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Our Ref: PSM3911-003L Rev2

29 October 2019

JBS&G
Level 1, 50 Margaret Street
Sydney NSW 2000
JRosner@jbsg.com.au

Attention: Joanne Rosner

Dear Joanne

RE: SYDNEY METRO NORTHWEST
HILL SHOWGROUND STATION PRECINCT
SSDA STAGE GEOTECHNICAL ASSESSMENT

1. Introduction

This letter presents the results of a geotechnical desktop assessment, prepared for Landcom on behalf of Sydney Metro, to support a concept development application (DA) for the Hills Showground Station Precinct (the Site).

This geotechnical assessment has considered information which is in the public domain including geological maps and factual and interpretive data supplied to tenderers for the SMNW project. It has also benefited from the extensive experience gained from our intimate involvement in the SMNW project from design through to construction. PSM were the geotechnical and mined tunnel designers engaged by the contractor that was awarded the Tunnel, Station and Civil (TSC) contract (from Bella Vista to Epping). In addition, PSM also completed the construction phase services scope which included completing additional geotechnical investigations, mapping and verifying the ground conditions during station and tunnel excavations across the full TSC alignment (including the Hills Showground Station box excavation).

In addition, the following documents supplied by the Client were reviewed:

- Department of Planning and Environment amended SEARs (ref. SSD 9653, dated 9 October 2019)
- Concept Proposal (ref. COX 2019)
- Over tunnel Building J Proof of Concept (ref. COX 2019)

2. Proposed Development

Based on the supplied documents, we understand that the Site is located adjacent to (on the north side of) Carrington Road, bound by Showground Road to the northeast, De Clambe Drive to the north and Cattai Creek to the west. The Site forms part of the broader Showground Station Precinct covering 271 hectares, rezoned in 2017 as part of the Department of Planning, Infrastructure and Environment's (The Department) priority precinct program. The rezoning of the Precinct, along with changes to height, density, and lot size controls, as well as other supporting controls will:

- transform the area around the new Hills Showground Station into a vibrant urban centre
- provide for a maximum of 5,000 new dwellings and 2,300 new jobs over 20 years

- deliver nearly two hectares of parks and new open space
- provide community facilities, recreation areas and a mix of housing choice for people at all life stages.

The Site is envisaged to be developed to accommodate a high-density mixed-use precinct in line with the planning controls:

- Hills Showground Precinct West (Lot 53 DP 1253217) is zoned B2 Local Centre with maximum height of 68 m (20 storeys)
- Doran Drive Precinct (Lot 55 DP 1253217) is zoned B2 Local Centre with maximum height of 68 m (20 storeys)
- Hills Showground Precinct East (Lot 56 DP 1253217) is zoned R1 General Residential with a maximum building height of 52 m (16 storeys)

Inset 1 presents the location of the Hills Showground Precinct, subdivided into three areas, Hills Showground Precinct East, Hills Showground Precinct West and Doran Drive Precinct.

Inset 1: Hills Showground Station Precinct

3. Ground Conditions

3.1 Surface Conditions

The Doran Drive Precinct and Hills Showground Precinct West was primarily a construction site for the SMNW project with construction of the station and multi-storey carpark completed. The natural landform generally slopes gently down from the east (Showground Road) to the west towards Cattai Creek with an elevation change of approximately 15 m.

Historical aerial photographs from May 2013 to August 2019 (sourced from Nearmap) are presented in Appendix A. Based on our knowledge of the Site and review of the historical aerial photographs, bulk earthworks (cut to fill) have been completed within the construction sites to provide a level surface.

The existing building in the Hills Showground Precinct East (former Hills Shire Council administration building) was used as the Sydney Metro Northwest construction office and comprises of a two-storey building with an internal perimeter road and carparking areas. We understand that it does not have a basement, only undercroft parking. Further, we understand that it will soon be demolished by way of a separate DA to Council (304/2020/LA), which was lodged on 9 September 2019, and currently under assessment.

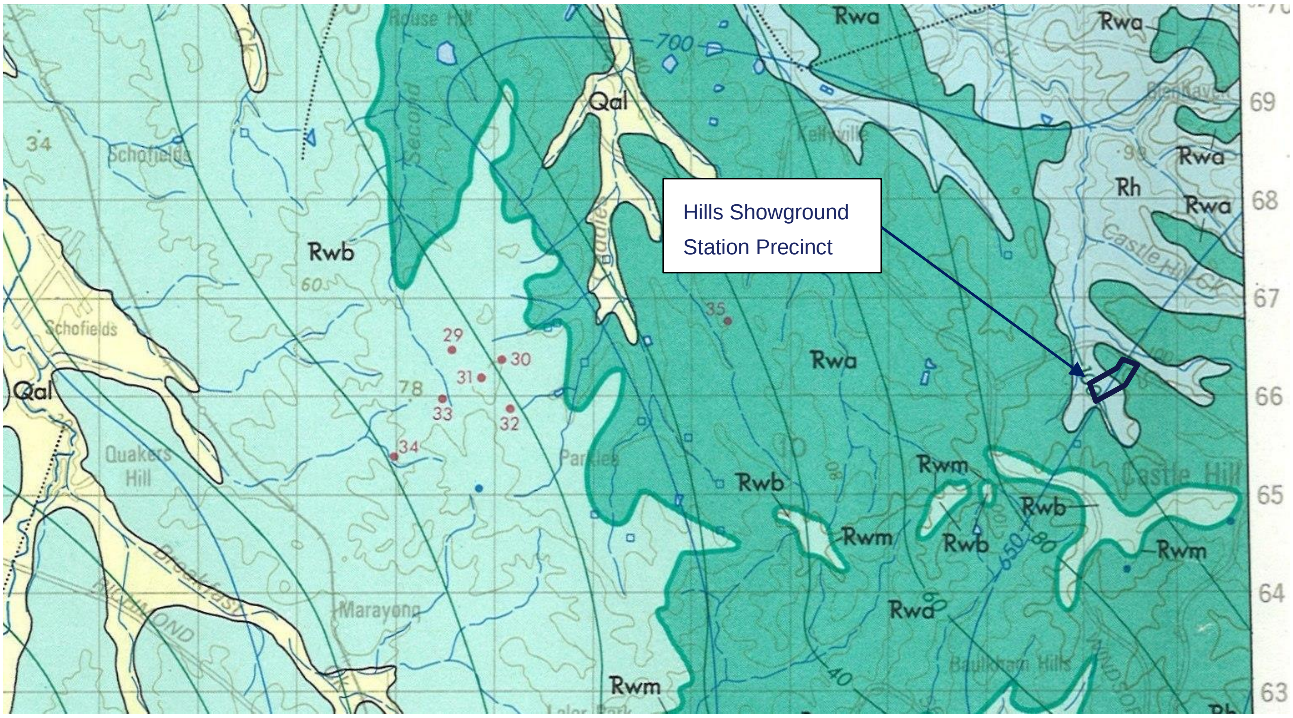
3.2 Geological Setting

The 1:100,000 Penrith Geological Map (Ed 1 1991) indicates the Site is at the boundary of Ashfield Shale (Rwa) and Hawkesbury Sandstone (Rh) (refer Inset 2). This is consistent with the available geotechnical data and site observations.

3.2.1 Ashfield Shale

Ashfield Shale is the basal unit of the Wianamatta Group (which overlies the Mittagong Formation and Hawkesbury Sandstone units). It comprises dark grey to black claystone and siltstone grading into a distinct laminite of fine sandstone and siltstone. The Ashfield Shale unit is up to about 60 m to 70 m thick comprising four siltstone and laminate sub units (youngest to oldest) namely, Mulgoa Laminite, Regentville Siltstone, Kellyville Laminite, Rouse Hill Siltstone.

- The laminated subgroups (Mulgoa and Kellyville) tend to remain intact and can form relatively steep quarry faces, while the siltstone subgroups (Regentville and Rouse Hill) tend to fret and weather more readily.
- The distinct character of the Kellyville Laminite provides a distinct marker unit. It is typically observed as regular equally spaced laminations of dark grey siltstone and fine-grained grey sandstone.
- The Rouse Hill Siltstone contains more geological structures than the overlying Ashfield Shale subgroups such as faults, shears, clay seams and slickensided defects.



Inset 2: **Site location on geological map (source: 1:100,000 Penrith Geological Map 1991)**

3.2.2 Mittagong Formation

The Mittagong Formation is a transitional formation that separates the Ashfield Shale from the underlying Hawkesbury Sandstone. It comprises fine grained brownish sandstone typically 0.5 to 1.5 m thick, over a 1 to 3 m thick (but up to 10 m) fine grained sandstone and interlaminated or interbedded dark grey siltstone.

The upper and lower boundaries of the Mittagong Formation are often difficult to identify. In places, the upper contact with the Ashfield Shale appears to be sharp and disconformable.

3.2.3 Hawkesbury Sandstone

Hawkesbury Sandstone is often described as a medium to coarse grained, quartzose sandstone deposited in 1 to 3 m thick layers (primary bedding planes). Shale breccia is common in the vicinity of bedding contacts.

Sandstone between the primary beds is described as either massive or cross bedded, the latter being referred to as 'sheet facies'. Sheet facies make up approximately 70% of the Hawkesbury Sandstone and ranges in thickness from less than 0.5 m to greater than 5 m but generally occur between 1 to 2 m.

Siltstone interbeds (laminites) form a minor part of the unit at around 5%. These laminites typically range in thickness from 0.5 to 3 m but generally occur less than 1 m and rarely up to around 12 m.

There is little data on the lateral extent of individual siltstone or laminite beds within the Hawkesbury Sandstone. Where exposed in outcrop they appear to be sheet-like and can be truncated laterally by erosional surfaces in contact with sandstone beds. Experience in Sydney suggests extents in excess of 500 m do occur.

3.3 Subsurface Conditions

Hawkesbury Sandstone has been observed in excavations and investigation for the majority of the Site. The typical subsurface profile is expected to comprise:

- Topsoil and fill over most, or all, of the Site. The topsoil is expected to be of relatively shallow depth and fill depth is expected to be variable due to the bulk earthworks completed as part of SMNW site establishment and demobilisation works
- Residual soil derived from sandstone bedrock to 3 m thick, comprising silty clay to sandy clay and generally have a stiff to very stiff consistency, of low to medium plasticity. In areas where the SMNW bulk earthworks are in cut, some or all of the residual soil could have been removed
- Hawkesbury Sandstone — extremely to moderately weathered, to between 5 m and 8 m depth comprising Class III to Class V Sandstone (rock mass classification per Pells et al. 1998)[1]
- Hawkesbury Sandstone — slightly weathered to fresh, to depths greater than 30 m comprising Class I to II Sandstone, with minor localised pockets of Class III due to closer defect spacing.

The Rouse Hill Siltstone (lowest sub unit of Ashfield Shale) overlying the Mittagong Formation and Hawkesbury Sandstone has been observed from site investigations towards the south eastern part of the Site (East Precinct). The siltstone (including some residual soil) is expected to be approximately 5 m to 6 m thick overlying fresh Hawkesbury Sandstone and is expected to grade from extremely weathered near the surface to slightly weathered at depth.

3.4 Geological Structures in Hawkesbury Sandstone

Based on a review of available information and experience with local conditions of the Site, no major regional geological structures such as significant faults or shears have been identified.

The sedimentary succession in the Sydney Basin is generally sub-horizontal. The regional dip of bedding is near horizontal with warping (gentle folding) producing regional dips of between 5° to 10° in places.

---

[1] Pells PJN, Mostyn G & Walker BF. (1998), Foundations on Sandstone and Shale in the Sydney Region, Australian Geomechanics, Vol 33(2) 17-29.

Cross bedding in the Hawkesbury Sandstone typically dips 20° towards the northeast. In less weathered and fresh sandstone, it forms a fabric in the rock but is essentially isotropic whereas in more weathered rock it may impart strength anisotropy.

Joints in the Hawkesbury Sandstone are usually widely spaced and vertical to sub-vertical. Occasionally, joints dip between 30° and 45°. Joints in the Hawkesbury Sandstone generally comprise an orthogonal pair of sub-vertical joint sets trending approximately north-northeast and a less developed set commonly observed striking east-southeast. Numerous lineaments can be observed in aerial photographs and topographic maps that align with these orientations. Individual joints in sandstone are typically not vertically continuous for more than 15 to 30 m but can be horizontally persistent for up to 100 m or more. Few joints were observed from the Hills Showground Station excavation.

Records of faulting within the Hawkesbury Sandstone in the Sydney region show that the main fault strikes are approximately north to northeast and to the northwest. Pervasive north to northeast-striking dip-slip faults mostly with normal displacements occur in the region. These faults occur between northwest-striking strike-slip faults which are the largest structures. Most faults in the Sydney area have normal net displacement of less than 1 m although some fault displacements could be up to several metres.

Summary sheets presented by Bertuzzi (2014)[2] provide useful example core photographs and typical geotechnical characteristics for the various classes of Hawkesbury Sandstone that are relevant to the subsurface conditions of the Site. Example photographs of excavated faces in Hawkesbury Sandstone are presented in Appendix B.

3.5 Groundwater

The regional groundwater table is expected to be within the Hawkesbury Sandstone at approximately RL 80 m(AHD), varying depths from the ground surface (i.e. depth from surface between 5 to 20 m). However, some “perched” groundwater is likely to be present in the soils in the top 3 to 5 m, especially after prolonged rainfall.

The hydraulic conductivity of the sandstone is low, and flow is essentially limited to seepage through rock defects such as joints, bedding partings and other defects where present. Bedding results in significant horizontal anisotropy.

Significant groundwater inflow was not observed during the excavation of the Hills Showground Station box.

4. Geotechnical Commentary

This section presents high level commentary on the various geotechnical aspects of the Site and the proposed development.

4.1 Excavation

4.1.1 Excavatability

The expected subsurface conditions are typical for many parts of Sydney and, based on our experience, excavation will be able to be undertaken using conventional approaches (e.g. large excavators with rock hammers and rock saws, and often where space permits with large bulldozers equipped with ripping tynes). It is expected that any excavation would be undertaken by contractors with suitable experience in rock excavation close to existing structures. The contractor will need satisfy itself regarding the suitability of its plant to the site conditions.

[2] Bertuzzi R. (2014), Sydney Sandstone and Shale Parameters for Tunnel Design, Australian Geomechanics, Vol 49(1) 4-39, Vol 49(2) 95-104.

4.1.2 Shoring

The conventional shoring system in these conditions is to construct bored reinforced concrete soldier piles around the excavation perimeter prior to excavation commencing, down to competent sandstone to support the soils and weathered rock. Ground anchors are then installed to support the piles as excavation progresses. The number of rows of anchors will be dependent on depth of excavations and ground conditions and is a matter of design. Shotcrete is typically applied to support the ground between the piles. This design approach would need a contingency to stabilise pile toes that are underlain by rock defects, and a contingency to install rock bolts/anchors to stabilise any faulted or jointed rock faces below the pile toes. A higher level of geotechnical construction oversight would also be required for such a design.

Where site constraints permit, batters and other retention systems could also be considered to support the soils and weathered rock.

Competent sandstone is often able to be excavated vertically and supported by spot or pattern bolting and shotcrete in some instances. Examples of typical excavation support types are shown in Appendix B.

4.1.3 Ground Movement due to Excavation

The road and rail authorities would often require assessment of the excavation induced ground movements on the adjacent infrastructure. A predicted effects assessment (geotechnical and structural) is generally undertaken to assess effects of new developments on existing infrastructure. Pre and post construction dilapidation surveys of adjacent infrastructure should also be allowed for, as well as survey of ground movement during the works which will likely include monitoring of the development and where required, monitoring of the existing infrastructure. Refer to Section 4.6 for discussion on impact assessments on Sydney Metro infrastructure.

4.2 Site Classification

Based on the available information, we have classified the site as Class "P" in accordance with Australian Standard AS 2870-2011 "Residential slabs and footings – Construction" due to the likely presence of fill on the Site. The Site may be reclassified following further investigation and assessment for specific lots.

4.3 Foundations

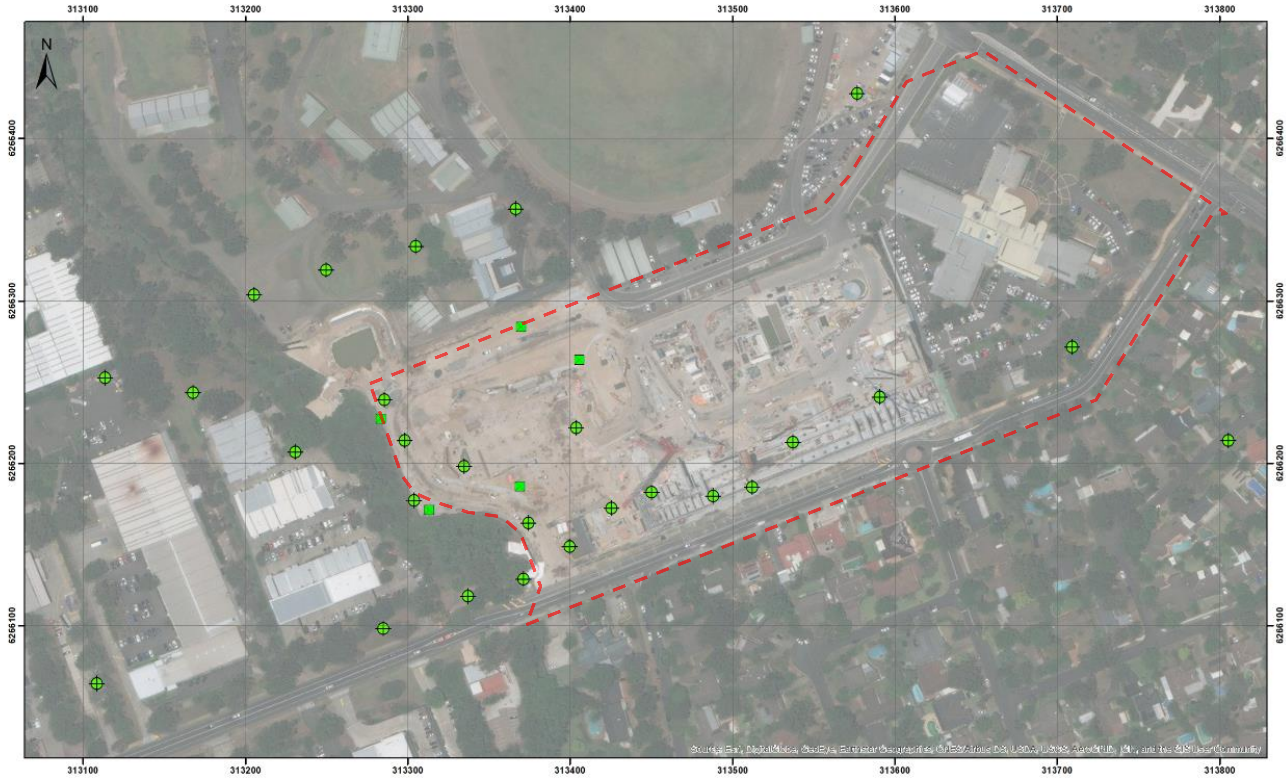
We expect that the building foundations are likely to be shallow pad footings founded on structural fill, residual soils or bedrock (dependant building type and loads). Where building loads are high, piles extending to the better-quality sandstone could be adopted, or the foundation design could involve larger/embedded pads or strip footings to reduce the bearing pressures. Where basements extend to the competent sandstone, pad footings founded on sandstone are likely to be suitable. All these options are conventional foundation types and the type adopted will depend on the structure and is a matter of design.

4.4 Civil Surface Works

Civil surface works such as pavements and low embankments should not present any unusual geotechnical challenges. Material won from any bulk excavation should be suitable to use as general compacted fill subject to development of a suitable earthworks specification. We expect that site won material will be able to be used on site or disposed of as VENM or ENM provided it is not contaminated. Further advice on material disposal should be sought from an environmental consultant at the appropriate future stage.

4.5 Geotechnical Investigation

Geotechnical investigations have been completed for the SMNW comprising boreholes and testpits. These investigations were focused around the SMNW alignment but do extend to the northern boundary of the Site towards De Clambe Drive (refer Inset 3). In addition, detailed mapping from the Hills Showground Station excavation could be available as an additional source of reliable data. We consider that the level of investigation completed to date is adequate for development concept planning and SSDA purposes. Further targeted geotechnical investigations are expected to be required at detailed design stage to supplement the existing information and fill any gaps identified by the designers. Investigation requirements will be dependent on the specific development and should be considered at the detailed design stage together with the historical data. In addition, Sydney Metro is likely to require investigation to be completed as part of the engineering impact assessment of the development on its infrastructure.



Inset 3: **Historical investigation locations**

4.6 Impact assessment of Sydney Metro infrastructure

Any planned development in the vicinity of Sydney Metro infrastructure will need to consider the protection corridor around such infrastructure. Development within the existing SMNW protection corridor would be required to meet the requirements set out in the TfNSW document specific to developments around Sydney Metro infrastructure, "Sydney Metro Underground Corridor Protection – Technical Guidelines" (ref NWRLSRT-PBA-SRT-TU-REP-000008, rev1, 16 October 2017) and TfNSW ASA Standard "Development Near Rail Tunnels" (ref. T HR CI 12051 ST, v2.0, 15 November 2018). The former is included as Appendix C for convenience.

The Sydney Metro Technical Guidelines sets out specific requirements at all stages of development including requirements for investigations and engineering assessments. We recommend that the Technical Guidelines be reviewed in detail as part of the planning stage works to understand TfNSW's / Sydney Metro's expectations. For example, Table 4 of the Sydney Metro Technical Guidelines also sets out various construction restrictions for the First Reserve and Second Reserve (reproduced as Inset 4). Further advice should be sought for specific developments proposed within the protection reserves with regards to investigation and engineering assessment requirements.

Table 4.5 Construction restrictions

Types of construction	First reserve	Second reserve
Excavation for basements, footings	Not allowed	▪ Excavations less than 2.0 m depth from surface level, assessment not required. ▪ Excavation greater than 2.0 m depth, assessment required.
Shallow footings or pile foundations	Not allowed	Allowed, subject to load restrictions. Assessment required.
Tunnels and underground excavations	Not allowed	Allowed, subject to assessment
Ground anchors	Not allowed	Allowed, subject to assessment
Demolition of existing subsurface structures	Not allowed	Allowed, subject to assessment
Penetrative subsurface investigations	Allowed away from support zone, Assessment required	Allowed, subject to assessment

Inset 4: Construction restrictions within protection reserves (source: Sydney Metro Technical Guidelines)

4.7 Proposed Development over SMNW Running Tunnels (subject to further detailed design and assessment)

4.7.1 Preamble

This section of the report specifically considers the part of the development located over the Sydney Metro Northwest (SMNW) running tunnels just to the east of the Hills Showground Station as highlighted in Inset 5. We understand that the current proposal is to locate a high rise building here (approximately 12 storeys, with at least two basement levels).

Inset 5: Hills Showground Station Precinct (source: Landcom presentation)

4.7.2 Local Ground Conditions

The existing topography at the highlighted site in Inset 5 grades gently from east to west and is at approximately RL100 m(AHD). The crown level of the existing SMNW running tunnels is approximate 20 m to 22 m below the existing surface level at this location.

A borehole (NWR-BH155) that was drilled as part of the SMNW geotechnical site investigation is located within the site. The encountered conditions within this borehole is summarised in Table 1. Rock mass has been classified into the Sydney Rock Mass Classification per Pells et al (1998).

Table 1 – Summary of ground conditions from borehole NWR-BH155

Approx. depth (m)	Ground description
0 to 2	Thin fill layer over residual soil comprising stiff to very stiff clay of low to medium plasticity.
2 to 4.5	Class V Siltstone – Extremely to moderately weathered and very low to low strength
4.5 to 6.5	Class III Siltstone – Moderately to slightly weathered and low to medium strength
6.5 to 35 (end of hole)	Class II Sandstone – Fresh Sandstone with some interbedded siltstone and laminate. Medium to high strength.

4.7.3 Foundations

Based on the encountered conditions, we expect that shallow pad footings should be able to be founded on the Class III Siltstone or Class II Sandstone. For preliminary design, the structural designer may proportion pad footings on the basis of an allowable bearing pressure (ABP) for centric vertical loads provided in Table 2. We understand that Wood & Grieve Engineers have assessed that for a 12 storey building with 2 to 2.5 basements, footings founded on Class III Siltstone with an ABP of 2 MPa would be in the order of 2 m x 2 m (plan dimensions).

Based on the proposed development and given the expected conditions, we do not expect that piles would be required. This will be confirmed with the structural designer at future detailed design stages.

Table 2 – Preliminary foundation engineering parameters of inferred geotechnical units

Inferred unit	Ultimate bearing pressure under vertical centric loading (MPa)[1,2]	Allowable bearing pressure under vertical centric loading (MPa)[1,3]
Class III Siltstone	6	2
Class II Sandstone	60	6

Notes: 1. Minimum plan dimension of 1.0 m and a minimum embedment depth of 0.5 m.
2. Ultimate values occur at large settlement (>5% of minimum footing dimensions).
3. End bearing pressure to cause settlement of <1% of minimum footing dimensions).

4.7.4 Interaction with Tunnels

Based on the above-referenced Technical Guidelines, any development at the site over the running tunnels (Inset 5) would fall within the Second Reserve. The construction restrictions are set out in the Table 4.5 of the Technical Guidelines (reproduced as Inset 4).

While excavations and foundations are allowed to be constructed within the Second Reserve, an assessment is required. The Technical Guideline is not explicit on the limit of applied loads but rather, requires the developer to demonstrate that the imposed loads from the proposed development does not adversely impact the Sydney Metro Northwest tunnels.

Without having undertaken any engineering analysis, it is difficult to provide certainty on the exact limits of development that would not adversely impact the tunnels. For this report we have provided a preliminary assessment based on our experience with similar projects.

Based on the inferred ground conditions, and approximate depth of the SMNW running tunnels, construction of a 12 storey building on the Site should be feasible. We understand that the current development proposal would require at least 2 levels of basement. Two levels appear feasible based on precedent in similar ground conditions. However, we also consider that deeper basements would be technically feasible.

The preliminary advice provided in this letter is subject to confirmation by further investigation and engineering impact assessment and shall not be relied on for detailed design.

5. Summary and Closure

In summary, we do not expect geotechnical conditions that are unusual for north western Sydney to exist on this Site. In general, normal civil engineering and building approaches will be satisfactory for geotechnical aspects of the proposed development.

We consider that development directly over the SMNW running tunnels is feasible and should be able to satisfy TfNSW / Sydney Metro requirements. At least two basement levels would appear feasible, based on previous similar projects.

We trust that this letter meets your requirements. Should there be any queries, do not hesitate to contact the undersigned.

For and on behalf of
PELLS SULLIVAN MEYNINK

BERNARD SHEN
PRINCIPAL

Appendix A
Historical Aerial Photographs

Notes:

1. Photograph source: Nearmap

2 Site boundary shown is schematic only

JBS&G	
Hills Showground Station Precinct	
Castle Hill NSW	
HISTORICAL AERIAL PHOTOGRAPH	
14 MAY 2019	
PSM3911-003L	APPENDIX A1

Notes:

1. Photograph source: Nearmap
2 Site boundary shown is schematic only

JBS&G	
Hills Showground Station Precinct	
Castle Hill NSW	
HISTORICAL AERIAL PHOTOGRAPH	
26 JUNE 2014	
PSM3911-003L	APPENDIX A2

Notes:

1. Photograph source: Nearmap

2 Site boundary shown is schematic only

JBS&G

Hills Showground Station Precinct

Castle Hill NSW

HISTORICAL AERIAL PHOTOGRAPH

19 JANUARY 2016

PSM3911-003L	**APPENDIX A3**

Notes:

1. Photograph source: Nearmap
2 Site boundary shown is schematic only

JBS&G

Hills Showground Station Precinct

Castle Hill NSW

HISTORICAL AERIAL PHOTOGRAPH

22 JULY 2017

PSM3911-003L	**APPENDIX A4**

Notes:

1. Photograph source: Nearmap
2 Site boundary shown is schematic only

JBS&G
Hills Showground Station Precinct
Castle Hill NSW
HISTORICAL AERIAL PHOTOGRAPH
16 AUGUST 2019

PSM3911-003L	**APPENDIX A5**

Appendix B
Example Photographs of Excavations in Sandstone

Photo 1: Exacation face in highly weathered Mittagong Formation and Hawkesbury Sandstone

Photo 2: Vertical excavation face in moderately weathered Hawkesbury Sandstone

JBS&G

Hills Showground Station Precinct

Castle Hill NSW

EXAMPLE PHOTOGRAPHS OF

EXCAVATIONS IN HAWKESBURY SANDSTONE

PSM3911-003L	**APPENDIX B1**

PSM

Photo 3: Vertical exacation face in fresh Hawkesbury Sandstone excavated by rock hammer

Photo 4: Typical excavation support in sandstone (cut batter, pattern rockbolts, shoring piles with anchors)

JBS&G	
Hills Showground Station Precinct	
Castle Hill NSW	
EXAMPLE PHOTOGRAPHS OF EXCAVATIONS IN HAWKESBURY SANDSTONE	
PSM3911-003L	APPENDIX B2

Appendix C
Sydney Metro Underground Corridor Protection – Technical Guidelines

Transport for NSW

Sydney Metro – Technical Services

Sydney Metro Underground Corridor Protection

Technical Guidelines

16 October 2017

Document No: NWRLSRT-PBA-SRT-TU-REP-000008

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Appendix A Sydney Metro

Glossary

CBD	Central Business District
IV	Independent Verification
TfNSW	Transport for New South Wales
Developer	The person or organisation responsible for the new construction and/or alteration works
Easement	A right to use for a specific purpose land owned by others. The easement can be limited in either height or depth or width or all. This is also referred as easement land
Stratum	Land owned for the metro which is limited in either height or depth or width or all. This is also referred as stratum land
Substratum	Land owned for the metro which is below surface level.
Development	The term "Development" in this document means new construction and/or alteration works that change the existing asset configuration and could affect existing or future underground metro infrastructure. These works may include demolitions, alterations of existing structures, basements, foundations, anchors, temporary and permanent groundwater drawdown, pipe jacking, site investigations, tunnel and retaining wall constructions.
NSW	New South Wales
Qualified Person	A person who is registered as a professional engineer or an architect or a surveyor under any law relating to the registration of engineers or architects or surveyors, as the case may be, and who under law is allowed to practice or carry on the business of a professional engineer or an architect or a surveyor.
SEPP	State Environmental Planning Policy
Support Zone	Zone where tunnel supports are located. Tunnel support can comprise permanent concrete linings, rockbolts and anchors, ground improvement measures such as grouted zones, rock pillar stich bolts, steel sets, lattice girders, brick lining, cast-in-situ lining, shotcrete lining and waterproof membranes
TfNSW	Transport for New South Wales
Underground Structures	Any engineering works below the surface of the ground

1. Introduction

Developments near existing metro underground infrastructure, such as running tunnels, station caverns and shafts have the potential to have an adverse impact on the structural stability and operations of this infrastructure. Similarly, developments proposed near planned metro underground infrastructure have the potential to impact on the feasibility of future metro construction.

TfNSW has an obligation to review the development applications of projects near to underground metro infrastructure, both planned and existing, on a case-by-case basis to ensure that their consequential impacts are appropriately assessed and managed. This guideline document has been developed to provide the requirements and technical guidance to assist developers with their assessment of development induced effects and the associated risks.

2. Purpose of this document

This guideline document provides the technical requirements to assess and manage the risks associated with developments near existing and future underground metro infrastructure. This document is based and builds on the ASA Standard T HR CI 12051 ST Developments Near Rail Tunnels.

The purpose of this guideline document is to assist external developers in the planning, design and construction near underground metro rail infrastructure. This guideline supports the key objective of the *State Environmental Planning Policy (Infrastructure) 2007* (Infrastructure SEPP) to protect the safety and integrity of key transport infrastructure from adjacent developments.

2.1 Scope

This guideline document covers the specific requirements and provides guidelines to be followed for new developments near existing and future underground Sydney Metro rail infrastructure (termed 'metro underground infrastructure' throughout this document) during development planning, designing, constructing and operating stages. In the context of this guideline document, future infrastructure is defined as infrastructure that has yet to be constructed but has an established rail corridor in accordance with the Infrastructure SEPP.

This guideline document primarily covers the developments near the following existing, under construction and future metro lines:

- Sydney Metro Northwest
- Sydney Metro converted Epping to Chatswood Rail Line (ECRL) and
- Sydney Metro City & Southwest.

It applies to new developments near Sydney Metro running tunnels and other underground infrastructure such as: cross passages between running tunnels; station caverns and adits; crossover caverns; station boxes and shafts; nozzle enlargements; ventilation shafts and dive/portal structures. Information regarding existing and planned new metro infrastructure can be sourced from TfNSW.

3. Reference Documents

The following documents have been referenced to prepare this document:

Transport for NSW standards

- T HR CI 12051 ST Developments Near Rail Tunnels.
- TS 20001 System Safety for New or Altered Assets
- T HR CI 12070 ST Miscellaneous Structures
- T HR CI 12075 ST Airspace Developments
- T HR CI 12080 ST External Developments
- T HR EL 12002 GU Electrolysis from Stray DC Current

Legislation and guidelines

- The Environmental Planning and Assessment Act 1979
- The Heritage Act 1977
- State Environmental Planning Policy (Infrastructure) 2007 (Infrastructure SEPP)
- Development Near Rail Corridors and Busy Roads 2008 – Interim Guidelines – Department of Planning, NSW Government

Other reference documents

- CIRIA C580, Embedded Retaining Walls, Guidance for Design, 2003

4. Protection reserves

Protection reserves define the extent of zones that have been established to protect existing metro infrastructure and protect the feasibility of planned metro infrastructure from future adjacent development activities.

For the purpose of assessing the effects of adjacent developments, underground metro infrastructure includes, but is not limited to, the following:

- running tunnels and interconnecting cross passages
- station caverns and adits
- crossover caverns
- station boxes and shafts
- nozzle enlargements
- ventilation shafts and
- dive and portal structures.

Appendix A includes descriptions of Sydney Metro infrastructure for each of the existing and future metro lines. These descriptions provide an overview of the metro alignments and general location of the underground elements for each section.

Protection reserves are defined in this document. Developers must establish the reserve zones based on the requirements provided within this document and ensure that the design and construction meet the stated requirements.

4.1 Protection reserves

The protection reserves are categorised as either the 'first reserve' or 'second reserve'. Figure 4.1 and 4.2 represent the zones that form the first reserve and the second reserve around metro underground infrastructure.

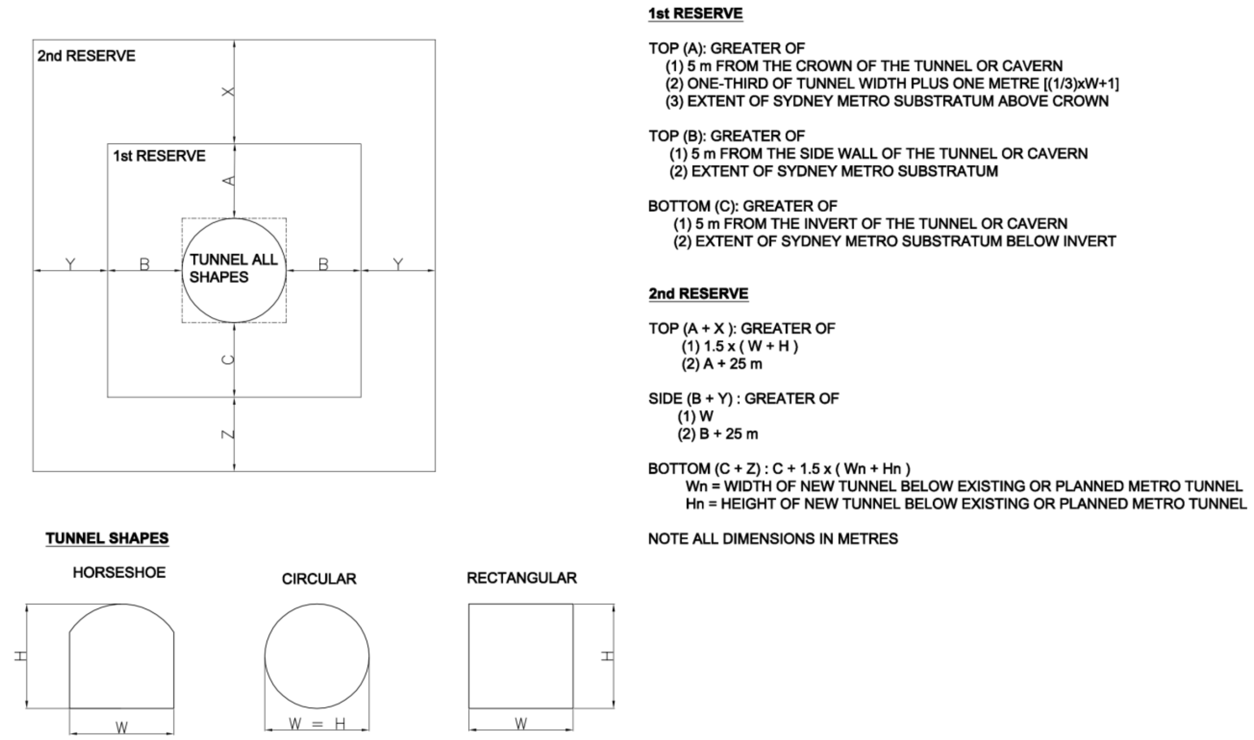

Figure 4.1 Protection reserves for metro tunnels and caverns

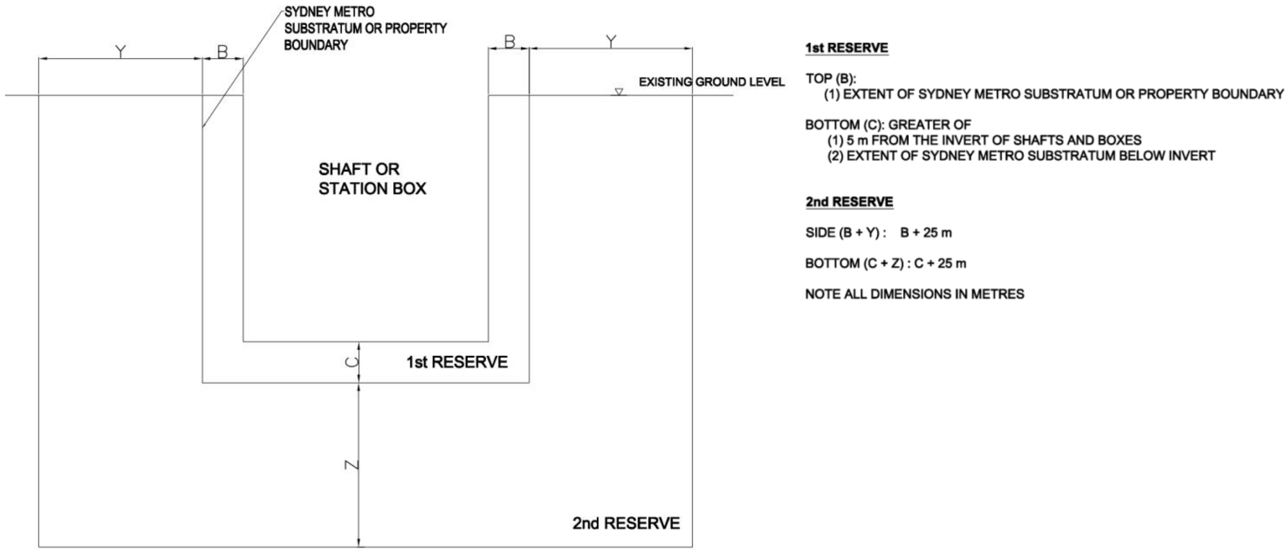

Figure 4.2 Protection reserves for shafts and station boxes

4.2 First Reserve

The first reserve encompasses the ground that immediately surrounds the underground metro infrastructure. This zone represents the area that must not be encroached upon by any future development and its construction.

The limits of this zone are indicated in Figure 4.1 and Figure 4.2. These limits are determined based on an appreciation of general ground support principles and the substratum acquired for the Sydney Metro.

Table 4.1 Definition of first reserve for tunnels and caverns

Boundary (Dimension Reference as shown in Figure 4.1)	Reserve dimensions (m)
Top (A)	The greater of the following: ▪ 5 m from the crown of tunnel or cavern ▪ Support zone based on 1/3*tunnel width plus 1 metre (1/3*W+1) ▪ Extent of Sydney Metro substratum above crown
Side (B)	The greater of the following: ▪ 5 m from side wall of tunnel or cavern ▪ Lateral extent of Sydney Metro substratum
Bottom (C)	The greater of the following: ▪ 5 m below the invert of the tunnel or cavern ▪ Extent of Sydney Metro substratum below invert

Table 4.2 Definition of first reserve for shafts and station boxes

Boundary (Dimension Reference as shown in Figure 4.2)	Reserve dimensions (m)
Side (B)	▪ Lateral extent of Sydney Metro substratum or property boundary
Bottom (C)	The greater of the following: ▪ 5 m below the invert of the shafts or boxes ▪ Extent of Sydney Metro substratum below invert

4.3 Second reserve

The second reserve zone surrounds the first reserve and covers the areas where development works have the potential to adversely impact on the performance of the support elements of underground infrastructure, metro operations or the feasibility of planned metro infrastructure.

Any developments that take place within the second reserve require an engineering assessment of the works to predict their effects on the underground rail infrastructure.

The limits that apply to the second reserve are summarised in Tables 4.3 and 4.4 below.

Table 4.3 Definition of second reserve for tunnels and caverns

Boundary (Dimension Reference as shown in Figure 4.1)	Reserve dimensions (m)
Top (A+X)	The greater of the following: ■ 1.5 x (W+H) ■ A+25 Where 'W' and 'H' are width and height of the existing rail tunnel
Side (B+Y)	The greater of the following: ■ W ■ B+25
Bottom (C+Z)	C + 1.5 x (W_n + H_n) Where, 'W_n' and 'H_n' are width and height of new tunnel under the existing metro tunnel or cavern

Table 4.4 Definition of second reserve for shafts and boxes

Boundary (Dimension Reference as shown in Figure 4.2)	Reserve dimensions (m)
Side (B+Y)	■ B+25 m
Bottom (C+Z)	■ C+25 m

The following factors have been considered to establish the extent of the second reserve:

- potential stress and displacement influence zones associated with external developments that consider the expected zone of negligible ground stress changes due to the construction
- extent of shear displacement of horizontal rock defect or bedding and joints during construction
- potential groundwater drawdown influence zone and
- vibration influence zone.

4.4 Construction restriction placed on protection reserves

Table 4.5 provides the construction restrictions that are applied to each reserve zone as shown in Figure 4.1 and Figure 4.2.

Table 4.5 Construction restrictions

Types of construction	First reserve	Second reserve
Excavation for basements, footings	Not allowed	▪ Excavations less than 2.0 m depth from surface level, assessment not required. ▪ Excavation greater than 2.0 m depth, assessment required.
Shallow footings or pile foundations	Not allowed	Allowed, subject to load restrictions. Assessment required.
Tunnels and underground excavations	Not allowed	Allowed, subject to assessment
Ground anchors	Not allowed	Allowed, subject to assessment
Demolition of existing subsurface structures	Not allowed	Allowed, subject to assessment
Penetrative subsurface investigations	Allowed away from support zone, Assessment required	Allowed, subject to assessment

5. Developments

5.1 General

Any new construction above, below or alongside the existing or future metro infrastructure, that is located within the protection reserves, are considered developments that fall within the scope of this guideline document. Any construction that is located outside these protection reserves, but still has the potential to cause construction-induced groundwater drawdown and vibration that will affect underground metro infrastructure are considered developments that fall within the scope of this guideline document.

Developments near metro infrastructure must be planned, designed, constructed and maintained to ensure the protection of existing and future metro infrastructure. These developments must not affect the metro operations including either the operational capacity or the efficiency of the network during any stage of the life cycle of that development.

Development related loads and ground displacements can cause deformation of existing tunnels and other associated structures and, in extreme situations, can cause structural failure and collapse. Deformation of the tunnel and cavern support elements and the surrounding ground is of concern as movement of structural lining can cause structural instability, groundwater ingress and encroachment of support into rail functional areas, such as rolling stock kinematic envelopes.

The following sections discuss those aspects of developments where construction restrictions are placed within the second reserve and includes safety and environmental considerations.

5.2 Construction restrictions

The following summarises key construction activities that are permitted, but have a potential to affect metro infrastructure, as such restrictions may apply to construction activity within the second reserve:

- Excavation for basements and shafts – above / beside or below
- Ground anchors – above / beside or below
- Shallow footing or pile foundation – above / beside or below
- Tunnels and underground excavations – above / beside or below
- Demolitions or existing structure – above or beside
- Geotechnical investigations / instrumentation – above / beside or below

Whilst these restrictions focus mainly on impacts to existing underground infrastructure, in many cases they are equally applicable to future metro infrastructure. In these cases the intent of the construction restrictions is to ensure the feasibility of future metro construction and operations is not adversely affected by new developments and their construction.

As a general note, the construction of new developments must take into account the construction constraints, particularly live road and rail operating conditions, noise and vibration restrictions and track possession constraints that are inherent to working near to an operating rail environment. Further consideration must be given to access requirements that may be necessary for inspection and maintenance purposes.

5.2.1 Open excavations

Open excavations can be above and/or to the side of underground metro infrastructure. Such excavations can alter the insitu stress regime in the ground that directly affects support elements of underground infrastructure and other sensitive infrastructure. The excavations can additionally reduce the structural support provided by the surrounding rock where the rock provides active support.

Temporary and permanent anchors can be part of the development to support open excavations, underground excavations and provide uplift resistance for construction cranes and basements. High stress concentrations around ground anchors can affect the surrounding ground locally and potentially impact on the stability of the rock and existing underground structures.

A range of excavation methods are available to excavate ground for new developments. Activities such as rock breaking, pile driving and rock drilling/cutting works have the potential to impose temporary loads and excessive noise and vibration on metro infrastructure. Vibration can dislodge rock wedges on existing metro tunnels and caverns, as well as impose additional non-uniform load patterns on the support of metro tunnels and caverns.

Ground improvement works such as grouting and ground freezing works can also affect existing metro tunnel and cavern structures. Grouting can block water drainage paths and impose excessive hydrostatic loads on tunnel and cavern support. Specialised techniques such as ground freezing can cause volume increase that can impose loads on nearby tunnel and cavern support.

In addition, excavation activities will induced ground borne vibration with the potential to affect metro infrastructure.

5.2.2 Foundations

Additional pressures from shallow spread footings and piled foundations designed to support new developments can increase the stresses in the permanent concrete structural linings of metro tunnels and caverns and the surrounding rock. The effects of the foundation loads must be considered, including opportunities to redistribute bearing pressures away from the protection reserves to minimise the impacts.

Of interest are the changes in stress distribution from foundations within the ground above or surrounding existing (or future metro) underground infrastructure as a consequence of development construction. Issues of potential concern relate to increase in vertical or horizontal pressures beneath foundation elements, increases in shear stress along known existing bedding planes in the rock mass and uplift pressures below the invert of metro underground infrastructure.

Ground borne vibration from activities such as pile driving or bored piles installation and sheet pile installation must be considered.

5.2.3 Underground excavation

Underground excavations include the construction of adjacent rail and road tunnels (above, to the side and below), utility tunnels, cable conduits, drainage pipes, and pedestrian walkways and underpasses. Such underground excavations can significantly alter the insitu stress field in the surrounding ground resulting in stress concentrations, stress relief and displacements. These changes can significantly affect the existing metro tunnel and cavern support elements.

In cases where underground excavations are designed to be drained structures (that is, the structural lining and ground support of tunnel and caverns are built to support the ground but permit groundwater to flow into the excavation) consideration must be given to the groundwater drawdown that this will cause and the impacts that this will have on nearby metro infrastructure.

Ground borne vibration caused by tunnelling must also be considered.

5.2.4 Demolition

The demolition of any existing buildings or basements has the potential to adversely affect existing metro underground infrastructure and cause disruption to metro operation. Where necessary, measures may be needed to protect metro assets during demolition works of existing buildings and structures as part of development construction.

5.2.5 Geotechnical investigations

Development activity requires geotechnical and subsurface investigations that can include drill holes, geophysical exploration, in-situ tests and permeability tests. During construction, instrumentation holes such as inclinometers, piezometers and extensometers can be drilled to measure the ground reaction and the impacts.

Importantly, the drilling of boreholes and installation of instrumentation must be planned to avoid existing metro infrastructure and avoid disruption to metro operations.

5.3 Safety

Developments near underground metro infrastructure must address the following aspects of safety in respect of the metro and its operation at any stage of the life cycle of that development:

- structural safety
- operational safety
- fire safety
- inspection and maintenance and
- floor protection.

Consideration must be given to maintenance and to future users of the development. Importantly, new development must not obstruct emergency access to metro infrastructure and any maintenance access requirements.

Approvals from TfNSW are required to enter into the metro assets for dilapidation survey, installation of instruments, monitoring and visual inspections. Persons carrying out these activities must be accompanied by safety personnel from TfNSW or from TfNSW approved organisations when entering metro tunnels.

5.4 Protection of environment

The developer must take into account the environmental impacts that can affect the metro with a view to minimising any effects during the whole life cycle of development. Typical considerations for developments in the urban environment are as follows:

- stormwater management
- noise and vibration
- air quality, particularly dust
- traffic impacts
- visual impact and amenity
- ability and ease to maintain and ‘retro-fit’ improvements over time
- disposal and re-use at life cycle end
- ecological impact due to draw-down

- groundwater contamination and
- construction materials to be as low toxicity as possible.

6. Development applications and construction

Proposed development which triggers the Infrastructure SEPP will require concurrence from TfNSW (or in some cases Sydney Trains). Different documentation is required at different stages to enable TfNSW to assess the potential impact on future corridors.

To assist TfNSW with their assessment, documentation must be provided at the planning stage and development application stages. Depending on the finding of the assessment by TfNSW documentation and supporting information may also need to be provided at the design, construction and operation stages of the development.

6.1 Planning stage

Where new developments are within the purview of the Infrastructure SEPP criteria it is recommended that the developer consult with Sydney metro and prepare the following documents during the planning stage (or pre-lodgement of DA stage) for preliminary comment and discussion purposes based on the development concept:

- location of site layout
- existing easements on land and for the metro underground infrastructure
- architectural layout showing the general arrangement of the development
- plans and drawings of existing metro infrastructure obtained from TfNSW that show protection reserve boundaries based on this guideline document
- section view and plan view of the proposed development (including the reduced level of basements) and protection reserves and
- site investigation plans (if they involve drilling within the protection reserves).

6.2 Development application (or concurrence) stage

The developer must submit the following documents to TfNSW as part of their development application:

- legal boundary alignment along the length of the proposed site identified by a NSW registered surveyor
- drawings showing the development in relation to the metro infrastructure in plan, elevation view and sectional view with dimensions and reduced levels
- easements (including right of ways) or stratums, covenants and caveats identified by a NSW registered surveyor, specifying the purpose of the easement and whom it is in favour of
- location of metro underground infrastructure and its dimensions, relative distances and reduced levels to the proposed excavation face and levels, foundations
- geotechnical investigation report with details in accordance with Section 7.1 of this guideline document
- impact assessment report with details in accordance with Section 7.2 of this guideline document and
- risk assessment report in accordance with Section 7.3 of this guideline document.

The following may also be requested by TfNSW based on the information provided at the planning stage:

- Detailed dilapidation survey report in accordance with section 7.4 of this guideline document.

6.3 Post development application

Based on the information provided to support the development application TfNSW may require the developer to provide the following information and documentation at the following stages of project development.

6.3.1 Prior to construction

The following documents may need to be submitted prior to construction commencement:

- detailed ground and vibration monitoring plan including trigger levels, action plans and remedial measures, details of the instrumentation and baseline monitoring readings (refer to Section 10)
- construction schedule, construction management plan including sequence plan identifying impacts
- construction layout of equipment relative to metro infrastructure
- final detailed work method statements (refer to Section 8)
- temporary safety plans and measures
- temporary works plan, temporary access, vehicle, plant and equipment such as cranes (including mobile cranes) and stockpiling
- noise, vibration and electrolysis studies and control measures
- a rail related risk assessment and management plan
- list of machinery to be used
- groundwater control plans, environmental aspects including contamination
- design loadings and certified drawings for construction related works that affect metro infrastructure
- agreed interface activities plan with TfNSW and
- condition and dilapidation survey reports of all metro infrastructure affected by the development (refer to Section 8.2).

6.3.2 During construction

The following documentation may need to be submitted to TfNSW at agreed intervals by the developer, during the development construction phase:

- monitoring report at agreed intervals, which includes monitoring results and assessment by the geotechnical or structural consultant
- notification of work progress at agreed intervals, which is applicable during excavations, foundations and support installations, superstructure construction up to the ground level
- interim dilapidation survey reports as appropriate
- any changes to the design and construction methods for approval by TfNSW and
- rock face mapping, inspection and assessment reports.

6.3.3 After construction completion and prior to issue of occupation certificate

TfNSW may request the following documentation from the developer, after completion of the construction:

- one set of as-built structural and foundation plans signed by qualified person
- one set of as-built drawings for ground anchors and other support details near the affected metro infrastructure
- monitoring summary report
- copy of the geotechnical mapping report carried out during excavation works
- dilapidation survey report conducted after construction completion (refer to Section 8.2)
- structural safety report
- operational safety report and
- current mitigation verification report, including maintenance base line measurements referenced to measured locations (refer to Section 9.4)

7. Engineering investigations and assessments

The developer must prepare the following documentation in support of their DA:

- geotechnical investigation report
- impact assessment report
- risk assessment report
- dilapidation survey report
- drainage report and
- a summary report that presents the main conclusion and results from the above reports.

This section of this guideline document provides an explanation of the information that needs to be included in these reports to enable TfNSW to ascertain the relative impact of the development on existing and future Sydney Metro underground infrastructure. In terms of the engineering investigations and assessments undertaken for future metro infrastructure, the intent of these is to ensure the feasibility of future metro construction is not adversely affected by new developments and their construction.

The main aim of these assessments and investigations is to demonstrate that there will be no adverse effects arising from the proposed development within the defined protection reserves. The acceptability of the effects predicted (as determined through investigation and assessment) must be viewed against the performance requirements described in section 9 of this guideline document, as well as compliance with relevant standards and codes.

The developer should approach TfNSW for information that defines the extent of existing and future metro infrastructure in order to undertake these investigations and assessments.

7.1 Geotechnical investigation

If required by TfNSW, the developer must carry out detailed geotechnical investigations of the soil or rock strata above, alongside and below existing and future Sydney Metro underground infrastructure, as appropriate, to establish the existing ground conditions within the area affected by the proposed development. Geotechnical investigations must be undertaken by suitably qualified and experienced consultant. The results of the investigation must be presented in a geotechnical investigation report.

The intent of these geotechnical investigations must be as follows:

- Provide information that enables a geological model to be developed. Based on this model sections should be able to be must be prepared that illustrate the ground conditions in and around the interface of the proposed development with the Sydney Metro underground infrastructure of concern.
- Establish the likely insitu stress conditions within the soils and underlying rockmass surrounding the interface.
- Define, if present, critical geological features such as bedding planes, joints and dykes.
- Present an interpretation of relevant rock and soil properties based on the results any insitu and laboratory testing that has been undertaken.
- Provide an interpretation of the existing groundwater regime within and surrounding the interface.
- Identify and describe the presence of any human-made features within the development site.

The scope of the geotechnical investigation undertaken to support the development application may comprise the following:

- drilled boreholes
- insitu testing
- geological mapping and
- geophysical exploration.

Whilst the installation of instrumentation and the drilling of investigation boreholes is permissible near to metro infrastructure, they should be located and orientated to avoid the supporting systems of existing metro underground infrastructure. This will require a detailed study of existing arrangements to demonstrate that risk to the underground infrastructure is appropriately managed for approval from TfNSW prior to the drilling of boreholes.

In some cases TfNSW may require that before drilling can take place a surveyor must establish the co-ordinates of the borehole at surface. In these cases drilling may only proceed after obtaining approval from TfNSW.

All boreholes must be carefully grouted to their full depth with a bentonite and cement grout mixture upon completion.

As a minimum the geotechnical investigation report will need to present the following information:

- borehole location plan, borehole logs, test results, geological mapping, photographic documentation and other relevant information
- description of the soil profile of the area
- critical geological features such as bedding planes, joints and dykes
- other relevant data from geotechnical investigation
- rock and soil properties, laboratory and insitu test results
- existing insitu stress states in soils and rocks
- groundwater levels and condition.
- detailed geotechnical model for the analysis including geotechnical design parameters
- recommended footing design, methods of shoring and excavation and
- a copy of all plans, geotechnical data, operations and maintenance records with any qualifications and limitations provided by TfNSW to the developer.

7.2 Engineering impact assessment

The developer must carry out an engineering analysis and impact assessment to demonstrate that the effects of the proposed development on tunnels and underground facilities will not cause unacceptable adverse impacts on future or existing Sydney Metro infrastructure. The engineering assessment must be carried out by suitably qualified persons with experience in tunnel design and analysis. In some cases TfNSW may request the developer to arrange independent verification of the engineering analysis and impact assessment based on the project complexity and the potential effects on metro infrastructure.

The results of the analysis and assessment must be presented in an engineering report. The engineering assessment report must be prepared and endorsed by a suitably qualified person and submitted to TfNSW.

The engineering analysis and impact assessment must take into account any other adjacent development activities planned for the future or that are taking place at the time of analysis. This information can be obtained from TfNSW.

Depending on the complexity of the development, a two-dimensional or three-dimensional numerical modelling (finite element [FE] or finite difference [FD]) may be requested by TfNSW to predict the effects on the underground construction at different stages of construction and the eventual or current operation of the metro. The modelling must also consider the effects of associated temporary works, such as construction loading (e.g. cranes and material stockpiling).

If undertaken, numerical modelling must fulfil the following requirements:

- be based on a realistic geological model derived from the subsurface information gathered through the geotechnical investigation
- must incorporate critical geological features that may be present, such as bedding planes, weak layers, joints and other discontinuities and
- take account of the existing condition of the tunnel lining including defects such as cracks, drainage conditions and support conditions as determined by dilapidation survey and insitu strength tests.

If necessary, the results from this numerical modelling may need to be validated during construction by comparison with the results from the field monitoring of installed instrumentation.

As a minimum the impact assessment report must include the following:

- Details of the scope of the development.
- Verified survey plans by a NSW registered surveyor that show the location of the proposed development in relation to the metro easements, protection reserves and the planned or existing metro alignment including track centre lines and details of the and underground structures.
- The metro underground infrastructure must be shown in plan and various sections with the inclusion of the protection reserves as defined in this guideline document to clearly illustrate the comparative position of the development in relation to the existing or planned metro infrastructure. They must also extend to the expected physical zone of influence, which is the extent to which the development is expected to affect the surrounding ground.
- Detailed drawings depicting structural layout, foundation layout, foundation loads, drainage plans, temporary works such as dewatering, shoring and anchoring and permanent works of the proposed development.
- Structural drawings that show the designs for shoring, as recommended by the developer's geotechnical consultant.
- Predicted displacements of existing or planned metro underground infrastructure (if constructed prior to the proposed development) due to proposed development at various stages, namely pre-construction (including demolition), excavation, development construction and post-construction.
- Predicted displacements, stresses and structural actions as imposed on the structural support of metro infrastructure structure at various stages of construction, namely pre-construction (including demolition), excavation, development construction and post-construction. In most cases this support will be in the form of watertight structural concrete linings.
- Structural assessments of these predicted effects on existing and planned metro infrastructure (if constructed prior to the proposed development). This must include as appropriate the structural integrity of underground support (such as structural linings), track beds, existing drainage structures, waterproofing measures and structural clearances.
- Appropriate sensitivity analysis to ensure that the predictions are not adversely affected by reasonable variations in input parameters and different conditions that can occur during all stages of development construction.
- Assessment of the effects of construction techniques and methodology on the underground metro infrastructure.

- Provide discussion on any design assumptions, qualifications or limitations that have been applied. This discussion must indicate how these have been considered as part of the sensitivity analysis and then integrated as identified risks as part of the risk assessment (as discussed below).
- Recommendations regarding any planned preventive or remedial action that may be required to limit development induced impacts on metro infrastructure.
- Noise and vibration assessment report (refer section 8.6).
- Stray currents report, including a risk assessment (refer to Section 9.4).
- Certification that the proposed development will not induce unacceptable adverse effects on metro infrastructure.

7.3 Risk assessment

The developer has a legal duty to eliminate risks to safe rail operations so far as is reasonably practicable (SFAIRP). As such the developer must identify all reasonably foreseeable safety risks and hazards to the metro or its operations and eliminate these risks where reasonably practicable and where it does not minimise each risk SFAIRP.

The identified risks and their SFAIRP demonstration must be documented in a manner that can be provided as assurance evidence to TfNSW. TS 20001 System Safety for New or Altered Assets describes the assurance for changes impacting rail or transport assets. Reference should also be made to T HR CI 12075 ST when preparing the risk assessment.

A rail related risk assessment report must be prepared and submitted for consideration and approval by TfNSW in accordance with the safety management system for TfNSW and address/include the following:

- safety in design that covers and the whole of asset life cycle, including all stages of construction
- identify all hazards and risks to the development and metro facilities including metro support elements and other infrastructure
- present the risk identification process that has been adopted which considers the entire asset life cycle of the metro infrastructure
- apply and present a risk ranking in accordance with the TfNSW safety management system
- confirm that all risk can and will be managed so far as is reasonably practicable (SFAIRP) and
- present the controls that are needed to manage risks from the development to metro infrastructure. These may include early warning criteria for monitoring.

7.4 Dilapidation survey

Dilapidation surveys of existing metro infrastructure may be requested by TfNSW during the planning stages and may need to be submitted as part of the development application. If required, the developer must arrange for a dilapidation survey to be undertaken of metro infrastructure in proximity to the development. The existing condition of the metro infrastructure must be established and considered as part of the risk assessment.

7.5 Drainage report

Where relevant TfNSW may request that a drainage report is prepared that details the proposed means of drainage that will be adopted to manage the collection of water, including groundwater, within basement levels of the proposed development.

7.6 Independent verification

Depending on the details of the proposed development and the proximity of planned or future metro infrastructure, TfNSW may request that an independent verification of the engineering analysis and impact assessment be carried out. If required, the independent verification must be arranged by the developer.

The independent verification must be carried out by an organisation that is independent of the organisation that prepared the engineering analysis. The independent verification organisation will be subject to the approval of TfNSW.

The independent verification must include detailed engineering proof checking of all aspects of the engineering analysis and impact assessment including any proposed temporary works.

The independent verification organisation must prepare a report that describes its verification activities and includes certification that the proposed development will produce no unacceptable adverse effects on existing metro infrastructure. The independent assessment report must be submitted to TfNSW with the engineering assessment report.

8. Construction requirements

8.1 General

All metro property must be fully protected during construction of the development and all site work (including clearances to metro tracks and protection reserves) must comply with the requirements outlined in this guideline document, as well as other relevant TfNSW standards relating to air space developments, external developments and tunnels, and safe working requirements.

All construction carried out on metro property must comply with the requirement of the relevant authorities and legislation including workplace health and safety (WHS) requirements and environmental requirements.

In the event that concurrence is provided by TfNSW the construction requirements described in this section apply.

8.2 Dilapidation survey

Before construction of the development can commence and an occupation certificate can be issued, a joint inspection of the existing metro near the proposed development may be requested by TfNSW. If requested the survey must be carried out by representatives of the developer and TfNSW. The existing condition of the metro infrastructure must be agreed and recorded. Additional joint inspections may be required during construction.

The extent of metro infrastructure that must be surveyed will be determined by TfNSW.

Detailed dilapidation reports must be submitted to TfNSW describing conditions before commencement of works and after completion of works.

The dilapidation report must include the following as a minimum:

- details of existing defects
- dimensions of existing cracks
- photos of defects with labels that indicate their locations and
- signs of wetness, staining and seepage from existing defects.

This inspection must establish the extent of any existing exposed cracks, such as those observed on the surface of concrete linings which support metro tunnels and caverns. These cracks must be suitably marked and identified to enable any deterioration to be monitored.

8.3 Risk assessments

Prior to commencing any works the risk assessment report issued in support of the DA must be updated based on the detailed design at construction. The updated risk assessment report must take into account any modifications to the design and the impact these may have on identified risks.

Safe work method statements must also be prepared that include, as a minimum, the following:

- detailed work methods including the incorporation of the controls as stated in the risk assessment plan and
- an emergency response plan.

The developer must submit the safe work method statements and updated risk assessment report to TfNSW for approval.

8.4 Demolition works and construction impacts

The demolition of any existing buildings or basements must be planned in such a way that no adverse risk is imposed on existing metro underground infrastructure. The developer is required to take every possible action to minimise imposed risks and is required to meet the costs of any protection of the metro infrastructure and any incurred disruption to metro rail operations.

The impact of any proposed underground demolition work (including de-stressing, unloading and resulting ground vibrations) must be assessed to ensure that there are no adverse effects on metro infrastructure. If large-scale demolition works are involved, then the developer is required to install a vibration monitoring system to monitor vibration levels near adjacent metro infrastructure.

Hydraulic rock breakers must not be used within five metres of any existing metro infrastructure.

The developer is required to arrange a structural investigation by appropriately qualified person to address the impacts.

Refer to T HR CI 12075 ST for further details.

8.5 Excavation works

The developer must submit the following for TfNSW's approval prior to commencing excavation for the development:

- An engineering assessment report which through the use of numerical modelling techniques (if required) demonstrates that the excavation will not cause any adverse effect on the underground metro infrastructure.
- Design reports that detail the shoring system that support excavations must be provided to TfNSW prior to construction and must include evidence of independent verification certification.
- A detailed monitoring plan for ground deformation, tunnel convergence, stress, crack width monitoring, vibration monitoring and reporting protocol for each party.
- Risk assessment and contingency plans.
- Detailed work method statements which include hold points at various stages of excavation and are linked to the acceptable monitoring results.

The following requirements apply to excavation and piling works at construction:

- The positon of underground metro infrastructure (outer walls) and protection reserves must be marked clearly on the ground for easy identification.
- All piling contractors must be made aware of the existing underground metro infrastructure adjacent to construction site.
- TfNSW must be informed of the progress of piling and excavation works on a daily basis.
- The results of field monitoring undertaken during excavation or piling works must be assessed by a suitably qualified person and reported to TfNSW at an agreed frequency.

Depending on the project complexity and potential impact on metro infrastructure, TfNSW can require the developer to engage a geotechnical consultant during the time of excavation process for visual verifications of substrata as identified during investigation, geological mapping where required and an assessment of monitoring results.

The developer must submit the monitoring results together with geotechnical consultant's assessment to TfNSW at agreed frequencies and stages of construction. A TfNSW nominated observer may be involved with the monitoring.

Monitoring must continue until construction of the building structure or superstructure is complete. With prior agreement with TfNSW, monitoring frequencies may be decreased when the basement construction is completed. Monitoring must continue after the completion of the construction activities until no changes occur in three consecutive monitoring cycles. TfNSW must be informed before termination of the monitoring activities.

8.6 Noise and vibration

The effects of noise and vibration on existing metro infrastructure and on the development must be considered as part of the design and construction of developments.

The construction of the development must be carried out such that the effects of noise and vibration on nearby metro structures and facilities are minimised. Prior to construction, an acoustic and vibration assessment report, including a vibration monitoring plan, must be prepared by a qualified person and submitted to TfNSW. This assessment must cover acoustic and vibration levels arising from the proposed development during construction and its operation after completion (including any machinery causing heavy vibration levels). The assessment must also determine the effects of noise and vibration on the metro infrastructure and its operations.

8.7 Contaminants and hazardous materials

The storage of potential contaminants and hazardous materials within the protection reserves will be subject to TfNSW approval. A risk assessment and appropriate safety precautions must be provided for storage of potential contaminants within any of the protection reserves, where there is potential for the contaminants to migrate to or come in contact with the metro underground infrastructure. This assessment must address the potential impact on the durability of concrete, grout, resin, steel, waterproofing gaskets and membranes and any other material forming the permanent works of the metro underground infrastructure.

The storage of potential contaminants and hazardous materials may be permitted if the results from the risk assessment demonstrate that the risk to the metro underground infrastructure can be appropriately managed.

9. Performance requirements

The design and construction of the development must be carried out with full recognition of the potential effects that could be imposed on the performance of the existing metro or the feasibility of the future metro. As an overarching principle the development must not affect the stability and integrity of the metro infrastructure and its safe operation. Broadly, the developer must ensure that the development and its construction do not adversely affect the performance of metro infrastructure in respect of the following:

- amenity
- aesthetics
- structural integrity
- durability
- function
- user/customer benefits
- safety during construction and operation and
- environmental performance.

It should be noted that throughout the developer's activities, the developer must monitor the actual effects of construction against design predictions and in accordance with the project-specific construction phase monitoring requirements.

Aspects of the development and its construction which could adversely affect the metro infrastructure include the following:

- loading or unloading from the development
- ground deformation resulting from excavations and external loading
- induced vibrations during construction and operation
- ground borne noise impacts
- electrolysis from earth leakage currents
- discharge of stormwater from the development
- changes to groundwater levels affecting design assumptions
- loss of support to any underground rail facility (including rockbolts and anchors)
- temporary structures and
- load from anchors

This section details the design and performance requirement that must be adhered to by the developer in order to address these issues.

9.1 Structural integrity

Development induced load and displacements must not have any adverse effects on the support structure or system of metro infrastructure in both the short and long term conditions.

Structures that are proposed to be constructed over and/or adjacent to metro underground structures must be suitably designed to take into account the presence of the existing metro infrastructure and future construction of metro infrastructure. Construction work methods must be developed as part of the design process.

The effects on metro support elements and other metro infrastructure at any stage of the whole life cycle of the development must be assessed to ensure that the works must remain compliant with relevant standards. These structural elements include, but not limited to, concrete (precast, insitu or sprayed) linings, load bearing columns, walls and roof beams, slabs, rock pillar supports, permanent rock anchors (or bolts), track slabs, drainage structure, shafts and underground stations.

Of particular interest is the possibility of increases in structural actions, such as axial loading and flexural bending, to support elements and structural linings of metro underground infrastructure, as a consequence of development loading.

9.1.1 Imposed loading

Any temporary or permanent works adjacent to the metro could be subject to the influence of train loading and as such will need to be assessed in accordance with AS 5100 for live load surcharge. Parts of the development that could be affected must be designed to comply with T HR CI 12070 ST Miscellaneous Structures, T HR CI 12075 ST Airspace Developments and T HR CI 12080 ST External Developments.

Permanent works adjacent to metro must take into account the design actions resulting from any proposed future metro construction. TfNSW will provide advice in relation to planned future metro infrastructure.

9.1.2 Induced movement

Displacement of metro infrastructure as induced by the development must not affect the operational functionality and durability of the affected infrastructure. Also, the developer must consider the possibility that future metro construction may induce movement on the development.

The following displacements limits apply:

- For metro cast insitu cavern and tunnel concrete linings, the allowable total movement in any direction is 10 mm and differential movement in any plane is 10 mm or 1:2000 whichever is less.
- For metro running tunnels that are supported by a precast concrete segmental lining, the allowable total movement in any direction is 10 mm and differential movement in any plane is 10 mm or 1:2000 whichever is less. The main purpose of these limits is to ensure that the watertightness of the lining through joints is not compromised as consequence of gasket decompression and/or damage.
- Shear movement across rock bedding as induced by the development activities must not exceed 10 mm where permanent rock bolts, installed as part of the metro infrastructure support system, intersect these bedding planes.

Any development activity, whether beneath or adjacent to contained metro tracks, that has the potential to cause track displacement must comply with the requirements of SPC 207 Track Monitoring Requirements for Undertrack Excavation. The track must be monitored and managed in accordance with the requirements stated in SPC 207 for monitoring, notification and intervention levels and emergency procedures.

9.1.3 Induced cracking

The extent of dilapidation surveys undertaken (and described previously in this document) of metro infrastructure must be determined based on predictions of deformation and the load influence zone imposed by the proposed development. The survey must establish the extent of any existing cracks. Where present these must be suitably marked and identified to enable any deterioration during and after the construction to be monitored.

The following technical criteria must be met regarding cracking, including the presence of pre-existing cracks on the face of metro concrete structures:

- No new cracking of metro concrete structures (both inside and outside of structures such as tunnel linings or other support elements) is allowed to be induced by the development and its construction. Compliance with this requirement must be confirmed by performing impact assessments during the design stage.
- Any existing cracks must not increase by more than 0.2 mm in width or increase in length by more than 300mm in total over the stages of development construction.
- The propagation of these existing cracks must comply with the following requirements:
  - The configuration of cracks must not result in concrete spalling or affect the safe operation of the metro system.
  - In the event that water seepage is observed (previously absent) through the cracks during development construction then TfNSW will on behalf of the developer seal the cracks by grouting the cracks until this seepage ceases.
- Engineering analysis and assessment undertaken for the development (as discussed within this guideline document) must take into account the presence of existing cracks of metro infrastructure.

The monitoring of existing cracks and critical structural elements during construction must form part of the overall monitoring plan.

9.2 Excavation and groundwater

Excavation for the development and all associated retaining works (along with other ground disturbance works associated with the proposed development) must not affect the safety and operational integrity of the metro or cause the destabilisation of metro infrastructure. The methods of excavation employed are of particular relevance in this regard, especially where methods employ chiselling, percussive pile driving or similar methods. Importantly, explosives must not be used for the splitting and removal of rock and excavation.

Typical issues associated with excavation works include slippage, slumping, creation of fissures or cracks, rock or earth falls, exacerbated ground movements, water inflows, cracking the supporting structural elements and in extreme cases structural failure. Excavation works must be undertaken in a manner that minimises the risk of such occurrences.

Sections of temporary shoring installed to support excavations for the development must have a minimum service life of 3 years, if their stability has the potential to affect metro infrastructure. Shoring systems must be designed by an approved design organisation and verified by an independent qualified person. Allowance should be provided for minimum unplanned excavation in accordance with CIRIA C580 Embedded Retaining Walls, Guidance for Design, 2003.

Ground anchors are not allowed within the first reserve zone. Any ground anchors within the second reserve must be assessed for their effect on metro underground infrastructure. Anchors must not be tested in cases where this testing could cause collapse or failure, or both, in the surround soil and rock structure.

Assessment of metro infrastructure from development excavation must also consider the loading that cranes (including their foundation anchorage) will impose within the excavation on metro infrastructure.

Construction near metro underground infrastructure can also impact the local groundwater regime. These impacts have the potential to cause adverse loading of the infrastructure, not contemplated and thus designed for over the design life of the metro. Critically, the watertightness and waterproofing must not be adversely affected or damaged.

The developer must carry out an engineering assessment of the impact of any changes to the groundwater regime that the development could cause. Issues of concern that have the potential to impact on metro infrastructure include the following:

- The development and its construction could create a water barrier that dams groundwater flow above the metro underground infrastructure.
- Groundwater ingress into excavations associated with the development can cause dewatering of the local water table. Importantly, dewatering must not commence without prior approval from TfNSW.

Consequently, the engineering assessment must address any temporary dewatering (at any stage of the development) to demonstrate that effects on underground metro infrastructure are acceptable.

9.3 Noise and vibration

The noise from construction and rail operation must be considered against statutory and project noise vibration limit requirements. TfNSW does not accept liability for the generation of noise and vibration from normal railway operations (including track maintenance), or for its transmission into developments above or adjacent to rail tunnels.

When designing developments above or adjacent to rail tunnels (existing or planned), consideration must be given to operational and construction vibration; as well as ground or structure borne noise emissions in accordance with Developments Near Rail Corridor and Busy Roads – Interim Guideline, Department of Planning, NSW Government 2008.

In planning development construction the following requirements apply.

Any development that occurs within a screening distance of 25 m horizontally from first reserve must consider the vibration on the metro infrastructure with the following assessment criteria of maximum peak particle velocity (PPV):

- 15 mm/s for tunnel and cavern cast insitu concrete linings that are in good condition.
- 20 mm/s at the running tunnels supported using a precast concrete segment lining.

It is important to note that more stringent limits may apply if rail equipment, that is sensitive to vibration, has the potential to be affected by the development and its construction.

During development construction vibration monitoring may be required of the underground metro support, such as concrete linings. This monitoring must be conducted based on the selection of appropriate trigger levels.

If the vibration levels exceed tolerable limits, then the developer must modify the construction methodology in such a way that the vibration limits are satisfied.

9.4 Stray currents and electrolysis

When designing developments above or adjacent to underground metro infrastructure consideration must be given to operational stray currents that may be present. The risk assessment must also consider the potential presence of stray currents.

TfNSW does not accept liability for the generation of stray currents from an operating electrified railway.

The potential effects of stray electrical currents and electrolysis in the electrified area of the metro network must be considered in accordance with T HR CI 12080 ST and T HR EL 12002 GU during the design of the development.

A suitable test program must be established during the early design phase to quantify a stray current signature for the development site prior to undertaking enabling works. Suitable stray current mitigation strategies must be integrated into the design of the development.

Following construction, stray current testing must be carried out to verify that electrolysis mitigation strategies are proven to be effective, which includes undertaking a comparison with the pre-development stray current signature. This information must also be used to establish maintenance baselines for the life of the development.

10. Monitoring

Monitoring provides a means of validating assumptions made to design the development and prove the acceptability of impacts that could affect metro performance.

The structural performance of the metro underground infrastructure must be monitored as necessary during construction of the development to verify predicted displacements, stress levels in structural elements and vibration levels. The monitoring regime must be developed by a qualified tunnel engineering consultant.

Where required, the developer must implement monitoring system that incorporates early warning criteria developed in agreement with TfNSW. The developer's geotechnical consultant must assess the monitoring results continually, and submit monitoring assessment reports to TfNSW for review.

The tables below indicate the circumstances where various types of monitoring are required. These requirements must be provided as a minimum. Figure 10.1 provides typical extents that monitoring must be provided in each case.

Table 10.1 Minimum monitoring requirement for development activities near rail tunnels - In ground

Type of instrument	Deep open excavations	Foundation works- shallow or deep	New underground excavation or new tunnel
Inclinometer	Yes	Yes	Yes
Water standpipe	If required by TfNSW	If required by TfNSW	If required by TfNSW
Piezometer	Yes	Yes	Yes
Extensometer	Yes	If required by TfNSW	Yes
Ground settlement markers	Yes	Yes	Yes
Building settlement markers	Yes	Yes	Yes

Table 10.2 Minimum monitoring requirement for development activities near rail tunnels – within existing rail tunnels

Type of instrument	Deep open excavations	Foundation works- shallow or deep	New underground excavation or new tunnel
Tunnel convergence	Yes	Yes	Yes
Tiltmeter	Yes	If required by TfNSW	Yes
Crack meter	Yes	Yes	Yes
Vibration sensor	Yes	Yes	Yes
Rail track monitoring (distortion)	Yes	If required by TfNSW	Yes
Strain gauges in lining	If required by TfNSW	If required by TfNSW	If required by TfNSW
Pressure cells in lining	If required by TfNSW	If required by TfNSW	If required by TfNSW
Real time monitoring such as EL beams, optical prism laser scanning	If required by TfNSW	If required by TfNSW	If required by TfNSW

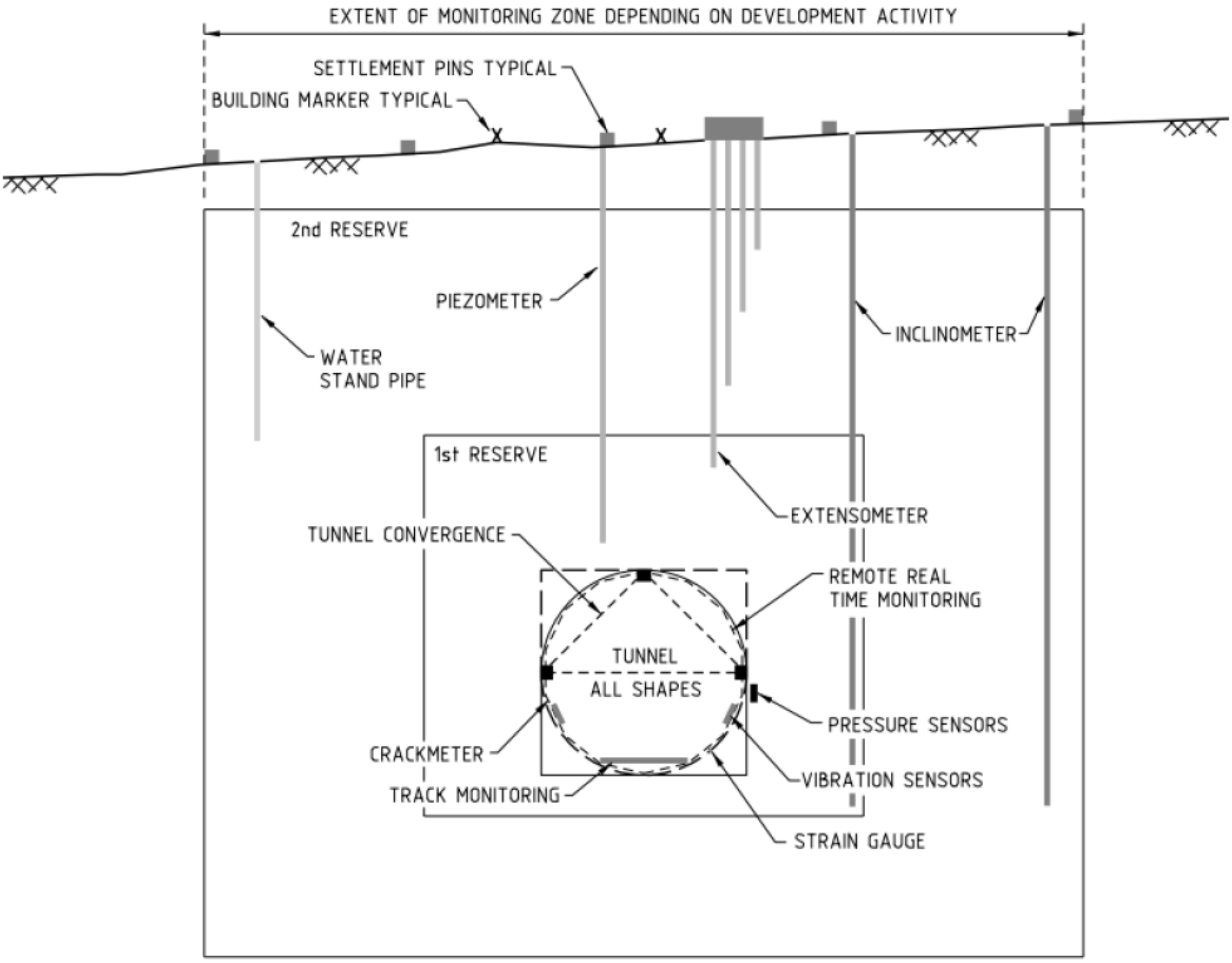

Figure 10.1 Typical instrumentation layout

Baseline data for each monitoring parameter must be established before commencement of development construction. The developer must provide as a minimum, three sets of monitoring data to establish a baseline prior to excavation.

The equipment that is used for remote monitoring (particularly for alarm or warning systems) must have proven reliability in similar applications.

Any alarm or warning system should have a visual and audible alarm system to activate and to stop all works as necessary and notify relevant personnel such as site manager, geotechnical consultant and nominated TfNSW representative.

Depending on the project complexity, physical inspections of existing metro infrastructure may be required on a regular basis during critical stages of construction. If necessary, these inspections should be undertaken jointly with the developer and TfNSW representative (including a representative from the metro operator as necessary).

Monitoring plans must be submitted to TfNSW for review and approval prior to the commencement of development construction. The monitoring plan must include a response regime and contingency plan. These must be agreed with TfNSW before work can commence.

Appendix A

Sydney Metro

Sydney Metro – Northwest

The Sydney Metro Northwest is the first dedicated metro line to be constructed for the metro and extends from Chatswood through to the Northwest. Sydney Metro Northwest incorporates 13 km of track and rail infrastructure between Epping and Chatswood that has been modified and segregated to form part of the Sydney Metro. The following are key features of the Sydney Metro Northwest.

Sydney Metro – Northwest Epping to Cudgegong Road

- 23 km of new track and rail infrastructure delivered through 15.5 km of twin tunnels and 4 km of elevated structure, with the remaining 3 km of rail infrastructure provided at-grade with some sections in cutting.
- Eight new stations are located at Cherrybrook, Castle Hill, Showground (to be known as Hills Showground), Norwest, Bella Vista, Kellyville, Rouse Hill and Cudgegong Road.
- The stations at Castle Hill, Showground and Norwest are contained within cut and cover concrete boxes, whilst stations Cherrybrook and Bella Vista follow an open cut station configuration. Stations at Kellyville and Rouse Hill are elevated. Cudgegong Road station is the only station that is at grade.
- The 15.5 km of twin running tunnels have an internal diameter of approximately 6.2 m and have been excavated predominantly through shale and sandstone using tunnel boring machines (TBMs). The tunnels are supported using a precast concrete segmental lining.
- There are 61 cross passages between running tunnels. These cross passages have been mined and are supported using a permanent cast insitu concrete lining.
- There are services shafts at Epping and Cheltenham area which are cut and cover structures. These shafts are supported using permanent cast insitu concrete lining.
- Other structures includes nozzle enlargement at the ends of stations at Castle Hill, Showground and Northwest. These have been mined and are supported using a permanent cast insitu concrete lining.
- A 159 m long mined crossover cavern is immediately east of Castle Hill Station. The cavern has a span of 21 m wide and has a height that varies from 14 m to 17 m. The cavern is supported by a permanent cast insitu concrete lining.

Sydney Metro – Northwest Epping to Chatswood (Existing ECRL)

- The 13 km length of existing track and rail infrastructure between Epping and Chatswood, which known as Epping to Chatswood Rail Link (ECRL), will be converted to form part of the Sydney Metro System.
- The underground infrastructure of ECRL comprises twin single track tunnels about 7 m in diameter and four underground stations completed in 2008. The depth of rail level varies from about 15 m at the portal to in excess of 60 m in other sections.
- The underground station structures at North Ryde, Macquarie Park and Macquarie University Stations consist of large span platform caverns typically of about 19 m in span and 13 m in height, together with concourse caverns, access tunnels, adits, shaft and associated plant and equipment rooms. The station caverns have been excavated in mainly competent, horizontally bedded sandstone and shales permanently supported using composite linings consisting of rock reinforcement in the form of rock bolts and shotcrete.
- Epping Station comprises two platform caverns connected by cross passages and accessed through escalator tunnels, lift shafts and two large plant room ventilation shafts. This station is located beneath the existing surface station.
- The running tunnels were excavated by rock tunnel boring machines (TBMs) and underground stations and associated structures were excavated using roadheaders, rock hammers and rock saws. The running tunnel support consists of temporary primary support using rock bolts and shotcrete, and final support using unreinforced cast-in-situ concrete lining, nominally 200 mm thick. A section of the running tunnels was lined with shotcrete for construction reasons. The invert of the tunnel consists of precast reinforced segments with a floating track slab.

Sydney Metro – City & Southwest

Sydney Metro City & Southwest will extend the metro rail under Sydney Harbour, through new stations in the lower North Shore, Sydney CBD and south west to Bankstown. This planned metro section will extend the network from Cudgegong Road through to Bankstown. The following are key features of this planned section of the metro system.

Sydney Metro - City

- The city section of the Sydney Metro will consist of underground infrastructure that extends from a dive and portal structure at Chatswood, under North Sydney and Sydney Harbour and then beneath the Sydney CBD to Central and through to Sydenham where the metro will daylight at a portal and dive structure at Marrickville.
- Seven new stations of varying configuration will be constructed at Crows Nest, Victoria Cross, Barangaroo, Martin Place, Pitt Street, Central and Waterloo.
- Twin running tunnels of approximately 14 km in length (portal to portal) will be excavated using TBMs and supported using a precast concrete segmental lining to create a watertight environment. The tunnels will predominantly align through siltstone and sandstone, except below the Sydney Harbour where TBM tunnelling will be required through marine ground sediments for a length of around 170 m.
- A total of 57 mined cross passages will be provided between running tunnels at regular intervals, with a maximum spacing of around 240 m. Of these cross passages eight will contain sumps at low points. The cross passages will be excavated using mechanical methods and supported using a watertight permanent lining, formed using cast insitu concrete. A services shaft will connect with a cross passage at Artarmon. The shaft will also be supported by permanent cast insitu concrete lining.
- Waterloo Station, Central Station, Barangaroo Station and Crows Nest Station will be constructed as cut and cover box structures that contain island platforms. The station will be typically 24 m in width and range from 200 m to 215 m in length. Pitt Street Station and Martin Place Station will have binocular platform caverns that connect with two entrance and services shaft structures, whilst Victoria Cross Station will have a single span cavern with an island platform, which also connects with two entrance and services shaft structures.
- At Martin Place Station and Pitt Street Station the platform caverns will range in length from 193 m to 246 m and have spans of approximately 12 m with an approximate height of 11 m. At the Victoria Cross the platform cavern will be approximately 174 m in length and have a span of 23 m with a height of 13 m. All the caverns and adits will be excavated using mechanical methods and supported using a watertight permanent lining, formed using cast insitu concrete.
- A mined cross over cavern which is 226 m in length will be constructed immediately north of Barangaroo Station. This cavern will have an internal span of 23 m wide and have a height that varies from 14 m to 17 m. The cavern will be supported using a watertight cast insitu concrete lining.
- Mined twin tunnel enlargements that are up to around 17 m in length will be provided to house tunnel ventilation fans at either end of the Victoria Cross Station caverns, the northern end of the rail crossover at Barangaroo, the southern end of Waterloo Station and at the northern end of Crows Nest Station. The nozzle enlargements will be excavated using mechanical methods and supported using a watertight permanent lining, formed using cast in-situ concrete.
- Dive structures and portal structures will be located at Marrickville and Chatswood. A stabling yard will be constructed at the Marrickville portal site.

Sydney Metro – Southwest

- This section of the metro is currently part of the Bankstown Line, but will be converted to form part of the metro system from Sydenham to Bankstown.
- The extension of the metro in the south west will be 13.4 km in length and will require existing rail track and stations to be upgraded.

- Eleven existing stations at Sydenham, Marrickville, Dulwich Hill, Hurlstone Park, Canterbury, Campsie, Belmore, Lakemba, Wiley Park, Punchbowl and Bankstown will be converted to the metro rail system.

Figure A.1 Sydney Metro