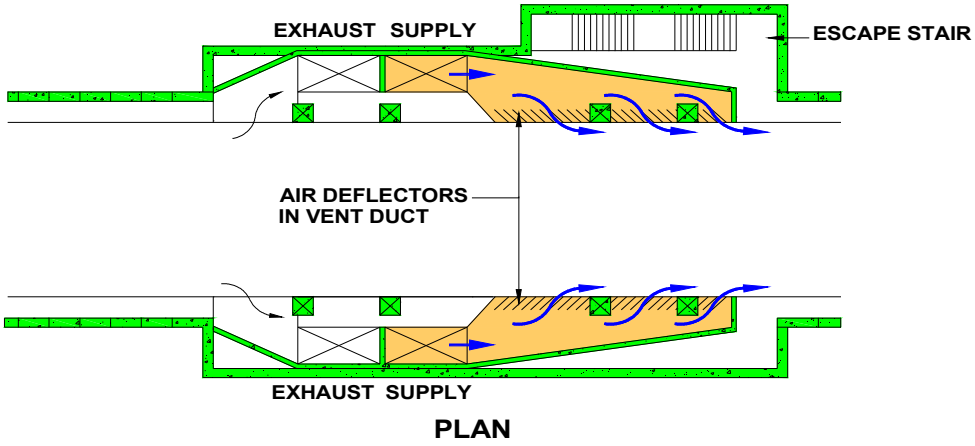
ESCAPE SHAFTS AT 1 km INTERVALS

CROSS PASSAGE AT 250m INTERVALS

VENTILATION
LOWER ROAD DECK



SECTION



PLAN

REVISION OF PLANNED EXCAVATION METHODS

Planned Drill & Blast with shotcrete temp. support tunnelling method and Cut & Cover method in South Drive revised, changed to closed TBM drive for:

Drill & Blast

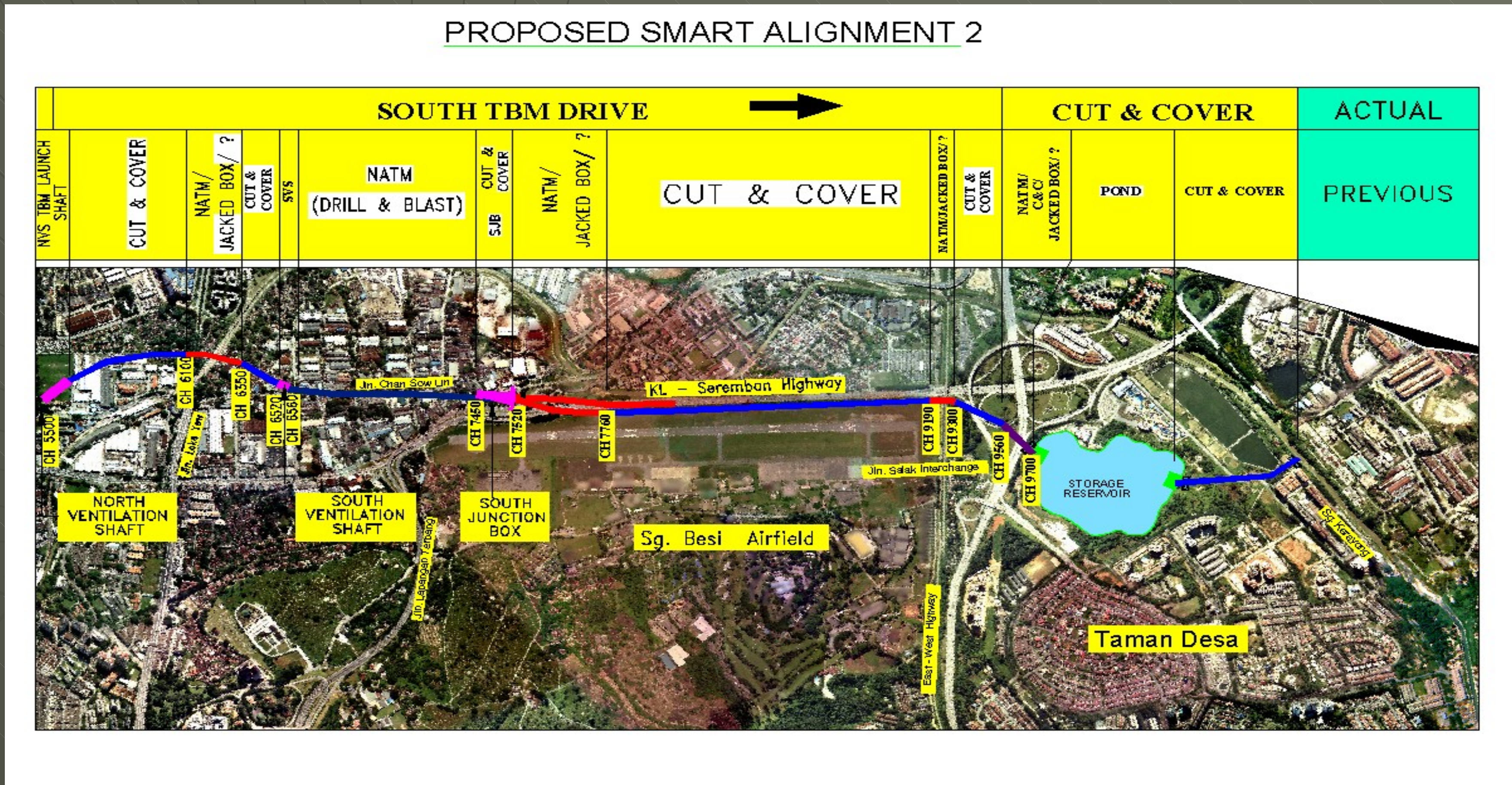
- Difficult to prevent groundwater drawdown, triggering sinkholes away from the alignment
- Risk of inundation if major open karstic system is encountered
- Major noise and vibration problems while blasting
- Erratic rockhead forces frequent excavation method changes
- Many sections require partial face excavations
- Difficult to support soft overburden in mixed faces while blasting rock

Cut & Cover

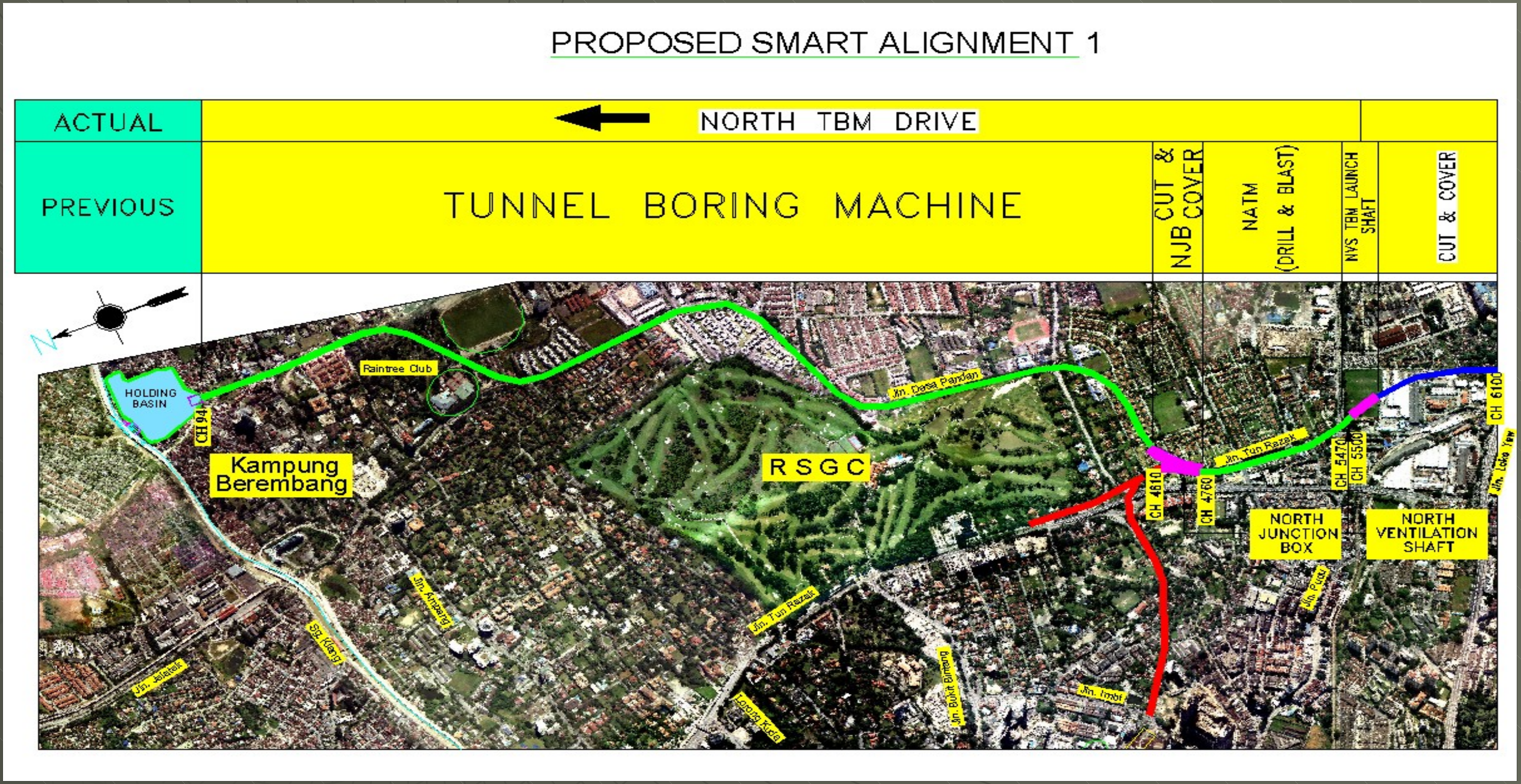
- Major disruption in an urban environment
- Difficult to prevent groundwater drawdown, triggering sinkholes away from the alignment
- Major noise and vibration problems while blasting over 1million m3 rock in the city
- Difficult temporary sidewall support
- Risk in passing under sensitive railway structures (ERL, KTM, LRT)
- Costly utilities diversions

THIS RISK MANAGEMENT DECISION INTRODUCED A NEW RISK; SLURRY SHIELD TUNNELLING WAS TO BE PERFORMED BY FIRMS WITH NO EXPERIENCE IN TUNNELLING. THE NEW RISK WAS PROVED TO BE EMINENTLY MANAGEABLE BY EMPLOYING A PROFESSIONAL TEAM.

METHOD SELECTION DEVELOPMENT SOUTH SECTION



METHOD SELECTION DEVELOPMENT NORTH SECTION



SHAFT EXCAVATION

Ventilation and TBM launch shaft

'Y' shaped junction box

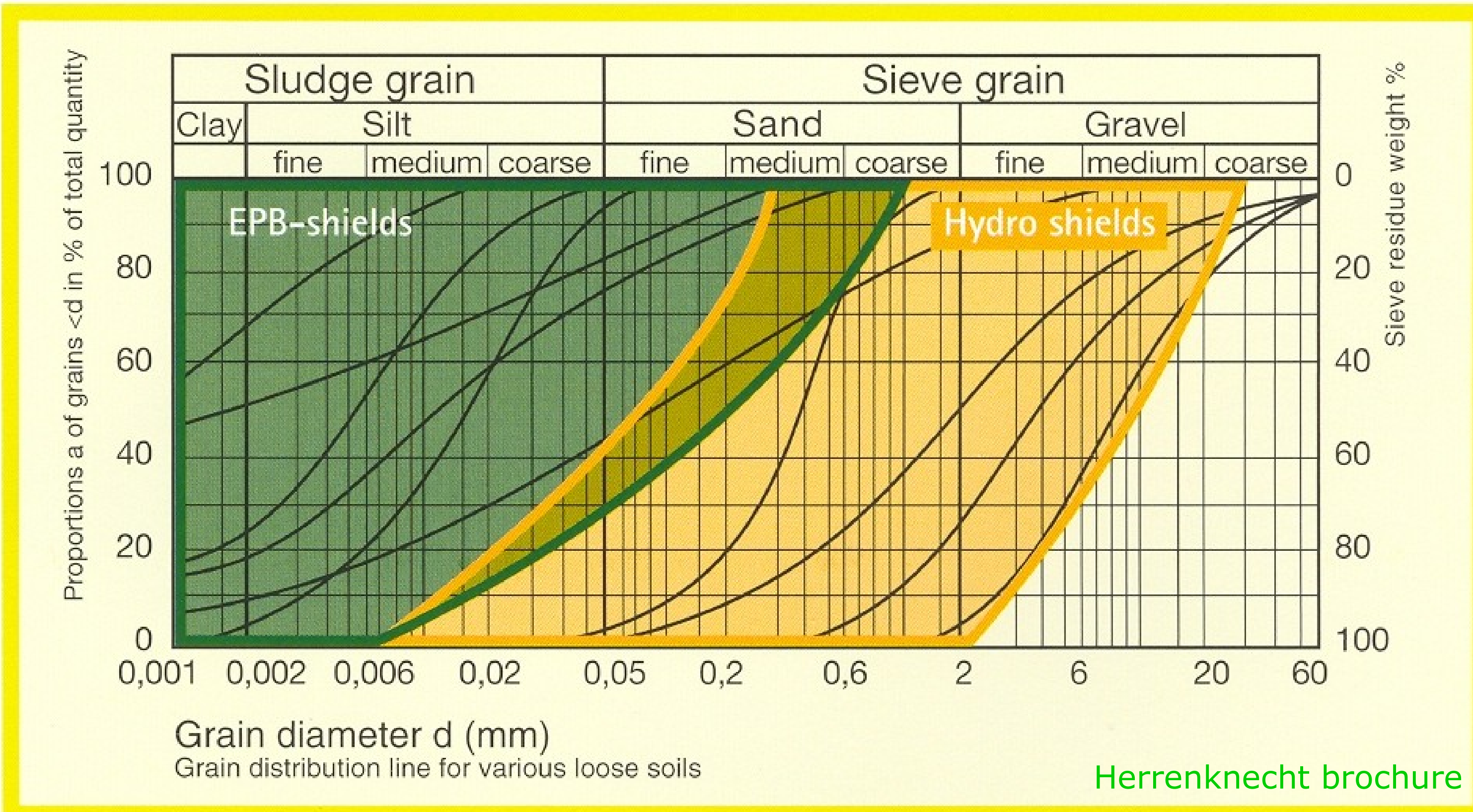
TBM SELECTION CRITERIA GENERAL

- Short, one year delivery time to satisfy tight concession contract program
- Design and build to high standards to survive long drive and difficult geology
- Large, 13,25m excavation diametre
- Able to negotiate tight R=200m curves; tunnel design R=250m curves
- Low overburden
  - Minimum 0.9D
  - Maximum 1.5D
- Urban tunnelling environment
- Restricted access to alignment at 2/3d of the cases for ground treatment

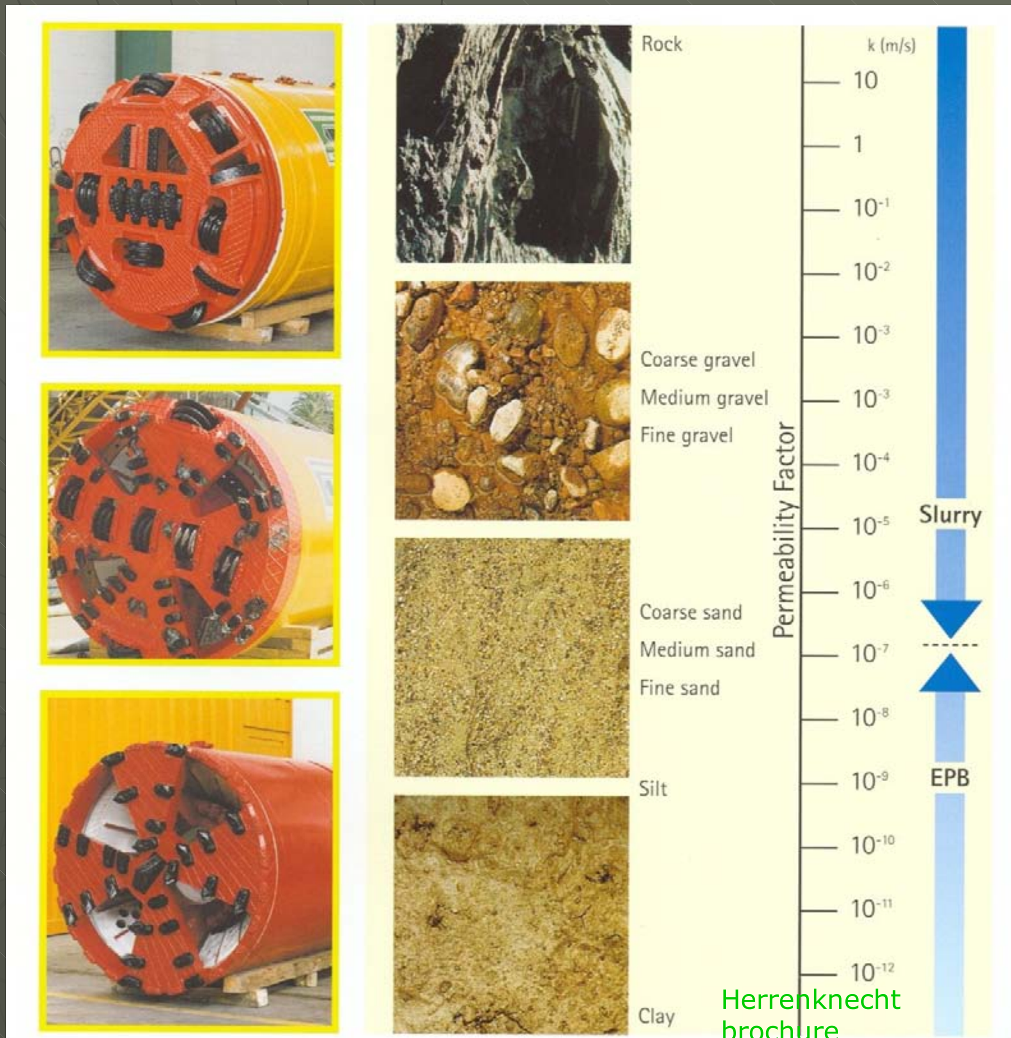
TBM SELECTION CRITERIA GEOTECHNICAL

- ~70% of tunnel in the KL Limestone Formation (marble)
- ~25% of tunnel in full face mine tailings at the North end
- ~5% of the tunnel in Kenny Hill formation (stiff soils of granitic origin)
- Karstic rock with solution features such as channels and interconnected cavities
- Highly variable, pinnacled rockhead causing frequent mixed face conditions
- Alluvial or mine tailing overburden with low SPT ‘N’ values
- High groundwater table close to surface
- Slump zones in the overburden above rockhead
- Solution channels, cavities mostly filled with slumped soil
- Extremely high permeability at open karsic solution channels
- Naturally occurring sinkholes caused by cyclical water table changes or during earthquakes

TBM SELECTION BASED ON SOIL PARTICLE SIZE DISTRIBUTION



TBM SELECTION BASED ON GROUND PERMEABILITY

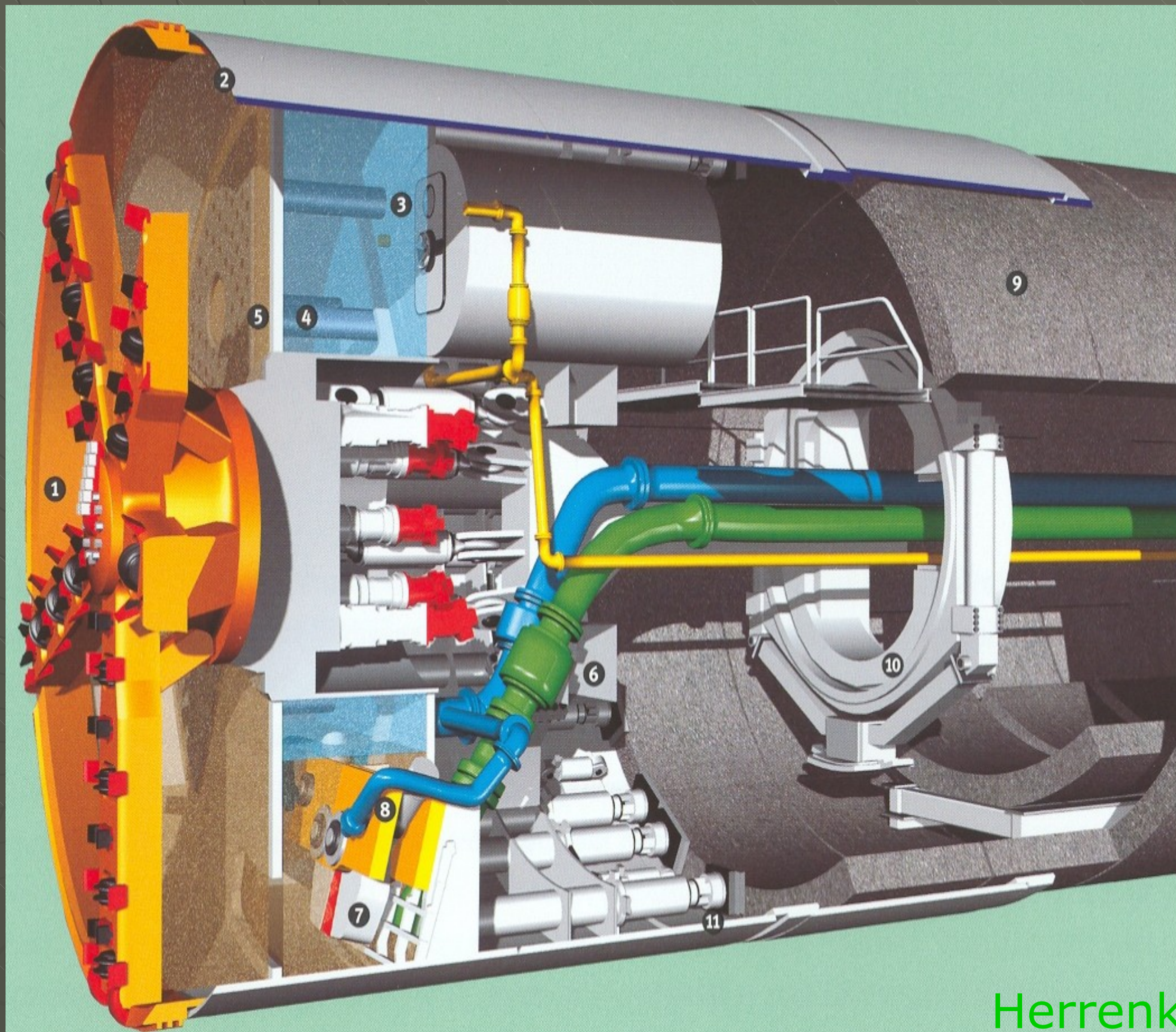


Herrenknecht brochure

The answer depends on placing the following foreseen situations in this table.

1. Fractured rock
2. Karstic rock with partly filled solution channels
3. Karstic rock with completely filled solution channels
4. Mixed face of soil and rock with all the above as possible combination

STM SCHEMATICS



The tunnelling principle: (1) behind the cutting wheel with muck bucket lips and cutter tools is a steel cylinder, the shield (2). It is within the protection of this shield that the tunnel is excavated. The space in front of the pressure bulkhead (3) is filled with a bentonite suspension which seals the existing soil. The pressure necessary to support the tunnel face is produced by means of a compressed air cushion (4) in the excavation chamber, which is divided by a submerged wall (5). The excavated soil is pumped into the slurry line (6) together with the suspension. Large rocks are broken down by a stone crusher (7). The suspension is supplied via the feed line (8). Protected by the shield, the reinforced concrete segments (9) are installed by an erector (10). To continue the advance, the machine presses against each previously installed segmental ring with hydraulic thrust cylinders (11). The annular gap between the segmental ring and the ground is continuously grouted with mortar as the machine advances. All operations are controlled from the control panel.

Herrenknecht brochure

TBM SELECTION
TECHNICAL COMPARISON POINTS

Description	Herrenknecht	Hitachi	Kawasaki	Mitsubishi	NFM
General	25	14	13	6	24
Cutterhead	85	53	57	33	72
Cutterhead Drive	65	63	50	43	62
Shield	44	30	27	21	29
Segment Handling	35	22	24	20	35
Probe drilling	10	7	7	6	12
Manlocks	17	16	8	8	24
Trailer	26	18	18	12	26
Guidance & Monitoring	44	28	31	27	42
Services	75	53	40	41	78
Slurry System	49	41	43	37	55
Total	**475**	**345**	**318**	**254**	**459**

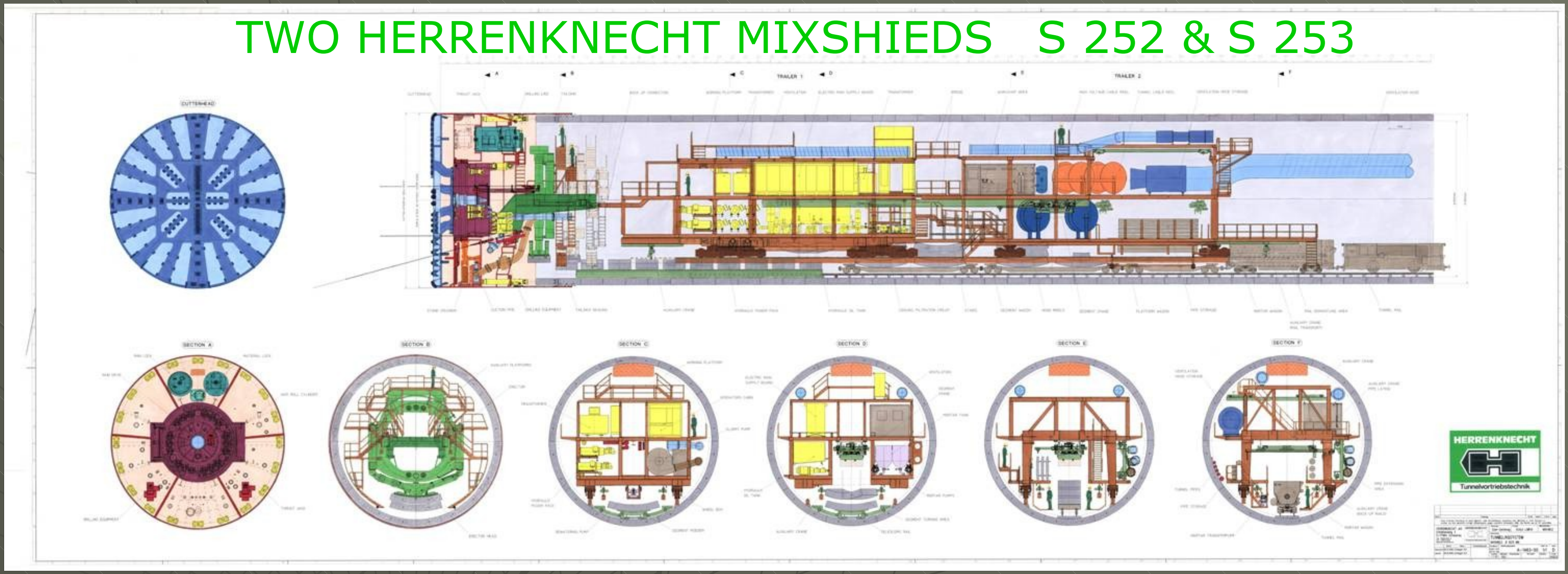
TBM SELECTION
COMMERCIAL COMPARISON

	Herrenknecht	**Hitachi**	**Kawasaki**	**Mitsubishi**	**NFM**
Price ratio	1.00	1.41	1.28	1.21	1.01

The prices were adjusted by:

- Cost of items not included in the offer but considered necessary and included by others
- Delivery time impact on schedule
- Finance costs

SELECTED TBMS



TWO HERRENKNECHT MIXSHIEDS S 252 & S 253

Cutterhead dia.: 13.260mm
Drive: 4.000kW hydraulic
Torque: 24.400kNm
Rotation: 0-3 rpm
Displacement thrust force: 28.900kN
Length of machine: 71m
Two trailer cars on haunch rails
Weight of machine: 2.500t

Length of shield : 10.245mm
Weight of shield : ~1.500t
Thrust cylinders: 3x16=48Nos
Max. thrust: 94.500kN
Grout lines: 8Nos
Guidance: VMT SLS T-APD
Tailseal: 3 rows, wire brushes
Disc cutters: 17”; 76 Nos

SPECIAL FEATURES

- **Spherical main bearing** to negotiate tight, min. R200m curves (tunnel min. radius R250m)
- **Cutterhead retraction** of 400mm by axial displacement through main bearing without shield movement for easier cutter replacement
- **Articulated tailskin** to negotiate the tight curves (at the time of manufacturing the largest in the world)
- **Cutterhead tilt moment indicator** to detect karstic features and mixed face conditions
- **Two probe drilling rigs** in fixed downward looking position, mounted on the erector the rig could drill through any port in the skin
- **Inflatable "pig"** (obdurator) for slurry pipe extensions
- **SSP** Sonic device mounted on the cutterhead to detect cavities and rock/soil interfaces (did not survive the mixed face environment)

THE TWO SEPARATION PLANTS

Refurbished plant used to build the Elbe tunnel in Hamburg

Capacity:
3x800=2400m³/óra

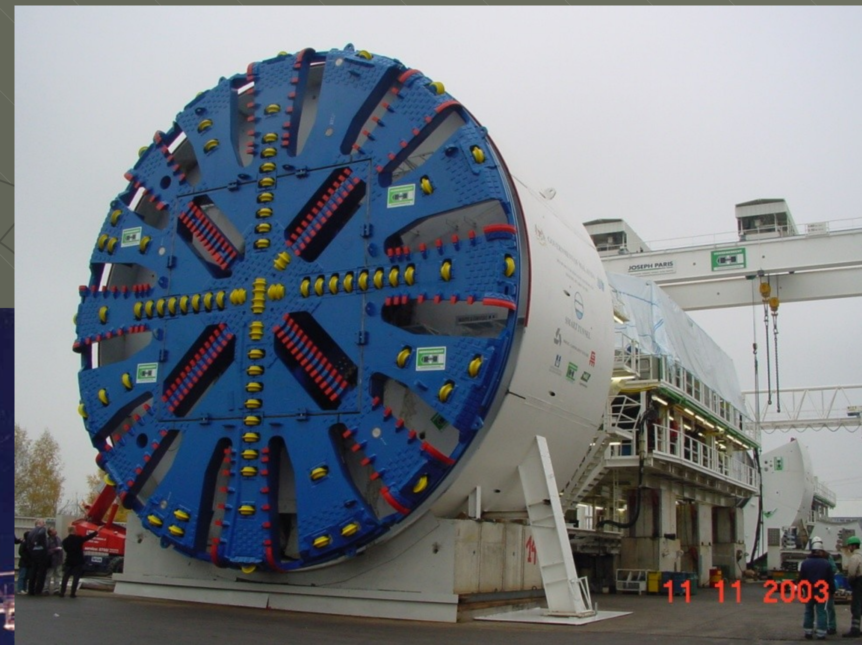
New plant of at the factory yard in Műhlheim

Capacity:
4x600=2400m³/óra

THE TBMs IN SCHWANAU AT THE HERRENKNECHT FACTORY

S

252
S 253



S 253

in winter

LIFTING OF THE 160t ARTICULATED TAIL SKIN

LIFTING THE S 252 CUTTERHEAD

The head segments were weldeded together by 8t of electrodes

Lifted load 295t

BREAKTHROUGH, NORTH DRIVE

MOVING THROUGH THE NORTH JUNCTION BOX

ASSEMBLY OF THE SOUTH TBM

THE SOUTH TUNNEL

1xΦ2000mm ventduct

2Φ500mm slurry pipes

2xΦ200mm cooling water

2xΦ200mm compressed air

The end of the trailer with the escape container

PASSING THROUGH A VENT SHAFT

BREAKTHROUGHS

IN ROCK

IN SOFT GROUND

PREPARATIONS TO RELAUNCH

Fixing of the starting seal ring in the eye.

Excvation of the road ramp during the relaunch of the TBM

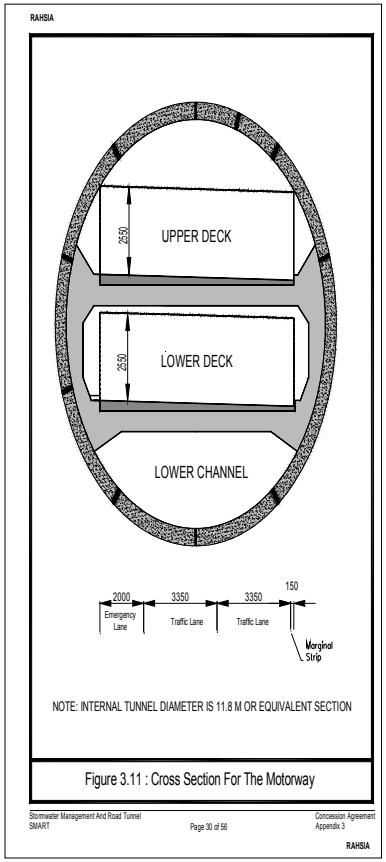
RELAUNCH AT THE SOUTH DRIVE

24th October

MMC-GAMUDA JV

SOUTH DRIVE PRODUCTION SUMMARY

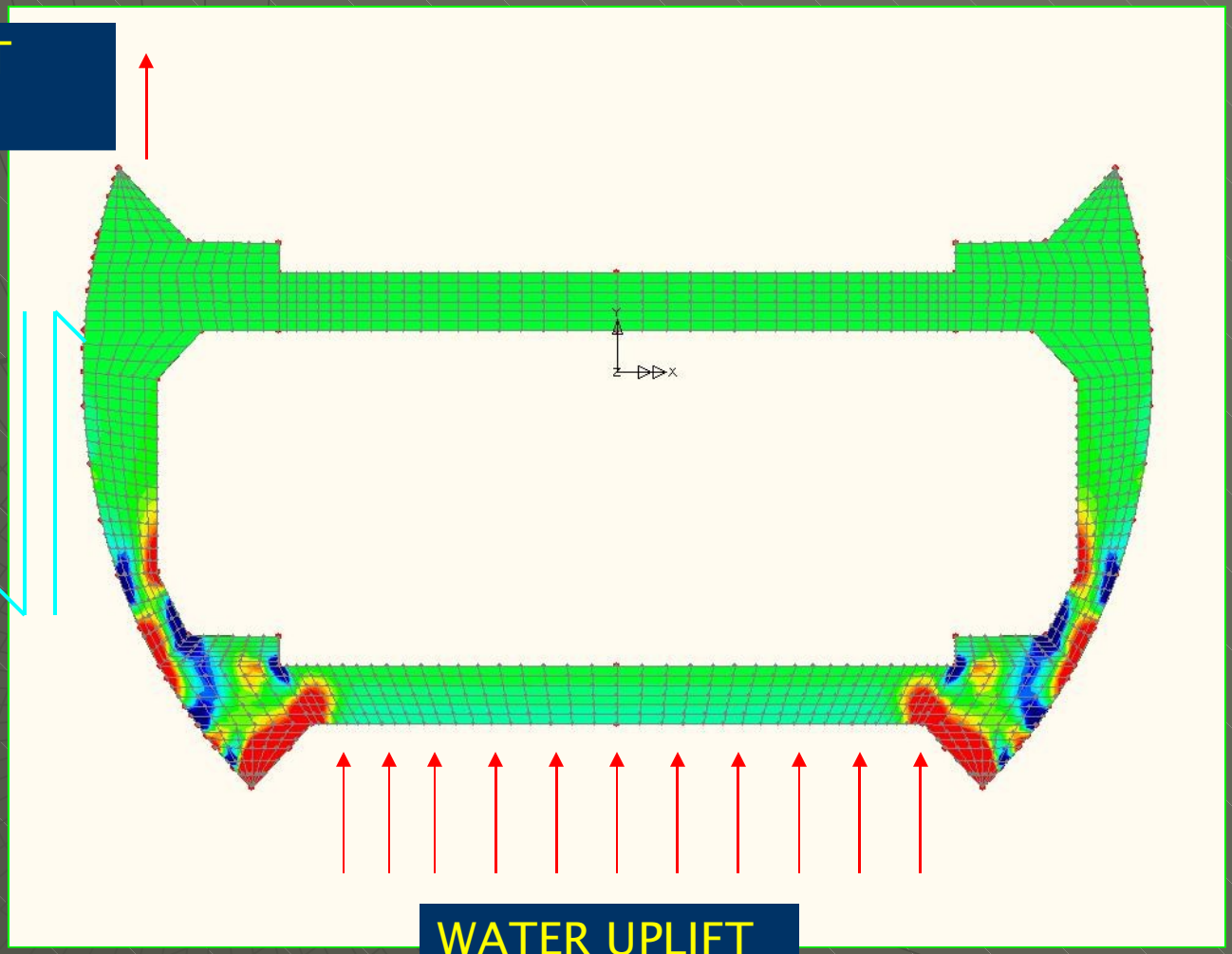
MOTORWAY TUNNEL CROSS SECTION



ANALYSIS OF ROAD DECK

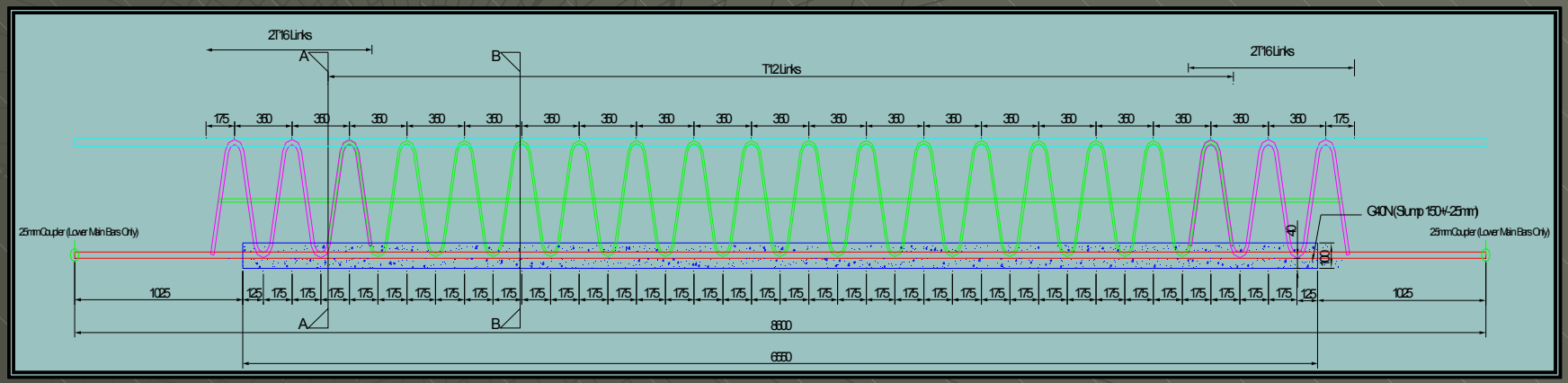
RESULTANT FORCE UP

LOAD TRANSFER TO SEGMENTS (TENSION AND SHEAR)



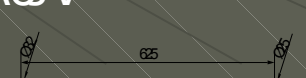
WATER UPLIFT

ROAD DECK

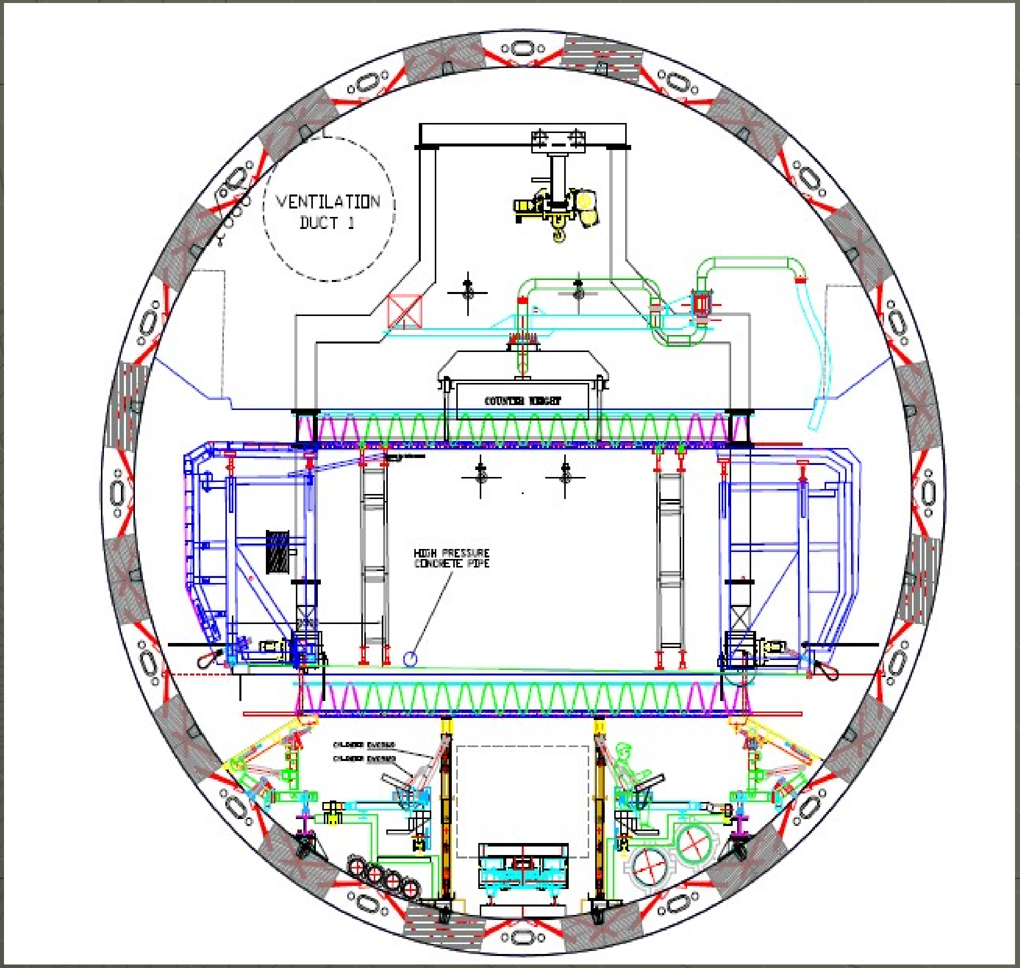


LONGITUDINAL SECTION

SCALE 1:125



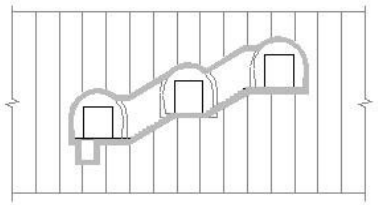
ROAD DECK CONSTRUCTION

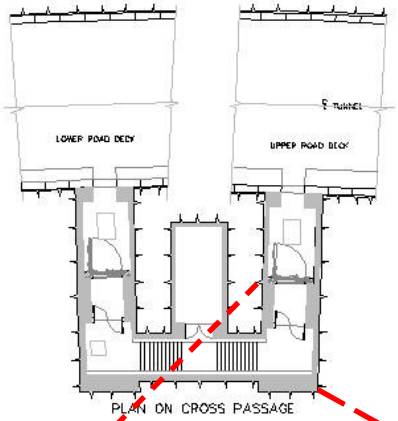


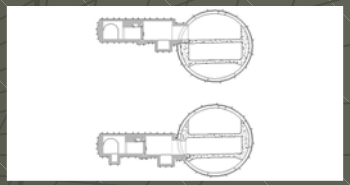
ROAD DECK CONSTRUCTION

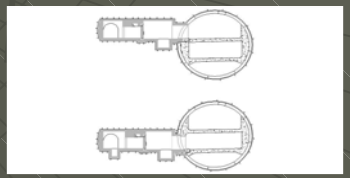
CROSS or ESCAPE PASSAGES AT 250M INTERVALS

Provide escape to smoke free environment between road decks









CROSS PASSAGE CONSTRUCTION

HOLDING POND & FOUNDATION OF THE WATER INTAKE TOWER

TWIN BOX CULVERT AT TAMAN DESA

TIME-CHAINAGE DIAGRAM SOUTH TUNNEL

TIME CHAINAGE DIAGRAM
NORTH TUNNEL

THE UPPER ROAD DECK BEFORE OPENING

THANK YOU

FOR YOUR PATIENCE