



**METRO NORTH
ORAL HEARING**

**PROOF OF EVIDENCE
GEOTECHNICAL
INVESTIGATIONS**

Stuart Cowan
Friday April 3rd 2009



Metro North Oral Hearing

Proof of Evidence

Geotechnical

Stuart Cowan

INTRODUCTION

Personal Details

My name is Stuart Cowan. I hold a Bachelor of Engineering degree in Civil Engineering and a Master of Science degree in Soil Mechanics from Imperial College, London. I am a Chartered Engineer and a Member of the Institution of Civil Engineers.

I have been employed in the geotechnical aspects of the design and construction of major infrastructure projects in the UK, Ireland and Hong Kong for 21 years. I have been responsible for the assessment of ground conditions and the preparation of geotechnical data and interpretive reports for several urban railway projects including Metro North, a section of the Shatin to Central Link railway in Hong Kong and Tseung Kwan O and Tiu Keng Leng MTR Stations, also in Hong Kong. I have extensive experience in many areas of geotechnical engineering including: ground investigation; foundations; retaining systems; slopes; earthworks; ground improvement; temporary works; and tunnelling. I have wide experience of managing and working in multi-disciplinary design teams and providing geotechnical advice to civil/structural engineers on major infrastructure projects.

Background

The Geotechnical Proof of Evidence relates to the Metro North ground investigation programme, the acquisition and utilisation of geotechnical data during design development and subsequently the communication of geotechnical data to the tenderers during the Invitation to Negotiate process.

Scope and Format of Geotechnical Written Evidence

A brief description of the scope and format of the Geotechnical Proof of Evidence is as follows:

Section 2 describes the Metro North ground investigation programme and other sources of geotechnical data such as the Geological Survey of Ireland and previous ground investigations for nearby projects. The numbers and types of exploratory holes undertaken are summarised and brief descriptions of the in situ field and laboratory testing and the instrumentation installed is given. The strategy for proposed additional ground investigation to assist with detailed design following contract award is also discussed.

Section 3 provides an overview of the work undertaken to derive the interpretation of the ground conditions in relation to the phased ground investigation programme and design development, including the preparation of various geotechnical reports and inferred geological sections.

Section 4 presents a summary of the inferred ground and groundwater conditions along the proposed route of Metro North and highlights the key geotechnical features relevant to Metro North.

Code of Practice for Risk Management of Tunnel Works

In January 2006, the International Tunnelling Insurance Group published 'A Code of Practice for Risk Management of Tunnelling Works'. The objective of this Code is to promote and secure best practice for the minimisation and management of risks associated with the design and construction of tunnels, caverns, shafts and associated underground structures. The Code sets out practice for the identification of risks, their allocation between the parties to a contract and contract insurers, and

the management and control of risks through the use of risk assessments and risk registers.

The Code requires that contract documentation includes Ground Reference Conditions, which shall be issued to tenderers as 'integral and formative information on which tenders shall be based'. In addition to the inclusion of Ground Reference Conditions, it is incumbent upon clients to collate the factual geotechnical information that has been gathered during the project development stage and disclose this information to tenderers in an organised manner. The factual information is normally presented in a Geotechnical Data Report. This information is required by tenderers to inform their design and construction methodology.

RPA has adopted and followed the requirements of the Code during the project development stage and, following award of the Contract, the Contractor is also required to follow the Code.

GROUND INVESTIGATION PROGRAMME

General

To date, the Metro North Ground Investigation Programme has provided both extensive and comprehensive ground investigation data to inform the Reference Design, the Invitation to Negotiate and the Railway Order stages of the project. RPA recognise that further ground investigation data will be required to inform the detailed design of Metro North and to address specific construction method related aspects.

The Metro North Ground Investigation Programme consists of the Preliminary Ground Investigation (PGI) carried out in 2006 and the Main Ground Investigation (MGI) carried out in 2007 and 2008. Ground investigation data from a number of other previous ground investigation contracts in the vicinity of the Metro North alignment has also been collated.

The Ground Investigation Programme comprises 241 boreholes, 95 trial pits, sample collection, various in situ and laboratory tests, surface and downhole geophysical surveys and installation and monitoring of groundwater observation wells. In addition, numerous previous ground investigation records have been obtained from the Geological Survey of Ireland and other sources.

Preliminary Ground Investigation

General

RPA appointed IGSL Ltd. in 2006, to carry out the Preliminary Ground Investigation works for Metro North. The fieldwork was carried out between May and November 2006. The Preliminary Ground Investigation Factual Report was submitted in April 2007. The scope of the PGI was to provide geotechnical information on the ground conditions and groundwater regime for use in preliminary design, optioneering and route selection.

Planning

The PGI was originally planned in 2004 to investigate three route options, West Central and East, for the proposed metro between the city centre and Dublin Airport. In late 2005, the ground investigation was extended to cover a proposed extension of the metro alignment northwards from the airport to the town of Swords. A total of 64 boreholes were carried out as part of the PGI.

Objectives

The PGI objectives were as follows:

- Investigate the ground conditions along the route;
- Determine rockhead levels where bored tunnelling was expected;
- At proposed cut and cover excavations for underground stops, determine the nature and extent of sand and gravel materials within the glacial deposits;
- Determine the stiffness of the glacial deposits for design of support to excavations; and
- determine the variation and the fracture state of the rock for design of open excavations, tunnels and mined stations in rock.

Fieldwork

The fieldwork was carried out between May and November 2006 and comprised the following:

- Cable percussion boreholes in superficial deposits;

- Rotary core drillholes in glacial till and rock using conventional triple tube and Geobor-S wireline drilling methods;
- Installation of groundwater observation wells; and
- Associated sampling and in situ testing.

The boreholes were constructed using a combination of light cable percussive drilling, rotary open hole drilling, rotary core drilling and Geobor-S wireline rotary drilling methods.

Of the 64 boreholes carried out as part of the PGI, six were light cable percussive boreholes, eight were rotary drillholes and fifty were combined light cable percussive and rotary drillholes. The depths of the light cable percussive boreholes ranged from 1m to 27m below ground level. The majority of the light cable percussive boreholes were less than 10m deep. The depths of the rotary drillholes ranged from 12m to 55m below ground level.

Surface geophysical surveys were carried out at seven separate locations using a combination of P-wave seismic refraction profiling and multichannel analysis of surface wave profiling.

Fifty five observation wells with response zones ranging from 5m to 48m below ground level were installed to provide groundwater level data. The wells were generally monitored for periods of between several days to approximately 2 months between June and December 2006.

Field testing comprised the following:

- Standard Penetration Tests in boreholes at between 1m and 2m depth intervals to provide soil strength data;
- Variable head permeability response tests in two groundwater observation wells to determine the permeability of the ground;
- Variable head permeability tests in three boreholes to determine the permeability of the ground;
- 59 packer permeability tests in rotary drillholes in rock to determine the permeability of the rock;
- Downhole geophysical tests comprising 19 borehole video imager, 28 high resolution acoustic televiewer and 9 No. 4-arm dipmeter tests to provide data on rock type, rock mass structure, and dip and orientation of bedding planes, fractures and joints; and
- Surface refractive and reflective profiling of selected sections of the alignment to map strata boundaries and geological features.

Laboratory Testing

The following soil laboratory testing was carried out to determine geotechnical and geochemical properties of the soils encountered: natural moisture content; Atterberg limits; particle size analysis; consolidated and quick undrained triaxial compression; sulphate, pH and organic matter content.

Rock laboratory testing to determine the properties of the various rock types encountered included the following tests: uniaxial compressive strength and deformability in uniaxial compression; point load strength index; natural moisture content, porosity and density; slake durability; Brazilian tensile strength; direct shear testing of rock joints; Cerchar abrasivity; and cuttability.

Main Ground Investigation

General

The Main Ground Investigation for Metro North was carried out from April 2007 to April 2008 as two separate contracts. IGSL Ltd. undertook one contract consisting of the Group A and Group B works and Norwest Holst Soil Engineering Ltd. undertook the Group C works contract.

Objectives

The purpose of the MGI was to provide sufficient geotechnical information on the ground conditions and groundwater regime to inform the Railway Order process, the tender process and the detailed design and construction planning process.

The areas covered by the MGI contracts were as follows:

- Group A works from Belinstown to Dublin Airport southern boundary;
- Group B works from Dublin Airport southern boundary to north of Dublin City University; and
- Group C works from north of Dublin City University to St. Stephen's Green.

Fieldwork

The fieldwork was carried out between April and October 2007 and comprised the following:

- Cable percussion boreholes in superficial deposits;
- Rotary core drillholes in glacial till and rock using conventional triple tube and Geobor-S wireline drilling methods;
- Trial pits to assess the near surface deposits;
- Installation of groundwater monitoring observation wells and piezometers; and
- Associated sampling and in situ testing.

A total of 177 exploratory holes were constructed using a combination of light cable percussive drilling, rotary open hole drilling, rotary core drilling and Geobor-S wireline rotary drilling methods.

The light cable percussive boreholes were completed at depths ranging from 1m to 27m below ground level, while the rotary drillholes were completed at depths ranging from 14m to 41m below ground level. Three inclined rotary drillholes, with lengths of 60m, were also completed at O'Connell Bridge.

A total of 95 machine excavated trial pits were excavated to inspect the near surface soils and to obtain samples for geotechnical testing.

Surface geophysical surveys were carried out at selected locations along the alignment using a combination of electromagnetic conductivity 2D resistivity profiling, P-wave seismic refraction profiling, multichannel analysis of surface wave profiling and microgravity surveys. The following locations were surveyed:

- St. Stephens Green to Collins Avenue;
- North of M50 to south of Dublin Airport;
- Dublin Airport;
- Fosterstown; and
- Lissenhall;

203 groundwater monitoring installations were constructed to provide groundwater level data. The Group A & B wells and piezometers were typically monitored by

IGSL on a weekly basis during the fieldwork period between May and October 2007. Following completion of the fieldwork, monitoring was subsequently carried out on a monthly basis between January and May 2008. The Group C wells and piezometers were typically monitored by Norwest Holst on a weekly basis between May 2007 and April 2008. The ongoing groundwater level monitoring programme is being co-ordinated by RPA.

Field testing comprised the following:

- Standard Penetration Tests in boreholes at 1.2m depth intervals to provide soil strength data;
- 80 variable head permeability tests in boreholes to determine soil permeability;
- 161 packer permeability tests in rotary drillholes to determine permeability of rock;
- Transmissivity testing in two drillholes at O'Connell Bridge to determine permeability response;
- Plate bearing tests at shallow depths to determine load bearing and stiffness properties of soils;
- Dynamic cone penetrometer tests at shallow depths to determine soil strength data;
- Downhole high pressure dilatometer tests in glacial till to determine ground stiffness;
- Downhole geophysical logging of drillholes in rock including 13 optical televiwer, 13 acoustic televiwer, 11 calliper, 11 gamma and 11 flow and temperature tests to provide data on rock type, rock mass structure, and dip and orientation of bedding planes, fractures and joints; and
- Surface geophysical surveys using various combinations of seismic refraction profiling, electromagnetic conductivity resistivity profiling, multichannel analysis of surface wave profiling and microgravity surveying at selected sections of the alignment to determine strata boundaries, geological features and ground stiffness parameters.

Laboratory Testing

The following soil laboratory testing was carried out to determine geotechnical and geochemical soil properties: natural moisture content; Atterberg limits; particle size analysis; consolidated and quick undrained triaxial compression; oedometer consolidation, dry density / moisture content relationship, moisture condition value; sulphate, pH, chloride and organic matter content.

Rock laboratory testing to determine the properties of the various rock types encountered included the following tests: uniaxial compressive strength; point load strength index; natural moisture content, porosity and density; Schmidt hammer; direct shear testing of rock joints; Cerchar abrasivity; cuttability; and carbonate content.

Other Sources of Ground Investigation Data

RPA has collated historical ground investigation data from a variety of sources in the vicinity of the Metro North alignment. The records of 327 light cable percussive boreholes, 104 rotary drillholes and 190 trial pits were obtained and reviewed. The majority of the historical ground investigation records were obtained from the Geological Survey of Ireland.

The relevant exploratory hole records, in situ field test and laboratory test report records are summarised in RPA's Geotechnical Data Report.

Ongoing Ground Investigation

As part of the ongoing tendering process, RPA requested each bidding group to provide details of additional ground investigation considered necessary for detailed design. It is RPA's intention to undertake specific additional ground investigation, based on the tenderers recommendations, prior to the appointment of the Contractor. It is anticipated that further specific additional ground investigation will subsequently be carried out following the appointment of the successful Contractor to inform their detailed design and construction methodology.

INTERPRETATION OF GROUND CONDITIONS

General

RPA carried out a significant number of engineering studies between 2001 and 2004 to support RPA's preliminary engineering and conceptual design of the project. The interpretation of ground conditions, included in the 2002 Geotechnical Desk Study formed part of these engineering studies.

In order to progress the Reference Design, RPA collated and reviewed available historical ground investigation data in the vicinity of the Metro North alignment. The data was assessed to produce inferred ground profiles along the Metro North alignment. Additionally, RPA collated published technical papers which contained pertinent information about ground profiles, ground properties and construction methods for underground construction projects in the Dublin area. The historical ground investigation data and the information contained in the published technical papers were used to determine preliminary geotechnical design parameters for soil and rock for use in the Reference Design.

The following geotechnical related deliverables were prepared in order to support the Metro North Invitation to Negotiate in May 2008:

- Geotechnical Data Report;
- Reference Ground Conditions Report for Information;
- Desk Study Review; and
- Inferred geological sections including MGI data.

All of these documents were provided to the tenderers along with the Metro North Ground Investigation Programme factual reports and relevant previous ground investigation records. Tenderers are required to make their own interpretation of the reports and shall be deemed to have satisfied themselves as to the nature of the ground and subsoil.

The scope and content of the Geotechnical Data Report and Reference Ground Conditions Report for Information follow the requirements of the International Tunnelling Insurance Group's Code of Practice for the Risk Management of Tunnelling Works.

The MGI factual reports were issued to RPA between January and April 2008. As a result, presentation and assessment of the MGI data was not included in the Geotechnical Data Report and Reference Ground Conditions Report for Information. Tenderers were required to include an assessment of the MGI data in their Tenderers Reference Ground Conditions Report.

The Reference Ground Conditions Report for Information includes inferred geological sections along the alignment, which are based on the PGI and available historical ground investigation data. RPA subsequently issued a separate set of inferred geological sections, which included preliminary rockhead level data from the MGI.

The geotechnical deliverables are described in the following sections.

Geotechnical Data Report

The Geotechnical Data Report is solely a factual report and summarises the geotechnical data obtained for the entire alignment. The Geotechnical Data Report includes the following:

- A description of the site conditions including the history of site development interpreted from historical maps and aerial photographs, the geological setting and the geotechnical hazards that are likely to be encountered;

- A summary of the existing ground investigation fieldwork data obtained from sources such as the Geological Survey of Ireland, previous ground investigations for adjacent projects and the Metro North Preliminary Ground Investigation. The numbers and locations of exploratory holes and field installations are presented, together with details of surface geophysical surveys and in situ tests;
- A summary of the laboratory test data obtained from ground investigations; and
- A discussion of various aspects of nearby previous construction projects involving underground excavations, which are considered to be relevant to Metro North. A list of relevant technical papers, which generally contain pertinent information in relation to ground profiles, ground properties and construction methods for similar underground construction projects in the Dublin area, is also included.

The Geotechnical Data Report also contains ground investigation location plan drawings and geological maps. Existing exploratory hole records and results of field and laboratory testing from previous investigations are bound as separate volumes; electronic copies of records have been provided to tenderers.

Reference Ground Conditions Report for Information

The Reference Ground Conditions Report for Information includes interpretation of the ground conditions and groundwater regime as they relate to the Reference Design and interpretation of engineering properties for translation into design parameters during the design process.

The purpose of the Reference Ground Conditions Report for Information is to present an interpretation of the anticipated physical ground conditions that will be encountered during the Metro North works, which are consistent with the alignments and layouts on which the Reference Design is based. The interpretation uses the geotechnical data obtained from a comprehensive search of published sources of ground investigations and from the Metro North Preliminary Ground Investigation.

The report contains exploratory hole location plans and detailed subsurface profiles showing the inferred ground conditions and groundwater regime along the entire Metro North alignment as well as descriptions of the soil and rock types encountered and plots of relevant geotechnical properties. The Reference Ground Conditions Report for Information includes the following:

- A description of the site conditions including the topography, the geological setting and the existing ground investigation data sources;
- An appraisal of the geotechnical data for soils, rocks and groundwater and a discussion on the inferred stratigraphy along the alignment;
- A presentation of and discussion on the properties of each soil and rock type determined from field and laboratory testing; and
- Discrete sections which have been left blank to allow tenderers to add their interpretation of the behavioural baselines relevant to their design and construction planning methodology. When completed, this will then form the basis of each tenderer's Reference Ground Conditions Report for Construction.

For ease of presentation, the stratigraphy is presented separately for each of the seven Railway Order Areas. Within each Railway Order Area, the ground profile stratigraphy descriptions have been subdivided in accordance with their geological

classification. The inferred ground conditions are presented in a series of combined exploratory hole location plans and geological sections.

The Reference Ground Conditions Report for Information has been compiled in line with suggested guidelines published by the American Society of Civil Engineers and the International Tunnelling Insurance Group's Code of Practice for Risk Management of Tunnel Works.

Desk Study Review

A Desk Study Review was carried out to identify potential constraints from previous site uses along the alignment and to inform both the design of the MGI and the Reference Design for Metro North.

The Desk Study Review consists of an appraisal of available historic map cover and selected aerial photography along the alignment of Metro North, together with the assessment of the results of enquiries of the Geological Survey of Ireland's well and karst databases. Historic maps were sourced from the Ordnance Survey of Ireland, Trinity College Library and RPA's Archaeological Assessment Report.

Inferred Geological Sections

The Reference Ground Conditions Report for Information includes a series of combined exploratory hole location plans and inferred geological section drawings, which are based on the PGI data and available geotechnical data from previous ground investigations.

An additional series of combined exploratory hole location plans and inferred geological section drawings, incorporating limited data from the MGI, were also produced by RPA in April 2008. The MGI data shown in the drawings is limited to preliminary rockhead level data only.

It is noted that the ground and groundwater conditions shown in the inferred geological sections were prepared based on fieldwork and monitoring undertaken at discrete locations. The intervening ground and groundwater conditions between discrete fieldwork locations can only be inferred, and, therefore, the actual sub-surface conditions may vary from those shown. It should be noted that the inferred geological sections present a simplification of the expected complexity of the glacial till formation, in terms of the inherent variability of grading and stratification of such materials.

Interpretation by Tenderers

It is recognised that each tenderer's proposed equipment and construction methods will influence the response of the ground to construction works and, therefore, behavioural baselines were not included in the Reference Ground Conditions Report for Information. In order to permit comparison of tender submissions, RPA requires tenderers to submit a Tenderer's Reference Ground Conditions Report with their tenders. The Tenderer's Reference Ground Conditions Reports will include each tenderer's interpretation of the baselines relevant to their design and construction approach. These reports will be reviewed by RPA and their technical advisers. The modified Tenderer's Reference Ground Conditions Report will then form part of the Contract for Metro North as the Reference Ground Conditions Report for Construction.

Tenderers are required to review the Reference Ground Conditions Report for Information and provide their own assessment of the ground conditions, including an assessment of the MGI data provided by RPA to the tenderers.

SUMMARY OF GROUND CONDITIONS

General Geological Conditions

The general stratification of the ground along the route of Metro North consists of the following:

- Made Ground;
- Alluvial/Estuarine Deposits;
- Fluvio-glacial deposits (Glacial Sands and Gravels);
- Glacial Till; and
- Bedrock – Carboniferous Limestone.

Locally extensive areas of Made Ground are present along the route. The composition of the Made Ground varies widely and generally consists of a mixture of waste materials including, for example, domestic refuse, clinker and demolition rubble. In the city centre, the thickness is generally between 1m and 4m, but locally deeper, and in general reduces to between 1m and 2m to the north of Mater Stop.

Alluvial Deposits, of generally limited extent, are present locally in the vicinity of the River Liffey, River Tolka and Broadmeadow River. Alluvial Deposits, of limited extent, are also likely to be present in areas associated with existing and former stream courses. The Alluvial Deposits generally consist of loose to medium dense, interbedded, organic silts, sands, gravels and cobbles. Bands of peat have been encountered locally within the Alluvial Deposits in the area of the River Liffey. Estuarine Deposits are also present in the vicinity of the River Liffey.

The Glacial Sands and Gravels comprise sands and gravels with cobbles and occasional boulders. The Glacial Sands and Gravels generally occur as layers or lenses within the predominantly clayey Glacial Till. However, in the area of the pre-glacial channel to the north of the River Liffey (and also to a lesser extent between the River Liffey and St. Stephen's Green) significant thicknesses are present. The geology of the pre-glacial channel area is complex with glacial tills occurring within glacial gravels and vice-versa and likely reflects the complexity of the variations and different stages of ice sheet advance and withdrawal. Artesian and / or sub-artesian groundwater conditions have been encountered within the Glacial Sands and Gravels in the O'Connell Street and Parnell Square areas.

The Glacial Till consists of a heterogeneous mixture of clay, silt, sand and gravel with cobbles and boulders. It is locally known as Dublin Brown or Black Boulder Clay. The till contains discrete, and in places extensive, layers, lenses and pockets of sand and gravel.

In Dublin city centre the Bedrock consists of carboniferous limestone interbedded with mudstone and shale (Calp limestone), whereas locally at the Airport, the limestone consists of massive limestone and mudstone (Waulsortian limestone). The Waulsortian limestone is more susceptible to the development of karst features. The bedrock has been faulted and partly folded and uplifted.

The groundwater level is typically between 2m and 4m below ground level in the city centre area and may be deeper where ground levels are more elevated. Sub-artesian groundwater pressure and / or running sands and gravels have been encountered in several areas, particularly associated with the pre-glacial buried channel to the north of the River Liffey.

Key Features

Several key geological features, which may impact on the design and construction of Metro North, have been identified. The key features described below require particular consideration in the selection of appropriate engineering solutions and construction methods.

Boulders in Glacial Till

The presence of boulders within the glacial till has the potential to disrupt bored tunnelling construction and also the construction of deep foundations. Previous experience indicates that boulders with maximum dimensions of greater than 0.5m are rarely encountered during construction works in Dublin.

Granular Materials within Glacial Till

Pockets, lenses and layers of granular material, of varying extent, exist within the glacial till, while extensive glacial gravel deposits are present to the north of the River Liffey. Therefore, engineering solutions will need to be capable of dealing with the potential risk of encountering groundwater in localised areas within the till; inflows have the potential to be sudden and variable, with the volume of inflow being dependent on the volume of granular material, interconnectivity with other gravel deposits and groundwater pressure. Saturated gravels with sub-artesian pressures are expected north of the Liffey and other areas; blowing sands and gravels have been encountered in a number of exploratory holes during ground investigation works.

The presence of sandy or gravelly soils within cut slopes can potentially lead to rapid dissipation of excavation induced negative pore water pressures and can lead to slope failures. The presence of such materials can also have adverse effects on deep foundation and shaft construction.

The glacial till is generally considered to be a good material for tunnel construction. However, lenses and layers of sand and gravel are present within the predominantly clay matrix that can contain groundwater under high pressure.

Weathered and Rafted Rockhead

The occurrence of weathered rockhead (typically the first few metres) is variable across the site. Where encountered, the engineering properties are likely to be poorer and can potentially cause problems in achieving an adequate cut-off for retaining walls. Design and construction solutions will need to consider the impact on foundation construction and make provision to achieve an adequate cut-off for retaining walls.

Alluvium

Soft silts and clays are likely to be present in the areas of the River Liffey, Tolka River and Broadmeadow River and other smaller streams and former river courses. Bands of peat were encountered locally within alluvial deposits in the vicinity of the River Liffey. The selected construction methods will need to address the potential for ground stability issues and excessive settlement associated with construction over and within these materials.

Karst

Karst features could be encountered within the Waulsortian Formation, which is present in the vicinity of Dublin Airport. The existence of water and clay filled voids in the form of an elongated vertical pipe has previously been reported in this area.

Tectonic Faulting and Folding

The locations of faults within the Dublin area are not well defined due to the thickness of the superficial deposits and the lack of marker beds in the Calp Limestone. Faults are known to be more prevalent in the limestones at the Airport.

Faulting along fold trends may have resulted in potential intense fracturing and cavities and the development of clay gouge of variable consistency. Folding may have resulted in the development of tight folds and intense fracturing, particularly in the vicinity of axial traces.

CONCLUSIONS

The Metro North Ground Investigation Programme has provided both extensive and comprehensive ground investigation data to inform the Reference Design, the Invitation to Negotiate and the Railway Order stages of the project. Interpretation of the ground conditions has been carried out by RPA, who have assessed the available geotechnical data for soils, rocks and groundwater and prepared inferred geological profiles along the alignment.

The Metro North Ground Investigation data and other relevant historical ground investigation records have been made available to tenderers in accordance with the International Tunnelling Insurance Group's Code of Practice for Risk Management of Tunnelling Works. The objective of this Code is to promote and secure best practice for the minimisation and management of risks associated with the design and construction of tunnels, caverns, shafts and associated underground structures. The successful Contractor will be required to follow the requirements of this code.

Tenderers are required to make their own interpretation of the geotechnical data provided to them. RPA recognise that further ground investigation data will be required to inform the detailed design of Metro North and to address specific construction method related aspects.

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