Emerging from the Clay

London in the 21st Century

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Speaker

Michael Francis

Practice Leader Tunnels

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- More than 35 years experience world wide
- Last 15 years London Tunnel planning design and construction
- British Tunnelling Society committee member 2005 - 2010
- Drafted BTS Spec 3rd Edition

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Outline of Presentation

1. History of Tunnelling in London
2. Transport Systems in London Today
3. London Geology
4. Tunnelling Today in London
5. Future Tunnelling in London
6. The Future - issues

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Timeline of Early Tunnelling in London

- 1808 --Thames Tunnel Attempt (Trevithick)
- 1825 – 1843 Rotherhithe Tunnel (Brunel)
- 1855 – 1874 London Main Drainage (Bazalgette)
- 1863 –First Post Office Tunnel
- 1864 --London Metro Tunnels
- 1884 --City & South London Railway
- 1894 --Waterloo & City Railway
- 1892 - 1897 First Blackwall Tunnel (Baker/Greathead)
- 1909—Main Post Office Tunnels

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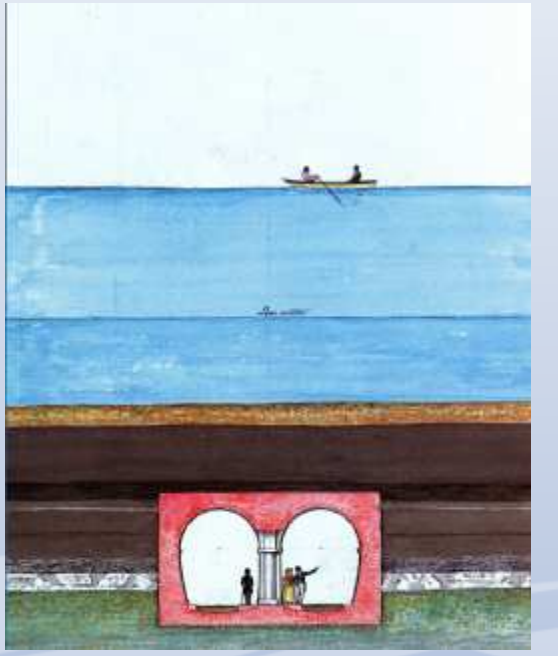
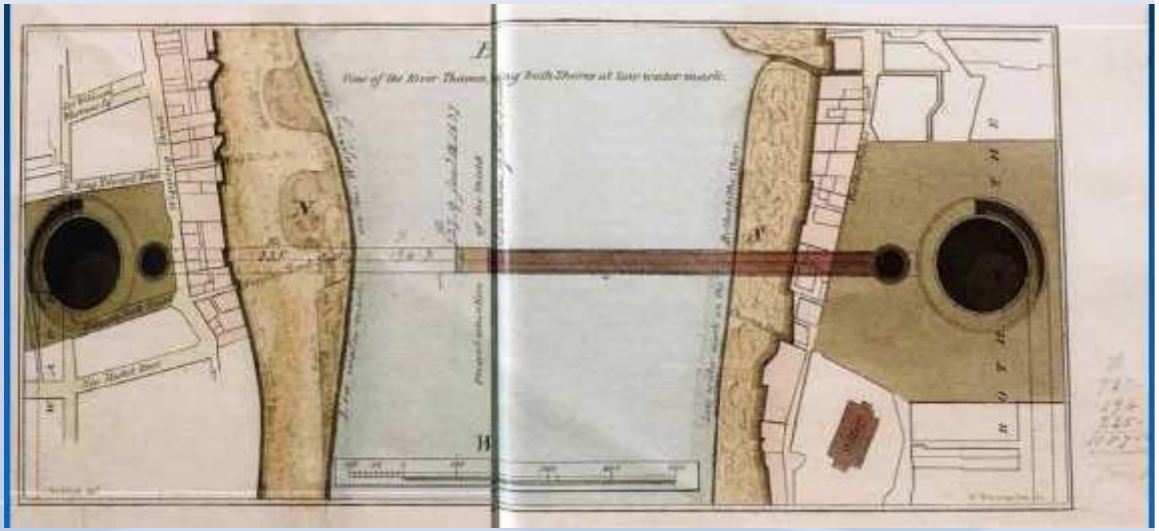
Brunel's Tunnel





First Underwater Tunnel - Rotherhithe to Wapping

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London Underground – Oldest Underground Railway

- World's First Public Passenger Carrying Railway – The Metropolitan
- Opened 10th January 1863
- 6 km Long, Paddington to Farringdon Street
- 26,500 Passengers per Day

The Metropolitan Railway

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Metropolitan Line

- Bill through Committee Stage in Parliament in 1 Day
- Problems raising Finance
- Cost of Line £950,000
- New Locomotives built 38 Tons – 22 No.
- 8 Wheel Carriages known as Long Charleys

Under construction

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Other Underground Lines

- Waterloo and City Opened in 1898
- Central London Railway (now Central Line) 1900
- Great Northern and City Railway (now Northern Line) 1904
- Great Northern, Piccadilly and Brompton Railway (now Piccadilly Line) 1906
- Baker Street and Waterloo Railway (now the Bakerloo Line) 1906
- Victoria Line 1960s
- Jubilee Line 1990s

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The Tube Today

- 3.4M Passengers per day
- 1.065 Bn Passengers/year
- 69 M Train km per year
- Maximum Depth below sea level 32m
- Maximum Depth below ground level 68.8
- 270 Stations
- Busiest - Victoria 77M passengers per year

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Geology of London

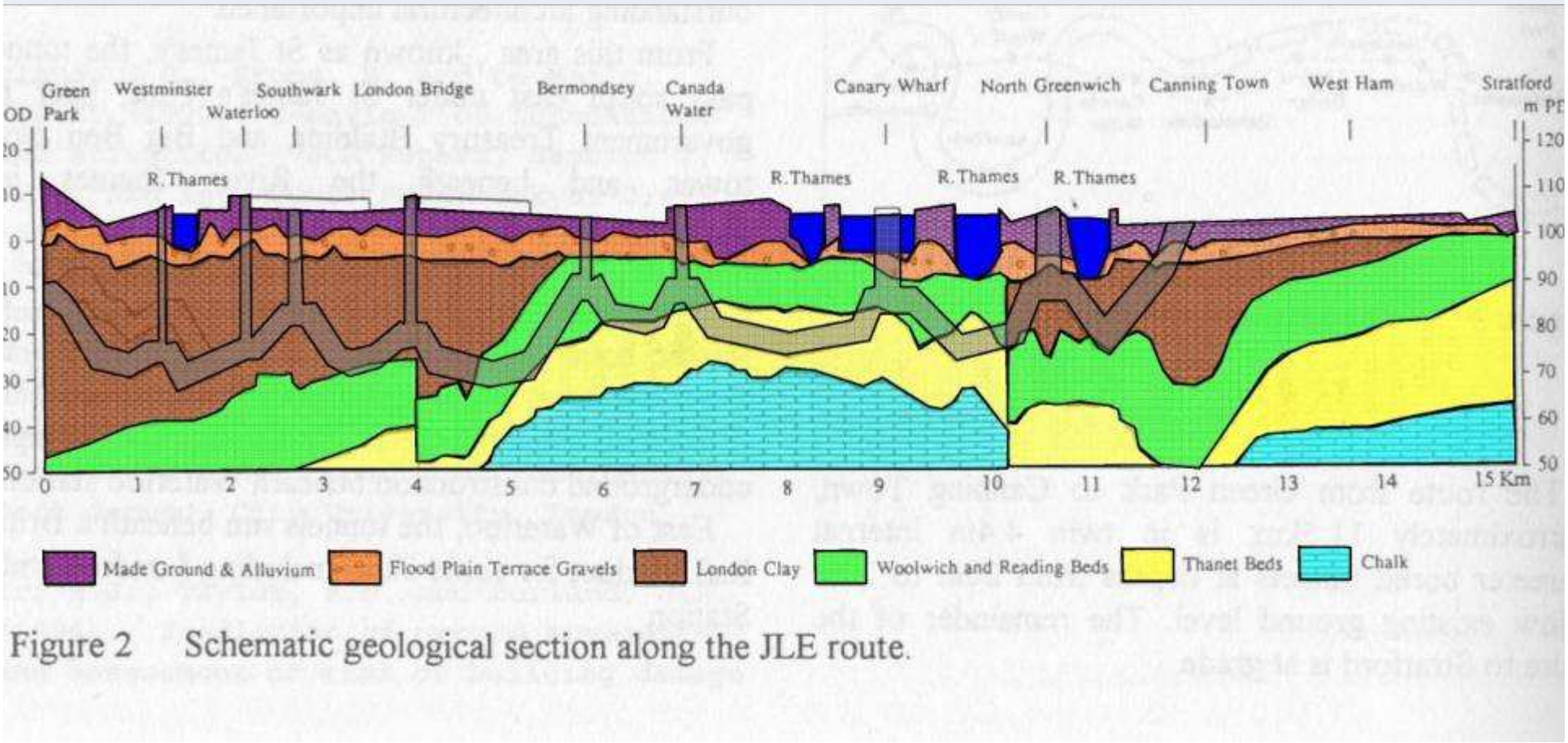

Figure 2 Schematic geological section along the JLE route.

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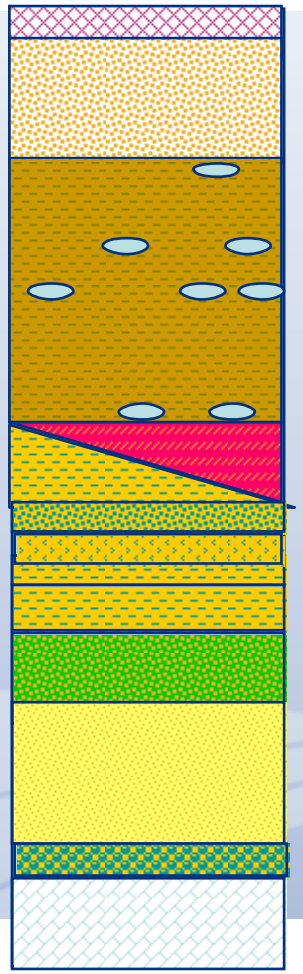
Geology of London



Formation Name	Lithological variation
MADE GROUND / FILL	HUGE! Everything and Anything left by man.
ALLUVIUM & THAMES GRAVEL	Not always Gravel! Varies from clay and peat to sands and Gravel, can change rapidly both vertically and laterally
LONDON CLAY	Not always Clay but usually is, stiff fissured clay with sand and silt partings, generally consistent and homogeneous. Can contain 'listric' ~ fault planes (greasy-backs) and claystone nodules.
HARWICH BEDS	An intermittent layer, more common in the East of London. Generally granular but variable.
LAMBETH GROUP *Woolwich & Reading Formation* *Upnor Formation*	Very high variability changing from clay to gravel laterally and vertically, in general terms the upper parts are dominated by clay the lower part is dominated by granular materials. Can contain tabular slabs of calcrete and ferricrete.Potential for adverse ground reactions.
THANET SAND	A very consistent dense silty SAND with occasional pebbled beds and silt partings.
Bullhead Beds	An intermittent deposit found at the top of the Chalk, typically flint gravel and cobbles in a silt host matrix
CHALK FORMATION	Massive but fissured, blocky, white limestone as found in the White Cliffs of Dover.

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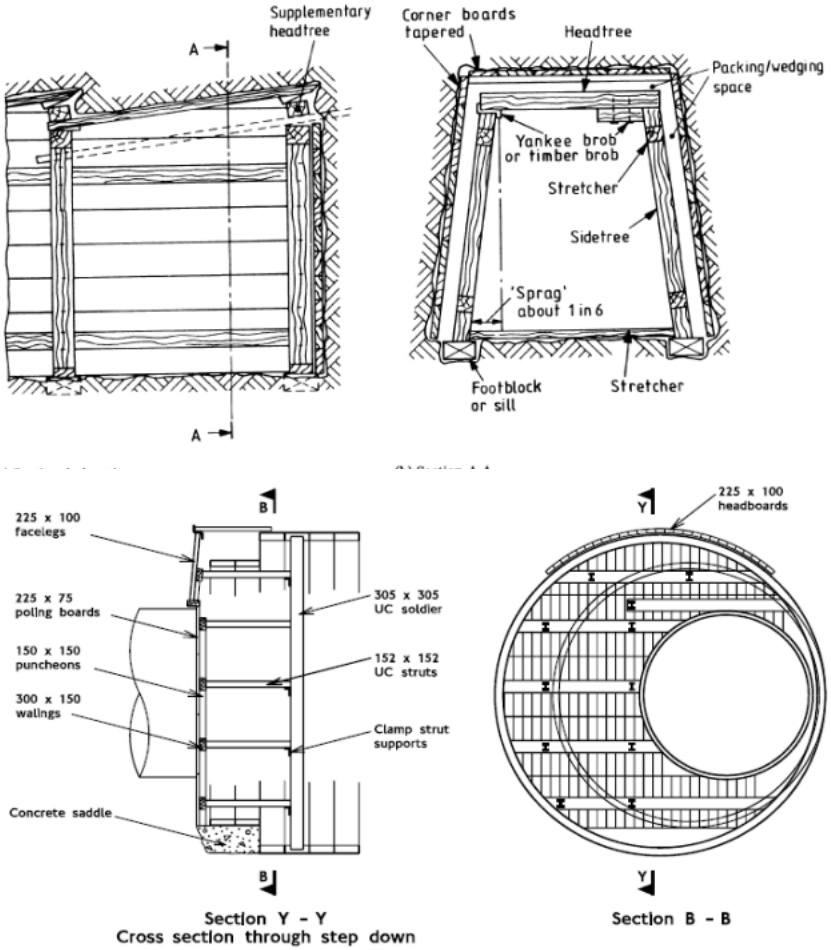
Influence of the Clay



- Perfect for Tunnelling
- Over Consolidated
- Mainly dry
- Easily excavated
- Long Stand Up Time

Traditional form of construction using timber and hand excavation

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Special Cast Iron Linings at Junctions

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Typical Expanded Linings for Running Tunnel in Clay

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Underground Development Using Sprayed Concrete Lining

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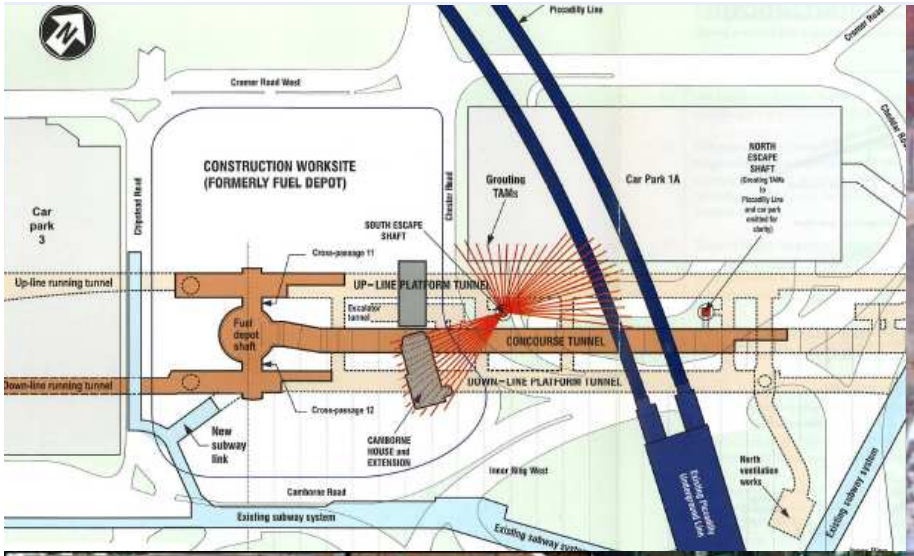

Heathrow tunnel collapse 1994

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London Bridge Station
JLE Concourse

SCL delayed by Heathrow – but continued

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Channel Tunnel Rail Link

- Earth Pressure Balance TBMs
- Slurry TBMs
- Dewatering Deep Well and Local
- Grouting/ Ground Treatment
- Occasionally Compressed Air

Running tunnels driven through Sands, Gravel and Chalk

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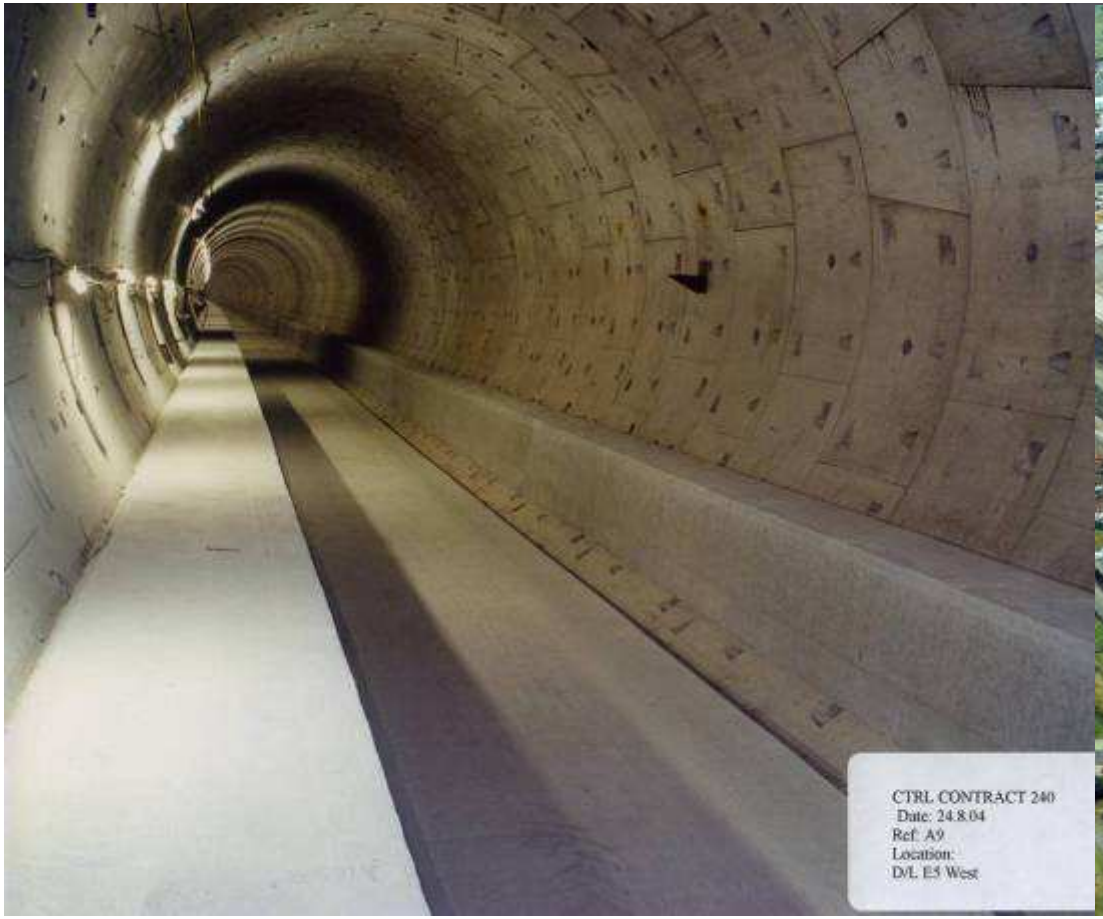
Channel Tunnel Rail Link



Running Tunnel with Tapered Wedgeblock Linings
- specially established manufacturing facilities

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Tunnelling today Crossrail

Mayor takes the photo opportunity

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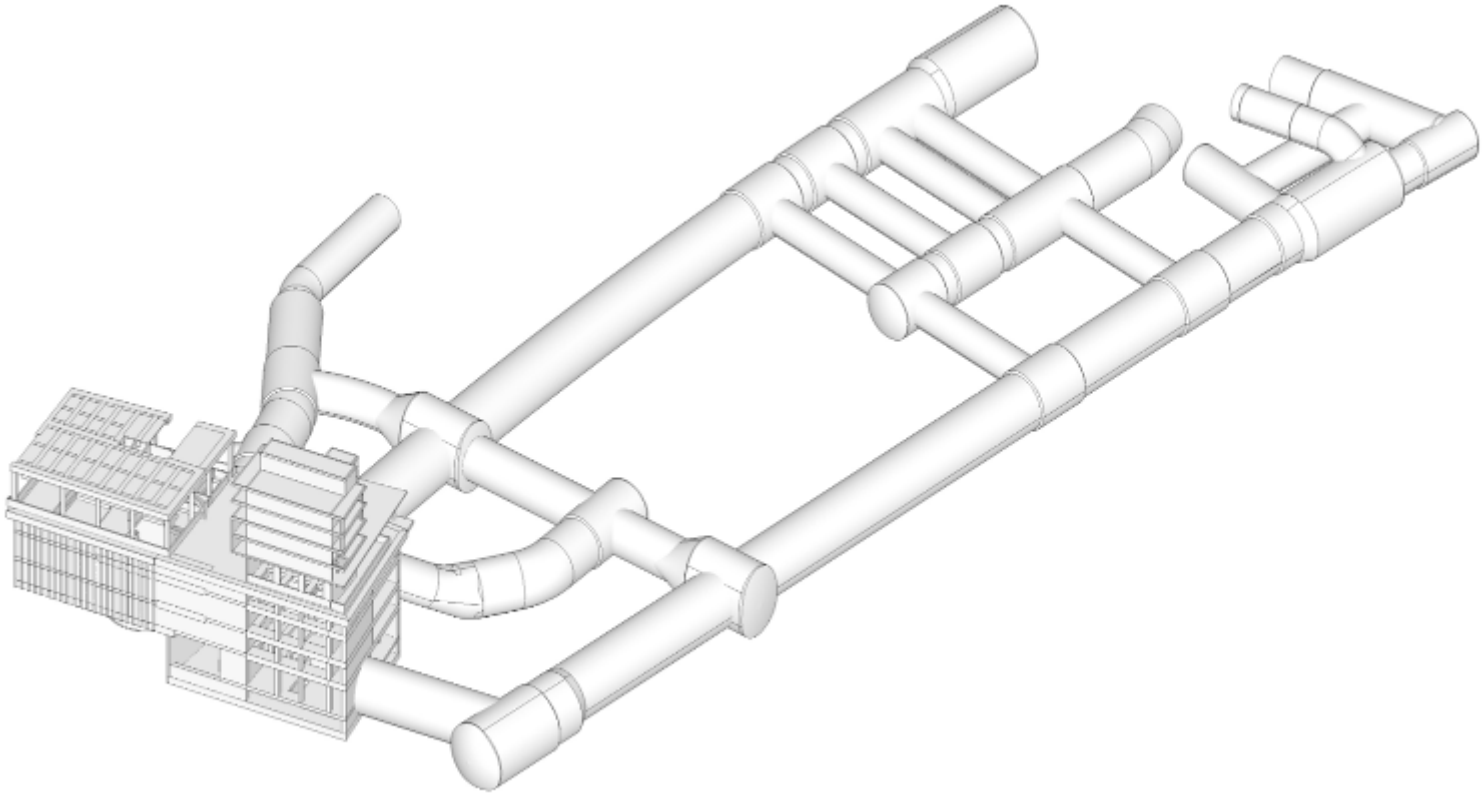
Complex stations on massive scale



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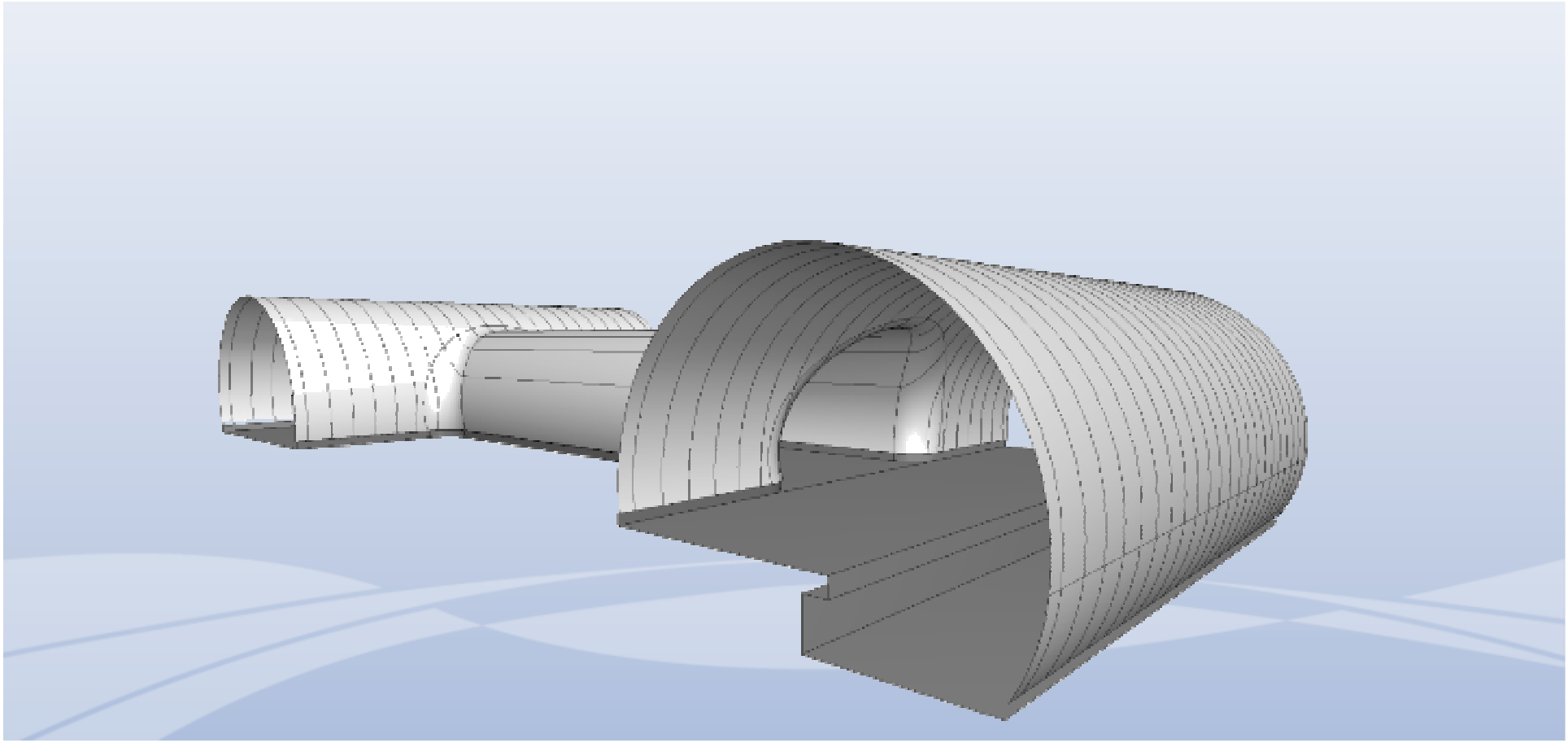
Helping people flow



Collaboration with architects

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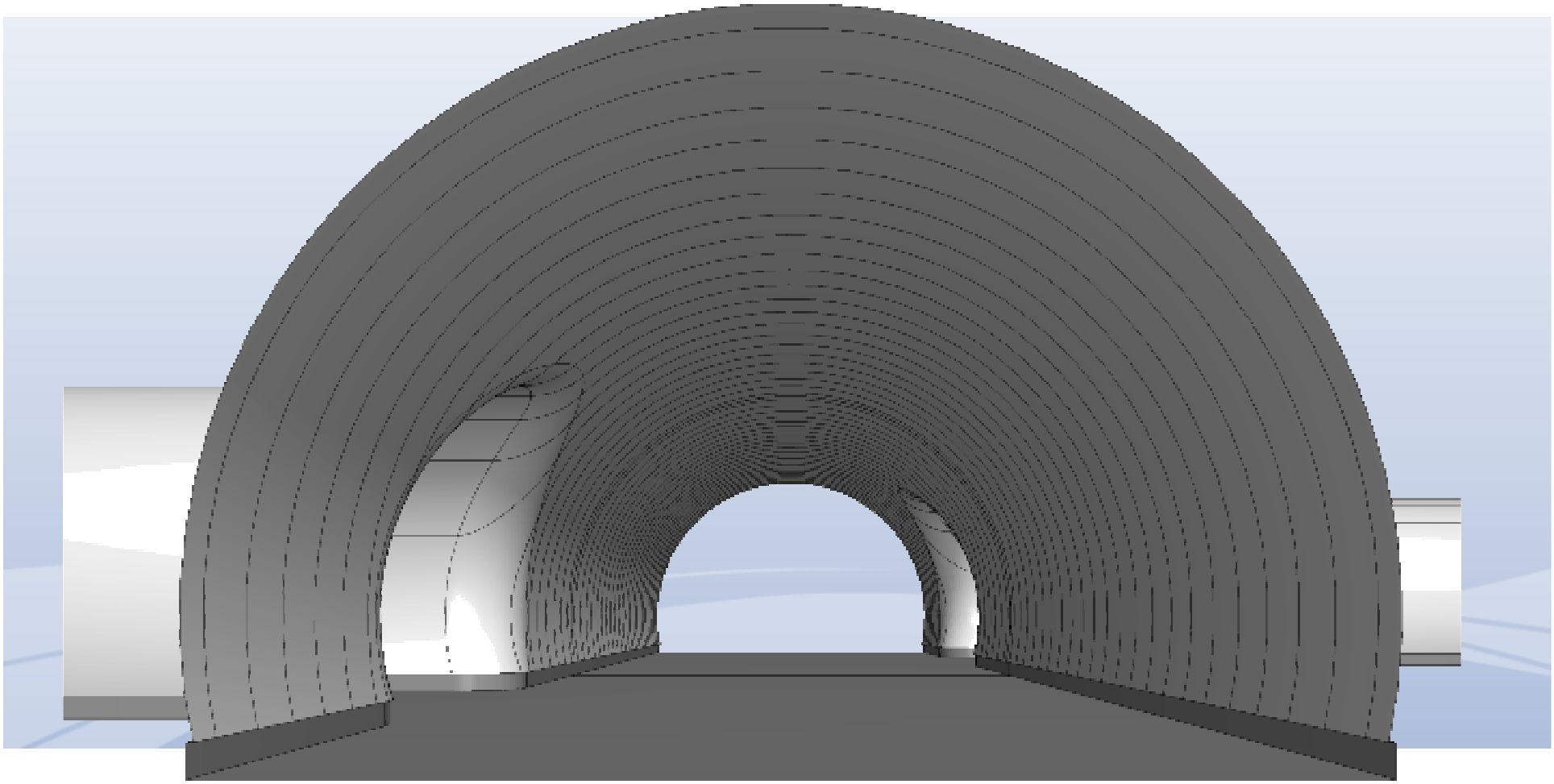
Crossrail stations



Sprayed concrete facilitates smooth junctions

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Tunnelling today – Lee Tunnel

- 7 m dia tunnel
- 6 km long
- 80 m Deep Shafts

Diversion and storage of sewer overflows

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Tunnelling today – Cable Tunnels
132 kV and 400 kV Circuitss

Different utilities have will not share space

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Tunnelling today – Cable Tunnels

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Tunnelling Today – Victoria Station Upgrade

- Reduce congestion and delays
- Provide more convenient access from areas to the north and east of the station
- Make the station more accessible for passengers with reduced mobility
- Achieve a world class transport interchange

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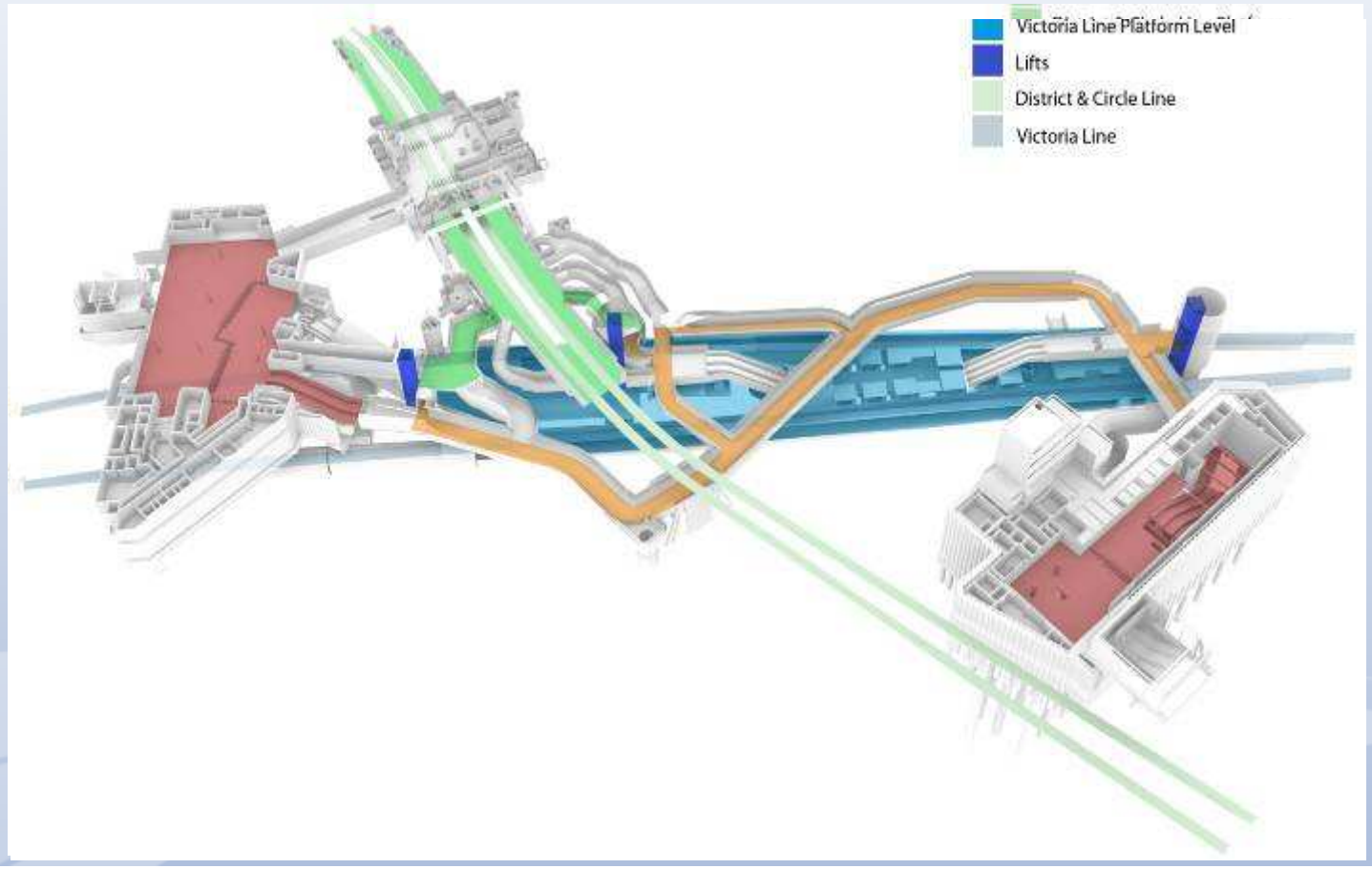
VSU Benefits



1.New Connections

2 .Step free access

3. Improved fire strategy

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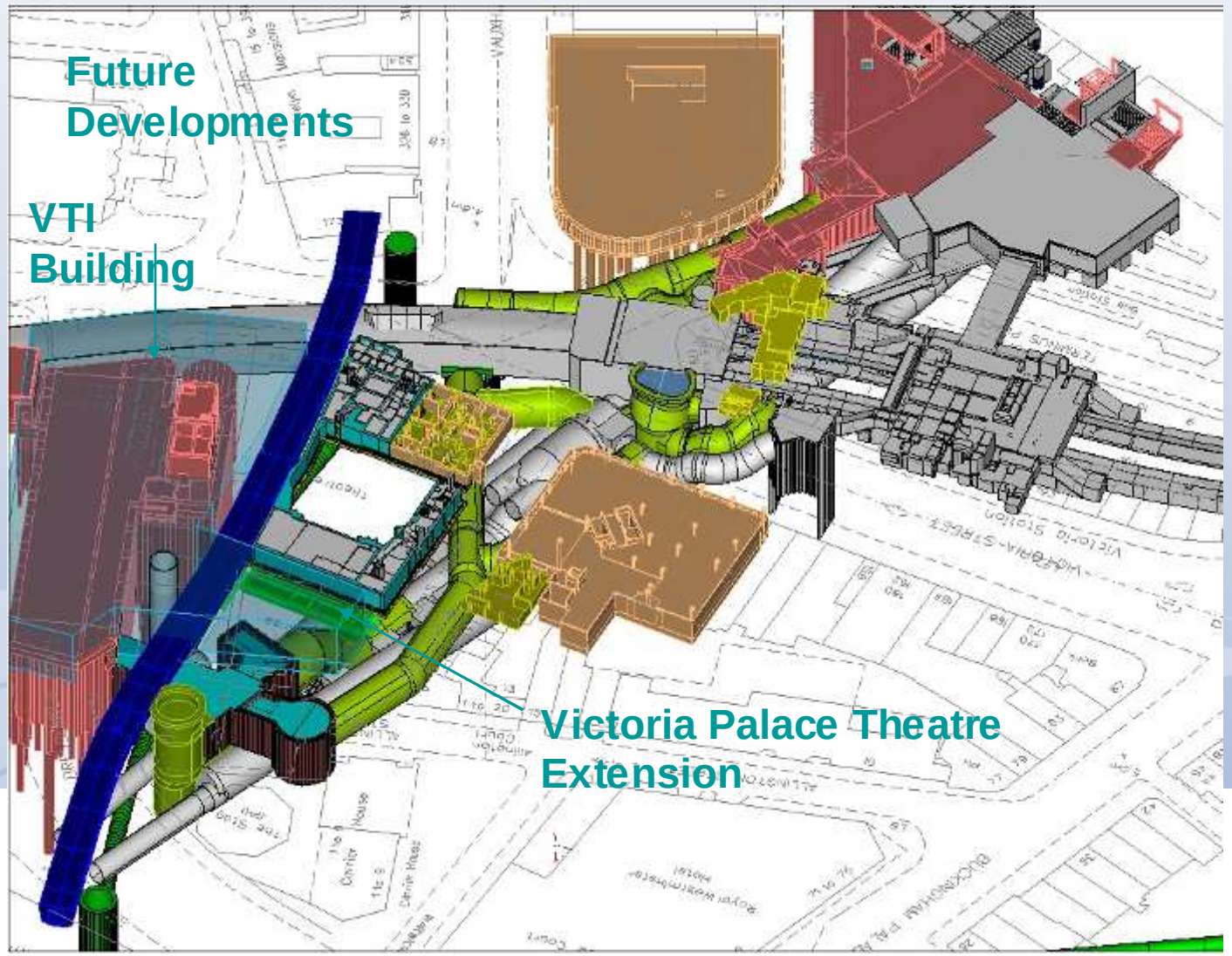
Victoria Station - Constraints



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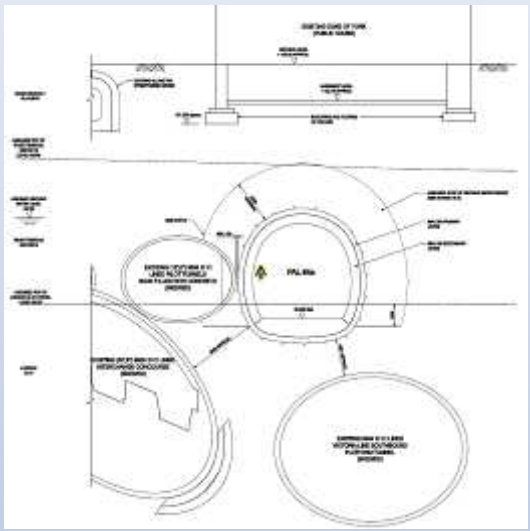
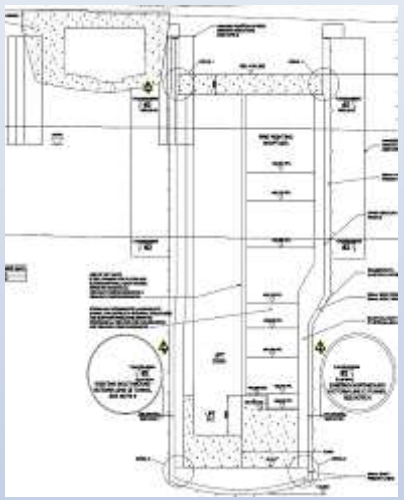
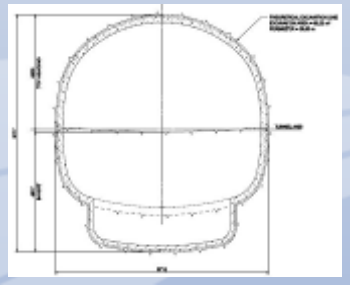
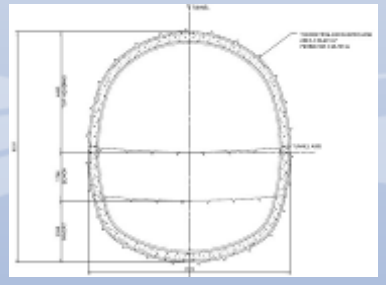
VSU Tunnels

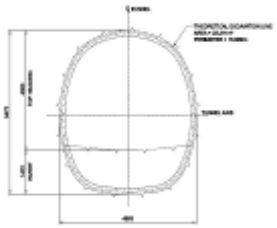
- Very variable tunnel cross sections to suit passenger envelopes and constraints when close to existing structures.
- Tunnels size ranging from 22.312 m^2 to 63.610 m^2











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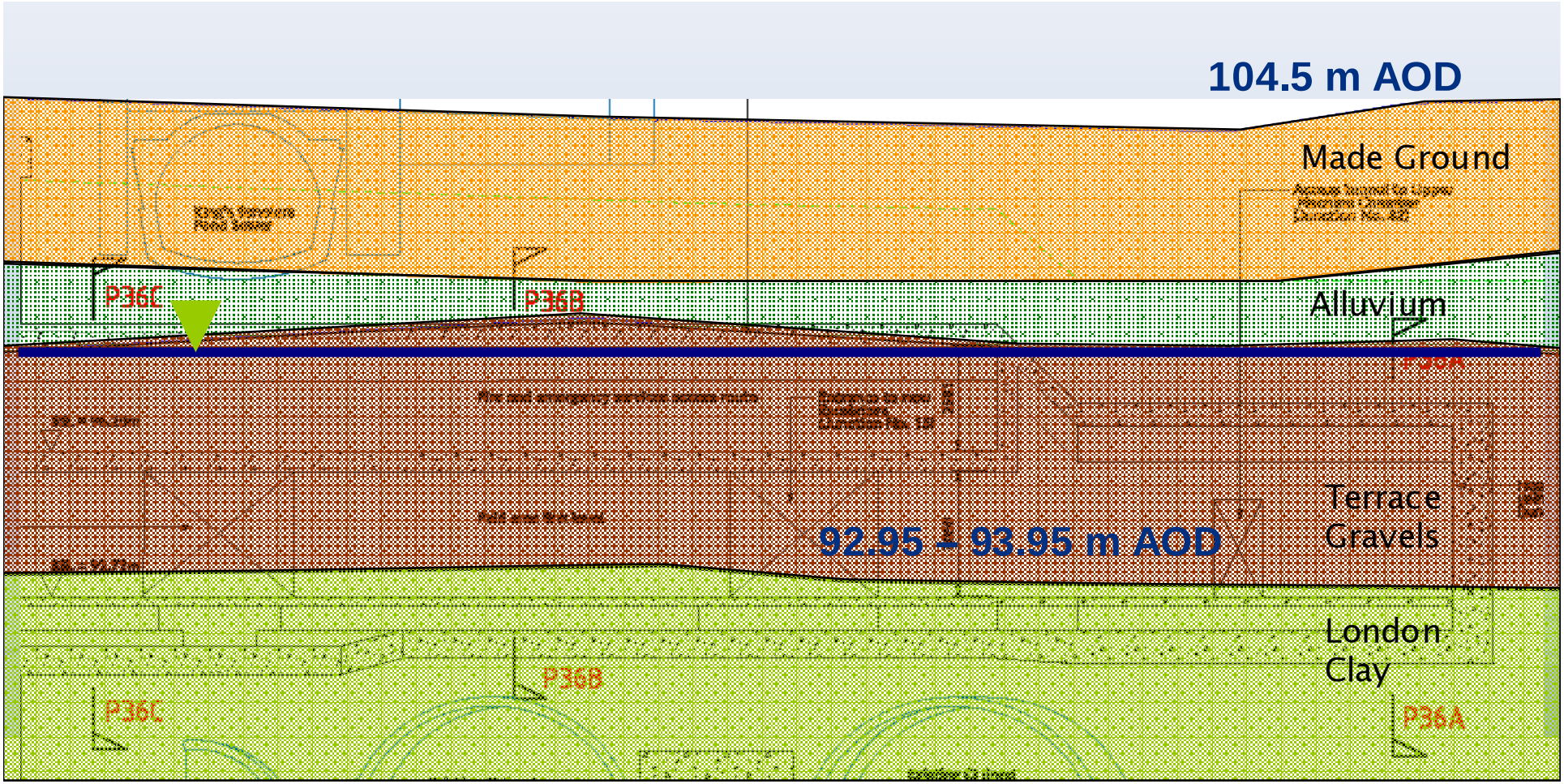
Challenging Ground Conditions



London Clay/Terrace Gravel Interface: 92.95 and 93.95 m AOD

Tunnel inverts: 92.23 to 95.51 m AOD

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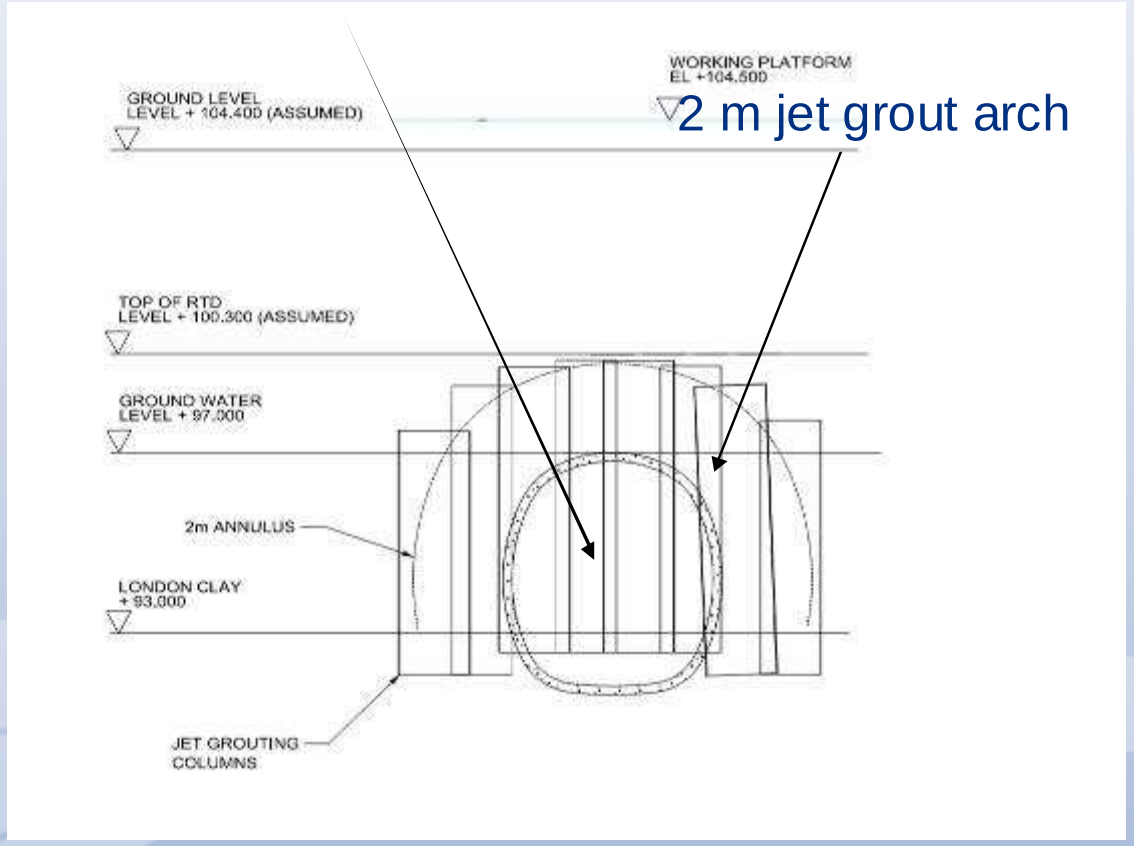
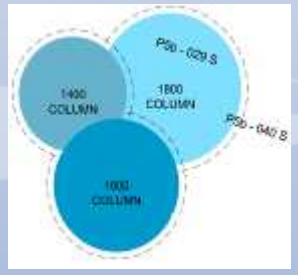
Ground Improvement

Full face jet grouting



<u>Performance Criteria</u>

- Jet Grout UCS > 1MPa
- Permeability < 5 x 10^{-8} m/s
- At least two rows of columns to overlap
- Column diameter ranging between 1400 and 1800 mm



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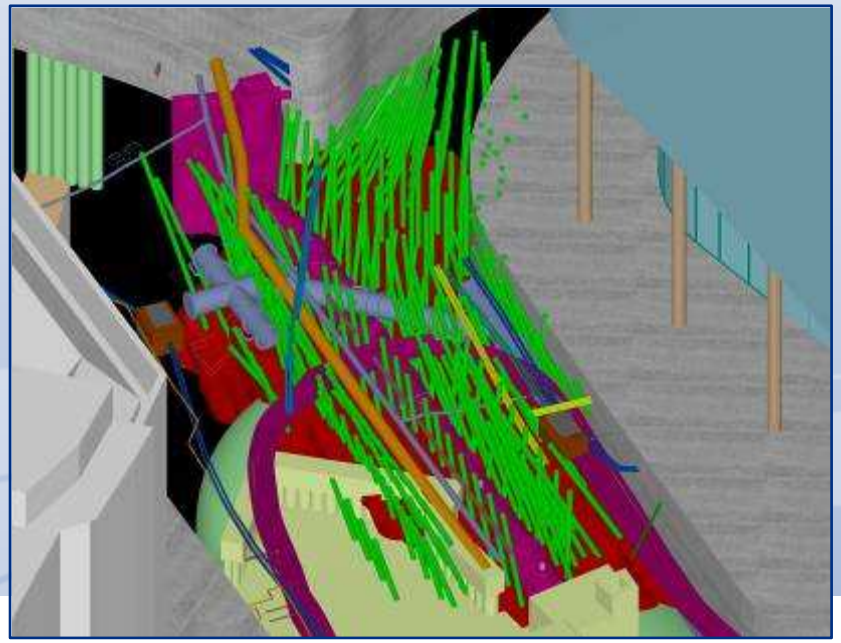
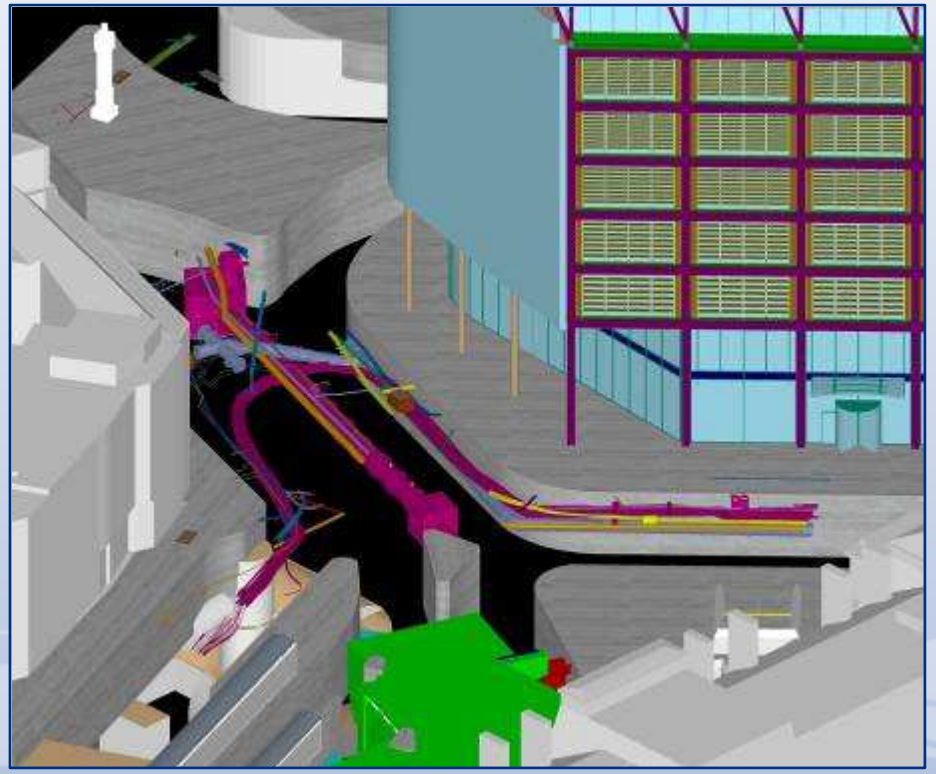
Ground improvement

- Detailed design by Keller
- Full use of 3d modelling.
- Buildings and topography modelled from surveys or external sources.





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Future London Tunnelling

- Bank Station
- Battersea Power Station Northern Line Extension
- Thames Tideway Thames Tunnel
- Silvertown Tunnel
- High Speed 2

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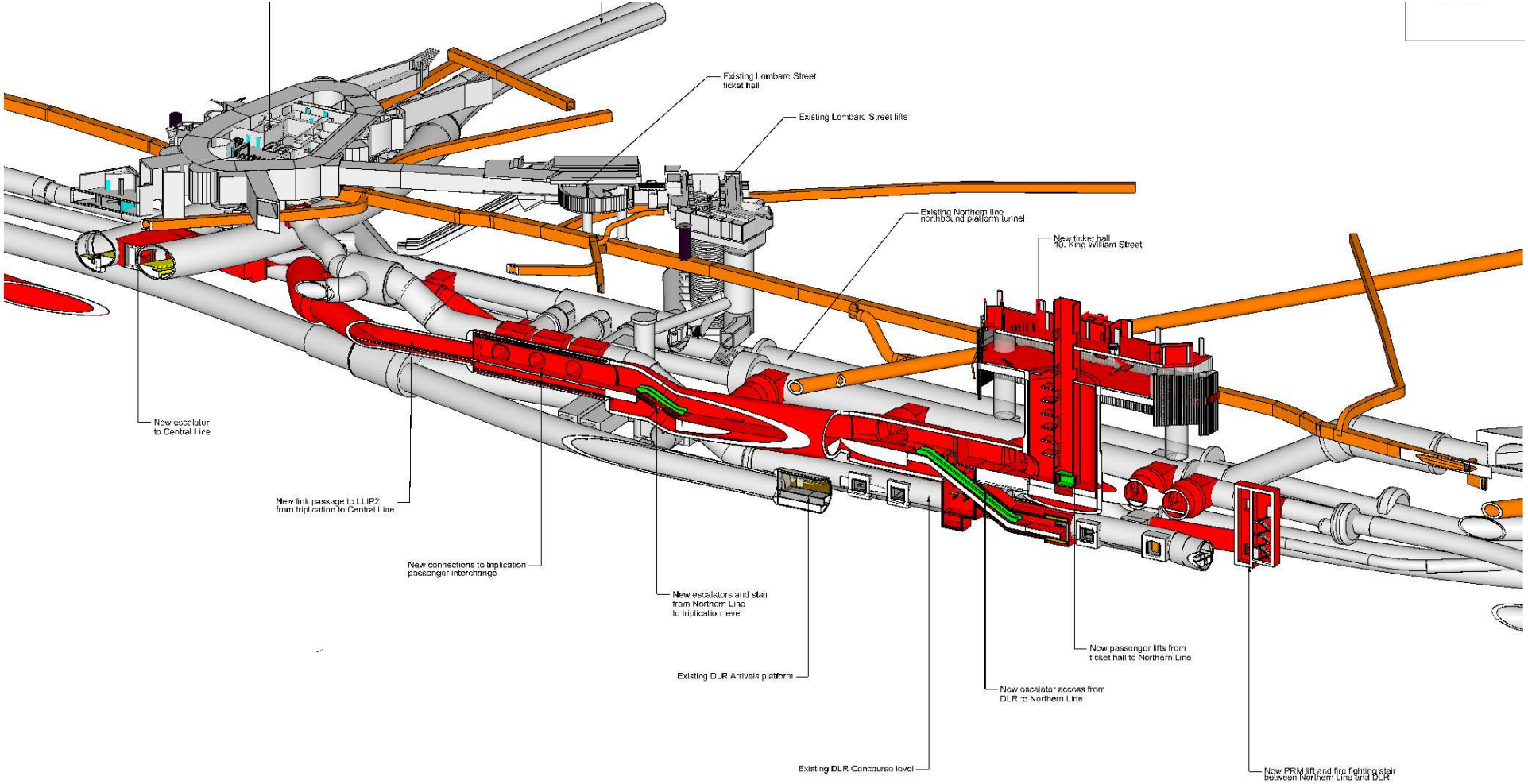
Bank Station Upgrade



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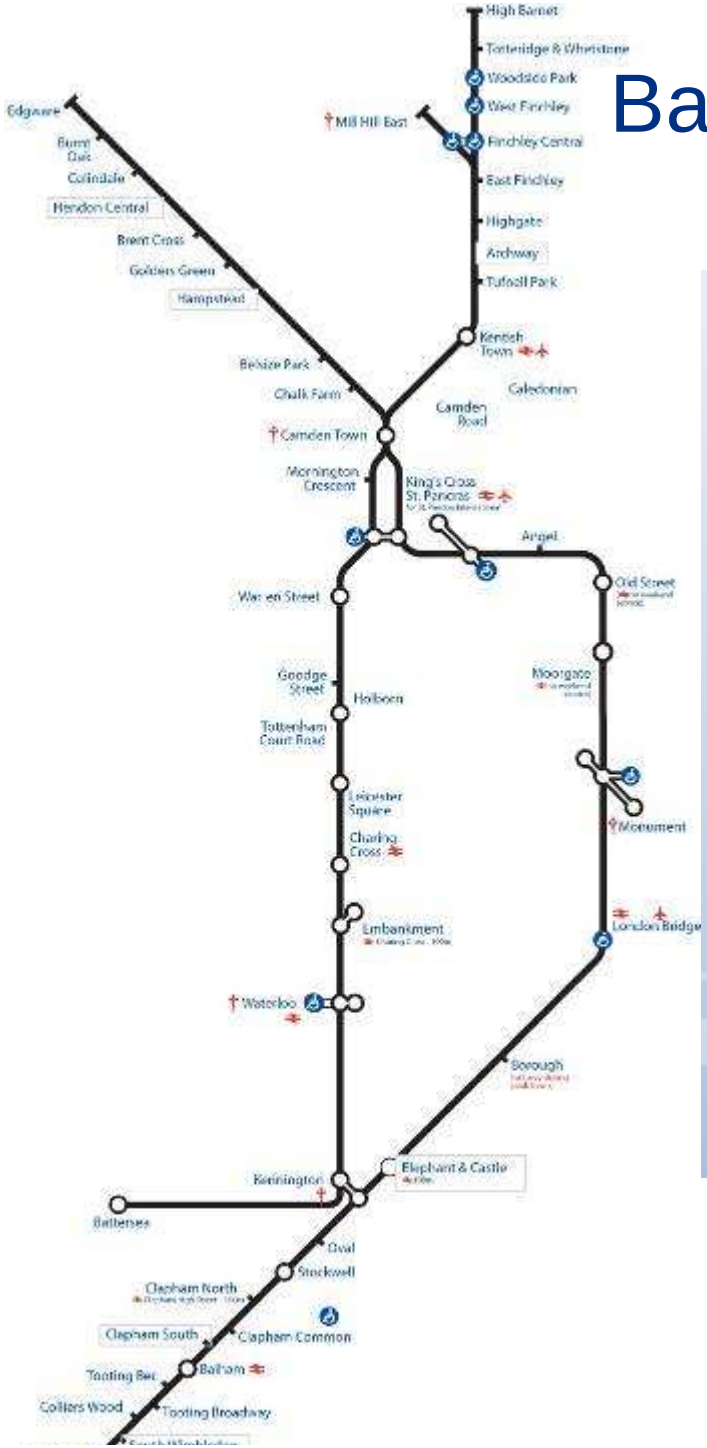
Battersea Northern Line Extension



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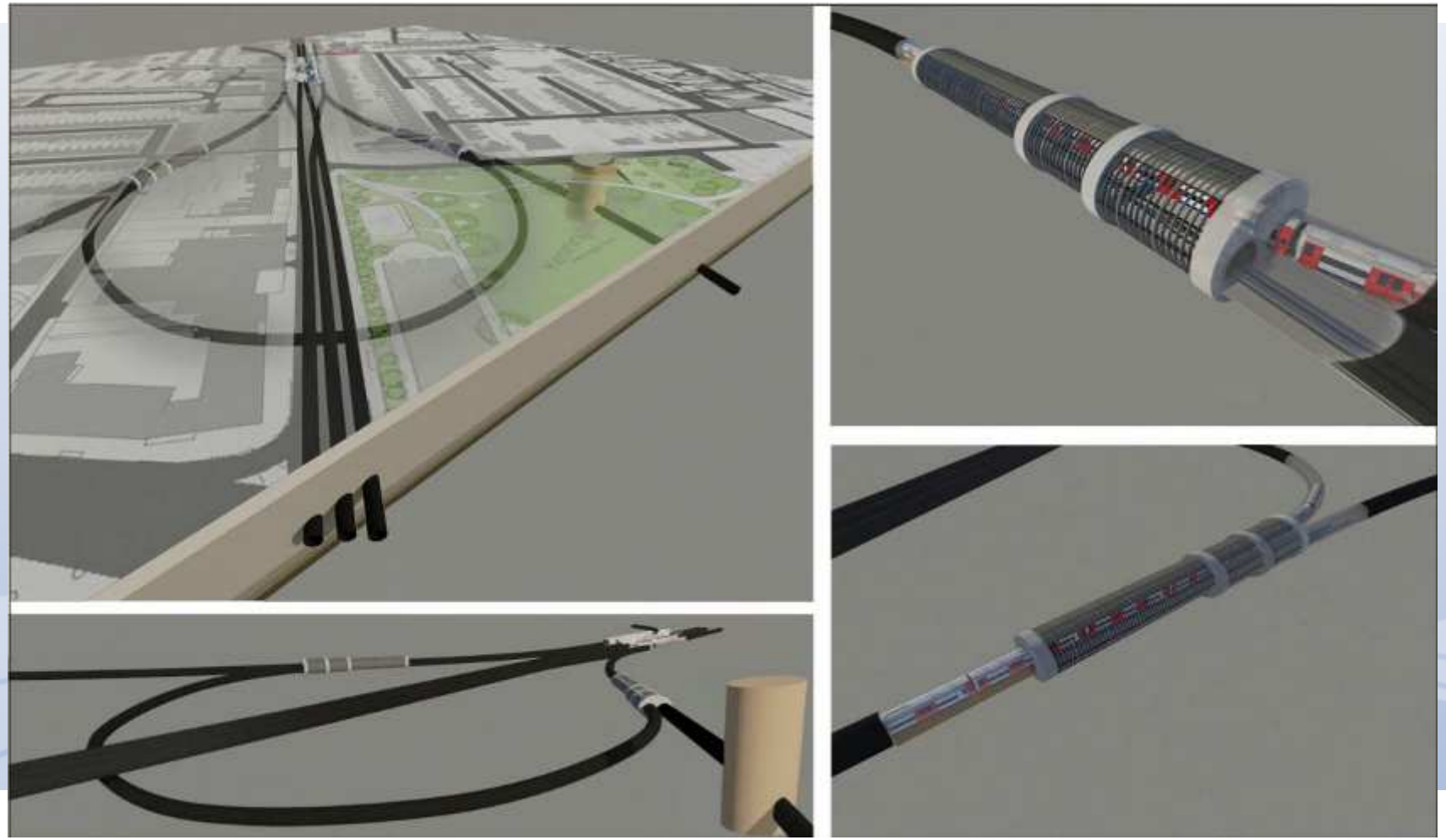
Kennington Connection



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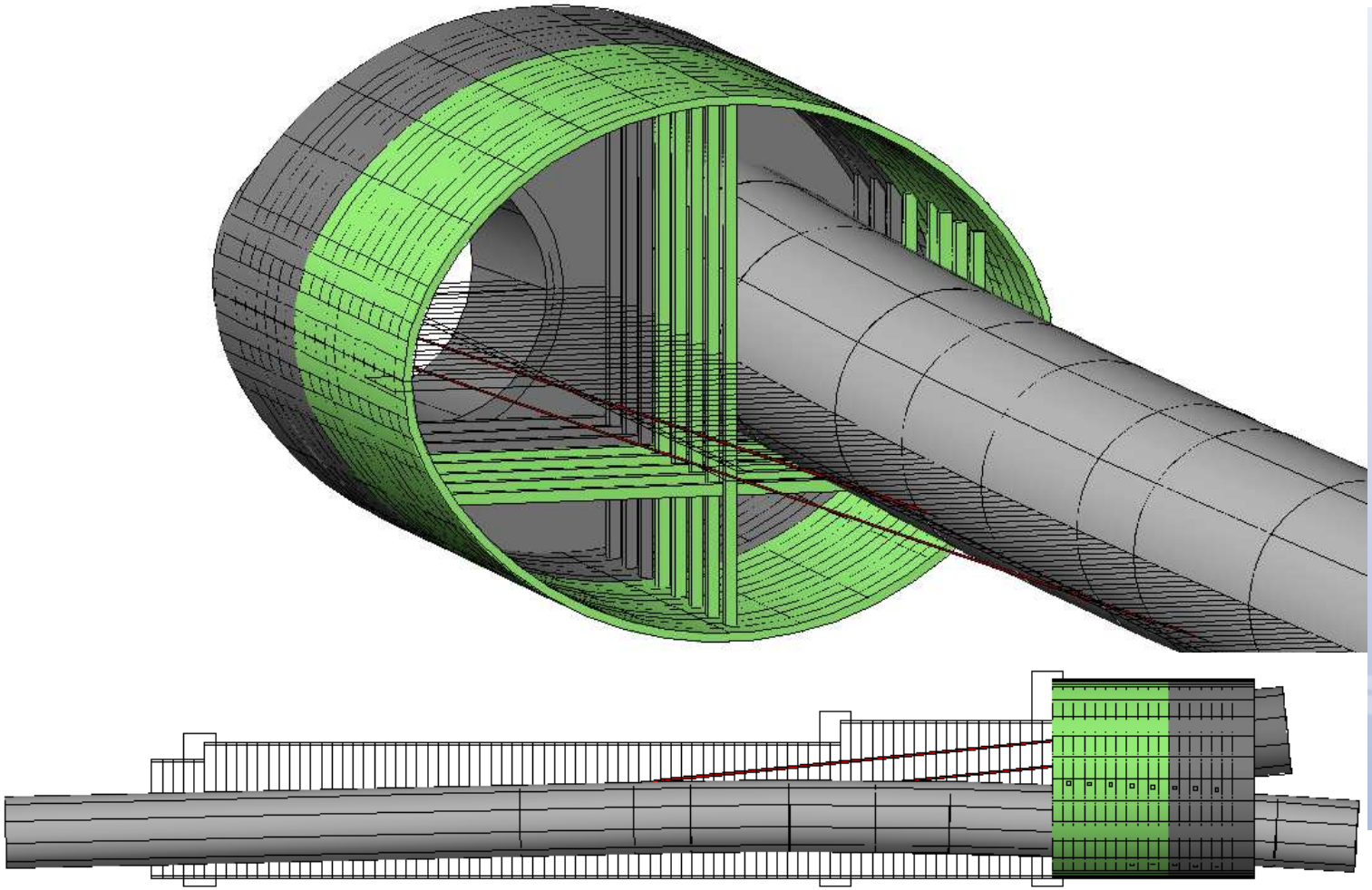
Kennington Connection – step plate junction



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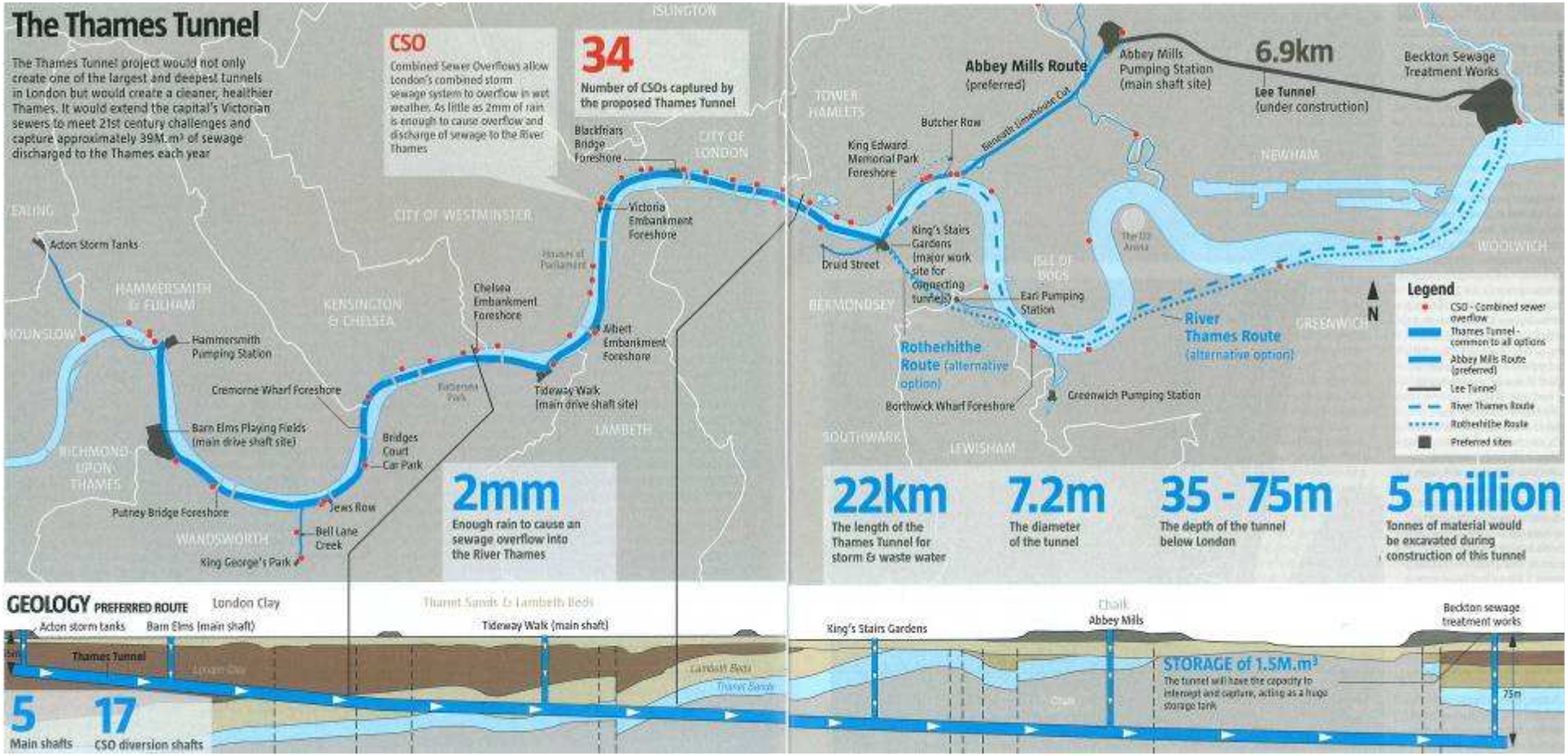
Thames Tideway



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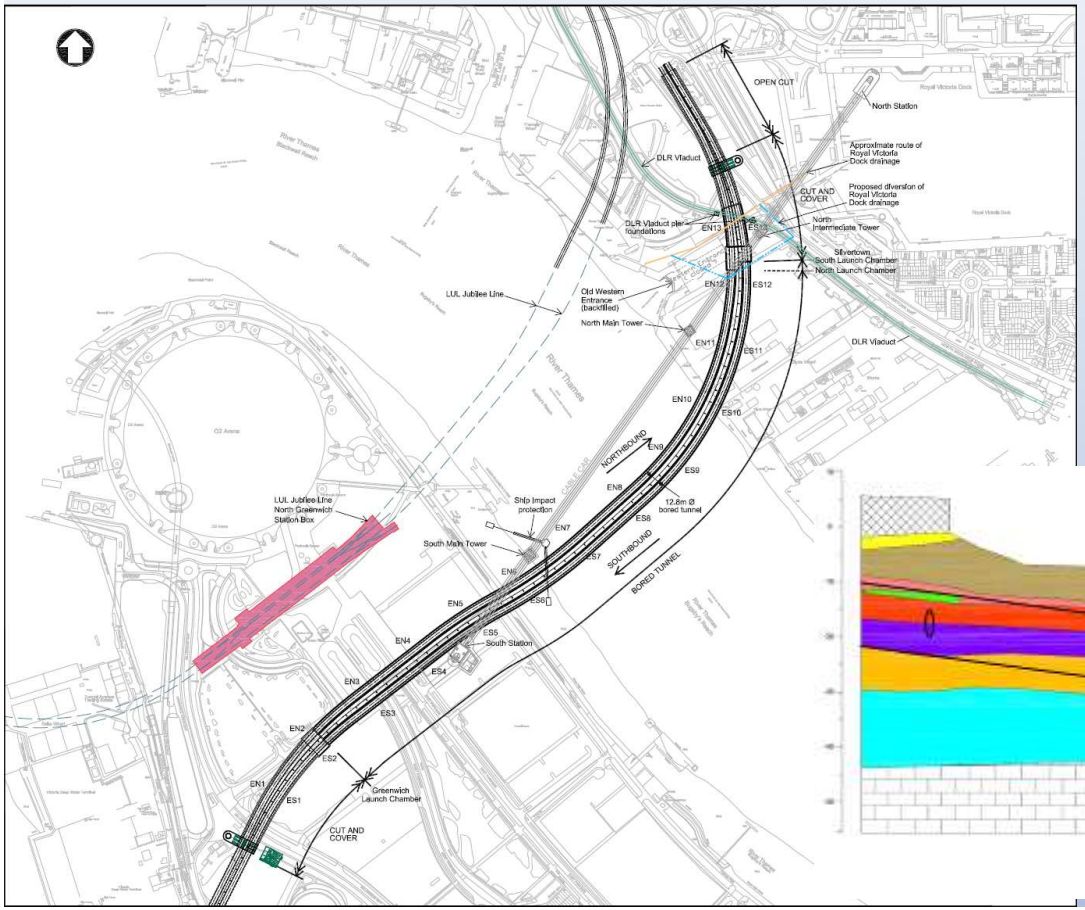
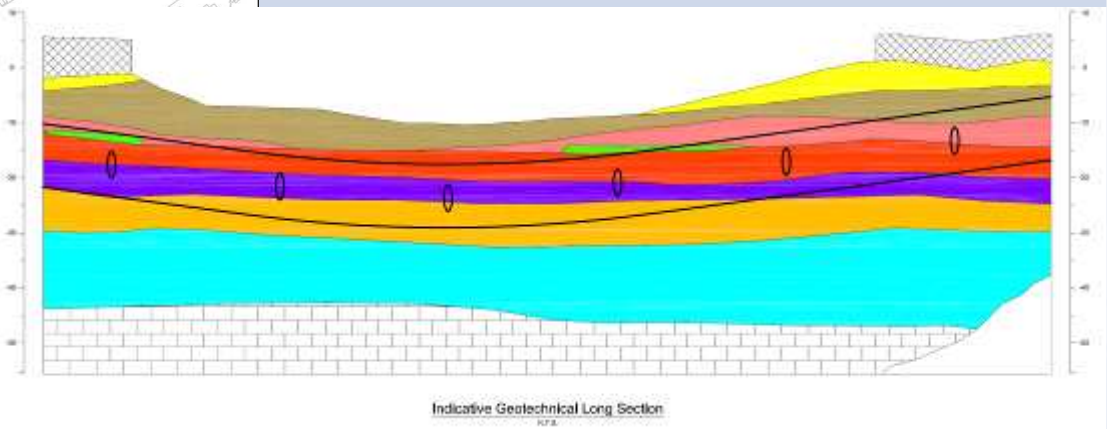
Silvertown
Road Crossing of the Thames





Challenging urban congestion
and ground conditions

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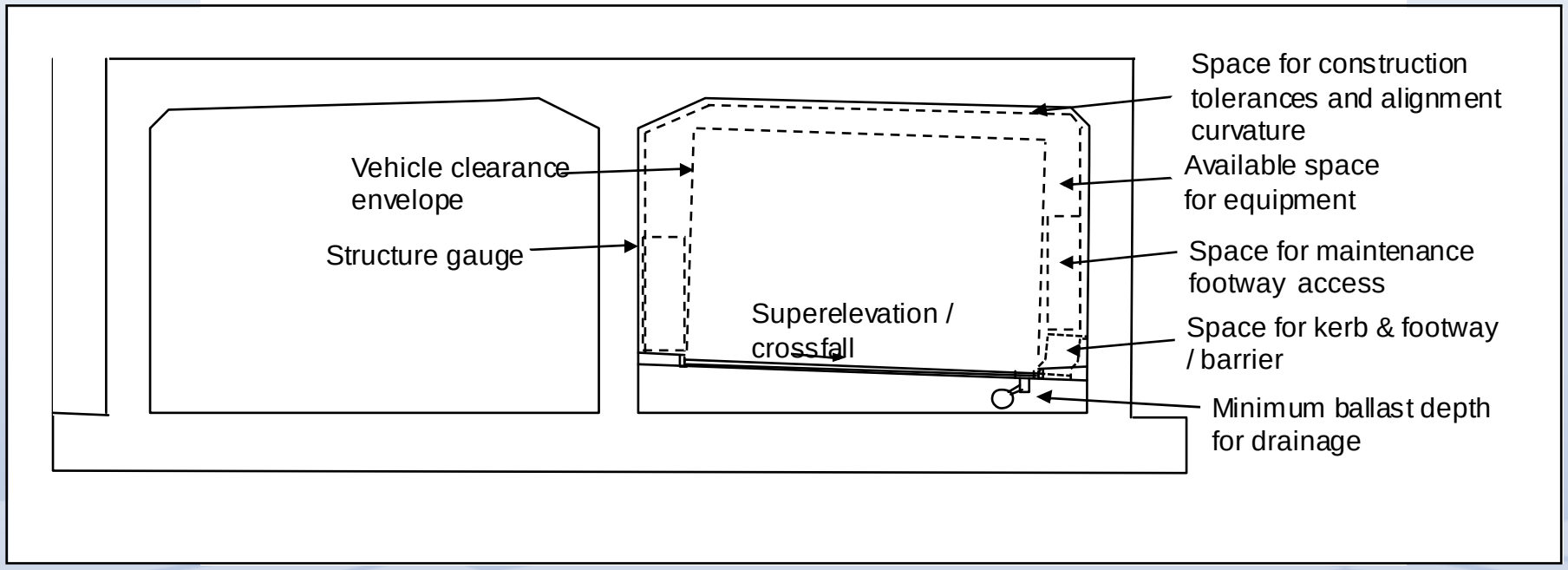
Silvertown



Bored ……. or ……. Immersed Tube

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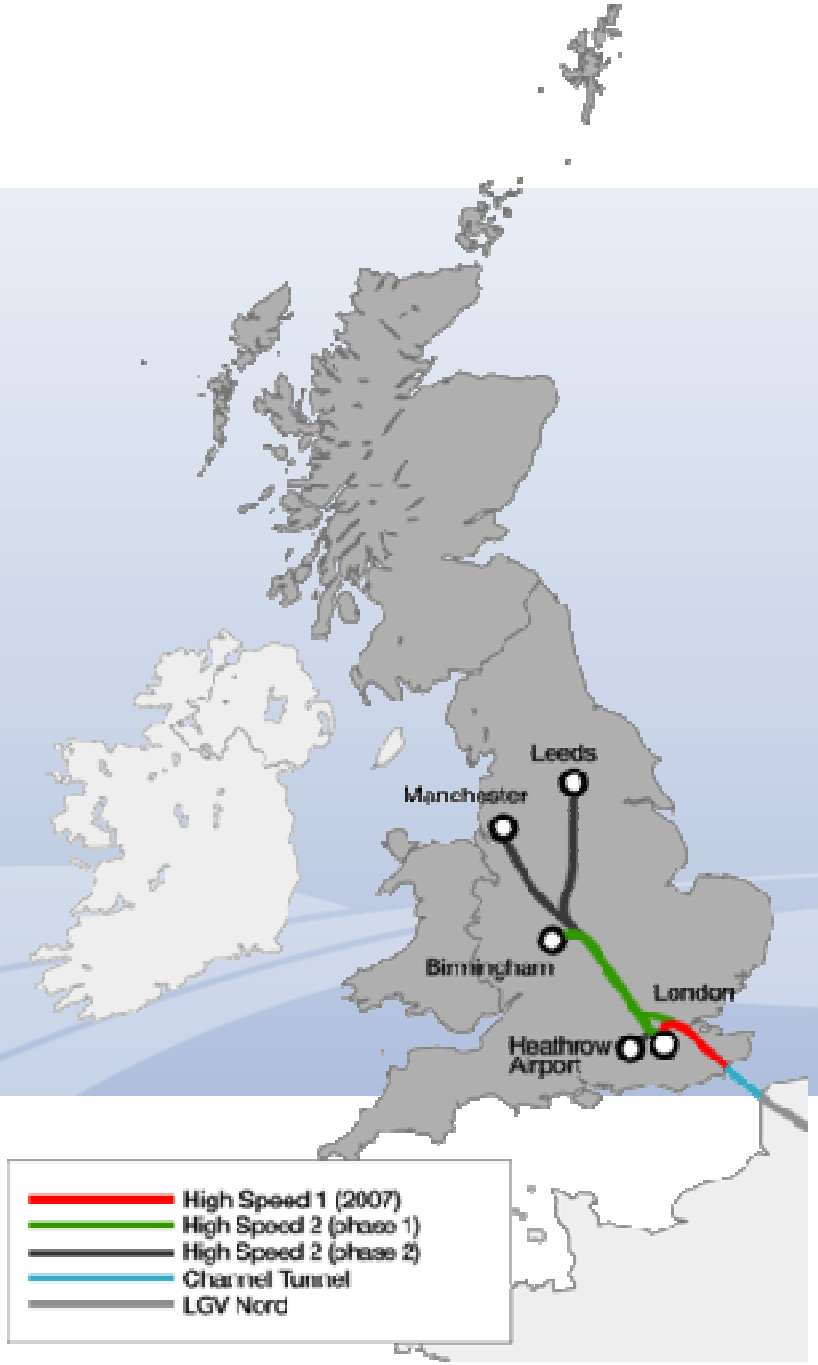
High Speed 2



- First phase London to Birmingham
- Tunnels from centre of London to outskirts
- Avoid sensitive areas

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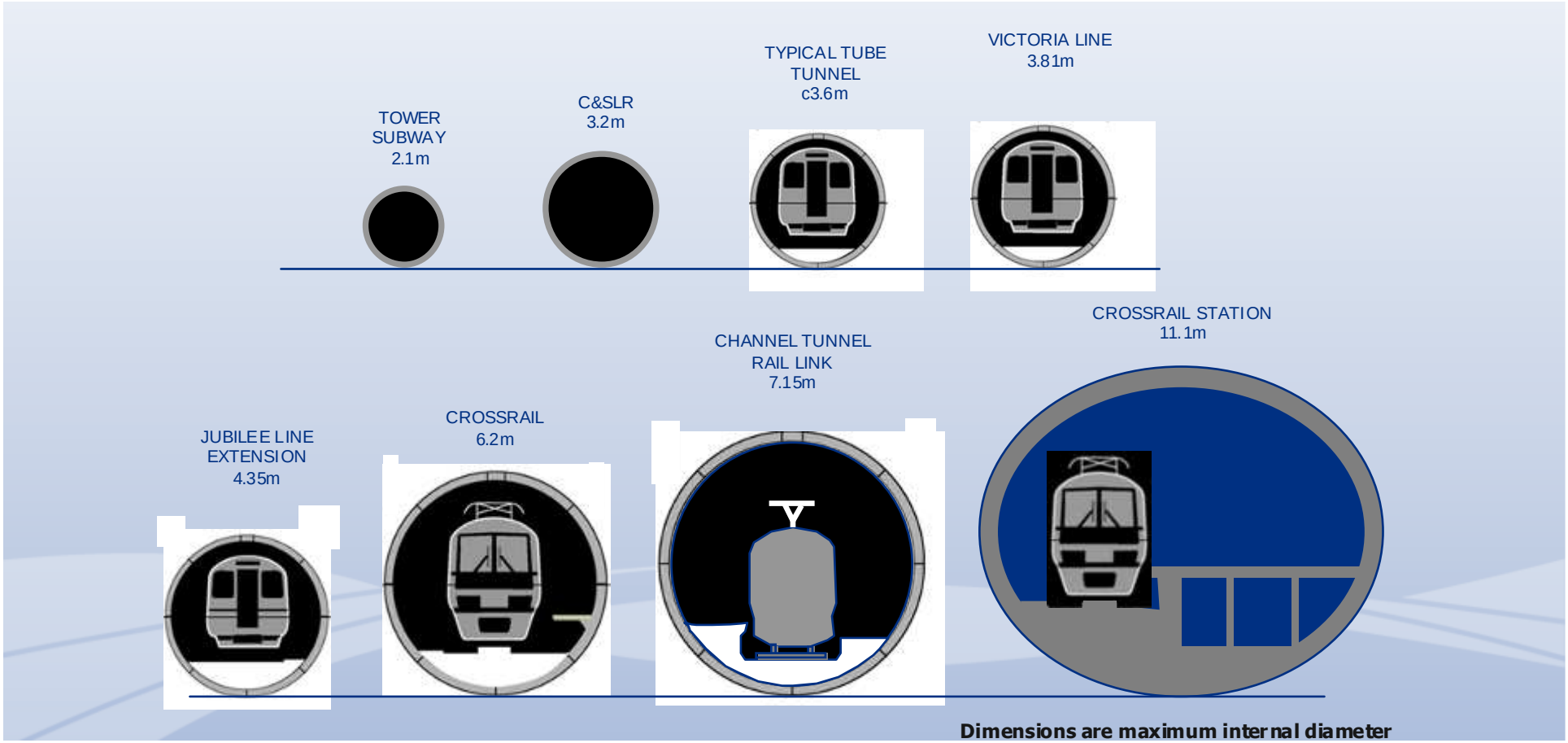
Conclusions



Growing size of tunnels

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Trends and Issues

- Increased tunnelling in difficult ground
- Underground congestion
- Challenge of Planning Permission
- Need for solution to road traffic
- Taking full advantage of BIM and 3D models
- Early/optimised or some other sort of contractor involvement
- Aggressive contract with risk on contractors

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Any questions

Michael Francis

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