Lecture 9 Special constructions

1st Hour

- U-polder and Membrane polder
- Surface level tunnels / New developments

2nd Hour

- Tramtunnel

Delft University of Technology, faculty of Civil Engineering

Dr. Ir. W. Broere and Ir. S. van der Woude

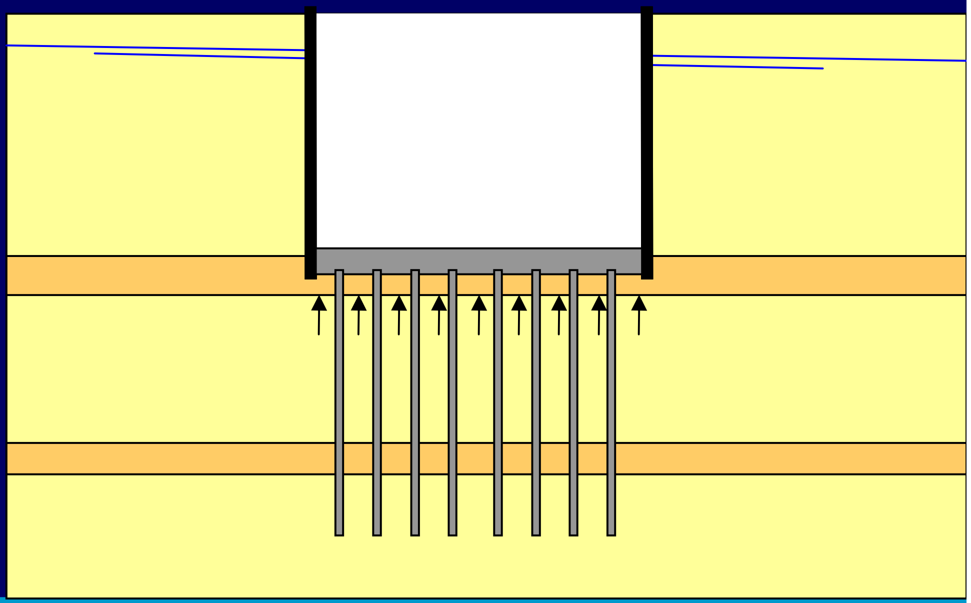
27 February 2009

Traditional Construction

- River crossings
  - As short as possible
  - As confined as possible

- Sheet pile walls
- Underwater concrete floor
- Tension piles

- Objective
  - As cheap as possible

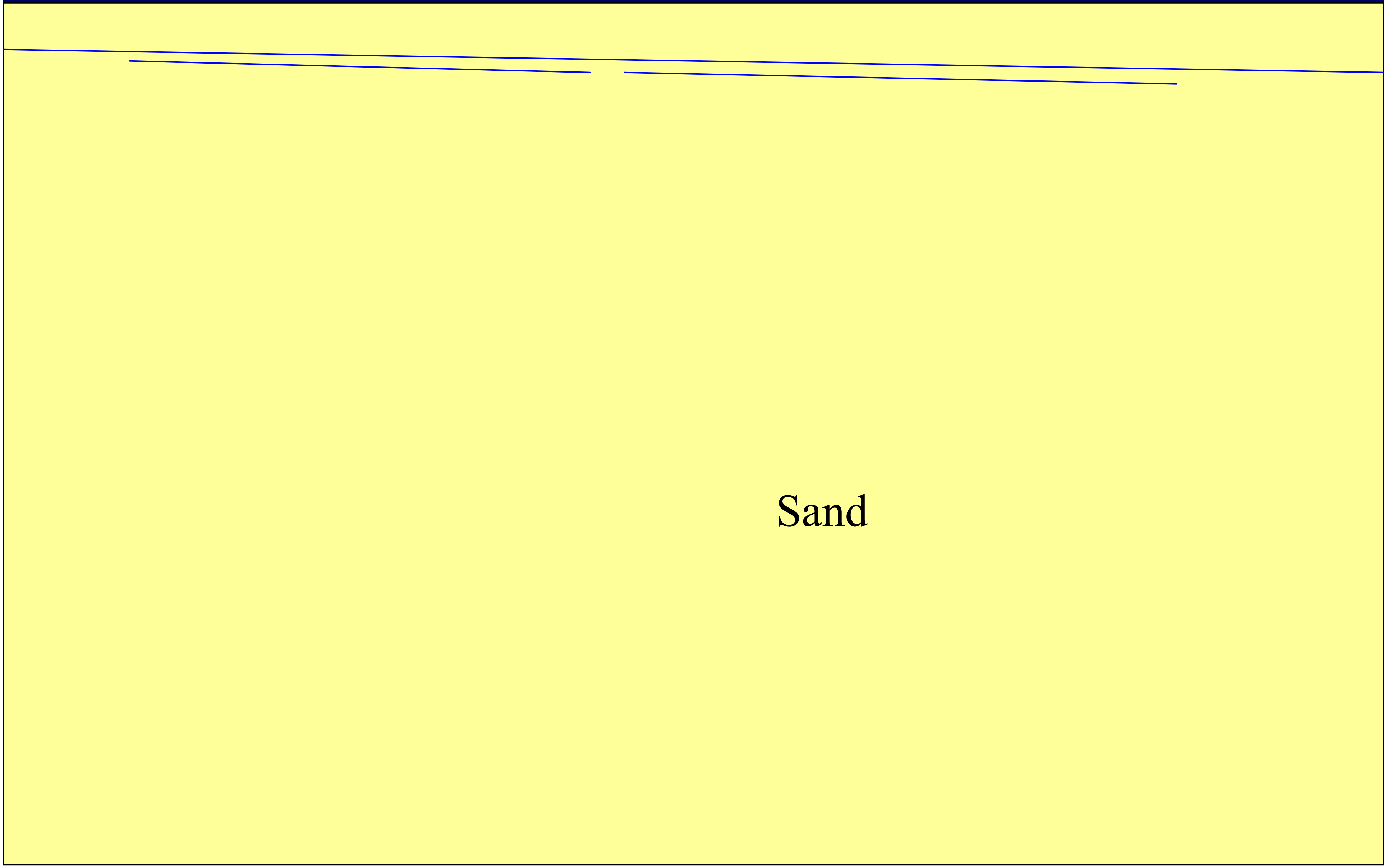


TU Delft

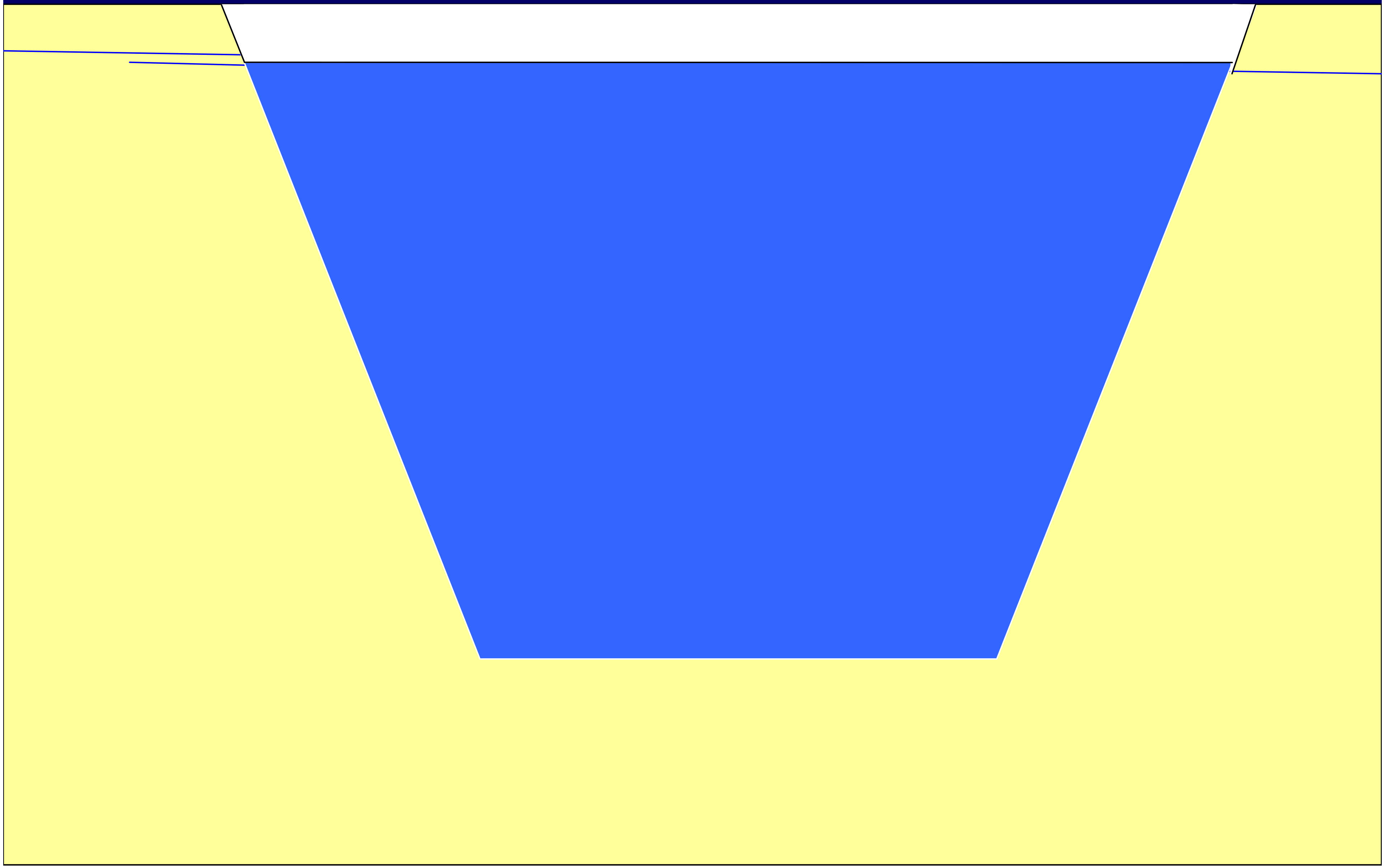
Aqueduct Gouda

Access roads to tunnel Dordrecht

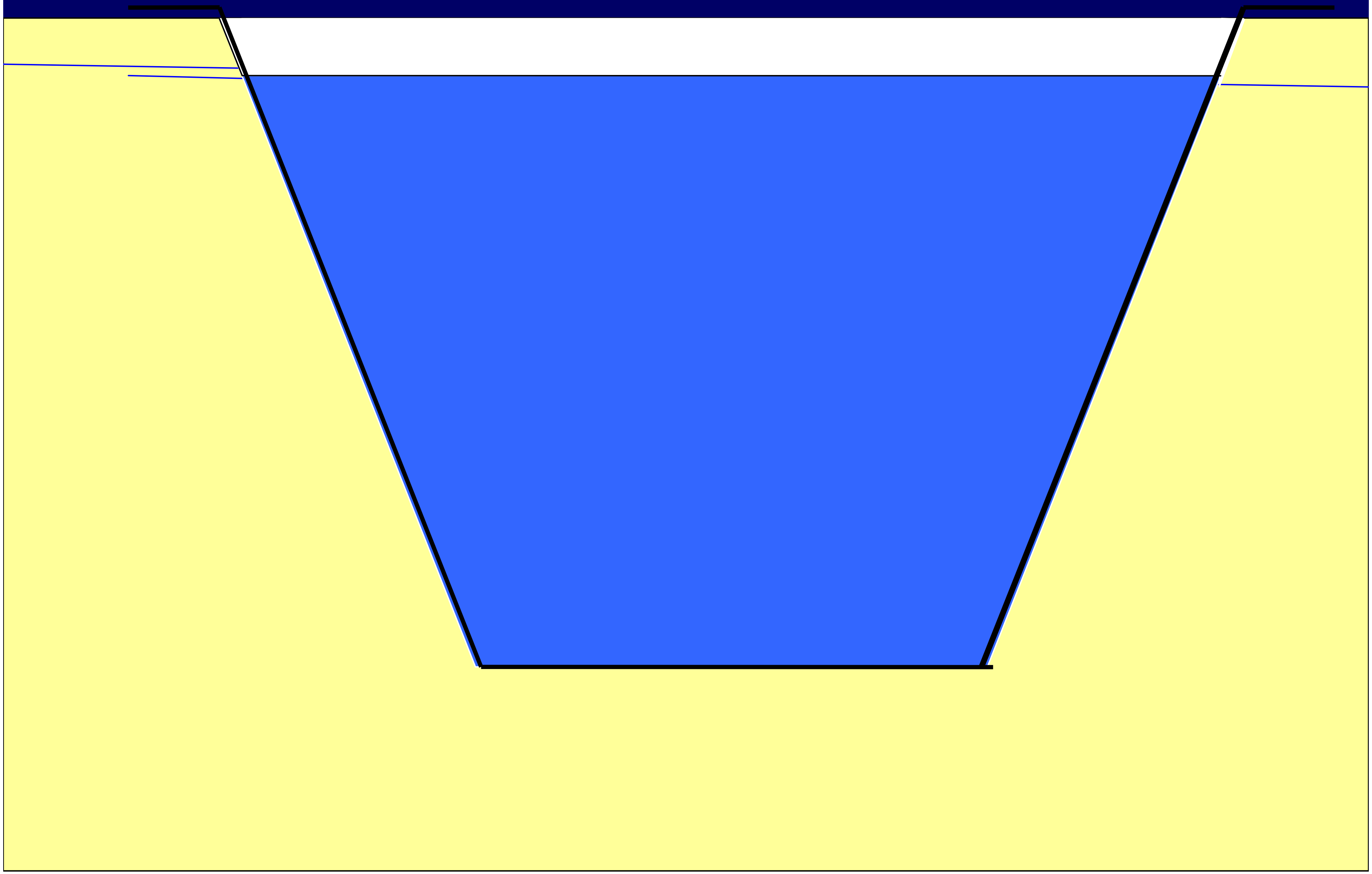
The Dredging alternative



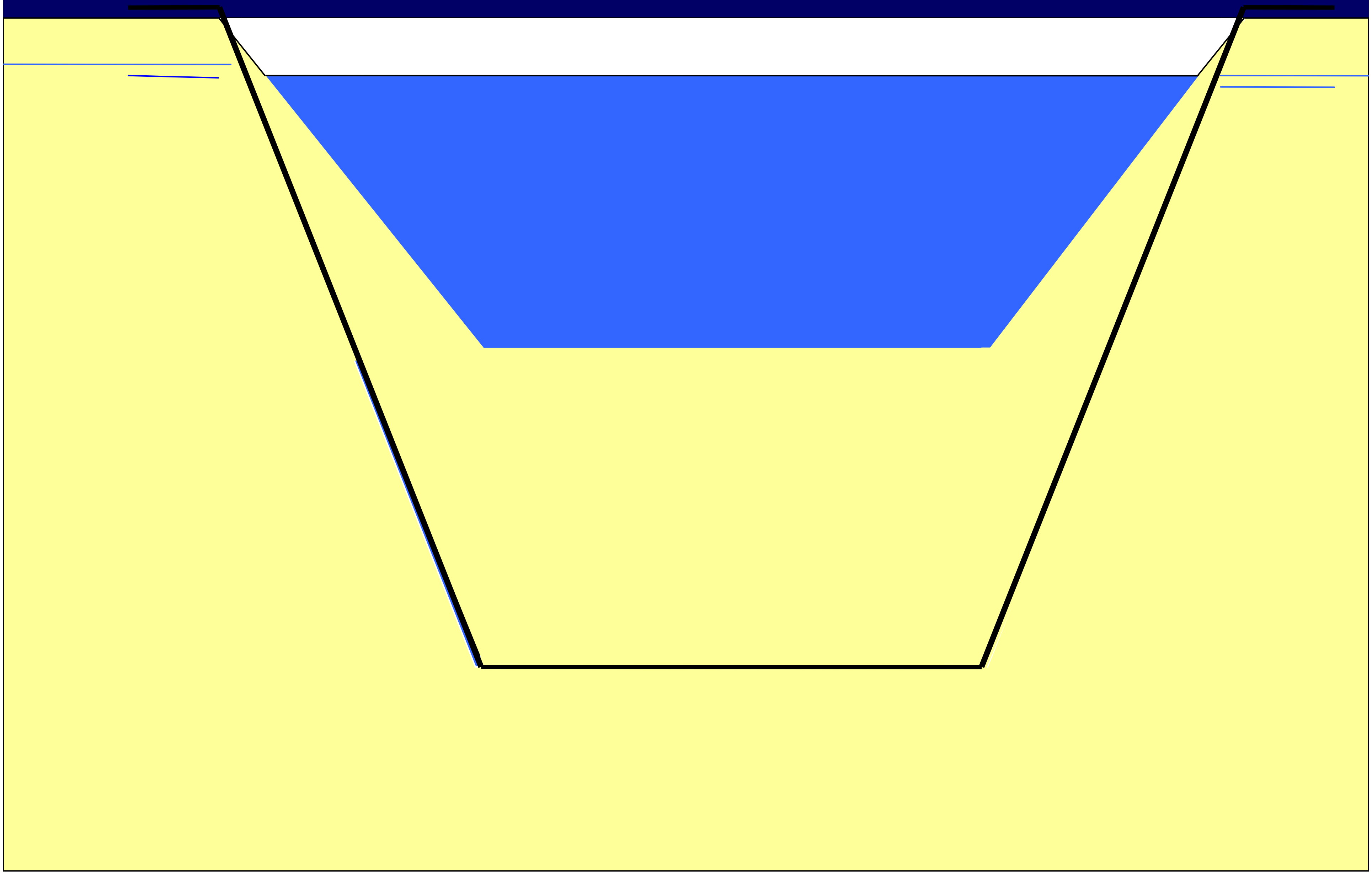
Step 1 : Dredging a deep channel



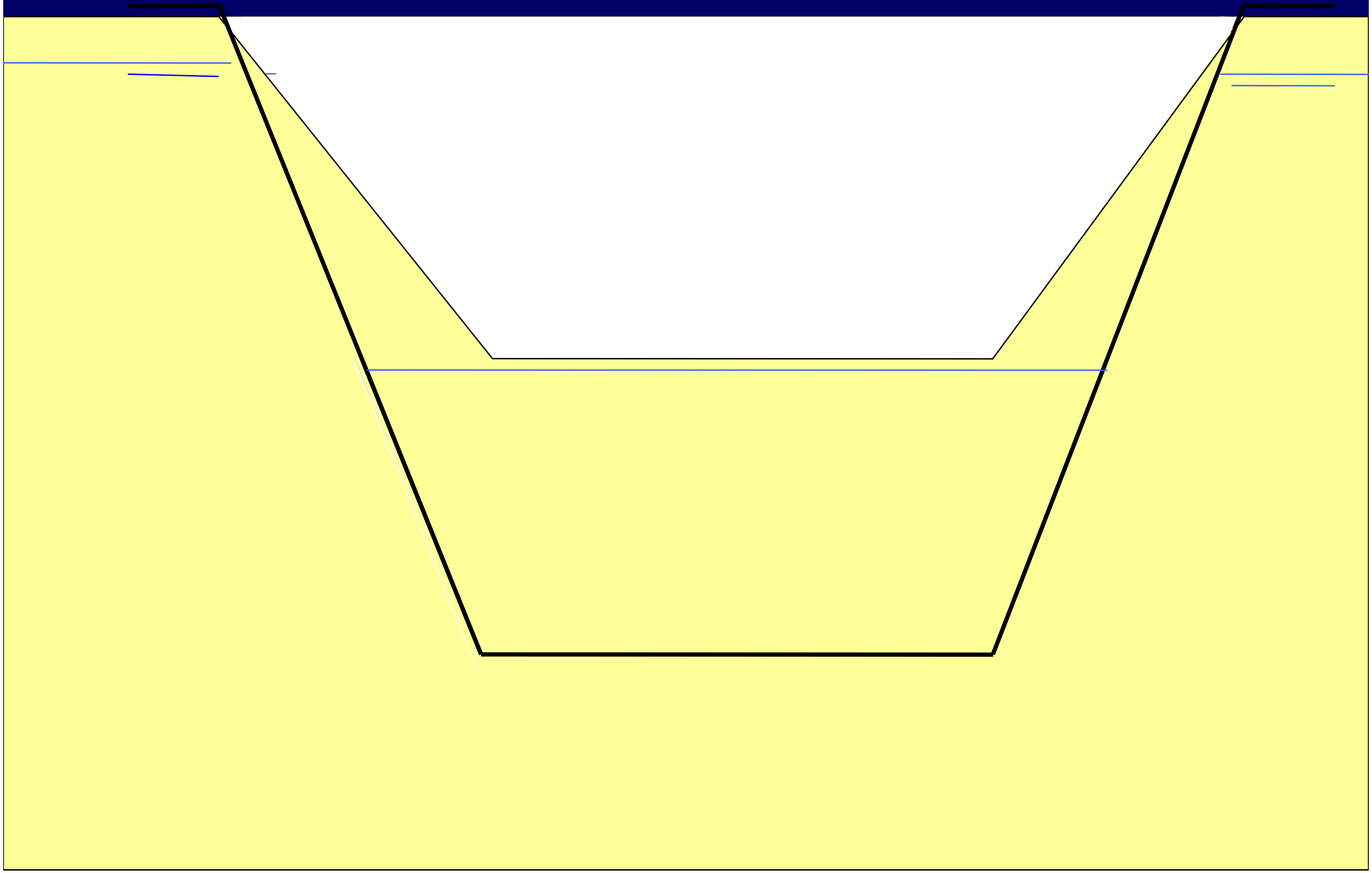
Step 2 : Installation of impermeable membrane



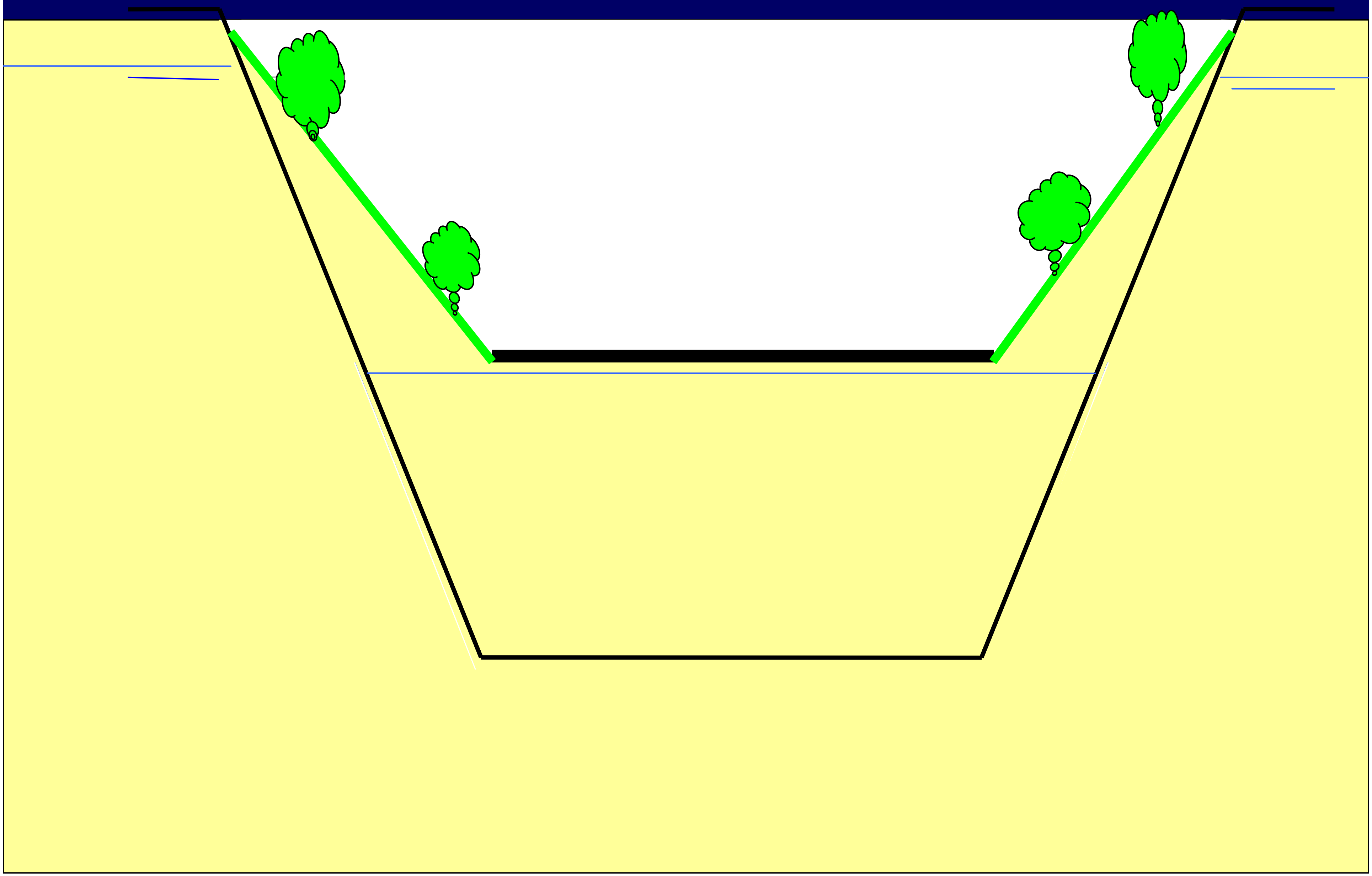
Step 3 : Partial refilling with sand



Step 4 : Lowering of the ground water table



Step 5 : Construction of road and green slopes

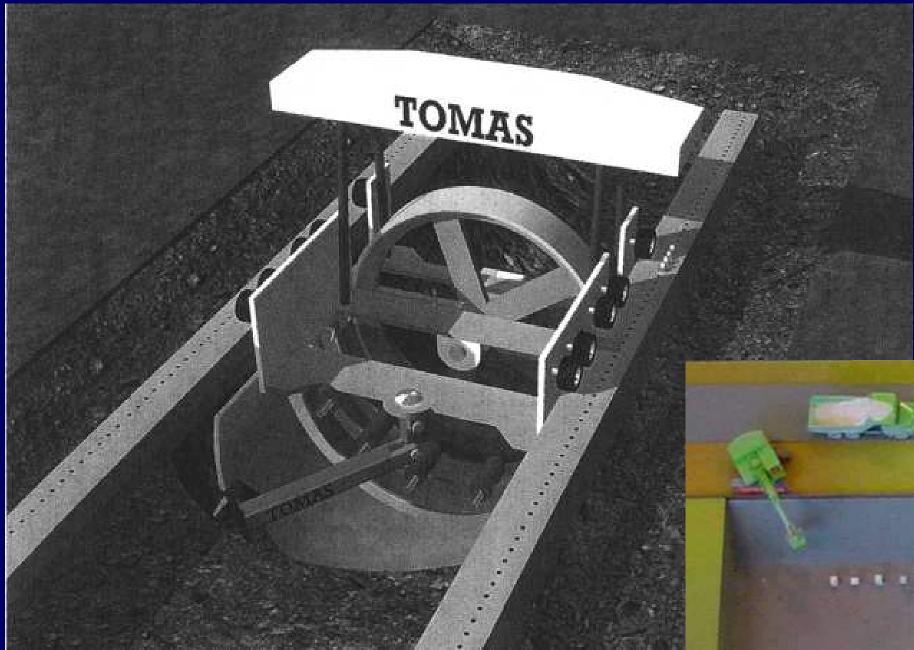


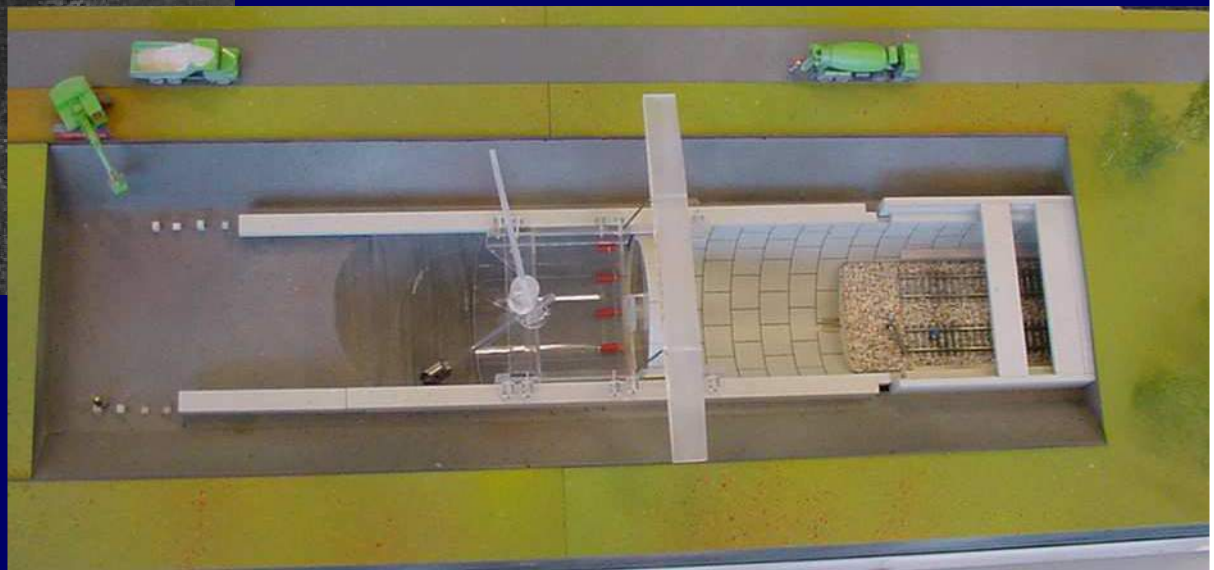

700 m
Grou
Idaerd
Jirnsum

Surface level tunnels
(special construction techniques / new devlopments)

- Tomas
- V-polder
- Supported membrane-polder
- U-polder
- Hollow dike
- Submerged tunnels
- Above ground tunnels

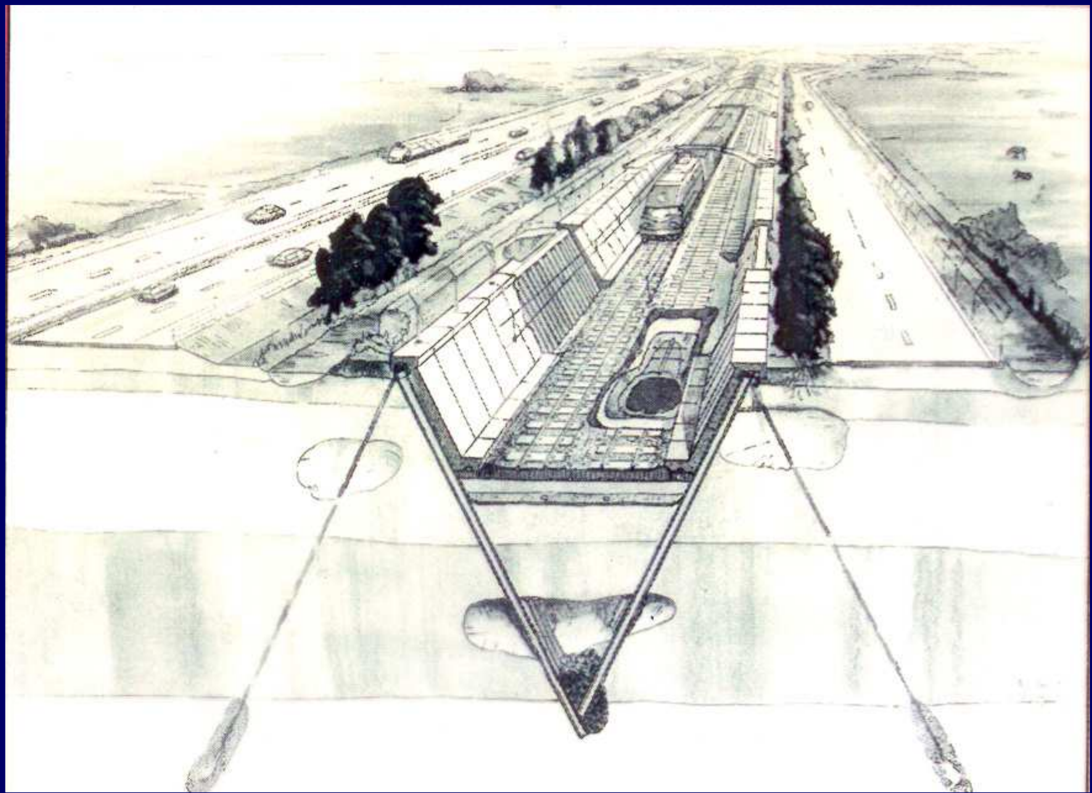
New developments TOMAS

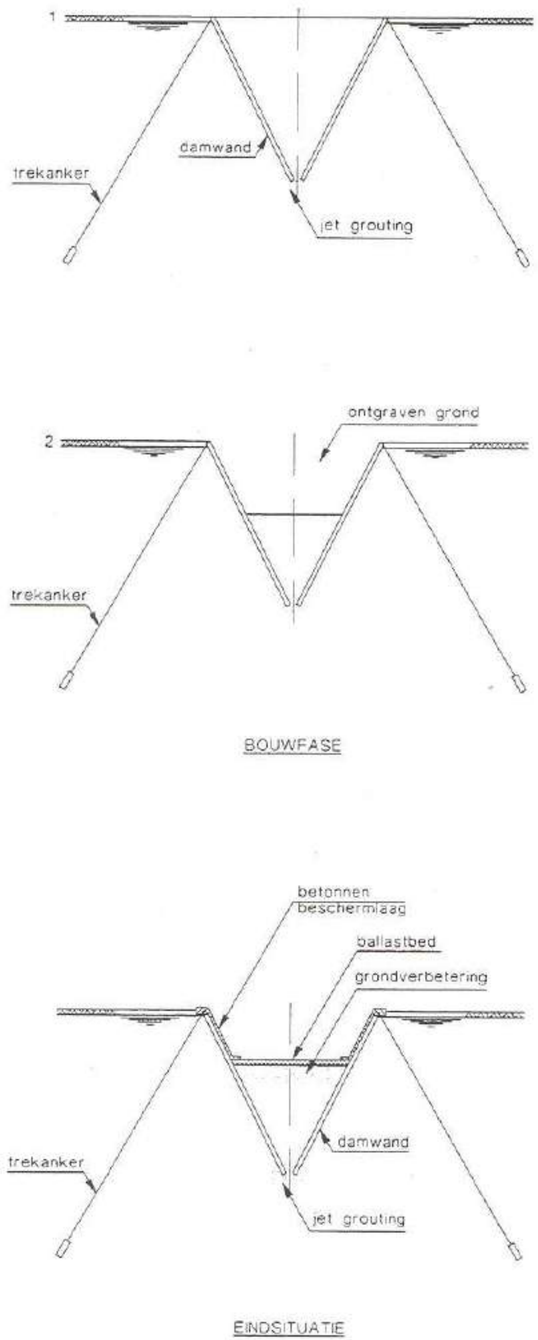




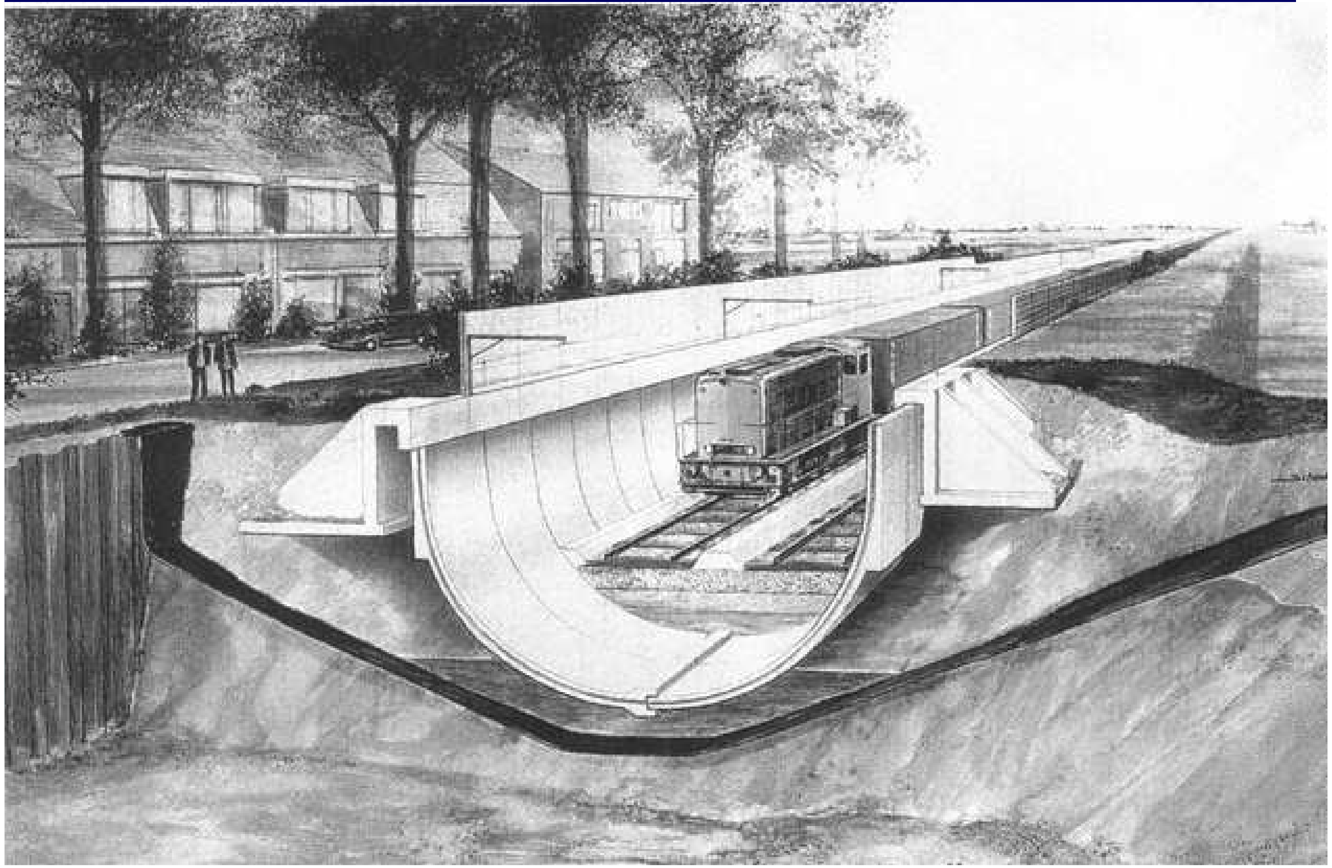
TU Delft

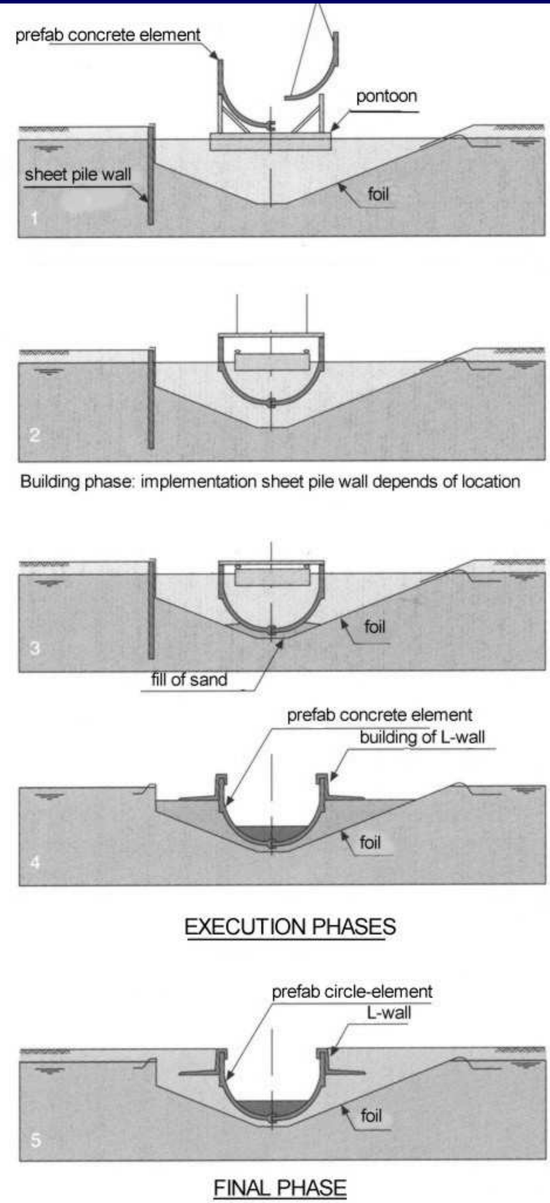
New developments
V-polder



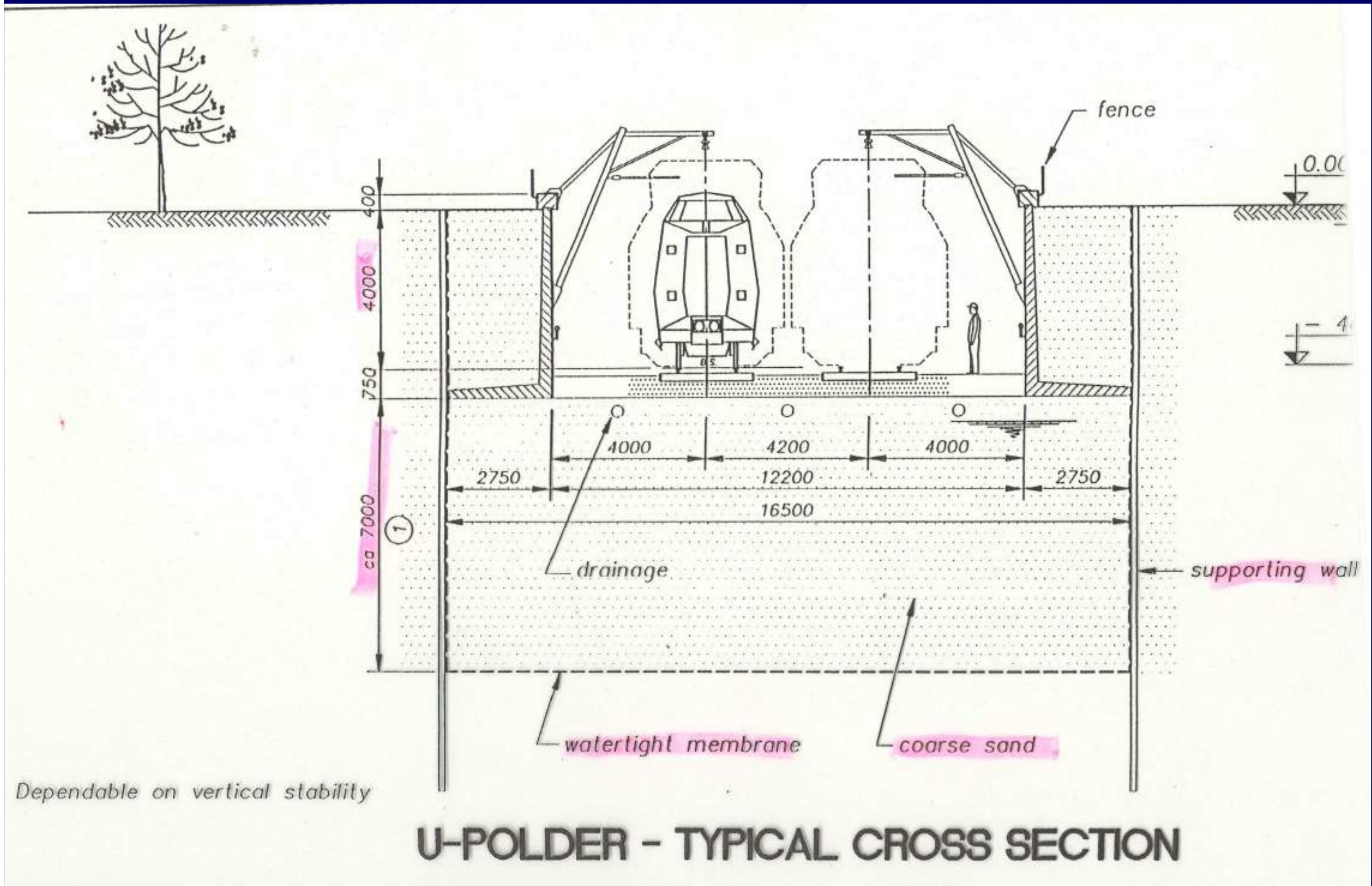


New development –special techniques membrane- polder



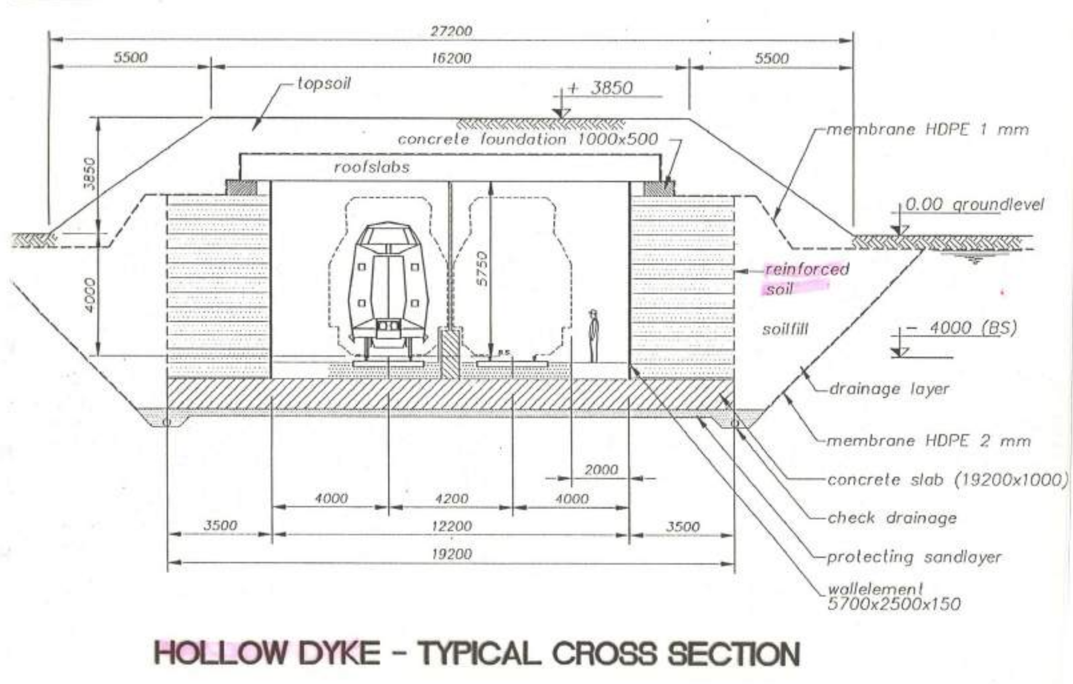


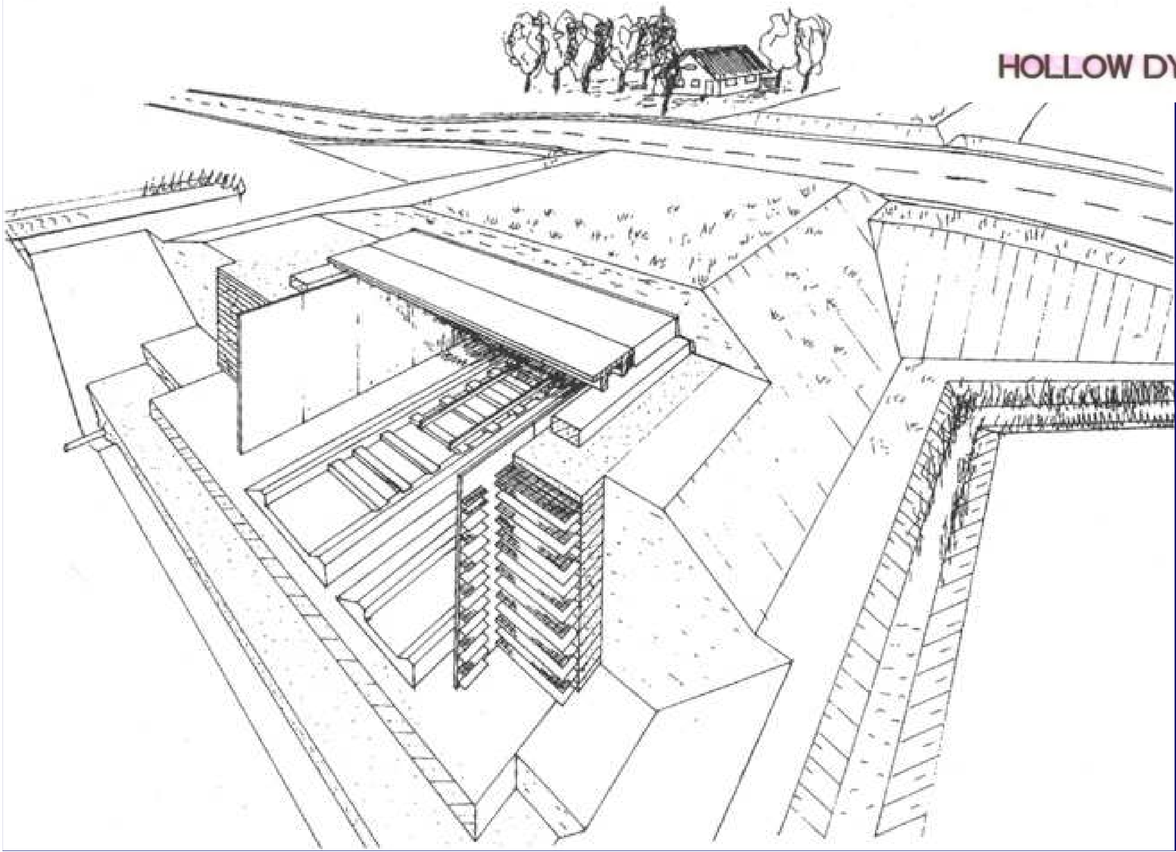
New developments Special techniques U-polder



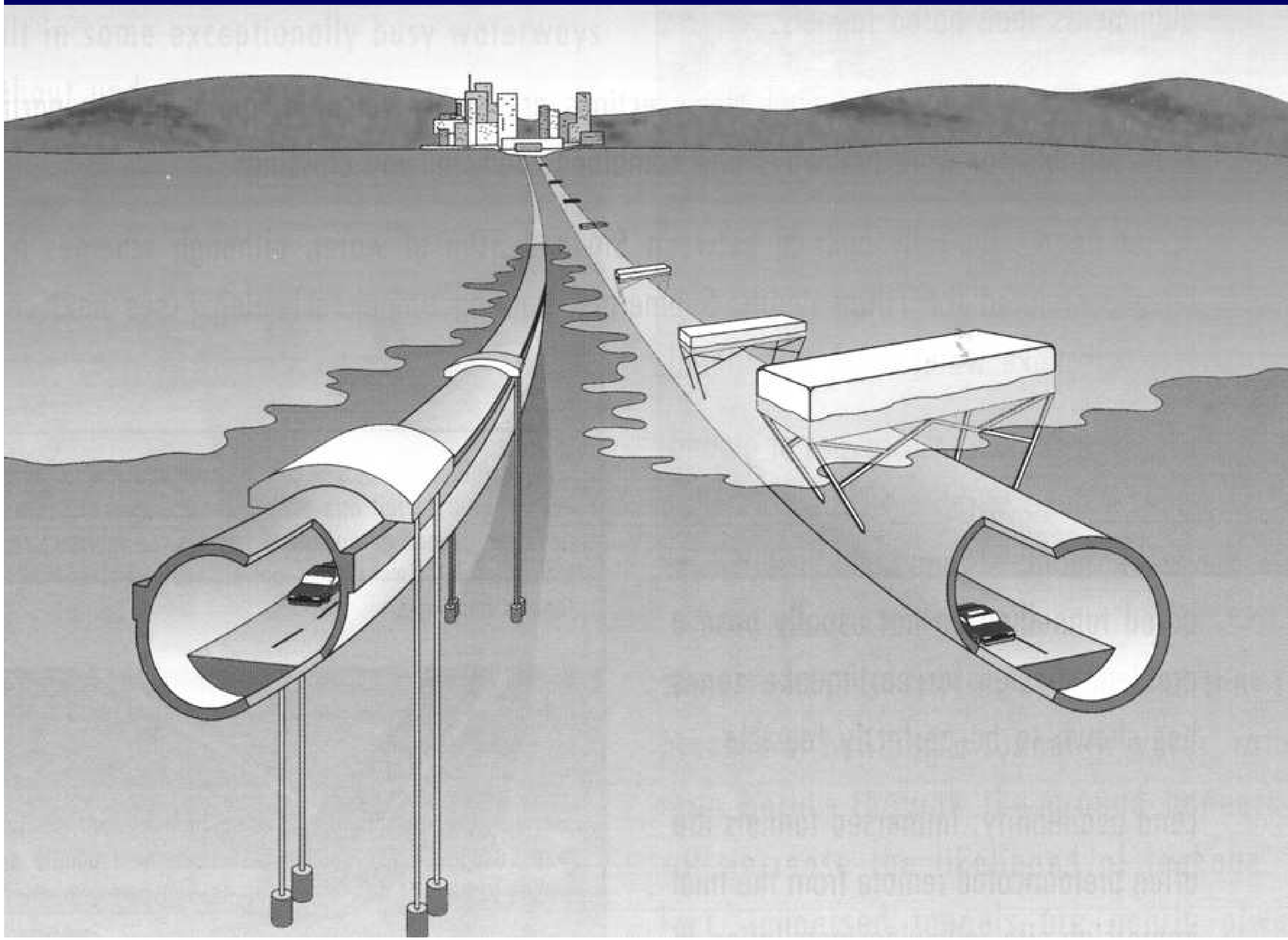
TU Delft

New developments
Hollow dike

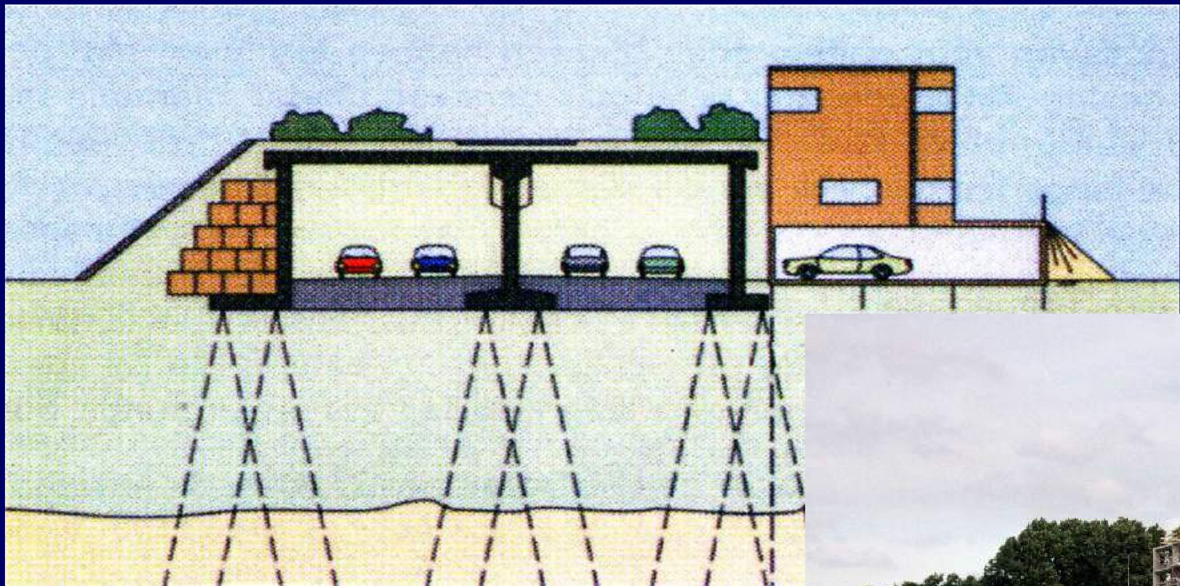




New developments submerged tunnels



New Developments Above ground tunnels



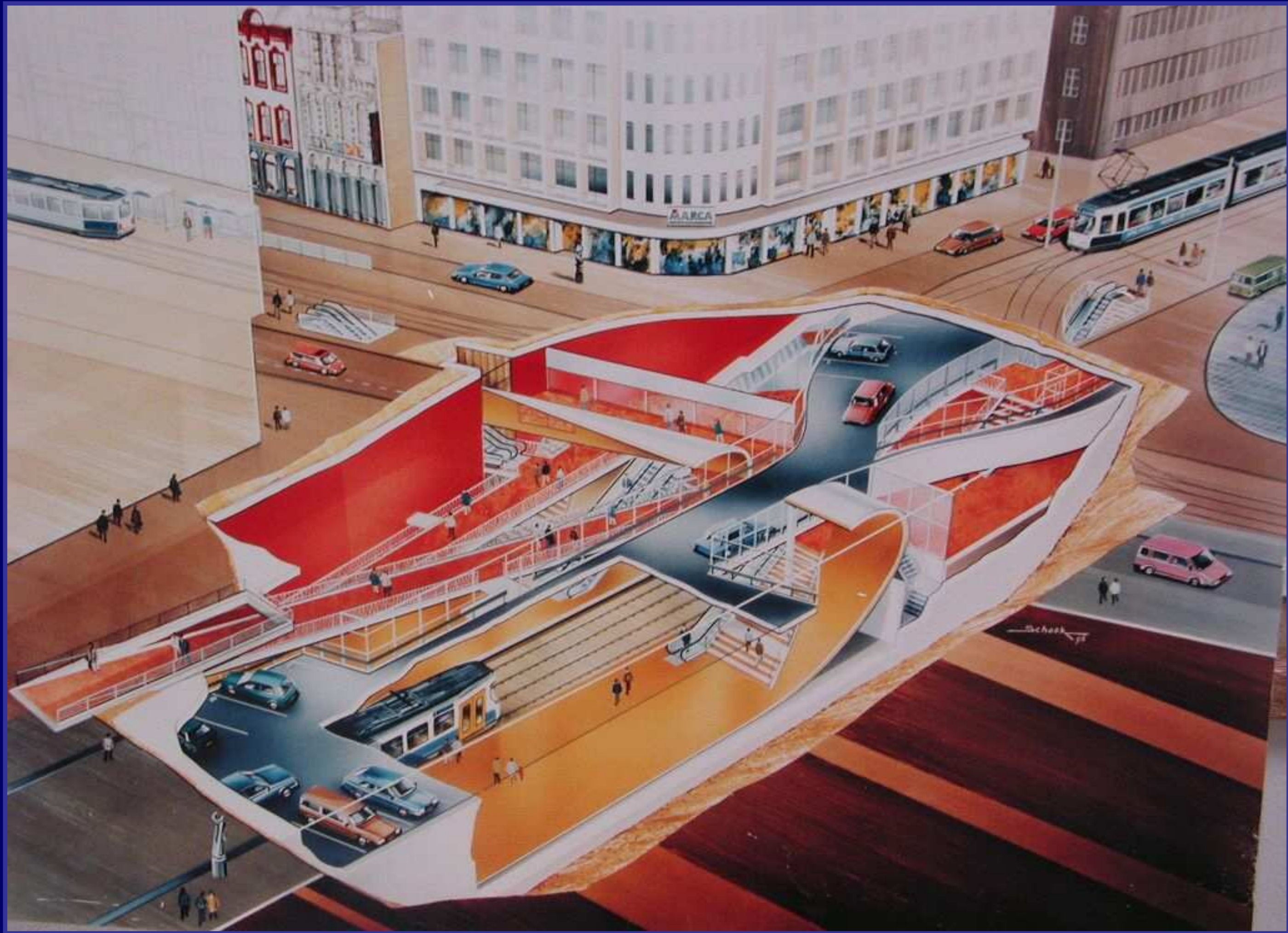
- Sijtwende

Case study Tramtunnel The Hague

- Introduction project
- Top down and reduced hindrance for the surroundings
  - Diaphragm walls >>>construction method
- "Challenging" Design
  - Grout Arch >>>construction method
  - Gel injections >>>construction method
- What went wrong?
- How was it solved?
- Lessons learned
  - Based on evaluation report of Prof. van Tol

TU Delft

Tramtunnel, introduction project



TU Delft

Tramtunnel, introduction project

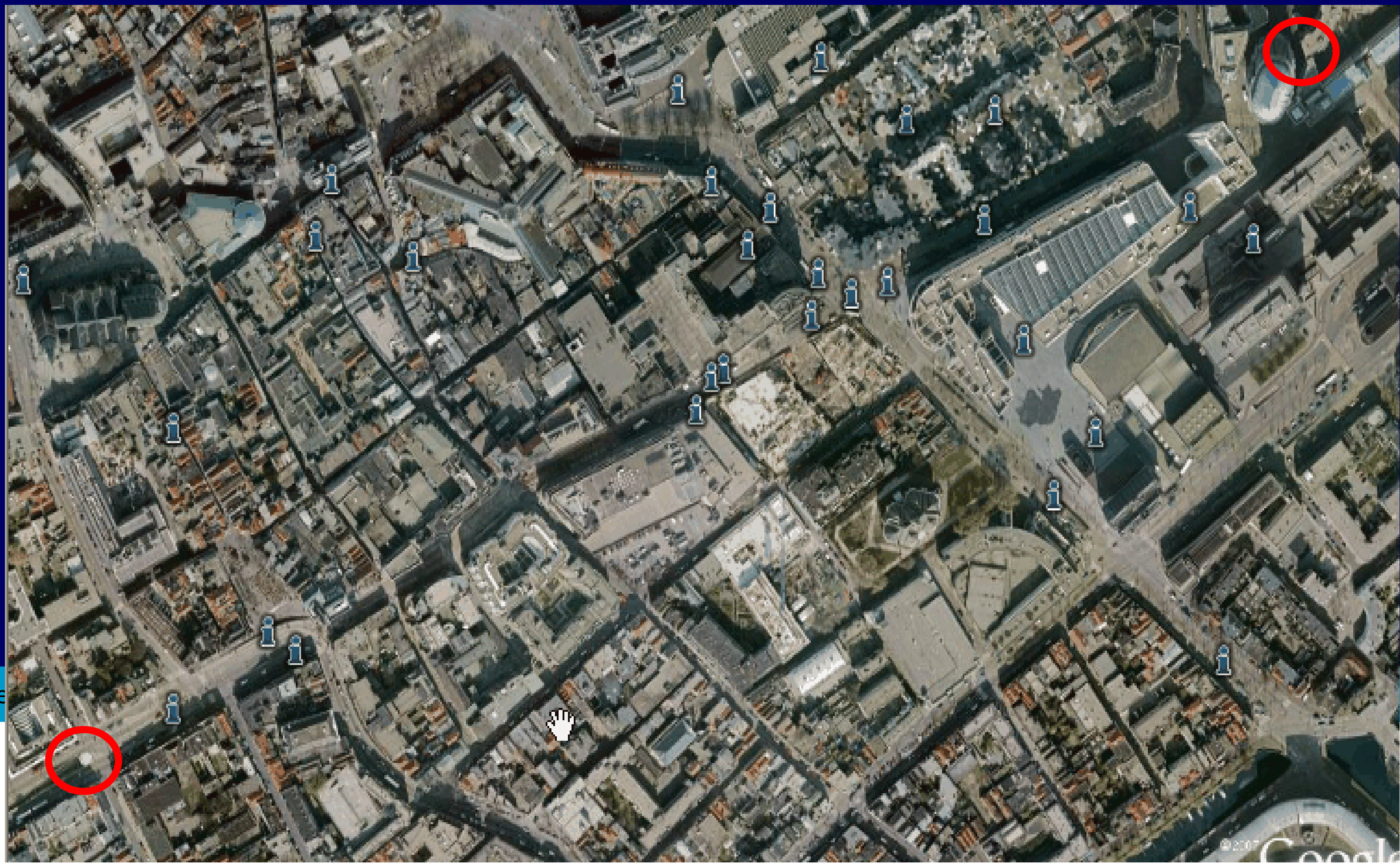
- Length 1250m
- 2 stations (“Grote markt” and “Spui”)
- Rail level -13,5m (surface level +2m)
- Opened in 2004

- Geology mainly sands and silts
- no reliable “impermeable” layer available

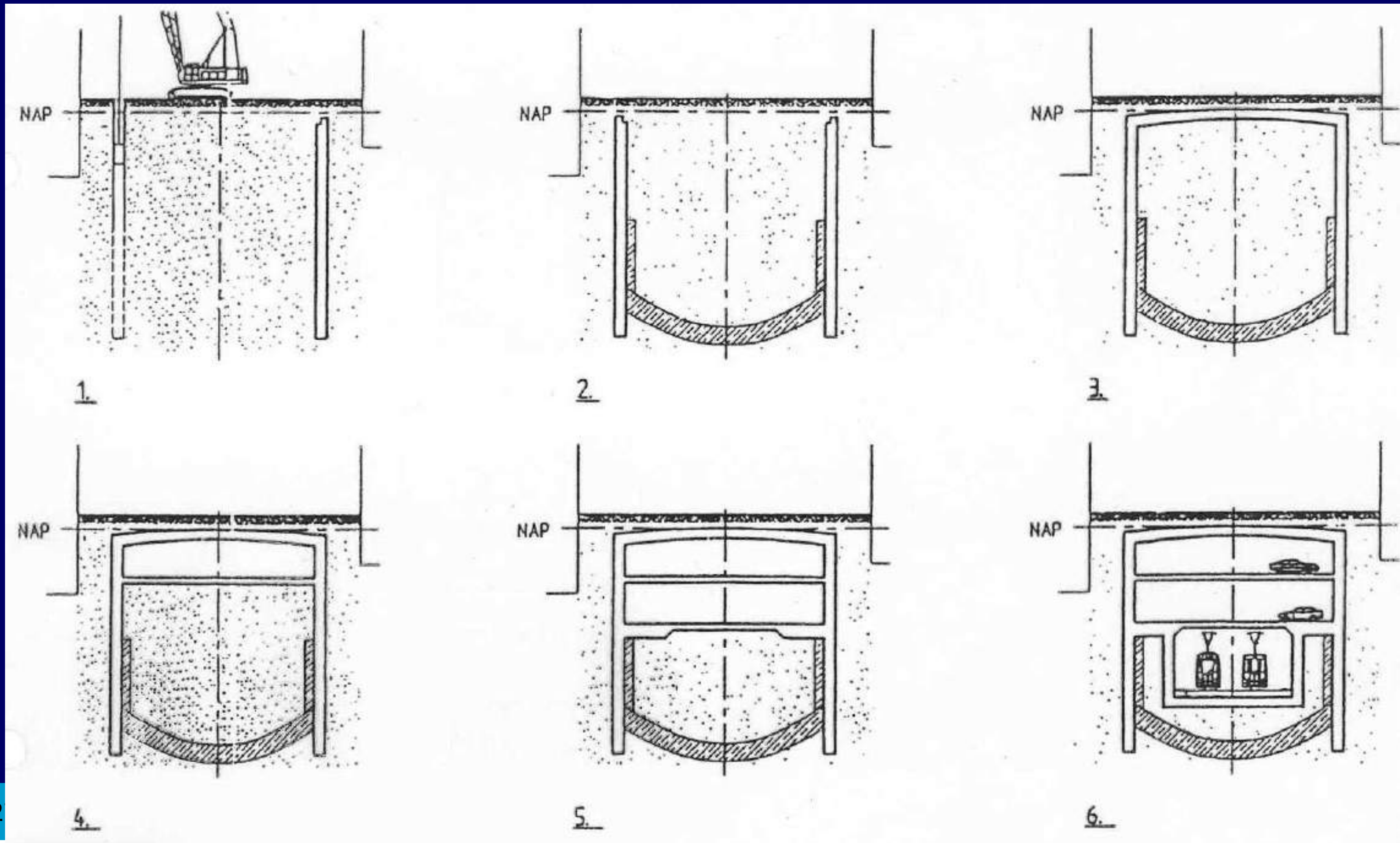
- Hindrance must be reduced to a minimum.
- >>> diaphragm walls (d-walls) (geology is suitable)
- >>> top down method

Tramtunnel, introduction project

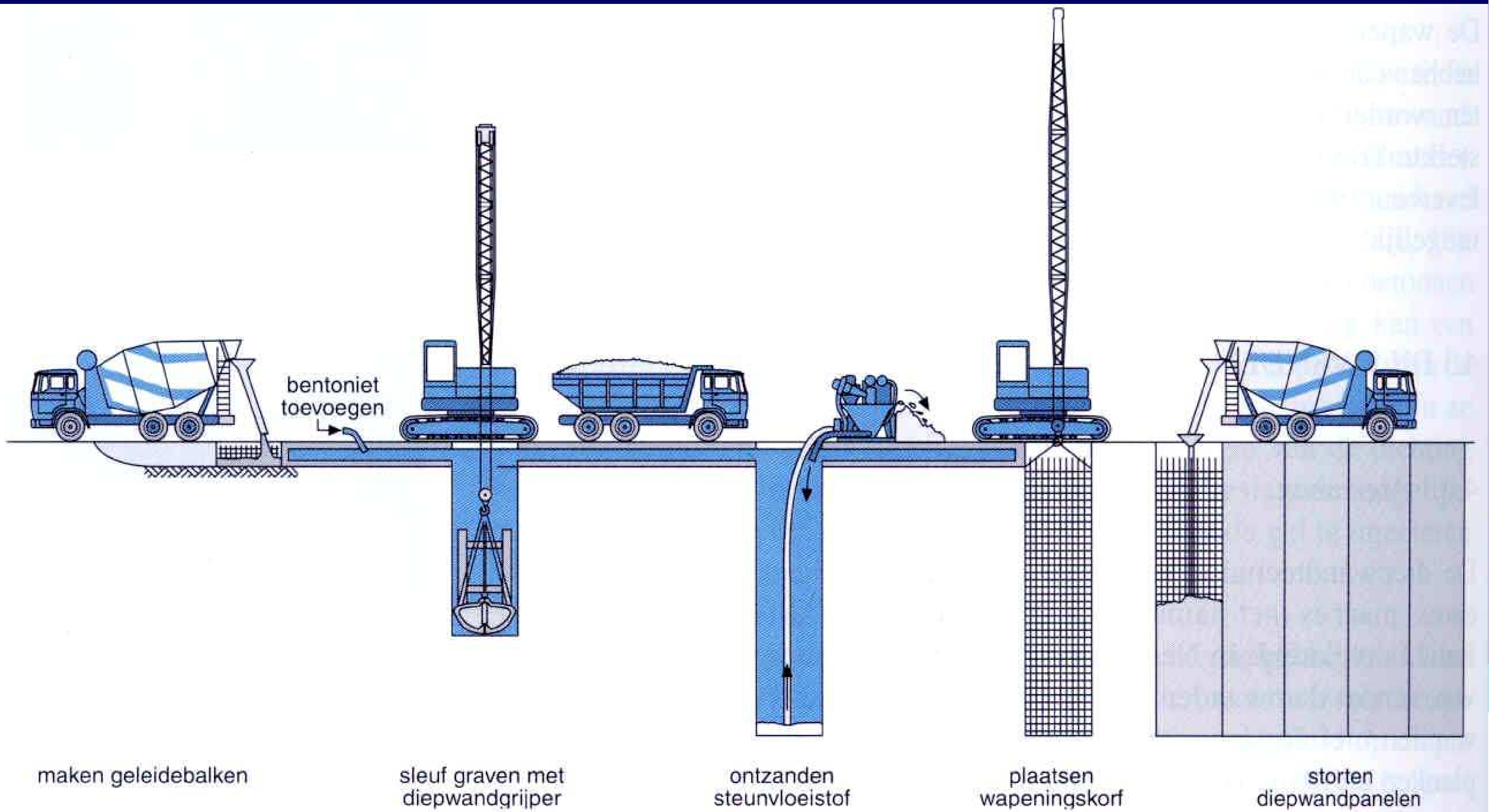
- A tunnel for the Tram combined with parking space below surface in the inner city of The Hague. The busiest part in town.

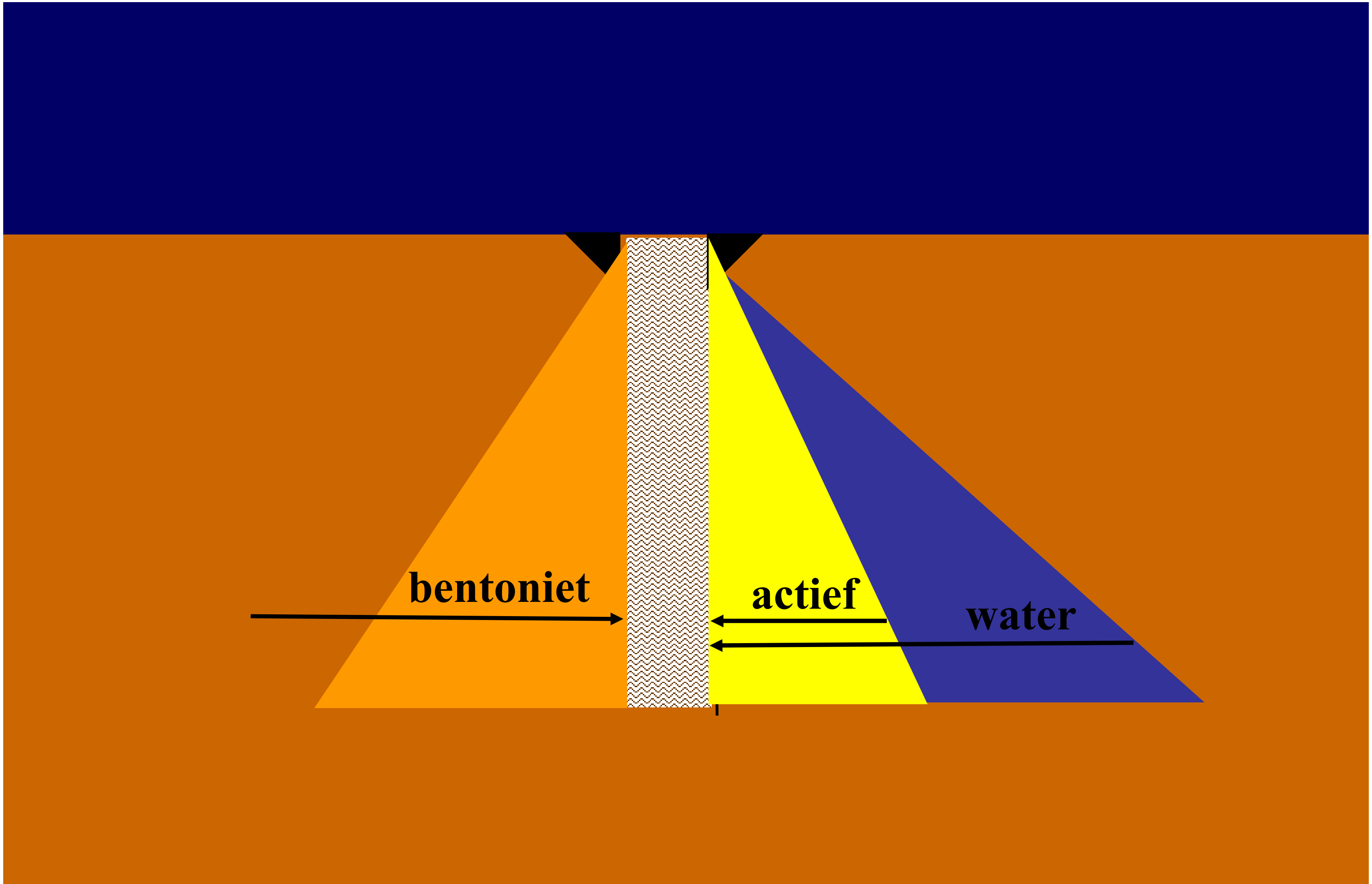


Tramtunnel, Top down D-walls



Tramtunnel, Top down D-walls





TU Delft

Tramtunnel, i

Minimized hindrance does not mean

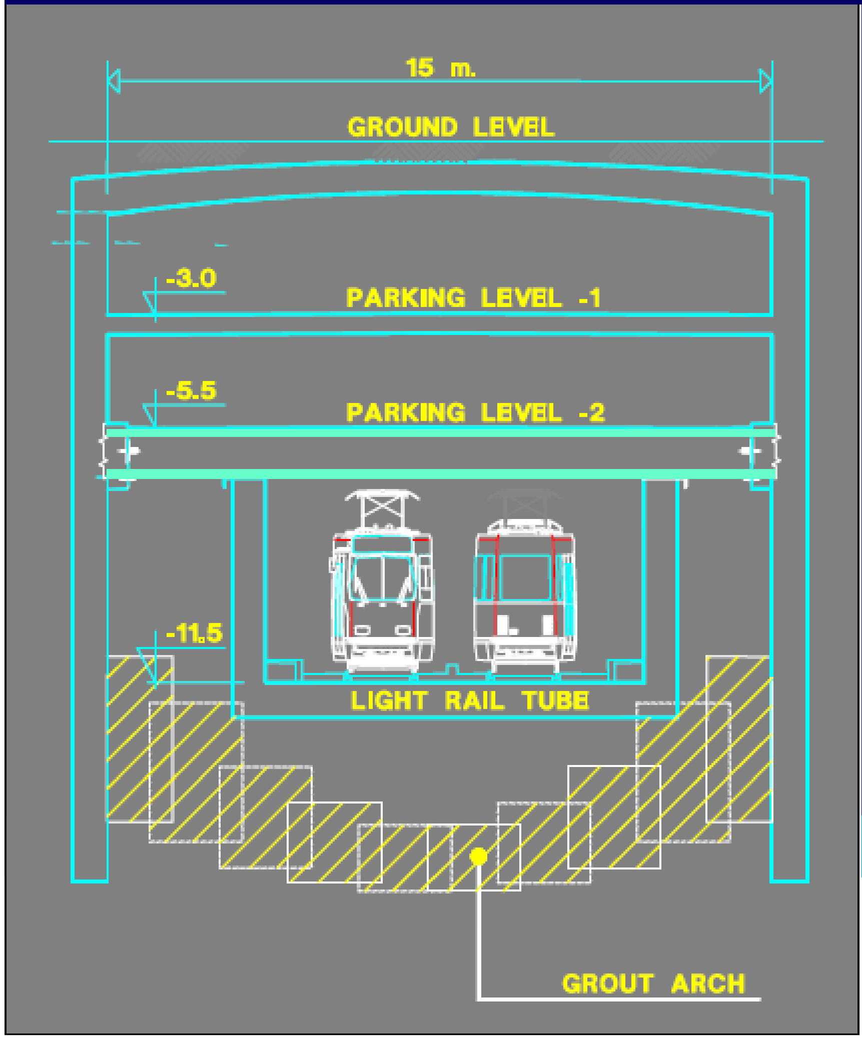
No hindrance

Tramtunnel,

Minimized hindrance does not mean
No hindrance

Tramtunnel, “challenging” design

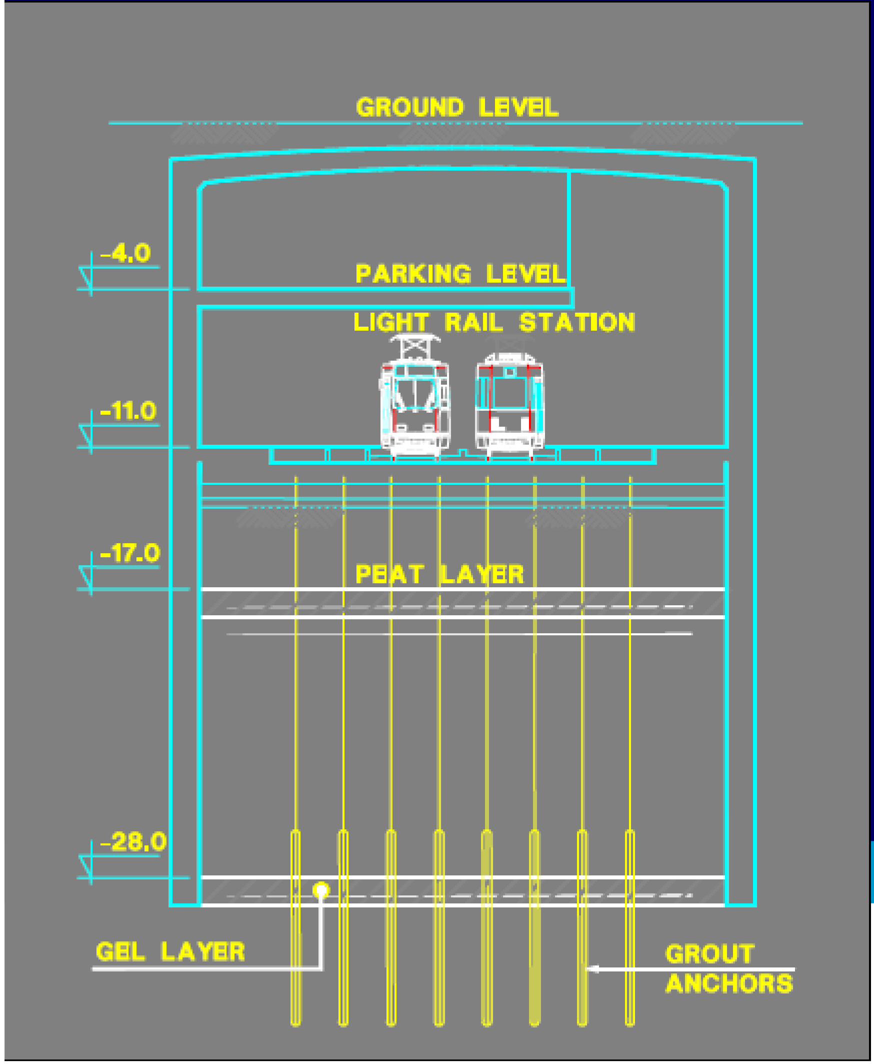
- Cross-section Grote markt straat



- Conventional Contract with Design risk “owned” by client
- Grout Arch Functions:
  - Strut below excavation level>>>
    - Short and slim D-walls
  - Sealing layer?
  - Discussion between client and contractor on the risks

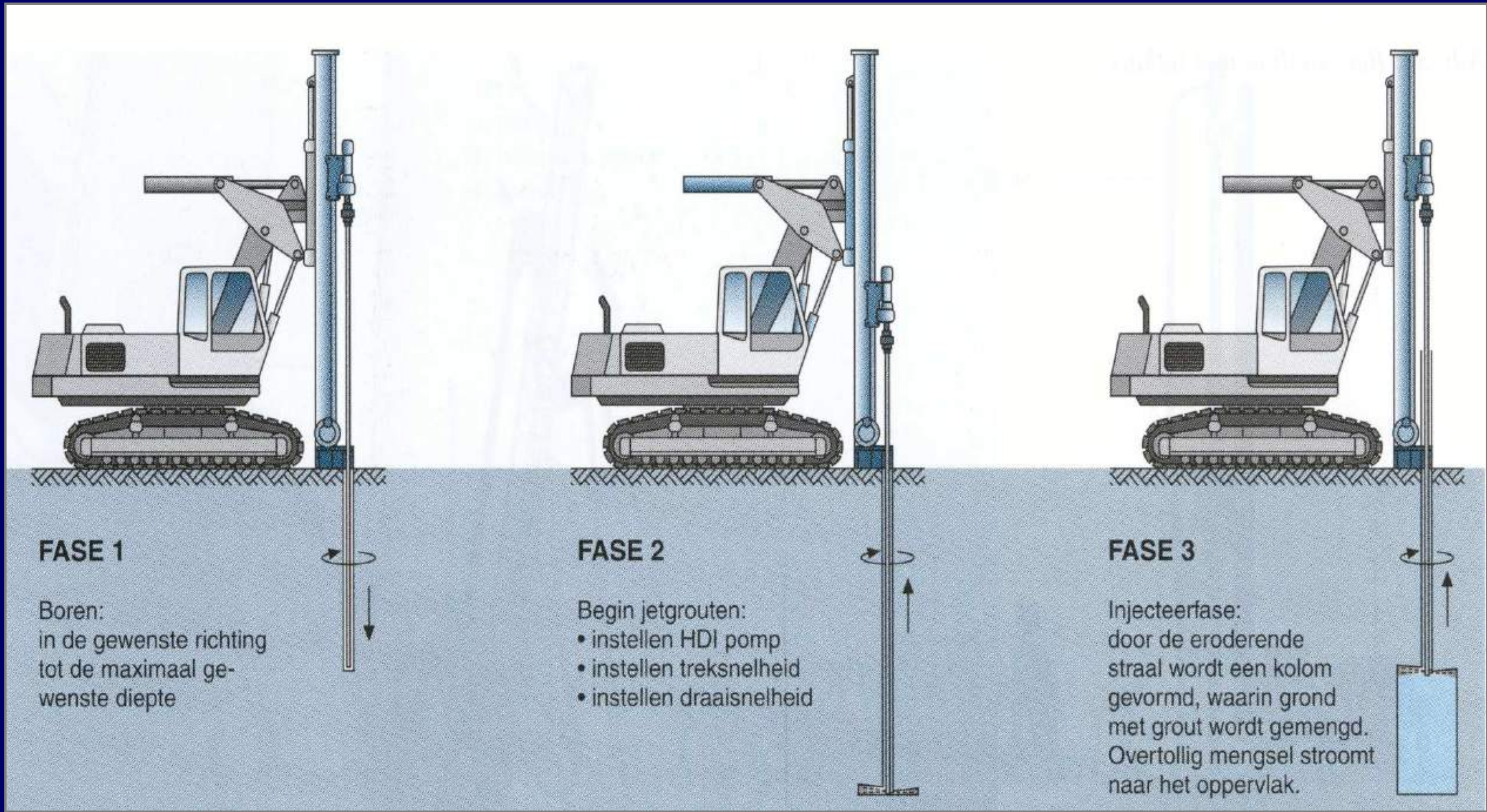
Tramtunnel, “challenging design

- Cross-section Spui

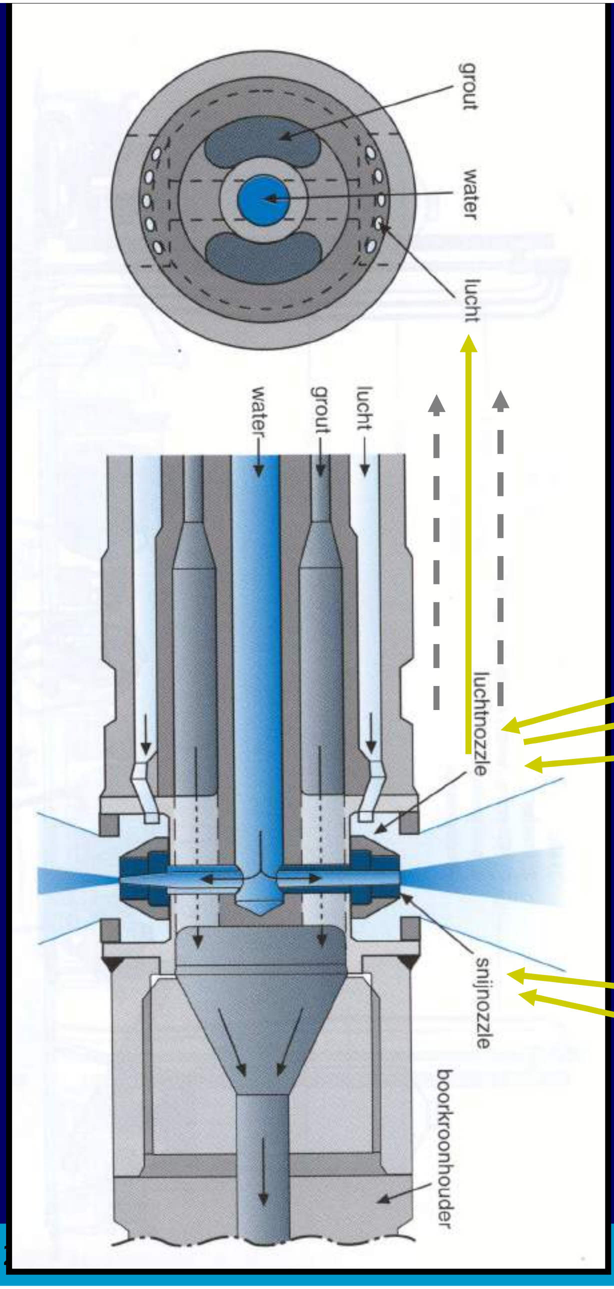


- Gel layer Functions:
  - Additional sealing extra to the peat layer to prevent “breaking up of the peat layer. (Combined with draining of the sand below the peat)

Tramtunnel, Jetgrouting



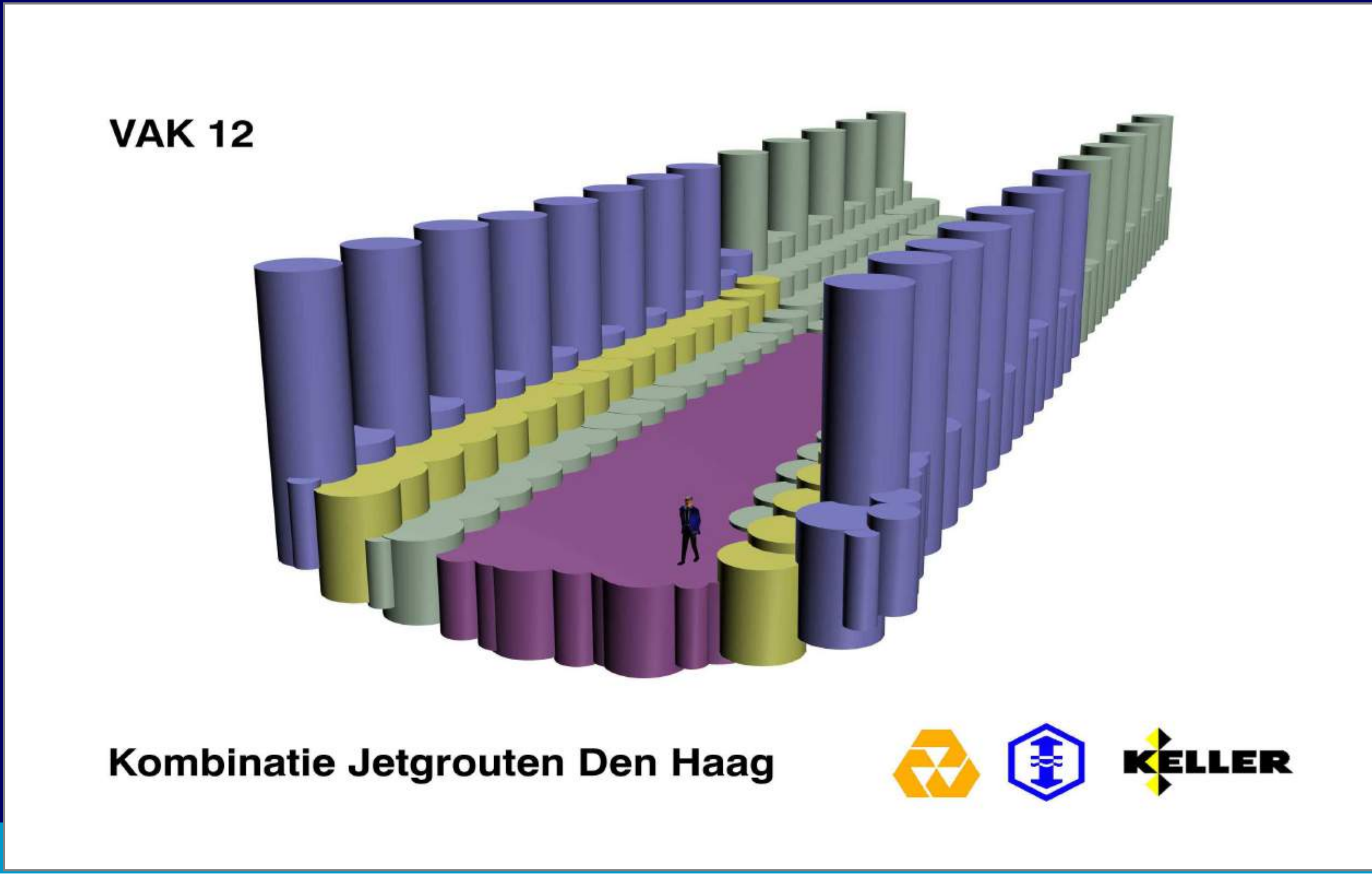
Tramtunnel, Jetgrouting



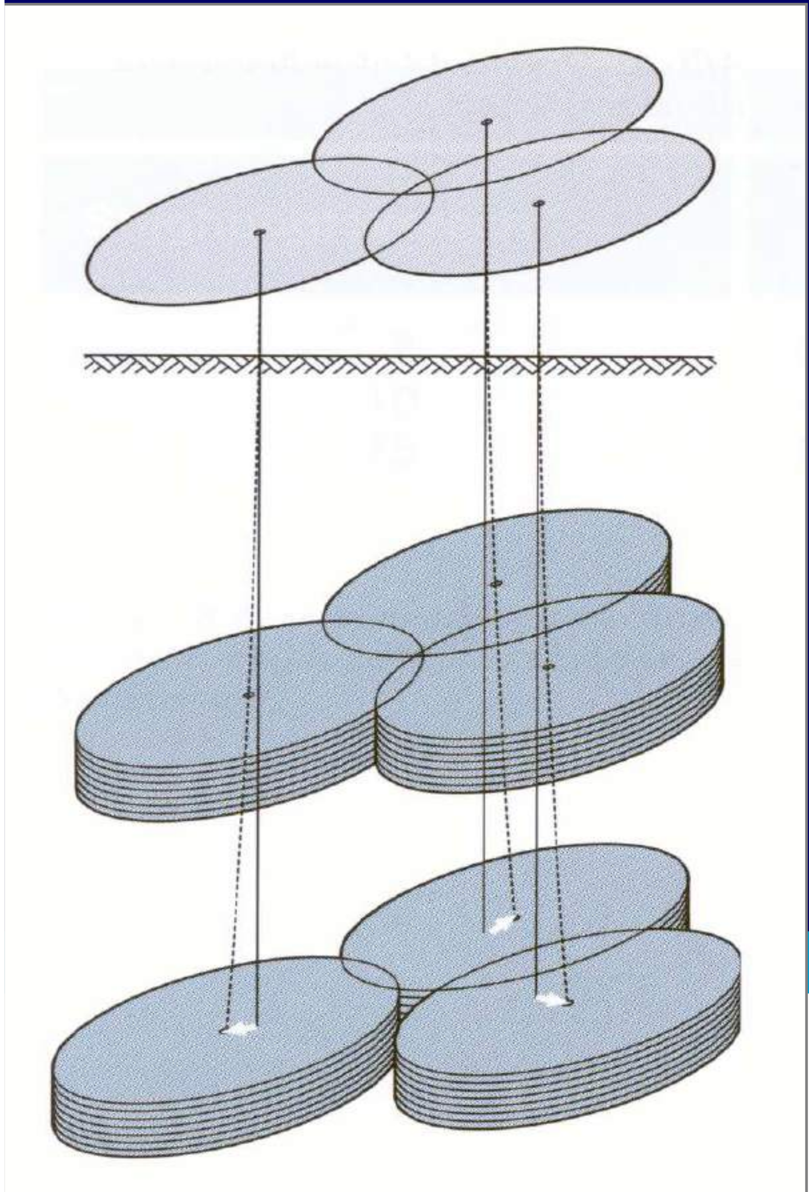
Jetting cutting: water & air

flushing: grout

Tramtunnel, Jet grouting



Tramtunnel, Jetgrouting

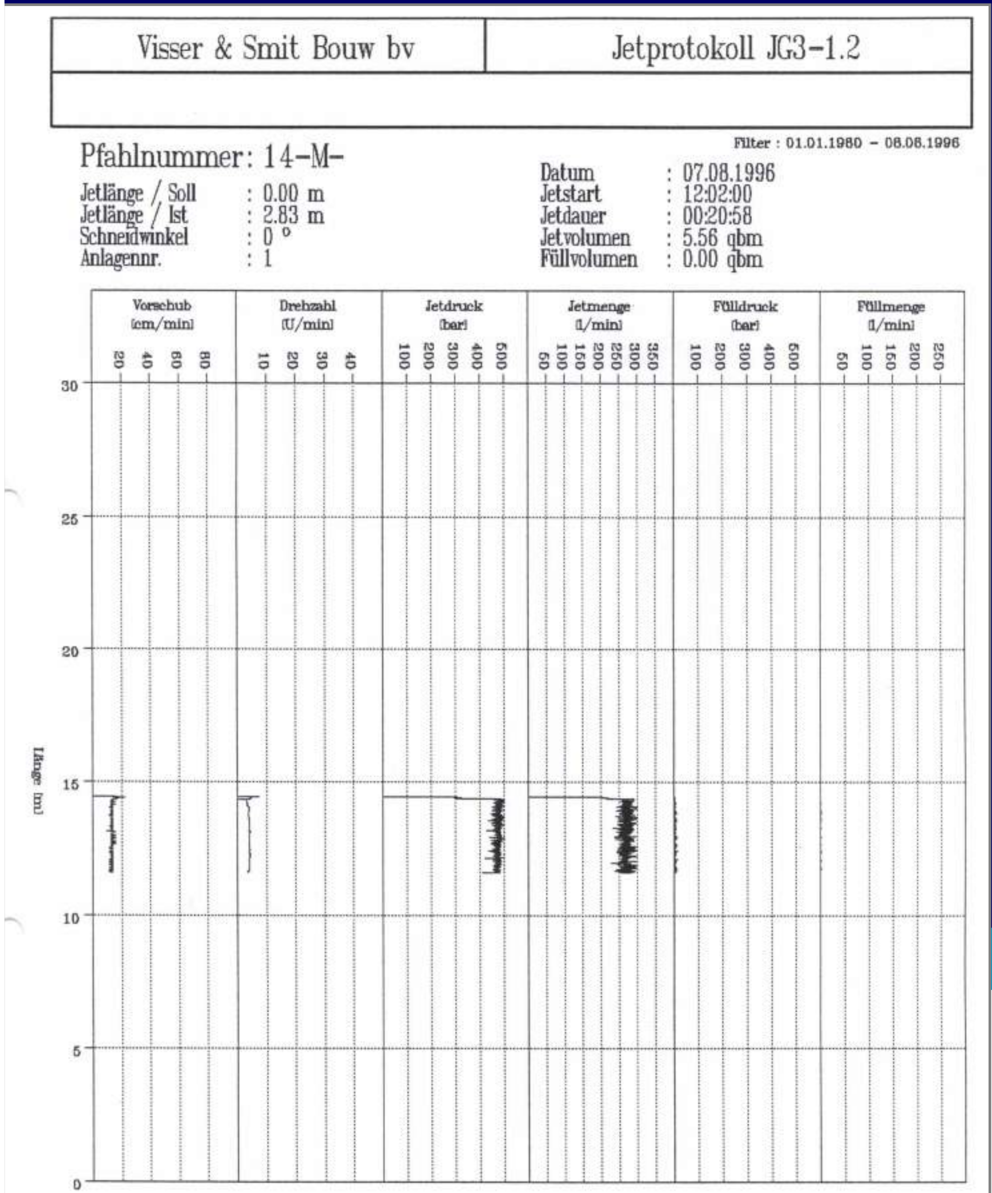


- Inclination and analysis

Tramtunnel, Jetgrouting

• diameter control

Tramtunnel, Jetgrouting



- Registration on the rig
  - Pulling velocity,
  - Rotation speed,
  - Torque,
  - Injection pressure,
  - Pump capacity of water jet and grout jet

Tramtunnel, Jetgrouting

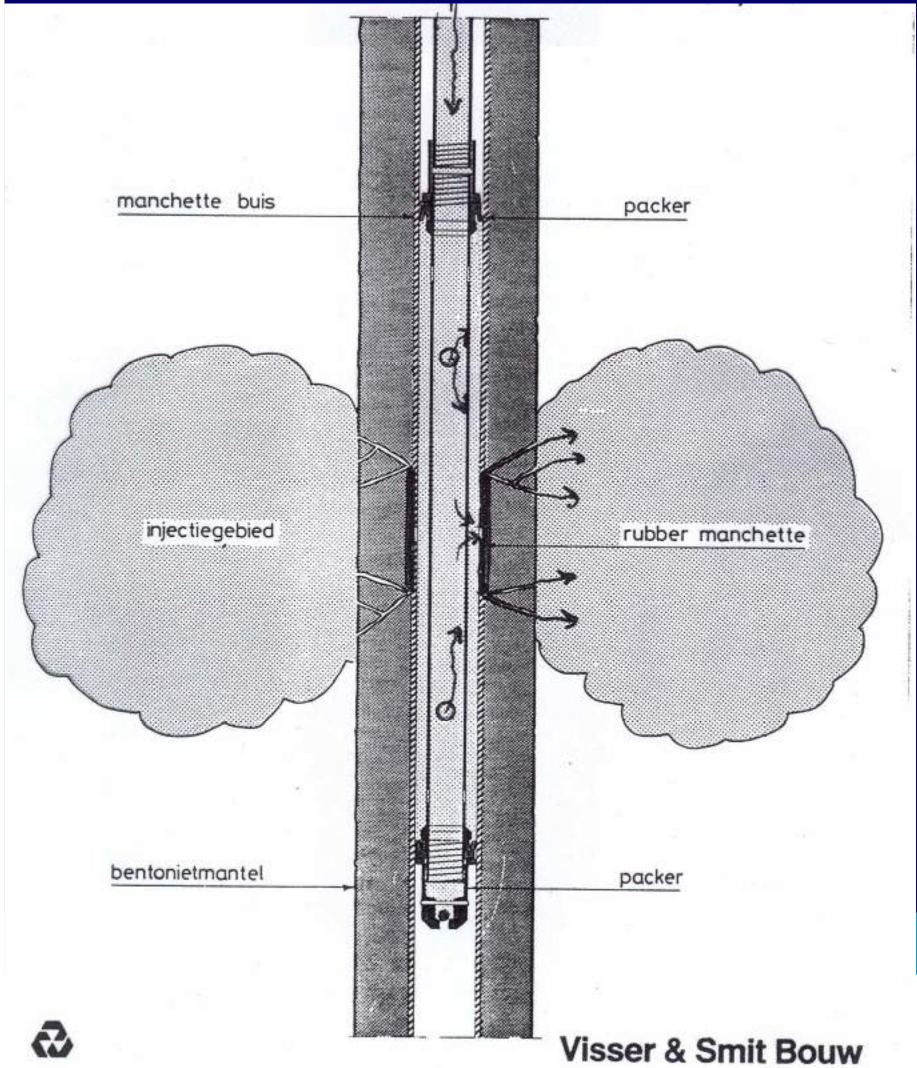
•Control of return fluid

Tramtunnel, Jetg

•Test columns real scale

27 February 2009

Tramtunnel, Gel injection



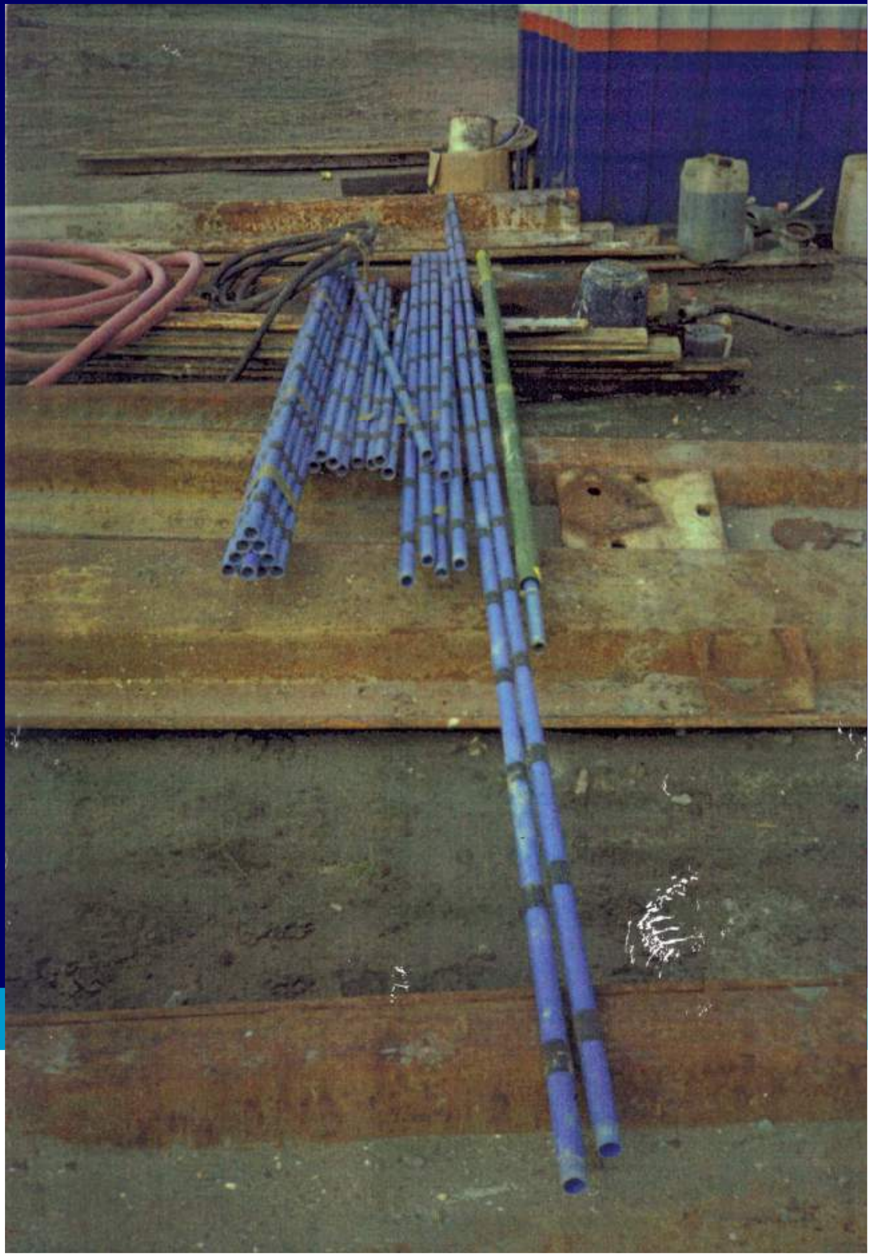
•Injection of chemicals that are injected via discrete injection openings.

•Injection in between the pores of the soil, this requires permeability

Delft University of Technology

Tramtunnel, Gel injection

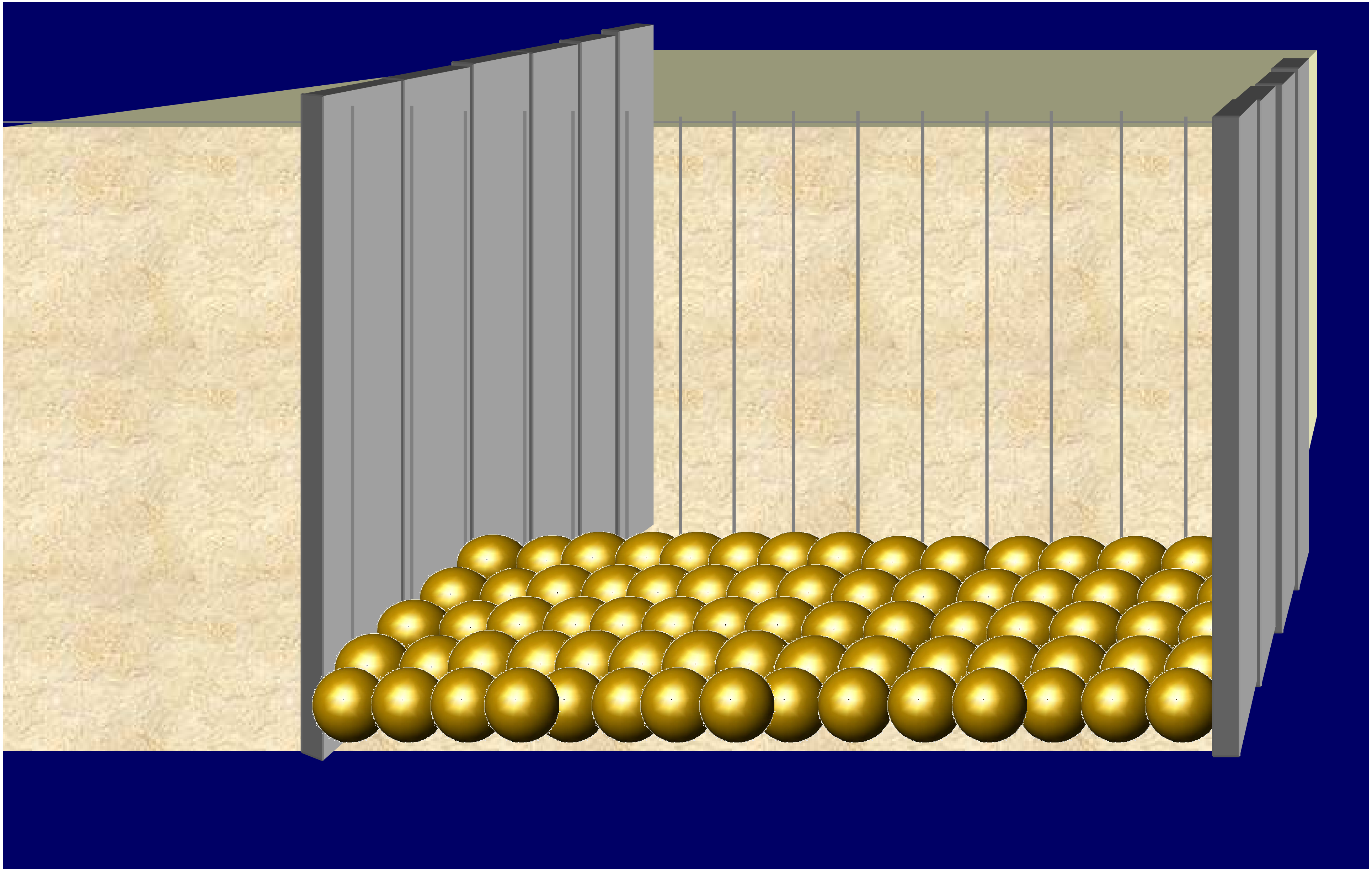
•Injection of chemicals that are injected via discrete injection openings.

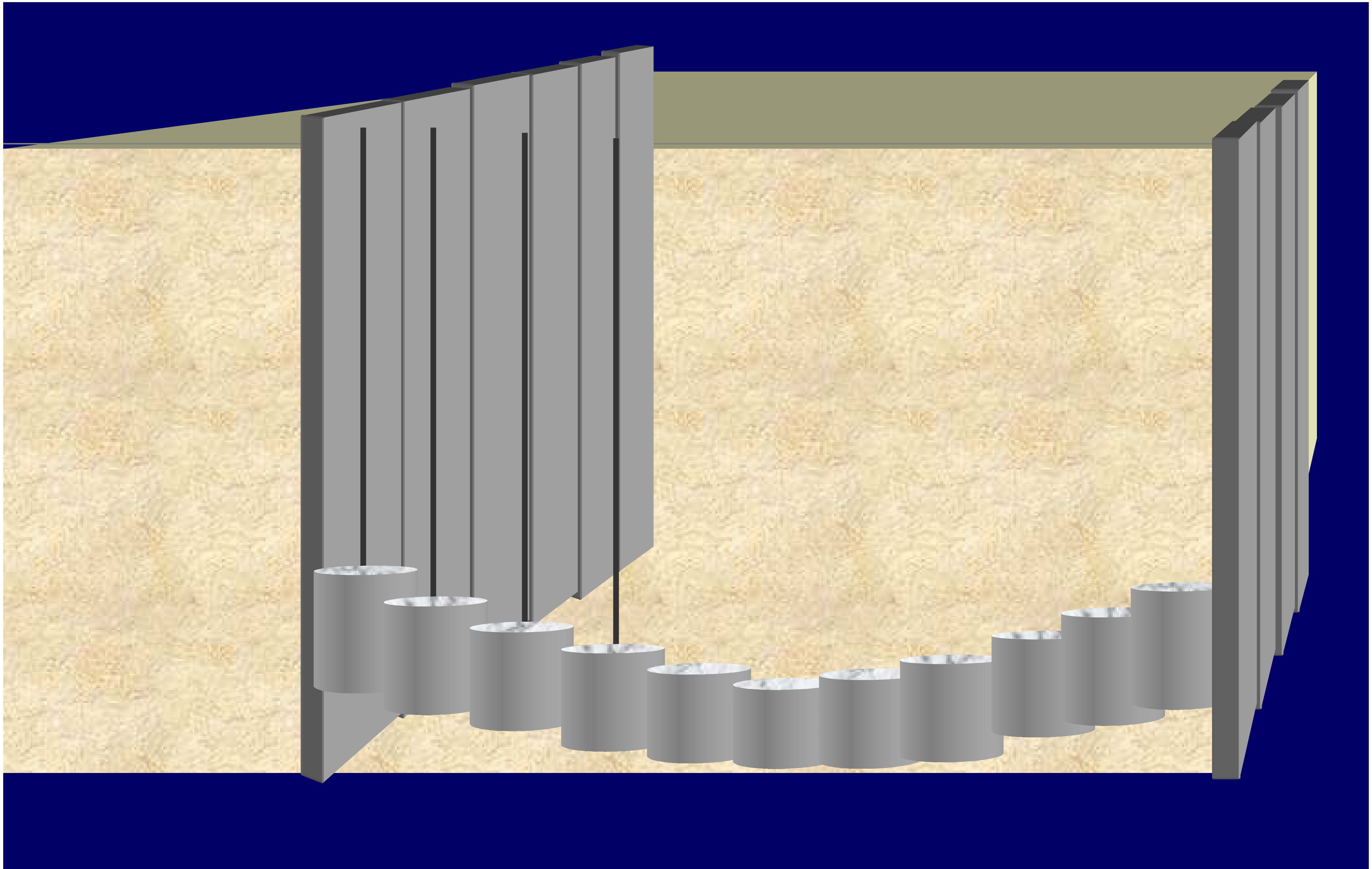


Tramtunnel, Gel injection

•Injection of chemicals that are injected via discrete injection openings.

27 February 2009



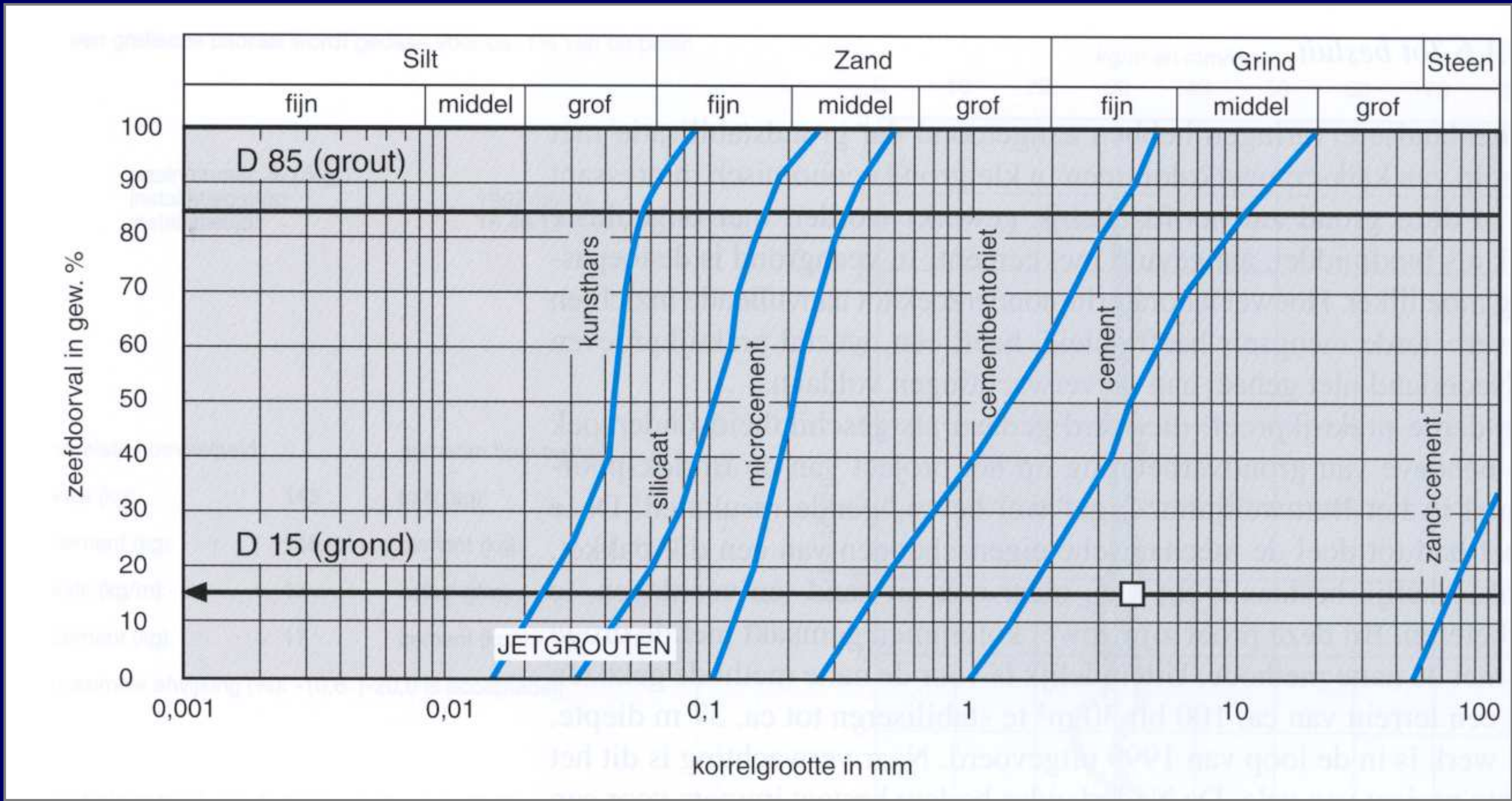


TU Delft

Tramtunnel, Comparison jet grouting and gel injection

Ground injection	Jetgrouting
•Low pressure 4 - 8 bar	•High pressure 300 - 500 bar
•Low capacity 4 - 8 ltr/minuut	•High pump capacity 125 - 300 ltr/min.
•Max. diameter 1,0 m	•Max. diameter 1,3 m – 5,0 m
•Flow through pores, no disturbance of the soil structure	•Cutting and partial replacement of soil structure
•Only possible in sand and gravel	•Possible in clay, silt and sands
•Method: stacked spheres injected after each other	•Method: slowly pulling a rotating injection tool
•Gluing of sand grains	•Mixing cement with soil
•Quick chemical reaction ca. 45 min.	•Reaction cementation after ca. 30 min.

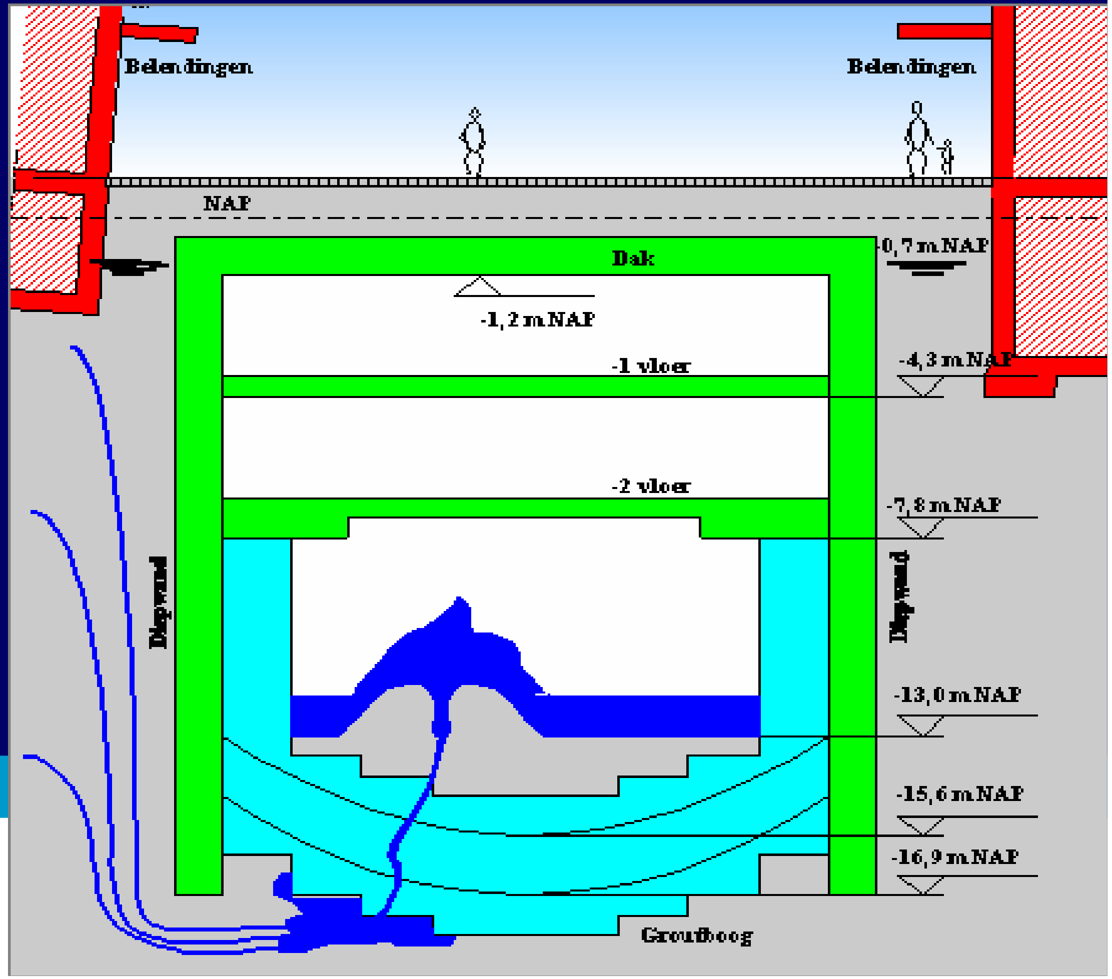
Tramtunnel, Comparison jet grouting and gel injection



Delft University of Technology

Tramtunnel, What went wrong

- February 1998 almost at depth at the Kalvermarkt,
- Leakage of the grout arch
  >injection
  >>Placing of ballast
  >>>Settlement beside pit
  >>>> filling of pit with water



Tramtunnel, what went wrong

- For 2 years this was the situation
- Discussion between client and contractor:
  - Determining remaining risk
  - Developing a plan of action

Tramtunnel, How was it solved?

Plan of Action:

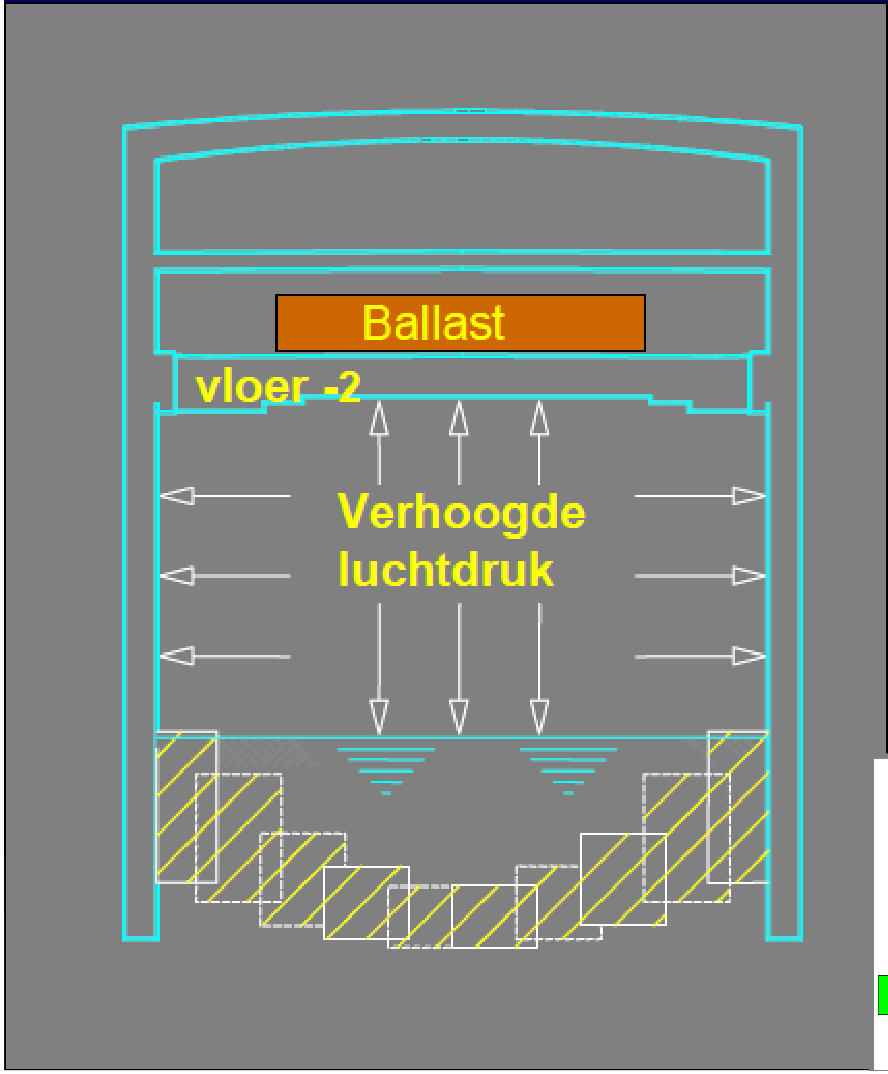
- Opening of the contract >>> D&C contract (for grout arch parts)
- Design risk transferred to contractor (for grout arch parts)

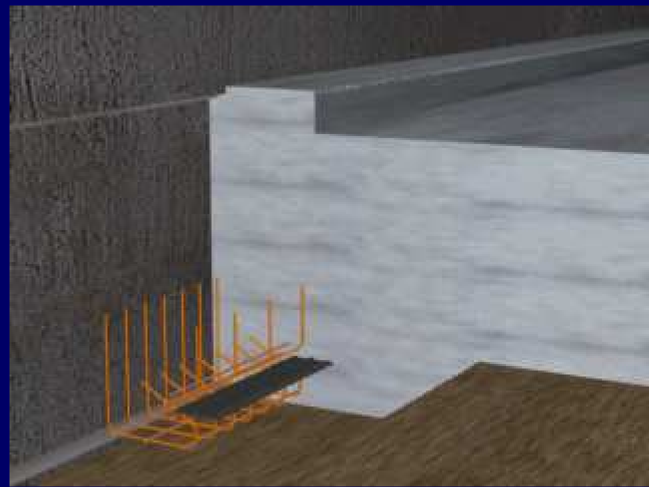
- Excavation under air pressure
    - Increasing strength of floors and connection (where possible)
    - Placing of additional weight on top of the floor
    - Additional support structure on top of the floor
    - Additional anchors
    - PVE is reduced (consequence for the rail system)

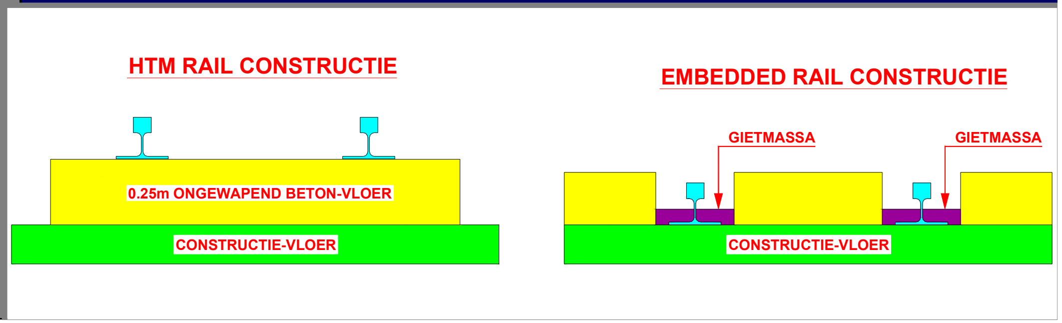
TU Delft

Tramtunnel, How was it soled

Cross-section Grote markt straat

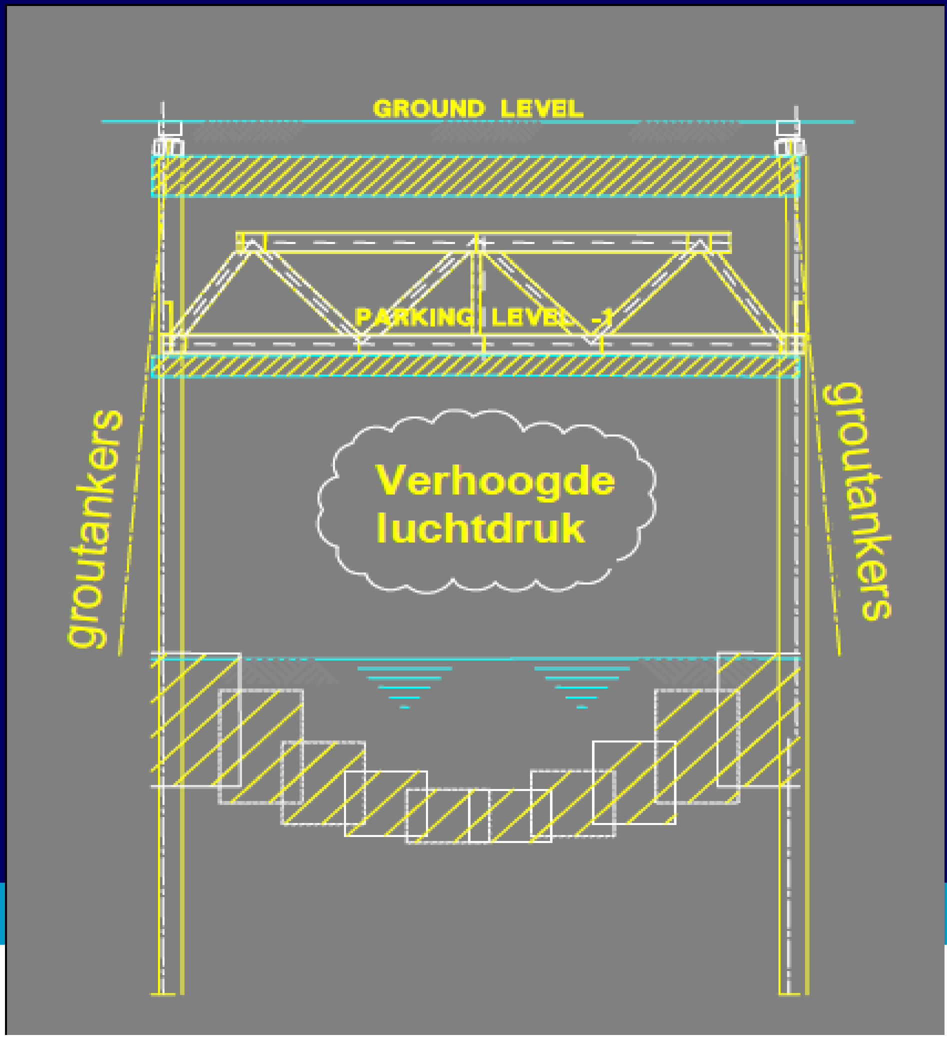






Tramtunnel, hyper barric works

Tramtunnel, How was it soled



Cross-section Kalvermarkt

- Floor-2 already cast
- Extra support structure
- Increase stiffness of the d-wall required.

TU Delft

Tramtunnel, hyper barric works

elft

Tramtunnel, hyper barric works

Tramtunnel, Hyper barric works

Tramtunnel, hyper barric works

Tramtunnel, hyper barric works

Tramtunnel, What went wrong part 2

- Problems solved
- Works were taken up in june 2000.
- Excavation was (re) started in Station Spui.
- leakage occurred directly adjacent to the section of the Kalvermarkt that was still filled with water.

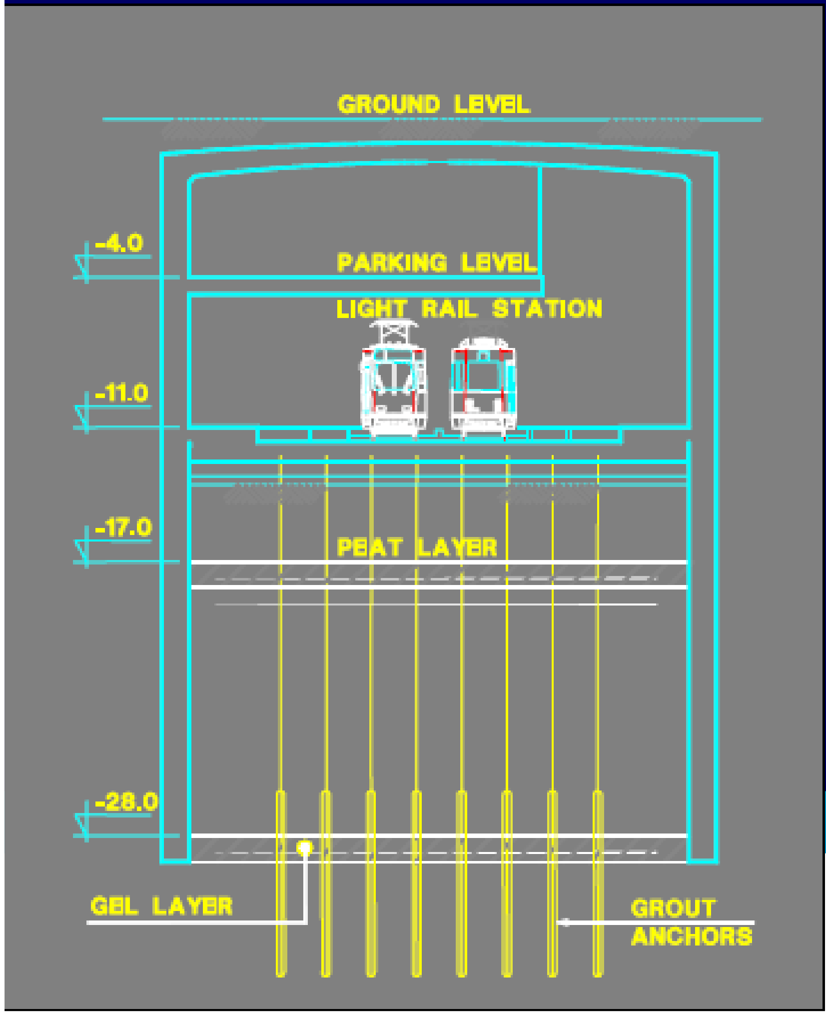
- Leakage of the gel layer and peat layer

  >deformation of the intermediate wall

  >>flooding of the station Spui

Tramtunnel, What went wrong part 2

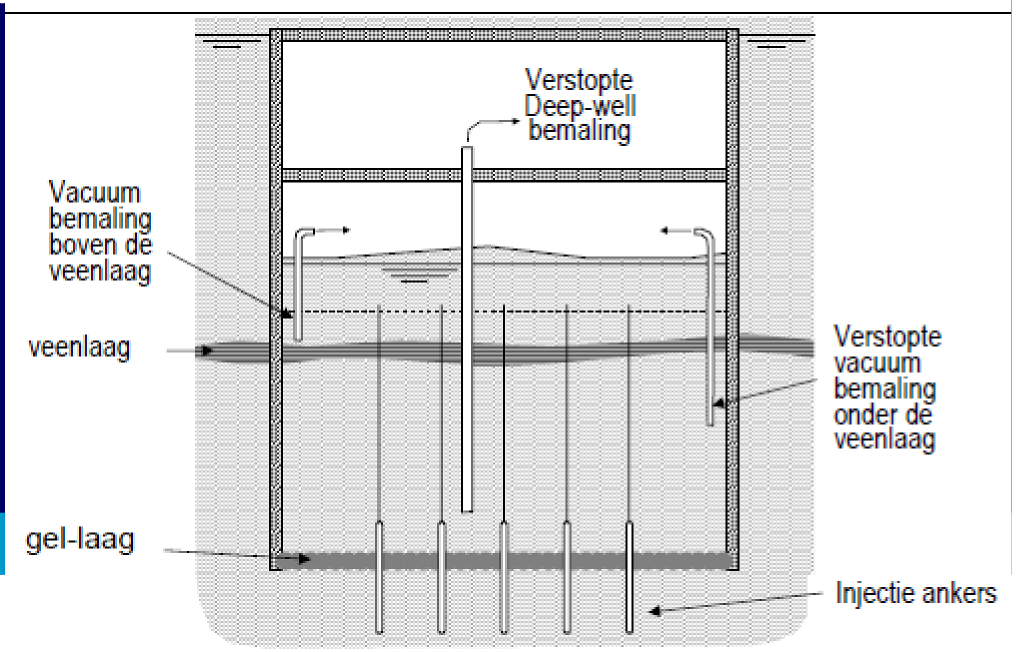
- Why did this leakage occur?
  - The deep wells did not function anymore!
  - High hydraulic head over the peat layer
  - Failure of the peat layer >>leakage.



Tramtunnel, What went wrong part 2

Why did deep wells not function?
"new" chemical phenomenon

- high pH in/around gel layer
- Organic matter dissolved
- Shallow surface >>lower pH
- Organic matter returns to solid
- Blocking the pores.
- Slow process but substantial due to the 2 years of still stand



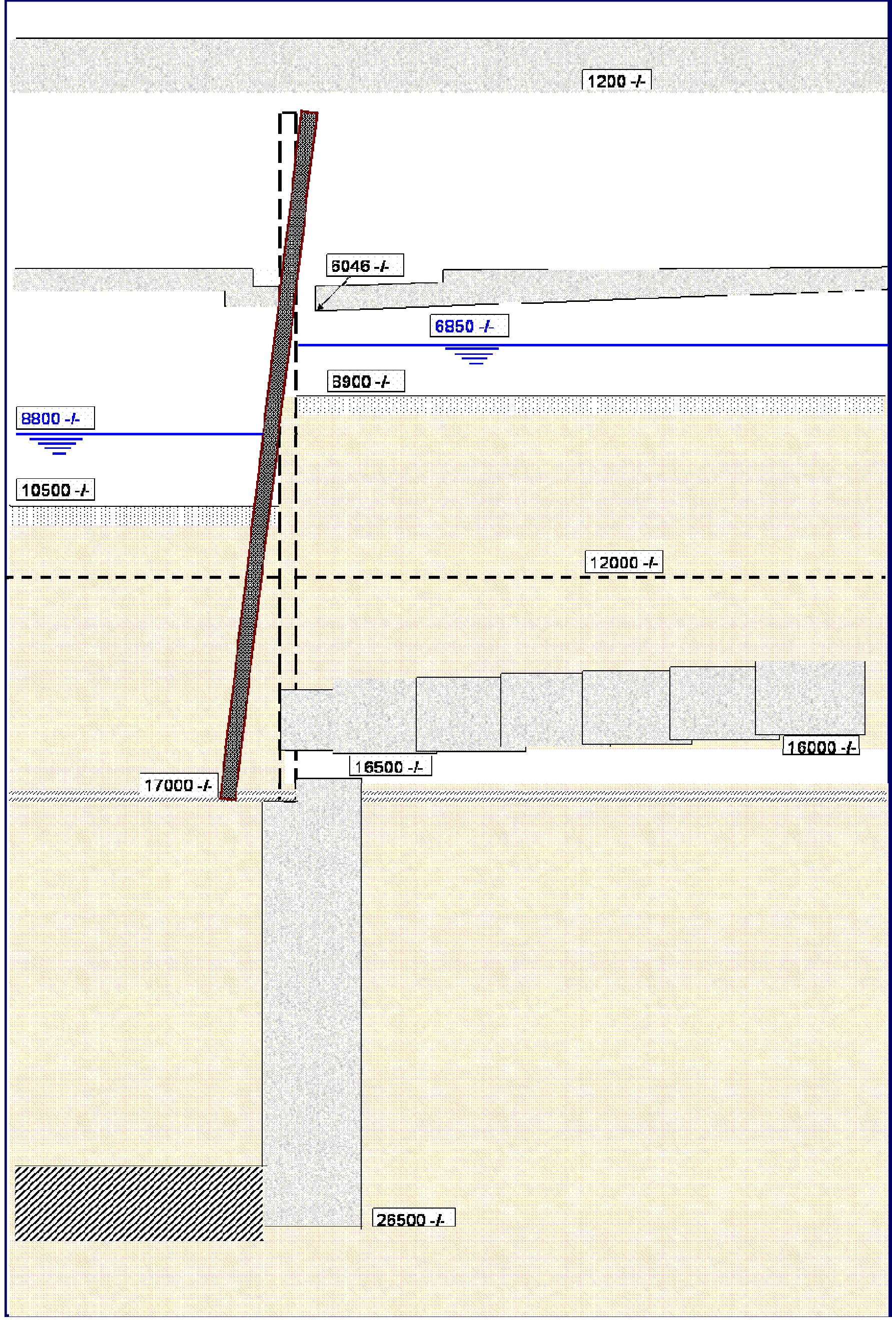
Tramtunnel, How was it solve

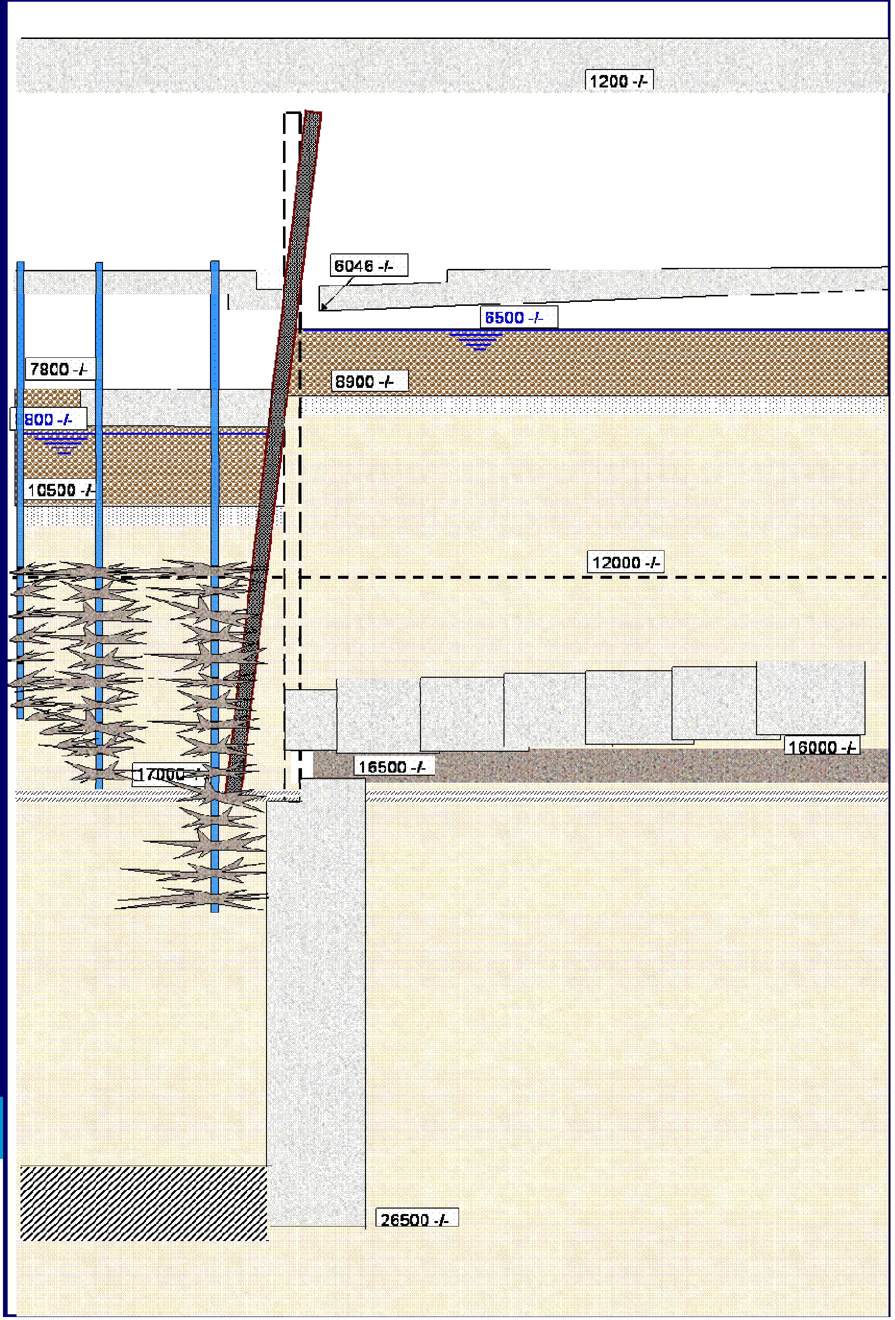
Plan of Action:

- Extensive repair works on the intermediate wall
- Account for risk of failure of the peat layer
- Account for the changed load case of the d-walls.

- Restart Excavation
  - Enormous extension of dewatering
    - New deep wells &
    - gravel piles.
  - Section wise excavation
  - Casting of a temporary floor
  - Anchoring of the temporary floor
  - Normal construction proceeds

VWS Geotechniek BV






VWS Geotechniek BV
DAF
HTM
HTM
HTM

Tramtunnel, What did we learn?

1. Injection layers built of columns (with jet grouting) and or injected spheres (gel injections) must be assumed to have defects.

2. Shallow injection layers with the purpose of sealing (close to the excavation level) should not be designed because of the risk off sand wells. Make sure that the covering layer has sufficient thickness and is drained properly.

3. Scientific research confirms that once a sand well occurs it quickly causes enormous movement of soil. Preventive measures must be taken within the hour.

TU Delft

Tramtunnel, What did we learn?

4. New phenomenon (blocking of pores due to solution and precipitation of organic matter under changing pH)

5. <u>Underground construction</u> requires the following:
    - Robust design (which can take up some degree of failure or errors)
    - In the design one should account for defects in the soil and variation in soil parameters.
    - Make a failure analysis for individual construction parts.
    - Prepare preventive measures for possible failure or errors.
    - SWO: A design in which you thrust on specialized construction techniques requires that experience (risk assessment) is involved in the design.

TU Delft