Stockland

601 Pacific Highway

Geotechnical Desktop Study Report

279347-ARP-GT-RPT-0001

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Contents

Tables

Figures

Appendices

1 Introduction

Arup has prepared this Geotechnical Desktop Study Report on behalf of Stockland Development Pty Ltd to support a Planning Proposal to amend the statutory planning controls that apply to 601 Pacific Highway, St Leonards (Lot 71 in Deposited Plan 749690) (**the site**) under North Sydney Local Environmental Plan 2013 (**LEP**).

The intended outcome of this Planning Proposal is to amend the LEP planning controls as follows:

- Establish a site-specific building height control, with maximum building height of RL259 metres; &
- Establish a site-specific floor space ratio (**FSR**) control, with a maximum FSR of 20:1.

The Planning Proposal does not amend the site's existing E2 Commercial Centre zoning. Future development aligned with the Planning Proposal is consistent with the permissible land uses and objectives of Zone E2.

The new planning controls seek to unlock the potential of a strategically located landholding within the St Leonards centre and facilitate a new commercial building in a precinct earmarked for density uplift.

This Planning Proposal will deliver strategic planning merits commensurate with State and Local government policy and align with the *St Leonards and Crows Nest 2036 Plan* adopted by NSW Department of Planning, Industry and Environment (**DPIE**) (August 2020). Future development of the site will generate substantial public benefit and make a significant contribution to the evolving character of St Leonards town centre.

2 Purpose

This report presents the results of a geotechnical desktop study undertaken by Arup for the indicative concept design for 601 Pacific Highway, St Leonards, NSW on behalf of Stockland.

The desk study has been prepared to support the preparation of a Planning Proposal for the redevelopment of the site. In particular the study focuses on the vicinity of the Sydney Metro City and South West (C&SW) tunnels to the redevelopment. For the purposes of this report the proposed development has been assumed to include a multi-storey (up to RL259) commercial building overlying a basement extending down to approximately 75mAHD.

Both newly constructed C&SW tunnels are located within the site footprint in an east west direction. The tunnel crown level varies between 61mAHD (eastern site boundary) and 57mAHD (western site boundary) while the invert level varies between 54 and 50mAHD.

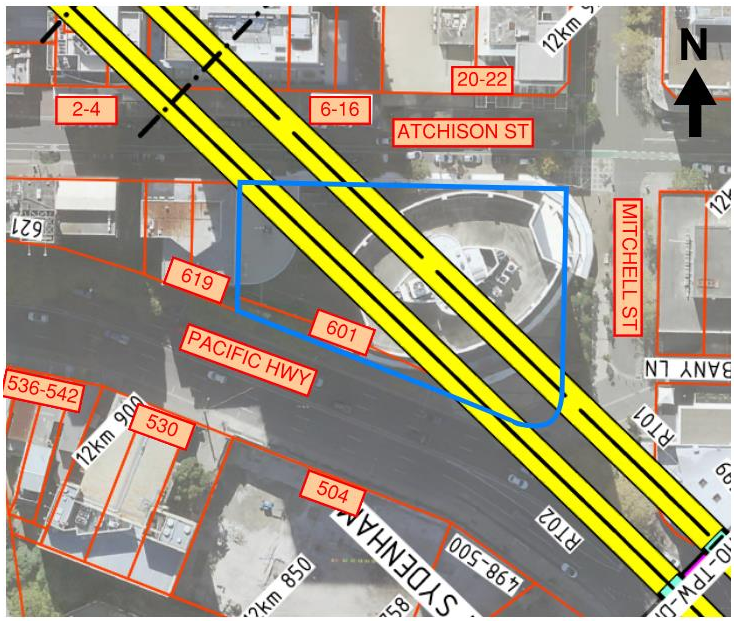

Figure 1: Site location plan including metro tunnel overlay

2.1 Scope of work

The purpose of this report is to collect available information and provide a high-level appraisal of the site and engineering interpretation of it. This includes:

- A description of the site and its setting within the local area and its historical use;
- Geotechnical interpretation of the existing ground information based on publicly accessible and Arup's own project data;
- Description of the underground constraints and reviewing Sydney Metro infrastructure within the site; &
- Summary of the geotechnical risks and opportunities and outlining further work required.

This report considers the requirements of our client. It is not intended for and should not be relied upon by any third party and responsibility is undertaken to any third party.

Information including drawings, reports, and extracts from drawings by others are included and presented in this report have been obtained for the purposes of informing this proposal only and should not be distributed widely.

2.2 Sources of Information

2.2.1 Published Information

A brief literature review of published mappings, imagery and research was completed. The following sources are referenced throughout this report:

- Australian Government Bureau of Meteorology (BoM), the National Groundwater Information System [1];
- Sydney Soil Landscape Map and Report [2], [3];
- CSIRO Atlas of Australian Acid Sulfate Soils [4];
- CSIRO Australian Soil Resource Information System (ASRIS) – Digital Atlas of Australian Soils [5];
- Sydney 1:100k Geological Map and Explanatory Notes [6];
- A search for existing utilities located within or adjacent to the site was undertaken using the Dial Before You Dig website, http://1100.com.au/. [7];
- ESRI (Environmental Systems Research Institute) aerial imagery [8];
- NSW Government, Environmental Protection Authority Contaminated Land Record [9];
- Seamless NSW Geological Map [10];
- NSW Government, Resources & Geosciences MinView Map [11];
- NSW Government Land and Property Information (SIXMaps) [12]; &
- Hewitt and Kitson (2020), Ground response due to deep excavations in Sydney Sandstone [13].

2.2.2 Council Development Applications

The following documents were made public for the purposes of development applications submitted to Lane Cove Municipal Council:

- New Hope Development, 496-520 Pacific Highway – DA 2015/212
    - Aargus, Preliminary Geotechnical Investigation Report - Nos. 500-520 Pacific Highway, St Leonards NSW 2065. Report No. GS5600-2B, dated 28 October 2014. [14]; &
    - Senversa, Preliminary Site Investigation - 95 Nicholson Street and 500 / 504 Pacific Highway, St Leonards, NSW. Dated 18 December 2015. [15]
- 88 Christie Street, St Leonards – DA 6/2018
    - WSP, JQZ Pty Ltd - 88 Christie Street, St Leonards - Geotechnical Report. Rev E, dated 16 January 2018. [16]

3 Site Description

3.1 Site Location

The site is in St Leonards (located approximately 333,100m E, 6,256,000m N GDA MGA 56), and is approximately 5 km north of Sydney CBD. The site is bounded by Atchison Street to the north, Mitchell Street to the east and the Pacific Highway to the south. The site location is shown in Figure 2.

Figure 2: 601 Pacific Highway, St Leonards Site Location (Source: SIXMaps)

3.2 Topography

The topographic contours obtained from SIXMaps NSW Land and Property Information are shown in Figure 3. These contours indicate that the site is moderately sloping from northeast towards the southwest. The relative elevation of the site varies from approximately 92m AHD at the north eastern corner to 87m AHD along the south western boundary.

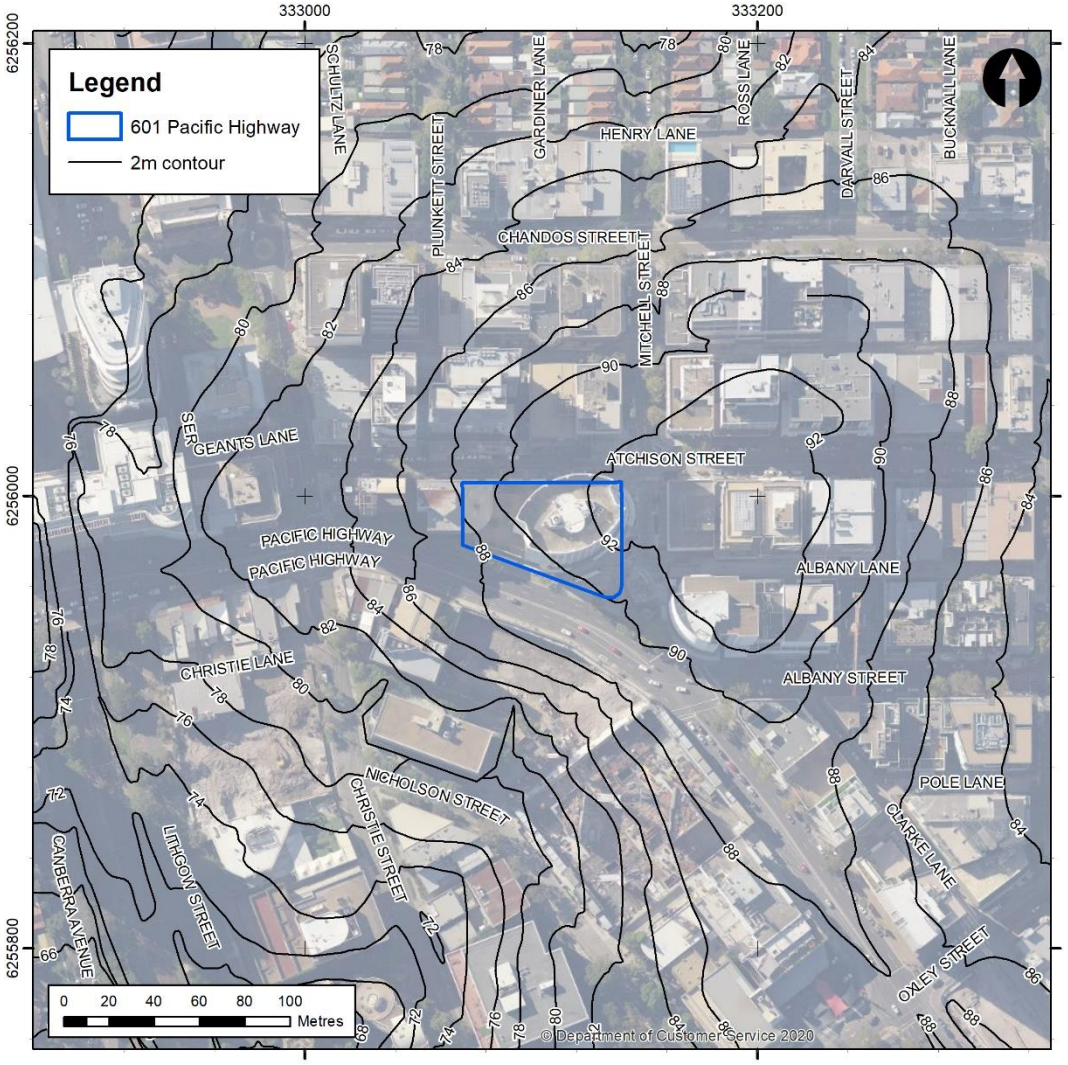

Figure 3: Site Topography (Source: SIXMaps)

3.3 Site History

3.3.1 Historical Developments

A review of the site historical development has been undertaken by reviewing historical imagery. From this, it was concluded that the site was occupied by small residential structures up until 1951 with a multi-storey building being developed between 1951 and 1961. The current building was first captured in imagery from 1991.

3.4 Existing structures

The existing 14-storey commercial building was completed in 1988 and has four basement levels that extend down to approximately 80.0mAHD.

3.5 Utilities

Details of the utilities located within and adjacent to the site were obtained from a Dial Before You Dig (DBYD) search competed on 30 November 2020. A summary of the asset owners contacted through this search and utilities indicated as present or nearby to site is presented in Table 1.

Prior to each round of intrusive works on site, the Contractor should undertake their own searches to ensure zones of excavation are clear of services.

Table 1: Summary of Utilities Asset Owners

Utilities Asset Owner	**Asset Affected**	**Note**
AARNet	No	-
Ausgrid	Yes	Infrastructure supplying site
Jemena	No	Pipes around site
NBN	Yes	Cables connecting site and around perimeter
Nextgen	No	-
North Sydney Council	No	Drainage pit and pipe nearby
Optus	Yes	Optus cables connecting site
RMS	No	-
Sydney Metro	Yes	Tunnels run under site
Sydney Water	Yes	Sewer line connecting site
Telstra	Yes	Cable connecting site
TPG	No	-
Verizon	No	-
Vocus	No	-

4 Ground Conditions

4.1 Published Geology

4.1.1 Soil

Given the variability of the underlying parent rock (Ashfield Shale and Mittagong Formation), the residual soils on the site are likely to vary from silty clays to clayey sands. The 1:100,000 scale soil landscapes map for Sydney indicates that the soil landscape on the site is composed of the Blacktown Group. Nearby boreholes indicate that these soils are typically 1 to 2m thick.

4.1.2 Geology

The 1:100,000 scale Sydney Geological map [6] indicates the site is underlain by Ashfield Shale of the Wianamatta Group. An excerpt of the geological map of the area is presented in Appendix A2. The Ashfield Shale is described as comprising black to dark grey shale and laminite.

4.1.3 Geological Structures

The 1:100,000 scale Sydney Geological map [6] shows no mapped structural features affecting the site.

4.2 National Groundwater Information System

The National Groundwater Information System has been consulted and indicates that there is currently no historic groundwater investigation data available within 100m of this site.

5 Preliminary Ground Model

5.1 Subsurface Profile

Arup previous project data and experience along with the following published information has been used to determine the anticipated subsurface profile:

- Hewitt and Kitson (2020), Ground response due to deep excavations in Sydney Sandstone [13];
- Information made publicly available for nearby Development Applications [14], [16]; &
- Sydney Metro data available at tender and Sydney Metro substratum (accessed through NSW Government Gazette [18]).

A summary of the anticipated subsurface ground profile of the site is provided in Table 2, with an Interpretive Geological Section attached in B2.

Table 2: Anticipated ground profile

Unit	Description	Approximate Thickness (m)
Fill / topsoil	Fill – material type and condition unknown	0.0 – 0.5
Residual soils	Silty clay, medium plasticity	1.5 – 3.0
Rock	Ashfield Shale and Mittagong Formation	2.7 – 15
	Hawkesbury Sandstone	Not penetrated

5.1.1 Residual Soil

Residual soil is observed to be predominantly a silty clay material with a very stiff consistency and medium to high plasticity. The soil is typically grey to light brown in colouration. The depth to the top of residual soil varies between 0.2m to 1.5m below ground level and is underlain by Ashfield Shale or Mittagong Formation geological unit.

5.1.2 Ashfield Shale and Mittagong Formation

The geological map in Appendix A2, indicates the site is underlain by Ashfield Shale and nearby investigation also encountered Mittagong Formation. Nearby investigations indicate significant variation in this thickness, from as little as 2.7m up to 10m thick.

5.1.3 Hawkesbury Sandstone

The top of Hawkesbury Sandstone with laminate layers was typically encountered around 78 m AHD in nearby investigations. The top of Class II sandstone was encountered between 72 and 78 m AHD. Based on the available borehole information and changes in topography the rock quality is expected to vary with depth as summarised in Table 3

Table 3: Rock mass classification summary.

Estimated Sydney Rock Mass Classification[+]	Encountered depth (mbgl)
V-IV	3 – 7
III	7 – 10
II or better	10 – 16
[+]Rock mass Classification as per Pells et al 2019	

5.2 Encountered geological structures

Whilst there are no mapped geological features in the immediate vicinity of the site, a fault zone was encountered in both 88 Christie Street (WSP, BH05 at 66.5 m AHD) and 496-520 Pacific Highway (Aargus, BH3 at 68.0 m AHD). This indicates that there is likely NNE-SSW faulting through the area, which is in keeping with the Sydney geology and inferred faults mapped by Och (2009) [17] in the area.

This indicates that there may be localised stress redistribution and that there is potential for lower quality rock at foundation level which will impact allowable bearing pressures.

5.3 In-situ Stress

It is well recognised that the virgin in-situ stress field in the Sydney Basin comprises high horizontal locked-in tectonic stress [19][21]. Based on this published literature, the major principal stress component at the site is inferred to be oriented N to NE and of magnitude two to five times vertical overburden pressure.

This high horizontal stress state strongly influences the induced ground movements due to excavation and tunnelling works. As a result, an unloading behaviour in the rock-mass surrounding the C&SW infrastructure will occur which may induce stresses in the tunnel lining.

5.4 Hydrogeology and Groundwater

There is likely to be infiltration groundwater above the rock level recharged with following rainfall typical of Sydney within this profile. Further investigation will need to be conducted to confirm the groundwater regime, if any, within the rock profile.

6 Underground Structures

6.1 Existing Foundations and Basement

At the time of writing this report, design drawings for the existing structure were not available for review. However, based on the information reviewed it is understood that the building basement is generally founded at approximately 80mAHD with localised deeper portions of sumps and lift over runs. It is anticipated that the basement is a drained basement and was formed using a cast in-situ soldier bored pile wall with the permanent concrete reinforced walls cast against the bored piles.

6.2 Neighbouring structures

It is noted that a number of multi-storey structures surround the site and are anticipated to have similar sized basements if not deeper. As the redevelopment proposal progresses further, information regarding the depth of neighbouring basements must be investigated and made available for consideration by the design team and other parties.

6.3 Appreciation of C&SW Infrastructure

Arup understands that tunnelling on new 15.5-kilometre twin railway tunnels between Chatswood and Sydenham was commenced in early 2018 and completed in early 2020.

The tunnels were constructed by tunnel boring machines (TBMs) with a cutting face diameter of 7.04 m. The tunnels below the site comprise a 50MPa steel fibre reinforced concrete (SFRC) segmental liners. The tunnel lining was constructed by automated assembly by the TBM train and formed within Hawkesbury Sandstone. The liner has six precast concrete panels in each ring connected with bolts in the circumferential direction and dowels in the longitudinal direction. The assembled ring has an external diameter of 6.69 m, an inner diameter of 6.17m, a thickness of 260mm and a clear opening (inner diameter less tolerances) of 6.0 m as highlighted in Figure 4.

Each panel has a gasket installed around its perimeter. These gaskets are anchored within the concrete during panel construction. The precise gasket efficacy is not known; however, it is considered the tunnel is designed as watertight for full hydrostatic pressure.

The annulus between the liner and surrounding sandstone rock was back-grouted with a 2 MPa strength grout pumped into the annulus at a pressure of 1 atmosphere (~100kPa).

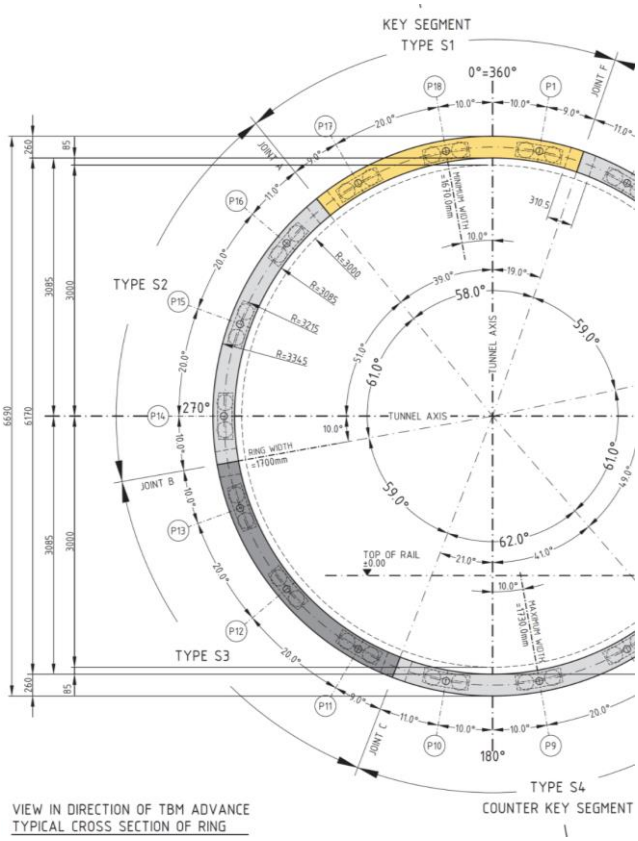

Figure 4: C&SW tunnel dimensions and ring assembly

6.3.1 Sydney Metro Protection Reserves

The SM rail protection reserves are categorised as either the ‘first reserve’ or ‘second reserve’ by the ‘Sydney Metro Underground Corridor Protection - Technical Guidelines’ (Document no. NWRLSRT-PBA-SRT-TU-REP-000008) and are established to protect the tunnel and rail infrastructure during the construction and operation of adjacent developments.

The relevant extents of the first reserve below the development site are governed by the extent of the Sydney Metro substratum. Figure 5 below shows the extents of the protection reserves relative to key development layout elevations. That is: up to 69.15m AHD above the crown (that is a minimum of 9m above the tunnel crown), 5 m distance either side of the tunnel, and approximately 7.5 m distance below the invert of the tunnel. The lateral extents of the first reserve across a plan of the site are also shown on Figure 5. The first reserve represents the area which should not be encroached upon by any future construction or development.

The relevant extents of the second reserve below the site extend: from the tunnel crown up to the ground surface, from the tunnel sidewalls out by 25 m, from the tunnel invert down by 25m. The second reserve represents the area where developments have the potential to impact on the performance of the tunnel support and its operation.

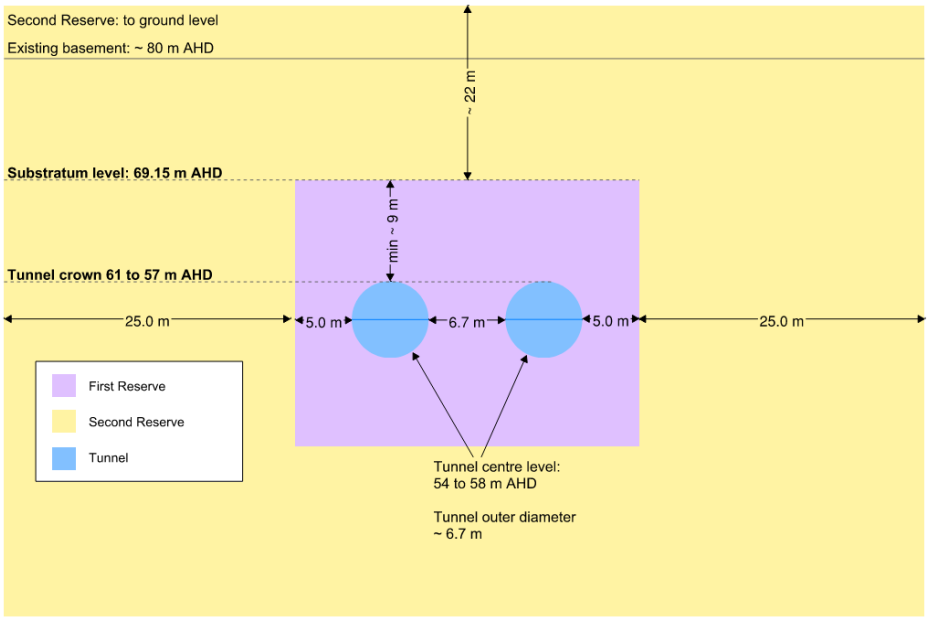

Figure 5: Diagram showing SM protection reserves

6.3.2 Implications for Design

On the basis of the properties of the Hawkesbury Sandstone and the TBM excavation and construction of the C&SW tunnel, it is reasonable to assume the majority of ground movement due to rock stress relief (that results from the tunnelling operation) would have occurred prior to completion of the tunnel lining. However, a significant proportion of the loading on the tunnel lining is expected to manifest as axial compressive stress within the tunnel lining ring (developing a beneficial hoop stress); which enables the section to resist higher bending moments, similar to the effect of post-tensioning.

Complete coupling between C&SW tunnel lining and the surrounding rock is assumed as a result of the back-grouting undertaken as part of the finishing works. As such any ground movements induced by the adjacent development is assumed to be directly applied to the C&SW tunnel lining.

The Sydney Metro Underground Corridor Protection - Technical Guidelines Document no. NWRLSRT-PBA-SRT-TU-REP-000008 provides limits on absolute and differential movement at the tunnel lining of 10mm and 1:2000 respectively.

7 Proposed Redevelopment

The current Planning Proposal includes an indicative concept which proposes a multi-storey office building (up to RL259) over a five storey basement.

Preliminary loading indicates that main column loads could be in the order of 80-90MN.

Deeping of the basement will result in undermining the existing retaining wall and require an additional retaining wall to be installed through the shales.

8 Geotechnical Considerations and Risks

8.1 Site Constraints

The following site constraints have been identified at the site:

- Substratum level [18] – from RL 69.15 m AHD for most of the site with the substratum starting at 67.15 m AHD in the northwest portion of the site. The substratum extends down to 45.95 and 43.95 m AHD in these areas respectively;
- Metro tunnel – tunnel crown varies from 57 to 61m AHD across the site;
- Neighbouring developments and associated basements surrounding the site; &
- Unknown depth to the transition between the shales and the sandstone rock.

The proposed redevelopment will need to limit ground movements and loading to tolerable levels such that existing structures are not adversely impacted. Sydney Metro requirements are quite onerous in order to maintain water tightness and limit the potential of induced cracking in the liner.

8.2 Ground movements

For the proposed development, ground movement is anticipated to occur during the following stages of construction:

- Demolition of the existing structure and deepening of the basement;
- Construction of the proposed development; &
- Operation of the building.

During demolition and excavation, ground movement will occur due to unloading of the foundations and vibration during removal of the existing building and footings. Retention systems will need to be designed to support the existing retaining walls that support soil and fractured rock. New retention system must also support the fracture rock and/or shale below the existing basement level till better quality rock or sandstone is encountered and can be excavated vertically without support.

During construction and operation, the new footing loads will be greater than that previously applied. Depending on the depth of the proposed excavation and therefore the loading above C&SW tunnels the following measures may be utilised to reduce the impacts onto the tunnels:

- Construct large pad footings to spread the loads over a larger area reducing the pressure at certain locations (preferred methodology);
- Construct sleeved piles so that the load is transferred below the C&SW;

- Construct load transfer beams or cantilevered structures.

Due to the proximity of the C&SW tunnels further detailed numerical analysis will be required to assess the load influences, resulting ground movements/stresses, and additional support requirements for the development.

However, for the purposes of the planning proposal, maintaining a minimum of 10m offset from the C&SW tunnel crown is recommended to minimise the impact to the tunnels due to unloading of the existing structure and excavation. Further, at this offset pad footings can be adopted as the impact to the tunnels would be minimal.

8.2.1 Demolition and excavation induced movements

As discussed above the demolition and additional excavation will induce ground movements due to lateral support.

Ground movements will need to be limited due to the presence of near-by structures and roads. It is anticipated that the existing perimeter walls may be retained and supported by bracing and/or ground anchors.

The excavation directly below the existing basement will expose shale bedrock. Due to the potential for increased fractures, an additional retention system will be required.

As the rock improves and transitions into Class III or better sandstone, the excavation can be cut vertically unsupported. Additional movement will occur due to the relief of in situ locked in horizontal stress.

The influence of stress redistribution on the neighbouring structures should be assessed during the detailed design process.

8.3 Foundations

The proposed redevelopment is anticipated to have relatively high column loads and the intended foundation methodology is high level pad footings founded on a minimum of Class III [19] or better sandstone. Based on the available subsurface conditions it is anticipated that the bulk excavation level may encounter the transition between laminites in the Mittagong formation and the Hawkesbury sandstone. This may expose localised poorer quality rock, requiring deepening of foundations to a suitable foundation material, with the minimum 10m offset to the C&SW tunnels maintained.

However, should the bulk excavation not penetrate the Mittagong formation, lightly loaded columns maybe supported on shallow footings within the Mittagong Formation, with bearing capacity varying between 1MPa to 3.5MPa allowable bearing pressure depending on the quality of the rock exposed. For higher column loads, piles/pile groups may be used to penetrate into the underlying sandstone to achieve higher bearing capacity while maintaining a minimum 7.5m offset from the C&SW tunnels.

Preliminary design of shallow foundations and piles may be designed in accordance to the following design parameters.

Table 4 Preliminary foundation design parameters

Sandstone Class [19]	Allowable bearing pressure (MPa)	Ultimate shaft resistance (kPa) compression	Design Young's Modulus
V	1	250	100
IV	3.5	500	400
III	6	1000	1000
II	10	2500	2000

Settlement of footings designed using the serviceability maximum allowable end bearing pressures provided should result in less than 1% of the least footing dimension.

8.4 Further Works

Based on the conclusions and risks identified in this report, the following further investigative work is recommended to aid the design development.

8.4.1 Ground investigation

Further geotechnical investigations are required to access the geohazards and geotechnical uncertainty to inform design development, approvals, detailed design, and excavation. More specifically, the following ground investigation are suggested to be undertaken to confirm the following site condition:

- Borehole drilling – to understand the rock quality at depth to inform foundation and basement structure design;
- Inclined borehole drilling to target potential faulting on site;
- Downhole imaging for defect orientation;
- Groundwater monitoring wells and hydrological testing – to understand the groundwater level, flow and flow direction to inform design for foundations, basement, and excavation;
- Water durability testing – for structure durability design. Groundwater chemistry can be undertaken at the same time to understand the need for any site treatment prior to discharge and to aid applications for discharge licence;
- Basement investigation – cored holes through existing basement perimeter walls to determine suitability for use as temporary retention and potential reuse for permanent retention.

8.4.2 Numerical analyses

Numerical analyses will be required to provide guidance on potential impact of the proposed redevelopment over the existing C&SW tunnels. The change in stress condition and anticipated ground movements (refer Section 8.2) caused by unloading from excavation and reloading during construction must be quantified during design.

8.4.3 Surveys

8.4.3.1 Adjacent and on-site structures

Existing basements on site and adjacent to the works to be surveyed to confirm inside line of wall to allow for basement space proofing/planning and retention design.

Condition surveys may also be required for these structures depending on their re-use strategy as temporary or permanent.

8.4.3.2 Dilapidation survey of C&SW tunnels

Prior to the commencement of works, a dilapidation survey will need to be completed to establish a record of existing conditions within the C&SW tunnels as agreed with Sydney Metro.

8.4.3.3 Location, construction details and condition of existing utilities, adjacent structures

A DBYD assessment of existing utilities has been completed as part of this desk study. This survey must be updated prior to any works on site. Due to the critical nature of some of the utilities in the project vicinity, survey locators will be required prior to the commencement of works.

8.4.4 Preparation of monitoring programs

Construction around existing rail tunnels will require an extensive instrumentation and monitoring plan to be implemented during the works. Monitoring program requirements are highlighted in Sydney Metro Underground Corridor Protection - Technical Guidelines' (Document no. NWRLSRT-PBA-SRT-TU-REP-000008)

8.4.5 Continued involvement of Sydney Metro and TfNSW

The proposed development will impact current SM and TfNSW assets, and therefore approval from these authorities will be required for the development to proceed. This should be flagged as a known approvals and technical risk to the project. Their continued involvement and acceptance during the investigation, design, monitoring, and construction process should be prioritized at all stages to mitigate and minimise disruption and abortive works.

8.4.6 Other Third-Party Assets

Assets belonging to other Third Parties (including utilities) could be impacted by the development. Details of these assets should be confirmed and surveyed during the design development stage to inform the impact assessment and design for the proposal. These impacts and an appropriate monitoring regime will need to be agreed with the asset owners.

9 Conclusion

This Geotechnical desktop Study Report assesses the structural feasibility of the indicative concept design scheme prepared by Architectus to inform the Planning Proposal. The studies undertaken and outcomes described in this report demonstrate that the site is capable of accommodating future development aligned with the proposed planning control changes, including compliance with the appropriate Sydney Metro corridor protection guidelines, the National Construction Code, and relevant Australian Standards.

A comprehensive assessment of the structural impacts associated with a detailed development proposal will be required as part of a future development application for the site.

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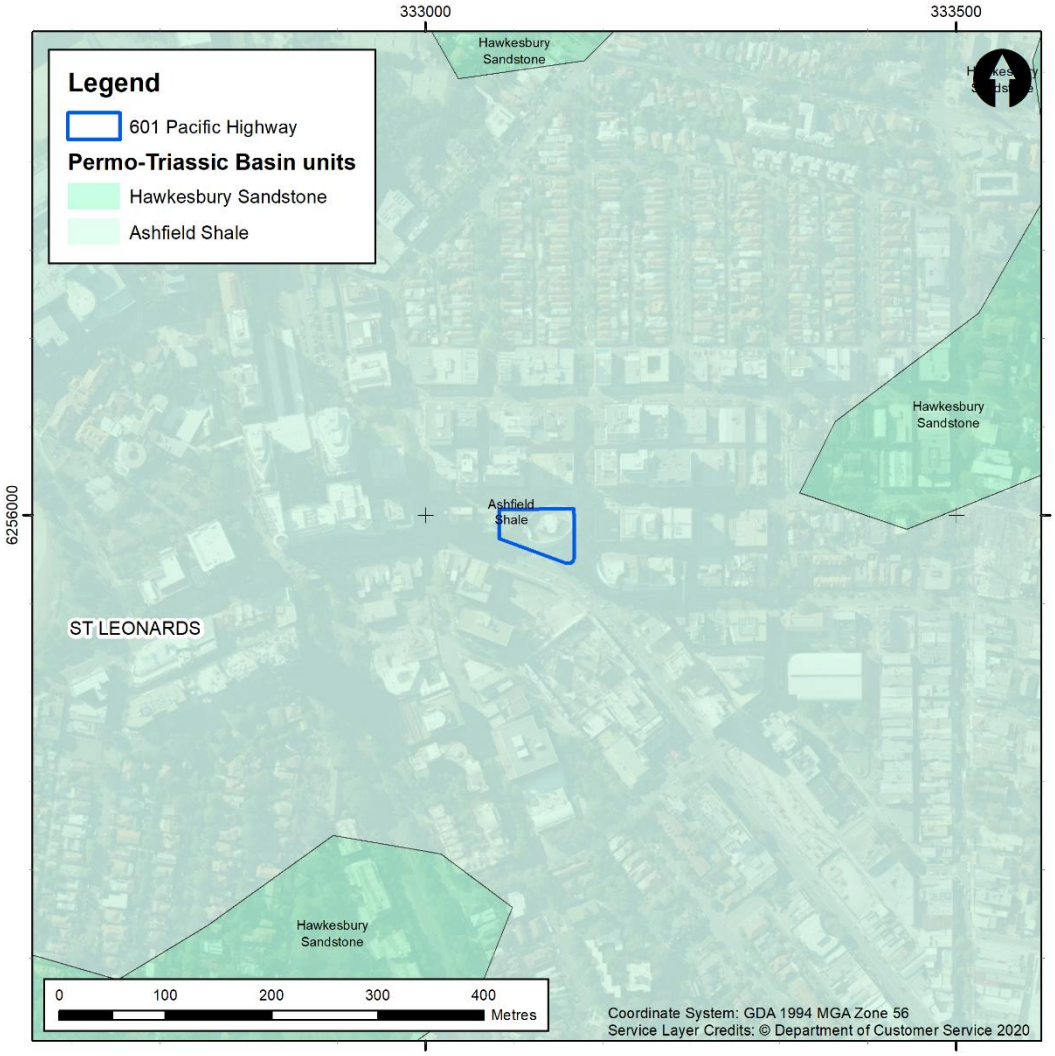
Appendix A

Soil and Geology Maps

A1 Soil landscape map

A2 Surface Geology Map

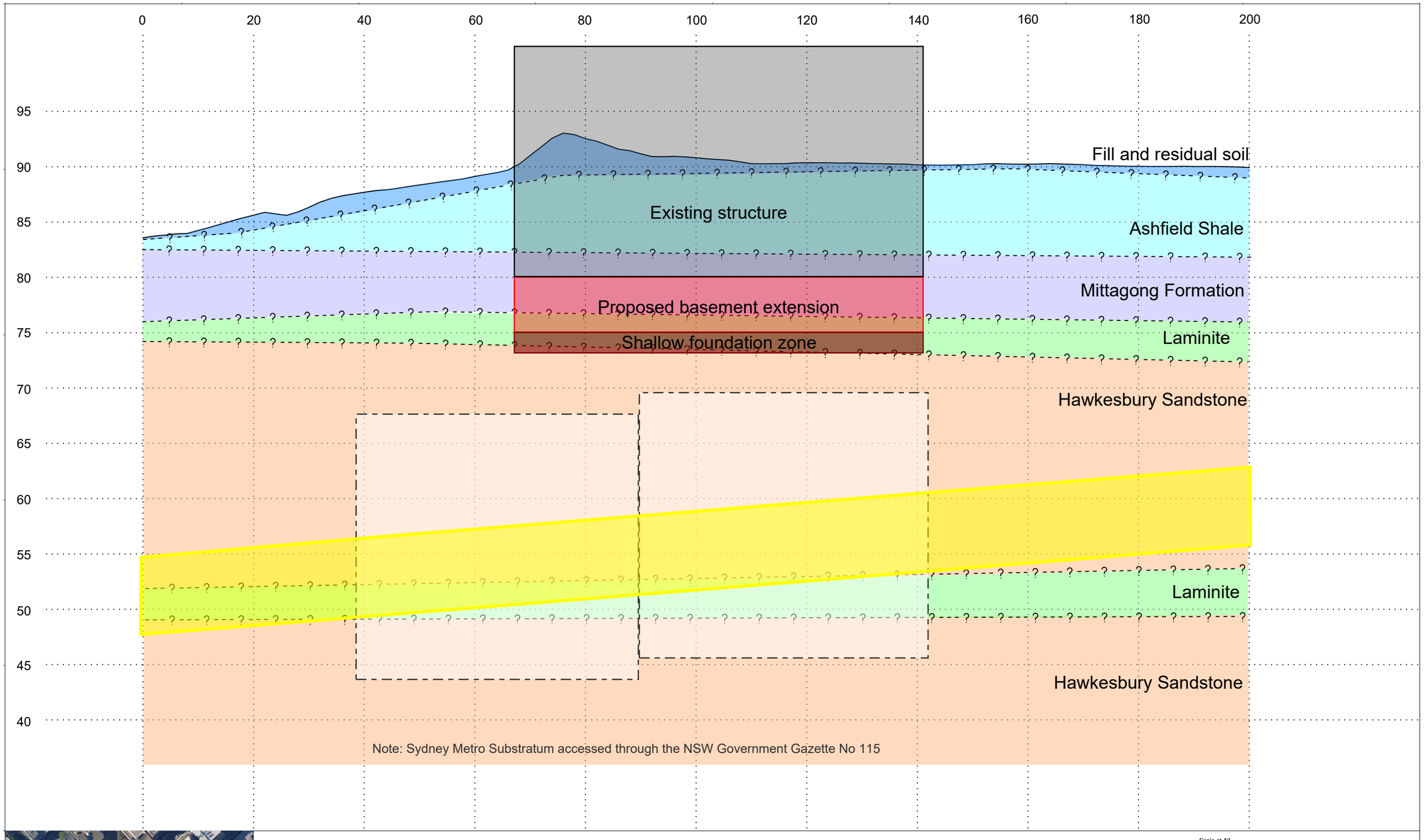


Appendix B

Site geotechnical data

B1 Existing Geotechnical Investigation Plan (Boreholes only)

B2 Interpretive Geological Section



Existing structure

Proposed basement extension

Metro alignment

Metro substratum

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Project Title
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Client
Stockland

Drawing Title
Desktop Study
Interpretive Geological Section

Scale at A3
2x vertical exaggeration

Arup Job No
279347

Rev
DRAFT

Rev	Date	By	Chkd	Appd
DRAFT	11/12/20	LF	AC	

Do not scale