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Job number 248446

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<tr>
<td>Michael Burgess</td>
<td>Ivan Varga Sampedro</td>
<td>Mathew Carter</td>
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Appendix A
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Executive Summary

Roads and Maritime Services (Roads and Maritime) propose to upgrade four intersections and introduce clearways between the Euston Road/Maddox Street intersection in Alexandria and the Anzac Parade intersection at Moore Park (the proposal). The proposal is located about three kilometres south of the central business district (CBD) in the suburbs of Alexandria, Waterloo, Moore Park within the City of Sydney local government area (LGA).

A flood impact assessment has been undertaken for the Alexandria to Moore Park Stage 1 Project (A2MP Stage 1) design. The assessment has involved reviewing and updating available TUFLOW flood models that cover the Alexandra Canal catchment, in which all physical road works within the proposal are located. Note that a flood assessment has not been undertaken for the small portion of the proposal located within the Botany Wetlands catchment (east of the crest at Dacey Avenue), as no physical works are proposed as part of the A2MP Stage 1 project.

The model updates included incorporating ground survey along the proposal route, incorporating finer surface features such as medians and gutters, along with other minor amendments. Baseline flooding conditions have been defined with the updated models. Flood events assessed include the 0.2 Exceedances per Year (EY) and 5 %, 2 % and 1 % Annual Exceedance Probability (AEP) events.

Flooding impacts, in terms of changes to flood levels and flood hazard, have been estimated for the design. Flood level increases of up to 0.25 m are predicted at McEvoy Street near the Fountain Street intersection, and up to 0.07 m near the Bowden Street intersection in the 1% AEP event. These impacts potentially affect existing buildings and properties along the project corridor and will be managed through design mitigation measures during the next stage of design. Flood impacts to properties outside of the proposal area are also predicted in Bowden Street of up to 0.02 m and in Wyndham Street of up to 0.06 m in the 1% AEP event.

Increases in the high flood hazard areas resulting from the proposal are predicted to be negligible. These increases are generally characterised as small fringe extensions of existing high flood hazard areas and in most cases any increases in high flood hazard area are offset by small reductions in other areas along the corridor. There is not expected to be a material increase in the flood risk to people and property resulting from the proposal.

The identified flood impacts are attributed to the proposed road design changing the road surface levels and geometry, including regrading and reconfiguration of the road and intersections and inclusion of new median kerbs and traffic islands. This results in redistribution of flows passing through the proposal site, such that some downstream areas experience increased flows and hence increased flood levels and depths, while other areas experience reduced flows, flood levels and depths.

Strategic consideration and refinement of aspects of the proposed design is recommended to mitigate these flood impacts where possible. This may include modifying road geometry, inclusion or omission of kerbs/traffic islands and
rationalising proposed drainage, with the overall objective of maintaining existing flow distributions as closely as possible. These modifications may occur during future design stages.

The impacts of construction phase works have been qualitatively assessed, and these may result in impacts to flooding mainly due to temporary stockpiles, safety barriers (e.g. concrete F-type barriers) and other elements being located within flood flow paths and obstructing flows during a flood event. Impacts could also potentially occur if drainage systems are temporarily decommissioned for any reason.

Temporary construction facilities, including site compounds and stockpile sites were identified at the following locations:

- The Roads and Maritime car park on the south-west corner of the McEvoy Street/Stokes Avenue intersection, Alexandria (Site 1)
- Road reserve at the southern end of Cope Street, Alexandria (Site 2)
- Road reserve at the southern end of George Street, Alexandria (Site 3)
- The vacant land (Lot 2 DP800705) at the corner of intersection of McEvoy Street and Bourke Street, Waterloo (Site 4)
- Lot 1, 2 and 3 DP 76985, Lot 4 DP 86722 and Lot 14 DP80926 on the west corner of the Lachlan Street/Amelia Street intersection, Waterloo (Site 5).

Site 1, Site 2 and Site 4 are generally outside of major overland flow paths, although portions of these sites may be impacted by shallow overland flows during flood events. It is considered that any stockpiles or other obstructions placed on these sites are not expected to result in significant flood impacts due to the shallow flow depths predicted (< 0.10m), however further flood modelling will be required to confirm if any flood impacts are likely during the construction phase.

Site 3 is located within a natural sag point near the intersection of George and McEvoy Street, and is likely to be affected by flooding. Further flood modelling will be required to confirm whether any stockpiles or other obstructions will create impacts on the surrounding properties and road users during the construction phase, due to the flood depths predicted at the locations of this site (> 0.5m).

Site 5 is not-flood-affected.

Recommendations for future flooding assessment include:

- Flooding impacts should be reassessed at future design stages to assess the impacts for both operational and construction stages of the proposal, as refinements to the road and drainage designs are expected to change the predicted flooding impacts. Flood risk to vehicles should also be reassessed and the design adjusted to provide safe flow conditions for vehicles if possible.
- Stormwater survey received from ongoing site investigations should be reviewed against the stormwater data incorporated in the baseline TUFLOW
model, and any necessary updates made to the TUFLOW model for both the baseline and design case scenarios.

- The identified mitigation measures should be reviewed and assessed to see if any adverse flood impacts noted in this report may be mitigated or removed.

- Flood impacts of the proposal on the probable maximum flood should be undertaken to assess any adverse flood impacts due to the proposal.

- Any residual flood impacts to properties after implementing feasible mitigation works should be quantified at future stages. Floor level survey data may be collected to quantify impacts to above-floor flooding of adjacent properties.

- Construction management plans should consider the potential impacts of temporary construction works including trenching, solid traffic barriers and stockpiles on overland flows and incorporate appropriate management measures to address these issues. Flood modelling of temporary construction scenarios be undertaken where it is considered that the construction phase works may materially impact flood behaviour.
## Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tr>
<td>Annual Exceedance Probability (AEP)</td>
<td>The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. In this study AEP has been used consistently to define the probability of occurrence of flooding. It is to be noted that design rainfalls used in the estimation of design floods up to and including 100 year ARI (i.e. 1% AEP) events was derived from 1987 Australian Rainfall and Runoff. The following relationships between EY, AEP and ARI apply to this study (AR&amp;R, 2016).</td>
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<table>
<thead>
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<th>Frequency Descriptor</th>
<th>EY</th>
<th>AEP (%)</th>
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<td>0.0002</td>
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<td>Extremely Rare</td>
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<tr>
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Australian Height Datum (AHD) A common national surface level datum approximately corresponding to mean sea level.
<table>
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<td>Average Recurrence Interval (ARI)</td>
<td>The long-term average number of years between the occurrences of a flood as big as or larger than the selected event. For example, floods with a discharge as great as or greater than the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event. The Annual Exceedance Probability (AEP) is the preferred notation for the frequency or magnitude of flood events. Refer to the definition for AEP in this glossary.</td>
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<tr>
<td>Catchment</td>
<td>The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.</td>
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<td>Development</td>
<td>Is defined in Part 4 of the Environment Protection and Assessment Act 1979 (EP&amp;A Act) In fill development: refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. New development: refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of exiting urban services, such as roads, water supply, sewerage and electric power. Redevelopment: refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.</td>
</tr>
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<td>DRAINS</td>
<td>DRAINS is a computer program which is used to simulate local catchment rainfall-runoff and stormwater system hydraulics and is widely used across Australia.</td>
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<td>Effective Warning Time</td>
<td>The time available after receiving advise of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.</td>
</tr>
<tr>
<td>Exceedances per Year (EY)</td>
<td>The number of times an event is likely to occur or be exceeded within any given year.</td>
</tr>
<tr>
<td>Flood</td>
<td>Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.</td>
</tr>
<tr>
<td>Flood fringe areas</td>
<td>The remaining area of flood prone land after floodway and flood storage areas have been defined.</td>
</tr>
<tr>
<td>Flood liable land</td>
<td>Is synonymous with flood prone land (i.e.) land susceptibility to flooding by the PMF event. Note that the term flooding liable land covers the whole floodplain, not just that part below the FPL (refer to flood planning area)</td>
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<tr>
<td>Term</td>
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<tr>
<td>Floodplain</td>
<td>Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is flood prone land.</td>
</tr>
<tr>
<td>Floodplain risk management options</td>
<td>The measures that might be feasible for the management of particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.</td>
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<tr>
<td>Floodplain risk management plan</td>
<td>A management plan developed in accordance with the principles and guidelines in this manual. Usually include both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defines objectives.</td>
</tr>
<tr>
<td>Flood plan (local)</td>
<td>A sub-plan of a disaster plan that deals specifically with flooding. They can exist at state, division and local levels. Local flood plans are prepared under the leadership of the SES.</td>
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<tr>
<td>Flood planning levels (FPLs)</td>
<td>Are the combination of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the “designated flood” or the “flood standard” used in earlier studies.</td>
</tr>
<tr>
<td>Flood proofing</td>
<td>A combination of measures incorporated in the design, construction and alteration of individual buildings and structures subject to flooding, to reduce or eliminate flood damages.</td>
</tr>
<tr>
<td>Flood readiness</td>
<td>Readiness is an ability to react within the effective warning time.</td>
</tr>
<tr>
<td>Flood risk</td>
<td>Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. Existing flood risk: the risk a community is exposed to as a result of its location on the floodplain. Future flood risk: the risk a community may be exposed to as a result of new development on the floodplain. Continuing flood risk: the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.</td>
</tr>
<tr>
<td>Flood storage areas</td>
<td>Those parts of the floodplain that are important for the temporary storage of floodwaters during passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas</td>
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<td>Term</td>
<td>Definition</td>
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<tr>
<td>Floodway areas</td>
<td>Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.</td>
</tr>
<tr>
<td>Freeboard</td>
<td>Provides reasonable certainty that the risk exposure selected in deciding on a particular design flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.</td>
</tr>
<tr>
<td>Hazard</td>
<td>A source of potential harm or situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community.</td>
</tr>
<tr>
<td>Local overland flooding</td>
<td>Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.</td>
</tr>
<tr>
<td>m AHD</td>
<td>Metres Australian Height Datum (AHD)</td>
</tr>
<tr>
<td>m/s</td>
<td>Metres per second. Unit used to describe the velocity of floodwaters.</td>
</tr>
<tr>
<td>m3/s</td>
<td>Cubic metres per second or “cumecs”. A unit of measurement of creek or river flows or discharges. It is the rate of flow of water measured in terms of volume per unit time.</td>
</tr>
<tr>
<td>Mainstream flooding</td>
<td>Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.</td>
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<tr>
<td>Overland flow path</td>
<td>The path that floodwaters can follow as they are conveyed towards the main flow channel or if they leave the confines of the main flow channel. Overland flow paths can occur through private property or along roads.</td>
</tr>
<tr>
<td>Probable Maximum Flood (PMF)</td>
<td>The largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation couplet with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain.</td>
</tr>
<tr>
<td>Probable Maximum Precipitation (PMP)</td>
<td>The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.</td>
</tr>
<tr>
<td>Risk</td>
<td>Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.</td>
</tr>
<tr>
<td>Runoff</td>
<td>The amount of rainfall which actually ends up as a streamflow, also known as rainfall excess.</td>
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<td>Term</td>
<td>Definition</td>
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</tr>
<tr>
<td>SOBEK</td>
<td>SOBEK is a computer program that simulates inundation for rivers, flood plains and urban drainage systems.</td>
</tr>
<tr>
<td>Stage</td>
<td>Equivalent to water level (both measured with reference to a specified datum)</td>
</tr>
<tr>
<td>TUFLOW</td>
<td>TUFLOW is a computer program which is used to simulate free-surface flow for flood and tidal wave propagation. It provides coupled 1D and 2D hydraulic solutions using a powerful and robust computation. The engine has seamless interfacing with GIS and is widely used across Australia.</td>
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### Acronyms

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<th>Acronym</th>
<th>Definition</th>
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<tr>
<td>A2MP</td>
<td>Alexandria to Moore Park</td>
</tr>
<tr>
<td>AEP</td>
<td>Annual Exceedance Probability</td>
</tr>
<tr>
<td>ARI</td>
<td>Average Recurrence Interval</td>
</tr>
<tr>
<td>ARR</td>
<td>Australian Rainfall and Runoff</td>
</tr>
<tr>
<td>CBD</td>
<td>Central Business District</td>
</tr>
<tr>
<td>CoS</td>
<td>City of Sydney</td>
</tr>
<tr>
<td>CSELR</td>
<td>City and South East Light Rail</td>
</tr>
<tr>
<td>EY</td>
<td>Exceedances per Year</td>
</tr>
<tr>
<td>LGA</td>
<td>Local Government Area</td>
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<tr>
<td>RCC</td>
<td>Randwick City Council</td>
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<tr>
<td>SLR DJV</td>
<td>Sydney Light Rail Design Joint Venture</td>
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1 Introduction

1.1 Project Background

As part of the NSW Government's investment in keeping Sydney moving and improving road safety, Roads and Maritime Services (Roads and Maritime) have led an investigation into intersection and traffic management improvements at four key intersections within the inner west of Sydney. The four intersections are located on the east-west route that includes Euston Road, McEvoy Street and Lachlan Street. These intersections were identified as part of a previous concept design known as the Alexandria to Moore Park Stage 1 (A2MP Stage 1) project.

Roads and Maritime are proposing to construct Stage 1 of A2MP Stage 1, which comprises:

- Intersection upgrades at four locations
  - McEvoy Street and Fountain Street
  - McEvoy Street and Botany Road
  - McEvoy Street and Elizabeth Street
  - Lachlan Street and South Dowling Street.
- New clearways on both sides of the full length of the Project
- Right turn bans at most intersections with lower order streets along the east-west route.

In parallel to the development of the project, the NSW Government through Transport for NSW developed and released Future Transport Strategy 2056 (or “Future Transport”) in 2018, which is underpinned by the Movement and Place framework. Through the lens of this framework, planning and managing a successful road corridor includes appropriate consideration of the strategic significance of the corridor in supporting both safe, efficient and reliable journeys for people and goods while enhancing the liveability and amenity of places. Ensuring the project appropriately responds to the needs of each has also formed a part of more recent challenge reviews of the project.

1.2 Project Description

Roads and Maritime Services (Roads and Maritime) propose to upgrade four intersections and introduce clearways between the Euston Road/Maddox Street intersection in Alexandria and the Anzac Parade, Alison Road and Dacey Avenue intersection in Moore Park (the proposal). The proposal is located about three kilometres south of the central business district (CBD) in the suburbs of Alexandria, Waterloo, Moore Park within the City of Sydney local government area (LGA).

The proposal consists of:
• New clearways on both sides of Euston Road and McEvoy Street between Maddox Street and Bourke Street from 6:00am to 7:00pm Monday to Friday and 9:00am to 6:00pm on weekends

• New clearways at all times along Lachlan Street and Dacey Avenue between Bourke Street and Anzac Parade

• Right turn bans at most intersections without traffic signals and a right turn ban into Bunnings from McEvoy Street

• Improving intersection capacity at:
  • Fountain Street and McEvoy Street
  • Botany Road and McEvoy Street
  • Elizabeth Street and McEvoy Street; and
  • South Dowling Street, Lachlan Street and Dacey Avenue

• Minor kerb adjustments at:
  • Stokes Avenue and McEvoy Street
  • Kensington Lane and McEvoy Street

• Landscaping adjustments and replacement tree planting where works are undertaken

• Relocation of utilities and adjustments to traffic signals and street lights

• Property acquisitions, leases and adjustments

• Temporary construction facilities, including site compounds and stockpile sites at:
  • Roads and Maritime car park on the south-west corner of McEvoy Street/Stokes Avenue intersection, Alexandria (Site 1) – road reserve (no lot and DP)
  • Road reserve at the southern end of Cope Street, Alexandria (Site 2) – road reserve (no lot and DP)
  • Road reserve at the southern end of George Street, Alexandria (Site 3) – road reserve (no lot and DP)
  • Vacant land at the corner of intersection of McEvoy Street and Bourke Street, Waterloo (Site 4) – Lot 2 DP 800705 – excluding area where heritage listed buildings are located
  • Lot 1 DP121915, Lot 2 DP1-54399 and road reserve on the eastern corner of the Lachlan Street/Amelia Street intersection, Waterloo (Site 5).

The duration of construction impacts within each of the four intersection construction zones would typically be between 6 to 18 months.
Figure 1 The Locality
Figure 2 The Proposal
Figure 2 The Proposal
Figure 2 The Proposal
Figure 2 The Proposal
1.3 **Study Objectives**

The objectives of this flood assessment include:

- Collect and review the available data and flood behaviour
- Update the Alexandra Canal TUFLOW model using the available detailed survey data for the proposal site
- Run the hydraulic models for a range of design flood events including the 2% AEP and 1% AEP events to define flood behaviour for the proposal area under the baseline case
- Update the Alexandra Canal TUFLOW model to represent the current design and then run the model for the same design flood events
- Quantify flood impacts due to the intersection upgrades and identify appropriate mitigation measures to address potential flood impacts for the operational phase. Flooding impacts are identified for the proposal area (as shown in Figure 2) in addition to areas within the floodplain and outside of the proposal area.
- Assess flood impacts for the construction phase and identify and assess mitigation options to address any flood impacts
- Prepare a stand-alone report (this report) on the flood impact assessment.

1.4 **Report Structure**

This report is structured with the following sections:

- Section 2: Assessment Requirements
- Section 3: Existing Environment
- Section 4: Assessment Methodology
- Section 5: Updated Flood Modelling
- Section 6: Existing Flooding Characteristics
- Section 7: Assessment of Operational Phase Flood Impacts
- Section 8: Management of Construction and Operational Impacts
- Section 9: Conclusions and Recommendations
- Appendix A: Baseline Case Flood Mapping
- Appendix B: Design Case Flood Mapping
2 Assessment Requirements

2.1 Policy and Planning Setting

The NSW Government’s *Floodplain Development Manual* (NSW Government, 2005) outlines the approach for floodplain planning and management of flood risk in NSW. The Floodplain Development Manual has been prepared in accordance with the NSW Government’s Flood Prone Land Policy, whose objective is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone land, and to reduce public and private losses resulting from floods. The Floodplain Development Manual sets out overarching principles for development in flood-prone areas and provides guidelines for defining flood behaviour and flood risk and considerations for managing existing flood risk.

The *Floodplain Development Manual* specifies that any new developments within flood prone land needs to be assessed cumulatively to ensure that it will not significantly impact on existing development. Mitigation measures need to be identified and incorporated where possible to mitigate or eliminate the potential flooding impacts resulting from new development.

2.2 Assessment Criteria

No specific criteria relating to flood impacts are recommended in the *Floodplain Development Manual*. Appropriate threshold levels for flooding impacts may vary depending on the catchment setting and presence and nature of existing development in the vicinity of the proposal site.

Adopted criteria for similar roads and infrastructure projects within urbanised environments, as specified by local councils and other agencies, have included:

- Increases in peak flood levels affecting existing properties upstream and downstream of the proposal site not to exceed 0.01m

These above criteria may be considered to be stringent. It is important to note that in the recent and similar projects it has not been reasonable or feasible to provide measures or works to fully mitigate the flooding impacts to satisfy these criteria, due to the level of existing development and significant project and site constraints. In these cases, non-conformances to the criteria were identified and justification provided to facilitate acceptance of the residual impacts by relevant authorities and stakeholders.

For the purposes of this flooding assessment on the design it is assumed that these criteria are appropriate.

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1 Note that for the purpose of this flood impact assessment, the flood impacts, depths and velocities are referred to the nearest 0.01m and not in millimetres, to avoid the misconception that flood modelling is accurate to the millimeter scale.
2.3 Assessment Area of Interest

The study brief outlines proposed assessment study areas which are limited to the vicinity of the proposal site itself. The “proposal area” refers to the area that would be directly impacted by the proposal. It encompasses the current road design, the total construction footprint, compound sites, stockpile sites and any other areas that would be temporarily disturbed (such as construction basins and access tracks), shown in Figure 2. The “construction footprint” includes any area subject to physical impacts (i.e. changes to ground levels) resulting from the proposal, and the construction site compound areas. Flooding impacts may be experienced within the proposal area due to physical works carried out, or temporary obstructions within the construction footprint areas.

However, flooding impacts may also be experienced at some distance away from the proposal itself, depending on the nature of works and interaction with floodwaters. This flooding assessment therefore investigates flooding within the proposal area as well as on a broader catchment scale, assessing the flood impacts resulting from the proposal across the catchments both upstream and downstream of the site to the catchment outlets. The objective is to ensure all impacts across the catchments are identified.

3 Existing Environment

3.1 Catchment Description

The proposal is situated almost entirely within the Alexandra Canal catchment. A very small portion of the proposal is situated within the Botany Wetlands catchment, with the catchment boundary located approximately 250 m west of the intersection of Dacey Avenue and Anzac Parade (refer to Figure 3). It should be noted that the extent of the proposal situated within the Botany Wetlands catchment does not involve any physical works altering the existing surface levels within this catchment. It can therefore be reasonably stated that there will be no flood impacts associated with the A2MP Stage 1 project within the Botany Wetlands catchment. All areas where alterations to the existing topography are proposed are situated within the Alexandra Canal catchment.

The Alexandra Canal catchment drains a total area of 13.8 km². The major sub-catchments contributing to Alexandra Canal are Sheas Creek, Rosebery, Munni Street-Erskineville and Alexandra Canal.

The proposal traverses east to west through the mid to upper sections of the catchment area, within the Sheas Creek sub-catchment. The catchment drains in a generally south to south-westerly direction to Alexandra Canal, which discharges to the Cooks River and then Botany Bay. The catchment drains a large part of inner Sydney and is fully urbanised. Developments consist of medium to high density housing, commercial and industrial development with some large open spaces that include Moore Park Playing Fields, Moore Park Golf Course, The Australian Golf Course, Sydney Park, Redfern Park, Waterloo Park and Alexandria Park. Drainage systems consisting of open channels, covered
channels, in-ground pipes, culverts and pits convey runoff from the catchment to Alexandra Canal. The majority of the trunk drainage system is owned by Sydney Water Corporation and the feeding drainage systems are primarily owned by City of Sydney.

The proposal is located within the City of Sydney (CoS) local government area (LGA). A number of council-commissioned flood studies have been conducted, refer to Section 4.2 for details.

Figure 3 Catchment boundaries and topography
3.2 Description of Flooding

3.2.1 Alexandra Canal Catchment

Flooding along the proposal alignment is generally dictated by shorter-duration storms of less than 2 hours duration, given the highly urbanised nature of most of the catchment. Flooding generally occurs due to the capacity of the underground stormwater network being exceeded, even in relatively frequent flood events, which gives rise to overland flow flooding conveyed primarily by the road network.

There are generally three main sub sections of the Sheas Creek sub-catchment that contribute to flooding of the proposal and include:

- The ‘Alexandria and Macdonaldtown Branch’
- The ‘Alexandra Canal Main Branch’
- The ‘Victoria Branch’.

The ‘Alexandria and Macdonaldtown Branch’ drains water from east of the Australian Technology Park primarily along Botany Road and Cope Street toward McEvoy Street. Floodwater is conveyed into the proposal site (McEvoy Street) from Fountain Street, Loveridge Street, Brennan Street and Wyndham Street and generally flows west, discharging onto the side streets on the southern side of the road, between Bowden Street and Botany Road. These overland flows are picked up by an open channel running south west through industrial properties from Wyndham Street to Bowden Street. Downstream of Bowden Street, the channel is larger and conveys flows into the upstream end of Alexandra Canal.

The ‘Alexandra Canal Main Branch’ drains water from near the intersection of Albion Street and Flinders Street to Alexandra Canal, through a series of low points in the road network where water ponds. Floodwater enters the proposal site primarily from Young Street, Morehead Street and Bourke Street, ponding in a sag point McEvoy Street before discharging onto Hunter Street and Young Street. These flows then discharge into the open channel downstream of Bowden Street via Bourke Road and Mandible Street, or discharge into Alexandra Canal via O’Riordan Street.

The ‘Victoria Branch’ drains the area to the east of South Dowling Street in areas of West Kensington and extending north into the Moore Park Golf Course towards Joynton Avenue. In the vicinity of the proposal area, floodwater is conveyed west along Dacey Avenue towards the intersection with South Dowling Street, where it predominantly discharges south along South Dowling Street towards the sag point approximately 250 m south of the intersection. A relatively minor amount of overland flow traverses across South Dowling Street and continues along Lachlan Street in the major flood events. Water ponds on Lachlan Street near Sam Sing Street and flows down Sam Sing Street toward Joynton Avenue. Runoff from the block to the north of Lachlan Street also contributes to the flooding of Lachlan Street.
3.3 Concurrent Infrastructure Developments

Concurrent infrastructure projects in the vicinity of the A2MP Stage 1 proposal site include the CSELR project and the WestConnex project.

The CSELR and WestConnex (St Peters interchange) projects are both nearing completion. As there are no physical works proposed as part of the A2MP Stage 1 project at these project interfaces, there is no need to consider any flooding issues associated with either of these projects.

4 Assessment Methodology

4.1 Overview

This working paper is required to assess the flood impacts of the proposal and propose potential mitigation options for the purpose of inclusion in the Review of Environmental Factors (REF). These flood impacts will be assessed with a hydrodynamic flood model covering the area.

The assessment methodology is summarised below:

- Obtain and review existing flood studies and models
- Update existing hydraulic model with ground survey along the proposal alignment
- Run the model to assess baseline conditions for the project’s flood impact assessment
- Update the hydraulic model to incorporate the project, including road and drainage designs
- Run the model to assess design case conditions, determine flooding impacts in terms of changes in flooding conditions from baseline case
- Identify potential mitigation measures and strategies to mitigate flood impacts.

4.2 Available Reports

4.2.1 Design Reports

4.2.1.1 Alexandria to Moore Park Stage 1 Design

Previous work has been undertaken on the drainage and flooding aspects of the proposal during early design stages. It has been identified that several sections of the proposal corridor are flooded in events as frequent as the 5 Year ARI (0.2 EY), indicating the existing stormwater network only has capacity for relatively frequent storm events. It has also been noted that several overland flow paths
traverse the proposal area, such as along Fountain Street/McEvoy Street/Bowden Street.

Given the known constraints to the existing drainage network, it is not possible to improve the flood immunity of the corridor that is formed by Euston Road, McEvoy Street and Lachlan Street without modifying the upstream and downstream networks, which is outside the scope of this study. Therefore, instead of designing to accommodate flooding that originates from beyond the proposal area, the drainage design has been developed to convey a 10% AEP event which collects runoff from within the proposal area catchment, (assuming sufficient capacity was available in the trunk stormwater network) and on providing sufficient drainage to maintain the existing flooding levels within the road corridor in the 1% AEP event.

4.2.2 Existing Flood Studies

The Alexandra Canal flood study, prepared for the CoS, covers the majority of the Project proposal area, including all areas in which physical works will be undertaken. Development of the flood modelling informing the flood study is summarised in the sections below.

4.2.2.1 Alexandra Canal Flood Study

The Alexandra Canal Flood Study was prepared by Cardno (2014) for CoS to define the flood behaviour in the study area, including both mainstream and overland flooding. The study area covered 93% of the total Alexandra Canal catchment (that part within the CoS LGA). It is roughly bounded by the Eastern Distributor and Moore Park in the east, Gardeners Road in the south, Sydney Park and Newtown in the west and Albion Street in the north-east. A detailed 1D/2D flood model was established for this area using SOBEK. The model consisted of a 4 m grid resolution and included pit and pipe data collected from CoS. Hydrologic modelling was undertaken through the application of the direct rainfall methodology. The model was calibrated and verified against four historical storm events: November 1984, January 1991, April 1998 and February 2001. The model was used to simulate the flood behaviour of the 1, 2, 5, 10, 20 and 100 year average recurrence interval (ARI) events and the probable maximum flood (PMF). An assessment of the impact of blockages of culverts and pits was undertaken as well as an assessment of the impact of climate change.

4.2.2.2 Alexandra Canal Catchment Flood Study Model Conversion Stage 1 Report

The Alexandra Canal Catchment Flood Study Model (Cardno 2014) was updated by BMT WBM (2015) for CoS, involving the conversion of the flood model from SOBEK to TUFLOW. The 1D/2D TUFLOW model consists of a 2.2 m grid, created from the 2008 LiDAR data that was used for the SOBEK model. The pit and pipe network from the SOBEK model was extracted and used in the TUFLOW model. Alexandra Canal bathymetry was also included in the TUFLOW model. The model also included elements from the Green Square
Trunk Drain – Hydraulic and Flood Modelling (WRL 2014) that was undertaken for Sydney Water Corporation and CoS. Hydrology was simulated by a DRAINS model and was compared to using the direct rainfall approach. The model was calibrated to the November 1984, January 1991 and March 2001 storm events. The 63 %, 39 %, 18 %, 10 %, 5 %, 2 %, 1 %, 0.5 % and 0.2 % AEP events (1, 2, 5, 10, 20, 50, 100, 200 and 500 year ARI events, respectively) were simulated for the 25, 60 and 120 minute storm durations. The hydrology was estimated using Australian Rainfall and Runoff 1987. The PMF event was also simulated for the 30, 45 and 90 minute storm durations. A 20 % blockage of on-grade pits and 50 % blockage of sag pits was assumed. A series of sensitivity analyses were undertaken for the modelled hydrologic and hydraulic parameters and an assessment of climate change was also part of the study.

5 Updated Flood Modelling

5.1 Adopted Flood Models

The Alexandra Canal TUFLOW model (BMT WBM 2015) was determined to be adequate for the purposes of this flood assessment and was adopted as the base model for the assessment of the proposal. The model covered almost the entire extent of the proposal, and incorporates all sections of the proposal in which physical works will be undertaken.

No flood modelling has been undertaken for the small section of the proposal within the Botany Wetlands catchment (Dacey Avenue). No physical works are being undertaken within this catchment, and therefore the proposal will not result in any flood impacts compared with the existing conditions.

5.2 Modifications to Hydraulic Model

5.2.1 Description

The configuration of the Alexandra Canal flood model was generally retained as per the BMT WBM setup. The following modifications were made to the model for the purposes of this flood assessment:

- Topographic survey along the proposal route was incorporated into the TUFLOW model to improve the definition of the ground features along the proposal corridor.
- 2d_zsh layers were prepared and added to the model to further formalise surface features along the proposal corridor in the TUFLOW model, including kerbs, gutters, medians and road crest levels.
- A small section near the intersection of Bourke Street and Potter Street (to the north of the proposal alignment) was modified to repair a depression in the model DTM caused by an interfacing issue between two ALS layers. Removal of the artificial depression from the model indicates that there is an additional overland flow path passing through the proposal corridor along Bourke Street.
For the assessment of the design case, the design road surface TIN was incorporated into the TUFLOW model for all areas where physical works are being proposed. Proposed surface features were formalised using 2d_zsh layers, as was the case in the existing baseline model. Proposed stormwater elements were also incorporated into the TUFLOW model for the design case.

It should be noted that, at the time of writing of this report, there is currently underground stormwater survey being undertaken along the proposal corridor. This information will need to be reviewed against the stormwater data currently incorporated in the Alexandra Canal TUFLOW model, as it is anticipated that the survey will provide additional detail on the existing network. For example, it is known that stormwater infrastructure exists at the South Dowling Street intersection which at this state has been incorporated into the baseline TUFLOW model.

5.2.2 Model Validation

Flood levels in the Alexandra Canal model (BMT WBM 2015) were observed to typically be +/-0.15 m between the A2MP Stage 1 model and the parent model following the updates made to the existing case model noted in Section 5.2.1. This is attributed to the inclusion of ground survey in the proposal corridor, changing the road surface levels and including finer surface features such as medians and gutters. Most of these changes in flood levels remain in the immediate vicinity of the proposal corridor.

The repair of the ALS layers at Bourke Street results in an overland flow path being predicted to enter the proposal corridor from the north along Bourke Street. The overland flow entering the corridor is either conveyed to the east along Lachlan Street towards the sag point at Sam Sing Street, west along McEvoy Street towards the sag point at Hunter Street or runs further south along Bourke Street. This change in the flow paths along Bourke Street between the parent and updated TUFLOW models are seen in Figure 4 and Figure 5.
Figure 4 McEvoy Street/Bourke Street/Lachlan Street intersection, flow paths before modification of DTM (location of terrain modification shown in yellow circle)

Figure 5 McEvoy Street/Bourke Street/Lachlan Street intersection, flow paths through intersection following modification of DTM (location of terrain modification shown in yellow circle)
5.3 Model Inflows

The Alexandra Canal TUFLOW (BMT WBM 2015) model utilises inflows from a separate DRAINS hydrologic model. The DRAINS model simulates runoff from hundreds of sub-catchments that are input into the TUFLOW model as overland flows at pit inlets or at the lowest point of the sub-catchment.

Hydrologic inputs into the hydraulic models are based on Australian Rainfall and Runoff (ARR)1987 design rainfall data. It is noted that updated design rainfall data from ARR 2016 is available, however it was not in the scope of the study to update the flood modelling to be based on the more recent design rainfall data.

5.4 Adopted Modelling Parameters

5.4.1 Manning’s n

The Manning’s n hydraulic roughness parameter values adopted in the Alexandra Canal model (BMT WBM 2015) have been retained in this flood assessment. These are summarised in Table 1.

Table 1 Alexandra Canal Model adopted Manning’s n values

<table>
<thead>
<tr>
<th>Land Use Category</th>
<th>Manning’s n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roads</td>
<td>0.02</td>
</tr>
<tr>
<td>Parks/Reserves</td>
<td>0.03</td>
</tr>
<tr>
<td>Residential/Commercial lots (excluding buildings)</td>
<td>0.04</td>
</tr>
<tr>
<td>Alexandra Canal open channel</td>
<td>0.018</td>
</tr>
</tbody>
</table>

5.4.2 Representation of Buildings

In the Alexandra Canal model, buildings with a roof area greater than 30 m$^2$ are typically represented as solid impermeable objects. For buildings with roof area less than 30 m$^2$ (typically garages and sheds), a depth-varying Manning’s n value was applied to represent the temporary flood storage in the building. Building depth-varying Manning’s n values are summarised in Table 2.

Table 2 Alexandra Canal Model adopted depth-varying Manning's n values

<table>
<thead>
<tr>
<th>Land Use Category</th>
<th>Manning’s n Depth &lt;= 0.05m</th>
<th>Manning’s n Depth &gt;= 0.10m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buildings</td>
<td>0.02</td>
<td>1.00</td>
</tr>
</tbody>
</table>

*Note where depths are greater than 0.05 m but less than 0.10 m, the Manning’s n value is interpolated between the values given in the table

5.4.3 Initial Water Levels

The initial water levels in the TUFLOW model were set based on the adopted static tailwater level. The adopted tailwater conditions vary with the design storm event, as outlined in Table 3. These tailwater levels mean that Alexandra Canal is
inundated, as well as the main channel discharging into the upstream end of the canal. In the 1 % AEP event, the tailwater level inundates the canal up to Maddox Street.

Table 3 Alexandra Canal Model adopted tailwater levels

<table>
<thead>
<tr>
<th>Design event</th>
<th>Tailwater level (m AHD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2 EY</td>
<td>2.0</td>
</tr>
<tr>
<td>5% AEP</td>
<td>2.15*</td>
</tr>
<tr>
<td>2% AEP</td>
<td>2.15*</td>
</tr>
<tr>
<td>1% AEP</td>
<td>2.5</td>
</tr>
</tbody>
</table>

* 5 % AEP tailwater level adopted for both the 5 % and 2 % AEP design flood simulations.

5.4.4 Blockage of Hydraulic Structures

5.4.4.1 Stormwater Pit Inlets

The pit blockage factors in the TUFLOW model have been assumed to be 20 % and 50 % blocked for on-grade and sag pits, respectively. These factors have been retained for the A2MP Stage 1 flood assessment.

5.4.5 Further Model Updates

It is known that there is additional underground stormwater survey being undertaken as part of the A2MP Stage 1 project to confirm the locations, pipe sizes, invert levels and connection points of the existing stormwater network through the proposal area. This information will need to be reviewed against the stormwater data currently incorporated in the TUFLOW model, as it is anticipated that the survey will provide additional detail on the existing network. There are some locations along the proposal corridor (e.g. at the intersection with South Dowling Street) where it is known that additional stormwater infrastructure exists which have not been incorporated into the baseline TUFLOW model.

It is recommended that both the baseline and the design case TUFLOW models be updated to incorporate this stormwater survey information once it is received, as this may influence flood levels within the corridor. This should be undertaken at the next design stage if possible.
6 Existing Flooding Characteristics

6.1 Storm Events Assessed

Flooding conditions have been assessed for the 0.2 EY (i.e. 5 year ARI) event and the 5%, 2% and 1% AEP events. The 25, 60 and 120 minute duration storms were run, being considered a suitable representation of the critical durations across the entire catchment area (BMT WBM 2015).

6.2 Flood Depths

The flood depths for baseline conditions are presented in Maps 1 to 4 in Appendix A. Areas of higher flood depths reflect main flow paths and ponding and storage areas in the catchments.

The proposal passes through several areas which are known flooding trouble spots, further details of which are provided below. The proposal is also impacted by a number of overland flow paths, most notably along McEvoy Street between Botany Road and Bowden Street. The extent of the proposal area that is impacted by flooding is likely to make it difficult to fully mitigate the adverse flooding impacts of the proposal.

McEvoy Street acts as an overland flow path conveying flows from Botany Road to Bowden Street. Along this section, flows are received from the north via Wyndham Street, Brennan Street, Loveridge Street and Fountain Street and are conveyed west along McEvoy Street, discharging to the south into Botany Road, Wyndham Street, Hiles Lane, Hiles Street, McCauley Street, Stokes Avenue and Bowden Street. There are also overland flow paths along Dacey Avenue between the catchment boundary (west of Anzac Parade) and South Dowling Street. Floodwaters flow in a westerly direction along before being conveyed either to the north or to the south along South Dowling Street.

Several portions of the proposal are subject to some degree of flooding in relatively frequent events (e.g. 0.2 EY), with flood extents increasing in larger flood events.

Critical sag points that are subject to flooding along the proposal alignment are listed below:

- McEvoy Street, between Fountain Street and Bowden Street on the westbound carriageway where water ponds before flowing into Bowden Street. Flood depths reach 0.59 m in the 0.2 EY event and 0.75 m in the 1% AEP event at this location

- Intersection of McEvoy Street and George Street on the eastbound carriageway. Flood depths in this location range from approximately 0.49 m in the 0.2 EY event to 0.61 m in the 1% AEP event

- McEvoy Street between Hunter Street and Young Street across both carriageways. Floodwaters enter this area from the north via Morehead Street and Young Street, and from the east via Bourke Street, before ponding in this
location. The overland flow leaves the site to the south along Hunter Street and Young Street. Flood depths reach 1.0 m in the 0.2 EY event and 1.2 m in the 1 % AEP event

- Lachlan Street, near the intersection with Sam Sing Street. The sag point in this area receives flow from Bourke Street, Gadigal Avenue and through a pedestrian plaza to the north of the sag point. Flood depths range between 0.70 m in the 0.2 EY event and 0.80 m in the 1 % AEP event.

Flood immunity of the road may be described in general terms as the smallest flood event which causes the road to become flooded and untrafficable. Given the catchment terrain and flooding behaviour along the proposal route, the proposal has a flood immunity more frequent than the 0.2 EY event. These existing flooding issues have been acknowledged in the development of the design, however the proposal is not able to improve the flood immunity of the upgraded road due to limited capacity of the existing drainage system and the presence of other site constraints. The proposal however, does not worsen the existing flood immunity.

6.3 Flood Hazard

As outlined in Appendix L of the Floodplain Development Manual (NSW Government, 2005), flood hazard can be categorised as either high hazard or low hazard. High hazard flooding represents areas with high depths, high flow velocities or both, and presents a possible danger to personal safety, difficulty for able-bodied adults to wade to safety, and potential for significant structural damage to buildings. Low hazard flooding represents areas with low depths and velocities where able-bodied adults would have little difficulty wading to safety.

Provisional hazard categorisation can be prepared for predicted flood depths and velocities using Figures L1 and L2 in the Floodplain Development Manual (NSW Government, 2005). These figures are reproduced in Figure 6 and Figure 7 below. They show approximate relationships between the depth and velocity of floodwater and resulting hazard, and the definition of provisional low and high hazard categories.
The TUFLOW model results were used to delineate the flood hazard areas for the study area, based on the hydraulic hazard category diagram presented in Figure 7. The TUFLOW model calculates the hazard rating at each cell and computational time step, rather than calculating the rating based on the peak depth and peak velocity. For the purposes of this study, the “Transitional” flood hazard areas (which may be updated to Low or High flood hazard, depending on catchment conditions such as rate of rise of floodwaters, effective warning times and evacuation difficulties) are assumed to be areas of high flood hazard. The flood...
hazard mapping for baseline conditions is presented on Maps 5 to 8 in Appendix A.

Brief descriptions on the high flood hazard through the proposal area under existing conditions are given below:

- On McEvoy Street there are only isolated areas of high hazard associated with gutter flows in the 0.2 EY event. These high hazard areas are more prominent in the less frequent events (e.g. 1 % AEP) but remain largely isolated small areas. A notable exception is along the southern side of McEvoy Street between Fountain Street and Bowden Street, where there is high flood hazard area that continues south down Bowden Street in the 2 % AEP and 1 % AEP events.

- A high flood hazard area along McEvoy Street exists between Hunter Street and Young Street, which becomes noticeable in events including and above the 5 % AEP. Floodwater entering the proposal from Young Street is classified as high hazard in the 2 % and 1 % AEP events, causing a high flood hazard at the intersection with McEvoy Street. To the south of the proposal, Hunter Street is classified as high flood hazard in all events including and above the 5 % AEP.

Floodwaters may pose a risk to vehicles using the roads within the study area. Smith (2015) describes that small vehicles may become buoyant and potentially swept away by floodwaters when depths exceed 0.3 m. Flow velocities greater than 1 m/s can reduce the threshold flood depths to 0.2 m or lower (refer to Figure 6). Floodwaters of such depths occur in the existing case along the proposal route. Hence, there is an existing risk to vehicles using the roads.

Brief descriptions on the areas through the proposal where an existing risk to vehicles are present are given below:

- McEvoy Street, between Fountain Street and Bowden Street. Both carriageways carry an existing risk to small vehicles in all events above and including the 0.2 EY. In the 1 % AEP event, a small section of the westbound carriageway is categorised as carrying a risk to vehicles. Similar risks to vehicles are present on Fountain and Bowden Streets, where the existing overland flow path passes through the corridor. Existing unsafe areas for vehicles are also present along both the eastbound and westbound carriageways of McEvoy Street between Fountain Street and Loveridge Street in the 2 % AEP and 1 % AEP events.

- McEvoy Street, east of the Elizabeth Street intersection. The sag point near the Morehead Street intersection carries an existing flood risk to vehicles, due to depths exceeding 0.5 m in events including and above the 0.2 EY. The risk to vehicles of the overland flow path down Young Street and Hunter Street also becomes significant in events including and above the 5 % AEP.

- Lachlan Street near Sam Sing Street. The sag point near the Morehead Street intersection carries an existing flood risk to vehicles, due to depths exceeding 0.5m in events including and above the 0.2 EY. The extent of the unsafe area increases slightly for all events up to the 1 % AEP, however the risk categorisation doesn’t get worse in the baseline case.
7 Assessment of Operational Phase Flood Impacts

7.1 Updates for Modelling of the Design Case

The Alexandra Canal TUFLOW model was run incorporating the road and stormwater design elements to represent the developed case. The design case models were run for the same design storms as the baseline case, and the model results compared to baseline conditions.

7.2 Change in Flood Levels

7.2.1 Discussion

The proposal area is flood-affected in events as frequent as the 0.2 EY in the existing case. The design does not change the flood immunity of the proposal area, that is, the road corridor remains flood-affected in all flood events assessed (i.e. all events above and including the 0.2 EY event). The proposal is not able to improve the flood immunity of the upgraded road due to limited capacity of the existing drainage system and the presence of other site constraints.

The change in flood levels resulting from the proposal are shown on Maps 9 to 12 in Appendix B. The flooding impacts and their causes are discussed for the areas in which physical works are proposed along the corridor, these being:

- McEvoy Street/Fountain Street intersection
- McEvoy Street/Botany Road intersection
- McEvoy Street/Elizabeth Street intersection
- Lachlan Street/Dacey Avenue/South Dowling Street intersection.

The remaining areas of the proposal do not involve any physical works, and therefore there will be no impacts to flooding resulting from the Project outside the areas noted above.

7.2.1.1 McEvoy Street/Fountain Street Intersection

Changes in peak flood levels across all events at this intersection are largely a result of changes to the road surface levels from existing conditions. The superelevation applied to the road through the intersection results in the surface levels generally being lowered from existing along the westbound carriageway of McEvoy Street. The finished surface level is raised along the eastbound carriageway of McEvoy Street for a length of approximately 200 m, including through the intersection, which is responsible for the predicted changes in flood levels. Changes in peak water levels for the 1% AEP event are shown in Figure 8.

Increases in peak water levels up to approximately 0.25 m are seen along the eastbound carriageway of McEvoy Street between the Fountain Street intersection...
and Stokes Avenue. This is a result of the raised road levels due to the superelevation applied in the road design, and the addition of a median along McEvoy Street on either side of the intersection. The median appears to detain some of the floodwater within the eastbound carriageway, preventing it from draining to the natural sag point on the southern side of the corridor.

Peak water levels are generally reduced along the westbound carriageway due to the general lowering of surface levels from existing conditions. There is a localised area at the intersection of Bowden Street in which peak flood levels are increased up to approximately 0.07 m from existing conditions in the 1% AEP event. This appears to be the result of the road crest being lowered from existing at this section of McEvoy Street, allowing for some equalisation of the water levels across the road carriageway compared to the existing case.

Figure 8 Change in peak water levels - McEvoy Street/Fountain Street intersection – 1 % AEP event

The adverse impacts within the project boundary will be difficult to eliminate without fundamentally changing the road design through this section of the corridor. Additional drainage within the proposal area is unlikely to alleviate the adverse impacts, as the performance of the drainage network is constrained by the trunk stormwater lines being at capacity.

Floor level survey of properties adjacent to the proposal corridor should be undertaken at future design stages to assess the potential consequences of the adverse flood impacts. Suitable mitigation measures can be proposed following this assessment for all adversely impacted properties.
Outside the proposal area, there are minor increases in peak water levels along Bowden Street. These increases appear as isolated bands in the peak water level mapping, and generally do not exceed 0.02 m in all events assessed. Further assessment will be required at future design stages to determine whether these are true impacts resulting from the proposal, or minor numerical instabilities in the TUFLOW model.

7.2.1.2 McEvoy Street/Botany Road Intersection

There are changes to the overland flow behaviour at this intersection due to the proposed A2MP Stage 1 design. A flow redistribution occurs in the proposed case due to the removal of the road crest along Botany Road, and regrading of McEvoy Street to provide a continuous longitudinal fall from east to west through the intersection. The change in overland flow through the intersection is shown in Figure 9 and Figure 10.
Figure 9 Existing case overland flow paths at McEvoy Street/Botany Road intersection, 1% AEP event (note depths not shown below 0.01 m)

Figure 10 Design case overland flow paths at McEvoy Street/Botany Road intersection, 1% AEP event (note depths not shown below 0.01 m)
The resultant impact is that more overland flow is conveyed west along McEvoy Street, before heading south along Wyndham Street in the proposed case in all events assessed. Flood level increases of up to 0.20 m in the 1 % AEP event are predicted along the westbound carriageway of McEvoy Street, and an increase of 0.06 m is predicted along Wyndham Street in the 1 % AEP event to the south of the proposal area. The increase in flood levels on Wyndham Street can be directly attributed to increased flow resulting from the changes in the road profile at the McEvoy Street/Botany Road intersection. Commensurate reductions in peak water levels are predicted on Botany Road to the south of the intersection, where overland flows are reduced from existing conditions.

Within the proposal area, changes in flood level are generally the result of changes to the road profile through the intersection, with the exception of the aforementioned flow path heading west along McEvoy Street. Flow depths through the intersection are generally shallow (< 0.05 m) in 1 % AEP event.

The change in peak water level in the 1 % AEP event can be seen in Figure 11. The changes along the Wyndham Street and Botany Road overland flow paths outside the proposal area are clearly illustrated.
The adverse impacts both within the proposal area and along Wyndham Street will be difficult to eliminate without fundamentally changing the road design at the McEvoy Street/Botany Road intersection. Additional drainage within the proposal area is unlikely to alleviate these adverse impacts, as the performance of the drainage network is constrained by the trunk stormwater lines being at capacity.

Floor level survey of properties adjacent to the overland flow path along McEvoy and Wyndham Street may be required to assess the potential consequences of the adverse flood impacts predicted. Suitable mitigation measures can be proposed following this assessment for all adversely impacted properties.

Increases in peak water levels (of up to 0.03 m) are predicted along the open channel downstream of Wyndham Street, particularly near Hiles Street and Hiles Lane. Further assessment will be required at future design stages to determine whether these are true impacts resulting from the A2MP Stage 1 project, or some minor numerical instabilities in the TUFLOW model.

### 7.2.1.3 McEvoy Street/Elizabeth Street Intersection

There are no meaningful changes to peak flood levels resulting from the A2MP Stage 1 project works at this intersection. Elizabeth Street is a high point along the proposal corridor, and overland flow paths are not appreciably altered in the
proposed case as the crest line running north to south along Elizabeth Street is retained as part of the A2MP Stage 1 design. Changes in peak flood levels illustrated on the maps the result of changes to the road surface levels from existing conditions and are generally confined to within the proposal area.

The change in peak water level in the 1% AEP event can be seen in Figure 12.

![Legend](Image)

**Figure 12**: Change in peak water levels - McEvoy Street/Elizabeth Street intersection - 1% AEP event

It should be noted that there are isolated spots where the change in water level exceeds +0.01 m on Pitt Street, just to the south of the proposal. Further assessment will be required at future design stages to determine whether these are true impacts resulting from the A2MP Stage 1 project, or minor numerical instabilities in the TUFLOW model.

It is considered that no flood mitigation measures or additional stormwater drainage (above that provided as part of the design for minor storm flows) will be required for this area.

### 7.2.1.4 Lachlan Street/Dacey Avenue/South Dowling Street Intersection

There are no significant changes to peak flood levels resulting from the A2MP Stage 1 project works at this intersection. Road design works are limited to minor kerbline adjustments and regrading work, and the natural crest points through the intersection are unaltered as part of the proposal.

The change in peak water level in the 1% AEP event can be seen in Figure 13.
Figure 13 Change in peak water levels - Lachlan Street/Dacey Avenue/South Dowling Street intersection – 1 % AEP event

It should be noted that there are existing stormwater lines along Dacey Avenue and South Dowling Street which have not yet been incorporated into the TUFLOW model, as additional survey is required to provide the necessary information on these assets. These stormwater lines should be added to the TUFLOW model and re-run to assess flood impacts at the next design stage, however it is not anticipated that the flood impacts will be appreciably altered because of this change.

It is considered that no flood mitigation measures or additional stormwater drainage (above that provided as part of the proposed design for minor storm flows) will be required for this area.

7.2.2 Impacts to Properties

The flood level increases due to the A2MP Stage 1 project have the potential to impact existing development and properties. Locations where the flood level increases potentially impact properties are summarised in Table 4. Properties have been deemed to be impacted if the flood level increases were up against the existing building outline.

No assessment of whether the flood levels affected building floor levels or building entrances has been undertaken at this stage, which would provide a more
detailed assessment of whether these buildings are materially impacted by the changes to flood levels.

An assessment of property floor level flood impacts will be undertaken at any affected properties to determine if there the impacts noted below are above the property floor level, and therefore potentially increasing flooding damage to properties. Mitigation measures such as new drainage infrastructure will be installed to avoid impacts, if present.

Table 4 Flooding Impacts to Existing Properties

<table>
<thead>
<tr>
<th>Location</th>
<th>Increase in Flood Level</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Within or immediately adjacent to the construction footprint</strong></td>
<td></td>
</tr>
<tr>
<td>McEvoy Street, near Bowden Street, westbound carriageway</td>
<td>+0.06 m in 1% AEP</td>
</tr>
<tr>
<td>McEvoy Street, near Fountain Street, eastbound carriageway</td>
<td>+0.25 m in 5% AEP</td>
</tr>
<tr>
<td></td>
<td>+0.25 m in 1% AEP</td>
</tr>
<tr>
<td>McEvoy Street, near Wyndham Street, westbound carriageway</td>
<td>+0.17 m in 0.2 EY</td>
</tr>
<tr>
<td></td>
<td>+0.21 m in 1% AEP</td>
</tr>
<tr>
<td>McEvoy Street, near Elizabeth Street, eastbound carriageway</td>
<td>+0.10 m in 1% AEP</td>
</tr>
<tr>
<td><strong>Outside of the construction footprint</strong></td>
<td></td>
</tr>
<tr>
<td>Bowden Street near McEvoy Street, Alexandria</td>
<td>+0.02 m in 0.2 EY</td>
</tr>
<tr>
<td></td>
<td>+0.02 m in 1% AEP</td>
</tr>
<tr>
<td>Wyndham Street, south of McEvoy Street Alexandria</td>
<td>+0.08 m in 0.2 EY</td>
</tr>
<tr>
<td></td>
<td>+0.06 m in 1% AEP</td>
</tr>
<tr>
<td>Open channel between Hiles Street and McCauley Street, Alexandria</td>
<td>+0.03 m in 0.2 EY</td>
</tr>
<tr>
<td></td>
<td>+0.01 m in 1% AEP</td>
</tr>
</tbody>
</table>

7.3 Change in Flood Hazard

The flood hazard mapping for the design case is presented on Maps 13 to 16 in Appendix B. There are no major changes to the location or extent of high flood hazard areas compared with baseline case.

Maps 21 to 24 in Appendix B present the change in high flood hazard areas between the baseline case and the proposed case for all flood events assessed. The mapping categories are denoted as follows:

- “Was High”: previously high hazard in the baseline case and now either low hazard or not flooded;
- “Now High”: previously low hazard or not flooded, and now high hazard.

An increase in the high hazard area for any particular flood event means that there has been an increase in the flood depth or flow velocity, or both, to shift flooding conditions in certain areas into the high hazard category. Flood conditions in these “now high” hazard areas represent an increase in the flood risk to public safety and to property.
Changes in flood hazard resulting from the A2MP Stage 1 project are minor and generally very isolated. The changes in flood hazard are the result of changes to the road profile within the construction footprint, which slightly alters the location of the main flow paths from their existing locations. Generally, increases in the high flood hazard areas (i.e. the “Now High” areas) are offset by the “Was High” areas.

Areas where changes in flood hazard are predicted due to the proposal are noted below:

- **McEvoy Street/Bowden Street intersection** – There are some isolated areas along Bowden Street where the high hazard area has been increased in all events including and above the 5 % AEP, however these changes are not considered significant. Changes to flood hazard on McEvoy Street at this intersection roughly offset each other and not also not considered to be significant.

- **Wyndham Street/Botany Road** – In the 2 % AEP and 1 % AEP flood events, isolated areas along Wyndham Street are shown as “Now High”, whereas isolated areas along Botany Road are shown as “Was High”. This is due to the flow redistribution described in Section 7.2.1.2, which results in more flow being diverted down McEvoy and Wyndham Streets in the proposed case, rather than down Botany Road. The changes in flood hazard resulting from this flow redistribution are nonetheless not considered significant.

- **McEvoy Street near Elizabeth Street intersection** – There are some isolated areas along McEvoy Street where the hazard categorisation has changed from existing. This is a result of the location of overland flow paths changing slightly due to kerb realignments, and some minor re-profiling of the road. The changes in flood hazard resulting from the proposal are nonetheless not considered significant.

- **Lachlan Street/Dacey Avenue/South Dowling Street intersection** - There are some isolated areas within the intersection and along South Dowling Street to the south of the proposal area where the hazard categorisation has changed from existing. This is a result of the location of overland flow paths changing slightly due to kerb realignments. The changes in flood hazard resulting from the proposal at this intersection are not considered significant.

As discussed in Section 6.3, small vehicles may become buoyant and potentially be swept away by floodwaters when depths exceed 0.3 m. Flow velocities greater than 1 m/s can reduce the threshold flood depths to 0.2 m or lower (refer to Figure 6). Floodwaters of such depths occur in the existing case along the proposal route.

With regard to the flood hazard to vehicles, flood depths along the proposal are generally similar to existing conditions, although the locations of maximum depths at intersections where physical works are being undertaken are shifted slightly due to changes to the road profile.

The only area where a visible change can be observed is on the westbound carriageway of McEvoy Street at the sag point between Fountain Street and Bowden Street, where the extent of unsafe area is slightly increased from existing. This is primarily due to the road being lowered from existing on this side (where
the curve superelevation is applied in the design), resulting in higher flood depths in all events compared to existing conditions. Conversely, there is reduction of unsafe area on the eastbound carriageway at this same location, due to flood depths being reduced compared to existing conditions.

The change in flood risk to vehicles noted above is very localised and not considered significant. Flood risk to vehicles outside the proposal area is unchanged compared with existing conditions.

7.4 Construction Related Impacts

This flood assessment has focused on flooding impacts during the operational phase of the proposal, when the permanent works are in place. The impacts of construction phase temporary works have not been assessed in the flood models and will need to be completed prior to construction.

Construction phase works may result in impacts to flooding mainly due to temporary stockpiles, safety barriers (e.g., concrete F-type barriers) and other elements being located within overland flow paths or flood storage areas. Impacts could also potentially occur if drainage systems are temporarily decommissioned for any reason. These risks are to be considered in the construction management plan at later project stages.

Once the construction sequence and staging is finalised, it is recommended that flood modelling of temporary construction scenarios be undertaken where it is considered that construction phase works may materially impact flood behaviour.

8 Management of Construction and Operational Impacts

8.1 Mitigation of Construction Related Impacts

As previously discussed the construction phase flood impacts have not been assessed in the flood models. Qualitatively, flood impacts during construction phase can appropriately be managed by situating site compounds away from main flood flow paths so that temporary stockpiles do not obstruct flood flows. Temporary construction facilities, including site compounds and stockpile sites were identified at the following locations:

- The Roads and Maritime car park on the south-west corner of the McEvoy Street/Stokes Avenue intersection, Alexandria (Site 1)
- Road reserve at the southern end of Cope Street, Alexandria (Site 2)
- Road reserve at the southern end of George Street, Alexandria (Site 3)
- The vacant land (Lot 2 DP800705) at the corner of intersection of McEvoy Street and Bourke Street, Waterloo (Site 4)
- Lot 1, 2 and 3 DP 76985, Lot 4 DP 86722 and Lot 14 DP80926 on the west corner of the Lachlan Street/Amelia Street intersection, Waterloo (Site 5).
Site 1, Site 2 and Site 4 are generally outside of major overland flow paths, although portions of these sites may be impacted by shallow overland flows during flood events. It is considered that any stockpiles or other obstructions placed on these sites are not expected to result in significant flood impacts due to the shallow flow depths predicted (< 0.10m), however further flood modelling will be required to confirm if any flood impacts are likely during the construction phase.

Site 3 is located within a natural sag point near the intersection of George and McEvoy Street, and is likely to be affected by flooding. Further flood modelling will be required to confirm whether any stockpiles or other obstructions will create impacts on the surrounding properties and road users during the construction phase, due to the flood depths predicted at the locations of this site (>0.5m).

Site 5 is not-flood-affected.

8.2 Mitigation of Operational Impacts

The flooding impacts identified during the early design stages are generally a result of changes to ground levels from the proposed intersection upgrades within the construction footprint. Localised adverse flood impacts occur on or adjacent to the roadway as a result of the proposal works adjusting the surface levels of the road pavement, in turn causing flood flows on that road pavement to be raised in elevation and hence increasing flood levels on adjacent areas.

The proposed design at the intersection of McEvoy Street and Botany Road results in a redistribution of overland flow, leading to adverse flood impacts along Wyndham Street to the south of the proposal area.

A potential modification that could be made to try and reduce adverse flood impacts would be to amend the proposed road profile through the McEvoy Street/Botany Road intersection, so that the existing crest line along Botany Road (traversing the intersection north to south) is retained. This will be undertaken during the next stage of design.

The current design grades out crest line, resulting in overland flow being conveyed to the west through this intersection along McEvoy Street and then south along Wyndham Street. Retaining the crest line at this intersection would prevent this flow redistribution and may alleviate the adverse flood impacts currently shown along Wyndham Street. This could be investigated through the remaining stages of the design. It should be noted that stormwater solutions are unlikely to improve the adverse flood impacts noted in the previous sections due to the capacity of the trunk stormwater network being exceeded in relatively frequent events (e.g. 0.2 EY).

It is recommended that an assessment of property floor level flood impacts be undertaken at the next stage of design to determine if there any impacts to above floor flooding, and therefore increased damage to properties, before considering any potential design modifications.
9 Conclusions and Recommendations

9.1 Conclusions

- Existing TUFLOW flood models covering the Alexandra Canal catchment were reviewed and updated with topographic survey to establish baseline flooding conditions in the Alexandra Canal catchment. Note that a flood assessment has not been undertaken for the small portion of the proposal located within the Botany Wetlands catchment (east of the crest at Dacey Avenue), as no physical works are proposed as part of the proposal.

- The Alexandra Canal flood model was updated with the current design of the road and drainage to represent the post-development conditions of the A2MP Stage 1 proposal.

- The following locations within the proposal corridor are predicted to experience increased flood levels as a result of the A2MP Stage 1 project:
  - McEvoy Street near Bowden Street, where flooding is predicted to increase by 0.06 m in the 1 % AEP event
  - McEvoy Street near Fountain Street, where flooding is predicted to increase by 0.25 m in the 1 % AEP event
  - McEvoy Street between Wyndham Street and Botany Road, where flooding is predicted to increase by 0.21 m in the 1 % AEP event
  - McEvoy Street, near Elizabeth Street, eastbound carriageway where flooding is predicted to increase by 0.10 m in the 1% AEP event.

- The following locations outside the proposal area are predicted to experience increased flood levels as a result of the proposal:
  - Bowden Street near McEvoy Street, where flooding is predicted to increase by 0.02 m in the 1 % AEP event
  - Wyndham Street, south of McEvoy Street, where flooding is predicted to increase by 0.08 m in the 0.2 EY event and by 0.06 m in the 1 % AEP event
  - At the open channel between Hiles Street and McCauley Street, where flooding is predicted to increase by 0.03 m in the 0.2 EY event and by 0.01 m in the 1 % AEP event.

- Potential design modifications have been identified to see if some of the adverse flood impacts noted above may be mitigated

- The proposal route is flood-affected in events as frequent as the 0.2 EY event under existing conditions. The proposed design does not change the flood immunity of the roads along the route, that is, the design remains flood-affected in the 0.2 EY event.

- There are no significant increases in high flood hazard areas (as defined in the NSW Floodplain Development Manual) as a result of the A2MP Stage 1 project. There is one location on McEvoy Street between Fountain Street and Bowden Street, where the extent of unsafe area for vehicles is increased slightly compared with existing conditions. This is primarily due to the road...
being lowered from existing on the western carriageway (where the curve superelevation is applied on the road in the proposed case). The change in flood risk to vehicles noted above is very localised not considered significant.

- Construction phase works may result in impacts to flooding mainly due to temporary stockpiles, safety barriers (e.g. concrete F-type barriers) and other elements being located within overland flow paths or flood storage areas. Impacts could also potentially occur if drainage systems are temporarily decommissioned for any reason. This shall be considered within the development of the construction management plan following detailed design.

- The two identified construction compound sites are outside of the main identified flow paths and temporary works on these sites are unlikely to cause flooding impacts due to shallow depths of flow.

### 9.2 Recommendations

- Flooding impacts should be reassessed at future design stages to assess the impacts for both operational and construction stages of the proposal, as refinements to the road and drainage designs are expected to change the predicted flooding impacts. Flood risk to vehicles should also be reassessed and the design adjusted to provide safe flow conditions for vehicles if possible.

- Stormwater survey received from ongoing site investigations should be reviewed against the stormwater data incorporated in the baseline TUFLOW model, and any necessary updates made to the TUFLOW model for both the baseline and design case scenarios.

- The identified mitigation measures should be reviewed and assessed to see if any adverse flood impacts noted in this report may be mitigated or removed.

- Flood impacts of the proposal on the probable maximum flood should be undertaken to assess any adverse flood impacts due to the proposal.

- Any residual flood impacts to properties after implementing feasible mitigation works should be quantified at future stages. Floor level survey data may be collected to quantify impacts to above-floor flooding of adjacent properties.

- Construction management plans should consider the potential impacts of temporary construction works including trenching, solid traffic barriers and stockpiles on overland flows and incorporate appropriate management measures to address these issues. Flood modelling of temporary construction scenarios be undertaken where it is considered that the construction phase works may materially impact flood behaviour.

### References


Appendix A

Baseline Case Flood Mapping
Appendix B

Design Case Flood Mapping
Legend

- Model Boundary
- Low Hazard
- High Hazard
- Proposal Area

Flood Hazard

- Dacey Avenue
- Lachlan Street
- South Dowling Street
- Bourke Street
- Elizabeth Street
- Botany Road
- Fountain Street
- South Dowling Street
- Bourke Street
- John Park Road
- Bowden Street
- Euston Road
- Joynton Avenue

Client: Roads and Maritime Services

Project Title: Alexandria to Moore Park Connectivity Upgrade - Stage 1

20% Detailed Design Case 2% AEP
Flood Hazard

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PO Box 76 Millers Point, Sydney NSW 2000
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www.arup.com

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Issue Date: 22-11-2019
By: MWB
Appd: IVS
Chkd: [ ]
Legend

Flood Hazard

- Model Boundary
- Low Hazard
- Proposal Area
- High Hazard

 Alexandrina to Moore Park Connectivity Upgrade - Stage 1

20% Detailed Design Case 1% AEP

Flood Hazard

Client: Roads and Maritime Services
Legend

<table>
<thead>
<tr>
<th>Change in Flood Level (m)</th>
<th>Color</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>&lt;-0.250</td>
<td>Blue</td>
<td>No Longer Flooded</td>
</tr>
<tr>
<td>-0.250 - -0.100</td>
<td>Light Blue</td>
<td>Newly Flooded</td>
</tr>
<tr>
<td>-0.100 - -0.050</td>
<td>Green</td>
<td>No Longer Flooded</td>
</tr>
<tr>
<td>-0.050 - -0.010</td>
<td>Light Green</td>
<td>Newly Flooded</td>
</tr>
<tr>
<td>-0.010 - +0.010</td>
<td>Yellow</td>
<td>No Longer Flooded</td>
</tr>
<tr>
<td>+0.010 - +0.050</td>
<td>Orange</td>
<td>Newly Flooded</td>
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<tr>
<td>+0.050 - +0.100</td>
<td>Dark Orange</td>
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<tr>
<td>+0.100 - +0.250</td>
<td>Red</td>
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<tr>
<td>&gt;+0.250</td>
<td>Brown</td>
<td>No Longer Flooded</td>
</tr>
</tbody>
</table>

Job Title: Alexandria to Moore Park Connectivity Upgrade - Stage 1
20% Detailed Design Case 5% AEP
Change in Flood Level

Client: Roads and Maritime Services

Scale: 1:7,300

Date: 22-11-2019

Issue: 1

Drawn by: GK
Checked by: MWB
Finalised by: IVS

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Job No: 248446
Figure No: Map 18
Coordinate System: GDA 1994 MGA Zone 56
Scale at A3
Figure Status: Draft
Change in Flood Level
Legend

Model Boundary
Proposal Area

Change in Flood Hazard
Was High
No Change
Now High

Roads and Maritime Services
Alexandria to Moore Park Connectivity Upgrade - Stage 1

30% Detailed Design Case 2% AEP Change in High Flood Hazard Area

Client: Roads and Maritime Services

Issue Date: 22-11-2019
Appd: GK, MWB, IVS

Scale: 1:7,500

GDA 1994 MGA Zone 56

0 300 600 900 Metres

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Figure Title
Alexandria to Moore Park Connectivity Upgrade - Stage 1
20% Detailed Design Case 2% AEP Change in High Flood Hazard Area

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Roads and Maritime Services

Issue Date
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20% Detailed Design Case 2% AEP Change in High Flood Hazard Area

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Figure Title
Alexandria to Moore Park Connectivity Upgrade - Stage 1
20% Detailed Design Case 2% AEP Change in High Flood Hazard Area

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Figure Title
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20% Detailed Design Case 2% AEP Change in High Flood Hazard Area

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Figure Title
Alexandria to Moore Park Connectivity Upgrade - Stage 1
20% Detailed Design Case 2% AEP Change in High Flood Hazard Area

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Issue Date
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Scale
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