Trenchless technology

Used for installation, renovation and repair of "small infrastructure systems"

Delft University of Technology, Faculty of Civil Engineering

Ir. S. van der Woude

Trenchless Technology

1st Hour

- Trenchless Technology
- Directional drilling
- Drilling fluid

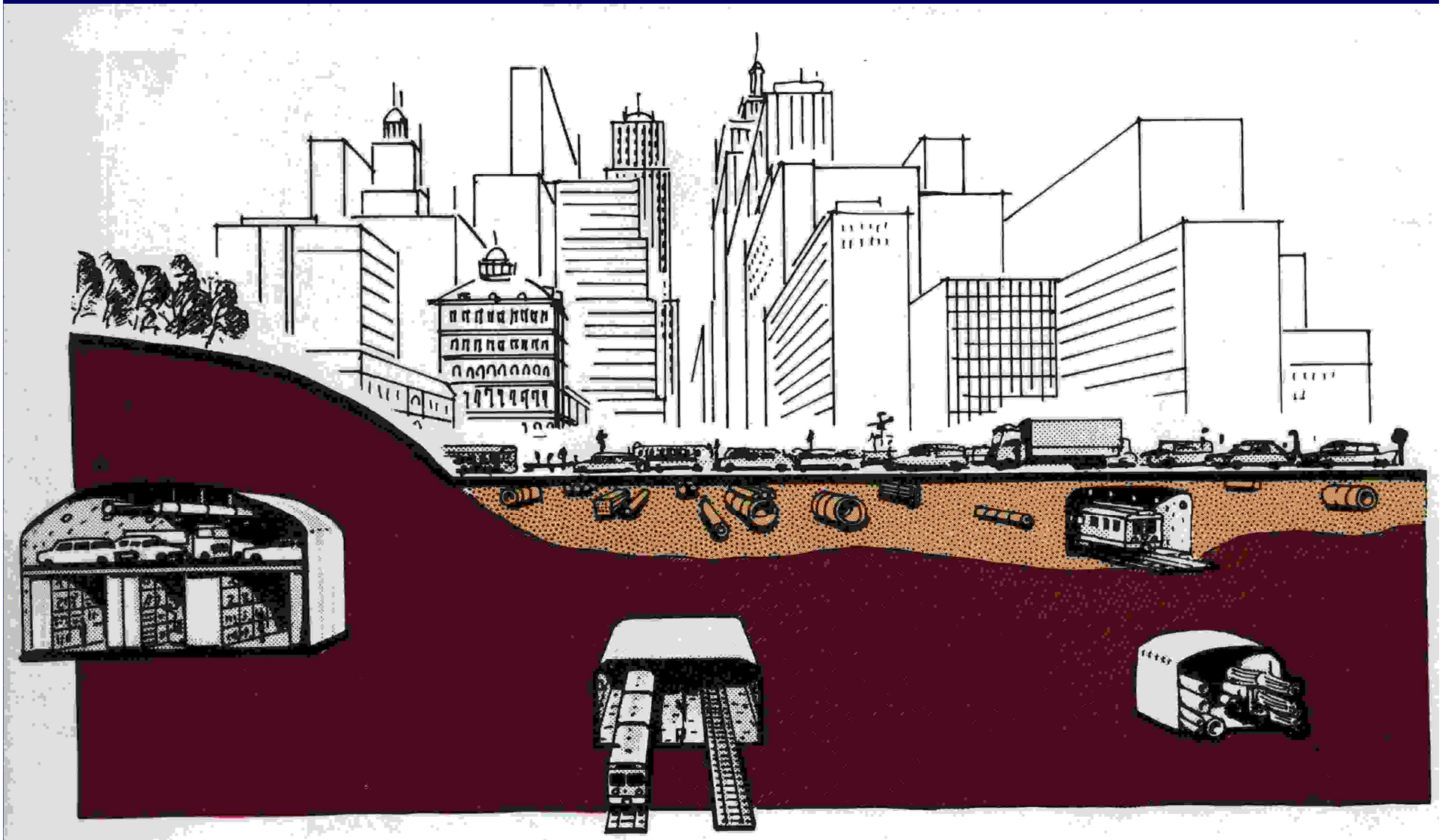
2nd Hour

- Open front techniques
- Pipe jacking
- Renovation techniques

- Case study?

Delft University of Technology, faculty of Civil Engineering

Ir. S. van der Woude



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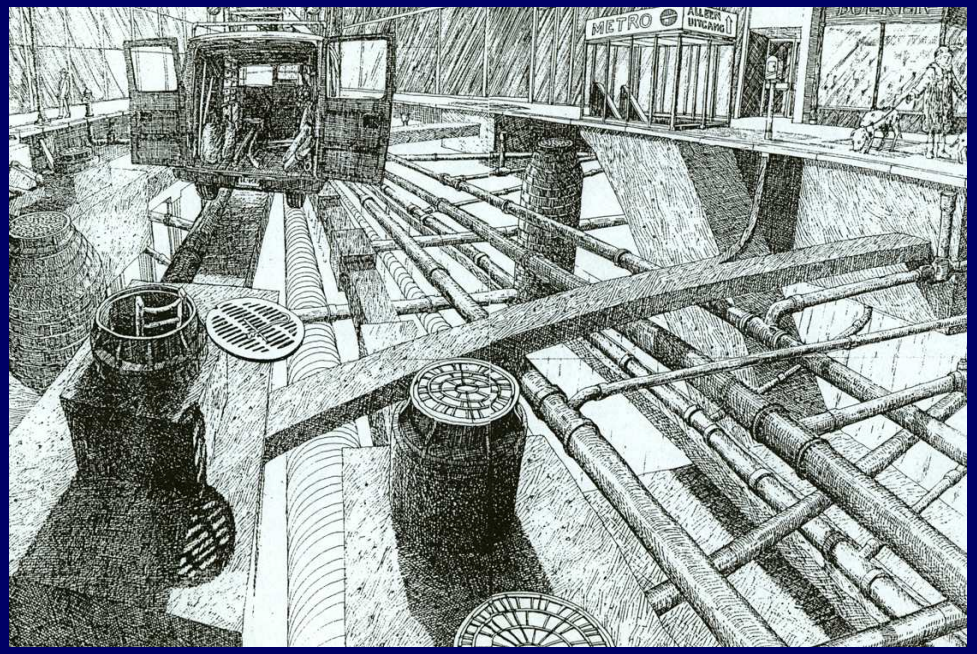
Small Infrastructure

Traditionally we find the following infrastructure in cities:

- Sewerage
- Waterworks
- Gas pipelines
- Electricity lines
- Telephone lines



Nowadays we also have:

- Glass fibre cables
- Central heating systems
- Separated systems for rain- and wastewater
- In future underground logistic systems

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Outside the cities we find an extensive infrastructure network:

- Gas transport network
- Waterworks transport lines
- Wastewater pressure lines
- Electricity transport networks
- Telephone (fiberglass) lines
- Heat transport lines
- Pipelines for chemical or non-liquid materials
- In future underground logistic systems

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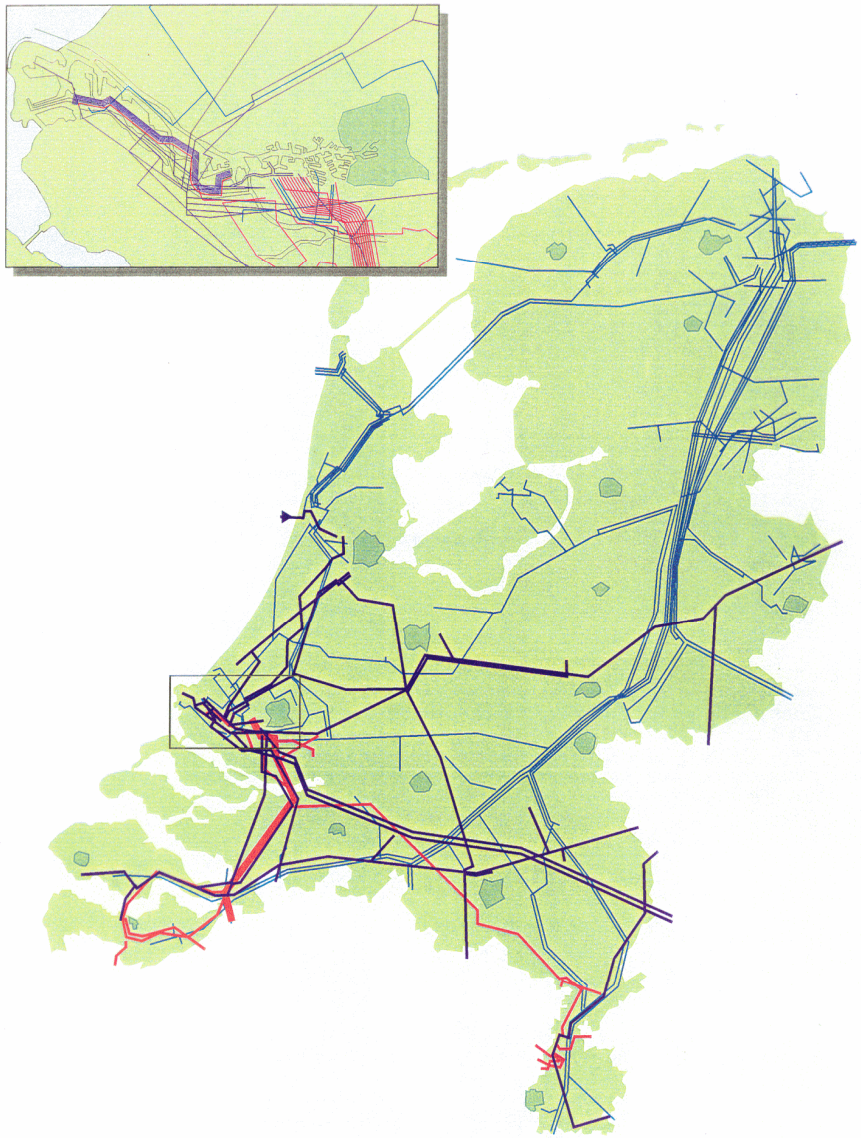
Buisleidingtransport in Nederland



Product (jaarcijfers)	Transport (mln.ton)	Export (mln.ton)	Leidinglengte (km)
Aardgas (hoofdtransport)	55	25	12000
Aardolie en aardolieproducten	115	50	1900
Chemische en overige producten	17	2	1400

Uitgave N.V. Nederlandse Gasunie 1996

Velin

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3. Comparison traditional and trenchless techniques

Trenches needed for cables, pipes etc. are often problematic:

- Limitation of space
- Deformation of surrounding grounds
- High ground water (deep wells/drainage)
- Bank protection works
- Polluted soils

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Trenching can be dangerous

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While filling up the trench, we find some potential problems:

- Quality of the fill
- Demanded compaction
- Renew damaged roads
- Protection of the installed pipe against damage

Towards the surroundings we find the following problems:

- Inconvenience for ship navigation in case of water way crossings
- Safety regulations have to be observed with the intersection of bank protection works
- Inconvenience for the traffic in case of road crossings
- Damage to or loss of agriculture grounds

A number of potential problems and risks can be avoided or minimized by using trenchless technologies

- No open trenches
- No immersed pipes in waterways
- No open dikes or bank protection works
- No excavation of polluted soils
- Less damage to the environment
- No open crossings with other infrastructure
- Higher production rate

Cost-profit ratio is better, taking all costs in consideration

certainly when structures are crossed

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Classifying Trenchless Technology

- Methods for repair or replacement
- Open front boring techniques
- Pneumatic boring techniques
- Closed front boring techniques (Pipe Jacking)
- Horizontal Directional Drilling (HDD)

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Before carrying out trenchless technology, one has to take notice of the following parameters:

- Geo technical parameters (also obstacles in the underground)
- Risk for damage, especial of existing structures (incl. C+P)
- Availability of the space above ground
    - Alignment
    - Entry and exit point
- Logistics for the different techniques
    - Installation of the pipe
    - Removal and treatment of excavated soil
    - Drilling fluid

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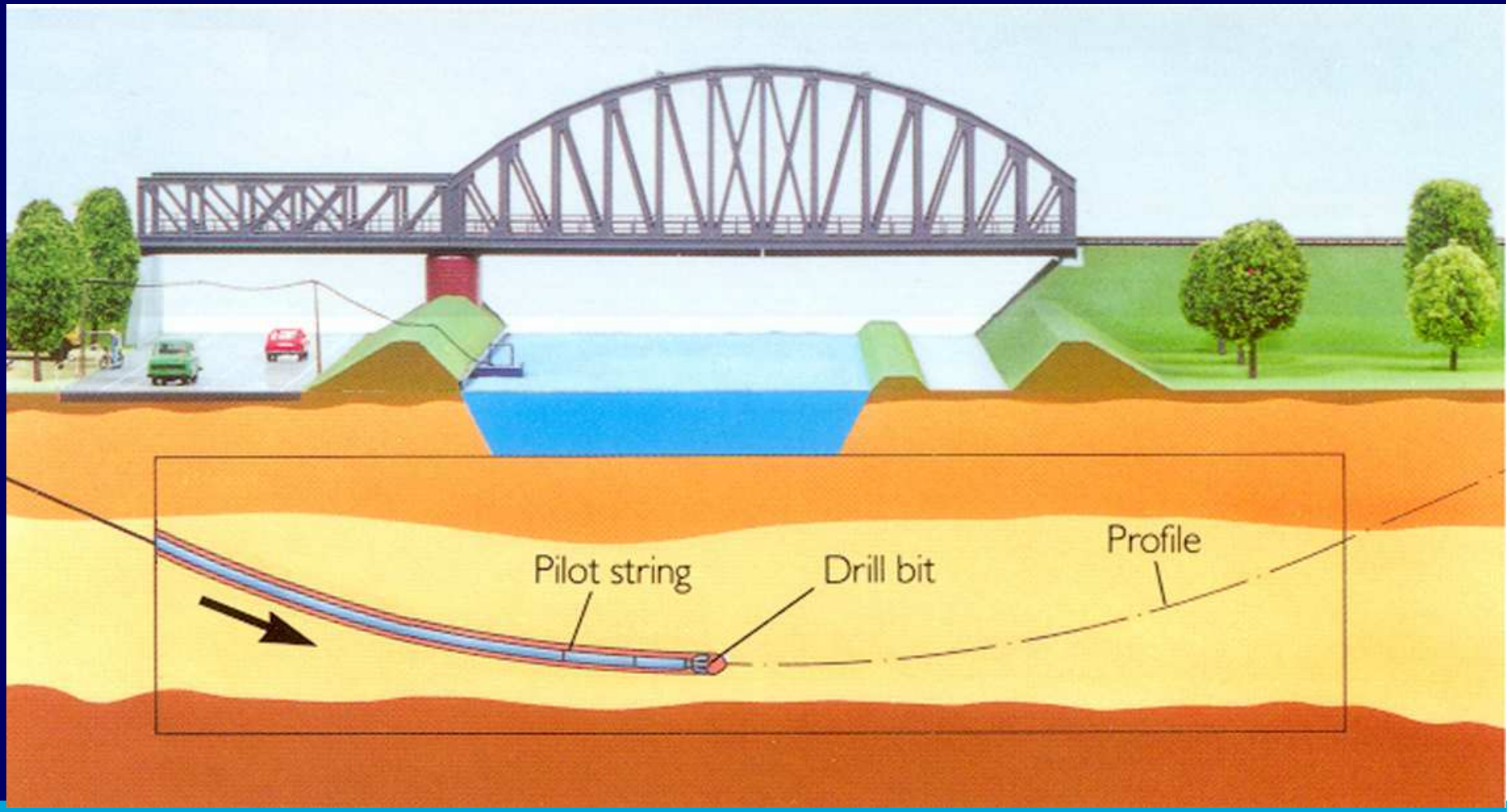
Horizontal Directional Drilling (1)



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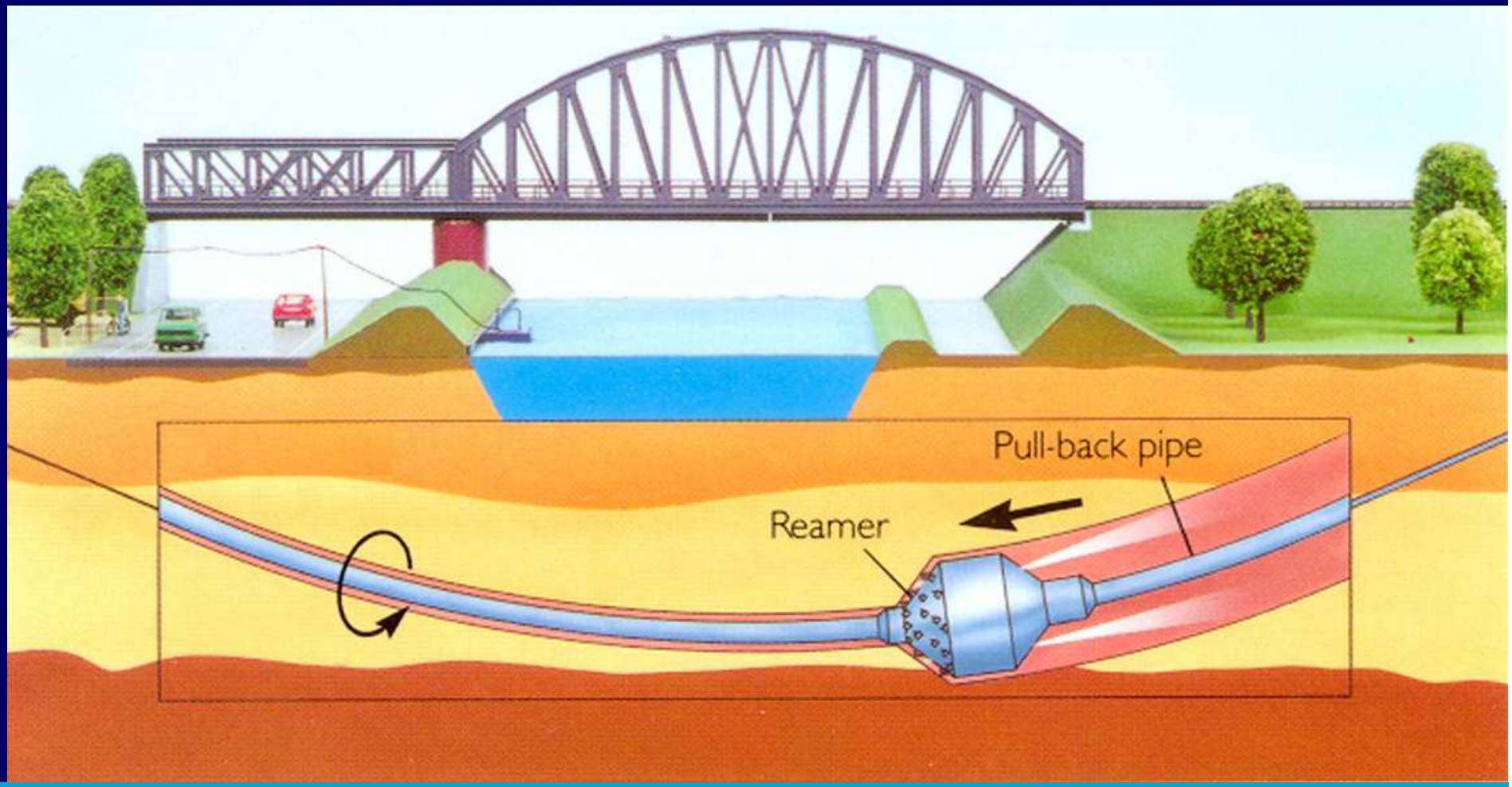
Horizontal Directional Drilling (2)



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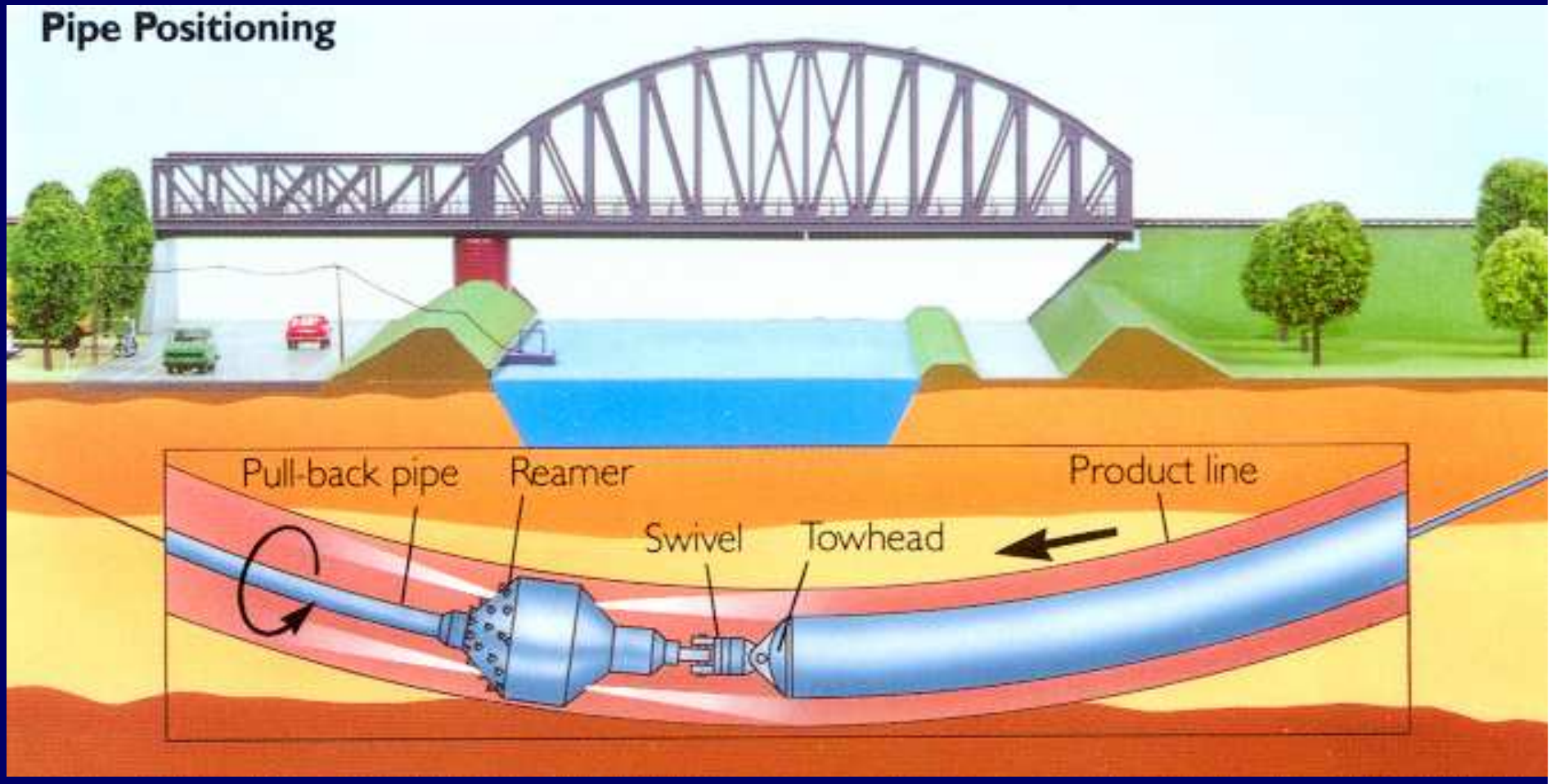
Horizontal Directional Drilling (3)



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Pilot boring

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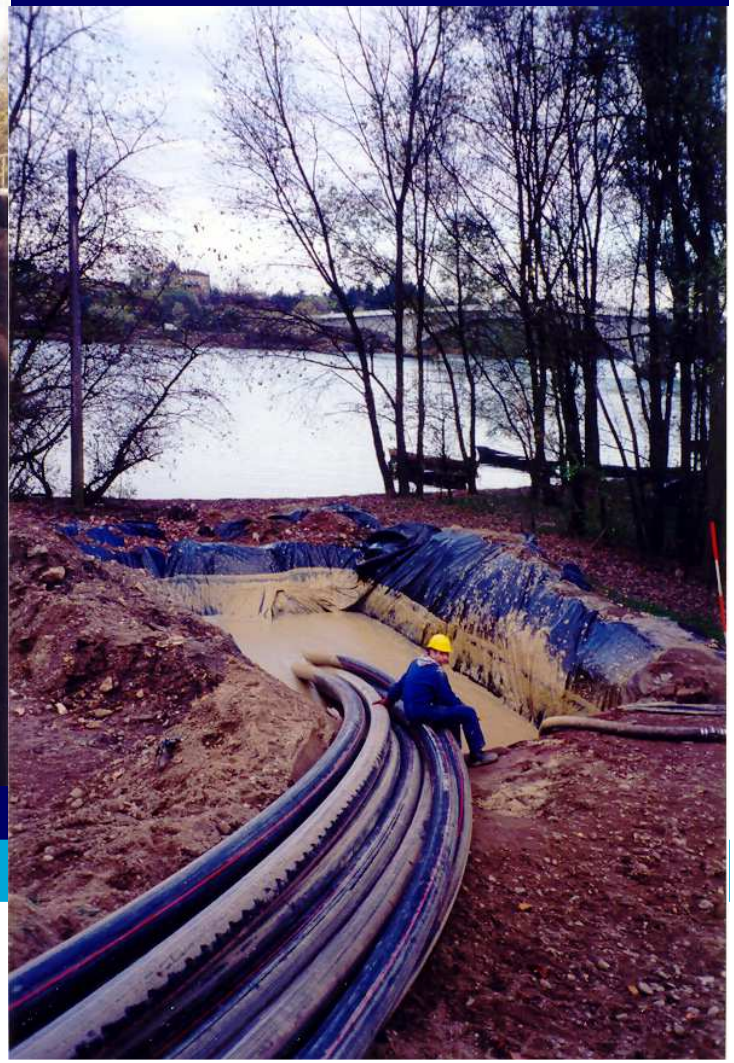
Reaming

13 March 2009

Reaming

Pulling the Pipe (s)



Pulling the Pipe (s)

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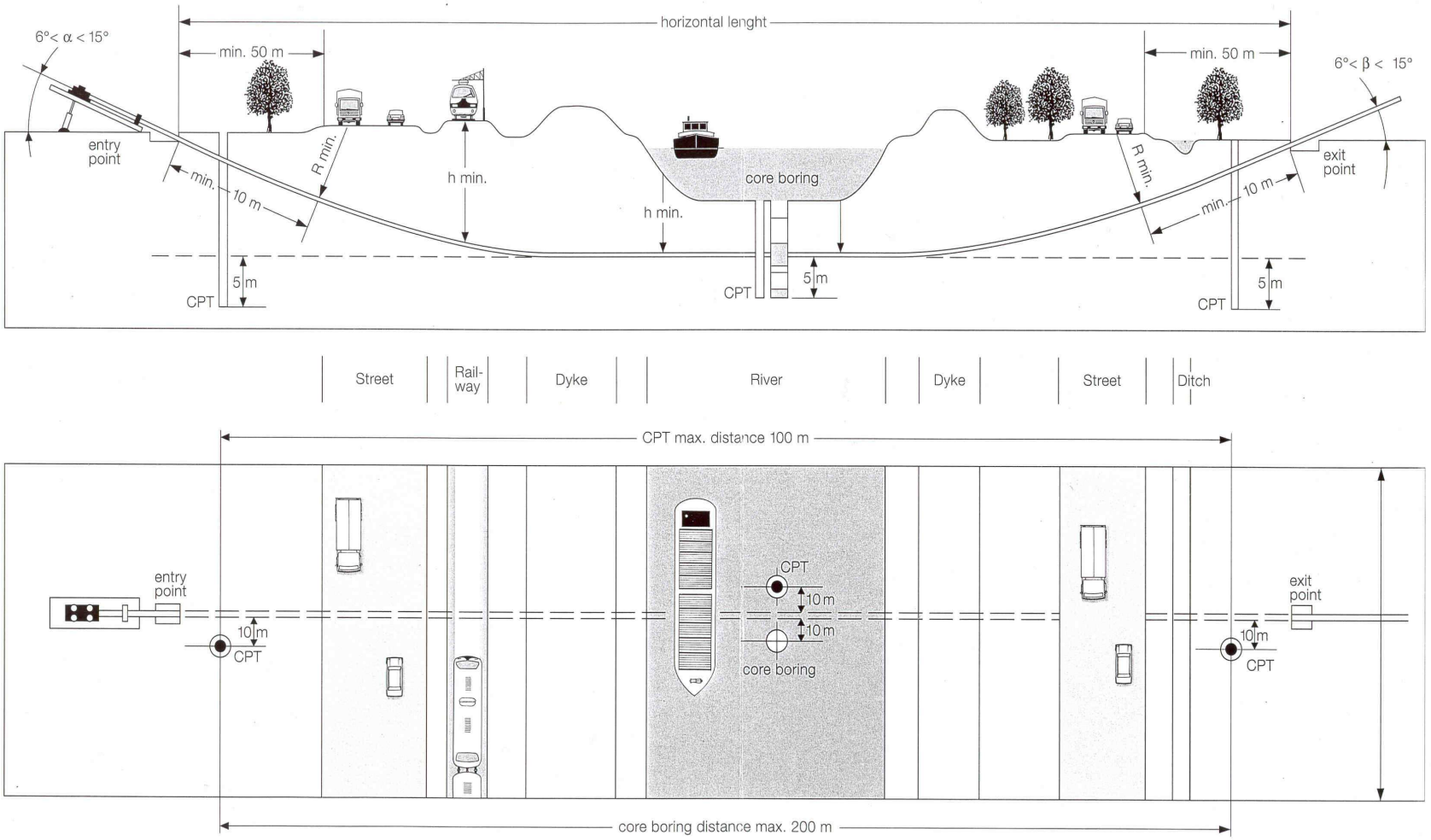
Drawing showing critical dimensions of drilling profile and positions of soil samples



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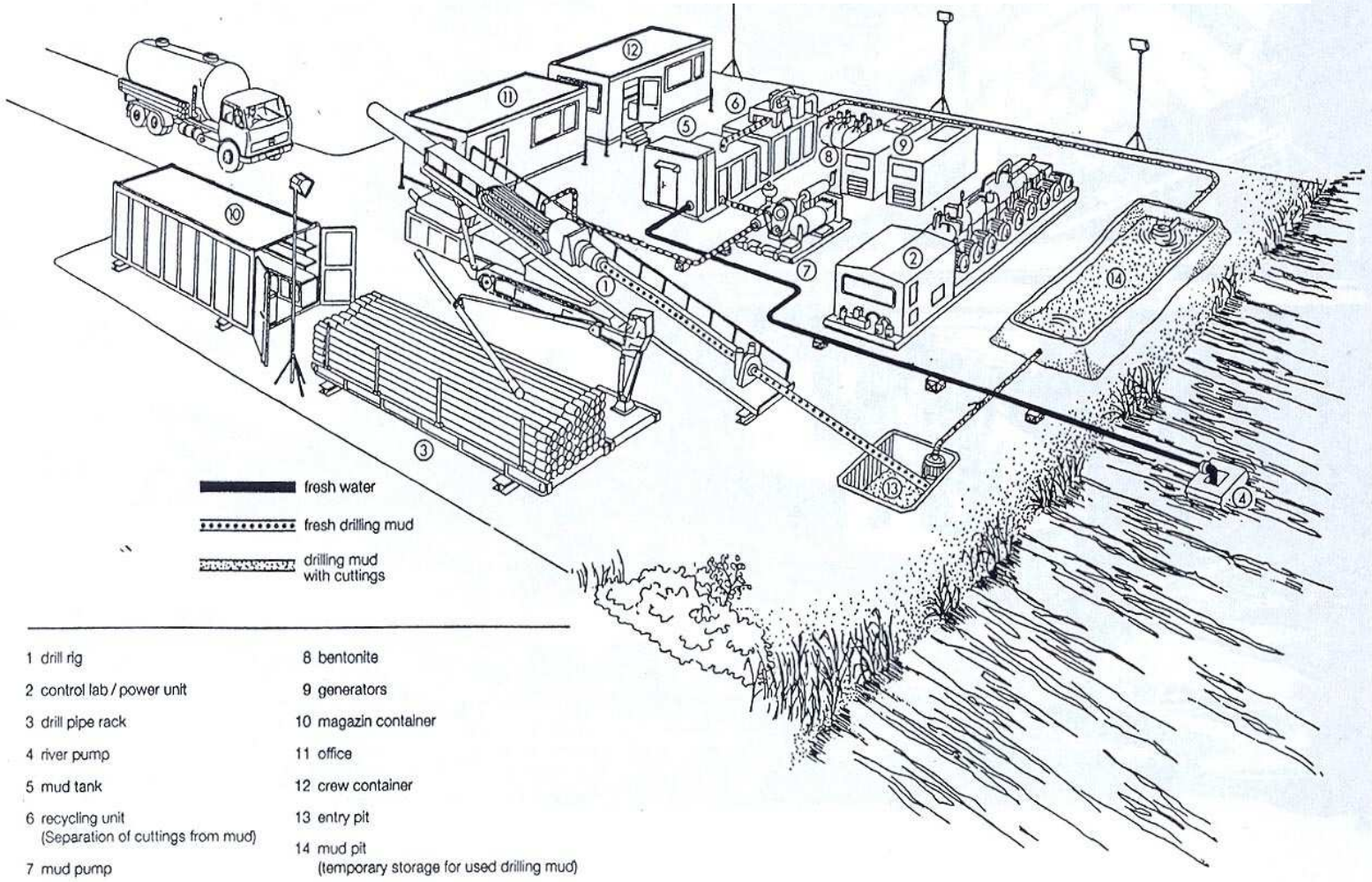
Layout of rig site



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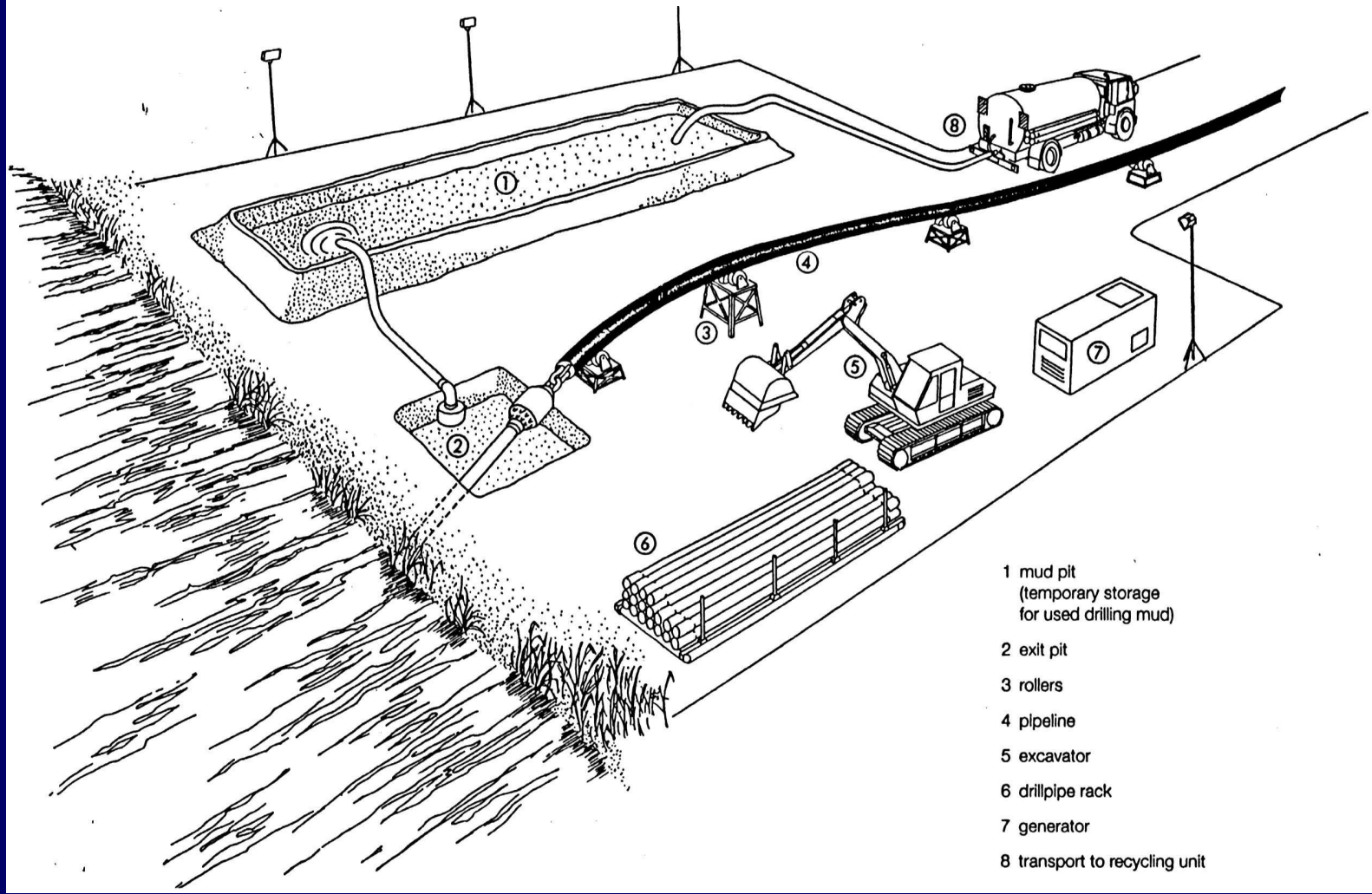
Layout of pipe site



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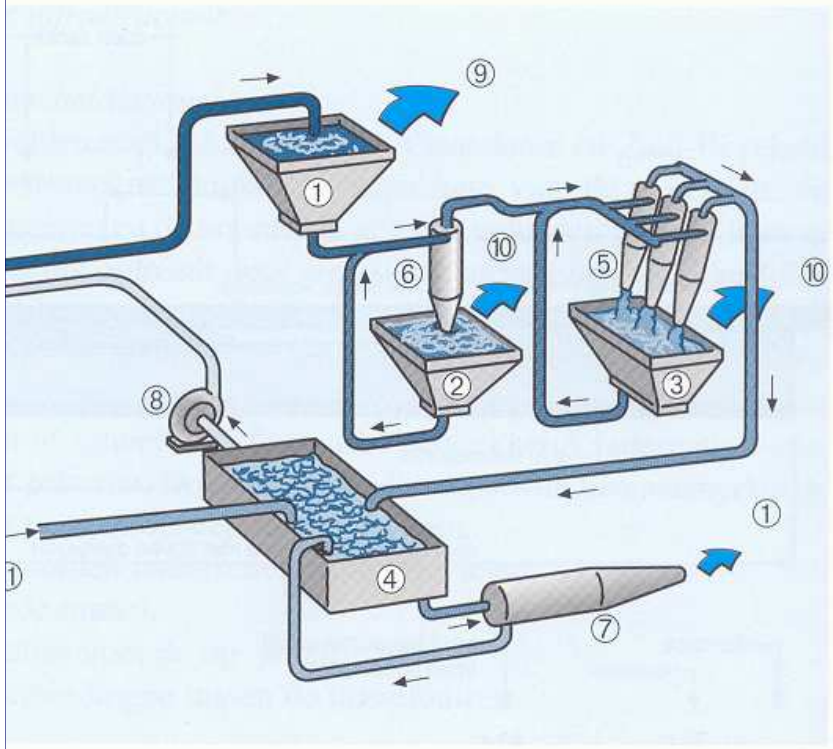
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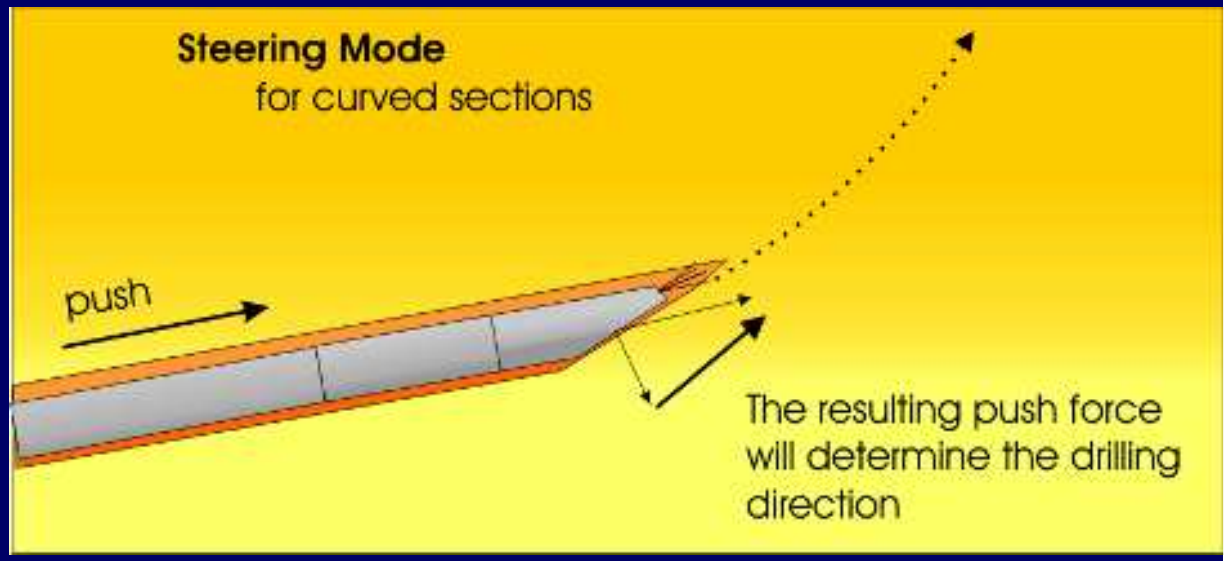
Pilot boring In Soil



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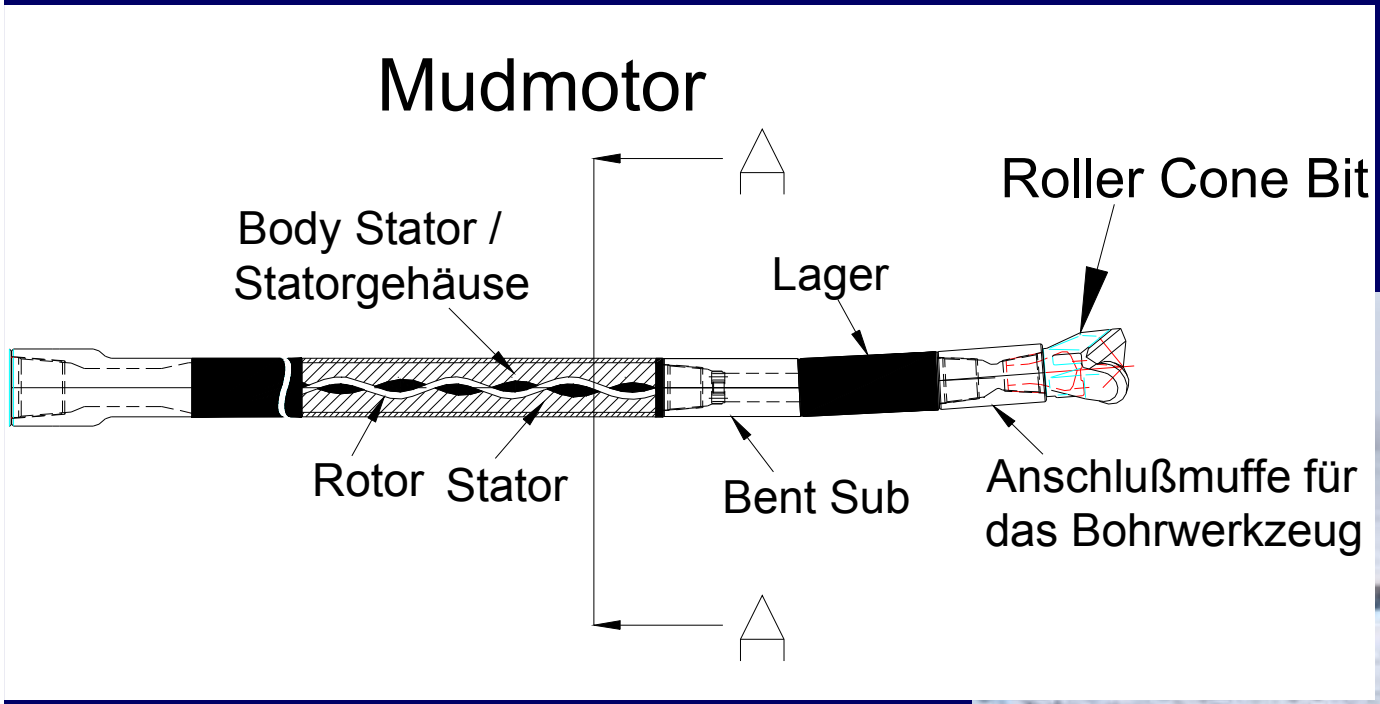
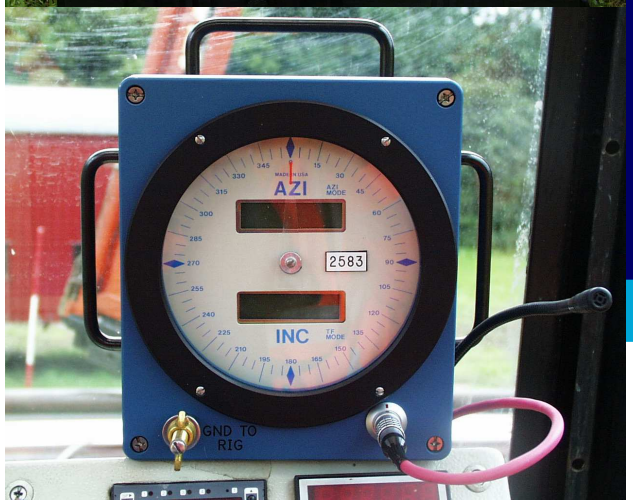
Pilot boring In Rock



Positioning

Positioning with "steering tool"

- Distance (drill rod)
- Azimuth (direction in360° to N)
- Inclination from surface
- Data transfer via cable



Steering tool

- Positions on earth magnetic field
- Unique on geographical position

True Track

- Magnetic field is forced with a coil and direct current
- Stronger signal and high accuracy

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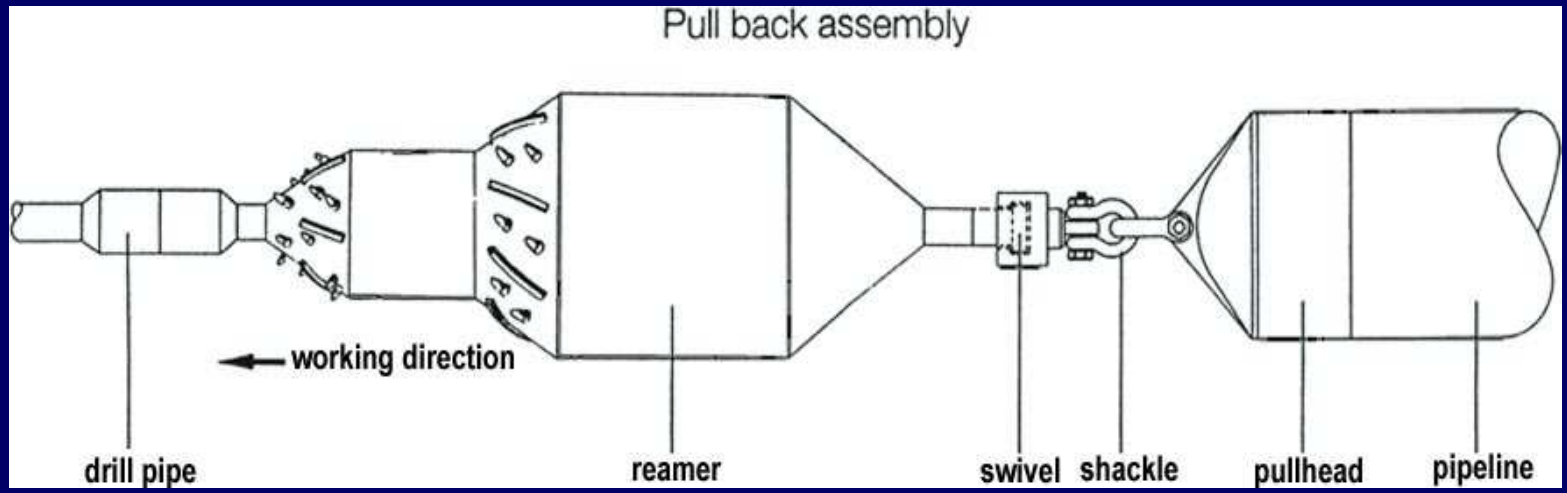
Barrel reamer
Bucket reamer
fly reamer
hole opener (in rock)



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Pulling in the pipe


VERHUISBEDRIJF
HENNEKEN BV

Drill fluid.

Normal drill fluid is a suspension made out of water and bentonite (composed mainly of mineral Montmorillonite, which is a highly swelling clay).

The functions of the drill fluid are:

- Excavation of the soil (jetting)
- Energy for the mud motor
- Lubrication and cooling of drillhead and reamer
- Transport of cuttings
- Stabilisation of the borehole

Sometimes biodegradable polymers may be added to improve the properties

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Drill fluid is of Vital importance at HDD

Risks

- Clogging of the borehole
- Settlement in the boreholes
- Not sufficient overpressure (water inflow and borehole collapse)

Sometimes biodegradable polymers may be added to improve or maintain the properties

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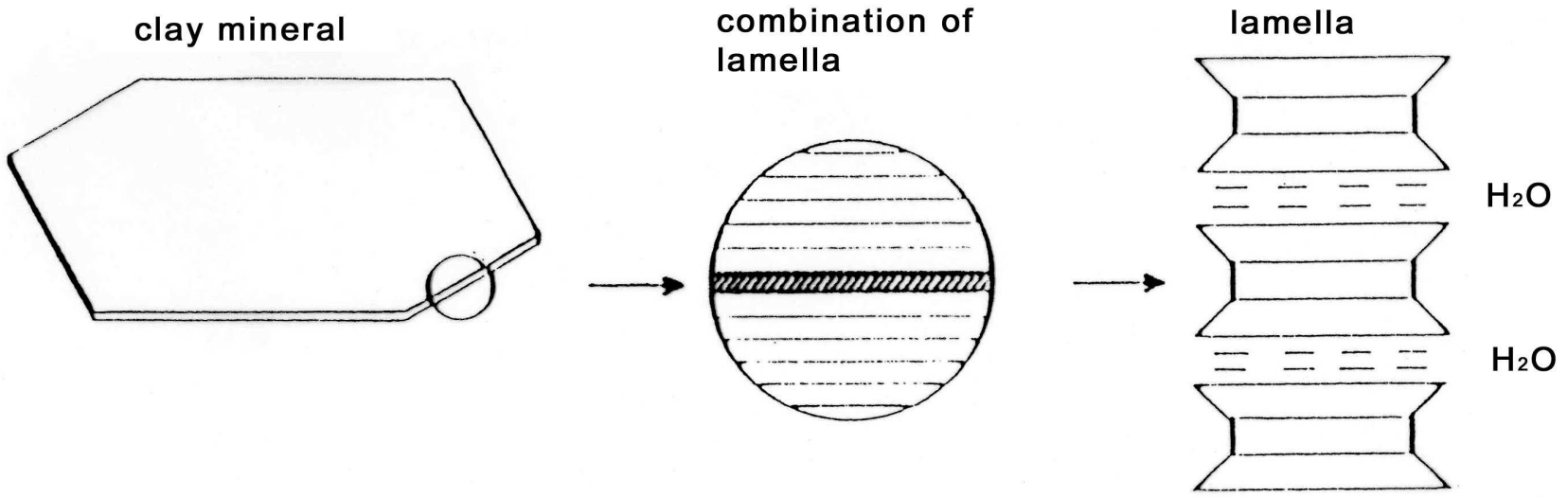
Montmorillonite



Flake crystalline structure of montmorillonite; because of negative surface charge, positive loaded ions (like Na^{+} and Ca^{2+}) are absorbed and will bind molecules of H_2O

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Drillingfluid properties

Filtercake

- filtration test
  - filtration value in [ml]
  - cake quality and thickness [mm]

Viscosity [Pa s] en yield strength [Pa]

-Bingham liquid

-Marshfunnel test >>>> Viscosity in seconds

-Rheometer >>>> Pv and Yp

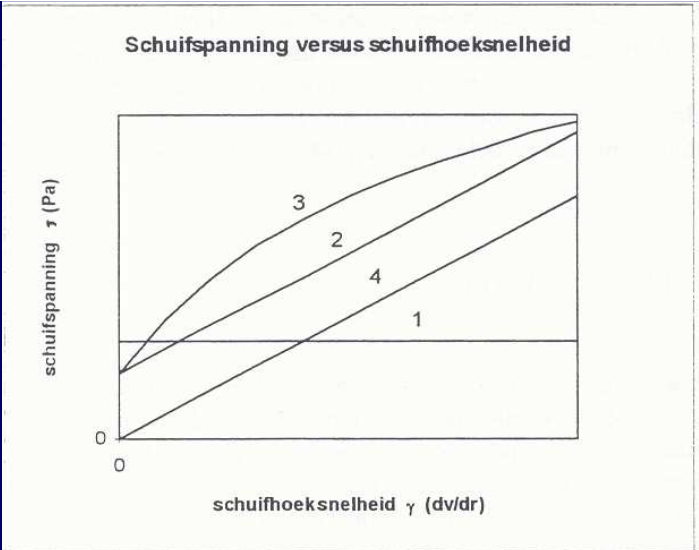
-"Kogelharp" >>>> Yield strength

Spesific weight [kN/m3]

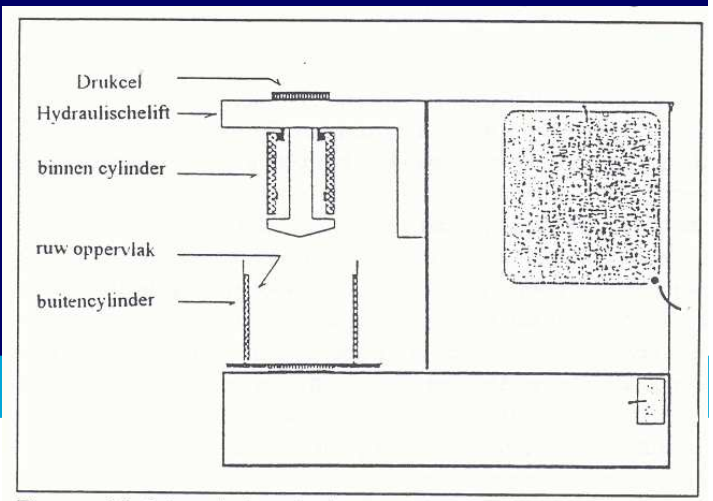
- "Mudbalance"

Sand content [%]

- Sandkit



Figuur 3.1: Rheologisch diagram. Met 1) ideaal plastische vloeistof, 2) en 3) Bingham vloeistof en 4) Newtonse vloeistof. Naar Janssen (1991).



Figuur: 6.9 Schematische tekening van de BML-viscometer, Wallevik (1995), figuur 1

“Kogelharp” and filter test

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Marshfunnel and sand kit

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Drill fluid additives and Problem soils

What to do with the following conditions?:

- Gravel with high permeability?
- Aquifer with water over pressure?
- Salt water (and High pH in peat)
- Over consolidated and swelling clay?

- Drain drilling (sanitation of polluted subsoil)?

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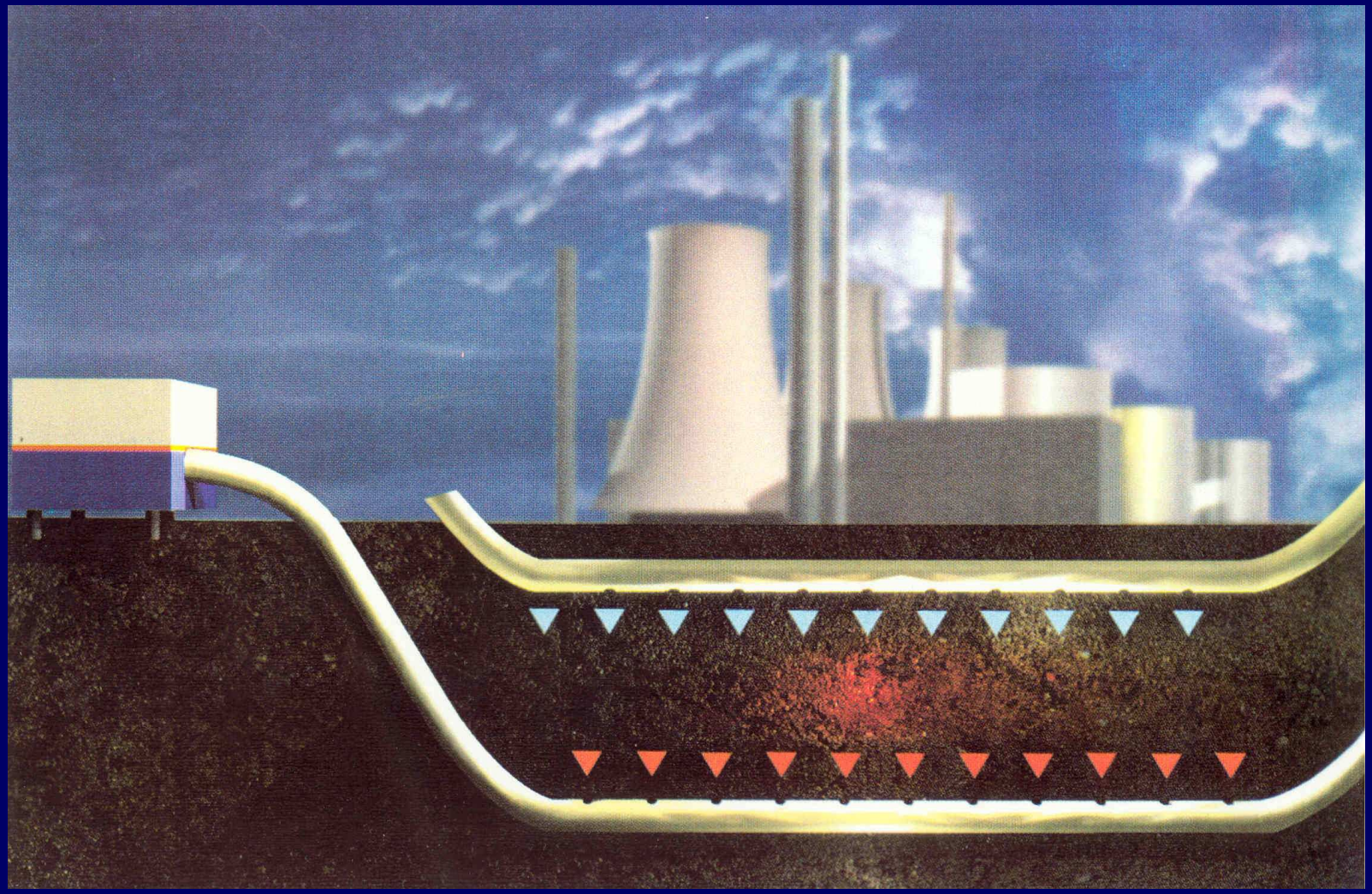
Drain drilling (maintain permeability)



Trenchless sanitation of polluted grounds

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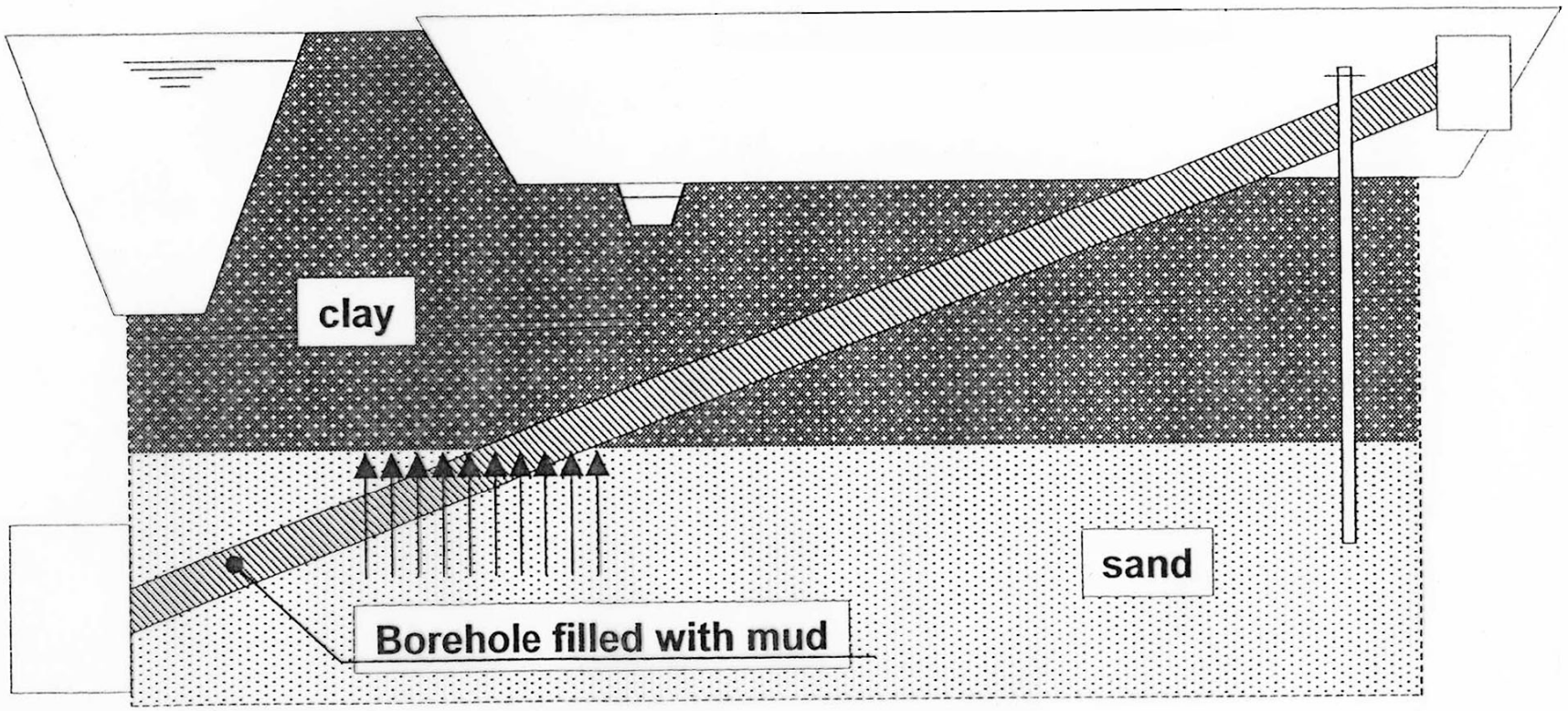

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Open front techniques

Open pipe Pushed/Hammered-Pulled through the soil.

Limited application

- Only above ground water in sandy soil

- Limited water pressure in impermeable soil

- In soft soil conditions only with small diameter (bridging of the soil is required)

Open front techniques

Different types of open front techniques

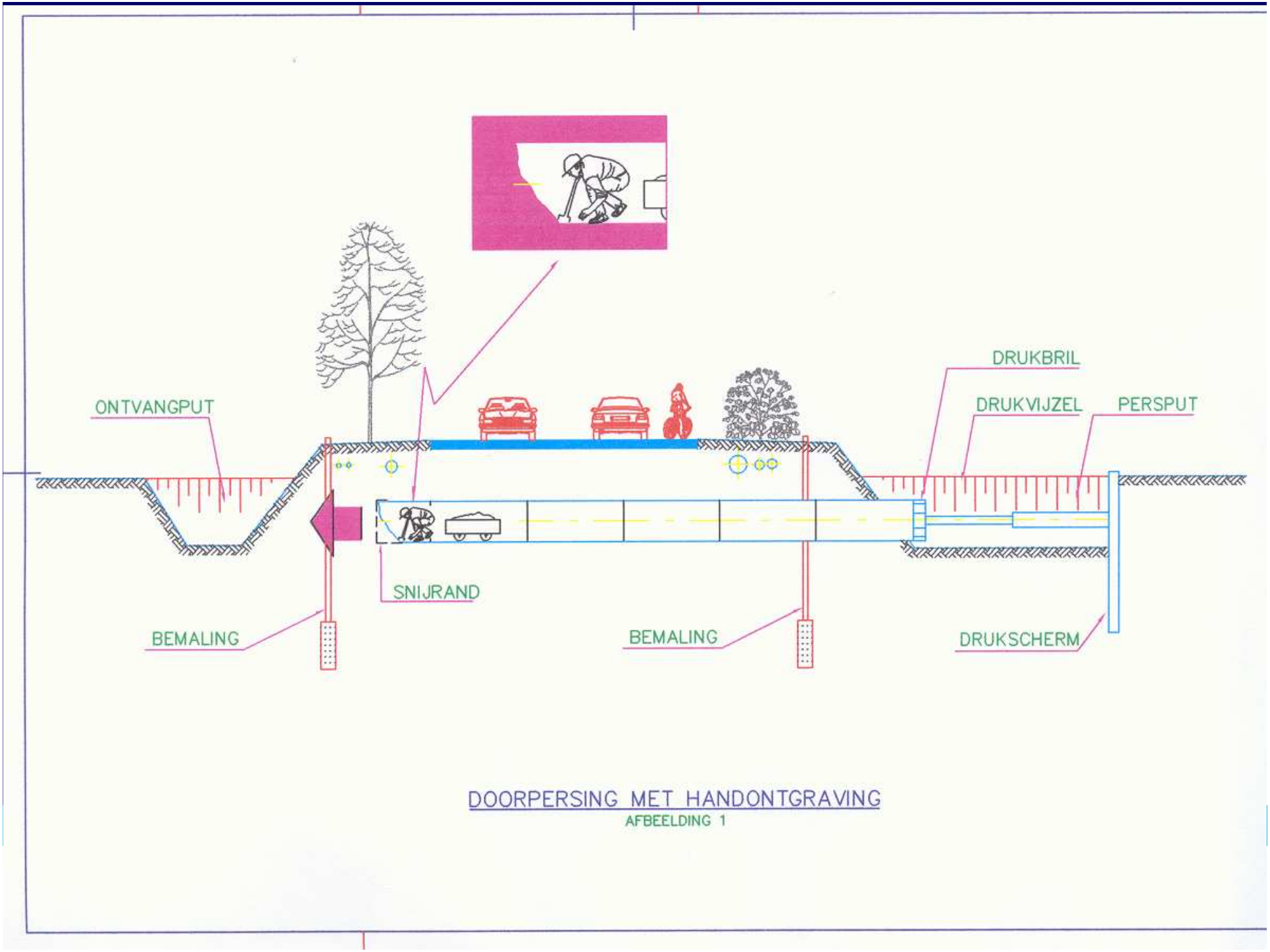
-Jacking of ramming of hollow pipe

-Auger drilling

Different types of pneumatic techniques

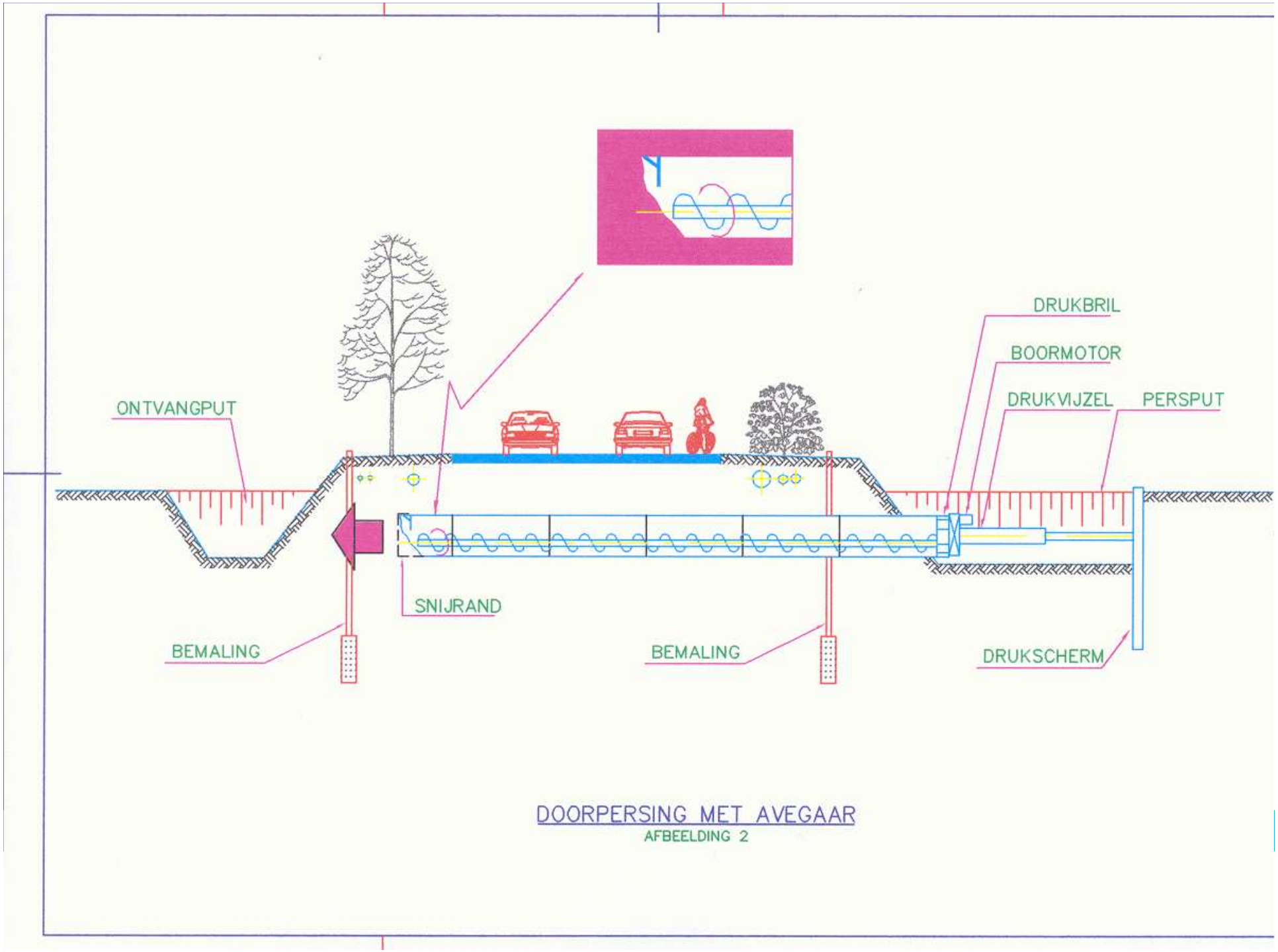
- Impact ramming

- Impact moling (Ground deformation)



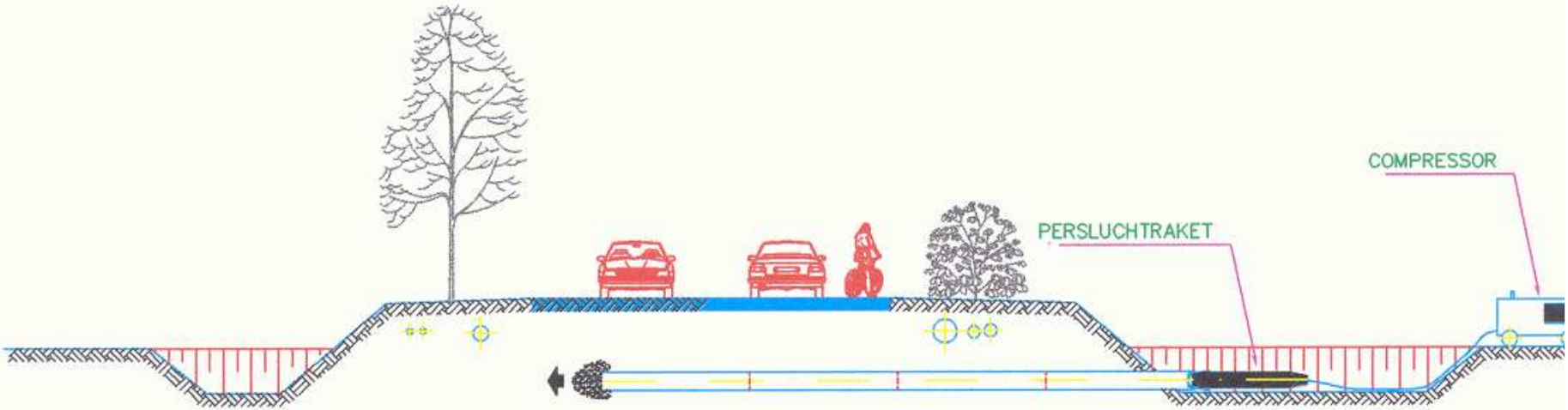
DOORPERSING MET HANDONTGRAVING

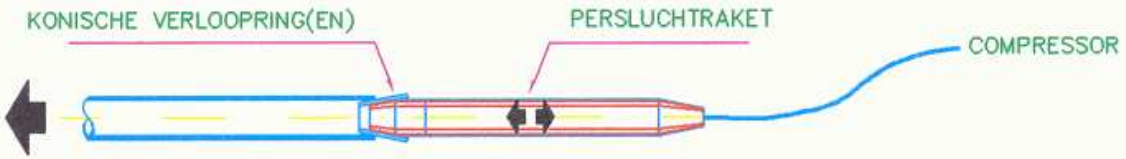
AFBEELDING 1



DOORPERSING MET AVEGAAR

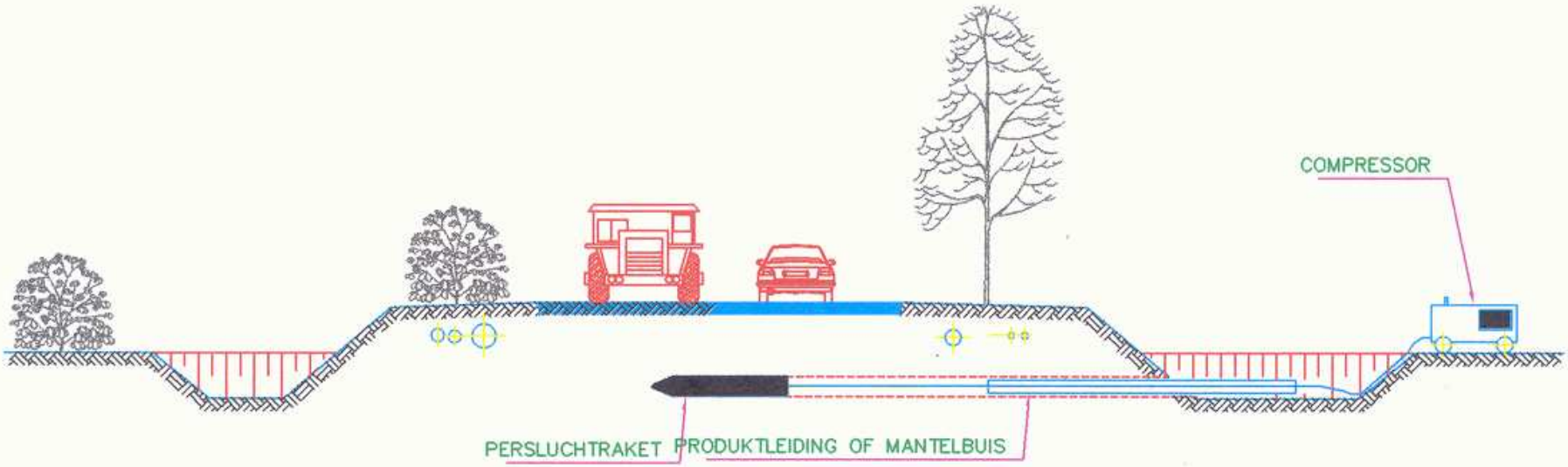
AFBEELDING 2

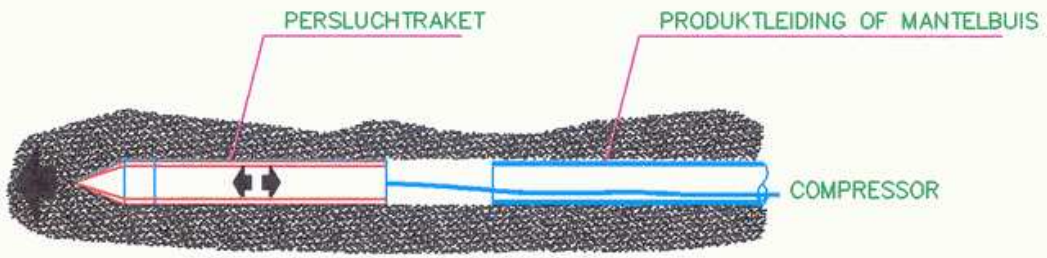




IMPACT RAMMING

AFBEELDING 3



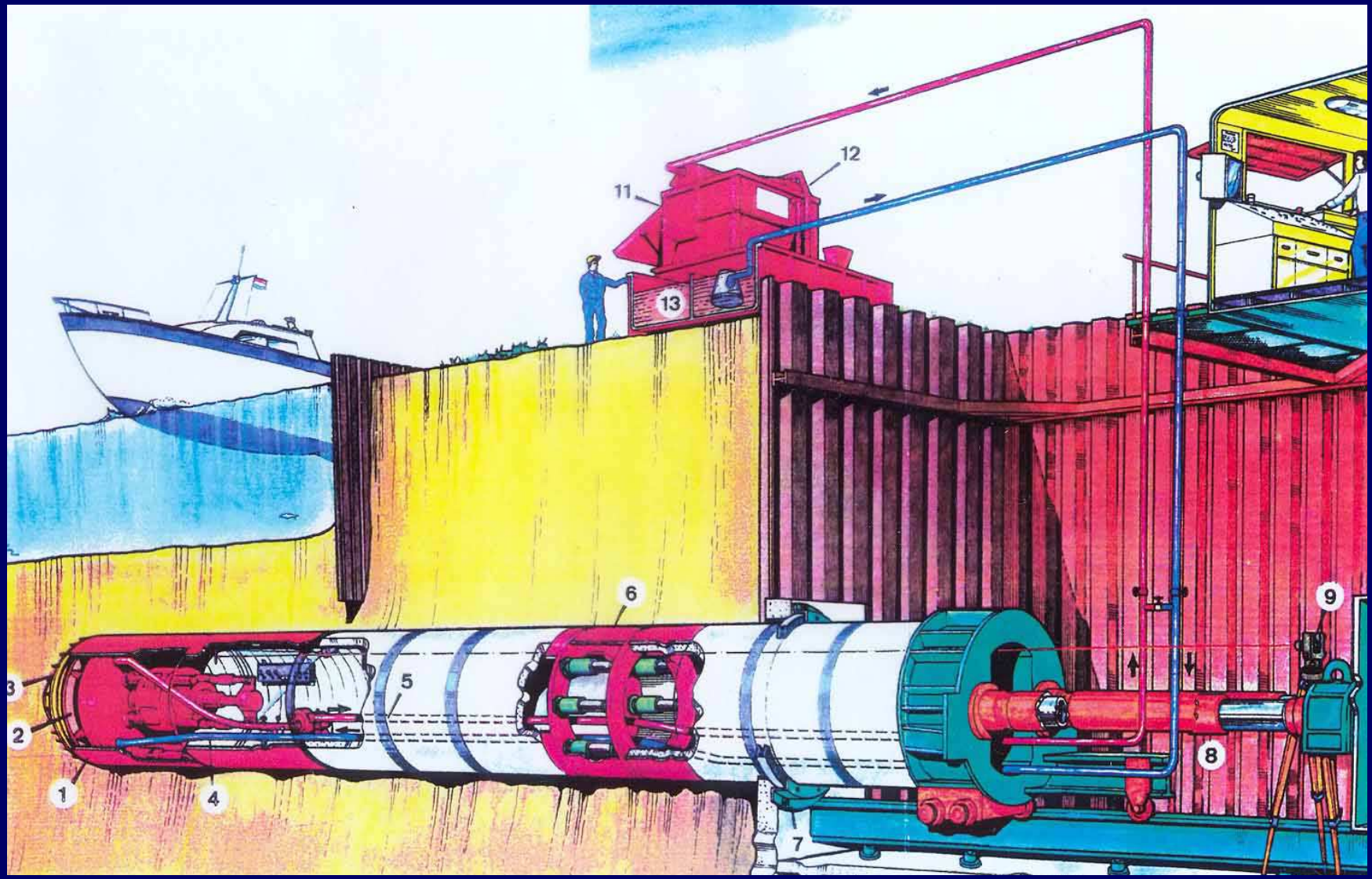


IMPACT MOLING

AFBEELDING 4

Open front techniques

- **Simple and cheap**
- **Risks**
  - Over excavation
  - Not stearable
  - Problems with excavation
  - Damage of the pipe
  - (High jacking forces), no lubrication
- **Limited application >>>> active support pressure**



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Pipe jacking

- **Logistics in shaft:**
  - -Feed pipe discharge pipe
  - -Ventilation
  - -Bentonite lubrication
  - -Electricity
  - -Laser
  - -Cooling water & compressed air
  - -Dummy
- **Equipment on surface:**
  - -Pipe storage
  - -Crane
  - -Hydraulic pump
  - -Generator
  - -Operation cabine
  - -Workshop
  - -Separation plant and pumps

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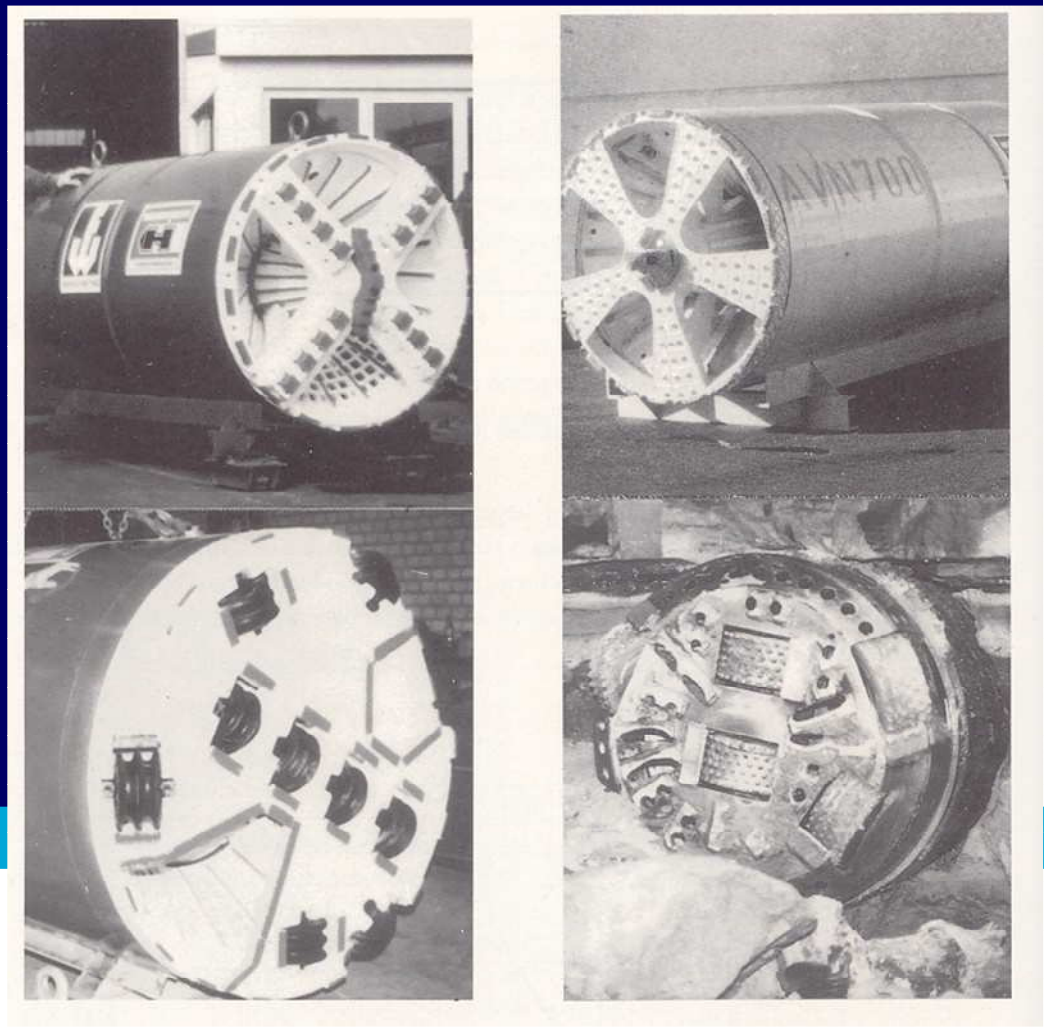
Pipe jacking with closed front

TBM

- -Shield
- -**Cutterhead**
- -Excavation chamber
- -Pressure wall
- -Main bearing
- -Steering jacks

Cutterhead depending on Geology

- •EPB shields
- •Slurry shields



Positioning

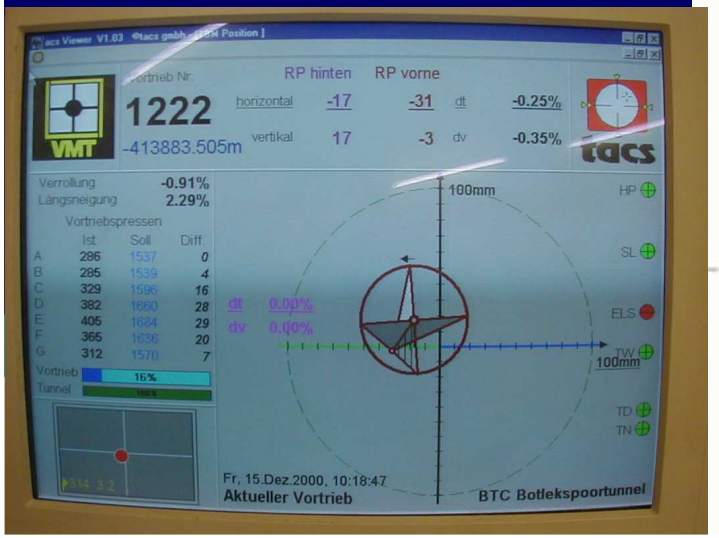
Positionering with laser system

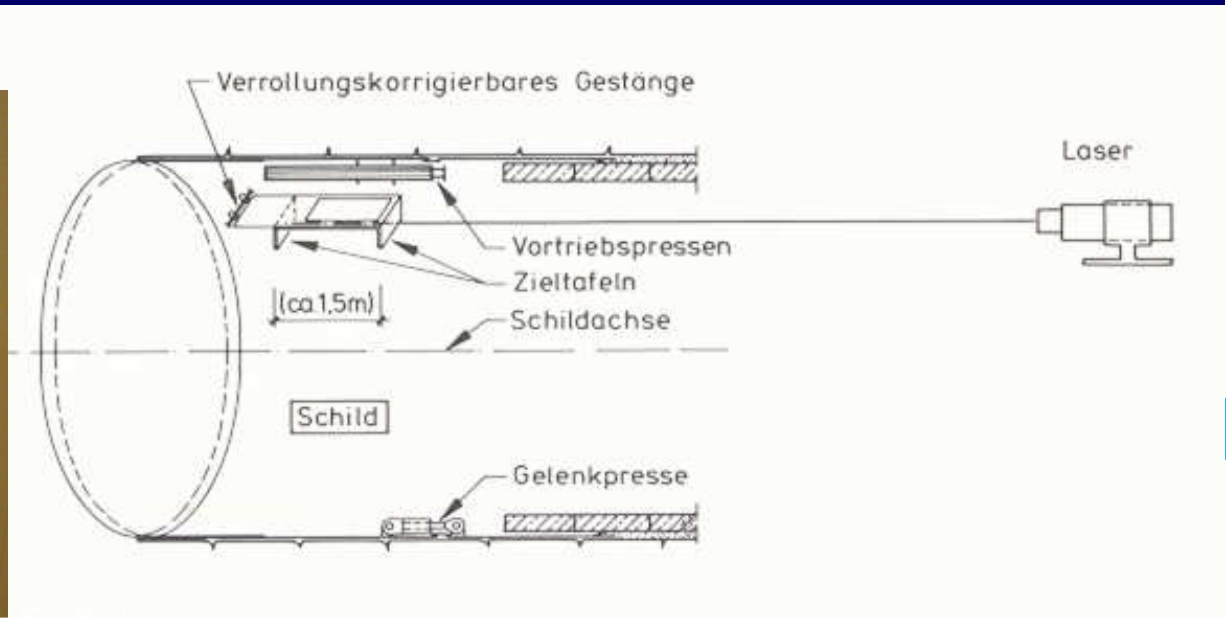
-Location

-Direction!!

"Make sure you have a good reference and long basis"

"double check position of launch and reception shaft"





Jacking force

Required jacking force $F_{tot} = F_m + F_s + F_a$

1 Mantle friction $F_m = \pi * \phi * L_{tot} * w$

w= factor 8 kN/m^2 with bentonite lubrication

2 Support pressure $F_s = (\pi * \phi^2) / 4 * P$

3 Thrust force on the cutterhead $F_a = (\pi * \phi^2) / 4 * I$

Empirical value on the Penetration resistance I= 50 kN/m^2

4 Loss of force due to steering ??!!!

Make sure you have extra capacity !

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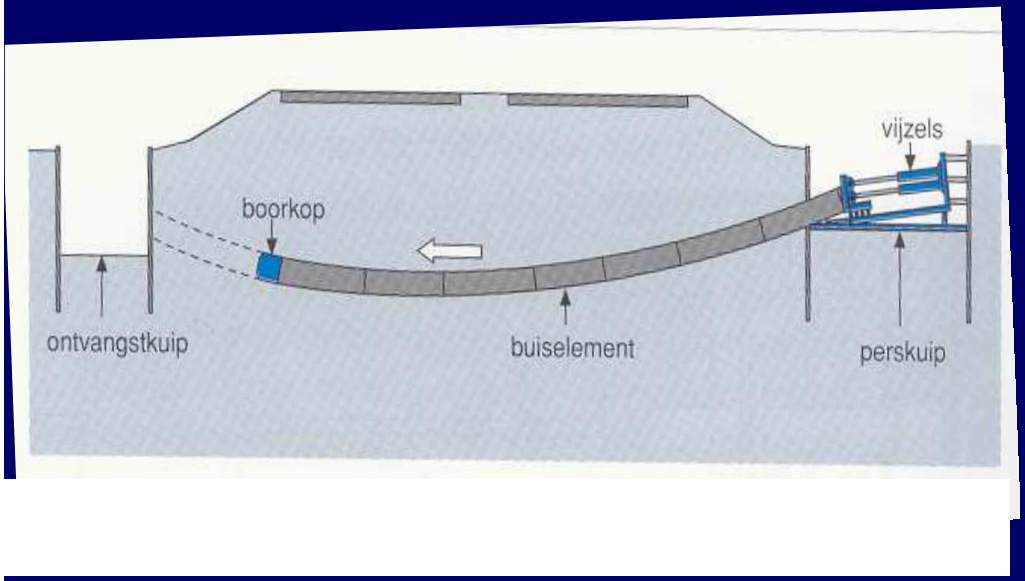
Jacking force

Maximum allowable jacking force

-Concrete strength of the pipes



Calculate curve with "Scherle"

Risks

- To high jacking forces Spalling of concrete
- "Knicking" of the pipe (leakage)

Mitigation

- No sharp curves
- Prevent sudden steering movements
- Intermediate jacking station

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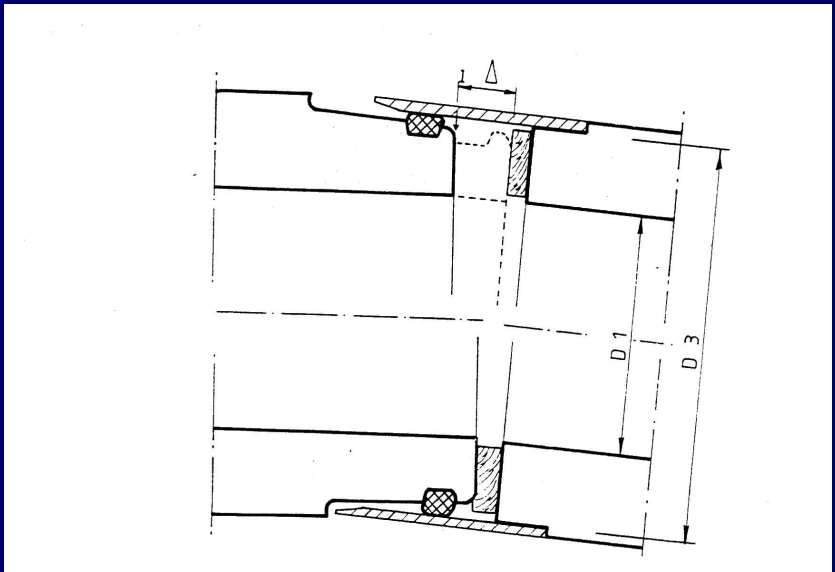
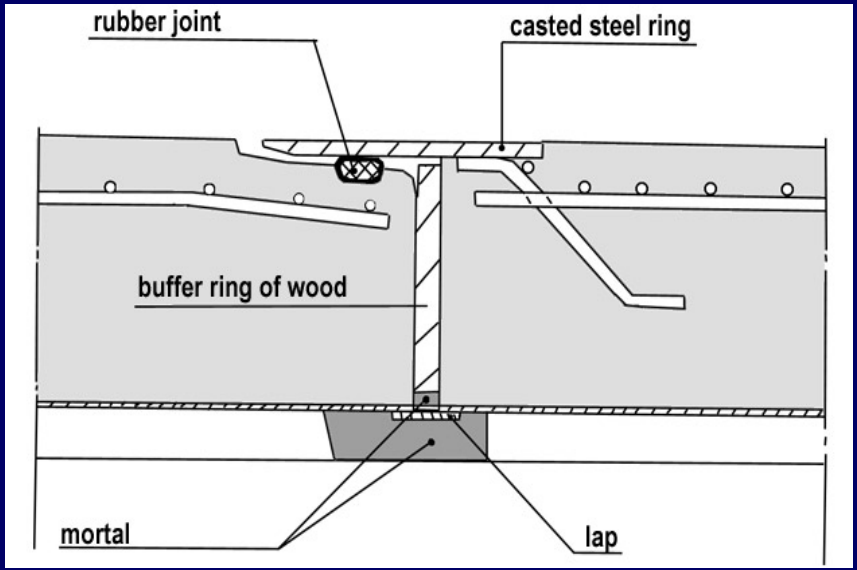
Joint of concrete pipes:



Pipe in bend



Straight pipe

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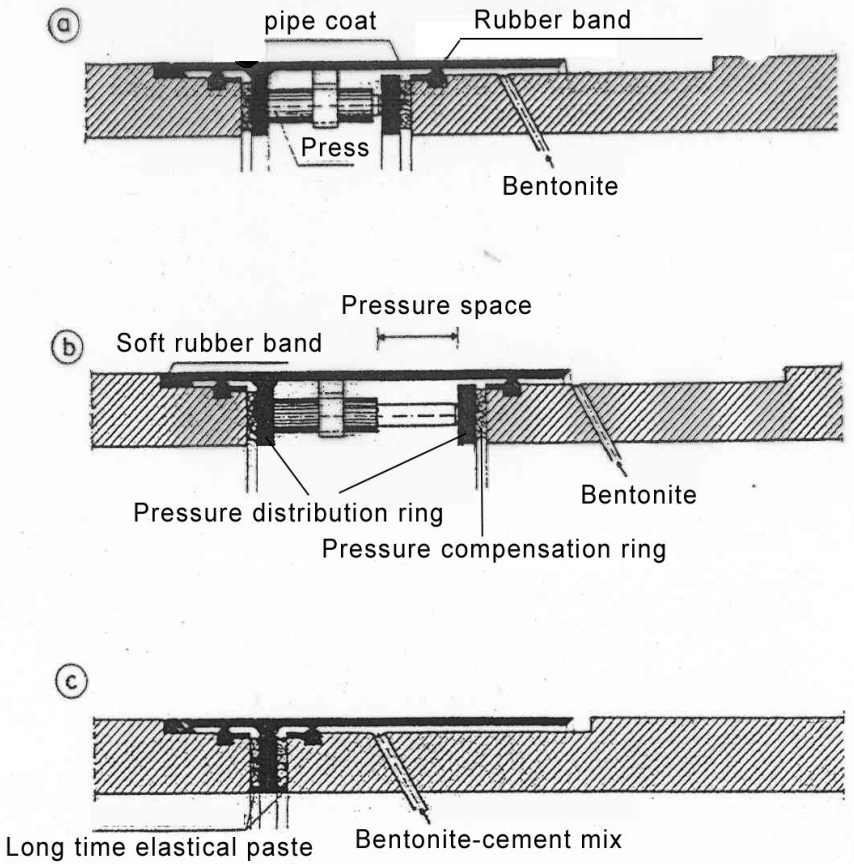
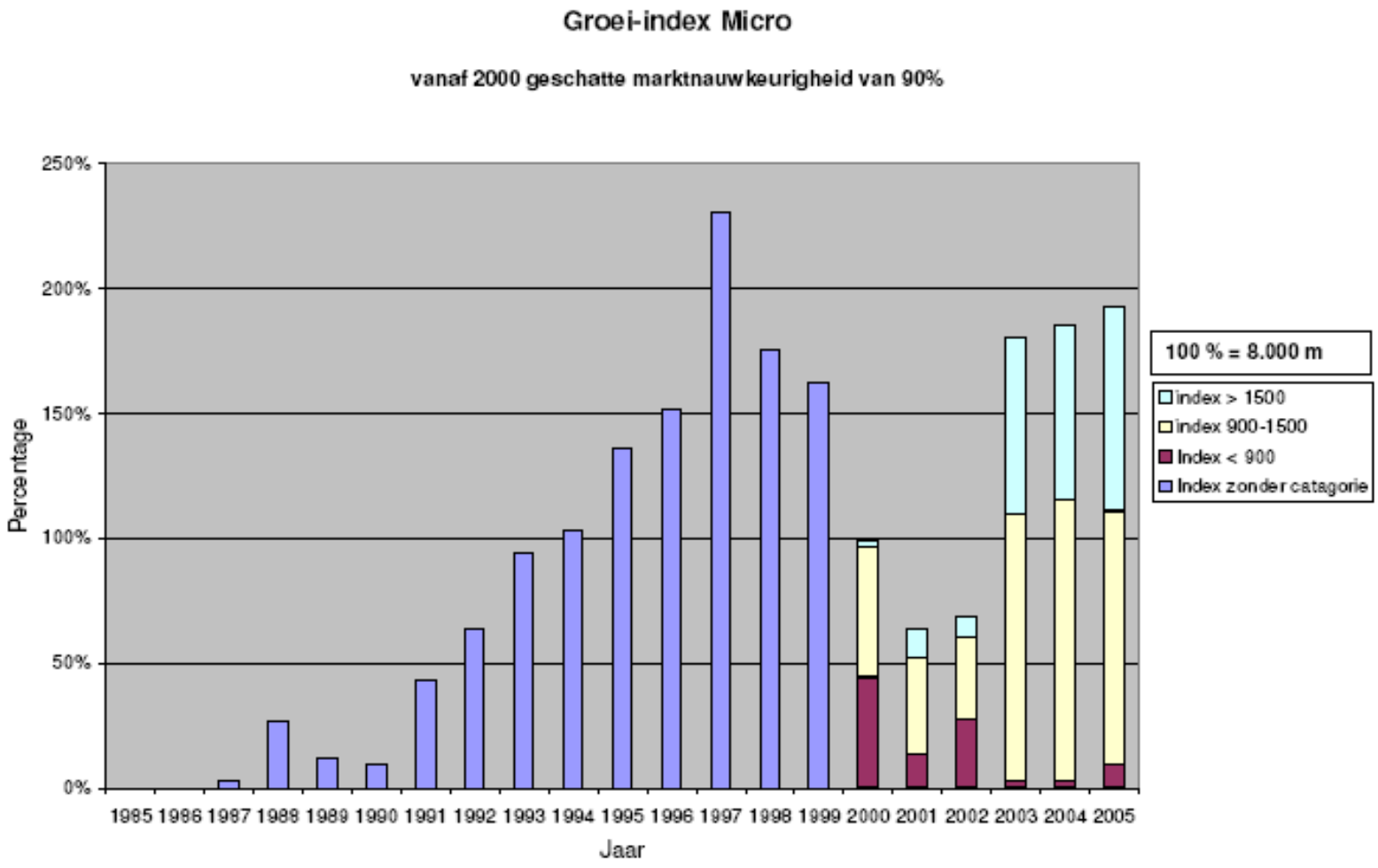
Intermediate jacking station

(to overcome high friction forces)



Functioning of an interjack station:
a) closed situation
b) open situation
c) situation after completion microtunneling

Productie pipe jacking



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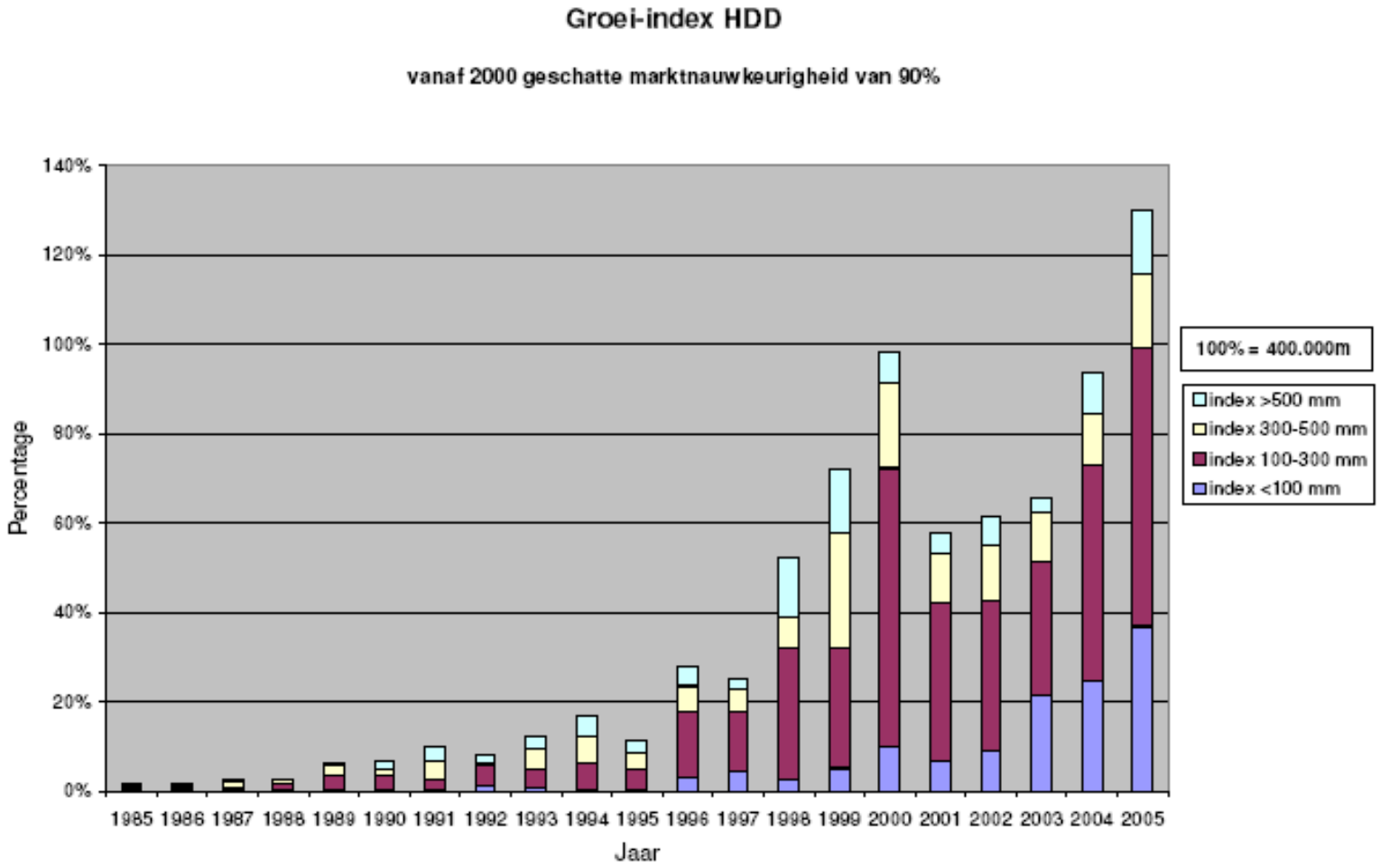
Production HDD



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Classifying Trenchless Technology

Open front boring techniques	<1m	
Pneumatic boring techniques	<0,8	
Pipe Jacking	0,6 to 3m	(< 0,8 km)
HDD	up to 1,6m	(< 2 km)

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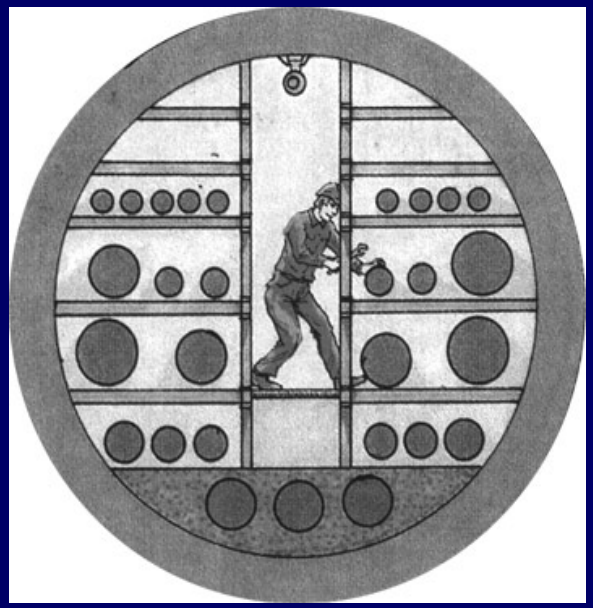
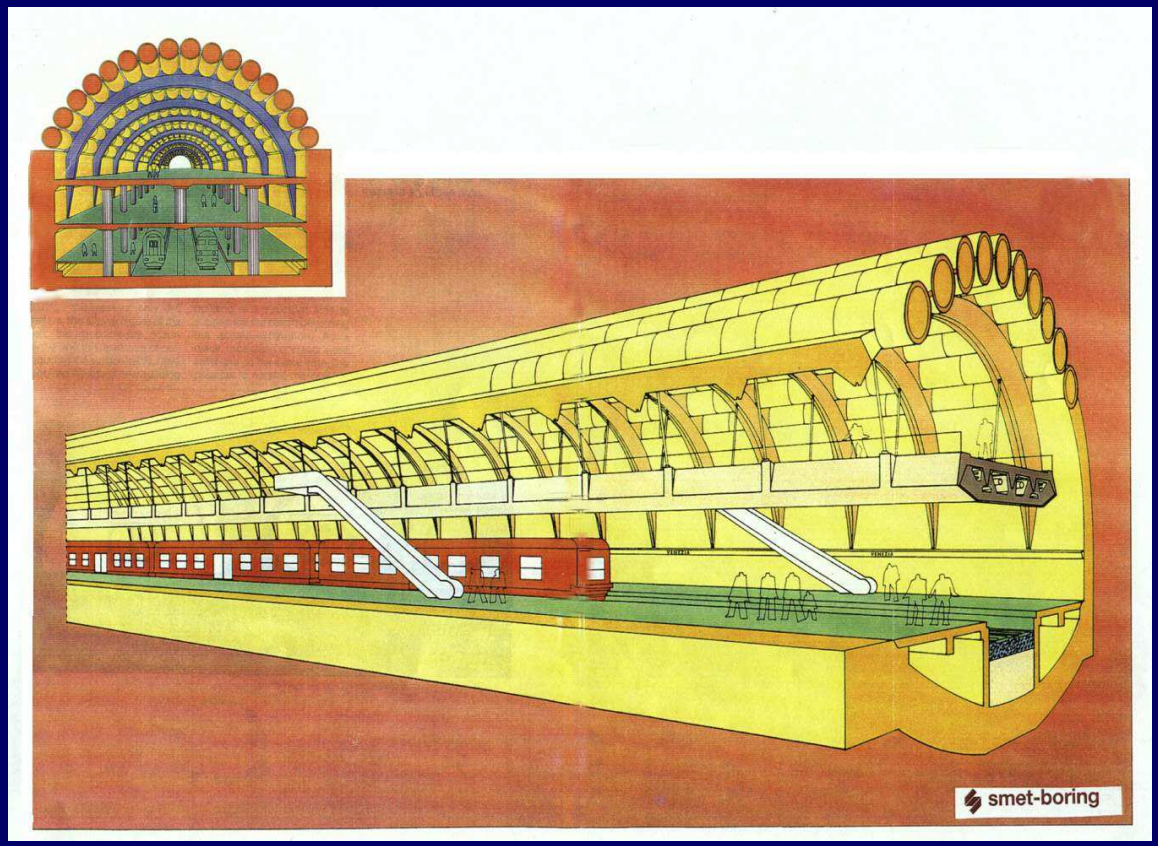
Increasing probabilities (2)



Multifunctional pipe line tunnel



Tubular roof construction

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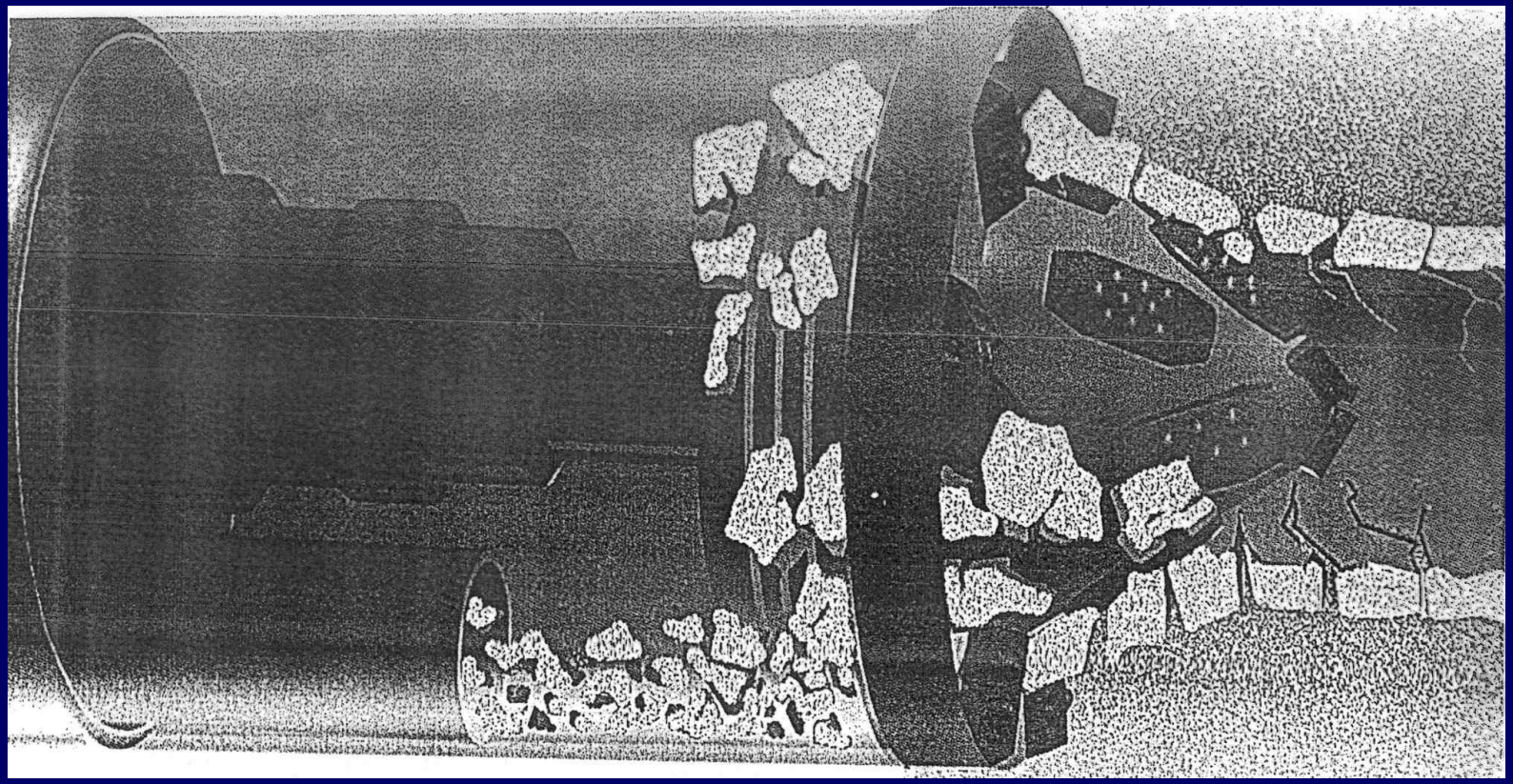

Boring machine eats old pipe!

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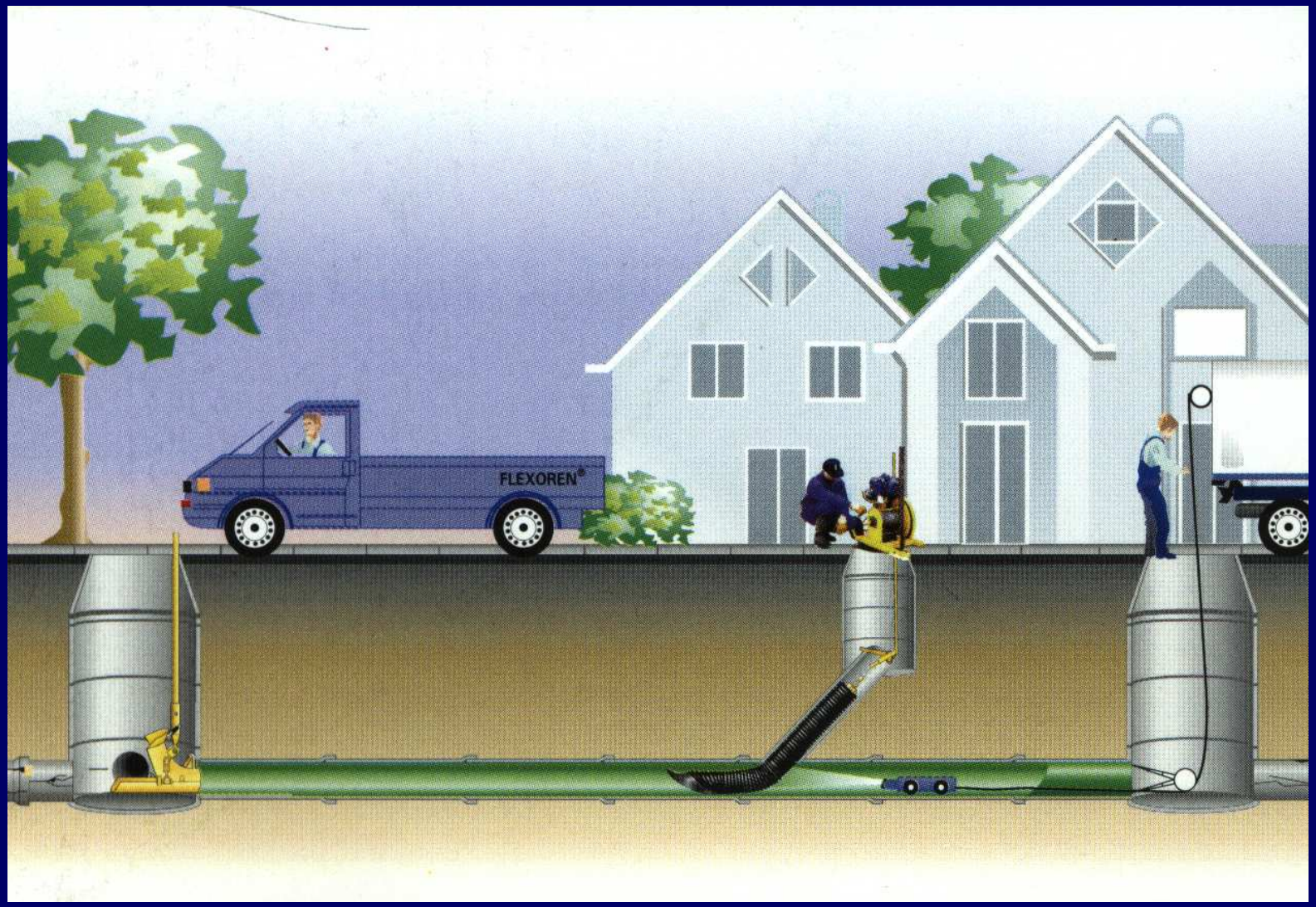
Pulling in the flexible pipe through the main pipe under TV observation:



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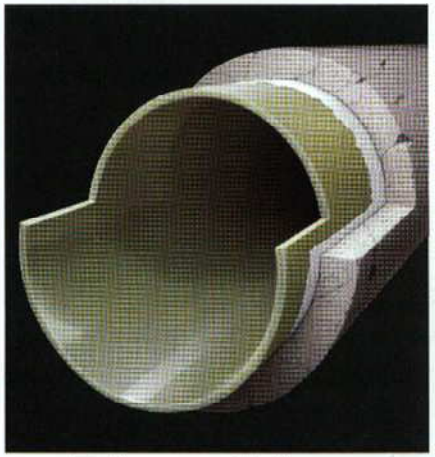
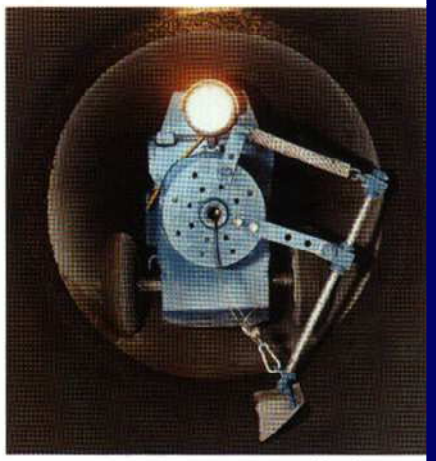
robotic system

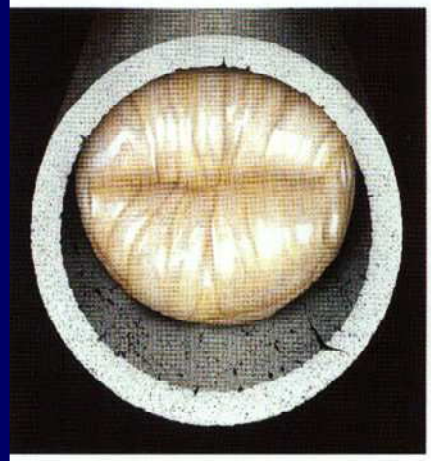


T-liner relining

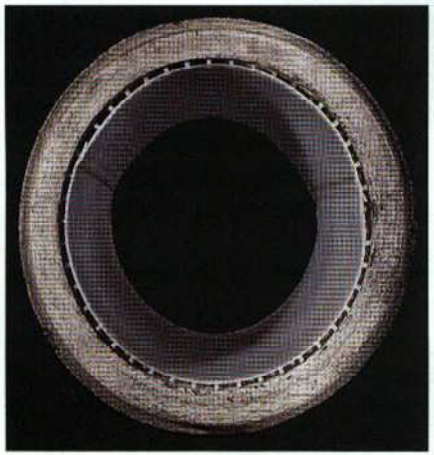
short pipe relining



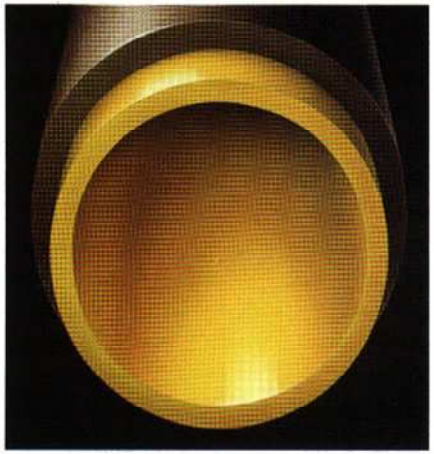
cement mortar lining



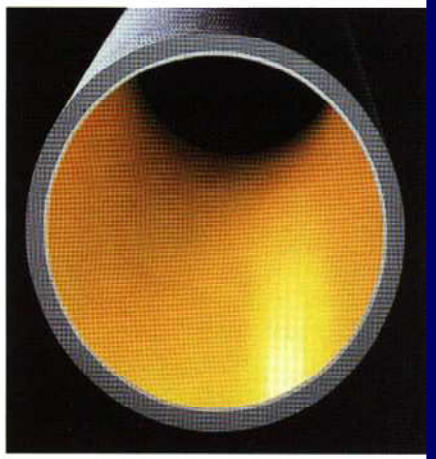
inpipe relining



trolining system



swage lining



woven fabric relining

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CT 3300 in relation to other courses

- Trenchless Technology>>>>>Chapter 11 of the reader
- CT 3300 Use of underground space.
  - Broad introduction
- CT 4780 Special Topics
  - New developments on UC
- CT 5305 Bored and immersed tunnels
  - In detail (also on lining design and settlment calculations)
- CT 5740 Trenchless Technology
  - Pipeline construction techniques in detail

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Case Study

- Crossing of a river in France
- Ground conditions
  - Top layers of silt/clay/sand
    0 to- 2m
  - Layer of Gravel
    -2 to -10m
  - Marl (claystone)
    below-10m
- L ca. 400m
- Single Gas pipe ca. 300mm
- Ca. 4 weeks

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Case Study

• To cross the layer of gravel a casing is used.

•Installed with impact ramming.

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Case Study

- With impact ramming the position of the first pipe is critical
- Correction is not possible
- Risk on damadge of the pipe
  - bij de slaghoed
  - bij het graaffront

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Case study

- Emptying the pipe
  - flush
  - Suction truck
  - "by hand"
- Problems with mobilizations.
- Problems with cleaning the pipe

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Case study

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Case study: Stones in stead of Gravel??

1) adapt drilling?
2) adapt pulling the pipe?

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Case study: Stones in stead of Gravel??

1) adapt drilling?
2) adapt pulling the pipe?

1) No

- Pilot allready with mudmotor
- Reaming with "Hole opener", sufficient overcut
- Stones are not a problem with the choosen equipment for the claystone.
- Drilling fluid

2) Yes

- Accept that stones will stay in the borehole!
- Increase protection with mantel pipe!

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Case Study

Mudmotor : - Pump must be in top shape (high pressures)
- Low sand content

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Case study

Advice was not followed up:

*** Pipe was pulled in with conventional thick coating**
*** Pipe head was protected with HDPE Head to prevent contact when pulling in the casing** (at own expense)

Result:
The electrical test showed that the coating was damadged
(About 7m below surface some 40 m behind exit point)

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Questions ?

Specific mineralogical characteristics of the soil

Sticking soils:

Attention must be paid to the phenomenon of sticking. This is not only important to the bore process of micro tunneling / pipe jacking, but also for HDD in connection with clogged passageways.

Abrasive soils:

Another important characteristics, especially in larger / longer works, is the abrasive character of the soil in which has to be drilled.

The previous characteristics do not get enough attention in the usual soil investigation. Moreover, research is necessary to be able to control the negative consequences of these characteristics.

Quality of surface water:

drilling fluid can be made using surface water and has to work in groundwater. Salt content and chemical pollution are important.

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Plastering

Plastering of a shallow bore hole aims to form a impermeable layer at the edge of the bore hole of HDD or at the boring front of micro- or macro tunneling, so the pressure of the soil can be withstood. The time to construct this layer and the depth of penetration of the boring fluid are correlated with the rheology of the boring fluid. The upper limit can be derived:

Intrusion depth = $\frac{8}{75}\frac{\Delta p}{T_y}D_h$

with:

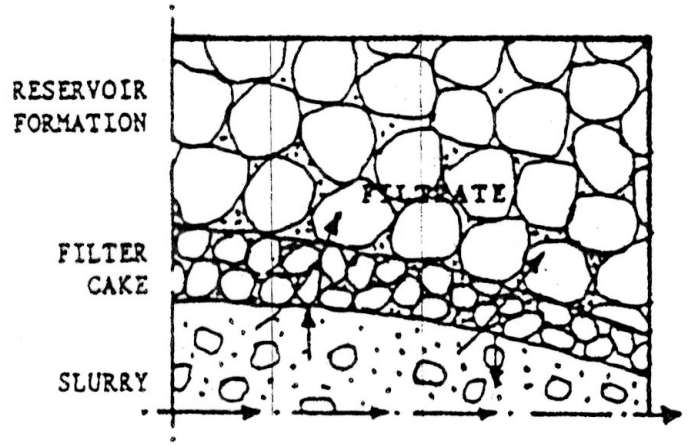
Δp = overpressure in boring hole

(support pressure) [Pa]

τ_y = yield pressure [Pa]

D_h = diameter of the pores in the soil [m]

Construction of filter layer around boring hole



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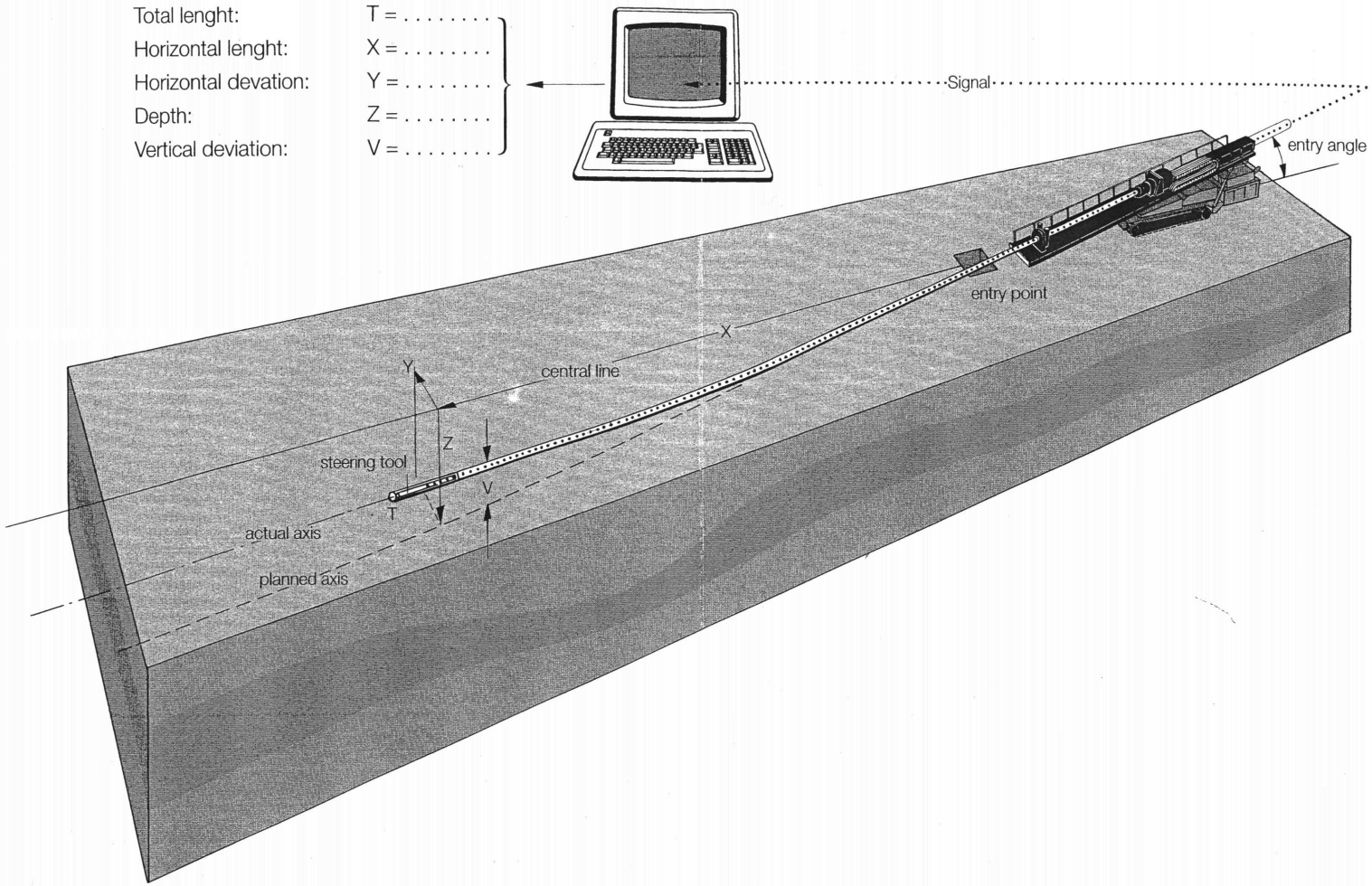
Total lenght: T = ...
Horizontal lenght: X = ...
Horizontal devation: Y = ...
Depth: Z = ...
Vertical deviation: V = ...
Signal
entry angle
entry point
X
Y
central line
Z
steering tool
V
T
actual axis
planned axis

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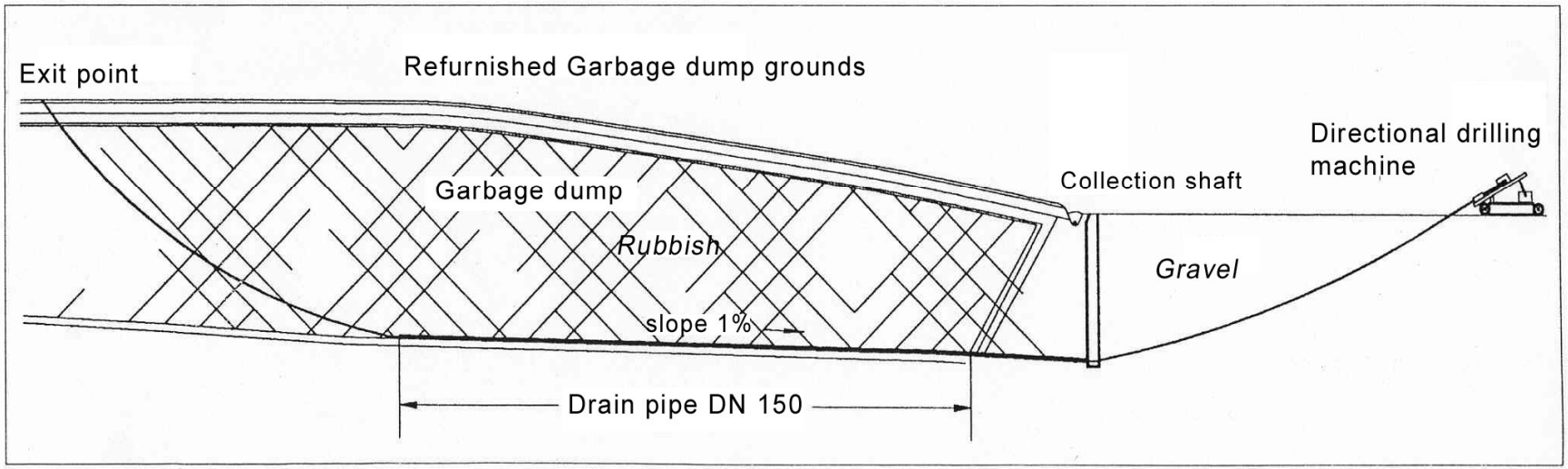
Trenchless sanitation of garbage dump drainpipes



In general for drainage systems

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