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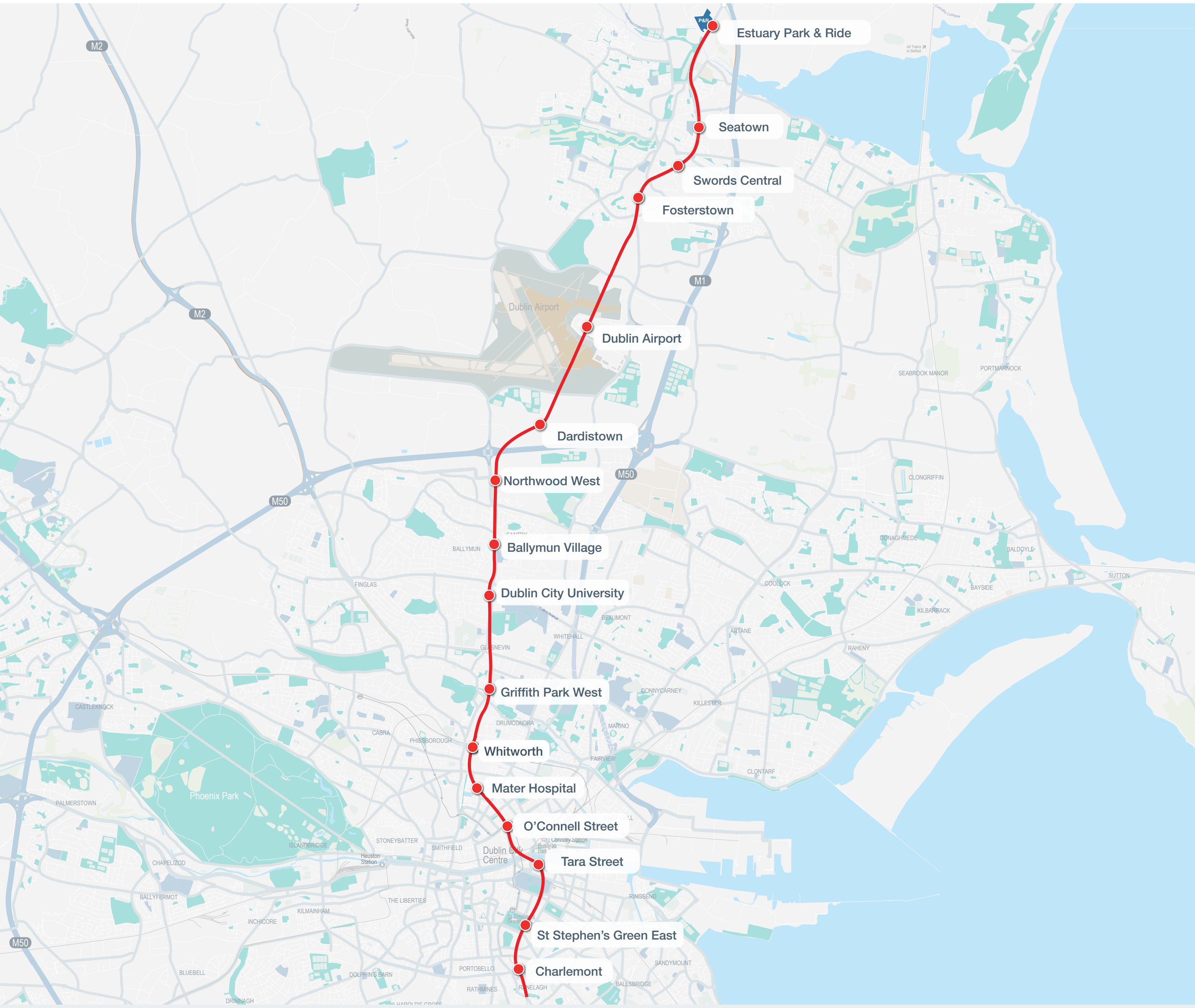
Final Issue

New Metro North

Concept Engineering Design Report

Volume 1: Main Report



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New Metro North Alignment Options Study

Concept Engineering Design Report

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1 Introduction

1.1 Background

New Metro North is a proposed metro line in Dublin providing a convenient, direct and dedicated rail link connecting Swords to the city centre via Dublin Airport. It will then connect at Charlemont station with the Luas Green Line which is planned to be upgraded from a tram system to a segregated metro system. Significant interchange stations will be provided with the Irish Rail system through a new station at Whitworth and the existing Tara Street station. There is a total of sixteen stations proposed for New Metro North, twelve of which are underground.

This report develops the concept engineering design for NMN on the basis of the Emerging Preferred Route (EPR) that was identified during the New Metro North Alignment Options Study.

1.2 Structure of this Report

The objective of this report is to outline the design basis supporting the concept engineering design of the EPR and this report will address the following items:

- Summary of changes from EPR to concept engineering design in Section 2
- Rail Alignment as detailed in Section 3
- Passenger Demand as detailed in Section 4
- Fire and Tunnel Ventilation Strategy as detailed in Section 5
- Station Planning as detailed in Section 6
- Tunnels as detailed in Section 7
- Civil Works as detailed in Section 8
- Estuary Depot as detailed in Section 9
- Park and Ride Facilities as detailed in Section 10
- Ground and Groundwater Conditions as detailed in Section 11
- Construction Planning as detailed in Section 12
- Cost estimate as detailed in Section 13

Concept Engineering Design Drawings are included in Volume 2 - Drawings.

1.3 Limitations and Exclusions

The following are not covered in this report, refer to the Alignment Options Study Report for further details:

- Options Selection of EPR

The following items are not part of the scope of the concept engineering design but will be addressed in the preliminary design:

- Green Line Tie-in
- Charlemont Station and Portal
- LUAS Green Line Upgrade works
- Tara Street Station Oversite Development
- Tara Street and Whitworth Irish Rail Stations

2 Emerging Preferred Route

2.1 Route Overview

The emerging preferred route (EPR) is taken forward from the Alignment Options Study and is developed to concept engineering design in this report. Figure 1 shows a high-level plan showing the horizontal alignment, the vertical alignment and the station locations.

Figure 1: Emerging Preferred Route for New Metro North

2.2 New Metro North Stations

The stations that are included in this report and are developed for concept engineering design are listed in Table 1. It should be noted that the design of Charlemont Station is not included in this report. The assessment and development of the stations is provided in Section 6.

Table 1: List of Stations on Alignment

Station No.	Station Name	Station Type
1	St. Stephen's Green East	Underground
2	Tara Street	Underground
3	O'Connell Street	Underground
4	Mater Hospital (at Eccles Road)	Underground
5	Whitworth	Underground
6	Griffith Park West	Underground
7	Dublin City University	Underground
8	Ballymun Village	Underground
9	Northwood West	Underground
10	Dardistown	Underground
11	Dublin Airport	Underground
12	Fosterstown	At Grade
13	Swords Central	Elevated
14	Seatown	Elevated
15	Estuary P&R	At Grade

2.3 EPR Alignment

The EPR alignment was developed in the Alignment Options Study using generic station depths which allowed a significant number of routes to be compared. However, for the concept engineering design, this alignment has been constantly adjusted as the design of the stations, portals, shaft and tunnels have been developed. The following summarises the changes to the EPR alignment, highlighting key decisions.

2.3.1 Horizontal Alignment

The horizontal alignment has not changed significantly from the route presented in the Alignment Options Study Report. Small changes have been made as stations have been developed. All horizontal alignment is designed as per Section 3.

2.3.2 Vertical Alignment

There was a significant development of the vertical alignment from the EPR stage to concept engineering design stage. The changes are due to the following general reasons:

- Station depths – shallowest station possible per location, with depth varying from a single level deep (i.e. -1 Level) to three levels deep (i.e. -3 Level)
- Tunnel pinch points where clearance is needed from the River Liffey, the River Tolka, the M50 etc.
- Tunnelling constraints such as minimum depth, ground movement
- Rail Alignment constraints such as permissible vertical gradient, horizontal alignment etc.
- Tunnels generally dip between stations. This allows gravity to aid acceleration when departing a station and deceleration when approaching a station.
- Low point sumps between stations where required
- Portal location
- Cross passage spacing

Throughout the design process there were several iterations as there is interaction between several of the elements (e.g. low point and alignment constraints).

The tunnel configuration chosen for the concept engineering design, as outlined in Appendix E also has an impact on the vertical alignment for the route. The twin bore single track configuration chosen has an internal diameter of 5.9m resulting in a minimum depth to rail of 13.5m which also had to be considered when designing the vertical alignment for route along with the constraints identified in Table 2 below.

Table 2: Vertical alignment changes EPR to Concept Engineering Design

Approximate concept engineering design chainage	Alignment Element	Vertical Alignment Comments	Track Level mOD
1+000	Green Line Tie-In	Fixed point, no change possible	+5.079
1+578	Low point	Provided with acceptable rail gradients.	-12.993
1+793 to 1+935	St. Stephen’s Green East Station	-2 Level station as space available on surface for longer station. Shallower station not possible as tunnelling connection too shallow for city centre location. Refer to drawings for depth to rail from surface.	-11.987
2+599	Low point	Moved to coincide with cross passage to avoid duplicate excavation and break out from	-22.369

Approximate concept engineering design chainage	Alignment Element	Vertical Alignment Comments	Track Level mOD
		tunnel. Provided with acceptable rail gradients.	
2+842 to 2+946	Tara Street Station	-3.5 level station as heavily constrained site at ground level and tunnels required to go deep to pass beneath foundations of proposed development to north. Refer to drawings for depth to rail from surface.	-21.060
3+100	River Liffey	Pinch point beneath the Liffey. The rail level should be below -21.5mOD which is based on clear distance between the tunnel crown and the river bed.	-22.400
3+193	Low point	Provided with acceptable rail gradients.	-23.176
3+630 to 3+727	O’Connell Street Station	-3 Level station as the site is constrained to the north at street level by junction. Shallower station not possible as longer station not acceptable and tunnels too shallow for city centre location. Refer to drawings for depth to rail from surface.	-18.664
3+727 to 4+595	Raising alignment	Alignment increases at 3% to gain elevation as ground level is rising. No low point in this section.	-18.664 to -2.121
4+595	Mater Hospital Station	-3 Level station as the site is constrained at street level by available land, notably the church to the south. Shallower station not possible. Refer to drawings for depth to rail from surface.	-2.121
4+869	Low point	Moved to coincide with cross passage to avoid duplicate excavation and break out from tunnel. Provided with acceptable rail gradients.	-3.193
5+357 to 5+474	Whitworth Station	-3 Levels station as the site is constrained by the Royal Canal and existing railways. Longer box not possible. Shallow tunnels not possible due to city centre location. Refer to drawings for depth to rail from surface.	+3.993
6+267	Low point	Provided with acceptable rail gradients.	-5.805

Approximate concept engineering design chainage	Alignment Element	Vertical Alignment Comments	Track Level mOD
6+270	Tolka River	Pinch point to provide tunnel clearance beneath River Tolka. Rail level to be at or below -5mOD.	-5.000
6+565 to 6+697	Griffith Park West Station	-3 Level station as alignment cannot be shallow enough for -2 level station. This is due to low point at River Tolka and alignment constraints. Refer to drawings for depth to rail from surface.	-2.926
6+907 to 7+707	Limiting maximum gradient of 4%.	51m horizontal transitions either side of Griffith Park West Station limit where the placement of the vertical curve can be placed to change gradients. The ground level increases towards the DCU Station and requires the use of a maximum limiting gradient of 4% to achieve a -2 level station at DCU. However, the available placement of the required vertical curve at Griffith Park West, in addition to the clearance required for the Tolka River forces Griffith Park West Station to be a -3 level station. No low point within this section.	-1.223 to +30.080
7+996 to 8+128	Dublin City University (DCU) Station	-2 Level station, shallower station not allowed due to tunnelling constraints. Refer to drawings for depth to rail from surface.	+32.97
8+417	Low point	Provided with acceptable rail gradients.	+31.004
8+934 to 9+066	Ballymun Village Station	-2 Level station, shallower station not allowed due to tunnelling constraints. Refer to drawings for depth to rail from surface. Refer to drawings for depth to rail from surface.	+43.615
9+554	Low point	Moved to coincide with cross passage to avoid duplicate excavation and break out from tunnel. Provided with acceptable rail gradients.	+39.224
10+103	Northwood West Station	-1 Level station as unconstrained site with sufficient space to allow shallow tunnel. Refer to drawings for depth to rail from surface.	+44.086
10+458	Low point	Moved to coincide with cross passage to avoid duplicate excavation and break out from	+42.843

Approximate concept engineering design chainage	Alignment Element	Vertical Alignment Comments	Track Level mOD
		tunnel. Provided with acceptable rail gradients.	
10+550	M50	Pinch point for rail beneath M50 must be lower than +45.5mOD to provide clearance between tunnel crown and M50.	+43.459
10+910 to 11+021	Dardistown Station	-1 Level station as unconstrained site with sufficient space to allow shallow tunnel. Refer to drawings for depth to rail from surface.	+48.563
11+815	Intervention Shaft	Shaft connects into alignment with no influence on the level.	+40.866
12+025	Low Point	Moved to coincide with cross passage to avoid duplicate excavation and break out from tunnel. Provided with acceptable rail gradients.	+38.968
13+049 to 13+181	Dublin Airport	-3 Level station to reduce the footprint at surface. Refer to drawings for depth to rail from surface.	+48.369
13+655	Low point	Provided with acceptable rail gradients.	+43.828
14+050 to 14+129	North Portal	Emerge from ground to -13mbgl in as short a length as alignment gradient allows	+47.535 to +48.352
14+675 to 15+198	Cut and cover	Cut and cover section required to pass beneath R132.	Varies
15+313 to 15+427	Fosterstown Station	Slightly cut station due to constraint of alignment emerging from cut and cover.	+41.136
15+427 to 18+265	Elevated Structure (including 2 stations)	Elevated to give clearance from roads and roundabouts	varies

All vertical rail alignment is designed as per Section 3.

3 Rail Alignment

3.1 Design Principles

This section contains the parameters and criteria to be applied in designing the track alignment for New Metro North, developed from the *Track Alignment – Design Handbook (RPA-CTD.DMR-0002-01).*

The parameters in this section are generally expressed as permissible maxima or minima, within which the extremes of the track alignment shall be designed. The designers are further required to optimise the design, within the limiting parameters by producing the 'smoothest' alignment possible such that:

- Passenger comfort is maximised
- Run time is minimised, and
- Wear and tear of the infrastructure and rolling stock is minimised

This section does not consider the analysis and dimensional evaluation aspects concerning wheel/rail interface or noise and vibration.

Where the track alignment is contained within the highway, its design shall be fully coordinated with the highway, thus ensuring that the optimum solution is obtained. Arriving at these optimum solutions is an iterative process that requires continual interaction between the track alignment and highway design teams. In a number of situations, either the track alignment, or highway design will be compromised to achieve the optimum solution.

The horizontal alignment shall be for the centre-line of each track and relate to ITM co-ordinates. The rail levels shall be for the top of new rail and relate to Ordinance Survey datum. On conventionally canted track, the rail level shall refer to the low rail.

The design alignment ties into the preferred LUAS Green Line tie-in as designed in B-NMN-0000-ML-S4401-B02, provided by TII with the datum chainage of 1+000.000m taken at the tunnel portal.

The alignment between stops shall, wherever possible be designed for a maximum line speed of 70km/h. When the maximum line speed cannot be achieved, a permanent speed restriction equal to the nearest 5km/h unit below the maximum permissible speed shall be applied.

3.2 Track Alignment Criteria

The Track Alignment Criteria can be found in **Appendix A** The order of each parameter in the track alignment criteria has been set up in a similar order as the designer would take when designing the track alignment, e.g. starting with the horizontal alignment and progressing to the vertical alignment etc.

3.2.1 Track Alignment Criteria Format

The parameters for each element of the Track Alignment Criteria have been broken up into three clearly distinguished ranges: Desirable, Limiting & Exceptional. Below is a brief explanation of the three ranges:

- Desirable – where possible the design of the track alignment shall comply with this criterion.
- Limiting – the above Desirable criterion may be exceeded on a case by case basis, up to a maximum, provided there is a net benefit to New Metro North. However, careful consideration shall be given to any adverse effect that may be caused in exceeding the Desirable criterion.
- Exceptional – the Desirable and Limiting criterion may only be exceeded in exceptional cases, up to a maximum, when circumstances and conditions, e.g. geographical constraints, dictate that this design is unavoidable. This is provided that all risks associated with the effects of exceeding the Desirable and Limiting criterion are assessed and measures to mitigate against adverse effects are implemented, and the residual risks are acceptable. Under no circumstances shall the Exceptional criterion be exceeded.

3.2.2 Track Alignment Criteria Notes

Additional notes have been added in **Appendix A** to explain the rationale in determining the criteria values and to provide a comprehensive understanding of the decisions made.

3.2.3 References used in the Track Alignment Criteria

The Track Alignment Criteria for New Metro North have been derived from the following references:

- Track Alignment – Design Handbook (RPA-CTD.DMR-0002-01)
- HMRI Railway Safety and Principles and Guidance – Guidance on Tramways (RSPG Part 2 Section G)
- Irish Draft Guidelines for The Design Of Railway Infrastructure And Rolling Stock (RSC-G-008-B Section 7)
- Track Alignments – Tramway Clearances Design Criteria (RPA-CTD-DMR-0001-02 Rev D)
- Track Design Handbook for LRT (TCRP Report 57)
- Track – Performance, Design and Configuration (London Underground) (S1157-A7)
- Track Design Criteria File Note, issued to TII on 10/03/17, with responses received on 16/03/17 (252252-ARP-RL-SW-FN-RT-0001)

3.3 Developed Kinematic Envelope

A Developed Kinematic Envelope (DKE), which is defined as the space swept out by a vehicle in motion, has been established by TII for the trains expected to use the New Metro North system.

The clearances from the DKE to the surrounding infrastructure are designed to be compliant with those outlined in the *Office of Rail Regulation (ORR) Railway Safety Publication (RSP2), Guidance on Tramways and RSP Section A* where applicable.

The vehicle used for the concept engineering design is 2.65m wide and 3.4m high. To ascertain a worst case DKE TII have created an overlay of the tram on minimum radii, please refer to **Appendix B** for a sketch showing the tram on both straight and curved track. The overlay provided the following results:

Table 3: DKE vs Horizontal Curves Worst-case DKEs

Curve Radius (m)	External DKE (m)	Internal DKE (m)
200	1.678	1.622
300	1.648	1.613
500	1.588	1.592
550	1.583	1.592
1000	1.548	1.598
Straight	1.510	1.510

3.4 Permanent Way Calculations

Permanent way calculations, i.e. the calculations based on the centreline geometry of the alignment based on the criteria as outlined in **Appendix A**, for the northbound track (the left-hand track observed with back to low chainage) have been added in **Appendix C** detailing the proposed radii and element/transition lengths.

3.5 Journey Time Calculations

Journey time calculations have been added in **Appendix D** to explain the rationale in determining the values. The key criteria assumed to ascertain the journey time values are outlined as follows:

- Station dwell time of 30s
- Single point target stop approach, rather than reduced speeds through platforms
- Acceleration and deceleration values of 1.18m/s^2 (12% of g), in light of a confirmed vehicle rolling stock
- Effect of vertical gradients is included by considering the effect of gravity based on the gradients where acceleration and deceleration take place.

3.6 Special Trackwork

Provision has been made for special trackworks along the route, that is to say turnbacks and emergency crossovers have been provided where necessary and practical. A line schematic of the route showing the locations of the special trackwork are shown in **Appendix I**, subject to an operational model at the next design stage.

3.7 Exclusions

This report details the concept track alignment only. The following elements have currently been excluded:

- Signalling requirements
- Overhead Catenary System (OCS)
- Operational requirements

4 Passenger Demand

4.1 Introduction

This section looks at the Metro train capacities required to cater for the anticipated peak Metro loadings. Different train configuration lengths and types are considered and a range of possible rolling stock configurations have been outlined.

4.2 Train Capacity Analysis

4.2.1 Peak Passenger Demand

Based on preliminary transport capacity analysis, it has been determined that the system should cater for a maximum line flow up to 20,000 passengers per direction per hour.

4.2.2 Train Capacity

AW (added weight) loading refers to the weight added to a vehicle to simulate passenger load. The following references are used in reference to train loading and capacity:

- AW-0 simulates an empty car
- AW-1 simulates a load with seated passengers only
- AW-2 simulates a load with some seated and some standing passengers
- AW-3 simulates a train with a crush load (the maximum number of passengers that can possibly be riding in the railcar, standing and sitting).

An assessment has been undertaken to establish the train capacity for each train length with the scenarios AW-2 and AW-3 for various headways i.e. time interval between trains.

4.2.2.1 Low floor Rolling Stock

For typical low floor rolling stock (e.g. LUAS tram, Siemens Avenio) the train capacity measured in number of passengers (i.e. pax) is assumed as follows:

AW2 = 4pax/m^2 standing
AW3 = 6pax/m^2 standing
Width = 2.45

Table 4: Low floor - Seat capacity per train size

Train length (m)	Min seats	Max seats
45	50	100
60	66	133
90	100	200

Note different loading conditions arise depending on whether the maximum or minimum number of seats is utilised with the added weight loading.

This capacity is based on the requirements of "*vehicles to be 2.4m or 2.65m wide, single saloon, articulated, bi-directional light rail vehicles, of a minimum length of 60m, and capable of being extended to up to at least 90m in length*". These requirements are set at the outset by the client based on expected patronage per the GDA Strategy.

Table 5: Low floor train capacity

Train length	Train capacity (AW2 + max seats)	Train capacity (AW3 + max seats)	Train capacity (AW3 + min seats)
m	A	B	C
45	284	386	477
60	378	514	636
90	568	772	954

Based on these train capacities the lineflow capacity, which is the total number of passengers per hour per direction, for different train lengths and headways is outlined below.

Table 6: Low floor lineflow capacity

Train Length	20tph			27tph			34tph			40tph		
Loading Condition	A	B	C	A	B	C	A	B	C	A	B	C
45	5680	7720	9540	7668	10422	12879	9656	13124	16218	11360	15440	19080
60	7560	10280	12720	10206	13878	17172	12852	17476	21624	15120	20560	25440
90	11360	15440	19080	15336	20844	25758	19312	26248	32436	22720	30880	3816

4.2.2.2 High Floor Light Metro Rolling Stock

For typical high floor, light Metro rolling stock (e.g. Ansaldo Driverless Metro) the train capacity is assumed as follows:

AW2 = 4pax/m^2 standing
AW3 = 6pax/m^2 standing
Width = 2.65m

Table 7: High floor - Seat capacity per train size

Train length (m)	Min seats	Max seats
45	40	80
60	53	106
90	80	160

Note different loading conditions arise depending on whether the maximum or minimum number of seats is utilised with the added weight loading.

Table 8: High floor train capacity

Train length	Train capacity (AW2 + max seats)	Train capacity (AW3 + max seats)	Train capacity (AW3 + min seats)
	A	B	C
45	330	440	500
60	440	587	667
90	660	880	1000

Based on these train capacities the lineflow capacity, i.e. total passenger numbers per hour per direction, for different train lengths and headways is as follows:

Table 9: High floor lineflow capacity

Train length	20tph			27tph			34tph			40tph		
Loading Condition	A	B	C	A	B	C	A	B	C	A	B	C
45	6600	8800	10000	8910	11880	13500	11220	14960	17000	13200	17600	20000
60	8800	11733	13333	11880	15840	18000	14960	19947	22667	17600	23467	26667
90	13200	17600	20000	17820	23760	27000	22440	29920	34000	26400	35200	40000

4.2.3 Demand vs Capacity

In order to accommodate a maximum lineflow of up to 20,000pph, there are a number of options available. For example, at a loading condition of 5pax/m^2 standing, a 90m low floor vehicle with a frequency of 30tph or a 90m high floor vehicle with a frequency of 27tph would be required. Residual capacity is available by either reconfiguring the trains to reduce the number of seats and increase standing room, or by increasing the frequency of the service.

5 Fire and Tunnel Ventilation Strategy

5.1 Codes and Standards

The concept engineering design fire and tunnel ventilation strategy for NMN has been developed in accordance with the following Codes and Standards:

- NFPA 130 – Standard for Fixed Guideway Transit and Passenger Rail Systems (2010)
- TSI – SRT (technical specification for interoperability relating to ‘safety in railway tunnels’ of the rail system of the European Union)
- UIC 779-9 (Safety in Railway Tunnels)
- RSC-G-032 (including Appendices 1-4) - Guideline for the Process of Authorisation for Placing in Service (APS) of Light Railway Subsystems
- RSC-G-033-B (including Appendix 1) - Guideline Providing List of Parameters and Requirements for Authorisation for Placing in Service (APIS) Light Rail Infrastructure, Energy and Command-Control Subsystems

5.2 Train Fire within a Tunnel

In general, in the event of a fire or other emergency incident on a train, the preferred strategy is for the incident train to continue along its route to the nearest station or portal for ease of evacuation and emergency response. Where this is not possible, and the train stops in the tunnel, fire and life safety provisions including intervention points and ventilation are required to maintain tenable conditions for an evacuation and enable an appropriate emergency response.

Fire and life safety considerations are addressed in this section focusing on the overall performance requirements of tunnel systems. Fire and life safety requirements relating to the station boxes are addressed under section 6.6.

The requirements for fire safety within the tunnels are:

1. To provide tenable conditions for evacuation and intervention
2. To allow passengers and train staff to access ground level or a place of relative safety from which access to ground level is not time-limited
3. To provide the emergency services with access from ground level to an incident

It is important to note that Points 1 and 2 are not exactly the same. A place of relative safety can be provided below ground, for example the non-incident bore accessed by cross-passages in a twin bore arrangement. However, cross-passages alone do not provide timely access for intervention. Refer to Section 7.1 for discussion on the tunnel configuration.

5.3 Intervention Points

In the event of an incident occurring within the tunnel requiring detrainment of passengers in the tunnel and emergency services access to the incident, intervention points provide facilities for evacuation and intervention.

An intervention point is a location from where emergency services can access the incident tunnel when required.

Intervention points may also allow train passengers and staff to escape from the incident tunnel to reach a place of safety. Intervention points can be in the form of:

- A station platform
- A tunnel portal
- An intervention shaft (extending up to the open air)
- In a twin bore arrangement each bore provides a place of relative safety for the other, accessed by cross-passages.

The provision of these intervention points and cross-passages is inter-related in so much as the distance between station and tunnel portals governs the requirement for intervention shafts and similarly the provision of cross passages may impact on the spacing between other types of intervention points.

Specifically, cross passages can be used as egress and access points between tunnel bores enabling regular egress from the incident tunnel to the non-incident tunnel.

Where intervention shafts are required, these typically comprise an egress/access stair and a passenger lift suitable for evacuation of mobility impaired persons as well as for firefighting access. Intervention shafts are fire separated from the tunnel with level access from the tunnel walkway.

The provision of these different types of intervention points is addressed further in the following sections in the context of means of escape and emergency services access for the recommended twin bore tunnel arrangements.

5.4 Means of Escape

In the event of a fire incident on a stopped train within a twin bore tunnel it is assumed:

- All trains ahead of the incident train and all trains in the non-incident bore will continue clear of the tunnel section
- No trains will be permitted to enter the tunnel section in either the incident or non-incident bore
- Any trains behind the incident train will also be stopped in the tunnel. Non-incident trains may be manoeuvred from the incident section.

On this basis, fire and life safety provision need to be provided for the incident train and any trains stopped in the tunnel behind.

This will typically entail longitudinal ventilation within the incident bore in the direction of travel of the incident train. This prevents smoke flow in the direction of any non-incident trains stopped behind the incident train and allows all occupants in the tunnel to evacuate safely upstream of the fire incident to an intervention point, station or portal.

In addition, the twin bore tunnel arrangement will incorporate cross passages between the two bores enabling occupants to evacuate from the incident bore to the non-incident bore.

Where cross passages are provided, the maximum spacing between these cross-passages is to be further developed subject to approval from the authorities having jurisdiction. For concept engineering design, the cross passage spacing has been taken as 244m in accordance with NFPA 130. It should be noted that European Standard SRT-TSI 4.2.1.5.2 does permit a cross passage spacing of up to 500m, but this would be subject to approval from the Dublin Fire Department, and previous discussions with them on other projects have indicated a strong resistance to increase the spacing beyond the maximum allowed under NFPA130.

Once occupants are within the non-incident bore, NFPA 130 does not place any additional restriction on the distance to intervention points. The TSI, meanwhile, has no requirements for additional intervention points for tunnel lengths of less than 5km (i.e. TSI maximum distance between intervention points is 5km). In both instances (NFPA and the TSI) it is assumed that once within the non-incident bore further egress is not time-limited and passengers are able to safely walk to the nearest station or tunnel portal.

5.5 Firefighting and Rescue

For emergency services access to an incident the fire service will typically enter the tunnel via the non-incident bore and access the incident bore at the closest upstream cross-passage.

To assist the emergency services in tackling an incident, intervention points are typically required at a more regular spacing than would be required for means of escape. Intervention shaft spacing of up 1.5km is common practice for fire service access with spacing in excess of 2km having been implemented recently in, for example, Crossrail and LU Northern Line.

Within the concept engineering design, intervention points are primarily designated as the tunnel portals and the stations as they are generally approximately 1km apart. The exception to this is that an intervention shaft is proposed between the Dardistown station and the Airport station. Agreement between all relevant stakeholders is required to confirm the provisions for intervention points and the specific requirements for intervention shafts in addition to tunnel portal and station access points.

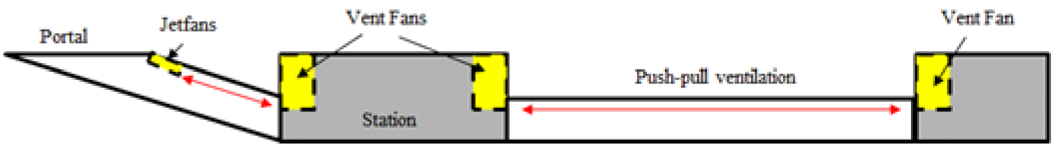
5.6 Tunnel Ventilation Principles

For concept engineering design, the assumed design fire load of the trains has been taken to be in the range of 15-18MW.

The exact fire load will be determined during detailed design once the selection of the rolling stock to be used is finalised. A push-pull ventilation system for smoke extraction is the preferred approach, with fans provided at both ends of each station. Natural ventilation may be used during the early stages of a fire to allow escape in both directions.

The current design is such that the ventilation system will force air at a sufficient velocity (critical velocity) to prevent smoke spreading upstream of the train and hence allowing for safe egress in the upstream direction. Due consideration will be taken to ensure that smoke does not pass the extraction vents downstream so stations and tunnels downstream will not be affected.

Figure 2: Schematic tunnel ventilation



5.7 Alternative Ventilation Approach with Single Tunnel Ventilation System (TVS) per Station

In the concept engineering design of stations ventilation fans have been provided at both ends of the station as part of the Tunnel Ventilation System (TVS). The option remains of reducing this to one set of fans per station. This option would slightly reduce the length of the station, as follows:

- 3 level – 10m reduction (117m to approximately 110m)
- 2 level – 10m reduction (132m to approximately 120m)

The number of shafts at ground level would also reduce from 4 to 3, as it is assumed that draft relief is still needed at the non-TVS plant end.

However, this would also result in the following impacts:

- Platform Screen Doors (PSDs) i.e. doors which screen the platform from the train have to be fire rated
- Larger Fans/Shafts may be required at the single end
- More complex control systems for TVS (fans have to perform more functions, multiple dampers etc.) operations
- Less redundancy/more complicated for System Safety Case and Reliability, Availability, Maintainability and Safety (RAMS) demonstration
- More complex and constrained train operations in a fire scenario (trains have to reverse on main line). This is possible for systems with Automatic Train

Operation (ATO) e.g. Copenhagen but may not be possible with Manual Operation with a single driver in the front cab.

- Alternatively, additional intermediate vent shafts may be required to meet the requirements of the 'one train per vent section' rule.

Therefore, at concept engineering design stage it is considered conservative to assume that fans should be included at both ends of the stations.

6 Stations

This section presents the background and design of the stations. It covers the planning and design principles behind the station development and presents the different station typologies proposed for the concept engineering design.

6.1 Planning Approach and Principles

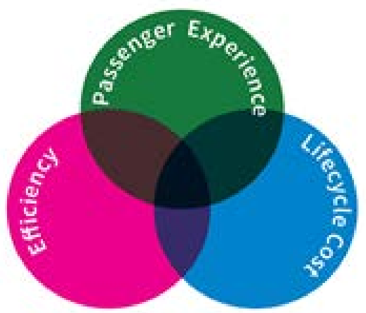
This Section outlines the principles adopted when performing concept design of the stations in terms of general design requirements, urban integration, passenger journey, system requirements and future proofing.

6.1.1 Design Principles

The aim at the project outset has been to develop an overarching design approach that brings novel design vision for the passenger and the city. This is described through a set of principles that ensure a seamless and intuitive system well integrated into the city fabric and generates a strong and coherent system identity throughout the length of the project. Additionally, these principles will safeguard delivery of a vision that meets the mobility requirement in a seamless, intuitive and a resilient manner.

The design approach described in the following sections abide to the three founding principles:

Figure 3: Design Approach Founding Principles

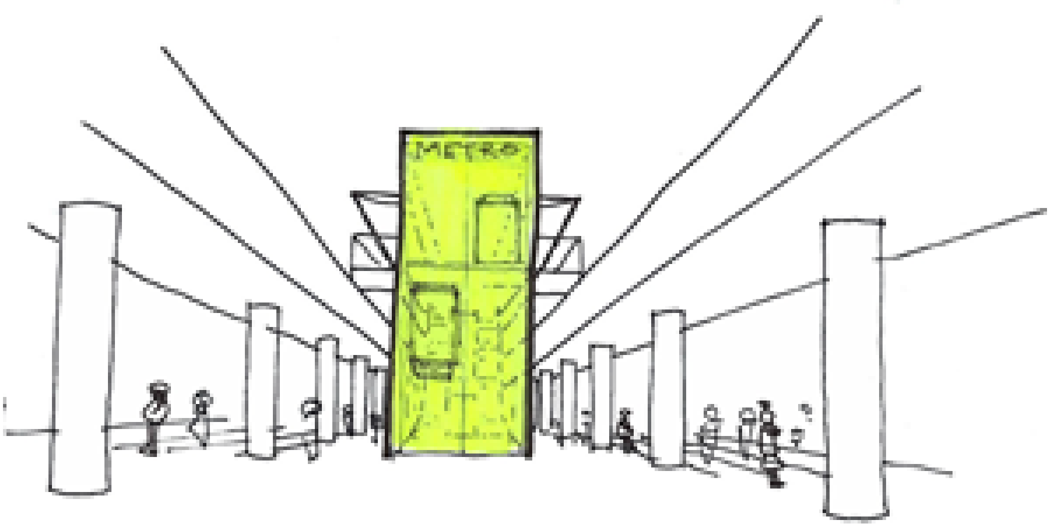


- **Passenger Experience:** The design should be passenger centric. This principle allows the development of a product that puts the passenger first – creating an uncompromised system that is intuitive, safe and pleasant for the end user.
- **Efficiency:** The system should be designed around the idea of efficiency, both from operational and user perspective. The fundamental function of a metro in the city is to mobilise the urban population in the most efficient and seamless manner.
- **Lifecycle Cost:** The system should be designed to optimise total lifecycle cost where both, the initial investment and the long-term costs are considered.

At a system level, the stations will have a common architectural language that ensures a strong and coherent system identity. All the station typologies, regardless of the station depth, will have a common scheme for vertical circulation and a front-of-house configuration which aims to familiarise the travelling passenger to the sequence of spaces to expect in all stations to provide ease of navigation and way finding. All platforms will have a standard design, with variations only in surface treatment.

This approach will allow the stations to become a coherent family of parts with well-choreographed passenger environment.

Figure 4: Common architectural language – vertical circulation



6.1.2 Urban integration & Place making

Figure 5: Copenhagen Metro in historic centre

A station in an urban location transforms its surroundings dramatically. The approach to design for the New Metro North line is urban integration focused. Careful incorporation of the stations into urban districts can act as a catalyst for economic growth, social mobility, regeneration and place-making. Various aspects including station location, public realm, over-site-development (OSD) potential and its impacts on existing urban infrastructure such as roads and services need to be carefully evaluated.

A station also creates a space around it; for meeting, gathering, waiting, and embarking on journeys. Stations are often also urban land-marks and points of references. Their visual identity and the potential for transforming the public realm requires that its urban context is understood and analysed thoroughly.

The New Metro North system will span across diverse districts of a city with distinctive urban characters. The attention to the local context creates an opportunity also to develop a unique identity for each station whilst enabling relationship between the urban context, station and the metro line.

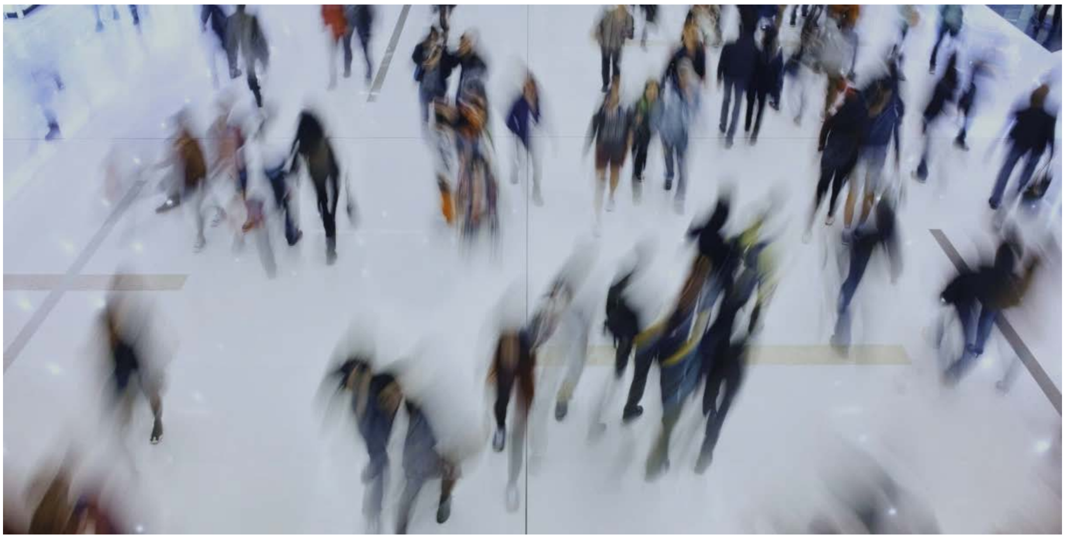
The opportunity for the New Metro North to become a development catalyst has been a key parameter in identifying the various station locations along the line Opportunities for each station to create public realm would be developed further for individual stations during the successive stages.

The following three scenarios demonstrate how the opportunity to transform the urban realm through station integration can be achieved.

- Entrances and the stations integrated with the existing traffic network.
- The station as a catalyst for enhancing heritage.
- The station as a threshold to green spaces.

6.1.3 Passenger journey

Figure 6: Passenger flow through station platform

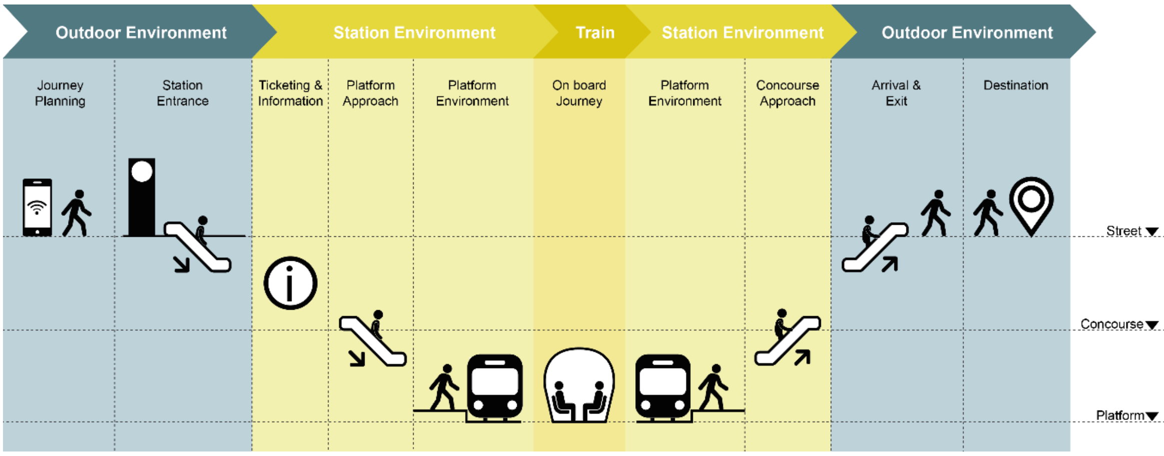


The concept of a trust-system-metro was explored where the use of gate lines is excluded in favour for a direct journey from street to the platforms. A gate line presents a physical barrier to control access to trains at concourse level to those with valid tickets only, which would add to the time required to access trains. The trust-system-metro relies on people having valid tickets before boarding the trains without the use of a physical barrier.

While minimising space-take at concourse level for any transfers and revenue protection, such a trust-system also benefits from smoother passenger journeys without queuing or crowding. Following Copenhagen Metro as a precedent, all NMN non-interchange stations are designed around this vision; with a single entrance at street level and a minimal lower level concourse serving only the most essential passenger facilities such as ticketing and information points. Tara Street station and Whitworth station present a unique entrance configuration due to interchanging with Irish Rail. Adopting such a system reduces the number of vertical transport elements required to service the station including escalators and lifts, where passengers could transit from street to the platforms with minimal changes.

Figure 7 below shows the system integration from origin (when the passenger decides to take public transport) to the destination in a schematic way and explains the simplicity of the system which makes the journey as linear as possible.

Figure 7: System interaction from origin to destination



6.1.4 The System

Line wide identity and common architectural language are identified as key aspects of the New Metro North design approach. Line identity and station localisation will be used to reflect the character of the station's immediate context above ground. Such identity will be developed using the idea of Continuity and Variation.

Skylights, entrance canopies and technical pop-ups at surface level are the elements that provide the identity to the system and standardise the design of the public realm. However, it is also assumed that while standardisation allows for a system to be perceived as a singular entity, variation within such a system is equally important with each station capable of responding to its local context within the city and attaining a distinctive character and identity. Such variation within the system can be achieved by using context specific landscape and material treatment while keeping the same module as in other stations.

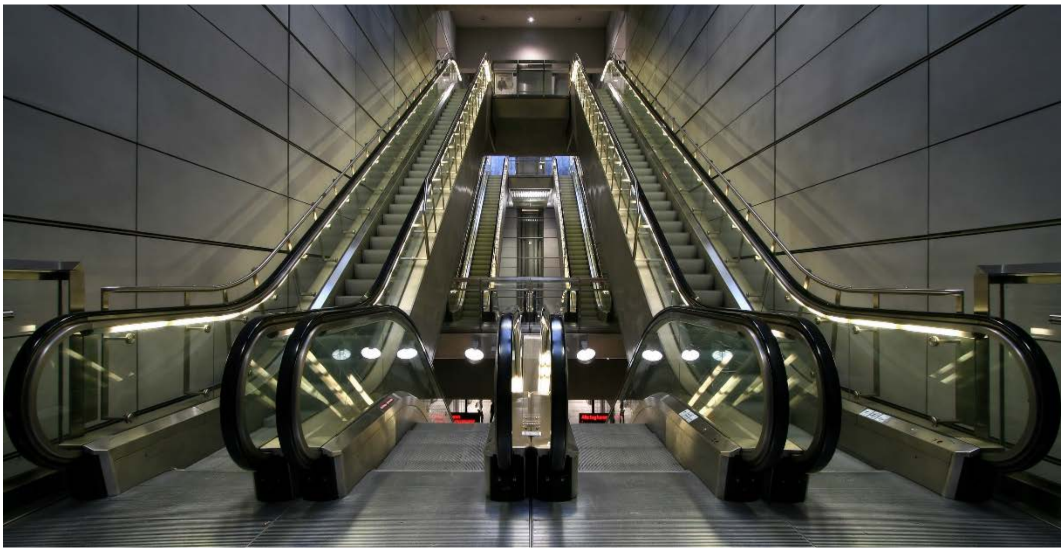
Underground elements within each station also adhere to the principle of continuity and variation where all concourse and platform elements can be consistent in terms of the module used (e.g. walls, floors & ceilings modules). Station furniture, signage, systems & equipment can remain consistent throughout the system.

Variation can be achieved within the underground environment by varying the material treatment and colour (e.g. walls, floors & ceilings finishes). Such variation may take into account the local context above ground and help create distinctive identity for each station, which in turn becomes a land marking device informing the passenger where they are within the overall route without relying on station signage.

Use of skylights has been identified as a special system feature that will be used where possible at each station.

6.1.5 Functional & Efficient

Figure 8: Functional & efficient

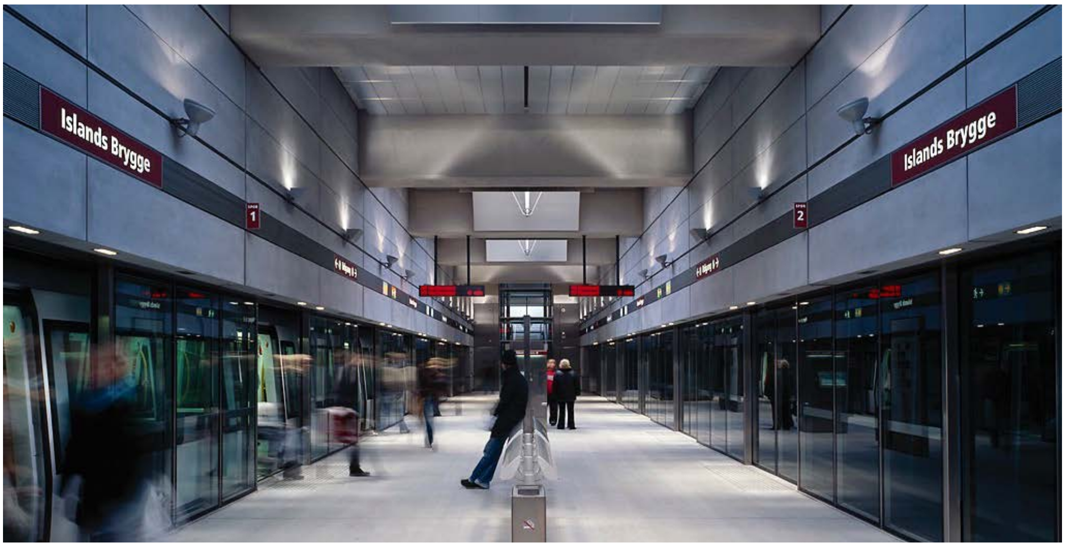


The primary function of a station is its efficiency, in how quickly and in a straight forward manner it can deliver its passenger to their destination. Efficiency is therefore identified as one of the founding principles for the design of the New Metro North stations. Clear, intuitive and shortest journey for the passenger, optimal configuration of visually connected station spaces, their sizes and sequence, consideration for design to respond to an incident or emergency, are some of the areas that have been looked at with sufficient care during the design process. Minimising the number of decision points, unnecessary articulation of spaces and their configuration is paramount in delivering a successful metro system.

It is also envisaged that there will be minimal, if any, passenger facing permanent staff in the stations, and that New Metro North will work on the very latest digital infrastructure available for station and system operation to service and run a metro system that is truly looking to the future.

6.1.6 Simplicity

Figure 9: Example showing efficient use of simplicity in material pallet



Stations should be simple, with a focus on mobilising the passenger in an uncomplicated and pleasant manner. Spatial and visual clarity is hence key to efficient station function. Hence de-cluttering and actively omitting over-design is maintained from both, clarity perspective and from a value engineering view point. Emphasis is placed on an uncomplicated and mute design that sits in harmony with its urban surroundings while developing station architecture.

6.1.7 A kit of parts

Figure 10: A kit of parts

Standardisation normally helps to do two things; one, it allows for a common language to develop, and two, it reduces the variation in station elements, within a single station or between stations along the line of route, and thereby reducing cost and easing the documentation, tendering, procurement, and installation process.

Following this principle, all stations are developed as a kit of parts wherever possible. This applies to large station components and their organisation and ensures the recognisability of the system.

The kit of parts on the stations, primarily are passenger areas, or front of house (FOH), and areas not for passengers defined as Back of House (BOH) areas. BOH includes zones for plant, equipment, functioning of the stations, emergency evacuation, etc. Passenger areas include entrances, vertical circulation elements, skylights, open concourses and platforms. Other architecturally significant elements such as fit out modules, furniture and fixtures are also included. Whereas back of house elements include all non-technical accommodation and plant areas as well as staffed BOH. There is a significant difference between the underground station types and the at grade or elevated stations, but this is mainly in relation to BOH areas, as consistency in FOH elements should be achieved.

Skylights are identified as intrinsic station elements and would be included where possible. In order for the architecture of the station to be a safe, positive and uplifting environment, the use of daylight in stations has been identified as an important architectural device. Use of daylight not only re-establishes the connection with surface level, enhances the quality of space and sense of wellbeing in underground environments, but also acts as an intuitive way finding tool and gives one a sense of time. Additionally, provision of skylights helps reduce energy consumption and allows natural smoke extraction in the event of fire. The use of daylight in the underground stations has hence become a much-appreciated feature in modern stations.

Skylights, entrance canopies and technical pop-ups at surface level are the elements that provide the identity to the system and standardise the design of the public realm.

Figure 11: Skylights in station environment

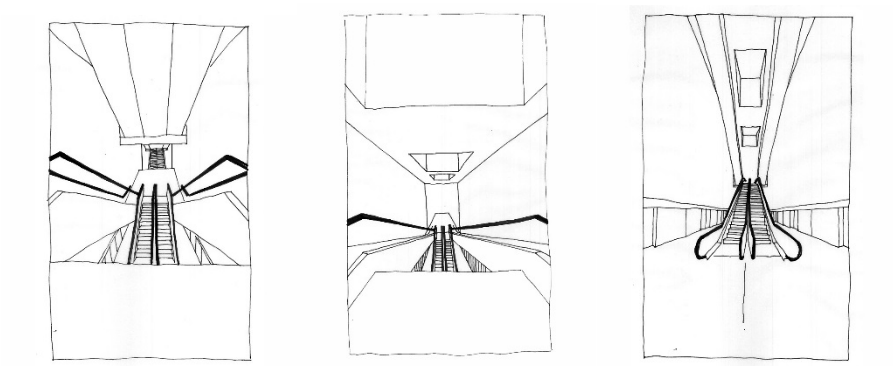


Figure 12: Daylight in in spatial volume at Timanfaya. Eduardo Chillida

Additionally, over ground elements might need to vary inevitably based on their local conditions and context. However, the intent would be to modularise variety of over ground elements and their overall look and feel.

6.1.8 Future-proof & Resilient

Investment in railway infrastructure for the city is long-term and permanent and affects the way a city develops and functions over a long period of time. It is therefore essential for railway to take into account the way cities transform over time and increase demand loads on this vital urban infrastructure. A number of these factors vary from socio-political to economic and cultural transformations, as well as rapid development in digital technologies.

The stations for New Metro North are designed with resilience in mind, where a platform length increase from 60m to 90m is accommodated within the concept engineering design. All station elements including platforms, vertical transport, passenger areas, technical accommodation and plant sizing is space-proofed to accommodate additional demand on the system over time. The station boxes are planned as a 90m long island platform with a typical width of 10m with the exception of interchange stations.

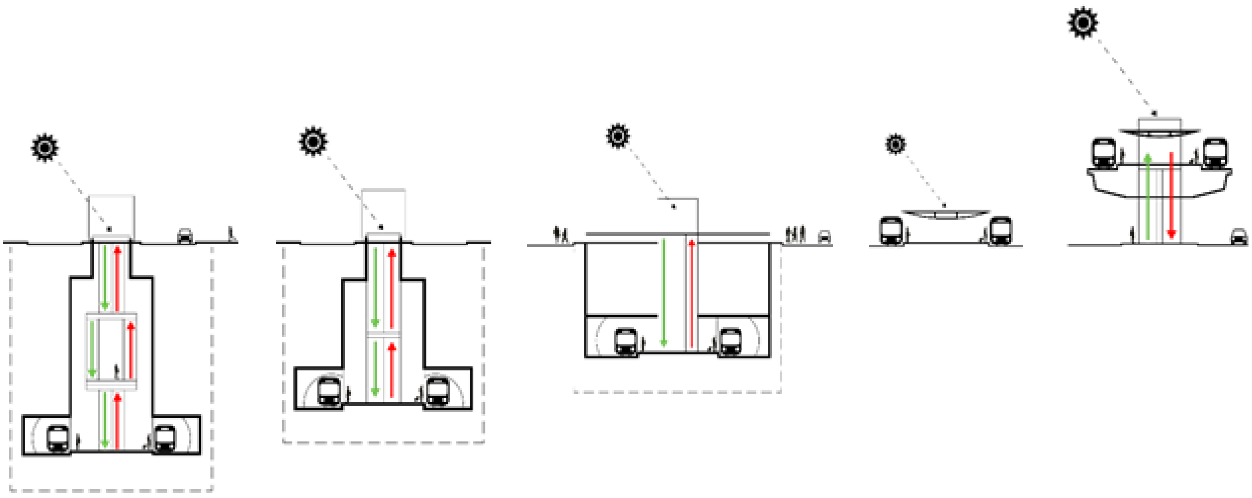
At operational level, it is assumed that New Metro North will capitalise on the latest developments in digital infrastructure for operation control, signalling, ticketing and revenue protection and communication systems.

Figure 13: Illustration showing fare collection system transformation over time

6.2 Station Typologies

6.2.1 General

Figure 14: Station Typologies



The approach taken at the concept engineering design stage is to develop stations as typology driven standard entities. This approach aims to identify a set of station types that can be applied to multiple stations along the route alignment. Such an approach maximises standardisation of whole stations or their component parts.

New Metro North preferred route alignment results in 5 major types of stations based on the platform depths along the route. These are -3 level stations, -2 level stations, -1 level stations, at grade and elevated stations as illustrated above. Additionally, there are two interchange stations at Tara Street and Whitworth.

6.2.2 Typologies

These station types are distributed along the line of route in the order presented in Table 10 below. The table also contains main box dimensions per station, without taking into account the alignment. It only shows the concrete box dimensions per each location. In particular, and in avoidance of doubt, “Box height” is the height of the concrete box, without considering the amount of soil on top of the box top slab. The amount of soil on top of the box top slab varies in accordance with the alignment. Table 10 below shows the depth of each station, in terms of depth to top of rail. For a better understanding of station dimensions and layout refer to Volume 2 drawings that shows the typical box arrangement.

Table 10: Station types per location

Station	**Station type**	**Box length (m)**	**Box width[1] (m)**	**Box height[2] (m)**	**Av. Depth to track (m)**
St. Stephen’s Green East	-2 levels	132	26.0	20.7	23.9
Tara Street	-3.5 levels	105 each side	27.5	29.2	24.8
O’Connell Street	-3 levels	117	26.0	25.9	24.0
Mater Hospital	-3 levels	117	24.5	25.9	25.0
Whitworth	-3 levels	129	27.5	30.0	23.9
Griffith Park West	-3 levels	117	24.5	25.9	24.0
Dublin City University (DCU)	-2 levels	132	24.5	20.7	18.3
Ballymun Village	-2 levels	132	24.5	20.7	18.0
Northwood West	-1 level	111	24.5	15.0	13.9
Dardistown	-1 level	111	24.5	15.0	19.0
Dublin Airport	-2 levels	132	26.0	20.7	18.9
Fosterstown	At grade	c.a. 112	18.0	N/A	N/A
Swords Central	Elevated	120	17m (width of viaduct at station location)	13.5m above ground, 6.5m concourse depth	N/A
Seatown	Elevated	120	17m (width of viaduct at station location)	13.5m above ground, 6.5m concourse depth	N/A
Estuary Park & Ride	At grade	c.a. 112	18.0	N/A	N/A

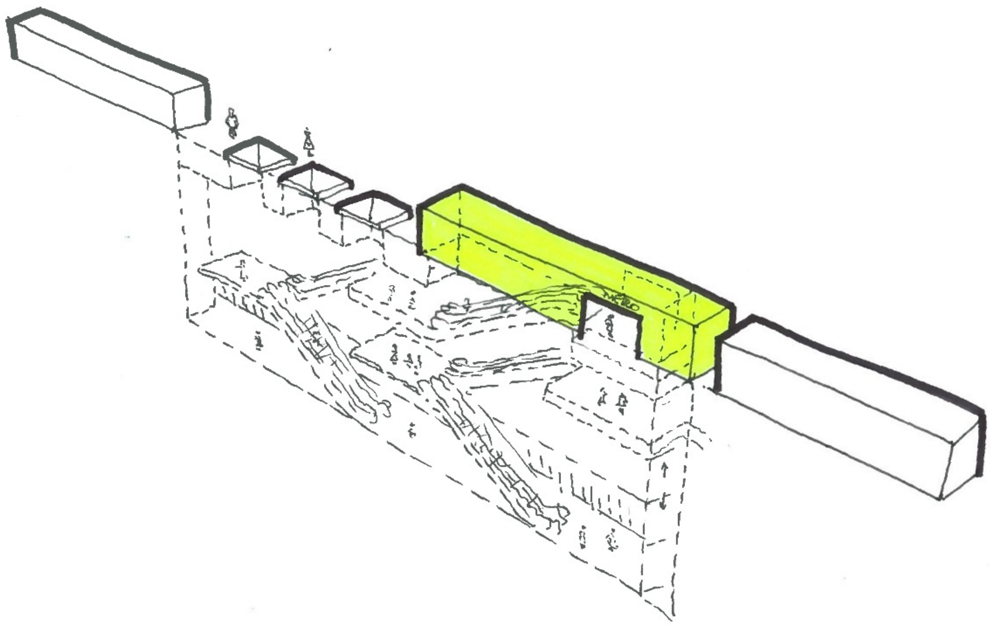
Notes

1. Box width = external width

2. Box height = top of roof slab to underside of base slab

6.2.2.1 -3 Level stations

Figure 15: -3 Level Station



The -3 level stations as shown above are the deepest of the NMN stations types. The island platforms are organised at 23.5m below ground. These stations are arranged over 3 levels within the cut & cover box. Passengers enter at surface level in the area shown shaded yellow. A set of two escalators and stairs deliver the passengers to concourse level, which contains two banks of two-escalators going down to platform level. The passenger areas are organised within a single volume with skylights. For emergency evacuation, stairs at either end of the station alongside two fire-lifts are provided. These stations have the tunnel-ventilation fans arranged in vertical configuration with Draft-Relief (DR) and Tunnel-Ventilation (TV) shafts organised at each end of the station. At surface level, these structures will be designed to minimise visual blight and relative space-take. Back of House for this typology is distributed over two levels across the station box.

Station entrances are envisioned to be light weight visually non-intrusive structures, with access to the entrance via a pedestrian crossing in cases where the station is located in the median. Station entrance box, skylights and the single circulation volume are key architectural features for this typology.

This station typology applies in the following locations:

- O’Connell Street
- Mater Hospital
- Whitworth
- Griffith Park West

6.2.2.2 -2 Level stations

Figure 16: -2 Level Stations

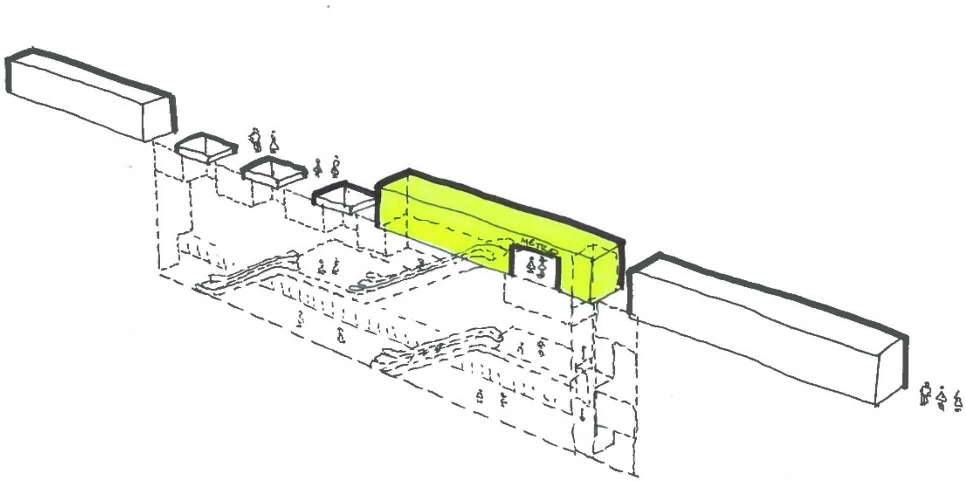
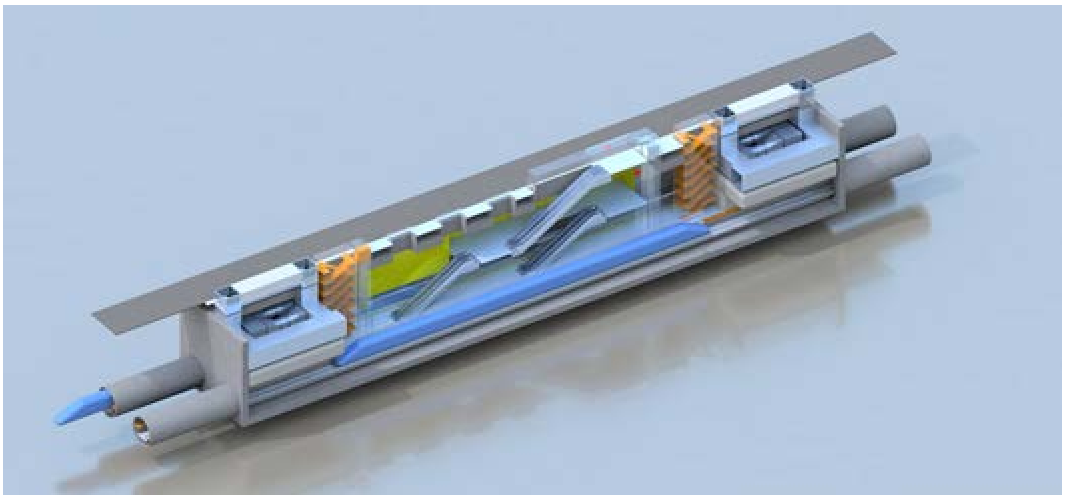


Figure 17: Deep underground station axonometric



The -2 level stations as shown above are the semi-deep type of the NMN stations. The island platform is organised at 18.25m below ground. These stations are arranged over 2 levels, with access again at surface level shown shaded yellow. Identical to the -3 Level stations, a set of two escalators and stairs deliver the passengers to concourse level which contains two banks of two escalators going down to platform with passenger areas within a single volume with skylights. The -2 level stations in this sense form a synchronised family with the deep stations. For emergency evacuation, stairs at either end of the station alongside two fire-lifts are provided. These stations have the tunnel-ventilation fans arranged in horizontal configuration with Draft-Relief (DR) and Tunnel-Ventilation (TV) shafts organised at each end of the station. Use of a horizontal fan arrangement makes this station longer than -3 level stations.

Following a consistent passenger environment for the ease of way finding, and system identity, these stations also feature the same entrance structure at surface level that minimises visual blight and relative space-take as -3 level station. Back of House for this typology is distributed over two levels across the station box.

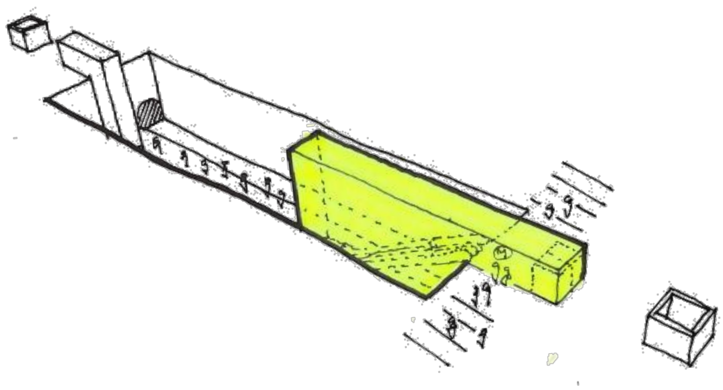
Identical to -3 level stations, entrances to these stations are envisioned to be light weight visually non-intrusive structures again with pedestrian crossings provided if located within the median.

This station typology applies in the following locations:

- St. Stephen's Green East
- Dublin City University (DCU)
- Ballymun Village
- Dublin Airport

6.2.2.3 -1 Level stations

Figure 18: -1 Level Stations



The -1-level station as shown above are the shallowest of the below ground stations types. The island platforms are organised at 12m below ground. These stations are organised within an open-cut box below ground. Identical to the -3 Level stations, a set of two escalators and stairs delivers the passengers directly to platforms. The light-weight glass structure shelters the passengers as well as TV elements, whereas the platform is provided with a lightweight canopy along its full length. For emergency evacuation, stairs at either end of the station are provided. These stations feature a set of two tunnel-ventilation fans arranged in horizontal configuration with Tunnel-Ventilation (TV) shafts organised at each end of the station without the Draft Relief (DR).

Following the system wide identity, these stations also feature the same entrance structure arrangement at surface level that minimises visual blight and relative space-take.

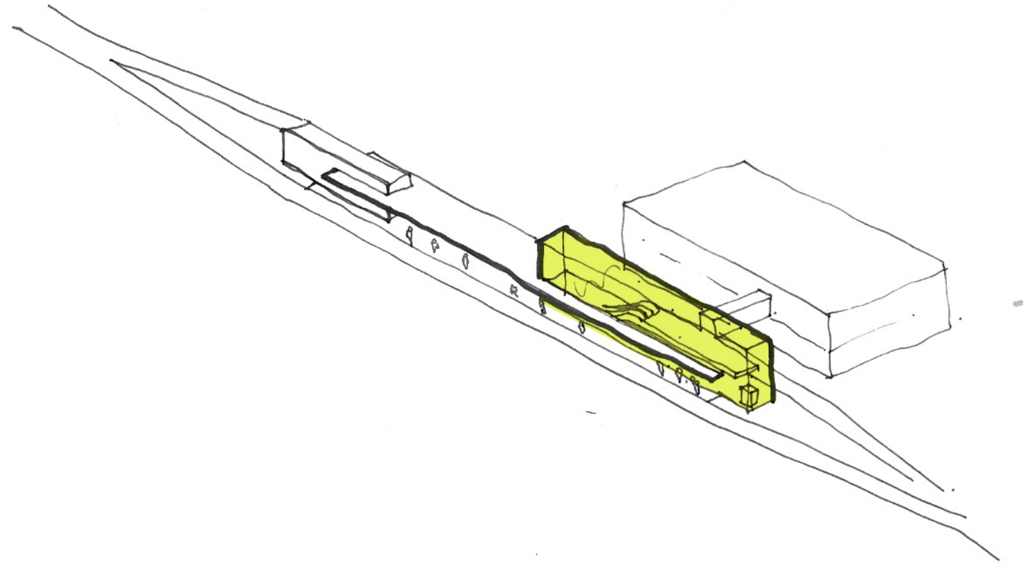
Back of House for this typology is organised at platform level below ground. Entrances to these stations are envisioned to be light weight visually non-intrusive structures.

This station typology applies in the following locations:

- Northwood West
- Dardistown

6.2.2.4 At grade stations

Figure 19: At Grade Stations



The island platform for this typology is organised at grade. Following consistent station language, these stations also feature light weight identical canopies along the full length of the platform. Fire escape for these stations is organised at grade. Back of House (BOH) for this typology is smaller than the one of all other station types and its provision is located at grade between the trackways.

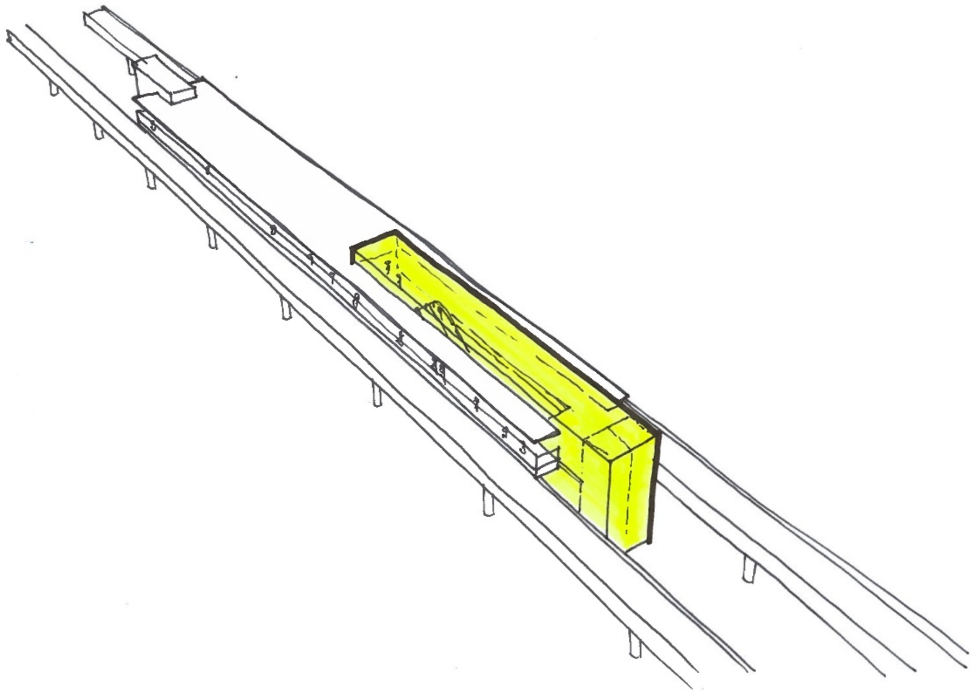
Access to these stations is organised via an over-bridge serviced by a set of escalators, stairs and a pair of lifts. Identical to other station typologies, entrances to these stations are envisioned to be light weight visually non-intrusive structures.

This station typology applies in the following locations:

- Fosterstown
- Estuary Park & Ride

6.2.2.5 Elevated stations

Figure 20: Elevated Stations



The stations for this typology are organised on an elevated viaduct that carries the tracks. The island platform for this typology is organised at 8.5m above surface level. Access to these stations is arranged via a set of escalators, stairs and a pair of lifts via an underground concourse. Following the system-identity and the ease of way finding, these stations also feature light weight canopies along the full length of the platform. Fire escape for these stations is through a set of stairs at the end of the station. Back of House (BOH) for this typology is organised over two levels at the end of the station.

Identical to other station typologies, entrances to these stations are envisioned to be light weight visually non-intrusive structures.

This station typology applies in the following locations:

- Swords Central
- Seatown

6.3 Functional requirements

6.3.1 Entrances

One single entrance is proposed to the underground stations with a shared area for lifts and escalators, so there is one single point of access. With the at grade and elevated stations, access will be provided via an over-bridge or underground concourse to a central point of access thereafter to the platforms. The lifts will generally be located above/below the platforms, allowing a direct journey from street to platform for passengers.

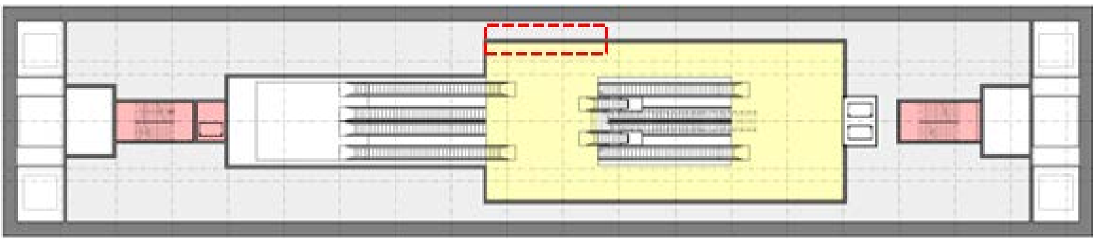
The entrances have been integrated into the urban realm, with pedestrian crossings to minimise the need for level changes and bridges.

The entrances to the underground concourse to access the elevated stations will be enclosed, with the possibility to close and lock the entrances at night.

6.3.2 Ticketing Strategy

It is assumed that the metro will be an 'open system' with no ticket gates. Purchasing of tickets will be on an 'honour system', with inspectors carrying out random ticketing checks on the trains.

Figure 21: Area for Topping Up



Ticket and topping up machines will be located at concourse level at underground stations, together with system and local maps – all of which act as an information wall. In the open cut, at grade and elevated stations, passenger facilities will be distributed along the platform using minimised furniture integrating information and equipment.

6.3.3 Front of House Floor Area

The front of house sizing is generally driven by passenger flow and distribution requirements. Critical sizing requirements are based on London Underground Limited (LUL) standards and have been identified as follows:

Table 11: Run-off Distances & Clearance Requirements

Run-off Distances & Clearance Requirements	**Metres**
Run-off at Top of Escalator	10m
Run-off at Bottom of Escalator	12m
Queuing at Lifts	2m
Min. public stair width	1.8m
Min. width escalators	1m

Note: Run-offs are measured from the working point of the escalators.

6.3.4 Back of House Floor Area

The back of house (technical areas) have been sized by benchmarking the stations against Copenhagen and London Bakerloo Line and it is set around 5,000m2.

6.4 Passenger flow and station capacity

Static analysis of passenger flows has been undertaken for three different station types as follows:

- Typical Station – St. Stephen's Green East.
- Interchange Station – Tara Street.
- Elevated Station – Swords Central has been analysed. The platform will be 8.5m above surface level for this station.

6.4.1 Station Passenger Demand

Indicative passenger boardings and alightings for metro are taken from the NTA East Regional Model, for a 2057[1] scenario with the 'GDA Strategy' implemented including the full metro service (i.e.Swords to Sandyford). The peak demand, including interchange flows (to/from other public transport modes) for each NMN station, is shown in Table 12. Further details on the transport modelling approach and tools used are provided in Appendix 8.1 of the New Metro North Alignment Options Report – Volume 2.

[1] A range is provided as the final choice of rolling stock or its internal configuration (number of seats vs standing room) has not been fixed at this time. This is intended to provide some robustness and confidence that the sizing of the system has sufficient resilience to cater for future changes as the design progresses.

Table 12: Passenger demand in the AM Peak Period (2057)

Station	AM Peak Hr – All Services (Both Directions) – No. of Passengers Alighting					AM Peak Hr– All Services (Both Directions) – No. of Passengers Boarding					AM Peak – Total
	Alighting	Final Destination	Transfer To Bus	Transfer To Luas	Transfer To Rail	Boarding	First Boarding	Transfer from Bus	Transfer from Luas	Transfer from Rail	Total Boarding + Alighting
Estuary Park & Ride	330	142	188	0	0	3,186	594	2,592	0	0	3,516
Seatown	450	450	0	0	0	735	430	305	0	0	1,185
Swords Central	857	747	111	0	0	2,518	1,749	770	0	0	3,376
Fosterstown	400	370	31	0	0	1,763	1,165	598	0	0	2,163
Dublin Airport	5,770	5,718	52	0	0	1,473	1,399	75	0	0	7,243
Dardistown	23	23	0	0	0	42	42	0	0	0	65
Northwood West	243	212	31	0	0	490	488	3	0	0	734
Ballymun Village	821	744	77	0	0	3,681	3,444	237	0	0	4,502
Dublin City University	2,559	2,445	115	0	0	1,523	1,449	74	0	0	4,083
Griffith Park West	1,092	1,092	0	0	0	819	819	0	0	0	1,911
Whitworth	1,867	331	74	0	1,462	8,256	579	510	0	7,166	10,123
Mater Hospital	1,792	1,577	215	0	0	1,203	680	523	0	0	2,995
O'Connell Street	3,403	3,094	72	219	18	1,674	1,238	198	210	27	5,077
Tara Street	8,223	4,387	1,381	761	1,693	6,854	1,004	1,643	1,094	3,112	15,077
St Stephens Green East	5,897	5,279	617	0	0	1,196	863	333	0	0	7,093

6.4.2 Fruin levels of service

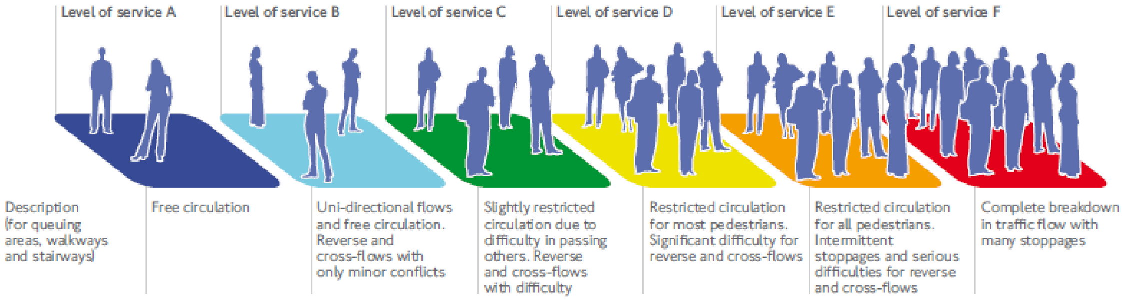
In the 1970s and 1980s, John Fruin pioneered pedestrian planning analysis and the development of Level of Service criteria for pedestrians – previously Level of Service metrics had only been used to describe vehicular traffic flow by highways agencies.

Fruin Level of Service (LoS) describes pedestrian movement, relating density of pedestrians and flow rates for walkways and circulation areas, stairs and in queues. LoS varies from LoS A which typifies free circulation to LoS F which is reflective of complete breakdown in movement.

Fruin describes LoS C as being free flow, assuming a normal walking speed with opportunity to overtake. However, there is potential for pedestrian conflicts where crossing movements and counter-flows exist.

LoS C is typically used for designing stations and transport interchanges as it provides a balance between congestion, design and infrastructure.

Figure 22: Fruin LoS ranges



London Underground Limited's (LUL) Station Planning Standards and Guidelines (SPSG)[2] document reflects and incorporates Fruin LoS ranges and have been applied on this project.

In line with Fruin, LUL standards recommend that most station areas be designed to perform at LoS C. However, on platforms, the design criterion is 0.93m^2 (average) of space provided per passenger which is equivalent to Fruin LoS B/C for a queuing or waiting type environment.

6.4.3 Static Analysis of Platforms

The SPSG approach is onerous and essentially assumes a simultaneous train arrival on each side of the island platform. In addition, to derive platform width, SPSG recognises that passengers are not evenly distributed along platforms, and at the busiest part of the platform it is assumed that 35% of the platform load i.e. the maximum number of passengers on the platform at any given time, occupies 25% of the platform[3].

The platform is sized to give each person 0.93m^2 space at Fruin LoS B/C. A further space of 2 x 0.5m (total of 1m) is added for edge effect at the back and front of the platform.

The platform length is 90m. Platform length is also an important consideration as longer platforms provide more space for waiting passengers.

Figure 23: LUL SPSG Platform Width Calculation

$$\text{platform width} = \left\{ \frac{\text{platform load per headway} \times P \times 0.93}{\text{platform length} \times 0.25} + 1 \right\} \text{m}$$

Where P is percentage of the passengers assumed occupying 25% of the platform, as explained above.

[2] Transport for London - London Underground, Guidance Document G371A Station Planning Standards and Guidelines

[3] Therefore the value of P in the formula shown is 0.35.

6.4.4 Static Analysis of Vertical Circulation

Using the following guidance, the number of escalators and staircase width are calculated using the formulae below:

- Flow rates of up to 100 passengers per minute are assumed on escalators in line with LUL guidance.
- For alighting passengers, a maximum 1.5-minute clearance time has been assumed reflecting the 2-minute headway of the proposed Dublin Metro North system.
- Two-way flow on stairs is 28 people per metre per minute in line with Fruin.

Figure 24: LUL SPSG Vertical Circulation Calculations

$$\text{number of escalators} = \left\{\frac{\text{peak minute one-way flow}}{100}\right\}$$

$$\text{two-way staircase width} = \left\{\frac{\text{average peak minute flow}}{28}\right\}\ \text{m}$$

6.4.5 Results for Typical Stations

Peak demand from the unconstrained end to end model run for all NMN stations is provided in Table 12. Three representative stations are described in more detail below.

6.4.5.1 St Stephen's Green East

For St Stephen's Green East, the combined AM peak hour demand is 4,198 passengers in 2027 and 7,093 passengers by 2057.

The concept engineering design developed provides an 11.5m wide platform. There are 4 escalators and 2 x 1.5m stairs from platform to concourse level but then only 2 escalators and 1 x 2m stair from concourse up to street level.

The platform width is calculated as the larger of the required width for demand and for vertical circulation. In this case the vertical circulation requirements govern.

The demand provided generates a minimum island platform width of 6.0m and 6.3m in 2027 and 2057 respectively using LUL standards, assuming 0.93m^2 per person (LoS B/C) on the platform. This provision is based only on for platform occupancy, not including vertical circulation (escalator/lift/stair) requirements.

The platform width required for vertical circulation is given by having 2.5m of clear platform on each side of the escalators/lifts/emergency stairs, resulting in min 11.5 m overall width at St Stephen's Green.

Therefore, the design platform width at St. Stephen Green is 11.5m. This is reflected in Table 13. This is also the case at O'Connell Street and Dublin Airport.

For the typical stations, vertical circulation requirements are also determining the design platform width. In this case the requirement of having 2.5m of clear platform on each side of the escalators/lifts/emergency stairs, results in 10m overall platform width. This is reflected in Table 13.

The drawings included in Volume 2 represent the typical station boxes and therefore show 10m wide platform.

Only 2 escalators are required in 2027. By 2057, both escalators will need to work in the up direction in the AM peak to clear projected alighting loads, with the single stair providing appropriate capacity for boarding demand. The peak one-minute boarding load is 24 passengers in 2057 meaning a 1.8m wide stair is more than sufficient.

The escalators can then switch to one up and one down outside of the AM peak period. Analysis indicates that one up and one down escalator should be sufficient for the PM peak also. For this peak, the 1.8m stair offers reserve capacity.

6.4.5.2 Tara Street

For Tara Street, the combined AM peak hour demand is 6,300 passengers in 2027 but this more than doubles to 15,077 passengers by 2057.

The concept engineering design developed provides a 13.0m wide platform. There are 4 escalators and 2 x 1.8m stairs from platform to concourse but then only 4 escalators from concourse up to street level.

The platform width is calculated as the larger of the required width for demand and for vertical circulation. In this case the vertical circulation requirements govern.

The demand provided generates a minimum island platform width of 6.0m in 2027. By 2057, the requirement increases to an island platform width of 10.8m.

The vertical circulation requirement of having 2.5m of clear platform on each side of the escalators/lifts/emergency stairs, results in 13m overall platform width. This is governing and therefore 13m is the platform design width. This is reflected in Table 13.

Four escalators to/from the platform are required to clear the platform in 1.5mins, two up and two down. The same requirement is shown up to street level. The design is therefore appropriate. Note Tara Street is not a typical -3 level station.

The 2 x 1.8m stairs from platform to concourse provide additional capacity for platform clearance.

6.4.5.3 Swords Central

For Swords Central, the combined AM peak hour demand is 2,127 passengers in 2027 and 3,376 passengers in 2057.

The concept engineering design developed provides 2 escalators and 1 x 2m stair from platform to street level.

The platform width is calculated as the larger of the required width for demand and for vertical circulation. In this case the vertical circulation requirements govern.

The demand provided generates a minimum island platform width of 6m which is the LUL minimum, 3m width to serve each side of the island platform. The actual capacity requirement at Swords Central is 4.0m wide platform by 2057 but the LUL minimum supersedes this to generate the 6m width for platform occupancy, not including vertical circulation (escalator/lift/stair) requirements.

The vertical circulation requirement of having 2.5m of clear platform on each side of the escalators/lifts/emergency stairs, results in 11m overall platform width. This is governing and therefore 11m is the platform design width. This is reflected in Table 13.

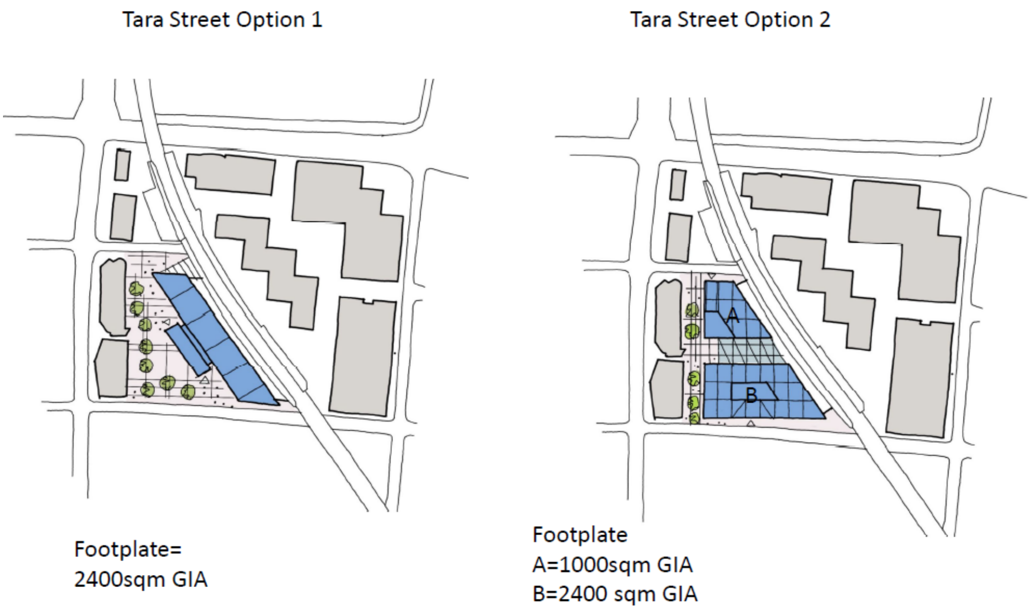
Two escalators, one up and one down, are sufficient even for 2057 flows.

The 2m stair offers reserve capacity and allows for escalator breakdown or maintenance and so provides resilience.

6.5 Tara Street Oversite Development Opportunities

Opportunities exist for a potential oversite property development (OSD) at Tara Street Station. Two options have been developed, refer Figure 25 below. Option 1 includes OSD above the station only. Option 2 includes a podium on top of which OSD can be located, providing more area for OSD as well as more flexibility in terms of buildings arrangement. The Figures also include an indicative Gross Internal Area (GIA)

Figure 25: Tara Street Oversite Development Options



6.6 Underground Station Fire Safety Requirements

6.6.1 Codes and Standards

The concept engineering design fire and evacuation ventilation strategy for the stations has been developed in accordance with the following Codes and Standards:

- NFPA 130 – Standard for Fixed Guideway Transit and Passenger Rail Systems (2010)
- Technical Guidance Document B (Fire Safety)
- BR 187 (Building Separation & Boundary Distances)
- TSI – SRT (technical specification for interoperability relating to 'safety in railway tunnels' of the rail system of the European Union)
- RSC-G-032 (including Appendices 1-4) - Guideline for the Process of Authorisation for Placing in Service (APS) of Light Railway Subsystems
- RSC-G-033-B (including Appendix 1) - Guideline Providing List of Parameters and Requirements for Authorisation for Placing in Service (APIS) Light Rail Infrastructure, Energy and Command-Control Subsystems

6.6.2 Means of Escape

Local standards and regulations in Ireland do not specifically address the fire safety complexities associated with a railway system and particularly underground railway systems.

The means of escape from the stations at this stage have been designed to meet the requirements of NFPA 130 (2017) with all aspects of the design subject to approval by the authorities having jurisdiction including the Dublin Fire Brigade.

For underground stations, NFPA 130 requires that there is sufficient egress capacity to evacuate the maximum peak period platform occupant load from the platform within four minutes. Subsequently, NFPA 130 also requires the station to permit evacuation from the most remote point on the platform to a point of safety within six minutes.

The typical underground stations comprise either a two level or three level configuration. For means of escape purposes the evacuation routes are, however, broadly similar.

Escape routes from platforms are provided by escalators supplemented by independent protected emergency escape staircases. At platform level, there are four escalators leading to the concourse level where they combine to two escalators leading up to the main station entrance/exit at street level. Platform, concourse and street level plans for the -3 level station are shown in Figure 26, Figure 27 and Figure 28 below with the pink shading denoting the independent protected staircases and the escalators shown connecting each level and exiting at street level. The yellow areas show Front of House areas.

Figure 26: -3 Level Box Platform Level

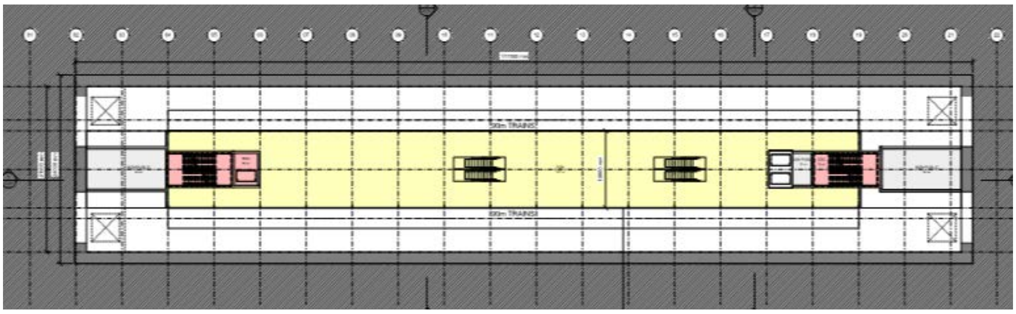


Figure 27: -3 Level Box Concourse Level

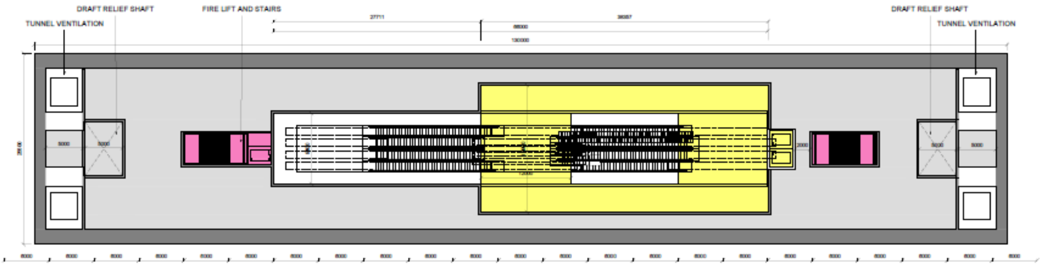
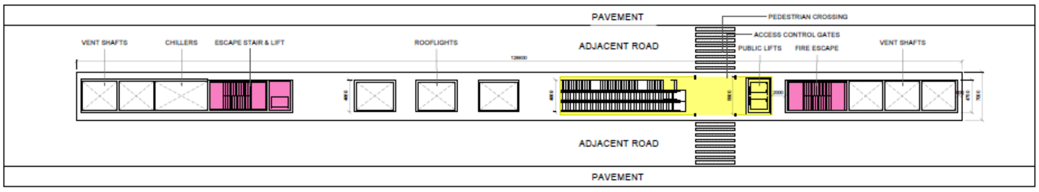


Figure 28: -3 Level Box Street Level



In normal operation half of the escalators will be operating in a downwards direction with half operating in an upwards direction.

In the event of an evacuation the up escalators will continue to run whilst the down escalators will be stopped and therefore can be used for means of escape by manually climbing the escalator. NFPA 130 provides specific guidance on the use of escalators for means of escape, including consideration for an escalator being out of service and this has been considered as part of the conceptual evacuation strategy.

In addition to escalators, there are also evacuation stairs provided from the platform level. These comprise two forms; firstly, an open stair running adjacent to the escalator bank, between concourse and street level, and, secondly, protected staircases located at either end of the platform (shown in pink in Figure 26 to Figure 28). The open stair, similar to the escalators, discharges via the main entrance/exit at street level shown shaded yellow.

The protected stairs similarly discharge at street level but from entering the stair at platform level, occupants remain within a protected route through to the final exit. This means that the protected egress route shall be fire separated from the remainder of the station (including the concourse) by fire resisting construction.

For Passengers with reduced mobility (PRM) egress, disabled refuges shall be provided at each end of platform level within the firefighting shaft and protected stairs. For additional protection these escape stairs shall be provided with positive pressurisation to reduce the risk of smoke entering the stair enclosures.

Subject to approval by the authorities having jurisdiction, the arrangement and width of the escape routes shall ensure that the egress capacity is in accordance with NFPA 130 (2017).

Within the concept engineering design, the following provisions have been made:

- Platform occupant load is based on a crush load train (954 people) arriving at the station.
- In addition, there will be a number of people waiting on the incident and non-incident platform sides (incident refers to the platform adjacent to the track on which the train affected by fire is located).

For St Stephen’s Green East station for example, the passenger load on the incident platform side is assumed to be 130 people as calculated using the Unconstrained Model Run passenger numbers shown in and the methodology set out in NFPA 130 Annex C (peak direction, assuming a missed headway) and 13 people on the non-incident platform side. Conservatively, therefore, the means of escape is being designed for a total combined evacuation load of 2,051 people.

On this basis (following the NFPA 130 calculations), the stair cores at each end of the platform i.e. the protected stairs referenced above, are designed as a scissor stair arrangement with each stair having a minimum clear width of 2.0m i.e. a total clear stair width of 8.0m between the four stairs combined. The escalators are 1.0m wide and the adjacent open stair between concourse and street level is 1.8m wide.

The calculations above have been based on St. Stephen’s Green station to represent a reasonable worst-case scenario. The intent at this stage is that the stair width shall be made consistent through all NMN stations. However, egress routes will be sized to meet the demand figures, so minimum required width can be calculated on a station by station basis which could yield marginally narrower escape routes for those stations with a lower passenger throughput.

6.6.3 Summary of Station Sizing Requirements

A summary of the station sizing and vertical circulation requirements for normal use and emergency escape are summarised in Table 13 below:

Table 13: Station Sizing and Vertical Circulation Requirements

				Platform				Concourse			
Station	**Peak hour total Boarding + Alighting (passengers)**	**Station Type**	**Platform Width (m)**	**No Escalators**	**FOH Stairs (m)**	**BOH Stairs (m)**	**Effective Clear Stair Width Provided (m) (deduct 0.5m in firemans stair)**	**No Escalators**	**FOH Stairs (m)**	**BOH Stairs (m)**	**Effective Clear Stair Width Provided (m) (deduct 0.5m in firemans stair)**
Estuary Park&Ride	3,516	At Grade	10	2	1 x 1.8	4 x 1.8	8.5	-	-	-	-
Seatown	1,185	Elevated	10	2	1 x 1.8	4 x 1.8	8.5	-	-	-	-
Swords Central	3,376	Elevated	11	2	1 x 1.8	4 x 1.8	8.5	-	-	-	-
Fosterstown	2,163	At Grade	11	2	1 x 1.8	4 x 1.8	8.5	-	-	-	-
Dublin Airport	7,243	2 level	11.5	4	2 x 1.8	4 x 1.8	9.2	2	1 x 1.8	4 x 1.8	8.00
Dardistown	65	1 level	10	2	1 x 1.8	4 x 1.8	8.5	-	-	-	-
Northwood West	734	1 level	10	2	1 x 1.8	4 x 1.8	8.5	-	-	-	-
Ballymun Village	4,502	2 level	10	4	-	4 x 1.8	6.2	2	1 x 1.8	4 x 1.8	8.00
DCU	4,083	2 level	10	4	-	4 x 1.8	6.2	2	1 x 1.8	4 x 1.8	8.00
Griffith Park West	1,911	3 level	10	4	-	4 x 1.8	6.2	2	1 x 1.8	4 x 1.8	8.00
Whitworth	10,123	3 level	13	4	2 x 1.8	4 x 1.8	9.8	4	-	4 x 1.8	6.20
Mater Hospital	2,995	3 level	10	4	-	4 x 1.8	6.2	2	1 x 1.8	4 x 1.8	8.00
O'Connell Street	5,077	3 level	11.5	4	2 x 1.5	4 x 1.8	9.2	2	1 x 1.8	4 x 1.8	8.00
Tara Street	15,077	3 level	13	4	2 x 1.8	4 x 1.8	9.8	4	-	4 x 1.8	6.20
St Stephens Green East	7,093	2 level	11.5	4	2 x 1.5	4 x 1.8	9.2	2	1 x 1.8	4 x 1.8	8.00

6.6.4 Fire Safety Systems

The fire safety systems shall be provided within the station to supplement the means of escape provisions. These shall be further designed at future stages and are expected to include:

- Automatic fire and smoke detection
- Voice alarm
- Emergency lighting
- Illuminated escape route signage
- Communication facilities associated with the Mobility Impaired Passenger (MIP) refuge point

It is not expected at this time that a fire suppression system (sprinkler system) will be provided.

6.6.5 Smoke Control Systems

The stations shall be provided with a smoke control system at platform level in order to manage smoke in the event of a train or platform fire, maintain tenable conditions for the period of the evacuation and to assist with firefighting operations.

The smoke control system for the station boxes is designed to be synonymous with the smoke control system for the tunnels and shall comprise vent shafts at both ends of the platform. The smoke control mechanism in the event of a fire in a tunnel is further described in Section 5.6. In the event of a fire at a station, dampers will automatically configure the vent shafts to extract fully through the over track exhaust (OTE).

The station smoke control system shall be designed to prevent smoke spreading from the platform level up to higher levels to maintain tenable conditions within the station during the evacuation period. The system shall be designed to address both train fires and platform fires.

An alternative smoke control solution may be to provide natural smoke vents at the top of the station box. In the event of a station platform fire, smoke would be allowed to rise through the station and naturally vent to the street. The design of this system would need to carefully consider the impact of smoke on occupants evacuating via the open stairs and escalators and may result in additional requirements for protected stairs from the platform level. A natural ventilation system for station smoke control presents a moderate approvals risk and any consideration for this approach would need to include early engagement with the authorities having jurisdiction.

In the current design of stations ventilation fans have been provided at both ends of the station. Refer to Section 5.6 for further discussion on this topic.

6.6.6 Firefighting Access and Facilities

In addition to the facilities provided for means of escape, specific firefighting systems are provided in each station. Facilities for firefighting shall be provided in accordance with Technical Guidance Document B which requires one firefighting shaft in each station.

The firefighting shaft shall be co-located with the protected evacuation stairs (remote from the main station entrance) and will include a firefighting lift and fire main.

Common practice for underground stations is to locate additional fire main outlets along all levels including platform level to meet the hose distance requirements of Dublin Fire Brigade and such that all parts of the station are within no more than 40m in a direct line from a fire main outlet.

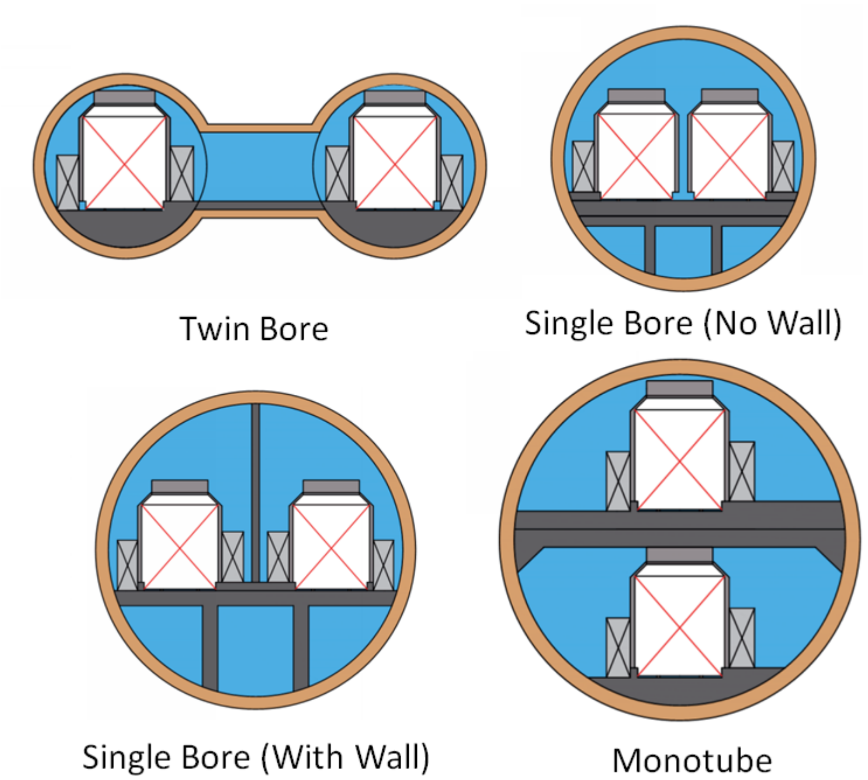
All aspects relating to firefighting access and facilities will need approval by Dublin Fire Brigade.

7 Tunnels

7.1 Tunnel configuration

A tunnel configuration study for New Metro North was carried out in 2017 and recommended four tunnel configurations that are to be considered for the New Metro North alignment study.

Figure 29: Recommended tunnel configurations from Tunnel Configuration Study



The three tunnel configurations (twin bore, single bore with a dividing wall, single bore without a dividing and monotube) have been assessed through several stages including a cost analysis for a generic alignment, a preliminary assessment on Stage 1 MCA route combination and Stage 2 MCA routes (including EPR). Additionally, a sensitivity check was carried out with additional stations considered. In addition to cost the following has been assessed:

- Waste generated;
- Emergency strategy;
- Future expansion;
- Programme;
- User Experience;
- Ground movement
- Noise and Vibration.

This assessment is provided in **Appendix E**. The conclusion of the assessment recommends twin bore as the preferred configuration for the Emerging Preferred Route (EPR). The twin bore is preferable under cost, waste, emergency strategy, programme and user experience. While not preferred for future expansion and noise and vibrations these do not shift the balance of favour toward another configuration. A typical section of the 5.9mID (internal diameter) twin bore is shown in drawing 252252-ARP-STU-SW-DR-CT-0001.

It is recommended that the single bore (with wall) and monotube are no longer considered as part of this study as the cost and waste produced is significantly higher than the twin bore. The single bore (no wall) is comparable in cost but is more limited with respect to fire and life safety with a significant number of shafts required to achieve safety standards. Refer to Appendix E for full assessment.

7.2 Tunnel Space proofing

A typical section of the 5.9mID twin bore is shown in drawing 252252-ARP-STU-SW-DR-CT-0001. The following elements and their respective sizing are allowed for within the tunnel, subject to confirmation:

Table 14: Tunnel space proofing details (dimensions in millimetres)

Element	**Details**
Tunnel Lining Thickness*	400mm
Dynamic Kinematic Envelope	Provided by TII
Tunnel lighting	2nos. 150mm x 200mm lights either side of tunnel
Lining tolerance on intrados+	100mm tolerance all around
Leaky feeder	2nos. 50mm line on either side of tunnel
Rail signal	160mm x 650mm signal light on one side
Low Voltage Cable zone	250mm x 800mm zone
Pumped drainage	150mm pipe with 300mm flanges
Maintenance Walkway	2000mm high walkway 450mm wide at base, increasing to 800mm wide at 1200mm height.
Cable trough	250mm x 150mm space beneath walkway for 100mm duct with 70mm copper earth cable
Gravity drainage pipe	225mm diameter pipe beneath track slab
Undertrack cable crossing	100mm diameter
Trackbed	600mm from base of concrete to top of rail
Floor of vehicle	350mm from track level to floor of vehicle
Emergency walkway level	70mm below vehicle floor
Tolerance+	150mm tolerance on envelope at sides
Pantograph Zone	400mm x 1900mm to2700mm
Tolerance+	75mm around pantograph
High voltage cable trough	500mm x 300mm trough beneath walkway

Element	Details
Fire Main	150mm pipe with 300mm flanges
Exit sign for cross passage	400mm x300mm sign above emergency walkway
Evacuation walkway	850mm x 2000mm evacuation walkway
Overhead control system zone	575mm x 1900mm zone for overhead systems

* Lining thickness based on similar diameter tunnel projects. Lining thickness is to be confirmed during subsequent design stages where it may reduce.

+ Construction tolerances provided to cater for any deformation in the circular lining or minor misalignment of the tunnel during construction. Tolerances are to be reviewed during subsequent design stages where they may be reduced.

7.3 Portals

There are two portals on the proposed alignment. The southern portal is made as part of the Green Line Tie-In at Charlemont and will act as the location for receiving the Tunnel Boring Machines (TBMs) from the southern drive. The northern portal is located near the Naul Road north of Dublin Airport and will act as the location for launching the TBMS for the northern drive. The portal geometry is defined by the depth at break-in / break-out, the gradient of the track, the gradient of the ground and the spacing of the tracks. Table 15 below summarises the key dimensions of the portals. A plan and section of the northern portal is shown on drawings 252252-ARP-SGN-SW-DR-RC-0005 and 252252-ARP-SGN-SW-DR-RC-0006.

Table 15: Key Portal Dimensions

Portal Dimension	Value
Portal depth (m)	13m to track level with allowance for track slab, base slab beneath track level
Portal Width at break-in / break out (m)	14.75m track separation with allowance for TBM, walkways and side walls outside this
Portal width at narrowest point (m)	3.4m track separation with allowance for walkways and side walls outside this
Portal Length (m)	Northern Portal – Approximately 79m Southern Portal – Approximately 320m

7.4 Intervention Shaft

In line with NFPA 130, cross passages between the tunnel bores are provided at 244m spacing with no shaft required for emergency egress. However, where the spacing between exit points (stations / portals) exceeds 1.5km a shaft is provided for emergency access. Therefore, a single intervention shaft is required along the alignment at approximately Ch11+826. This shaft is provided to allow for emergency egress for passengers and staff from the tunnel between Dardistown and Dublin Airport stations. It is also provided to allow access for emergency personnel to attend any emergency that occurs within this section of tunnel. As a result, the shaft requires the following elements:

- Surface space for parking emergency vehicles
- Road access to the shaft
- Two sets of emergency escape stairs for emergency egress in a scissors arrangement
- Dedicated stairs for emergency personnel for emergency access
- A fire lift
- A safe space for disabled passengers to wait for rescue; and
- Ventilation.

The above is proposed to be provided in a rectangular 13.8m x 20m shaft. This shaft will be excavated from surface to tunnel level where it will sit between the two tracks. Access is provided from the emergency walkway in each tunnel to the shaft by means of a short cross passage. Plans and sections of the intervention shaft are shown on drawing 252252-ARP-SGN-SW-DR-RC-0001 and 252252-ARP-SGN-SW-DR-RC-0002.

7.5 Cross passages

In line with NFPA 130, cross passages are to be provided along tunnelled sections where the length of clear tunnel is greater than 244m. On the basis of the current alignment and station / portal / shaft / low point spacing the estimated number of required cross passages is 43.

The cross passages are primarily provided so that in the event of an emergency the second bore can be used as a place of safety. However, they may also have a secondary function as technical rooms for the system operations, and also to accommodate equipment such as drainage sumps and sump pumps. As a result, those cross passages required to accommodate technical equipment are proposed to be 4m diameter (approx. 3.3m internal) passageways. Those that are only required for escape can be reduced to 3m diameter (approx. 2.3m internal). All access doors to the cross passages will be fire-rated in line with Section 9 of this report. The details of the equipment within the cross passages is to be developed at the next stage of design. A list of the cross-passage locations is provided in Table 16. The general arrangement of the cross passage is shown on drawing 252252-ARP-STU-SW-DR-CT-0002.

Table 16: List of cross passages locations

Cross Passage	Chainage	Comment	Cross Passage	Chainage	Comment
XP1	1+193		XP23	7+760	
XP2	1+385		XP24	8+261	
XP3	1+578	Low Point Sump	XP25	8+417	Low Point Sump
XP4	2+150		XP26	8+589	
XP5	2+375		XP27	8+762	
XP6	2+599	Low Point Sump	XP28	9+310	
XP7	3+193	Low Point Sump	XP29	9+554	Low Point Sump
XP8	3+411		XP30	9+737	
XP9	3+959		XP31	9+920	
XP10	4+171		XP32	10+458	Low Point Sump
XP11	4+383		XP33	10+694	
XP12	4+869	Low Point Sump	XP34	11+234	
XP13	5+113		XP35	11+426	
XP14	5+672		XP36	11+618	
XP15	5+870		XP37	12+025	Low Point sump
XP16	6+068		XP38	12+230	
XP17	6+267	Low Point Sump	XP39	12+435	
XP18	6+416		XP40	12+640	
XP19	6+910		XP41	12+845	
XP20	7+122		XP42	13+418	
XP21	7+335		XP43	13+655	Low Point Sump
XP22	7+547				

Note: Intervention shaft at CH11+800 replaces cross passage required in this section of track

8 Civil Works

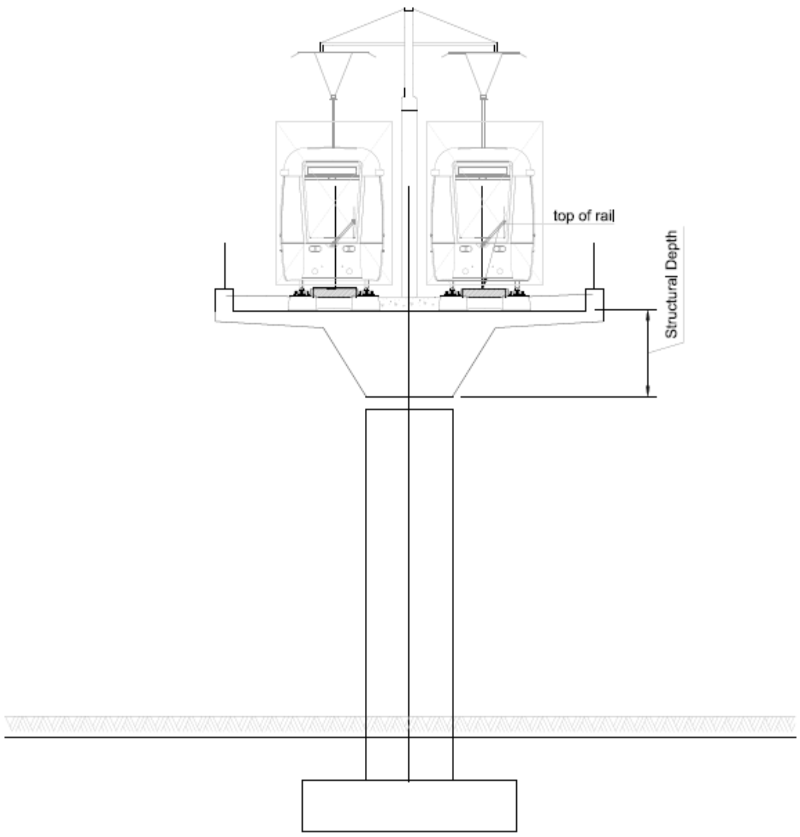
8.1 Viaduct Design

The total length of the viaduct is circa 3.2km. Due to the plan curvature, there will be torsional effects induced by the curvature, which needs to be considered in the structural design. Some widening of the structure width will be necessary to accommodate any cant and throw effects.

The viaduct is located within the central median of the R132 road spanning over three roundabouts. There are no significant crossings or obstacles known at this time.

Due to the long length, visual impact of the viaduct, and the generally good ground conditions, a viaduct of medium span length is recommended. The use of regular span intervals with a constant structural depth will create a visually appealing and elegant structure that blends naturally into the road and town landscape environment. The recommended option should permit flexibility in construction methods and material types. Thus, a box girder superstructure is the recommended option at this stage of design development. Span lengths of circa 36 to 40m are considered to be most economic for this configuration with structural depths of up to 2.5m. Refer to Figure 32 below for a typical detail of a box girder arrangement for the viaduct.

Figure 30: Box Girder Typical Detail



8.2 Road Design

New road alignments are proposed to provide access to the underground station at Dardistown, north of the M50, and to provide a signalised junction for access to the Park & Ride facility at Estuary.

These new roads and realigned roads have been designed in accordance with the current Design Manual for Roads and Bridges (DMRB)[4] and the Design Manual for Urban Roads and Streets (DMURS)[5] road design standards with inclusion of provision for pedestrian and cyclists in all instances.

Upgrades to the existing road network in the vicinity of the station accesses were also carried out to integrate the stations into the receiving environment and to provide improved facilities for pedestrians, cyclists, public transport users and mobility impaired and disabled users.

The R132 dual carriageway road is also realigned to provide a widened median to cater for both the viaduct piers and the entrances to the elevated stations, refer to Figure 31 and Figure 32 below.

[4] Design Manual for Roads and Bridges, Volume 6 Road Geometry

[5] Design Manual for Urban Roads and Streets, Department of Transport, Tourism and Sport and the Department of Environment, Community and Local Government, April 2013

Figure 31: Typical Cross Section along the R132

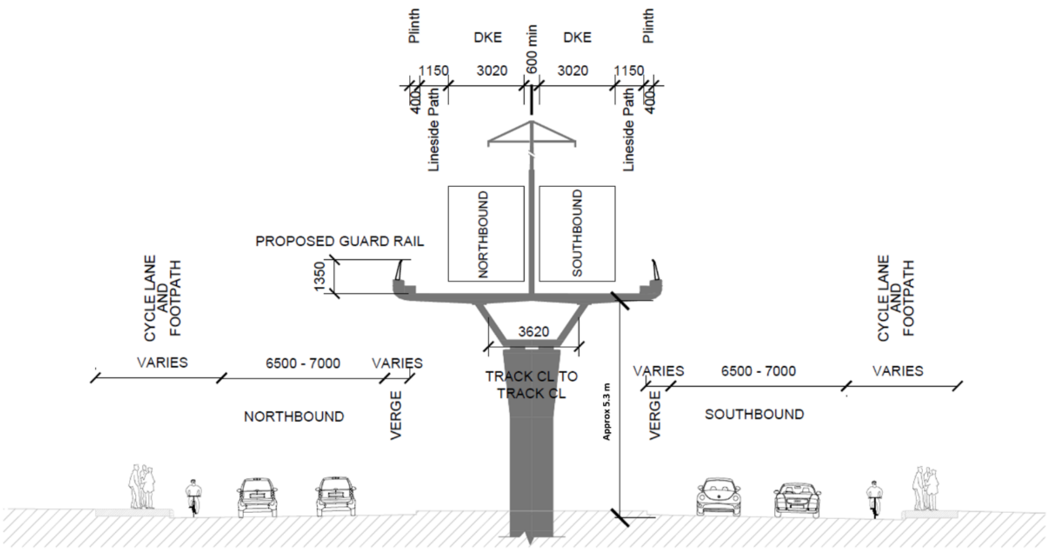
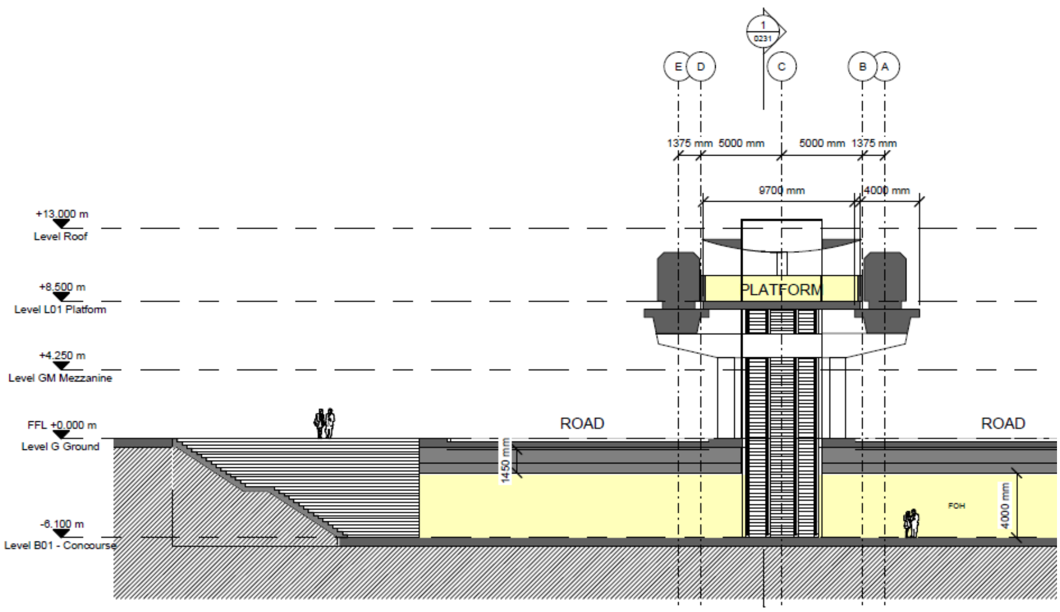


Figure 32: Typical Elevated Station Section



8.3 Utilities

Utility conflicts will be treated in one of the following four ways:

1. Utility conflicts will be permanently relocated from the route of the metro.
2. Utility conflicts will be relocated to a temporary location in advance of the works and maintained in operation, this will be replaced with a new element in its original position after the work are complete.
3. Utility conflicts will be retained in its original position and protection measures will be executed in agreement with the utility owner.
4. Utility conflicts which are scheduled for relocation to a temporary site in the enabling works in advance of the works will be reinstated to their original position during the construction works.

Table 17 below outlines the major known utilities encountered along the route which will need to be diverted.

Table 17: Major Known Utilities Encountered

Location	Utilities Provider	Conflict Details
St Stephens Green Station	ESBi	110kV Underground ESB Line
St Stephens Green Station	Irish Water	400mm Diameter Trunk Watermain Gravity Pipe In Service. 0.9m Cover Level. Install Year - 1990
Tara Street Station	ESBi	38kV Underground ESB Line
Tara Street Station	Irish Water	610mm Diameter Trunk Watermain Gravity Pipe In Service. 0.9m Cover Level. Install Year - 1927
O'Connell Street Station	ESBi	38kV Underground ESB Line
O'Connell Street Station	ESBi	110kV Underground ESB Line
O'Connell Street Station	Irish Water	400mm Diameter Trunk Watermain Gravity Pipe In Service. 1.2m Cover Level. Install Year - 2005
Mater Hospital Station	Irish Water	405mm Diameter Trunk Watermain Gravity Pipe In Service. 1.2m Cover Level. Install Year - 1900
Whitworth Station	ESBi	38kV Underground ESB Line
Griffith West Station	N/A	N/A
DCU @ Collins Avenue Station	ESBi	38kV Underground ESB Line
DCU @ Collins Avenue Station	Irish Water	305mm Diameter Trunk Watermain Gravity Pipe In Service. 0.9m Cover Level. Install Year - 1965
DCU @ Collins Avenue Station	Irish Water	800mm Diameter Trunk Watermain Gravity Pipe In Service. 0.9m Cover Level. Install Year - 2005
DCU @ Collins Avenue Station	Irish Water	305mm Diameter Trunk Watermain Gravity Pipe In Service. 0.9m Cover Level. Install Year - 1965
Ballymun Village Station	Irish Water	300mm Diameter Trunk Watermain Gravity Pipe In Service. 1.3m Cover Level. Install Year - 2003
Ballymun Village Station	Irish Water	305mm Diameter Trunk Watermain Gravity Pipe In Service. 0.9m Cover Level. Install Year - 1965
Ballymun Village Station	Irish Water	305mm Diameter Trunk Watermain Gravity Pipe In Service. 0.9m Cover Level. Install Year - 1965
Ballymun Village Station	Gas Networks Ireland	Gas Networks Transmission Line
Northwood West Station	N/A	N/A
Dardistown Station	N/A	N/A

Location	Utilities Provider	Conflict Details
Dublin Airport Station	N/A	N/A
Fosterstown Station	N/A	N/A
Swords Central Station	N/A	N/A
Seatown Station	N/A	N/A
Estuary Park & Ride Station	Irish Water	762mm Diameter Trunk Watermain Gravity Pipe In Service. 0.9m Cover Level. Install Year - 1970
Elevated - Chainage 16+550	Irish Water	305mm Diameter Trunk Watermain Gravity Pipe In Service. 0.9m Cover Level. Install Year - 1980
Elevated - Chainage 17+850	ESBi	38kV Underground ESB Line
Elevated - Chainage 18+060	Irish Water	762mm Diameter Trunk Watermain Gravity Pipe In Service. 0.9m Cover Level. Install Year - 1970
Elevated - Chainage 18+160	Irish Water	762mm Diameter Trunk Watermain Gravity Pipe In Service. 0.9m Cover Level. Install Year - 1970
At Grade - Chainage 18+850	Irish Water	762mm Diameter Trunk Watermain Gravity Pipe In Service. 0.9m Cover Level. Install Year - 1970

8.4 Lighting

It is assumed for the basis of the concept engineering design that running tunnel lighting will be installed on both sides of the tunnel in order to provide required lighting levels to the passenger escape walkway. A similar lighting system will also be used in the cross passages which will also include an illuminated emergency exit sign. The emergency lighting throughout will provide for a minimum of 25% of the normal full illumination level in all areas for passenger and staff evacuation.

For underground stations and the multi-storey park and ride facility, lighting will be determined at the next phase in line with architectural requirements and to be consistent with the urban realm space to be developed. However, it is assumed that the control system for the station or facility will allow the option to automatically switch the lights on during operating hours and to a reduced predetermined level when closed for cleaning or maintenance. Where the architectural design introduces daylight onto the concourse, mezzanine or platform levels, daylight linked control will automatically dim the lighting to maintain the required lux level.

For above sections running either at grade or on viaduct the lighting will be combined with the OCS poles.

For the above ground stations, the lighting will be column mounted on dedicated columns or onto columns also being used for CCTV cameras, public address systems or for OCS.

8.5 Drainage

8.5.1 Tunnel

Drainage within the bored tunnels, cut and cover sections and underground stations is not exposed to rainfall but will require a system to accommodate seepage and potential fire flows.

For cut and cover sections, such as portals or underpasses, where the depths are too deep to be served by gravity, surface water pumping stations will be required.

The tunnels will be served by a surface water drainage collection system which will connect to pump stations and rising mains that are routed back to the nearest station. From here it is pumped to surface level and following appropriate treatment measures for tunnel discharge in line with local authority requirements it will outfall to existing watercourses or storm sewer system.

In line with the Greater Dublin Regional Code of Practice[6] and Greater Dublin Strategic Drainage Study[7], attenuation structures will be designed for the 100year storm event to control discharge to agreed discharge rates in line with greenfield runoff rates.

Table 18: Tunnel Drainage Outfall Locations

Outfall Location	Outfall Type
St. Stephen's Green East	DCC Sewer System
Tara Street	River Liffey
O'Connell Street	DCC Sewer System
Mater Hospital	DCC Sewer System
Whitworth	River Tolka
Griffith Park West	River Tolka
Dublin City University (DCU)	DCC Sewer System
Ballymun Village	DCC Sewer System
Northwood West	River Santry
Dardistown	Turnapin Stream
Dublin Airport	Wad Stream

8.5.2 Viaduct

For the elevated viaduct sections, a system of dished channels and gullies, or longitudinal drainage channels will discharge to downpipes at pier locations. The same system will be used at the elevated stations at Swords Central and Seatown. These will connect to a land drain or piped gravity system in the grassed median or verge of the R132.

On approach embankments to the viaduct water will percolate through the free draining granular fill and collect at a low level in the back of wall drainage in accordance with DMRB BD70.

The gravity drainage in the median and verge will discharge at appropriate locations to existing unnamed watercourses following treatment and attenuation in line with the Local Authority's requirements.

8.5.3 At Grade

It is assumed that the at grade track will be slab track. The track will be connected to either carrier drains or swales which will discharge to existing drainage systems or watercourses. The flow rate will be restricted to greenfield runoff rates by a flow control device located at the outfall.

[6] Greater Dublin Regional Code of Practice for Drainage Works, Version 6.0
[7] Greater Dublin Strategic Drainage Study, April 2005

The at grade station at Fosterstown will discharge to an existing unnamed watercourse following treatment and attenuation in line with the Local Authority’s requirements.

The at grade station, park and ride facility and depot at Estuary will discharge to the Broad Meadow River following treatment and attenuation in line with the Local Authority’s requirements.

9 Estuary Depot

A depot is required to store the fleet of vehicles which are not in use or which are being serviced. The depot is located at the northern terminus of the NMN project. This location is chosen because as it located at the end of proposed scheme in an area where the track is running at grade with green space available for construction.

The detail of the requirements and layout are set out in this section. The sizing of the depot is linked to the track layout within the depot as track criteria apply to the track in the depot in a similar manner as it does on the mainline. Therefore, the tracks are set out to meet the functional requirements of the depot initially and other elements are then situated around same.

9.1 Functional Requirements

9.1.1 Spatial organisation

The concept engineering design of the depot layout is based on the functions outlined in Table 19 below.

Table 19: Depot Functional Requirements

Major functions	Description
Tracks	Access tracks will be implemented to guarantee smooth operations on site and in connection to the network. The target is to have at least two entrances to the depot, to avoid blocking situations and increase flexibility.
Stabling area	The stabling area is used to store trams when they are not on duty or under maintenance. Being a key function of a depot, it should be the first area to be designed. The target is to achieve the greatest capacity and the best flow for vehicles. Critical points are the vehicle movements between the stabling area and the network, and between the stabling area and the maintenance hall.
Maintenance hall	The maintenance hall should be designed after the stabling area capacity (track lengths) has been defined. Several tracks are needed for maintaining the vehicles and their number will depend on the number of vehicle types and maintenance levels. They will be equipped with berths, pits and platforms. A wheel lathe has to be placed on one of these tracks to enable fleet operators keep wheelsets in condition without the need to remove from the vehicle for machining.
Washing plant	This installation is used to clean the exterior of trams. It can be located either inside or outside the depot and is often located en route to the maintenance hall.
Interior cleaning area	This installation is for cleaning the interior of trams; it is usually located next to the washing plant.
Sanding plant	The sanding plant is used to fill the sand reservoirs of the trams which is used to enhance the breaking of the vehicle by being released when in operation. It is often located close to the entrance next to the washing plant. Sand silos should be made accessible for delivery trucks.

Major functions	**Description**
Dirty workshop	This area is designed for the maintenance of bogies and other equipment that has been removed from the vehicles. A bogie turntable may be added to facilitate movement of bogies. This area must be accessible by trucks.
Electronics workshop	A specific workshop for electronics will be needed to check and repair on-board equipment.
Technical installations rooms	Rooms will be required for technical installations such as pumps, water boilers, heating systems, substations, etc.
Warehouse	This area is for storing spare parts and consumables. It has to be accessible to forklifts or trucks and can be equipped with a racking system. Several warehouses may be planned for security reasons, for storing dangerous products.
Control room	The flow of vehicles is managed from a control room with a global view of the depot and tracks.
Offices	Offices are required for management staff (IT services, corporate services, human resources). An open office solution can be planned.
Reception area	The reception will be located at the entrance to welcome visitors and staff.
Drivers room	The drivers' room will be located close to the stabling area, to allow quick access to the vehicles.
Changing rooms	Separate male and female facilities with showers and lockers must be planned.
Toilets	Toilets should be distributed all around the building.
Medical room	A medical room, designed to offer excellent accessibility, enables treatment of minor injuries and implementation of medical checks.
Cafeteria	A cafeteria for depot staff and drivers is useful. It should be equipped with reheating facilities and vending machines. It is also useful to add a terrace.

Table 20: Additional Depot Functional Requirements

Additional functions	Description
Body and painting workshop	A space is needed for the repair of vehicle bodies and painting activities. This activity can be subcontracted to the vehicle manufacturer.
Relaxation room	A dedicated quiet space can be added, to enable depot staff and drivers to take a quick but restful break.
Conference room	A conference room is useful for organising information or training sessions.
Waste storage	Specific waste storage systems must be planned in depots.
Parking	Parking facilities for cars, motorbikes and bicycles should be planned on the site. Since depot staff and drivers start/stop working at inconvenient times of the day, car use is often high.

9.2 Stabling area and Maintenance Hall

9.2.1 Sizing the Depot

The stabling area is the largest and most important facility in a depot and it must be designed first. The number of vehicles to be stored and their length will mostly determine the size of the stabling area and the length of the tracks. The target is to maximise storage capacity, without reducing vehicle flows. Regarding the maintenance hall, if the fleet is made up of a single type of vehicle, the quantity of vehicles and the kind and scope of work to be carried out will determine the required quantity of work stands. As this requirement will of course have a direct impact on the maintenance hall's design, it will usually be discussed with the rolling stock manufacturer.

Table 21 below gives a recommendation on the quantity of vehicles required based on a 2-min headway for a round trip. The trip time is based off the journey time, as outlined in **Appendix D**, of 7.9 mins between Estuary and Dublin Airport, 19 mins between Dublin Airport and Ranelagh, in addition to a 15-min journey time between Ranelagh and Sandyford (existing LUAS Green Line journey time) with provision of 10 min driver rest period split between terminus stations.

Table 21: Estimated Fleet Size

Round trip time	2027	2057
Sandyford – Ranelagh		
Service (trams per hour)	9tph	15tph
No. of train sets	7	11
Ranelagh – Dublin Airport		
Service (trams per hour)	18tph	30tph
No. of train sets	16	27
Dublin Airport – Estuary P&R		
Service (trams per hour)	9tph	15tph
No. of train sets	5	7
Hot standby	3	3
Allowance for spares & maintenance	10%	10%
Fleet (total)	35	53

An initial assumption that **7** vehicles can be stabled at the existing Sandyford Depot site to make provision for the northbound start of service is provided in both phases, thus requiring a fleet of 28 vehicles to be stored at Estuary Depot in 2027, increasing to 46 vehicles by 2057. It is assumed that 90m vehicles are to be used for the service.

Table 22 below gives a recommendation based on the assumption that most of the maintenance work (except heavy maintenance) is carried out in the tram depot. It does not take into consideration special work places for painting or for wheelset machining.

Table 22: Recommended Work Stands

Kind of work stand	Recommended quantity of work stands* for a fleet quantity of 50
Outside vehicle cleaning	1
Thorough vehicle cleaning	0
Preventive maintenance of vehicles	1
Inspection	1
Corrective maintenance (multiple use)	4
Work stands (total)	7

Source: VDV Recommendations 823: Recommendations on the Design of Depots for LRVs and Tramcars, Köln 10/01

Table 23 below gives a recommendation of the key figures for the Estuary Depot.

Table 23: Key Figures

Stabling	
Stabling area	18,000 m^2
Number of tracks	12
Maximum capacity for trams	48
Length of the tracks	4,620 m (12 x 385 m)
Length of the tracks (expressed in number of standard vehicles with a length of 90 m)	48
Maintenance	
Maintenance area	3,200 m^2
Number of tracks	7
Maximum capacity for trams	7
Average number of trams	4
Length of the tracks	770 m
Warehouse area	400 m^2
Administration	
Offices & other rooms	3,000 m^2

9.2.2 Warehouse

A warehouse is for storing spare parts and consumables. It has to be accessible by forklifts or trucks and can be equipped with a racking system. Several warehouses may be planned for security reasons, to store dangerous products (solvents, batteries, etc.), often in line with local legislation. The design of the warehouse usually depends on the company’s chosen management system (barcodes, RFID tags, etc.). The main factors to be taken into account are:

- Vehicle types
- Scope of the maintenance
- Depot size.

9.3 Track map and Access

9.3.1 Description

The Estuary depot is designed to accommodate 46 vehicles of 90m length. The operators headquarters and parking provision are to be accommodated within the site layout.

Public road vehicles are separated from the track, with the depot access controlled by a security gate. Track crossings within the depot are limited to two at the entry/exit of the maintenance hall to allow access to the service stations, plant and waste storage. The separation between tracks and roads is very useful and allows the smooth flow of vehicles. The layout is adapted to the available space provided. The fact that both the access and the flows are independent ensures a high level of safety in relation to traffic accidents.

Turnback provision is allowed between Estuary Park &Ride station and the depot entrance, with a scissors crossover with 110m of run off track provided to allow for turnback operation with one or two rail tracks.

In general, the adopted track plan has taken into account the economic constraints and the depot functionality. A minimum radius of 50m with virtual transitions meet the track criteria for 15kph linespeed.

The depot is limited to one point of entry/exit to the main line due to the site layout, subsequently there are three distinct entries provided as branches within the depot allowing for different functions within the depot as follows:

- Direct entry/exit from the stabling area (future provision for ATO – run-around track to separate maintenance, cleaning and workshop from ATO section).
- Direct entry/exit from the maintenance hall and service stations.
- Two entry/exits points provided for the stabling area, maintenance and cleaning and workshop allowing for optimum operational movements with the layout.
- Shunting is not required for any vehicle movements to/from the stabling area and the maintenance, cleaning and workshop.
- Engineering sidings and test tracks are provided with access to the stabling area achieved through shunting on the loop line.
- The pedestrian pathways between car parks and workplace can be shortened to a minimum. Tram drivers do not have to cross the tram, which protects them from accidents with moving trams.

A plan of the depot showing the track system is provided in **Appendix H**.

9.3.2 Recommendations

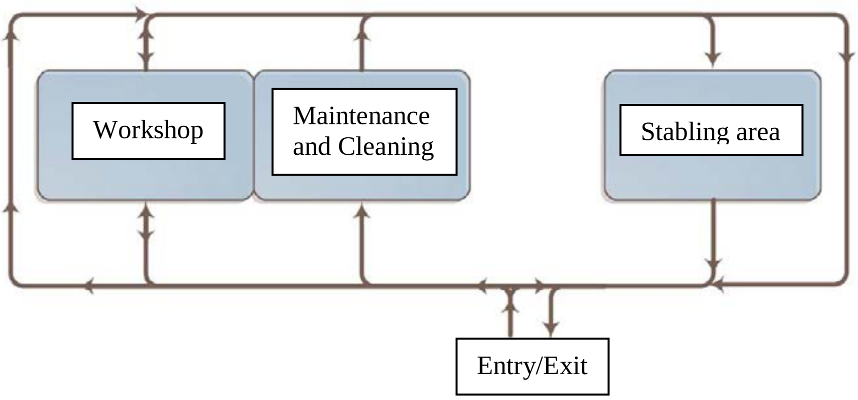
The track map consists of the various tracks necessary to move the vehicles in the depot area. It is strongly influenced by the construction site chosen for the project. The main goal when designing the track map is to ensure a smooth flow of trams, allowing flexibility and reliability.

Wherever possible, it is important to ensure that a depot always has at least two different exits and is linked to the network by two different routes. A 'spiderweb'-shaped network including many lines can facilitate this. There are several drawbacks to having just one entrance to the maintenance and stabling areas: this makes movements around the site more complicated and means there is no back-up solution in the case of an unexpected event occurring on the main entrance/ exit track. A back-up solution ensures the depot's operability even when a tram blocks one of the entrances. While this situation is relatively rare, it can lead to major delays in operations, thus downgrading the quality of service for customers.

Therefore, the right choice is a compromise between duplication costs and flexibility, if an incident or malfunctioning occurs. Each track section is renewed at least once every 30 years and usually for curves or switches. If the switches in front of the main depot entrance have to be renewed, the whole depot must be closed. Even if it is closed for just one weekend or during the summer holiday, this causes considerable organisational problems, such as relocation of drivers and new timetables. Another problem in this situation is that Sandyford Depot does not have the capacity to store more vehicles.

It is recommended that the different depot units be directly connected, to boost efficiency and avoid track crossings through anti-clockwise vehicle driving (rightdriven tracks). The implementation of a loop line, which encircles the depot and is accessible at several points, is recommended. This enables trams to leave and enter the different areas, such as stabling or maintenance, without the need to pass through them. This is outlined below.

Figure 33: Loop Line



Source: VDV Recommendations 823: Recommendations on the Design of Depots for LRVs and Tramcars, Köln 10/01

Pedestrian pathways between car parks, public-transport stops and the workplace should be as short as possible. These pathways should not cross the tram track and certainly should not cross the tram switches, in order to protect staff from accidents with moving trams.

Every track map is organised by taking into account a certain distance between adjacent trams on tracks. The recommendations for the Estuary Depot are detailed in Table 24 below.

Table 24: Distance between Adjacent Trams

Distance between the middle of two adjacent tracks (m)	Distance between two trams (m)	Remarks
3.8	1	Based on tram width of 2.65m.

Implementation of an automatic management system is highly recommended, to optimise tram movements on the site and prevent accidents.

9.4 Power supply

9.4.1 Electrical Division

The depot should be divided into main electric areas linked to the different maintenance and operation activities, for example workshop and maintenance area, washing area and stabling area.

Each area must have its own power supply and be electrically separated from the others, so that a power cut in any one area does not affect the others. It is also recommended that the depot be electrically insulated from the main power line. However, it is possible to connect the mainline to the depot in safety mode, to compensate for potential loss of traction power supply.

Each maintenance track must be supplied with electricity or insulated from other tracks by a traction switch box.

A neutral section makes it possible to separate the overhead line of the tracks inside the workshop from those outside. It can also be used for interlocking and protection against short-circuits.

9.4.2 Catenaries

Electrical power to the vehicles is mostly supplied through overhead lines called catenaries, which are in contact with the trams' pantographs. The traction power supply distributes a direct current (DC) at a voltage of 600V or 750V.

Most depots are equipped with flexible catenaries, similar to those found on the above ground section of the route. The nominal diameter of the contact wire may differ among operators, but a standard cross-sectional area of at least $100mm^2$ and preferably $120mm^2$ seems to the most economic.

A depot can also be equipped with fixed catenaries, which require less maintenance and provide a better power supply. Their major disadvantage is high installation costs.

Table 25: Catenaries Advantages and Disadvantages

	Advantages	Disadvantages
Flexible catenaries	Suitable for different tram heights	More maintenance
Fixed catenaries	Little maintenance required Better power supply More secure as they will not fall if broken	High purchasing costs

9.4.3 Security issues

Use of low-floor trams means that the roof of vehicles must be accessible for maintenance of the roof-mounted equipment. Specific safety measures must be foreseen to avoid staff being injured by the high voltage passing through the catenaries. Warning lights must be installed along and above each track, to inform drivers and technicians about the status of the track and whether the power supply is on. Emergency stop buttons must be implemented throughout the depot, so the power supply can be cut when necessary. If it is necessary to access the roofs of trams and to climb on platforms, the overhead current must be switched off and the switch secured by a lock. Any person working on the roof will have a personal access key for the lock, to ensure the current remains off until the work is complete, and it is safe for the current to be restored. Access stairs to the roof-level walkway will also have a locked gate, which can only be unlocked if the current is off.

Maintenance areas can be designed without catenaries to limit electrocution risks. In this case, tram movements are performed with towing vehicles (minimovers). Such a decision may be imposed by local legislation, to ensure high safety standards in the building.

9.5 Offices and Welfare Facilities

Besides maintenance and storage areas, large tram depots must include offices and welfare facilities. Welfare is an important factor and must not be neglected, as it increases staff motivation and performance. The challenge is to give administration and welfare areas a nice and relaxing atmosphere. Local legislation is very important here, as it clearly describes the minimum requirements for each kind of function. Nevertheless, project-makers may wish to offer more comfortable areas, in order to underline how much the company maintains a healthy and safe working environment whilst improving staff motivation and productivity. Design of the administration and welfare facilities should be thoroughly studied with workers' representatives, as well as health and security departments. The following areas should be included when designing the building:

A **reception area** including the visitors' entrance, reception desk and a waiting area.

Supervisors' rooms for managers organising the maintenance activities and hosting meetings with their staff. This/these room(s) must be adjacent to the drivers' room, to improve the communication.

Drivers' rooms meant for the daily start of services by tram drivers. This/these room(s) ideally should offer direct access to the storage area, in order to enhance the service. It/they may also include charts and display screens with operational information, computer terminals providing drivers with information, and lockable mailboxes for the transmission of instructions or data to the drivers.

Offices must be well planned, allowing both permanent staff and visitors to work in comfort. In most cases, rolling stock suppliers will request offices for their staff, particularly when part of the maintenance is subcontracted out.

Changing rooms: Every worker must be offered the use of a locker room and a wardrobe with a padlock in which personal belongings can be left. Maintenance staff can use double storage closets fitted with a separation, for separate storage of workshop clothing that may be dirty.

Showers and lavatories: Showers and lavatories should be installed adjacent to the changing rooms and separated for male and female staff (sized accordingly). Lavatories must be distributed throughout the premises.

Cafeteria and rest rooms: A cafeteria should be planned, to allow workers to share meals together. As tram depots are often located outside of the city, restaurants and snacks are seldom available within walking distance. Rest rooms allow staff to take a break in a quiet environment. These rooms should be equipped with entertainment equipment. Depending on the depot's time schedule, it may be useful to build overnight stay rooms for maintenance workers or drivers with late or early duties.

Medical room: This room is intended for dealing with minor injuries or holding more serious cases while awaiting professional medical assistance. A doctor's office is also advised, enabling a complete physical examination of patients: this office should include an examination bed and offer isolation to guarantee a patient's privacy.

Medical records must be stored with medical confidentiality in mind. The medical room must be easily accessible from all parts of the depot area and is best located on the ground floor, where an injured person can easily access it and/or be transported on a stretcher or in a wheelchair.

10 Park and Ride Facilities

10.1 Location

The park and ride facility for the new Metro North scheme is located at the end of the line north of Swords at the Estuary station. This location was chosen as a suitable area for a new facility based on the recommendation established in the GDA Transport Strategy document.

A Park and Ride facility on NMN is considered a strategic site. Such sites are generally located on the outskirts of the contiguous built-up area, or prior to the start of where significant congestion levels occur on the strategic road network. These sites are also located on the main orbital route to the city and close to strategic radial routes prior to congestion commencing. The primary function of such sites is to intercept car trips from the adjacent radial route, attracting trips from a number of origins whilst minimising abstraction from existing public transport services. Equally, the facilities must improve public transport accessibility without unduly worsening road congestion, or increasing the total distance travelled by car within the GDA. This means that Park and Ride should be located in areas where the road network has the capacity to absorb the impact of car traffic.

This facility will provide for 3,000 parking spaces in a multi storey building constructed alongside the Estuary at grade station.

10.2 General design principles

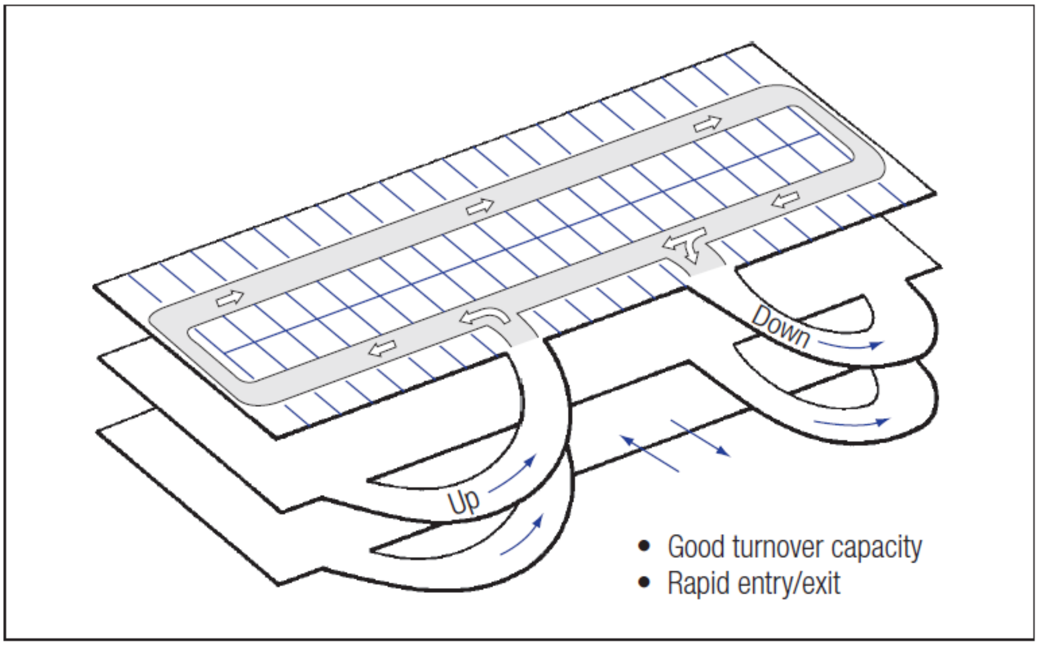
The space proofing for the building has been sized based on The Institution of Structural Engineers *Design Recommendations for Multi-Storey and Underground Car Park, 4th Edition.*

For larger car parks, such as the proposed facility at the Estuary Park and Ride, the preferred layout is usually a flat deck with straight or helical clearway ramps, as shown in Figure 34 below.

Design Assumptions include:

- Bay Size = 4.80m x 2.40m
- 90° parking angle
- Aisle – one way – 6m wide
- Flat deck car park with external ramps
- Maximum search path for incoming drivers - 500 bays = 1,150m
- Two emergency access stairs
- Access bridge to central platform from Level +1

Figure 34: Flat deck car park with external ramps



The space available at Estuary station for a multi-storey park and ride facility has an available footprint of approximately 16,000m^2.

Assuming four circulation lanes will be required and a required parking bay area of 11.52m^2 approximately 766 spaces can be accommodated per floor meaning the multi-storey building will need to be at least 4 storeys tall.

11 Ground and Groundwater Conditions

11.1 Available Information

11.1.1 Background

In preparing and interpreting the ground conditions along the alignment all exploratory information within 100m of the alignment has been considered. There are a total of 624 exploratory locations along the alignment. The locations have a variety of sources which include the preliminary and detailed site investigations for the Old Metro North project as well as multiple non-project specific boreholes. The quality of this information varies due to the age and reason for investigation. The information includes:

- Trial Pits
- Cable Percussion Boreholes
- Rotary Coreholes
- Geophysical Investigations
- In-situ tests
- Laboratory tests

Geological plans and profiles are provided in drawings 252252-ARP-EGT-SW-DR-CG-0028-0067. The concept engineering design for the geotechnical engineering of the stations is developed from this information.

11.1.2 Ongoing Site Investigation for Concept Engineering Design

A gap analysis of the available information was carried out to determine any area where there is a significant shortage of ground information. As a result of this analysis four exploratory locations were recommended for further site investigation to be carried out. A combination of cable percussion, and Rotary Core (Geobore-S and conventional HQ coring) holes are investigated. The locations of the proposed boreholes are shown on drawings 252252-ARP-EGT-SW-DR-CG-0028-0067.

11.1.3 Other Sources of Information

Additional resources have been used to help inform the ground conditions along the route. These include:

- Ordnance Survey Maps
- Aerial Photography
- Geological Survey of Ireland Mapping

- Teagasc and the Environmental Protection Agency Irish Soil Information System
- Environmental Protection Agency (EPA) Datasets
- Topographical Maps
- Lidar Data

11.2 Geological Setting

The drift and bedrock geology of Dublin along the New Metro North route are presented on drawings 252252-ARP-EGT-SW-DR-CG-0028 to 0067. The overburden and bedrock maps were produced from an ESRI GIS shape file issued by the Geological Survey of Ireland (GSI) in 2016. The project area has been highlighted and the approximate route has been superimposed for clarity.

The geological development of the bedrock and soils in the Dublin area has been dominated by:

- Erosional processes during the Tertiary period immediately preceding the "ice age", which can be attributed to the uneven surface of the underlying Carboniferous bedrock, consisting of limestone, mudstone and shale strata,
- Glacial and post-glacial processes related to various glaciations of the Dublin area, resulting in the deposition of glacial and fluvioglacial sediments, while glacial erosion led to small-scale undulation of the rock surface,
- Alluvial, marine and estuarine sedimentation processes, resulting in the deposition of recent soft alluvial and estuarine deposits, and
- Human activities, leading to the reclamation of large estuarine areas by deposition of artificial, man-made materials and re-deposited natural materials.

The generalised soil sequence along the alignment consists of glacial deposits overlying Carboniferous Limestone bedrock. In the centre of Dublin and in other urban areas, made ground overlies the glacial deposits. Alluvial and estuarine deposits are generally found in the river valleys.

11.3 Groundwater

Numerous groundwater installations were installed as part of the Preliminary Site Investigation and the Main Ground Investigation of Old Metro North. The data typically indicates the presence of two phreatic surfaces, an upper phreatic surface in the overburden that is confined by the Dublin Boulder Clay, and a lower phreatic surface located 40-50 m below ground level in the bedrock. An analysis of the fluctuations in groundwater level between summer and winter was carried out based on the groundwater monitoring and little difference was noted. A characteristic value for the groundwater level has been identified at each station location and is summarised in **Appendix F**.

11.4 General Stratigraphy

11.4.1 Introduction

The ground stratigraphy along the route is variable with a typical simplified downward sequence of

- Made Ground
- Estuarine/Alluvial or Glaciomarine deposits.
- Dublin Boulder Clay and/or Glacial Sand/s/Gravels
- Bedrock

The following sections provide a more detailed description of each of these strata.

11.4.2 Made Ground

As expected with an urban route much of the upper surface is covered by Made Ground, varying from hardcore and road building materials to general in-filling of depressions/regrading of slopes to more substantial filling closer to the River Liffey.

Medieval maps of Dublin show the original broad expanse of the River Liffey which opened into Dublin Bay much further west than at present. There would also have been much stronger tidal currents than they are at present. Many areas have been artificially raised during eleven hundred years of continuous habitation rebuilding. The locations of several former quarries and gravel pits are indicated by historic plan, most notably at the Dublin Airport station. It is likely that these former quarries and pits were backfilled in an uncontrolled, or non-engineered, fashion.

Previous ground investigation reports state that the Made Ground encountered typically varied between 0.8m and 9.0m in thickness and was found in a relatively high proportion of exploratory holes. Where encountered, the Made Ground was generally comprised of gravel and cobbles sized fragments of limestone and mudstone, together with a mix of brick and concrete, although locally other materials such as wood, glass and pottery were identified.

Due to its variable nature, the excavated Made Ground is unlikely to be suitable for refuse as a fill material and will probably be sent to a licensed or permitted site for disposal.

Locally extensive areas of Made Ground are located at the following locations:

- North and south of the River Liffey in Dublin City Centre – up to 5m at Earlsfort Terrace;
- Along Ballymun Road between Dublin City University and Ballymun Village Stations;
- Along the Swords by-pass between the Fosterstown-Swords Central-Seatown Stations.

11.4.3 Estuarine/Alluvial Clays & Silts

The proposed route crosses the River Liffey at Ch 3+100. The medieval river channel extended further to the North and to the South than its present course. Within the estuarine area soft to stiff estuary clays and silts (with occasional interbedded sands) are likely to overlie an upper alluvial gravel horizon. Young silts and sands were also likely to be deposited in old ponds, streams or small-scale depressions, and may be found as isolated pockets or along infilled channels on top of the boulder clay. The subsequent developments on either side of the River Liffey has probably resulted in the Estuarine/Alluvial clays and silts being consolidated by the overburden and led to stiff to locally very stiff consistencies. The silts are expected to contain some organic matter.

Alluvial silts and sands are also anticipated along the Tolka River, Broad Meadow River and also may occur along superficial natural streams or drainage channels which were frequently filled with made ground within recent centuries.

11.4.4 Estuarine/Alluvial Sands & Gravels

Water-saturated estuarine/alluvial gravels and sands commonly form the uppermost strata along the existing River Liffey channel and the prehistoric/pre-glacial river channel located to the north of the existing course. The usually dense to very dense sub-angular to sub-rounded sandy gravels and gravelly sands are locally overlain by a thin layer of very recent soft alluvial clays and silts or glaciomarine sediments. Alluvial gravels and sands may also occur along superficial natural streams or drainage channels which were frequently filled with made ground within recent centuries.

11.4.5 Glaciomarine Clays, silts & sands

Glaciomarine sediments consist of soft to firm sandy, clayey silts and medium dense to dense silty sands, locally interstratified with thin laminae of clay. In some cases, the strata will contain shelly fragments. The deposit is overlain by the most recent estuarine/alluvial gravels and underlain by a previous generation of estuarine/alluvial gravels or boulder clay. The clays, silts and sands were deposited under marine interglacial conditions along the coast and within the ancient estuary areas of the River Liffey. The top and the base of the sequence are often characterised by a transitional zone of clayey, silty gravels.

11.4.6 Dublin Boulder Clay (DBC)

Dublin Boulder Clay is a stiff to very stiff glacial till found throughout the route. The till is a well graded soil with numerous cobbles and boulders (the size of the boulders can vary from 0.5m to 3.0m). It is present close to the ground surface along the majority of the alignment apart from the following locations:

- In the vicinity of the River Liffey; and
- In the vicinity of the Pre-Glacial Liffey Channel

The till is predominantly derived from Carboniferous Limestone, although the lower units include Old Red Sandstone, schists, quartzites, vein quartz and igneous rocks including a number of granites (Long and Menkiti, 2006)[8].

The construction of the Dublin Port Tunnel (DPT), which runs approximately 1-2kms parallel to Metro North between Griffith Avenue and Ballymun, has allowed investigators to examine the stratification of Dublin Boulder Clay (DBC) in detail. Skipper et al. (2005)[9] have presented a detailed interpretation of the glacially derived quaternary geology while Long and Menkiti (2006 and 2007)[8,10] have presented a detailed summary of the geotechnical characteristics.

The Dublin Boulder Clay is reinterpreted to comprise of four major units and associated sub units. The following descriptions of the units are taken from Long and Menkiti (2007)[10].

11.4.6.1 Upper Brown Boulder Clay (UBrBC)

This is the weathered uppermost formation of the DBC. It is a 2–3m thick, stiff to very stiff, brown, slightly sandy clay, with rare silt/gravel lenses and some rootlets, particularly in the upper metre. Farrell et al. (1995)[11] have confirmed that this material is the weathered zone of the underlying Upper Black Boulder Clay (UBkBC), and that oxidation has produced the brown colour. The UBrBC represents a complex pedogenic horizon, which developed during a period of climate warming and glacial retreat after the deposition of the UBkBC. Farrell and Wall (1990)[12] note that not all brown boulder clays are products of weathering of the underlying UBkBC. The brown colour is from a concentration of material of that colour and these would be expected to have similar properties to the UBkBC.

11.4.6.2 Upper Black Boulder Clay (UBkBC)

This is a very stiff, dark grey, slightly sandy clay, with some gravel and cobbles. It is typically 4 – 12m thick. Rare, sub-vertical, rough and very tightly closed fissures spaced at 0.5 – 0.75 m were observed at some locations. Considerable mechanical effort was required to excavate the material, which tended to break into peds of similar dimensions. In the DPT project, these fissures were observed to be so tightly closed in the in-situ material that they could not be seen in borehole cores and were obvious only in excavated material and slopes owing to the manner in which the material broke apart.

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[8] Long, M. and Menkiti, CO. (2006). Characterisation and Engineering Properties of Dublin Boulder Clay. The Second International Workshop on Characterisation and Engineering Properties of Natural Soils, Singapore, 29 November - 1 December 2006
[9] Skipper, J., Follet, B., Menkiti, C. O, Long, M. and Clarke-Hughes, J. (2005). The engineering geology and characterisation of Dublin Boulder Clay. Q. J. Engng Geol. Hydrogeol. 38, No. 2, 171– 187.
[10] Long, M. & Menkiti, C. O. (2007). Geotechnical properties of Dublin Boulder Clay, Géotechnique 57, No. 7, 595–611
[11] Farrell, E. R., Coxon, P., Doff, D. & Pried'homme, L. (1995a). Genesis of brown boulder clay in Dublin. Q. J. Engn geol. 28, No. 2, 143–152.
[12] Farrell, E. R. & Wall, D. (1990). The soils of Dublin. Trans. Instn Engrs Ireland 115, 78–97.

Thin horizontal cobble lines of striated, faceted cobbles are frequently seen, which persist laterally for tens of metres before terminating abruptly. These are associated with the sub-horizontal discontinuities and possibly with shear planes within the lodgement till. Occasional small gravel lenses occur along the cobble lines, and these may be water bearing.

It was observed during the Dublin Port Tunnel (DPT) project that the gravel lenses and cobble lines constitute a network that appears to be hydraulically interconnected in some areas and hydraulically isolated elsewhere.

11.4.6.3 Lower Brown Boulder Clay (LBrBC)

The LBrBC exists as a 5 – 9m thick, hard, brown, silty clay, with gravel, cobbles and boulders. It has previously been called the 'sandy boulder clay' as it is similar to but siltier than the UBkBC above. The unit contains more frequent, larger and more complex silt/gravel lenses and cobble lines than the UBkBC. At the DPT site a continuous 2m thick layer of silty sand/fine gravel exists within the unit at 10 – 16m depth.

11.4.6.4 Lower Black Boulder Clay (LBkBC)

The LBkBC is a patchy layer of hard, slightly sandy, gravelly clay with an abundance of boulders. It is generally more plastic to the touch than the LBrBC. Its thickness does not exceed 4m and is typically less than 2m.

11.4.6.5 Glacial Sands & Gravels

Glacial gravels within the boulder clay consist typically of very dense, angular to sub-angular sandy, slightly silty gravels or very gravely, slightly silty sands.

The deposits occur commonly as water bearing lenses of variable lateral and vertical extent and thickness, ranging from several centimetres to several meters, and are commonly not inter-connected. They were presumably deposited under fluvioglacial conditions in glacial ponds or small streams.

Buried glacial river channels of possibly larger linear extent, filled with glacial sediments, are expected within the Pre-Glacial Liffey channel located north of the present course in the area around the Mater Hospital and Parnell Square, where O'Connell Street Station is located. The geology of the pre-glacial channel is complex with Dublin Boulder Clay generally occurring above and below the glacial sands and gravels.

11.4.6.6 Bedrock

Limestone is the predominant rock type for the route and can be split into three different formations:

- Calp/Lucan Limestone Formations (varied dark grey to black fine grained, graded limestone interbedded with poorly fossiliferous shale in several different formations that are undifferentiated on the geological map) underlies the alignment from St Stephen's Green East station to just north of the M50 between the Northwood West and Dardistown stations.;
- The Tober Colleen Formation (dark grey, calcareous, commonly bioturated mudstones and subordinate thin micritic limestones) extends from between the Northwood West and Dardistown stations north to Dublin Airport;
- Waulsortian Limestones (massive unbedded reef limestones) underlie only the area around Dublin Airport;
- The Malahide Formation (Calcareous shales, siltstones and sandstone, and thin limestones; pedoidal and oncholotic, occasionally nodular, micrites; fossiliferous limestones and shales, with oolites and sandstone; argillaceous limestones, nodular limestones and shales) underlies the alignment north of the airport to Estuary Park and Ride.

11.5 Ground Conditions Along Route

The ground conditions expected along the route, at station locations, at portal locations and at the intervention shaft are shown on a series of geological long sections presented on drawings 252252-ARP-EGT-SW-DR-CG-0026 to 0067.

These conditions are generalised and are presented for concept stage only and are subject to further development/refinement during subsequent design stages. A description at each station and alignment section is provided in **Appendix F**.

11.6 Support of Excavations (SOE)

This section summarises the support of excavation (SOE) required at each of the major excavations along the New Metro North alignment.

11.6.1 Support of Excavation (SOE) Types

For the concept engineering design, there are four types of SOE considered for the station, portal and shaft excavations. The primary design considerations for the SOE system are:

- To support the lateral pressures imposed during the temporary construction stage and permanent conditions;
- To ensure satisfactory toe stability during excavation;
- To support vertical loads where applicable;
- To minimise lateral movements and associated ground movements;
- To ensure a satisfactory factor of safety against flotation and uplift; and
- To provide an adequate embedment to provide hydraulic cut-off.

These considerations are non-exhaustive and some only apply to fixed wall solutions. These four types are chosen to reflect the key variations in the depths and geological conditions at all the station that have been identified at this stage.

1. Open Cut – This system is comprised of battered (sloped sides) excavation down to the formation level. The slopes may require some slope support measures depending on the available land and depth required.
2. Secant Pile Wall - This system consists of a stiff reinforced concrete wall formed from overlapping hard and soft piles. The overlap allows a watertight connection to be formed. Additional support is required in the form of external ground anchors or internal props to support the wall as excavation advances.
3. Open Cut or Secant Wall Pile with Rock Support – This system is used where rockhead is shallow and a significant portion of the excavation will be formed in rock. The overlying overburden is supported using an open cut or fixed wall system as described above. The rock is excavated and support is provided in the form of shotcrete and rock bolts installed in the rock face.
4. Diaphragm Wall – This system consists of a series of very stiff reinforced concrete panels installed around the perimeter of the excavation. This forms an effective watertight barrier. Additional propping is required to support the wall as excavation advances.

A summary of the key considerations with each system is provided in Table 26 below.

Table 26: SOE Key Considerations

Factor	**Open Cut (in Rock)**	**Secant Pile**	**Open Cut or Secant Pile with Rock Support**	**Diaphragm Wall**
Water Tightness	Additional water control measures required, if necessary	Effective at shallow to medium depths	Additional water control measures required, if necessary	Very Effective
Wall Stiffness and Ground Movement	Good control of adjacent movement only on Rock but wider influence of works due to slope. (Not appropriate to soil due to large temporary slope angles)	Offers good control of ground movements	Offers good control of ground movements, however open cut will have wider influence	Stiffest system would offer the best control of ground movement
Construction	Simplest form of construction, requires less specialist sub-contractors	Moderate sized equipment required on site	Moderate sized equipment required on site	Large sized equipment required on site

Factor	Open Cut (in Rock)	Secant Pile	Open Cut or Secant Pile with Rock Support	Diaphragm Wall
Economy	Most cost-effective solution for shallow excavations where there is limited adjacent structures or services.	Cost effective for shallow wall depths (<18m). Suitable for contoured walls.	Cost effective method of removing overburden to allow excavation in rock	Most expensive but cost effective for large deep sites (>18m). International contractors only

11.6.2 Proposed SOE solutions

The following SOE are proposed for the stations for the concept engineering design stage. The proposed solutions are not final and are subject to a detailed review of the ground conditions and final station layout at each location.

Table 27: SOE solutions for Underground Stations

Station	Station Type	Av. Depth to track (m)	SOE Type
St. Stephen's Green East	-2 levels	23.9	Secant pile and Rock Support
Tara Street	-3.5 levels	24.8	Secant pile and Rock Support
O'Connell Street	-3 levels	24.0	Diaphragm Wall
Mater Hospital	-3 levels	25.0	Diaphragm Wall
Whitworth	-3.5 levels	23.9	Diaphragm Wall
Griffith Park West	-3 levels	24.0	Diaphragm Wall
Dublin City University	-2 levels	18.3	Secant Pile Wall
Ballymun Village	-2 levels	18.0	Secant Pile Wall
Northwood West	-1 level	13.9	Open Cut
Dardistown	-1 level	19.0	Open Cut
Dublin Airport	-2 levels	18.9	Secant Pile and Rock Support

The following SOE are proposed for the portals for the concept engineering design stage.

Table 28: SOE solutions at portal locations

Station	Portal Length	Depth (m) to track	SOE Type
Charlemont Portal	320m	0 to 13m	Secant pile
Northern Portal	79m	0 to 13m	Secant pile

The support of excavation measures for the intervention shaft are proposed to be a secant pile wall.

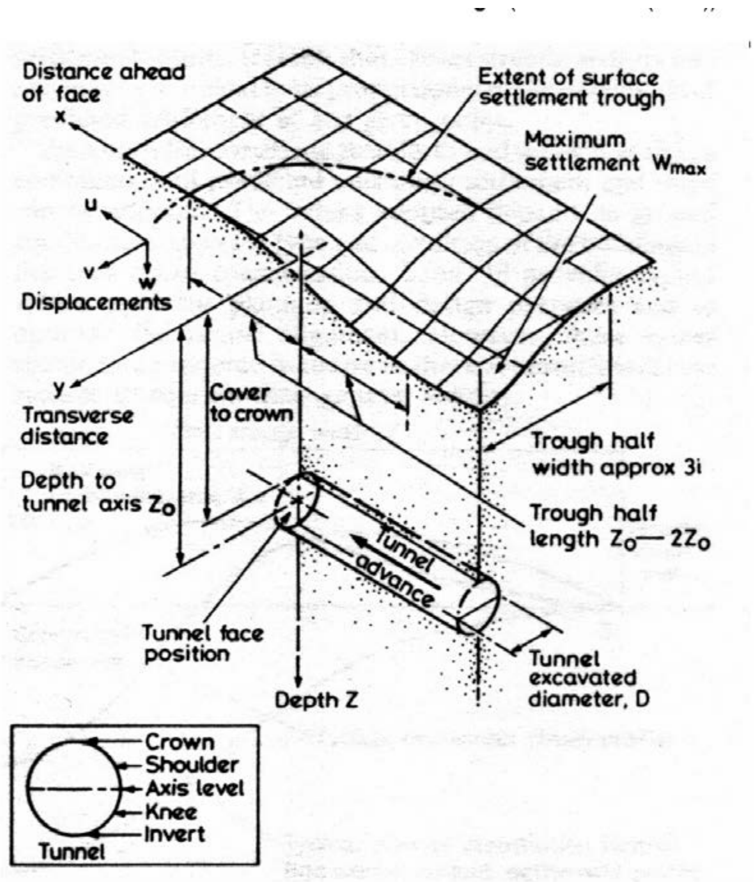
11.7 Ground Movement

A preliminary settlement assessment has been carried out along the alignment using Oasys Xdisp, a programme used to calculate ground movements due to the underground works. Xdisp was used to calculate vertical at ground level due to the tunnels, stations, shaft and portals only.

The tunnel movement is assessed using gaussian curve theory, which is an empirical method widely used in assessing settlement due to the tunnelling works. A schematic diagram of a 3D settlement profile of a tunnel is shown in Figure 35.

The ground movement for the shaft, stations and portal uses typical ground movement profiles behind a secant pile / diaphragm wall in line with CIRIA 580[13].

Figure 35: 3D Schematic of Settlement Trough (Yeates, 1985)[14]



The following assumptions were used in the assessment of the settlement:

- Assessment is preliminary only and provided for information. Further assessment is required as the design is developed and the ground model is refined.

[13] Construction Industry Research and Information Association (CIRIA) Report C580 (2003). Embedded retaining walls - guidance for economic design.
[14] Yeates J (1985). The response of buried pipelines to ground movements caused by tunnelling in soil. In: Geddes JD(ed) Ground Movements and Structures. Pentech Press, Plymouth. pp 145–160.

- Tunnel level based on the latest vertical alignment
- Ground level based on LiDAR survey
- No settlement where the tunnel is located entirely within rock
- Typical volume loss of 1.5% taken as a conservative value for preliminary assessment
- Volume loss of 2.0% taken within the pre-glacial Liffey channel
- Assessment does not take into account any building within the zones or propose any contingency measures at this stage. A staged assessment of the buildings within the settlement contours will be required at subsequent stages of design

The ground movement contours are shown in **Appendix G.**

12 Construction Planning

12.1 General principles

The Concept Design construction strategy has been developed on the following assumptions:

- Tunnels will be constructed by TBM.
- Two drives of two machines each are envisaged, one southwards from the north portal at Naul Road to Griffith Park West Station, and one southwards from Griffith Park West Station to the Charlemont tie in.
- The viaducts could be constructed either by in-situ method or by using a precast system.
- The underground stations will generally be constructed using a bottom up method where possible as this is lowest cost and quickest. A topdown approach may be required in the city centre areas where a full open cut is not possible (e.g. O'Connell St and St Stephens Green)
- Elevated Stations will be constructed using in-situ methods. Some precasting of repetitive elements e.g. platform slabs, staircases could be possible to maximise offsite time and minimise construction disruption.

12.2 TBM Launch Sites

As outlined above, two TBM launch sites are required for the scheme to meet the construction programme. The first of these will be located north of the Naul Road in an area of open agricultural land where the TBM section ends and it transitions to at grade running. Such a location is desirable as it is co-located at the end of the TBM and at the construction site for a portal which facilitates this transition from underground to at grade running. The location is also desirable due to ease of access to the road network and availability of sufficient space for the necessary infrastructure needed to launch a TBM and store material associated with tunnelling works and construction.

The second launch site is required approximately half way along the TBM length meaning where possible between Collins Avenue and Phibsborough. In selecting a suitable location, the launch site needed to be located along the tunnel alignment, to have road access and sufficient open space available for constructing the launch portal and storage of materials. In addition to these requirements it was deemed preferable to co-locate the launch site with an underground station to make use of the excavation completed for the launch portal to construct the station thereby not only reducing costs but all minimising impacts on the receiving environment.

12.3 TBM Tunnels

There is a total of approximately 13km of twin track tunnel to be excavated by TBM. It is proposed to split the tunnelling into two main drives with each drive utilising two tunnel boring machines. The project will use a total of four TBMs.

The first drive is proposed from the Northern Portal at Naul Road to Griffith Park West Station. A TBM staging area is required at the northern portal to provide back-up to the 7.6km northern drive. A plan of the staging area is shown on 252252-GEN-SW-DR-CX-0002.

The second drive is proposed from Griffith Park West Station to the Southern Portal at Charlemont. A TBM staging area is required at Griffith Park West Station to provide backup to the 5.4km southern drive. A plan of the staging area is shown on 252252-GEN-SW-DR-CX-0003.

As the tunnels are advanced, there will be different interactions between the stations and tunnels. Some stations will not have excavated to tunnel level prior to the TBM passing and the TBM will “drive through” the station and the station excavation will involve the careful excavation around and dismantling of the tunnel lining. The second scenario is where the station has already been excavated to tunnel level and the TBM is “pulled through” the station and relaunched at the opposite end.

Cross passages will be constructed using traditional mining methods after completion of the main TBM tunnel drives.

12.4 Spoil Management

The civil works for New Metro North will generate a significant volume of spoil, particularly from the tunnel, underground station, portal and shaft works. The current estimate is that 2.5M to 3.0M tonnes of soil, rock and contaminated ground will be generated over the duration of the project. The storage, transport and disposal of this material will present a serious challenge. The current cost estimates allow for transport and disposal of all material to landfill with high costs for transport and waste levies. Any opportunities for potential re-use of the material on the Metro North project or on any other local or national project should be explored as significant savings on spoil disposal could be realised.

Typically, the spoil will be generated locally at underground station, portals, shafts locations as well as at the northern and southern tunnel launch sites. The material will be locally stockpiled temporarily on these sites before being transported by truck for re-use / disposal. Special treatment may be required for any contaminated material. Once the location for the spoil has been identified a spoil management plan should be prepared detailing the source, destination, number of truck movements and routes for transport of the spoil.

13 Cost Estimate

A cost estimate has been prepared for the concept engineering design alignment including all elements from the Green Line Tie-In to Estuary Park and Ride and Depot. The detailed cost estimate is provided in document reference 252252-ARP-GEN-SW-RP-CX-022. The costs shown in . The costs are based on 2017 prices and the total includes for direct cost of works, preliminaries, tunnelling, rolling stock, line-wide services (power, P-way, OHL, M&E), property acquisition, contractor overhead, contractor profit, bonds and sureties, design, project management, insurance and contingencies.

It should be noted that these Direct and Indirect Costs are prepared based on the level of engineering detail (concept design) at this stage. These costs are not fixed and are subject to further assessment once the Preliminary Engineering Design has been developed, confirmation of the final operating philosophy is finalised and a final assessment of the risk/contingency at that point in time.

Table 29: Concept engineering design costs (Green line tie-in to Estuary Depot)

Cost Item	Direct Costs	Contingency	Indirect Cost
Stations	*€850M*	*€252M*	*€125M*
Intervention Shaft	*€14M*	*€4M*	*€2M*
Tunnelling	*€538M*	*€120M*	*€74M*
Portal	*€17M*	*€5M*	*€2M*
Cut and Cover	*€58M*	*€17M*	*€9M*
Surface	*€167M*	*€42M*	*€24M*
Line-wide services	*€447M*	*€150M*	*€68M*
Depot	*€90M*	*€36M*	*€14M*
Park and Ride	*€47M*	*€12M*	*€7M*
Others	*€25M*	*€7M*	*€4M*
Third Party	*€137M*	*€36M*	*€20M*
Testing and Commissioning	*€17M*	*€7M*	*€3M*
Subtotal	*€2,406M*	*€688M*	*€350M*
TOTAL COST	**€3,444M**		

Notes:
1. Direct cost includes cost of works, preliminaries, contractors' overheads, contractor's profits and bonds and sureties
2. Contingency is 25-40% of the direct costs (varies by cost item).
3. Indirect costs include insurance, design costs and project management costs.

The following items are excluded from the cost estimate:

No.	Exclusion
1	Ground improvement works
2	Mitigation measures
3	Works related to building damage due to the works
4	Utility diversions except major utilities at stations
5	Re-use of material beyond an assumed 25%
6	Connections to existing infrastructure except Tara station

14 Conclusion

In summary, this Concept Engineering Design Report has outlined the design basis supporting the concept engineering design of the EPR for New Metro North.

The report covered the development of the route from EPR to concept, the expected passenger demand, the alignment, the fire and life safety strategy, station design, tunnel design, civil works, depot sizing, ground conditions and construction planning. There is also a cost estimate has been carried out and determined the total cost of the concept engineering design to be €3,444M based on the design drawings in Volume 2 of this report. Volume 2 contains the following drawings relating to each of the design elements:

- Rail Alignment as detailed in the:
  - Plan and profile drawings 252252-ARP-RL-SW-DR-RX-0001 to 0042
- Fire and Tunnel Ventilation Strategy as detailed in the:
  - Plan and profile drawings 252252-ARP-RL-SW-DR-RX-0001 to 0042
  - Intervention Shaft drawings 252252-ARP-SGN-SW-DR-RC-0001 to 0002
  - Cross Passage drawings 252252-ARP-STU-SW-DR-CT-0002
- Station Planning as detailed in:
  - Typical -3 Level Stations 252252-ARP-AGN-SW-DR-AX-0101 to 0103 and 252252-ARP-AGN-SW-DR-AX-0201 to 0202
  - Typical -2 Level Stations 252252-ARP-AGN-SW-DR-AX-0111 to 0113 and 252252-ARP-AGN-SW-DR-AX-0211 to 0212
  - Typical -1 Level Stations 252252-ARP-AGN-SW-DR-AX-0141 to 0142 and 252252-ARP-AGN-SW-DR-AX-0241 to 0242
  - Typical Elevated Stations 252252-ARP-AGN-SW-DR-AX-0121 to 0123 and 252252-ARP-AGN-SW-DR-AX-0221 to 0222
  - Typical At Grade Stations 252252-ARP-AGN-SW-DR-AX-0131 to 0132 and 252252-ARP-AGN-SW-DR-AX-0231 to 0232
  - Tara Street Station 252252-ARP-AGN-A1-DR-AX-2101 to 2105 and 252252-ARP-AGN-A1-DR-AX-2201 to 2202
  - Whitworth Station 252252-ARP-AGN-A1-DR-AX-5101 to 5106 and 252252-ARP-AGN-A1-DR-AX-5201 to 5202
- Tunnels as detailed in:
  - Plan and profile drawings 252252-ARP-RL-SW-DR-RX-0001 to 0042
  - Cross Passage drawings 252252-ARP-STU-SW-DR-CT-0001
  - Northern Portal Plan and Sections 252252-ARP-SGN-SW-DR-RC-0005 to 0006
- Civil Works as detailed in:

- Station Street Level Layouts 252252-ARP-AGN-A1-DR-AX-0001 to 0004
- Station Street Level Layouts 252252-ARP-AGN-A2-DR-AX-0005 to 0011
- Station Street Level Layouts 252252-ARP-AGN-A3-DR-AX-0012 to 0015

- Estuary Depot as detailed in:
  - Depot Layout 252252-ARP-RL-SW-DR-RT-0034
- Ground and Groundwater Conditions as detailed in:
  - Plan and profile drawings 252252-ARP-EGT-SW-DR-CG-0026 to 0067
  - Ground Movement drawings 252252-ARP-EGT-SW-DR-CG-0068 to 0076
- Construction Planning as detailed in:
  - Northern Launch Site Plan 252252-ARP-GEN-SW-DR-CX-0002
  - Southern Launch Site Plan 252252-ARP-GEN-SW-DR-CX-0003

Appendix A

Track Alignment Criteria

Table 30: Track Alignment Criteria

Ref		Parameter	Unit	Desirable	Limiting	Exceptional
1		**Design Speed (V)**				
	a)	Maximum line speed for Running Lines	km/h		70	
	b)	Maximum line speed for Depot Lines	km/h		15	
2		**Geometric Element**				
	a)	Minimum length of horizontal straight and circular curve element	m	V/1.8	30	12
	b)	Minimum length of transition curve element	m	See Ref 6	See Ref 6	
	c)	Minimum length of vertical straight element	m	V/1.8	30	
	d)	Minimum length of vertical curve element	m	See Ref 7	See Ref 7	
3		**Horizontal Curve**				
	a)	Minimum horizontal radius without applied cant	m	$0.15V^2$	$0.12V^2$	
	b)	Minimum horizontal radius with applied cant	m	$0.059V^2$	$0.054V^2$	
	c)	Maximum horizontal radius	m			25,000
	d)	Minimum horizontal radius in platforms	m	Straight	Straight	1,000
4		**Acceleration and Cant**				
	b)	Maximum horizontal non-compensated centrifugal acceleration	m/s^2 (g)	0.52 (0.053)	0.65 (0.066)	
	e)	Maximum applied cant Maximum applied cant in platforms	mm		120 0	
	f)	Excess cant	mm	0	Excess cant, subject to approval, may occur on curves near stops due to the acceleration and deceleration of trams	
	g)	Negative cant	mm	0	Negative cant is only permitted on or adjacent to switches and crosses and at particular road crossings	
	h)	Maximum cant deficiency	mm	80	100	
	i)	Excess cant deficiency	mm	25	C/CD Ratio of 100%	
	j)	Rate of change of cant (RoCC)	mm/s	30.70	55	
	k)	Rate of change of cant deficiency (RoCD)	mm/s	30.70	60.80	
	l)	Maximum jerk rate	m/s^3	0.2	0.3	0.4
	m)	Maximum cant gradient Minimum cant gradient	mm/m (1 in)	180/V or 2 (500) 45/V	180/V or 3 (333) 45/V	180/V or 4 (250) 45/V
5		**Transition Curve**				

Ref		Parameter	Unit	Desirable	Limiting	Exceptional
	a)	Transition curves shall be clothoids				
	b)	Virtual transitions should not be used		In exceptional circumstances, for example in station areas and other areas with spatial constraints, the principle of a virtual transition may be applied. The length to be used for the virtual transition shall be 12m		
	c)	Reverse horizontal curves (with zero length straight between curves or transitions)		Could be implemented in particular situations if the minimum horizontal straight length is not achievable, once the following criteria are met: $CG_{curve\ 1} = -CG_{curve\ 2}$ $RoCD_{curve\ 1} = RoCD_{curve\ 2}$		
5.1	a)	Minimum transition curve length based on RoCD		0.0090 x CD x V	0.0046 x CD x V	
	b)	Minimum transition curve length based on passenger comfort		0.0076 x CD x V	0.0061 x CD x V	0.0046 x CD x V
	c)	Minimum transition curve length based on no cant applied		0.107 x V^3/R	0.071 x V^3/R	0.054 x V^3/R
	d)	Minimum transition curve length based on RoCC (cant applied)		0.0090 x CD x V	0.0051 x CD x V	
5.2		Determination of transition curve length will be the greater of NOTE: In addition to the criteria listed 6.1 a) – d) above, other criteria such as Cant, Cant Deficiency, Cant Gradient and Jerk Rate also need to be satisfied		0.0090 x (CD1-CD2) x V or 0.0090 x (C1-C2) x V	0.0046 x (CD1-CD2) x V or 0.0051 x (C1-C2) x V	
6		**Vertical Curve**				
	b)	Maximum vertical gradient	%	2.0	4.0	*Platforms max. 4.0. 6.0, along a max. 15m section. 8.0, along a max. 250m section, straight section only and where no planned stopping will occur.
	c)	Minimum vertical gradient	%	1.0	0.5	0.0 in platform in underground stations
	f)	Maximum vertical centrifugal acceleration	m/s^2 (g)	0.20 (0.02)	0.30 (0.03)	
	g)	Minimum radius of vertical curve	m	$0.386V^2$ (+) 600m (sag)	$0.257V^2$ (+) 350m (sag) (-) 700m (hog)	

Ref		Parameter	Unit	Desirable	Limiting	Exceptional
	i)	Minimum length of vertical curve, based on gradient change	m	$(g1-g2)V^2/259$	$(g1-g2)V^2/389$	
	j)	Maximum gradient for hump profile at stations Minimum vertical gradient length	% m	 200	2.86	

A1.1 Design Speed

The maximum line speed will be 70km/h for Running Lines, and 15km/h for Depot Lines.

A1.2 Geometric Element

The desirable length of horizontal straight and circular curve element should be based on a minimum vehicle travel of 2 seconds of line speed, as defined below, or 30m, whichever is greater:

$$L_{des} = \frac{V}{1.8}$$

where:
Ldes desirable minimum length of horizontal element (m)
V speed (km/h)

The exceptional limiting length of horizontal straight and circular curve element shall be based on the longest length of section of the vehicle, 12m.

$$L_{exp} = 12m$$

where:
Lexp exceptional minimum length (m)

The desirable and limiting length of horizontal transition curve elements are outlined in relevant section below.

The desirable length of vertical element should be based on a minimum vehicle travel of 2 seconds of line speed, as defined below, or 30m, whichever is greater:

$$VL_{des} = \frac{V}{1.8}$$

where:
VLdes desirable minimum length of vertical element (m)
V speed (km/h)

The desirable and limiting length of vertical curve elements are outlined in the criteria for the relevant section below.

A1.3 Horizontal Curve

The minimum horizontal radius is dependent on the design speed.

The minimum horizontal radius without applied cant shall be taken as:

$$R_{des} = 0.15 \; x \; V2$$

$$R_{lim} = 0.12 \; x \; V2$$

where:
Rdes desirable minimum radius (m), with CD = 80mm
Rlim limiting minimum radius (m), with CD = 100mm
V speed (km/h)
CD cant deficiency (mm)

The minimum horizontal radius with applied cant shall be taken as:

$$R_{des} = 0.059 \; x \; V2$$

$$R_{lim} = 0.054 \; x \; V2$$

where:
Rdes desirable minimum radius (m), with CD = 80mm
Rlim limiting minimum radius (m), with CD = 100mm
V speed (km/h)
CD cant deficiency (mm)

The maximum horizontal radius shall be taken as 25,000m.

It is desirable for platforms to have a straight alignment to reduce stepping distances for passengers. The start of a horizontal curve, transition curve or turnout shall have a minimum distance of 20m from the platform end. If, in certain platforms, straight tracks cannot be achieved along the whole length of the platform, a curve alignment may be considered subject to approval. The limiting minimum horizontal radius shall be taken as 1,000m.

A1.4 Acceleration and Cant

The horizontal non-compensated centrifugal acceleration is determined by the formula:

$$a = \frac{V^2}{R}$$

where:
a horizontal acceleration (m/s2)
V operating speed (km/h)
R radius (m)

The maximum horizontal non-compensated centrifugal acceleration shall be taken as:

$$a_{des} = 0.52 m/s^2 \; (0.053g)$$

$$a_{lim} = 0.65 m/s^2 \; (0.066g)$$

where:
ades desirable maximum horizontal n/c centrifugal acceleration (m/s2), CD = 80mm

alim limiting maximum horizontal n/c centrifugal acceleration (m/s2), CD = 100mm
CD cant deficiency (mm)

The horizontal centrifugal acceleration can be compensated using applied cant and is determined by the formula:

$$a = \frac{V^2}{R} - g\ x\ \frac{C}{Dist.}$$

where:

a	horizontal acceleration (m/s2)
V	speed (km/h)
R	radius (m)
g	gravity acceleration (9.81m/s2)
C	applied cant (mm)
Dist.	distance between rail axis (1503mm)

The equilibrium cant is calculated from the compensated horizontal acceleration, considering a = 0, giving:

$$C_{EQ} = (\mathrm{C} + \mathrm{CD}) = \frac{11.82\ x\ V^2}{R}$$

where:

CEQ	equilibrium cant (mm)
C	applied cant (mm)
CD	cant deficiency (mm)
V	speed (km/h)
R	radius (m)

All applied cant values shall be rounded to the nearest 5mm, where the maximum applied cant, Cmax shall be:

$$C_{max} = 120mm$$

Cant will not be applied through platforms.

Excess cant shall be avoided where practicable. There shall be no excess cant on any curve for the normal operation speeds. Excess cant shall be examined with respect to the actual speed of running at reduced speed. Excess cant, subject to approval, may occur on curves near stops due to the acceleration and deceleration of trams.

Negative cant is only permitted on or adjacent to switches and crosses and at particular road crossings.

The maximum cant deficiency, CD shall be:

$CD_{des} = 80mm$ $\qquad CD_{lim} = 100mm$

Cant deficiency shall have a desirable excess of 25mm applied to provide positive wheel guidance through curves, with a limiting C/CD ratio of 100%.

The rate of change of cant is governed by rotational consideration on passengers and rolling stock. The rate of change of cant, RoCC is determined by:

$$RoCC = \frac{V\ x\ C}{3.6L}$$

where:
RoCC rate of change of cant (mm/s)
C applied cant (mm)
V speed (km/h)
L length of transition (m)

$$RoCC_{des} = 30.7mm/s$$

$$RoCC_{lim} = 60.8mm/s$$

The rate of change of cant deficiency, RoCD, is determined by:

$$RoCD = \frac{V\ x\ CD}{3.6L}$$

where:
RoCD rate of change of cant deficiency (mm/s)
CD cant deficiency (mm)
V speed (km/h)
L length of transition (m)

$$RoCD_{des} = 30.7mm/s$$

$$RoCD_{lim} = 55.0mm/s$$

The jerk rate, J, is the change in lateral acceleration with respect to time and is determined by the formula:

$$J = \frac{(a_2 - a_1)}{t_{1,2}} \qquad J = \frac{(a_2 - a_1)}{L} x\ V$$

where:
J jerk rate (m/s3)
a difference in lateral acceleration between pt.1 & pt.2 (m/s2)
t running time between pt.1 & pt.2 (s)
L length of transition (m)
V speed (m/s)

The maximum jerk rate, J, shall be:

$$J_{des} = 0.2m/s^3 \qquad J_{lim} = 0.3m/s^3 \qquad J_{exp} = 0.4m/s^3$$

The cant gradient, CG, is the change in cant with respect to distance and is determined by the formula:

$$CG = \frac{C}{L}$$

where:

CG cant gradient (mm/m)
C applied cant (mm)
L length (m)

The maximum cant gradient, CGmax, shall be:

$$CG_{max} = \frac{180}{V}$$

The minimum cant gradient, CGmin, shall be:

$$CG_{min} = \frac{45}{V}$$

where:
CG cant gradient (mm/m)
V speed (km/h)

The maximum cant gradient, CG, shall be:

$CG_{des} = 2mm/m$ (1:500)

$CG_{lim} = 3mm/m$ (1:333)

$CG_{exp} = 4mm/m$ (1:250)

A1.5 Transition Curve

Transition is a curve between a straight and a circular curve, or between circular curves of different radius, along which the radius changes at constant rate. Transition curves shall be clothoids.

Virtual transitions should not be used. In exceptional circumstances, for example in station areas and other areas with spatial constraints, the principle of a virtual transition may be applied. The length to be used for the virtual transition shall be 12m.

Reverse horizontal curves (with zero length straight between curves or transitions) could be implemented in particular situations if the minimum horizontal straight length is not achievable, once the following criteria are met:

$$CG_{curve\ 1} = -CG_{curve\ 2}$$

$$RoCD_{curve\ 1} = RoCD_{curve\ 2}$$

where:
CG cant gradient (mm/m)
RoCD rate of change of cant deficiency (mm/s)

NOTE: In addition to the criteria listed a) – d) below, other criteria such as Cant, Cant Deficiency, Cant Gradient and Jerk Rate will also need to be satisfied.

Transition curves shall always be provided between compound curves if:

- Applied cant is different on each curve;
- Change of radius is greater than 15% of the smaller radius;
- Jerk Rate is greater than $0.2 m/s^3$ with a minimum transition length of 12m.

A1.6 Criteria for Transition Curve Length

Based on rate of change of cant deficiency (RoCD):

$$L_{1\,des} = 0.0090\ x\ CD\ x\ V$$

$$L_{1\,lim} = 0.0046\ x\ CD\ x\ V$$

where:
L1 transition length based on RoCD (m)
CD cant deficiency (mm)
V speed (km/h)

Based on passenger comfort.
The limiting maximum rate of change in acceleration shall be 0.03g/s, with exceptional maximum 0.04g/s. Therefore, using the maximum horizontal non-compensated centrifugal acceleration from section 5 b):

$$L_{2\,des} = 0.0076\ x\ CD\ x\ V$$

$$L_{2\,lim} = 0.0061\ x\ CD\ x\ V$$

$$L_{2\,exp} = 0.0046\ x\ CD\ x\ V$$

where:
L2 transition length based on passenger comfort (m)
CD cant deficiency (mm)
V speed (km/h)

Based on no cant applied.
The limiting maximum rate of change in acceleration shall be 0.03g/s, with exceptional maximum 0.04g/s. Therefore, using the maximum horizontal non-compensated centrifugal acceleration from section 5 b):

$$L_{3\,des} = 0.107\ x\ \frac{V^3}{R}$$

$$L_{3\,lim} = 0.071\ x\ \frac{V^3}{R}$$

$$L_{3\,exp} = 0.054\ x\ \frac{V^3}{R}$$

where:
L3 transition length based on no applied cant (m)
V speed (km/h)
R radius (m)

Based on rate of change of cant (RoCC) (when cant is applied):

$$L_{3\,des} = 0.0090\ x\ C\ x\ V$$

$$L_{3\,lim} = 0.0051\ x\ C\ x\ V$$

where:

L3	transition length based on RoCC (m)
C	applied cant (mm)
V	speed (km/h)

A1.7 Determination of Transition Curve Length

The length of the transition is the greater of the following formula:

$$L = \frac{V\ x\ (CD_1 - CD_2)}{3.6\ x\ RoCD} \quad \text{or} \quad L = \frac{V\ x\ (C_1 - C_2)}{3.6\ x\ RoCC}$$

Considering desirable and limiting values of RoCC and RoCD above, the length of compound transition curve shall be:

$$L_{des} = 0.0090\ x\ (CD_1 - CD_2)\ x\ V \quad \text{or} \quad L_{des} = 0.0090\ x\ (C_1 - C_2)\ x\ V$$

$$L_{lim} = 0.0046\ x\ (CD_1 - CD_2)\ x\ V \quad \text{or} \quad L_{lim} = 0.0051\ x\ (C_1 - C_2)\ x\ V$$

where:

L	transition length (m)
C	applied cant (mm)
CD	cant deficiency (mm)
V	speed (km/h)

A1.8 Vertical Curve

The vertical gradient is the change in level over a given length and is expressed as a percentage:

$$VG = \left(\frac{\Delta h}{L}\right)\ x\ 100$$

where:

VG	vertical gradient (%)
Δh	change in level (mm)
L	length (mm)

The maximum vertical gradient, VG, shall be:

$$VG_{des} = 2.0\%$$

$$VG_{lim} = 4.0\%$$

The use of vertical gradients greater than 4.0% shall be avoided, where possible and, on approaches to junctions’ due to the negative impact on acceleration/deceleration.

In exceptional circumstances, a steeper gradient may be applied using the following conditions:

- 6.0% along a maximum of 15m section.
- 8.0% along a maximum of 250m section, providing straight section only and where it can be ensured that no planned stopping will occur.

To ensure the proper functioning of the drainage system, the vertical gradient, VG, is limited to a minimum of:

$$VG_{des} = 1.0\%$$

$$VG_{lim} = 0.5\%$$

The use of vertical gradients shallower than 0.5% shall provide mitigation measure to ensure the track drainage functions properly.

When vertical gradient of straight section is changed from one to another the vertical parabolic curve is implemented to optimise passenger comfort and minimise vertical acceleration. The parabolic curve is defined by equation:

$$y = \frac{x^2}{2\ x\ R}$$

where:
R parabolic vertical radius (m)

The vertical acceleration is determined by the formula:

$$a = \frac{V^2}{R}$$

where:
a vertical acceleration (m/s2)
V speed (km/h)
R parabolic vertical radius (m)

The maximum vertical centrifugal acceleration, with regards to passenger comfort, shall be taken as:

$$a_{des} = 0.20 m/s^2\ (0.02g)$$

$$a_{lim} = 0.30 m/s^2\ (0.03g)$$

The minimum radius of vertical curve shall be taken as:

$$R_{des} \geq 0.386\ x\ V^2$$

$$R_{lim} \geq 0.257\ x\ V^2$$

where:
V speed (km/h)

R parabolic vertical radius (m)

In particular circumstances, resulting speed restrictions may allow for reduced parabolic curve radii. Due to rolling stock characteristics, the following absolute minimum values could be applied:

- 600m (+ve) desirable minimum sag curve;
- 350m (+ve) absolute minimum sag curve;
- 700m (-ve) absolute minimum hog (crest) curve.

The length of vertical curve is determined by the formula:

$$LVC = R\ x\ \frac{(g_2 - g_1)}{100}$$

where:
LVC length of parabolic vertical curve (m)
R parabolic vertical radius (m)
g2 – g1 algebraic difference between two adjacent grades (%)

The length of vertical curve based on gradient change is determined by the formula:

$$LVC_{des} = \frac{(g_1 - g_2)\ x\ V^2}{259}$$

$$LVC_{lim} = \frac{(g_1 - g_2)\ x\ V^2}{389}$$

where:
LVC length of parabolic vertical curve (m)
g1 – g2 algebraic difference between two adjacent grades (%)
V speed (km/h)

NOTE: If the algebraic difference between adjacent gradients is less than 0.2% a vertical curve may not be required. SD Calculations may be used to support this.

If the longitudinal profile so permits, gradients up to and down from stations (i.e. hump profiles) shall be provided as follows:

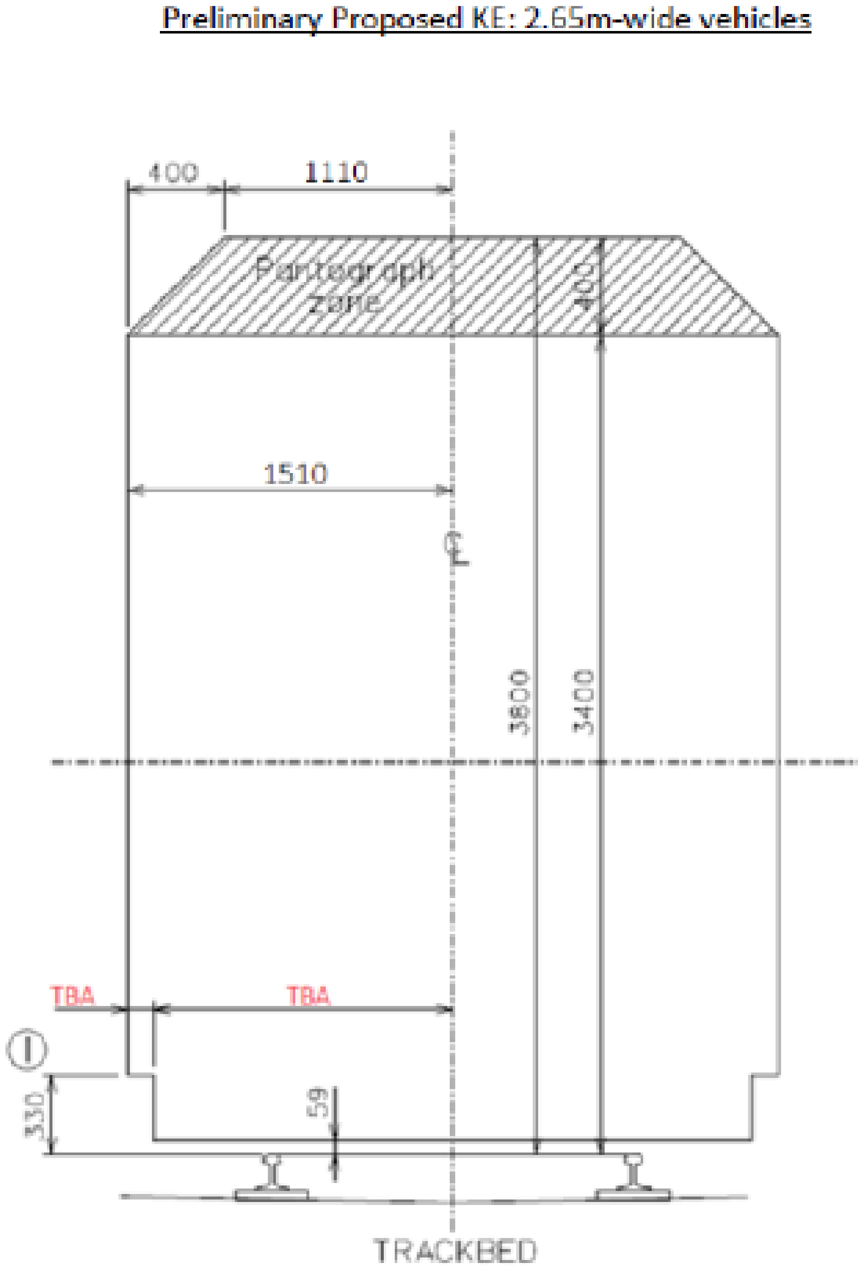
$$VG_{max} = 2.86\%$$

$$VL_{min} = 200\text{m}$$

Appendix B

Developed Kinematic Envelope Sketch

Figure 36: Preliminary Proposed Kinematic Envelope



Appendix C

Permanent Way Calculations

Table 31: Permanent Way Calculations

		Design speed							Transition length	Rates of change of cant and deficiency		Jerk rate	Cant gradient
Chainage		V	Radius	a_L	C_{EQ}	C	CD	CD/C Ratio	TL	RoC	RoCD	J	CG
From	To	kph	m	%g	mm	mm	mm	%	m	mm/s	mm/s	mm/s^3	1 in
492.344	632.325	70	STRAIGHT		0	0	0						
632.325	657.283	50							24.958	0.00	17.38	0.11	0
657.283	798.922	50	-946.8	-0.021	-31	0	-31						
798.922	823.922	50							25	0.00	17.35	0.11	0
823.922	823.922	50	STRAIGHT		0	0	0						
823.922	848.922	50							25	0.00	54.75	0.36	0
848.922	895.328	50	300	0.066	99	0	99						
895.328	920.328	50							25	0.00	54.75	0.36	0
920.328	999.999	70	STRAIGHT		0	0	0						
999.999	999.999	70							VT	0.00	25.04	0.16	0
999.999	1043.301	70	-3750	-0.010	-15	0	-15						
1043.301	1043.301	70							VT	0.00	50.08	0.33	0
1043.301	1086.602	70	3750	0.010	15	0	15						
1086.602	1086.602	70							VT	0.00	25.04	0.16	0
1086.602	1361.518	70	STRAIGHT		0	0	0						
1361.518	1422.467	70							60.949	22.33	22.46	0.15	870.7
1422.467	1593.964	70	412.75	0.047	140	70	70	101					
1593.964	1654.913	70							60.949	22.33	22.46	0.15	870.7
1654.913	2330.320	70	STRAIGHT		0	0	0						
2330.320	2390.320	70							60	22.69	24.26	0.16	857.1429
2390.320	2780.320	70	-400	-0.050	-145	-70	-75	107					

		Design speed							Transition length	Rates of change of cant and deficiency		Jerk rate	Cant gradient
Chainage		V	Radius	a_L	C_{EQ}	C	CD	CD/C Ratio	TL	RoC	RoCD	J	CG
From	To	kph	m	%g	mm	mm	mm	%	m	mm/s	mm/s	mm/s^3	1 in
2780.320	2840.320	70							60	22.69	24.26	0.16	857.1429
2840.320	2983.111	70	STRAIGHT		0	0	0						
2983.111	3033.111	70							50	19.44	25.63	0.17	1000
3033.111	3113.014	70	-500	-0.044	-116	-50	-66	132					
3113.014	3163.014	70							50	19.44	25.63	0.17	1000
3163.014	3243.014	70	STRAIGHT		0	0	0						
3243.014	3293.647	70							50.633	19.20	24.20	0.16	1012.66
3293.647	3584.753	70	512.75	0.042	113	50	63	126					
3584.753	3635.386	70							50.633	19.20	24.20	0.16	1012.66
3635.386	3765.386	70	STRAIGHT		0	0	0						
3765.386	3805.386	70							40	19.44	27.50	0.18	1000
3805.386	4149.453	70	-600	-0.038	-97	-40	-57	141					
4149.453	4189.453	70							40	19.44	27.50	0.18	1000
4189.453	4286.628	70	STRAIGHT		0	0	0						
4286.628	4327.051	70							40.423	19.24	26.25	0.17	1010.575
4327.051	4534.447	70	612.75	0.036	95	40	55	136					
4534.447	4574.868	70							40.421	19.24	26.25	0.17	1010.525
4574.868	4953.737	70	STRAIGHT		0	0	0						
4953.737	5003.737	70							50	19.44	25.63	0.17	1000
5003.737	5267.866	70	500	0.044	116	50	66	132					
5267.866	5317.866	70							50	19.44	25.63	0.17	1000
5317.866	5529.402	70	STRAIGHT		0	0	0						
5529.402	5579.402	70							50	19.44	25.63	0.17	1000

		Design speed							Transition length	Rates of change of cant and deficiency		Jerk rate	Cant gradient
Chainage		V	Radius	a_L	C_{EQ}	C	CD	CD/C Ratio	TL	RoC	RoCD	J	CG
From	To	kph	m	%g	mm	mm	mm	%	m	mm/s	mm/s	mm/s^3	1 in
5579.402	5769.558	70	500	0.044	116	50	66	132					
5769.558	5819.558	70							50	19.44	25.63	0.17	1000
5819.558	6319.558	70	STRAIGHT		0	0	0						
6319.558	6370.558	70							51	28.59	30.32	0.20	680
6370.558	6509.105	70	-375	-0.053	-155	-75	-80	106					
6509.105	6560.105	70							51	28.59	30.32	0.20	680
6560.105	6690.227	70	STRAIGHT		0	0	0						
6690.227	6741.227	70							51	28.59	30.32	0.20	680
6741.227	6804.788	70	-375	-0.053	-155	-75	-80	106					
6804.788	6855.788	70							51	28.59	30.32	0.20	680
6855.788	7132.056	70	STRAIGHT		0	0	0						
7132.056	7182.689	70							50.633	19.20	24.20	0.16	1012.66
7182.689	7281.386	70	512.75	0.042	113	50	63	126					
7281.386	7332.019	70							50.633	19.20	24.20	0.16	1012.66
7332.019	7843.692	70	STRAIGHT		0	0	0						
7843.692	7873.692	70							30	19.44	26.08	0.17	1000
7873.692	7957.600	70	-825	-0.027	-70	-30	-40	134					
7957.600	7987.600	70							30	19.44	26.08	0.17	1000
7987.600	8109.700	70	STRAIGHT		0	0	0						
8109.700	8160.334	70							50.633	19.20	24.20	0.16	1012.66
8160.334	8233.267	70	512.75	0.042	113	50	63	126					
8233.267	8283.901	70							50.633	19.20	24.20	0.16	1012.66
8283.901	8483.992	70	STRAIGHT		0	0	0						

		Design speed							Transition length	Rates of change of cant and deficiency		Jerk rate	Cant gradient
Chainage		V	Radius	a_L	C_{EQ}	C	CD	CD/C Ratio	TL	RoC	RoCD	J	CG
From	To	kph	m	%g	mm	mm	mm	%	m	mm/s	mm/s	mm/s^3	1 in
8483.992	8523.992	70							40	19.44	20.80	0.14	1000
8523.992	8727.531	70	-700	-0.028	-83	-40	-43	107					
8727.531	8767.531	70							40	19.44	20.80	0.14	1000
8767.531	8804.963	70	STRAIGHT		0	0	0						
8804.963	8855.596	70							50.633	19.20	24.20	0.16	1012.66
8855.596	8897.158	70	512.75	0.042	113	50	63	126					
8897.158	8947.792	70							50.633	19.20	24.20	0.16	1012.66
8947.792	9047.417	70	STRAIGHT		0	0	0						
9047.417	9077.512	70							30.095	0.00	18.60	0.12	0
9077.512	9148.226	70	2012.75	0.019	29	0	29						
9148.226	9178.322	70							30.095	0.00	18.60	0.12	0
9178.322	9377.867	70	STRAIGHT		0	0	0						
9377.867	9407.867	70							30	0.00	25.04	0.16	0
9407.867	9473.646	70	-1500	-0.026	-39	0	-39						
9473.646	9503.646	70							30	0.00	25.04	0.16	0
9503.646	9695.531	70	STRAIGHT		0	0	0						
9695.531	9735.954	70							40.423	19.24	26.25	0.17	1010.575
9735.954	9939.522	70	612.75	0.036	95	40	55	136					
9939.522	9979.944	70							40.423	19.24	26.25	0.17	1010.575
9979.944	10365.940	70	STRAIGHT		0	0	0						
10365.940	10396.130	70							30.191	12.88	23.97	0.16	1509.55
10396.130	10842.204	70	1012.75	0.025	57	20	37	186					
10842.204	10872.394	70							30.191	12.88	23.97	0.16	1509.55

		Design speed							Transition length	Rates of change of cant and deficiency		Jerk rate	Cant gradient
Chainage		V	Radius	a_L	C_{EQ}	C	CD	CD/C Ratio	TL	RoC	RoCD	J	CG
From	To	kph	m	%g	mm	mm	mm	%	m	mm/s	mm/s	mm/s^3	1 in
10872.394	11408.697	70	STRAIGHT		0	0	0						
11408.697	11458.697	70							50	19.44	25.63	0.17	1000
11458.697	11692.819	70	-500	-0.044	-116	-50	-66	132					
11692.819	11742.819	70							50	19.44	25.63	0.17	1000
11742.819	12847.192	70	STRAIGHT		0	0	0						
12847.192	12877.383	70							30.191	12.88	23.97	0.16	1509.55
12877.383	13000.713	70	1012.75	0.025	57	20	37	186					
13000.713	13030.903	70							30.191	12.88	23.97	0.16	1509.55
13030.903	14226.490	70	STRAIGHT		0	0	0						
14226.490	14226.490	70							VT	0.00	25.04	0.16	0
14226.490	14336.241	70	3750	0.010	15	0	15						
14336.241	14336.241	70							VT	0.00	25.04	0.16	0
14336.241	14386.241	70	STRAIGHT		0	0	0						
14386.241	14386.241	70							VT	0.00	25.04	0.16	0
14386.241	14495.992	70	-3750	-0.010	-15	0	-15						
14495.992	14495.992	70							VT	0.00	25.04	0.16	0
14495.992	14563.986	70	STRAIGHT		0	0	0						
14563.986	14603.986	70							40	19.44	27.50	0.18	1000
14603.986	14721.684	70	-600	-0.038	-97	-40	-57	141					
14721.684	14761.684	70							40	19.44	27.50	0.18	1000
14761.684	15038.590	70	STRAIGHT		0	0	0						
15038.590	15038.590	70							VT	0.00	25.04	0.16	0
15038.590	15148.341	70	-3750	-0.010	-15	0	-15						

		Design speed							Transition length	Rates of change of cant and deficiency		Jerk rate	Cant gradient
Chainage		V	Radius	a_L	C_{EQ}	C	CD	CD/C Ratio	TL	RoC	RoCD	J	CG
From	To	kph	m	%g	mm	mm	mm	%	m	mm/s	mm/s	mm/s^3	1 in
15148.341	15148.341	70							VT	0.00	25.04	0.16	0
15148.341	15198.341	70	STRAIGHT		0	0	0						
15198.341	15198.341	70							VT	0.00	25.04	0.16	0
15198.341	15308.092	70	3750	0.010	15	0	15						
15308.092	15308.092	70							VT	0.00	25.04	0.16	0
15308.092	15416.559	70	STRAIGHT		0	0	0						
15416.559	15476.559	70							60	22.69	24.26	0.16	857.1429
15476.559	15773.901	70	400	0.050	145	70	75	107					
15773.901	15833.901	70							60	22.69	24.26	0.16	857.1429
15833.901	15886.019	70	STRAIGHT		0	0	0						
15886.019	15886.019	70							VT	0.00	25.04	0.16	0
15886.019	15997.103	70	-3750	-0.010	-15	0	-15						
15997.103	15997.103	70							VT	0.00	25.04	0.16	0
15997.103	16037.103	70	STRAIGHT		0	0	0						
16037.103	16037.103	70							VT	0.00	25.04	0.16	0
16037.103	16148.192	70	3750	0.010	15	0	15						
16148.192	16148.192	70							VT	0.00	25.04	0.16	0
16148.192	16299.425	70	STRAIGHT		0	0	0						
16299.425	16349.425	70							50	19.44	25.63	0.17	1000
16349.425	16682.874	70	-500	-0.044	-116	-50	-66	132					
16682.874	16712.874	70							30	19.44	18.11	0.12	1000
16712.874	17003.493	70	-1000	-0.025	-58	-20	-38	190					
17003.493	17033.493	70							30	12.96	5.82	0.04	1500

		Design speed							Transition length	Rates of change of cant and deficiency		Jerk rate	Cant gradient
Chainage		V	Radius	a_L	C_{EQ}	C	CD	CD/C Ratio	TL	RoC	RoCD	J	CG
From	To	kph	m	%g	mm	mm	mm	%	m	mm/s	mm/s	mm/s^3	1 in
17033.493	17227.224	70	-2000	-0.019	-29	0	-29						
17227.224	17257.224	70							30	12.96	5.82	0.04	1500
17257.224	17406.617	70	-1000	-0.025	-58	-20	-38	190					
17406.617	17436.617	70							30	12.96	24.60	0.16	1500
17436.617	17827.641	70	STRAIGHT		0	0	0						
17827.641	17877.870	70							50.204	27.11	26.53	0.17	717.2
17877.870	18110.520	70	418.4	0.046	138	70	68	98					
18110.520	18160.749	70							50.204	27.11	26.53	0.17	717.2
18160.749	18363.646	70	STRAIGHT		0	0	0						
18363.646	18413.646	70							50	19.44	25.63	0.17	1000
18413.646	18466.290	70	500	0.044	116	50	66	132					
18466.290	18516.290	70							50	19.44	25.63	0.17	1000
18516.290	18789.027	70	STRAIGHT		0	0	0						
18789.027	18839.027	70							50	27.22	27.08	0.18	714.2857
18839.027	18916.031	70	415	0.046	140	70	70	99					
18916.031	18966.031	70							50	27.22	27.08	0.18	714.2857
18966.031	19240.118	70	STRAIGHT		0	0	0						

Figure 37: Curvature Diagram

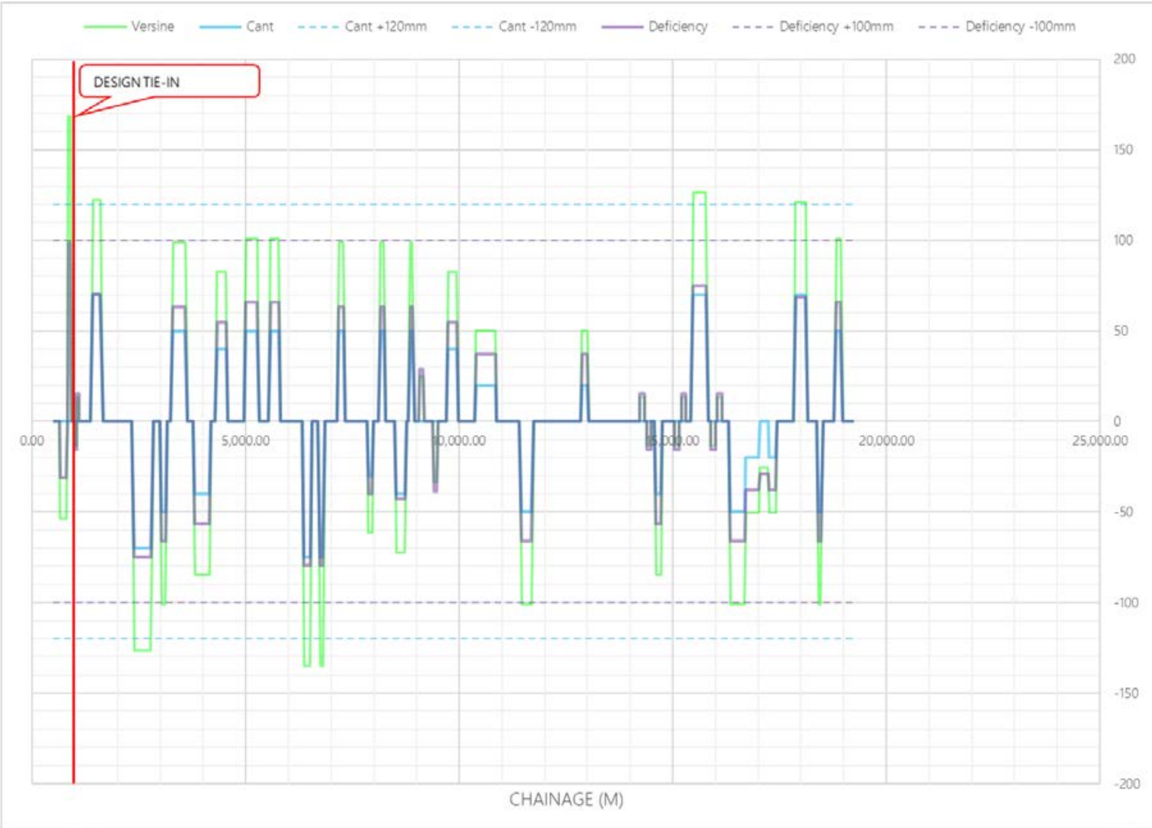
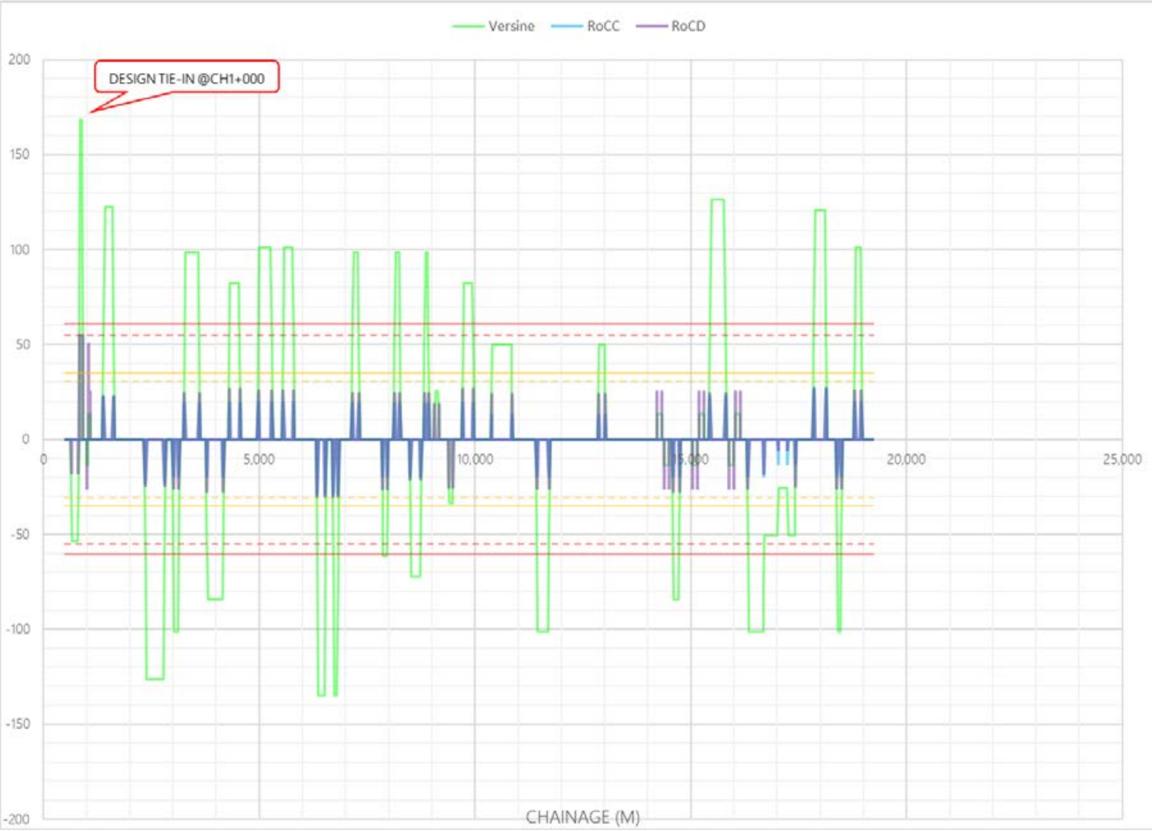


Figure 38: Rate of Change Diagram



Appendix D

Journey Time Calculations

Table 32: Journey Time Calculations

	Journey Time TOTAL		1627.19	27:07

V (kph)	s (m)	t (sec)	t_{acc} (sec)	t_{acc} (min:sec)
RANELAGH - CHARLEMONT	Assuming 50kph		66.12	01:06
CHARLEMONT - CH 1+000.000				
Station Dwell Time		30.00	86.93	01:27
Acceleration (0-70kph)	137.440	12.22		
Vertical Length (@70kph)	610.360	31.39		
Deceleration (70-0kph)	156.940	13.32		
ST. STEPHEN'S GREEN EAST - CH 1+904.740				
Station Dwell Time		30.00	95.14	01:35
Acceleration (0-70kph)	169.040	15.33		
Vertical Length (@70kph)	706.090	36.31		
Deceleration (70-0kph)	160.210	13.50		
TARA STREET - CH 2+940.080				
Station Dwell Time		30.00	82.69	01:23
Acceleration (0-70kph)	169.040	15.33		
Vertical Length (@70kph)	463.920	23.86		
Deceleration (70-0kph)	160.210	13.50		
O'CONNELL STREET - CH 3+733.250				
Station Dwell Time		30.00	92.83	01:33
Acceleration (0-70kph)	213.880	18.94		
Vertical Length (@70kph)	590.930	30.39		
Deceleration (70-0kph)	160.210	13.50		
MATER HOSPITAL - CH 4+698.270				
Station Dwell Time		30.00	81.06	01:21
Acceleration (0-70kph)	169.040	15.33		
Vertical Length (@70kph)	435.780	22.41		
Deceleration (70-0kph)	156.940	13.32		
WHITWORTH - CH 5+460.030				
Station Dwell Time		30.00	104.88	01:45
Acceleration (0-70kph)	171.240	15.87		
Vertical Length (@70kph)	884.885	45.51		
Deceleration (70-0kph)	160.210	13.50		
GRIFFITH PARK WEST - CH 6+676.365				
Station Dwell Time		30.00	114.66	01:55
Acceleration (0-70kph)	171.240	15.87		
Vertical Length (@70kph)	1078.605	55.47		
Deceleration (70-0kph)	156.940	13.32		
DCU @ COLLINS AVE. JNC. - CH 8+083.150				

Station Dwell Time		30.00	91.78	01:32
Acceleration (0-70kph)	171.240	15.87		
Vertical Length (@70kph)	634.620	32.64		
Deceleration (70-0kph)	155.800	13.27		
BALLYMUN VILLAGE - CH 9+044.810				
Station Dwell Time		30.00	101.81	01:42
Acceleration (0-70kph)	170.550	15.77		
Vertical Length (@70kph)	830.750	42.72		
Deceleration (70-0kph)	156.940	13.32		
NORTHWOOD WEST - CH 10+203.050				
Station Dwell Time		30.00	83.41	01:23
Acceleration (0-70kph)	169.040	15.33		
Vertical Length (@70kph)	477.985	24.58		
Deceleration (70-0kph)	160.210	13.50		
DARDISTOWN - CH 11+010.285				
Station Dwell Time		30.00	152.84	02:33
Acceleration (0-70kph)	170.550	15.77		
Vertical Length (@70kph)	1819.400	93.57		
Deceleration (70-0kph)	160.210	13.50		
DUBLIN AIRPORT - CH 13+160.445				
Station Dwell Time		30.00	157.40	02:37
Acceleration (0-70kph)	169.040	15.33		
Vertical Length (@70kph)	1938.250	99.68		
Deceleration (70-0kph)	147.710	12.39		
FOSTERSTOWN - CH 15+415.445				
Station Dwell Time		30.00	86.81	01:27
Acceleration (0-70kph)	166.150	16.06		
Vertical Length (@70kph)	504.445	25.94		
Deceleration (70-0kph)	174.730	14.81		
SWORDS CENTRAL - CH 16+260.770				
Station Dwell Time		30.00	87.86	01:28
Acceleration (0-70kph)	169.040	15.33		
Vertical Length (@70kph)	539.070	27.72		
Deceleration (70-0kph)	174.730	14.81		
SEATOWN - CH 17+143.610				
Station Dwell Time		30.00	140.95	02:21
Acceleration (0-70kph)	169.040	15.33		
Vertical Length (@70kph)	1584.750	81.50		
Deceleration (70-0kph)	167.150	14.12		
ESTUARY P&R (TERMINUS) - CH 19+064.55				

Appendix E

Tunnel Configuration Note

National Transport Authority

New Metro North Alignment Study

Appendix E - Tunnel Configuration for MCA Stage 2 Route Options

252252-ARP-GEN-SW-RP-CX-022

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Job number 252252-00

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		Signature			

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Contents

1 Introduction

The selection of a tunnel configuration to be used in the concept design for the emerging preferred route is a key decision as it impacts the rail alignment, station layout, portal size, intervention shafts, ground movement and volume of waste.

The Tunnel Configuration Study recommended three potential configurations for the New Metro North project. This report summarises the recommended configurations and assesses them against the route options considered in the alignment study. This is done in several stages:

- Establishing the context of the configurations on a generic route;
- Developing an initial assessment for route types considered in MCA Stage 1;
- A more detailed analysis on the two routes considered for MCA Stage 2;
- Sensitivity on the emerging preferred route; and
- Sensitivity on a selection of routes not carried forward to MCA Stage 2.

This assessment was combined with some issues not related to alignment but solely to the configuration and a final tunnel configuration recommendation for the study is made on the basis of:

- Cost;
- Waste generated;
- Emergency Strategy;
- Future expansion;
- Programme;
- User Experience and;
- Noise and vibration.

2 Recommendations from Tunnel Configuration Report

2.1 Overview of Tunnel Configuration Study

The Tunnel Configuration Study for New Metro North (April 2017) was carried out in order to input into the subsequent stages of planning and design for the New Metro North project. The key objectives of the study were:

• Carry out a comprehensive review of developments in underground urban railway design schemes, design and construction;

• Develop generic tunnel and station designs for various options;

• Carry out a technical assessment of the various tunnel and station designs;

• Identify all compliance requirements applicable to the tunnel and station combinations and

• Recommend an optimal generic tunnel and station combination for each of the new Metro North and DART Underground projects.

The report concluded that three configurations were comparable under the conditions examined in the study. The recommendations are summarised below.

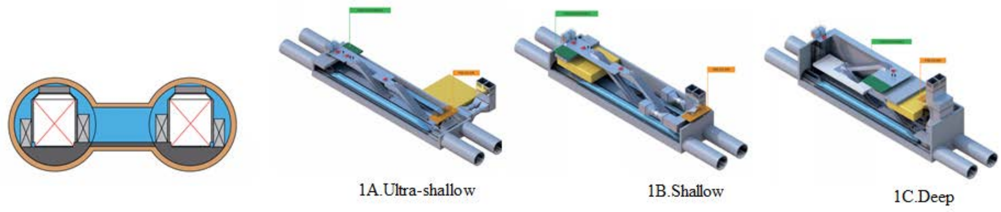
2.2 Summary of Recommended Configurations

The following configurations were recommended in the Tunnel Configuration Study. Additional considerations are presented in Appendix A1.

2.2.1 Recommendation 1: Twin Bore (option 1A, 1B and 1C)

The first recommendation is the twin bore family of tunnels and stations. The stations all have an island platform configuration and range in depth from ultra-shallow to deep. The tunnels are twin 5.9m internal diameter bores with cross passages at regular intervals. An overview of the twin bore option is shown in Figure 1.

Figure 1 - Overview of twin bore configuration

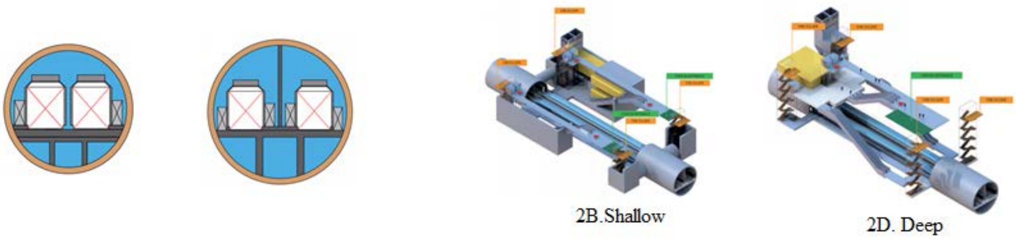


In this report this option is referred to as ***Twin Bore***.

2.2.2 Recommendation 2: Single Bore Twin Track (side by side), option 2B and 2D

The second recommendation is the single bore family of tunnels and stations. The stations all have the side platform configuration and range in depth from shallow to deep. The configuration can have a dividing wall or not depending on the emergency escape strategy. The tunnel without a dividing wall is a 10.3m internal diameter bore while the tunnel with a dividing wall is 12.6m internal diameter. An overview of the twin bore option is shown in Figure 2.

Figure 2 - Overview of single bore configuration



In this report this option is referred to as ***Single Bore***.

2.2.3 Recommendation 3: Single Bore Twin Track (stacked), Option 4, Monotube

The final recommendation is the monotube configuration. In this configuration station platforms are provided within the bore in a stacked arrangement which is only achievable at depth. The tunnel / station platform is a 13.9m external diameter bore. An overview of the monotube option is shown in Figure 3.

Figure 3 - Overview of monotube configuration

In this report this option is referred to as ***Monotube.***

3 Characteristics of Route Options

3.1 Alignment Characteristics from MCA Stage 1

There are numerous options considered in the alignment study at MCA Stage 1 with the general characteristics by area defined below:

Area A

All options for Area A are underground with four stations. The underground lengths vary from 4.3km to 4.8km. A single underground turnback and single underground crossover are expected in Area A.

Area B

The options for Area B split into two distinct types. The first type is for options that run at surface, elevated or in cut and cover in Ballymun and proceed underground again south of the Airport. The underground lengths for this type range from 2.5km to 3.9km with two or three underground stations. There is a single underground crossover, no underground turnback and two portals expected for this type.

The second type is for options which are entirely underground. For these options the underground lengths vary from 7.6km to 8.1km with five or six underground stations. There are two underground crossovers, no underground turnback and no portal expected for this type.

It should be noted that the consideration of alignment options which are entirely underground to the airport was not anticipated at the time of the carrying out of the Tunnel Configuration Study (A route of 5.8km from city centre to Ballymun was considered). However, based on the cost analysis from MCA Stage 1 the alignment options which remain underground remain cost competitive against overground option primarily due to the cost of portals.

Area C

Similarly to Area B, the options for Area C split into two distinct types. The first type is for options that emerge north of the Airport and run at surface, elevated or cut and cover. The underground length for this type range is approximately 1km with no underground stations. There is no crossover, one underground turnback and one portal expected for this type.

The second type is for options which are have extended underground lengths. For these options the underground length is approximately 4.3km with two underground stations. There is no crossover, one underground turnback and one portal expected for this type.

A summary of the alignment combinations by area are summarised in Table 1.

Table 1 - Summary of potential alignment options

Ref	Area A	Area B	Area C	Length of Tunnel (km)	No. of Under-ground Stations	Crossovers	Turnbacks	Portals
I	Type 1	Type 1	Type 1	7.8-9.7	6-7	2	2	3
II			Type 2	11.1-13.0	8-9	3	2	3
III		Type 2	Type 1	12.9-13.9	9-10	2	2	1
IV			Type 2	16.2-17.2	10-11	3	2	1

Ref I = Area A Type 1 + Area B Type 1 + Area C Type 1
Ref II = Area A Type 1 + Area B Type 1 + Area C Type 2
Ref III = Area A Type 1 + Area B Type 2 + Area C Type 1
Ref IV = Area A Type 1 + Area B Type 2 + Area C Type 2
Refer to above for form of construction for each type for each area

3.2 Assessment of Potential Routes from MCA Stage 1

The four alignment options (I-IV) identified in Table 1 are assessed using a similar high level cost model used to produce the MCA Stage 2 costs. The model assumes a station depth of 20m (as per MCA Stage 1) and is carried out for upper and lower bound station numbers and tunnel lengths. The results are shown in Figure 4 and Figure 5 below. For route reference I-IV please refer to Table 1.

Figure 4 - Relative cost comparison of upper bound options I – IV

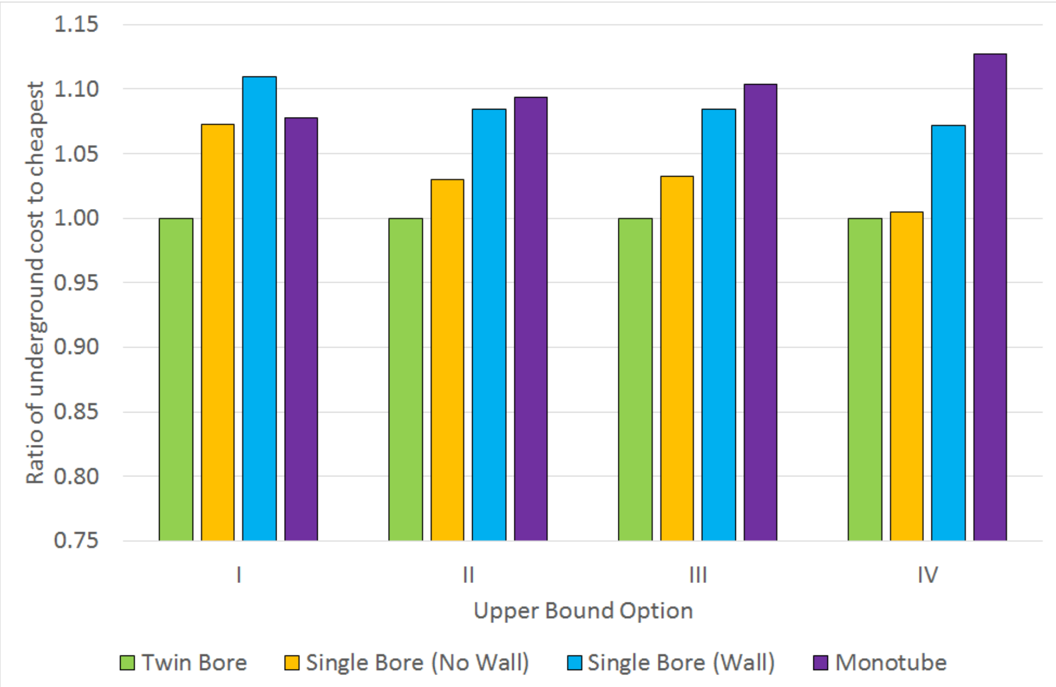
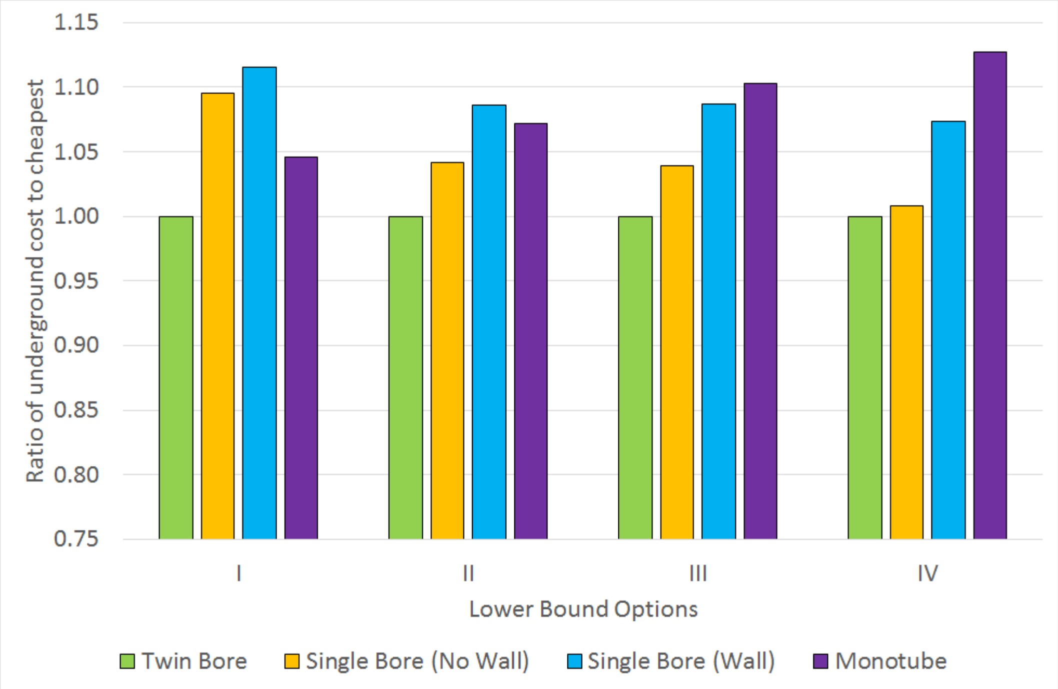


Figure 5 - Relative cost comparison of lower bound options I - IV



The figures above show that the twin bore is generally favourable for all options with the single bore option with no wall generally comparable with the exception of Option I. The single bore option with wall and monotube are both unfavourable for all options.

This check is again limited as it ignores other alignment elements and the actual spacing of shafts along an alignment. The final check is a detailed costing by configuration on the routes carried forward to MCA Stage 2. The subsequent assessments will be more detailed and include considerations of:

- Costs (including crossovers, turnbacks and shafts);
- Waste;
- Emergency strategy;
- Future expansion;
- Programme;
- System Operations;
- User Experience and;
- Noise and Vibration.

4 MCA Stage 2 Route Assessment

The following section summarises the options for MCA2 and assesses them against the recommended tunnel configurations from the Tunnel Configuration Study.

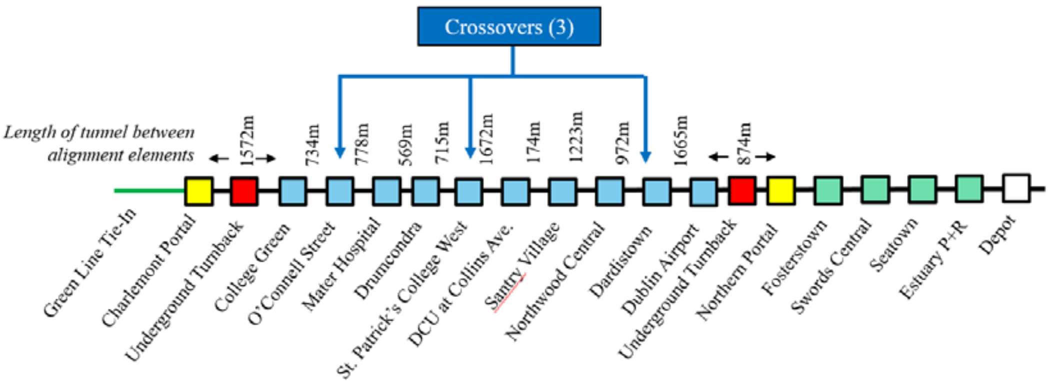
4.1 Summary of MCA Stage 2 Routes

There are ten routes considered from MCA Stage 2 as summarised below.

4.1.1 Option 1: A1-B6-C4

A1-B6-C4, or Option 1, is a route which runs from the city centre entirely underground, via Drumcondra, to the Airport and runs at surface or elevated through Swords to Estuary. The alignment length is 17.24km and there are fourteen stations with 11.0km of tunnel and ten stations underground. There are two portals, two underground turnbacks and three underground crossovers.

Figure 6 - Summary of Option 1 (A1-B6-C4)

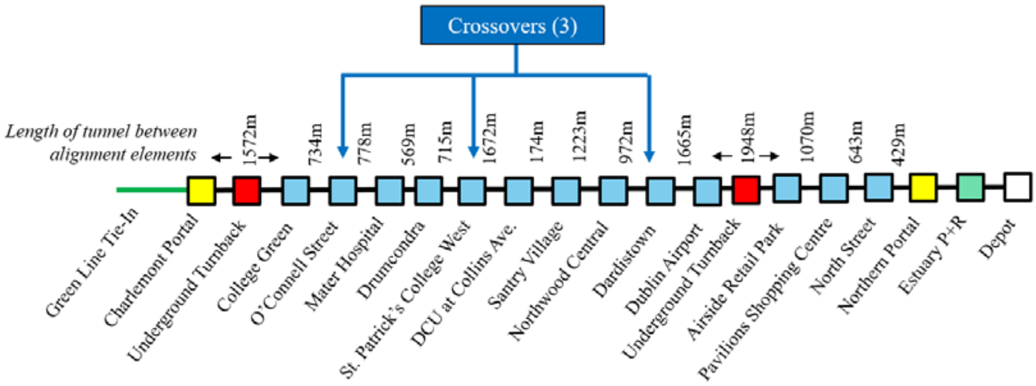


Note: The exact number and location of the crossovers and turnbacks to be confirmed during concept design for EPR only

4.1.2 Option 2: A1-B6-C11

A1-B6-C11, or Option 2, is a route which runs from the city centre entirely underground, via Drumcondra, to the Airport and continues underground through Swords to Estuary. The alignment length is 16.9km and there are fourteen stations with 14.2km of tunnel and thirteen stations underground. There are two portals, two underground turnbacks and three underground crossovers.

Figure 7 - Summary of Option 2 (A1-B6-C11)

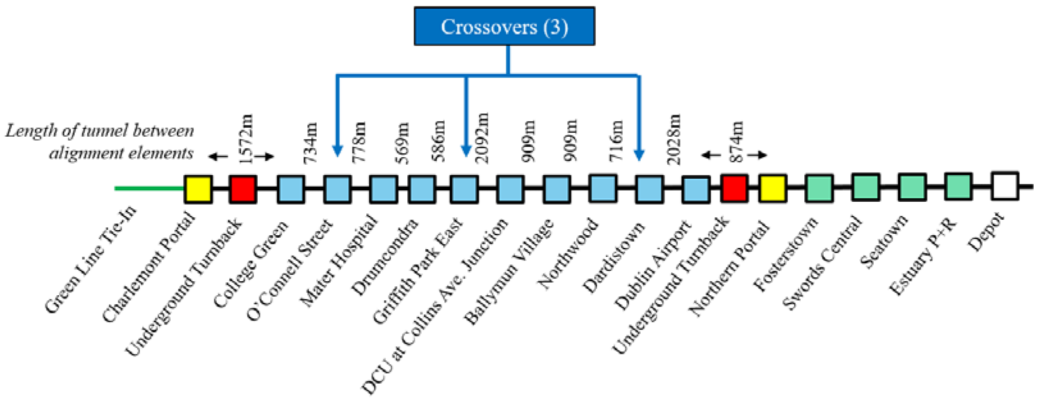


Note: The exact number and location of the crossovers and turnbacks to be confirmed during concept design for EPR only

4.1.3 Option 3: A1-B10-C4

A1-B10-C4, or Option 3, is a route which runs from the city centre entirely underground, via Drumcondra, to the Airport and runs at surface or elevated through Swords to Estuary. The alignment length is 17.48km and there are fourteen stations with 11.3km of tunnel and ten stations underground. There are two portals, two underground turnbacks and three underground crossovers.

Figure 8 - Summary of Option 3 (A1-B10-C4)

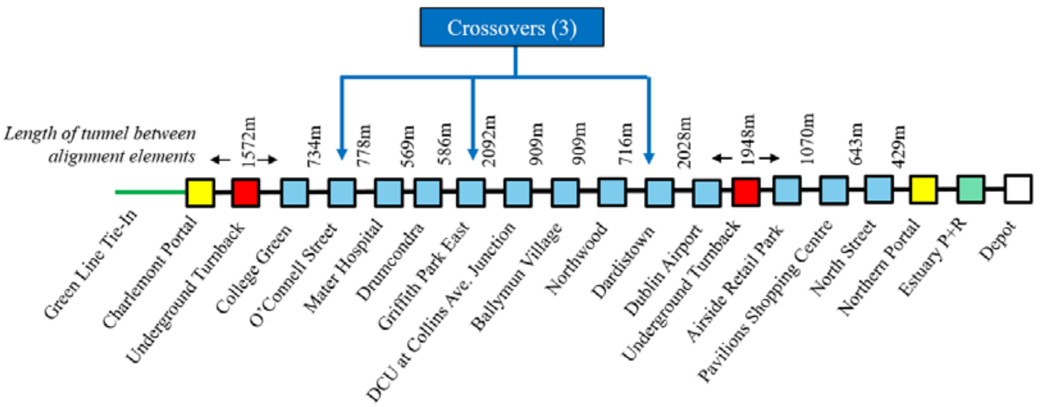


Note: The exact number and location of the crossovers and turnbacks to be confirmed during concept design for EPR only

4.1.4 Option 4: A1-B10-C11

A1-B10-C11, or Option 4, is a route which runs from the city centre entirely underground, via Drumcondra, to the Airport and continues underground through Swords to Estuary. The alignment length is 17.15km and there are fourteen stations with 14.4km of tunnel and thirteen stations underground. There are two portals, two underground turnbacks and three underground crossovers.

Figure 9 - Summary of Option 4 (A1-B10-C11)

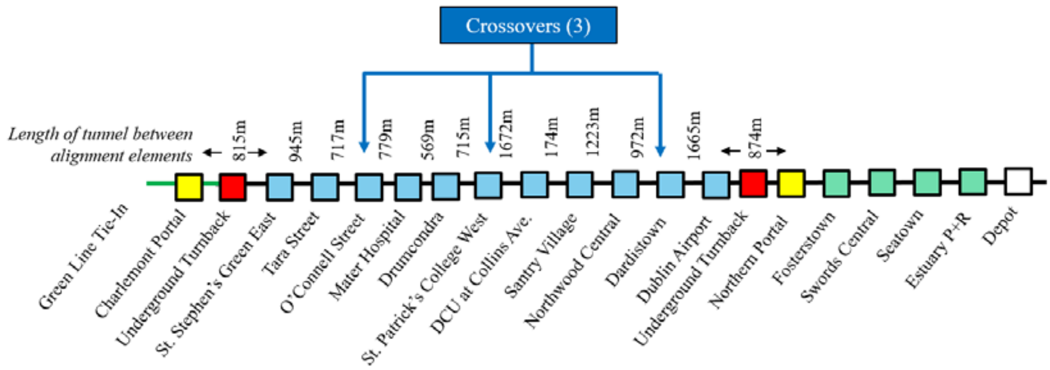


Note: The exact number and location of the crossovers and turnbacks to be confirmed during concept design for EPR only

4.1.5 Option 5: A2-B6-C4

A2-B6-C4, or Option 5, is a route which runs from the city centre entirely underground, via Drumcondra, to the Airport and runs at surface or elevated through Swords to Estuary. The alignment length is 17.38km and there are fifteen stations with 11.0km of tunnel and eleven stations underground. There are two portals, two underground turnbacks and three underground crossovers.

Figure 10 -- Summary of Option 5 (A2-B6-C4)

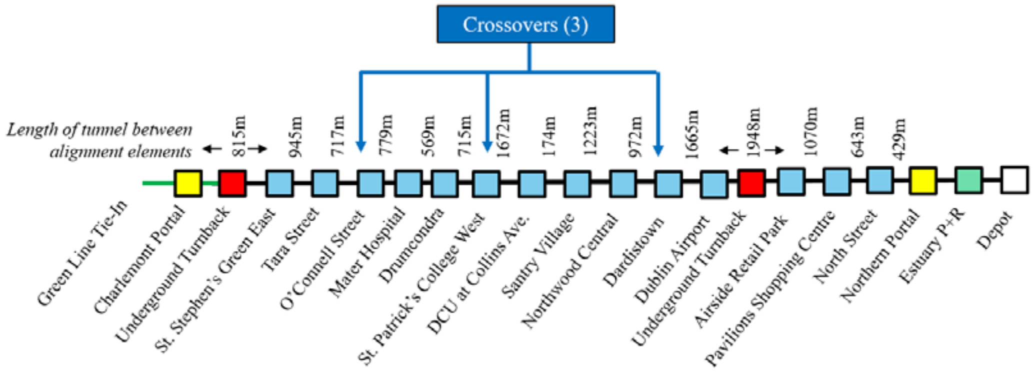


Note: The exact number and location of the crossovers and turnbacks to be confirmed during concept design for EPR only

4.1.6 Option 6: A2-B6-C11

A2-B6-C11, or Option 6, is a route which runs from the city centre entirely underground, via Drumcondra, to the Airport and continues underground through Swords to Estuary. The alignment length is 17.06km and there are fifteen stations with 14.2km of tunnel and fourteen stations underground. There are two portals, two underground turnbacks and three underground crossovers.

Figure 11 - Summary of Option 6 (A2-B6-C11)

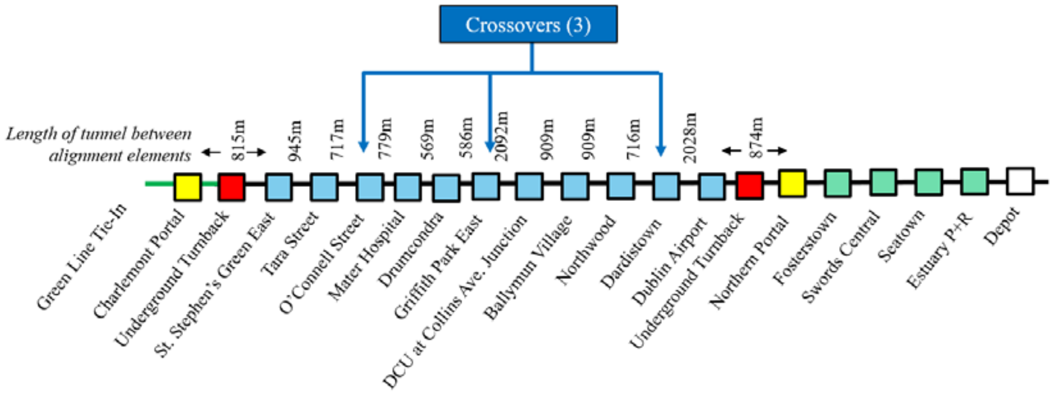


Note: The exact number and location of the crossovers and turnbacks to be confirmed during concept design for EPR only

4.1.7 Option 7: A2-B10-C4

A2-B10-C4, or Option 7, is a route which runs from the city centre entirely underground, via Drumcondra, to the Airport and runs at surface or elevated through Swords to Estuary. The alignment length is 17.6km and fifteen stations with 11.3km of tunnel and eleven stations underground. There are two portals, two underground turnbacks and three underground crossovers.

Figure 12 - Summary of Option 7 (A2-B10-C4)

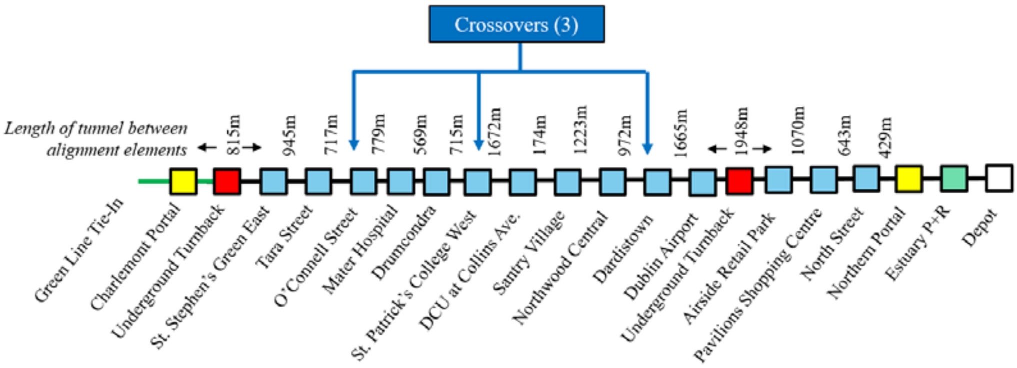


Note: The exact number and location of the crossovers and turnbacks to be confirmed during concept design for EPR only

4.1.8 Option 8: A2-B10-C11

A2-B6-C11, or Option 8, is a route which runs from the city centre entirely underground, via Drumcondra, to the Airport and continues underground through Swords to Estuary. The alignment length is 17.06km and there are fifteen stations with 14.2km and fourteen stations underground. There are two portals, two underground turnbacks and three underground crossovers.

Figure 13 - Summary of Option 8 (A2-B10-C11)

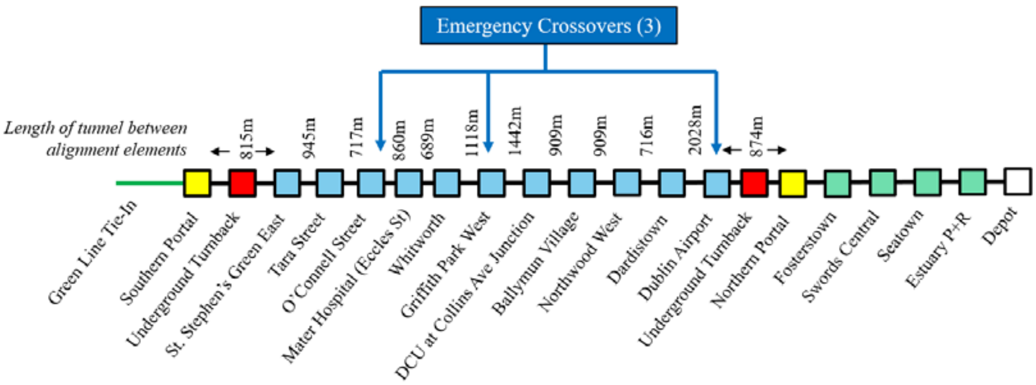


Note: The exact number and location of the crossovers and turnbacks to be confirmed during concept design for EPR only

4.1.9 Option 9: A4-B12-C4

A4-B12-C4, or Option 9 is a route which runs from the city centre entirely underground, via Whitworth, to the Airport and runs at surface or elevated through Swords to Estuary. The alignment length is 17.7km and fifteen stations with 11.36km of tunnels and eleven stations underground. There are two portals, two underground turnbacks and three underground crossovers.

Figure 14 - Summary of Option 9 (A4-B12-C4)

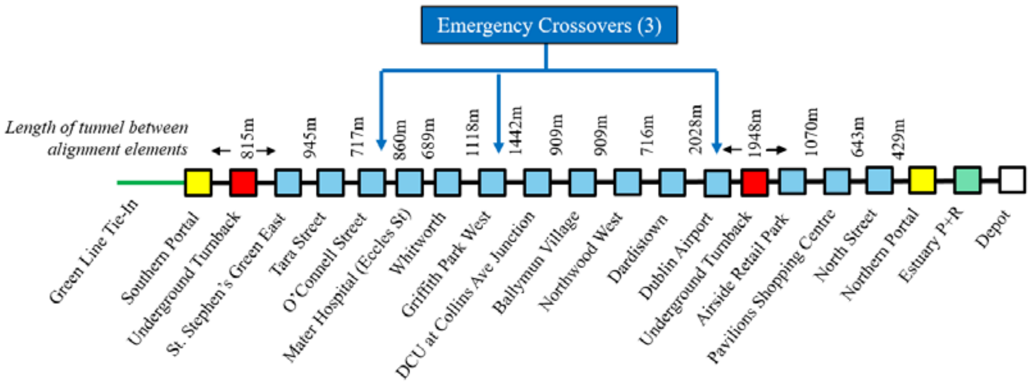


Note: The exact number and location of the crossovers and turnbacks to be confirmed during concept design for EPR only

4.1.10 Option 10: A4-B12-C11

A4-B12-C11, or Option 10, is a route which runs from the city centre entirely underground, via Drumcondra, to the Airport and continues underground through Swords to Estuary. The alignment length is 17.36km and there are fifteen stations with 14.2km and fourteen stations underground. There are two portals, two underground turnbacks and three underground crossovers.

Figure 15 - Summary of Option 9 (A4-B12-C11)



4.2 Costs

The tunnel configuration cost assessment for the MCA Stage 2 options is carried out in the same way as the cost assessment for MCA Stage 2 with a few additions related to the tunnel configurations. These additions are:

- Added cost of turnbacks;
- Added cost of crossovers;
- Variation in tunnelling rates by configuration;
- Variation in waste volume by configuration;
- Variation in number of shafts by configuration, with both 1km and 762m considered for single bore (no wall);
- Variation in Portal length by configuration and;
- Variation in station cost by configuration.

For the station costs in the alignment study MCA stages a generic sized station box with a depth of 20m has been assumed. For this assessment the generic box cost will be used for twin bore and single bore configurations with no variation in station cost between these configurations. For the monotube option, an equivalent cost is used. All the configurations are assumed to be in typical Dublin ground conditions with no variation between them.

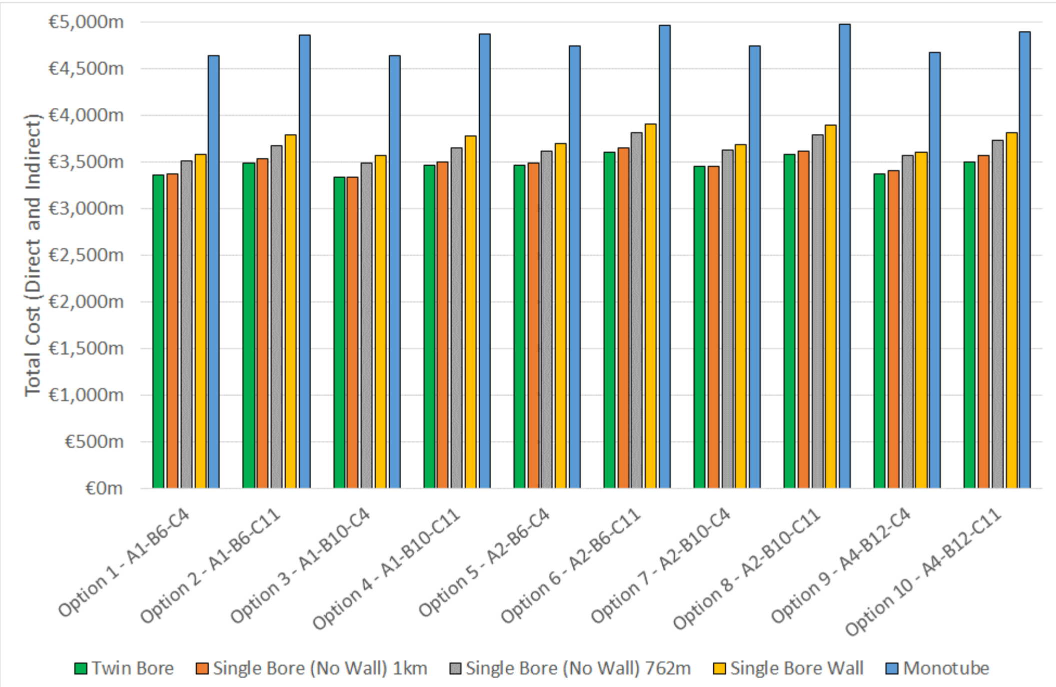
A summary of the above is provided in Table 2 with the results shown in Figure 16.

Table 2 - Summary of variations by configuration

Configuration / Variable		Twin Bore 1.5km	Single Bore (No Wall) – 1km*	Single Bore (No Wall) – 762m*	Single Bore (Wall) 1.5km	Monotube 1.5km
Tunnel Ext. Diameter (m)		6.7	10.3	10.3	12.6	13.9
No. of Shafts	1. A1-B6-C4	3	4	10	3	3
	2. A1-B6-C11	4	6	12	4	4
	3. A1-B10-C4	3	3	10	3	3
	4. A1-B10-C11	4	5	12	4	4
	5. A2-B6-C4	2	3	9	2	2
	6. A2-B6-C11	3	5	12	3	3
	7. A2-B10-C4	2	2	10	2	2
	8. A2-B10-C11	3	4	12	3	3
	9. A4-B12-C4	1	3	10	1	1
	10. A4-B12-C11	2	5	12	2	2
Tunnel Rate (per m)		€34,686	€35,146	€35,146	€50,338	€68,759
TBM Cost		€14m	€22m	€22m	€25m	€40m
Station Cost		MCA2 (€55m)	MCA2 (€55m)	MCA2 (€55m)	MCA2 (€55m)	Monotube (€41m)
Mined Crossover		3	0	0	0	0
Mined Turnbacks		2	2	2	2	0
Turnback length (m)		247	374	374	374	N/A
Volume of Bore (per m)		$71m^3$	$83m^3$	$83m^3$	$125m^3$	$152m^3$

*Shaft spacing relevant to single bore (no wall)

Figure 16 - Results of Cost Assessment for MCA Stage 2 Routes

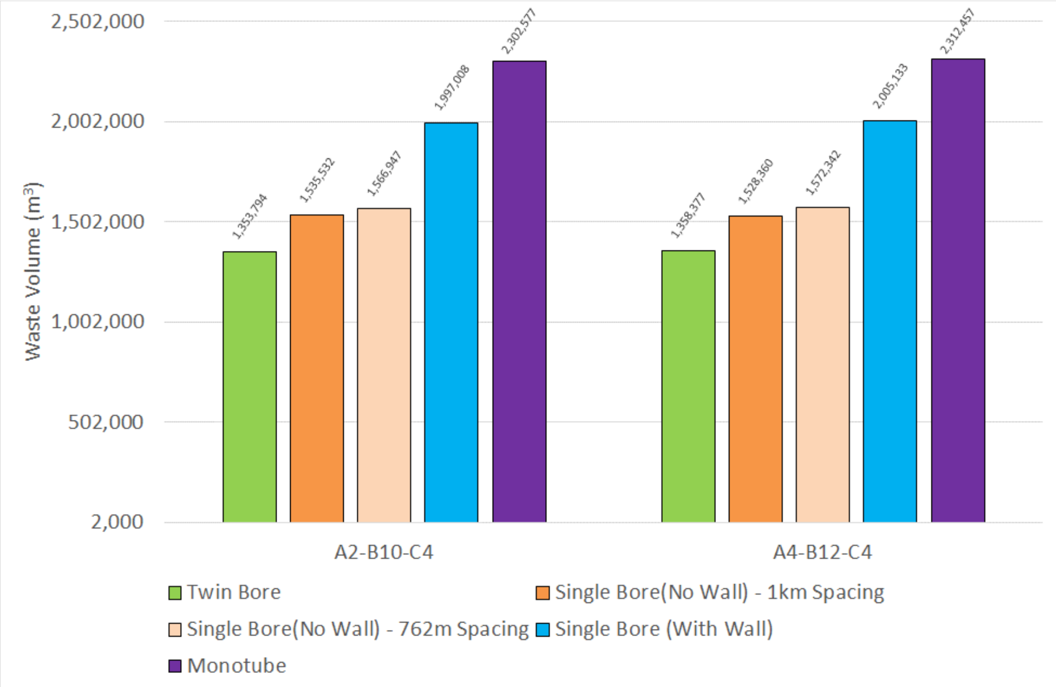


This costing exercise is more detailed than the previous assessments and considers the precise alignment features as detailed in the alignments assessed in MCA stage 2 with added alignment elements which are relevant to the tunnel configurations. The results show that the twin bore option is considered favourable compared to the other options. The single bore (no wall) with shafts at 762m is notably more expensive, which is mainly due to the cost of adding shafts. The single bore (with wall) is comparable with the added cost of tunnelling offset against the savings in shafts, crossovers and turnbacks. The monotube is significantly more expensive due to the cost of tunnelling.

4.3 Waste

An assessment of the waste by configuration has been carried out. Additional waste incurs additional cost of disposal, however this has been included in the cost assessment. Secondary considerations for the added waste include increased number of truck movements, environmental considerations (added energy of removing the spoil) and increased ground movement (considered in Section 4.5). The plot in summarises the waste produced by configuration.

Figure 17 - Summary of waste by configuration



The plot shows the total volume including stations, tunnels and portals only. The results clearly show the twin bore option is preferred from a waste perspective. The single bore (no wall) is comparable with single bore (with wall) and monotube producing significantly more waste.

4.4 Emergency Strategy

There are two distinct emergency escape plans depending on whether or not a place of safety can be provided underground. An intermediate place of safety can be provided in the twin bore (non-incident bore), single bore (with wall) and in a Monotube (with either a dividing wall or stairs between levels). However, no intermediate place of safety can be provided within a single bore (no wall). For the options with a place of safety, these are to be provided at a maximum spacing of 244m as per NFPA 130.

The maximum spacing of intervention shafts /stations is reduced when no place of safety can be provided. It is assumed that NFPA130 rules would be invoked, imposing a spacing for the single bore (no dividing wall) to be reduced to 762m between intervention shafts (as considered in the costing). TSi-SRT rules would permit up to 1km spacing but more onerous NFPA130 have been considered for the purposes of this assessment. Both options are considered safe as can be designed using risk based approach. Additionally, it is considered that there is significant approvals risk from Dublin Fire Brigade with the single bore (no wall) option.

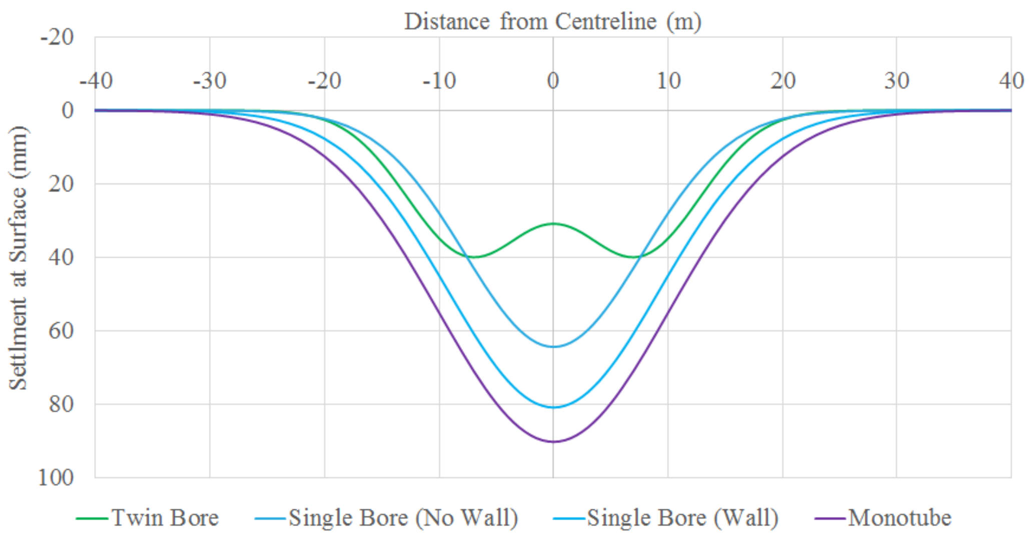
For shaft spacing of 1km, two shafts are required between Dardistown and the Airport as the location for a single shaft is constrained by airside (taxiway and runway). Where NFPA130 is invoked, a shaft is required at 762m spacing, which would mean a shaft would need to be provided airside, adding complexity to the approvals and emergency strategy.

In summary, with respect to emergency strategy, the key risks are the provision of shafts, approvals risk for single bore (no wall) and the potential requirement for a shaft within the airside area at Dublin Airport. The twin bore, single bore (wall) and monotube are all preferred in this respect with twin bore (no wall) adding considerable risk and expense.

4.5 Ground Movement

A ground movement assessment of the alignment with detailed assessment of the buildings, depths and other considerations is not possible until the concept design of the emerging preferred route has been completed. However, a generic assessment of the tunnel options on a comparable basis can be carried out. A shallow limit of one tunnel diameter is considered standard practice so therefore each option would be considered at this depth with the resultant ground settlement profiles compared. This is shown in Figure 18.

Figure 18 - Settlement profile by configuration



The settlement assessment is based on a 1.5% volume loss in a cohesive material (typical of Dublin Boulder Clay, which is encountered through many portions of the alignment). The twin bore shows the least overall settlement, while the single bore shows the lowest maximum differential (slope). There are benefits to both of these however it should be considered that the twin bore option is significantly shallower than the single bore (no wall) option and this has benefits for costs and waste in the assessment. The single bore (with wall) and monotube both cause significantly more movement.

4.6 Tunnel Boring Machine Operation

Typically, the operation of the various tunnel boring machines will be broadly similar with the only impacts being related to the size of the machine (controlled by configuration). In soft ground operations, it is critical to control the face pressure to prevent any excessive movement or groundwater inflow. This is usually done with a slurry or earth pressure balance machine where a pressurised slurry or mixture of excavated material is maintained at the tunnel face. This method of face pressure control is more difficult for larger machines with potential for the pressure to be too high (which could cause heave in the surrounding ground, particularly at shallow depths) or too low (which could cause overexcavation resulting in excessive ground movement).

4.7 System Expansion

4.7.1 Additional Stations

The future-proofing of expansion of the system should be considered. This is the addition of new stations to the alignment once operations have commenced. The ease of adding in the future needs to be considered with the cost of adding the stations during the initial construction. In order to test this by configuration, Option 9 has been amended to include two new additional stations and assessed using the same method as in Section 4.2. The stations were added in locations with the largest spacing between stations. It should be noted that the station locations are not proposed for future expansion but simply used as a test for this comparative assessment.

Figure 19 - Summary of Option 9 with 2 added stations

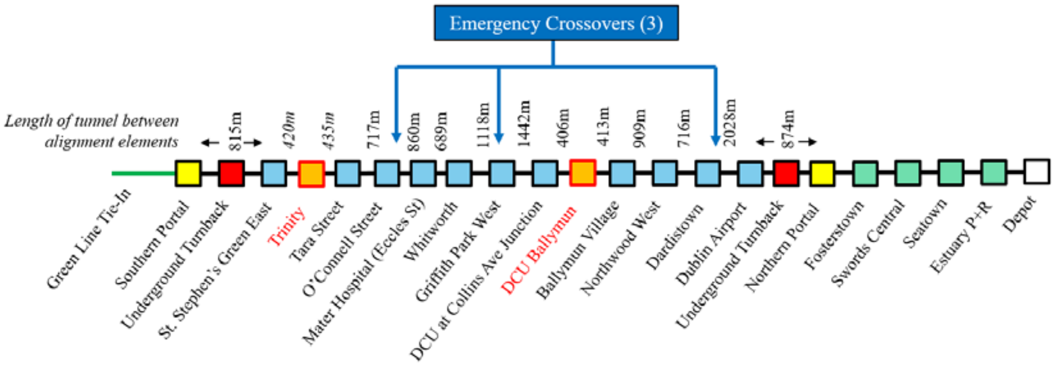


Table 3 - Summary of costs

Configuration	Option 9: A4-B12-C4		
	15 Stations 11 Underground	**17 Stations 13 Underground**	**Cost of Additional Stations**
Twin Bore	€3,366m	€3,479m	€113m
Single Bore (No Wall) - 1km shaft spacing	€3,406m	€3,519m	€113m
Single Bore (No Wall) – 761m shaft spacing	€3,562m	€3,631m	€69m
Single Bore (Wall)	€3,602m	€3,711m	€109m
Monotube	€4,668m	€4,760m	€92m

Figure 19 and Table 3 show that the additional cost of three stations would not change which is the cheapest configuration (twin bore). The added stations start to favour the monotube configuration due to the cost saving at each station and the twin bore (without wall) at 762m shaft spacing due to the reduction in shafts.

In terms of the cost of the additional stations, they range from €69m (single bore, no wall 1km spacing) to €113m (twin bore). The reason for the difference in this cost is related primarily to the reduction in station spacings and hence a reduction in the number of shafts.

4.7.2 Future Expansion

With respect to future expansion, these costs for including the stations during the construction stage would be considered a minimum cost and would likely be significantly more due to impacts on the operating system, as well as a requirement to provide intervention shafts in the interim. The costs for adding stations to the monotube would be relatively cheaper compared to the twin and single bore options as there would less impact to the operating system.

4.8 Programme

Considerations for programme at this stage are made at a high-level due to the early stage of the project. In general, the configuration of the tunnel has a significant impact to the tunnelling works programme but may not impact the overall programme of Metro North as the other works will likely control the overall length of the construction. Without a detailed breakdown of contracts and / or programme it is difficult to determine the effect of configuration on the overall programme so therefore programme is not considered at this stage in differentiating between the configurations.

Another key consideration is programme flexibility, where multiple machines allow some redundancy for follow-on elements. For example, a twin bore where a single machine breaks down - the second machine can continue with work continuing on the invert, tunnel fixings, trackwork etc. However, in the event of a single bore machine failing, all work within the tunnel can be potentially impacted. This flexibility in the programme is extremely beneficial from a risk reduction perspective.

4.9 System Operations

The tunnel configuration will have an impact on system operations and procedures, mostly related to issues on separated vs. non-separated track. The following are considered for the two potential tunnel configurations.

4.9.1 Broken down train in tunnel

In the unlikely event of a train breaking down in a tunnelled section of the alignment, safe access and egress must be provided to allow repair works to be carried out and / or evacuation of passengers to the nearest station or shaft.

For the twin bore configuration, single bore (with wall) and monotube this access can be provided down the incident bore as no trains will be operating in the tunnel at that time. Services can therefore continue in the non-incident bore allowing partial operation of the system. In the event of evacuation, passengers can also use the walkway within the incident bore.

For single bore (no wall), it is likely that service in both directions would have to be stopped or severely limited as it would be unsafe to run trains through the entire section during repair work or evacuation.

4.9.2 Maintenance on live tracks

During planned or emergency maintenance works on the tracks or other elements within the tunnels there can be no running of trains through the tunnel where the work is taking place. For single bore (no wall) this would prevent any running of rolling stock during maintenance period. For twin bore, single bore (with wall) and monotube maintenance is possible in one bore / track while maintaining the other bore /track for running of operational rolling stock.

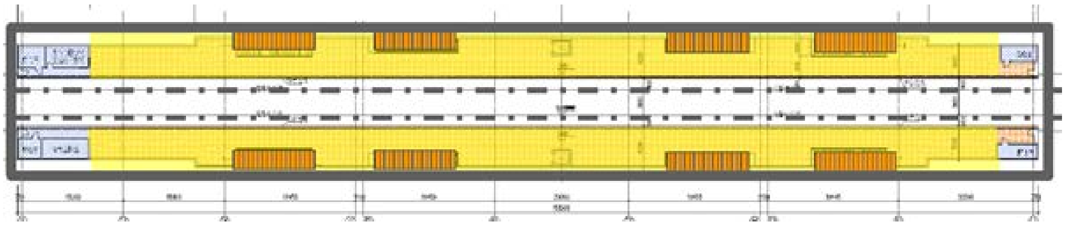
4.10 User Experience

The following compares various platform configurations related to the tunnel configurations with respect to station planning, circulation, engineering and operations.

4.10.1 Side Platform

This arrangement consists of two platforms that sit either side of two central tracks so that each direction is served by a single platform. It is more difficult to transfer and wayfinding is slightly more difficult as decisions by passengers accessing the station have to be made at ground or concourse level. The side platform sits naturally with single bore twin track (side by side) as the tracks are together as the tunnel enters the station, meaning no transition box is required. It can potentially work with the twin bore single track configuration however it would require a transition on approach to the station to combine the tracks.

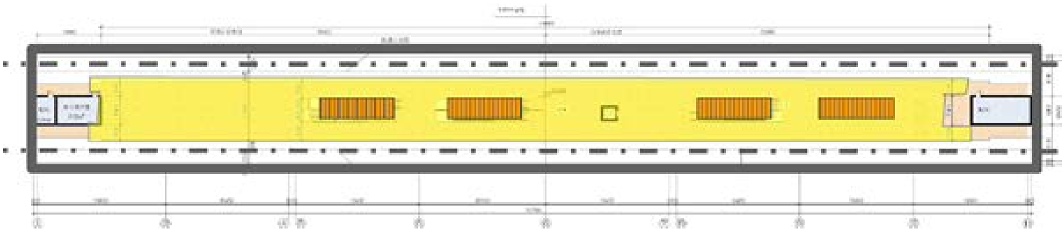
Figure 20 - Typical Underground Station Side Platform Layout



4.10.2 Island Platform

This arrangement consists of a single platform that sits between two tracks so that both directions are served by a single platform. It has benefits for transfers and passenger experience as it simplifies the wayfinding in the station. The island platform sits naturally with twin bore single track as the two tunnels can be spaced to enter the station at the required separation, meaning no transition in an additional excavation is required. It can potentially work with the single bore twin track (side-by-side) configuration however it would require a transition on approach to the station to separate the tracks.

Figure 21 - Typical Underground Station Island Platform Layout



4.10.3 Comparison between Platform arrangements

The following section compares side platform against island platform under station planning, vertical circulation elements and architecture, engineering considerations and station operations.

A. Station Planning

- Way Finding is easier with island platform as the decision point for boarding passengers is at the platform. Side Platform requires a decision point at the concourse level for boarding passengers.
- Side Platform has cross flow from fare collection gates to vertical circulation points.
- If unpaid links are required along the length of the concourse (e.g. if entrances are at either end) this is difficult to accommodate with a Side Platform configuration
- Easier to accommodate future entrance connections into the concourse with island platform station
- Island platform is more suitable for extreme crowd events e.g. train evacuation, or very high one way flow conditions such as sporting events, concerts etc.
- Island platform accommodates tidal AM/PM peaks better

B. Vertical Circulation Elements and Architecture

- Side Platform requires more escalators, stairs and lifts than Island Platform
- Less architectural wall cladding for island platforms
- More possibility for natural light into the station (e.g. if skylights are in road median)

C. Engineering Considerations

- Single bore tunnel needs to be deeper due to required cover on top and hence could make the platform level deeper
- Side Platform station box could be wider than Island Platform
- Side Platform configuration may require a waler beam adjacent to the long escalator/stair openings in the concourse slab
- Plant rooms may be duplicated at the ends of island platforms, and in addition the platform ends are narrow which may not be suitable
- For single bore tunnel with dividing wall, evacuation walkways are in middle of tracks and thus evacuating passengers from tunnels have to cross tracks to reach platforms
- Smaller Tunnel Ventilation plant and vent shafts required for twin track/island platform configuration

D. Station Operations

- Side Platform requires more operational staff e.g. station attendants on platform
- More equipment (lifts, escalators, lighting etc.) to operate and maintain

Overall, the island platform has significant advantages under most headings in particular with wayfinding, the amount of plant required and emergency escape. Therefore, it is considered that tunnel configurations that suit island platforms are preferable.

4.11 Noise and Vibration

During construction there is the potential to cause noise and vibration which may affect private and public properties. The impact of this by configuration is assessed.

During construction, the noise and vibration of the works are exclusively related to the operation of the tunnel boring machine, except where additional shafts are required for the single bore (no wall) configuration. In general, the operation of tunnel boring machines will cause short term noise and vibration at surface. This may be negligible but the following configuration related aspects will affect the level caused:

- Size of machine – a larger machine will cause more noise and vibration;
- Number of machines – two machines operating will cause more noise and vibration but typically two machines will operate with one in advance of the other so the duration of the noise may be longer but the intensity reduced.
- Depth and ground conditions – Deeper tunnels tend to be in rock, which if passing a building with piles founded in rock will cause more noise and vibration. A deeper tunnel in soil will cause less noise and vibration as the soil will help to dampen the impact at surface.

Overall, the twin bore as the shallowest and with two machines could cause more noise and vibration, however as it's the smallest machine and is likely to be operating in soft ground compared to a single bore or monotube depth at the same location and will probably cause less overall.

5 Summary and Recommendation

The three tunnel configurations from the tunnel configuration study have been assessed through several stages including a cost analysis for a generic alignment, a preliminary assessment on MCA Stage 1 route combination, MCA Stage 2 (including EPR) and a sensitivity on adding stations and on strong potential options not carried forward to MCA Stage 2. In addition to cost the following has been assessed:

- Waste;
- Emergency strategy;
- Future expansion;
- Programme;
- User Experience and;
- Noise and Vibration.

With all of this considered the recommended option for the Emerging Preferred Route (EPR) is the twin bore configuration. The twin bore is preferable under cost, waste, emergency strategy, programme and user experience. While not preferred for future expansion and noise and vibrations these do not shift the balance of favour toward another configuration.

It is recommended that the single bore (with wall) and monotube are no longer considered as part of this study. With reference to Figure 22 the monotube should only be considered if the alignment moves deeper and more stations are added. With reference to the same figure, the single bore (with wall) option is only preferred if the single bore (no wall) option is rejected and more stations are added. Both of these scenarios are not considered likely when considering the alignment options.

The single bore (no wall) should only be considered further if the requirement for shafts for this configuration is set as 1km and several stations are added. If the shaft requirement is set at 762m then a large number of stations will need to be added to justify selecting this configuration.

Additional Information

A1 Considerations from Tunnel Configuration Study

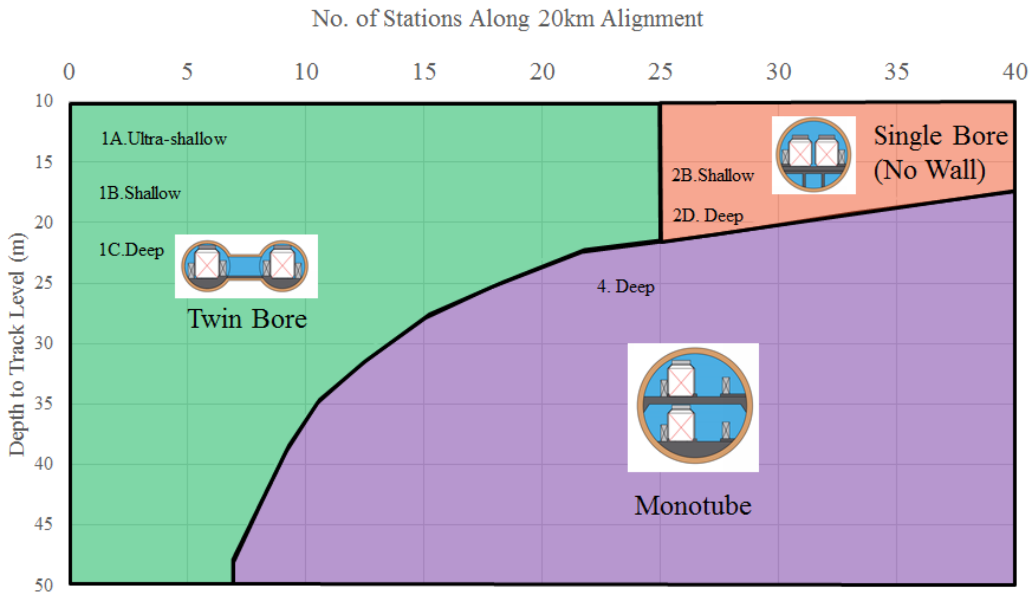
The three options were carried forward as the final configuration could not be determined within the parameters of the study. The options were all assessed for a single station and 1km of tunnel with additional elements (portals, crossovers, turnbacks) based on an underground alignment of 5.8km. As the three configurations were comparable, varying these parameters could favour any of the options.

As part of the New Metro north Alignment Options Study, an assessment of the costs was carried out on a theoretical 20km underground alignment. The cost basis for this assessment is based on the latest cost information on the alignment study. The following elements were fixed for the purposed of the assessment:

- Two portals;
- Intervention shafts at 1.5km spacing for twin bore, single bore (with wall) and monotube and at 762m spacing for single bore (no wall);
- Two underground turnbacks; and
- Three underground crossovers.

The assessment considered track depths from 10m to 50m and station numbers from 2 (10km spacing) to 40 (500m spacing). These extremes are tested to determine the type of alignment which suits each configuration. The results of this high level analysis are shown in Figure 22.

Figure 22 - Favourable conditions for each configuration (for example alignment)



While the above is developed for a generic alignment, it shows some clear scenarios which favour each configuration. Typically shallow alignments with longer spacing between stations suit the twin bore option, shallow alignments with shorter spacing between stations suit the single bore option and deep alignments with shorter station spacing suit the monotube configuration. The limitations of this assessment are that it assumes consistent station depth and spacing, which is not realistic.

A2 Sensitivity

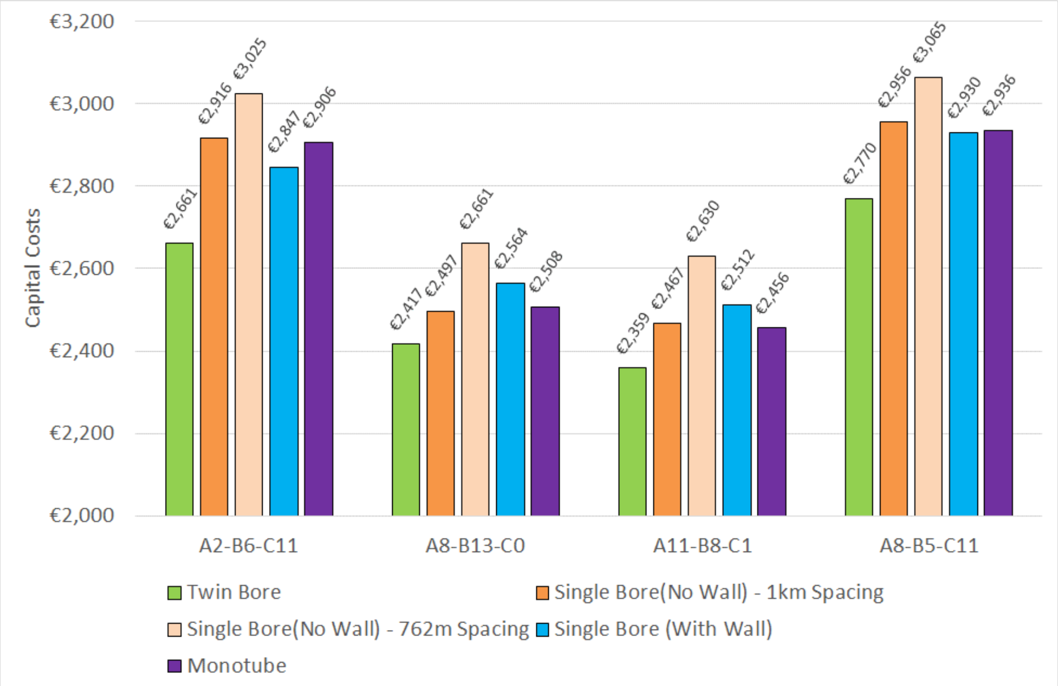
A2.1 Non-MCA Stage 2 Routes

While the assessment is presented for MCA Stage 2 routes, there is the potential that the EPR may change or be adjusted. As such, a range of options that were not considered for MCA Stage 2 are considered below as a sensitivity on the tunnel configuration. These options are:

- A2-B6-C11 – Entirely underground route from City Centre to Swords
- A8-B13-C0 – Elevated in Ballymun and at grade at swords
- A11-B8-C1 – At-grade in Ballymun and at grade at swords
- A8-C5-C11 – Cut and cover in Ballymun and underground in swords

A similar level of detail used in the assessment in Section 4.2 has been carried out. The results of the analysis are shown in Figure 23.

Figure 23 – Sensitivity check on non MCA2 Routes



The results of the sensitivity check above show that the twin bore option remains favourable in terms of cost for all options considered.

A2.2 Multiple Tunnel Configurations

There is potential to use a combination of tunnel configurations for the new Metro North, however this depends on several factors such as number of drives, emergency strategy, transitions and construction issues.

There are two mainline tunnel drives expected for the MCA2 Routes. The first is from Griffith Park to the City Centre (Charlemont Portal) and the second is from

North of the Airport to Griffith Park. The only transition at this point is from the tunnel launch location in Griffith Park which is at a station location (Griffith Park West). The station would have to be designed to cater for this transition, which could add significant cost.

Additionally, the switch from single to twin, or from twin to monotube would mean that different sections of track would have two different escape strategies (i.e. cross passage vs stairs etc.), which would both have to be communicated to the passengers. This could potentially cause confusion during an emergency.

A final consideration is the lining segment production. The segments are cast to a high level of precision for a specific machine which requires several sets of expensive moulds. The duplication of the moulds for a second machine could add cost and also impact the segment transportation logistics.

Overall, it is not recommended to use multiple tunnel configurations for the current MCA Stage 2 routes. Where the drives are geographically separate (i.e. routes that surface in Ballymun) there may be more merit as the transition is built into the portal, but the size and cost of an underground transition within Ballymun would negate any benefits to the use of multiple configurations.

Appendix F

Geotechnical Conditions Along Route

National Transport Authority

New Metro North Alignment Study

Concept Design Report - Appendix F

252252-ARP-GEN-SW-RP-CX-0022

Issue | 19 February 2018

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Contents

1 Ground Conditions Along Route

The following section summarises the ground conditions expected along the route, at station locations, at portal locations and at the intervention shaft. These conditions generalised and are presented for concept stage only and are subject to further development/refinement during subsequent design stages. The order of the description follows the alignment along the chainage from Charlemont in the South to Estuary in the North.

1.1.1 Charlemont Portal

The Charlemont Portal will be constructed south of the Grand Canal, south-east of the current Charlemont Luas Green Line station to a level of approximately (+3.1mOD). Existing ground level is +13.8mOD. The ground conditions at Charlemont Portal are summarised in Table 1.

Table 1 – Stratigraphy at Charlemont Portal

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Made Ground	0	15.22 – 16.09	1.7 – 2.9
Soft, light brown sandy gravelly CLAY with occasional cobbles (UBrBC)	2.9	13.19	0.9
Stiff to very stiff brown sandy gravelly CLAY with occasional cobbles (UBrBC) Glacial sand lense within glacial till found at 7.49mOD – 0.7m thick	1.7 – 3.8	12.29 – 13.69	7.6 – 9.2
Very strong to medium strong, medium to thinly bedded, grey/dark grey/black, fine-grained Limestone	9.3 – 10.6	3.99 – 4.74	Not proven

1.1.2 Tunnel 1 – Charlemont Portal to St. Stephen’s Green East Station

This section of the alignment from Ch. 1+000 to Ch.1+900 of track will run beneath the Grand Canal from Charlemont portal north beneath Earlsfort Terrace to St. Stephen’s Green East Station. The tunnel elevation varies between 3.14mOD to -8.7mOD at its lowest point before rising to -7.36mOD at Stephen’s Green and will run predominantly in rock, except for a small section around the Grand Canal where it straddles the overburden/bedrock boundary. The ground conditions along this section are summarised in Table 2.

Table 2 - Stratigraphy of Charlemont Portal to St.Stephen's Green East Station

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Made Ground	0	0	0.8 – 8.5

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Soft to stiff brown sandy gravelly CLAY with occasional cobbles (UBrBC)	0.8 – 8.5	10.71 – 13.22	0.55 – 3.4
Stiff to very stiff black sandy gravelly CLAY with occasional cobbles (UBrBC)	2.8 – 10.35	8.41 – 11.8	2.5 – 5.2
Medium strong to very strong (locally weak), thinly bedded, grey to black, fine-grained Limestone	7.2 – 13.5	5.4 – 8.42	Not proven

1.1.3 St. Stephen's Green East Station

St. Stephen's Green East Station will be constructed on St. Stephens Green East at approximately -7.356mOD (ground level is approximately 11.9mOD). The station box is expected to be constructed within rock. The ground conditions at St. Stephen's Green Station are summarised in Table 3.

Table 3 Stratigraphy of St. Stephens Green East Station

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Topsoil/Made Ground	0	11.6	0.5
Firm brown/brownish grey slightly sandy slightly gravelly CLAY with occasional cobbles and boulders (UBrBC)	0 – 0.5	11.1 – 11.5	4.5 – 8
Stiff dark grey brown slightly sandy slightly gravelly CLAY (UBkBc)	0 – 8	3.5 – 11.7	1.8 – 10.6
Strong to very strong grey to dark grey argillaceous LIMESTONE interbedded with Moderately weak to predominantly strong black calcareous MUDSTONE	10 – 10.6	1.2 – 1.5	Not proven
Characteristic groundwater level (mOD)			7.9 - 9.5

1.1.4 Tunnel 2 – St. Stephen's Green Station East to Tara Street Station

This section of the alignment from St. Stephens' Green East Station to Tara Street Station (2+000 to 2+900) consists of twin bored tunnels which will be constructed entirely within bedrock, running beneath Government buildings and Trinity College. The tunnel level varies in elevation between -7.4mOD at its highest to -21.1mOD at its lowest point with ground level varying between 11.8mOD to 3.9mOD moving north towards the River Liffey. The ground conditions along this section are summarised in Table 4.

Table 4 Stratigraphy between St. Stephen's Green East and Tara Street Station

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Made Ground/Topsoil	0	2.3 - 11	0.9 – 4.8
Soft to very soft grey slightly sandy slightly gravelly silty CLAY containing lenses of orange slightly sandy SILT and occasional shell fragments (Glaciomarine)	0.9 – 1.9	1.2 – 1.4	1.1 – 1.4
Medium dense to dense brownish grey silty sandy fine to coarse SAND/GRAVEL (Alluvial Sands and Gravels)	2.8 – 3.9	-1.2 – (+)5	1.6 – 7.6
Soft to firm dark grey brown slightly sandy slightly gravelly CLAY with occasional cobbles (UBrBC)	0.9 – 4	2.3 – 9	1.7 – 2.4
Stiff to very stiff dark grey/black slightly sandy slightly gravelly CLAY with cobble and boulder content (UBkBc)	2.6 - 7	-4 – (+) 7.3	0.6 – 10.3
Weathered bedrock - Limestone	7 - 12	-9 – (+)0.9	0.2 – 2.1
Moderately strong to very strong, thinly to thickly bedded, grey to black, fine to medium grained LIMESTONE	7 - 17.2	-13.88 – (-0.6)	Not Proven

1.1.5 Tara Street Station

The Tara Street Station will be constructed at the junction of Tara Street and Townsend Street, at approximately -24.559mOD with ground level at 3.34mOD to 3.786mOD. The station is likely to be constructed in limestone bedrock. The ground conditions at Tara Street Station are summarised in Table 5.

Table 5 Stratigraphy of Tara Street Station

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Made Ground	0	3.5 – 3.7	3 – 3.6
Alluvium (Silts and Clays)	3 – 3.6	3.2 – 3.95	0.4 – 3
Alluvium (Sands and Gravels)	3.3 – 6	-0.1 – (+)0.7)	2.5 – 3.4
Weathered bedrock – Limestone gravels, cobbles and boulders	6.3 – 9.4	-5.7 – (-)2.8	0.4 – 0.8
Moderately strong to very strong, thinly to thickly bedded, grey to black, fine to medium grained LIMESTONE	7.1 – 9.8	-6.1 – (-3.6)	Not Proven
Characteristic groundwater level (mOD)			-1.2 – 0.6

1.1.6 Tunnel 3 – Tara Street Station to O'Connell Street Station

The section of alignment from Tara Street to O'Connell Street station (Ch.3+000 to 3+900) will consist of twin bore tunnels running beneath the River Liffey and adjacent to O'Connell Street at levels of approximately -20.465mOD to -12.424mOd with a low point of -24.99mOD at Ch.3+200 beneath the River Liffey.

This section of the alignment traverses the Pre-Glacial Liffey Channel from approximately Ch.3+400. The channel represents a previous course that the River Liffey took prior to being infilled by sediment during glacial activity.

1.1.6.1 Tunnel 3 - 3+000 to 3+400

The tunnel alignment is expected to be constructed within bedrock between Ch.3+000 to 3+400. The ground conditions along this section are shown in Table 6.

Table 6 Stratigraphy between Tara Street Station and Ch 3+400

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Made Ground	0	-4.3 to (+)4.8	0.9 – 10.5
Loose to medium dense fine to medium grey to dark grey/brown sandy slightly silty GRAVEL	0.9 – 4.2	-8 – (+)2.3	0.2 – 7.2
Very soft to firm grey to dark grey organic SILT with some small stones (Alluvial clays and silts)	3.1 – 10.5	-6.8 – (+).7	1.2 – 2.7
Soft to firm grey slightly sandy organic SILT with some laminations and shell fragments (Glaciomarine)	5.5 – 6	-4.3 – (-)3.9	1.1 – 3.6
Very stiff grey slightly sandy slightly gravelly CLAY with occasional cobble (UBkBc)	4.4 – 6	-2.8 – (-)0.6	0.3 – 6.7
Stiff to very stiff brown very gravelly CLAY with high cobble content (UBrBc)	4.3 – 5.3	-0.6 – (+)0.2	0.3 – 6.7
Stiff dark grey slightly sandy gravelly CLAY with high cobble content (UBrBc)	5.2 – 6.8	-2.3 – (-)0.5	2.2 – 3.8
Weathered Rock	3 – 7.6	-6 – (-)0.9	1.2 – 1.8
Moderately strong to very strong, thinly to thickly bedded, grey to black, fine to medium grained LIMESTONE/ Moderately weak to strong, thinly laminated, dark grey/black, carbonaceous MUDSTONE	16.1	2.94	Not Proven

1.1.6.2 Tunnel 3 - 3+400 to 3+900

At approximately 3+400 there is a transition from alluvial sands and gravels to more dense sands and gravels believed to be of glacial origin. The tunnel alignment is expected to straddle the overburden/rock boundary from Ch.3+400 onwards, so mixed face conditions should be expected. The ground conditions along this section are shown in Table 7.

Table 7 Stratigraphy between Ch3+400 and O'Connell Street Station

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Made Ground	0	4.2 – 5.9	2 – 4.2
Dense to very dense grey/brown slightly sandy GRAVEL (Glacial Gravels)	3.1 – 4.2	0.7 – 2.2	2.9 – 20.7
Dense to very dense brown and grey fine to coarse slightly gravelly SAND (Glacial Sands)	6	-1.4	6.4
Stiff brownish grey slightly sandy slightly gravelly CLAY (LBrBc)* *only encountered in MGI/BH708	12.4	-7.8	2.4
Moderately strong to very strong, thinly to thickly bedded, grey to black, fine to medium grained LIMESTONE/ Moderately weak to strong, thinly laminated, dark grey/black, carbonaceous MUDSTONE	14.75 – 24.8	-19.9 – (-)10.1	Not Proven

1.1.7 O'Connell Street Station

The Parnell Square station will be constructed at the northern end of O'Connell Street at approximately -12.4mOD (ground level is approximately 8.2mOD to 10mOD). The station is likely to be constructed within the overburden, consisting of sands and gravels. The station is located within the Pre-Glacial Liffey Channel discussed in 5.3.6 above, consisting of thick deposits and sand and gravel deposited as a result of glacial activity. The ground conditions at O'Connell Street station are summarised in Table 8.

Table 8 Stratigraphy of O'Connell Street Station

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Made Ground	0	4.9 – 5.9	3.9 – 4.2
Medium dense to very dense grey/brown sandy (slightly clayey in sections) GRAVEL (Glacial Gravels)	3.9 – 4.2	0.7 – 2	18.8 – 21.7
Very dense brown and grey fine to coarse SAND and subangular to rounded fine to coarse GRAVEL of limestone, sandstone and quartzite. (Glacial Sands)	3.5	2	23.6

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Moderately strong to very strong, thinly to thickly bedded, grey to black, fine to medium grained LIMESTONE/ Moderately weak to strong, thinly laminated, dark grey/black, carbonaceous MUDSTONE	21.2 – 25.6	-19.9 – (-16.1)	Not Proven
Characteristic groundwater level (mOD)			0.3 – 0.5

1.1.8 Tunnel 4 – O'Connell Street Station to Mater Hospital Station

This section of the alignment from O'Connell Street to Mater Hospital stations (Ch. 3+700 to Ch.4+600) consists of twin bore tunnels running at levels of approximately-20m to -30m (ground level varies from 5m to 20m.

This section of the alignment traverses the Pre-Glacial Liffey Channel as discussed in Section 5.3.6, consisting of thick deposits of glacial sands and gravels. The ground conditions along this section are summarised in Table 9.

Table 9 Stratigraphy between O'Connell Station and Mater Hospital Station

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Made Ground/Topsoil	0	8.8 – 21.4	0 – 4.2
Stiff brown slightly sandy gravelly CLAY with occasional cobbles. (UBrBc)	0.6 – 4.2	5.4 – 16.5	0.8 – 8.2
Very stiff grey slightly sandy gravelly CLAY with occasional cobbles. Sand is fine to coarse. (UBkBc)	2.3 – 4.2	8.7 – 15.3	1.5 – 11
Medium dense to very dense grey/brown sandy (slightly clayey in sections) GRAVEL (Glacial Gravels)	5.1 – 14.7	-1.4 – (+)12.2	2 – 20
Very dense brown and grey fine to coarse SAND and subangular to rounded fine to coarse GRAVEL of limestone, sandstone and quartzite. (Glacial Sands)	10.3 – 15.8	-7 – (+)8.3	0.9 – 14.2
Very stiff to hard brown slightly sandy slightly gravelly CLAY with occasional medium gravel sized pockets of fine to medium sand. (LrBrBc)	14 – 15.7	1.6 – 3.3	5.8 – 11.2
Moderately strong to very strong, thinly to thickly bedded, grey to black, fine to medium grained LIMESTONE/ Moderately weak to strong, thinly laminated, dark grey/black, carbonaceous MUDSTONE	16.9 – 30.3	-15.8 – (-)4	Not Proven

1.1.9 Mater Hospital Station

The Mater station will be constructed on the south-east side of the Mater Hospital between Berkeley Road and Eccles Street. The ground level is at approximately

+20mOD. The station is likely to be constructed within the overburden consisting of clay and gravels. The ground conditions at Parnell Square are summarised in Table 10.

Table 10 Stratigraphy of Mater Hospital Station

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Made Ground/Topsoil	0	19-20	0.1 0.5
Stiff brown slightly sandy gravelly CLAY with occasional cobbles. (UBrBc)	0.0 – 0.5	18-20	3.0 - 8.0
Medium dense to very dense grey/brown sandy (slightly clayey in sections) GRAVEL (Glacial Gravels)	7.0 – 9.0	11-12	5 - 10
Very stiff to hard brown slightly sandy slightly gravelly CLAY with occasional medium gravel sized pockets of fine to medium sand. (LrBrBc)	12 - 18	2.0 – 8.0	10 - 15
Moderately strong to very strong, thinly to thickly bedded, grey to black, fine to medium grained LIMESTONE/ Moderately weak to strong, thinly laminated, dark grey/black, carbonaceous MUDSTONE	28 - 29	-9 - -10	Unproven
Characteristic groundwater level (mOD)			13-15

1.1.10 Tunnel 5 – Mater Hospital Station to Whitworth Station

This section of the alignment from Mater Hospital to Whitworth stations (Ch. 4+700 to Ch.5+300) consists of twin bore tunnels running at levels of approximately-10m to 0m (ground level varies from 20m to 23m. The ground conditions along this section are summarised in Table 11.

Table 11 - Stratigraphy between Mater Hospital and Whitworth Stations

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Made Ground/Topsoil	0	20 - 23	2 – 4
Stiff brown slightly sandy gravelly CLAY with occasional cobbles. (UBrBc)	2-5	18 – 20	3 – 9
Very stiff grey slightly sandy gravelly CLAY with occasional cobbles. Sand is fine to coarse. (UBkBc)	9 – 12	11 - 15	1 – 11
Very stiff to hard brown slightly sandy slightly gravelly CLAY with occasional medium gravel sized pockets of fine to medium sand. (LrBrBc)	12 – 16	4 - 11	2 – 3
Moderately strong to very strong, thinly to thickly bedded, grey to black, fine to medium grained LIMESTONE/ Moderately	14 - 18	2 - 9	Unproven

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
weak to strong, thinly laminated, dark grey/black, carbonaceous MUDSTONE			

1.1.11 Whitworth Station

Whitworth Station will be constructed at the junction of Finglas Road, Botanic Road and Prospect Avenue at a level of approximately 8.7mOD. Ground level at this location is 27.3mOD. The station is likely to be constructed within the overburden, while it is possible that rock will be encountered towards the bottom of the excavation. The ground conditions at Whitworth Station are summarised in Table 12.

Table 12 - Stratigraphy of Whitworth Station

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Made Ground/Topsoil	0	20 - 23	2 – 4
Firm to stiff brown slightly sandy slightly gravelly CLAY with occasional cobbles (UBrBC)	2-5	18 – 20	3 – 9
Very stiff to hard dark grey/black slightly sandy slightly gravelly CLAY with cobble and boulder content (UBkBc)	9 – 12	11 - 15	1 – 11
Stiff to locally firm, dark brown, sandy gravelly CLAY with occasional cobble (LBrBc)	12 – 16	4 - 11	2 – 3
Moderately strong to very strong, thinly to thickly bedded, grey to black, fine to medium grained LIMESTONE/ Moderately weak to strong, thinly laminated, dark grey/black, carbonaceous MUDSTONE	14 - 18	2 - 9	Unproven
Characteristic groundwater level (mOD)			7.5 – 9.6

1.1.12 Tunnel 5 – Whitworth to Griffith Park West

The section of alignment from Whitworth to Griffith Park West stations (Ch.5+500 to 6+550) consists of twin bore tunnel which run beneath Botanic Road at a level of approximately 8.7mOD to -1.3mOD with a low point of -6.08mOD beneath the Tolka River. Ground level varied from 27.129mOD to

20.9mOD, with a general fall in topography towards the Tolka River. The ground conditions along this route are summarised in Table 13.

Table 13 Stratigraphy of Whitworth to Griffith Park West Station

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Made Ground/Topsoil	0	17.3 – 23.4	0 – 1.4
Firm to stiff brown slightly sandy slightly gravelly CLAY with occasional cobbles (UBrBC)	1.4	22	0.5
Very stiff to hard dark grey/black slightly sandy slightly gravelly CLAY with cobble and boulder content (UBkBc)	1.9	21.5	12.8
Moderately strong to very strong, thinly to thickly bedded, grey to black, fine to medium grained LIMESTONE/ Moderately weak to strong, thinly laminated, dark grey/black, carbonaceous MUDSTONE	12 – 14.7	5.3 – 8.7	Not Proven

1.1.13 Griffith Park West Station

Griffith Park West station will be constructed adjacent to St. Mobhi Road at a level of approximately -1.294mOD (ground level varies from 20.9mOD to 22.76mOD), beneath Na Fianna GAA sports grounds. The station is likely to be constructed in a mix of overburden and bedrock. The general ground conditions at Griffith Park West Station are summarised in Table 14.

Table 14 Stratigraphy at Griffith Park West

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Made Ground/Topsoil	0	19	1.0
Firm to stiff brown slightly sandy slightly gravelly CLAY with occasional cobbles (UBrBC / UBkBc / LBrBC / LBkBC)	1	18	15
Moderately strong to very strong, thinly to thickly bedded, grey to black, fine to medium grained LIMESTONE/ Moderately weak to strong, thinly laminated, dark grey/black, carbonaceous MUDSTONE	16	3	Not Proven
Characteristic groundwater level (mOD)			18 - 19

1.1.14 Tunnel 6 – Griffith Park West to DCU

The section of alignment from Griffith Park West to DCU stations (Ch.6+700 to 7+600) consists of twin bored tunnels which will run beneath St. Mobhi Road at levels of approximately -1.3mOD to 30.8mOD. Ground level varies from to 22.77mOD to 46mOD. The tunnels are expected to straddle the overburden/bedrock boundary, so mixed face conditions should be expected. The ground conditions along this section are summarised in Table 15.

Table 15 Stratigraphy of Griffith Park West to DCU

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Made Ground/Topsoil	0	29.1 – 45.2	0.2 – 1
Firm to stiff brown slightly sandy slightly gravelly CLAY with occasional cobbles (UBrBC)	0.5 – 1.2	28.6 – 44	1.9 – 2.9
Very stiff to hard dark grey/black slightly sandy slightly gravelly CLAY with cobble and boulder content (UBkBc)	2.9 – 3.4	25.7 – 42	6 – 25.1
Stiff to locally firm, dark brown, sandy gravelly CLAY with occasional cobble (LBrBc)	3.9 – 9.2	31.22 - 36	8.47 – 10.8
Moderately strong to very strong, thinly to thickly bedded, grey to black, fine to medium grained LIMESTONE/ Moderately weak to strong, thinly laminated, dark grey/black, carbonaceous MUDSTONE	16.1	2.94	Not Proven

1.1.15 DCU Station

DCU Ballymun Road Station will be constructed at a level of approximately 30.83mOD (ground level varies from 46mOD to 48.621mOD) beneath Ballymun Road adjacent to Albert College Park. The station box is expected to be constructed close to or within an old infilled river channel. The ground conditions at DCU Ballymun Road Station are summarised in Table 16.

Table 16 – Stratigraphy at DCU Station

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Made Ground/Topsoil	0	45.2 – 48.7	0.2 – 1.8
Firm to stiff brown slightly sandy slightly gravelly CLAY with occasional cobbles (UBrBC)	0.3 - 2	44 – 47.2	1.5 – 3.2
Very stiff to hard dark grey/black slightly sandy slightly gravelly CLAY with cobble and boulder content (UBkBc)	2.9 – 3.5	42 – 45.3	2.9 – 6.1

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Stiff to locally firm, dark brown, sandy gravelly CLAY with occasional cobble (LBrBc)	6.4 – 9.6	36 – 42.3	2.9 – 16.9
Very stiff grey slightly sandy slightly gravelly CLAY with occasional cobble (LBkBc)	12.5	34.5 – 36.2	Not Proven
Dense to very dense brown to grey slightly sandy angular to sub-rounded fine to coarse GRAVEL	11.9 – 15.8	31.196 - 33.28	1.7 - >8.1
Characteristic groundwater level (mOD)			40 - 42

1.1.16 Tunnel 7 – DCU to Ballymun Village

This section of the alignment from DCU to Ballymun Village stations (Ch.7+700 to 9+100) consists of twin bore tunnels running beneath Ballymun Road at levels of approximately 30.83mOD to 47mOD with a low point of 25.484mOD at Ch.8+100. Ground level varies from 48.62mOD to 62.02mOD. Ground conditions along this section are summarised in Table 17.

Table 17 The stratigraphy of DCU to Ballymun Village

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Made Ground/Topsoil	0	48.7 – 61.9	0.1- 4.1
Firm to stiff brown slightly sandy slightly gravelly CLAY with occasional cobbles (UBrBC)	0.2 – 2	46.7 – 61.7	0.4 – 5
Very stiff to hard dark grey/black slightly sandy slightly gravelly CLAY with cobble and boulder content (UBkBc)	1.3 – 5.2	45.2 – 60.4	0.2 – 20.6
Stiff to locally firm, dark brown, sandy gravelly CLAY with occasional cobble (LBrBc)	4.2 - 12	39 – 49.8	1 – 14.5
Very stiff grey slightly sandy slightly gravelly CLAY with occasional cobble (LBkBc)	12.5 – 20.2	31 - 38	1.1 – 7.7
Medium dense, grey/brown, clayey, very sandy, fine to medium, angular to sub rounded GRAVEL with cobbles* Description from RC26. All other encounters described as “returns of gravels and cobbles with some clay”	7.4 – 16.7	42.093 – 53.148	3.5 - 7
Moderately strong to very strong, thinly to thickly bedded, grey to black, fine to medium grained LIMESTONE/ Moderately weak to strong, thinly laminated, dark grey/black, carbonaceous MUDSTONE	19.3 – 24.2	29.6 – 39.5	Not Proven

1.1.17 Ballymun Village Station

Ballymun Village Station is located on the Ballymun Road at a level of 47mOD. Ground level at this location is 62mOD. The station box is expected to be in both overburden and possible rock. The ground conditions at Ballymun Village Station are summarised in Table 18.

Table 18 Stratigraphy of Ballymun Village Station

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Made Ground/Topsoil	0	61.7 – 63.6	0.2 – 1.8
Firm to stiff brown slightly sandy slightly gravelly CLAY with occasional cobbles (UBrBC)	0.2 – 1.3	60.5 – 62.4	0.9 – 1.8
Very stiff to hard dark grey/black slightly sandy slightly gravelly CLAY with cobble and boulder content (UBkBc)	1.5 - 3	59.1 – 60.6	1.3 – 20.6
Dense grey/brown, coarse sub-angular to angular GRAVEL/Dense, brown, fine to coarse SAND	8.7	53.17	18.3
Stiff to locally firm, dark brown, sandy gravelly CLAY with occasional cobble (LBrBc)* Only encountered in RC509	16.5	47.1	3.5
Moderately strong to very strong, thinly to thickly bedded, grey to black, fine to medium grained LIMESTONE/ Moderately weak to strong, thinly laminated, dark grey/black, carbonaceous MUDSTONE** Only encountered in RC507	23.2	38.49	Not Proven
Characteristic groundwater level (mOD)			58 - 59

1.1.18 Tunnel 8 – Ballymun Village to Northwood West

The section of alignment from Ballymun Village Station to Northwood West (Ch.9+200 to 10+050) will consist of twin bored tunnel with levels of approximately 46.95mOD to 42.44mOD, running beneath Ballymun Road to Ch. 9+500 before veering off beneath Gulliver's Retail Park. Ground Level is approximately 62.27mOD to 57.567mOD. The ground conditions along this section are summarised in Table 19.

Table 19 Stratigraphy of Ballymun Village to Northwood West

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Made Ground/Topsoil	0	58.3 – 63.6	0.2 - 1

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Firm to stiff brown slightly sandy slightly gravelly CLAY with occasional cobbles (UBrBC)	0.2 – 1.2	58.4 – 63.4	0.1 – 1.8
Very stiff to hard dark grey/black slightly sandy slightly gravelly CLAY with cobble and boulder content (UBkBc)	0.8 – 3	56 – 60.8	1.7 – 18.3
Stiff to locally firm, dark brown, sandy gravelly CLAY with occasional cobble (LBrBc)* Only encountered in RC509	16.5	47.1	3.5
Moderately strong to very strong, thinly to thickly bedded, grey to black, fine to medium grained LIMESTONE/ Moderately weak to strong, thinly laminated, dark grey/black, carbonaceous MUDSTONE** Only encountered in RC507	15.4	47.6	Not Proven

1.1.19 Northwood West Station

Northwood West station will be located at the rear of Gulliver's Retail Park at a level of approximately 42.45mOD (ground level is 58 – 57mOD). The station box is expected to be constructed in both rock and overburden. The ground conditions at Northwood Station are summarised in Table 20.

Table 20 - Stratigraphy at Northwood West Station

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Made Ground/Topsoil	0	57.4 – 59.6	0.2 – 0.5
Firm to stiff brown slightly sandy slightly gravelly CLAY with occasional cobbles (UBrBC)	0.2 – 0.7	57.2 – 59.3	1.6 – 7.6
Very stiff to hard dark grey/black slightly sandy slightly gravelly CLAY with cobble and boulder content (UBkBc)	2 – 7.9	51.7 – 57.1	2.5 – 8.4
Moderately strong to very strong, thinly to thickly bedded, grey to black, fine to medium grained LIMESTONE/ Moderately weak to strong, thinly laminated, dark grey/black, carbonaceous MUDSTONE	16.3	43.3	Not Proven
Characteristic groundwater level (mOD)			56-59

1.1.20 Tunnel 9 – Northwood West to Dardistown

This section of the alignment from Northwood West Station to Dardistown Station (Ch.10+200 to 10+900), consists of twin bore tunnels at levels of approximately 42.4mOD to 43.704mOD with a low point of 37.3mOD at Ch.10+450. Ground level varies from 57.5mOD to 64.995mOD. This section of the alignment will run beneath the M50. The ground conditions along this section are summarised in Table 21.

Table 21 Stratigraphy of Northwood West to Dardistown

Geological stratum	**Depth to top of stratum (m)**	**Level of top of stratum (mOD)**	**Thickness range (m)**
Made Ground/Topsoil	0	58 – 65.7	0.3 – 1
Firm to stiff brown slightly sandy slightly gravelly CLAY with occasional cobbles (UBrBC)	0.3 - 1	57 – 64.7	1.6 – 4.3
Very stiff to hard dark grey/black slightly sandy slightly gravelly CLAY with cobble and boulder content (UBkBc)	2.2 – 4.6	58.6 – 63.1	2.4 – 2.8
Firm to stiff brown to dark brown sandy gravelly CLAY with some cobbles (LBrBc)* *zones of clayey SAND	7	56.2	9.1
Stiff, black, sandy gravelly CLAY with occasional cobbles and boulders (LBkBc)	16.1	47.1	4.1
Moderately strong to very strong, thinly to thickly bedded, grey to black, fine to medium grained LIMESTONE/ Moderately weak to strong, thinly laminated, dark grey/black, carbonaceous MUDSTONE	20.2	43	Not Proven

1.1.21 Dardistown Station

The Dardistown Station will be constructed in a green filed site north of the M50 at approximately 43.7mOD (ground level is 62-62.5mOD). The station box will be constructed in both overburden and bedrock. The ground conditions at Dardistown Station are summarised in Table 22.

Table 22 Stratigraphy of Dardistown Station

Geological stratum	**Depth to top of stratum (m)**	**Level of top of stratum (mOD)**	**Thickness range (m)**
Firm to stiff brown slightly sandy slightly gravelly CLAY with occasional cobbles (UBrBC)	0	61 - 62	5 - 6

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Very stiff to hard dark grey/black slightly sandy slightly gravelly CLAY with cobble and boulder content (UBkBc)	0 - 3	59 - 62	2 – 10
Brown sandy gravelly CLAY (LBrBc)	13	48	5 - 6
Moderately strong to very strong, thinly to thickly bedded, grey to black, fine to medium grained LIMESTONE/ Moderately weak to strong, thinly laminated, dark grey/black, carbonaceous MUDSTONE	14 - 18	44 - 48	Not Proven
Characteristic groundwater level (mOD)			52-55

1.1.22 Tunnel 10 – Dardistown to Dublin Airport

The section of the alignment from Dardistown Station to Dublin Airport (CH.11+000 to 13+000) consists of twin bored tunnels varying in elevation 36.53mOD to 48.35mOD with the lowest point being at Ch.11+700, the location of an intervention shaft for emergency egress and access. The intervention shaft will require two short passages to connect the shaft to each of the tunnels. Ground level varies from 61.2mOD to 67mOD moving north to Dublin Airport. The tunnels are expected to be constructed within overburden but mixed face conditions are also possible as the alignment straddles the overburden/rock boundary in places. Overburden consists of Dublin Boulder Clay with some granular lenses. Towards the airport the tunnels will enter rock at approximately Ch.12+850. The ground conditions along this section are summarised in Table 23.

Table 23 Stratigraphy of Dardistown to Dublin Airport

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Made Ground/Topsoil	0	58.4 – 67.2	0.2 – 2.8
Firm to stiff brown slightly sandy slightly gravelly CLAY with occasional cobbles (UBrBC)	0.3 – 2.8	58 – 65.2	0.4 – 4.6
Very stiff to hard dark grey/black slightly sandy slightly gravelly CLAY with cobble and boulder content (UBkBc)	0.8 – 4.7	54.7 – 64.4	3.6 – 26.5
Firm to stiff brown to dark brown sandy gravelly CLAY with some cobbles (LBrBc)	6.8 – 11.7	48.4 – 57.4	10.6 - 20

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
*zones of slightly clayey slightly gravelly SAND/clayey very sandy GRAVEL at top and bottom of strata			
Stiff, black, sandy gravelly CLAY with occasional cobbles (LBkBc) *zones of gravels and cobbles at top of strata	20.8 – 25.4	35.3 – 38.8	9 - 13
Moderately strong to very strong, thinly to thickly bedded, grey to black, fine to medium grained LIMESTONE/ Moderately weak to strong, thinly laminated, dark grey/black, carbonaceous MUDSTONE	2 – 34.6	24.8 – 65.2	Not Proven

1.1.23 Dublin Airport Station

The Dublin Airport Stop will be constructed on a site at the rear of the existing multi storey car part in Dublin Airport at approximately 48.3mOD (ground level is 67 to 68mOD). The desk study indicates that there was a former quarry located nearby to the east of the proposed stop. The desk study also indicates that there is a fault between the Malahide and Waulsortian Limestones running just north or through the stop in a NW – SE orientation. The ground conditions at Dublin Airport Station are summarised in Table 24.

Table 24 Stratigraphy of the Dublin Airport station

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Made Ground/Topsoil	0	67 - 68	0 - 2
Soft dark grey brown slightly sandy slightly gravelly CLAY with occasional cobbles (UBrBC)	0.1 – 1.8	66 - 67	1 – 2
Stiff to very stiff dark grey/black slightly sandy slightly gravelly CLAY with cobble and boulder content (UBkBc) *BH304 50m north of station	1 – 3	65 – 67	1 – 18
Moderately strong to very strong, thinly to thickly bedded, grey to black, fine to medium grained LIMESTON	1 - 5	63 - 67	Not proven
Characteristic groundwater level (mOD)			62-63

1.1.24 Tunnel 11 - Dublin Airport to Northern Portal

From Dublin Airport Station to the northern portal (13+100 to 13+950) the proposed tunnel alignment will run beneath the northern section of Dublin Airport varying in elevation from 48.3mOD to 39mOD at its lowest point (ground level varies from 67.34mOD to 62.2mOD moving north). The tunnel will likely be constructed in rock north of Dublin Airport, however there is a sharp drop in rockhead upon leaving Dublin Airport Station which continues north, so mixed face conditions should be expected.as the tunnel alignment straddles the overburden/bedrock boundary. The ground conditions in this section are summarised in Table 25.

Table 25 - Stratigraphy of Airport to Northern Portal

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Made Ground/Topsoil	0	64.6 – 66.8	0.3 – 1.3
Stiff to very stiff brown slightly sandy gravelly CLAY with some cobbles (UBrBC)	0.3 – 1.3	63.4 – 66.4	0.5 – 2.2
Stiff to very stiff dark grey/black slightly sandy slightly gravelly CLAY with cobble and boulder content (UBkBc)	1.5 – 2.5	62.1 – 65.2	6.2 – 16.4*
Stiff dark brown sandy gravelly CLAY with occasional cobbles (LBrBc) *Only encountered north of BH303	14.5*	50.1 – 51.2	7.5 - 10
Moderately strong to very strong, thickly bedded to thinly laminated dark grey to black, calcareous MUSDSTONE/Strong to very strong and locally moderately strong, massive grey/white mottles. Fine to medium grained, fossiliferous LIMESTONE	8 – 24.5	40.1 – 58.8	Not Proven

1.1.25 Northern Portal

The alignment will emerge from the tunnelled section at Ch.14+000 via a portal of approximately 60m in length and will then cross two existing watercourses via embankments of 4 and 8m height running north. Overburden cover to the tunnel ranges from 7m at 30m south of the portal, to 13m at 100m from the portal face and consists of glacial till. The portal level is 47.2mOD and is expected to be excavated into a north facing slope through glacial till with ground level falling from approximately 57mOD to 47mOD over the course of 50m, however rock is expected 100m south of the slope face, so mixed face conditions should be expected here which will serve as the location of the northern TBM drive. The ground conditions at the Northern Portal are summarised in Table 26.

Table 26 Stratigraphy of Northern Portal

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Topsoil	0	42.6 – 63	0.3
Made Ground	0 – 0.2	42.6 - 63	1 – 1.5
Stiff to very stiff brown slightly sandy gravelly CLAY with some cobbles (UBrBC)	0.2 – 1.2	42.3 – 58.2	1.2 – 1.9
Stiff to very stiff dark grey/black slightly sandy slightly gravelly CLAY with cobble and boulder content (UBkBc)	1.5 – 2.4	40.5 – 61.5	7.6 – 13.4
Stiff dark brown sandy gravelly CLAY with occasional cobbles (UBrBc) *Only encountered north of RC212 (open hole, little recovery)	10*	49.4	17.5
Weathered Bedrock	14	49	0.5
Moderately strong to very strong, thickly bedded to thinly laminated dark grey to black, calcareous MUSDSTONE/Strong to very strong and locally moderately strong, massive grey/white mottles. Fine to medium grained, fossiliferous LIMESTONE	14.5 – 27.5	27.1 – 48.5	Not Proven
Characteristic groundwater level (mOD)			50

1.1.26 Northern Portal to Fosterstown

This section of the alignment from the northern portal to Fosterstown Station (Ch.14+100 to 15+300) consists of two embankments crossing existing watercourses at Ch. 14+100 and 14+300, an at-grade section from Ch.14+300 to 14+500 and a 700m cut and cover section beneath the R132 to Fosterstown Station from 14+500 to 15+300. Alignment level varies from 51.04mOD at its highest to 39.6mOd at its lowest point in the cut and cover section. The cut and cover section will be an open cut excavation from ground surface to 10m depth. The cut section is expected to be within glacial till. The ground conditions in this section are summarised in Table 27.

Table 27 Stratigraphy of Northern Portal to Fosterstown Station

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Made Ground/Topsoil	0	43.9 – 48.2	0.05 – 1.4
Firm to stiff brown slightly sandy gravelly CLAY with some cobbles (UBrBC)	0.3 – 1.4	46 – 47.5	0.7 – 2.3
Stiff to very stiff dark grey/black slightly sandy slightly gravelly CLAY with cobbles (UBkBc)	1.2 – 2.9	43.6 – 47.9	5.8 – 35.7
Weak to very strong, thickly bedded to thinly laminated dark grey to black, calcareous MUSDSTONE/Strong to very strong and locally moderately strong, massive grey/white mottles. Fine to medium grained, fossiliferous LIMESTONE	19.5 – 29.2 >38.2 in RC65	17.86 – 24.44 <8.55 in RC65	Not Proven

1.1.27 Fosterstown Station

The Fosterstown Station will be constructed adjacent to the R132 road, close to existing ground level (44.3mOD) at the rear of Airside Retail Park. Minimum excavation (~1m will be required). The ground conditions at Fosterstown Station are summarised in Table 28.

Table 28 Stratigraphy of Fosterstown Station

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Made Ground/Topsoil	0	43.1 – 45.2	0.3 – 0.4
Firm to stiff brown slightly sandy gravelly CLAY with some cobbles (UBrBC)	0.3 – 0.4	42.8 – 44.9	1 – 3
Stiff to very stiff dark grey/black slightly sandy slightly gravelly CLAY with cobbles (UBkBc)	1.2 – 2.8	40.9 – 44.8	14.8 – 17.2
Weak to very strong, thickly bedded to thinly laminated dark grey to black, calcareous MUSDSTONE/Strong to very strong and locally moderately strong, massive grey/white mottles. Fine to medium grained, fossiliferous LIMESTONE	17.6 – 19.5	23.7 – 26.1	Not Proven
Characteristic groundwater level (mOD)			26-27

1.1.28 Fosterstown to Swords Central

The section of alignment from Fosterstown to Swords Central Stations (Ch.15+350 to 16+100) consists of 100m of at-grade tracks before rising on an elevated section of track in the median of the R132 to Swords Central Station. The alignment level varies from 43.83mOD to 33.4mOD (ground level varies from 43.75mOd to 26.29mOD). The elevated section will be approximately 8m high at its highest point. The ground conditions along this section are summarised in Table 29.

Table 29 Stratigraphy from Fosterstown to Swords Central Station

Geological stratum	**Depth to top of stratum (m)**	**Level of top of stratum (mOD)**	**Thickness range (m)**
Made Ground/Topsoil	0	26 – 43.7	0.1 – 2.2
Alluvial Clays and Silts	0.2 – 2.3	25 – 29	0.3 – 0.8
Alluvial Sands and Gravels	0.8 – 2.7	24.6 – 29.2	0.9 – 6.4
Firm to stiff brown slightly sandy gravelly CLAY with some cobbles (UBrBC)	0.2 – 1.9	25.8 – 43.3	0.5 – 4.8
Stiff to very stiff dark grey/black slightly sandy slightly gravelly CLAY with cobbles (UBkBc)	1.5 – 5	23.8 – 40.9	0.4 – 17.2
Weak to very strong, thickly bedded to thinly laminated dark grey to black, calcareous MUSDSTONE/Strong to very strong and locally moderately strong, massive grey/white mottles. Fine to medium grained, fossiliferous LIMESTONE	5.4 – 19.4	18.2 – 26.1	Not Proven

1.1.29 Swords Central Station

Swords Central Station will be constructed on an elevated deck on piers in the median of the R132 at 32-33mOD, approximately 6m high. Ground level at the station is approximately 25-26mOD. The ground conditions at Swords Central Station are summarised in Table 30.

Table 30 Stratigraphy of Swords Central Station

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Made Ground/Topsoil	0	24.5 – 26.9	0 – 0.3
Firm brown slightly sandy gravelly CLAY with some cobbles (UBrBC)	0 – 1	24.2 – 26	2.1 – 7.3
Stiff to very stiff dark grey/black slightly sandy slightly gravelly CLAY with cobbles (UBkBc) *13.5m was recorded in SWRCF where rock was not encountered	3 – 7.6	16.9 - 23.9	1.4 – 13.5*
Weak to very strong, thickly bedded to thinly laminated dark grey to black, calcareous MUSDSTONE/Strong to very strong and locally moderately strong, massive grey/white mottles. Fine to medium grained, fossiliferous LIMESTONE	12.5 – 16.7	8.8 – 12.9	Not proven
Characteristic groundwater level (mOD)			22-23

1.1.30 Swords Central to Seatown

The section of alignment from Swords Central to Seatown stations (Ch.16+150 to 17+000) will consist of elevated decks on piers along the median of the R132 and over the Pavilions Roundabout. The elevated section varies from 31.9mOD to 24.4mOD in height, moving north (ground level varies from 25.7mOD to 15mOD). The ground conditions along this section are summarised in Table 31.

Table 31 Stratigraphy of the Swords Central to Seatown section

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Made Ground/Topsoil	0	15.1 – 26.9	0.1 – 1.1
Firm brown slightly sandy gravelly CLAY with some cobbles (UBrBC)	0.2 – 3.1	13.9 – 26.6	0.5 – 6
Stiff to very stiff dark grey/black slightly sandy slightly gravelly CLAY with cobbles (UBkBc)	0.6 – 8	11.9 – 23.9	0.9 – 20.9

Geological stratum	**Depth to top of stratum (m)**	**Level of top of stratum (mOD)**	**Thickness range (m)**
Weathered bedrock/Possible infilled cavity *Ch. 16+750 competent rock not proven	11.1	10.55	9.1*
Weak to very strong, thickly bedded to thinly laminated dark grey to black, calcareous MUSDSTONE/Strong to very strong and locally moderately strong, massive grey/white mottles. Fine to medium grained, fossiliferous LIMESTONE	10.8 – 22.8	1.58 – 11.3	Not Proven

1.1.31 Seatown Station

Seatown Station will be constructed as an elevated station in the median of the R132 near Swords Business Park at a level of 24.4mOD to 23.4mOD (ground level varies from 15.059 to 13.459mOD. The station will be an elevated deck on piers. The ground conditions at Seatown Station are summarised in Table 32.

Table 32 – Stratigraphy at Seatown Station

Geological stratum	**Depth to top of stratum (m)**	**Level of top of stratum (mOD)**	**Thickness range (m)**
Made Ground/Topsoil	0	13.1 – 15.1	0.2 – 1.2
Firm brown slightly sandy gravelly CLAY with some cobbles (UBrBC)	0.2 – 1.2	12.1 – 13.9	0.7 – 3.1
Stiff to very stiff dark grey/black slightly sandy slightly gravelly CLAY with cobbles (UBkBc)	1.6 – 3.2	10 – 12.5	1.9 – 6.7
Weathered bedrock/Possible infilled cavity	9.85	5.2	0.95
Weak to very strong, thickly bedded to thinly laminated dark grey to black, calcareous MUSDSTONE/Strong to very strong and locally moderately strong, massive grey/white mottles. Fine to medium grained, fossiliferous LIMESTONE	5.1 – 10.8	4.3 – 8.2	Not Proven
Characteristic groundwater level (mOD)			22-23

1.1.32 Seatown to Estuary

The section of alignment from Seatown to Estuary Park and Ride (Ch.17+050 to Ch. 18+800) consists of elevated decks on piers leaving Seatown Station, running along the median of the R132 and passing over Seatown Road Roundabout and Belinstown Roundabout before falling to at-grade level from 18+100 to the terminus at Estuary. Elevation of the track falls from 23.4mOD to 9.0mOD (ground level varies from 13.459mOD to 6.5mOD) moving north towards Estuary Station. There is a local low point of 4mOD where the Broadmeadow River crosses the alignment at Ch.18+400. The ground conditions along this section are summarised in Table 33.

Table 33 Stratigraphy of Seatown to Estuary Park and Ride

Geological stratum	Depth to top of stratum (m)	Level of top of stratum (mOD)	Thickness range (m)
Made Ground/Topsoil	0	3.1 – 12.4	0.1 – 1
Alluvial Clays	0.3 – 0.9	3.6 – 5.9	1.5 – 1.7
Alluvial Sands and Gravels	0.3 – 2.6	2.1	0.3 – 6.2
Firm brown slightly sandy gravelly CLAY with some cobbles (UBrBC)	0.1 – 1.6	2.8 – 7.8	0.8 – 7
Stiff to very stiff dark grey/black slightly sandy slightly gravelly CLAY with cobbles (UBkBc)	2 – 5.5	0.1 – 9.5	0.2 – 5
Weak to very strong, thickly bedded to thinly laminated dark grey to black, calcareous MUSDSTONE/Strong to very strong and locally moderately strong, massive grey/white mottles. Fine to medium grained, fossiliferous LIMESTONE	2.8 – 9	-5.1 – (+)8.8	Not proven

1.1.33 Estuary Park and Ride Station

Estuary Park and Ride will be constructed at-grade in agricultural fields adjacent to the R132 close to existing ground level (6.5 - 8mOD). The ground conditions at Estuary Station are summarised in Table 34.

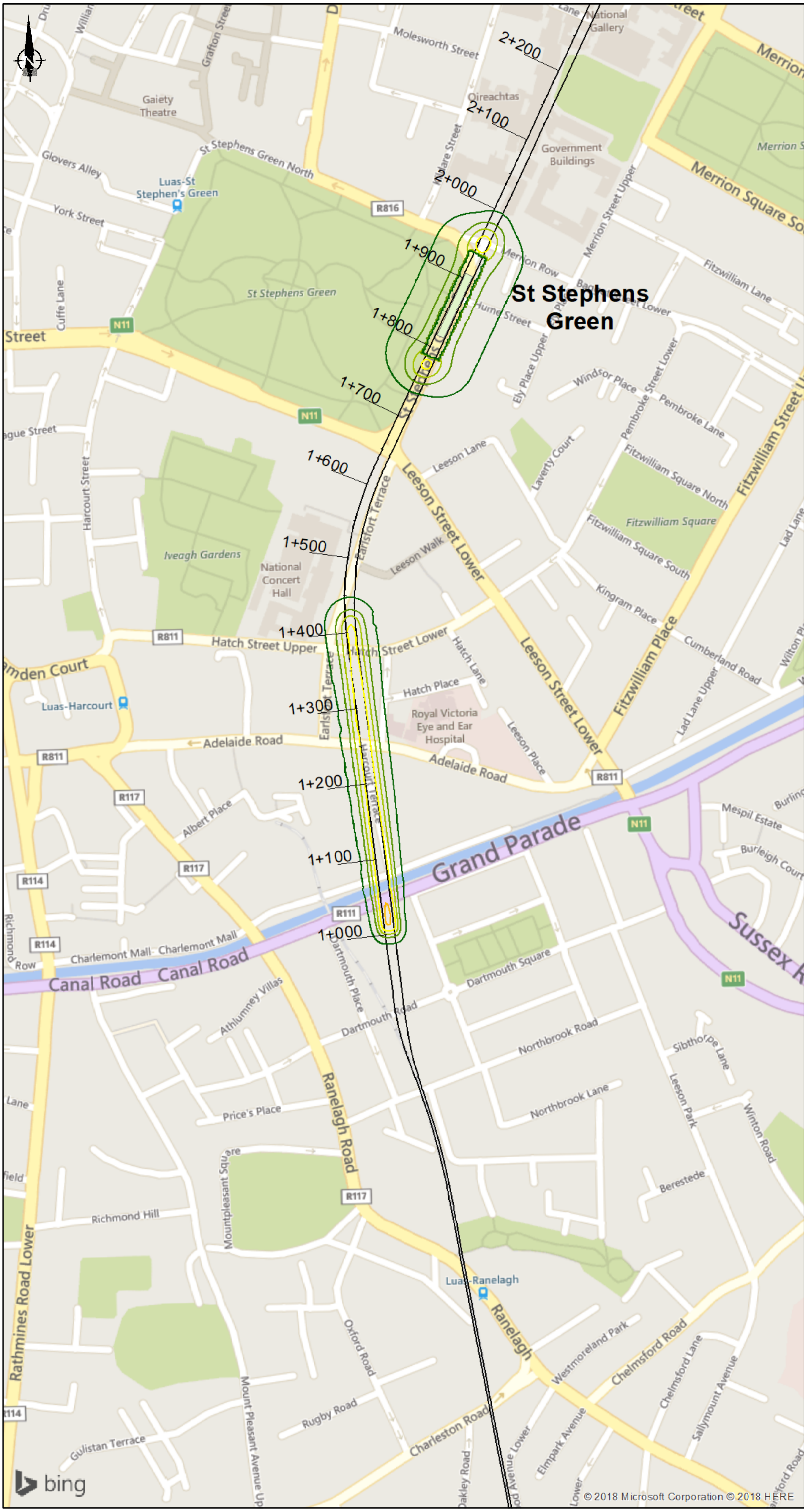
Table 34 Stratigraphy of Estuary Park and Ride Station

Geological stratum	**Depth to top of stratum (m)**	**Level of top of stratum (mOD)**	**Thickness range (m)**
Made Ground/Topsoil	0	6 - 8	0.1 - 0.3
Dublin Boulder Clay (UBrBC)	0.1- 0.3	4 - 5	1 – 2
Dublin Boulder Clay (UBkBc)	2 - 3	2 - 4	1 - 2
Mudstone/Limestone bedrock	5 - 6	-1 – (+)2	Not Proven

Appendix G

Ground Movement Drawings

A3



Legend

Ground Movement Contours (mm)

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- 10
- 20
- 30
- 40
- 50
- 60

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P02	26/02/2018	OA	SR	PS

Metres
0 50 100 200

ARUP
Corporate House
City East Business Park
Ballybrit, Galway, Ireland
Tel +353 (0)91 460675
www.arup.ie

Client
Údarás Náisiúnta Iompair
National Transport Authority
TII

Job Title
New Metro North

Ground Movement Contours
Sheet 1 of 8

Scale at A3
1:5,000

Job No	Drawing Status
252252-00	For Information

Drawing No	Issue
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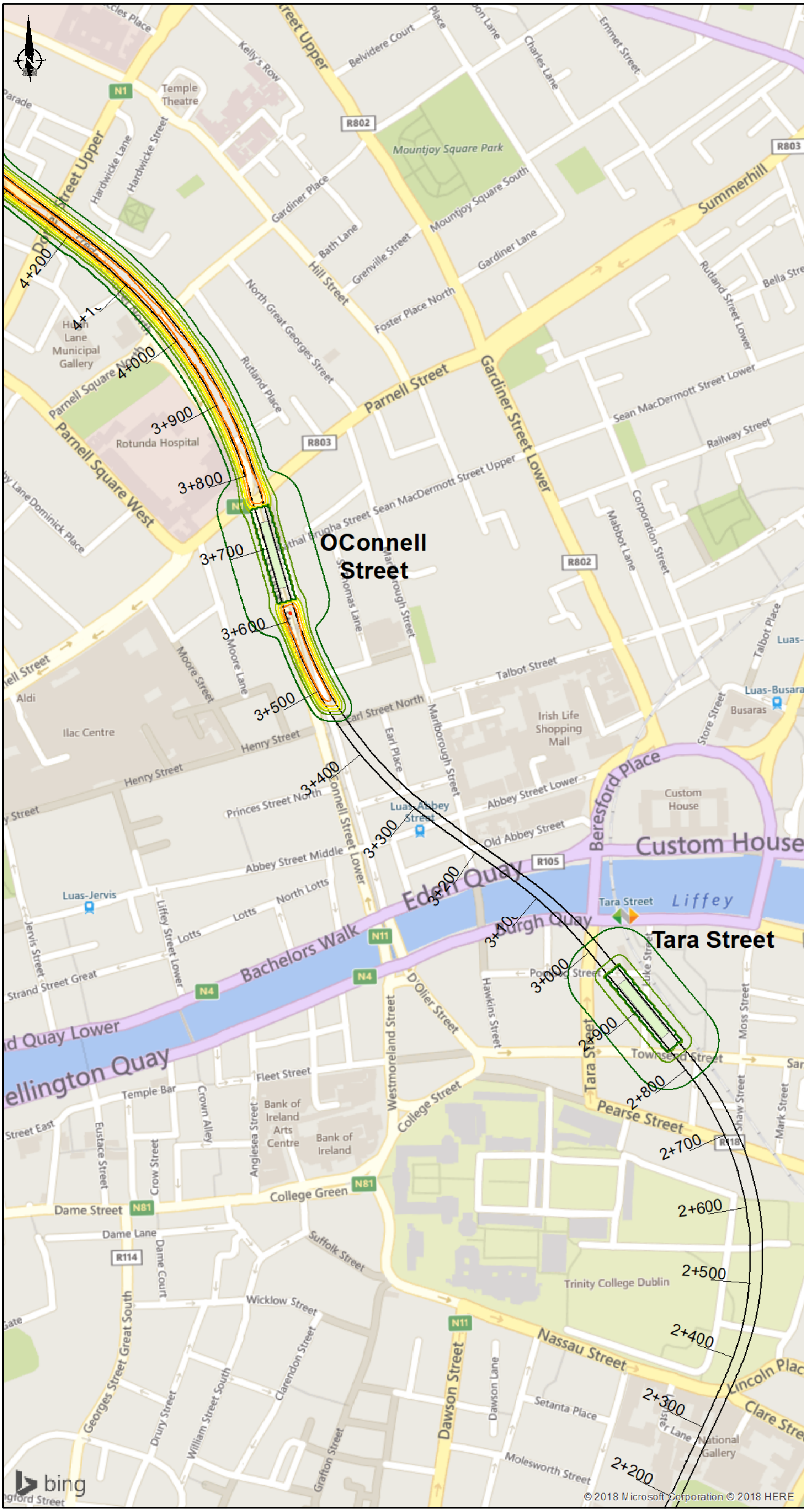

Legend

Ground Movement Contours (mm)

- 1
- 10
- 20
- 30
- 40
- 50
- 60

Issue	Date	By	Chkd	Appd
P02	26/02/2018	OA	SR	PS

Metres
0 50 100 200

ARUP
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Client

Údarás Náisiúnta Iompair
National Transport Authority

Job Title

New Metro North

Ground Movement Contours
Sheet 2 of 8

Scale at A3
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Job No	Drawing Status
252252-00	For Information

Drawing No	Issue
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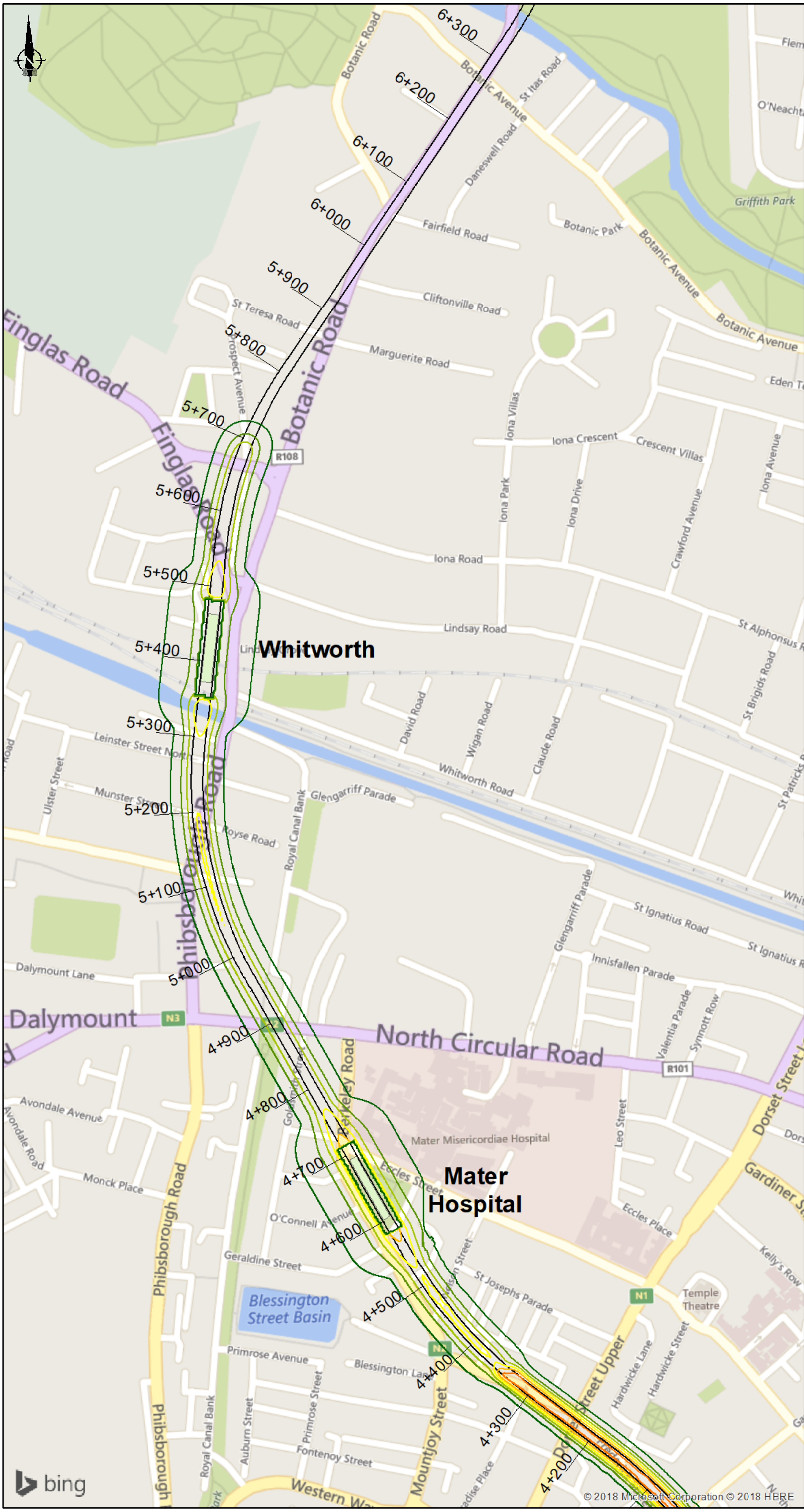
A3



Legend

Ground Movement Contours (mm)

- 1
- 10
- 20
- 30
- 40
- 50
- 60

Issue	Date	By	Chkd	Appd
P03	26/02/2018	OA	SR	PS

Metres
0 50 100 200

ARUP
Corporate House
City East Business Park
Ballybrit, Galway, Ireland
Tel +353 (0)91 460675
www.arup.ie

Client
Údarás Náisiúnta Iompair
National Transport Authority
TII

Job Title
New Metro North

Ground Movement Contours
Sheet 3 of 8

Scale at A3
1:5,000

Job No	Drawing Status
252252-00	For Information

Drawing No	Issue
252252-ARP-EGT-SW-DR-CG-0071	P03

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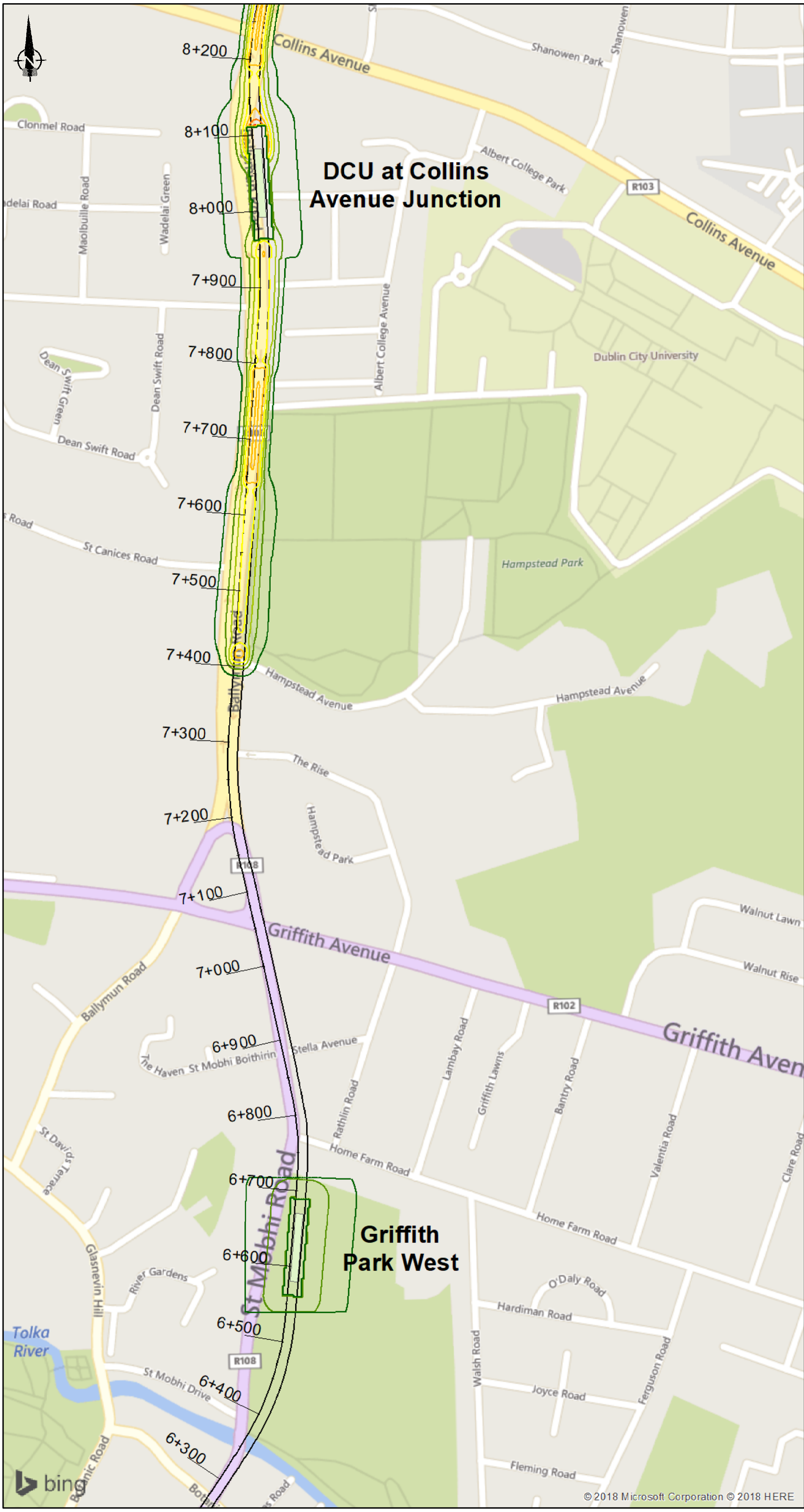
A3



Legend

Ground Movement Contours (mm)

- 1
- 10
- 20
- 30
- 40
- 50
- 60

Issue	Date	By	Chkd	Appd
P02	26/02/2018	OA	SR	PS

Metres
0 50 100 200

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TII

Job Title
New Metro North

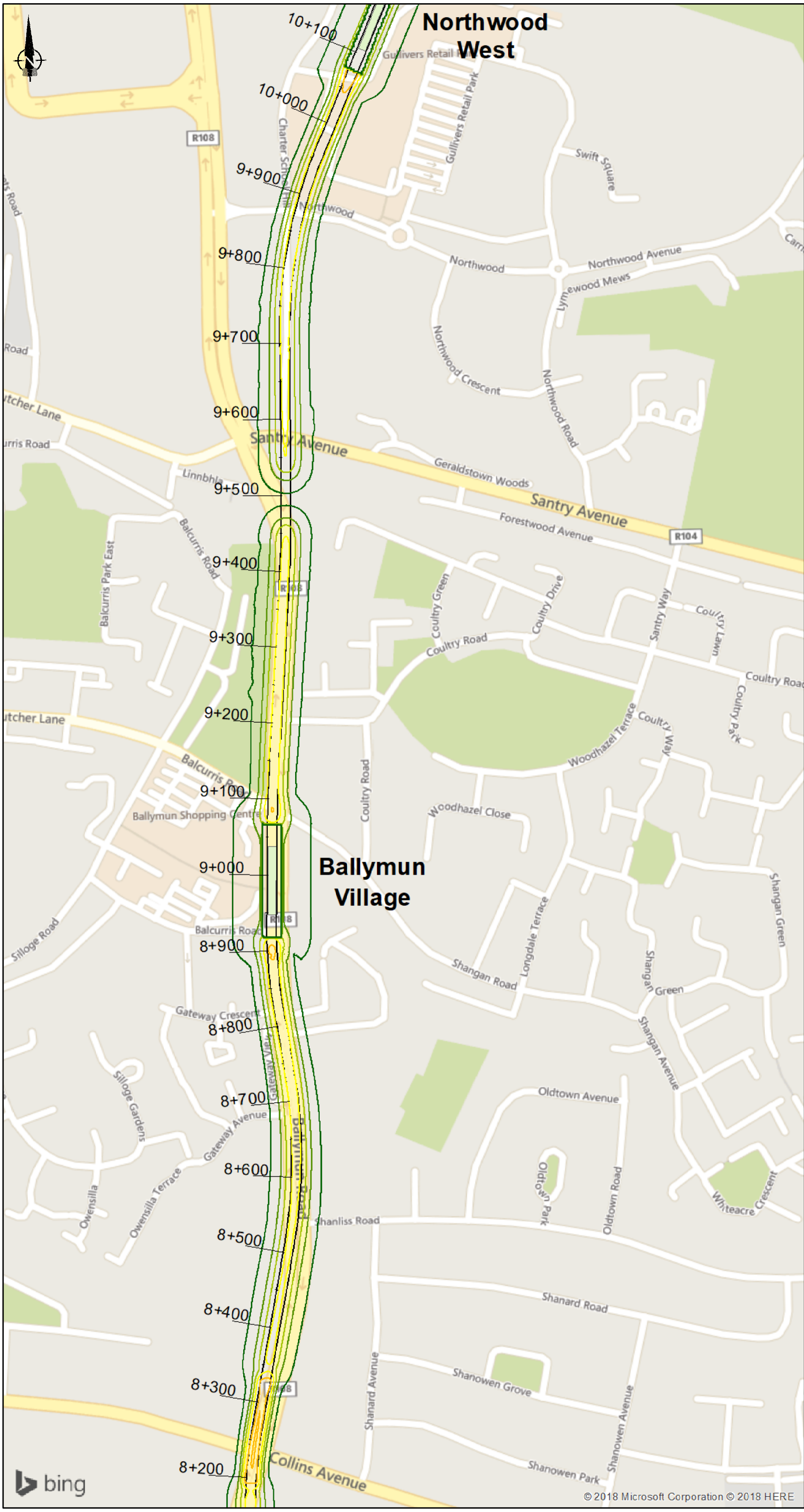
Ground Movement Contours
Sheet 4 of 8

Scale at A3
1:5,000

Job No	Drawing Status
252252-00	**For Information**

Drawing No	Issue
252252-ARP-EGT-SW-DR-CG-0072	**P02**

A3



Legend

Ground Movement Contours (mm)

- 1
- 10
- 20
- 30
- 40
- 50
- 60

Issue	Date	By	Chkd	Appd
P02	26/02/2018	OA	SR	PS

Metres
0 50 100 200

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National Transport Authority
TII

Job Title
New Metro North

Ground Movement Contours
Sheet 5 of 8

Scale at A3
1:5,000

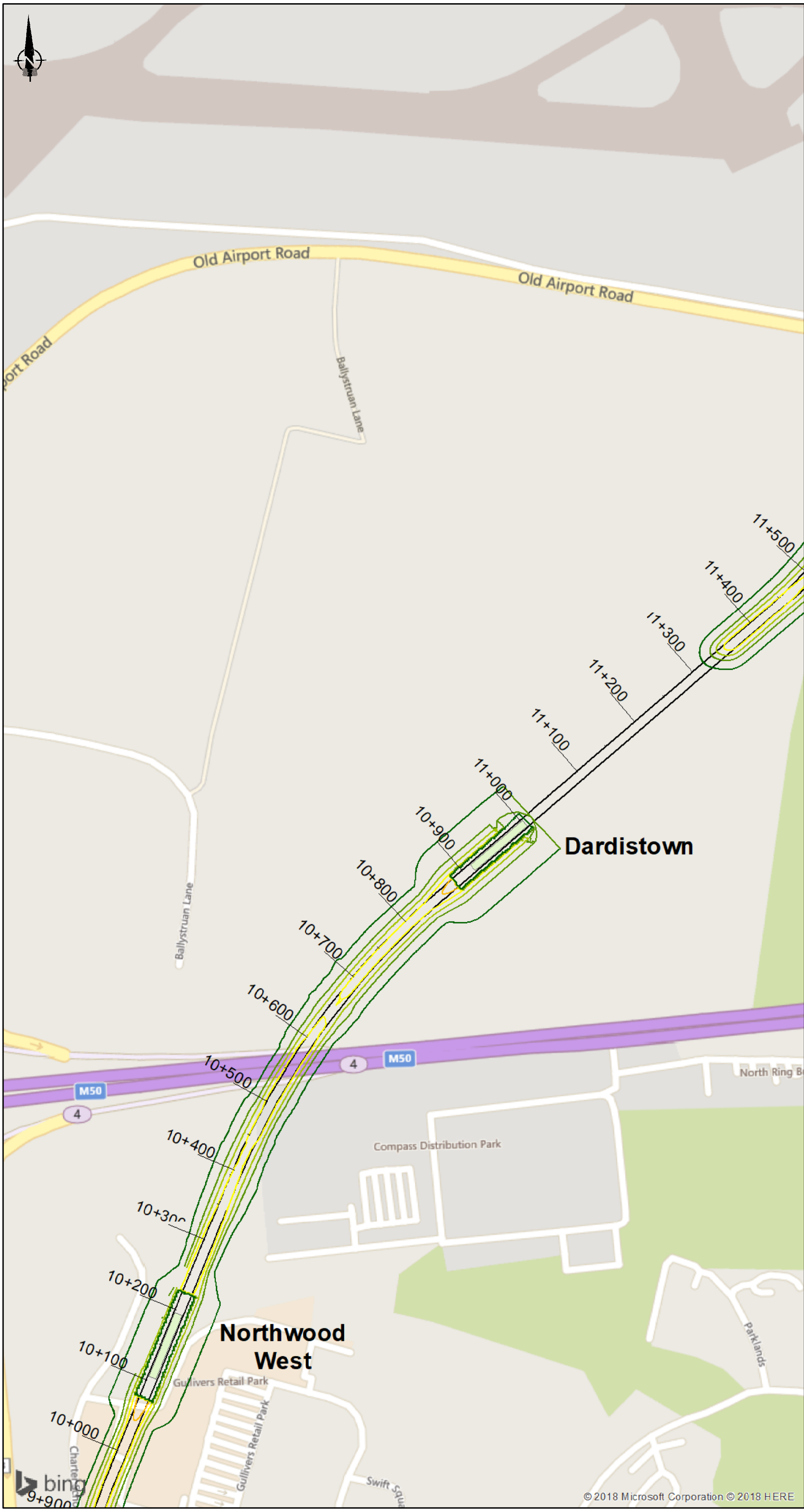
Job No
252252-00

Drawing Status
For Information

Drawing No
252252-ARP-EGT-SW-DR-CG-0073

Issue
P02

A3



Legend

Ground Movement Contours (mm)

- 1
- 10
- 20
- 30
- 40
- 50
- 60

Issue	Date	By	Chkd	Appd
P02	26/02/2018	OA	SR	PS

Metres
0 50 100 200

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Client

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National Transport Authority

TII

Job Title

New Metro North

Ground Movement Contours
Sheet 6 of 8

Scale at A3
1:5,000

Job No	Drawing Status
252252-00	**For Information**

Drawing No	Issue
252252-ARP-EGT-SW-DR-CG-0074	**P02**

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A3

Legend

Ground Movement Contours (mm)

- 1
- 10
- 20
- 30
- 40
- 50
- 60

Issue	Date	By	Chkd	Appd
P02	26/02/2018	OA	SR	PS

Metres
0 50 100 200

ARUP

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Ballybrit, Galway, Ireland
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Client

Údarás Náisiúnta Iompair National Transport Authority

TII Bonneagar Iompair Éireann Transport Infrastructure Ireland

Job Title

New Metro North

Ground Movement Contours
Sheet 7 of 8

Scale at A3
1:5,000

Job No
252252-00

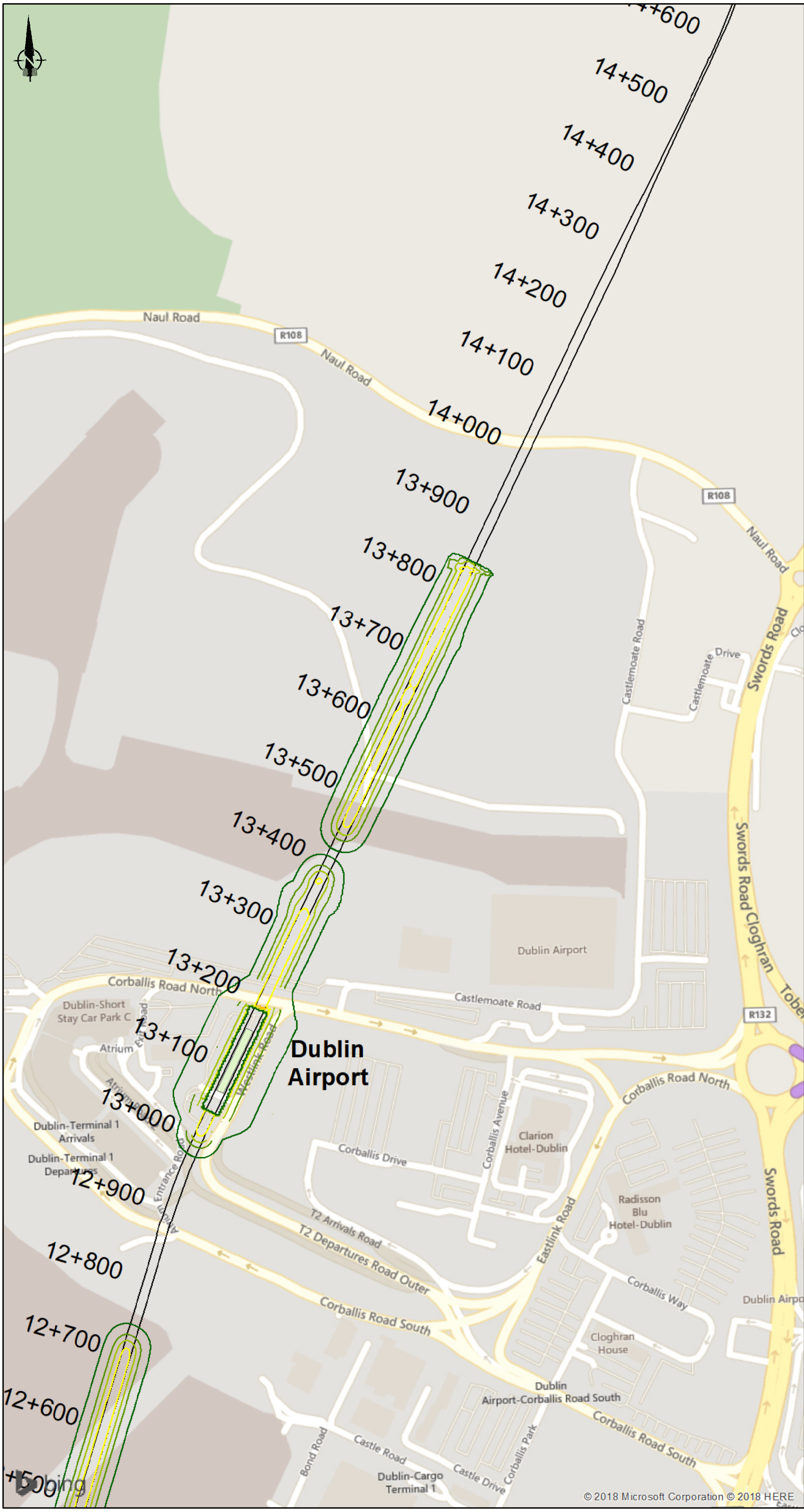
Drawing Status
For Information

Drawing No
252252-ARP-EGT-SW-DR-CG-0075

Issue
P02

MXD Location: c:\projectwise\arup_europe_2\paul.sweeney\dms01509\252252-ARP-EGT-SW-DR-CG-0075.mxd

A3



Issue	Date	By	Chkd	Appd
P02	26/02/2018	OA	SR	PS

Metres
0 50 100 200

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Client

Údarás Náisiúnta Iompair National Transport Authority
TII Bonneagar Iompair Éireann Transport Infrastructure Ireland

Job Title

New Metro North

Ground Movement Contours
Sheet 8 of 8

Scale at A3
1:5,000

Job No
252252-00

Drawing Status
For Information

Drawing No
252252-ARP-EGT-SW-DR-CG-0076

Issue
P02

MXD Location; c:\projectwise\arup_europe_2\ozgur.alper\dms01509\252252-ARP-EGT-SW-DR-CG-0076.mxd

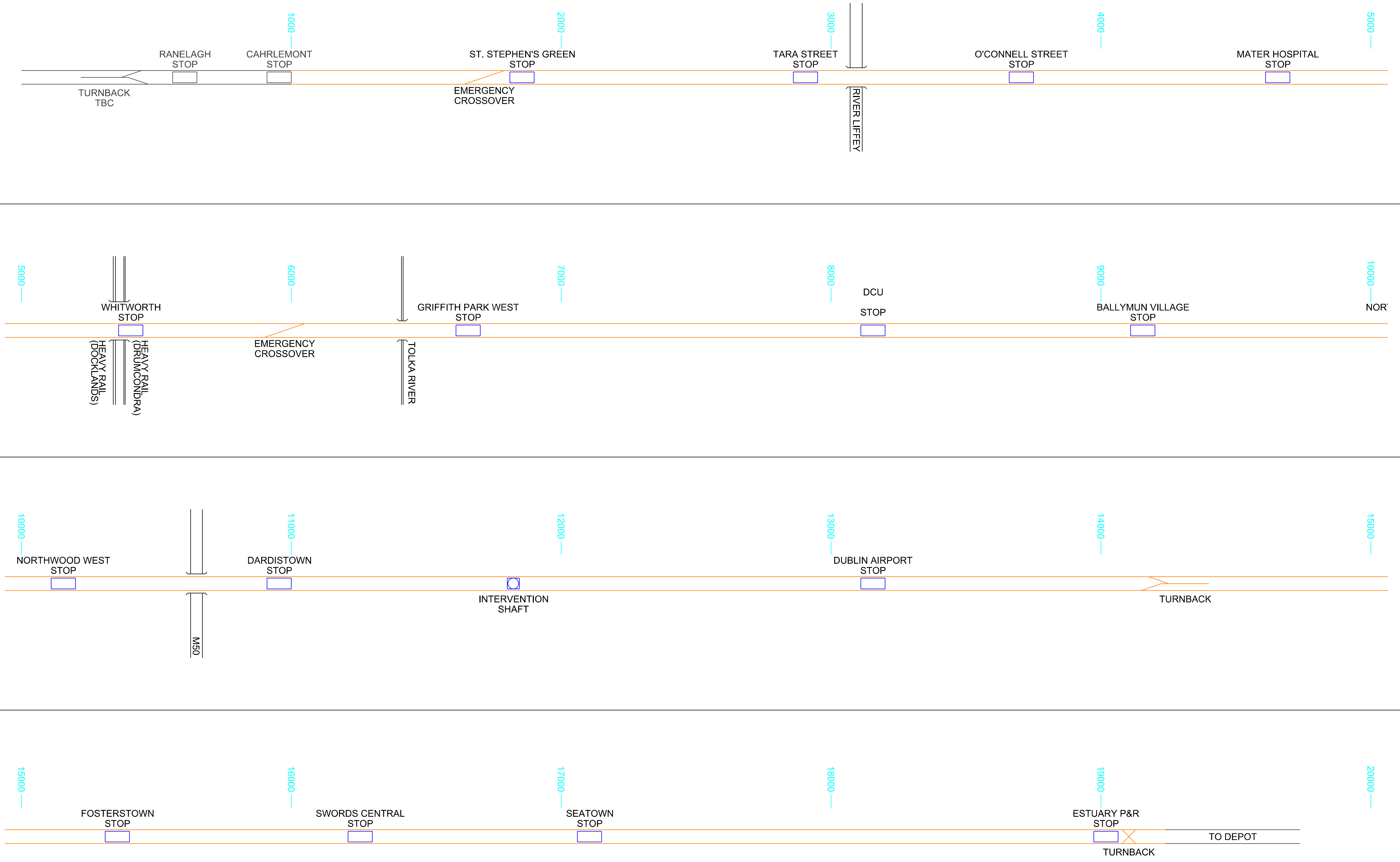
Appendix H

Estuary Depot Layout

ESTUARY P&R DEPOT LAYOUT

Appendix I

Line Schematic



1000
2000
3000
4000
5000
RANELAGH STOP
CAHRLEMONT STOP
TURNBACK TBC
ST. STEPHEN'S GREEN STOP
EMERGENCY CROSSOVER
TARA STREET STOP
RIVER LIFFEY
O'CONNELL STREET STOP
MATER HOSPITAL STOP
6000
7000
8000
9000
10000
WHITWORTH STOP
HEAVY RAIL (DOCKLANDS)
HEAVY RAIL (DRUMCONDRA)
EMERGENCY CROSSOVER
TOLKA RIVER
GRIFFITH PARK WEST STOP
DCU
STOP
BALLYMUN VILLAGE STOP
NOR
11000
12000
13000
14000
15000
NORTHWOOD WEST STOP
M50
DARDISTOWN STOP
INTERVENTION SHAFT
DUBLIN AIRPORT STOP
TURNBACK
16000
17000
18000
19000
20000
FOSTERSTOWN STOP
SWORDS CENTRAL STOP
SEATOWN STOP
ESTUARY P&R STOP
TURNBACK
TO DEPOT