Douglas Partners

Geotechnics / Environment / Groundwater

Report on
Geotechnical Assessment for SSDA

SSDA1 - Sydney International Convention, Exhibition
and Entertainment Precinct (SICEEP)
Darling Harbour

Prepared for
Darling Harbour Live

Project 72959.00
March 2013

Integrated Practical Solutions

Douglas Partners

Geotechnics | Environment | Groundwater

Document History

Document details

Project No.	72959.00	Document No.	1
Document title	Report on Geotechnical Assessment for SSDA		
Site address	SSDA1 - Sydney International Convention, Exhibition and Entertainment Precinct (SICEEP), Darling Harbour		
Report prepared for	Darling Harbour Live		
File name	P: 72959.00\Darling Harbour Geotechnical Report for SSDA1.pdf		

Document status and review

Revision	Prepared by	Reviewed by	Date issued
0	G R Boyd	M J Thom	15 February 2013
1	G R Boyd	M J Thom	5 March 2013

Distribution of copies

Revision	Electronic	Paper	Issued to
0	1	0	Mr Robert Thorburn – Lend Lease

The undersigned, on behalf of Douglas Partners Pty Ltd, confirm that this document and all attached drawings, logs and test results have been checked and reviewed for errors, omissions and inaccuracies.

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Report on Geotechnical Assessment

Proposed Sydney International Convention, Exhibition and Entertainment Precinct (SICEEP)

Darling Harbour, Sydney

1. Introduction

This report presents the results of a geotechnical assessment undertaken by Douglas Partners Pty Ltd (DP) for the proposed Public Private Partnership (PPP) component of the proposed Sydney International Convention, Exhibition and Entertainment Precinct (SICEEP) at Darling Harbour, Sydney. The assessment was commissioned by Lend Lease Pty Ltd, a part of the Darling Harbour Live consortium, in a letter dated 7 June 2012 and was undertaken in accordance with DP proposal dated 16 March 2012 (Proposal SYD120287) to address the Director General's Requirements (DCTRs).

This report supports a State Significant Development Application (SSD 12_5752) submitted to the Minister for Planning and Infrastructure pursuant to Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

The Application seeks approval for construction of the Public Private Partnership (PPP) component of the Sydney International Convention, Exhibition and Entertainment Precinct (SICEEP) Project at Darling Harbour.

The SICEEP Project will deliver Australia's global city with world class convention, exhibition and entertainment facilities that can compete effectively in the national and international events markets. The SICEEP Project importantly forms a critical element of the NSW Government's aspiration to "make NSW number one again". The SICEEP Project also involves the creation of a new neighbourhood and a community hub.

The assessment was carried out to compile available information on subsurface conditions for the preliminary planning and design of foundations, earthworks, retaining walls, floor slabs and pavements.

The assessment included a review of available information from previous investigations on and near the site by DP and other geotechnical consultants. The details of previous field work carried out by DP are included, together with preliminary comments relating to design and construction.

This assessment has been carried out for preliminary design of the proposed structures. Further investigation of the site will be required at a later stage to provide additional information regarding the geological profile and to confirm the recommendations provided within this report.

2. Background

The Darling Harbour site is understood to have originally been part of Cockle Bay and its tributaries. The area was filled with various materials, including medium and high strength sandstone boulders (understood to have been won from tunnel excavations in Sydney) to form a platform for industrial development on site such as railway yards, factories, a council depot etc. In the 1980s the area was redeveloped with the construction of the Entertainment Centre and the Exhibition Centre.

Specific review of the construction of the existing development has not been included as part of this report. However, reference is made to a paper presented by A.B. Phillips and G.S. Young at the Fifth Australia-New Zealand Conference on Geomechanics, Sydney (1988) titled "Behaviour of Piles Driven to Rock at Darling Harbour, Sydney" which indicates that the Darling Harbour Convention and Exhibition Centre buildings are supported on enlarged based (750 mm diameter) Frankipiles that are supported on sandstone bedrock.

3. Previous Geotechnical Investigations

Coffey Geotechnics Pty Ltd (Coffey) has been commissioned by Infrastructure NSW to carry out two separate geotechnical investigations for the SICEEP as follows;

- Proposed Sydney International Convention and Entertainment Centre: Darling Harbour South dated 4 August 2011 (GEOTLCOV24303AA-AE).
- Proposed Sydney International Convention, Exhibition and Entertainment Precinct: Darling Harbour dated 25 May 2012 (GEOTCOV24303AC-AD).

Numerous other geotechnical investigations have been carried out by DP and other consultants for various developments on and around Darling Harbour. Available reports that have been reviewed are listed below (ordered by date):

- Coffey Report on Preliminary Foundation Investigation dated May 1978 for the Haymarket Redevelopment: Entertainment Centre (Report No. 6063-AA).
- Coffey Report on Foundation Investigation dated 18 July 1979 for the Haymarket Redevelopment: Parking Station (Report 6269-AB).
- Coffey Report on Supplementary Site Investigation dated 30 January 2013 for the SICEEP (Report GEOTCOV24303F-R01a).
- DP Report on Site Investigation dated 16 August 1979 for the Proposed Haymarket Entertainment Centre (Project SSI/1-6509).
- Coffey Additional Report on Geotechnical Investigation dated 26 June 1980 for the Haymarket Redevelopment: Parking Station (Report 6269/2-AA).
- Coffey Preliminary Report on Geotechnical Investigation dated 26 July 1985 for the Proposed Convention Centre (Report 7759/3-AB).
- ARUP Geotechnics Pty Ltd (ARUP) Report on Geotechnical Investigation dated April 1986 for the Harbourside Park development (Job No. 4105/GSY/BT).

- ARUP Report on Geotechnical Investigation dated April 1986 for the proposed Darling Harbour Development at Pier Street, Harbour/Day Streets, Darling Harbour (Job No. 4106/GSY/BT).
- ARUP Report on Geotechnical Investigation dated January 1987 for the Hay Street Sewerage Sub-Main (Job No. 4456).
- DP Borehole logs dated February and March 1990 for the Proposed Motor Inn at Harbour Street, Haymarket (Project 13458 and 13458A).
- DP Report on Foundation Investigation dated 20 November 1992 for the Proposed Theatre, Darling Harbour (Project No. 19013).
- DP Report on Foundation Investigation dated 18 April 1994 for the Proposed Market City Redevelopment, Ultimo (Project 19807A).
- DP Report on Geotechnical Investigation dated 23 February 1996 for the Proposed University of Technology Sydney (UTS) Law Building at Quay Street, Ultimo (Project 23667).
- DP Report on Geotechnical Investigation dated 23 January 1997 for the Proposed UTS, Extensions to Faculty of Business and Education Building at Quay Street, Ultimo (Project 24214).
- DP Report on Geotechnical Investigation dated 1 July 1997 for the proposed Pier Street Maintenance Building at Pier Street, Darling Harbour (Project 24540).
- DP Cone Penetration Tests (CPTs) dated October 1997 for the Proposed Darling Lane Off Ramp (Project 9808B).
- DP Report on Geotechnical Investigation dated 12 June 1998 for the proposed Sydney Entertainment Centre service yard at Harbour Street, Ultimo (Project 27427).
- DP Report on Geotechnical Investigation dated 5 July 2006 for the Proposed Control Box at Palm Cove, Darling Harbour (Project 43938).
- DP Report on Assessment of Heritage Wall (Façade) Foundations dated 8 March 2007 for the Hotel Inn Motel, Darling Harbour (Project 44394A).

The results and information contained within these reports, borehole logs and drawings have been considered in the formulation of the geological model of the site and preparation of comments provided in this report.

4. Site Description

The SICEEP Site is located within the Darling Harbour precinct. Darling Harbour is a 60 hectare waterfront precinct on the south-western edge of the Sydney Central Business District that provides a mix of functions including recreational, tourist, entertainment and business.

With an area of approximately 20 hectares, the SICEEP Site is generally bound by the Light Rail Line to the west, Harbourside shopping centre and Cockle Bay to the north, Darling Quarter, the Chinese Garden and Harbour Street to the east, and Hay Street to the south.

The SICEEP Site has been divided into three distinct redevelopment areas (from north to south) – Bayside, Darling Central and The Haymarket. The PPP Application Site area is located within Bayside and Darling Central as shown in Figure 1.

Figure 1: The SICEEP Site

5. Regional Geological Mapping

Reference to the Sydney 1:100 000 Geological Sheet indicates that the site is underlain by man made fill and alluvial sediments of Quaternary Age overlying Hawkesbury Sandstone of Triassic Age. The geological map also indicates that the southern part of the site is bisected by the Great Sydney Dyke, an igneous intrusion. Figure 2 in Appendix A shows the approximate boundaries of the various geological units as shown on the regional map.

Also included in Figure 2, is reference to the GPO Fault Zone and the Martin Place Joint Swarm. These structural features are referenced in "Map and Selected Details of Near Vertical Structural Features in the Sydney CBD" by Pells, Braybrooke and Och (2004).

6. Geological Profile

6.1 Significant Geological Features

Review of the available information has indicated that the geological profile of the area is complex and varies over different parts of the site. In broad terms the main geological features include:

- Filling – including alluvial and estuarine sediments, high strength sandstone boulders and building rubble which is of variable compaction and depth.
- Deep palaeochannels through the site.
- Highly variable sandstone bedrock levels.
- Relatively shallow groundwater levels.
- Possible presence of GPO fault (or sheared zone) projected through the southern side of the site.
- The Great Sydney Dyke crossing the southern part of the site.

6.2 Subsurface Conditions

The subsurface profile of the site may be broadly summarised as follows;

- **Filling** including estuarine and alluvial sediments together with sandstone cobbles and boulders to depths of 0.4 m to 14.5 m (RL 1.1 to -10.6 m). The compaction of the fill is likely to be variable.
- **Alluvium and Estuarine Deposits** – very loose to medium dense sands and clayey sands together with very soft to stiff clays to depths of 0.4 m to 14.5 m (RL 0.0 to -10.6 m). This unit ranges in thickness from 1.4 m to 14.3 m.
- **Residual Soils** – stiff clayey sands or sandy clays above the bedrock to depths of 1.4 m to 14.7 m (RL 1.4 to -11.7 m). This unit, where present, ranges from 0.4 m to 5.3 m thick.

- **Sandstone (Class V/IV)** – very low to low strength, extremely and highly weathered to depths of 4.3 m to 20.8 m (RL -1.5 to -15.3 m). This unit ranges from 0.1 to 4 m thick. The depths to rock vary significantly over the site, probably as a result of a deep palaeochannel that bisects the site.
- **Sandstone (Class III)** – medium strength, slightly to moderately weathered sandstone to depths of 12.9 m to 23.5 m (RL -1.7 to -20.8 m). Some areas in this unit include shearing and numerous steeply dipping joints.
- **Sandstone (Class II/I)** – high strength, fresh sandstone.

Some Interpreted sections through the site showing the variability in conditions are given in the Coffey reports of August 2011 and May 2012.

6.3 Groundwater

Groundwater levels on site have been measured at depths of 1.6 m to 4.7 m depth (RL -0.7 to RL 1.7). Given the close proximity to Cockle Bay, it is likely that the groundwater levels are subject to variations from tidal flows.

6.4 Great Sydney Dyke

The Great Sydney Dyke (GSD) has been identified on the southern section of the site. Details regarding the GSD are documented in the paper "Igneous intrusives in the Greater Sydney Region" by Peter Rickwood (refer Engineering Geology of Sydney Region 1985 edited by P.J.N . Pells). This paper indicates that the GSD ranges in width from approximately 2.5 m to 12 m, has a strike ranging from 111° to 121° to true north and has been recorded at the Entertainment Centre as dipping to the south-west at angles of ranging from 56° to 82°.

Detailed site investigations have indicated that the GSD:

- typically weathered to form clay to depths in excess of 30 m.
- ranges in width from 3 m to 8.5 m, although it locally may increase to up to 12 m thick. Coffey suggest that the 12 m thick section may be a result of either the curvature of the dyke or a possible secondary dyke.
- comprises extremely weathered dolerite with stiff clay-like properties and highly weathered to fresh dolerite but also includes large sandstone fragments at some locations. The dolerite is more weathered near the surface. Fresh dolerite has been recorded below RLs -16 and -24.
- The sandstone within 1 m to 2 m of the contact with the dyke appears to have been slightly metamorphosed resulting in high strength sandstone. Shearing, jointing, fracturing and possible faulting are present in the contact zone.

6.5 Sheared Zone

Coffey's report indicates the possible presence of a shear zone with a trend in a north-north east direction. The width of this shear zone is unknown although it has been estimated by Coffey in their drawings as 10 – 15 m wide. The shear zone has been inferred from numerous joints and defects in the rock profile. It is possible that this shear zone is part of the GPO Fault Zone that has not been mapped through Darling Harbour but could be projected through the site based on its known orientation through the Sydney Central Business District.

6.6 Test Bores

The locations of the bores, where able to be approximately determined, are shown on Drawings 1 to 3, Appendix A. These drawings include the approximate RL (m AHD) of medium strength sandstone where this level has been determined.

The detailed results of DPs, Coffey's or ARUP's investigations for the development have not been reproduced in this report and reference should be made to their individual reports. It is noted that the specific Coffey's reports for the SICEEP development included cross-sections and contouring of the top of medium strength sandstone. These sections and contouring appear to be based, at least in part, on the results from other investigations in the area that have not been sighted by DP.

7. Proposed Development

7.1 Background of Proposed Development

The existing convention, exhibition and entertainment centre facilities at Darling Harbour were constructed in the 1980s and have provided an excellent service for Sydney and NSW.

The facilities however have limitations in their ability to service the contemporary exhibition and convention industry which has led to a loss in events being held in Sydney.

The NSW Government considers that a precinct-wide renewal and expansion is necessary and is accordingly committed to Sydney reclaiming its position on centre stage for hosting world-class events with the creation of the SICEEP Project.

Following an extensive and rigorous Expressions of Interest and Request for Proposals process, Darling Harbour Live (formerly known as 'Destination Sydney'- a consortium comprising AEG Ogden, Lend Lease, Capella Capital and Spotless) was announced by the NSW Government in December 2012 as the preferred proponent to transform Darling Harbour and create the new Sydney International Convention, Exhibition and Entertainment Precinct.

Key features of the Darling Harbour Live Preferred Master Plan include:

- Delivering world-class convention, exhibition and entertainment facilities, including:
  - Up to 40,000 m^2 exhibition space;
  - Over 8,000 m^2 of meeting rooms space, across 40 rooms;
  - Overall convention space capacity for more than 12,000 people;

  - A ballroom capable of accommodating 2,000 people; and
  - A premium, red-carpet entertainment facility with a capacity of 8,000 persons.
- Providing up to 900 hotel rooms in a hotel complex at the northern end of the Precinct.
- A vibrant and authentic new neighbourhood at the southern end of the precinct, called 'The Haymarket', home to an IQ Hub focused on the creative industries and high-tech businesses, apartments, student accommodation, shops, cafes and restaurants.
- Renewed and upgraded public domain, including an outdoor event space for up to 25,000 people at an expanded Tumbalong Park.
- Improved pedestrian connections linking to the proposed Ultimo Pedestrian Network drawing people between Central, Chinatown and Cockle Bay Wharf as well as east-west between Ultimo/Pyrmont and the City.

7.2 Overview of Proposed Development

The proposed development involves construction of the PPP component of the SICEEP Project, comprising new, integrated and world-class convention, exhibition and entertainment facilities with associated retail and public domain upgrades.

The application more specifically seeks approval for the following development:

- Demolition of existing improvements on the site, including existing Sydney Convention Centre (part) and Sydney Exhibition Centre.
- Associated tree removal and replanting.
- Construction of a new, integrated and world-class Convention, Exhibition and Entertainment Centre.
- Public domain improvements, including:
  - reinvigorating and expanding Tumbalong Park;
  - provision (part) of a new active north-south pedestrian connection (known as the Boulevard);
  - provision of new east-west connections, including Harbourside Place and Tumbalong Place;
  - Provision of a pedestrian bridge link from Quarry Street;
  - Retention of the tidal cascade water feature;
  - Reconfiguration and upgrade of Darling Drive (part);
  - Provision of a new square adjoining the Chinese Garden;
  - Provision of a new open space 'event deck' (connected with the Exhibition Centre);
  - Integrated art, play zones, water play and recreation areas;
  - Provision of retail kiosks;
- Provision of ground level parking within the Exhibition and Entertainment Centre facilities.

- Ground and elevated loading docks (accessed off Darling Drive) for Convention, Exhibition and Entertainment Centre facilities.
- Two vehicle drop off points off Darling Drive;
- Provision of signage; and
- Extension and augmentation of physical infrastructure / utilities as required.

8. Comments

8.1 Geotechnical Issues

The geological conditions on-site are complex. The variability in subsurface conditions will result in challenges during the construction process that will need to be considered during the design and planning stages. These issues are summarised below:

- **Filling:**
  - the filling includes sandstone boulders and building rubble that could be difficult to penetrate using conventional piling methods. In addition, the presence of a high groundwater table, sands and very soft to soft clays will result in collapsing ground conditions for open hole piles. Therefore careful selection of the piling methods will be required.
  - the filling is likely to settle at different rates due to different materials and variable compaction resulting in differential settlement. Footings and floor slabs will therefore need to be supported/suspended on piled foundations. Pavements and filled embankments supported on filling, even with ground improvement and geotextile support, will probably be subjected to ongoing settlements and will subsequently need monitoring and repair as required.
  - the filling may not be of sufficient strength to support large piling rigs. Therefore, it is anticipated that bridging layers will be required to create suitable work platforms.
  - Re-use of filling materials on-site may require significant moisture conditioning and sieving of suitable and unsuitable materials into separate stockpiles prior to re-use of suitable materials.
- **Natural Soils** – the alluvial and estuarine sediments include very soft and soft clays as well as very loose and loose sands. The presence of these sediments will need to be considered in the piling method selection. In addition, these sediments may contribute significantly to the amount of settlement experienced beneath structures.
- **Variable rock levels** – the significant variation in rock levels across the site will result in large differences in piling depths over relatively short distances.
- **Dyke** – large building loads cannot be supported by the highly weathered dyke and will need to be supported on piles founded outside the dyke and dyke affected areas.
- **Sheared Zone** – the presence of the sheared zone may require increased founding depths of piles.

Comments addressing these issues are provided below.

It is understood that a separate report addressing environmental issues, waste classification and acid sulphate soils is being prepared by another consultancy firm.

8.2 Foundations

8.2.1 Existing Piles

The existing piles on site may be able to be re-used for the proposed development if they are located in positions that can be used. It is understood that Frankipiles were used under the Convention and Exhibition Centre buildings and were originally designed for a working load of 2650 kN. Care would need to be taken during demolition to ensure that the Frankipiles are not damaged. Consideration of the remaining design life of the piles should be carried out if proposed for re-use. Integrity testing would need to be undertaken on each pile proposed to be reused to confirm their suitability for re-use.

8.2.2 Design – Axial Loads

Footing loads for the various multi-storey buildings are understood to vary but could be up to 35,000 kN

The maximum allowable and ultimate bearing pressures and shaft adhesions for the various bedrock layers are provided in Table 1. Where ultimate bearing pressures are adopted a geotechnical reduction factor should be applied. The geotechnical reduction factor adopted is dependent on the level of risk associated with pile design. It is suggested that at this stage, a geotechnical reduction factor (Φ_g) of 0.6 be adopted. This value (Φ_g) may be increased dependent on the amount of additional investigation as well as pile testing and geotechnical supervision during construction.

Table 1: Maximum End Bearing Pressures, Shaft Adhesion and Elastic Modulus Values

Material Description	Working Stress Design Values		Limit State Design Values		
	Allowable End Bearing Pressure (kPa)	Allowable Shaft Adhesion (kPa)	Ultimate End Bearing Pressure (kPa)	Ultimate Shaft Adhesion (kPa)	Elastic Modulus (MPa)
Very low and low strength sandstone (Class V/IV)	1000	75	4000	200	100
Medium strength sandstone (Class III)	3,500	350	20,000	1000	1000
High strength sandstone (Class II)	6,000	600	40,000	2000	1500

Settlements for working (allowable) pressures are not expected to exceed 1% of the pile diameter using the above recommended maximum values. Ultimate capacities are expected to mobilise at settlements greater than 5% of the pile diameter.

Where piles are designed in tension the design values in Table 1 should be reduced by 50% in addition to the geotechnical reduction factor. Piles designed in tension should also be checked for cone-pullout failure.

The foundation design parameters assume that the foundation excavations (e.g. pads or piles) are clean and free of loose debris, with pile sockets free of smear and adequately roughened immediately prior to the placement of concrete.

It is recommended that all load bearing foundations be inspected by an experienced geotechnical engineer or engineering geologist.

8.2.3 Design – Lateral Loads

Design of piles for lateral or moment loadings may be based on elastic analysis methods. For elastic moduli parameters refer to Table 1.

While it is reasonable to allow for some contribution to deflection performance from the overburden soils there is a significant variability in strength, depth and consistency of soils on this site. Consequently, it is recommended that, for lateral deformations, the design is based on the rock socket only with deformations calculated assuming fixity about 0.5 m below the top of the rock surface.

In order to resist lateral loads and to take into consideration potential buried steps within the sandstone surface, it is recommended that piles be socketed at least three pile diameters into sandstone of at least low strength. To cope with strength variability and fractured zones as encountered in the bores, it is suggested that the actual socket length be at least 0.5 m longer than the minimum required socket.

Design should be based on a geotechnical reduction factor (Φ_g) of 0.6. This value (Φ_g) may be increased if additional investigation as well as pile testing (lateral) and geotechnical supervision during construction is carried out.

During detailed design when specific pile locations and loads are known a more rigorous analysis of lateral pile deflection modelling of the piles using the PYGMY computer program should be carried out.

8.2.4 Construction

Footings for the development should be supported on competent bedrock. Therefore piling will be required to support the buildings. The relatively shallow depth of groundwater together with the presence of collapsing soil conditions, possible sandstone boulder obstructions and the depth of sandstone bedrock presents challenging piling conditions. Possible piling methods include:

- Cased bored piles or continuous flight auger (CFA) piles.
- Frankipiles, which have been used successfully on site previously.
- Driven piles. However, driven piles are usually associated with significant noise and vibrations that could disturb neighbours.

All these piling methods, however, may refuse prematurely on sandstone boulder obstructions. It is recommended that the piling contractor be consulted prior to engagement and made aware of the potential difficulties during construction.

8.2.5 Great Sydney Dyke

The weathered dyke material (clay) cannot support heavy structural loads. It should also be assumed that the sandstone within 2 m to 3 m of the edge of the dyke has been altered and is difficult to drill. On the southern side of the GSD, it should be assumed that the edge of the dyke is dipping at 55° to the south-west unless proven otherwise. Therefore, piles should be positioned so that there is at least 5 m of high strength sandstone bedrock between the base of the pile and the possible edge of the GSD.

8.2.6 Seismic Design

In accordance with the Earthquake Loading Standard, AS1170.4 – 2007, most of the site can probably be assessed to have a Site Sub-Soil Class of “Ce”, however, the foundations beneath individual structures should be reassessed during detailed design.

8.3 Earthworks

8.3.1 Site Preparation Measures

The following subgrade preparation measures are recommended for the construction of pavements, the filled embankment and working platforms:

- Remove all vegetation-affected filling, deleterious materials and any topsoil;
- Proof roll the exposed surface using a minimum 10 tonne smooth drum roller in non-vibration mode. The surface should be rolled a minimum of six times with the last two passes observed by an experienced engineer to detect any ‘soft spots’;
- Any heaving materials identified during proof rolling should be removed, or otherwise treated (e.g. with geosynthetics or bridging layers), as directed by the engineer;
- Any new filling should be placed in layers of 300 mm maximum loose thickness and compacted to a dry density ratio of between 100% and 103% Standard compaction and with moisture contents maintained within 2% of Standard optimum moisture content;
- Imported fill material should preferably be free of oversize particles (>100 mm) and deleterious material and be non-saline to slightly-saline, non-dispersive, have a plasticity index of less than 25% and a California bearing ratio of greater than 5%;
- Excavated filling on-site may be suitable for re-use as filling on site, from a geotechnical perspective, provided it does not contain peaty clays, excessively silty material, vegetation or deleterious materials (e.g. rubbish, building rubble). An environmental consultant should be consulted as to the waste classification of materials on site and its appropriateness for re-use.

- Moisture conditioning of fill materials proposed for re-use may need to be carried out. If excessively wet, moisture conditioning is likely to involve drying using one of the following methods:
  - exposure to sunny and/or windy weather;
  - mixing with drier materials; and,
  - stabilisation using either lime or cement. The choice and amount of stabilising material is dependent on the type of filling proposed for re-use and its moisture content.

  Drying methods that are dependent on exposure to the environment are obviously associated with a risk of being affected by wet weather.
- Density testing of the filling should be carried out in accordance with AS3798 "Guidelines for Earthworks for Commercial and Residential Developments".

Drainage measures should be included within all earthworks operations carried out on site.

8.3.2 Working Platforms

Piling rigs and cranes will need a suitable working platform during construction. At this stage, investigations suggest that the filling is highly variable across the site. In addition, the presence of service trenches across the site could adversely affect the platform. The thickness of any working platform is dependent on the load applied and the consistency and strength of the underlying subsurface material. As there are many unknown variables associated with working platform design, the advice provided at this stage is preliminary and should be assessed during construction when the specific working platform areas have been defined. Where a good quality and uniform filling subgrade is present, this subgrade may be suitable to support some rigs. Where a poor quality and non-uniform subgrade is present preliminary analysis suggests that a working platform approximately 0.8 m to 1.2 m thick of high quality bridging material, such as crushed sandstone or recycled concrete, will be required to support a tracked rig with an applied pressure of 150 kPa. The thickness of this bridging layer can be reduced with the use of a high strength geosynthetic.

8.4 Filled Embankment

8.4.1 General

A filled embankment, up to 9 m high with an approximate 2:1 (Horizontal: Vertical) batter is proposed to place adjacent to proposed buildings for aesthetic reasons. It is understood that fill material obtained elsewhere on-site will be used to construct the filled embankment.

8.4.2 Foundations

The filled embankment will apply a surcharge load to the underlying ground. The amount of surcharge is dependent on the height of the batter. Surcharge pressures applied from the filled embankment will range from 0 kPa at its toe to about 200 kPa at its crest. Settlements will be induced on the ground surface beneath the filled embankment; however, given the variable nature of the strength and quality of the underlying fill together with the uneven loading conditions it is very difficult to predict the amount of total or differential settlement that will occur beneath the embankment. If settlements in the embankment can be tolerated then the embankment could be placed on the subgrade prepared as described in Section 8.4.1. If settlements beneath the embankment cannot be tolerated or need to be limited then either bridging layers, piles or a slab suspended on piles could be considered.

8.4.3 Batters

The stability of this fill embankment will depend on the fill materials. A 2:1 batter would be appropriate where a high quality fill material, such as a crushed sandstone or recycled concrete, is proposed. However, if a poorer quality fill material is used, such as the clays included in the fill won on site, then a heavy duty geogrid placed at 1 m intervals will probably be required.

8.4.4 Retaining Wall Design

The filled embankment will apply a pressure to the adjacent walls of the building which should therefore be designed to support these loads. It is assumed that filling will not be placed against these walls until the structure has been constructed.

Design for lateral earth pressures for a multi-propped wall system may be based on a uniform rectangular earth pressure distribution over the bottom 80% and triangular distribution over the upper 20% of the wall height. A design horizontal active pressure of 4H (H = height to be retained) or 7H (where lateral movements are to be limited) should be adopted over the bottom 80% of the wall height. Additional lateral pressures due to surcharge loadings behind the wall and hydrostatic pressures (as appropriate) should be allowed for within the structural design.

In order to adequately restrain the toe of the retaining walls, the piles will need socketing into natural bedrock. The following ultimate passive values may be adopted for pile design:

- Very low to low strength sandstone (Class V/IV) 4,000 kPa
- Medium strength sandstone (Class III) 20,000 kPa
- Medium to high strength sandstone (Class II) 40,000 kPa

If the deflection of the wall is to be limited, the walls may need to include support using temporary anchors or props until the permanent structure is erected. Further advice should be sought regarding ground anchors if they are proposed.

8.5 Retaining Walls

The proposed development is likely to include retaining walls up to 3 m in height for loading docks, garden beds and other minor structures.

Cantilevered retaining walls, up to 3 m high, for which some deflection is acceptable, could be designed on the basis of a triangular earth pressure distribution using a bulk unit weight of 20 kN/m^3 for the retained material, and an active earth pressure coefficient (K_a) of 0.3 or an at rest earth pressure coefficient (K_o) of 0.5 (for level backfill conditions). If a limit state approach is adopted for the design of the retaining walls, these values should be appropriately factored in accordance with AS4678 “Earth Retaining Structures” (2002).

Wall design using these parameters assumes the following:

- a level surface behind the top of the excavation;
- retaining walls will need to allow for full hydrostatic pressures from the ground surface level if drainage measures behind walls are not provided;
- construction traffic and other surcharge loadings (e.g. stacked materials) are not applied at the crest of the retaining walls, for a distance of say 5 m behind the wall/shoring (otherwise the resultant additional lateral loads need to be considered).

8.6 Pavements

It is understood that lightly trafficked pavements, predominantly used by pedestrians and the occasional emergency vehicle, are proposed for the site. If settlements of the pavement cannot be tolerated then the pavement should be supported by suspended slabs supported on piles that are founded on bedrock. However, if some ongoing settlement of the pavement can be tolerated, with associated maintenance, then it may be supported by a subgrade prepared in accordance with Section 8.3.1. The placement of heavy duty geogrids and bridging layers will control the differential settlement of the pavement.

8.7 Floor Slabs

Given the variable subsoil profile including uncontrolled filling of variable compaction as well as the estuarine and alluvial sediments of variable thickness and strength it is recommended that all floor slabs be suspended on piles supported on bedrock.

8.8 Drainage

Surface and subsurface drainage should be incorporated into the design to protect footings and pavements. All collected stormwater and roof runoff should discharge into the stormwater disposal system.

8.9 Further Work

The following further work is recommended:

a) Geotechnical investigation of the site at locations where the available information is limited, such as beneath the multi-storey buildings. This investigation should include diamond core drilling with at least 5 m of sandstone bedrock and possibly more if sockets into high strength sandstone are required. A plan showing suggested test locations is included in Appendix A.

b) Installation and monitoring of standpipes across the basement footprint to measure variations in water levels from tidal flows and rainfall.

c) Further investigations for foundations in the vicinity of the GSD once the footing design has progressed.

The structural engineer should be consulted prior to further investigation to confirm where high structural loads are proposed and that sufficient investigation in these areas are proposed.

9. Feasibility of Project

This project is considered feasible to develop, from a geotechnical perspective, if design and construction is carried out in accordance with the comments provided in this report together with good engineering principles and practice.

10. Limitations

Douglas Partners (DP) has prepared this report for the proposed Sydney International Convention, Exhibition and Entertainment Precinct (SICEEP) at Darling Harbour, Sydney in accordance with DP's proposal dated 23 March 2012 and acceptance email from Mr Robert Thorburn of Lend Lease on 7 June 2012. The report is provided for the exclusive use of the Lend Lease Pty Ltd for this project only and for the purpose(s) described in the report. It should not be used for other projects or by a third party. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

The results provided in the report are indicative of the sub-surface conditions only at the specific sampling or testing locations, and then only to the depths investigated and at the time the work was carried out. Sub-surface conditions can change abruptly due to variable geological processes and also as a result of anthropogenic influences. Such changes may occur after field testing has been completed.

DP's advice is based upon the conditions presented in the various geotechnical reports. The accuracy of the advice provided by DP in this report may be limited by the accuracy of undetected variations in ground conditions between sampling locations. The advice may also be limited by budget constraints imposed by others or by site accessibility.

This report must be read in conjunction with all of the attached notes and should be kept in its entirety without separation of individual pages or sections. DP cannot be held responsible for interpretations or conclusions made by others unless they are supported by an expressed statement, interpretation, outcome or conclusion given in this report.

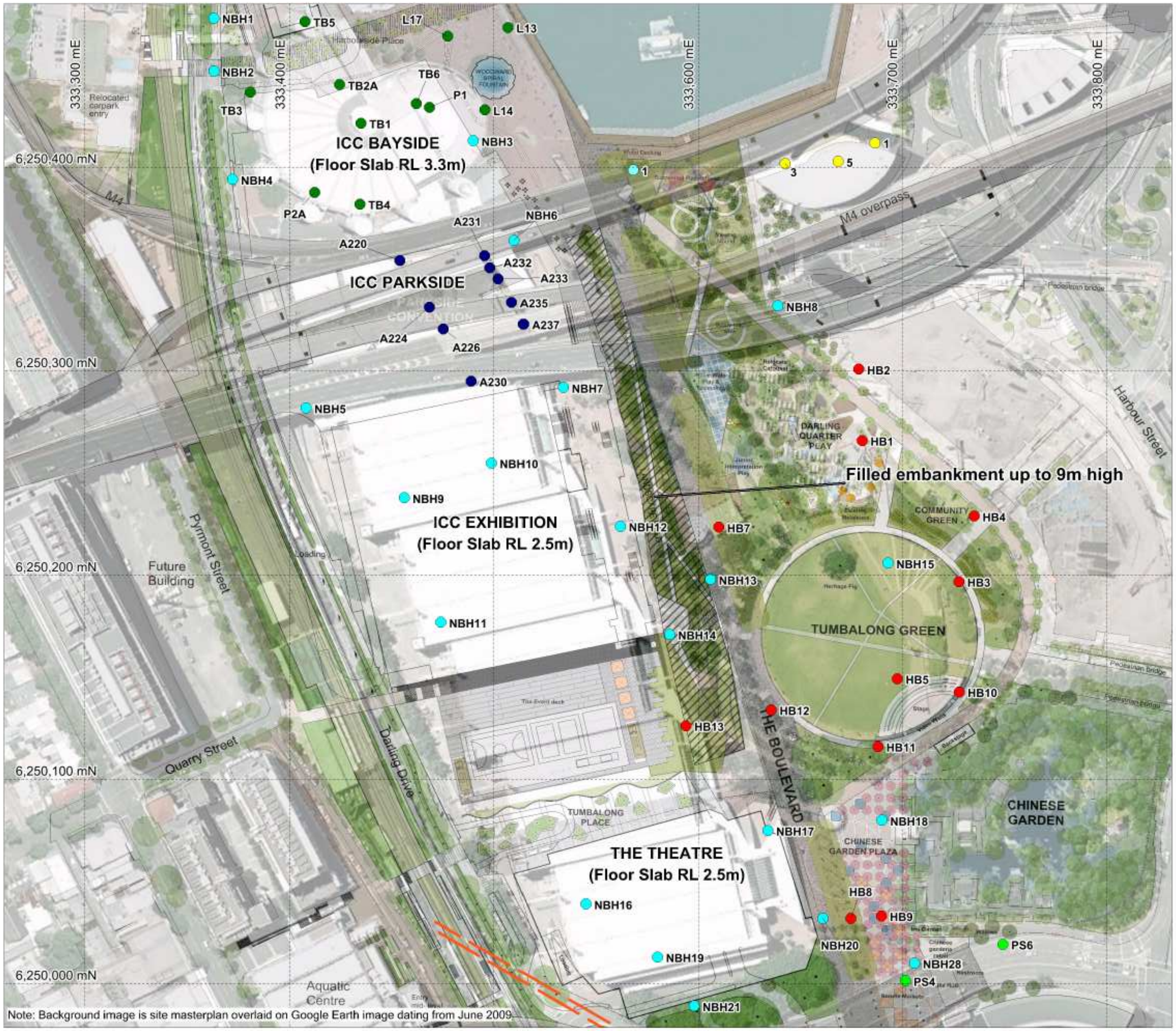
Douglas Partners Pty Ltd

Appendix A

Drawings 1 to 2

Figure 2

About this Report



Legend

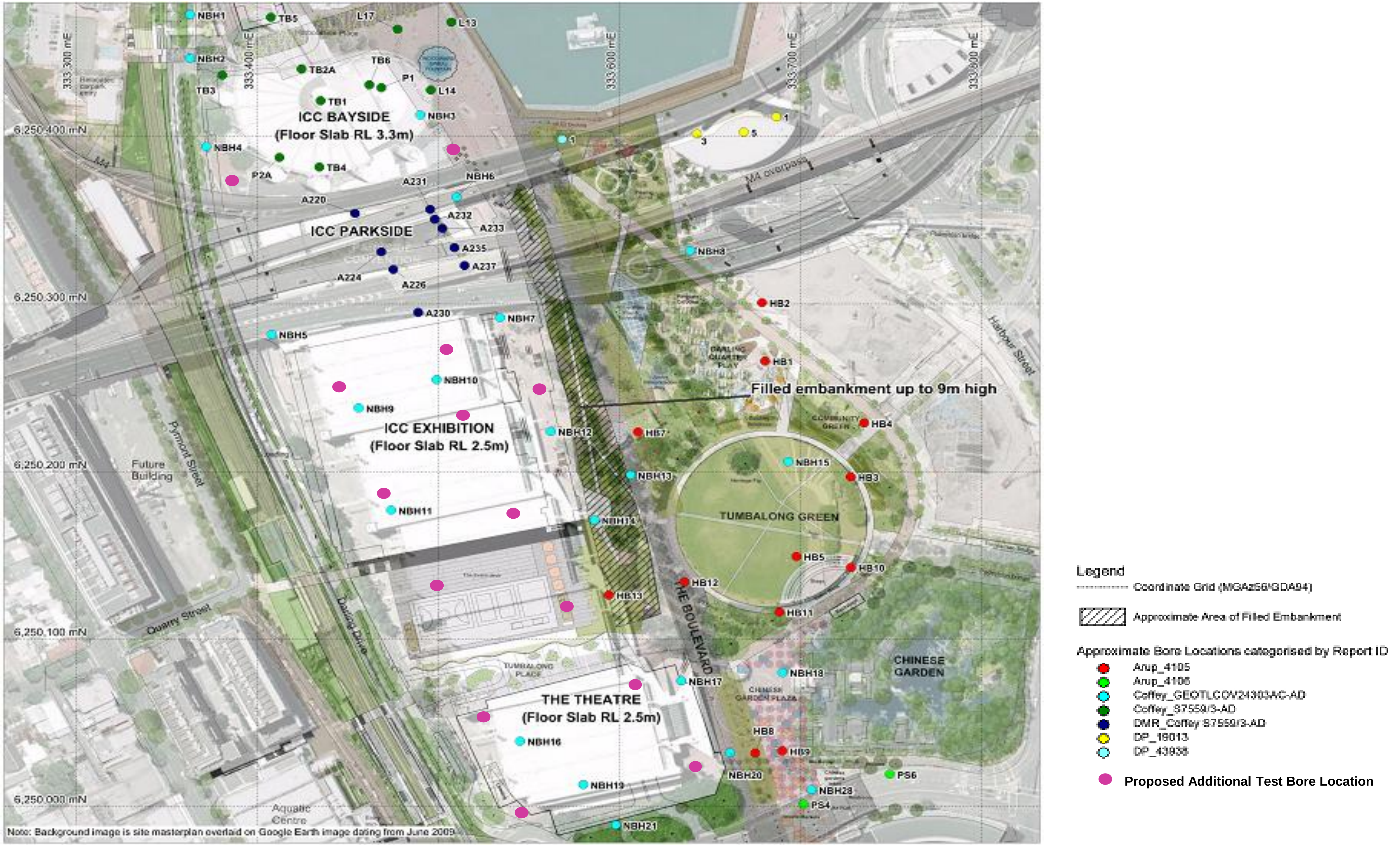
- Coordinate Grid (MGAz56/GDA94)
- Approximate Area of Filled Embankment

Approximate Bore Locations categorised by Report ID

- Arup_4105
- Arup_4106
- Coffey_GEOTLCOV24303AC-AD
- Coffey_S7559/3-AD
- DMR_Coffey S7559/3-AD
- DP_19013
- DP_43938

- Projected alignment of dyke detected in Coffeys bores

Douglas Partners Geotechnics / Environment / Groundwater	CLIENT: Darling Harbour Live		TITLE: PPP Site Plan with Test Bore Locations Proposed Sydney International Convention, Exhibition and Entertainment Precinct, Darling Harbour	PROJECT No: 72959.0
	OFFICE: Sydney	DRAWN BY: AT		DRAWING No: 1
	SCALE: 1:2000 @ A3	DATE: 28.02.2013		REVISION: A



Douglas Partners *Geotechnics / Environment / Groundwater*	CLIENT: Darling Harbour Live		TITLE:	**PPP Site Plan with Proposed Additional Test Bore Locations**	PROJECT No: 72959
	OFFICE: Sydney	DRAWN BY: GRB		**Proposed Sydney International Convention, Exhibition and**	DRAWING No: 2
	SCALE: NTS	DATE: 15.02.2013		**Entertainment Precinct, Darling Harbour**	REVISION: A

About this Report

Douglas Partners

Introduction

These notes have been provided to amplify DP's report in regard to classification methods, field procedures and the comments section. Not all are necessarily relevant to all reports.

DP's reports are based on information gained from limited subsurface excavations and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

Copyright

Borehole and Test Pit Logs

The borehole and test pit logs presented in this report are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on frequency of sampling and the method of drilling or excavation. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, but this is not always practicable or possible to justify on economic grounds. In any case the boreholes and test pits represent only a very small sample of the total subsurface profile.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes or pits, the frequency of sampling, and the possibility of other than 'straight line' variations between the test locations.

Groundwater

Where groundwater levels are measured in boreholes there are several potential problems, namely:

- In low permeability soils groundwater may enter the hole very slowly or perhaps not at all during the time the hole is left open;
- A localised, perched water table may lead to an erroneous indication of the true water table;
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report; and
- The use of water or mud as a drilling fluid will mask any groundwater inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water measurements are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from a perched water table.

Reports

The report has been prepared by qualified personnel, is based on the information obtained from field and laboratory testing, and has been undertaken to current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal, the information and interpretation may not be relevant if the design proposal is changed. If this happens, DP will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface conditions, discussion of geotechnical and environmental aspects, and recommendations or suggestions for design and construction. However, DP cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions. The potential for this will depend partly on borehole or pit spacing and sampling frequency;
- Changes in policy or interpretations of policy by statutory authorities; or
- The actions of contractors responding to commercial pressures.

If these occur, DP will be pleased to assist with investigations or advice to resolve the matter.

About this Report

Site Anomalies

In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, DP requests that it be immediately notified. Most problems are much more readily resolved when conditions are exposed rather than at some later stage, well after the event.

Information for Contractual Purposes

Where information obtained from this report is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. DP would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

The company will always be pleased to provide engineering inspection services for geotechnical and environmental aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.