Robert Bird Group

PLANS AND DOCUMENTS
referred to in the PDA
DEVELOPMENT APPROVAL

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Queensland Government

Design Criteria Report

Albert Street OSD

Issue: E

21 December 2022

Prepared For: CRR Albert Street Pty Ltd (ACN 660 319 693) as trustee for CRR Albert Street Trust

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Report Amendment Register

Issue Ref	Amended Section(s)	Issue / Amendment Details	Author(s)	Reviewer	Date
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Date: 21 December 2022

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1 Introduction

1.1 Purpose of Report

This report sets out the proposed design codes and standards, proposed loading information, and proposed design criteria for the structural design and documentation carried out by Robert Bird Group (**RBG**) on the commercial development on Lot 2 Albert Street Brisbane (**Albert Street OSD**) for QIC.

This document sets out the basic parameters used in the structural design of the project. It is the main reference document to obtain critical design information, including loads, material properties and performance criteria. This document references codes and standards and provides a history of structural design and how it has developed to date.

This document is a live document and will be updated throughout the life of the project. Items highlighted in Red are live items that require close-out. Updates may be proposed by any member of the RBG engineering team. Updates will only be made with the authority of the Project Engineer. At the end of the project, this document will form part of RBGs record of the structural design.

1.2 Site Details

The proposed Albert Street Over Station Development is located on Lot 2 of the Albert Street Station site for Cross River Rail. The site is located opposite the proposed Albert Street Cross River Rail Station. The site is noted as FOSD Lot 2 on the map below.

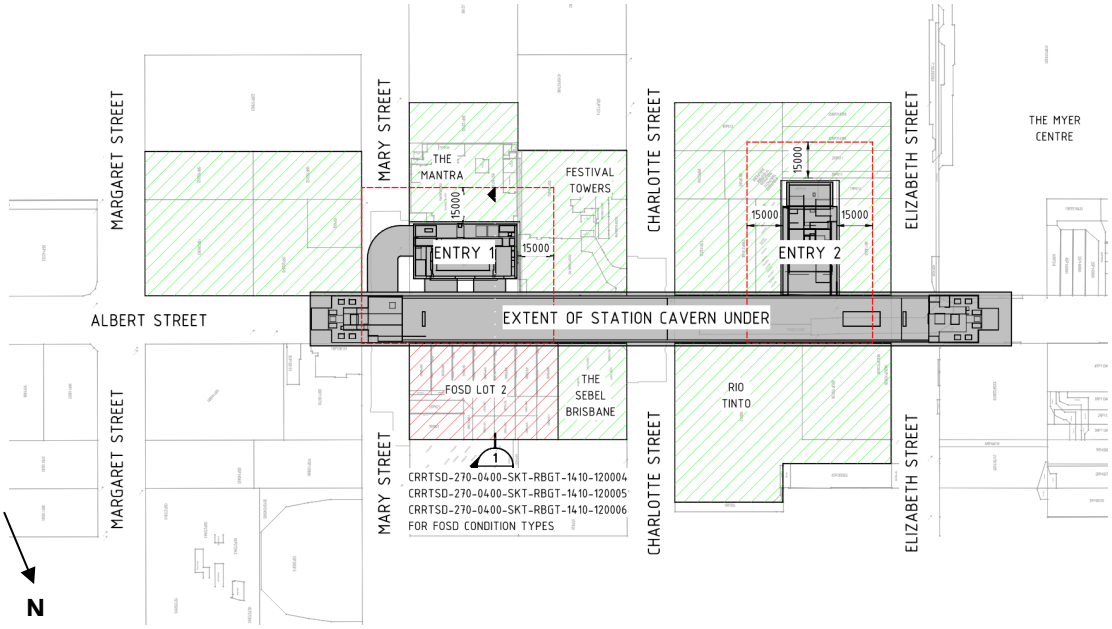


Figure 1 - Site Map

The site abuts the Station Cavern that runs under Albert Street and sits between Mary Street and the Brisbane Sebel development. Two developments abut the Northern boundary, being 110 Mary Street and 119 Charlotte Street. Refer to Figure 2 below.

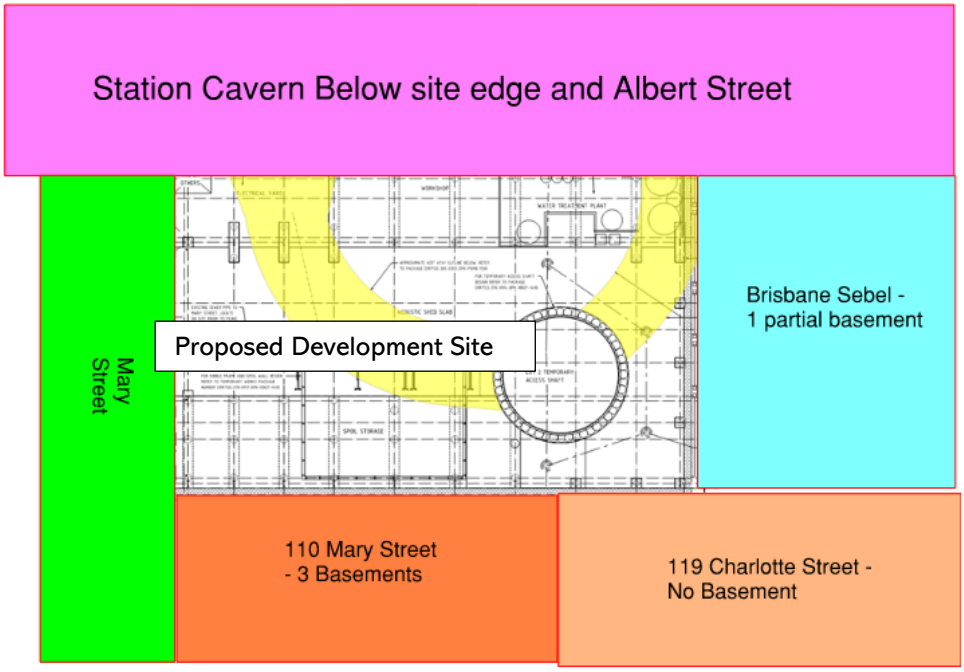


Figure 2 - Site Plan

1.3 Proposed Development

The proposed development is anticipated to comprise of a predominantly commercial tower that will sit above Podium retail and Basement parkingThe commercial tower will be split into four rises, Low, Mid, High and Sky Rise. Above the commercial at L37 will be a Destination Rooftop with an external terrace.

The building will include two basement levels over the full site, with B01 containing the Loading Facilities with the balance of B1 and B2 being car parking. A part-size basement level between B1 and Ground will house the End of Trip facilities. The finished floor level of Basement 2 is currently proposed at RL -5.00m.

Figure 3 - Proposed Tower Render (By Henning Larsen/Architectus)

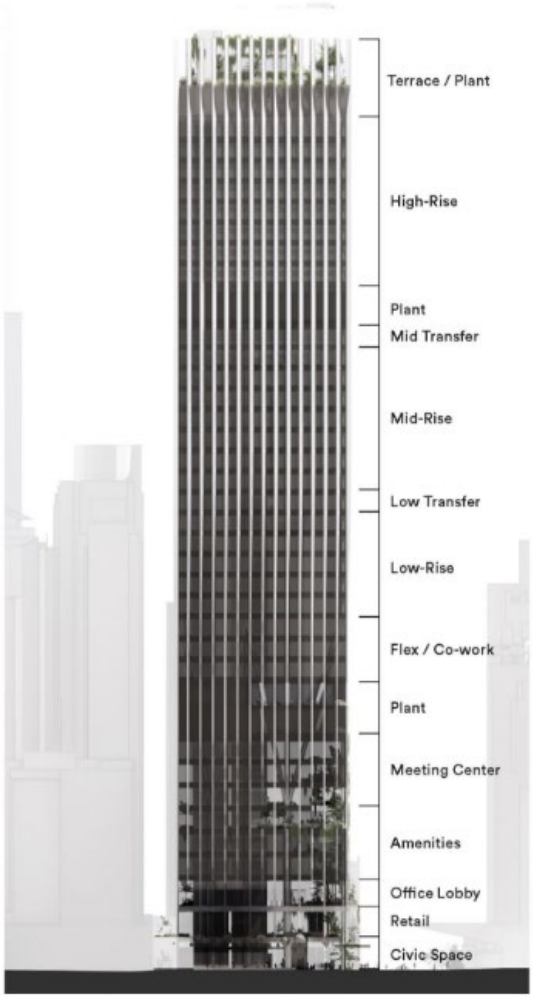


Figure 4 - Proposed Elevation (By Henning Larsen/Architectus)

1.4 Cross River Rail Assets

The development site is adjacent to and partially over major Cross River Rail Assets associated with the Albert Street Station. The major adjoining asset of most importance is the Station Cavern that runs under Albert Street. This cavern sits just under the site boundary of Albert Street. The cavern is a mined arched structure with its base at circa RL-30m and its crown at circa RL -13m. There are duct and escape passages below the cavern that link back to the primary station structure located on the opposite side of Albert Street.

Figure 5 illustrates the location of the cavern and station relative to the development site.

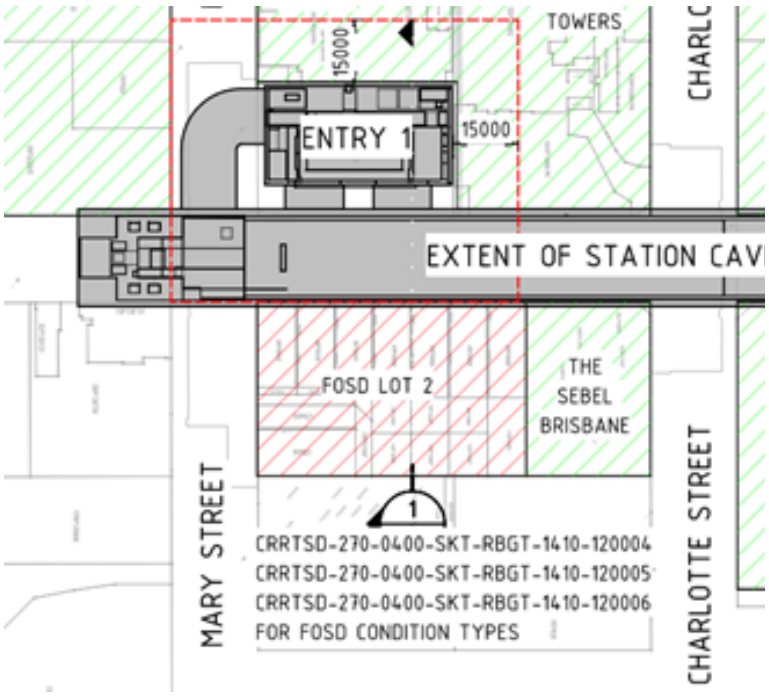


Figure 5 - Development Site and CRR Assets

Figure 6 below illustrates a section through the development site and the adjacent cavern and station structure. The extent of the proposed basement on the development site is also illustrated.

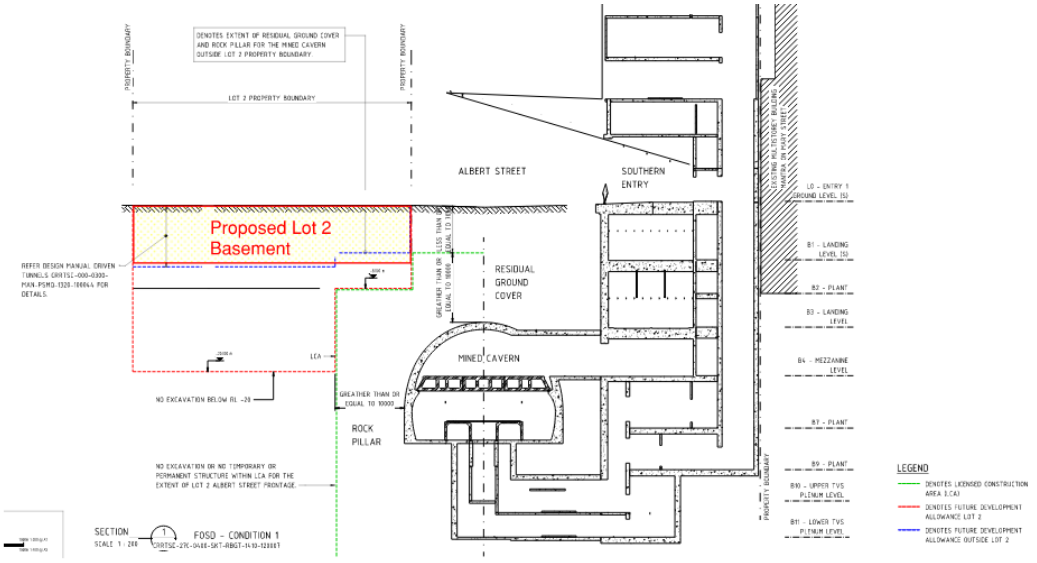


Figure 6 - Section through Prosed Development site and CRR Assets

The development site is currently occupied by an acoustic shed as part of the construction of the Albert Street Station. Within the shed is a 12m diameter temporary access shaft that extends down to nearly RL-30m. This access shaft links to two temporary adits that curve and join to the station cavern.

The acoustic shed, access shaft and connecting adits are all temporary structures. Upon completion of the station, we understand that the acoustic shed and its base slab will be removed. The adits and the access shaft, we understand, will be filled with cementitious material of similar stiffness to the adjacent ground for materials located below the base of excavation and engineered fill for materials above the base of the excavation.

Existing pile heads will be cut down below the proposed new basement or below any new pile cap. New piles will be positioned to be clear of existing piles. At this stage, there is no reuse proposed for existing piles.

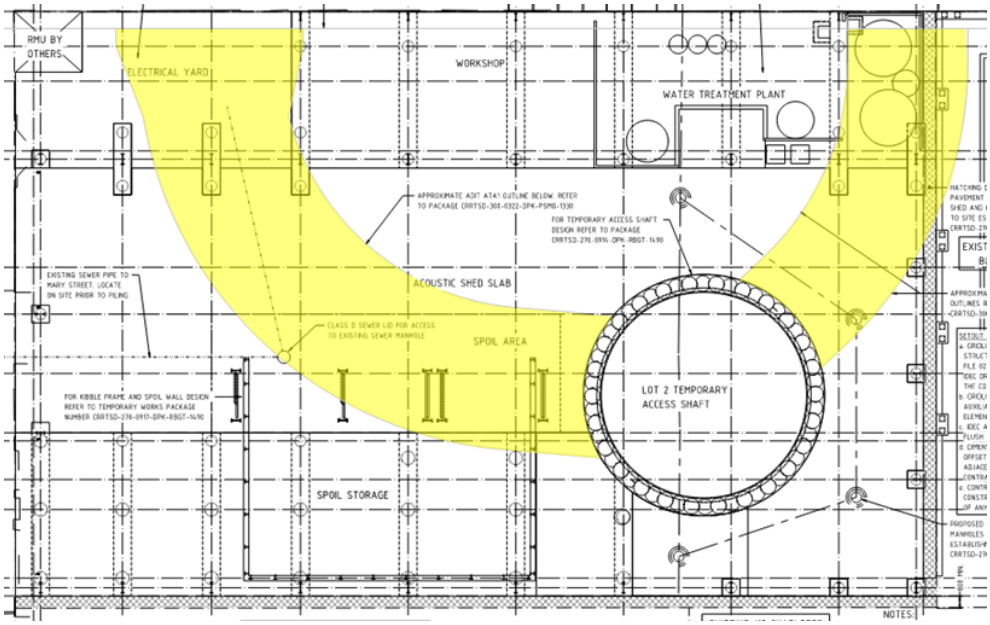


Figure 7 - Acoustic Shed, Access Shaft and Temporary Adits

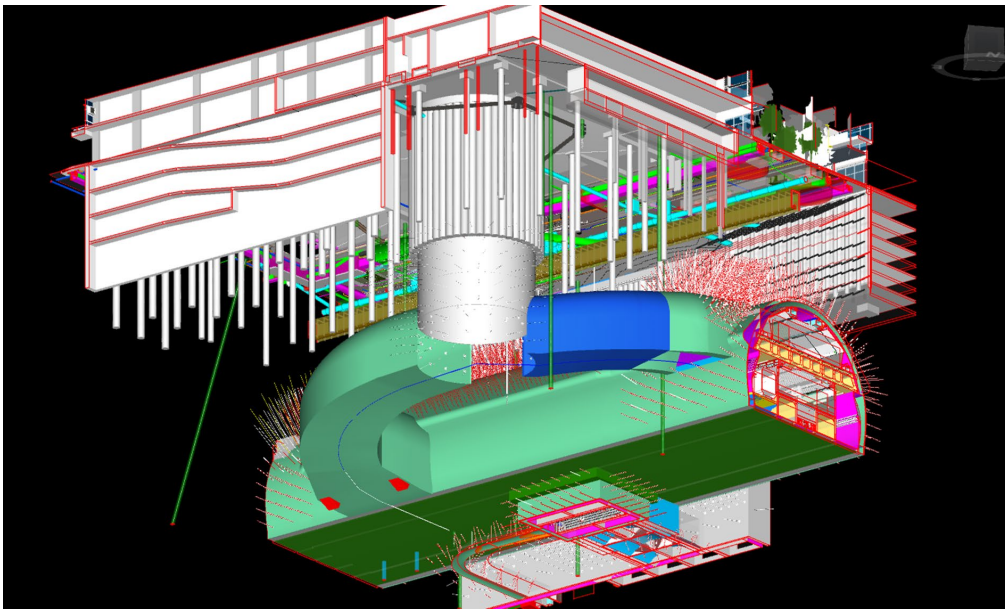


Figure 8 - Extract of CRR BIM Model below Lot 2

2 Referenced Documents

2.1 Standards and Codes

The following Standards and Codes are applicable to the design of the structural elements:

- National Construction Code of Australia – 2022.
- AS1170.0:2002 General Principles (Up to and Including Amdt 5).
- AS1170.1:2002 Imposed Loads (Up to and Including Amdt 2).

- AS1170.2:2021 Wind Code
- AS1170.4:2007 Earthquake Code (Up to and Including Amdt 2).
- AS3600:2018 Concrete Structures (Up to and Including Amdt 2).
- AS3735:2001 Concrete Structures Retaining Liquid (Up to and Including Supp1).
- AS3700-2018 Masonry Structures.
- AS4100-2020 Steel Structures (Up to and Including Amdt 1).
- AS4678:2002 Earth-retaining structures (Up to and Including Amdt 2).
- AS2327-2017 Composite Structures – Simply Supported Beams (Up to and Including Amdt 1).
- AS2159-2009 Piling – Design and Installation (Up to and Including Amdt 1).

Any code referenced in this report is to be interpreted as the revisions specified above.

2.2 Referenced Cross River Rail Reports

In preparing RBG's design response, we have made reference to and placed reliance on several existing documents. These include but are not limited to:

- Design Manual – Stations **CRRTSD-000-0401-MAN-RBGT-1470-191101**
- Design Manual – Driven Tunnels **CRRTSD-000-0300-MAN-PSMQ-1320-100044**
- Geotechnical Interpretive Report (**GIR**) **CRRTSD-000-351DPK-PSMQ-1120-000100**
- Hydrogeological Interpretive Report (**HIR**) **CRRTSD-000-0354-RPT-PSMQ-1120-040028**
- Albert Street Temporary Access Shaft – Rev C **CRRTSD_270-0460-DAN-PSMQ-1120**
- Factual Report on Geotechnical Investigation Cross River Rail-Tunnel, Stations, and Development – Douglas Partners – **CRRTSD- 97335.00.IFI.00.01**
- Albert Street Station Main and Northern Entrance Shafts – **CRRTSD-270-0940-DAN-PSMQ-1490-230078**
- Station Cavern and Adit Loads – **CRRTSD-000-0401- DAN-RBGT-1490-190380**
- Albert Street Station Utilities Assessment -**CRRTSD-000-0352-DAN-PSMQ-1124-060063**
- Geotechnical Interpretive Report (GIR) – **CRRTSD-000-0351-RPT-PSMQ-1120-030021**
- Albert Street Station **– CRRTSD-270-0904-DPK-RBGT-1490-000100**
- Albert Street Lot 2: Temporary Retention and Bulk Excavation – **CRRTSD-270-0914-DPK-RBGT-1490-231400**
- Albert Street Station Design of Acoustic Shed and Foundations - **CRRTSD-270-0904-DPK-RBGT-1490-000100**
- Permanent Works Design report – Permanent Lining (Tunnel- Albert Street) – **CRRTSD-300-0323-RPT-PSMQ-1330-190089**

3 Design Life/Durability/Fire Resistance Periods

3.1 BCA Structural Importance Level

The structural importance level assessed under the National Construction Code 2022: Building Code of Australia – Volume 1 (**NCC**) for this project is Structural Importance Level 3.

3.2 Design Life

The design and documentation of the project will comply with all relevant Australian Standards and the National Construction Code 2022 (Building Code of Australia – Volume 1). The structures will be designed to meet durability requirements for a design life of 50 +/- 20% years. Design life is the period for which a structure or structural member is to remain fit for use for its designed purpose with appropriate maintenance.

3.3 Annual Probabilities of Exceedance

Probabilities of exceedance for determining design loads are to be as follows:

Table 1 - Annual Probabilities of Exceedance

Load Type	Ultimate	Permissible	Service
Wind (Non-Cyclonic)	1:1000	1:100	1:25
Seismic	1:1000	-	-

3.4 Fire Rating

Structural elements are to be designed in accordance with the NCC and the relevant Australian Standards to satisfy the required FRL levels for fire unless advised otherwise by the Project Fire Consultant or by the Principal Certifying Authority for the project. A general guide for the design of the columns and core walls through the basement and podium levels is as follows:

Carpark	120/120/120
Retail	180/180/180
Commercial	120/120/120
Loading Dock	240/120/120
Substation	120/120/120

Note that these are a guide only, and the Architectural Fire Compartment Plans should be referred to for design. Where required, steelwork fire ratings are to be achieved by fire protective cladding/coatings to Architectural details, in accordance with the NCC. Fire engineering will be considered in future stages to reduce some ratings and potentially the extent of fireproofing. In the absence of accepted fire engineering advice, the above values will be adopted.

4 Design Loads

4.1 Loading Criteria

The following outlines the structural design loading criteria for the development. Notwithstanding the below, the structure will allow for all imposed loads as outlined by the relevant Australian Standards. Any additional loads imposed during and from the selected construction methodology for the project works, where advised in advance by the Contractor, will also need to be allowed for.

4.2 Dead, Superimposed Dead and Live Loads

4.2.1 Gravity Loads

4.2.2 Structure Self-Weight

The structure self-weight will be calculated from the unit weight of materials in AS1170.1 Table A1 Appendix A or unit weight of materials in technical specifications provided by contractors/suppliers as appropriate for the specific material.

For the purpose of the design of slabs, beams and the strength design of walls and columns, the self-weight of concrete shall be taken as not less than 24kN/m^3.

For axial shortening calculations and vibration analysis, concrete self-weight shall be taken as per the supplier's recommendations but not less than 23.5 kN/m^3.

The self-weight of structural steel sections will be as per the manufacturers' data. For fabricated sections, the self-weight of structural steel shall be taken as 78.5 kN/m^3.

4.2.3 Superimposed Dead and Imposed Live Loads

The Superimposed Dead Loads (**SDL**) and Live Loads (**LL**) are established based on the Architectural floor plans and in accordance with the Principal's Project Requirements.

Live load reduction in accordance with AS1170.1 will be incorporated into the design of columns and walls. Pattern live loading is to be considered for all elements where required by AS1170.1.

The table below outlines the SDL and LL allowances for each occupancy type. SDLS represent the combination of floor finishes/build-up, partitioning and ceiling services. The classification of Live Load Reducible or Unreducible is based on code recommendations and common practice.

Table 2 - Project Superimposed Dead and Live Loads

Loading Details	Super Imposed Dead Load [Kpa]	Live Load [Kpa]	Reducible	Comments
Carparks/Ramps/Bike Store	0.5	2.5	×	Falls assumed to be poured with structural slab thickness
Concierge/Commercial Lobby/Business Lounge	2.5	4.0	×	
Lift Lobbies	1.5	4.0	×	
Recreational/ Gym	2.5	5.0	×	
Heavy Load Area (5% of NLA/ typical commercial floor)	1.5	7.5	×	Final location/s to be agreed
Storage	0.5	2.4 for each metre of storage height	×	
Substation	2.5	15	×	Blast loading to walls taken as 2.0kPa. TBC.
Commercial	1.5	3.0	✓	
Fire Stairs	0.5	4.0	×	
General Plant	2.5	5.0	×	Unless noted otherwise.
Plant – Heavy	2.5	7.5	×	Heavy plant is any area that requires equipment greater than 2.5t maximum unit mass, such as generators, chillers, transformers, cooling towers etc.
Ground Floor	4.0 min	15	×	Based upon RL5.2 flood level plus 300mm freeboard. Lower ground

Loading Details	Super Imposed Dead Load [Kpa]	Live Load [Kpa]	Reducible	Comments
				plane subject to construction loading of 15kPa.
Vehicle Loading Dock and access ramp	2.5	15.0	×	As per AS 5100 Point Load 80kN, but final design to be checked for moving wheel loads to match maximum GVM expected for the loading dock.
Retail	2.5	5.0	✓	
Back of house	2.5	4.0	×	
Planter Soil Loads	Self-Weight as Calculated	4.0	×	Density of 18kN/m^3 Specific tree weights to be confirmed for large trees
Roof	2.5	not less than 4.0	×	Allow 100mm of screed for falls. Plus allowance for planters as noted above.

4.3 Façade loads

Table 3 summarises façade and cladding loading in accordance with AS3600 2018.

Table 3 - Façade and Cladding Load Summary

Façade Option	Load [Kpa]
Curtain Walls and External Walls – lateral loading	As specified in the façade wind pressure study by the wind engineer for the project
Façade self-weight	1.0 *subject to final GRC support structure*

4.3.1 Building Maintenance Unit (BMU) Load

The building is proposed to be serviced by a single BMU. The BMU is proposed to be located above the high-rise lift core structure. BMU loads are subject to confirmation by the supplier.

4.4 Lateral Loads

4.4.1 Wind Loads

The design wind loading for the structure will be based on the wind speeds derived from the wind climate study and wind tunnel study by the wind engineering consultant. Where any exclusions in the reports occur, the following Code wind parameters are to be adopted:

- Region B
- V1000 = 60m/s (Ultimate)
- V50 = 44m/s (permissible)

- V25 = 39m/s (service)
- Terrain Category 4
- Wind direction multiplier Md = 0.95
- Shielding multiplier Ms = 1.0
- Topographic multiplier Mt = 1.0

Final building design actions will be based on wind tunnel testing.

4.4.2 Earthquake Load Criteria

Seismic loads will be calculated in accordance with AS1170.4-2007 for the design of the primary structure comprising a superstructure lateral load-resisting frame, below-ground works and foundations. Design specifications will be provided for design by others for secondary structure, non-structural components and connections to comply with performance requirements.

- EDCIII
- The Tower is to have seismic loads determined based on its fundamental period
- Site Sub-Soil Class = C
- Hazard Factor Z = 0.08
- Structural Ductility Factor, $\mu =$
  - 2.0 above top of raking columns (all elements)
  - 1.0 below top of raking columns (corebox, L6 and L14 diaphragm floor framing, tower columns and corebox pile cap and bored piers)
- Structural performance Factor, Sp = 0.77

4.4.3 Robustness

Design for Robustness will be carried out to satisfy the requirements of AS 1170.0 Section 6 and verified for Performance Requirements of Section B Subsections BP1.1(a) and BV2 of NCC 2022. Alternative load paths are being provided in the diaphragm floor systems at level 6 and level 14.

4.4.4 Load Combinations

Ultimate Strength and Stability

Design load combinations for structure and components will be in accordance with AS1170.0 Section 4, and AS 4678 Appendix J. Generally, the following base combinations are considered:

1.35G

0.9G

1.2G+1.5Q

$1.2G+W_U+\Psi_C Q$, $0.9G+W_U+\Psi_C Q$

$1.2G+S_U+\Psi_C Q$

$G+E_U+\Psi_E Q$

The out-of-balance soil loads are considered a permanent load case and are to be accounted for in all load combinations where applicable.

Serviceability

Load combinations for serviceability will be derived from AS1170. Generally, the following base load combinations should be considered:

(1) $G+\Psi_S Q$

(2) $G+\Psi_L Q$

(3) $G+W_S+\Psi_C Q$

(4) $G+E_S+\Psi_C Q$

(5) $G+S_S+\Psi_C Q$

4.5 Boundary Surcharges and Bounding Structures

As per Figure 2 above, the site is fronted by Albert Street and Mary Street with adjoining buildings 110 Mary Street and 119 Charlotte Street to the North, and the Brisbane Sebel to the West

Mary Street and Albert Street shoring and retention is to be designed for a 25kPa Live Load surcharge to the roadway and footpath to allow for construction activities and traffic. Reference should be made to the CRRDA design drawings for the finished level to Albert Street and for any proposed planters and structures that may contribute to a self-weight surcharge.

Brisbane Sebel The Brisbane Sebel tower was designed by Robert Bird Group (Refer Job No.96246) and constructed in 1996. It includes a single basement that is set back away from the property boundaries. The basement edge setback is circa 3.0m from the common boundary with the Albert Street OSD. The building features a reinforced concrete frame with 32 levels above the ground floor. The building is founded on driven precast piles driven to the refusal in the medium strength rock. There are driven 350mm square piles whose centreline is circa 500mm from the common property boundary with the Albert Street OSD. Piles are estimated to be found below RL-10m based on the geotechnical report for the Sebel and are, therefore not anticipated to surcharge the proposed excavation of the Albert Street OSD. Due consideration must be made to the precast piles and their stability during shoring and retention works. Both Ground Floor and the Basement Floor are designed as spanning slabs and therefore do not surcharge the soil or proposed shoring to the Albert Street OSD. The Sebel boundary wall to the Albert Street OSD is supported on a continuous reinforced concrete ground beam that spans between pile caps that support the boundary columns. We recommend a nominal live load surcharge of 10kPa be allowed even though the adjoining structure is suspended and pile-supported.

110 Mary Street – The 110 Mary Street building (Matisse Tower) was constructed in circa 2006 and was designed by Bruce Lemcke Engineering (Job No 06995). The tower is a reinforced and post-tensioned concrete frame with 22 levels above ground and three basements. The basements extend to the site boundary. The retention system is a diaphragm wall which is stated to be found at RL-11.8m. The lowest basement B3 has a finished floor level that varies between RL-5.42m & RL -6.085m. The building is founded on reinforced concrete barrettes that are generally 2700mm by 600mm that found in medium to high-strength rock. This was estimated to be between 18 and 21m below the original surface level (circa RL4m), giving a founding level of at least RL-14. The lowest basement is designed as a suspended slab on grade over a drainage layer. The basement floor is not designed as hydrostatic and is designed to be drained via the drainage layer to pump out pits. As the basement, retention system and barrettes are found below the proposed basement of the Albert Street OSD, there will be no surcharge to the retention system of the OSD from 110 Mary Street.

Construction activities on the Albert Street OSD site will need to consider the retention of 110 Mary Street and limit surcharges during construction works. The designers of 110 Mary may need to be consulted to understand the walls surcharge capacity for temporary loading conditions.

The design drawings do not provide retention wall details as it is noted as a "Design and Construct" item by others. Given the proposed basement to the Albert Street OSD is at a similar level to 110 Mary Street, there is not likely to be an issue with surcharge impacts from the OSD on 110 Mary under permanent load conditions. The shoring system should be designed to support the 110 Mary street job against out-of-balance soil loads.

119 Charlotte Street – The 119 Charlotte Street project (Martin Campus) was constructed in circa 2000 and was designed by Robert Bird Group (Job No.99166). The building is a 12-storey concrete framed education facility with no basement. The building is supported on driven precast piles that are found in the low-strength rock (estimated top of weak rock between RL-4.0m – RL -8.0m advised in the project geotechnical report by Butler Partners).

Based on a review of this geotechnical report for the project the area adjacent to the OSD shows the top of the low-strength rock at RL-8.0m to RL -8.6m along the common boundary implying the Martin Campus piles will be founded well below the proposed basement to the OSD. The ground floor was designed as a suspended slab on grade and varies in finished level from RL 3m to RL 4.5 m. Precast boundary walls were supported on pile-supported reinforced concrete ground beams. On the Albert Street OSD boundary, the driven piles were located 600mm from the boundary to the centreline of the piles. Piles closest to the boundary are 300mm square driven precast piles. We recommend a nominal surcharge of 10kPa be allowed even though the adjoining structure is suspended and pile-supported.

5 Design Parameters

5.1 Deflection Criteria

Vertical

Horizontally spanning elements such as slabs and beams have been designed to limit vertical deflection under serviceability loading. The deflection of these elements is limited to accommodate and avoid any detriment to floor finishes, partitions, and sensitive equipment which may be used.

The deflection limits used for the detailed design are outlined in the table below. These criteria apply to both Steel and Concrete framing throughout the project:

Table 4 - Vertical Deflection Limits

Element	Deflection	Deflection Limit For Spans	Deflection Limit For Cantilever
All members	Total deflection	Span/250 or 35mm max	Span/125
All members	Incremental deflection	Span/500 or 25mm max	Span/250
Façade Beams	Incremental deflection (after façade installation)	Span/500 or 20mm max	Cantilever Span/250 or 15mm max
Transfer Member	The total deflection	Span/500 or 10mm max	1/250

5.1.1 Creep and Shrinkage

Action Effects of Creep and Shrinkage will be included in the analysis and design of the superstructure and components.

5.1.2 Axial Shortening

Table 5 indicates expected differential movements. Note that the expected movements under axial shortening are in addition to floor displacements.

Table 5 - Expected Differential Movements for Façade and Finishes due to Axial Shortening

Design Consideration	Expected Movement
Maximum long-term inter-storey vertical shortening of columns due to wind, elastic, creep and shrinkage based on a typical floor-to-floor height of 3000mm. Refer "Note 1"	5mm
Maximum long-term column differential shortening between adjacent column along the tower perimeter (causing racking of the façade and curvature in the floor finishes).	20mm Or Span/500 (Whichever is greater)
Maximum long-term column differential shortening between adjacent external and internal elements (causing curvature in floor finishes).	Span/300
Maximum long-term lateral movement (inter-storey drift).	Height/500

Note 1 – Maximum vertical differential shortening of a column between two floors.

Note 2 – Note that the expected movements under axial/vertical shortening are in addition to floor movements outlined in Section 2.0.

Recommended stack joint provision for opening/closing movement of - 10mm opening and 20mm closing

The façade and finishes are to be designed to accommodate construction tolerances.

5.2 Floor Vibration Criteria

The preferred structural floor plate system shall be designed to achieve a multiplying factor for exposure to continuous vibration (Response Factor) of RF 6 for 90% of the Lettable floor area with no areas exceeding RF8 for general office floors and retail areas in accordance with recommendations of SCI P354.

5.3 Lateral Design Criteria

Horizontal

(a) Wind Drift

Serviceability criteria for lateral movements under wind loads are to be as follows:

- Total displacement at any level not greater than H/500 under V100 (permissible wind)
- Inter-storey displacement at any level not greater than Storey Height/500 under V25 (service wind)
- Maximum acceleration in accordance with ISO 6897 – 1984 for a 10-minute period of a 5-year return period. Tower accelerations will be assessed as part of RWDI's wind study.

  Displacements are to be determined as the average across the floor diaphragm. Displacements will be based on a non-linear material staged analysis of gravity and lateral mode. Accelerations are to be determined similarly.

(b) Seismic Drift

In accordance with AS 1170.4, the inter-storey drift at the ultimate limit state under the dynamic seismic forces shall not exceed 1.5% of the storey height for each level.

5.4 Foundation Design Criteria

Primary Tower columns (dark blue in Figure 9) and core walls are to be supported on large-diameter bored piers that are found in medium or high-strength rock greater than 10m from the face of the CRR Cavern (outside the licenced area). Bored Pier socket length requirements are discussed in the geotechnical desktop report. The bored pier primary tower foundations are to find and develop all shaft capacity below the influence zone of the proposed Cross River Rail Albert Street Station Cavern. Piles are to be lined in the influence zone and have their full vertical capacity developed below the influence zone of the Cavern. The requirement for pile liners is to be assessed by the geotechnical engineer in the design development phase.

The line of podium columns along the Albert Street frontage (light blue) and the first row of carpark-only columns (green), are to be found on high-level pad foundations above the cavern licence area (above RL-8.0m). If the bearing strata at that level is not suitable, it may be required to replace the pad footings with a raft foundation(s) to reach a suitable bearing stratum without extending below RL-8m. Current data indicates the required bearing stratum can be achieved through pad foundations and raft foundations.

Refer to Figure 9 Below for an illustration of the proposed foundation solution.

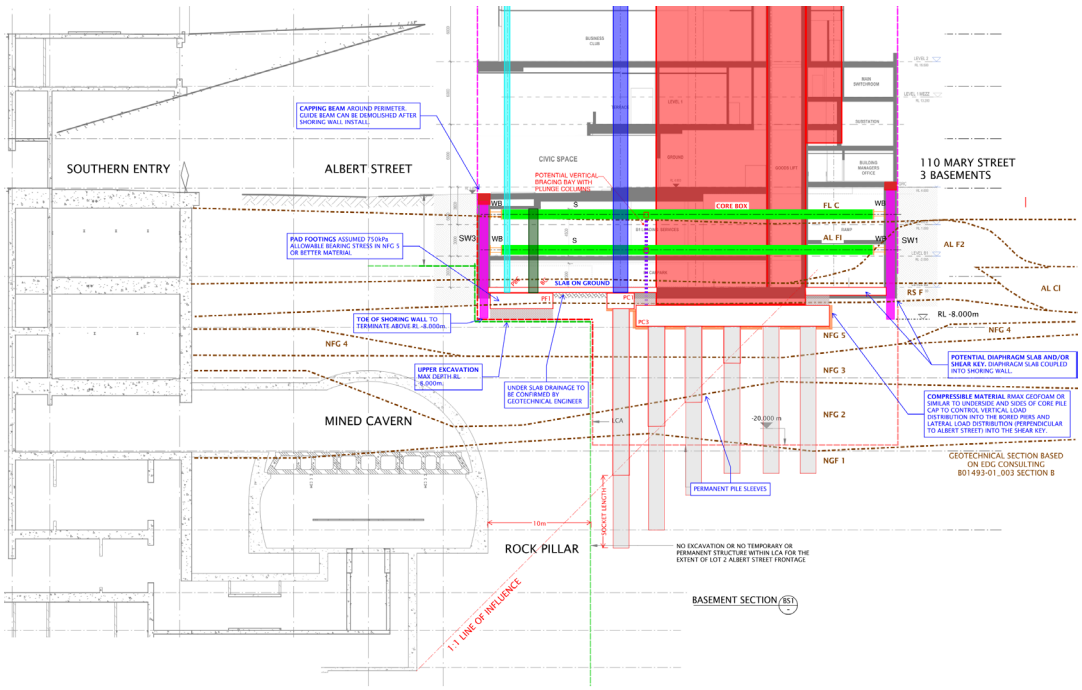


Figure 9 - Proposed Foundation Solution

5.5 Retention System Design Criteria

The retention system shall be designed to limit lateral movement at the site boundaries and to provide stability to the required basement excavation. It shall be designed as the permanent retention system and be designed to resist the boundary surcharges as set out in section 4.5 of this report.

The retention system shall be designed in accordance with the codes and standards listed in this report, together with other relevant Australian Standards. The retention wall shall be designed to resist a full hydrostatic load in addition to soil dead and live load surcharges with the water level at the 1% ARI flood level of RL4.6m.

The shoring system is to comprise bored cast-in-place reinforced concrete soldier piles. Pile spacing for preliminary Wallap runs by the Geotech engineer were based on 2D. A permanent reinforced concrete shotcrete wall shall be constructed progressively between the soldier piles. Geotechnical engineer to confirm maximum excavation lifts for the spray-creating operation. The soldier piles to the Albert Street face and 10m of the return face to the Brisbane Sebel and Mary Street are not to extend below RL-8.0m. (in the Cavern Licence area)

The shoring system is to be internally strutted with no rock anchors (temporary or permanent). Internal struts are to support a temporary steel perimeter waler beam that, in turn, supports the soldier piles. The geotechnical engineer is to model the combined system to demonstrate predicted maximum displacements and determine if one or two rows of internal strutting is required. Current preliminary modelling indicates two rows of strutting will be required.

The shoring system including internal strutting system and whalers shall be designed for various groundwater and flood conditions as outlined in the EDG Geotechnical Report - Albert Future Over Station Development Report – B01493-1AC.

The maximum lateral displacements for the system as designed shall be as follows:

- To Albert Street frontage - 15mm maximum horizontal displacement.

- To 110 Mary Street and 119 Charlotte Street - 15mm maximum horizontal displacement.
- To Mary Street and Brisbane Sebel - 25 mm maximum horizontal displacement.

The above is based on The Sebel foundation system consisting of driven piles which we believe extend below our lowest basement level and that there are no current known sensitive assets within Mary Street. The shoring wall deflection criteria will be developed during the Detailed Design Stage as additional existing structure and services information come to hand. If additional shoring wall stiffness is required we have the option to include additional temporary struts and close up the centres of the proposed soldier piles.

The geotechnical engineer is to advise the degree of pre-loading for the struts to achieve the design displacement. Steel struts may need to be externally insulated to reduce thermal effects. This will be examined following detailed modelling.

A detailed design brief will be prepared during the tender documentation phase.

5.6 Cross River Rail (Extracted Design Criteria)

Design loads and excavation criteria for the Albert Street Station Cavern are set out in the PSM Design Manual – Driven Tunnels – Document CRRTSD-000-0300-MAN-PSMQ-1320-100044

Section 11.6 of the above document is extracted below.

11.6 Over Station Development (OSD) and Future Over Station Development (FOSD)

11.6.1 Project-wide Requirements

Section 5.2.3.9 of the PSTR Annexure B outlines the future development loads which must be accounted for in the permanent support design:

- *The design shall allow for the future development of the land above and adjacent to the Tunnel and Underground Structures by designing and constructing for loading and unloading in addition to the applicable design loads* (TUS-64)
- *Tunnel and Underground Structures shall be designed for additional loading and unloading from future developments which have been approved by BCC or the State, current at the date of execution of the Project Agreement* (TUS-65)
- *Tunnel and Underground Structures at or adjacent to Underground Stations shall be designed for the Over Station Development (OSD) and Future Over Station Development (FOSD) loading and unloading as specified in Section 5.6* (TUS-66)
- *Tunnel and Underground Structures (excluding cut and cover structures) which pass beneath or adjacent to developable land shall, as a minimum, be designed for the additional loading and unloading cases as detailed in Appendix B2 Table B2 A for case 1 and Table B2 B for case 2* (TUS-67). Refer to Table 19 and to Figures 12 to 15.

For primary support design, the timing of when the FOSD to be constructed will be taken into account.

Table 19 Future development allowance

Case	Additional Loading	Excavation / Distortion
1	Vertical load of 50kPa acting on the ground 1 m from the Tunnel crown (assumed to apply on lining directly) 20kPa applied at ground surface	Continuous Excavation i) Up to 7m below natural surface to allow for future development ii) with a minimum of 'X'm residual ground cover above the Tunnel crown iii) with a minimum 'X'm pillar width between the side wall of the Tunnel and any adjacent building basement excavation. 'X'=7m for running tunnels and 10m for station caverns
2	Live load surcharge of 75kPa applied at ground surface 20kPa applied at ground surface	Distortion Permanent support to accommodate additional distortion of 15mm/span. This is analysed by reducing the horizontal / vertical ground load to produce the additional distortion

Note: Loading and excavation / distortion to be applied separately and together, including asymmetrical arrangements, and in any order to give the most unfavourable loading condition.

Figure 10 - Extract PSM Tunnel Design Manual – Section 11.6

The Albert Street OSD at Lot 2 is also designed for specific criteria as set out in section 11.6.2 of the above report, which states the following:

- PSTR OSD-31, OSD-46, OSD-47, and OSD-48 nominate site-specific FOSD requirements for Lot 2 at Albert Street. Paragraph OSD-48 permits excavation down to RL -20m, except within 10m horizontally from the cavern sidewall (Figure 16). Within this area excavation down to RL -8m is to be considered (OSD-46).

The referenced Figure 16 from the PSM Design manual is extracted below:

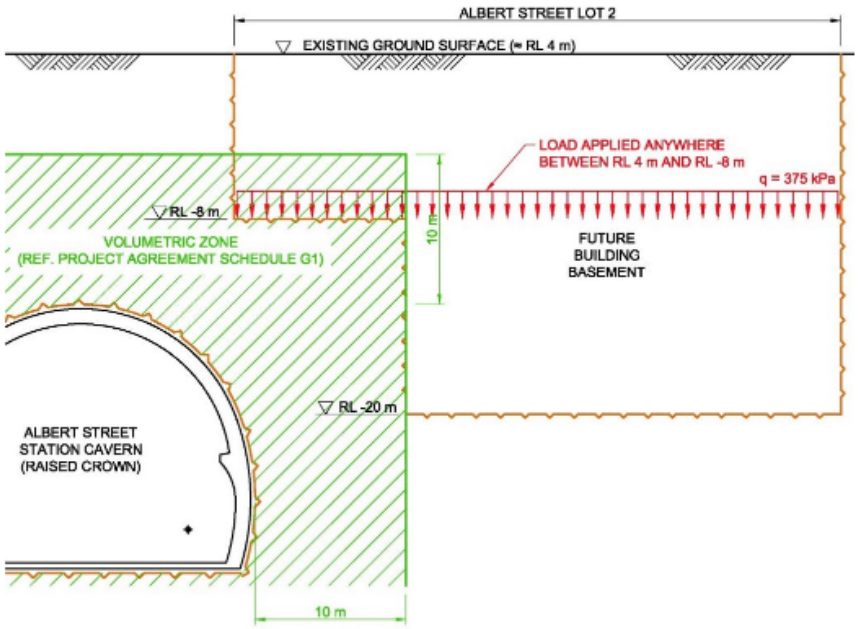


Figure 16 FOSD requirements for Albert Street Lot 2.

Figure 11 - Extract of Figure 16 from PSM Tunnel Design Manual

The design of the Albert Street Station is covered in a separate design manual by Robert Bird Group – Document No. CCCTSD-000-0401-MAN-RBGT-1470-191101.

Section 6.2.6 of the above report covers design allowances for over-station development and future over-station developments. It also sets out the specific PSTR Clauses relevant to future OSDs. It is extracted below.

6.2.6 Over Station Development (OSD) and Future Over Station Development (FOSD) Allowances

The loadings described in this section are applied to Underground Structures constructed by open cut bottom up construction technique only, referred to in the PSTR interchangeably as "station boxes", "station shafts" and/or "station cut-and-cover structures". They do not apply to underground caverns, tunnels or adits; the reader should refer to relevant reports for OSD and FOSD loadings on these structures.

Loads applied to the Underground Station Structures due to OSD and FOSD are in accordance with the PSTR requirements interpreted as described in Table 34. Table 35 addressed ODS and FOSD loads only. Refer to other relevant sections of this report for other surface loadings.

Table 34 OSD and FOSD Load Interpretation

PSTR Clause	Requirement	Interpretation & Practical Application
TUS-64	The design shall allow for the future development of the land above and adjacent to the Tunnel and Underground Structures by designing and constructing for loading and unloading in addition to the applicable design loads.	Station Underground Structures designed for OSD and FOSD loads as described in Table 35 and sketches in Appendix B.
TUS-65	Tunnel and Underground Structures shall be designed for additional loading and unloading from future developments which have been approved by BCC or the State, current at the date of execution of the Project Agreement.	Station Underground Structures designed for OSD and FOSD loads as described in Table 35 and sketches in Appendix B.
TUS-66	Tunnel and Underground Structures at or adjacent to Underground Stations shall be designed for the Future Over Station Development (FOSD) loading and unloading as specified in Section 5.6.	Refer to Table 35 which defines how the loads specified in PSTR Annexure B Section 5.6 have been applied to the Primary Underground Structures.
TUS-68	Cut and cover Tunnel and Underground Structures which pass beneath or adjacent to developable land shall, as a minimum, be designed for the additional loading and unloading as detailed in Appendix B2 Table B2-C.	Loading and unloading requirements Station Underground Structures as per PSTR Appendix B2 Table B2-C have been applied to developable land. Extent of developable land as defined in sketches in Appendix B.
TUS-69	For each future development scenario, the Tunnel and Underground Structure design shall allow for the additional loading and unloading to be applied separately and together in any order, including asymmetrical arrangements, to give the most unfavourable condition.	The loads described in this Table 35 are applied in accordance with the clause.
OSD-1	Provision for FOSD shall be made at Roma Street Station, Woolloongabba Station and Boggo Road Station.	Station Underground Structures designed for FOSD loads as described in Table 35 and sketches in Appendix B.
OSD-2	Provision for FOSD shall be made at Albert Street Station.	Albert Street Station Underground Structure designed for FOSD loads as described in Table 35 and sketches in Appendix B2.
OSD-8	The Underground Station design shall provide a structural arrangement that facilitates the construction of the functional FOSD to the maximum permissible building envelope of the relevant planning provisions.	Station Underground Structures designed for FOSD loads as described in Table 35 and sketches in Appendix B. FOSD loads in excess of those allowed for will need to be supported by piled foundations which do not transmit load (vertical or lateral) onto the Station Underground Structures.
OSD-19	The anticipated vertical loadings, either temporary, construction or permanent loadings, of the FOSD shall be allowed for in the structural design of the Underground Stations	Temporary, construction and permanent loads to comply with the loading allowances nominated in Table 35 and sketches in Appendix B.
OSD-20	The anticipated lateral loadings, either temporary, construction or permanent loadings, of the FOSD shall be allowed for in the structural design of the Underground Stations.	Temporary, construction and permanent loads to comply with the loading allowances nominated in Table 35 and sketches in Appendix B.

Table 35 Station Specific OSD and FOSD Application

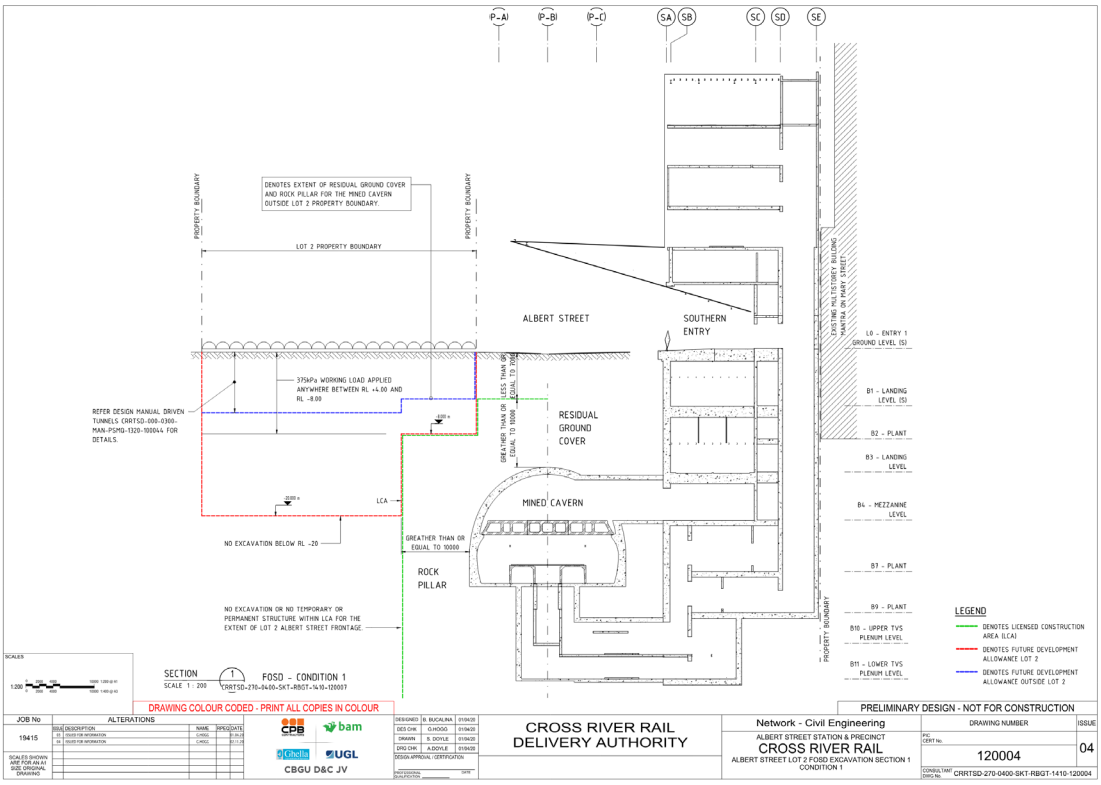
Underground Station	PSTR Clause	Requirement	Interpretation & Practical Application
Roma Street	OSD-23	• FOSD to be the most onerous of hotel or commercial uses, both above and beside the station.	FOSD loading allowed for on adjacent developable land as indicated on sketch CRRTSD-250-0400-SKT-RBGT-1410-110001-01 in Appendix B1.
	OSD-26	• Allow for future excavation to minimum of 3 m horizontally from outside edge of permanent station wall, to maximum depth of either 10 m from finish surface level or 10 m differential.	• Future excavation allowed for to minimum 3m horizontally from outside edge of permanent station wall within developable land footprint. Maximum excavation depth 10m measured from finished design surface level, including unbalanced cases due to 10m deep excavation on one side, with no excavation on the opposite side. Refer to sketch CRRTSD-250-0400-SKT-RBGT-1410-110001-01 in Appendix B1.
	OSD-27	• Allow for additional development loading to and excavation to be applied separately and together, including asymmetrical arrangements, and in any order to give the most unfavourable conditions on the station.	• The loads and excavations described above are applied in accordance with this requirement.
Albert Street	OSD-31	• Allow for FOSD loading of 375kPa working load applied over all or part of Albert Street Lot 2 site, applied between RL +4.0m and -8.0m, to give the most unfavourable loading conditions on the station	• 375kPa applied as indicated on sketch CRRTSD-270-0400-SKT-RBGT-1410-120004-01 in Appendix B2.
	OSD-46	• Allow for excavation of the entire Lot 2 site to RL -8.0m	• Excavation allowed for to RL -8.0 as indicated on sketch CRRTSD-270-0400-SKT-RBGT-1410-120005-01 in Appendix B2.
	OSD-47	• Allow for excavation over the entire Albert Street Lot 2 site (excluding the volumetric zone described in the Project Agreement Schedule G1) to RL-20.0m.	• Excavation allowed for to RL -20.0 as indicated on sketch CRRTSD-270-0400-SKT-RBGT-1410-120006-01 in Appendix B2.
	OSD-48	• Allow for future development loading and unloading cases as detailed in Appendix B2 Table B2-A for case 1 and Table B2-B for case 2.	This clause is assumed to apply to developable land adjacent to Albert Street Underground Station Entry Buildings other than Lot 2. Refer to sketch CRRTSD-270-0400-SKT-RBGT-1410-120007-01 in Appendix B2 for assumed extent of developable load. Loads applied to the Underground Station Entry Buildings from Tables B2-A and B2-B have been applied as follows: <u>Additional Loading</u> • 75kPa live load surcharge applied at ground level (finished design surface level) **AND** • 20kPa surcharge due to surface level buildup <u>Continuous Excavation</u>

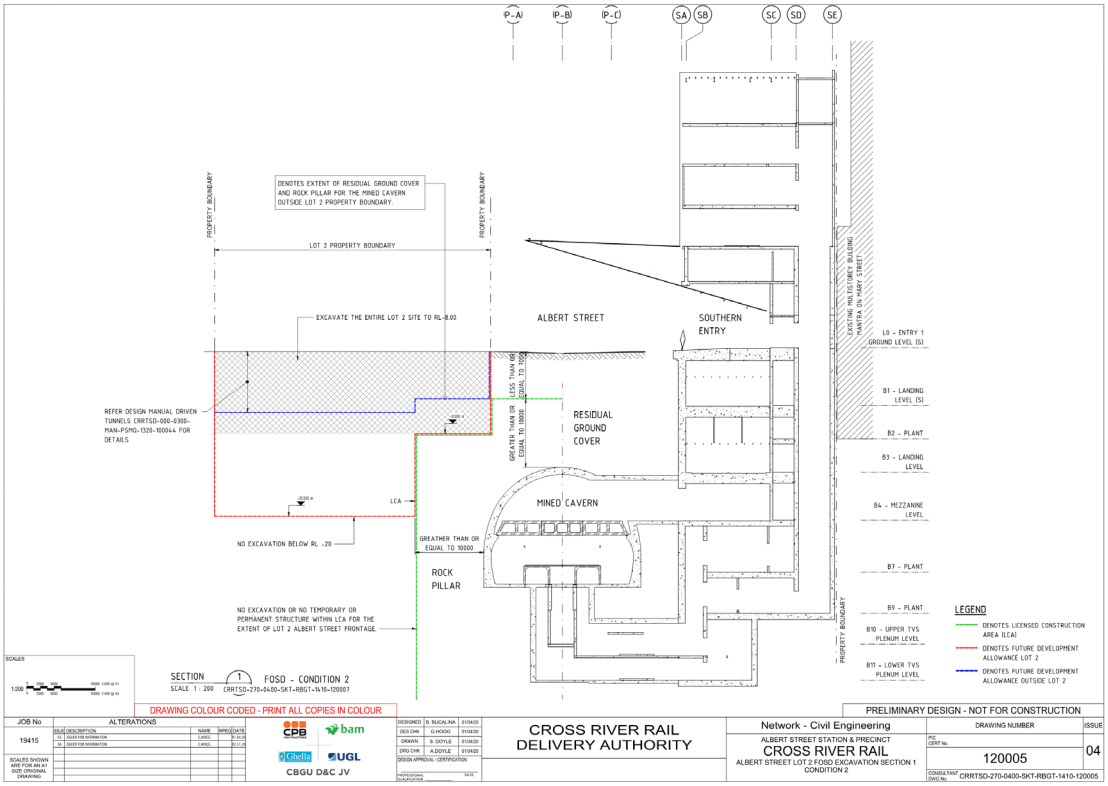
Underground Station	PSTR Clause	Requirement	Interpretation & Practical Application
			• Up to 7m below natural surface (existing street) level for future development • With a minimum 7m residual cover over running tunnels and 10m over station caverns • With a minimum pillar width of 15m between perimeter wall of station boxes and any future adjacent building basement excavation
Woolloongabba	OSD-35	• FOSD to be the most onerous of retail, hotel, and commercial uses beside the station.	• FOSD loading allowed for on adjacent developable land as indicated on sketch CRRTSD-410-0400-SKT-RBGT-1410-130012-01 in Appendix B3.
	OSD-37	• Allow for future excavation to minimum 3m horizontally from outside edge of permanent station wall, to maximum depth of either 10 m from finished surface level or 10 m differential.	• Future excavation allowed for to minimum 3m horizontally from outside edge of permanent station wall within developable land footprint. Maximum excavation depth 10m measured from finished design surface level, including unbalanced cases due to 10m deep excavation on one side, with no excavation on the opposite side. Refer to sketch CRRTSD-410-0400-SKT-RBGT-1410-130012-01 in Appendix B3.
	OSD-38	• Allow for additional development loading and excavation to be applied separately and together, including asymmetrical arrangements, and in any order to give the most unfavourable conditions on the station.	The loads and excavations described above are applied in accordance with this requirement.
Boggo Road	OSD-39	• FOSD to be the most onerous of commercial, science, medical, or education uses, both above and beside the station.	3kPa live load allowance adopted for the 12 storey high FOSD. This includes the following uses in accordance with AS1170.1: • Offices for general use • Operating theatres, X-ray rooms, laboratories • Residential activities including hotel rooms • Institutional assembly areas including classrooms and lecture theatres • Refer to sketch CRRTSD-420-0400-SKT-RBGT-1410-140007-01 in Appendix B4 for further details.

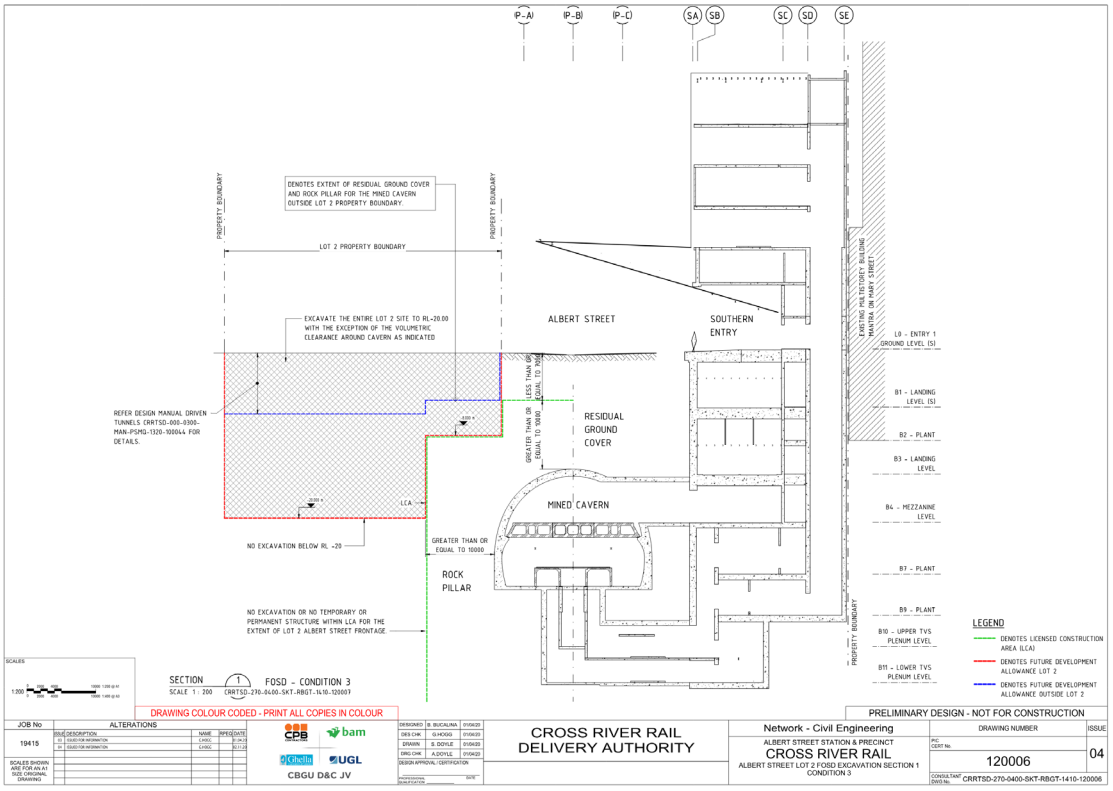
Underground Station	PSTR Clause	Requirement	Interpretation & Practical Application
	OSD-41	• Boggo Road Station and the Tunnel shall provision for loading from a minimum 12 storey high FOSD on the Lot 2 on Plan SP217441.	• 12 storey building allowed for in accordance with sketches in Appendix B4.
	OSD-44	• The roof slab of the Boggo Road Station, over the Boggo Road Lot 2 on Plan SP217441, shall allow FOSD loadings applied at roof slab level. These FOSD loads are to assume the ground is removed above the Underground Station/Tunnel roof slab	• Loads on roof allowed for in accordance with sketches in Appendix B4.
	OSD-45	• Allowance shall be made for FOSD loadings to be placed on the Boggo Road Station box perimeter walls.	• Loads on station box perimeter walls allowed for in accordance with sketches in Appendix B4.

Figure 12 - Extract of PSTR Clauses from RBG Station Design Manual

Appendix B of the RBG Station Design Manual contains drawings that illustrate the design considerations for the Albert Street OSD. These drawings are extracted below.







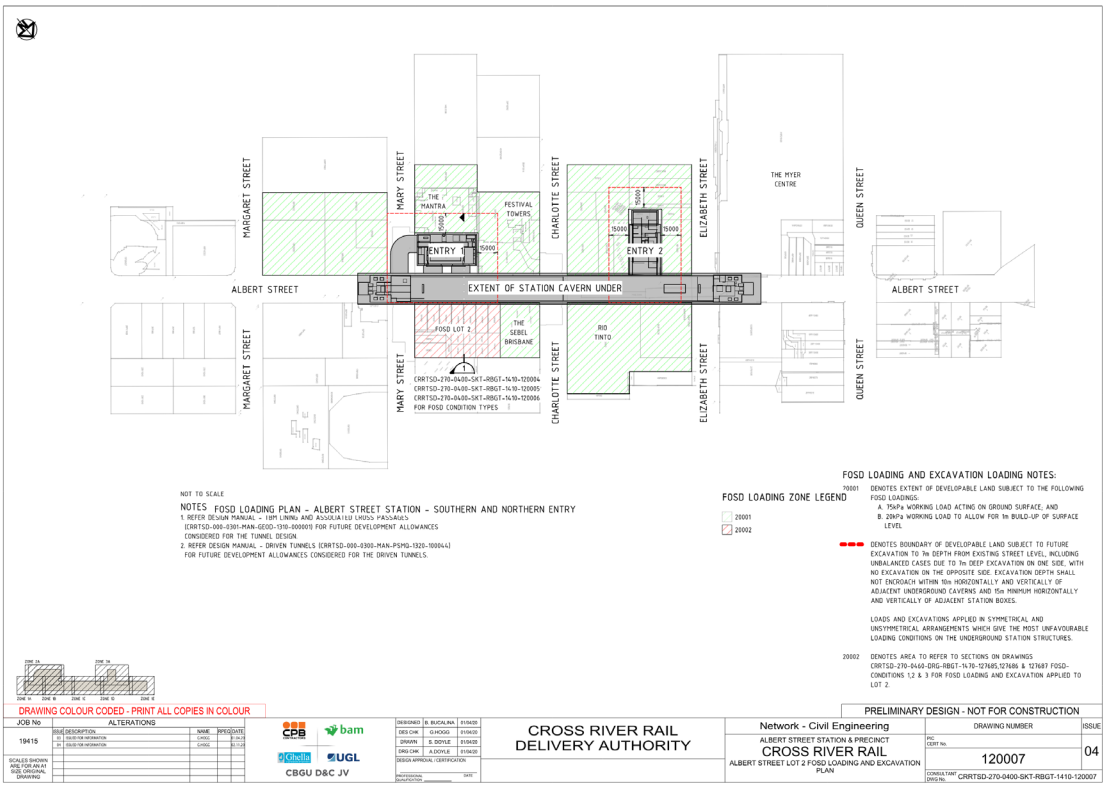
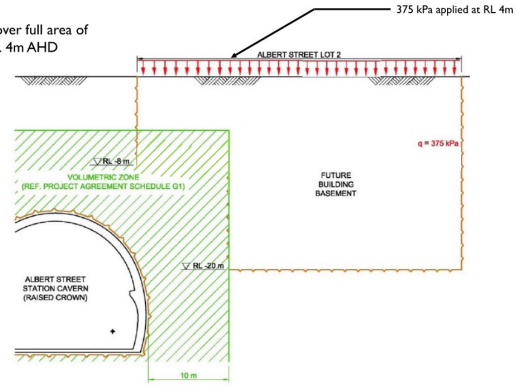


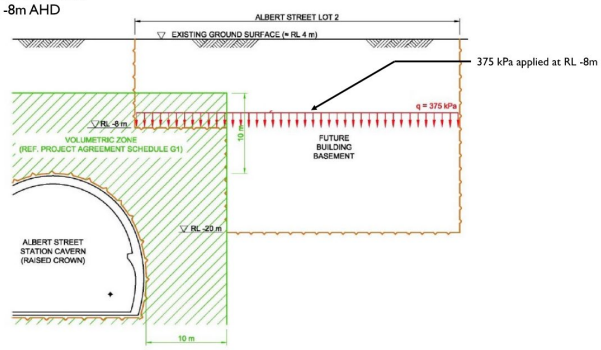
Figure 13 - Extracts RBG Station Design Manual

The summary of the above CRR PSTR load and excavation cases, as referenced in the EDG Geotechnical Report - Albert Street Cavern Assessment Report – B01493-1AE, are shown below:

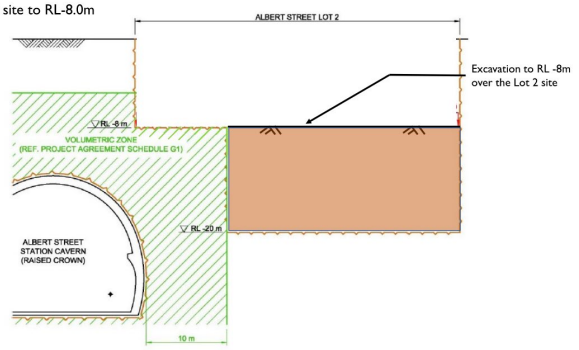
Case 1 – 375kPa over full area of Lot 2, applied at RL 4m AHD **(OSD-31)**



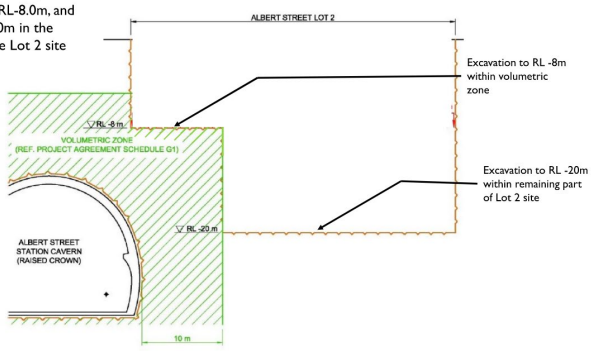
Case 2 – 375kPa over full area of Lot 2, applied at RL -8m AHD **(OSD-31)**



Case 3 – Excavation over the entire Albert Street Lot 2 site to RL-8.0m **(OSD-46)**



Case 4 – Excavation in the volumetric zone to RL-8.0m, and excavation to RL -20m in the remaining part of the Lot 2 site **(OSD-47)**



Case 5:
- 50kPa applied at 1m above cavern crown
- 20kPa applied at ground surface

(OSD-48)

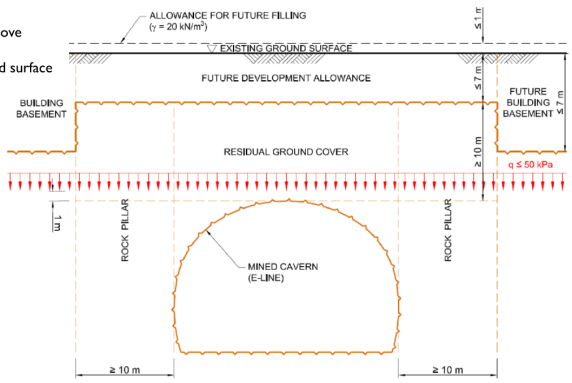


Figure 13 FOSD loading for caverns – Future development allowance Case 1 (Ref. Table B2-A, Annexure B, PSTR)

Case 6:
- 7m excavation over Lot 2 site to RL -3m

(OSD-48)

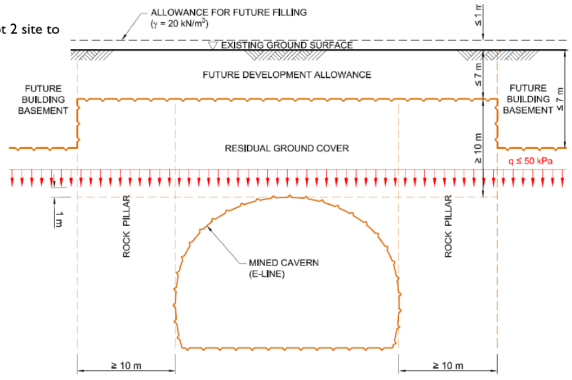


Figure 13 FOSD loading for caverns – Future development allowance Case 1 (Ref. Table B2-A, Annexure B, PSTR)

Case 7:
- 75kPa applied at ground surface
- 20kPa applied at ground surface
- Additional cavern distortion of ±15mm on diameter

(OSD-48)

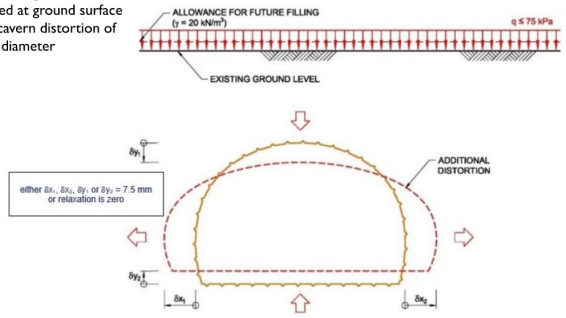


Figure 15 FOSD loading for caverns – Future development allowance Case 2 (Ref. Table B2-B, Annexure B, PSTR)

Figure 14 - Extracts EDG Cavern Assessment Report

The actual proposed building load and excavation case is shown below in Figure 15.

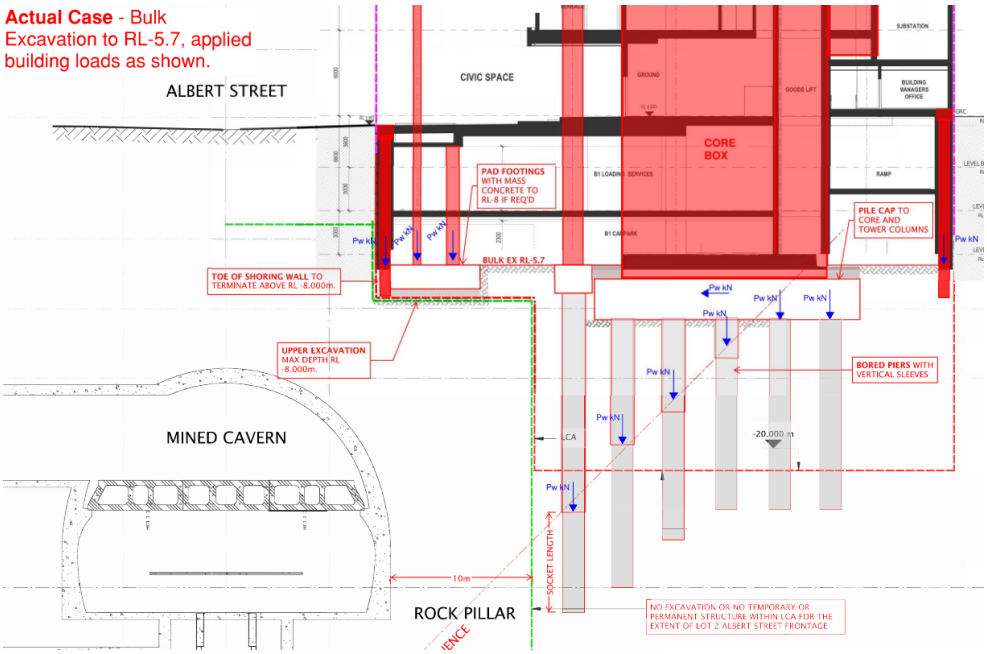


Figure 15 – Actual Proposed Building Load and Excavation Case

The proposed basement excavation extent satisfies the PSM and RBG criteria set out in the two respective design manuals. The tower loads have been placed on large-diameter bored piers founding below the influence zone of the Cavern and the Station Box, therefore, satisfying the intent surcharge loading criteria by placing the loads outside the influence zone of the Cavern. The podium columns and basement columns that land above the licenced cavern area have been load limited by only extending the columns to Level 10.

Whilst the tower column bored piers will extend below the RL-20m maximum excavation zone, the intent of this excavation limit is related to unloading or out-of-balance loading to the station cavern. The local pier excavations will result in insignificant amounts of unloading compared to the mass of rock that is proposed to remain above the maximum excavation limit.

Similarly, if local excavation to place mass concrete is required to find a suitable founding stratum for the podium column pad footings the extent is similarly small compared to the volume of soil that will remain above the maximum excavation level above the licenced cavern area.

External levels in Albert Street are essentially as-designed by the CRRDA with no significant additional street surcharge proposed by the Albert Street OSD.

PSTR Clause OSD-20 states, "The anticipated lateral loadings, either temporary, construction or permanent loadings, of the FOSD shall be allowed for in the design of the underground station" Neither design manual states what these loads were and as such it is proposed that EDG as the OSD geotechnical engineer will apply both the proposed building vertical and lateral loads within the cavern assessment modelling.

A geotechnical assessment of the normal stress on the cavern lining and cavern vertical and horizontal distortion based on the proposed building vertical and lateral loads has been undertaken by EDG to demonstrate these are below that arising from the CRR PSTR FOSD load cases. The results of this analysis have been presented within EDG Geotechnical Report - Albert Street Cavern Assessment Report - B01493-1AE. The outcome of the geotechnical assessment suggests that the predicted effects associated with the proposed building loads are within the effects associated with the PSTR design load cases.

5.7 Construction Vibration Criteria

Vibration monitoring is proposed for the construction of Lot 2 OSD. A detailed monitoring plan will be prepared by a specialist consultant prior to operational works approval. At this stage, we propose that monitoring occurs in the station Cavern only. We recommend this commence at least one week prior to QIC or their contractor undertaking any site works. We recommend that two vibration monitoring stations are established in the cavern on the mezzanine level closest to the proposed OSD. Refer monitoring plan diagram in Figure 15 Below. Monitoring for a week prior to site activities on the Lot 2 site will allow the establishment of benchmark background vibration from station operations. Limits may be adjusted following background testing to eliminate any regular background-generated alerts. We recommend a triaxial geophone assembly be mechanically anchored to the face of the cavern lining above the mezzanine floor level (closest point to the likely vibration source) with three-channel recording and a live monitoring function and alert system. The vibration monitoring system shall be configured to alert relevant construction personnel immediately via SMS should the pre-agreed vibration threshold be exceeded. The threshold for alerts should be 5mm/s, 8mm/s, and greater than 10mm/s.

The proposed vibration alert criteria are as follows:

(1) Less than 5mm/s – No action required

(2) Between 5mm/s and 10mm/s – Log vibration and alert relevant Client and Construction personnel – advise CRRDA. Assess activity and modify, if possible, to reduce vibration impacts

(3) Greater than 10mm/s – Cease works and advise relevant personnel and CRRDA. Propose a modified activity/ method to reduce vibration impact, and only re-commence once approved.

Vibration monitoring at other locations is not anticipated unless agreed with adjacent owners as a communications management exercise.

Vibration monitoring shall remain in place and be actively monitored until the completion of all of the following activities:

- Site clearing and levelling.
- Piling to building and retention system is completed.
- Excavation, including detailed foundation excavation.
- Breaking down of any existing piling or redundant structures is completed.

5.8 Heritage Structures and Sensitive Inground Services

The proposed Albert Street OSD adjoins the Brisbane Sebel, Martin Campus Building, and 110 Mary Street buildings. None of these structures is listed on the State or BCC Heritage structures register.

The nearest listed heritage structures are as follows:

- Mooneys Building 130-132 Mary Street – 40m to OSD at the closest point.
- 138 Mary Street – 60m to OSD at the closest point.
- Perry House 167 Albert Street – 115m to OSD at the closest point.
- Charlotte House 139-145 Charlotte Street - 60m to OSD at the closest point.
- Brisbane Synagogue 98 Margaret Street – 150m to OSD at the closest point.

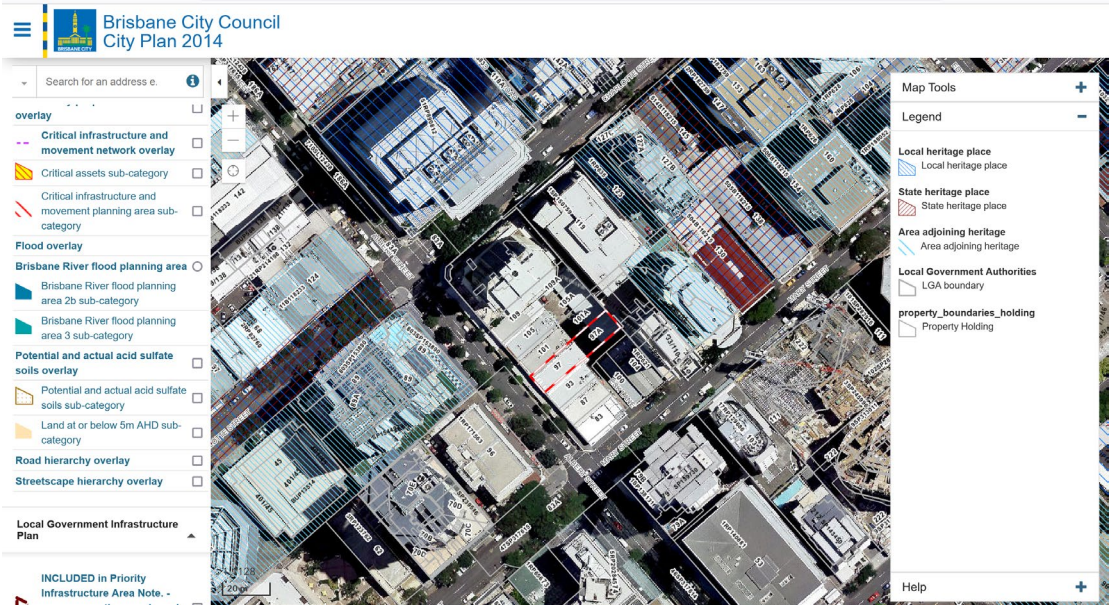


Figure 16 - City Plan Heritage Sites Overlay

The proposed basement to the OSD requires an excavation of circa 10m depth maximum at the boundary. The zone of influence for the retention system will not exceed twice the retained height (20m). Based on this, there are no listed buildings in the influence zone to the retention system.

The existing static water table is below the level of the proposed basement excavation. Local perched areas of groundwater are likely to be encountered; however, the static water table is below the proposed Basement 2 level. As such, the proposed Albert Street OSD is not anticipated to impact groundwater levels which could impact adjoining structures (particularly heritage structures).

The excavation is substantially in the existing fill and alluvial material, with possible local areas of extremely weak rock just exposed by the excavation. There is minimal excavation in the weak rock (generally classified as Neranleigh Fernvale Group NFG4 & NFG5). The use of heavy rock-breaking equipment is not anticipated with the removal of material by conventional excavators and dozers.

Building foundations will be either pad footings (for podium columns) or large-diameter bored piles for the tower columns. Bored soldier piles are anticipated for the retention system. The use of driven piles is not anticipated.

As such there are no major sources of excessive construction-generated vibration anticipated and as such, the influence zone for vibration is also unlikely to extend beyond the same 20m influence zone proposed for retention influence.

As such there are no heritage structures in the influence zone of construction-generated vibration.

There is a 450mm diameter sewer that runs centrally under Albert street at an approximate depth of 3m which is regarded as a piece of sensitive infrastructure. This sewer service pre-dated the station works that involved significant blasting and excavation in rock. During Station construction, a vibration limit of 25mm/s was applied to this service and works were completed with no known impact. Given the nature of the proposed works on the OSD, site vibration is unlikely to approach anywhere near the previous limit imposed for this service. Bored piling generally is regarded as producing accelerations less than 5mm/s at a distance of 5m. Similarly, the use of a large excavator (45t) is also unlikely to produce accelerations greater than 5mm/s at distances greater than 5m. As such, vibration monitoring in Albert Street is not proposed. To protect the service, however, we have

reduced the lateral movement criteria for the Albert Street shoring to 15mm maximum (Rather than 25mm proposed for Mary Street). CCTV condition inspection of accessible services in Mary and Albert Street shall be undertaken prior to Operational Works approval.

5.9 Dilapidation Study Extent

Given the limited influence zone of the proposed OSD on Lot 2 dilapidation study of the following properties and infrastructure is recommended:

- Martin Campus 119 Charlotte Street
- The Sebel Brisbane Corner Albert and Charlotte Streets.
- Matisse Tower 110 Mary Street.
- Albert Street Station Cavern – Lot 2 site plus extend 50m on each side of Lot 2.
- Albert Street Station Box
- Albert Street and both Albert Street footpaths from Charlotte to Mary Street.
- Mary Street and both Mary Street footpaths from the station side to the east corner of 110 Mary Street site.
- CCTV inspection of accessible sewer and stormwater pipes for extent of site frontages to Mary and Albert Street

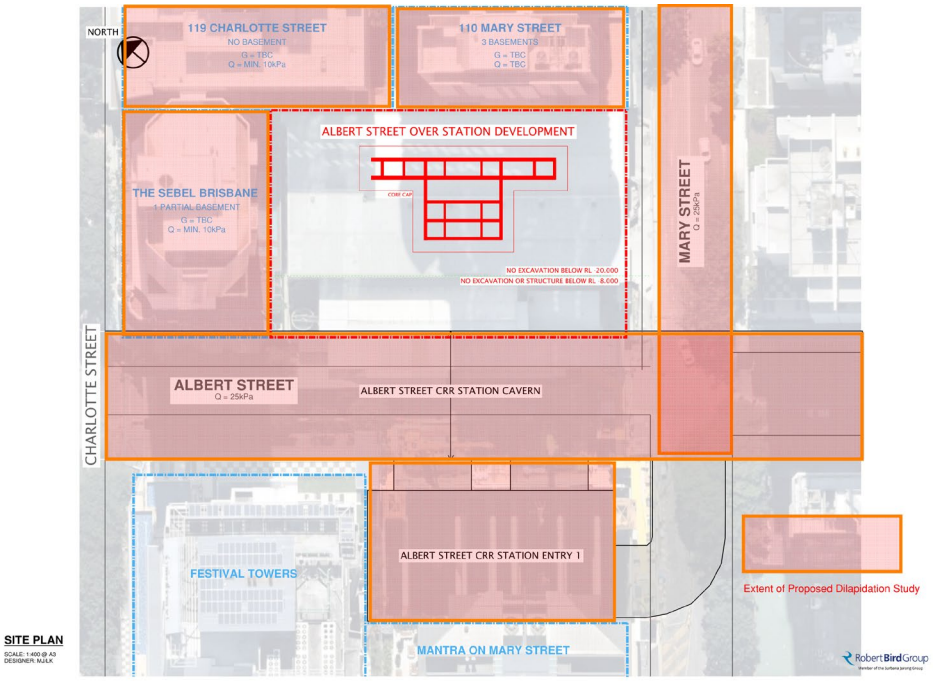


Figure 17 - Extent of Sites Recommended for Dilapidation Surveys

Dilapidation surveys shall include inspection of all accessible spaces for each nominated building with a photographic record of all observed defects, including cracking, spalling, settlement, differential movement, separation at building joints, damaged finishes, water leaks or points of mechanical damage. Photos must be dated, time-stamped, and referenced to the relevant building and location. For the Sebel and Matisse Tower, we recommend at least three typical tower floors be inspected. Where possible, cracking shall be photographed with a crack gauge reference across the crack. Refer to additional notes for CRRDA Assets.

Inspections of the streets and footpaths should include a photographic record of all observed defects, including cracking, loose pavement, potholes, kerb or finish damage, damaged service covers, damaged line marking or damaged signage and any areas of local subsidence, together with photographs showing the general condition of street and footpath pavement. Photos must be dated and time-stamped and referenced to the relevant location.

Dilapidation studies shall be provided in electronic PDF Format with separate reports for each building and street and CRRDA Asset. Original Photo files shall be retained for reference by the author for the duration of the project and defects period.

5.9.1 Preliminary Monitoring Plan Retention System

The proposed shoring and retention system shall be monitored for movement from the commencement of works to the completion of the basement up to and including the completion of the ground floor slab. Monitoring is to include survey pins on the proposed retention capping beam, fixed siting prisms on existing buildings, survey pins in Albert Street paving and inclinometers in the retention system.

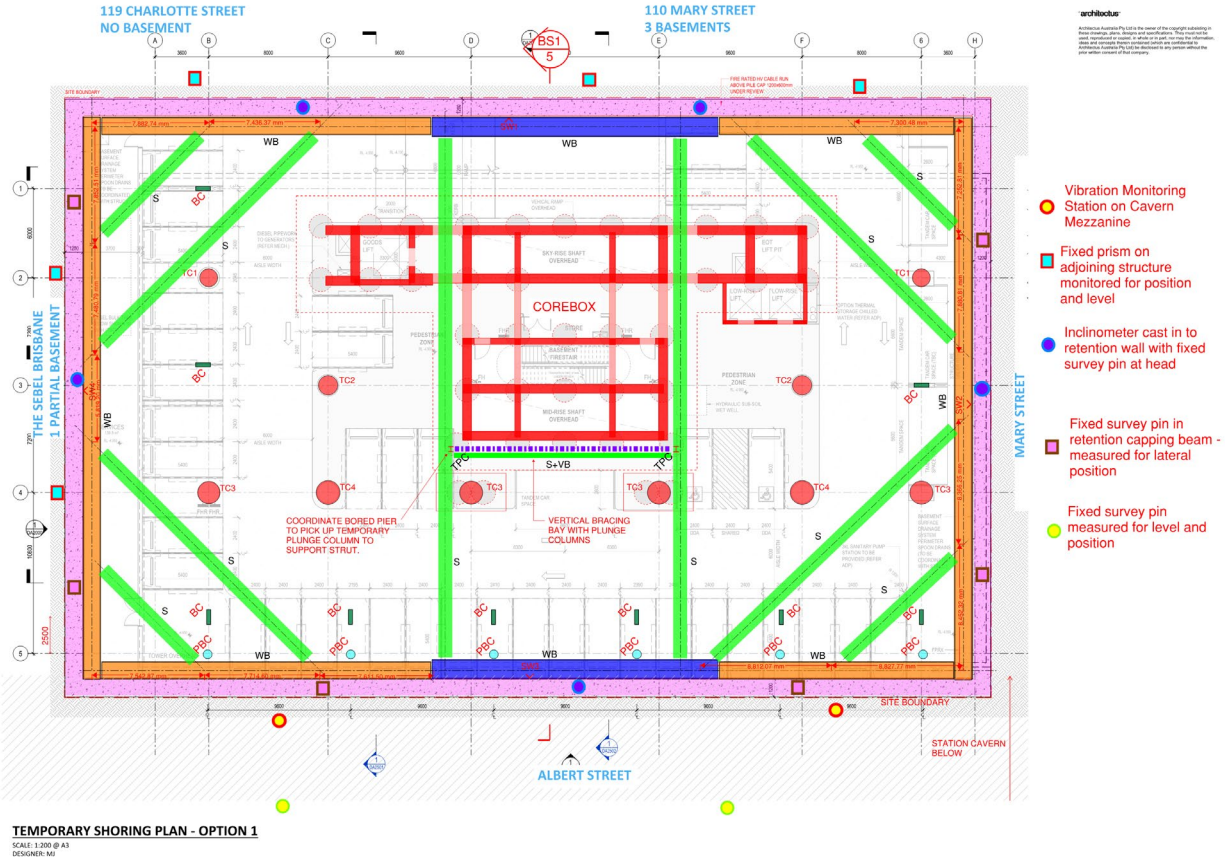


Figure 18 - Extent Survey and Monitoring Points

5.10 Monitoring Procedure

Limiting criteria are provided for each monitored item. All measurements taken during construction are to be assessed in comparison to the limiting criteria. The limiting movement criteria for retention is set out in Section 5.5 above. The following criteria will be used to evaluate the results.

Condition Green for values 0 to 75% of limiting criteria

Condition Amber for values 75% to 90% of limiting criteria

Condition Red for values 90% to 100% of limiting criteria

If condition Red is reached, then a review of the consequences of exceeding the limiting criteria is required, and the need for remedial work is considered before work continues. The frequency of monitoring shall increase with each condition.

The frequency of monitoring is to be as follows:

- Weekly under condition Green.
- Every 4 Calendar days condition Amber.
- Daily condition Red.

5.10.1 Wall Movement

Five geotechnical inclinometers shall be installed along the boundary as shown on the drawings. The inclinometers shall measure the wall movement during bulk excavation and basement construction. The inclinometers shall be bi-axial type inclinometers installed such that the axes are perpendicular and parallel to the wall. Measurements shall be taken at 0.5m intervals over the full height of the wall.

In the event an inclinometer is damaged, all work in the area of the inclinometer shall cease unless in the opinion of the Engineer, such work is required to stabilise the excavation.

The top of the inclinometers shall be surveyed, and the measurements reported in a baseline report prior to any excavation work. The top position of the inclinometers shall be surveyed and reported at each survey interval.

Fixed survey marks and fixed prism locations shall be positioned as shown on the drawings.

The results reported shall include the following:

- A full survey of each survey point, including Northing, Easting and RL, before any demolition or new works commence.
- Monitoring during the works shall be at the frequencies noted above.
- Full survey to be also carried out at the completion of Ground Floor
- Intermediate surveys can be in the direction of concern only.

Survey accuracy shall be to +/- 1.0mm.

5.10.2 CRRDA Assets

In addition to the proposed dilapidation survey of the CRR Station and Cavern and the proposed vibration monitoring, we recommend that crack monitoring be implemented in the station Cavern's internal concrete lining. The extent of cracks to be monitored shall be determined following the dilapidation inspection. Fixed crack monitoring locations will be agreed upon with CRRDA. Crack monitoring shall be undertaken monthly unless a condition red report for movement is received or if a vibration event greater than the threshold agreed occurs (greater than 10mm/s) at which point crack monitoring shall increase to weekly (if no change in crack widths is detected (within accuracy range) and daily if an increase in crack width is detected. The accuracy of crack monitoring shall be to +/- 0.2mm.

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