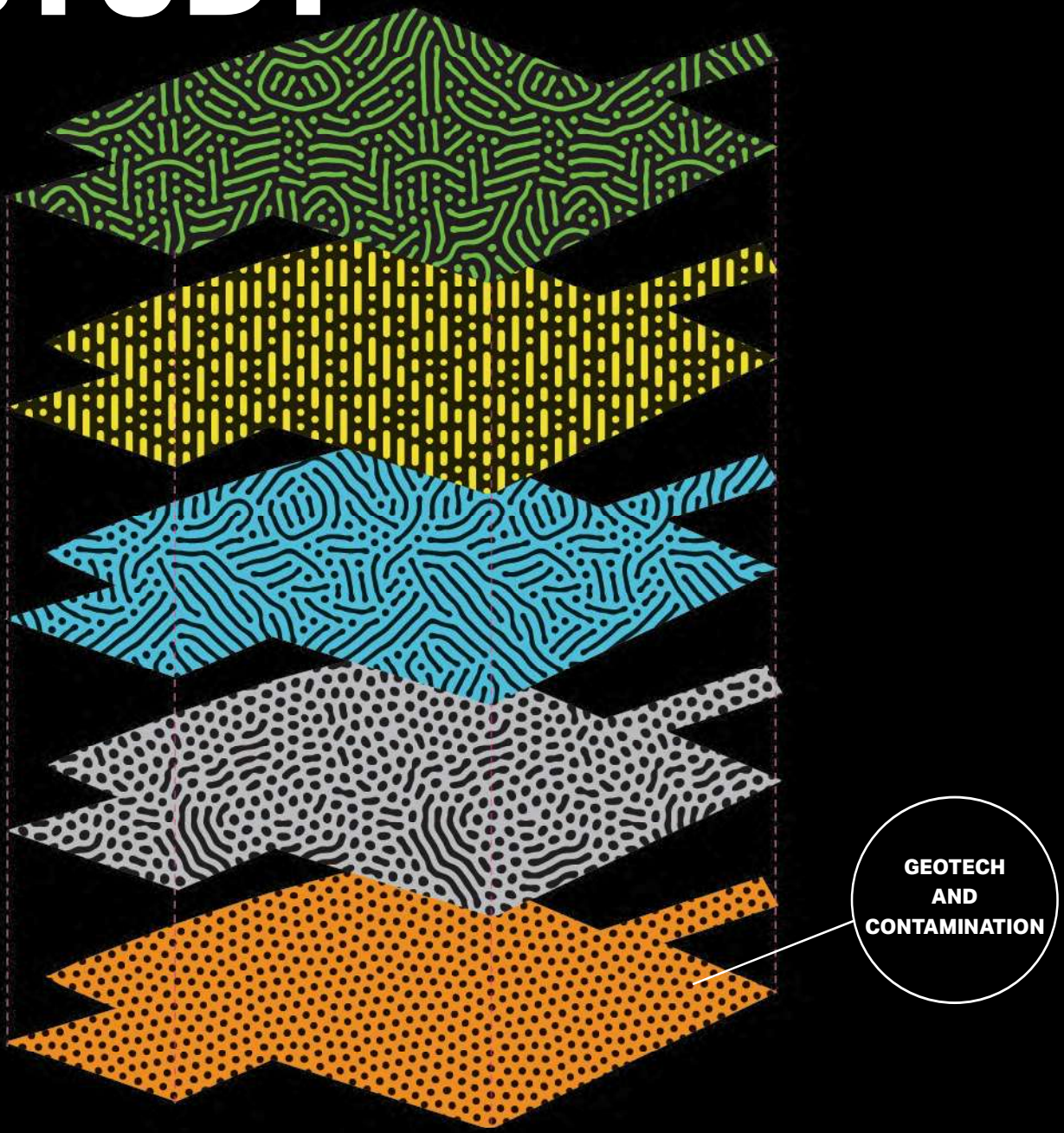
Attachment B28(a)

Geotechnical and Contamination Study – Waterloo Estate (South) – Land and Housing Corporation

WATERLOO SOUTH

GEOTECH AND CONTAMINATION STUDY



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Abbreviations

ACM	Asbestos Containing Materials
AHD	Australian Height Datum
ARR	Average Risk Rating
ASC	Assessment of Site Contamination
ASS	Acid Sulfate Soils
ASSMP	Acid Sulfate Soils Management Plan
BTEX	Benzene, Toluene, Ethylbenzene and Xylene
CEMP	Construction and Environment Management Plan
CFA	Continuous Flight Auger
CGIs	Computer Generated Images
CLM	Contaminated Land Management
CoPC	Contaminants of Potential Concern
CoS	City of Sydney
CSM	Conceptual Site Model
DA	Development Application
DCP	Development Control Plan
DLPMA	Department of Land and Property Management Authority
DQO	Data Quality Objective
EPA	Environmental Protection Authority
FSR	Floor Space Ratio
GFA	Gross Floor Area
HASP	Health and Safety Plan
ISD	Integrated Station Development
LAHC	Land and Housing Corporation
LEP	Local Environment Plan
LGA	Local Government Area
MMP	Materials Management Plan
NEPM	National Environment Protection Measure
OCP	Organochlorine Pesticides
OEH	Office of Environment and Heritage
OPP	Organophosphorus Pesticides
OSD	Over Station Development
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyls
PoEO Act	Protection of Environment Operations Act
QhD	Quaternary Alluvium
RAP	Remediation Action Plan
RMS	Roads and Maritime Services
SAQP	Sampling, Analysis & Quality Plan
SEPP	State Environment Protection Policy
SSP	State Significant Precinct
TRH	Total Recoverable Hydrocarbons
UCS	Uniaxial Compressive Strength
ULS	Ultimate Limit State
LaHC	NSW Land and Housing Corporation
UXO	Unexploded Ordnance
VOC	Volatile Organic Compounds
WSUD	Water Sensitive Urban Design

Executive Summary

AECOM Australia Pty Ltd (AECOM) was engaged by NSW Land and Housing Corporation (LAHC) to undertake a Geotechnical Assessment and a Stage 1 Preliminary Site Investigation (Stage 1 PSI) of the Waterloo Housing Estate, Waterloo, New South Wales (hereafter referred to as the Estate). The Estate will be redeveloped to provide a vibrant mixed-use precinct consisting of residential, non-residential, community facilities, and retail uses with the adjacent Waterloo metro station.

AECOM understands that the Metro Quarter (encompassing 1.9 hectares) and the Estate (encompassing 18 hectares) will form the proposed Waterloo Precinct; however, this report is focused on the Waterloo South planning proposal. While it provides comprehensive baseline investigations for Waterloo Estate, it only assesses the proposed planning framework amendments and Indicative Concept Proposal for Waterloo South.

The overarching objective of the report is to address the requirements outlined in Section 21 (Geotechnical and Contamination) of the State Significant Precinct (SSP) Study Requirements to evaluate the suitability of the proposed land uses at the Estate. To achieve this overarching objective, the following specific objectives were undertaken:

- Review of existing geotechnical and contamination data points and results;
- Analysis of geotechnical risks;
- Identify whether potential contamination issues may be associated with the Estate;
- Evaluate whether potential contamination issues are likely to preclude the Estate from being suitable for the proposed redevelopment; and
- Make recommendations to assist in making the Estate suitable for the proposed land use, which will inform the proposed redevelopment.

To achieve the objectives, the following works were undertaken:

- Analysis of surrounding borehole information;
- Study of desktop geotechnical information (including geological sheets);
- Review of NSW Environment Protection Authority (EPA) records, historical aerial photographs, land ownership details, published maps and other records;
- Development of a conceptual site model (CSM) to identify potential sources of contamination, human health and environmental receptors and pathways in which these receptors may be exposed to the identified contamination;
- Estate inspection observations; and
- Risk ranking of the potential pollutant linkages to illustrate the relative risk of each pathway to current and future human health and environmental receptors.

Key findings of this report include:

- The study area is underlain by Quaternary Sediments (Qhd), described as medium to fine grained “marine” sand with podsols;
- The underlying bedrock is either Ashfield Shale underlain by Mittagong Formation and/or Hawkesbury Sandstone;
- The top of bedrock at the site ranges from about RL+9.5 m AHD in the north to about RL +6.5 m AHD in the south;
- The historical presence of nearby commercial and light industrial properties adjacent to the Estate, including car repair centres (J&S Smash Repairs), car servicing and mechanical repairs (All Mechanic Repairs and Waterloo Automotive), panel beaters and/or spray painters, cleaning product manufacturers, printer machinery and supplies, sheet metal workers, woodworking machinery and battery manufacturers;
- Presence of dry cleaning facilities including Waterloo Laundry;
- Presence of service station including former Total Service Station;
- Use of fill material of unknown origin that could potentially contain or be impacted with contaminants;

- Historical use of asbestos containing materials (ACM) within buildings and structures erected since the 1920s; and
- Historical use of lead based paints on the interior and exterior of historical and current buildings.

Potential sources of contamination identified during the Stage 1 PSI which may impact the condition of soil and groundwater within the Estate and its surrounds include the following:

- Use of fill material of unknown origin that could potentially contain or be impacted with contaminants;
- Historical use of asbestos containing materials (ACM) within buildings and structures erected since the 1920s;
- Historical use of lead based paints on the interior and exterior of historical and current buildings;
- Surrounding areas of former and current buildings erected since the 1920s which are likely have been constructed using potentially contaminating or hazardous materials including asbestos and lead based paints (primarily located to the northeast and east of the Estate);
- Light industrial and commercial properties surrounding the Estate including dry cleaning facilities, service stations, car repair centres, furniture manufacturers and cleaning product manufacturers; and
- Groundwater in the vicinity of the Estate that may be contaminated from the historical surrounding commercial and industrial land uses in surrounding areas. It is noted that the Estate footprint is located within the Botany Sands Beds aquifer which has been contaminated as a result of historical industrial land use activities.

Only where the following three pollutant linkages are present, a high risk to human health and/or the environment will be expected and will include cost implications from management or remediation. These linkages have been identified during the Stage 1 PSI and will be subject to further Stage 2 investigations.

- The historical and current commercial/light industrial activities undertaken in proximity to the Estate may have resulted in contaminants of potential concern (CoPC) being released into the environment. Although it is understood that the redeveloped Estate is likely to be capped with limited access to soil, future sub-slab intrusive works may be required for service maintenance purposes. As such, there is a potential for workers to come into direct contact (i.e. incidental ingestion and/or dermal contact) with and/or inhale CoPC in soil/dust. It is assumed that groundwater will not enter a service trench excavation as it is unlikely to be encountered within the Estate at depths shallower than 1 m below ground surface. Additionally, a number of CoPC are considered to be volatile e.g. light-end total recoverable hydrocarbons (TRH) fractions, benzene, toluene, ethylbenzene and xylenes (BTEX) and volatile organic compounds (VOCs). Therefore, future residents, commercial workers or construction/intrusive maintenance workers may be exposed to volatile CoPC via inhalation;
- Since 1930, a number of buildings within the Estate have been demolished and erected potentially depositing CoPC such as asbestos containing materials (ACM) and lead onto the soil. Therefore, there is a potential for intrusive maintenance workers to come into direct contact (i.e. incidental ingestion and/or dermal contact) with and/or inhale asbestos and lead in soil/dust; and
- Although specific areas could not be identified where fill material may have been used it is likely to be present across given the level nature the Estate. Imported fill material of unknown origin can contain a range of CoPC. Therefore, there is a potential for intrusive maintenance workers to come into direct contact (i.e. incidental ingestion and/or dermal contact) with and/or inhale CoPC in soil/dust. Additionally, future residents, commercial workers or construction/intrusive maintenance workers may be exposed to volatile CoPC via inhalation if not managed or remediated appropriately.

Based on the findings of this report AECOM recommends the following:

- Geotechnical: We recommend an allowance for up to 15 cored boreholes to 20 m depth and five standpipe piezometers in five of these boreholes to allow for groundwater monitoring. If site-specific information can be relied upon and is of a suitable scale and distribution then geotechnical investigations may not need to be as extensive;
- Contamination: Completion of a stage 2 contamination assessment to characterise the nature and extent of potential soil and groundwater contamination, targeting the potential areas of concern identified within the Study Area. Soil and groundwater samples should be analysed for the identified CoPCs listed in and assessed in accordance with the National Environment Protection (Assessment of Site Contamination) Measure 1999 (ASC NEPM, 2013). The cost of the initial Stage 2 Contamination Assessment would be informed by the proposed development plans for the Study Area and existing access constraints.

Based on the findings of the Stage 1 PSI and CSM developed for the Estate, AECOM recommends undertaking the following additional stages of work to ensure the SSP study requirements are being fulfilled. It is noted that the additional work scope would be undertaken during the detailed development application stage:

- A Stage 2 contamination assessment to characterise the nature and extent of potential soil and groundwater contamination identified within the Estate to confirm that the Estate is either suitable in its current condition or can be made suitable following remediation for the proposed land use and zoning in accordance with clause 6(1)(b) of SEPP 55;
- In accordance with clause 6(1)(c) of SEPP 55, remediation and/or management of impacted areas may be required to mitigate risks associated with the identified impacts during the proposed construction works;
- Development of a Construction and Environment Management Plan (CEMP) to manage risks to construction and maintenance workers from erosion, impacted soils and groundwater during the redevelopment of the Estate; and
- Development of a Materials Management Plan (MMP) to include a strategy for the management of materials so that impacted material can be reused in less sensitive areas or managed within the Estate to manage erosion, salinity (if encountered) and mitigate off-site disposal of excavated material.
- In the event that potential or actual acid sulfate soil is identified, preparation of an acid sulfate soils management plan (ASSMP) to manage material that may require disturbance and/or movement.

Based on the investigations undertaken, the ground conditions and likely contaminants encountered can be suitably managed during the DA phase and therefore the site is fit for its intended use. The SSP Study Requirements outlined in Section 21 have been wholly satisfied, with appropriate future investigations recommended for further development applications relating to detailed design.

1.0 Introduction

The Greater Sydney Region Plan and Eastern City District Plan seek to align growth with infrastructure, including transport, social and green infrastructure. With the catalyst of Waterloo Metro Station, there is an opportunity to deliver urban renewal to Waterloo Estate that will create great spaces and places for people to live, work and visit.

The proposed rezoning of Waterloo Estate is to be staged over the next 20 years to enable a coordinated renewal approach that minimises disruption for existing tenants and allows for the up-front delivery of key public domain elements such as public open space. Aligned to this staged approach, Waterloo Estate comprises three separate, but adjoining and inter-related stages:

- Waterloo South;
- Waterloo Central; and
- Waterloo North.

Waterloo South has been identified as the first stage for renewal. The lower number and density social housing dwellings spread over a relatively large area, makes Waterloo South ideal as a first sub-precinct, as new housing can be provided with the least disruption for existing tenants and early delivery of key public domain elements, such as public open space.

A planning proposal for Waterloo South is being led by NSW Land and Housing Corporation (LAHC). This will set out the strategic justification for the proposal and provide an assessment of the relevant strategic plans, state environmental planning policies, ministerial directions and the environmental, social and economic impacts of the proposed amendment. The outcome of this planning proposal will be a revised planning framework that will enable future development applications for the redevelopment of Waterloo South. The proposed planning framework that is subject of this planning proposal, includes:

- **Amendments to the Sydney Local Environmental Plan 2012** – This will include amendments to the zoning and development standards (i.e. maximum building heights and floor space ratio) applied to Waterloo South. Precinct-specific local provisions may also be included.
- **A Development Control Plan (DCP)** – This will be a new part inserted into 'Section 5: Specific Areas' of the Sydney DCP 2012 and include detailed controls to inform future development of Waterloo South.
- **An infrastructure framework** – in depth needs analysis of the infrastructure required to service the needs of the future community including open space, community facilities and servicing infrastructure.

1.1 The Precinct

Waterloo Estate

Waterloo Estate is located approximately 3.3km south-south-west of the Sydney CBD in the suburb of Waterloo (refer to **Figure 1**). It is located entirely within the City of Sydney local government area (LGA). Waterloo Estate is situated approximately 0.6km from Redfern train station and 0.5km from Australia Technology Park. The precinct adjoins the new Waterloo Metro Station, scheduled to open in 2024. The Waterloo Metro Quarter adjoins Waterloo Estate and includes the station and over station development and was rezoned in 2019. Waterloo Estate comprises land bounded by Cope, Phillip, Pitt and McEvoy Street, including an additional area bounded by Wellington, Gibson, Kellick and Pitt Streets. It has an approximate gross site area of 18.98 hectares (14.4 hectares excluding roads). Waterloo Estate currently comprises 2,012 social housing dwellings owned by LAHC, 125 private dwellings, a small group of shops and community uses on the corner of Wellington and George Streets, and commercial properties on the south-east corner of Cope and Wellington Streets.

A map of Waterloo Estate and relevant boundaries is illustrated in **Figure 2**.

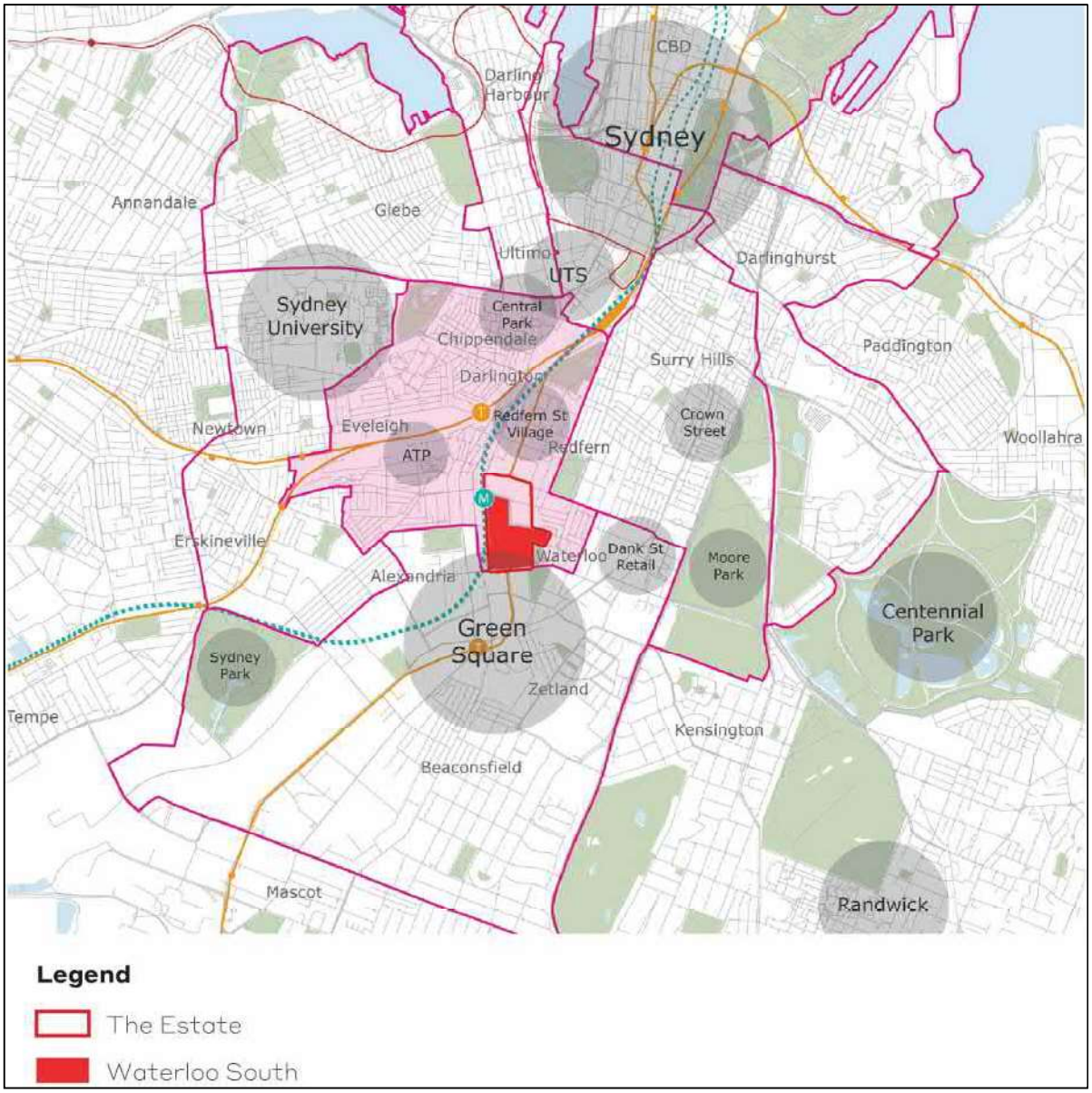


Figure 1 | Location Plan of Waterloo Estate and Waterloo South

Source: Turner Studio

Waterloo South

Waterloo South includes land bounded by Cope, Raglan, George, Wellington, Gibson, Kellick, Pitt and McEvoy Streets, and has an approximate gross site area of 12.32 hectares (approximately 65% of the total Estate).

Waterloo South currently comprises 749 social housing dwellings owned by LAHC, 125 private dwellings, and commercial properties on the south-east corner of Cope and Wellington Streets. Existing social housing within Waterloo South is predominantly walk up flat buildings constructed in the 1950s and '60s, and mid-rise residential flat buildings (Drysdale, Dobell & 76 Wellington Street) constructed in the 1980s. Listed Heritage Items within Waterloo South include the Duke of Wellington Hotel, Electricity Substation 174 on the corner of George and McEvoy Streets, the terrace houses at 229-231 Cope Street and the Former Waterloo Pre-School at 225-227 Cope Street. The State Heritage listed 'Potts Hill to Waterloo Pressure Tunnel and Shafts' passes underneath the precinct.

A map of Waterloo South and relevant boundaries is illustrated in **Figure 2**.

Figure 2 | Waterloo Precinct

Source: Ethos Urban

1.2 Redevelopment Vision

The transition of Waterloo Estate will occur over a 20-year timeframe, replacing and providing fit for purpose social (affordable rental) housing as well as private housing to create a new integrated and inclusive mixed-tenure community.

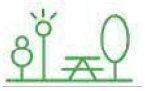
This aligns with Future Directions for Social Housing in NSW – the NSW Government's vision for social housing. It also aligns with LAHC's Communities Plus program, which is tasked with achieving three key objectives:

1. Provide more social housing
2. Provide a better social housing experience
3. Provide more opportunities and support for social housing tenants

The following is LAHC's Redevelopment Vision for Waterloo Estate, which was derived from extensive consultation and technical studies:

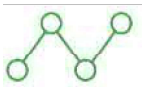
Culture and Heritage

- Recognise and celebrate the significance of Waterloo's Aboriginal history and heritage across the built and natural environments.
- Make Waterloo an affordable place for more Aboriginal people to live and work.
- Foster connection to culture by supporting authentic storytelling and recognition of artistic, cultural and sporting achievements.



Communal and Open Space

- Create high quality, accessible and safe open spaces that connect people to nature and cater to different needs, purposes and age groups.
- Create open spaces that bring people together and contribute to community cohesion and wellbeing.



Movement and Connectivity

- Make public transport, walking and cycling the preferred choice with accessible, reliable and safe connections and amenities.
- Make Waterloo a desired destination with the new Waterloo Station at the heart of the Precinct's transport network – serving as the gateway to a welcoming, safe and active community.

Character of Waterloo

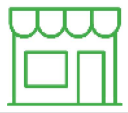
- Strengthen the diversity, inclusiveness and community spirit of Waterloo.
- Reflect the current character of Waterloo in the new built environment by mixing old and new.

Local Employment Opportunities

- Encourage a broad mix of businesses and social enterprise in the area that provides choice for residents and creates local job opportunities.

Community Services, Including Support for Those Who Are Vulnerable

- Ensure that social and human services support an increased population and meet the diverse needs of the community, including the most vulnerable residents.
- Provide flexible communal spaces to support cultural events, festivals and activities that strengthen community spirit.



Accessible Services

- Deliver improved and affordable services that support the everyday needs of the community, such as health and wellbeing, grocery and retail options.

Design Excellence

- Ensure architectural design excellence so that buildings and surrounds reflect community diversity, are environmentally sustainable & people friendly – contributing to lively, attractive and safe neighbourhoods.
- Recognise and celebrate Waterloo's history and culture in the built environment through artistic and creative expression.
- Create an integrated, inclusive community where existing residents and newcomers feel welcome, through a thoughtfully designed mix of private, social (affordable rental) housing.

1.3 Purpose

This report relates to the Waterloo South planning proposal. While it provides comprehensive baseline investigations for Waterloo Estate, it only assesses the proposed planning framework amendments and Indicative Concept Proposal for Waterloo South.

The key matters addressed as part of this study, include:

- Ground conditions assessment;
- Contamination assessment of soil and groundwater; and
- Site specific management plans.

2. Study Requirements

On 19 May 2017 the Minister issued Study Requirements for the nominated Precinct. Of relevance to this study are the following requirements. While this project is going through a different planning pathway, the overall SSP study requirements are still relevant and addressed below in **Table 1**:

Table 1 | Study Requirement Reponses

Waterloo Housing Estate Requirements	Geotechnical and Contamination Responses
21. Geotechnical and Contamination	
21.1. Provide an assessment of the local soil, outlining its suitability for the proposed uses with respect to erosion, salinity and acid sulphate soils.	An assessment of the local soil conditions specifically addressing erosion, salinity and acid sulfate issues has been included in this report. Erosion, salinity and acid sulfate soil, if encountered, would be managed in accordance with Site specific management plans developed for the Estate.
21.2. Provide an assessment of the proposed land uses in accordance with State Environmental Planning Policy No 55 – Remediation of Land (SEPP 55).	An assessment of the proposed land uses satisfying the State Environmental Planning Policy No. 55 – Remediation of Land (SEPP 55) has been provided in this report, specifically addressing Clause 6(1)(b),(c). It is noted that: - A Stage 2 contamination assessment is required to characterise the nature and extent of potential soil and groundwater contamination identified within the Estate to confirm that the Estate is either suitable in its current condition or can be made suitable following remediation for the proposed land use and zoning in accordance with clause 6(1)(b) of SEPP 55. - In accordance with clause 6(1)(c) of SEPP 55, remediation and/or management of impacted areas may be required to mitigate risks associated with the identified impacts during the proposed construction works.

3.0 Planning Proposal

The planning proposal will establish new land use planning controls for Waterloo South, including zoning and development standards to be included in Sydney LEP 2012, a new section in Part 5 of DCP 2012, and an infrastructure framework. Turner Studio and Turf has prepared an Urban Design and Public Domain Study which establishes an Indicative Concept Proposal presenting an indicative renewal outcome for Waterloo South. The Urban Design and Public Domain Study provides a comprehensive urban design vision and strategy to guide future development of Waterloo South and has informed the proposed planning framework. The Indicative Concept Proposal has also been used as the basis for testing, understanding and communicating the potential development outcomes of the proposed planning framework.

3.1 Indicative Concept Proposal

The Indicative Concept Proposal comprises:

- Approximately 2.57 hectares of public open space representing 17.8% of the total Estate (Gross Estate area – existing roads) proposed to be dedicated to the City of Sydney Council, comprising:
    - Village Green – a 2.25-hectare park located next to the Waterloo Metro Station; and
    - Waterloo Common and adjacent – 0.32 hectares located in the heart of the Waterloo South precinct.
    - The 2.57 hectares all fall within the Waterloo South Planning Proposal representing 32.3% of public open space (Gross Waterloo South area – proposed roads)
- Retention of 52% of existing high and moderate value trees (including existing fig trees) and the planting of three trees to replace each high and moderate value tree removed.
- Coverage of 30% of Waterloo South by tree canopy.
- Approximately 257,000 sqm of GFA on the LAHC land, comprising:
    - Approximately 239,100 sqm GFA of residential accommodation, providing for approximately 3,048 dwellings comprising a mix of market and social (affordable rental) housing dwellings;
    - Approximately 11,200 sqm of GFA for commercial premises, including, but not limited to, supermarkets, shops, food & drink premises and health facilities; and
    - Approximately 6,700 sqm of community facilities and early education and child care facilities.

The key features of the Indicative Concept Proposal are:

- It is a design and open space led approach.
- Creation of two large parks of high amenity by ensuring good sunlight access.
- Creation of a pedestrian priority precinct with new open spaces and a network of roads, lanes and pedestrian links.
- Conversion of George Street into a landscaped pedestrian and cycle friendly boulevard and creation of a walkable loop designed to cater to the needs of all ages.
- A new local retail hub located centrally within Waterloo South to serve the needs of the local community.
- A target of 80% of dwellings to have local retail services and open space within 200m of their building entry.
- Achievement of a 6 Star Green Star Communities rating, with minimum 5-star Green Star – Design & As-Built (Design Review certified).
- A range of Water Sensitive Urban Design (WSUD) features.

The proposed land allocation for the Waterloo South precinct is described in **Table 2** below.

Table 2 | Breakdown of allocation of land within the Waterloo South

Land allocation	Existing	Proposed
Roads	3.12ha / 25.3%	4.38ha / 35.5%
Developed area (Private sites)	0.86ha / 6.98%	0.86ha / 7%
Developed area (LAHC property)	8.28ha / 67.2%	4.26ha / 34.6%
Public open space (proposed to be dedicated to the City of Sydney)	Nil / 0%	2.57ha / 20.9% (32.3% excluding roads)
Other publicly accessible open space (Including former roads and private/LAHC land)	0.06ha / 0.5%	0.25ha / 2%
TOTAL	**12.32ha**	**12.32ha**

The Indicative Concept Proposal for the Waterloo South is illustrated in **Figure 3** below.

Figure 3 | Indicative Concept Proposal

Source: Turner Studio

4.0 Geotechnical Baseline Investigation

4.1 Data Sources

AECOM has looked at the following sources of information:

- Sydney 1:100,000 Geological Series Sheet 9130;
- The NSW Office of Environment and Heritage Acid Sulphate Soil Map;
- Sydney Local Environmental Plan (LEP) 2012, the ASS map Sheet 010; and
- Borehole information from the AECOM database.

4.2 Estate Description

The Estate is about 3.3 km south of the Sydney CBD and is bounded by Phillip, Cope, McEvoy and Pitt Street. The proposed redevelopments within the Estate comprise low, medium and high density, commercial and residential buildings, potentially with basement car parking and ancillary basement uses.

The Estate is rectangular and about 630 m long, extending between Phillip and McEvoy Streets; and 300 m wide, extending between Cope Street and Pitt Street. This area is occupied by medium and high-density housing in general, with minor commercial properties.

To the east of the main part of the Study Area there is a small site extending about 80 m between Wellington and Kellick Streets and extending about 120 m between Pitt and Gibson Streets. This site is occupied by medium density residential up to 5 storeys.

The ground surface in the locality is relatively flat, with the ground elevation ranging between about RL+30 m AHD in the north east to about RL+15 m AHD in the south west.

4.3 Site Condition and Surrounding Environment

4.3.1 Estate Land Use and Zoning

The zoning of the Estate comprises Zone B4 Mixed Use, Zone R1 General Residential and Zone SP2 Infrastructure (Classified Road) under the Sydney LEP 2012. The site zoning map is provided in the Lotsearch Report in **Appendix B**.

The Waterloo House Estate, as inspected on 22 May 2017, currently consists of medium to high density social housing including car parking and recreational open space, two substations (one on McEvoy Street and one on Cope Street), an IGA supermarket (Wellington Street), the Duke of Wellington Pub (corner of Wellington and George Streets), some private terrace houses, high density apartment buildings and a child care centre (corner of West and Wellington Streets).

4.3.2 Surrounding Land Use

Land uses surrounding the Estate identified during the site visit on 22 May 2017 are described below:

- North: Phillip and Raglan Streets. National Centre of Indigenous Excellence including sports field. Residential properties are located further to the north along George, Cope and Pitt Streets.
- East: Pitt Street and low to medium density residential housing, parkland surrounding Our Lady of Mount Carmel catholic school and some commercial properties.
- South: McEvoy Street, high density housing, Waterloo Oval recreational open space and commercial properties including McDonalds Waterloo and commercial/industrial factories further south.
- West: Cope Street, Waterloo Metro Quarter, medium density housing and commercial and industrial properties for example; restaurants, furniture stores, fitness centres, factory outlets and bicycle store further south.

4.3.3 Topography and Drainage

The Estate grades from east to west with surface elevations ranging from approximately 40 m AHD in the east to 16 m AHD in the west. The Estate generally slopes to the west.

Two topographical surface elevation high points are located immediately east of the Estate. The surrounding areas reduce in elevation in a southerly and westerly direction away from the Estate.

No major easements were identified by Property Boundary & Topographic Data (as presented in the Lotsearch Report, **Appendix B**) or during the site inspection on 22 May 2017 within the Estate; however six undefined easements were identified within 1 km of the Estate boundaries – north (365 m), south east (381 m), east (381 m), east (870 m), north (889 m) and north (925 m).

4.3.4 Surface Water and Flood Potential

No obvious surface water bodies were observed within or surrounding the Estate during the site inspection on 22 May 2017. Sheas Creek is noted to be located approximately 494 m south south-west of the Estate.

It is noted that development within the Estate or land surrounding may be subject to flood related development controls i.e. 110 Wellington Street, Waterloo (AECOM, 2014).

4.3.5 Regional Meteorology

According to the Bureau of Meteorology Station (www.bom.gov.au) at the Sydney Airport monitoring station (066037) (data from 1929 to 2017), which is located approximately 5.3 km from the Estate, the Estate could expect to experience:

- Moderate to warm summers, with a mean maximum temperature of 26.6ºC in January;
- Mild to cool winters, with a mean minimum temperature of 7.2ºC in July; and
- Average annual rainfall of approximately 1085.8 mm, which is generally highest from February through to June.

4.3.6 Geology and Acid Sulfate Soils

The Estate is located within the Sydney Basin, which in turn forms part of the Cumberland Plain.

According to the 1:100,000 Sydney Region Geological Map from NSW Department of Industry, Resources & Energy (see Lotsearch Report, **Appendix B**), the Estate is underlain by Quaternary age medium to fine-grained marine sand with podsols. To the northwest of the Estate (about 400 m) is Triassic Ashfield Shale of the Wianamatta Group. The Ashfield Shale is described as black to dark grey shale and laminate.

Further north of the Estate (about 800 m) is an unknown land filling area containing dredged estuarine sand and mud, demolition rubble, industrial and household waste) which overlays silty to peaty quartz sand, silt and clay with ferruginous and humic cementation in placed and common shell layers. Due to the previous and current land uses at the Estate, fill material is generally expected to be present on-site overlying the natural soils.

Soils within the Estate are classified as Acid Sulfate Soil (ASS) – Soil Class 5 (indicating no known risk of acid sulfate soils), see Lotsearch Report, **Appendix B**.

4.3.7 Hydrogeology

The Estate is situated on the Botany Sands, an unconfined aquifer, which has large groundwater capacity. The Hydrogeology Map of Australia (see Lotsearch Report, **Appendix B**) described the local aquifers underlying the Estate as porous, extensive highly productive aquifers.

The Botany Sands aquifer recharges from the following sources:

- Infiltration of rainfall into the unconsolidated sediments;

- Open space areas including five local golf courses, Randwick Racecourse and Centennial Park;
- Direct run-off from the Hawkesbury Sandstone rim; and
- Discharge of water from springs rising through cracks and bedding planes in the Hawkesbury Sandstone.

The groundwater levels in the Botany Basin are highly variable depending on topographic relief, ranging between 0.0 m and 23 m below ground surface (m bgs) (see Lotsearch Report in **Appendix B**). For the identification of hydraulic gradient, the hydrogeological position of the nearest water body relative to the Estate has been used. Therefore it has been assumed that groundwater flow direction is to the southwest towards Sheas Creek and the Alexandra Canal.

The Lotsearch Report indicate that there are no registered groundwater bores within the Estate and 4 registered groundwater bores within 200 m of the Estate. These are summarised in Table 3 below. An annotated map of groundwater bores is provided in the Lotsearch Report (**Appendix B**).

Table 3 | Registered Groundwater Bore Summary

Bore ID	Depth of Bore (m bgs)	SWL (m bgs)	Approximate distance and direction from Estate	Purpose
GW114895	6	4.20	109m south-west	Monitoring
GW071907	180	11.6	179m north-east	Recreation
GW113037	5	-	188m south-west	Monitoring
GW113038	5	-	195m south-west	Monitoring

Notes:
m bgs – metres below ground surface
- denotes no information available

4.3.8 Existing Rail Tunnel

The existing T8 Airport & South Line rail tunnel runs underneath George Street within the Estate (see Lotsearch Report in **Appendix B**). Record drawings and long sections from Railcorp indicate that the rail tunnel between Redfern Station and Green Square Station has a depth from surface ranging between 20m and 30m. Further investigation is required to confirm the exact location and geometry of the rail tunnel and associated easements. This will allow checks to be made on clearances between the rail tunnel and its easements against the development basement and foundation levels proposed as part of the Estate development plan.

Specifically, post rezoning, potential impacts from the development of the Estate on the existing Airport line should be reviewed against the following guidelines:

- Development Near Rail Tunnels (Nov, 2018);
- Technical note – TN 043: 2017 External Developments Standard; and
- Airport Line Tunnel Protection Guidelines, Part B (Technical Matters), Rail Access Corporation 2000 (see **Appendix D**)

Besides the key loading/structural requirements outlined in the guidelines, other items that should be considered include:

- Clearance assessments;
- Construction management plans (during detailed design stage);
- Potential impacts on the direction, quantity or quality of surface and groundwater within the rail corridor; and
- Potential for ground movements impacting on track vertical and horizontal alignments

4.4 Ground Conditions

4.4.1 Regional Geology

Based on the Sydney 1:100,000 Geological Series Sheet (9130), the Estate is underlain by Quaternary Sediments (Qhd). These deposits are commonly referred to as the Botany Sands and are described as medium to fine grained "marine" sand with podsols. Figure 4 shows an extract of the geological sheet showing the Estate.

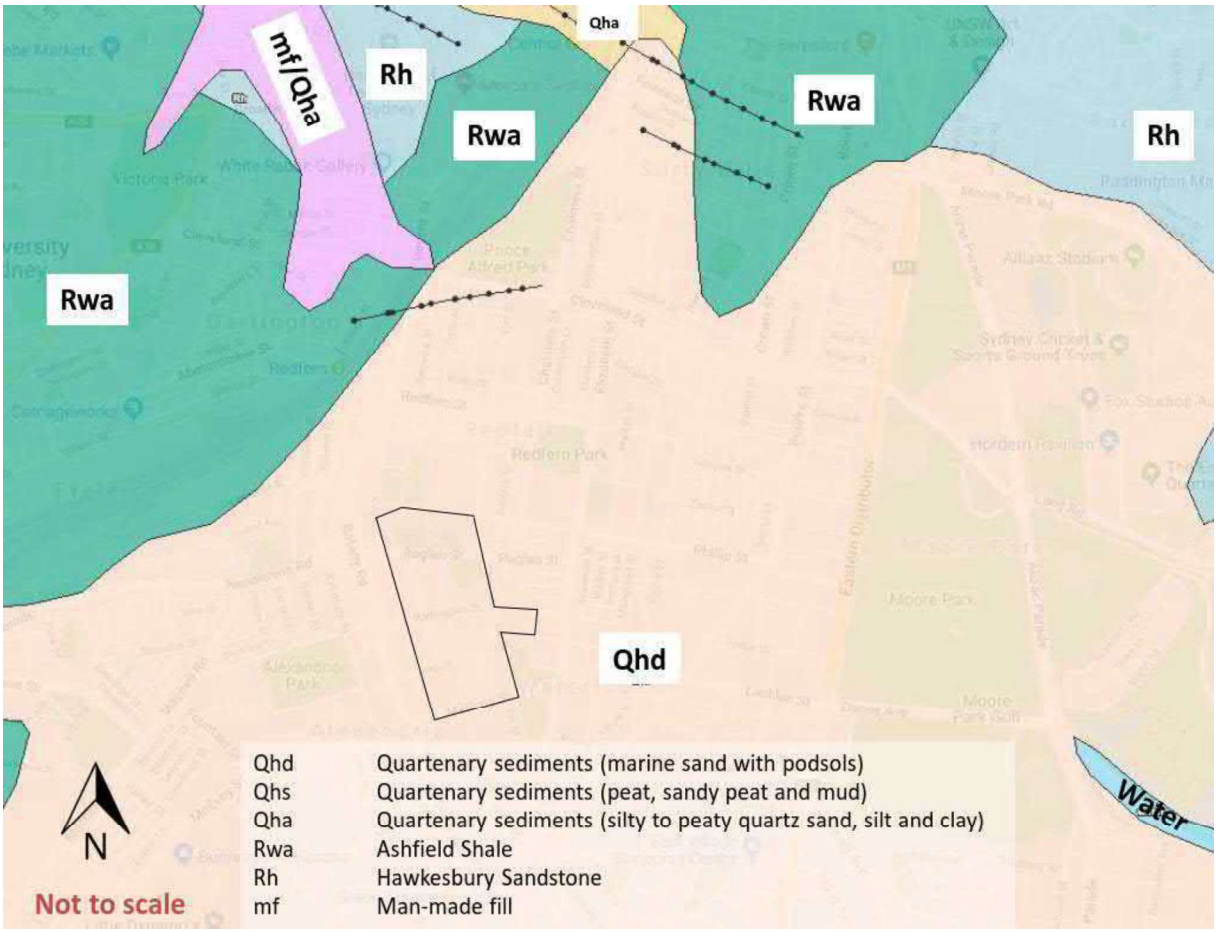


Figure 4 | Extract from the Sydney 1:100,000 Geological Sheet

The bedrock underlying the Botany Sands is either:

- Ashfield Shale underlain by Mittagong Formation and/or Hawkesbury Sandstone. Or,
- Hawkesbury Sandstone.

The Ashfield Shale is expected across most of the Estate. Faulting has led to uplifting and removal of the Ashfield Shale through erosion to the east of the Estate. The inferred boundary between the Ashfield Shale and Hawkesbury Sandstone is shown in Figure 8.

The geology sheet describes the Ashfield Shale as black to dark grey shale and laminite. The Mittagong formation is an intermediate unit sometimes present between the Ashfield Shale and Hawkesbury Sandstone. It is sometimes referred to a transition bed between the fine-grained Ashfield Shale and relatively coarse-grained Hawkesbury Sandstone and is described as shale, laminite, and medium grained quartz sandstone. The Hawkesbury Sandstone is described as medium to coarse-grained quartz sandstone, very minor shale and laminite lenses.

4.4.2 Acid Sulfate Soils

The Acid Sulfate Soils (ASS) Map provided by the NSW office of Environment and Heritage shows no potential ASS occurrence within the Estate.
The Sydney Local Environmental Plan (LEP) 2010, the ASS map Sheet 010 indicates the Estate is within Class 5 Land. The Sydney LEP requires development consent for works on Class 5 land that meets the following criteria:

- within 500 m of Class I, 2, 3 and 4 land,
- below 5 m Australian Height Datum (AHD), and
- groundwater is likely to be lowered below 1 m AHD on the adjacent Class 1, 2, 3 and 4.

If tanked basements are used, long-term groundwater impact beyond the basement boundary are not expected to be an issue.

4.4.3 Preliminary Geotechnical Model

We have used borehole data within the vicinity of the Estate from our database to develop the preliminary geotechnical model in Table 4.

The depth to fill in the Estate could be highly variable due to the varied past land uses. Locally deeper fill than indicated in our inferred model could be found. Of the natural soils, the alluvium of the Botany Sands is underlain by residual soils formed by weathering of the underlying Shale bedrock that is in turn underlain by Sandstone bedrock. The top of bedrock at the site ranges from about RL+9.5 m AHD in the north to about RL +6.5 m AHD in the south.

Table 4 | Indicative Ground Profile

Geotechnical Unit	Description	Depth to Top of Unit (m)	Unit thickness (m)
1. Fill	Likely to be variable Sands or Clays containing Silt, Gravel, possibly waste materials	Ground surface	Less than 1
2. Alluvium/Marine Sediments	Sand: mainly fine to medium grained, loose and medium dense SPT 'N' values ranging from 15 to 30	0.6 to 1.6	1 to 6
3. Residual Soil	Silty Clay: medium plasticity, very stiff and hard. SPT 'N' values ranging from 26 to refusal	2.2 to 5.2	2.7 to 6
4. Ashfield Shale 4a. Shale Class V and IV (Note 1)	Shale: extremely weathered to highly weathered, very low to medium strength	7.8 to 10.2	1.2 to 5.2
4b. Shale Class II or better (Note 1)	Shale: slightly weathered and fresh, medium and high strength	9.8 to 14.6	4.8 to 9.2
5. Mittagong Formation and/or Hawkesbury Sandstone	Sandstone: mainly fresh rock with medium to high strength	9.2 to 22.5	Not proven

Note 1: Rock classifications based on Pells et al 1998.

The unit depths, thicknesses and material properties presented in Table 4 should not be assumed to represent the maximum or minimum values on the site. Actual unit boundaries and material properties can be highly variable, particularly for fill.

Figure 5 to Figure 9 present inferred surfaces of the tops of Units 2, 3, 4a, 4b and 5. The surfaces representing the unit boundaries are based on interpolation, often between widely and variably spaced boreholes. Actual unit boundaries in the Study Area may vary significantly from those shown. Features such as erosion channels, faults and igneous intrusions into the sedimentary bedrock sequences can affect bedrock surfaces within the Sydney region.

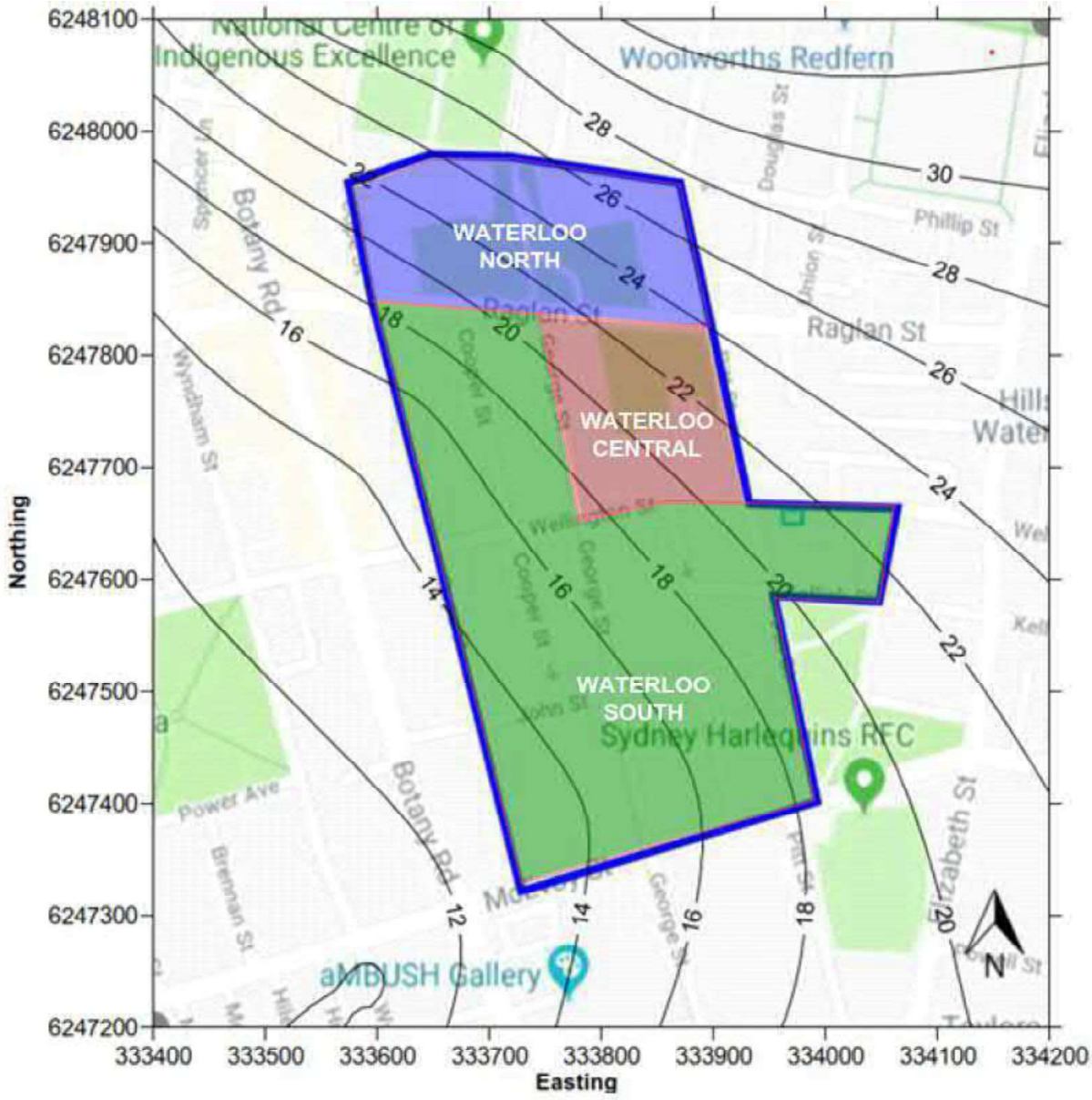


Figure 5 | Inferred Contours of Elevation of Top of Unit 2 - Alluvium/Marine Sediments

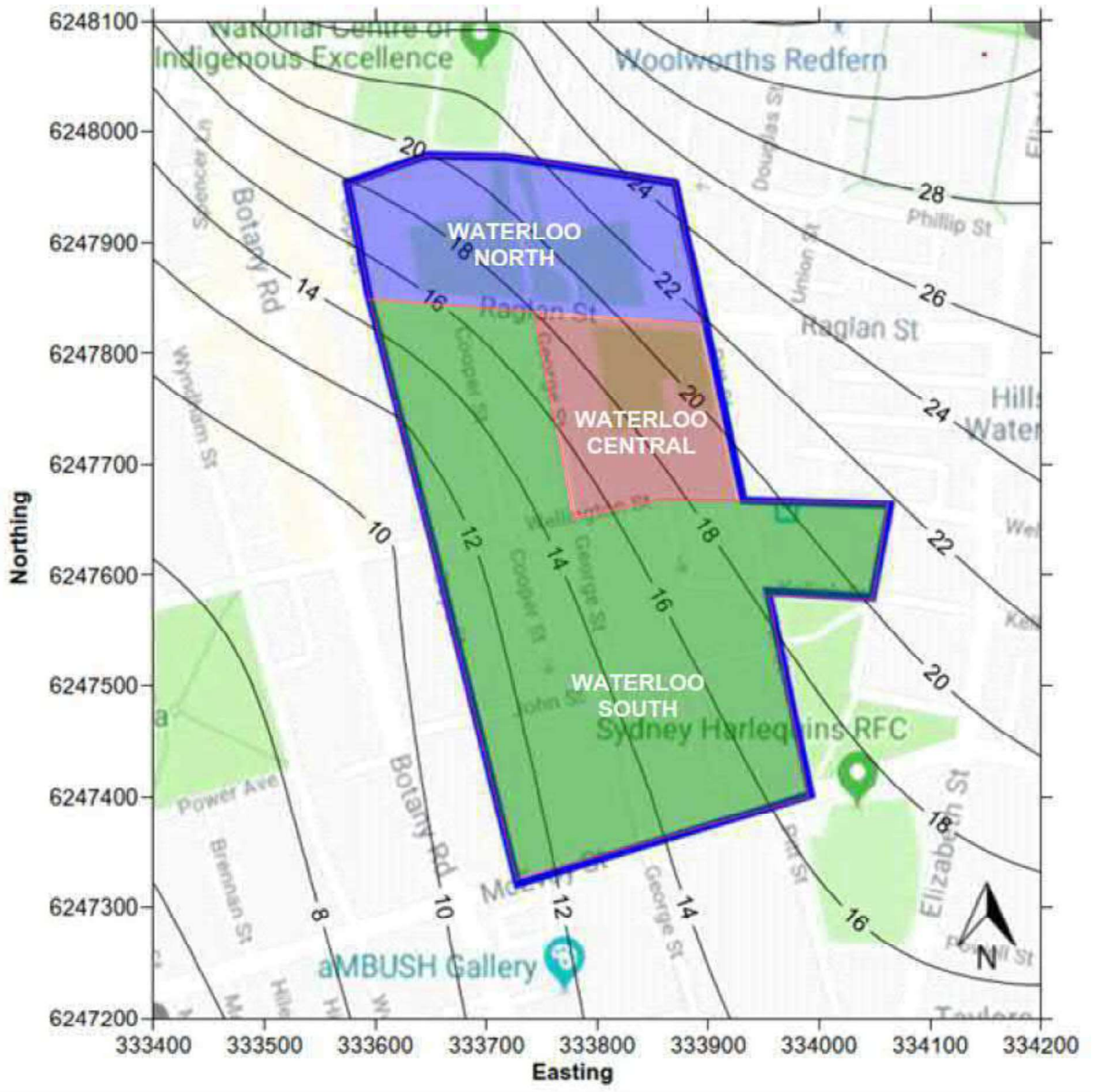


Figure 6 | Inferred Contours of Elevation of Top of Unit 3 – Residual Soil

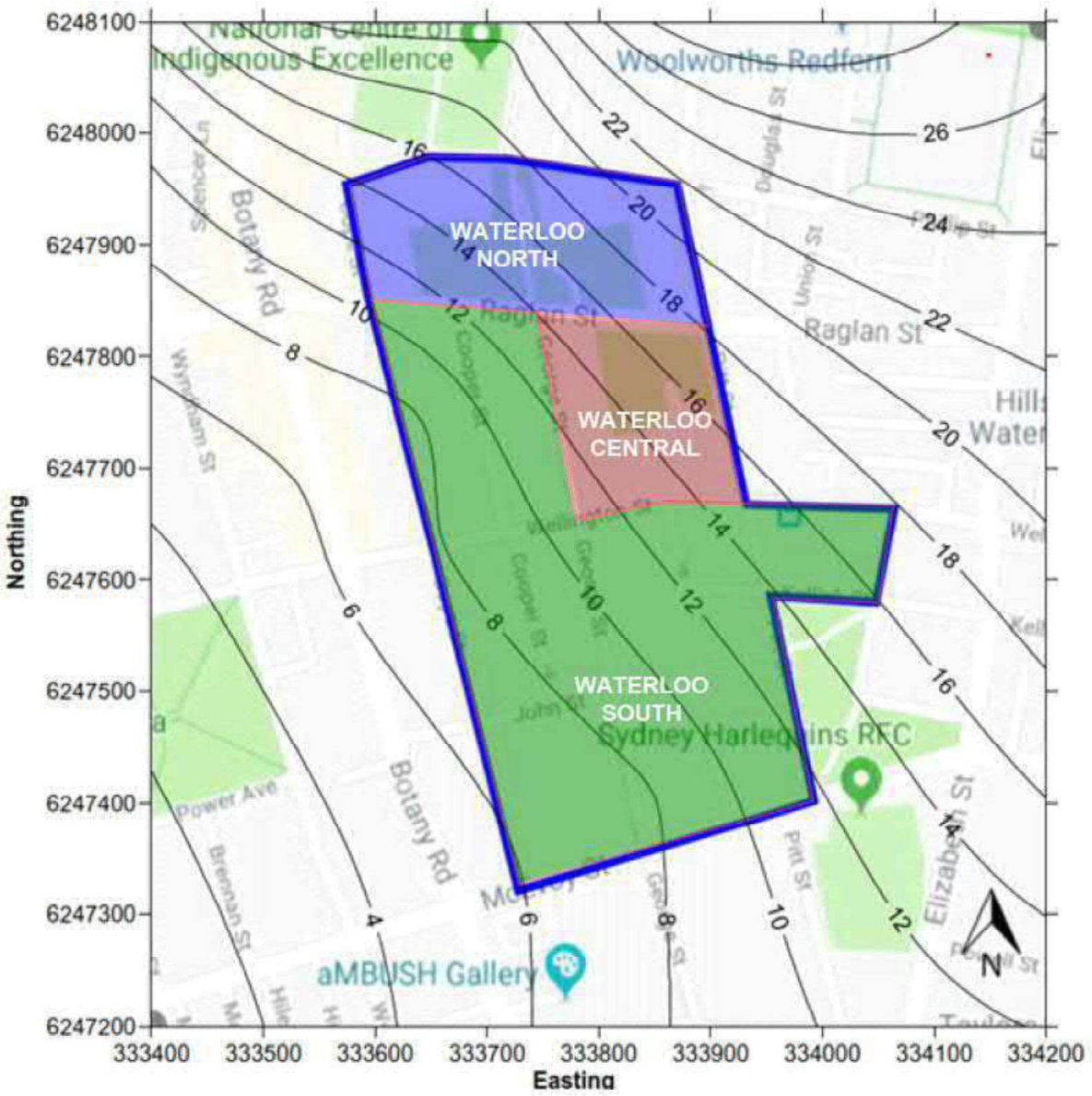


Figure 7 | Inferred Contour of Elevation of Top of Unit 4a – Class V and IV Shale

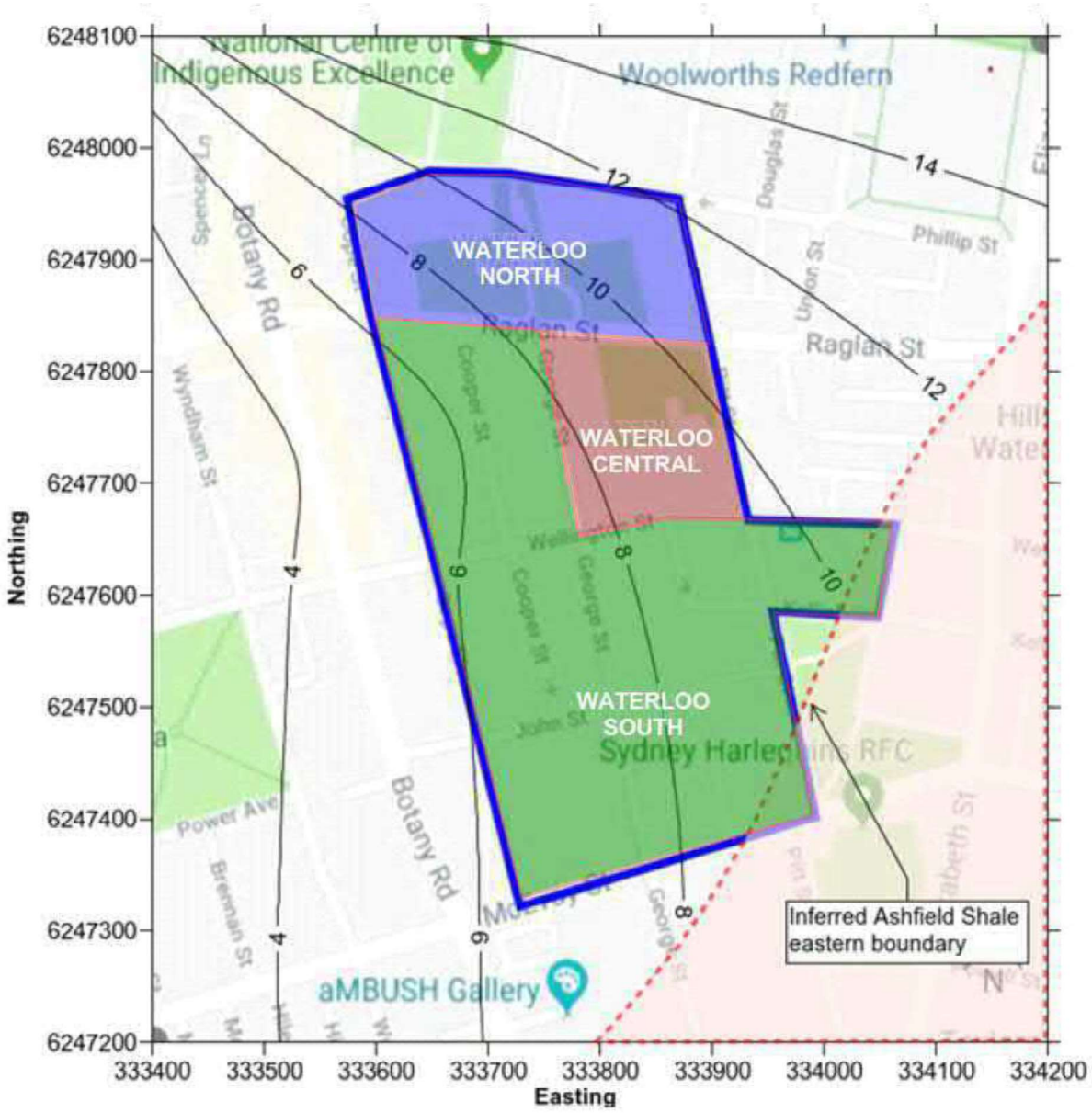


Figure 8 | Inferred Contours of Elevation of Top of Unit 4b – Class II Shale or better

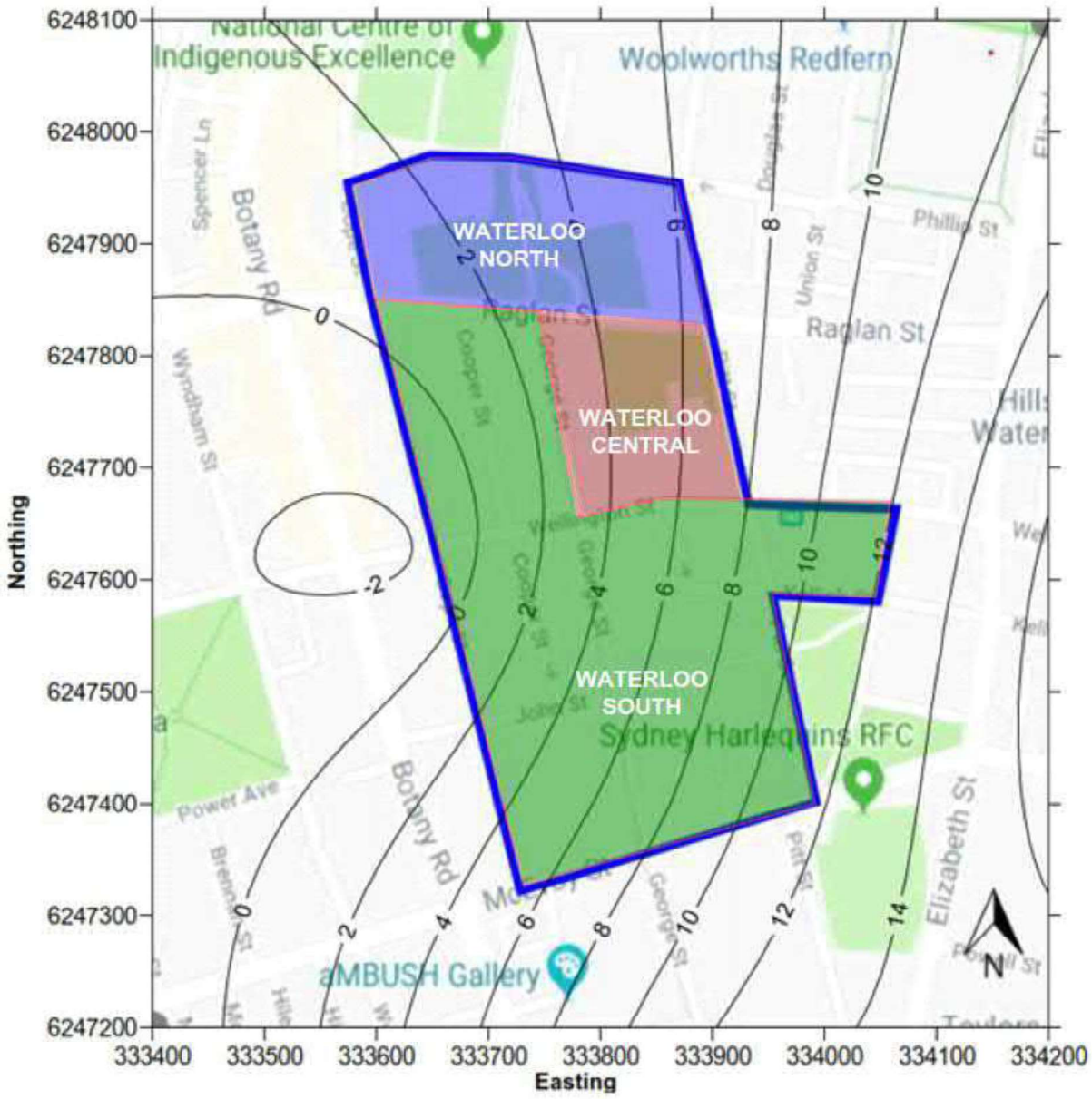


Figure 9 | Inferred Contours of Elevation of Top of Unit 5 – Class II Sandstone or better

4.4.4 Groundwater

Groundwater is likely to be relatively shallow in this locality. Standing groundwater levels have been monitored in the Unit 2 – Alluvium/Marine Sediments, at depths ranging from 2.1 m to 3.1 m below ground surface in the Study Area and surrounding areas where borehole information is available. Figure 10 shows inferred contours of groundwater elevation based on available data.

It should be noted that the groundwater data from the AECOM database was collected at different times. Local and regional groundwater levels can vary over time. Hence, this inferred groundwater surface is not at a particular point in time and should be used with caution. Furthermore, in this relatively low- lying area groundwater levels can rise to the ground surface, depending on infiltration rates, flood levels and drainage paths.

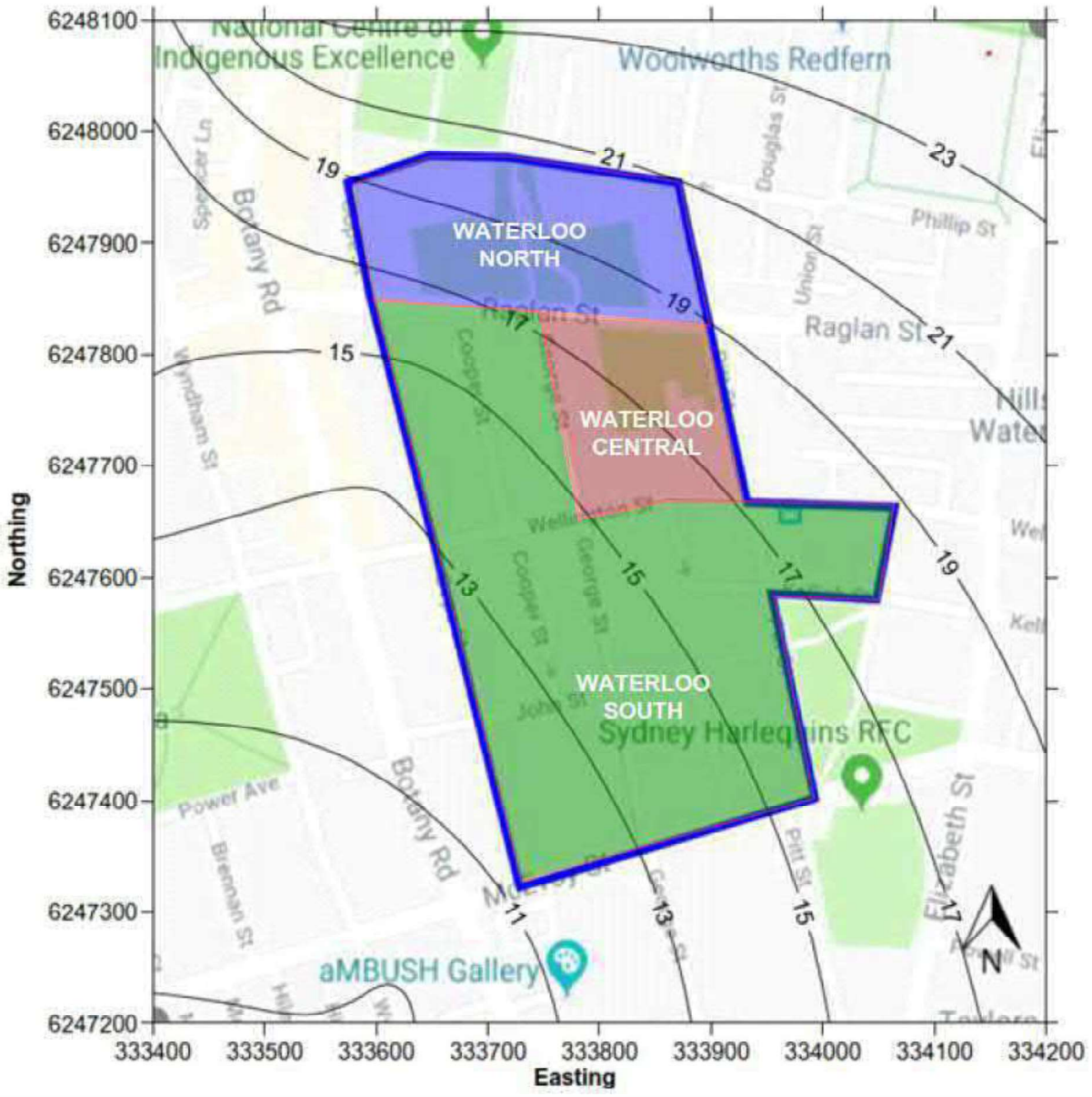


Figure 10 | Inferred Contours of Groundwater Elevation

4.5 Discussion and Recommendations

4.5.1 Geotechnical Risks

Commercial and residential development with basements should be practicable within the Study Area with conventional structural elements and normal construction techniques. However, some geotechnical challenges exist that include:

- High groundwater table and the potential for rapid rises in groundwater level during heavy rainfall events. There is the potential for groundwater to rise to the ground surface during flooding events;
- Potentially saturated cohesionless soils (Unit 2 – Botany Sands), requiring watertight retention systems to prevent groundwater inflows and running sands;
- There may be other sensitive structures and services that require protection. Restrictions associated with existing structures may result in increased site retention and foundation costs and impact on construction programs; and
- The risk associated with underground services. Retention system design will have to consider the risk of excavation induced ground movements on existing services. Relatively stiff retention systems may be required to limit ground displacements beyond the site boundaries.

The predominantly sandy soils at the site are unlikely to be highly erodible. However, sediment or dust could still be an issue during construction under adverse conditions such as during very wet or dry weather. Erosion and sediment control would be managed using standard construction methods managed in accordance with a construction environmental management plan (CEMP) and material management plan (MMP).

In the following sections, preliminary comments and recommendations are provided on geotechnical issues associated with basement excavation and structural design and building foundations. Preliminary parameters are provided for concept design, but are based on very limited data from boreholes that were not drilled for this project and should not be relied upon.

4.5.2 Groundwater and Excavation Retention Systems

A tanked retention system will be required for the development of basements through the Botany Sands (Unit 2) that are laterally continuous and of relatively high permeability. Dewatering using drilled or jetted spear points may be possible within an excavation enclosed by a groundwater cut-off such a sheet pile wall. If excavations extend into the Residual Soil (Unit 3) they should be able to be maintained dry by pumping from sumps, provided lateral inflows from the overlying sands are cut off.

Given the presence of a relatively low permeability clay layer (Unit 3 – Residual Soil) a lateral groundwater cut-off within the Botany Sands Unit 2 should be able to be formed by driven steel sheet piles or a secant pile wall. A hydrostatic slab will be required to tank the base of the excavation. If it can be demonstrated that basements penetrate into a very low permeability strata then it may be possible to adopt a semi-tanked basement. The retaining walls would be tanked and the basement slab designed with a drainage layer to relieve any hydrostatic pressures from groundwater inflows through the foundations. The drainage system would need to be designed with flushing points to enable removal of mineral precipitants to prevent blocking of drainage pipes. Such a semi-drained basement would be subject to regulatory approvals.

Driven steel sheet piles could be considered to form a temporary retention system to allow dewatering and excavation prior to constructing a permanent cast in place retaining wall. The sheet piles may have to be sacrificial where used as formwork for the permanent retaining wall.

Secant pile walls need to be constructed carefully to maintain pile verticality and avoid gaps between piles through which groundwater and soil could flow. Soldier pile walls with shotcrete infill panels or contiguous bored piles are unlikely to be practicable through the Botany Sands. These wall types are not suitable for cohesionless and/or saturated soils.

The parameters in Table 7 can be used for preliminary design of retention systems. If temporary ground anchors are required, provision should be made for effectively sealing up the anchor heads to prevent groundwater ingress should the groundwater level rise to above the anchor head.

Depending on factors such as construction sequence and structural stiffness, even well-constructed anchored retaining walls can deflect laterally in the order of 0.1 % to 0.3% of the wall height. Detailed soil-structure interaction analysis should be carried out to assess the lateral and vertical ground movements that could result from basement excavation as well as the structural loads acting on the retaining system.

4.5.3 Material Properties

Based on the results of in-situ testing from our database we infer the soil and rock properties summarised in Table 5 and Table 6.

Table 5 | Inferred Unit 1, 2 and 3 Soil and Unit 4a Rock Properties

Geotechnical Unit	Bulk Density, γ_b, kN/m^3	Undrained Cohesion, c_u, kPa	Drained Cohesion, c', kPa	Drained Friction Angle, Φ', degrees	Drained Young's Modulus, E', MPa
1. Fill (Note 1) variable Sands or Clays	20	-	0	25	5 to 10
2. Alluvium/Marine Sediments Sand	20	0	0	33	25 to 50
3. Residual Soil Silty Clay	20	100	10	25	20 to 30
4a. Shale Class V and IV	22	500	10	28	50 to 300

Note 1. Existing fill should be treated as uncontrolled fill and should not be relied upon to support structures. The parameters for fill are for estimating retaining wall earth pressures and displacements and should not be used to assess existing fill as a bearing stratum.

Table 6 | Preliminary Rock Strength Estimates and Rock Mass Classifications

Geotechnical Unit	Point Load Strength, I_{s50}, MPa	Uniaxial Compressive Strength, UCS, MPa (Note 1)	Rock Mass Classification based on Pells et al 1998
4a. Shale	<0.1	<2	Class V and IV
4b. Shale	1.0 to1.1	20 to 22	Class II or better
5. Sandstone	1.0 to 1.5	20 to 30	Class II or better

Note 1. UCS has been estimated based on I_{s50} values, assuming a multiplier of 20 to convert point load strength to UCS.

4.5.4 Temporary Ground Anchors

Typically, exclusion zones are declared around buried structures associated with infrastructure such as shafts, station boxes and running tunnels associated with metro lines. Such exclusion zones restrict the imposition of additional stressed on the ground that may affect the buried infrastructure. The feasibility of installing temporary ground anchors should consider such exclusion zones as they may prevent anchors being adopted or require them to be inclined more steeply which reduces their efficiency.

Table 7 provides recommendations for preliminary design of ground anchors. The parameters are valid for anchors with bond lengths between 3 m and 7 m. In addition to bond and structural capacity, anchors should be checked for a cone pullout failure mechanism.

Table 7 | Preliminary anchor design parameters

Geotechnical Unit	Ultimate Bond Stress kPa
4b. Shale – Class II or better	600
5. Sandstone Class II or better	1,000

4.5.5 Foundations

Given the nature of the proposed development within the Estate, building loads are likely to be relatively heavy and require piled foundations. There may also be a requirement for deep piles to take loads to levels below which they may affect the existing T8 Airport & South Line rail tunnel. Open bore piles are unlikely to be practicable unless temporary liners are installed through the Unit 2 Botany Sands and a seal can be achieved in the residual soils or bedrock. Continuous flight auger (CFA) piles should be practicable.

Care will be required if CFA piles are required to have long sockets into relatively high strength rock, resulting in slow auger penetration rates. If there are loose sands within the Unit 2 Botany Sands they could be drawn into the auger while the rock socket is being drilled. This can result in loosening of the sands and potentially unexpected ground movements near the piles. This aspect should be further assessed with additional investigation of the sand density, as the risk is lower in more dense sands.

If the piles are to be located within Zone 1 or Zone 2 of any airport rail tunnel infrastructure (Refer to **Appendix D** for Zone Definitions) there may also be a need to isolate pile shafts from the rock so that loads are not transferred to rail structures. One potential option to achieve this could be the use of sacrificial steel sleeves.

Table 8 presents preliminary pile design parameters.

Table 8 | Preliminary Pile Design Parameters

Geotechnical Unit	Ultimate End Bearing Capacity, Mpa Note 1	Serviceability Bearing Pressure, Mpa Note 2	Ultimate Shaft Adhesion, kPa Note 3	Elastic Modulus, E, Mpa Note 4
4a. Shale Class V and IV	3	0.7	100	100
4b. Shale Class II or better	60	6	800	1,000
5. Sandstone Class II or better	100	10	1,400	1,600

Note
1. End bearing pressures assume a minimum embedment of 0.3 m into the relevant bearing stratum.
2. End bearing pressures should be checked under Serviceability Limit State (SLS) loads against the Serviceability Bearing Pressure value to confirm that the base of piles remain within the elastic range.
3. Ignore shaft adhesion where the embedment total embedment into rock is less than 1 pile diameter 1 pile diameter.
4. Pile settlement should be calculated using SLS loads and the elastic modulus values in the table.

To design piles in accordance with AS 2159-2009 a geotechnical strength reduction factor, Φ_g, should be applied to check pile capacity under Ultimate Limit State (ULS) loads. The value will depend on a calculated Average Risk Rating (ARR) that considers various factors such as the level of investigation, level of redundancy in capacity, pile load testing, and level of construction review.

Typically for single (low redundancy) piles that develop most of their capacity in Sydney sedimentary rock strata the ARR is less than or equal to 2.5. We estimate an ARR of about 2 should be able to be assessed for this site, from which a Φ_g value of 0.56 can be assessed without pile load testing to verify the design ultimate geotechnical strength. Minimum pile testing requirements for serviceability is still recommended.

4.5.6 Further Geotechnical Investigations

This desktop study has been based on a limited number of boreholes from within and surrounding the Estate. Comprehensive geotechnical models will be required for design of specific sites. A further desktop study should be carried out to make use of additional information that becomes available and to scope investigations.

7.0 Important information about this Geotechnical and Contamination Report

Client details, scope and reliance

AECOM has prepared this report for the sole use of the Client and for a specific purpose, each as expressly stated in the report. No other party should rely on this report without the prior written consent of AECOM. AECOM undertakes no duty, nor accepts any responsibility, to any third party who may rely upon or use this report. This report has been prepared based on the Client's description of its requirements and AECOM's experience, having regard to assumptions that AECOM can reasonably be expected to make in accordance with sound professional principles. AECOM's findings represent its reasonable judgment within the time and budget context of its commission and utilising the information available to it at the time.

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AECOM may have relied on information provided by the Client and third parties (Information Providers) to produce this report and arrive at its conclusions. AECOM has not verified information provided by the Information Providers (unless specifically agreed as part of AECOM's scope of work) and we assume no responsibility and make no representations with respect to the adequacy, accuracy or completeness of such information. AECOM assumes no responsibility for inaccuracies in reporting by the Information Providers including, without limitation, by the Client's employees or representatives or for inaccuracies in any other data source whether provided in writing or orally used in preparing or presenting the report.

Variability in conditions and limitations of data

Subsurface conditions are formed through a variety of natural processes and can be altered by human activities. The behaviour of the ground, groundwater and contaminants are complex and conditions can vary across a particular Estate. As a result, subsurface conditions cannot be exhaustively defined by investigations at discrete locations. Therefore, it is unlikely that the results and assessments expressed in this report will represent conditions at any location removed from the specific points of sampling. The precision with which conditions can be inferred depends largely on the uniformity of subsurface conditions and on the frequency and method of sampling as constrained by factors such as project budget and time limitations and physical constraints.

Furthermore, subsurface conditions can change over time, which should be considered when interpreting or using the data within this report.

Verification of opinions and recommendations

The opinions and recommendations in this report apply to the proposed development and the Estate existing at the time of our investigation and cannot necessarily apply to changes in the proposed development or Estate changes of which AECOM is not aware and has not had the opportunity to evaluate. Our recommendations should be considered to be preliminary and subject to verification during project implementation. If conditions encountered within the Estate are subsequently found to differ significantly from those anticipated, AECOM must be notified and be provided with an opportunity to review the recommendations.