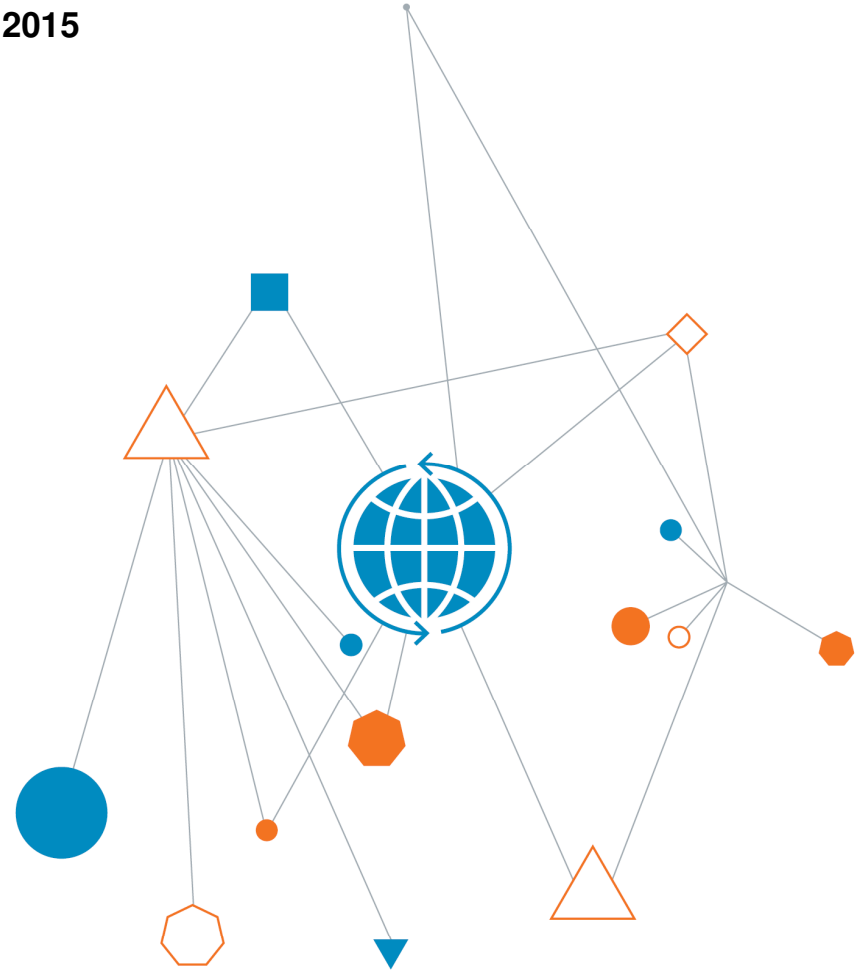
Crown Resorts Limited

Barangaroo Stage 1C – Retention System, Remediation & Bulk Excavation

Preliminary Geotechnical Assessment

19 March 2015



When you think with a global mind problems get smaller

Level 19, Tower B, 799 Pacific Highway
Chatswood
NSW 2067 Australia

t: +61 2 9406 1000
f: +61 2 9406 1002

coffey.com

Crown Resorts Limited
Level 2, 8 Whiteman Street
Southbank VIC 3006

19 March 2015

Attention: Mr Daniel Prince

Dear Daniel

RE: Barangaroo Stage 1C – Preliminary Geotechnical Assessment for Excavation Retention, Remediation & Bulk Excavation

Coffey Geotechnics Pty Ltd (Coffey) is pleased to present the results of a geotechnical assessment carried out for the proposed retention, remediation and bulk excavation to be constructed at the Barangaroo Stage 1C site in the following report.

Coffey understands that the proposed development is to include the installation of a retention system to facilitate remediation and bulk excavation to approximately -9.5 m AHD. Coffey has assessed the proposed retention and excavation scheme in the context of the existing geotechnical conditions on the site and concludes that the site is suitable for its intended use.

While the site contains a number of geotechnical challenges including the presence of a dyke, a high groundwater table, highly variable rock levels, deep fill deposits and contaminated soil and groundwater, Coffey is satisfied that these challenges can be adequately addressed through the use of industry standard design and construction techniques and practices.

Should you have any questions regarding this report, please contact the undersigned on 9406 1009.

For and on behalf of Coffey

Max Foweraker
Senior Engineering Geologist

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FIGURES

1. INTRODUCTION

At the request of Crown Resorts Limited (Crown), Coffey has carried out a preliminary geotechnical assessment for the proposed retention, remediation and bulk excavation works at the Barangaroo Stage 1C site to support a State Significant Development Application (SSDA). The objectives of the geotechnical assessment include:

- Development of a preliminary geotechnical model for the site based on site investigations carried out by Coffey, or information gathered by others for previous investigations
- Assessment of the proposed development scheme in the context of the geotechnical conditions on the site and confirm that the site is, or can be made suitable for its intended use
- Provide preliminary assessment and recommendations for the following aspects in context of the proposed development(s) scheme:
    - Excavation conditions and support requirements
    - Groundwater conditions and dewatering requirements
    - Expected soil aggressivity to buried structural elements
    - Expected seismic design parameters.

2. PROJECT OVERVIEW

2.1. General

The works the subject of the SSDA are termed the Stage 1C remediation and earthworks. The land which is the subject of the Stage 1C remediation and earthworks SSDA is located in the north-western corner of Barangaroo South. With reference to the Barangaroo 'development blocks', as identified within the approved Concept Plan Urban Design Controls (MP06_0162 MOD 6), the Stage 1C remediation and earthworks area is located to the west of Blocks 4A, 4B and 4C and incorporates part of Globe Harbour.

The Stage 1C remediation and earthworks are described as follows:

- Carrying out of remediation and validation within the Stage 1C remediation and earthworks area to ensure it is suitable for the intended future uses of the land;
- Construction of a perimeter retention wall system and internal stabilising walls (the Stage 1C groundwater retention wall system) to the west of Block 4B and Block 4C. The Stage 1C groundwater retention wall system would be fully integrated with the Stage 1B retention wall system (as specified by Lend Lease in the EIS for SSD 5897-2013), with direct connections to create a unified groundwater retention wall system across Stage 1B and Stage 1C; and
- Bulk excavation within the perimeter of the Stage 1C groundwater retention wall, and the installation of lateral restraining structures to support the perimeter retention wall system.

2.2. Background

The excavation area for Stage 1C of the Barangaroo Development accounts for approximately 5,800 m^2 of land that was previously occupied by the former shipping and overseas passenger terminal. Figure 1 presents the location of the Stage 1C site, together with an approximate outline of the adjacent Stage 1A and 1B sites and the Hickson Road alignment.

Retention, remediation and excavation for the Stage 1C site will involve the installation of a perimeter retention system that will also act as a cut-off to groundwater flow through the high permeability fill and underlying estuarine and alluvial sediments, remediation and excavation of soil material to -9.5mAHD (excavation volume of approximately 68,000 m^3).

2.3. Site Description

Barangaroo Stage 1C is within the Barangaroo South precinct with an area of approximately 10,200 m^2. It is located immediately to the west of the Barangaroo Stage 1B site and shares a common boundary (refer Figure 1). The site is situated within the local government area (LGA) of the City of Sydney Council and comprises part of Lots 5 and 6 in Deposited Plan (DP) 876514.

The current zoning of the eastern and western part of the site is Zone B4 and Zone RE1 that permits mixed land uses and public recreation. The parts of the site are currently being temporarily used as staging and batching plant areas to facilitate construction works currently underway in the Barangaroo South precinct and partial access for public recreation.

3. DESK STUDY INFORMATION

3.1. Geology and Site History

The Sydney 1:100,000 Geological Sheet indicates that the site locality is underlain by fill and Quaternary alluvium overlying Triassic age Hawkesbury Sandstone. An igneous dyke (the Pittman LIV Dyke), inferred to be of Jurassic Age, is also shown in close proximity to the site.

A detailed summary of the site history was included as part of the geotechnical report prepared by Coffey for the Barangaroo South site (Coffey, 2010), including a review of the historical aerial photographs, archaeological records and historical maps available for the region.

Historic gasworks infrastructure was located to the east of the site and extended to the area currently occupied by Hickson Road. The gas works operated at the site for approximately 80 years, prior to the demolition in 1925, and is known to have included the construction of at least three gas holders, one tar tank and a number of operational buildings. Two of the original gas works buildings remain, situated between the current The Bond, 30 Hickson Road, and 38 Hickson Road.

Following the demolition and backfilling of the gas works in 1925, timber wharves were constructed in its place and further northward so that by the early 1930s, the entire shoreline in the site area was fronted with timber wharfs (numbered 3 to 13 from north to south) extending from a sandstone seawall at the northernmost point.

From the mid-1960s to the early 1970s a concrete seawall was constructed parallel to and some 150 m out from the former seawall. The concrete seawall is approximately 1 km long and was constructed by sinking of pre-cast concrete segments over a dredged sea floor.

Significant filling occurred within the site area of Barangaroo South during the construction of finger wharves to prior to early 1950s and after the demolition of the wharves during late-1960s to late 1980s.

In 1999, Wharf 8 Overseas Passenger Terminal was constructed within the site area and was then demolished in 2010 for the Barangaroo South development.

3.2. Previous Geotechnical Investigations

Extensive geotechnical site investigations have been carried out by Coffey and others within the Barangaroo South area, in particular Stages 1A and 1B. However, limited geotechnical investigations have been completed within the Stage 1C area.

The following reports were used to assess the geotechnical/geological conditions for the Stage 1C site:

- Environmental Site Assessment, East Darling Harbour, Sydney, NSW, Final Report (June 2007), ERM.
- Additional Investigation Works at Barangaroo, Hickson Road, Millers Point, NSW (July, 2008), ERM.
- Data Gap Investigation, EPA Declaration Area (Parts of Barangaroo and Hickson Road), (July 2010), AECOM.
- Groundwater Discharge Study, Stage 1 Barangaroo Development (August, 2010), AECOM.
- Barangaroo Stage 1 Development Geotechnical Report, (October, 2010), Coffey.
- Barangaroo Stage 1B Geotechnical Investigation and Testing (December, 2013), Coffey.

4. PRELIMINARY GEOTECHNICAL MODEL

4.1. General Soil and Rock Profile

Based on the previous site investigation data for Barangaroo South, the geotechnical conditions at the site of Stage 1C are assessed to comprise the following:

- Asphalt pavement and heterogeneous fill (Unit 1), overlying;
- Alluvial and estuarine sediments (Unit 2A and Unit 2B) of variable thickness, overlying;
- Residual soils (Unit 3) and Hawkesbury Sandstone bedrock (Unit 4).

The Pittman LIV dyke crosses the Stage 1C site as shown in Figure 2. The dyke is interpreted to be a near vertical structure approximately 3 m wide, generally orientated in an east-west direction. The dyke is completely weathered to stiff clay to approximately 6 m below the surrounding bedrock surface.

Table 1 presents an overview of subsurface conditions and geotechnical units.

Table 1 – Overview of Subsurface Conditions and Geotechnical Units

Unit	Typical Thickness (m)	Description
1. Fill	15 to 16	Surface conditions typically consist of a thin asphalt layer, with occasional concrete slab below, overlying a mixture of sand and gravel, mainly derived from crushed sandstone, with minor quantities of clay. The fill is observed to contain sandstone cobbles, brick fragments and timber. The fill may contain large boulders, timber and possibly buried wharves, timber piles, boats and other abandoned infrastructure. The base of the fill has been interpreted as highly irregular and has often mixed with the upper surface of the underlying natural soil during placement.
2A. Estuarine Sediments	1 to 2	Typically dark grey to black silty/sandy clays with sub-ordinate clayey sands. Typically contains shells and shell fragments and organic material. Organic/peaty clay horizons may be present, possibly corresponding to an area where mangrove swamps once existed. Often exhibits sulphurous odour.
2B. Alluvial Sediments	1 to over 10 (increasing in thickness to the west)	Clayey sand with subordinate and interbedded silty clays and sandy clays. Inferred to be derived from weathered sandstone from neighbouring sandstone 'highland'. Typically brown, orange brown, red brown and yellow, of medium dense to dense relative density.
3. Residual Soil	Generally absent to <1	Due to the erosional nature of the overlying alluvial deposits, residual soil is generally absent and where present is typically limited to less than 1 m.
4. Sandstone	4A less than 1 4B typically 1 4C 2 to 3 4D not proven	Extremely low strength and extremely to highly weathered close to the top of the unit grading to high strength and fresh at depth. The sandstone bedrock has been sub-divided into a number of separate units based on the Pells *et al.* (1998) rock classification system as follows: • Unit 4A – Class V Sandstone • Unit 4B – Class IV Sandstone • Unit 4C – Class III Sandstone • Unit 4D – Class II or better Sandstone Class V Sandstone is extremely to highly weathered with extremely low to low strength, frequent zones of clay seams, highly fractured or fragmented. Class II Sandstone or better is generally fresh to slightly weather with medium to very high strength, slightly fractured to unbroken.

Figure 2 presents a bedrock contour plot, showing the inferred top of sandstone (Class V) based on the information obtained from the available investigation data listed in Section 4.2. Based on limited geotechnical information, we have assessed that rock levels vary from approximately -15 mAHD at the boundary between the Stage 1B and Stage 1C site to -28 mAHD at the closest point of the wall to Darling Harbour. It is likely that as the rock levels drop towards Darling Harbour, the alluvial deposits increase in thickness.

Figure 3 presents an interpreted cross-section along the eastern boundary of the Stage 1C site.

4.2. Igneous Dyke

A dolerite intrusion, numbered LIV on the Pittman numbering system, is known to trend in a general east west direction in the northern extent of the site area. The approximate location of the Pittman LIV Dyke is shown in Figure 2, based on the earlier Barangaroo South investigations and observations during construction of the residential building at 38 Hickson Road. Water pressure testing within previous boreholes that have encountered the dyke have indicated variable rock mass permeability.

The dyke is observed to be generally near vertical, 3 m wide, low to medium strength dolerite feature which was observed grey prior to oxidising to a pale brown. The feature was observed is strike in an east-west direction, dipping at approximately 80° to the south. The boundaries of the dyke were observed to include a high plasticity grey clay.

4.3. Joints and Bedding Planes

Within the unweathered sandstone bedrock jointing or bedding partings are typically very widely spaced. Where encountered the bedding planes are generally observed to dip between 10° and 20° from horizontal (to the north and north east)

Joints are relatively rare within the sandstone, with logging of the earlier investigation indicating near vertical fractures striking between 010°MN and 040°MN and between 100°MN and 140°MN, where observed. Evidence of the near vertical jointing has been encountered in recent excavation along the Hickson Road boundary for the Stage 1A construction, where the joints have been found sub-parallel to the excavation face, resulting in small wedge overbreak in the cutting.

The defects in the Hawkesbury Sandstone at Barangaroo are consistent with the regional structural geology regime of sub-horizontally bedded sandstone and subordinate interbedded shale horizons with two dominant joint sets trending north north east and west north west.

4.4. Buried Sandstone Cliffs

The sub-horizontally bedded sandstone is inferred to step down towards Darling Harbour in a series of buried cliffs and possible overhangs paralleling the natural shoreline geometry. Figure 4 shows the key characteristics of sandstone cliffs encountered in the Sydney region.

The key features to note are the sub-vertical faces formed by relatively massive, more homogeneous sandstone which is separated by weaker beds (such as shales, siltstones, mudstones and weaker sandstones). These weaker beds provide breaks in the cliff faces often forming the sub-horizontal areas of the overall cliff profile. These weaker beds can also promote undercutting of the sandstone above; weathering more readily than their more resistant sandstone counterparts. The presence of these weaker horizons in boreholes within the upper bedrock profile may indicate the presence of a nearby cliff line.

The other key features of sandstone cliffs are the wide, open, sub-vertical joints at the cliff margins which may or may not be infilled with soil strength material. These joints will eventually propagate the formation of large detached sandstone blocks. The presence of these types of defects within boreholes may be an indication of a nearby cliff line.

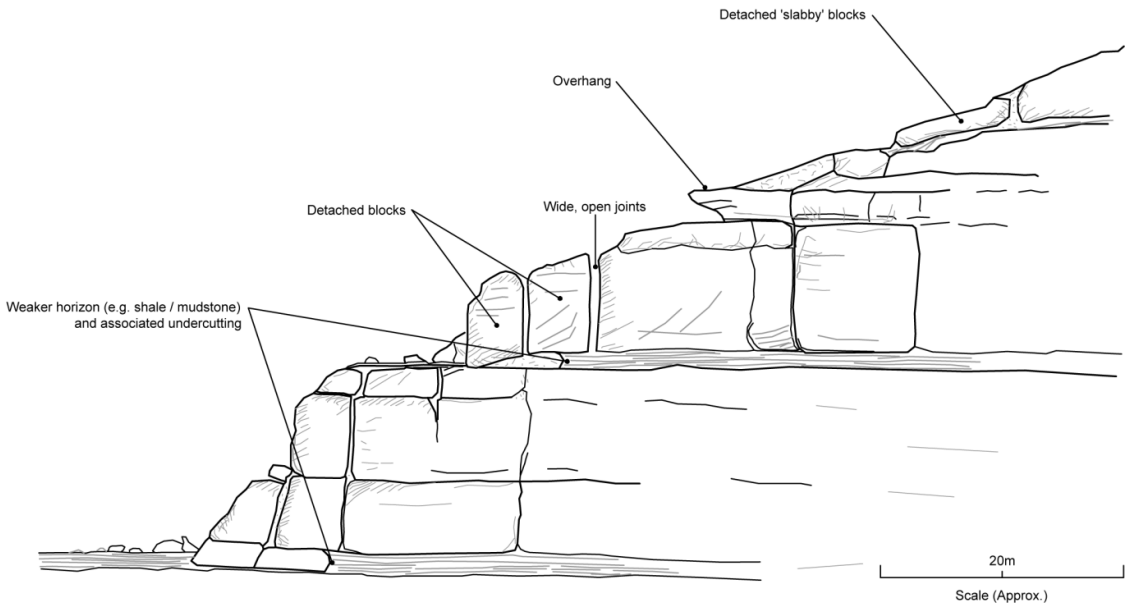


Figure 4 – Key Characteristics of Sydney Sandstone Cliffs

4.5. Groundwater

Based on the monitoring during previous investigations and construction work at the adjacent Stage 1A site, groundwater tidal fluctuations were recorded. Groundwater variation in the soil profile (fill or estuarine sediments) varied from near 100% of tidal variation for piezometers installed near the northern limit of the Stage 1A area within 40 m of the harbour wall to 14% in the south east corner of the Stage 1A area near Hickson Road. It is expected that similar strong tidal response will be apparent within the fill at the Stage 1C site.

The following water level information has been provided within the Marine Report carried out for the Scheme C Barangaroo Tender Design.

- The existing Highest Astronomical Tide (HAT) is 1.175 m AHD; and
- The existing Mean High Water Springs (MHWS) is 0.67 m AHD.

Previous investigations indicated that the fill material across the site is assessed to be highly permeable. The near surface water table responds strongly to tidal variations.

5. PRELIMINARY DISCUSSION AND RECOMMENDATIONS

Based on the findings of our geotechnical assessment and experience of the Barangaroo Stage 1A development, the proposed retention, remediation and excavation for Stage 1C is considered feasible from a geotechnical perspective. The proposed development should present a low risk to surrounding structures provided appropriate additional site investigation, design assessments, and construction monitoring normally associated with this type of development are carried out.

5.1. Excavation Conditions

The proposed development will be excavated to approximately -9.5mAHD and is expected to be within Unit 1 Fill material. Construction dewatering will be required to facilitate excavation.

5.2. Retention System

The retention system for the excavation is required to be reasonably watertight and designed for tidal variation. The retention system will also provide a cut-off to groundwater flow through the highly permeable fill and estuarine/alluvial deposits and be keyed into a low permeability alluvial layer (if present) or sandstone bedrock. The following retention/cut-off options could be considered:

- Diaphragm wall
- Sheet piles in a cement/soil trench
- Secant pile wall (using cased CFA piles or with jet grouting)
- Cutter soil mix wall

Temporary ground anchors drilled into the sandstone rock may be required to provide support to the retention system. Due to the relatively high water table within the site soils, due to tidal fluctuations, water is likely to flow into the excavation at the head of wall anchors. Consideration needs to be given to providing water management systems, such as sealing of anchor heads, seepage collection systems and the disposal options.

Installation of ground anchors beyond the site boundaries will require careful consideration, It is considered that conventional temporary ground anchors (e.g. pre-stressed multi-strand steel anchors) may be installed for wall retention, which will be de-stressed after construction of the permanent wall support.

5.3. Design Parameters

For the preliminary design of retention systems, the parameters in Table 2 may be adopted:

Table 2 – Preliminary Retaining Wall Design Parameters

Unit	Description	Bulk Unit Weight (kN/m^3)	Effective Cohesion (kPa)	Effective Friction Angle (degrees)	Elastic Modulus (MPa)
1	Fill	18-20	0	30	5-15
2	Alluvium	18	0	25	5-10
3	Residual Soil	20	5	25	60
4A	Class V Sandstone	23	20	35	80

Retaining walls should be designed for appropriate hydrostatic and surcharge loads.

5.4. Groundwater Conditions

The fill material across the site is assessed to be highly permeable. The near surface water table responds strongly to tidal variations.

A barrier to groundwater flow during is required to control groundwater ingress as excavations progress below the groundwater table. The barrier should be keyed into the low permeability material. An appropriate dewatering system will need to be employed to lower the groundwater level.

The detailed assessment and design of groundwater management is beyond the scope of this report and should be addressed by a hydrogeological investigation.

5.5. Excavation Induced Ground Movements

Walls retaining soil strength material will laterally deflect up to 1% of the retained height, depending on the stiffness of the retaining wall system.

The potentially damaging effects of stress redistribution in the vicinity of excavations should be assessed as part of the detailed design. Lateral displacements of retaining walls due to stress redistribution may also result in settlement. For preliminary assessment of impacts we recommend that potential settlement be assumed to be equal to predicted lateral displacements. Typically, ground movements (lateral displacement and settlement) are greatest at the excavation face and decrease to negligible values at a distance of up to 1.5 times the excavation depth.

For preliminary impact assessment purposes the above guidelines on displacements may be used. If such movements cannot be tolerated for sensitive features, then retaining walls should be designed for higher earth pressures. Depending on the specific retention system, basement excavation details and the nature of adjacent structures, a more detailed analysis will be required.

5.6. Soil Aggressivity

Comparison of the laboratory test results on soil samples from the Stage 1B investigations with the criteria set out in Table 6.4.2(C) of AS2159-2009 (assuming highly permeable ground conditions which are in groundwater) indicates that the soil tested can be classified as 'mild' exposure classification with respect to concrete piles. Furthermore, based on the chloride and pH test results, an exposure classification of 'Non-aggressive' ground conditions for steel piles, as per the criteria in Table 6.5.2(C).

Further soils and groundwater aggressivity testing should be carried out at the site to allow greater site coverage and better understanding of chemical conditions to assist detailed design.

5.7. Seismic Design

Selection of seismic parameters for design of soil retention structures should follow the requirements of:

- AS 4678-2002 Earth Retaining Structures
- AS 1170.4-2007 Structural Design Actions – Part 4: Earthquake Action in Australia

The probability factor (k_p) for the annual probability of exceedance shall be selected in accordance with AS1170.4 as appropriate for the limit state under consideration. A hazard factor (Z) of 0.08 is appropriate for the Barangaroo site. Based on the findings of the geotechnical investigations carried out at Barangaroo, conditions are considered to most closely resemble the site sub-soil class of Class C_e, as defined in Section 4 of AS 1170.4.

6. CONCLUSION

Retention, remediation and excavation for the Stage 1C site will involve the installation of a perimeter retention system that will also act as a cut-off to groundwater flow through the fill and underlying high permeability estuarine and alluvial sediments, remediation and excavation of soil material to -9.5 mAHD.

Coffey has assessed the proposed retention, remediation and excavation for Stage 1C in the context of the existing geotechnical conditions on the site and has concluded that the site is suitable for its intended use.

While the site contains a number of geotechnical challenges including the presence of an igneous dyke, high groundwater table that responds to tidal variation and potential presence of buried cliffs and variable rock levels, Coffey is satisfied that these challenges can be adequately addressed through the use of industry standard design and construction techniques and practices.

7. LIMITATIONS

The preliminary geotechnical assessment and recommendations presented in this report are based on a desk study of previous investigations by Coffey and others. Ground conditions can vary over relatively short distances and site specific investigation for the various individual structures for the development and construction stage geotechnical assessments should be undertaken to manage geotechnical risk.

The attached document entitled “Important Information about your Coffey Report” provides additional information on the uses and limitations of this report.

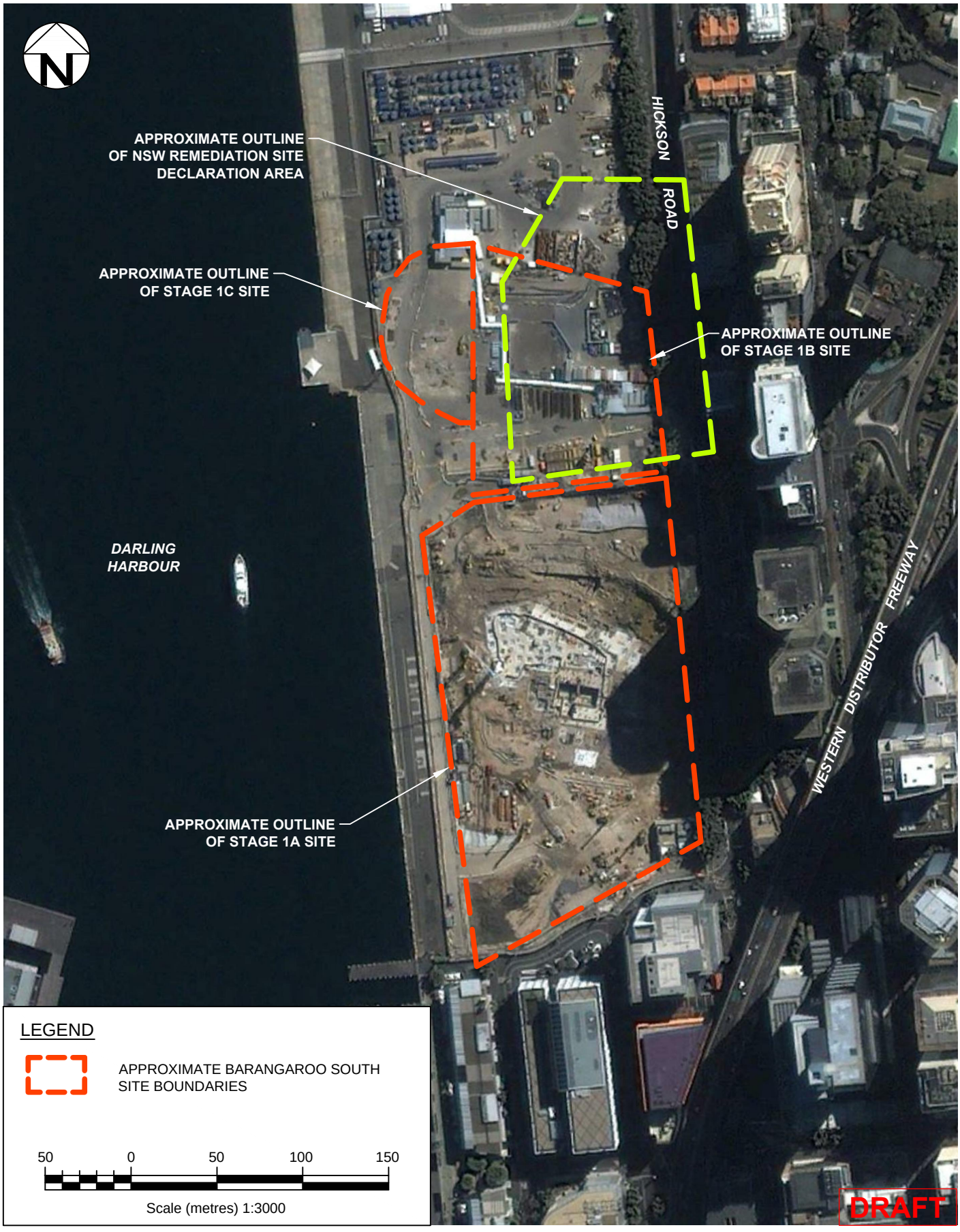
For and on behalf of Coffey

Max Foweraker
Senior Engineering Geologist

REFERENCES

Pells *et al.* (1998) “Foundations on Sandstone and Shale in the Sydney Region” Aust. Geomech.Jnl. Dec 1998

New South Wales Department of Mineral Resources, Geological Series Sheet 9130 (Edition 1), Sydney 1:100,000 Scale, 1983



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approved	-
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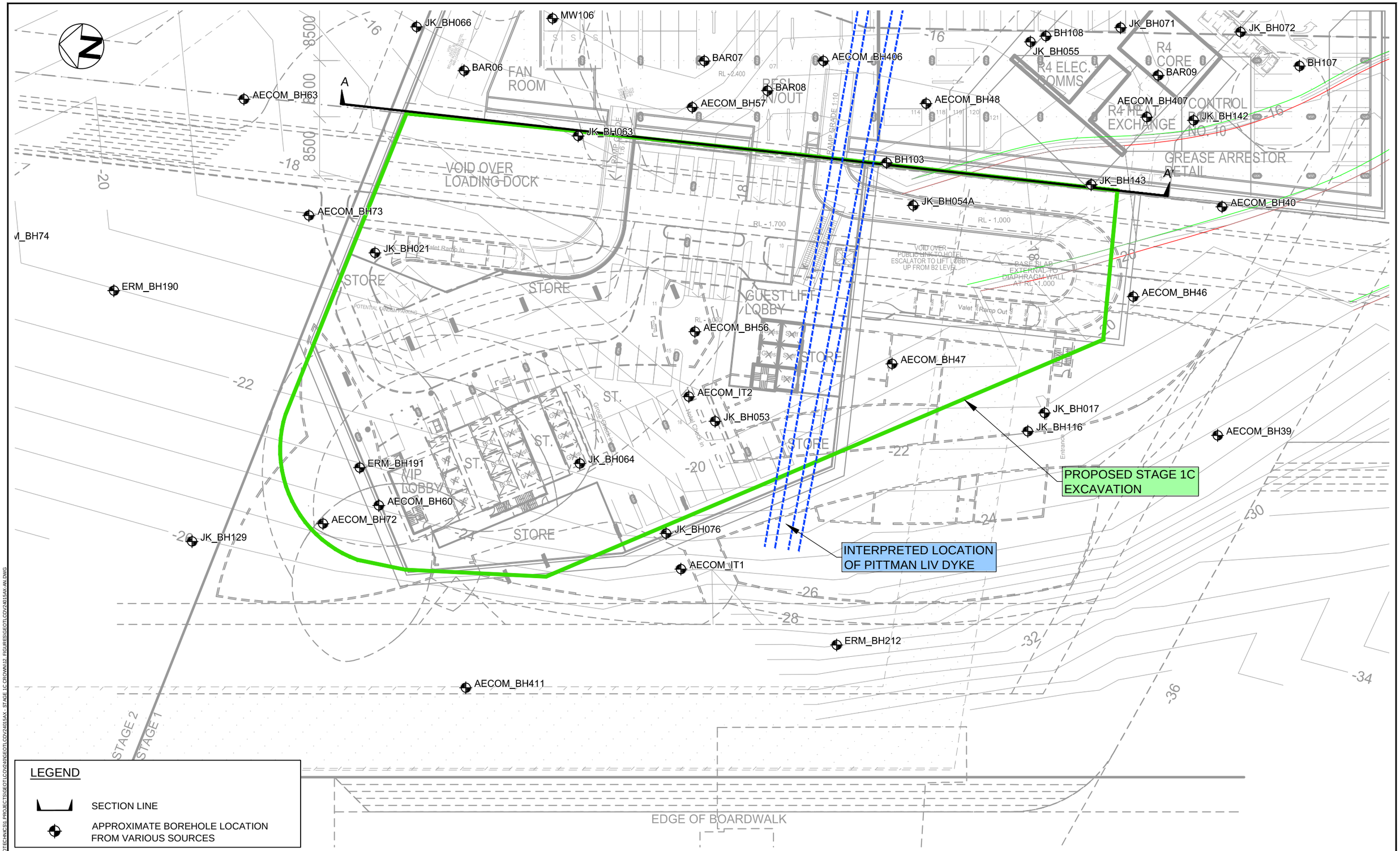
original size	A4

client:	CROWN RESORTS LTD
project:	BARANGAROO STAGE 1C - CROWN HOTEL PRELIMINARY GEOTECHNICAL ASSESSMENT
title:	SITE LOCALITY PLAN
project no:	GEOTLCOV24015AX-AN
figure no:	FIGURE 1



LEGEND

- SECTION LINE
- APPROXIMATE BOREHOLE LOCATION FROM VARIOUS SOURCES

revision	description	drawn	approved	date

5 0 5 15 25

Scale (metres) 1:500

drawn	HC / AW
approved	-
date	17 / 02 / 14
scale	1:500
original size	A3

coffey

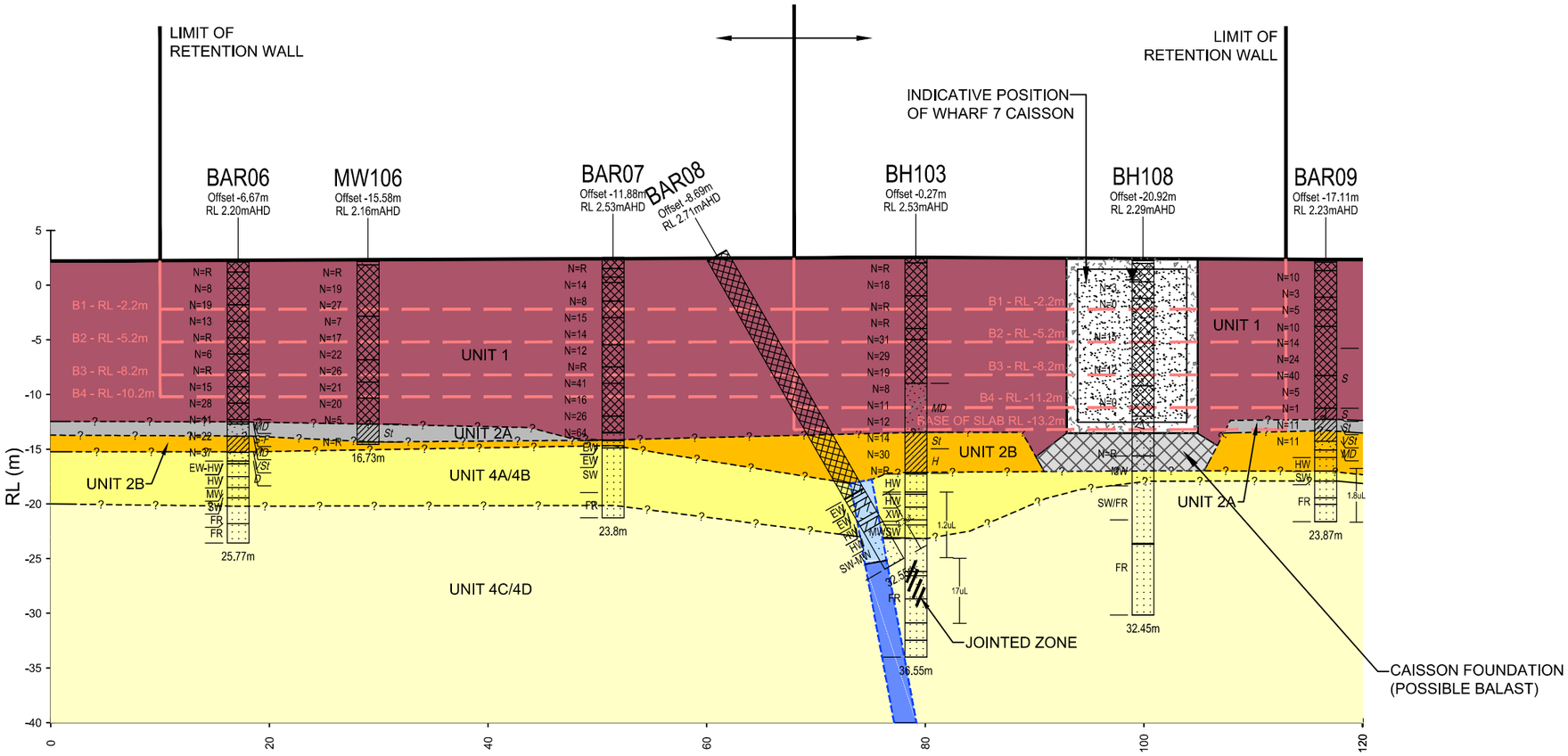
client: CROWN RESORTS LTD

project: BARANGAROO STAGE 1C - CROWN HOTEL
PRELIMINARY GEOTECHNICAL ASSESSMENT

title: INFERRED BEDROCK CONTOURS & DYKE LOCATION

project no: GEOTLCOV24015AX-AN

figure no: FIGURE 2



SECTION A-A'

LITHOLOGY KEY:

- UNIT 1 (Fill)
- UNIT 2A (Holcene Estuarine Sediments)
- UNIT 2B (Pleistocene Alluvium)
- UNIT 4A/4B (Class V & Class IV Hawkesbury Sandstone)
- UNIT 4C/4D (Class III & Class II & better Hawkesbury Sandstone)
- UNIT 5A COMPLETELY WEATHERED DOLERITE DYKE
- UNIT 5B DOLERITE DYLE
- BRECCIA

NOTES:

GEOTECHNICAL SECTION INCLUDES BOREHOLES DERIVED FROM EXTERNAL SOURCES. NO ASSURANCES CAN BE GIVEN AS TO THE ACCURACY AND RELIABILITY OF THIS INFORMATION.

THE GEOTECHNICAL MODEL PRESENTED IS BASED ON RELATIVELY WIDELY SPACED BOREHOLES. THE BOREHOLE LOGS USED DESCRIBE SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC BOREHOLE LOCATIONS AND ACTUAL BOUNDARIES BETWEEN GEOTECHNICAL UNITS MAY VARY FROM THOSE SHOWN ON THE INTERPRETED SECTON.

revision	description	drawn	approved	date

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Horizontal Scale (metres) 1:500

5 0 5 15 25
Vertical Scale (metres) 1:500

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approved	-
date	12 / 12 / 13
scale	1:500
original size	A3

coffey

client: CROWN RESORTS LTD

project: BARANGAROO STAGE 1C - CROWN HOTEL PRELIMINARY GEOTECHNICAL ASSESSMENT

title: CROSS SECTION A-A'

project no: GEOTLCOV24015AX-AN

figure no: FIGURE 3