Melbourne Metro Rail Project

MELBOURNE METRO
RAIL AUTHORITY

MMR-AJM-PWAA-RP-NN-004175 FUTURE DEVELOPMENT LOADING REPORT TO SUPPORT GC82

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1 Executive Summary

Melbourne Metro Rail Authority (MMRA) and the appointed Tunnel and Stations Public Private Partnership (PPP) contractor, Cross Yarra Partnership (CYP), have refined the planning, design, and engineering work, and have identified various design changes which are necessary for the construction and operation of the Metro Tunnel Project. To ensure the Metro Tunnel is adequately protected from future development taking into account the proposed design changes, MMRA proposes to request the Minister for Planning to implement a Planning Scheme Amendment (PSA) to amend the existing Design and Development Overlay Schedule (DDO) area. The Melbourne Metro Rail Project – Infrastructure Protection Areas Incorporated Document (December 2016) will automatically apply to the DDO area as amended.

The Metro Tunnel Project was the subject of an Environment Effects Statement (EES), a multi-disciplinary impact assessment, which included the preparation of a Land Use and Planning Impact Assessment (Technical Appendix E to the EES), to which the “Future Development Loading” Report was a supporting document. Following the EES, the joint Inquiry/Advisory Committee issued its report to the Minister for Planning on 21 November 2016. The Minister for Planning then issued his Assessment of the EES in December 2016.

This report is an update to the Future Development Loading report, and supports a revision of the DDO boundary to reflect the design changes. The report describes the approach taken in updating the DDO, and provides an update as to how the Overlay is currently working and is expected to continue to work in the future. This report also identifies the types of issues, potential limitations, and some potential mitigation measures that future developers might need to consider in order to protect both Metro Tunnel Project assets and the future developments.

The constraints created by the Metro Tunnel Project for future developments constructed in its vicinity generally fall into the following five broad types:

- Avoiding direct contact with and providing a safe working clearance around Metro Tunnel Project structures
- Avoiding loading onto Metro Tunnel Project structures that leads to structural damage with an associated reduction of structural capacity, damage detrimental to the serviceability of the structures (leading to effects such as increased leakage of groundwater into the underground structures), and displacement of Metro Tunnel Project assets to the detriment of operations
- Avoiding excavations or other unloading of the ground around Metro Tunnel Project underground assets that would generate unfavourable reduction in the stresses in the ground that leads to structural, serviceability, or operational damage of Metro Tunnel Project assets, analogous to the loading case discussed previously
- Avoiding construction methods or operations in the development that would generate unacceptable levels of vibration in Metro Tunnel Project structures and equipment
- Avoiding new development works that rely upon direct structural support from Metro Tunnel Project assets unless specifically envisaged in Metro Tunnel Project design.

The DDO and the Infrastructure Protection Areas Incorporated Document have been in operation since the gazettal of Planning Scheme Amendment GC45 in January 2017 and has been used to protect the tunnels, station and other infrastructure from inconsistent developments, thereby addressing these issues on an ongoing basis.

The purpose of this report is to:

- Identify the appropriate area of land to which the revised DDO and the Infrastructure Protection Areas Incorporated Document should apply to provide for protection of Metro Tunnel Project infrastructure;

- Identify the types of issues, potential limitations, and potential mitigation measures that future developers might need to consider; and

- Detail proposed updates to the DDO.

The DDO and Infrastructure Protection Areas Incorporated Document work in conjunction with the establishment of easements, title acquisition and strata acquisition. The DDO schedule clearly identifies the land to which it applies in the accompanying planning scheme maps, and the Infrastructure Protection Areas Incorporated Document applies to land identified in the DDO Schedules.

The DDO and Infrastructure Protection Areas Incorporated Document are used to trigger planning approval for buildings and works within the DDO area which require referrals of applications to the Secretary to the Department of Economic Development, Jobs, Transport and Resources (**Secretary**) (and VicTrack from 31 December 2026) to ensure they have an opportunity to assess and advise on how a proposed development could impact on the Metro Tunnel Project. Within the DDO and Infrastructure Protection Areas Incorporated Document in the planning schemes, a list of application requirements ensures that the responsible authority and MMRA, on behalf of the Secretary, have the correct level of information to assess the relevant impacts of the proposed development. An application under the DDO or Infrastructure Protection Areas Incorporated Document must could include pre-application meetings with MMRA which ensure appropriate application information is submitted, providing transparency of details prior to application lodgement with the Responsible Authority. To this point, it is estimated that at least 42 development referrals have been received by MMRA, and assessed technically.

The design of Metro Tunnel Project incorporates allowances for the possible future development of the land above and adjacent to the proposed tunnels, caverns and other underground structures, by including specific but limited additional design loading cases. These would be added to the applicable design loads for the existing conditions.

In defining the appropriate extent of the proposed DDO around Metro Tunnel Project underground assets, the objective is to select a distance within which proposed future developments that could potentially load the Metro Tunnel Project underground structures beyond their design limits are identified. These would be referred through the planning process to the relevant referral authority for assessment as to whether or not the development does in fact raise concerns.

The extents of the DDO have been identified based on a conservative view of the maximum loading in the surface area influencing the tunnels and other underground structures, and considering this with respect to the design allowances at the tunnels and other structures. The design allowances that are incorporated into the Metro Tunnel design process do not represent a particular building and could be applied by many different configurations of development. The analyses have indicated that there are different offsets at which development loads of different magnitudes and loading areas would apply loads approaching the design allowances at Metro Tunnel Project's underground structures.

The recommended extents of the areas at the existing surface have been calculated by modelling the offsets and sloping planes from the revised Metro Tunnel Project structures and determining where such planes intersect with the surface. The resulting updated offsets of the proposed DDO boundaries are a function of the depth of Metro Tunnel Project tunnels or other Metro Tunnel Project structures below the surface.

Plans showing the proposed updated DDO boundary together with the current DDO boundary are included in Appendix A of this report.

2 Introduction and Purpose

After completion of the Metro Tunnel Project, new buildings and infrastructure will be constructed in the vicinity of Metro Tunnel Project structures and infrastructure. The Metro Tunnel Project itself would be a catalyst for some of this development, as occurred around the Melbourne Underground Rail Loop (City Loop), but most of the new works would come from the natural growth and development of Melbourne.

During 2016, the Metro Tunnel Project was the subject of an Environment Effects Statement (EES), a multi-disciplinary impact assessment, which included the preparation of a Land Use and Planning Impact Assessment (Technical Appendix E to the EES). In Section 5.3 of the *Technical Appendix E Land Use and Planning*, a range of considerations were discussed to formally identify and protect the proposed Metro Tunnel Project infrastructure from inappropriate development within the planning legislation.

Following the EES, the joint Inquiry/Advisory Committee issued its report to the Minister for Planning on 21 November 2016. The Minister for Planning then issued his Assessment of the EES in December 2016. The Minister's Assessment confirmed that a DDO was the preferred planning mechanism to afford this protection, which was subsequently implemented into the Melbourne, Port Phillip and Stonnington Planning Schemes through the introduction of Planning Scheme Amendment GC45, gazetted on 5 January 2017 (DDO Schedule 70 in the Melbourne Planning Scheme, DDO Schedule 3 in the Port Phillip Planning Scheme, and DDO Schedule 20 in the Stonnington Planning Scheme). In each of the relevant planning schemes, the Melbourne Metro Rail Project - Infrastructure Protection Areas Incorporated Document (December 2016) was also introduced as an Incorporated Document.

The DDO alerts developers to the presence of the tunnels and other underground structures and formulates a referral process, applies permit triggers for various development, and sets out purposes, application requirements and decision guidelines. The Infrastructure Protection Areas Incorporated Document applies to the land affected by the relevant DDO, and reflects the purposes, application triggers and decision guidelines of the DDO but applies a permit trigger for demolition. Applications under the DDO or Infrastructure Protection Areas Incorporated Document must be referred to the Secretary (in practice, MMRA) during the design and construction phases until end 2026, then to VicTrack during operation.

Melbourne Metro Rail Authority (MMRA) and the appointed Tunnel and Stations Public Private Partnership (PPP) contractor, Cross Yarra Partnership (CYP), have refined the planning, design and engineering work, building on the Concept Design. This analysis has identified various design changes which are necessary for the construction and operation of the Metro Tunnel Project. To ensure the Metro Tunnel is adequately protected from future development taking into account the proposed design changes, MMRA proposes to request the Minister for Planning to implement a Planning Scheme Amendment (PSA) to amend the existing DDO Schedule (DDO) area. The Infrastructure Protection Areas Incorporated Document will automatically apply to the DDO area as amended.

The primary changes associated with the design include the following:

- Minor adjustments to vertical and horizontal tunnel alignment
- Refined design of station structural outlines

A “Future Development Loading” report was prepared to support the EES *Technical Appendix E Land Use and Planning,* which was to be read in conjunction with EES *Technical Appendix P Ground Movement and Land Stability*. This report is an update to the Future Development Loading report that was prepared for the EES, and supports an update to the DDO boundary to reflect the detailed design changes. The report describes the approach taken in revising the DDO, and provides an update as to how the Overlay is currently working and is expected to continue to work in the future. This report also identifies the types of issues, potential limitations, and some potential mitigation measures that future developers might need to consider to protect both Metro Tunnel Project assets and the future developments.

2.1 Introduction

The constraints created by the Metro Tunnel Project for future developments constructed in its vicinity generally fall into the following five broad types:

- Avoiding direct contact with and providing a safe working clearance around Metro Tunnel Project structures
- Avoiding loading onto Metro Tunnel Project structures that leads to structural damage with an associated reduction of structural capacity, damage detrimental to the serviceability of the structures (leading to effects such as increased leakage of groundwater into the underground structures), and displacement of Metro Tunnel Project assets to the detriment of operations
- Avoiding excavations or other unloading of the ground around Metro Tunnel Project underground assets that would generate unfavourable reduction in the stresses in the ground that leads to structural, serviceability, or operational damage of Metro Tunnel Project assets, analogous to the loading case discussed previously
- Avoiding construction methods or operations in the development that would generate unacceptable levels of vibration in Metro Tunnel Project structures and equipment
- Avoiding new development works that rely upon direct structural support from Metro Tunnel Project assets unless specifically envisaged in Metro Tunnel Project design.

On 5 January 2017, the Minister for Planning approved Planning Scheme Amendment GC45 (GC45), giving the Metro Tunnel Project planning approval by reference to the Concept Design assessed in the EES, having considered the findings of the Inquiry and Advisory Committee and the Minister’s Assessment. One aspect of the planning approval was to apply the DDO to protect the underground tunnels, stations, and other infrastructure during the construction and future operation of the Metro Tunnel from future development, and the Infrastructure Protection Areas Incorporated Document. The DDO and Infrastructure Protection Areas Incorporated Document have been in operation since gazettal of GC45 in January 2017, with MMRA as the Determining Referral Authority on behalf of the Secretary.

The amendment also introduced the following general changes to the Melbourne, Port Phillip and Stonnington Planning Schemes:

- Introducing a new Schedule to Clause 43.02 – DDO and amend the Planning Scheme maps to apply the DDO to land above, below or in close proximity to the Project’s tunnels, stations and associated infrastructure.
- Amending the Schedule to Clause 52.03 – Specific Sites and Exclusions to identify land affected by the relevant DDO as being subject to the specific controls in the “Melbourne Metro Rail Project – Infrastructure Protection Areas Incorporated Document, December 2016”.
- Amending the Schedule to Clause 66.04 to make the Secretary to the Department of Economic Development, Jobs, Transport and Resources (and VicTrack from 31 December 2026) the determining referral authority for applications under the relevant DDO and the “Melbourne Metro Rail Project – Infrastructure Protection Areas Incorporated Document, December 2016”.

Amending the Schedule to Clause 81.01 to insert an incorporated document titled “Melbourne Metro Rail Project – Infrastructure Protection Areas Incorporated Document, December 2016”. Proposed Planning Scheme Amendment GC82 is required in order to replace the schedules to Clause 52.03, Clause 61.01 and 81.01 of the Melbourne, Port Phillip and Stonnington Planning Schemes by inserting an amended incorporated document titled the *Melbourne Metro Rail Project Incorporated Document, February 2018* (incorporated document). The incorporated document is required to be amended to include all Project Land, changed as a result of detailed design. The remainder of the incorporated document generally retains the structure and content of the original incorporated document.

The revised DDO is consistent with the changes in Project Land, but also reflects the changes in the design of the Project. It contains the same controls as have been in operation since its original introduction in January 2017. Similarly, no change to the controls in the Infrastructure Protection Areas Incorporated Document are proposed but the demolition permit and referral trigger would continue to apply in the DDO area as amended.

2.2 Purpose

The purpose of this report is to:

- Identify the appropriate area of land to which the revised DDO and Infrastructure Protection Areas Incorporated Document should apply to provide for protection of Metro Tunnel Project infrastructure;
- Identify the types of issues, potential limitations, and potential mitigation measures that future developers might need to consider; and
- Detail proposed updates to the DDO area.

3 The Use of the Design and Development Overlay

Given the merging of applications and infrastructure protection analysis in practice, to simplify the discussion below, the combined controls applied under the DDO and the Infrastructure Protection Areas Incorporated Document which applies to the DDO area, are referred to below as the 'DDO'.

The DDO has been in operation in the Melbourne, Port Phillip and Stonnington Planning Schemes since the gazettal of Planning Scheme Amendment GC45 in January 2017. Planning Scheme Amendment GC67 was gazetted 8 June 2017 and updated the original incorporated document. It did not, however amend the DDO as the affected works did not affect the existing DDO.

Due to the large scale of the Metro Tunnel Project, the number of properties it passes under, and its impact on multiple municipalities, the DDO clearly identifies the area in which tunnel protection considerations arise in the Melbourne, Port Phillip and Stonnington Planning Schemes. This ensures that proponents of future development that may affect Metro Tunnel Project assets would become aware of the potential issues through normal planning processes and vendor statements, and can plan development accordingly. The rationale for this was discussed in the Metro Tunnel Project EES (Section 5.3 of Technical Appendix E *Land Use and Planning).*

The DDO works in conjunction with the establishment of easements, title acquisition and strata acquisition. The DDO schedule clearly identifies the land to which it applies in the accompanying planning scheme maps. The DDO is used to trigger planning approval for buildings and works within the DDO area and which require referrals of applications to the referral authority to ensure they have an opportunity to assess and advise on how a proposed development could impact on Metro Tunnel Project. Within the DDO in the planning schemes, a list of application requirements ensures that the Responsible Authority and MMRA have the correct level of information to assess the relevant impacts of the proposed development. An application under the DDO must include pre-application meetings with MMRA which ensure appropriate application information is submitted, providing transparency of details prior to application lodgement with the Responsible Authority. Up to the time of this report, 42 development referrals have been received by MMRA, and assessed technically.

Any planning approval sought solely pursuant to the DDO is exempt from notice obligations and third party review rights, so any technical issues can be resolved between the proponent, MMRA and the responsible authority.

In cases where a development had an existing approval when the DDO was introduced, the Metro Tunnel design criteria require that loading effects and clearances of that development are included in the design process.

The future unloading design allowances and excavation clearances will not be applied to cut and cover structures, such as the proposed North Melbourne (formerly named Arden), Parkville, and Anzac (formerly named Domain) stations, the entrance shafts, and like structures, other than will be already included for the specific allowances for over-site development. In the case of future adjacent excavations, these Metro Tunnel Project structures would be assessed and protected similarly to current practice for the deep basements of buildings. While this does not preclude excavations adjacent to these structures, the future development would need to be constructed using methods that allow for the fact that lateral unloading from any future unknown developments has not been included in the design of these Metro Tunnel Project structures.

The derivation of clearances and loads described in Section 4 is based upon technical requirements for protecting the structural integrity of Metro Tunnel Project structures.

This report does not address any constraints on future development at surface as a result of divestment or acquisition of subsurface land, as this would depend on acquisition footprint and planning controls on a site specific basis. Further, this report does not address operational characteristics of Metro Tunnel Project, for example the generation of vibration. While such effects are regulated under the Environmental Protection Requirements set out in the Environmental Management Framework for the Project for the existing conditions, future developments, if more sensitive, would need to include appropriate mitigation measures within their own works.

4 Impact on Future Development

4.1 Design Allowances for Future Development

The design of Metro Tunnel Project incorporates allowances for the possibility of future development of the land above and adjacent to the proposed tunnels, mined stations and other underground structures, in areas where future development is feasible within the 100-year design life of the tunnel infrastructure. This is effected by including specific but limited additional design loading cases in the design criteria. These would be in addition to the applicable design loads for the existing conditions and known development that was permitted prior to gazettal of GC45 on 5 January 2017.

The form and effects of developments over the later life of the tunnels could be of many different types and magnitudes. Therefore, additional loadings and unloading (beyond the existing conditions), based upon engineering experience, together with recent examples of developments and typical contemporary construction (both methods and form), were used to develop technical design requirements for the project infrastructure. They will not accommodate all possible developments nor all aspects of potential construction. However, the design allowances will provide additional strength above the structural capacity required for the current conditions to offer some flexibility for future changes.

The design allowances, per se, do not define the restrictions on future developments, but would indicate what might be changed around the tunnel without special mitigation measures. Developments that might otherwise impose greater change in loadings on Metro Tunnel Project assets may be possible, but would require detailed technical and risk assessments and, potentially, physical mitigation measures to be incorporated in their design and construction to ensure that Metro Tunnel Project assets are not affected adversely. On the other hand, the allowances should not be treated as criteria for acceptability at face value. Even developments appearing to fall within the design allowances would require review by experienced people to confirm that there is not something within the proposal that was not contemplated in the original Metro Tunnel Project design.

It will be necessary for the assessment of a particular development to be conducted with a knowledge of the other changes around the proposed tunnels that occur following their construction. Therefore, it will be important for the relevant referral authority to have access to information on all new material works in the vicinity after the date the DDO was applied to the land, and MMRA has been recording and collating this since January 2017.

4.2 Envisaged Process for Review of Proposed Future Developments

The following sections indicate the types and extent of constraints that might apply to future developments above and adjacent to the underground structures of Metro Tunnel Project. They include two main components:

- Requirements for physical separation of the components of a development from Metro Tunnel Project assets
- Limits on both additional loading and excavation leading to ground relaxation resulting from the construction and use of a development.

Irrespective of whether or not a proposed development appears to fall within the Metro Tunnel's design allowances, proposed developments will be reviewed by the relevant referral authority. The review process includes:

- The right of the relevant referral authority to impose any other requirements that are deemed necessary for safeguarding of Metro Tunnel Project assets and the development, such as clearances and vibration from construction methodology
- Measures by the relevant referral authority to verify that the design and construction of the proposed development comply with the stipulated requirements or conditions.

The outcomes of the review by the referral authority might include:

1. Confirmation that the developer has conducted an appropriate risk assessment of construction in the vicinity of Metro Tunnel Project underground assets
2. Confirmation that the proposed development would not cause the assets of Metro Tunnel Project to be stressed beyond acceptable structural limits
3. Confirmation that deep foundations, secant pile walls, contiguous bored pile walls, sheet pile walls, diaphragm walls, ground anchors or similar are not within a zone that would create unacceptable risk for Metro Tunnel Project assets
4. Where applicable, information on how the proposed development might be affected by vibration and noise as a result of the operation of Metro Tunnel Project, noting whether the design of the development has taken these effects into consideration
5. Measures to verify that the developer undertakes its works to the satisfaction of the relevant referral authority and in accordance with the mitigation measures identified in its risk assessment.

It might be that the development would need to include mitigation measures to reduce the risk to Metro Tunnel Project assets and itself. These could include modifications such as changing the levels of its foundations, adopting stiffer supports for excavation works, changing the sequence of excavation and buildings, and including additional structural systems to limit the change of stress or displacement in the ground around Metro Tunnel Project assets. In some cases, the presence of Metro Tunnel Project assets might require the development to span over specified areas and to limit the extent of excavations over or adjacent to Metro Tunnel Project assets.

It will be important that all buildings or other works that have been completed after the construction of Metro Tunnel Project are considered, rather than assessing the effects of an individual development in isolation.

4.3 Issues to be Considered for Future Developments

The detailed design of the Metro Tunnel Project includes some limited allowances for the construction of future developments in close proximity and the potential changes in load that might result from such developments. These values are unchanged from those that were described in the EES.

4.3.1 CLEARANCES ALLOWED FOR AROUND METRO TUNNEL PROJECT STRUCTURES

The physical clearance to be maintained between the constructed elements of new development and the Metro Tunnel Project assets depends upon the risks of damage, and therefore it depends as much upon the degree of control applied as the type of construction itself. Furthermore, the proximity of some elements such as shallow footings and deep piles could also be controlled by the limits of additional loading on Metro Tunnel Project structures. The loading limits types are described in Section 4.3.2.

A second consideration, particularly with respect to bulk excavations, is the amount of ground remaining adjacent to the tunnel or mined excavations to support the redistributed vertical loading (arching) over the structure. If this ground is overstressed, it could apply excessive loads onto both Metro Tunnel Project structure and the development, or lead to unacceptable settlements. At the same time, the ground movements associated with the adjacent development excavations would affect the stresses in the linings of the Metro Tunnel Project structures, and thus, the unloading effects described in Section 4.3.2 would need to be considered along with the physical clearances.

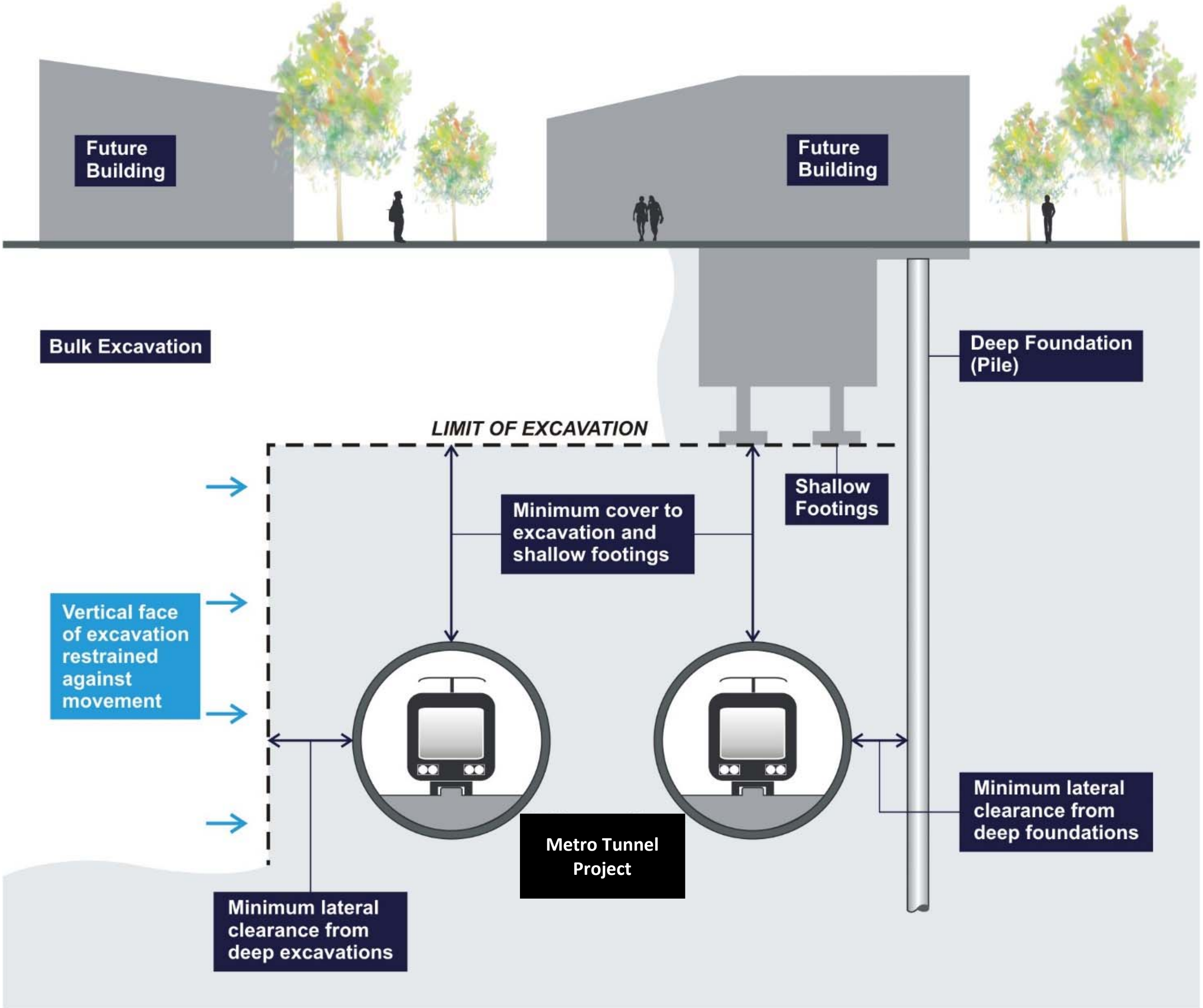


FIGURE 4-1 TYPES OF CLEARANCES FROM FUTURE DEVELOPMENTS CONSIDERED IN METRO TUNNEL PROJECT DESIGN

The activities and structures of potential future developments that would be considered in the detailed design of the structures of the Metro Tunnel Project comprise:

- Individual piled foundations bored adjacent to Metro Tunnel Project
- Individual piled or spread footing excavated over Metro Tunnel Project
- Bulk excavation adjacent to Metro Tunnel Project, including retention systems comprising secant piles, diaphragm walls or similar.

The clearances that would be adopted for use in the detailed design of Metro Tunnel Project would be based on the following considerations:

- Typical construction methods for excavation
- Typical construction tolerances for the position of piles down to the greatest depth of the Metro Tunnel Project structures together with a clearance of a diameter from a typical large pile
- Potential for clashes with redundant rock bolts or cables and their consequences for Metro Tunnel Project.

These clearances, adopted for detailed design of Metro Tunnel Project, would not necessarily define the minimum clearances that would be acceptable for future development within the DDO in all circumstances. Clearances less that the allowances included in the design might be agreed to, if the developer is able to demonstrate that the risk to Metro Tunnel Project, and the development can be maintained at acceptable levels. The developer's submissions to the referral authority would need to include details of how this would be achieved. The following are general examples of assurances that might need to be shown to gain acceptance of smaller clearances:

- Specific and more rigorous than usual construction controls would be applied effectively
- Local loadings on Metro Tunnel Project structures from footings in close proximity are acceptable
- Ground movement from excavations in close proximity to the Metro Tunnel Project would not have detrimental effects
- Acceptable measures would be applied if redundant rock bolts are encountered, both for the construction of the development and to avoid damage of the permanent Metro Tunnel Project lining, and particularly the waterproofing
- The stability of the narrower rock pillar between Metro Tunnel Project and the bulk excavation, carrying the loads from the structure and the loads arching through the rock above, is maintained.

4.3.2 GENERAL LOADING ALLOWANCES FOR FUTURE DEVELOPMENT

Additional loading (e.g., due to future building foundation loads) and load relaxation (e.g., reduction of ground stress due to future building basement excavations) need to be considered at all locations where the Metro Tunnel Project underground structures pass under or are adjacent to developable properties or land. These loads might be applied at any time during the design life of the structure, and would rely upon Metro Tunnel Project structures retaining their design capacity, consistent with their 100 year design life.

The design requirements for Metro Tunnel Project underground structures, as shown in Figure 4-2, would include allowances for future developments, defined as:

- Two vertical loading cases, expressed in units of pressure, kPa, representing:
  - New building loads, and
  - An increase in ground level above Metro Tunnel Project asset
- A vertical unloading case (defined by depth and representing bulk excavation over the Metro Tunnel Project asset)
- A lateral release defined by the allowable ground movement at the face of the excavation (representing a deep excavation beside the Metro Tunnel Project asset).

As an indication, the increase in building load from future developments for underground structures such as tunnels or mined station would be generally 50 kPa, which is equivalent to the average loading from a typical five storey building directly over a shallow tunnel.

The change in ground level represents the effect of lifting the whole area over the tunnels by 1 m.

The unloading case, again in isolation, would represent an excavation for two basement levels, provided that a minimum cover is maintained over the Metro Tunnel Project structure. Excavations of this depth have generally been accommodated by the Melbourne Underground Rail Loop (City Loop) tunnels in Melbourne, and the allowance is similar to that adopted, again, for the Legacy Way project in Brisbane. The unloading allowances have not been included for the cut and cover structures. While this does not preclude excavations adjacent to these structures, the future development would need to be constructed using methods that allow for the fact that any lateral unloading has not been included in the design of these Metro Tunnel Project structures.

These effects could be considered in combination, where compensating effects could allow additional loading of one aspect to be considered when determining likely acceptable values of another. For example, if there was to be no change in ground level, the allowance for increase of ground levels could be added to the building load. Another case could be where basements were excavated, reducing the load on the Metro Tunnel Project asset and allowing additional building loading to be applied compared with a building with no basement before the same net loading is reached. However, the excavation staging and re-loading would have to be appropriately modelled to make sure that there were no problems associated with the interim stages.

The design would also include the combination of the allowance loadings that creates the most severe case for Metro Tunnel Project structures. This could mean applying the loadings over only part of the possible area, and is described as pattern loading in the following discussion.

At the same time, future developments must be assessed for their own effects together with any other cumulative effects that would have occurred following the completion of the Metro Tunnel Project structures, so that the changes in ground stress or deformation can be considered in comparison with conditions at the time that construction of Metro Tunnel Project structures has been completed.

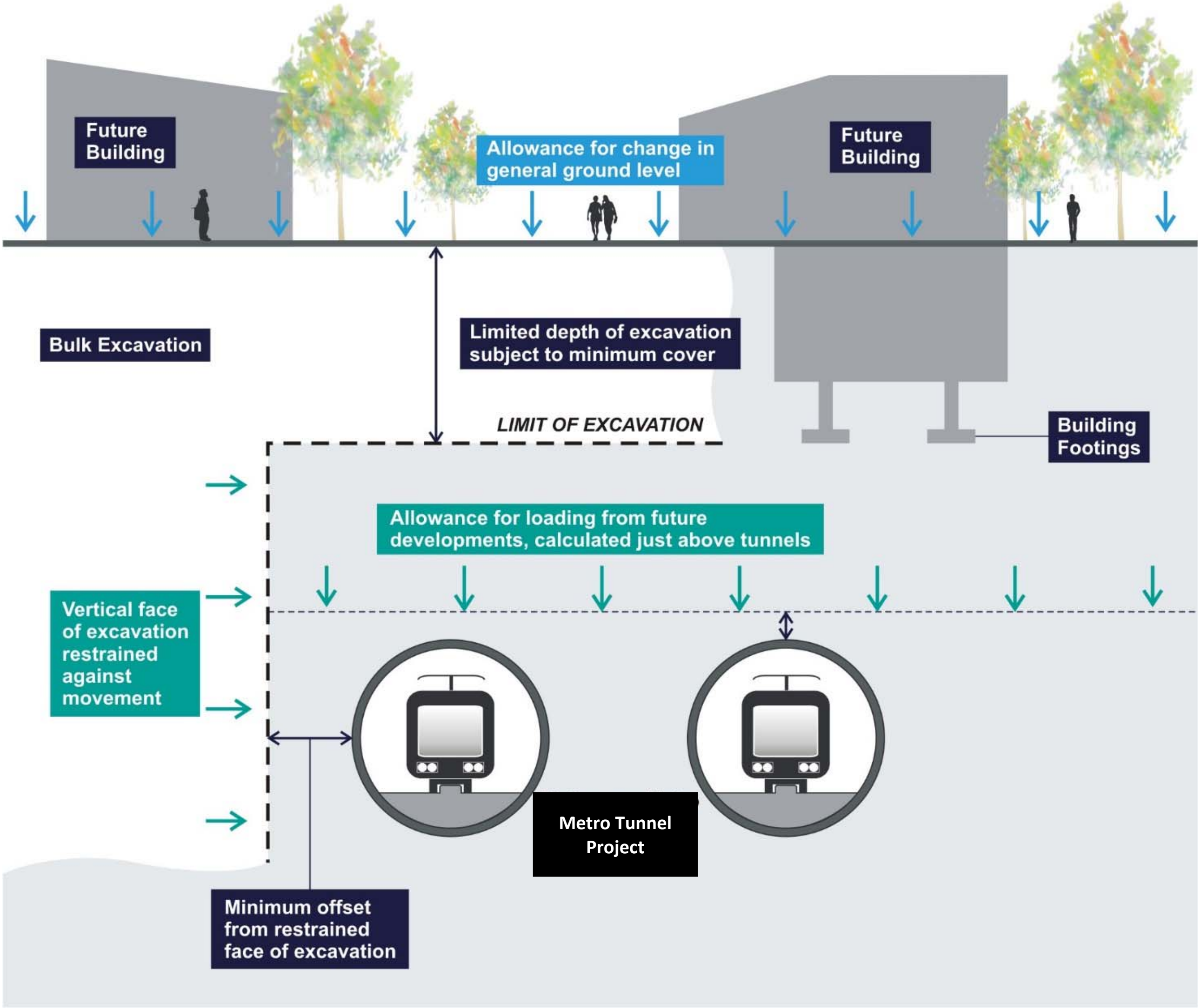


FIGURE 4-2 TYPES OF LOADS FROM FUTURE DEVELOPMENTS CONSIDERED IN METRO TUNNEL PROJECT DESIGN

Submissions that might lead to agreement from the referral authority to increase the size of a proposed future development adjacent to Metro Tunnel Project tunnels, mined stations, or other underground structure could include:

- Development of structural options to divert ground loading away from Metro Tunnel Project structures
- Assessment of specific load changes on Metro Tunnel Project and demonstrated acceptability at the particular position based upon loading history and geological conditions. The assessment must consider both structural integrity and preservation of serviceability of Metro Tunnel Project
- Demonstration of the stability of a narrower rock pillar between the Metro Tunnel Project structures and the excavation carrying the loads from the Metro Tunnel Project structures and the loads arching through the rock above.

Cut and cover structures of Metro Tunnel Project will be designed for a similar set of future loadings (but with different values). However, these structures, typically station boxes or entrance shafts, would not include any specific design allowances for future excavations immediately adjacent to them. These structures would be assessed and protected similarly to current practice for the deep basements of existing buildings.

5 Extent of the Design and Development Overlay

The assessment of proposed developments in the vicinity of the Metro Tunnel Project assets are triggered by a formal process that captures potential works and provides clarity on what needs to be considered.

In order to ensure that appropriate developments that are a potential risk to the Metro Tunnel Project structures are referred, without adding an unnecessary burden of referral and review, specified minor works are exempt.

5.1 Background for Design and Development Overlay Boundaries

In defining the appropriate extent of the proposed DDO around Metro Tunnel Project underground assets, the objective is to select a distance within which proposed future developments that could potentially load the Metro Tunnel Project underground structures beyond their design limits are identified. These would be referred through the planning process to the relevant referral authority for assessment as to whether or not the development does in fact raise concerns. The question to be considered can be re-phrased as “At what distance is any development loading, no matter how large, unlikely to be of concern to Metro Tunnel Project assets?”.

As outlined in Section 4, the tunnels, caverns and other underground structures will include a design allowance for future development loading. The allowances do not represent a particular building and could be applied by many different configurations of development. This is illustrated in the schematic examples shown in Figure 5-1, which shows a hypothetical area over a tunnel. The future development loading allowance at the tunnel of 50 kPa (a pressure equivalent to five tonnes per square metre) would result from a development of around five storeys extending well beyond the area directly over the point of the tunnel being considered. A similar peak level loading at the tunnel would be applied by a higher building, for example of eight storeys, but with a limited footprint. Similar orders of stress at the tunnels would also be applied by even higher buildings but at increasing horizontal offsets from the tunnels, with the loading applied near the surface.

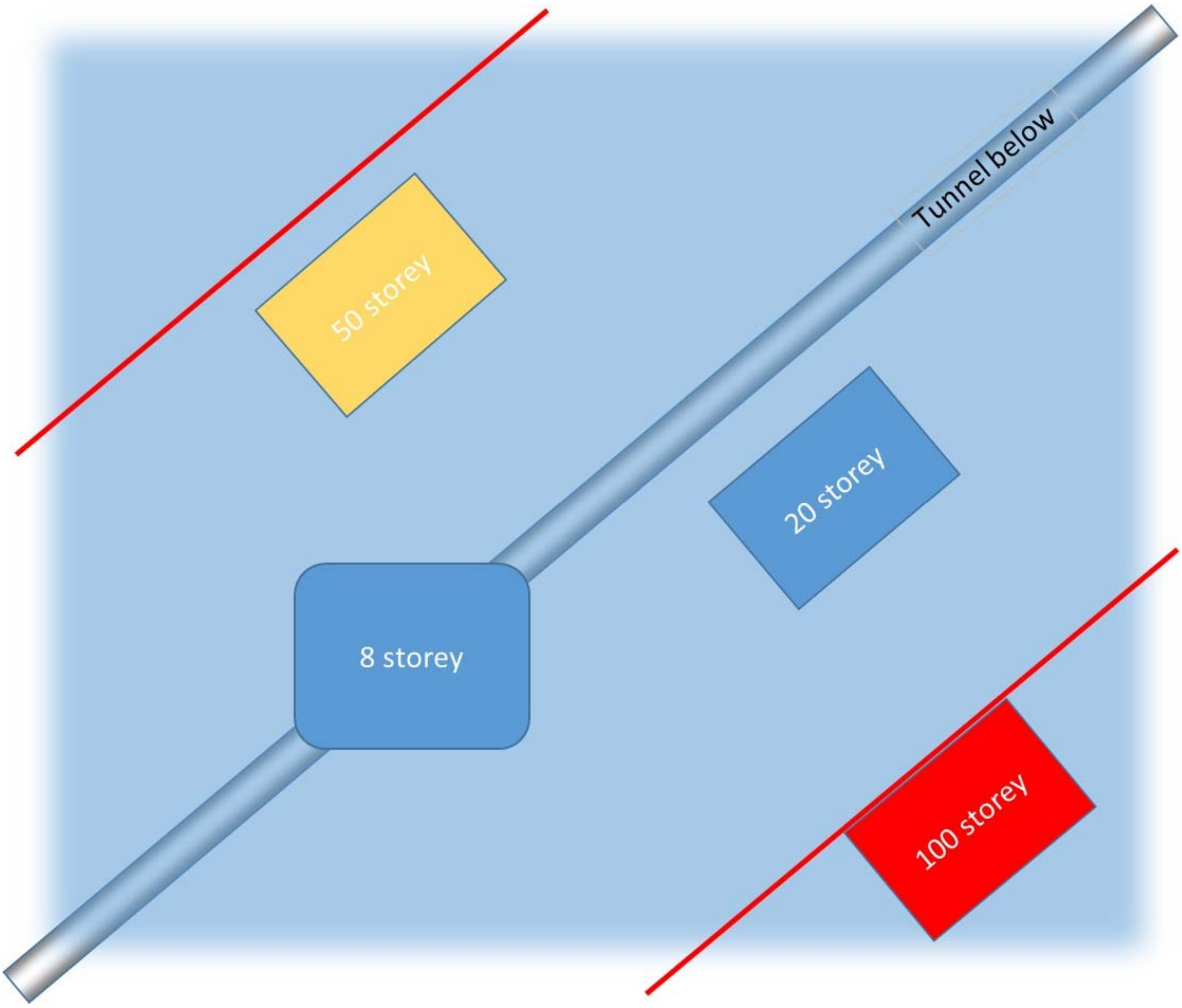


FIGURE 5-1 STRUCTURES WITH EQUIVALENT LOADING ON A TUNNEL

In developing the initial recommendations for the current DDO boundaries, a number of matters needed to be included in the considerations.

- It has been assumed that the Metro Tunnel Project structures designs would be generally adapted to the immediate conditions and the design allowances for future developments are all the capacity that Metro Tunnel Project structures have to accommodate future additional loading.
- Current planning controls that apply maximum height have not been considered relevant to the assessment of future loading, noting that planning controls may change over time.
- While there may be some future development outside the proposed DDO boundary that could impact on loading for Metro Tunnel Project structures, this risk may be mitigated somewhat by the fact that, with sufficient extents drawn up for the proposed DDO boundary, any such development beyond the DDO boundary would be expected to be very large and well publicised. Furthermore, at least based on today's technology, such a structure would be expected to be founded at depth and, hence, to apply less loading on the relatively distant Metro Tunnel Project assets when compared with a load applied at the surface.
- The ground conditions would affect the interaction between a future development and Metro Tunnel Project assets in a number of ways
  - » Stronger ground would provide stiffer support around the tunnel linings, giving them greater capacity to resist additional loading. However, such ground conditions could provide more favourable founding

conditions for a proposed development, allowing it to be founded higher in the ground, with the associated greater loading effects on the proposed Metro Tunnel Project. For the current assessment, it has been assumed that the tunnel or other underground structures have been designed for the local ground conditions, and any loading above the design parameters based upon the existing or known future loads would take the structures above their design capacity.

» At the same time, the way in which a loading pressure applied near the surface disperses through the ground is somewhat sensitive to differences in stiffness created, for example, where a soft layer overlies a harder layer. This has been considered by analysing different ground models.

5.2 Geology and Metro Tunnel Project Structures

For the purposes of the analyses of loading effects with different ground conditions, the geology along the Metro Tunnel has been divided into a series of segments containing similar geotechnical conditions. These segments have been derived from Table 1 and Appendix A - *Melbourne Metro Rail Project – Geotechnical Interpretive Procurement Stage Report Rev 2 (Golder Associates*). This is a revision of the document which was included in EES Appendix P *Ground Movement and Land Stability*. A summary is presented in Table 5-1 where the geological segments are listed under Metro Tunnel Project precincts.

TABLE 5-1 SUMMARY OF THE METRO TUNNEL DESIGN SHOWING THE GEOLOGICAL SEGMENTS WITH THE ASSOCIATED CONSTRUCTION TYPE

METRO TUNNEL PROJECT PRECINCT	PROJECT ELEMENT AND APPROXIMATE EXTENT	GEOLOGICAL SEGMENT	KEY ELEMENTS
1	Twin Tunnels – Western Portal to Lloyd Street.	4	Bored tunnels (TBM) through weak rock.
	Twin Tunnels – Lloyd Street to Essendon Flyover.	5	Bored tunnels (TBM) through dense clayey sand and sand with cross passage.
	Twin Tunnels – Essendon Flyover to North Melbourne Station (formerly Arden Station).	6	Bored tunnels (TBM) through soft to stiff cohesive soils, some gravel and sand.
	Twin Tunnels – North Melbourne Station (formerly Arden Station) to Curzon Street.	8	Bored tunnels (TBM) through mixed face conditions comprising dense sands, clayey sands and weak rock.
	Twin Tunnels – Curzon Street to Parkville Station.	9	Bored tunnels (TBM) through weathered siltstone and sandstone.
	Twin Tunnels – Parkville Station to State Library Station (formerly CBD North Station)	11	Bored tunnels (TBM) through weathered to fresh siltstone and sandstone.
	Twin Tunnels – State Library Station (formerly CBD North Station) to Town Hall Station (formerly CBD South Station).	13	Mined tunnels through weathered siltstone and sandstone.
	Twin Tunnels – Town Hall Station (formerly CBD South Station) to Flinders Street.	15	Bored twin tunnels (TBM) through weathered siltstone and sandstone.
	Twin Tunnels – Flinders Street to Alexandra Avenue (under Yarra River).	16	Bored tunnels (TBM) through variable, mixed face conditions comprising high strength basalt rock, dense sand and soft to stiff clay.
	Twin Tunnels – Alexandra Avenue to CityLink tunnels.	17	Bored tunnels (TBM) through weathered siltstone and sandstone.

METRO TUNNEL PROJECT PRECINCT	PROJECT ELEMENT AND APPROXIMATE EXTENT	GEOLOGICAL SEGMENT	KEY ELEMENTS
	Twin Tunnels -CityLink Tunnels to Victoria Barracks.	18	Bored tunnels (TBM) through mixed face conditions with dense sand, hard clay and weathered siltstone and sandstone. In close proximity to the existing CityLink tunnels.
	Twin Tunnels - Victoria Barracks to Anzac Station (formerly Domain Station).	19	Bored tunnels (TBM) through weathered siltstone and sandstone.
	Twin Tunnels - Anzac station (formerly Domain Station) to Caroline Street.	21	Bored tunnels (TBM) through weathered siltstone and sandstone.
	Twin Tunnels – Caroline Street to Eastern Portal.	22	Bored tunnels (TBM) through mixed face conditions comprising weathered siltstone and sandstone, dense sand and hard clay.
2	Western Portal tie-ins.	1	Surface works and embankment widening on potentially soft soils.
	Western Portal approaches.	2	Decline structure including retained excavation through soft soils and weak rock.
	Western Portal and TBM shaft.	3	Cut and cover excavation for TBM shaft and portal within weak rock.
3	North Melbourne station (formerly Arden Station).	7	Cut and cover station excavation through soft to stiff cohesive soils, some gravel and sand.
4	Parkville station.	10	Cut and cover station excavation through weathered and jointed siltstone and sandstone.
5	State Library Station (formerly CBD North Station).	12	Underground mined excavation in weathered to fresh siltstone and sandstone with deep access shafts.
6	Town Hall Station (formerly CBD South Station)	14	Underground mined excavation in weathered to fresh siltstone and sandstone with deep access shafts. Deepening of existing City Square basement excavation.
7	Anzac Station (formerly Domain Station)	20	Cut and cover station excavation through weathered and jointed siltstone and sandstone, dense sand and hard clay.
8	Eastern Portal tie-ins and TBM Shaft.	23	Cut and cover shaft and decline structure in dense sand and hard clay. Widening of existing rail corridor excavations in dense sand and hard clay.

5.3 Analytical Approach

5.3.1 RUNNING TUNNELS AND STATION PLATFORM TUNNELS

The first step in the assessment of the effects of future loadings on Metro Tunnel Project tunnels was to consider what surface stress levels would be significant for the proposed Metro Tunnel Project, which have a design allowance of loading of 50 kPa for increase in the ground stress at the tunnels resulting from a future loading. This is analogous to knowing the answer to a problem and needing to formulate the question. The selection of the design allowance is discussed in more detail in Section 4.1.

There are already examples of buildings in Melbourne approaching 100 storeys. Therefore, this value was considered to be a reasonable and feasible structure to be viewed as a future development loading potential, irrespective of the current planning limits. The loading adopted for the assessments represents a row of such buildings running parallel with the tunnel. The loading of 1,000 kPa at the surface is somewhat conservative, as, in reality, a structure of this height would currently be expected, to be founded below the surface.

The change in the stress in the ground at depth and offset from an additional loading at the surface decreases as the distance from the loaded area increases. This was determined for a number of cases in simplified 2D models. The ground was represented in the models using elastic parameters (simplified representations of the stiffness of the ground) and the ground was modelled as a layered material, with the stiffness set to match a typical geological section with the precinct. An example of the model is shown in Figure 5-2.

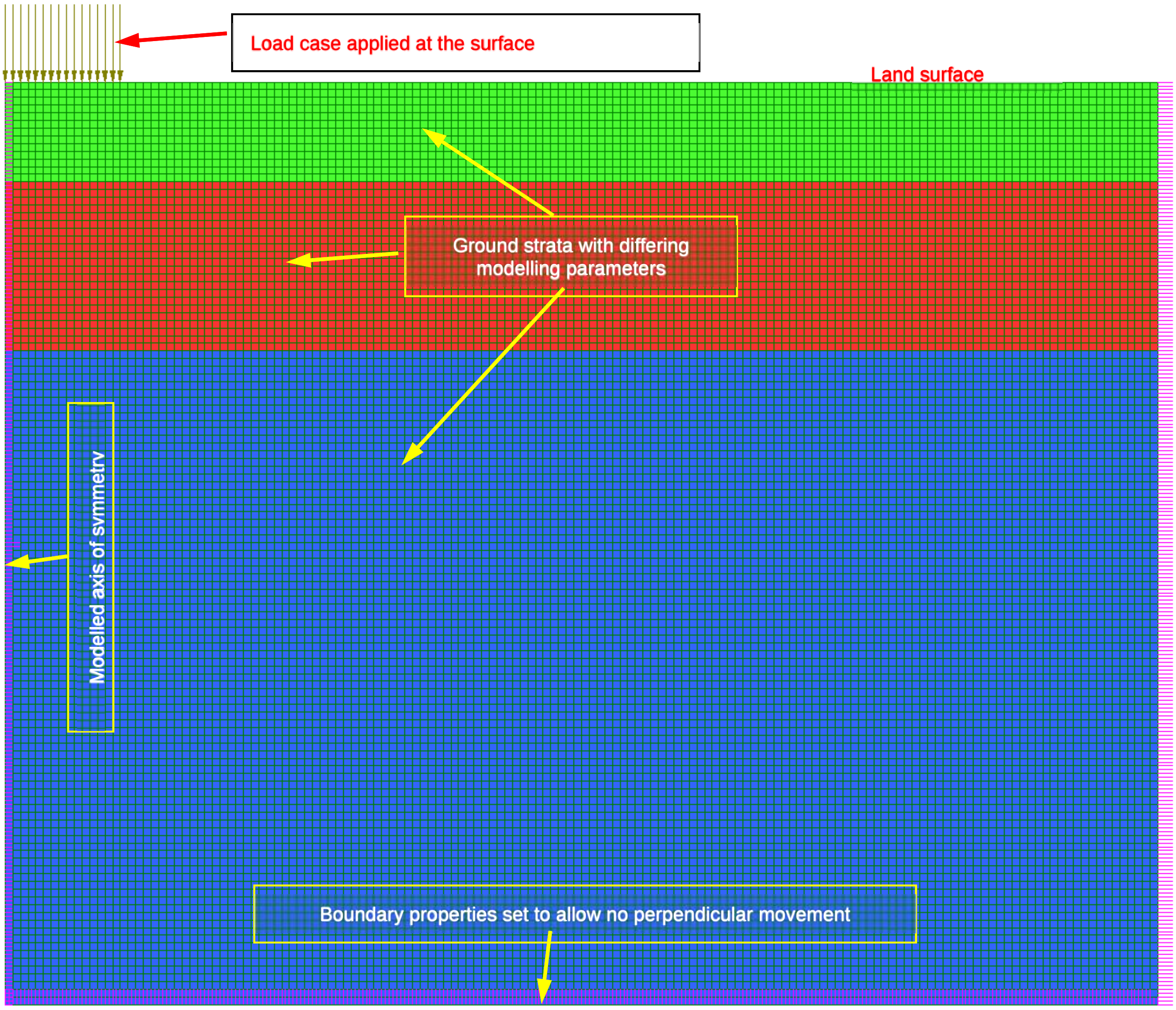


FIGURE 5-2 EXAMPLE OF THE NUMERICAL MODELLING OF A LOAD ON THE SURFACE (1 METRE GRID)

The ground models were 150 m wide, but effectively 300 m wide, and the loaded area was 15 m wide, but effectively 30 m wide, because the model is symmetrical about its left-hand side as viewed in Figure 5-2. The model was 120 m deep to limit the influence of the bottom boundary of the model. The elastic properties of the layered models are discussed together with the ground models for the precincts.

Each model was run with a surface loading of 1000 kPa so that the increased ground pressures could be readily interpreted and compared with the design allowances discussed in Section 4.

An example of the output from a model is shown in Figure 5-3. The shaded areas are between contours of equal stress increase in the ground and are scaled to be in 50 kPa increments. The changes in ground stress on the upper right hand side of the part of the model shown are between 0 kPa and 50 kPa, and then increase through each zone to a maximum value immediately beneath the loading area. The 50 kPa contour is outlined in the figure.

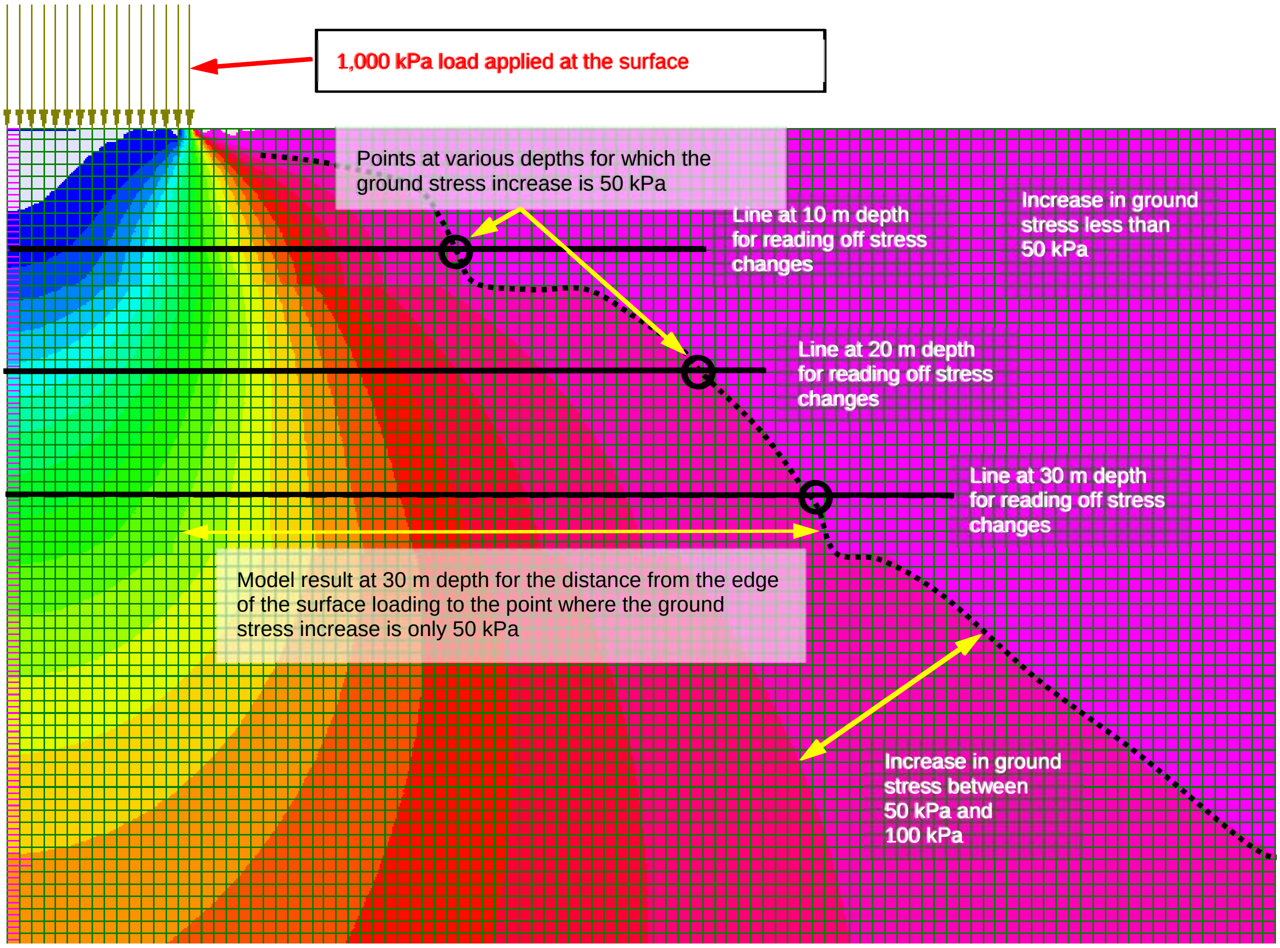


FIGURE 5-3 EXTRACT OF A TYPICAL STRESS DISTRIBUTION IN A MODEL SHOWING CONTOURS OF STRESS INCREASE IN 50 kPa STEPS (50 kPa CONTOUR OUTLINED IN BLACK DASHED LINE)

From each model, the increase in compressive stress in the ground was reviewed at a series of depths covering the range of depths for the Metro Tunnel Project. At each depth below the surface, the offset from the edge of the surface loading at which the ground loading increases were 50 kPa was determined, in a similar way to that indicated on Figure 5-3 for the offset at 30 m depth. An example of these plots of the full series of offsets with depth for a particular model is shown in Figure 5-4 is indicated by the irregular sloping line.

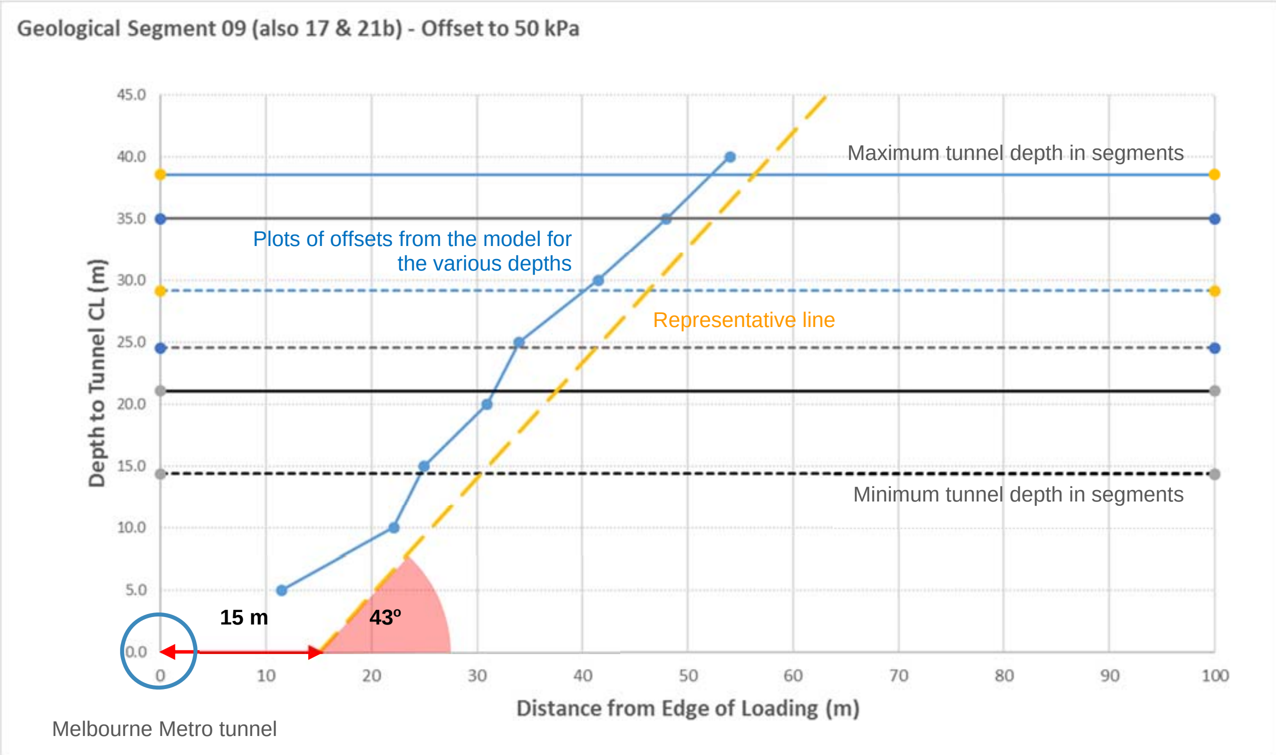


FIGURE 5-4 EXAMPLE OF DISTRIBUTION OF DEPTH VERSUS OFFSET TO 50 kPa STRESS FROM EDGE OF LOADING (SEGMENT 09)

With the results plotted together, a representative straight line was developed to form an approximate bound on the analytical results. The best fits were found to be in the form of an offset from the centre of the tunnel, and then a line at an angle to horizontal. These were set to suit, preferentially, the range of depths of the tunnel that would occur within the respective geological segments.

The sets of lines were used in 3D geometric modelling software to determine where they intersected the surface as shown in Figure 5-5, as the definition of the proposed boundary of the DDO.

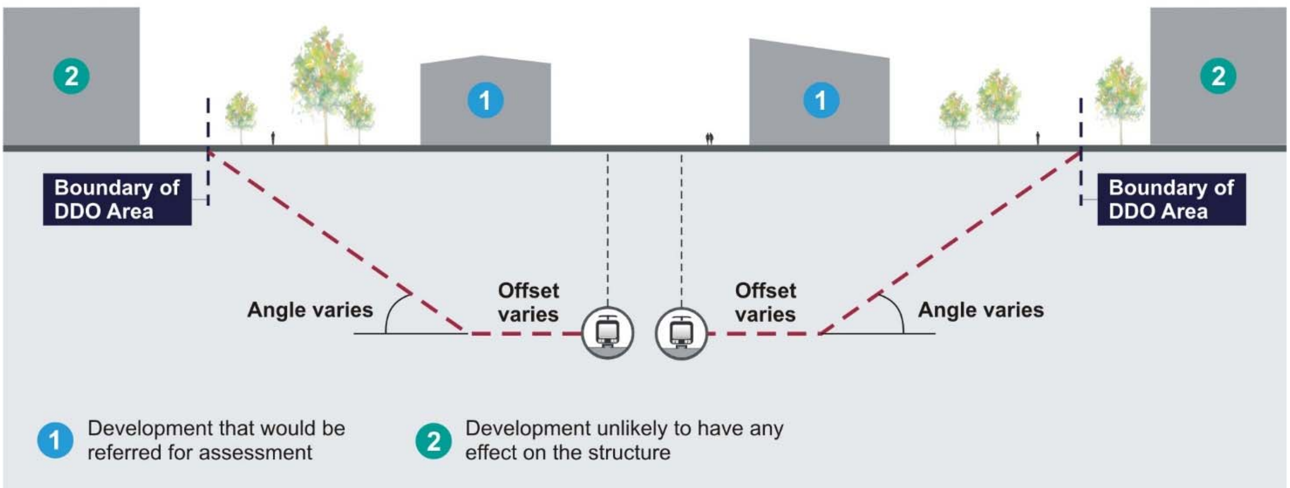


FIGURE 5-5 DERIVED LINES DEFINING THE PROPOSED EXTENT OF THE DDO

The representative lines, shown as the dashed straight lines on Figure 5-5 for each geological segment are summarised in Table 5-4.

5.3.2 SHAFTS AND CUT AND COVERS TUNNELS

The structures of the three cut and cover stations, along with similar structures at the portals and entrance shafts, differ from the tunnels and cavern stations in several important ways in their response to future developments loadings. Firstly, these structures with vertical walls would be primarily sensitive to changes in the horizontal ground pressures, with much less effect from changes in adjacent vertical pressures. Furthermore, except for the western portal, the cut and cover structures would be designed for a lesser additional loading (25 kPa) than the mined or tunnel structures.

However, as the effects of the 1,000 kPa loadings applied at the surface in proximity to these structures are also affected by the different stiffness in the ground strata, a further set of models was run for the cut and cover structures to assess the distribution of the stress from additional loading. The models used the same properties for the ground strata as were adopted for the tunnel analyses, as listed in Table 5-3. Except for the cut and cover tunnels at the Western Portal, these were plotted and compared within lines that rise from the top level of the base slab at 30 degrees until they reach the ground surface. The line is analogous to the one developed for the tunnelled or mined structures. When these were plotted for each cut and cover station, they were found to align reasonably with the outer contours of loading effects. A summary of the offsets from the cut and cover structures to the proposed DDO boundaries is given in Section 5.6.6.

The analyses at the Western Portal indicated that the effects of the various softer and stiffer layers, combined with the relative shallowness of the cut and cover structure meant that a best fit was provided by a single offset as is shown in Figure 5-10.

5.4 Analyses for Precinct 1 - Tunnels

As discussed in Section 5.2, Precinct 1 is divided into a series of geological segments based on the different ground that the tunnels would encounter. Stress from new surface loads disperses through the geological strata differently, depending on how the stiffness of the material varies with depth. This influences the distance that additional surface loading would be from the tunnels before the 50 kPa change in stress in the ground at the tunnels is reached. To account for these differences, twelve numerical models were established to represent the primary variances in geology along the tunnel alignment.

The ground descriptions including the rock mass classification (linked in part to the degree of weathering) are consistent with the *Melbourne Metro Rail Project – Geotechnical Interpretive Procurement Stage Report Rev 2 (Golder Associates*). This is a revised version of the report included in the EES documents, and reflects the additional testing and interpretation conducted since. The ground is represented in the modelling by the use of elastic parameters, which are a simplified representation of the stiffness of the ground. These are the elastic modulus and Poisson’s ratio of the ground and the values used in the analyses are listed in Table 5-2. The Melbourne Formation has been modelled using parameters, adopted from recommendations by Golder Associates, appropriate for the small strains that would be expected away from the Metro Tunnel Project construction where the ground movements would be minor.

TABLE 5-2 GEOLOGICAL UNITS

GEOLOGICAL UNIT	GRADE (INCLUDING CLASSIFICATION FOR ROCK)	ELASTIC MODULUS (MPA)	POISSON'S RATIO
Other than rock (OTR)			
Fill		10	0.3
Holocene Alluvium		15	0.3
Werribee Formation		95	0.3
Brighton Group	Cohesive (upper layer)	35	0.3
	Granular (lower layer)	80	0.3
Coode Island Silt		4.9	0.4
Fishermens Bend Silt		30	0.3
Pleistocene Alluvium		12	0.3
Early Pleistocene Alluvium		60	0.3
Rock			
Melbourne Formation	MF4 (extremely to highly weathered)	100	0.3
	MF3 (highly weathered)	325	0.25
	MF2 (moderately weathered)	1000	0.2
	MF1 (slightly weathered to fresh)	4000	0.2
Older Volcanics	OV (RS) (fully decomposed)	55	0.3
	OV4 (extremely to highly weathered)	300	0.3

Broadly speaking, the stiffness of the geological strata tends to increase from low stiffness at the surface to higher stiffness at depth. However, it is the differences in the stiffness of the upper layers near the surface and around the level of the proposed tunnels which have the most significant influence on the distribution of stress around the tunnels. Table 5-3 presents the geological segments modelled and shows the anticipated strata that was used in each model. For the purposes of modelling, some segments were combined because of the similarities in the modelling properties of the geological strata.

TABLE 5-3 GEOLOGICAL SEGMENTS MODELLED FOR PRECINCT 1 - TUNNELS

GEOGRAPHIC LOCATION	GEOLOGICAL SEGMENT	GEOLOGICAL UNIT (INCLUDING CLASSIFICATION FOR ROCK) AND THICKNESS	KEY ELEMENTS
Western Portal to Lloyd Street	4	Fill / Soil (2 m) Older Volcanics (OV4) (7 m) Older Volcanics (RS) (6 m) Older Volcanics (OV4) (10 m) Werribee Formation (8 m) Melbourne Formation (MF3) (1 m) Melbourne Formation (MF2) (1 m) Melbourne Formation (MF1) to model base	Bored tunnels (TBM) through weak rock. Alternating stiff rock and soil layers.
Lloyd Street to Essendon Flyover	5	Fill / Soil (7 m) Older Volcanics (OV4) (4 m) Werribee Formation (17 m) Melbourne Formation (MF3) (6 m) Melbourne Formation (MF2) (4 m) Melbourne Formation (MF1) to model base	Bored tunnels (TBM) through dense clayey sand and sand with cross passage. Thick soil layer between stiff rock.
Essendon Flyover to Upfield Line	6(a)	Fill / Soil (1 m) Coode Island Silt (CIS) (15 m) Fishermans Bend Silt (FBS) (7 m) Melbourne Formation (MF3) (4 m) Melbourne Formation (MF2) (4 m) Melbourne Formation (MF1) to model base	Bored tunnels (TBM) through soft to stiff cohesive soils, some gravel and sand. Deep layers of soft sediments over stiff rock.
Upfield Line to North Melbourne Station (formerly Arden station)	6(b)	Fill / Soil (3 m) Coode Island Silt (CIS) (5 m) Pleistocene Alluvium (6 m) Fishermans Bend Silt (FBS) (7 m) Early Pleistocene Alluvium (3 m) Melbourne Formation (MF3) (3 m) Melbourne Formation (MF2) (3 m) Melbourne Formation (MF1) to model base	Bored tunnels (TBM) through soft to stiff cohesive soils, some gravel and sand. Soft sediments over stiff rock.
North Melbourne Station (formerly Arden Station) to Curzon Street	8	Fill / Soil (1 m) Older Volcanics (OV4) (7 m) Werribee Formation (7 m) Melbourne Formation (MF3) (2 m) Melbourne Formation (MF2) (2 m) Melbourne Formation (MF1) to model base	Bored tunnels (TBM) through mixed face conditions comprising dense sands, clayey sands and weak rock. Soil layer between stiff rock.
Curzon Street to Parkville Station	9	Pleistocene Alluvium (1 m) Melbourne Formation (MF4) (8 m) Melbourne Formation (MF3) (9 m) Melbourne Formation (MF2) (8 m) Melbourne Formation (MF1) to model base	Bored tunnels (TBM) through weathered siltstone and sandstone. Gradually increasing stiffness in rock.
Parkville Station to State Library Station (formerly CBD North Station)	11	Melbourne Formation (MF4) (2 m) Melbourne Formation (MF3) (14 m) Melbourne Formation (MF2) (14 m) Melbourne Formation (MF1) to model base	Bored tunnels (TBM) through weathered to fresh siltstone and sandstone. Gradually increasing stiffness in rock.

GEOGRAPHIC LOCATION	GEOLOGICAL SEGMENT	GEOLOGICAL UNIT (INCLUDING CLASSIFICATION FOR ROCK) AND THICKNESS	KEY ELEMENTS
State Library Station (formerly CBD North Station) to Town Hall station (formerly CBD South Station)	13	Fill / Soil (1m1m) Melbourne Formation (MF3) (10 m) Melbourne Formation (MF2) (10 m) Melbourne Formation (MF1) to model base	Mined tunnels through weathered siltstone and sandstone. Stiff rock.
Town Hall Station (formerly CBD South Station) to Flinders Street	15 (segment 13 model adopted)	Fill / Soil (1m) Melbourne Formation (MF3) (10 m) Melbourne Formation (MF2) (10 m) Melbourne Formation (MF1) to model base	Mined tunnels through weathered siltstone and sandstone. Stiff rock.
Flinders Street to Alexandra Avenue	16 (segment 6a model adopted)	Fill / Soil (1 m) Coode Island Silt (CIS) (15 m) Fishermans Bend Silt (FBS) (7 m) Melbourne Formation (MF3) (4 m) Melbourne Formation (MF2) (4 m) Melbourne Formation (MF1) to model base	Bored tunnels (TBM) through soft to stiff cohesive soils, some gravel and sand. Deep layers of soft sediments over stiff rock.
Alexandra Avenue to CityLink Tunnels	17 (segment 9 model adopted)	Pleistocene Alluvium (1 m) Melbourne Formation (MF4) (8 m) Melbourne Formation (MF3) (9 m) Melbourne Formation (MF2) (8 m) Melbourne Formation (MF1) to model base	Bored tunnels (TBM) through weathered siltstone and sandstone. Gradually increasing stiffness in rock.
CityLink Tunnels to Victoria Barracks	18	Fill / Soil (2 m) Brighton Group (cohesive) (7 m) Brighton Group (granular) (8 m) Melbourne Formation (MF3) (11 m) Melbourne Formation (MF2) (12 m) Melbourne Formation (MF1) to model base	Bored tunnels (TBM) through mixed face conditions with dense sand, hard clay and weathered siltstone and sandstone. In close proximity to the existing CityLink tunnels. Gradually increasing stiffness in soil over rock.
Victoria Barracks to Anzac Station (formerly Domain Station)	19	Fill / Soil (2 m) Melbourne Formation (MF4) (6 m) Melbourne Formation (MF3) (8 m) Melbourne Formation (MF2) (8 m) Melbourne Formation (MF1) to model base	Bored tunnels (TBM) through weathered siltstone and sandstone. Gradually increasing stiffness in rock.
Anzac Station (formerly Domain Station) to Park Street	21(a)	Brighton Group (cohesive) (6 m) Brighton Group (granular) (6 m) Melbourne Formation (MF4) (3 m) Melbourne Formation (MF3) (13 m) Melbourne Formation (MF2) (12 m) Melbourne Formation (MF1) to model base	Bored tunnels (TBM) through weathered siltstone and sandstone. Gradually increasing stiffness in soil over rock.
Park Street to Caroline Street	21(b) (segment 9 model adopted)	Pleistocene Alluvium (1 m) Melbourne Formation (MF4) (8 m) Melbourne Formation (MF3) (9 m) Melbourne Formation (MF2) (8 m) Melbourne Formation (MF1) to model base	Bored tunnels (TBM) through weathered siltstone and sandstone. Gradually increasing stiffness in rock.

GEOGRAPHIC LOCATION	GEOLOGICAL SEGMENT	GEOLOGICAL UNIT (INCLUDING CLASSIFICATION FOR ROCK) AND THICKNESS	KEY ELEMENTS
Caroline Street to Eastern Portal	22	Brighton Group (cohesive) (7 m) Brighton Group (granular) (7 m) Melbourne Formation (MF4) (3 m) Melbourne Formation (MF3) (12 m) Melbourne Formation (MF2) (12 m) Melbourne Formation (MF1) to model base	Bored tunnels (TBM) through mixed face conditions comprising weathered siltstone and sandstone, dense sand and hard clay. Gradually increasing stiffness in soil over rock.

As shown in Figure 5-4, the required offsets from the tunnel to define the offset at which the ground stress increase matches the design allowance are defined by a representative inclined line and the horizontal distance from the centre of the tunnel to the base of the inclined line. These dimensions for each of the geological segments assessed in the Tunnels Precinct 1 are presented in Table 5-4.

TABLE 5-4 DEFINITION OF REPRESENTATIVE LINE FOR TUNNELS TO ACHIEVE 50 kPa

GEOGRAPHIC LOCATION			GEOLOGICAL SEGMENT	OFFSET FROM CENTRE OF TUNNEL TO BASE OF THE INCLINED LINE	ANGLE OF LINE FROM THE HORIZONTAL FROM BASE TO SURFACE (DESIGN & DEVELOPMENT OVERLAY BOUNDARY)
Western Portal	to	Lloyd Street	4	15 m	50°
Lloyd Street	to	Essendon Flyover	5	20 m	50°
Essendon Flyover	to	Upfield Line	6(a)	25 m	45°
Upfield Line	to	North Melbourne Station (formerly Arden Station)	6(b)	18 m	40°
North Melbourne Station (formerly Arden Station)	to	Curzon Street	8	8 m	38°
Curzon Street	to	Parkville Station	9	15 m	43°
Parkville Station	to	State Library Station (formerly CBD North Station)	11	15 m	45°
State Library Station (formerly CBD North Station)	to	Town Hall Station (formerly CBD South Station)	13	10 m	38°
Town Hall Station (formerly CBD South Station)	to	Flinders Street	15 (segment 13 model adopted)	10 m	38°
Flinders Street	to	Alexandra Avenue	16 (segment 6a model adopted)	25 m	45°
Alexandra Avenue	to	CityLink Tunnels	17 (segment 9 model adopted)	15 m	43°
CityLink Tunnels	to	Victoria Barracks	18	17 m	45°

GEOGRAPHIC LOCATION			GEOLOGICAL SEGMENT	OFFSET FROM CENTRE OF TUNNEL TO BASE OF THE INCLINED LINE	ANGLE OF LINE FROM THE HORIZONTAL FROM BASE TO SURFACE (DESIGN & DEVELOPMENT OVERLAY BOUNDARY)
Victoria Barracks	to	Anzac Station (formerly Domain Station)	19	12 m	40º
Anzac Station (formerly Domain Station)	to	Park Street	21(a)	15 m	42º
Park Street	to	Punt Road	21(b) (segment 9 model adopted)	15 m	43º
Punt Road	to	Eastern Portal	22	15 m	40º

5.5 Analyses for Trinocular Mined Stations and Entrance Shafts

The approach adopted for the analyses of the change in loading on the platform tunnels and thus, the derived offset for the proposed DDO boundary, followed the same general principles used for the analyses of the running tunnels (refer to Section 5.3.1).

The zones of protection around the major shafts at the two mined stations were assessed as described in Section 5.3.2, and in a similar manner as for the cut and cover stations. However, the stress plots, and the greater depths of these shafts lead to a more complex calculation for the DDO boundary, incorporating the combination of a horizontal offset and an inclined line.

5.5.1 ANALYSES FOR PRECINCT 5 – STATE LIBRARY STATION (FORMERLY CBD NORTH STATION)

State Library station is the deeper of the two mined stations to be constructed, and would be founded in good quality rock at depth. Table 5-5 summarises the geological model adopted for State Library station.

TABLE 5-5 GEOLOGICAL SEGMENT MODELLED FOR PRECINCT 5 - STATE LIBRARY STATION (FORMERLY CBD NORTH STATION)

GEOGRAPHIC LOCATION	GEOLOGICAL SEGMENT	GEOLOGICAL UNIT AND THICKNESS		KEY ELEMENTS
State Library Station (formerly CBD North Station	12 (segment 11 model adopted)	Melbourne Formation (MF4) Melbourne Formation (MF3) Melbourne Formation (MF2) Melbourne Formation (MF1)	(2 m) (14 m) (14 m) to model base	Underground cavern excavation in weathered to fresh siltstone and sandstone with deep access shafts. Gradually increasing stiffness in rock with depth.

Figure 5-6 shows the representative horizontal offset and inclined line from the rail alignment through the station that define the surface offset from the centre of the tracks within the platform tunnels. Figure 5-7 shows the representative horizontal offset and inclined line from the base slabs of shafts. The offset parameters for both the station and the shafts are summarised in Table 5-6.

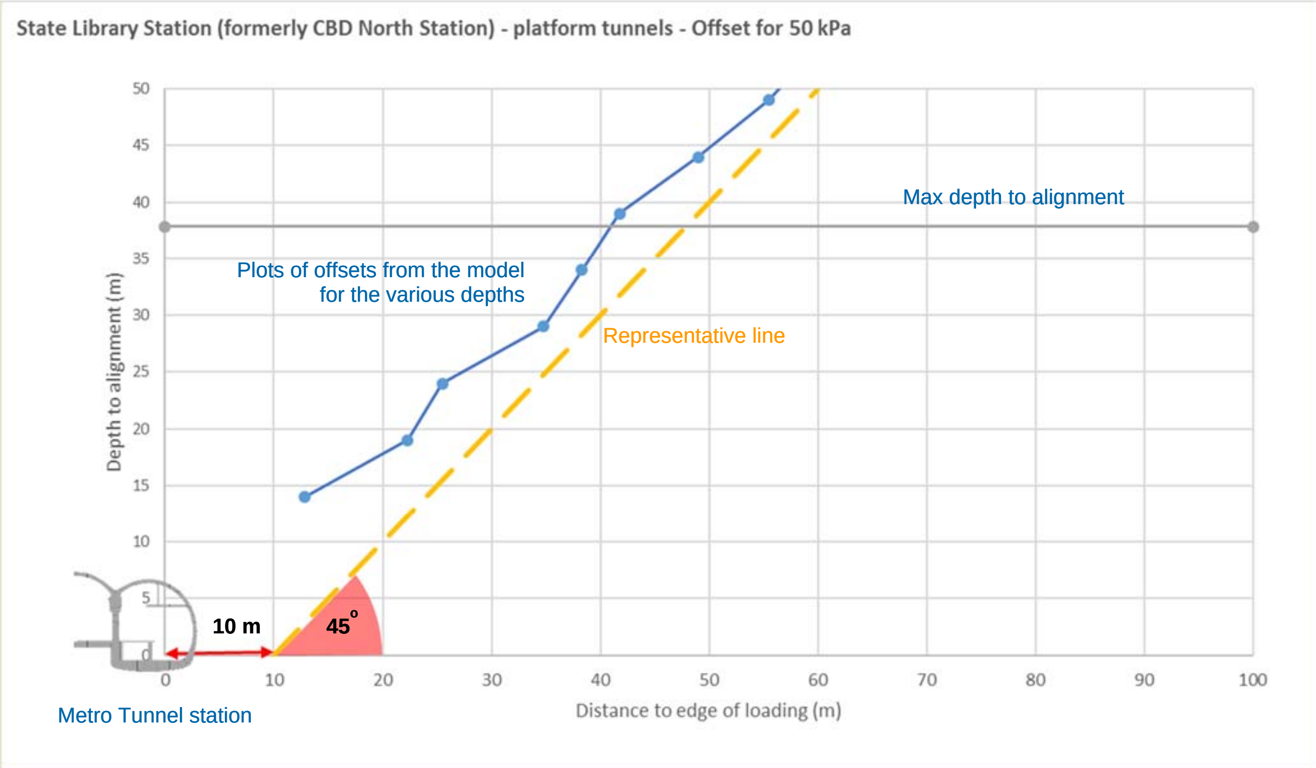


FIGURE 5-6 DISTRIBUTION OF DEPTH VERSUS OFFSET TO EDGE OF LOADING AT STATE LIBRARY STATION (FORMERLY CBD NORTH) PLATFORM TUNNEL TO LIMIT STRESS TO 50 kPa

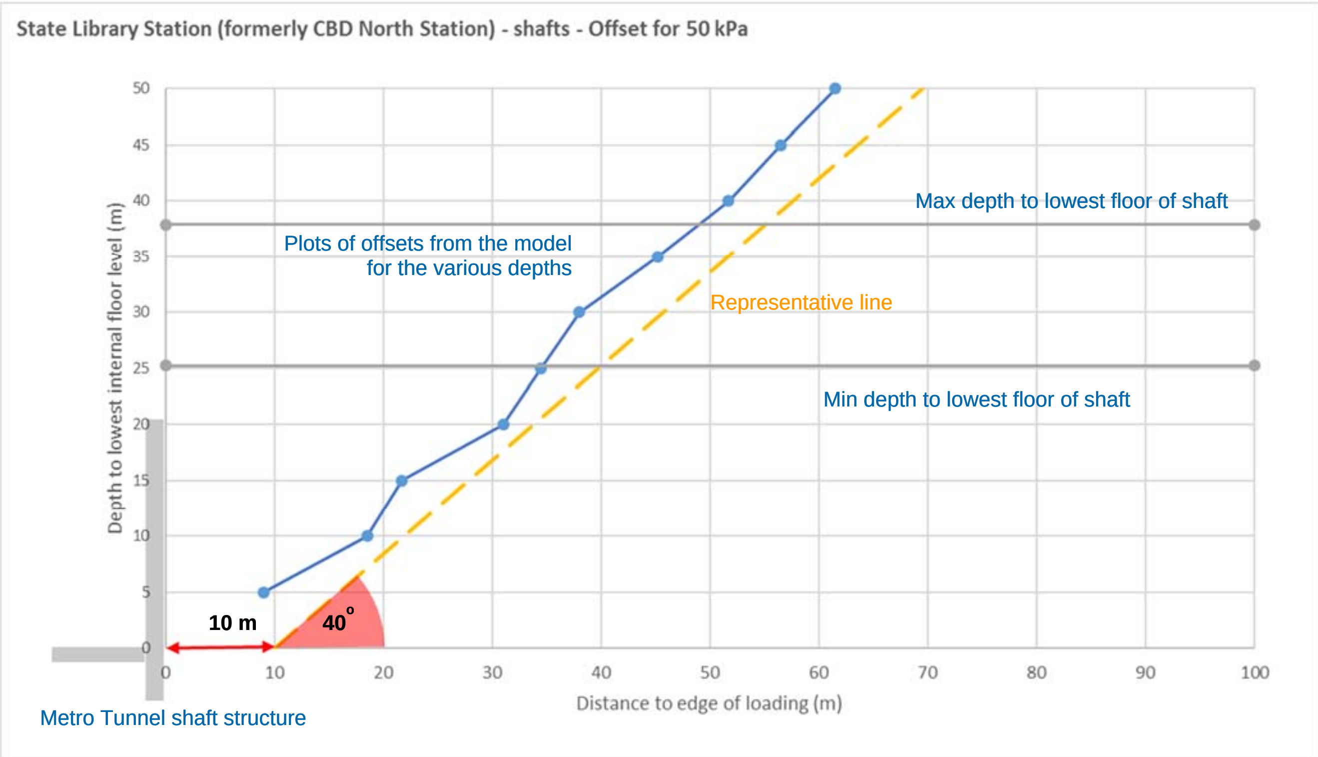


FIGURE 5-7 DISTRIBUTION OF DEPTH VERSUS OFFSET TO EDGE OF LOADING AT STATE LIBRARY STATION (FORMERLY CBD NORTH) SHAFTS TO LIMIT STRESS TO 50 kPa

TABLE 5-6 DIMENSIONS DEFINING THE REPRESENTATIVE LINE FOR STATE LIBRARY STATION (FORMERLY CBD NORTHSTATION) CAVERN

GEOGRAPHIC LOCATION	GEOLOGICAL SEGMENT	OFFSET FROM CENTRE OF TUNNEL TO START OF LINE	ANGLE OF LINE FROM THE HORIZONTAL FROM BASE TO SURFACE
Platform tunnels	12 (segment 11 model adopted)	10 m	45^{o}
Shafts	12 (segment 11 model adopted)	10 m	40^{o}

5.5.2 ANALYSES FOR PRECINCT 5 – TOWN HALL STATION (FORMERLY CBD SOUTH STATION)

Town Hall Station (formerly CBD South Station) will be shallower than the State Library Station (formerly CBD North Station) station, but would still be in reasonable quality Melbourne formation. The geological model used for this cavern is outlined in Table 5-7.

TABLE 5-7 GEOLOGICAL SEGMENT MODELLED FOR PRECINCT 6 – TOWN HALL STATION (FORMERLY CBD SOUTH STATION)

GEOGRAPHIC LOCATION	GEOLOGICAL SEGMENT	GEOLOGICAL UNIT AND THICKNESS	KEY ELEMENTS
Town Hall Station (formerly CBD South Station)	14 (segment 11 model adopted	Melbourne Formation (MF4) (2 m) Melbourne Formation (MF3) (14 m) Melbourne Formation (MF2) (14 m) Melbourne Formation (MF1) to model base	Underground cavern excavation in weathered to fresh siltstone and sandstone with deep access shafts. Deepening of existing City Square basement excavation. Gradually increasing stiffness in rock with depth.

Figure 5-8 shows the representative horizontal offset and inclined line from the rail alignment through the station that define the surface offset from the centre of the tracks within the platform tunnels. Figure 5-9 shows the representative horizontal offset and inclined line from the base slabs of shafts. The offset parameters for both the station and the shafts are summarised in Table 5-8.

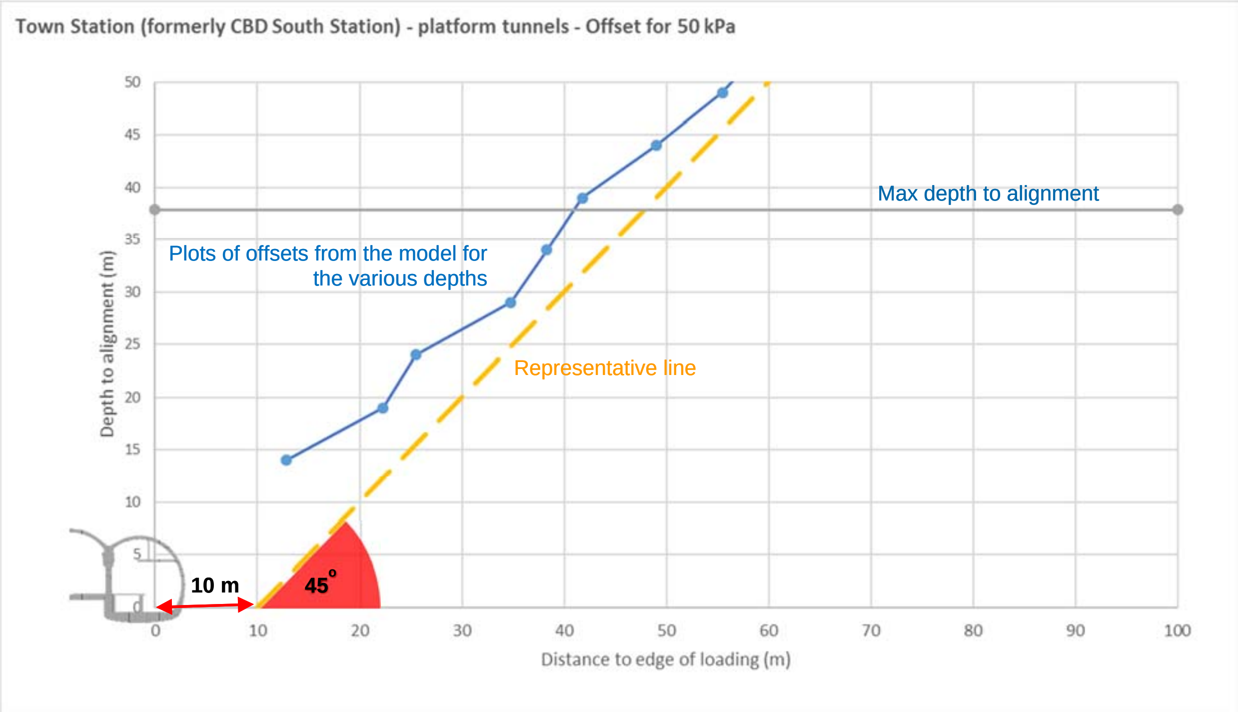


FIGURE 5-8 DISTRIBUTION OF DEPTH VERSUS OFFSET TO EDGE OF LOADING AT TOWN HALL STATION (FORMERLY CBD SOUTH) PLATFORM TUNNEL TO LIMIT STRESS TO 50 kPa

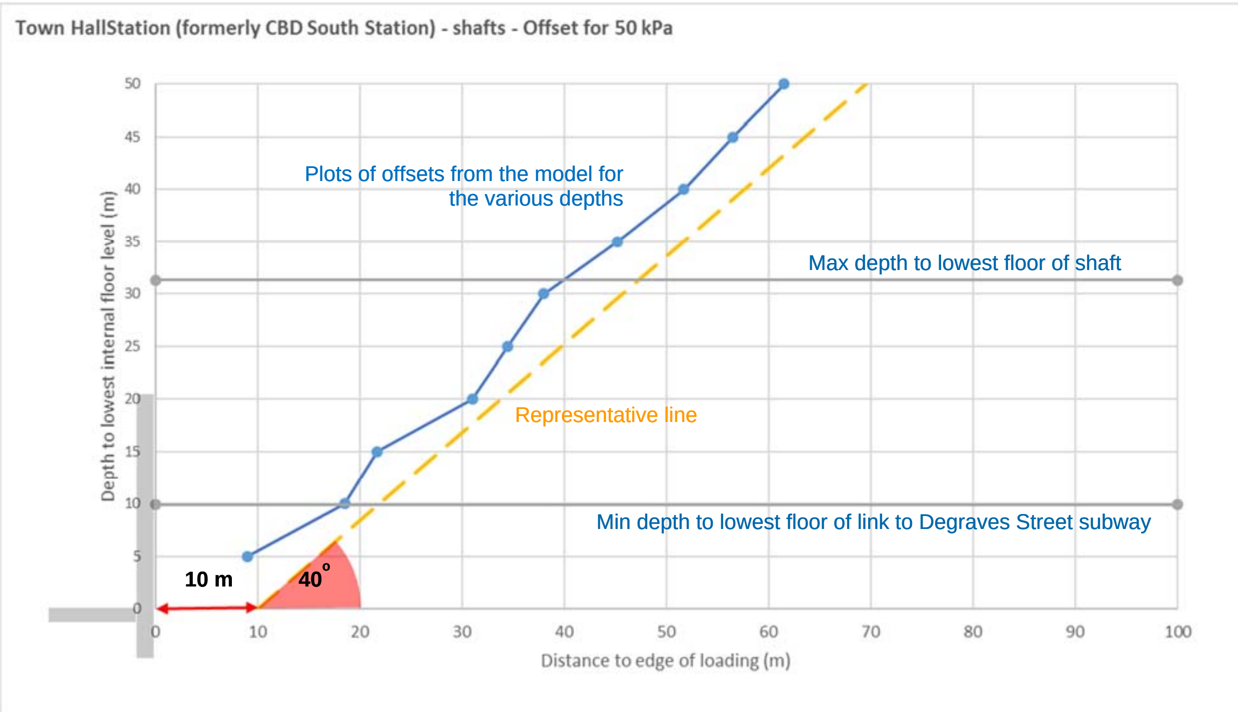


FIGURE 5-9 DISTRIBUTION OF DEPTH VERSUS OFFSET TO EDGE OF LOADING AT TOWN HALL STATION (FORMERLY CBD SOUTH) SHAFTS TO LIMIT STRESS TO 50 kPa

TABLE 5-8 DIMENSIONS DEFINING THE REPRESENTATIVE LINE FOR TOWN HALL STATION (FORMERLY CBD SOUTH STATION) CAVERN

GEOGRAPHIC LOCATION	GEOLOGICAL SEGMENT	OFFSET FROM CENTRE OF TUNNEL TO START OF LINE	ANGLE OF LINE FROM THE HORIZONTAL FROM BASE TO SURFACE
Platform tunnels	14 (segment 11 model adopted)	10 m	45^{o}
Shafts and links	14 (segment 11 model adopted)	10 m	40^{o}

5.6 Analyses for Cut and Cover structures

5.6.1 ANALYSES FOR PRECINCT 2 - WESTERN PORTAL CUT AND COVER TUNNEL

The geological model adopted for the western portal structures is outlined in Table 5-9, with the representative 30-degree line plotted against the stress change contours in Figure 5-10. The tunnels beneath Childers Street are the only cut and cover section that have been designed for an adjacent loading of 50 kPa from future development loading in the Concept Design.

TABLE 5-9 GEOLOGICAL SEGMENT MODELLED FOR PRECINCT 2 – WESTERN PORTAL CUT AND COVER TUNNEL

GEOGRAPHIC LOCATION	GEOLOGICAL SEGMENT	GEOLOGICAL UNIT AND THICKNESS		KEY ELEMENTS
Western Portal Cut and Cover Tunnel	2	Fill / Soil	(2 m)	Cut and cover excavation for TBM shaft and portal within weak rock. Gradually increasing stiffness in soil over rock.
		Coode Island Silt	(3 m)	
		Holocene Alluvium	(6 m)	
		Older Volcanics (OV4)	(7 m)	
		Werribee Formation	(8 m)	
		Melbourne Formation (MF3)	(3 m)	
		Melbourne Formation (MF2)	(15 m)	
		Melbourne Formation (MF1)	to model base	

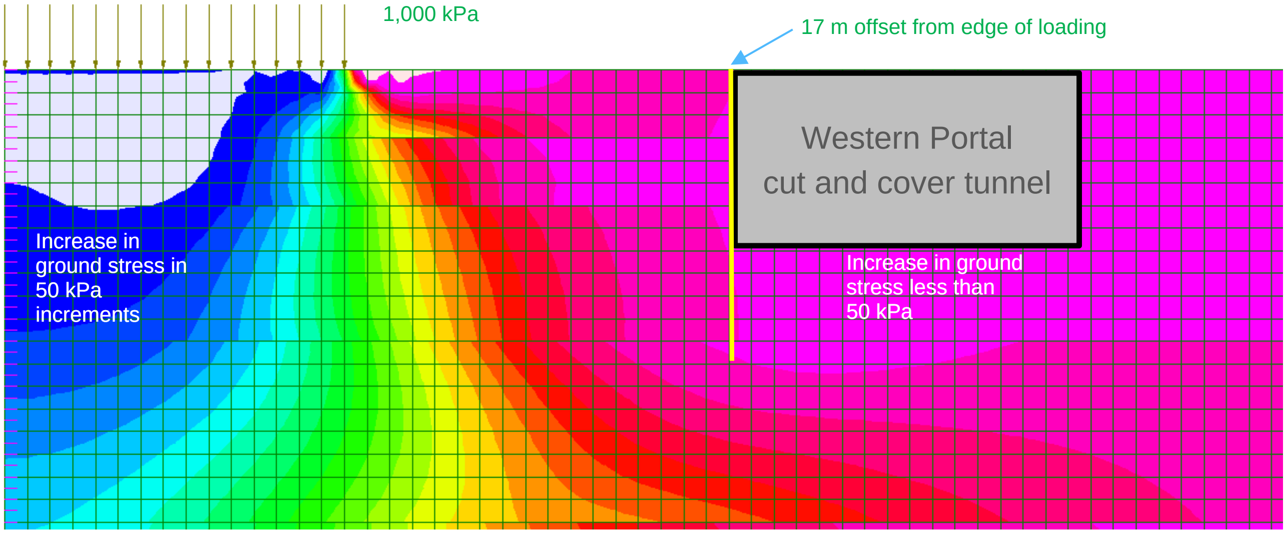


FIGURE 5-10 WESTERN PORTAL VERTICAL LINE

5.6.2 ANALYSES FOR PRECINCT 3 – NORTH MELBOURNE STATION (FORMERLY ARDEN STATION)

The geological model adopted for the North Melbourne Station (formerly Arden Station) structure is outlined in Table 4-6, with the representative 30 degree line plotted with the stress change contours in Figure 5-11.

TABLE 5-10 GEOLOGICAL SEGMENT MODELLED FOR PRECINCT 3 – NORTH MELBOURNE STATION (FORMERLY ARDEN STATION)

GEOGRAPHIC LOCATION	GEOLOGICAL SEGMENT	GEOLOGICAL UNIT AND THICKNESS		KEY ELEMENTS
Upfield Line to North Melbourne station	7 (segment 6b model adopted)	Fill / Soil Coode Island Silt (CIS) Pleistocene Alluvium Fishermens Bend Silt (FBS) Early Pleistocene Alluvium Melbourne Formation (MF3) Melbourne Formation (MF2) Melbourne Formation (MF1)	(3 m) (5 m) (6 m) (7 m) (3 m) (3 m) (3 m) to model base	Cut and cover station excavation through soft to stiff cohesive soils, some gravel and sand. Soft sediments over stiff rock.

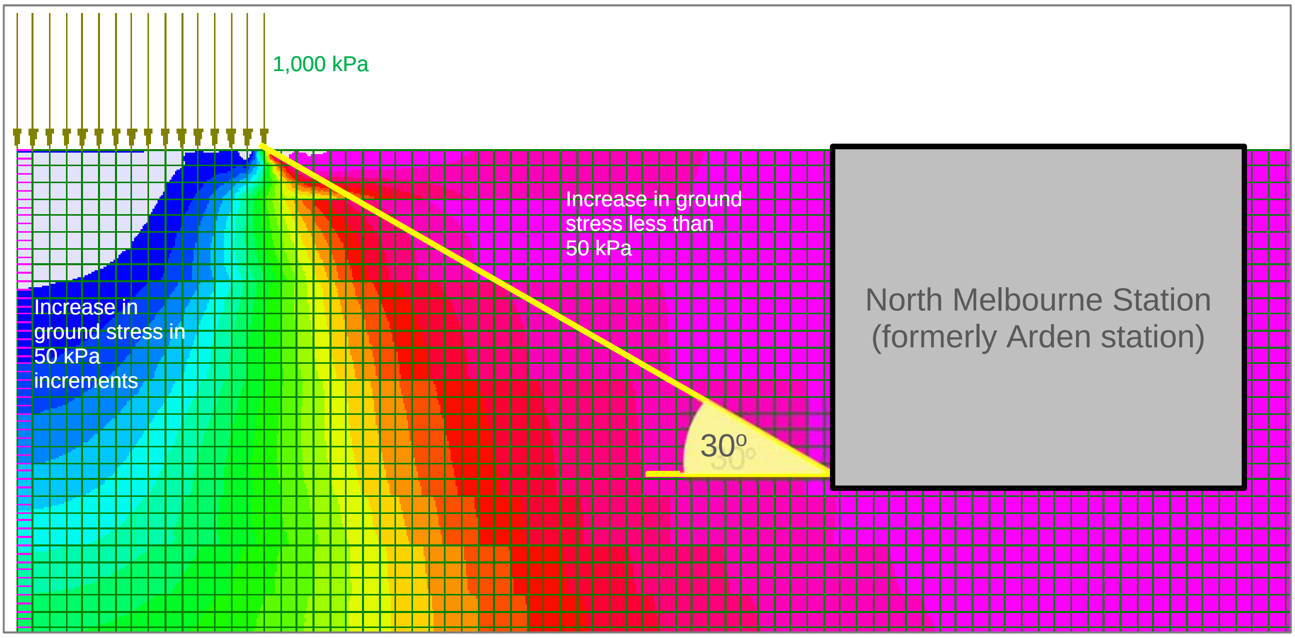


FIGURE 5-11 NORTH MELBOURNE STATION (FORMERLY ARDEN STATION) 30 DEGREE LINE

5.6.3 ANALYSES FOR PRECINCT 4 - PARKVILLE STATION

The geological model adopted for the Parkville station structure is outlined in Table 5-11, with the representative 30-degree line plotted with the stress change contours in Figure 5-12.

TABLE 5-11 GEOLOGICAL SEGMENT MODELLED FOR PRECINCT 4 – PARKVILLE STATION

GEOGRAPHIC LOCATION	GEOLOGICAL SEGMENT	GEOLOGICAL UNIT AND THICKNESS		KEY ELEMENTS
Parkville station	10 (segment 11 model adopted)	Melbourne Formation (MF4) Melbourne Formation (MF3) Melbourne Formation (MF2) Melbourne Formation (MF1)	(2 m) (14 m) (14 m) to model base	Cut and cover station excavation through weathered and jointed siltstone and sandstone. Soft sediments over stiff rock.

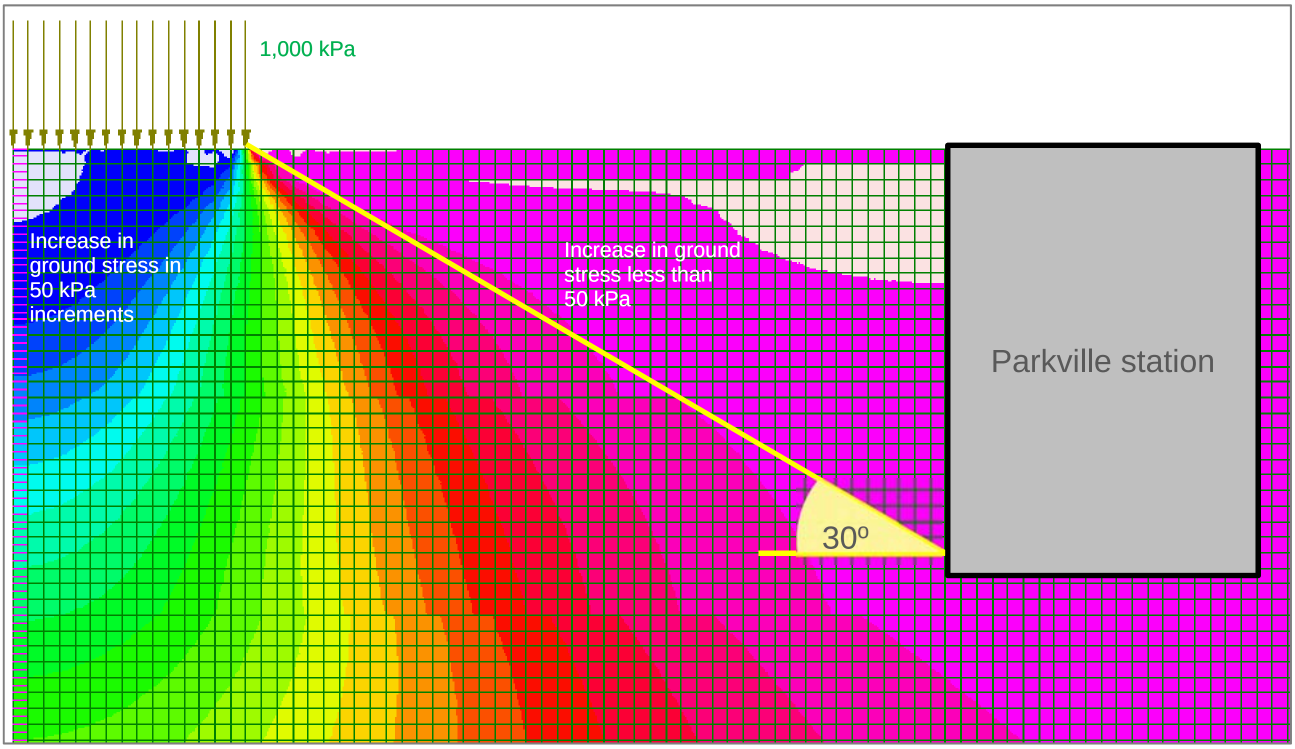


FIGURE 5-12 PARKVILLE STATION 30 DEGREE LINE

5.6.4 ANALYSES FOR PRECINCT 7 – ANZAC STATION (FORMERLY DOMAIN STATION)

The geological model adopted for the Anzac Station (formerly Domain station) structure is outlined in Table 5-12, with the representative 30 degree line plotted with the stress change contours in Figure 5-13.

TABLE 5-12 GEOLOGICAL SEGMENT MODELLED FOR PRECINCT 7 – ANZAC (FORMERLY DOMAIN) STATION

GEOGRAPHIC LOCATION	GEOLOGICAL SEGMENT	GEOLOGICAL UNIT AND THICKNESS	KEY ELEMENTS
Anzac station	20 (segment 22 model adopted)	Brighton Group (cohesive) (7 m) Brighton Group (granular) (7 m) Melbourne Formation (MF4) (3 m) Melbourne Formation (MF3) (12 m) Melbourne Formation (MF2) (12 m) Melbourne Formation (MF1) to model base	Cut and cover station excavation through weathered and jointed siltstone and sandstone, dense sand and hard clay. Gradually increasing stiffness in soil over rock.

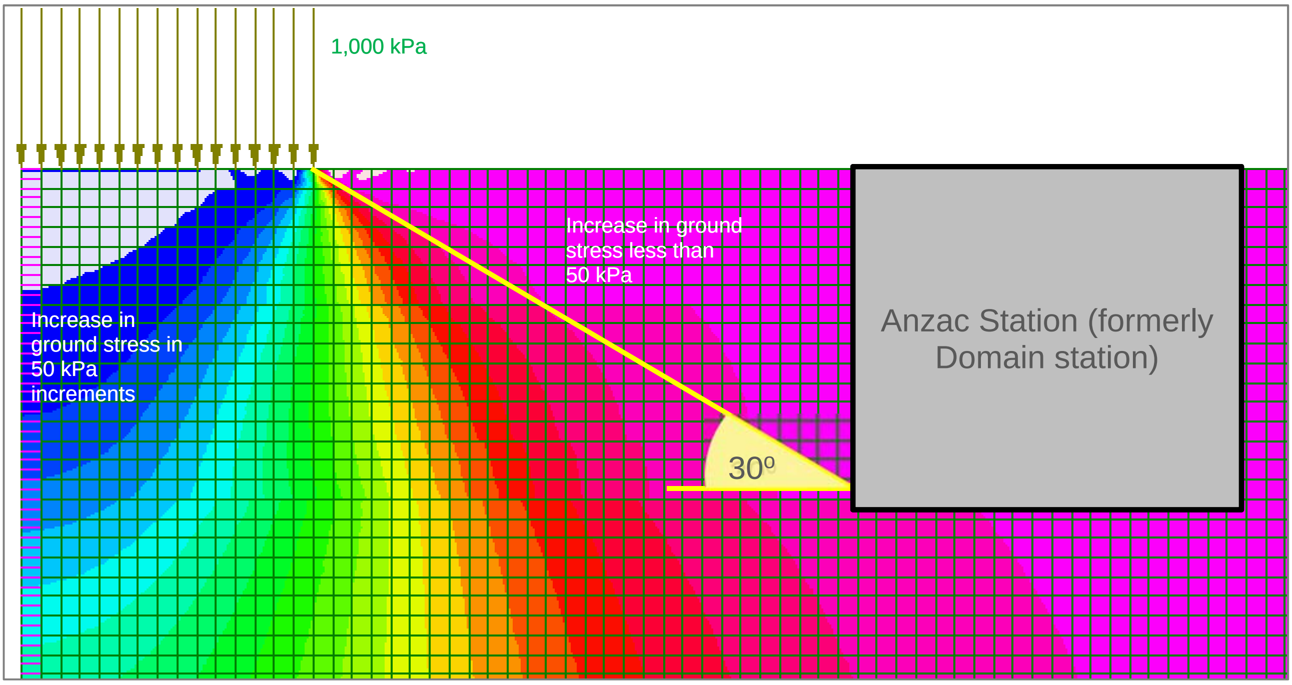


FIGURE 5-13 ANZAC STATION (FORMERLY DOMAIN STATION) 30 DEGREE LINE

5.6.5 ANALYSES FOR PRECINCT 8 - EASTERN PORTAL CUT AND COVER TUNNEL

The geological model adopted for the Eastern Portal structures is outlined in Table 5-13, with the representative 30 degree line plotted with the stress change contours in Figure 5-14.

TABLE 5-13 GEOLOGICAL SEGMENT MODELLED FOR PRECINCT 8 – EASTERN PORTAL CUT AND COVER TUNNEL

GEOGRAPHIC LOCATION	GEOLOGICAL SEGMENT	GEOLOGICAL UNIT AND THICKNESS	KEY ELEMENTS
Eastern Portal Cut and Cover Tunnel	23 (segment 22 model adopted	Brighton Group (cohesive) (7 m) Brighton Group (granular) (7 m) Melbourne Formation (MF4) (3 m) Melbourne Formation (MF3) (12 m) Melbourne Formation (MF2) (12 m) Melbourne Formation (MF1) to model base	Cut and cover shaft and decline structure in dense sand and hard clay. Widening of existing rail corridor excavations in dense sand and hard clay. Gradually increasing stiffness in soil over rock.

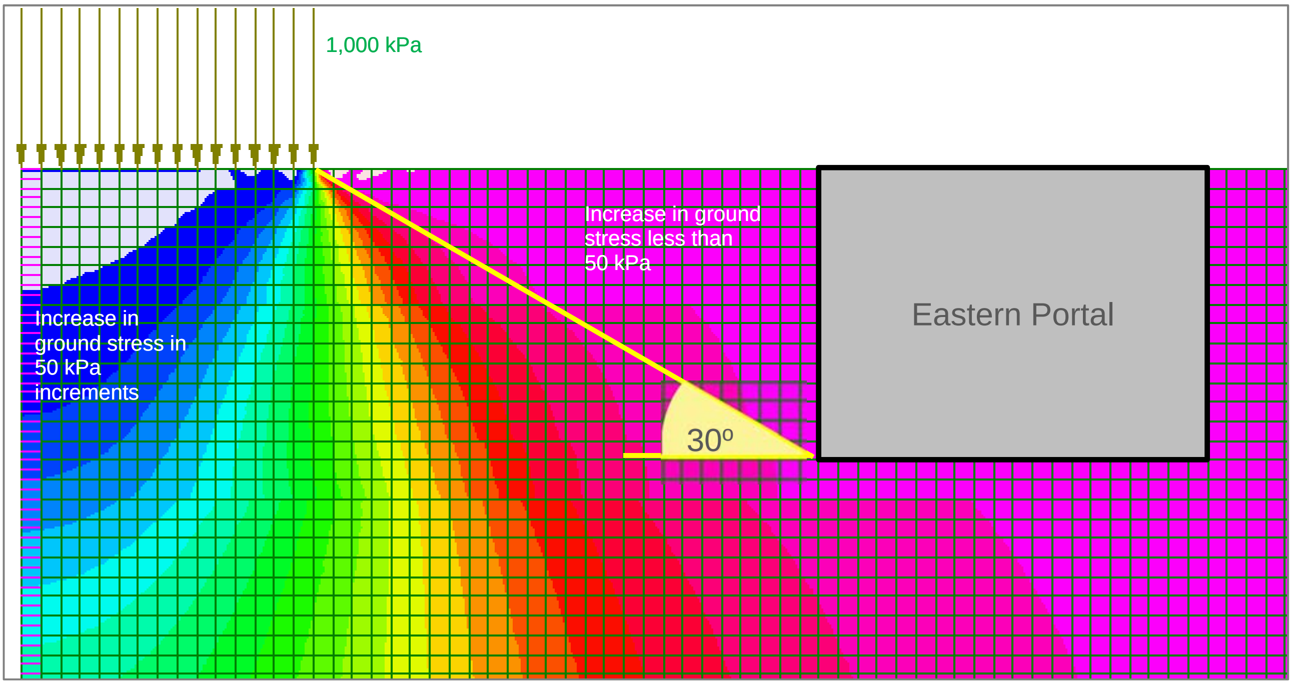


FIGURE 5-14 EASTERN PORTAL 30 DEGREE LINE

5.6.6 ADOPTED OFFSET FOR THE DESIGN AND DEVELOPMENT OVERLAY FOR THE CUT AND COVER STATIONS

In a similar manner as was done for the tunnels, the sets of lines at each cut and cover structure were used in 3D geometric modelling software to determine where they intersected the surface as shown in Figure 5-15, as the definition of the proposed boundary of the DDO.

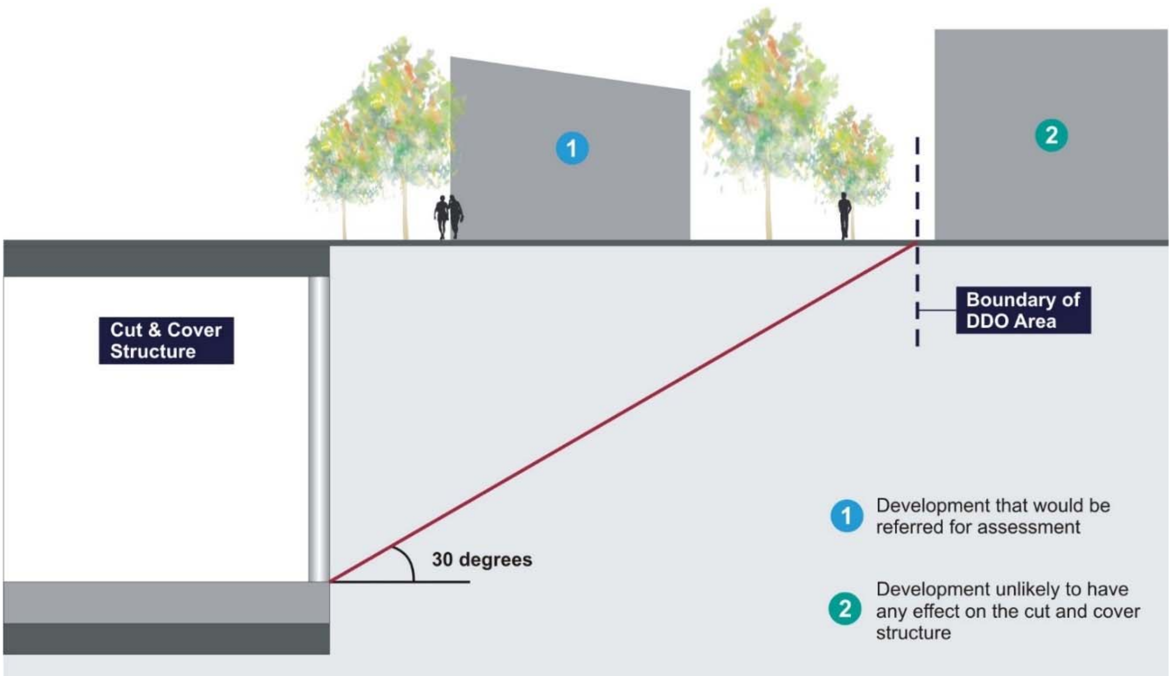


FIGURE 5-15 PROPOSED LINES FOR CUT AND COVER STATIONS

The derived offsets to the DDO boundaries for the cut and cover structures vary with the depth of the particular sections being considered, e.g., main station box or entrance, and the slope of the existing surface. The indicative range of offsets is provided in Table 5-15.

5.7 Extent of Design and Development Overlay

The objective of the assessments conducted was to select an area within which proposed future developments that could potentially affect Metro Tunnel Project assets to their detriment would be assessed by a referral authority before they are constructed. Theoretically, any change in near surface conditions, even at a considerable distance, has some effect upon an underground asset. However, such effects diminish with greater offset of the surface changes from the tunnels. The assessment provides a basis for identifying a distance from the tunnels beyond which a new development, built potentially considerably in the future, would have an acceptably low risk of having an adverse effect on Metro Tunnel Project assets.

The assessments have indicated that there are different offsets at which development loads of different magnitudes and loading areas would apply loads approaching the design allowances at Metro Tunnel Project's underground structures. These are managed by applying a DDO around the Metro Tunnel Project assets for referral, capturing all construction other than minor works defined in a list of exemptions.

The extents of the DDO have been identified on the basis of a conservative view of the maximum loading in the surface area influencing the tunnels and other underground structures, and matching this to the design allowances at the tunnels and other structures.

The recommended extents of the areas at the existing surface have been calculated by modelling the offsets and sloping planes from Metro Tunnel Project structures and determining where such planes intersect with the surface. The offsets and slopes have been derived from the assessments of the distributions of surface loads through the ground. A terrain model using the Metro Tunnel Project alignment and current surface profile was used to calculate the offsets to the DDO boundary.

The resulting offsets of the proposed DDO boundaries become a function of the depth of Metro Tunnel Project tunnels or other Metro Tunnel Project structures below the surface. Some statistics of the calculated offsets from the tunnel centres are shown in Table 5-14 and Table 5-15.

TABLE 5-14 SUMMARY OF DESIGN AND DEVELOPMENT OVERLAY EXTENT (EXCLUDING STATIONS)

VALUE	DESIGN AND DEVELOPMENT OVERLAY BOUNDARY – OFFSET FROM CENTRE LINE OF TUNNEL
Approximate average value	45 m
Approximate maximum value	60 m

TABLE 5-15 OFFSETS TO THE DESIGN AND DEVELOPMENT OVERLAY BOUNDARIES AT CUT AND COVER STRUCTURES AND MAIN SHAFTS

CUT AND COVER STRUCTURES	INDICATIVE LARGETS OFFSET FROM METRO TUNNEL PROJECT STRUCTURE TO DDO BOUNDARY
North Melbourne station	29 m (Main station structure)
Parkville station	51 m (Main station structure)
State Library station	61 m (A'Beckett Street shaft)
Town Hall station	48 m (City Square shaft)
Anzac station	29 m (Main station structure)

For comparison, while the existing Melbourne Underground Rail Loop (City Loop) does not have formal widths defined for initiating its review process, informally, VicTrack has used widths of approximately 40 m from the centre of tunnels and 80 m from the stations as indicative offsets of proposed developments that require review. Internationally, Singapore’s Railway Protection Zone extends to 40 m outside the structure of the tunnel (as opposed to the centre). The associated Railway Safety Zone extends to 60 m outside the structure of the tunnel. The Land Transport Authority, the referral authority in Singapore for rail, retains the right to impose some restrictions on activities in this latter zone, but the submission of development details is less onerous.

6 Conclusion

The underground structures of Metro Tunnel Project are being designed for the known surrounding conditions during the detailed design phase.

Potential future developments could be of many forms and, given the planned long life of the Metro Tunnel Project, would be probably beyond the foreseeable future. Therefore, the design of the Metro Tunnel Project structures includes an allowance for future developments, but the design does not accommodate all possible future changes.

The assessment of proposed developments in the vicinity of Metro Tunnel Project assets needs to be instigated by a formal process that creates certainty in capturing potential works and clarity on what needs to be considered. The DDO together with the Infrastructure Protection Areas Incorporated Document was introduced in 2017 and provides an important and appropriate mechanism to review and assess future development and impose appropriate conditions.

The area affected by the DDO was determined using the Concept Design for the Metro Tunnel Project assessed in the EES. As foreshadowed in the EES, now that the detailed design of the Metro Tunnel has been progressed, it has been important to update the assessment of the DDO area to reflect the design. However, the associated controls in the existing Overlay are not proposed to change.

In order to ensure that developments that are a potential risk to Metro Tunnel Project structures are referred without adding an unnecessary burden of referral and review, specified minor works will remain exempt.

The design of future developments would be influenced by the presence of Metro Tunnel Project assets. Assessment of each proposed future development will need to take into account the cumulative effects of other nearby development, and this is likely to become more relevant for development further into the future. The records kept by the referral authority, and consultation with the referral authority, will be important in ensuring that developers have access to relevant information.

In most cases, it is considered very unlikely that the existing Metro Tunnel Project would completely preclude an adjacent development, but there are likely to be circumstances where additional engineering solutions would be needed to protect Metro Tunnel Project assets.

It would need to be confirmed that the proposed works are not creating an unacceptable risk, and this might be the case for a development as initially proposed. In such circumstances, the development would need to include mitigation measures, such as changing the levels of its foundations, adopting stiffer supports for excavation works, changing the sequence of excavation and buildings, and including additional structural systems to limit the changes in the ground conditions around assets. In some cases, the presence of Metro Tunnel Project assets would require the development to span over specified areas and to limit the extent of excavations over or adjacent to Metro Tunnel Project assets.

Through the referral process outlined in the DDO, development that could potentially affect the Metro Tunnel Project infrastructure would be subject to a formal assessment process by experienced technical personnel, so that future development is designed and constructed to not adversely impact the Metro Tunnel Project infrastructure.

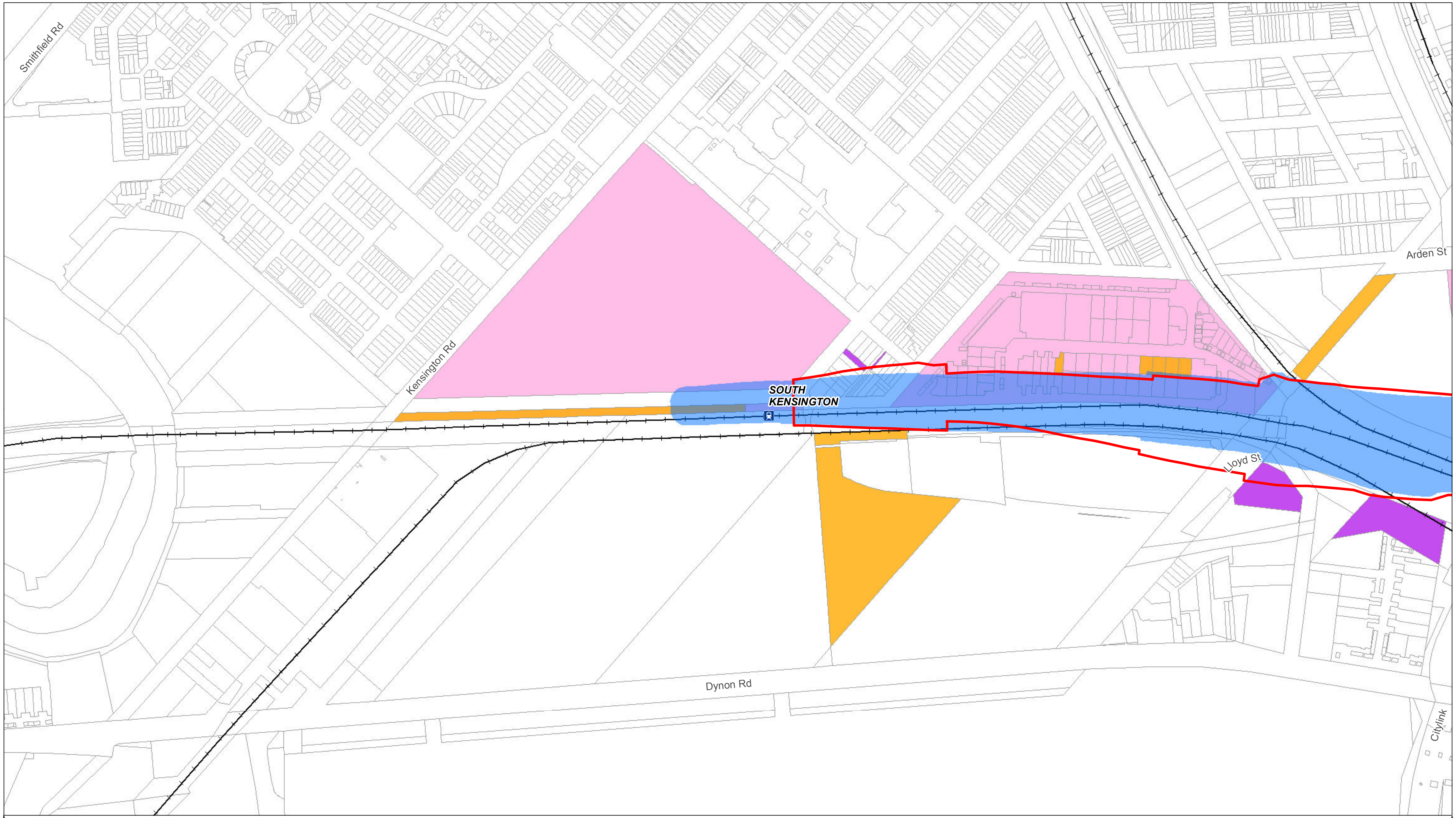
Appendix A

DDO Proposed Boundary Drawings

Appendix A

Maps:

Existing and Proposed DDO Comparison, Drawing Number: MMR-AJM-PWAA-MP-CC-500848, Map 1 of 7 to Map 7 of 7

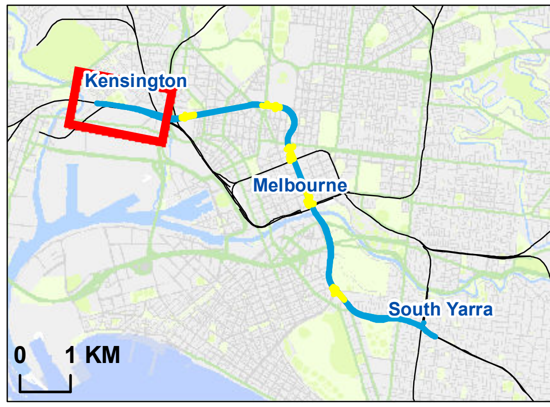


Legend

- Rail Station
- Existing Railway
- Existing MMRP DDO
- Proposed amended DDO - 7/02/2018
- Newly Affected Parcels
- Parcels No Longer Affected
- Parcels with Increased DDO Coverage
- Cadastre

Data Sources:
Proposed Infrastructure: AJM 2018
Contains Vicmap Information

Map 1 of 7



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Title:

Existing and Proposed DDO Comparison

Drawing Number:			Revision:
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Drawn By: BB	Approved By: MT	Date: 14/03/2018	Map Size: A3

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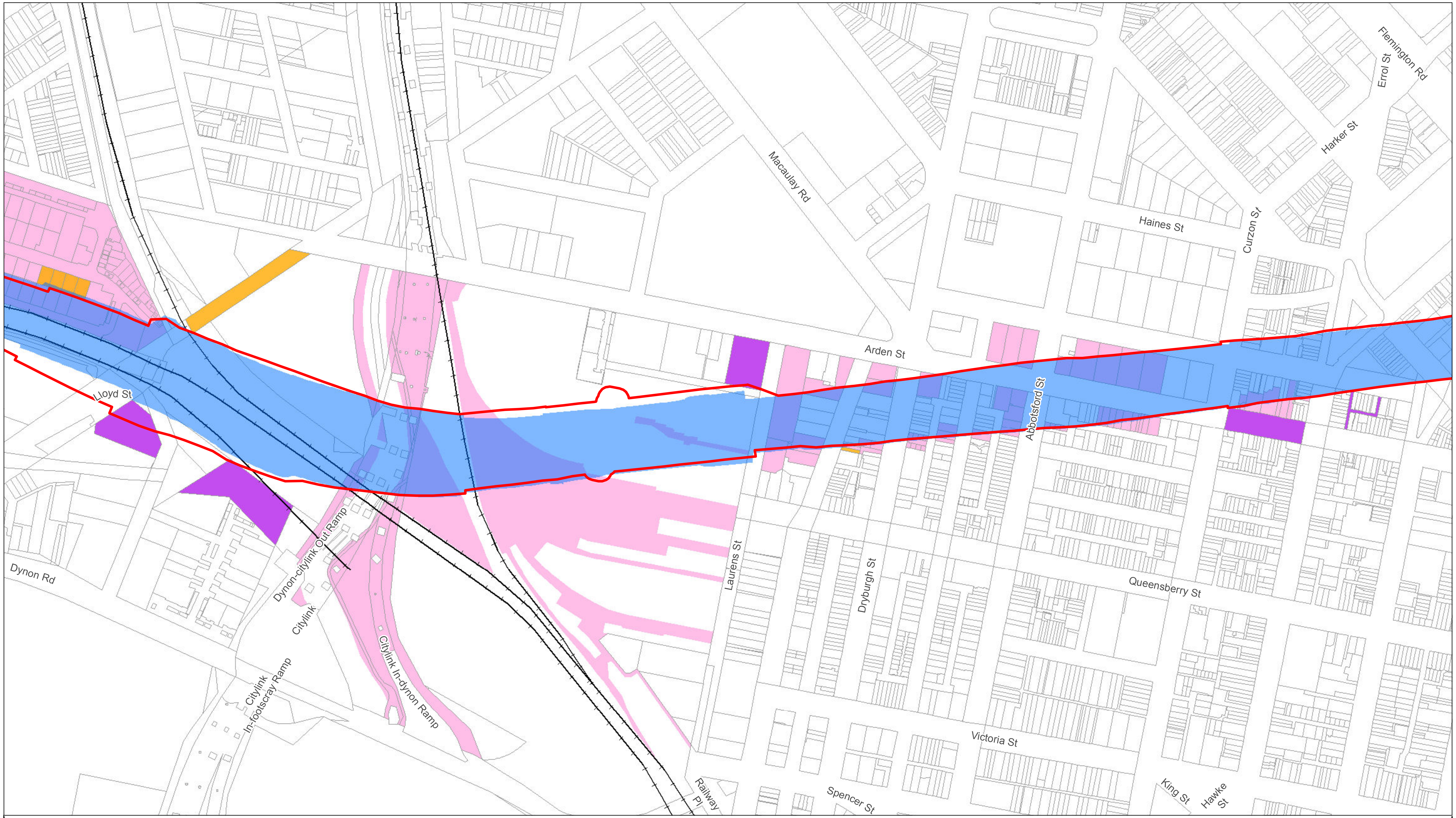

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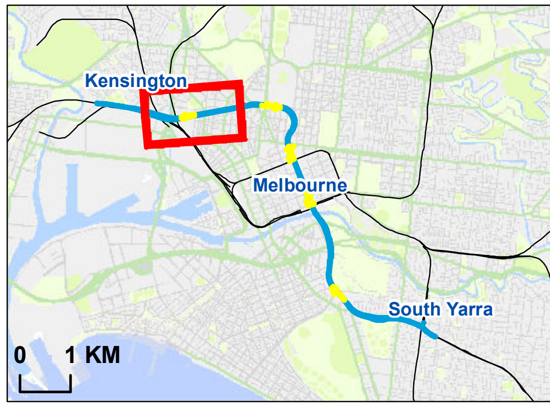

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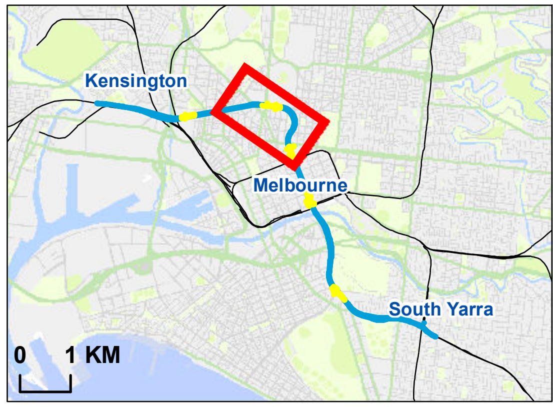
Map 3 of 7



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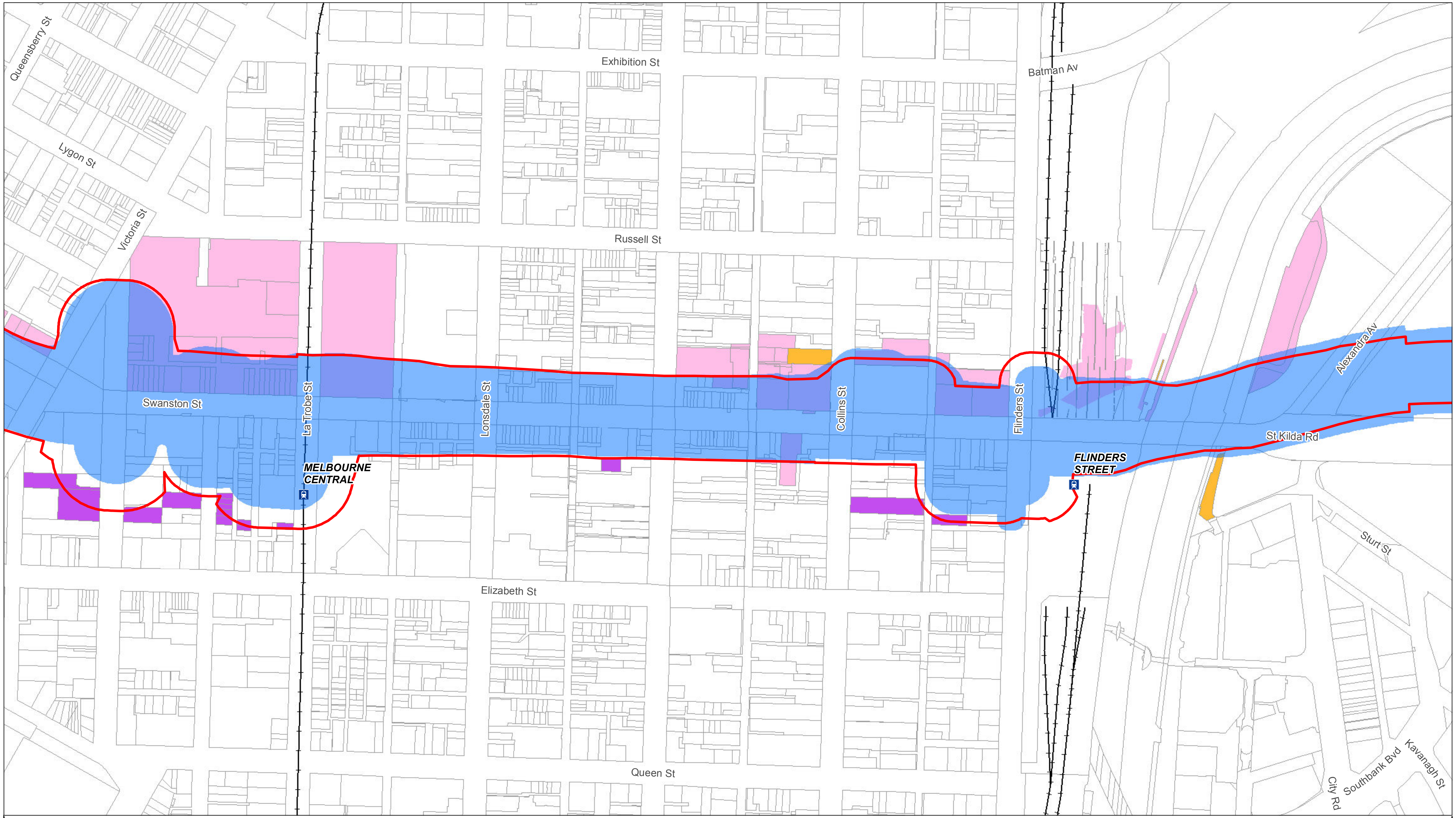

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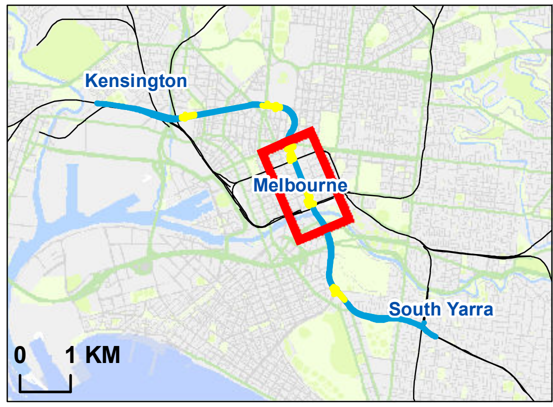
Map 4 of 7



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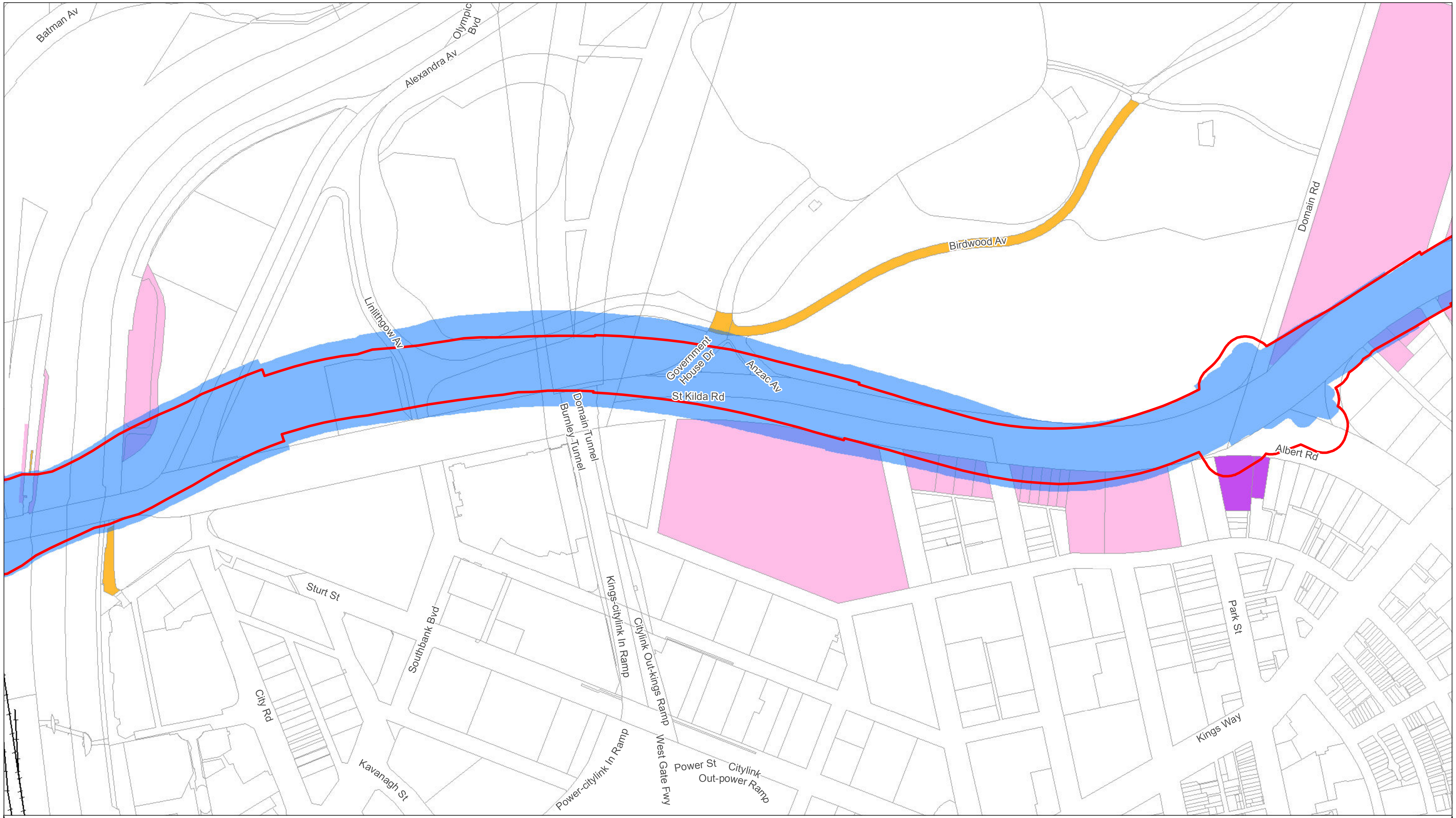

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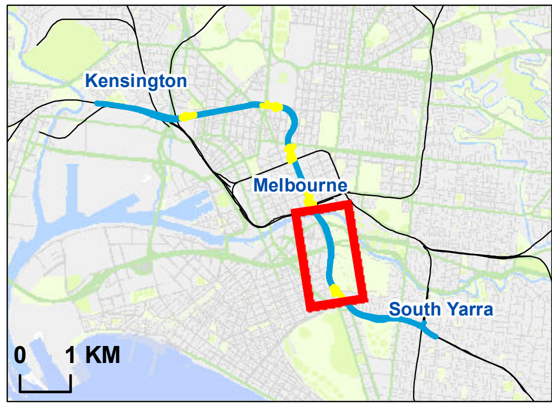

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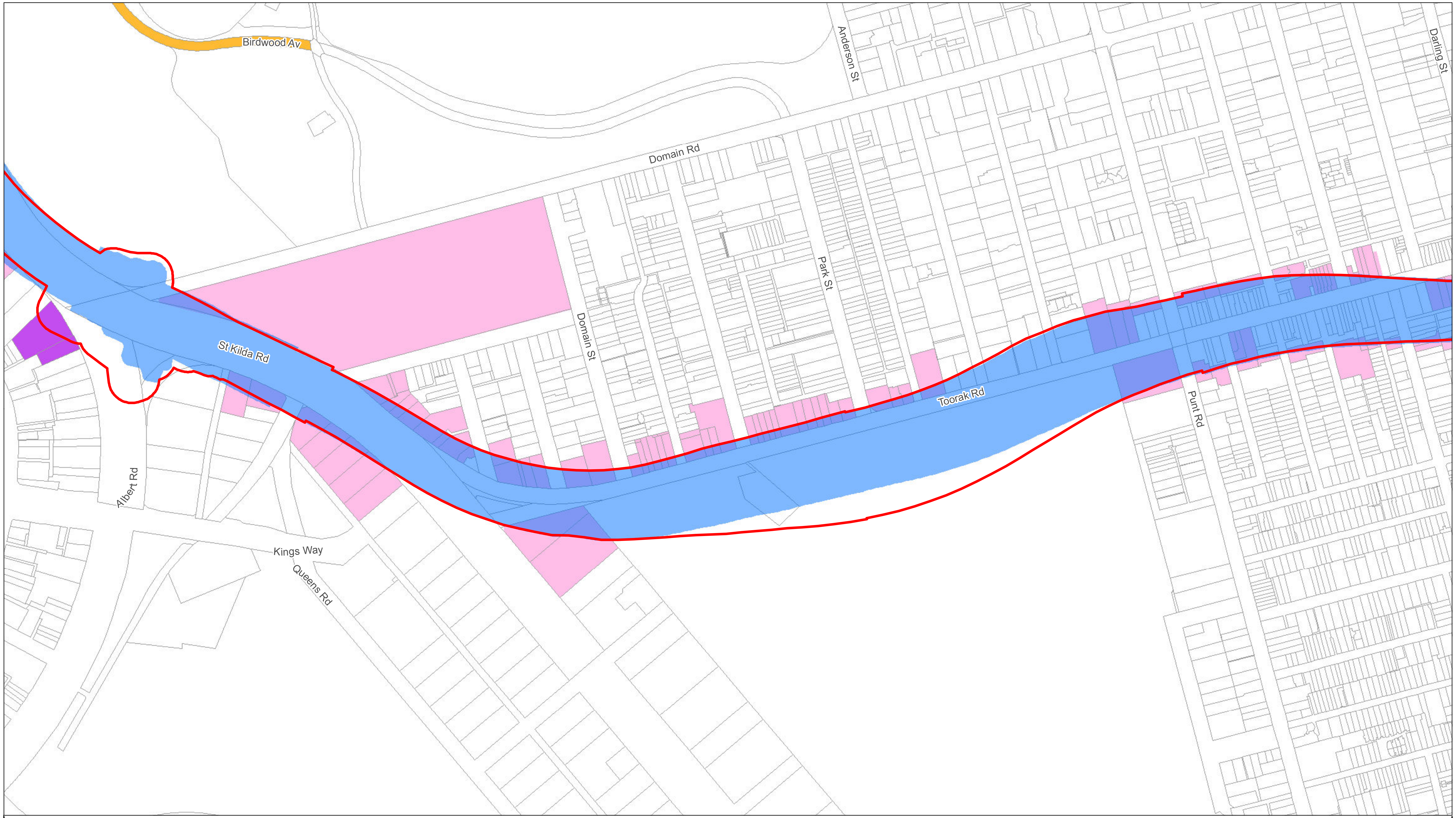

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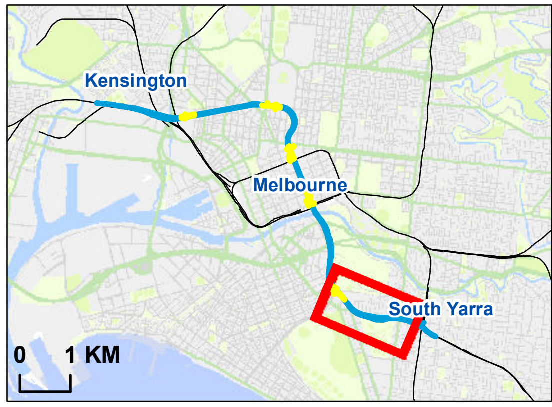
Map 6 of 7



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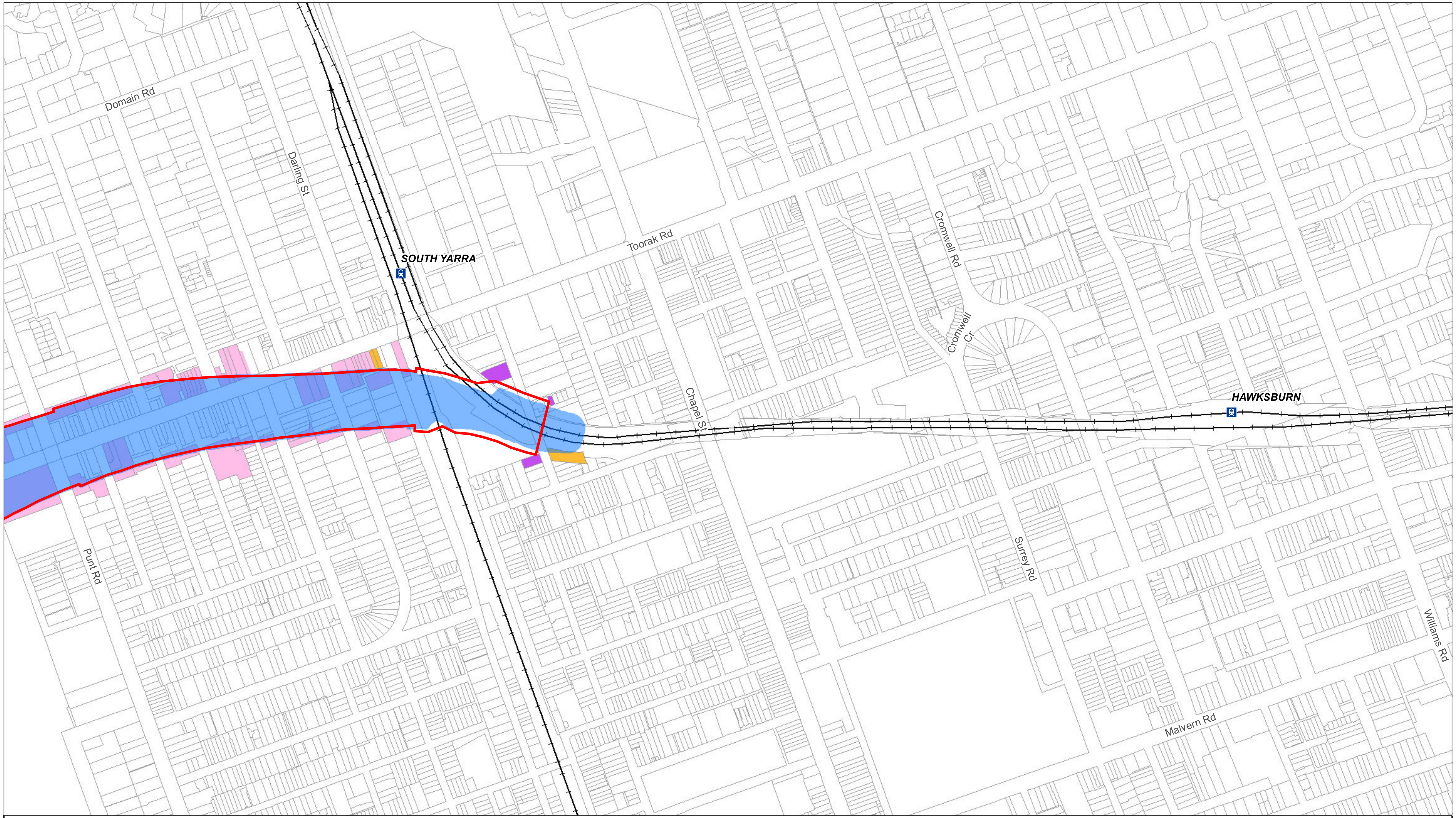

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Map 7 of 7

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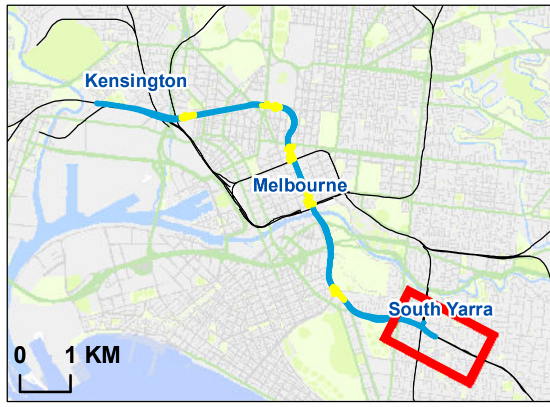

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