

# Welcome – KAL Cloudburst tunnel

Client



Consultant





# Kalvebod Brygge Cloudburst tunnel - DFTU -

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HOFOR og Frederiksberg Forsyning

NIRAS

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27-11-2019

By  
Bo Tvede-Jensen (NIRAS)



# Presentation of the agenda

1. General Project Presentation
2. Hydraulic models
3. Contamination
4. Tunnel alignment and structures
5. Shaft at Sønder Boulevard
6. Pumping Station at Kalvebod Brygge
7. Outlook

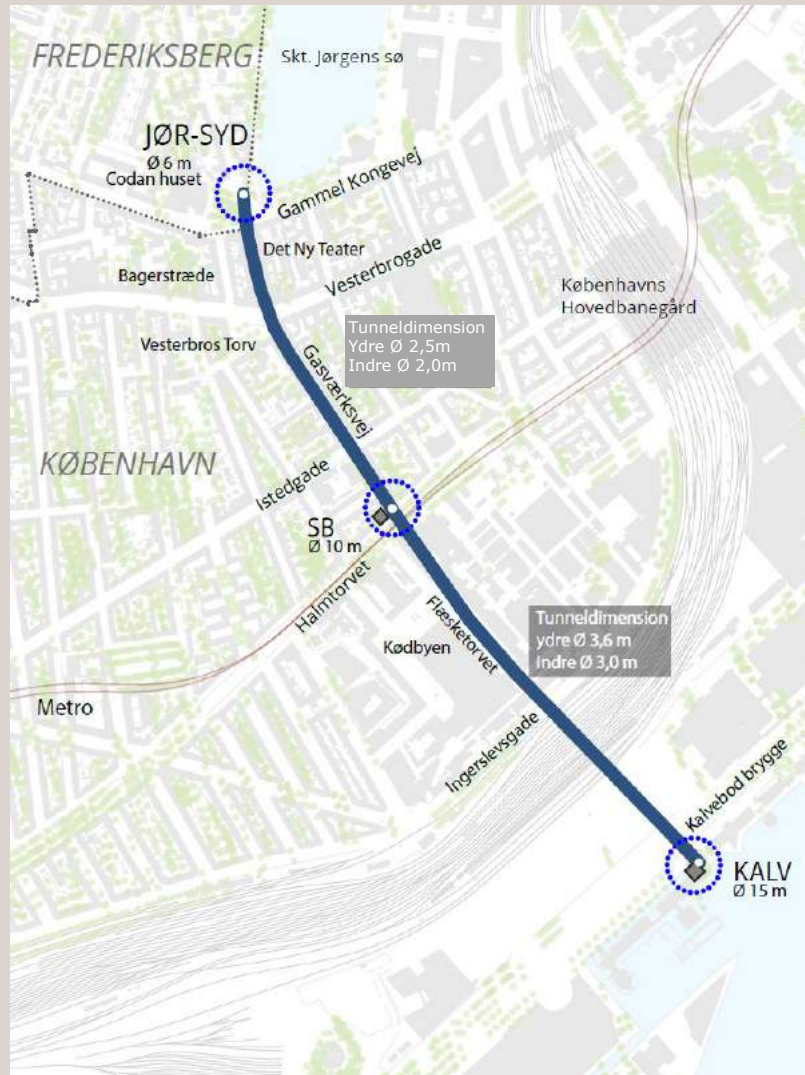


# Kalvebod Cloudburst tunnel





# Kalvebod Cloudburst tunnel



## Project facts:

### Shafts:

- Jør Syd
- SB
- KALV

### Tunnel:

- Stretch KALV to SB\_DN3000, length: 725 m
- Stretch JørSyd to SB\_DN2000, length: 540 m

### Project period:

2015-2025

**Estimated budget:** 341 mio. kr.

# Purpose of the unique project

**Kalvebod Skybrudstunnel is "one puzzle" of an ambitious cloudburst plan**

**The Skybrudstunnel is one of many coming projects**

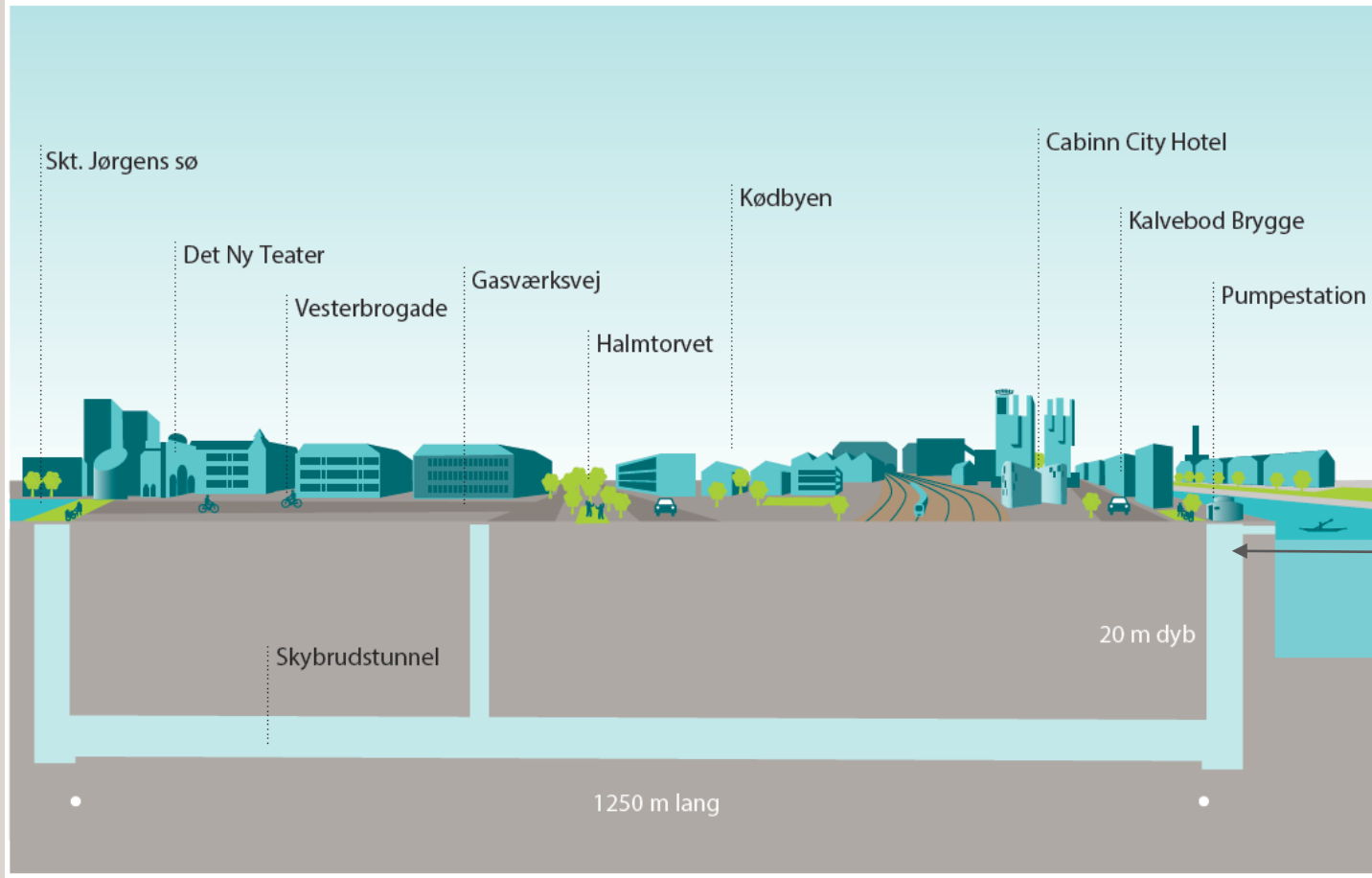
**We work across the boarder of 2 authorities and utility owners**

# Project – Unique Project

## KALVEBOD BRYGGE SKYBRUDSTUNNEL

High complexity considering the Interfaces and location

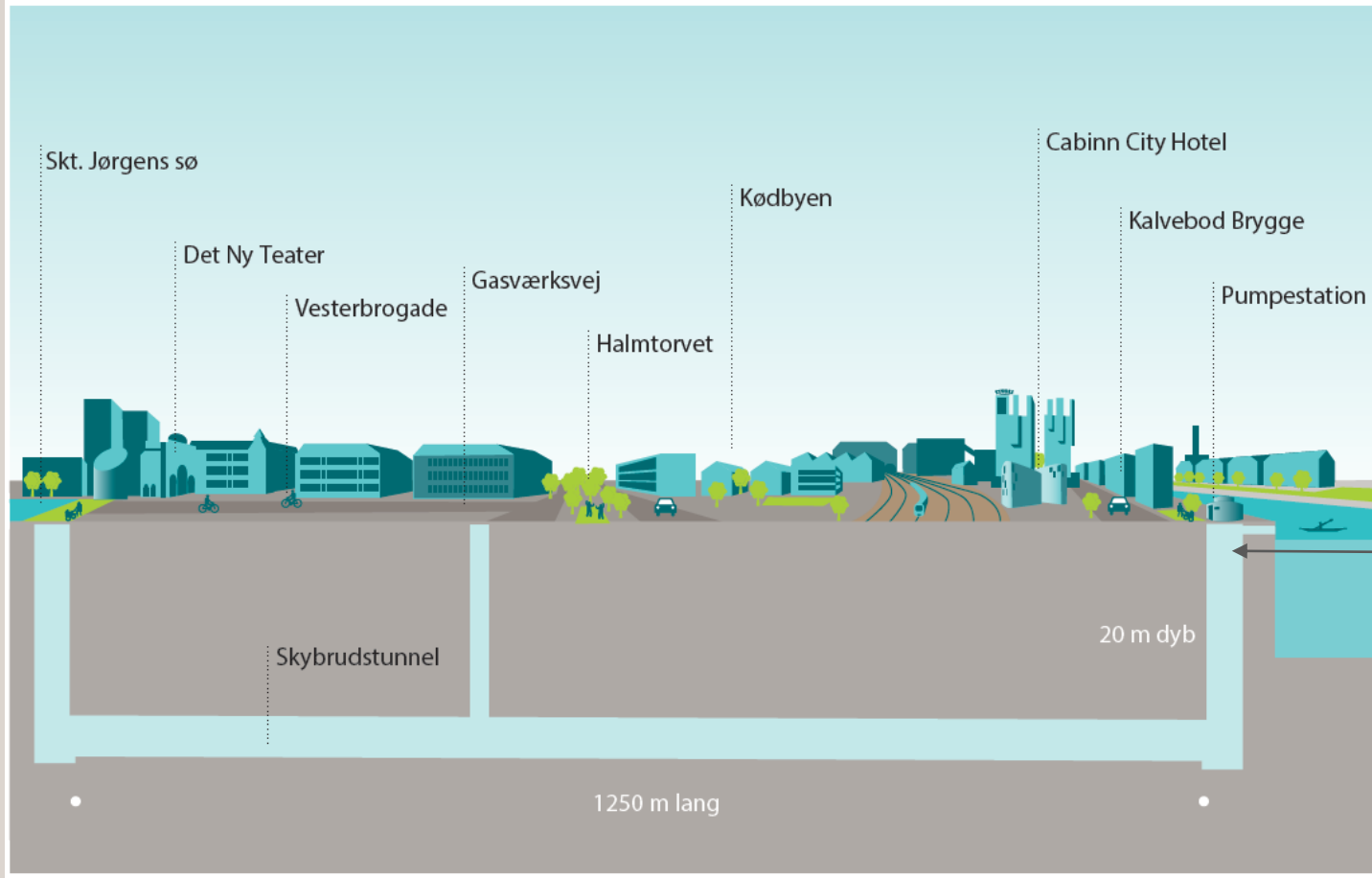
“Biggest” Pumping station in Scandinavia, 20m<sup>3</sup> / s



# Project – Unique Project

## KALVEBOD BRYGGE SKYBRUDSTUNNEL

High complexity considering the Interfaces and location



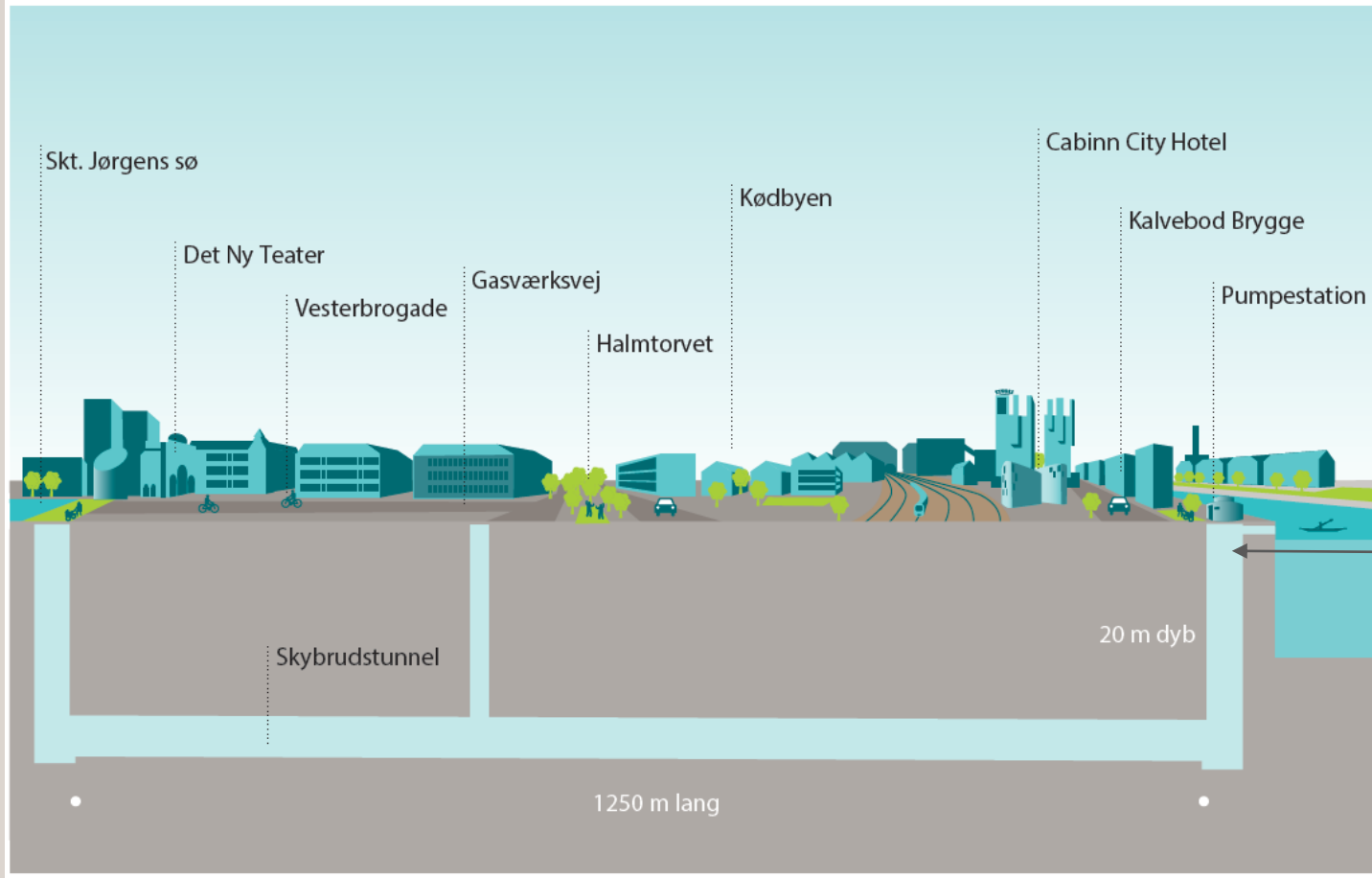
- Demolish 30m existing harbour structure
- Build an 18m wide outlet structure into new harbour front



# Project – Unique Project

## KALVEBOD BRYGGE SKYBRUDSTUNNEL

High complexity considering the Interfaces and location



- >20m deep excavation few meter from the harbour (S-piles vs D-walls)

# Project – Unique Project

## KALVEBOD BRYGGE SKYBRUDSTUNNEL

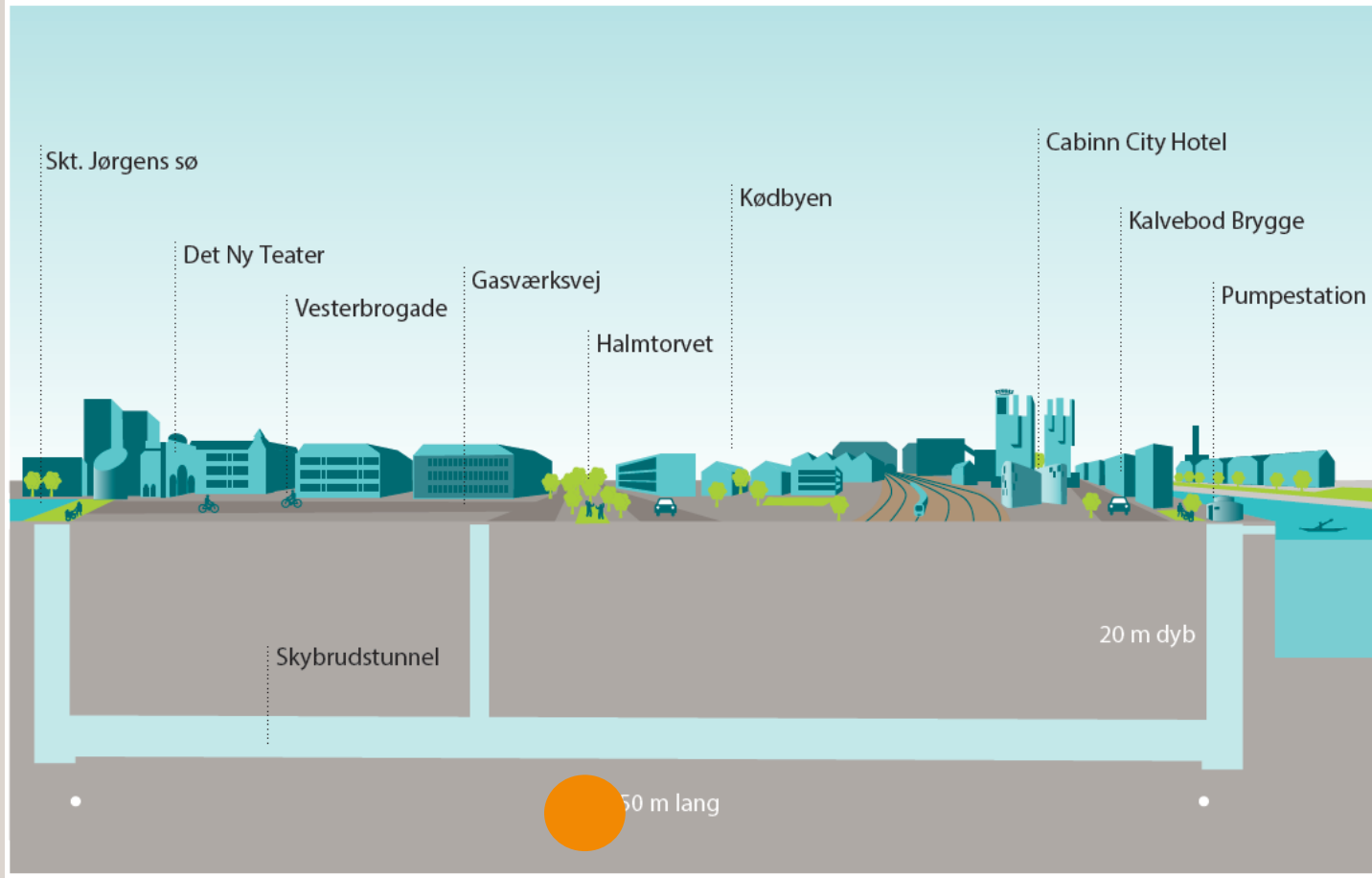


High complexity considering the Interfaces and location

Unique Landmark at the harbor front

# Project – Unique Project

## KALVEBOD BRYGGE SKYBRUDSTUNNEL



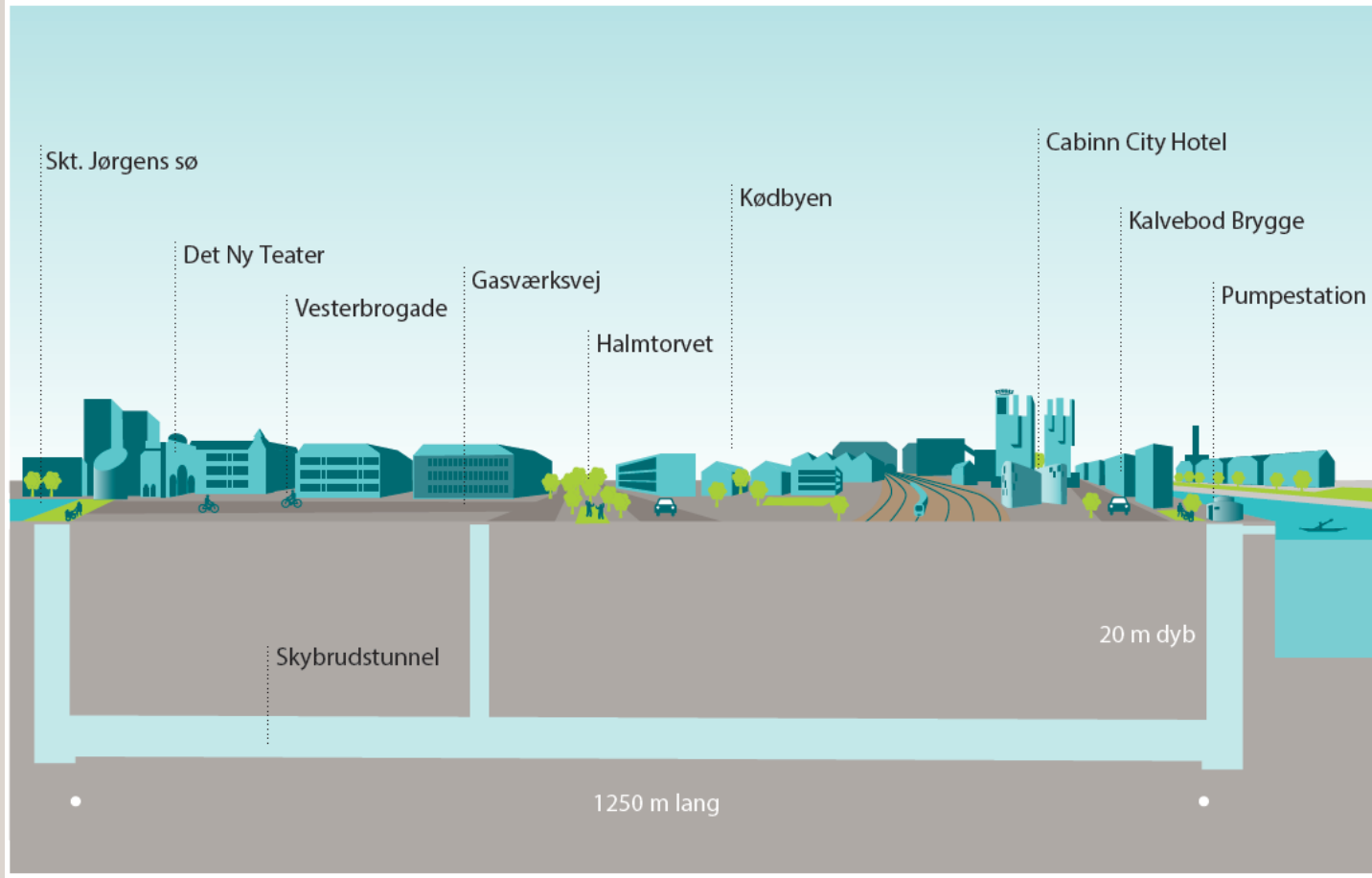
### Tunnel Alignment:

- Below Det Nye Teater
- 1m above operating Metro Cityringen
- Passing the most busy part of Danish railway system
- Tunnel below Kødbyen in highly polluted ground/groundwater
- General: Tunnel below residential buildings



# Project – Unique Project

## KALVEBOD BRYGGE SKYBRUDSTUNNEL



SB shaft:

- Deep shaft 5-8m from residential building

JørSyd shaft:

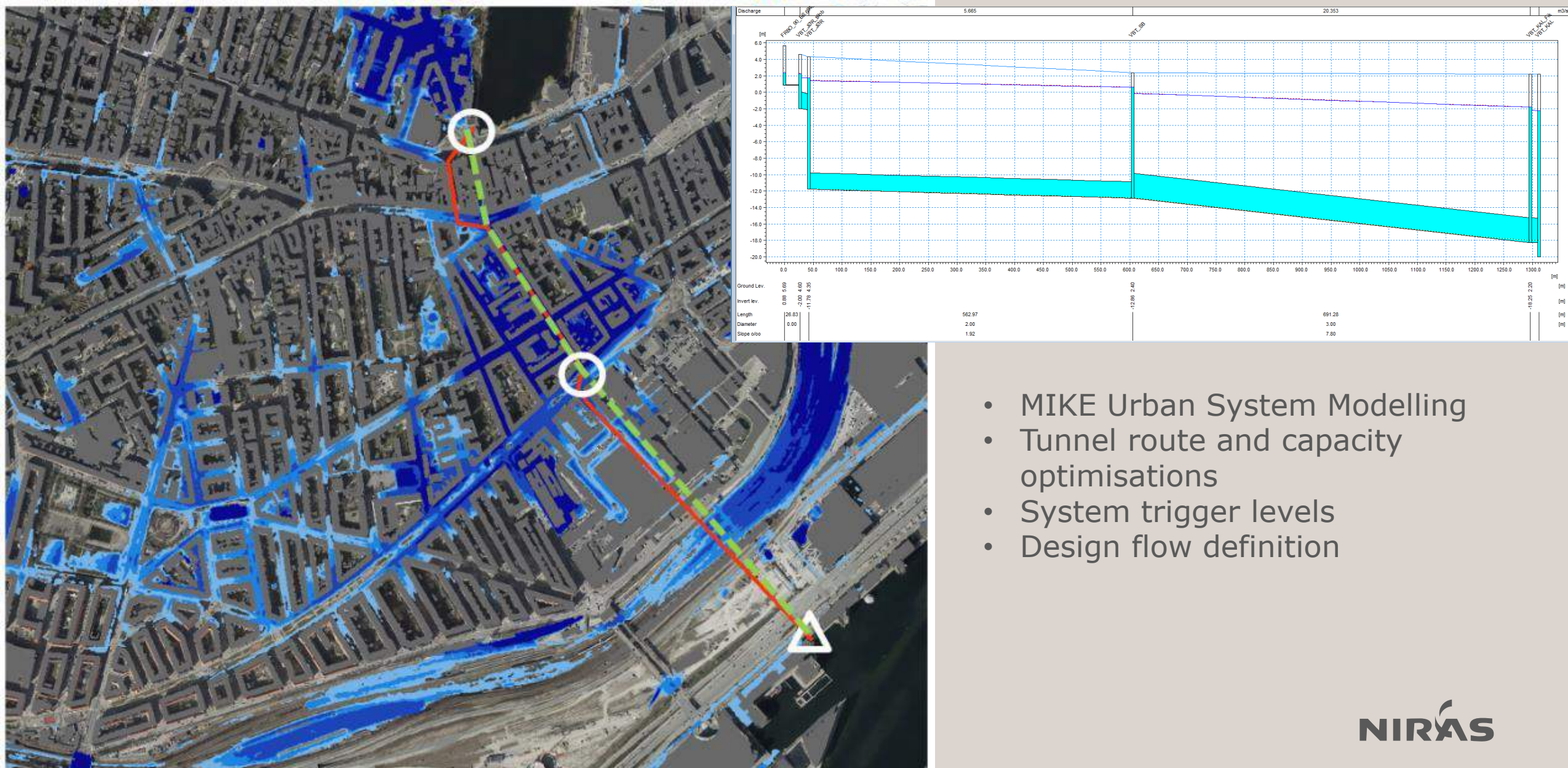
- Connect the tunnel to an >100 years old sewerage

Service life

- 100 years service life

# | Hydraulic

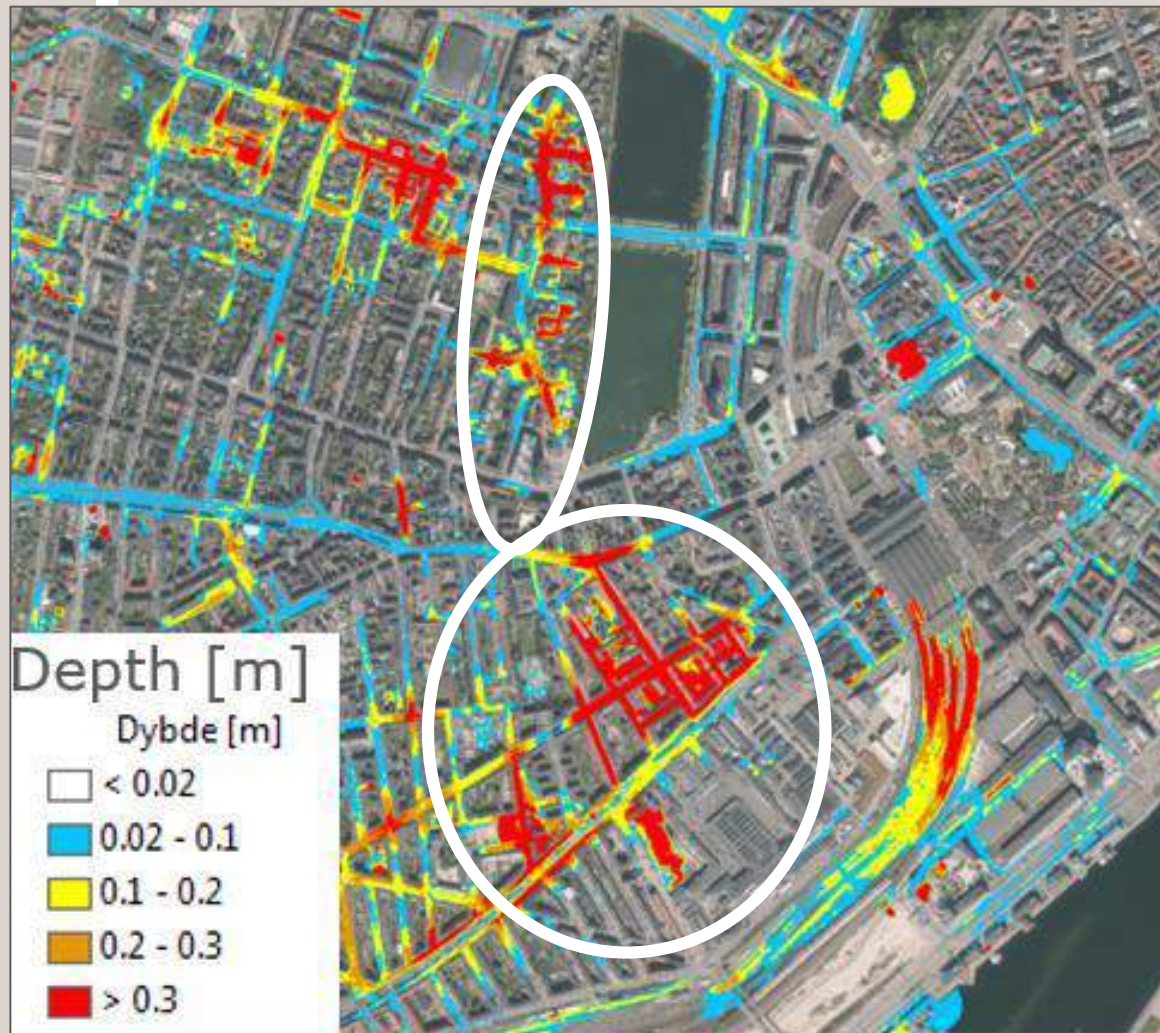
# Baseline Flood Modelling & Design Concept



- MIKE Urban System Modelling
- Tunnel route and capacity optimisations
- System trigger levels
- Design flow definition

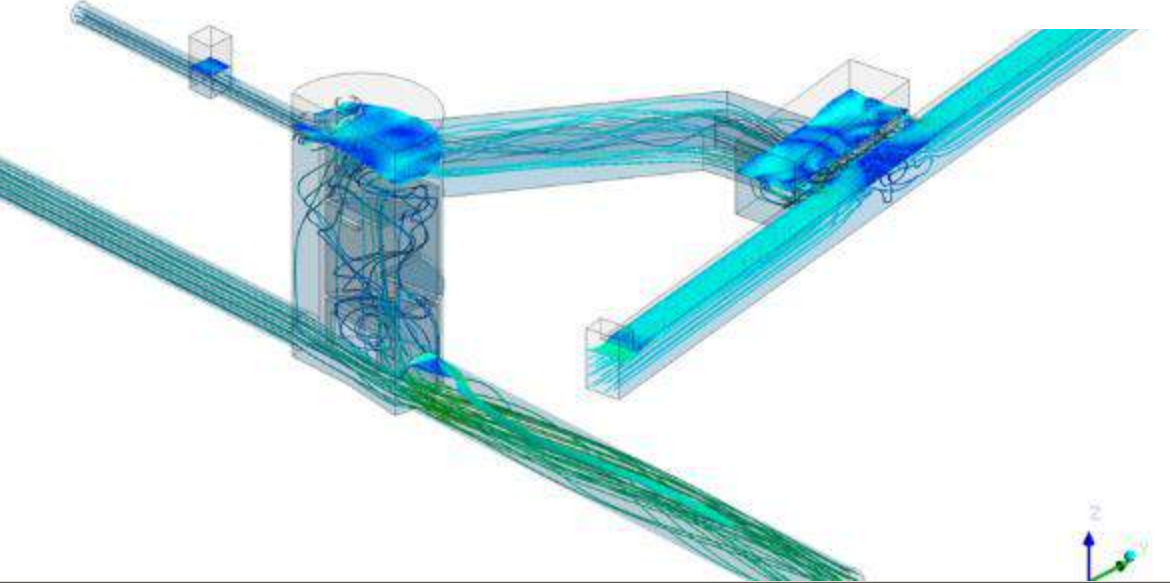


# Tunnel Impact

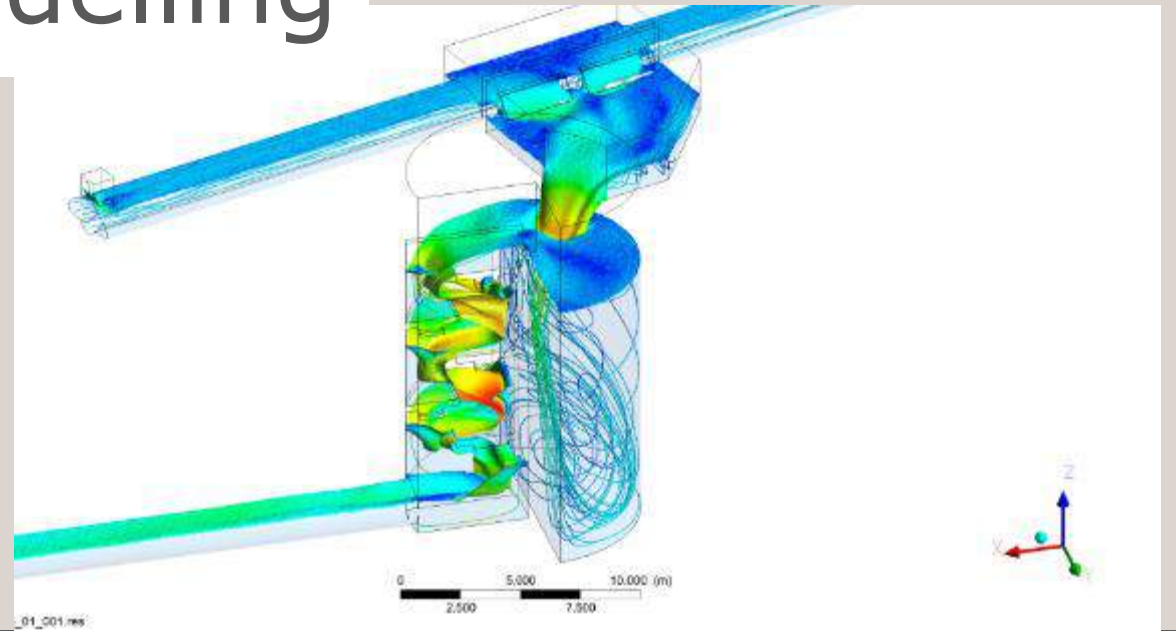




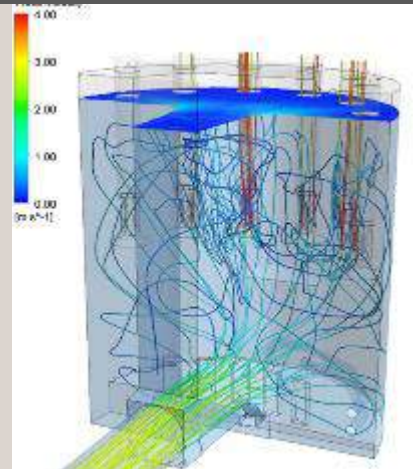
# CFD Modelling



Drop Shaft



Drop Shaft

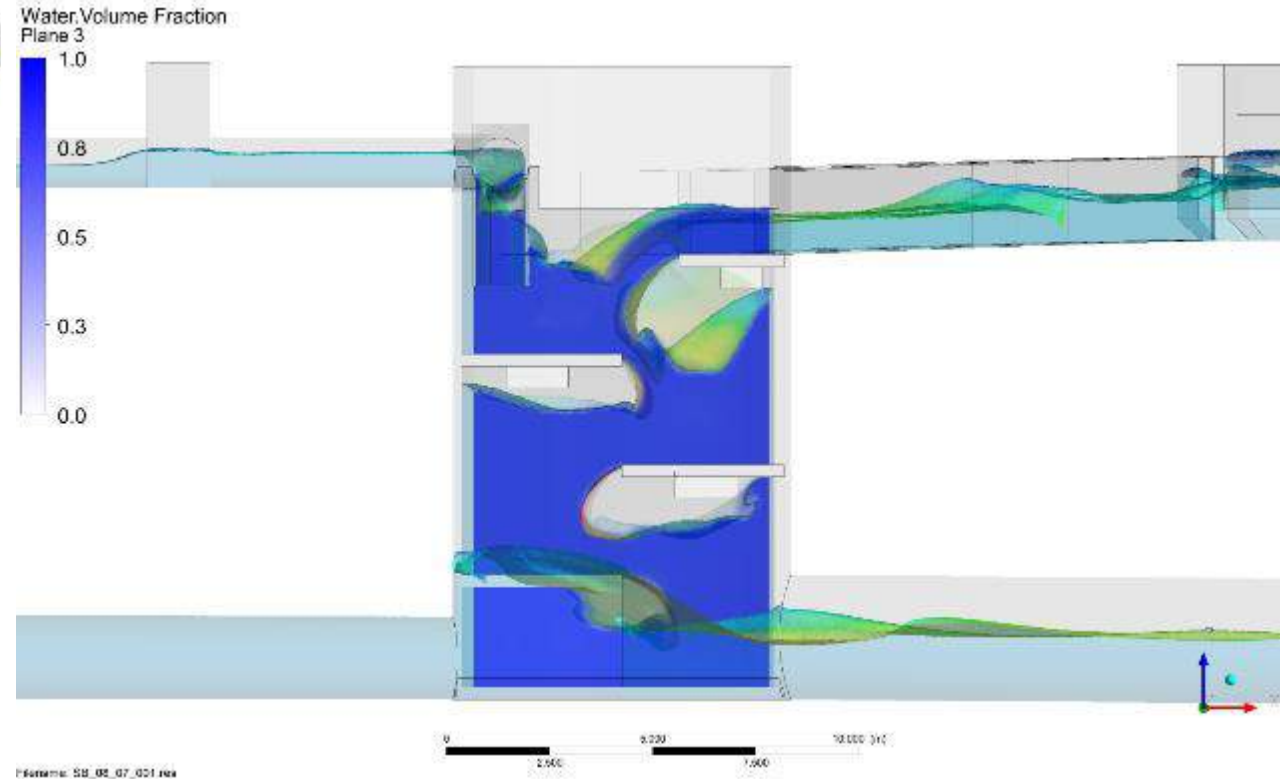
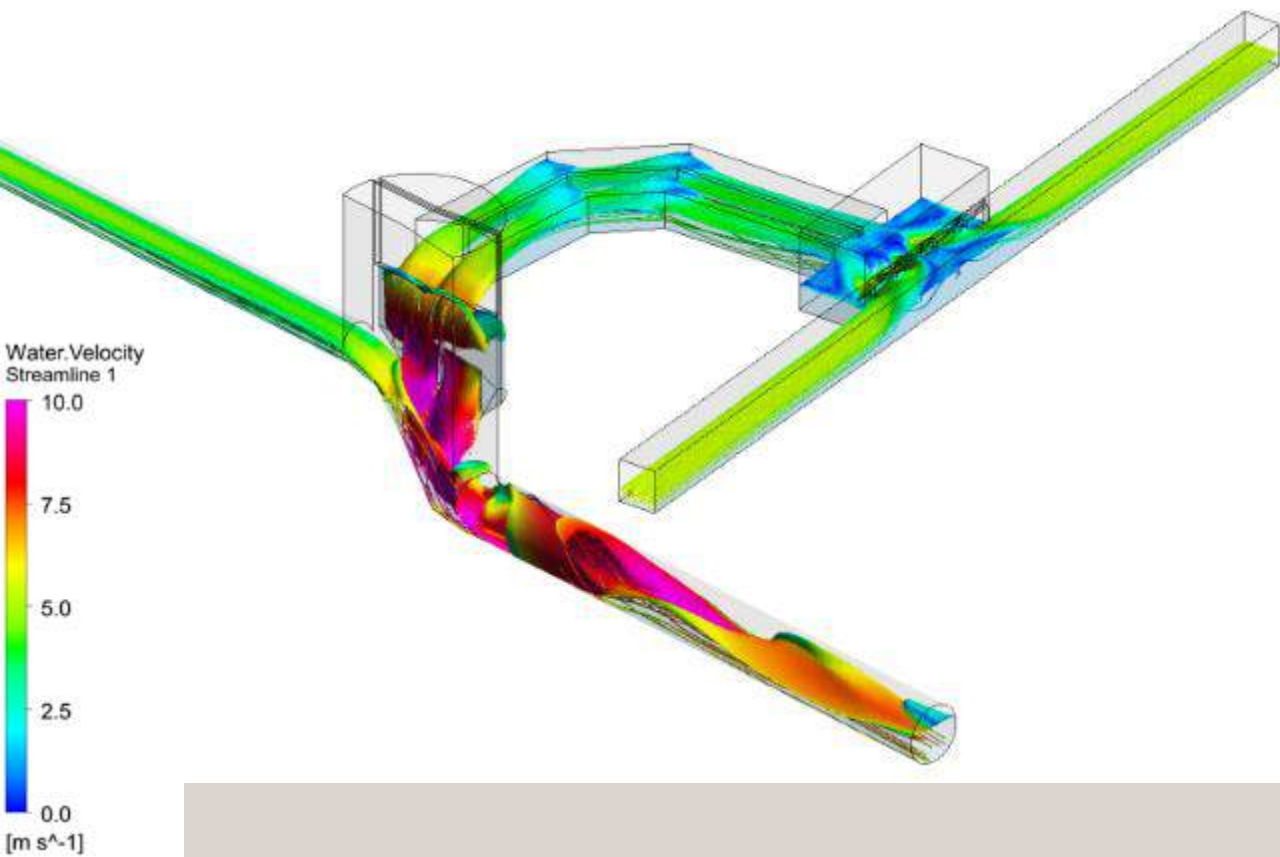


Pumping Station



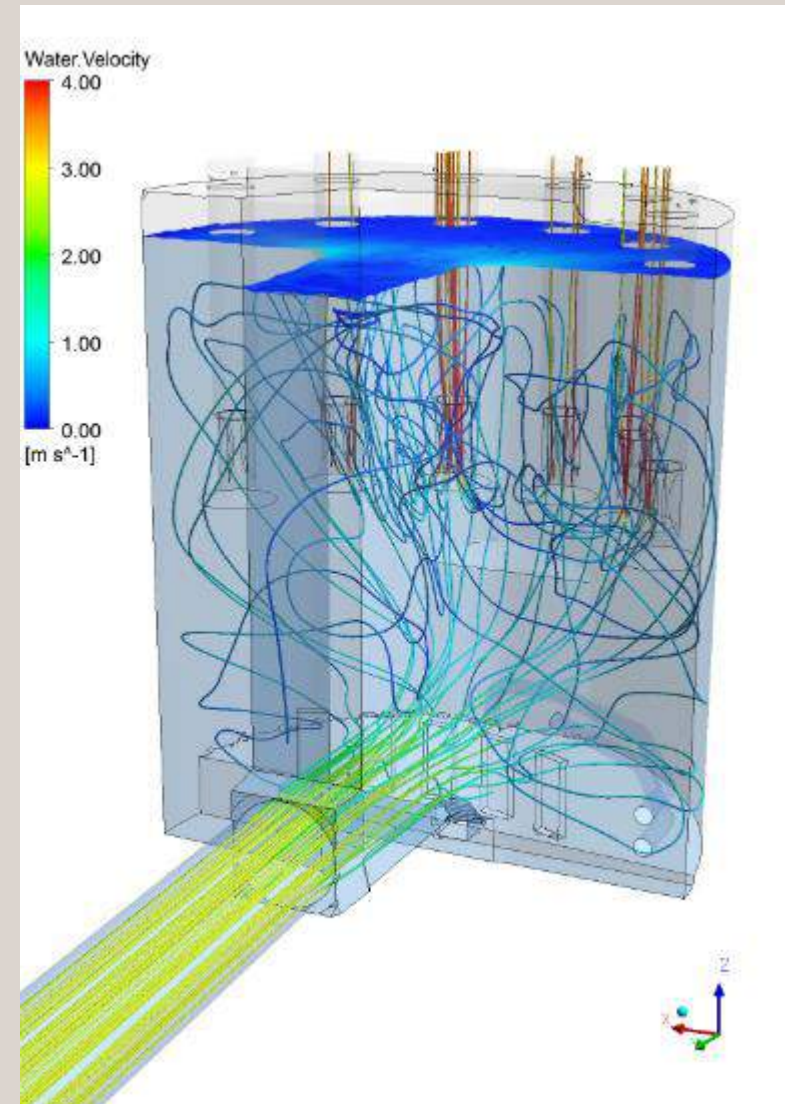
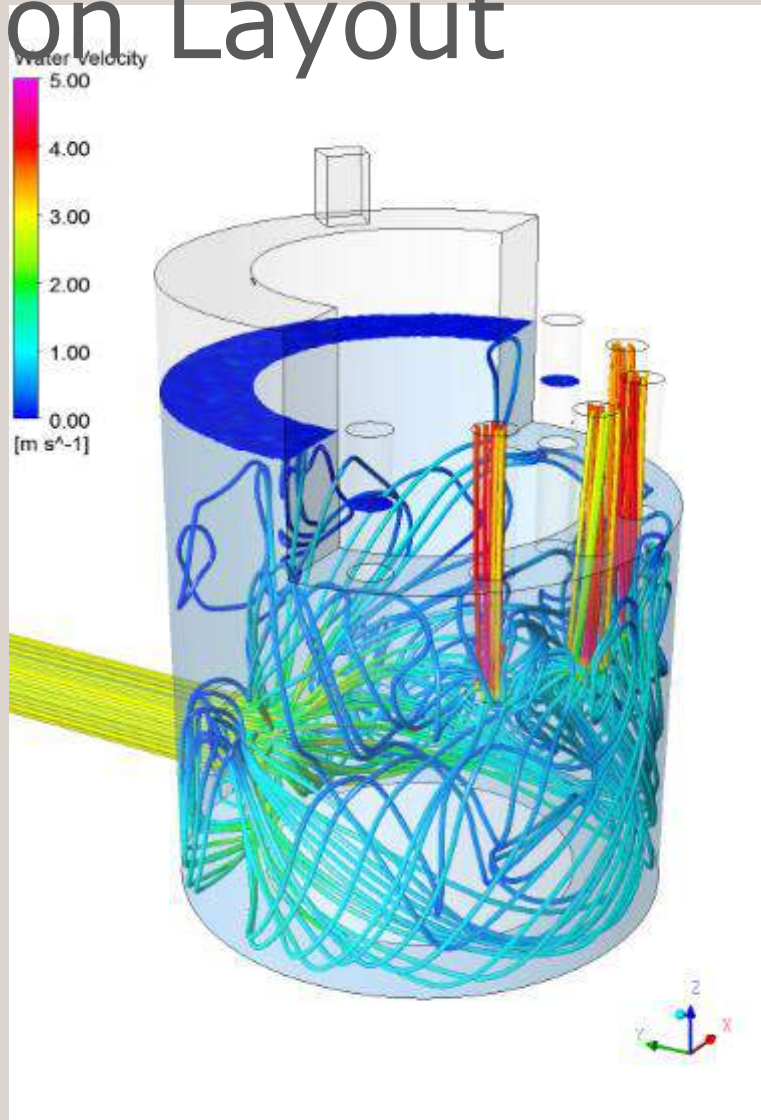
Improved Hydraulic Design

# CFD Design Development: Baffle Drop

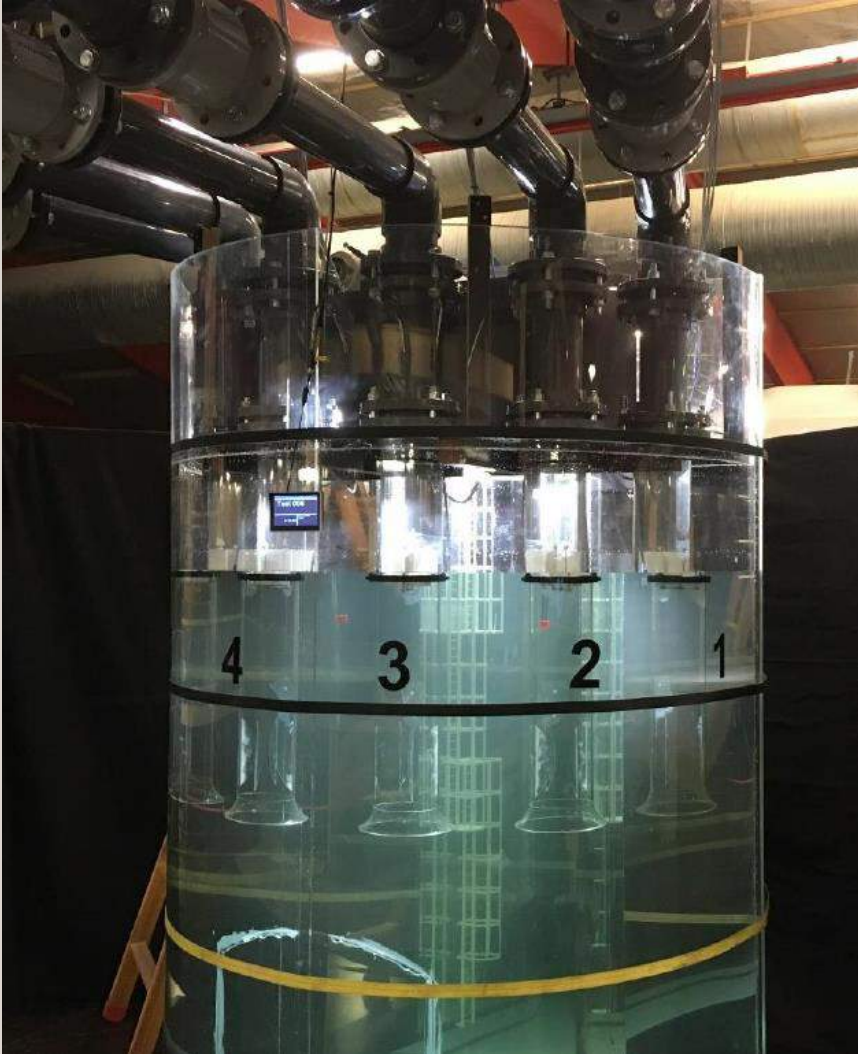




# CFD Design Development: Storm Pumping Station Layout



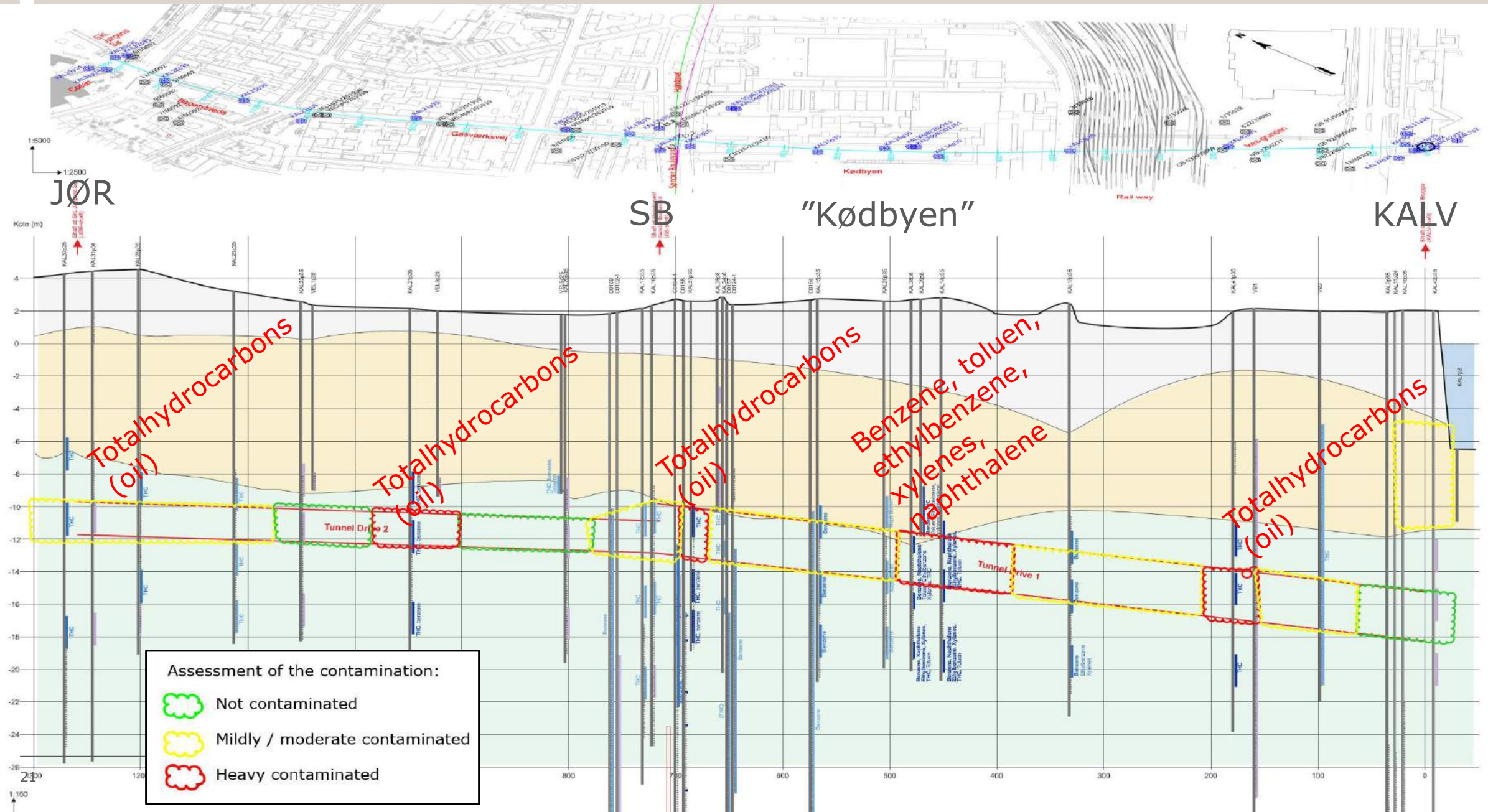
# Physical model test – pumping station



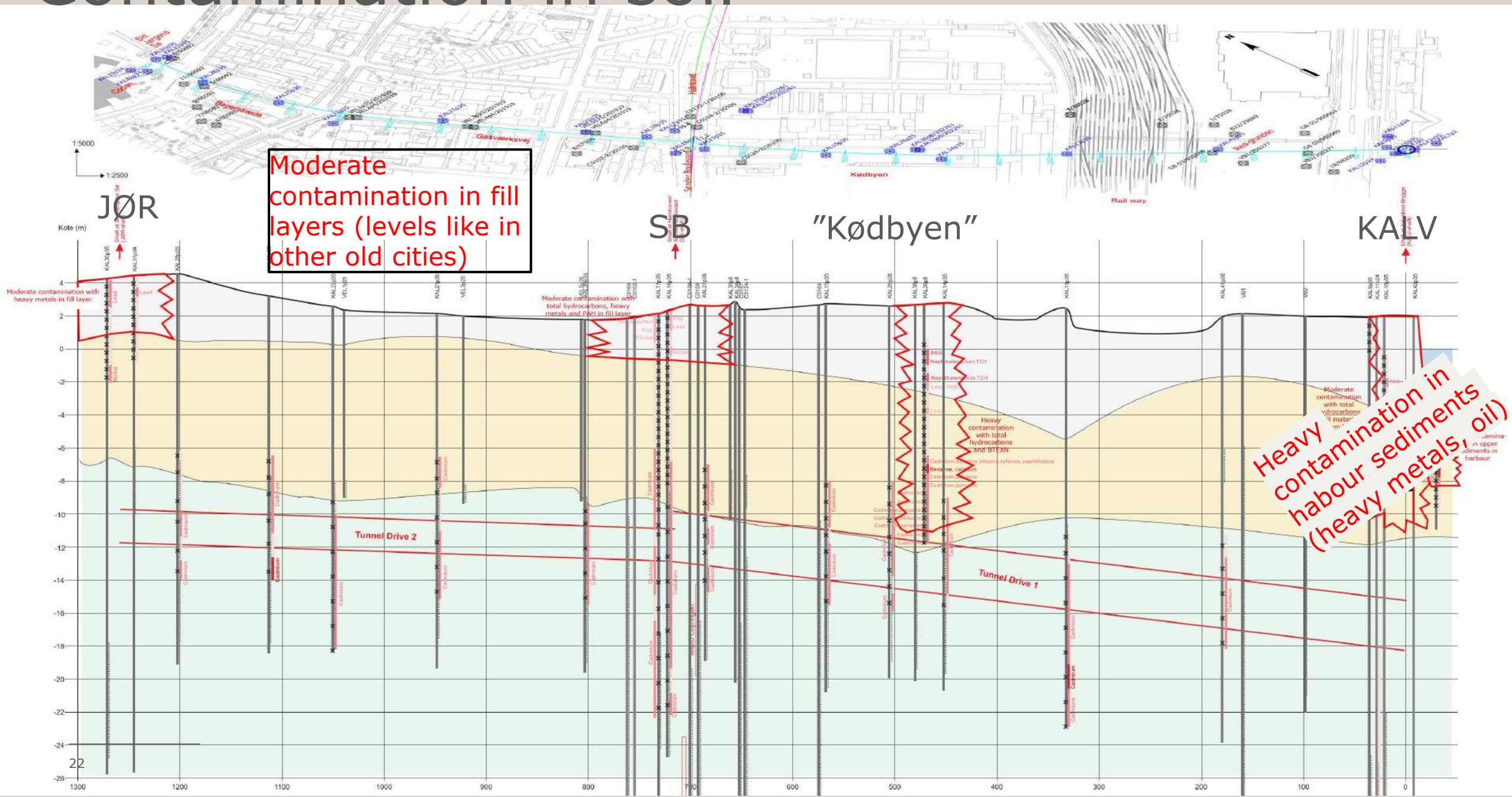
# | Contamination



# Contamination in groundwater



# Contamination in soil





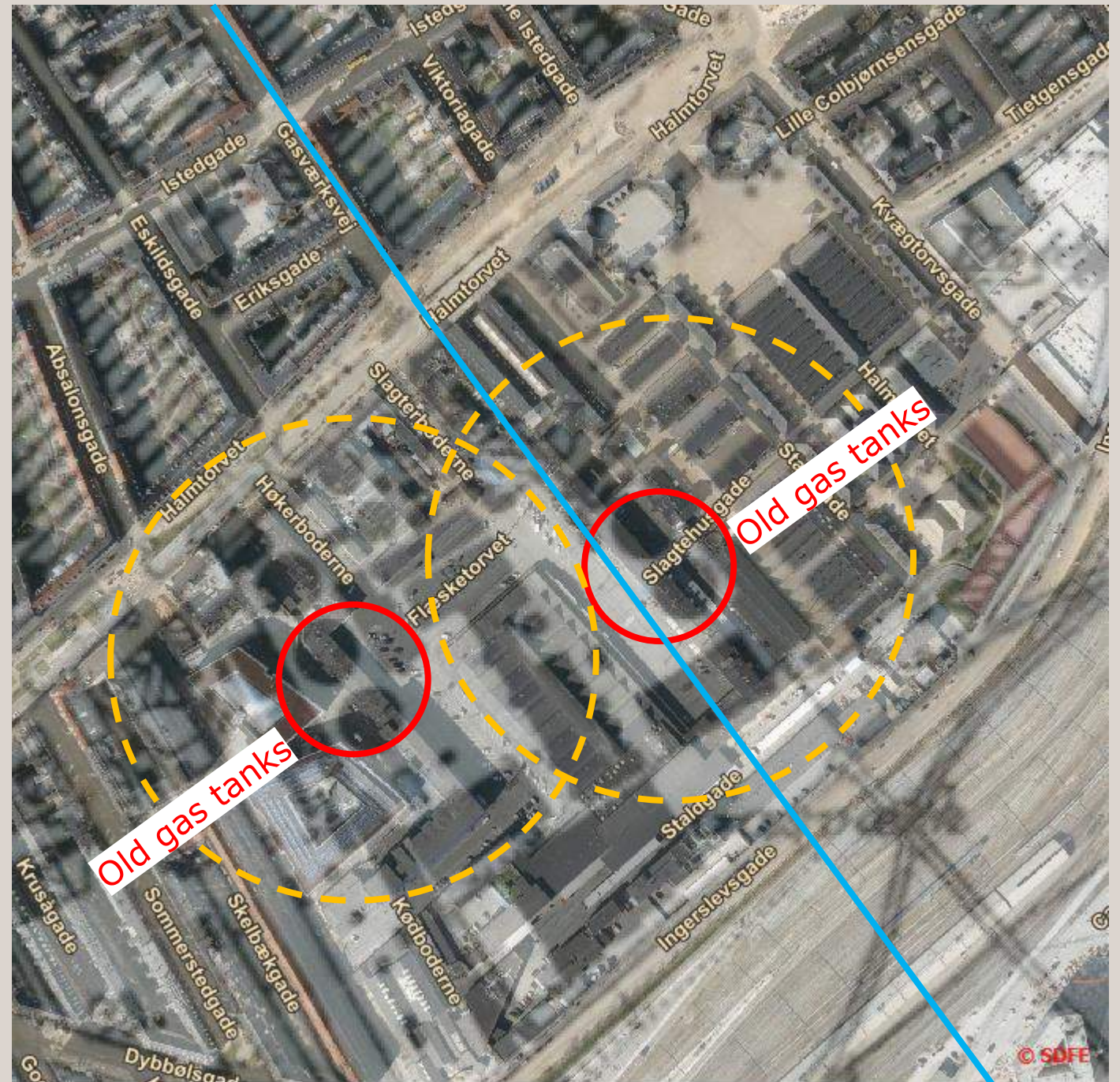
"Kødbyen":

Heavy contamination with  
BTEXN (benzene, toluene,  
ethylbenzene, xylenes and  
naphthalene)

From old, large and deep gas  
tanks



kbhbilleder.dk





# Contamination in soil and groundwater

Shafts: generally moderate contamination in upper soil layers (like in other old cities) – but heavy contamination in upper sediments in harbour. Heavy contamination in groundwater near SB-shaft (hydrocarbons)

Tunnel: contamination in groundwater – especially under “Kødbyen” (BTEXN)  
No contamination in soil samples except for cadmium (naturally content)

		BTEX	Total hydrocarbons	PAH	Chlorinated solvents	Phenols	Cyanide	Heavy metals	Comments (S = soil) (G = groundwater)
Sediments in harbour	<b>Near KALV</b> - Soil - Groundwater		+++	++				++	S: only upper sediments in the harbour.
	<b>KALV</b> - Soil - Groundwater	-	+ -	- -	-	-	-	+ -	S (&G?): contamination with oil (according to borehole profile for KAL10 and KAL42)
Shafts	<b>SB</b> - Soil - Groundwater	- +++	+ +++	+ +	- +	++	-	+ + Ni*	S: contamination in the upper soil layers. G: Heavy contamination in KAL27, but not in KAL16 & KAL17 (all near SB-shaft)
	<b>JØR</b> - Soil - Groundwater	-	- ++	- -	-		-	+ -	
Tunnel	<b>KALV -&gt; SB</b> - Soil - Groundwater	- (+) +++	- +++x	- +++	- +	+	- +	++ Cd* -	S: benzene cont. just above tunnel depth G: heavy contamination in several boreholes (especially in “Kødbyen”)
	<b>JØR -&gt; SB</b> - Soil - Groundwater	+	- +++	- +	+	+	-	+ Cd* + Ni*	G: only heavy contamination in KAL21

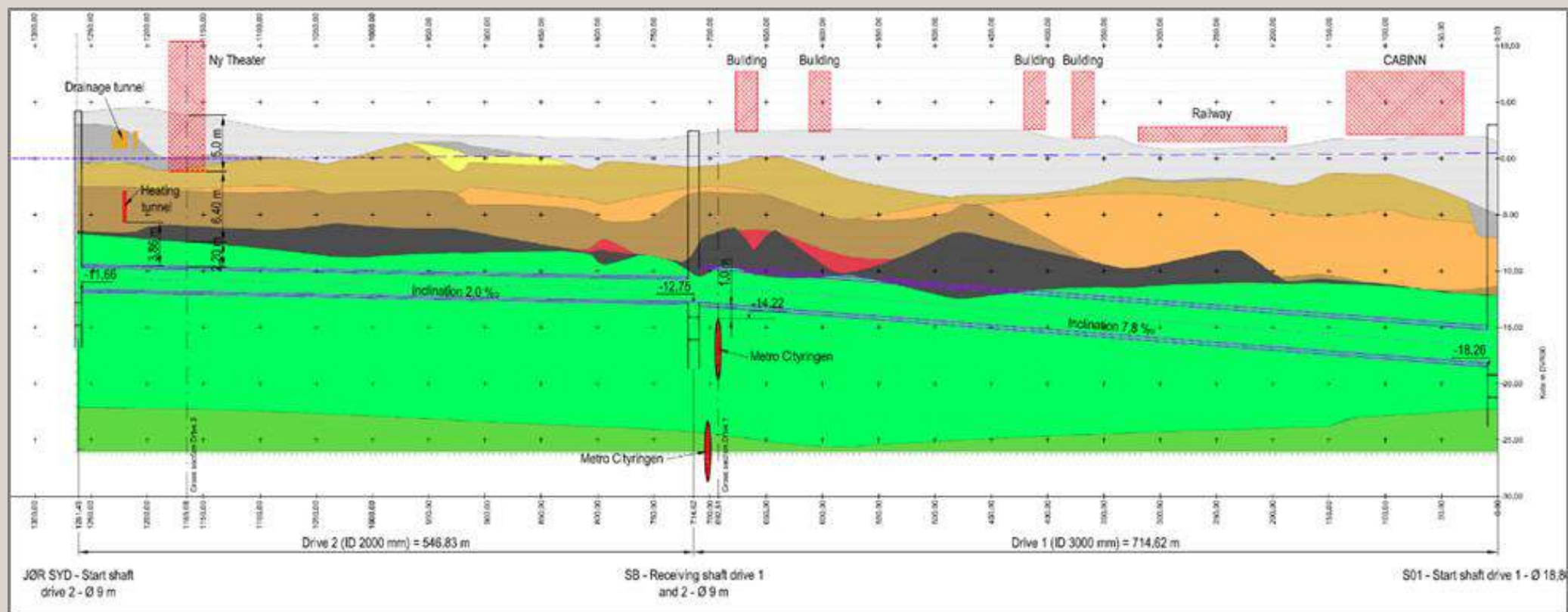
Red Values = soil samples; Blue Values = groundwater samples; \* = is assumed to be of natural origin, x = in form of BTEXN

-	No contamination	under Danish soil criteria	under Danish groundwater criteria
+	Mildly contaminated	1-10 x soil criteria	1-10 x groundwater criteria
++	Moderately contaminated	10-30 x soil criteria	10-100 x groundwater criteria
+++	Heavily contaminated	> 30 x soil criteria	> 100 x groundwater criteria

BTEXN = benzene, toluene, ethylbenzene, xylenes and naphthalene

# Tunnel alignment and structures

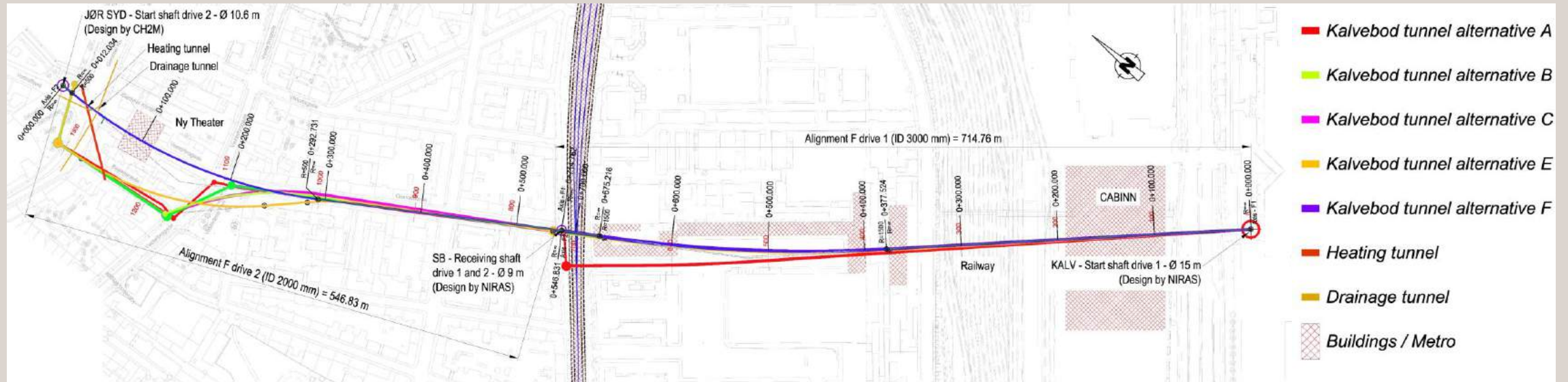
# Geological Longitudinal Profile





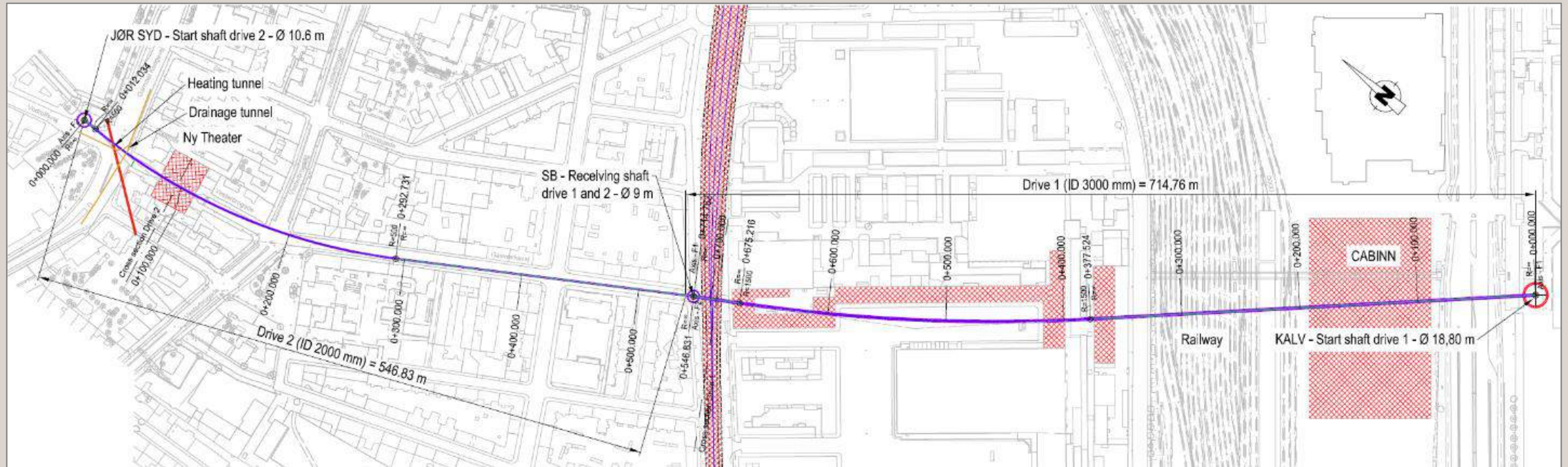
# Tunnel Alignment

## Development of the alignment



# Tunnel Alignment

Alternative F – the final one



1 drive ID 3000 mm = 725 m  
3 shafts

1 drive ID 2000 mm = 545 m

# Tunnel Requirements

## 1. Closed mode

→ Due to groundwater and contamination

## 2. Sensitive Sections

→ Mitigation of Settlement

→ Face Support Calculation

→ Active Monitoring

→ Adaption of working hours

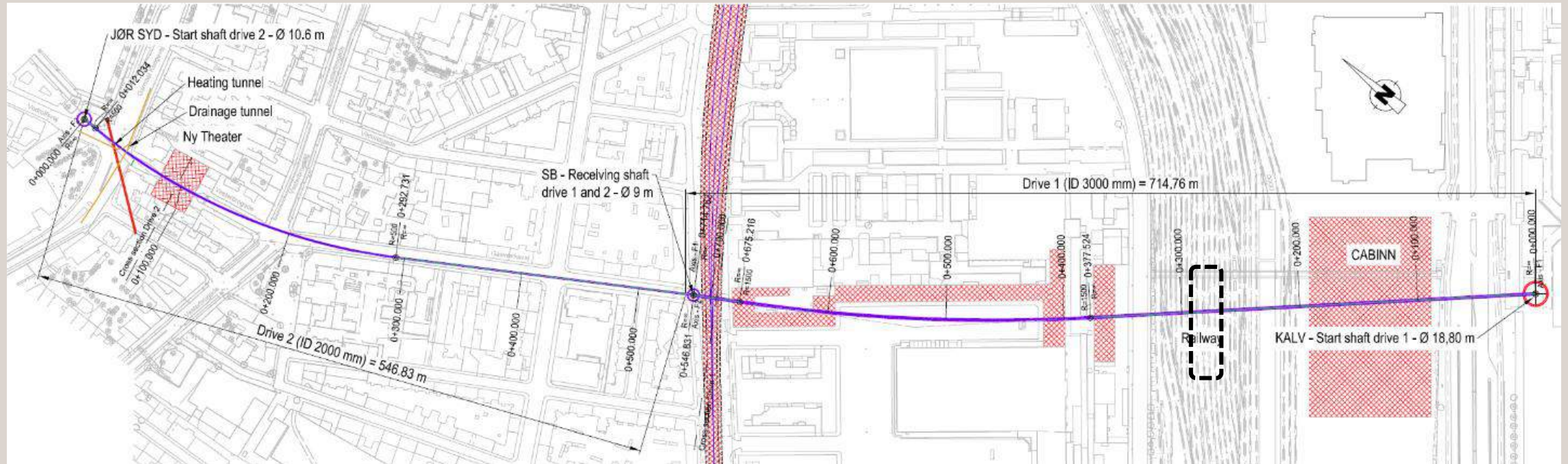
## 3. Settlements

→ Small settlements allowed due to crossed **roads, buildings, railway** and **metro**



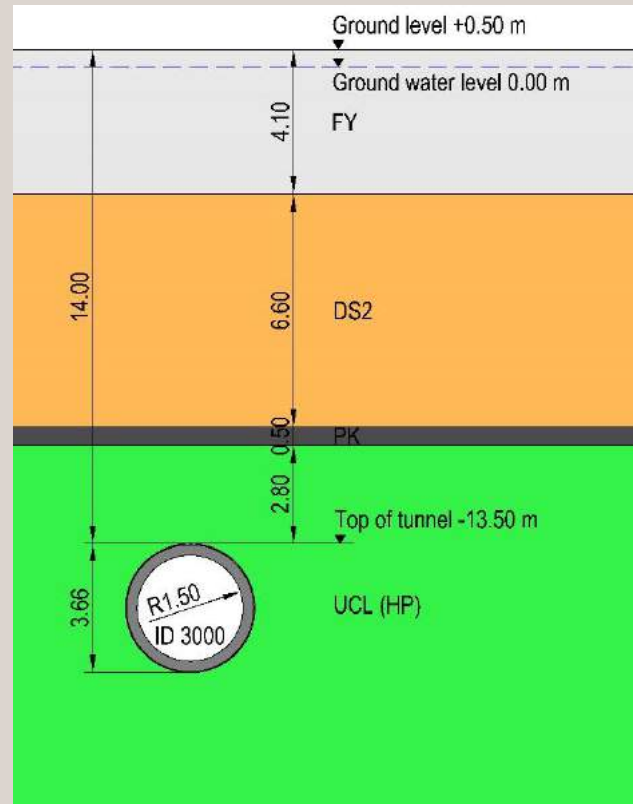
# Sensitive Sections

E.g Crossing Railway



# Sensitive Sections

E.g. Crossing Railway

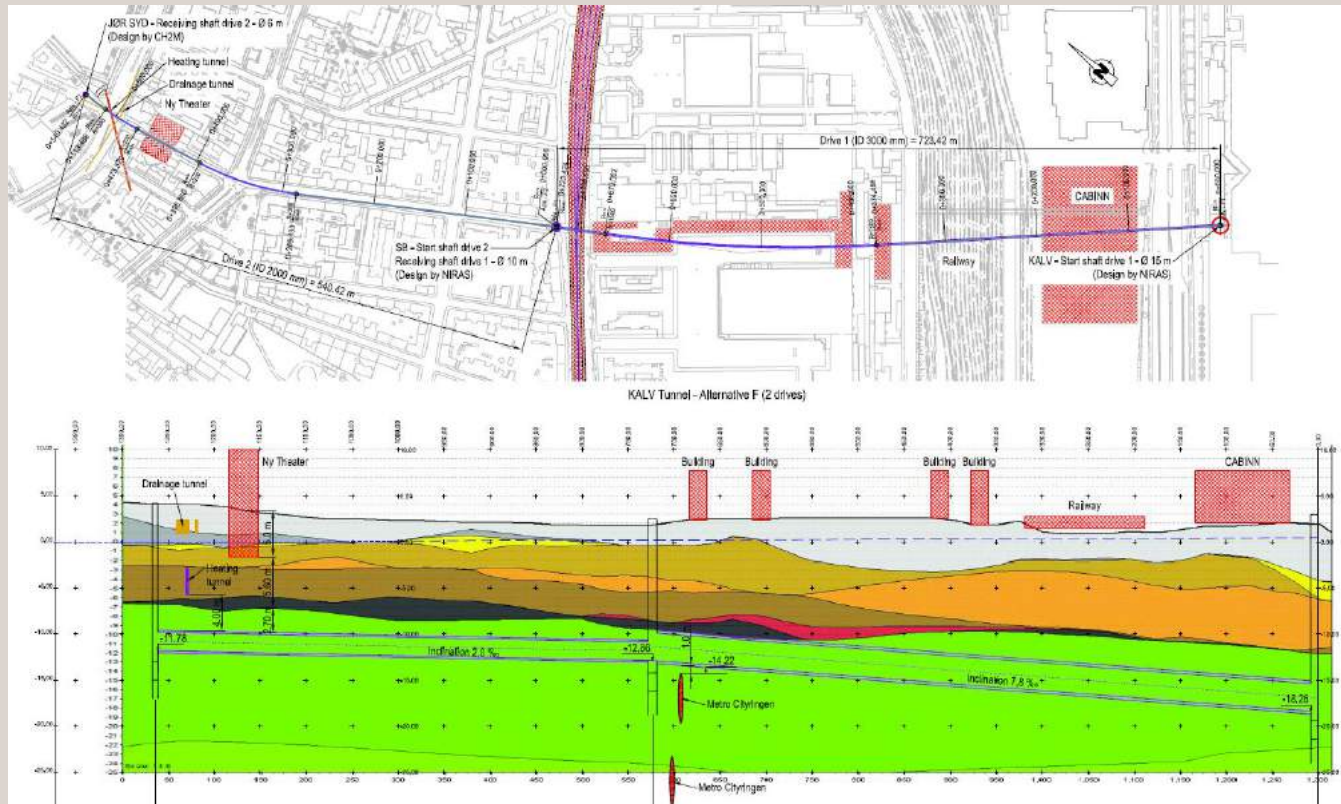


# Sensitive Sections

E.g. Crossing Railway

- Face Instabilities and Settlements – Mitigation:

Ground Investigation





# Sensitive Sections

E.g. Crossing Railway

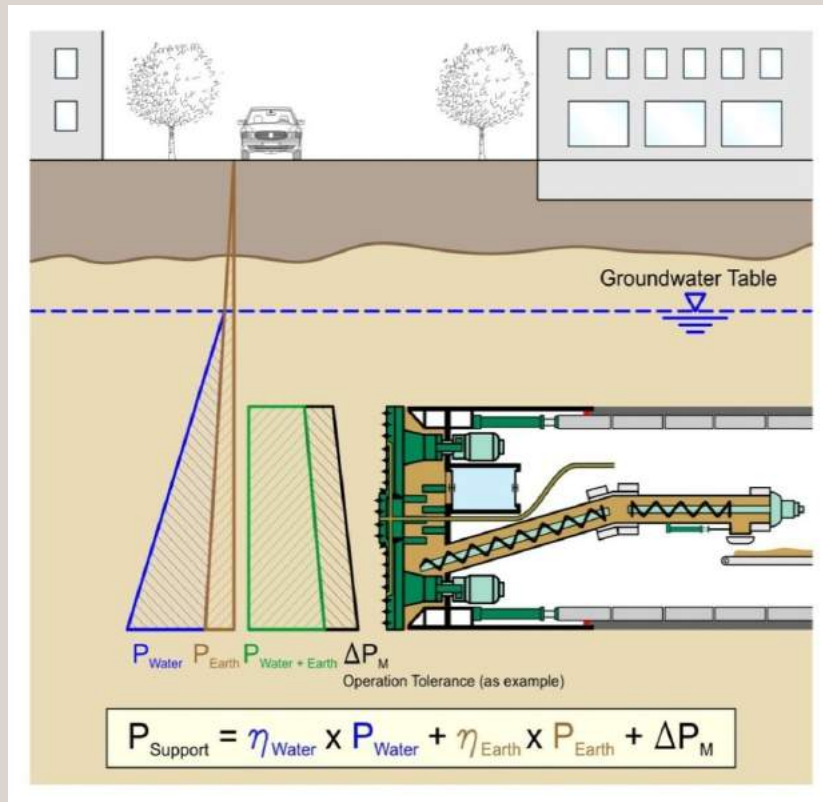


- Face Instabilities and Settlements – Mitigation:

TBM Choice: Closed mode  
Slurry/ EPB

# Sensitive Sections

E.g. Crossing Railway

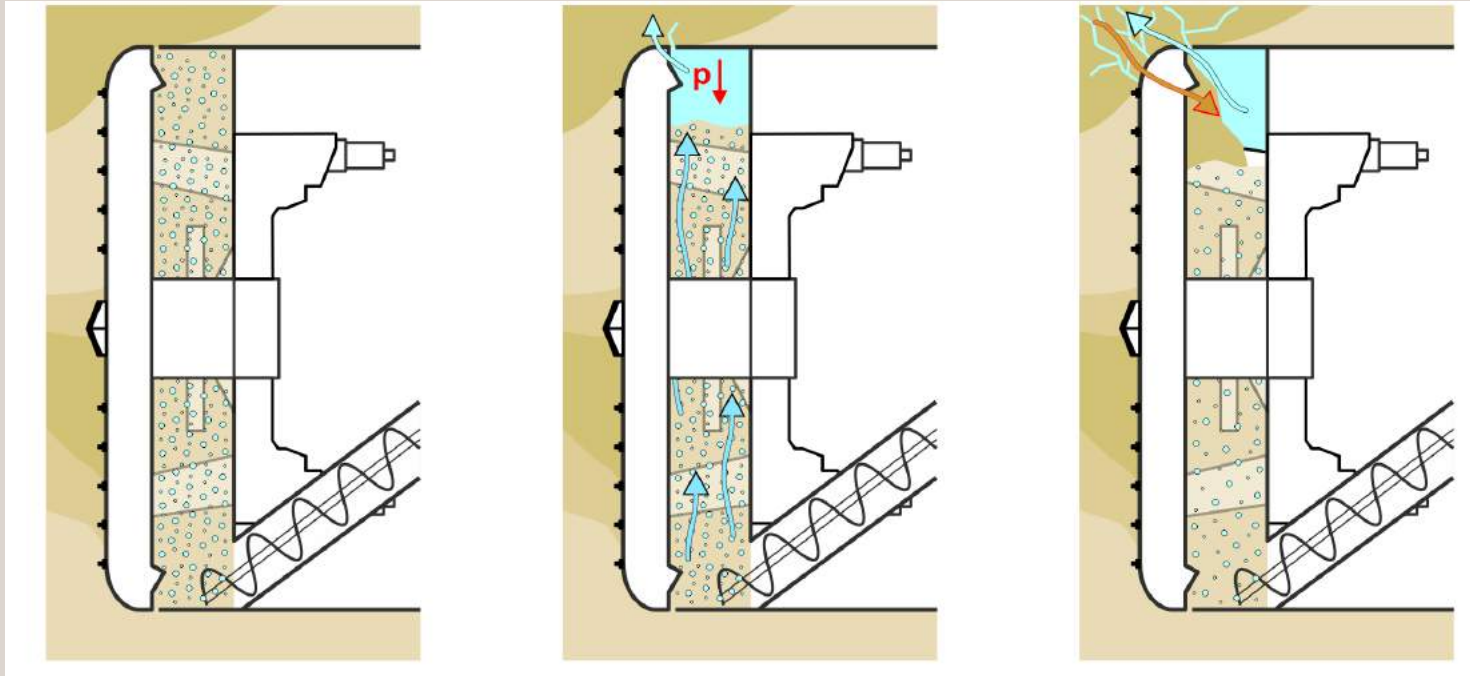


- Face Instabilities and Settlements – Mitigation:

Face Support Calculation

# Sensitive Sections

E.g. Crossing Railway



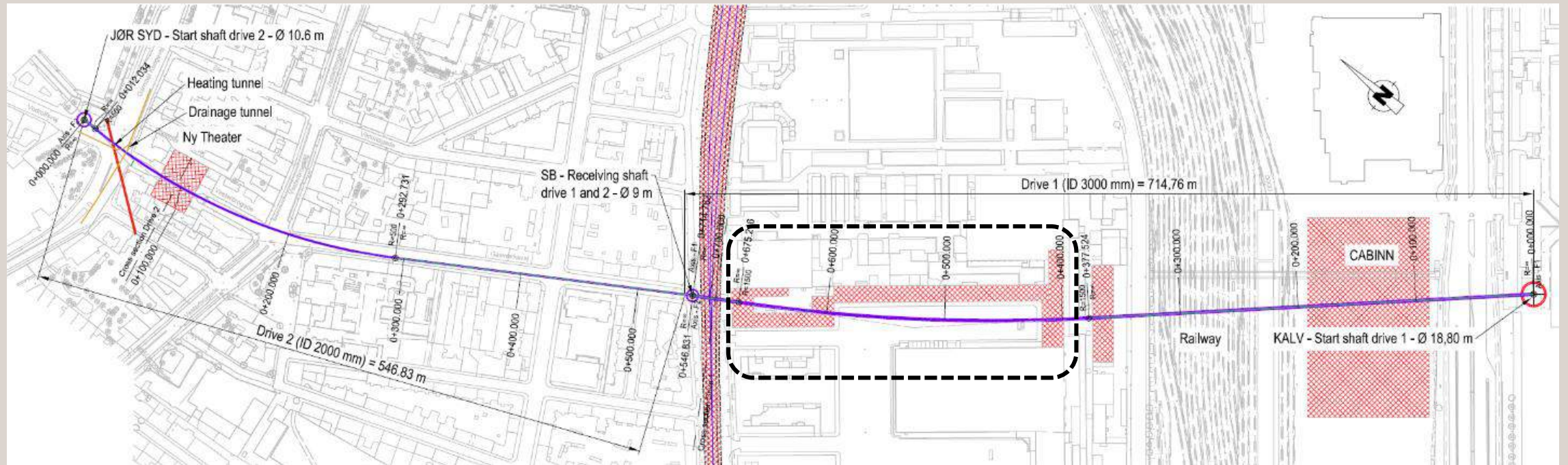
- Face Instabilities and Settlements – Mitigation:

24/7 (no disruption in progress)



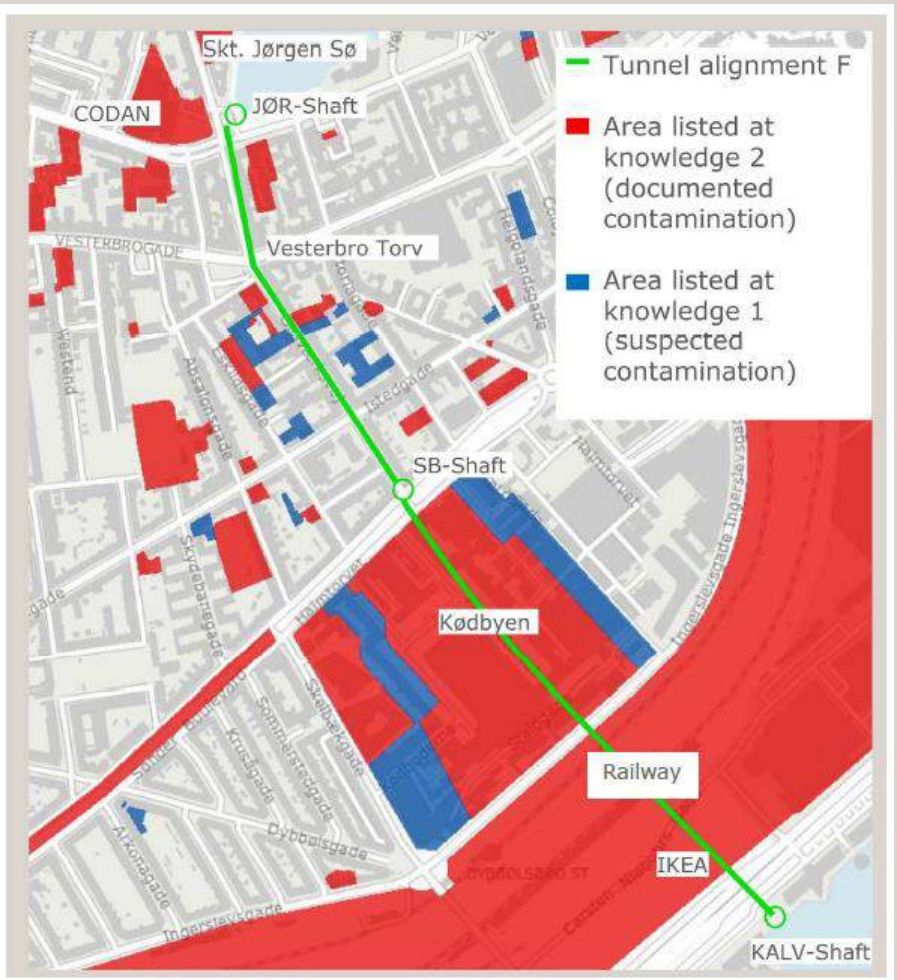
# Sensitive Sections

## Kødbyen Contamination



# Sensitive Sections

## Kødbyen Contamination



Benzene	
Conc. in ground-water (mg/l)	~ 1 - 65 <sup>1)</sup>
(mg/m <sup>3</sup> )	= 1000 - 65000
Conc. in solid matter (mg/kg)	0.2 - 15
Limit value conc. in solid matter (mg/kg)	0.4
Conc. in air volume between soil pores in excavated soil (mg/m <sup>3</sup> )	max. 15 000
Conc. in air, influencing work security (mg/m <sup>3</sup> )	>0.8 <sup>3)</sup>
Max. limit value conc. in air for working in the tunnel (mg/m <sup>3</sup> )	1.6

# Sensitive Sections

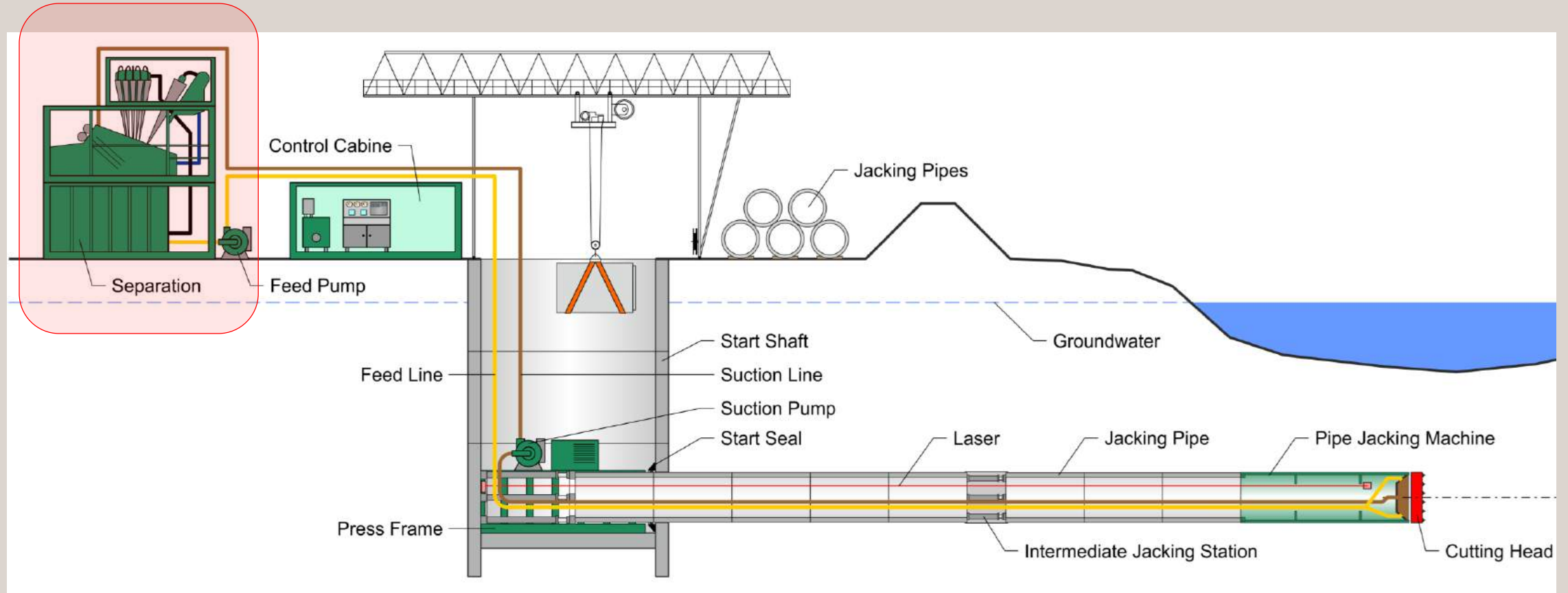
## Kødbyen Contamination

- Contamination of the tunnel air is not quantifiable, but qualitatively assessable
  - I.e. definite pollutant evaporation due to pressure reduction during tunnelling
  - Exact concentration is irrelevant since a concentration of benzene  $> 5 \mu\text{g}/\text{m}^3$  is carcinogenic and release during tunnelling will be higher
  - No contact allowed
- No personnel in tunnel
  - Standard for Slurry
- Ventilation in tunnel and on surface (+ foam issue at landfill)
- Contaminated Soil:
  - Slurry: contamination only on surface, thus no contamination in confined



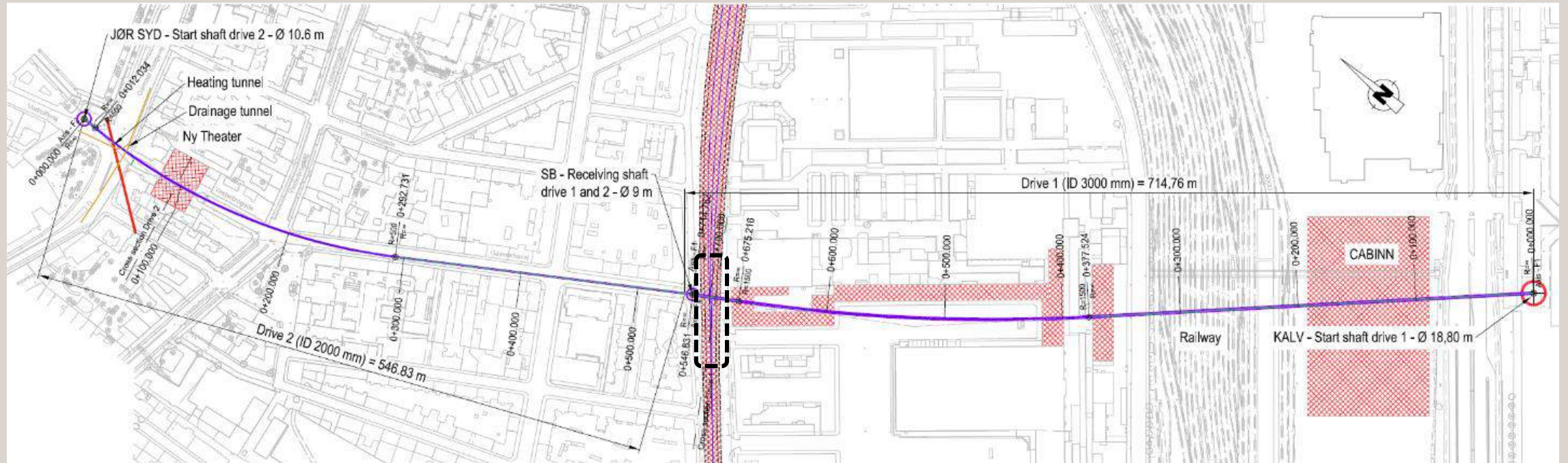
# Sensitive Sections

## Kødbyen Contamination



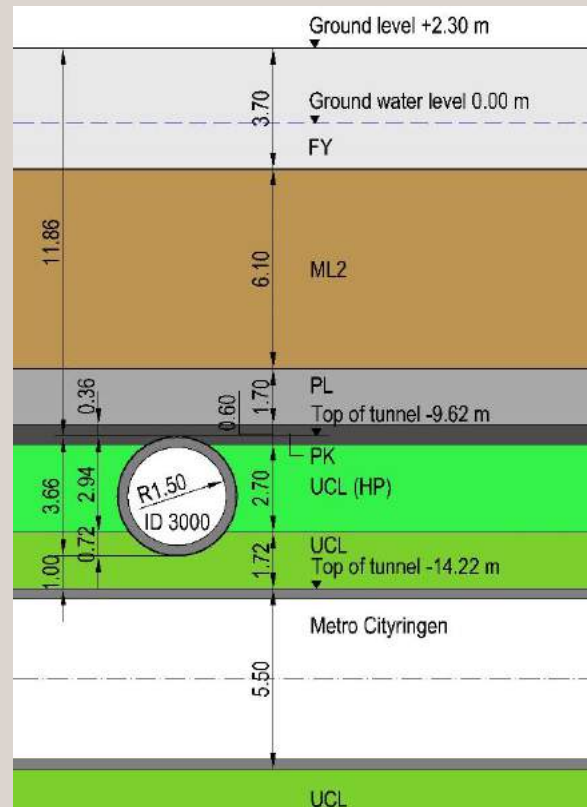
# Sensitive Sections

## Crossing Cityringen



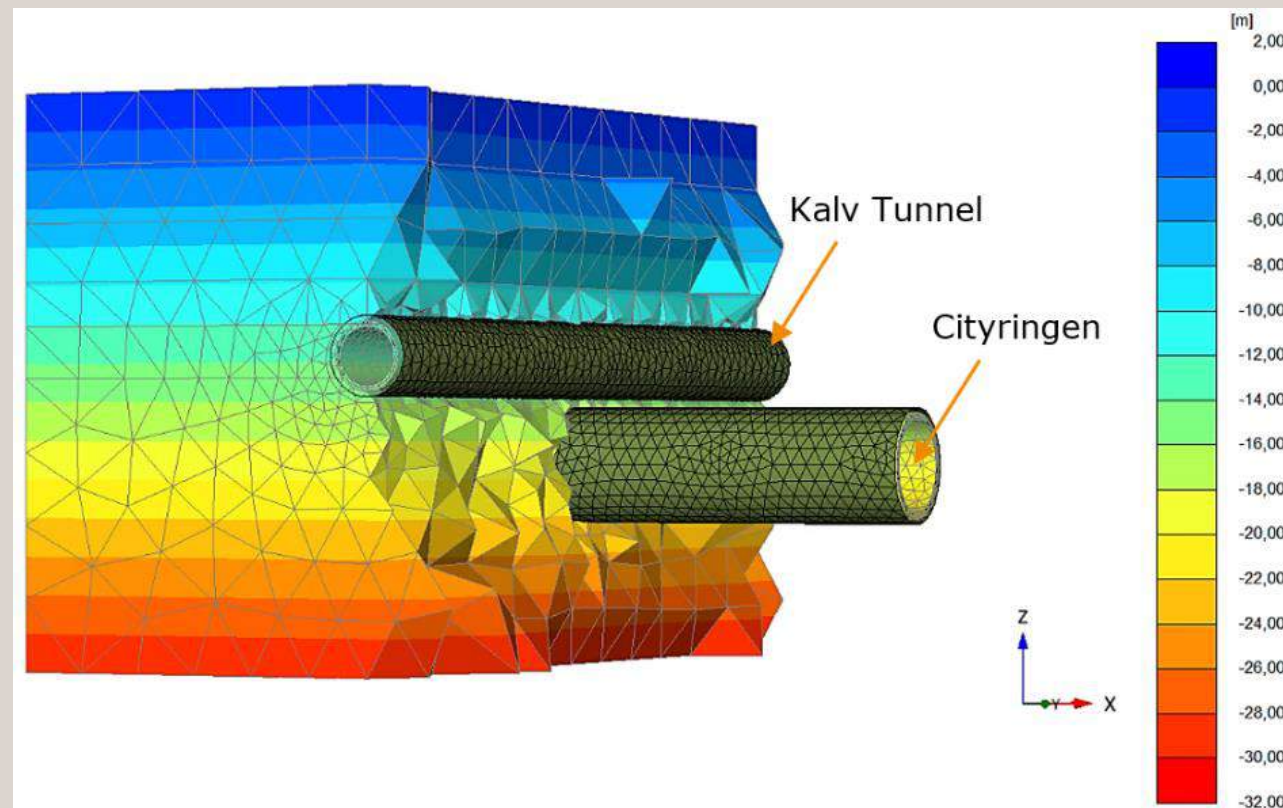
# Sensitive Sections

## Crossing Cityringen



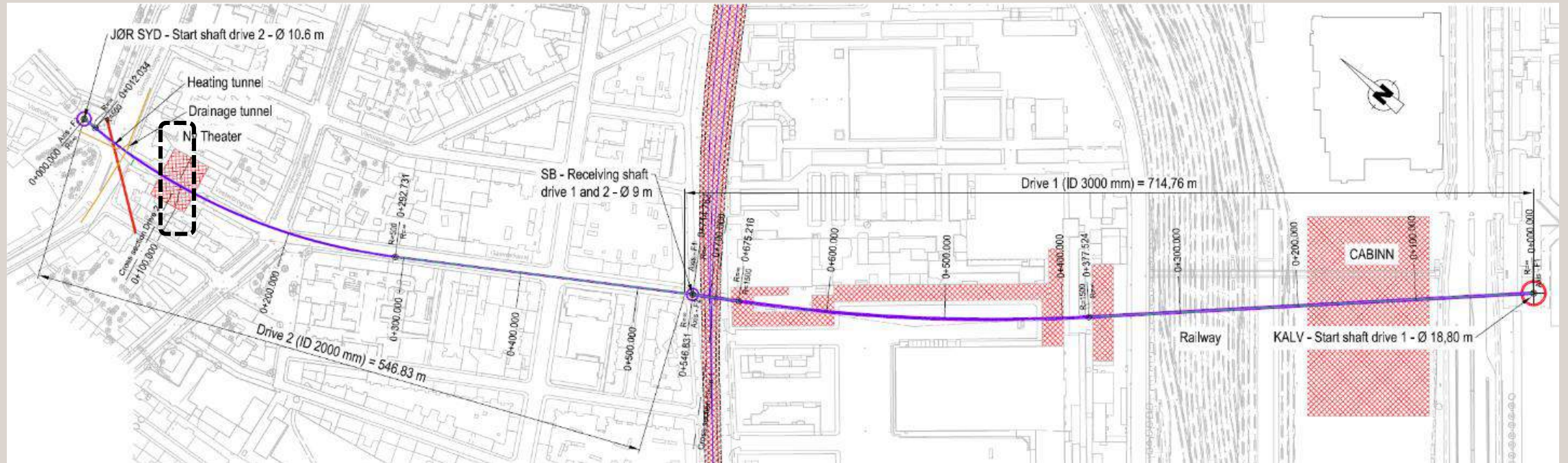


# FEM 3D Model



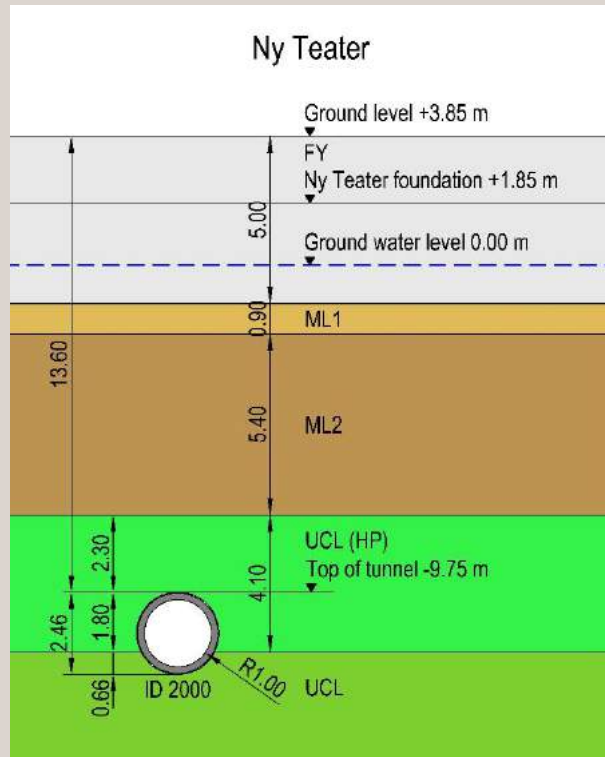
# Sensitive Sections

## Crossing Ny Teater



# Sensitive Sections

## Crossing Ny Teater



- **Settlement Mitigation:**

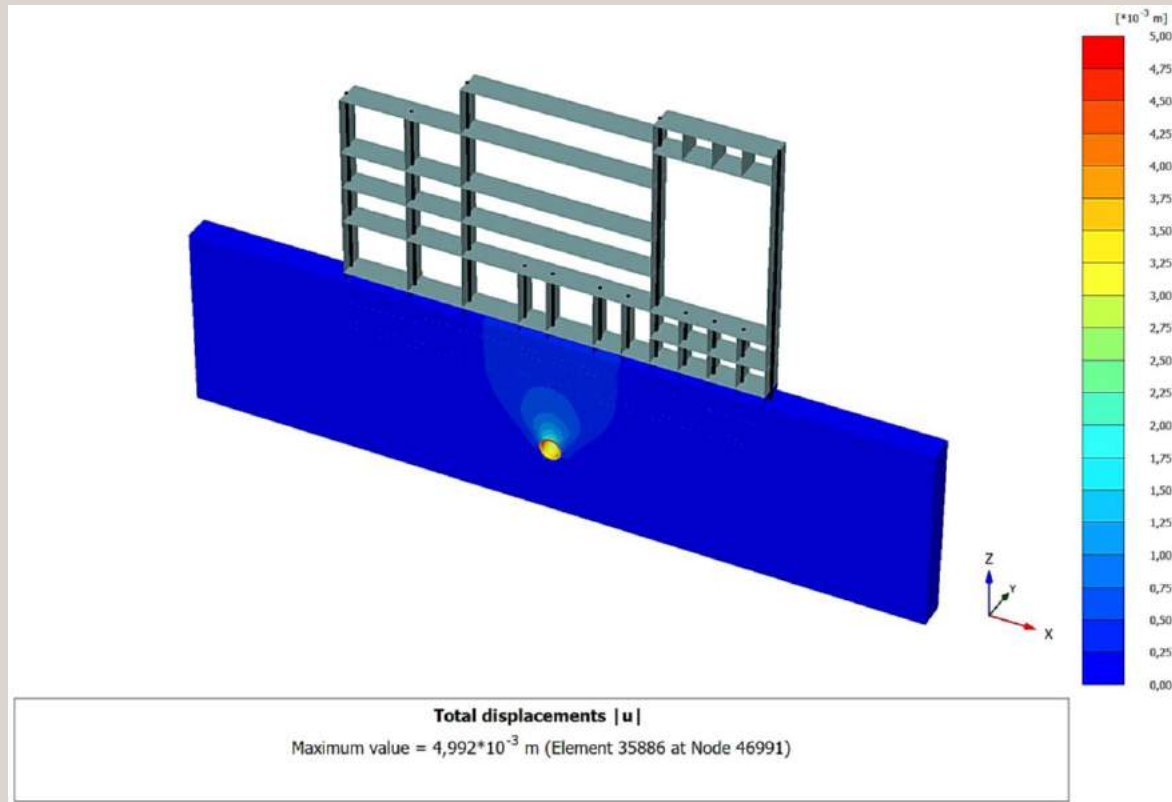
1. Ground Investigation
2. TBM Choice
3. Face Support Calculation
4. Active Monitoring
5. 24/7 (no disruption in progress)

→ Same as for railway crossing



# Sensitive Sections

## Crossing Ny Teater



- Maximum total displacement of pipe:  
5.0mm at tunnel crown
- Maximum vertical displacement of foundation of the Ny Teater:  
0.47 mm

# Proposed Monitoring System

For Railway and Cityringen crossing

- General concept as described in HOFOR's *Kravspecifikation, Bilag 2, „Bygningsrisikoanalyse og monitoring“*
- Additional monitoring of critical structures and infrastructure:

Structure	Instrumentation/Method
Railway	Automated (robotic total station, prisms)
Ny Teater	
Buildings	Manual (e.g. theodolite, prisms)
Kødbyen	
Metro	Optical fiber inclinometer

- Monitoring of control cross-sections via extensometer

# Proposed Monitoring System

For Railway and Cityringen crossing

- Monitoring of Surface Settlements: Automated
- In zones with no/restricted access, i.e. railway tracks or the Ny Teater
- Robotic total station and fixed critical points (prisms)





# Proposed Monitoring System

Ny Teater



- Building Facade

# Proposed Monitoring System

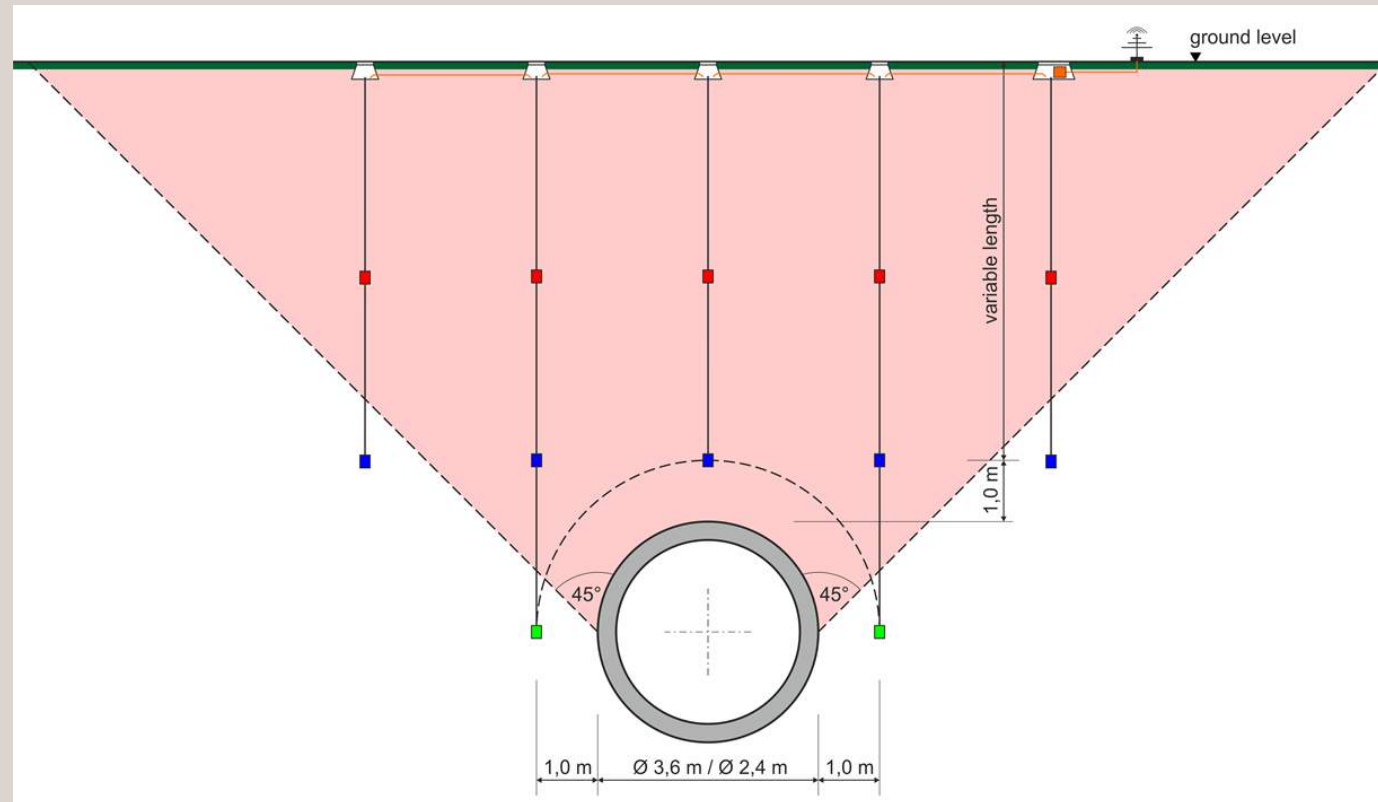
Ny Teater



- Inside the building

# Proposed Monitoring System

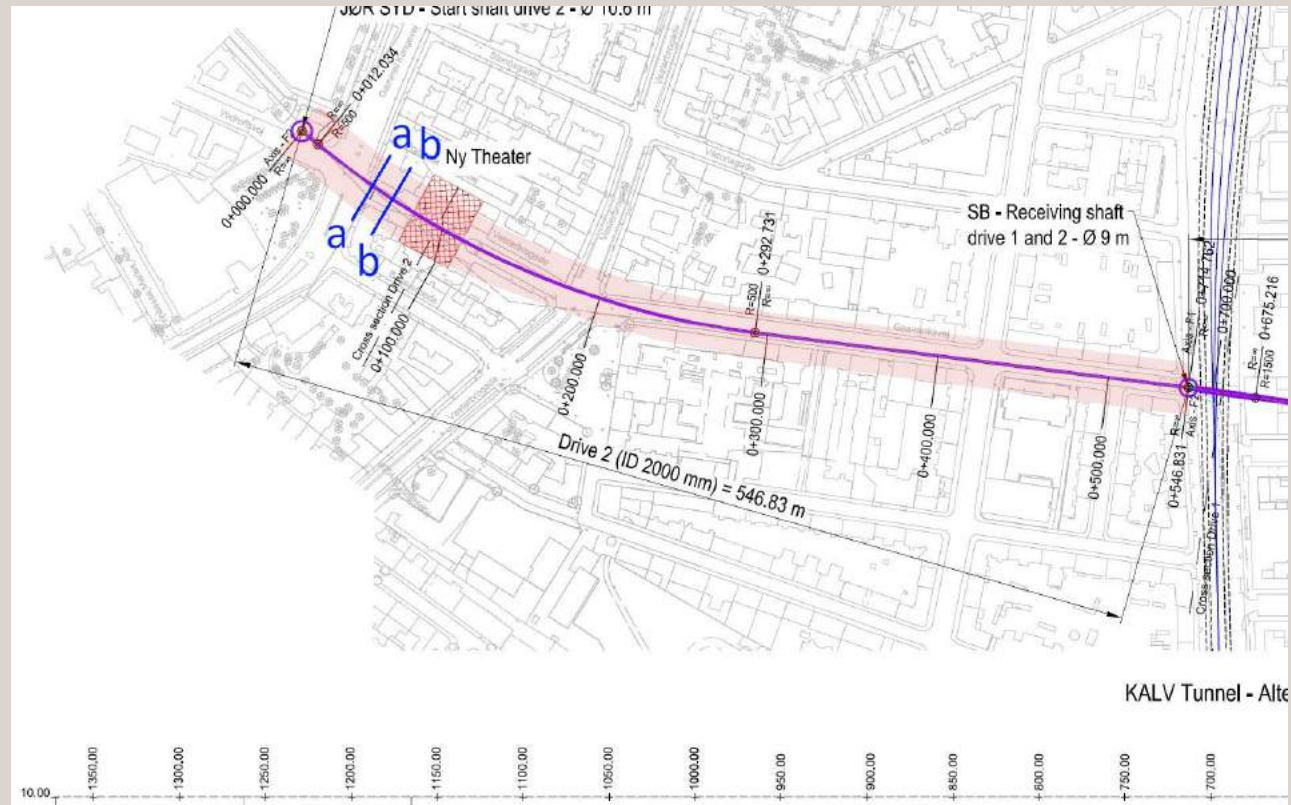
Generally: extensometer setup for defined control cross-sections





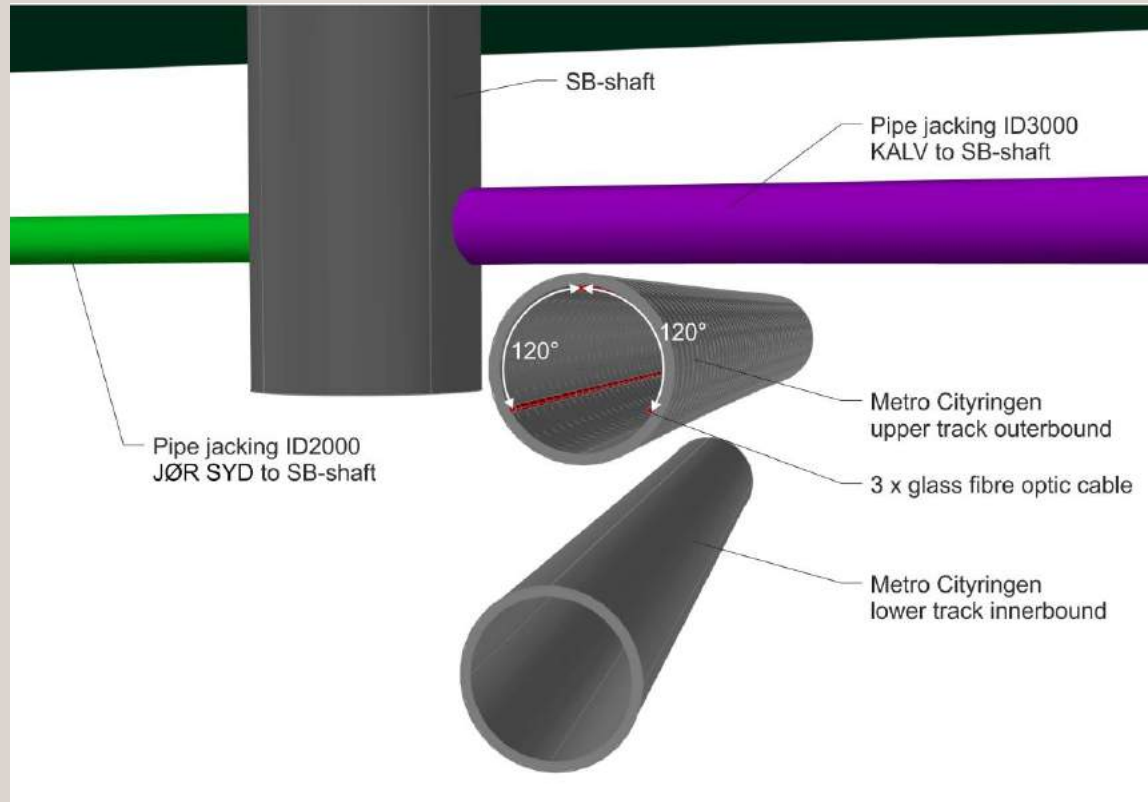
# Proposed Monitoring System

Example of planned extensometer cross-sections for the tunnel drive



# Proposed Monitoring System

For Railway and Cityringen crossing



- Optical fiber inclinometer

# Kalvebod Pumping Station

1. **Structure - Pumping station & Marine Works**
2. **Constraints & challenges**
3. **Construction sequence**



# Structure - Pumping station & Marine Works

“Biggest” Pumping station in Scandinavia, 20m<sup>3</sup>/ s

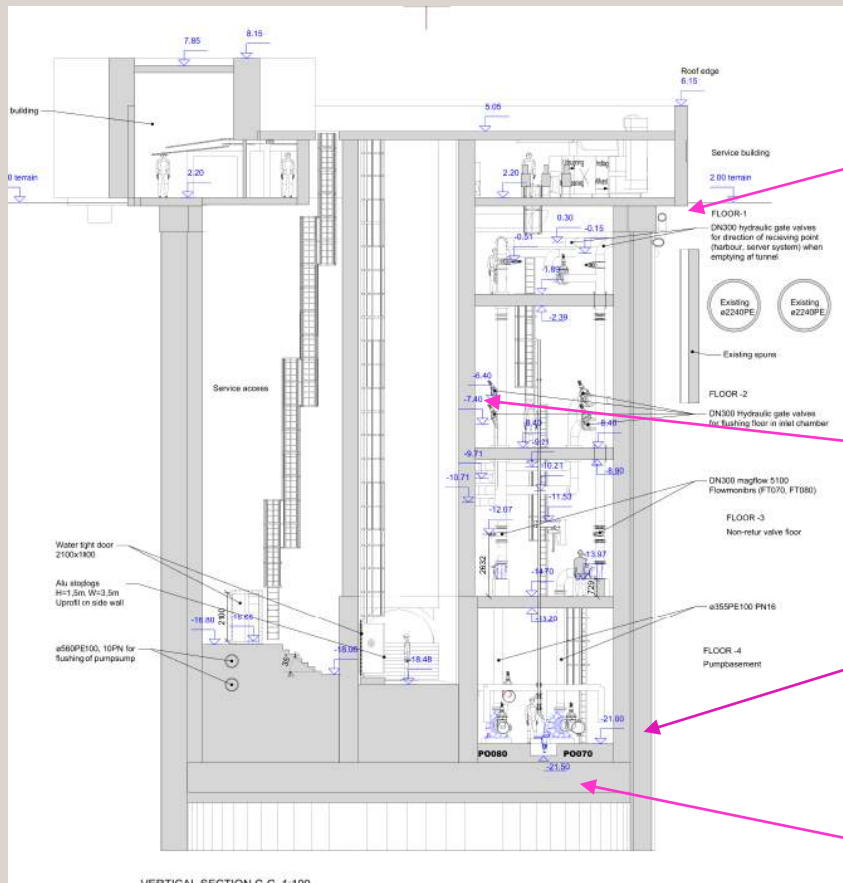
Demolish 30m of existing harbour structure

Build an 18m wide outlet structure into new harbour front

>20m deep shaft excavation

# Pumping station and outlet structure

- Internal diameter 18.8m and depth 23.8m
- Location



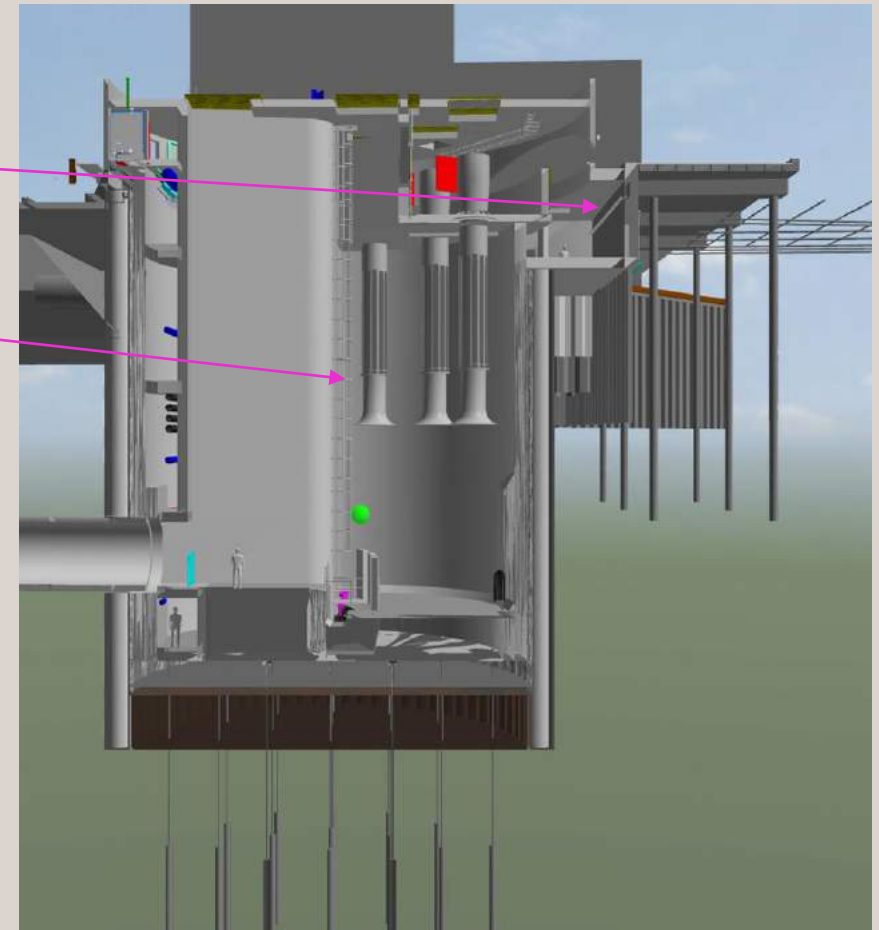
Outlet

Pumps

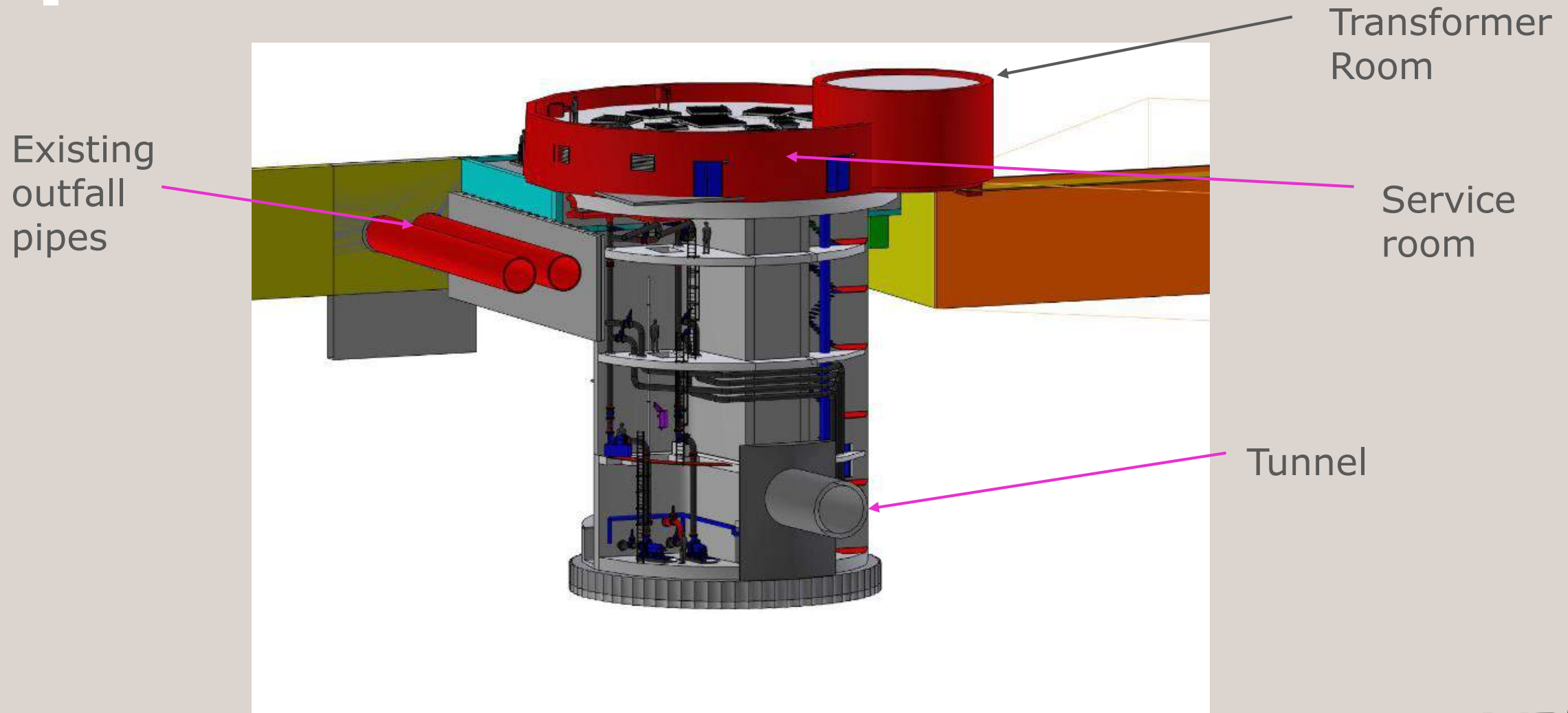
Internal walls  
& liner

Secant piled  
shaft

Base slab

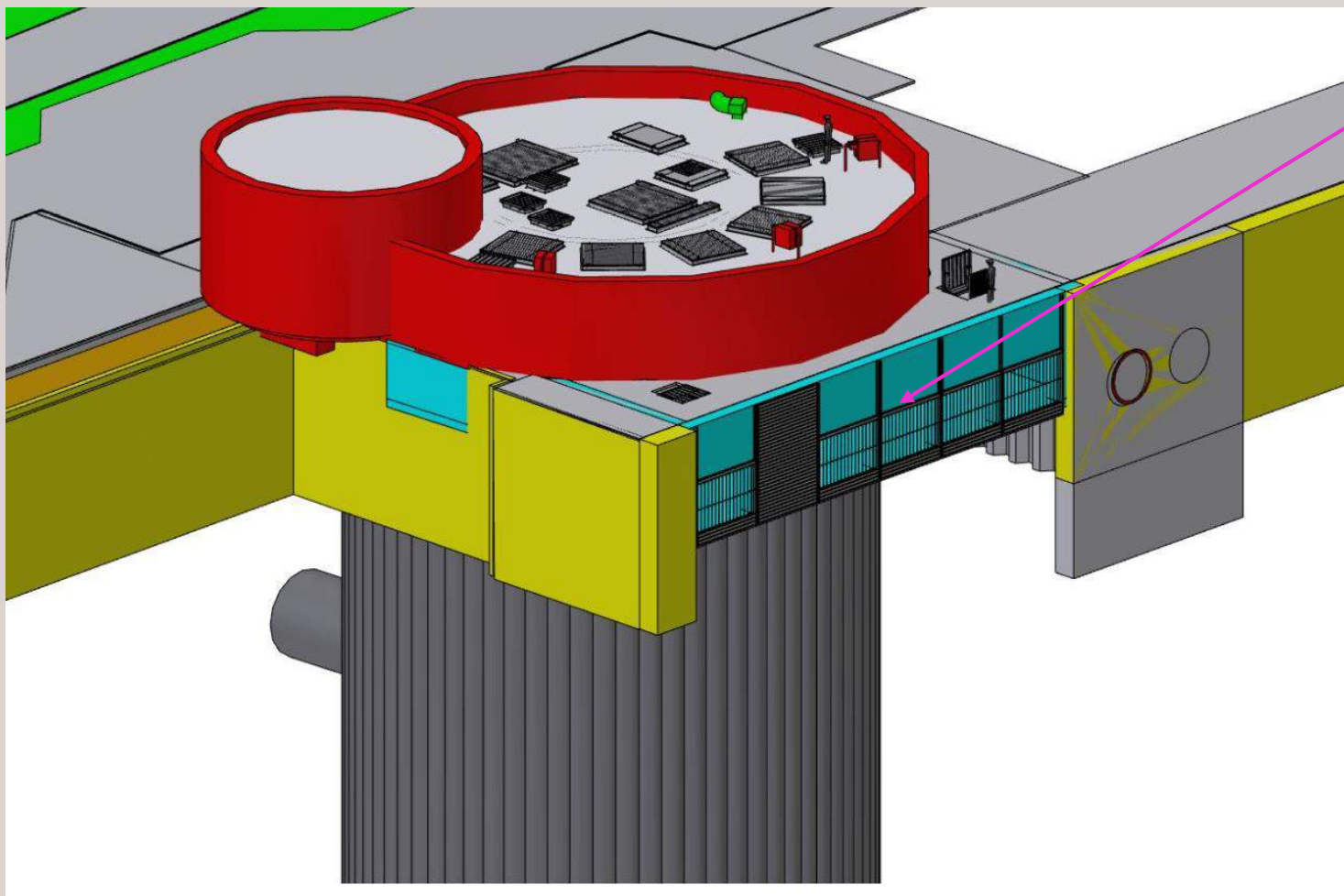


# Pumping station with M&E and internal Walls and floors





# Service building and Outfall



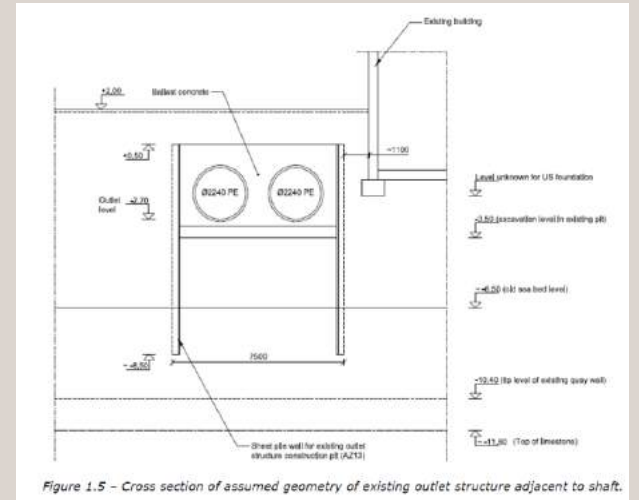
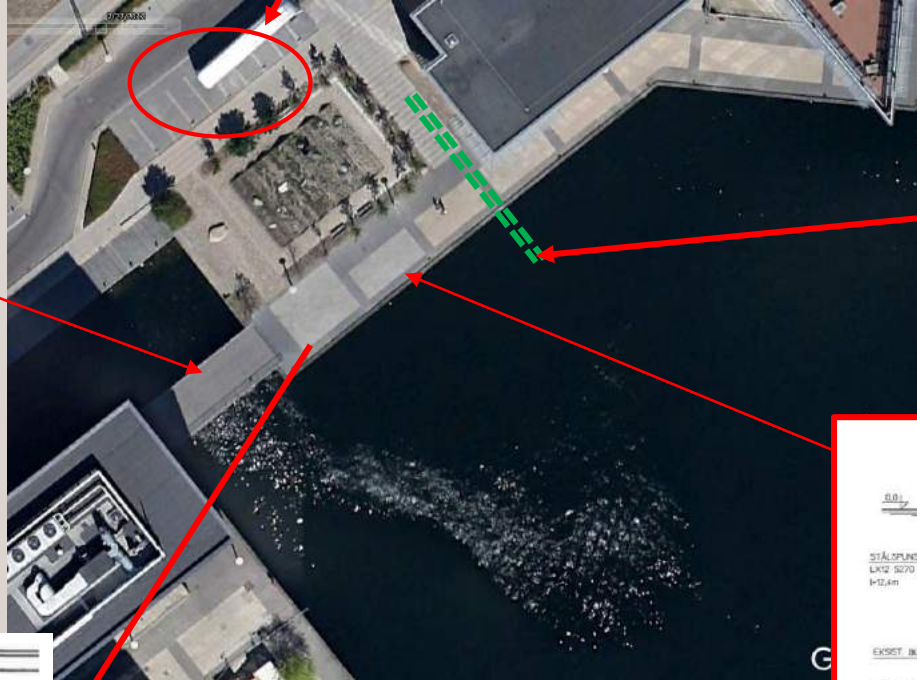
Outfall structure

# Constraints

Existing bridge to be removed

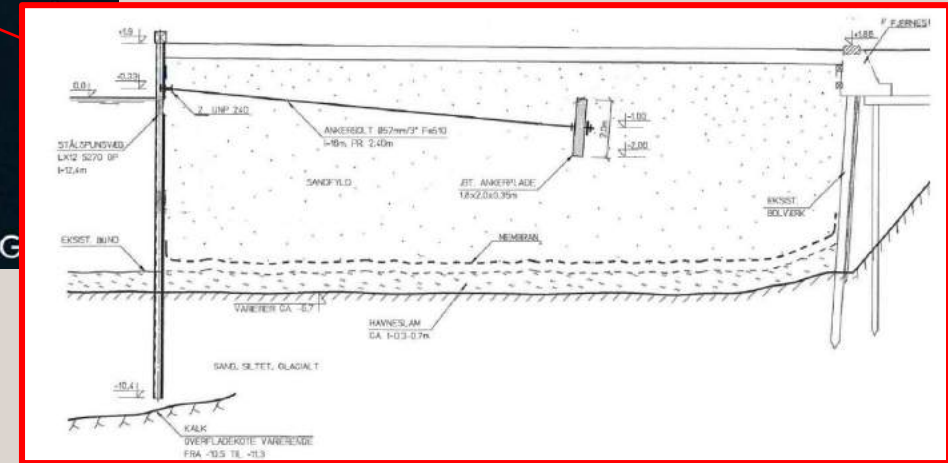
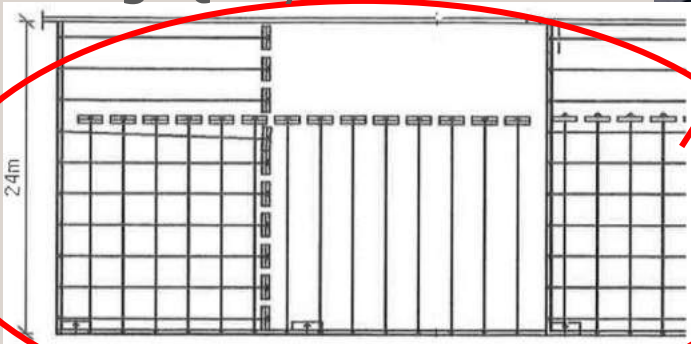


Utilities and parking



Existing outfall structure

Existing Quayside



# Constraints & Challenges

- Constraints
  - Location
  - Maintenance of existing access
  - Architectural Requirements
  - Fire Access
- Design Challenges
  - Varying operational conditions
  - Consideration of construction sequencing
  - Exposure classes and durability



# Challenges

- Existing utilities (for example gravity pipe next to SB shaft)
- Nearby buildings
- Existing sewer protection (minimising load transfer from connection box)
- Traffic diversion and planning
- Heavy crane movement (TBM lowering)

# Outlook

## Tender TD4 - Kalvebod tunnel, pumping station and shafts :

- Detail Design/ Tender Design: Ongoing until July 2020
- PQ: July 2020
- Tender submission: August 2020
- Construction 2021-2025

Thank you for your attention!



**NIRÁŠ**

**HOFOR**

**NIRÁŠ**