Lend Lease (Millers Point) Pty Limited

Barangaroo South - R8 & R9 Residential Buildings

Geotechnical Report - Project Application

Barangaroo South - R8 & R9 Residential Buildings

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Contents

1 Introduction

This report supports a Project Application (MP11_0002) submitted to the Minister for Planning pursuant to Part 3A of the Environmental Planning and Assessment Act 1979 (EP&A Act). The Application seeks approval for construction of two residential flat buildings (known as Buildings R8 and R9) and associated works at Barangaroo South as described in the Overview of Proposed Development section of this report.

1.1 Overview of Proposed Development

The R8 and R9 Project Application seeks approval for the construction and use of two residential flat buildings comprising 159 apartments, ground floor retail, allocation of car parking spaces from the Bulk Excavation and Basement Car Parking Project Application, and the construction of the surrounding ancillary temporary public domain and landscaping.

1.2 Site Location

Barangaroo is located on the north western edge of the Sydney Central Business District, bounded by Sydney Harbour to the west and north, the historic precinct of Millers Point (for the northern half), The Rocks and the Sydney Harbour Bridge approach to the east; and bounded to the south by a range of new development dominated by large CBD commercial tenants.

The Barangaroo site has been divided into three distinct redevelopment areas (from north to south) – the Headland Park, Barangaroo Central and Barangaroo South.

The R8 and R9 Project Application Site area is located within Barangaroo South as shown in Figure 1. The Project Application Site extends over land generally known and identified in the approved Concept Plan as Block X.

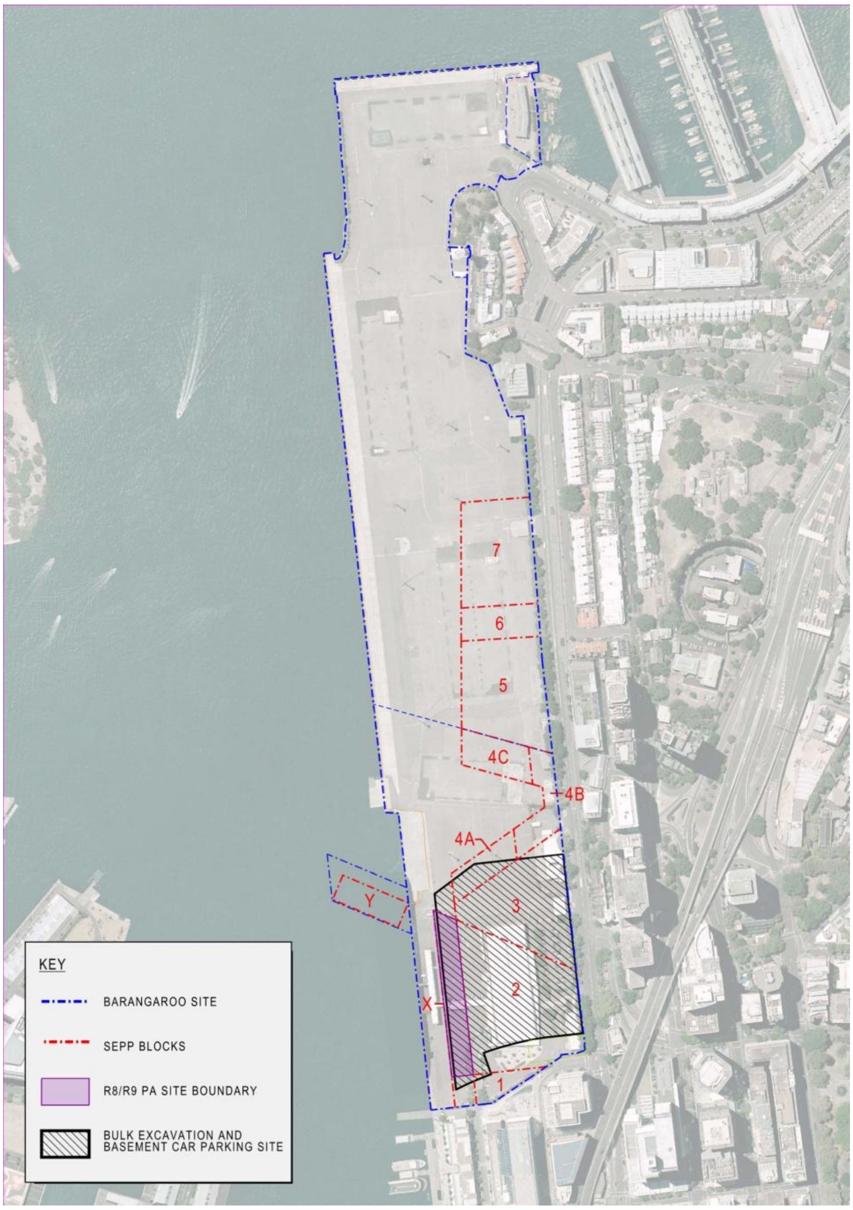

Figure 1: R8 and R9 Residential Building Project Application (MP11_0002) Aerial Site Location Plan

1.3 Purpose of this Report

This report has been prepared to accompany the Project Application for the R8 & R9 Residential Buildings and associated works at Barangaroo South. It addresses the relevant Director-General Requirements for the project.

These Director-General Requirements are discussed in the Environmental Assessment Report (EAR) that has been prepared to support the application.

This report has been prepared on the basis of existing information that is available for the site, information from adjacent sites and other geological / geotechnical information available within the public arena.

The R8 & R9 Residential Buildings Project Application is limited to the extent of the subject site discussed in Section 1.2. This assessment report supports and informs the application but also discusses the geotechnical issues associated with the wider Barangaroo South site in the context of the scope of the Project Application.

1.4 Scope

This geotechnical report has been prepared to support the Project Application for the R8 & R9 Residential Building and to inform the early stages of design. The report includes the following:

- Site description including discussion on topography and regional geology, soils and groundwater regimes;
- A brief discussion of the historical development of the site;
- Summary of existing investigative information for the site and the surrounding area;
- Development and discussion of a preliminary geological model for the site including preliminary design parameters for the various soil and rock units encountered;
- Development and discussion of a preliminary hydro-geological model for the site and discussion on potential impacts of the development on those conditions; and
- Preliminary engineering advice appropriate to the Project Application for the R8 & R9 Buildings.

1.5 Limitations

This report contains an interpretation of existing available geotechnical information of the site. The ground is a product of continuing natural and man-made processes and therefore exhibits a variety of characteristics and properties which vary from place to place and can change with time. Geotechnical and environmental engineering involve gathering and assimilating limited facts about these characteristics and properties in order to understand or predict the behaviour of the ground and groundwater on a particular site under certain conditions. Arup may report such facts obtained by inspection, excavation, probing, sampling, testing or other means of investigation. If so they are directly relevant only to the ground and groundwater at the place where and at the time when the investigation was carried out and is believed to be reported accurately. Any interpretation or recommendation given by Arup shall be understood to be based on judgement and experience and not on greater knowledge of the facts than the reported investigations would imply. The interpretation and recommendations are therefore opinions provided for our Client's sole use in accordance with a specific brief. As such they do not necessarily address all aspects of ground behaviour on the subject site.

2 The Site

2.1 Existing Structures

There are a number of existing structures on or surrounding the site comprising the following:

- A temporary cruise passenger terminal to the north;
- A number of low rise commercial / industrial buildings exist along the eastern boundary of the site associated with the former port operation, which have been demolished under consent S07/01342-1.
- The existing caisson walls that form the edge of the existing wharf area as described in Section 3.2.1. This includes the walls of the infilled Wharf 7 that are anticipated to remain buried towards the northern extent of the site.

In addition to the structures described above, it is anticipated that a significant number of remnant structures related to the long maritime usage of the site remain in-situ. These structures may include dock walls and piles of various types and sizes.

2.2 Topography

The ground surface over the entire site lies at an elevation of approximately +2mAHD. The surface of the site is paved with either asphalt or concrete.

The surrounding landform rises rapidly towards the east. A significant sandstone cliff exists on the eastern side of Hickson Road/Sussex Street which is in the order of 8-10m in height. This is consistent with the sandstone landform which weathers along the sub-vertical defects in the rock mass to create a series of steps. It is likely that this stepped structure continues beneath the fill and alluvial materials present on the site.

2.3 Regional Geology and Geomorphology

The Sydney Geological Map scale 1:100,000[1] (see Figure 2) and the Sydney Geological Map scale 1:250,000[2] indicate that the site is underlain by the Hawkesbury Sandstone of the Wianamatta Group, which is overlain by Quaternary sediments and manmade fill. The geological map indicates that the majority of the Barangaroo South site is underlain by manmade fill. This is consistent with the knowledge that the majority of the site has been reclaimed successively since the late 1800's.

The Barangaroo South site is located adjacent to the Sydney Harbour. The Sydney Geology Sheet Memoir (Herbert, 1983) states that Sydney Harbour is a drowned river valley system characterised by steep sided valleys in Hawkesbury Sandstone.

The Hawkesbury Sandstone is a medium to coarse grained quartz sandstone, with occasional minor shale and laminite lenses. The sandstone comprised massive,

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1 *Geological Map of Sydney, Geological Series Sheet 9130, N.S.W Department of Mineral Resources, First Edition 1983*

2 *Geological Map of Sydney, Geological Series Sheets S1 56-5, Geological Survey of N.S.W, Third Edition 1966*

bedded and cross-bedded units (massive and sheet facies). Structure within the Hawkesbury Sandstone generally comprises sub-horizontal undulating bedding plane seams and cross bed partings and two sub-vertical joint sets with general orientations of approximately 100 - 140° and 350-20°.

Several well documented structural lineaments pass through the Hawkesbury Sandstone beneath the greater Sydney CBD [3], generally striking in a NNE direction. These features generally comprise significant closely spaced sub-vertical jointing and faulting with significant vertical and horizontal continuity. The rock mass surrounding these features may be more weathered and of lower strength than adjacent areas.

In addition a number of igneous dykes are present, generally orientated approximately orthogonal to the structural lineaments. These intrusions are generally sub-vertical with thicknesses of 0.5m to several metres.

The dyke material is often highly weathered to significant depths and can comprise high to very high strength rock at depth. The rock mass around these intrusions can be disturbed with significant sub-parallel fracturing, associated deeper weathering and reduced strength.

Both the structural lineaments and dykes can be associated with instability and elevated groundwater inflows when encountered in excavations.

The location of structural lineaments and igneous dykes within proximity of the site are illustrated in Figure 2.

The Luna Park Fault Zone has been mapped in the Luna Park excavation, Towns Place basement excavation, Star City basement and in a rail cutting near the Fish Markets[4]. Thrust faulting, significant shear zones and significant sub-vertical jointing have been recorded in observations of the Luna Park Fault Zone. In addition, the fault zone is associated with significant reductions in rock strength. Extrapolation of the alignment of the fault zone shows it to cross the site near the northern extent of Barangaroo South.

The Pittman LIV Dyke traverses the CBD, sub-parallel to Grosvenor and Bridge Streets. The location of the dyke is inferred to cross near to the northern extent of Barangaroo South.

2.4 Soil Landscapes

The Sydney Soil Landscape Map scale 1:100,000[5] indicates the site is underlain by disturbed soils (see Figure 2).

The acid sulphate soil risk map for the site (Prospect/Parramatta River 1:25,000 Scale, 1997) indicates the site is underlain by disturbed terrain. A high probability of acid sulphate soil is associated with estuarine sediments in Sydney Harbour which are likely to underlie the manmade materials. The presence of disturbed ground is in agreement with the known progressive reclamation of the area since the late 1800's.

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3 *Map and Selected Details of Near Vertical Structural Features in the Sydney CBD*

4 *Sydeny metro Authority, CBD Metro, Geotechnical Interpretative Reportr CBD-2110-GHD-R-GE-001-[F], GHD Ceotechnics*

5 *Soil Landscapes Map of Sydney, Soil Landscape Series Sheet 9130, Soil Conservation Service of N.S.W., First Edition 1983.*

2.5 Hydrogeology

Data obtained from the Department of Natural Resources in 2006[6] identified 32 registered groundwater bores within 4km of the site. Of these 22 were for monitoring, 8 for recreation and 3 for irrigation. None of these boreholes were registered for drinking water purposes. No registered groundwater bores were identified on or adjacent to the site.

Considering the proximity to the harbour and the adjacent steep landform to the east, the hydrogeological conditions beneath the site are anticipated to be influenced by both groundwater flow from the east beneath the CBD and tidal fluctuations associated with the harbour. The groundwater profile would be expected to be approximately coincident with the harbour level near the western edge of the site, rising slightly to the east as the topographic influence takes effect.

ERM (2007)[7] indicates that the depth to water was recorded during July 2006 as ranging between 1.7 m and 2.5 m below ground level, and levels ranging from RL +0.07mAHD to RL +0.65mAHD.

Short term variations in groundwater levels were reported as occurring during drilling, particularly in locations close to the seawall. This, along with the generally saline nature of the groundwater, indicates that the groundwater regime on the site is likely to be strongly influenced by tidal fluctuation.

It is anticipated that the groundwater in the fill and alluvial materials is connected to that within the underlying Sandstone.

6 *ERM. 2007. Environmental Site Assessment East Darling Harbour, Sydney, NSW. Final Report – Rev 1. Report Ref 0044432RP02 Rev01 Final.*

7 *ERM. 2007. Environmental Site Assessment East Darling Harbour, Sydney, NSW. Final Report – Rev 1. Report Ref 0044432RP02 Rev01 Final.*

3 Site History

3.1 Historical Development

Early maps from around 1788 show a small settlement around the south western extent of Sydney Cove and the Tank Stream inlet. It is not until the map of 1836 that infrastructure and several small buildings are present near the eastern boundary of the site. It is envisaged that these roads and buildings are on the high ground to the east of the Hickson Road cliff line.

The historical maps and photography indicate that the majority of the site has been produced by land reclamation since the late 19th Century, and that it has predominantly been used for the berthing of ships and storage of materials from shipping.

A gas works operated by the Australian Gas and Light Company was located immediately northeast of the site between 1840 and 1921.

An account of the historical development of the site is illustrated in Figure 3 to Figure 5 and is summarised in Table 1.

Table 1: Summary of site history.

Date	Site	Surroundings
1836	The shoreline runs approximately along the line of the current Hickson Road.	There is development of the city in the Rocks and the CBD area. It appears to be largely housing with the military barracks located to the west of the current Wynyard Park and Fort Philip where the Observatory is currently located.
1840	A gasworks operated by The Australian Gas Light Company is present to the northeast of the site (ERM, 2008)	No information available.
1888	The gas works is located to the northeast of the site (tanks and wharves are shown on the map). A number of finger wharves are present within the site orientated east-west. The wharves continue south into Darling Harbour.	Reclamation of land around Millers Point has occurred along with the construction of several finger wharves orientated approximately north-south. Much of the current road network has been constructed from Millers Point through to the CBD. A number of small finger wharves had been constructed in the area that is currently known as Walsh Bay.
1922-1925	The gas works above ground were demolished and the gas holding tanks were backfilled (ERM, 2008).	No information available.

Date	Site	Surroundings
1951	Finger wharves (orientated east-west) have been established throughout the southern two thirds of the Barangaroo site.	The reclamation around Millers Point has been extended to (approximately) its current extent. A main road leading to the Harbour Bridge and toll booths has been constructed along with the approach ramp to the Cahill Expressway. The current large finger wharves in Walsh Bay have been constructed.
1961	Reclamation of the site is in progress. Wharf 7 remains open along with the finger wharves to the north and south.	The Cahill Expressway has been completed. No other significant changes.
1968	Warehouses have been built around the water's edge of the site and to the south.	No significant changes.
1970	Little change has occurred within the site.	The four remaining finger wharves in the centre of the site have been removed and the area was being reclaimed except for a small area between wharves 6 and 7. Tower blocks have been constructed in the Sydney CBD such as the Observatory Hotel and Australia Square.
1986	Little has changed on the site.	Reclamation of the area to the north of Wharf 7 is complete. Warehouses have been established in this area. Building heights throughout the CBD increased.
2000	The final dock area has been reclaimed (Wharf 7). Two warehouses had been removed and the Cruise Passenger Terminal has been constructed.	No significant changes.
2004	A short section (approx. 30m) of wharf extending westwards had been added in the location of the old finger wharf 6 (the berthing area for the Spirit of Tasmania).	No significant changes.
2008	All buildings on the site except for the Cruise Passenger Terminal and smaller ancillary buildings have now been removed.	No significant changes.

3.2 Underground Structures

3.2.1 Sea Wall

An assessment of the seawalls was undertaken in August 2005 by Sinclair Knight Merz (SKM). The report indicates that the construction of these seawalls is as follows:

- Wharves 3, 4, 5 & 8 – The wharves comprise of a reinforced concrete caisson construction filled with a sand material and topped with a concrete slab. The concrete slab level is approx. RL+3.0m with the toe of the caisson at RL-12 to -13m. The typical cross sections indicate that base of the caisson is approximately 11.9m in width and that there is “select sandstone fill” behind the caisson. The lateral extent of this sandstone fill is not reported but is shown to be approximately 6m wide at the level of the top of the caisson with a 1:1 rear slope.

- Wharf 3 – At the western end of the wharf is a sandstone wall construction topped with a concrete slab.
- Wharf 7 – 100m in length and just to the north of the recently demolished Cruise Terminal and comprises five rows of steel piles topped with a suspended concrete slab. The exact location of these rows of piles is not indicated in the drawings. Beneath the suspended slab, fill material slopes down to the harbour floor at a 2:1 gradient. The surface of the slope is protected with a 1200mm thick layer of rock armour.

A typical section through Wharves 3, 4, 5 & 8 is provided in Plate 1 below. The coping detail of Wharf 8 is slightly different to the others sections but the general cross section is similar. A typical cross section through Wharf 7 is provided in Plate 2 below.

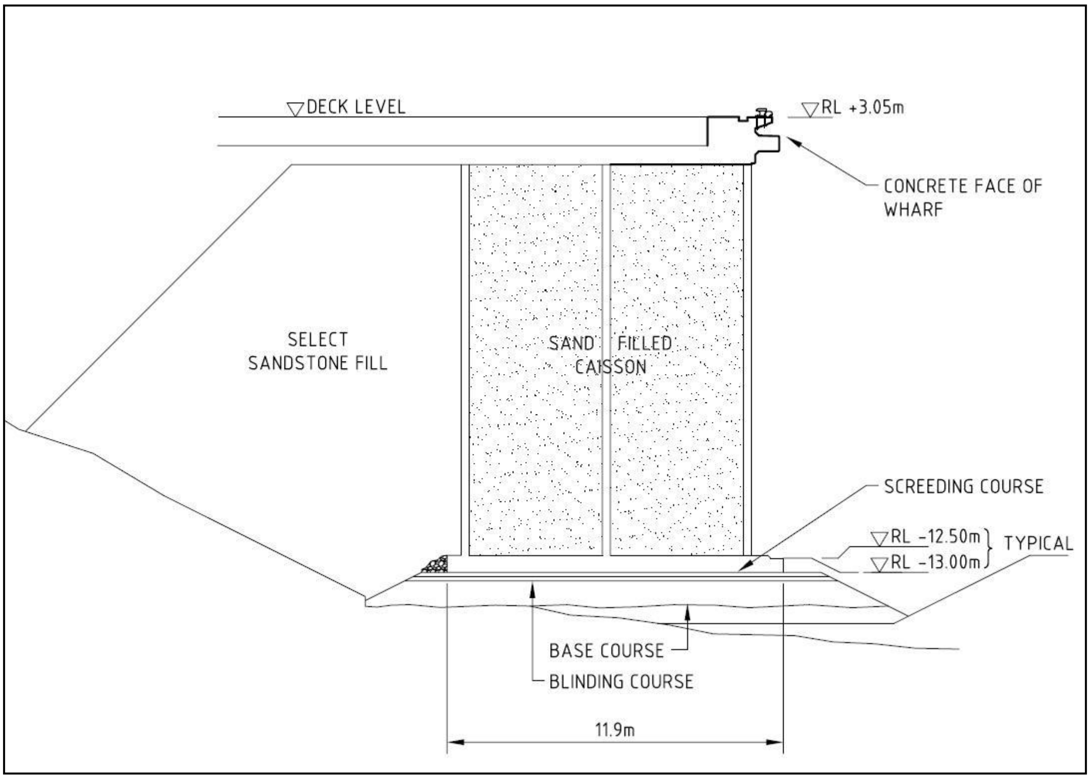

Plate 1: Typical Section of Wharves 3, 4, 5 & 8 (SKM August 2005)

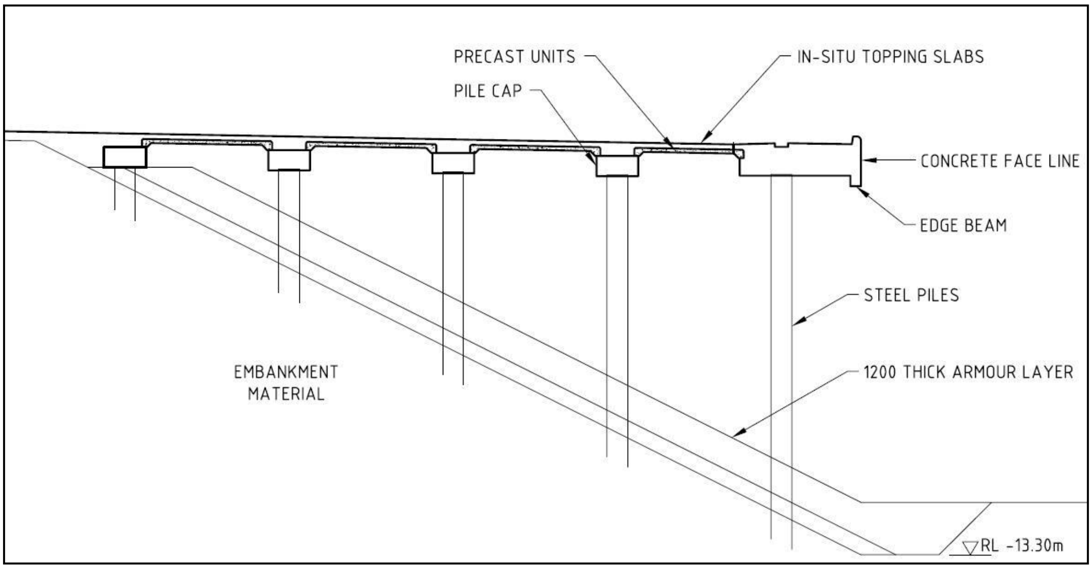

Plate 2: Typical Section of Wharf 7 (SKM August 2005)

The SKM report does not contain information about the form of sea wall that was used to support the northern and southern side of the former dock at Wharf 7; the last of the docks to be infilled. Aerial photography from 1961 (Figure 4) clearly shows the reclamation of the area to the south of Wharf 7. Evidence of caisson units similar to those used to support Wharves 3, 4, 5 and 8 can be seen in the photograph. Similarly, aerial photography from 1970 (Figure 4) shows the reclamation of the area to the north of Wharf 7. Again, similar caisson units are clearly visible along the north extent of the former dock.

On the basis of the aerial photography, it is envisaged that the northern and southern sides of the former dock were formed using caisson units similar to those used to support Wharves 3, 4, 5 and 8.

In addition, photography from August 1982 (not published herein) shows 2 ships berthed in the former dock, one berthed along each of the northern and southern sides of the dock. This suggests that it was dredged to a depth similar to that of the other wharves.

3.3 Existing Foundations

It is likely that remnant foundations and other underground elements remain in-situ from many of these former structures including; wharf structures, historic dock walls, building foundations etc. Reference should be made to the Non Indigenous Archaeological Assessment [8] (Casey and Lowe, May 2010) in which historical maps document the development of the Barangaroo site up to the present day. The historical maps could be used to provide an indication of the location of potential obstructions for further investigation or to inform construction activities.

The exact source and nature of the fill used in the reclamation of the site is unknown. Significant construction activities ongoing in Sydney around the time of the reclamation include the construction of the Eastern Suburbs Railway, Australia Square and Centre Point. Although it could be anticipated that the majority of the fill was derived from excavation in Hawkesbury Sandstone

8 *Casey & Lowe, May 2010. Archaeological Assessment, Barangaroo, South, Draft*

associated with construction, it is anticipated that little control was placed on the material or placement and the presence of foreign matter such as demolition rubble, construction waste, refuse and other undesirable material should be anticipated.

3.4 Future Metro

The CBD Metro was approved on Jan 1, 2010, and subsequently cancelled by the NSW Government. However, the corridor of the proposed CBD Metro is required to be respected.

The corridor of the proposed CBD Metro runs beneath the southern extent of the Barangaroo South site. The proposed foundations of R9 are in the vicinity of the Metro tunnel. Refer to the Assessment of Interaction with Sydney Metro Report for further detail.

4 Existing Information

4.1 Previous Site Investigations

There have been several site investigations carried out across the Barangaroo area. The investigations include:

- ERM. 2007. Environmental Site Assessment East Darling Harbour, Sydney, NSW. Final Report – Rev 1. Report Ref 0044432RP02 Rev01 Final;
- ERM. 2008. Draft Stage 2Remedial Action Plan for Barangaroo, Hickson Road, Sydney. Report Ref 0087036R03 Draft Rev02;
- Jeffery and Katauskas Pty Ltd (J&K). May – July, 2006. For Sydney Harbour Foreshore Authority;
- Arup Pty Ltd. Jan 1986 (Arup). For Maritime Services Board of NSW;
- Coffey Geotechnics. 2009. CBD Metro Contract 136 – Geotechnical Data Report. Central Station to Rozelle. Report Ref GEOTLCOV23558AB-AG dated 27 February 2009.

Figure 6 shows borehole locations from these investigations.

Additional drilling has been undertaken during the first quarter of 2010 for the purposes of contamination studies. To date, Arup has not been issued with this data. The drilling was concentrated between the northern end of the recently demolished Cruise Terminal and Function Centre at Wharf 8 and the northern extent of Barangaroo South.

4.2 Relevant Site Investigations at Nearby Sites

4.2.1 Walsh Bay Investigations

During the period from 1997 to 2001, Arup Geotechnics undertook several phases of investigation over the wider Walsh Bay area to inform the redevelopment of the Walsh Bay Finger Wharves and a number of the Bond buildings on the southern side of Hickson Road; in particular Bond Store 3 and 4.

Boreholes located along Hickson Road to the north of Walsh Bay revealed that the ground is generally underlain by fill, marine deposits, residual soil and sandstone. The rockhead profile varies between -16.71mAHD and +2.7mAHD dipping from south to north. Two boreholes exhibit fractured core and closely spaced high angle jointing. These boreholes are generally along the apparent strike of the Luna Park Fault Zone.

In addition, bathymetric survey work was completed in the harbour around and to the north of the finger wharves. This survey clearly identified a significant depression in the rock head along the apparent strike of the Luna Park Fault Zone.

4.2.2 Bond Store 1, Walsh Bay

The work carried out was part of the redevelopment of the Bond Store 1 site into a new seven storey commercial building. The development includes a four level basement excavated in Sandstone and associated shallow foundations.

The investigation was completed in a number of phases. In total, the investigation comprised the drilling of 7 boreholes, including 2 inclined holes, 4 coreholes through the southern masonry retaining wall and 7 test pits within the site.

The investigation concluded that the site was underlain by fill, residual soil and sandstone. The rockhead profile varies between -1.25mAHD and +1.7mAHD. Inclined boreholes were drilled to investigate the presence and proximity of the Luna Park Fault Zone. No evidence of the fault zone was found within the site or within a distance that would impact the development.

It is noted for completeness, that the Luna Park Fault Zone was encountered along the eastern face of the Towns Place excavation immediately to the west of the Bond Store 1 site.

4.2.3 30 The Bond

30 The Bond is located at 30 – 38 Hickson Road and comprises commercial and residential buildings. Several investigations have been carried out on this site including:

- October 1999, Woodward Clyde. Three boreholes cored to approximately 12m below ground level for the purpose of assessing the sandstone material for heritage Yellow Block use.
- October 1999. Woodward Clyde. A desk study based on data from previous investigations by Hyder, Axis, LHO and Woodward Clyde. This assessment was principally targeted at contamination issues with only indirect reference to geotechnical conditions.
- February 2002. URS. Two monitoring wells were installed for contamination and hydraulic conductivity testing. In conjunction with this, investigations were also undertaken to investigate a buried tar tank (one hole) close to the western boundary and to determine the depth to bedrock at the northern end of the property.
- April 2002. Coffey Geosciences Pty Ltd. A desk study based on reports by Woodward Clyde, URS, and Coffey. This report included information from previous investigations of 127 Kent Street (Esso House Extension) and 189-193 Kent Street. Face mapping of adjacent exposed rock was also undertaken.

The findings of the reports indicate that the site is generally underlain by a shallow layer of fill overlying sandstone. Deeper areas of fill occur in areas where former gas works structures / excavations have been backfilled.

4.2.4 Sydney Metro Ground Investigations

Ground investigations were undertaken for North West and CBD Metros between July 2008 and February 2009 by Coffey Geotechnics. The investigations involved extensive geotechnical investigations between Central Station and Rozelle including:

- Borehole drilling;
- Laboratory testing;
- Water pressure testing;

- In-situ stress testing;
- Borehole imaging; and
- Geophysical investigations.

The results of the investigations are published in a number of Coffey Geotechnics reports.

The investigation involved the drilling of a number of deep boreholes towards the southern end of the site including downhole borehole imaging, in-situ stress measurement, groundwater installations and laboratory testing. In addition, a number of overwater boreholes and CPT tests were completed in Darling Harbour to the west of the site.

Interpretation of the investigation is reported in GHD Report; Sydney Metro Authority, CBD Metro, Geotechnical Interpretative Report, August 2009.

In addition to the geotechnical investigation, marine bathymetry surveys have been completed within Darling Harbour to the west of the site.

The former Sydney Metro Authority (now part of the Department of Transport) has granted the Barangaroo Delivery Authority permission to use the information from the metro investigation for the purpose of the Barangaroo project.

5 Ground Conditions

5.1 General – Ground Conditions

The following sections are intended to provide an appreciation of the anticipated ground conditions and properties of the various soil and rock units encountered. It is noted that this interpretation is based on information from a range of different sources. The majority of the geological and geotechnical information that exists for the site has been obtained for the purpose of investigating the known contamination on the site and hence contains little geotechnical information. The interpretation provided below has been prepared to support the R8 & R9 Building Project Application and to inform the early stages of design. This report does not replace the need to undertake a detailed geotechnical investigation. The interpretation and associated recommendations will need to be revisited following completion of the detailed investigation.

5.2 Encountered Stratigraphy

The geotechnical information indicates the presence of a number of soil and rock types across the site. These materials have been categorised into soil and rock units with similar geological and engineering characteristics.

The entire Barangaroo South site is underlain with a variable depth of fill which generally deepens in a westerly direction towards the existing sea wall. Underlying the fill is a variable depth of natural material. There is significant inconsistency in the logging of this material between the subsequent investigations which makes interpretation difficult. The majority of the material appears to be of marine or estuarine origin. However, some of the materials do display characteristics of residual soil. For the purpose of this report, all of these materials are considered to be marine / estuarine deposits. This is consistent with the depositional environment where any mantle of residual soil and weathered rock would most probably have been eroded during formation of the harbour, prior to the deposition of further sediments. This should be considered further during the detailed ground investigations.

To obtain a thorough understanding of the variable stratigraphy across the Barangaroo South site, the boreholes from the previous investigations (refer Section 4) were entered into a GIS model and from this data surfaces for the various rock and soil units have been created.

The GIS model has been utilised in conjunction with the geotechnical database for the site to produce a number of geological cross sections which are presented as Figure 7 to Figure 11.

A general description of the ground conditions encountered across the site is presented in Table 2.

Table 2: Summary of Stratigraphy.

Unit	Description	Gauged Thickness (m)	Typical Distribution
1	Fill : concrete and asphalt, granular material, comprising sandy GRAVELS, gravelly SANDS, sand, clayey SILT, crushed rock, building rubble, re-worked marine sediments	2.4m to 21m	Increasing in thickness in a westerly direction towards the existing sea wall.
2	Marine / Estuarine Sediments: silty CLAY, sandy CLAY, silt, and clayey SILT, and clayey SAND	0m to 14.2m	Thickening in sequence to the west with the maximum thickness west of centre. Notably absent to the north east of the site.
3	Hawkesbury SANDSTONE: medium to coarse grained with layers of SILTSTONE and laminite	Unproven.	Bedrock shallow along the eastern boundary and generally increases in depth towards the west. Distinct northwest trending trough across the centre and south of the site. Bedrock drops steeply to the west towards the north of the site.

The GIS model in conjunction with the geotechnical database has been used to create contoured surfaces of the following transitions:

- The base of the fill / top of the marine / estuarine sediments – refer Figure 12
- The base of the marine / estuarine sediments / top of the sandstone – refer Figure 13.

5.3 Fill

5.3.1 Description and Classification

The whole of the site is capped with a layer of asphalt and/ or concrete which is typically between 25mm and 200mm thick.

The fill beneath the site comprises a highly variable material placed during successive stages of reclamation and development. The fill generally comprises granular material such as crushed rock, sand and gravel. Occurrences of decayed organic matter, igneous gravel, furnace clinker, brick, glass, ash, tile, charcoal, steel and timber are reported, as well as sandstone boulders and concrete. Infrequent occurrences of clay and silt are noted.

During the J&K investigation concrete layers were encountered up to 0.5m in thickness in a limited number of the boreholes, below which sample recovery was not possible. It is considered that the boundary between the fill and underlying strata may vary from that indicated on the logs. The 1986 Arup investigation boreholes for the upgrade of Wharves 7 and 8, suggest a zone where the granular fill material has mixed with the underlying alluvium, however this is not indicated on the J&K borehole logs.

The concrete obstructions encountered in the J&K boreholes and a timber obstruction, 0.5m in thickness in Arup BH7 may represent former structures buried during the reclamation.

Directly behind the caissons that form the sea walls of wharves 3, 4, 5, and 8, an area of select sandstone fill is expected. The select fill forms a block approximately 6m wide before sloping downwards at a gradient of 1:1.

The colour of the fill varies from black and tar stained through to white and orange.

The fill is generally moist, which is to be expected given the site's proximity to the harbour.

The consistency of the fill is also highly variable; reported as loose to dense; however no in situ testing was carried out with depth in the J&K boreholes and no Standard Penetration Test (SPT) results were reported on the ERM boreholes. Based on the material descriptions, numerous loose zones are present within the fill profile, with no discernible pattern. However, the loose nature of the material may be a product of the drilling method used in the J&K boreholes. The boreholes drilled as part of the 1986 Arup investigation suggest that the fill material is generally very loose to loose in density with 4 of the boreholes suggesting loose fill for the full depth and the remaining boreholes suggesting medium dense fill near the surface becoming loose with depth.

SPT N values recorded as part of the Arup investigation within the fill generally ranged between 4 to 12, and where refusal was recorded this would reflect the sandstone, brick or concrete fill within the material. Within the Coffey boreholes, SPT N values within the fill ranged between 2 to 32 and refusal.

5.3.2 Engineering Properties

Preliminary engineering properties for the fill are provided in Table 3. It is noted that fill material is variable and uncertainties exist on the method and control of fill placement during the reclamation process.

Table 3: Preliminary engineering properties for fill

Property	**Fill**
Bulk Unit Weight (γ_{sat})	18 kN/m^3
Angle of Shearing Resistance (ϕ')	28° (26° for loose materials)
Cohesion (c')	0 kPa
Drained Modulus (E')	10,000 kPa
Poisson's Ratio (ν')	0.3
Hydraulic Conductivity	10^{-1} to 10^{-3} m/day

5.4 Marine / Estuarine Sediments

5.4.1 General – Marine / Estuarine Sediments

As discussed in Section 5.2 there is significant inconsistency in the logging between the various investigations, which makes it difficult to distinguish between materials of marine or estuarine origin and those that may be residual soil. For the purpose of this report, these materials are treated as a common unit. This interpretation may change once further information is available from the detailed investigation. It is important that the future investigation and testing regime (in-situ and laboratory) address this inconsistency as it may have a significant impact on the design.

5.4.2 Description and Classification

The marine/estuarine deposits typically comprise either:

- Clayey or silty fine to coarse SAND, generally dark grey to grey and orange brown, with clay bands, trace organic matter, occasional ironstone gravel and some shell fragments; or
- Silty and sandy CLAY, generally low to medium plasticity, light to dark grey and red brown mottled grey with moisture contents above the plastic limit. Trace shell fragments noted. A peaty clay was encountered in two of the Arup boreholes varying in thickness between 1m to 1.5m and described as stiff in BH4.

Within the J&K boreholes, no in-situ testing (SPT) was carried out within the marine/estuarine deposits and based on visual material descriptions noted on the ERM borehole logs, the granular material is described as loose to dense. SPT N values within the granular material recorded in the Arup boreholes ranged between 3 to 46 and within the Coffey boreholes within the site boundary ranged between 4 and 8.

The cohesive material has been described as ranging between very soft to stiff in consistency. An SPT N value of 2 was recorded within one of the Coffey boreholes.

The marine/estuarine sediments generally thicken towards the west of the site with thicker deposits located towards the centre and west of centre of the site and towards the south of the site.

5.4.3 Engineering Properties

Preliminary engineering properties have been provided for both cohesive and non-cohesive materials. Given the variability in these materials, the designer should make their own assessment of the appropriate material behaviour given the ground conditions and the design under consideration. Further delineation and classification of these materials will be provided following the detailed investigation.

Preliminary engineering properties for the fill are provided in Table 4

Table 4: Preliminary engineering properties for marine sediments

Property	**Marine Clay**	**Marine Sand**
Bulk Unit Weight (γ_{sat})	18 kN/m^3	18 kN/m^3
Angle of Shearing Resistance (ϕ')	27°	30°
Cohesion (c')	0 kPa	0 kPa
Drained Modulus (E')	5,000 kPa	10,000 kPa

Property	Marine Clay	Marine Sand
Drained Poisson's Ratio (ν')	0.3	0.3
Undrained Shear Strength (c_u)	20 to 30 kPa	N/A
Undrained Modulus (E_u)	6,000 kPa	N/A
Undrained Poisson's Ratio (ν_u)	0.5	N/A
Hydraulic Conductivity	10^{-5} to 10^{-7} m/day	10^{-1} to 10^{-3} m/day

5.5 Sandstone

5.5.1 Description

The Hawkesbury Sandstone comprises quartz sandstone with minor shale lenses. Two sandstone facies have been identified; a massive facies and a sheet facies. Both will exist below the site. The sandstone is variably weathered and ranges from extremely weathered to slightly weathered and fresh. The depth of weathering is likely to extend at least 10m below the top of rock.

The contours of the surface of the Hawkesbury Sandstone (refer Figure 13) illustrate three troughs in the bedrock surface. At the north of the site a NE-SW trending trough is very likely to be an expression of the Luna Park Fault. In the centre of the site an E-W trending trough is likely to be an expression of the Pittman LIV dyke. At the southern end of the site a NW-SE trending bedrock trough is not associated with any mapped geological structure. However, its trend is typical of many dykes in the Sydney CBD.

5.5.2 Classification

The sandstone has been classified in accordance with the classification system recommended by Pells [9] in order to obtain an appreciation of the nature and consistency of the rock mass. The classification is included on the geological cross section presented as Figure 7 to Figure 11.

The sandstone encountered in the investigations typically comprises orange brown to grey mottled brown red becoming light grey to grey, fine to medium massive sandstone.

In general, based on the Pells classification, about 0.5m to 5m of Class V and, or Class IV sandstone was found to overlie generally Class III sandstone. At depth the sandstone is predicted to be Class III or better. It should be noted that not all the J&K boreholes were cored, and where cored the sandstone was generally penetrated to between 1.6m to 5.9m. Interpretation of the Coffey boreholes suggests Class II sandstone to occur with depth, generally 2 to 3m below the upper surface of the bedrock.

In the majority of the cored boreholes, some sub horizontal and trace sub vertical joints were noted within about 3m of the upper surface of the bedrock.

[9] *Foundations on Sandstone and Shale in the Sydney Region, Pells, Mostyn and Walker, Australian Geomechanics – December 1998.*

5.5.3 Structure

Downhole borehole wall imaging (conducted by RAAX Australia Pty Ltd) was carried out within 3 of the CBD Metro boreholes drilled within the south of the site. Defect dip orientations and magnitude were recorded in addition to defect interpretation.

The log for BH214 [10] indicates a Class III sandstone zone within 3m from the upper surface of the sandstone. Numerous joints were recorded within this zone based on the core description. The RAAX imaging indicates 2 shear zones within this section of the core with dip magnitudes of 9 to 15 degrees and dip directions to the southwest (196 to 267 degrees) and northwest (334 degrees). The thicknesses of the shear zones were reported to range between 52mm to 145mm. Three joints were recorded in the imaging with dip magnitudes between 22 to 49 degrees generally to the south west (237 to 266 degrees). Remaining defects with depth were recorded as partings and occasional joints.

The log for BH215 [10] indicates 1.5m of Class III sandstone below the upper surface of the bedrock. Seams and partings were recorded on the core description. The RAAX imaging indicates 3 joints within this zone with dip magnitudes ranging between 10 to 24 degrees with varying directions (east, south and west).

A sub vertical joint was recorded dipping to the North West at 31m depth. Two shear zones with dip magnitudes of 3 and 11 degrees and dip directions generally to the south west were recorded between 19m to 24m. Remaining defects include partings and bedding laminations.

The log for BH216 [10] indicates 2.5m of Class IV sandstone below the upper surface of the bedrock. Seams and partings were recorded on the core description. The RAAX imaging indicates that the majority of the defects are partings and bedding laminae. One shear zone is recorded at 13.6m with a dip magnitude of 11 degrees to the north east. Three shear zones are recorded between 28m to 32.5m with dip magnitudes between 11 to 23 degrees and directions to the north east (31 to 56 degrees). Shear zone thicknesses of between 14mm to 60mm were recorded. Subvertical joints dipping to the west were recorded below 35m

5.5.4 In-situ Stress Field

High in-situ stress fields in a rock mass can result in stress relief movements during excavation. Stress relief movements in the order of 0.5 – 2mm per metre of excavation can be expected during deep excavations in Hawkesbury Sandstone due to this effect. Scholey & Speechley reported significant stress relief movements during excavation on the KENS site between Kent and Sussex Streets. Movement of up to 30mm occurred in the walls of the excavation and apparent floor heave lead to the opening of bedding planes.

The presence of high lateral in-situ stresses in the Hawkesbury Sandstone is well documented by authors such as Pells (1985 and 1990), Enever (1990 and 1999) and McQueen (2004). Whilst there are a number of postulated models for the in-situ stress field beneath Sydney, it must be recognised that there are a number of features that may lead to local variations; including:

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10 Coffey Geotechnics. 2009. CBD Metro Contract 136 – Geotechnical Data Report. Central Station to Rozelle. Report Ref GEOTLCOV23558AB-AG dated 27 February 2009.

- Topographical influences including stress relief due to cliff lines and the concentration of stress beneath valleys and palaeochannels;
- The presence of geological features such as faults and dykes may cause local concentrations or local relief;
- The presence of weak layers and competent layers may lead to local reductions and local concentrations respectively; and
- Previous excavations may have resulted in localised stress relief.

Two of the postulated models for the horizontal stress field in the Sydney Basin are as follows:

Enever, 1999, suggested the following model for in-situ stresses to a depth of 200m:

- Major Horizontal Stress (σ_H) = 2.5 x σ_V, orientation 28° magnetic (40° true, NNE)
- Minor Horizontal Stress (σ_h) = 1.5 x σ_V, orientation 118° magnetic (130° true, ESE)

McQueen, 2004, suggested the following model for upper limit in-situ stresses:

- σ_H = 2.5MPa + σ_v down to 20 m depth, then σ_H = 6.5MPa + σ_v down to 200 m depth
- σ_h = 2 MPa + σ_v down to 20 m depth, then σ_h = 4.5MPa + σ_v down to 200 m depth

Stress testing carried out as part of the CBD Metro indicates that in general the principal horizontal stress direction (σ_H) measured is generally aligned north to north east. Stress testing was conducted in BH2103 34 towards the south east of the site on Napoleon Street (near the intersection with Kent Street). Four tests were conducted at reduced levels between -17.1m to -30.3m AHD. Two of the tests recorded the principal stress direction to the north but the remaining two results recorded stress directions varying from south west to North West.

Based on all stress tests conducted, an increase of σ_H with depth of 0.17MPa/m and an increase of minor principal stress (σ_h) with depth of 0.1MPa/m. was suggested by Coffey Mining. The results generally trend towards the upper bound model suggested by McQueen (2004) described above.

It is recommended that movement assessments are undertaken on the basis of the upper bound stress fields postulated by McQueen. The use of this upper bound stress field is considered consistent with the topographic location of the site and the possible concentration of the stress field beneath the Hickson Road cliff line and the palaeochannel beneath Darling Harbour.

5.5.5 Engineering Parameters

Geotechnical parameters for the purpose of retaining structure design are presented in Table 5.

Table 5: Preliminary engineering parameter for Sandstone

Material	**Bulk Unit Weight** γ' **(kN/m^3)**	**Angle of Shearing Resistance** φ' **(^{o})**	**Cohesion** **c' (kPa)**
Class V sandstone	22	35	15
Class IV sandstone	24	40	30
Class III sandstone	24	50	100
Class II sandstone	24	NA	NA

Recommended allowable bearing pressures for shallow and piled foundations and allowable shaft friction for piled foundations are presented in Table 6 below for the various sandstone rock classes in accordance with Pells et al (1998). The fill material and marine/estuarine sediments are not considered suitable founding stratums.

Table 6: Preliminary foundation design parameters for Sandstone

Material	**Allowable Bearing Pressure (MPa)[1]**	**Ultimate Bearing Pressure (MPa)[2]**	**Allowable Shaft Friction (kPa)[3]**	**Ultimate Shaft Friction (kPa)[3]**	**Young's Modulus E (MPa)**
Class V sandstone	1	3	100	150	100
Class IV sandstone	2.5	9.5	250	500	400
Class III sandstone	4.5	30	450	1100	750
Class II sandstone	9	60	900	2250	1500

[1] Allowable end bearing pressure for settlement of <1% of minimum pile diameter

[2] Ultimate end bearing pressure for settlement of >5% of minimum pile diameter

[3] Socket to be cleaned to roughness category R2 or better

For foundation purposes the rock class may require reclassification to allow for seams within the defined zone of influence for the chosen foundation type. For pad footings, the zone of influence is defined as 1.5 times the least footing dimension. For piled foundations, the zone includes the length of the socket plus a further depth equal to two times the pile diameter.

5.6 Groundwater

Groundwater across the site is heavily influenced by tidal fluctuations of the adjacent Darling Harbour.

Work done by ERM in 2008[11] monitored groundwater levels across the site found that at high tide, groundwater flowed inland at a gradient of 0.003, and at low tide towards the harbour at a gradient of 0.006.

In monitoring wells MW206 and MW209 (located on the eastern border of Barangaroo South), groundwater was observed to be flowing eastwards, and a high hydraulic conductivity in this area is indicative of direct hydraulic connection with Darling Harbour.

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[11] *ERM, 2008. Draft Stage 2Remedial Action Plan for Barangaroo, Hickson Road, Sydney. Report Ref 0087036R03 Draft Rev02*

At high tide, groundwater velocities were found to range from 3.2 and 28m/day inland and at low tide velocities were found to range from 6.3 to 57m/day. These values suggest that much of the site would be subject to significant seawater flushing.

Daily tidal ranges for Darling Harbour are typically 0.5m to 1.5m AHD. Sydney Ports give values for maximum high tide (Spring Tide) of 1.6m AHD, and minimum high tide (Neap Tide) of 1.3m AHD.

The exposed rock faces along Hickson Road were mapped for discontinuities and seepage. Minor seepage was noted from only one joint towards the northern end of the Barangaroo South area.

6 Engineering Advice

6.1 General

The following sections provide outline geotechnical advice that should be considered during the finalisation of the concept plan for the R8 & R9 Residential Building. The advice is preliminary in nature and should be reconsidered following the completion of the detailed ground investigation.

The advice provided herein has been constrained to advice related to the engineering of buildings R8 & R9 only. Advice related to the development of the wider Barangaroo South site and the common basement can be found in the following reports:

- Concept Plan Amendment – Arup Report 'Barangaroo South – Concept Plan Amendment – Modification No.4 (MP06_0162 MOD 4)', July 2010;
- Common Basement – Arup Report 'Bulk Excavation and Basement Car Parking (MP10_0023)', June 2010.

6.2 Foundations

6.2.1 General

Foundation conditions will vary across the site depending on building location, presence of a basement and proposed basement depth. Dependent upon the final building / basement geometry and the foundation loads, the following foundation options are considered feasible.

6.2.2 Shallow Foundations

Where rock is present at the basement level, spread footings are considered a feasible foundation option. The recommended foundation design parameters for the various rock classes are presented in Table 6. Settlements in the order of 1% of the minimum footing dimension can be anticipated for footings founded on rock using the design parameters provided above.

All spread footings should be socketed a minimum of 0.5m into the designated rock class. A geotechnical engineer should be engaged during construction to log the proof cores (where required) and to confirm the exposed foundation material satisfies the design requirements.

6.2.3 Piled Foundations

Where fill or marine/estuarine sediments are present at basement level or where foundation loads yield shallow foundations unfeasible, piled foundations to rock will be required. Bored piles may need to be cased over the depth of fill and marine/estuarine sediments to prevent collapse of this material into the shaft during construction. Alternatively, the pile bores could be constructed under support fluid such as bentonite.

Preliminary design of piled foundations should be undertaken using the foundation design parameters presented in Table 6. Piles should be designed with a nominal embedment into the design class of rock of 0.5m to develop the full design end bearing.

Rock socket design should utilise the parameters presented in Table 6 in conjunction with a design method that allows for stress distribution between the socket and the base. The geotechnical reduction factor (φ_g) should be adopted from AS2159 in accordance with the design case being considered and the quantum of available ground investigation information. Given the current level of ground investigation information, including limited information for the sandstone, a geotechnical reduction factor of $\varphi_g = 0.40$ is considered appropriate.

The information provided above is appropriate for preliminary design. The recommendations, including refinement of the geotechnical reduction factor will be provided following completion of the detailed investigation.

6.2.4 Site Seismicity

The Earthquake Design Category (EDC) for each of the buildings should be determined in accordance with AS/NZS1170.0–2002 and 1170.4–2007.The determination of the EDC is related to the following components.

The Hazard Factor (Z) and the Probability Factor (k_p) are specific to the location and type of building being designed and are not influenced by geotechnical conditions. Empirical data is presented in AS/NZS1170.4–2007 for annual probability of exceedance and hazard factors determined by area (for example Sydney is given a hazard factor of 0.08).

The Site Sub Soil Class is related to the stratigraphy and nature of materials beneath a site. A sequence of soft or loose materials overlying rock is anticipated to underlie the R8 & R9 footprint in the basement, resulting in a Site Sub-Soil Class of D_e or E_e.

The structure height also forms part of the EDC evaluation, and with regards to R8 & R9 it is anticipated that a preliminary EDC Class of III could be adopted.

6.2.5 Liquefaction

Based on the limited in situ testing completed to date and material observations there are zones within the fill and marine / estuarine deposits that are described as granular, loose and saturated. It is considered that liquefaction is a potential risk in these zones during a seismic event. Further testing is recommended to assess density and classification of these materials as the drilling methods utilised during the existing investigations may have loosened the material leading to inaccurate assessments. Investigation using CPT methods will provide the information required for this assessment. It is recognised that investigations using CPT methods may be problematic due to the variable nature of the fill and presence of obstructions.

The impact of potential liquefaction on temporary and permanent structures will require detailed assessment following completion of the detailed ground investigation.

6.3 Soil and Groundwater Aggressivity

6.3.1 Soil Aggressivity

Soil and groundwater aggressivity assessment for concrete and steel piles is generally carried out in accordance with AS3600-2001 'Concrete Structure' and AS2159-2009 'Piling Design and Installation'. Both standards require evaluation against soil pH, sulphate and chloride content in addition to location relative to sea water. Sulphate screening was undertaken by ERM, (2007) [12] with concentrations in soil varying between no trace and an isolated very high concentration of 31,500mg/kg. It is noted that no reference was provided as to the test method so direct comparison with AS2159 and AS3600 should be undertaken with caution. No reference to testing for Chloride or pH of the soil or soil/water extract is made.

A high potential of acid sulphate soil is associated with the estuarine sediments in Sydney Harbour and it is anticipated that the estuarine sediments underlying the site could have acid sulphate soil potential. Actual acid sulphate conditions only occur when the materials are exposed and allowed to oxidise. Where these sediments are to be exposed in excavations, aggressive conditions are likely to result. Durability design will need to assess this issue carefully.

Based on the variable nature of the soils beneath the site and the known presence of contaminants it is anticipated that aggressive conditions are likely to occur. In addition, given the proximity to the Sydney Harbour and the known high hydraulic conductivity of the granular fill materials, it is anticipated that exposure categories of Moderate to Severe in accordance with AS2159 are appropriate and B2 and C in accordance AS3600 are appropriate.

6.3.2 Groundwater Aggressivity

Sulphate concentrations of between 26mg/L to 3240mg/L, and pH ranging from 6.2 to 9.9 were recorded during the ERM [13] investigation.

When compared against the assessment criteria in AS3600:2001, the surface and exposure environment of B2 and C is appropriate depending on proximity to the harbour edge.

When compared assessed in accordance with AS2159:2009, considering the highly permeable soil condition and proximity to the harbour an exposure classification of moderate to severe is appropriate. Classification against pH suggests a mild exposure classification in accordance with AS2159:2009 which is considered un-conservative in this environment.

6.3.3 Further Testing

Further detailed testing in accordance with the requirements of AS2159 and AS3600 will be required during the detailed ground investigation to confirm the exposure classification and durability design requirements.

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12 *ERM. 2007. Environmental Site Assessment East Darling Harbour, Sydney, NSW. Final Report – Rev 1. Report Ref 0044432RP02 Rev01 Final.*

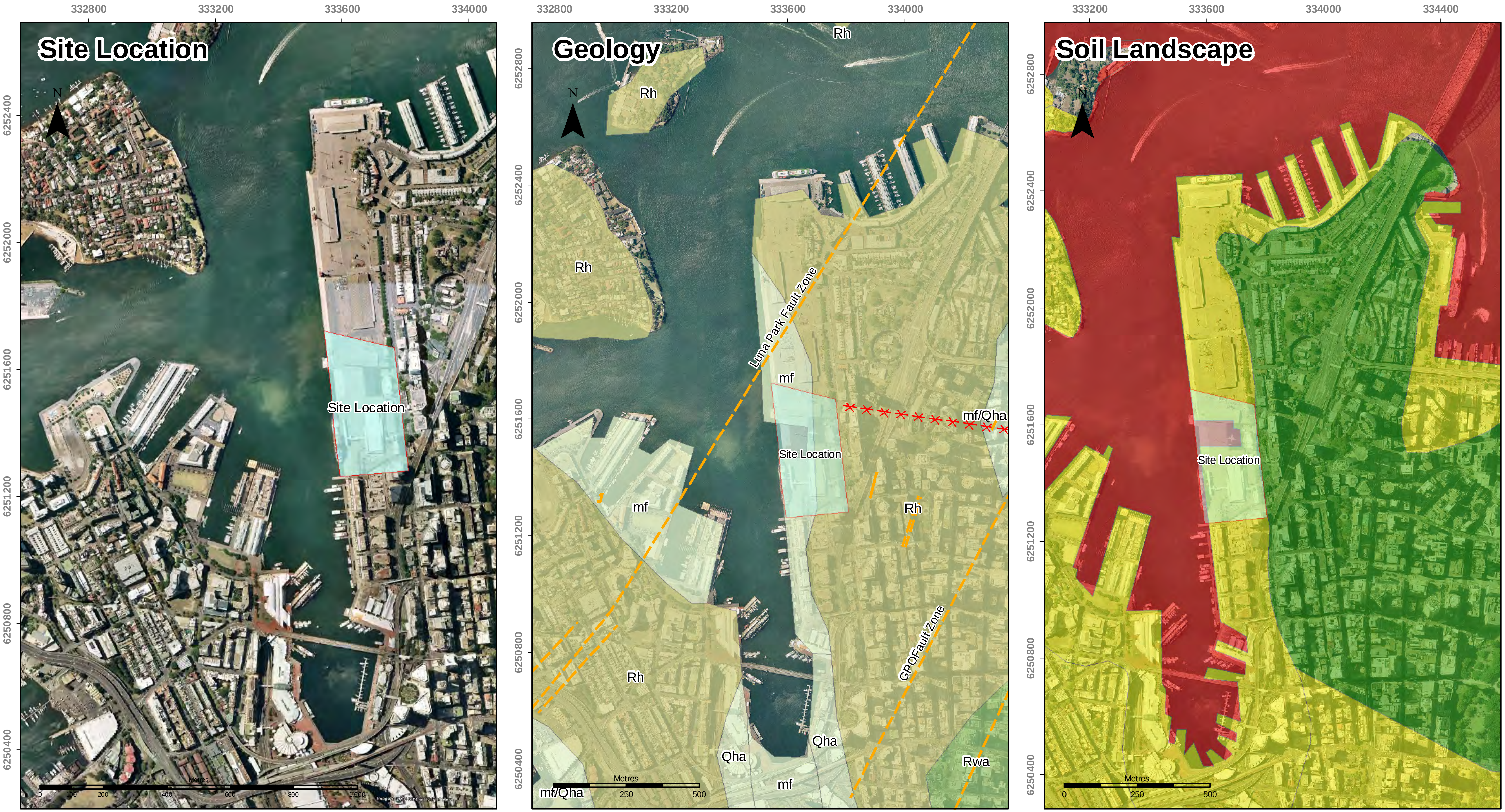
13 *ERM. 2007. Environmental Site Assessment East Darling Harbour, Sydney, NSW. Final Report – Rev 1. Report Ref 0044432RP02 Rev01 Final.*

7 Conclusion

This report identifies and discusses geotechnical issues relating to the R8 & R9 Residential Building development proposed as part of the Barangaroo South site. The purpose of the assessment is to inform and accompany the R8 & R9 Residential Building Project Application.

The geotechnical considerations highlighted in this report are appropriate for preliminary design purposes and will require validation and refinement during further geotechnical investigation to input into detailed design. Reference should be made to Section 1.5 of this report regarding the limitations of this assessment.

Based on the understanding of the ground conditions presented herein, our conclusion is that the project presented in the proposed R8 & R9 Residential Building Project Application can be designed and constructed utilising industry standard and proven design and construction techniques.



Legend

General

- Site Location

Geology

- Hawkesbury Sandstone
- Man-made Fill

Structural Geology

- Structural Zone
- Dyke

Soil Landscape

- High ASS Risk
- Disturbed Soils
- Low ASS Risk

Client
Lend Lease (Millers Point) Pty Ltd

Job Title
Barangaroo Stage 1
C4 Commercial Building

Issue	Date	By	Chkd	Appd
I3	26-05-2010	CB	MA	
I2	28-04-2010	CB	MA	
I1	13-04-2010	ICD	MA	AB

Drawing Title
Site Location and Geology

ARUP

Level 10 201 Kent Street
PO Box 76 Millers Point
Sydney, 2000
Tel +61 (2) 9320 9320 Fax +61 (2) 9320 9321
www.arup.com

Scale at A3
See Scale Bar

Drawing Status
Issue

Job No	Drawing No	Issue
220316-00	Figure 2	I3

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Legend

Phase 1 Area

Coast Outline (2010)

Metres
0 100 200 400

Client
Lend Lease (Millers Point) Pty Ltd

Issue	Date	By	Chkd	Appd
I3	26-05-2010	CB		
I2	28-04-2010	CB	MA	
I1	13-04-2010	ICD	MA	AB

Job Title
Barangaroo Stage 1
C4 Commercial Building

Drawing Title
Historical Map 1836 - 1951

ARUP

Level 10 201 Kent Street
PO Box 76 Millers Point
Sydney, 2000
Tel +61 (2) 9320 9320 Fax +61 (2) 9320 9321
www.arup.com

Scale at A3
1:8,000

Drawing Status
Issue

Job No	Drawing No	Issue
220316-00	Figure 4	I3

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Legend

- Phase 1 Area
- Coast Outline (2010)

Metres
0 100 200 400

Client
Lend Lease (Millers Point) Pty Ltd

Job Title
Barangaroo Stage 1
C4 Commercial Building

I3	26-05-2010	CB	MA	
I2	28-04-2010	CB	MA	
I1	13-04-2010	ICD	MA	AB
Issue	Date	By	Chkd	Appd

Drawing Title
Historical Map 1961 - 1970

ARUP

Level 10 201 Kent Street
PO Box 76 Millers Point
Sydney, 2000
Tel +61 (2) 9320 9320 Fax +61 (2) 9320 9321
www.arup.com

Scale at A3
1:8,000

Drawing Status
Issue

Job No	Drawing No	Issue
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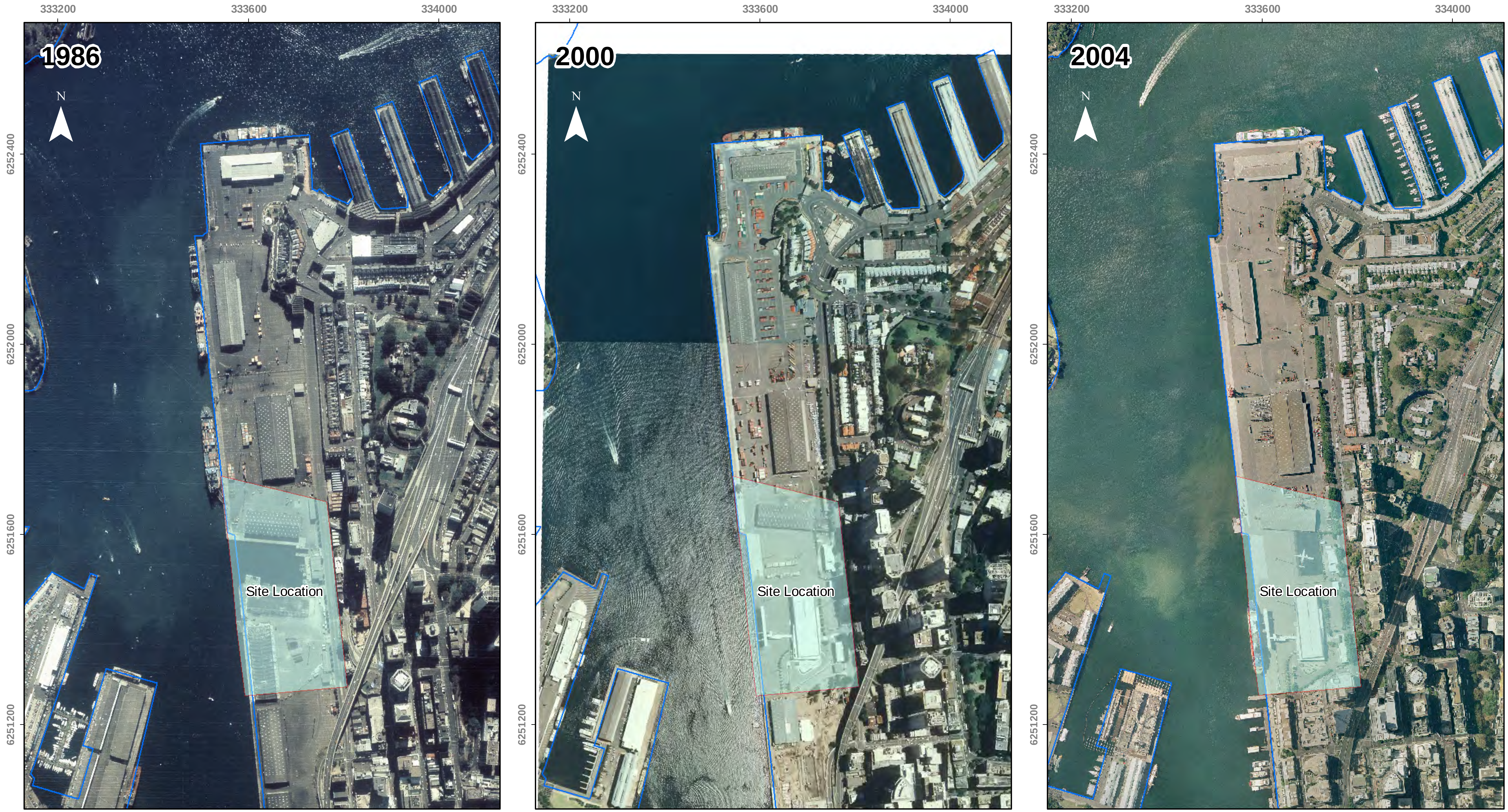

Legend

- Phase 1 Area
- Coast Outline (2010)

Metres
0 100 200 400

Client
Lend Lease (Millers Point) Pty Ltd

I3	26-05-2010	CB	MA	
I2	28-04-2010	CB	MA	
I1	13-04-2010	ICD	MA	AB
Issue	Date	By	Chkd	Appd

Job Title
Barangaroo Stage 1
C4 Commercial Building

Drawing Title
Historical Map

ARUP

Level 10 201 Kent Street
PO Box 76 Millers Point
Sydney, 2000
Tel +61 (2) 9320 9320 Fax +61 (2) 9320 9321
www.arup.com

Scale at A3
1:8,000

Drawing Status
Issue

Job No	Drawing No	Issue
220316-00	**Figure 6**	**I2**

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Legend

General

Phase 1 Area

Previous Investigations

- 30 The Bond
- CBD Metro
- ERM
- Jeffery and Katauskas Pty Ltd

Client
Lend Lease (Millers Point) Pty Ltd

Job Title
Barangaroo Stage 1
C4 Commercial Building

Drawing Title
Previous Site Investigations and Geological Cross Section Locations

Scale Metres
0 50 100

Issue	Date	By	Chkd	Appd
I3	26-05-2010	CB	MA	

ARUP

Level 10 - 201 Kent Street
Sydney, NSW, 2000
Tel +61 (2)9320 9320 Fax +61 (2)9320 9321
www.arup.com

Scale at A4
1:2,000

Drawing Status
Issue

Job No	Figure No	Issue
220316-00	Figure 7	I3

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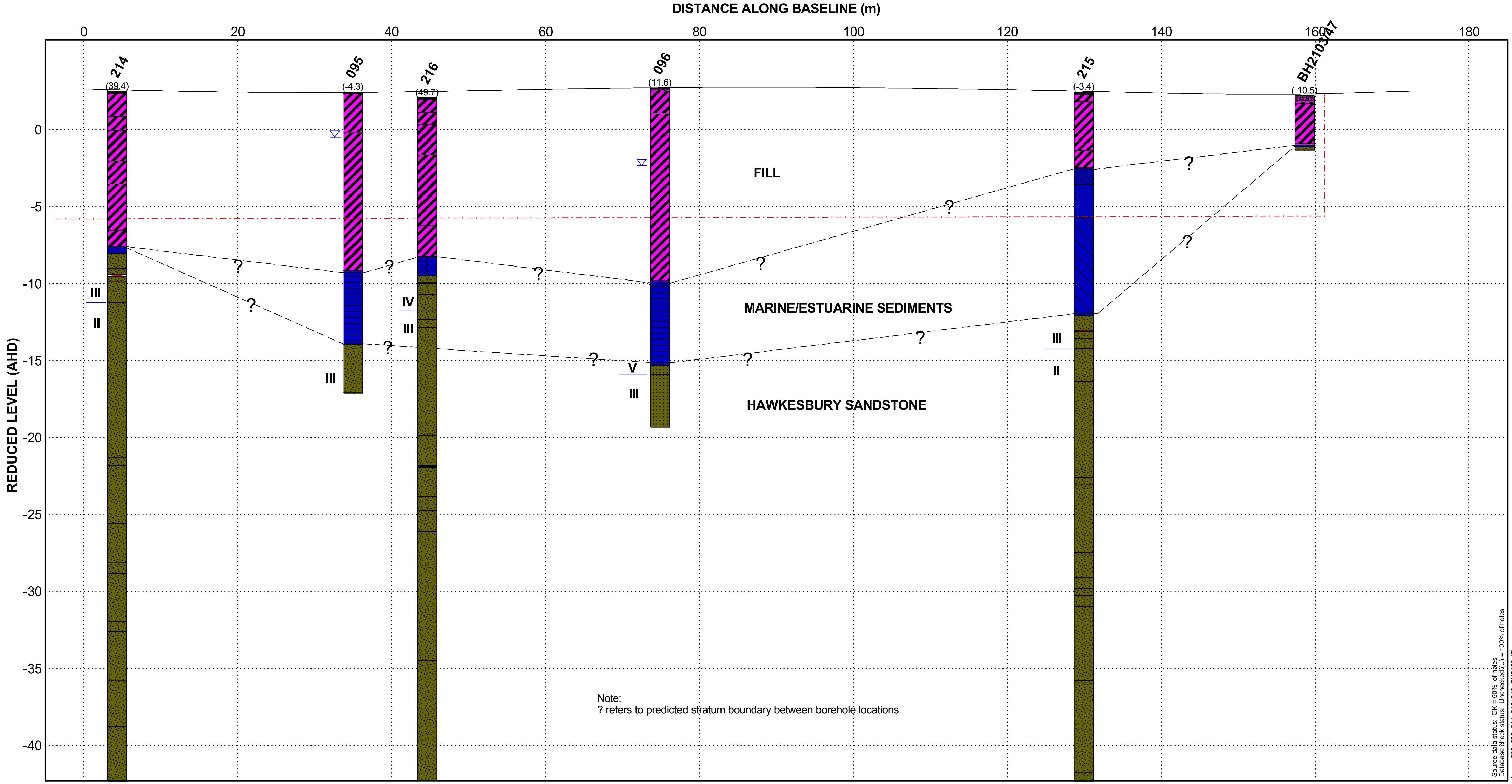

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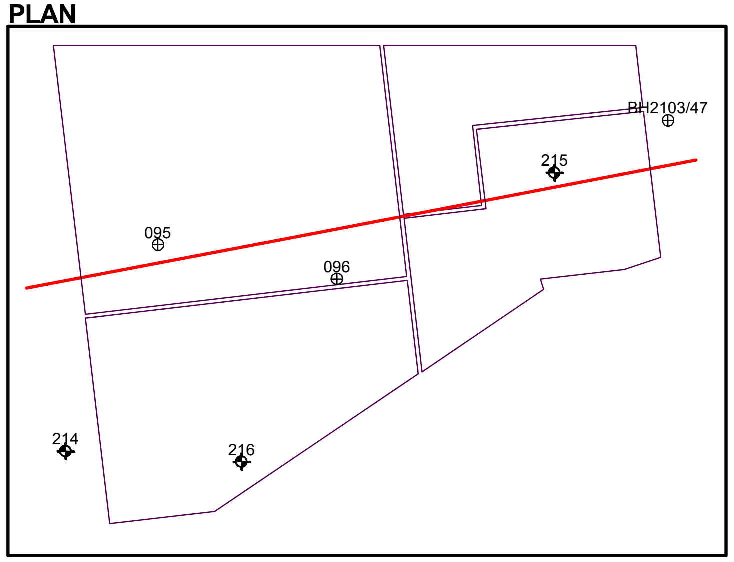
HoleID

(Offset)

SPT N value, * denotes N extrapolated by gINT:
* from main blows
** from seating blows

N20*

PLAN



- Water [WATER]
- Void / air [VOID]
- Hawkesbury Shale [Rhs]
- Hawkesbury Sandstone [Rh]
- Marine/Estuarine Sediments [RES]
- Marine/Estuarine Sediments [MARINE]
- Fill [FILL]
- Conglomerate [Cong]
- Concrete slabs, floor slabs etc [CONCRETE]
- Road surfacings [ASPHALT]

- Asphalt
- Fill
- Low plasticity inorganic Clay
- Sandstone (Australian version)
- Concrete
- Sandstone
- Clayey Sand
- Core loss
- Medium plasticity inorganic Clay
- Poorly graded Sand
- Silty Sand
- Siltstone (Australian version)

BARANGAROO SOUTH
CONCEPT PLAN AMENDMENT
GEOLOGICAL CROSS SECTION
Section A_A
220316

FIGURE 8

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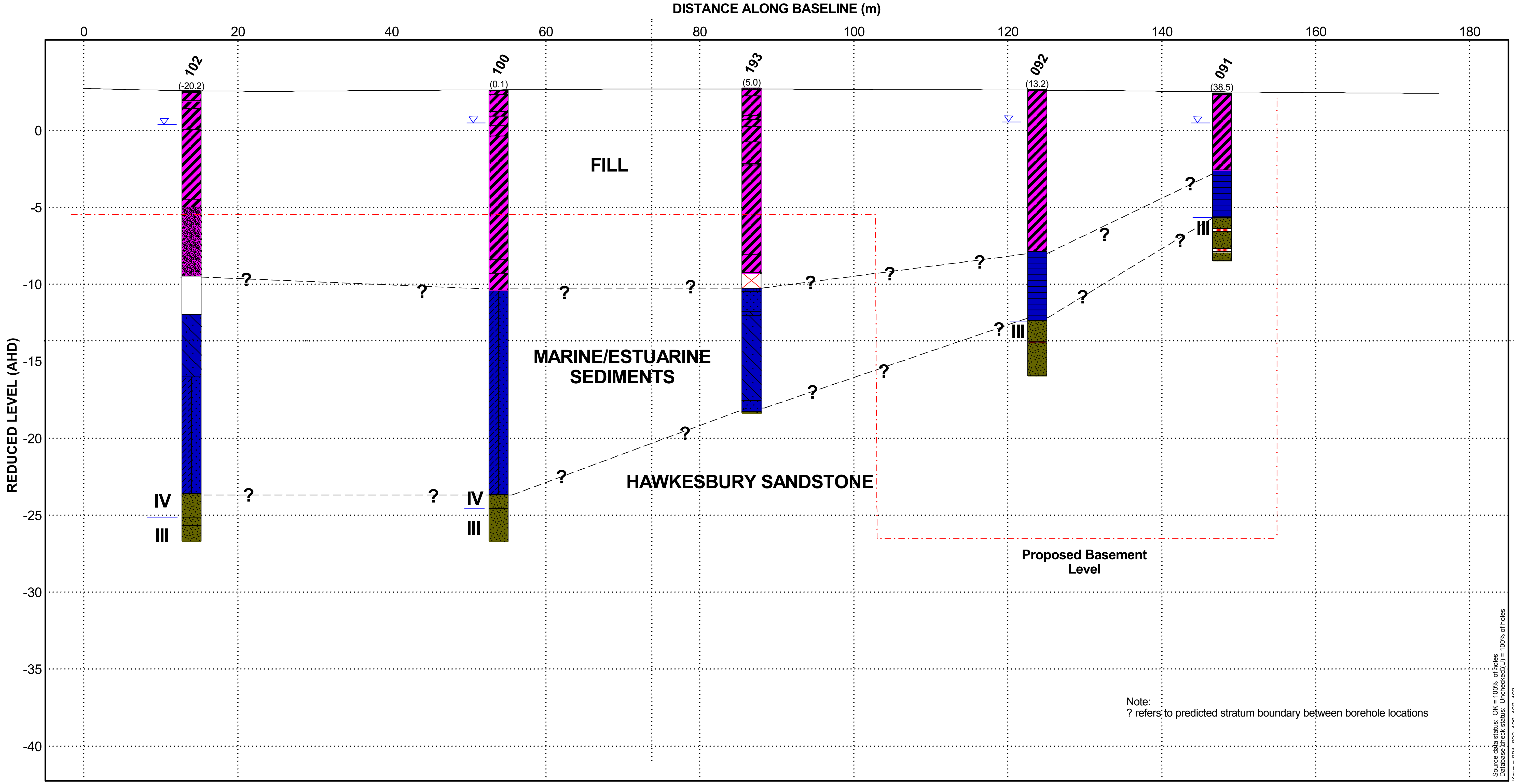

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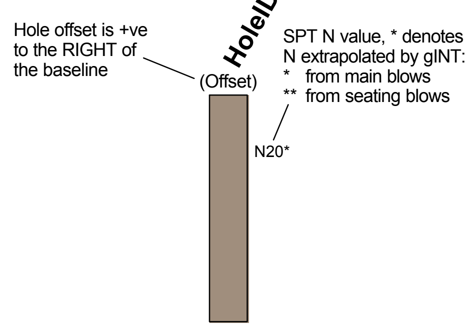
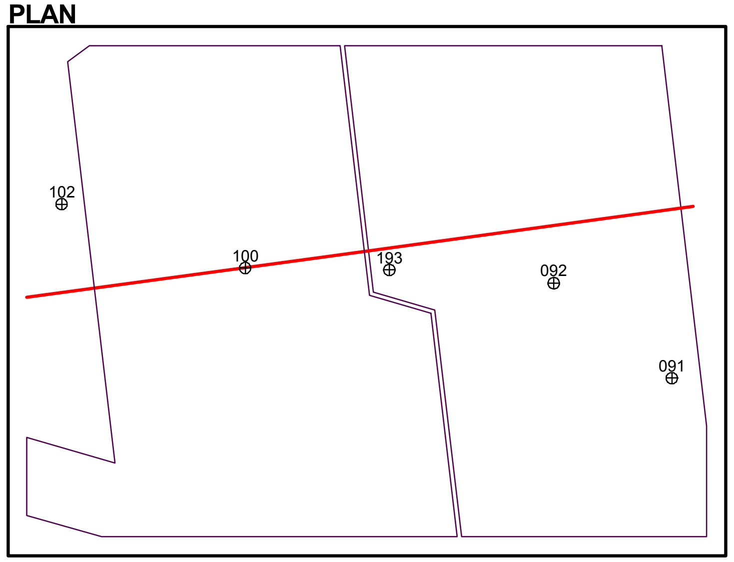


PLAN



- Water [WATER]
- Void / air [VOID]
- Hawkesbury Shale [Rhs]
- Hawkesbury Sandstone [Rh]
- Marine/Estuarine Sediments [RES]
- Marine/Estuarine Sediments [MARINE]
- Fill [FILL]
- Conglomerate [Cong]
- Concrete slabs, floor slabs etc [CONCRETE]
- Road surfacings [ASPHALT]

- Asphalt
- Fill
- Low plasticity inorganic Clay
- Sandstone (Australian version)
- Core loss
- Silty Sand
- Concrete
- Void/Air
- Clayey Sand
- High plasticity inorganic Clay
- Poorly graded Sand

BARANGAROO SOUTH
C4 COMMERCIAL BUILDING
GEOLOGICAL CROSS SECTION
Section B_B

220316

FIGURE 9

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Library : j:\220316-00 barangaroo\04_arup project data\04-09_gint\library\aus_library_v18_20091214.glb
Fence: 2.1.01 SIMPLE CROSS SECTION (A3) (rev 14Aug09 not checked!)
gINT output page 0 of 0. Made 28Apr10 14:06

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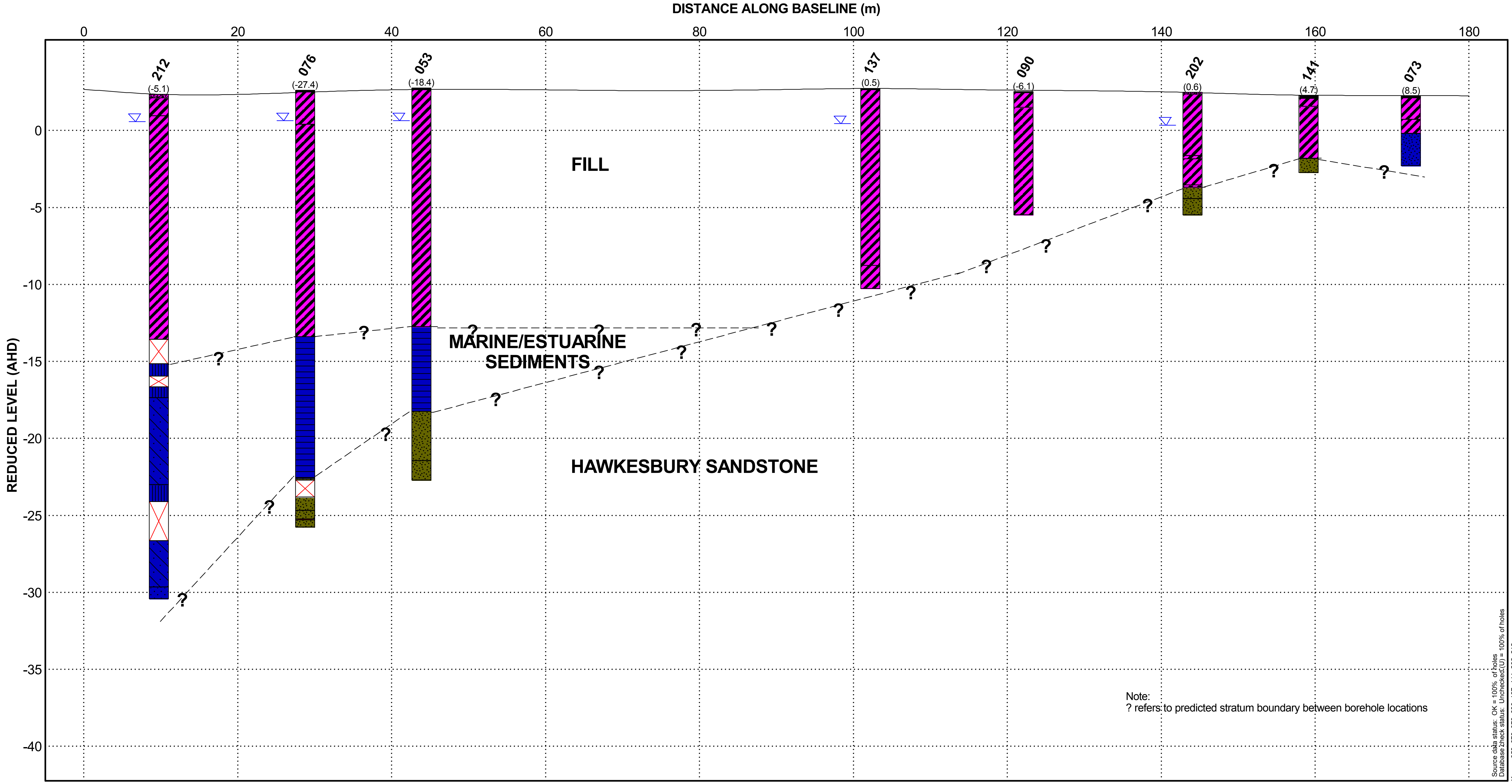

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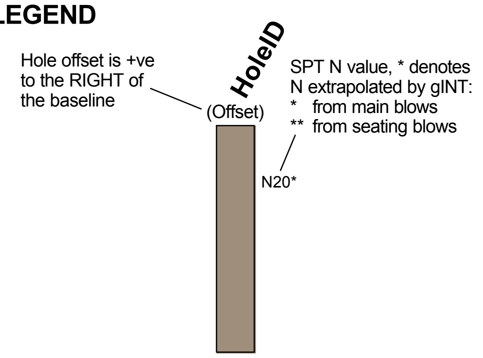
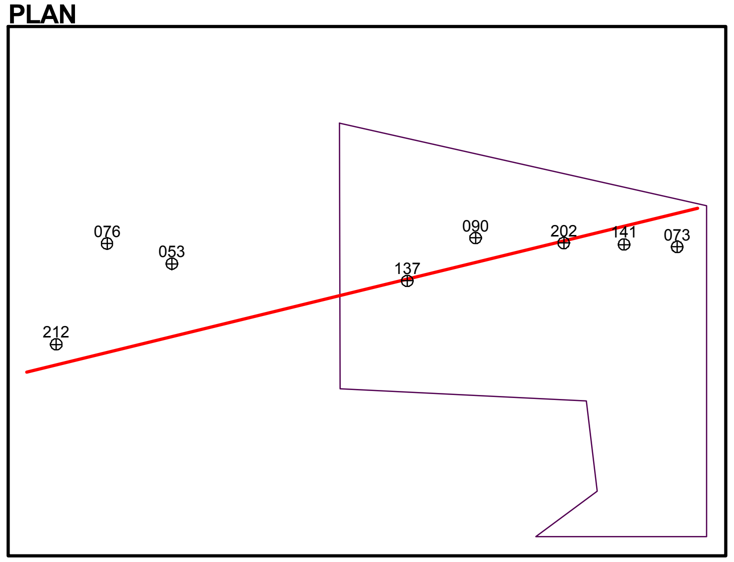
Database check status: Unchecked (U) = 100% of holes
Keys = 053, 073, 076, 090, 137, 141, 202, 212

SCALE 1:250V 1:500H @ A3L

LEGEND



PLAN



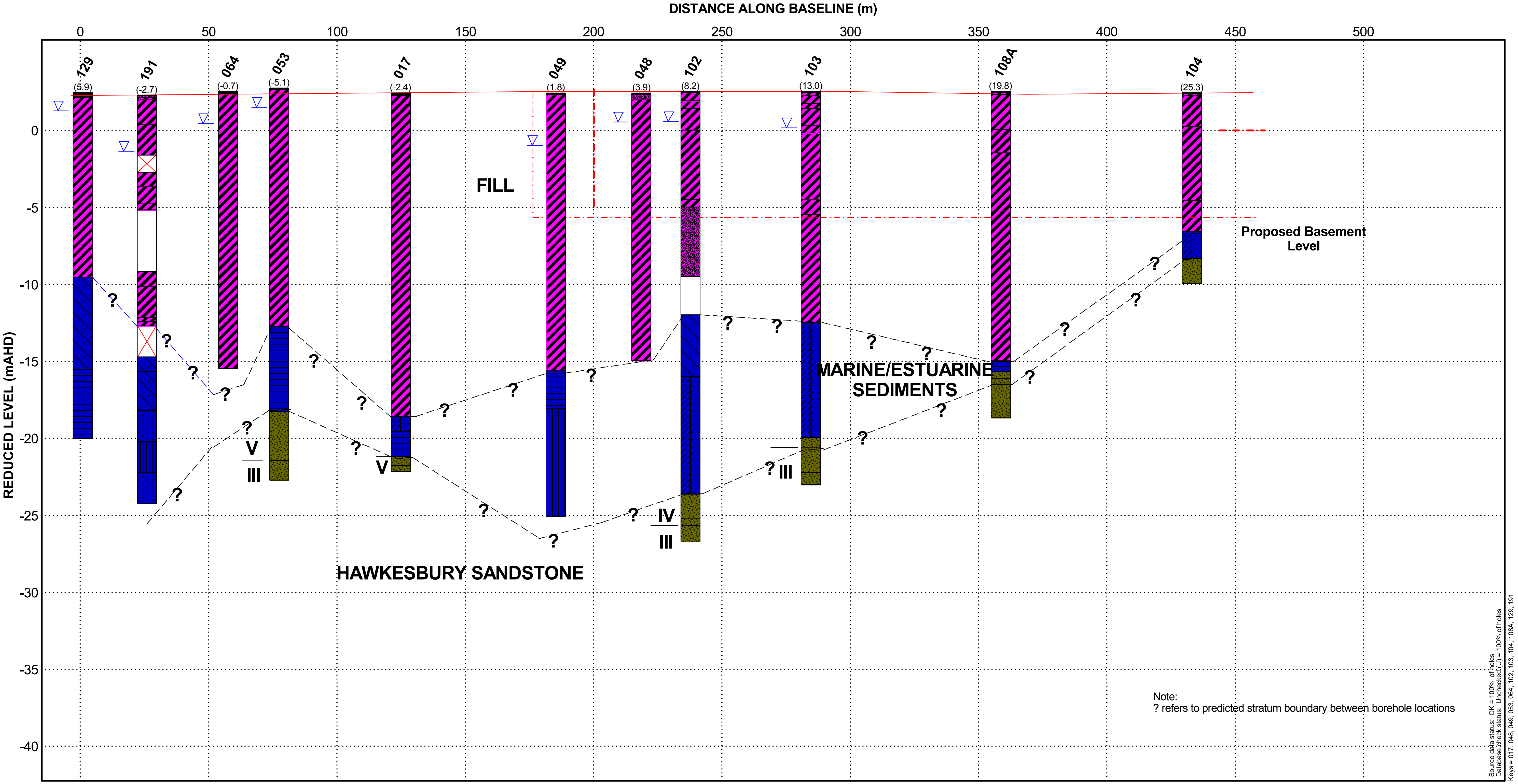
- Water [WATER]
- Void / air [VOID]
- Hawkesbury Shale [Rhs]
- Hawkesbury Sandstone [Rh]
- Marine/Estuarine Sediments [RES]
- Marine/Estuarine Sediments [MARINE]
- Fill [FILL]
- Conglomerate [Cong]
- Concrete slabs, floor slabs etc [CONCRETE]
- Road surfacings [ASPHALT]
- Asphalt
- Fill
- Low plasticity inorganic Clay
- Sandstone (Australian version)
- Core loss
- Concrete
- High plasticity inorganic Clay
- Clayey Sand
- Poorly graded Sand

BARANGAROO SOUTH
C4 COMMERCIAL BUILDING
GEOLOGICAL CROSS SECTION
Section C_C
220316

FIGURE 10

gINT v8.1.020 Licenced to Arup
Project : j:\220316-00 barangaroo\04_arup project data\04-09_gint\dataset\barangaroo_phase1_3dmodel160410.gpj
Library : j:\220316-00 barangaroo\04_arup project data\04-09_gint\library\aus_library_v18_20091214.glb
Fence: 2.1.01 SIMPLE CROSS SECTION (A3) (rev 14Aug09 not checked!)
gINT output page 0 of 0. Made 28Apr10 14:33

J:\220316-00 BARANGAROO\04_ARUP PROJECT DATA\04-09_GINT\OUTPUTS\FOR SUBMISSION\EDITED DRAWINGS\C4\SECTION C_C FINAL.GDW



SCALE 1:250V 1:1500H @ A3L

LEGEND

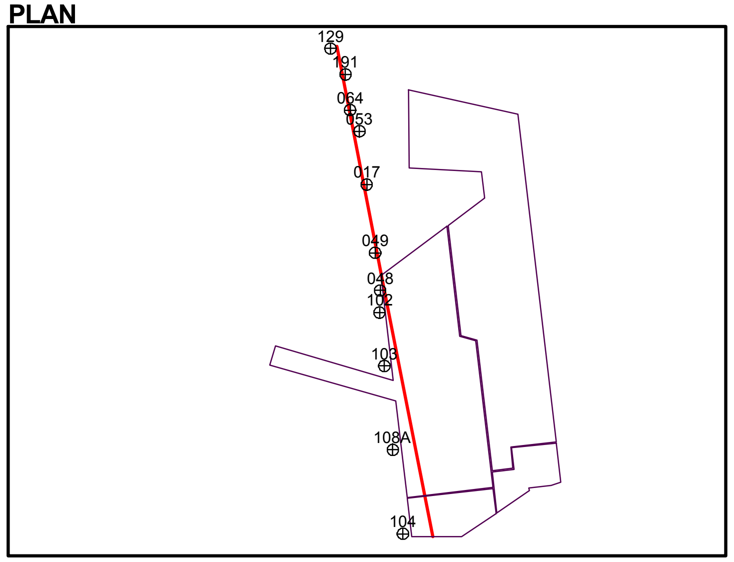
Hole offset is +ve to the RIGHT of the baseline

HoleID (Offset)

SPT N value, * denotes N extrapolated by gINT:
* from main blows
** from seating blows

N20*

PLAN



- Water [WATER]
- Void / air [VOID]
- Hawkesbury Shale [Rhs]
- Hawkesbury Sandstone [Rh]
- Marine/Estuarine Sediments [RES]
- Marine/Estuarine Sediments [MARINE]
- Fill [FILL]
- Conglomerate [Cong]
- Concrete slabs, floor slabs etc [CONCRETE]
- Road surfacings [ASPHALT]

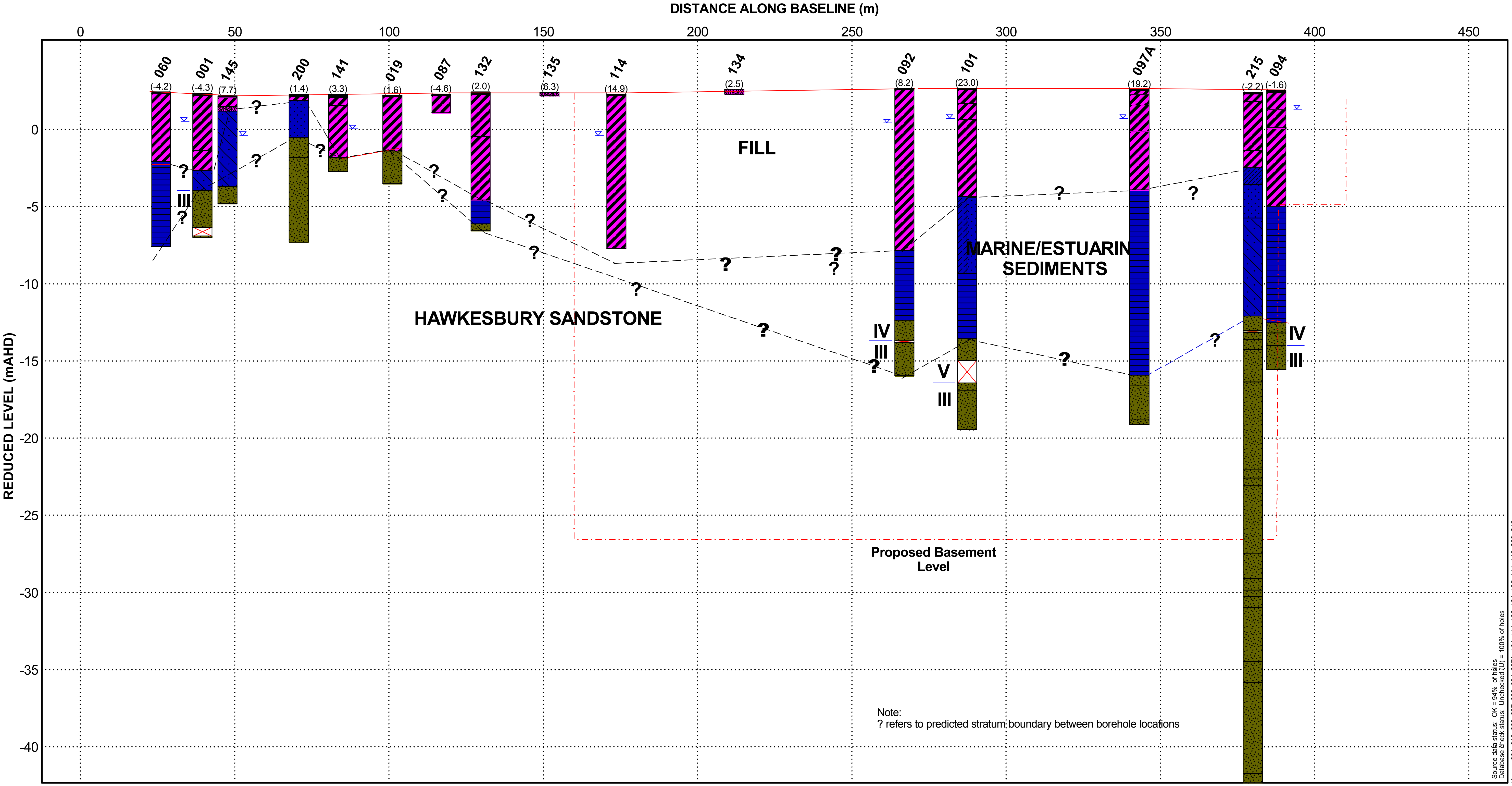
- Asphalt
- Fill
- Silty Sand
- Low plasticity inorganic Clay
- Sandstone (Australian version)
- Concrete
- High plasticity inorganic Clay
- Void/Air
- Clayey Sand
- Core loss
- Poorly graded Sand

BARANGAROO SOUTH
C4 COMMERCIAL BUILDING
GEOLOGICAL CROSS SECTION
Section D_D
220316

FIGURE 11

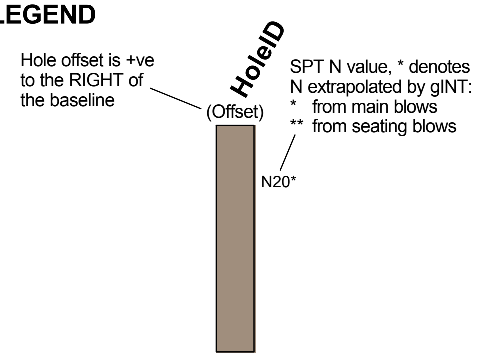
gINT v8.1.020 Licenced to Arup
Project : j:\220316-00 barangaroo\04_arup project data\04-09_gint\dataset\barangaroo_phase1_3dmodel160410.gpj
Library : j:\220316-00 barangaroo\04_arup project data\04-09_gint\library\aus_library_v18_20091214.glb
Fence: 2.1.01 SIMPLE CROSS SECTION (A3) (rev 14Aug09 not checked!)
gINT output page 0 of 0. Made 28Apr10 14:53

J:\220316-00 BARANGAROO\04_ARUP PROJECT DATA\04-09_GINT\OUTPUTS\FOR SUBMISSION\EDITED DRAWINGS\C4\SECTION D_D FINAL.GDW

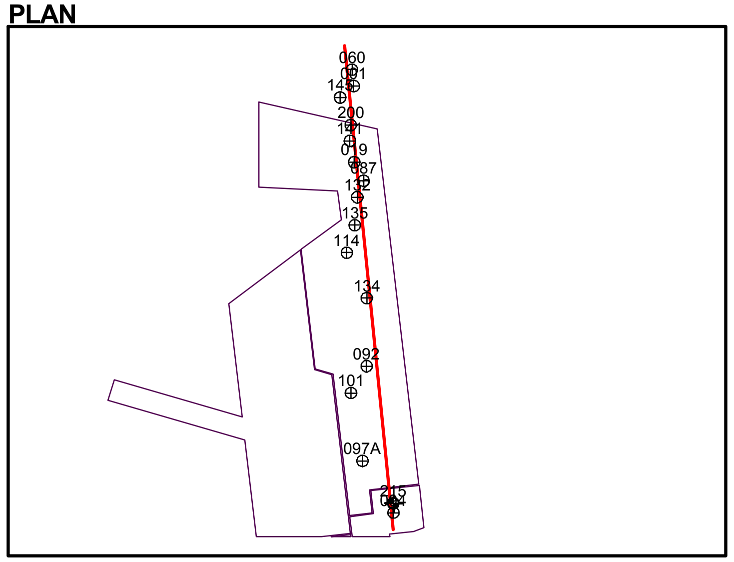


SCALE 1:250V 1:1250H @ A3L

LEGEND



PLAN



- Water [WATER]
- Void / air [VOID]
- Hawkesbury Shale [Rhs]
- Hawkesbury Sandstone [Rh]
- Marine/Estuarine Sediments [RES]
- Marine/Estuarine Sediments [MARINE]
- Fill [FILL]
- Conglomerate [Cong]
- Concrete slabs, floor slabs etc [CONCRETE]
- Road surfacings [ASPHALT]
- Asphalt
- Fill
- Clayey Sand
- Sandstone (Australian version)
- Core loss
- Low plasticity inorganic Clay
- Concrete
- Silty Sand
- Poorly graded Sand
- Medium plasticity inorganic Clay

BARANGAROO SOUTH
C4 COMMERCIAL BUILDING
GEOLOGICAL CROSS SECTION
Section E_E
220316

FIGURE 12

Source data status: OK = 94% of holes
Database check status: Unchecked(U) = 100% of holes
Keys = 001, 019, 060, 087, 092, 094, 097A, 101, 114, 132, 134, 135, 141, 145, 200, 215

gINT v8.1.020 Licenced to Arup
Project : J:\220316-00 barangaroo\04_arup project data\04-09_gint\dataset\barangaroo_phase1_3dmodel160410.gpj
Library : J:\220316-00 barangaroo\04_arup project data\04-09_gint\library\aus_library_v18_20091214.glb
Fence: 2.1.01 SIMPLE CROSS SECTION (A3) (rev 14Aug09 not checked!)
gINT output page 0 of 0. Made 28Apr10 15:39

J:\220316-00 BARANGAROO\04_ARUP PROJECT DATA\04-09_GINT\OUTPUTS\FOR SUBMISSION\EDITED DRAWINGS\C4\SECTION E_E FINAL.GDW

Client
Lend Lease (Millers Point) Pty Ltd

Job Title
Barangaroo Stage 1
C4 Commercial Building

Drawing Title
Base of Fill Contour Plot

Scale — Metres: 0, 50, 100

I1	28-04-2010	TM/CB	MA	
Issue	Date	By	Chkd	Appd

ARUP

Level 10 - 201 Kent Street
Sydney, NSW, 2000
Tel +61 (2)9320 9320 Fax +61 (2)9320 9321
www.arup.com

Scale at A4
1:2,000

Drawing Status
Issue

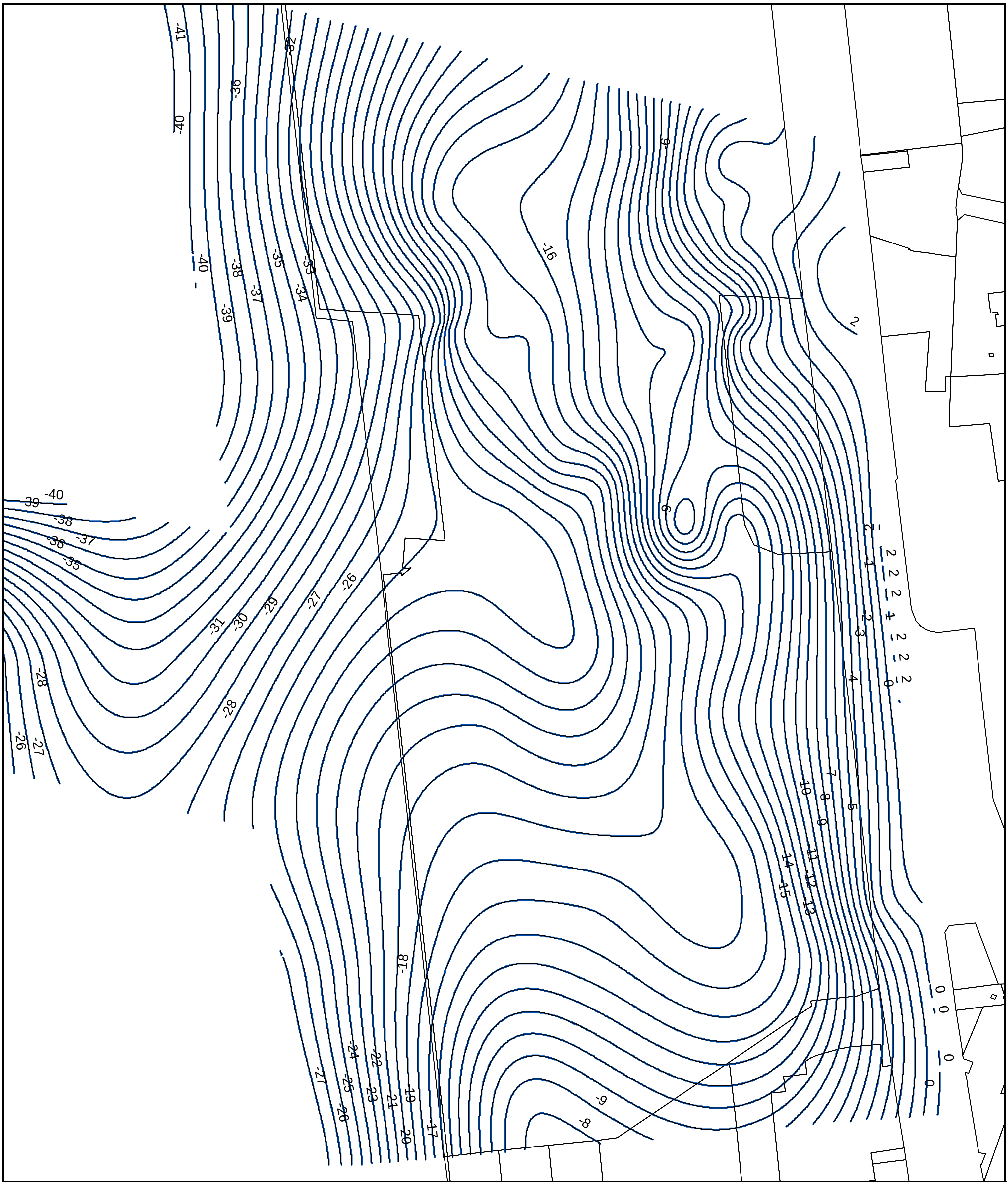
Job No	Figure No	Issue
220316-00	**Figure 13**	**I1**

Legend

Base of Fill

Barangaroo Cadaster

oFileLocation



Legend

Top of Bedrock

bedtopclip_3Dcontours

Barangaroo Cadaster

Client
Lend Lease (Millers Point) Pty Ltd

Job Title
Barangaroo South
C4 Commercial Building

Drawing Title
Top of Bedrock Contour Plot

Scale 0 50 100 Metres

Issue	Date	By	Chkd	Appd
I1	28-04-2010	TM/CB	MA	

ARUP

Level 10 - 201 Kent Street
Sydney, NSW, 2000
Tel +61 (2)9320 9320 Fax +61 (2)9320 9321
www.arup.com

Scale at A4
1:2,000

Drawing Status
Issue

Job No	Figure No	Issue
220316-00	Figure 14	I1