Central Barangaroo

Infrastructure Report

Prepared for: Infrastructure NSW

Project No: SYD1104
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Creating great environments with great people

Project:	Central Barangaroo
Location:	Central Barangaroo Hickson Rd, Barangaroo NSW 2000
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Contents

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1. Report Summary

1.1 Summary of Proposed Infrastructure Connections

Service/Utility	Proposed Connection	
	Central Barangaroo	Public Domain
Stormwater	Drainage generally in westerly direction to Sydney Harbour via existing 600mm pipes, with notable quality management systems: • New rainwater harvesting for reuse in toilet flushing and public domain irrigation. • Active distribution via integrated treatment swale. • Overflow in new passively dispersed stormwater treatment zones	
Potable Water	Existing 300mm Sydney Water Main, Hickson Road	Proposed 250mm Sydney Water Main, Barton Street
Wastewater	Existing 375mm Sydney Water Sewer Main, Hickson Road	Existing 375mm Sydney Water Sewer Main, Hickson Road via Central Barangaroo
Recycled Water	Proposed new on-site filtration and disinfection equipment for irrigation	Proposed new on-site filtration and disinfection equipment for irrigation
Electrical	Existing Ausgrid 11kV network from City North Zone Substation	Existing Barangaroo Reserve 800A Supply
Telecommunication	Options from existing network providers on Kent St, Hickson Rd, Napoleon St.	N/A
Natural Gas	Existing capped 110mm LP 7kPa gas main, west Hickson Rd	N/A
Chilled Water	New stand-alone centralised Harbour Heat Rejection, 23MW.	N/A

2. Introduction

2.1 Acknowledgment of Country

We would like to acknowledge the Gadigal people who are the Traditional Custodians of this land. We would also like to pay respect to the Elders both past and present of the Eora Nation and extend that respect to all Aboriginal people.

2.2 Statement of Compliance with Director General's Requirements

This report addresses the following sections of the Director General's Requirements of Section 75W of the Environmental Planning and Assessment Act, 1979.

> Section 15 – Drainage and Stormwater

> Section 16 - Utilities

2.3 Introduction to Central Barangaroo

Central Barangaroo is located between the Barangaroo Reserve, Barangaroo South and the nearby historic suburbs of Miller Point and Walsh Bay and adjacent to Barangaroo Station. As Barangaroo's keystone project, Central Barangaroo will complete the sweep of city and foreshore experiences along the western waterfront of Sydney's CBD to become the vibrant civic and community heart of Barangaroo.

Central Barangaroo is proposed as a dynamic mixed-use foreshore precinct that draws together and integrates high quality foreshore public spaces with city living, next generation workspace, community and cultural uses, a bustling shopping and dining precinct, all easily connected to Sydney's new metro network.

Barangaroo Station will significantly improve access for visitors, residents, workers and shoppers alike and transform how people arrive in Sydney CBD and on the harbour foreshore. Central Barangaroo will connect seamlessly to the new metro station and create the new place to arrive in and experience the city.

Central Barangaroo comprises the remaining development blocks 5, 6 and 7 of the approved Barangaroo Concept Plan and Harbour Park connecting to the western harbour foreshore.

The Central Barangaroo Urban Design Report builds upon the key objectives and core principles of the SOM Master Plan Framework for Central Barangaroo to ensure the proposed built form creates an appropriately scaled visual transition between the natural setting and scale of Barangaroo Reserve and Nawi Cove, to the bustling, high rise central business district scale of Barangaroo South.

The recently completed Wulugul Walk now extends along the entire Barangaroo waterfront as a vital section of the 14km Woolloomooloo to Glebe foreshore walk. Central Barangaroo's Harbour Park will create a major western harbour public open space that seamlessly integrates with Wulugul Walk, to diversify and enhance the city's waterfront experience. To the south, Central Barangaroo will shape and activate Hickson Park as a city park and to the north, help create Nawi Cove as the new place to arrive in the city.

2.4 Proposed Modification to Barangaroo Concept Plan for Central Barangaroo (MOD 9)

To allow for development within the Central Barangaroo precinct and below Barangaroo Reserve, Modification 9 to the Barangaroo Concept Plan (MP06_0162 MOD 9) proposes:

1. An increase in total permissible GFA from 602,354 sqm to 708,041sqm, with the following within Central Barangaroo and Barangaroo Reserve:
   a) up to 116,189sqm of above ground GFA within Blocks 5, 6 and 7;
   b) up to 28,166sqm of below ground GFA within Blocks 5, 6 and 7;
   c) a minimum of 2,800sqm of Community uses GFA within Blocks 5, 6 and 7; and
   d) a minimum of 6,000sqm and up to 18,000sqm of Community uses GFA within the RE1 Zone of Barangaroo Reserve, to allow for future community / cultural facilities located in the Cutaway.

2. An increase in the overall provision of new public open space / public domain, including three new publicly accessible spaces within the development blocks and a new pedestrian bridge over Hickson Road.
3. Modifications to Barangaroo's movement network to redirect and reduce the impact of vehicular traffic and significantly improve pedestrian movement, safety, and amenity, including the removal of vehicular traffic from Block 5 and 6 and the extension of Central Barangaroo's Harbour Park.
4. Modifications to the Central Barangaroo building envelope that allow for greater variation in building heights across Blocks 5, 6 and 7 to enable building form, massing and modulation that is responsive to context and adjusts the development boundary for Block 5.
5. Introduction of Design Guidelines for Central Barangaroo.
6. Consequential amendments to the State Significant Precincts SEPP.
7. Revisions to the Barangaroo Concept Plan Statement of Commitments.

2.5 Central Barangaroo - Proposed GFA and Maximum Building Heights

The existing and proposed GFA and maximum building heights for each Barangaroo development block, comprising Barangaroo South, Central Barangaroo and including Barangaroo public domain (RE1), are tabulated below:

Precinct and Block	Total GFA (Max) (sqm)	Residential GFA (Max) (sqm)	Height (m) (Max AHD)	Height above existing ground level (m)
BARANGAROO SOUTH - Existing				
Block 1	1,927	0	RL 25	23
Block 2	197,280	0	RL 180	178
Block 3	129,934	10,515	RL 209	207

Precinct and Block	Total GFA (Max) (sqm)	Residential GFA (Max) (sqm)	Height (m) (Max AHD)	Height above existing ground level (m)
Block 4A	92,629	91,816	RL 250	248
Block 4B	21,508	20,637	RL 107	173
Block X	18,908	16,463	RL 41.5	39.5
Block Y	77,500	22,600	RL 275	273
Barangaroo South subtotals	539,686	162,031		
CENTRAL BARANGAROO - Proposed				
Blocks 5, 6 and 7 above ground	116,189	28,000	Block 5 & 6: RL44.5 Block 7: RL73.7	Block 5 & 6: 42.0 Block 7: 71.2
Blocks 5, 6 and 7 (below ground)	28.166	0	n/a	n/a
Blocks 5, 6 and 7 subtotals	144,355	28,000		
COMMUNITY AND ACTIVE USES (RE1)				
Community uses (in the Cutaway, located below the Barangaroo Reserve RE1 Zone)	18,000	0	n/a	n/a
Active uses in the RE1 Zone	5,000		RL 25	23.0
Community uses in the RE1 Zone (Central Barangaroo and Barangaroo South)	1,000		RL 25	23.0
Community and active uses subtotals	24,000			
BARANGAROO CONCEPT PLAN TOTAL	**708041**			

NOTE: The currently approved Barangaroo Concept Plan defines Community uses and Active uses as follows:

> Community uses include child care centres, community facilities, educational establishments, entertainment facilities (other than cinemas and amusement centres) information and education facilities, landside ferry facilities, places of public worship, public administration buildings, public halls, recreations areas, recreation facilities (major, outdoor and indoor) and health services facility;

> Active uses include café kiosks, retail kiosks, pavilions, ferry ticket office, public convenience (toilet facilities) and small equipment storage spaces and the like.

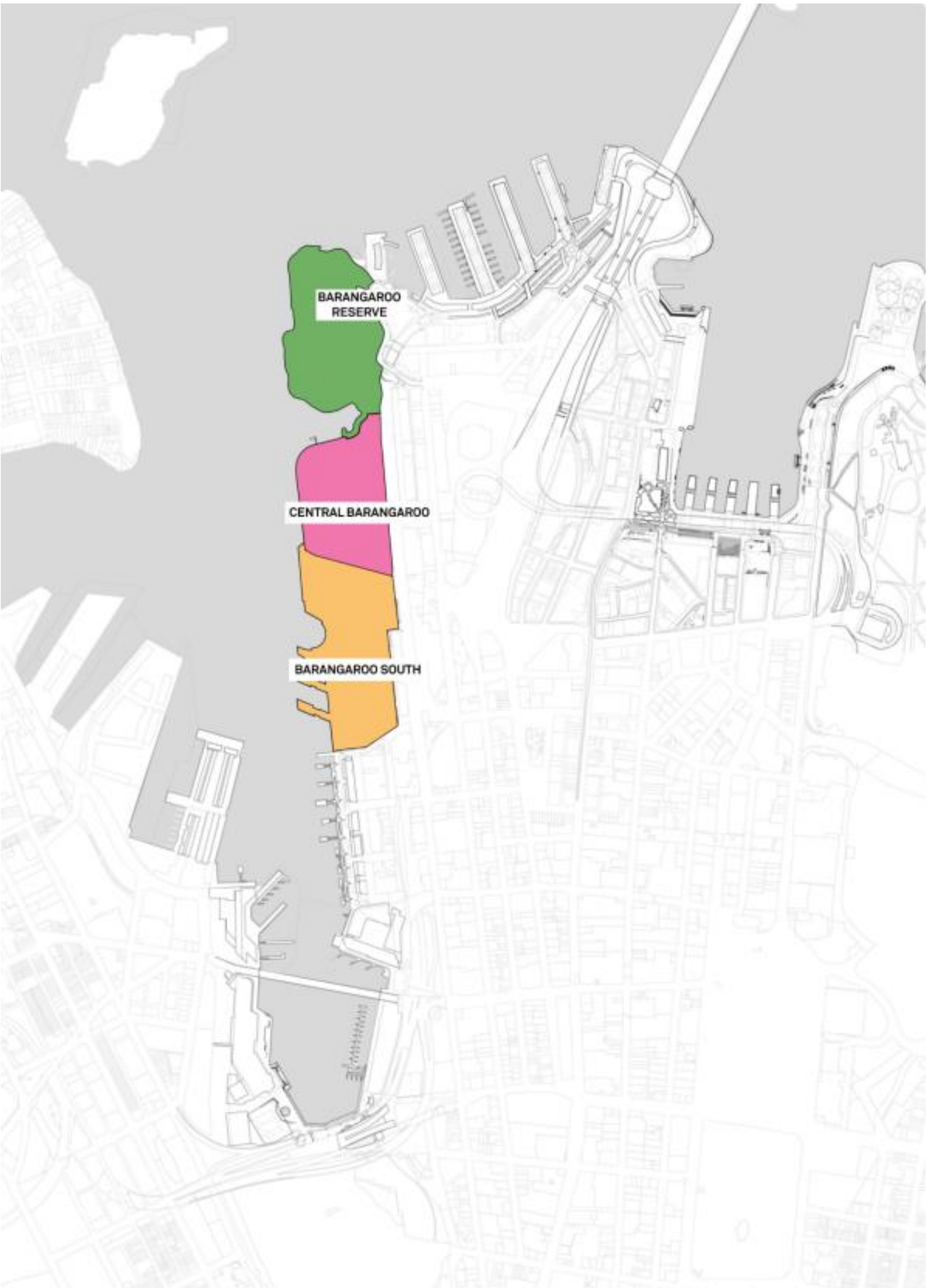


Figure 1a: Barangaroo precincts map

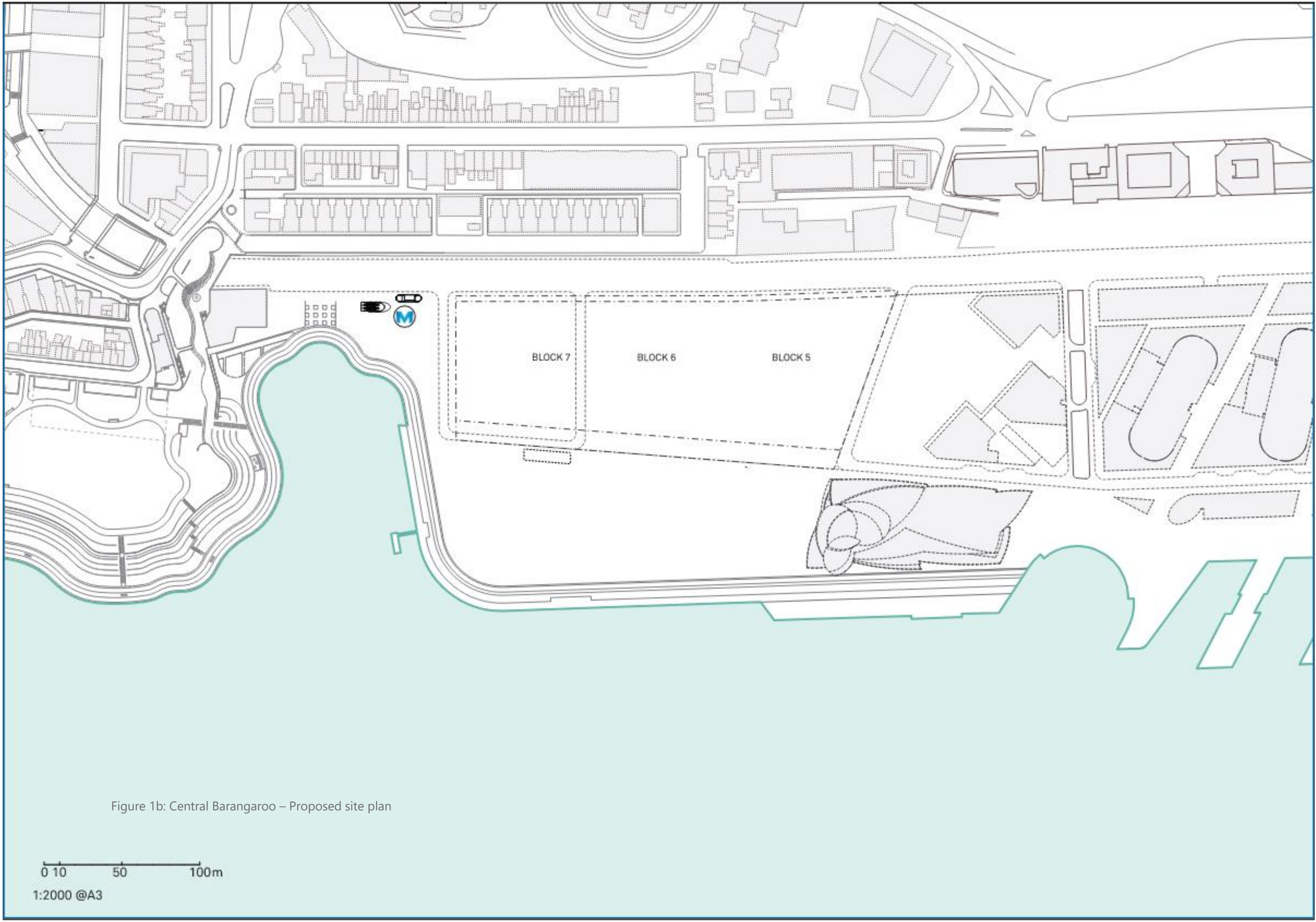


Figure 1b: Central Barangaroo – Proposed site plan

3. Integrated Water Management

3.1 Sustainability Vision

The Sustainability Vision for Central Barangaroo is to be "a globally recognised exemplar in sustainable urban development delivering positive outcomes for climate, water, nature and people, both now and in the future."

The project will:

- Complete and enhance the NSW Government's vision for Climate Positive outcomes for the whole Barangaroo Precinct.
- Deliver measurably positive outcomes for Carbon, Water, Nature and People during design, construction and operation.
- Provide industry leadership through practical and innovative solutions that, through their replicability, have the potential to deliver market transformation in Australia and globally.
- Deliver value to all stakeholders through the application of a whole-of-life approach.
- Provide resilience to shocks and stresses in the face of an evolving and changing future

3.2 Sustainability Strategy Structure

To deliver the vision, the design, construction and operation of Central Barangaroo will be guided by the Central Barangaroo Sustainability Strategy (CENSuS) which will provide an overarching framework for all sustainability aspects of the development.

3.3 Sustainability Strategy Alignment

The CENSuS will support achieving Infrastructure NSW (INSW)'s core sustainability commitments for the Barangaroo precinct (Carbon Neutral, Water Positive, Zero Waste emissions and Community Wellbeing) and align with the following:

- UN Sustainable Development Goals.
- The Green Building Council of Australia's seven megatrends in sustainability
- City of Sydney's Sustainable Sydney 2030 strategy
- Planning Priority E19 of the Eastern City District Plan
- Other relevant plans and policies

Further to this, the City of Sydney's Development Control Plan (DCP), which provides detailed planning and design guidelines, is applicable to the Central Barangaroo development. The DCP's IWMS objectives are as follows:

- Ensure an integrated approach to water management across the City through the use of water sensitive urban design principles.
- Encourage sustainable water use practices.
- Assist in the management of stormwater to minimise flooding and reduce the effects of stormwater pollution on receiving waterways.
- Ensure the development manages and mitigates flood risk and does not exacerbate the potential for flood damage or hazard to existing developments, Metro Train Station and to the public domain.

- Ensure that development above the flood planning level as defined in the Sydney LEP 2012 will minimise the impact of stormwater and flooding on other developments and the public domain both during the event and after the event.
- Ensure that flood risk management addresses public safety and protection from flooding.

3.4 Integrated Water Management Strategy

Central Barangaroo's hydraulic and civil design will incorporate exemplary water efficiency and conservation. The following initiatives have been identified as integral components of the IWMS:

- Best practice in demand reduction, water efficiency, metering and controls to reduce the water footprint of the buildings and the precinct.
- Harbour heat rejection avoiding water consuming heat rejection equipment such as cooling towers.
- Climate-appropriate landscaping and water sensitive irrigation techniques.
- Rainwater from non-trafficable roofs to be collected separately and used for irrigation and other non-potable uses.
- All stormwater leaving the site to comply with DCP stormwater pollution reduction targets.
- Best practice Water Sensitive Urban Design principles will be applied, including raingardens and biodiverse swales, where appropriate, to treat stormwater run-off
- Recycled water reticulation infrastructure for all non-potable water uses connected to on-site and off-site recycled water supply infrastructure.
- Investigate options to invest in regional water projects (similar in principle to carbon offsets and biodiversity offsets) to support water infrastructure in water stressed areas of regional NSW.

Based on the overarching water conservation and efficiency strategy, preliminary water balance modelling has been completed for the project.

4. Stormwater

4.1 Stormwater – External Catchments

4.1.1 Overview

Delineation of external catchments has been based on TfNSW contour data, and a site survey issued by Rygate Surveyors.

The external catchments and the impact of any drainage flows from these catchments are to be separated from the internal catchments of Central Barangaroo. These external catchment flows need to be diverted around the Central Barangaroo development.

The external drainage system needs to cater for all flows up to and including the 1 in 100 year ARI event for the associated catchments.

The external catchments directly impacting on Central Barangaroo can be broadly defined by two main catchments, identified within this report as Kent Street and Hickson Road catchments. There are five existing Ø600 mm pipe networks within the project boundary that currently convey stormwater drainage from the High Street area, Hickson Road, and Central Barangaroo through Central Barangaroo directly into Sydney Harbour. These existing pipe networks in Hickson Road within the Metro Station box area have been removed (in part) and replaced by an alternative stormwater drainage diversion system as part of the Barangaroo Station works.

4.1.2 External Catchment – Kent Street

This external catchment area draining from Kent Street, east of the site, is approximately 4.5 hectares. It is characterised by residential areas and road reserves and flows towards Hickson Road. Stormwater drainage from the external Kent Street catchment is to be diverted around the Central Barangaroo site and discharge into the existing 1050mm pipe outfalls north west of Central Barangaroo into the harbour.

4.1.3 External Catchment – Hickson Road

The external catchment area adjacent to the site in Hickson Road, approximately 0.92 hectares, is to be diverted to an external pipe network, which with the Kent Street catchment which in principle will discharge north west of Central Barangaroo into the harbour.

As part of the Metron Stage 3 Design for Hickson Road, GRC Hydro, in conjunction with Warren Smith & Partners have undertaken a flood modelling exercise, which includes the stormwater drainage strategy for Hickson Road. The flood modelling takes into account the proposed raising of Hickson Road on the west up to RL of 3.50m.

The Flood Study includes a proposed drainage system comprises of several parallel stormwater lines with varying pipes sizes running north along Hickson Road. The drainage system starts adjacent to the High Street steps and augments up to twin Ø900 and twin Ø600 stormwater pipes. The eastern drainage lines cross Hickson Road to the north of Barangaroo Station before converging into 2 x Ø1050 stormwater pipes and finally discharging into the southern corner of Nawi Cove.

On this basis it is assumed that any upstream catchment including Hickson Road catchment is discharging to the north within the Hickson Road road reserve and is not impacting or passing through the Central Barangaroo site. In the event that the stormwater drainage in Hickson Road is not constructed prior to Central Barangaroo basement excavation works, stormwater will be temporarily diverted around the site during construction.

A further flood model assessment has been undertaken by GRC Hydro to assess the impact of Barangaroo Station, Hickson Road Stage 3 Design dated June 2021. Although the report does not consider the Central

Barangaroo post development condition the report indicates that for the ultimate Hickson Road north design there is minimal impact on the Central Barangaroo site.

4.1.4 Barangaroo Station Stormwater Diversion Works

As part of the Barangaroo Station works, a temporary drainage system has been installed which has been noted to accommodate the 1 in 20-year storm event. There are no documented details of the management of the 1 in 100-year storm event. This stormwater diversion is temporary and will be removed by Sydney Metro after completion of the Metro Tunnelling and Stations Excavation Project.

The temporary Barangaroo Station stormwater drainage system shows the diversion of a number of existing stormwater pipes passing west under Hickson Road. The stormwater has been diverted into a Ø900mm stormwater pipe network located on the eastern side of Hickson Road. The stormwater pipe runs to the North, past Barangaroo Station before crossing to the West across Hickson Road and connecting back into the existing 600ømm stormwater network which discharges into the Harbour.

4.2 Stormwater – Central Barangaroo

4.2.1 Design Objectives

Stormwater drainage for Central Barangaroo is to comply with requirements specified in the City of Sydney Development Control Plan (DCP), and the City of Sydney Interim Floodplain Management Policy and designed so rainfall runoff from and across the site are safely and effectively managed and treated by appropriately sized drainage systems.

4.2.2 Internal Catchment Areas

Due to the proposed locations of internal roads and the public domain (catchment approx. 3.26 ha), the Central Barangaroo development site will be divided into three internal sub-catchments. These are loosely defined by the proposed locations of the three development Blocks 5, 6, and 7. The drainage strategy for the internal catchment areas is for stormwater to be drained independently of the external catchment areas in accordance with City of Sydney's Development Control Plan, and City of Sydney Interim Floodplain Management Policy.

The internal drainage strategy will make use of the 5 existing pipes and outlets that currently discharge directly into the Harbour. Central Barangaroo rainwater and stormwater runoff will be either captured and recycled or discharged directly towards the harbour in a westerly direction following appropriate treatment as required and is therefore not reliant on the north western pipe outfalls or Hickson Road drainage systems.

4.2.2.1 Internal Catchment 1 – Block 7

Internal Catchment 1 is bound by Hickson Road to the east, the harbour foreshore to the north, and the public open space to the west. The development consists of a multiple buildings of varying heights. The total area of Internal Catchment 1 is 0.76 ha.

4.2.2.2 Internal Catchment 2 – Block 6

Internal Catchment 2 is bound by Hickson Road to the east, Block 7 to the north, and the public open space to the west. The development consists of a single building with varying heights. The total area of Catchment 2 is 0.67 ha.

4.2.2.3 Internal Catchment 3 – Block 5

Internal Catchment 3 is bound by Hickson Road to the east, Block 6 to the north, and the public open space to the west. The development consists of a single building of varying heights. The total area of Catchment 3 is 1.28 ha.

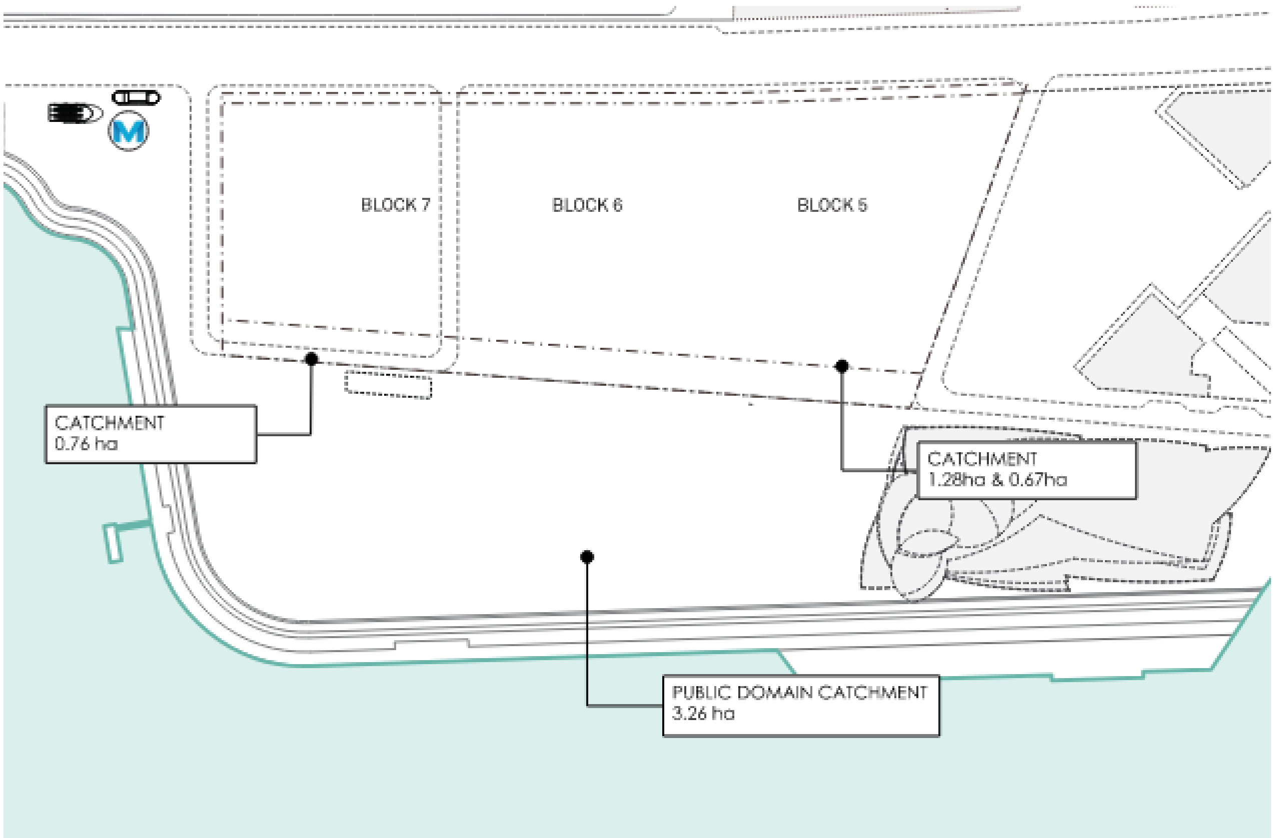


Figure 2 – Internal Catchments

4.2.3 Proposed Building Ground Floor Levels

The ground floor level for the development for blocks 5, 6 and 7 will need to reflect the flood modelling report undertaken by INSW on the Hickson Road upgrade. Hickson Road western carriageway will be raised to facilitate access into the buildings' basements and also DDA compliant access for all pedestrian access into the development.

Flood modelling from GRC on the Hickson Road upgrade – Barangaroo (Reference Appendix A for an extract of this report) has found the peak flood level in the PMF event (including sea level rise predictions) varies from 3.5m AHD on the Northern most point of the Central Barangaroo development to 3.6m AHD at the High Street steps. Central Barangaroo Master plan minimum finish floor levels reflect PMF flood levels indicated in the Hickson Road flood study. Refer Figure 3 for post-development PMF flood map for reference.

Figure 3 – Extract from GRC Flood Report (August 2020) - Post-development PMF flood depths

4.2.4 Stormwater – Proposed

The proposed Central Barangaroo stormwater drainage design considers site catchment and overland flows from within the Central Barangaroo (including public domain) only. We therefore assume that all external catchments (including Hickson Road), all overland flow, and flood impact from external catchments is being directed around Central Barangaroo site as part of the wider precinct infrastructure upgrade works. On this basis, the stormwater drainage design for Central Barangaroo will be independent from and not interface with any future Hickson Road upgrades or Barangaroo Station infrastructure works.

The stormwater drainage design includes a conventional gravity system for the collection of all rainwater from roofs, podium hardstand areas, laneways and roads, carpark areas, roads, landscaped areas and terraces within the development. The internal road ways and hardstand areas are designed to protect the site from upstream catchment in the PMF event as well as allow for overland flow from within the site to discharge in a westerly direction. Stormwater from Central Barangaroo will either be captured for re-use in line with the overall Integrated Water Management Principles or discharge in a westerly direction with the public domain drainage to the harbour, through the series of existing 600mm diameter pipes, which will be replaced or augmented as required subject to a condition and capacity assessment of the existing outfall drains. The Central Barangaroo stormwater drainage and treatment systems located within the Public Domain, will be subject to titling arrangements, and will require easements or right of access.

4.3 Stormwater Quality Management

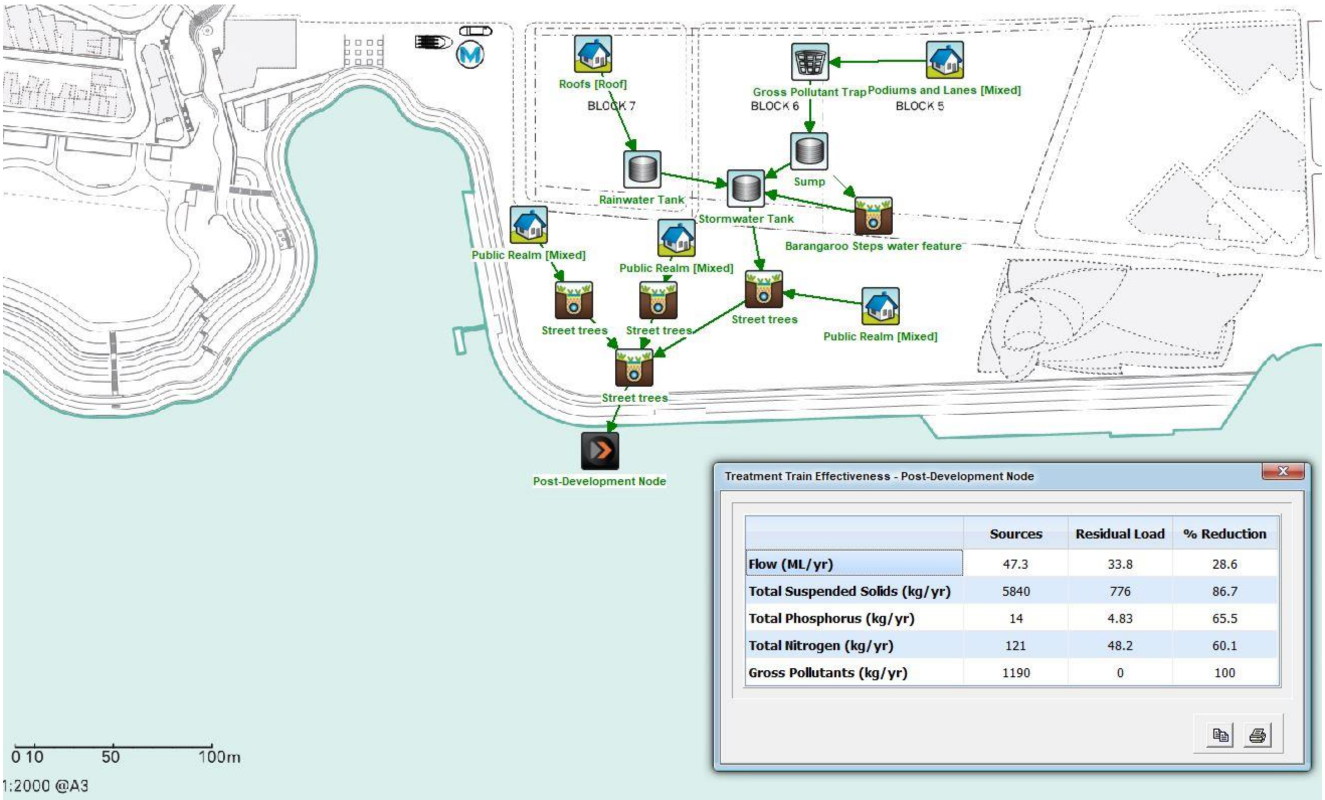
4.3.1 Design Objectives

Stormwater treatment for Central Barangaroo will comply with the City of Sydney's Development Control Plan (DCP) stormwater pollution reduction targets as indicated in table below.

Table 1. City of Sydney DCP stormwater treatment targets.

	% reduction of baseline annual load
Water Quality Parameters	**City of Sydney DCP Targets***
Total Suspended Solids (TSS)	85%
Total Phosphorus (TP)	65%
Total Nitrogen (TN)	45%
Gross Pollutants (> 5 mm)	90%

** City of Sydney. (2012). Development Control Plan. Section 3. December 2012*



	Sources	Residual Load	% Reduction
Flow (ML/yr)	47.3	33.8	28.6
Total Suspended Solids (kg/yr)	5840	776	86.7
Total Phosphorus (kg/yr)	14	4.83	65.5
Total Nitrogen (kg/yr)	121	48.2	60.1
Gross Pollutants (kg/yr)	1190	0	100

Figure 4 - MUSIC model for the preliminary treatment strategy for the site

4.3.2 Water Sensitive Urban Design Constraints and Opportunities

The public domain includes landscaped areas, engaging water features, and a waterfront promenade connecting the project to the harbour. This maximises the visual and recreational amenity of the development and provides opportunities for incorporating vegetated Water Sensitive Urban Design (WSUD) elements.

4.3.3 WSUD Design

Refer to Central Barangaroo proposed stormwater reticulation path for high level indicative stormwater flow path diagram and MUSIC model diagram with indicative WSUD strategy.

The preliminary stormwater treatment strategy achieves a high level of treatment, complying with the DCP stormwater pollution reduction targets. The treatment strategy includes:

> Rainwater harvesting from building roofs, and stormwater collection from podium hardstand and laneways/roads, with reuse for toilet flushing and public domain irrigation. Preliminary modelling indicates that the site will be capable of harvesting and re-using up to 8ML per annum based on historical rainfall data. It is estimated that 15 ML of irrigation water will be required for the public domain.

> Active distribution of collected stormwater through integrated treatment swale and water features.

> Overflow from the rainwater collection system combined with low flow runoff from the public domain passively dispersed through a series of stormwater treatment zones across the public domain (tree pits and raingardens).

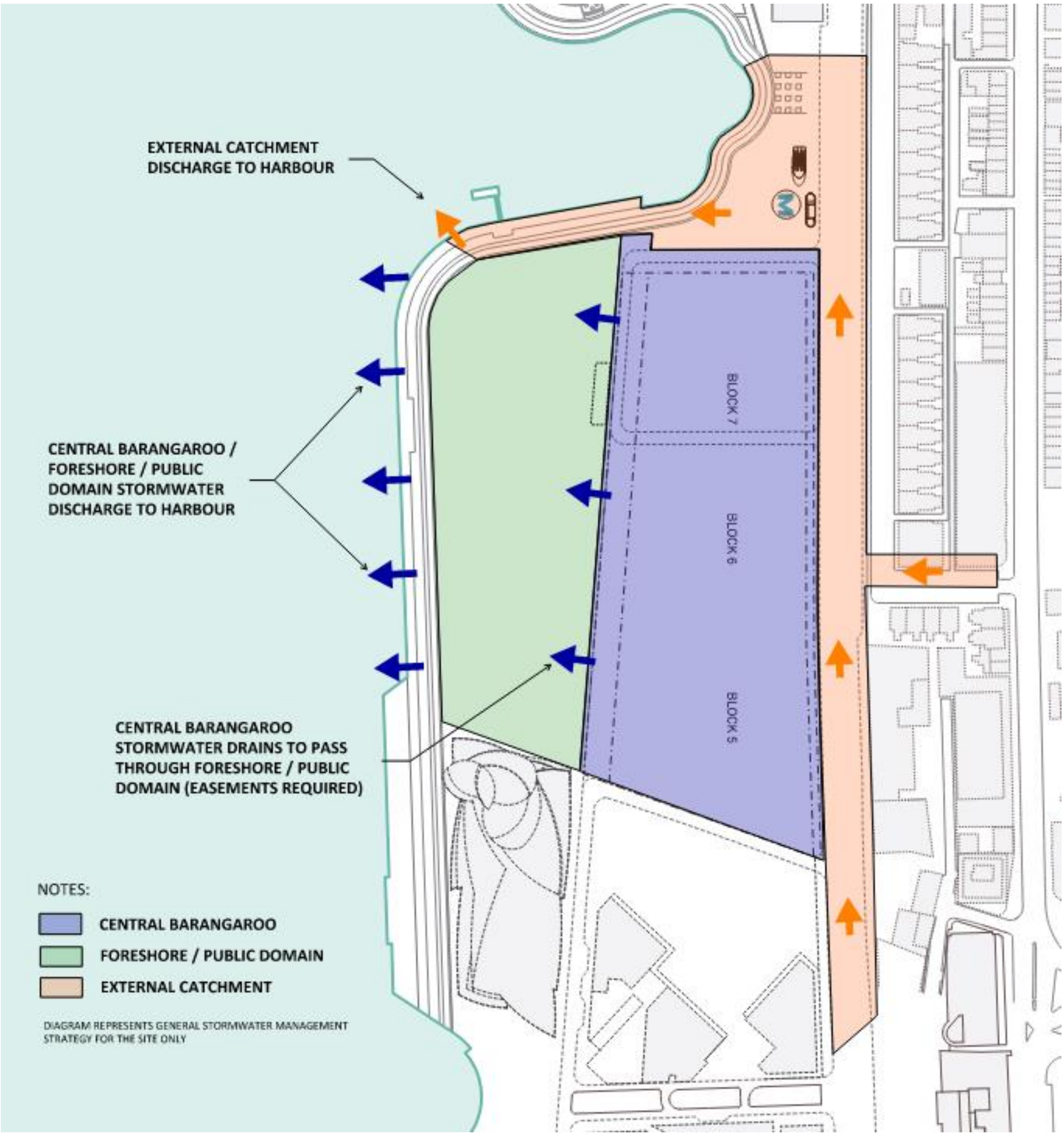


Figure 5 – Catchment drainage strategy for the site

4.4 Climate Change Considerations

The most recent State of the Climate report by CSIRO and the Bureau of Meteorology (2020)[1] provides a summary snapshot of the projected climate trends both globally and Australia wide. Climate trends include temperature, rainfall, and extreme weather events. The report states that there has been a significant decrease in growing season rainfall and significant drying in the southeast of Australia.

[1] CSIRO, & Bureau of Meteorology. (2020). State of the Climate 2020.

Rainfall in the southeast of Australia for the 20-year period 1996-2015 has been seen to decrease by 11 percent since records began in 1900. Since 1996, this steady decline from the long-term average has increased to around 25 per cent.

In addition to the extended dry periods and lower overall rainfall, more frequent extreme weather events have been seen and are predicted to continue to increase. Monsoonal weather patterns in northern Australia have been very much above average and in the southeast, the current one in 100-y extreme storm surge could be occurring around every five years by the year 2070 (http://www.ces.vic.gov.au/soe/climate-change).

It will be critical that the predicted increases in peak flows, storm surge, and seas level rise across the site are accommodated within the civil and stormwater design for Central Barangaroo. This will be achieved through careful consideration of appropriate flood levels and a factor of safety above the design flood levels (freeboard), and allowance within onsite detention and storage systems.

The potential impacts of climate change on the project are being addressed through:

- Installing site stormwater discharge points at a level to allow gravity discharge of stormwater to the Harbour;
- Design of stormwater systems to incorporate partial inundation from tide flows;
- Specification of materials to marine grade to prevent accelerated degradation;
- Use of tidal flaps on stormwater discharge points;
- Employing overland flow paths across the site to retain flow above the ground as much as possible and enabling runoff drainage even if discharge points are inundated; and.
- Employing a range of water sources such that sole reliance is not placed on rainwater or stormwater collection for use in the development.

5. Potable water

5.1 Potable water – Existing

A Sydney Water 300mm potable water main currently resides on the western side of Hickson Road at the south end of the site, and as part of the Barangaroo Station works has been recently redirected to the eastern side of Hickson Road around the Barangaroo Station box excavation.

5.2 Potable water – Proposed

It is proposed that Central Barangaroo will be supplied with potable water from the existing 300mm diameter Sydney Water main in Hickson Road (subject to confirmation and assessment by Sydney Water).

It is highlighted that the original water supply scheme identified three separate water supply tapping locations to service each of the blocks within Central Barangaroo. As part of the revised masterplan the water supply tapping locations will need to be adjusted to suit based on layout, staging and titling arrangements - refer to Appendix B.

The potable water demands for the project comprise all indoor uses, except toilet flushing and will be reticulated throughout the site for connection to each area of the site, including residential, commercial and retail.

As part of the Barton Street works, Sydney Water records indicates a proposed 250mm potable water supply to be reticulated on the southern side of Barton Street. It is proposed that a separate water supply tapping is made to this water main to provide the Public Domain potable water supply.

Metro/INSW has provisioned for connection points to the Sydney Water potable water main at Streets C & D as part of the Hickson Road north upgrade. This is shown is Metron's Stage 3 Design drawing SMCSWSBR-MET-SBR-CE-DWG-014004.

6. Wastewater

6.1 Wastewater – Existing

Sydney Water 225mm gravity and 375 GRP (Glass Reinforced Plastic) sewer drainage infrastructure are located within Hickson Road and discharge to an existing Sydney Water Sewer Pump Station (SPS1129) located within the Central Barangaroo site. Sewage that is received at this pump station is then pumped through a DN400 rising main that discharges into a sewer oviform that runs along Kent Street to the Bondi Sewage Treatment plant. The existing pump station serves catchments extending to Sussex Street and Kent Street. There are ongoing discussions with Sydney Water to integrate the existing pump station with the Central Barangaroo Development and relocate SPS1129 to the basement level of block 5

Updated Barangaroo Station records show a proposal to redirect the existing 225mm authority sewer from the west to the eastern side of Hickson Road to avoid station works. These changes will remain after completion of the Metro Tunnelling and Barangaroo Station's Excavation Project.

6.2 Wastewater – Proposed

Recycled water infrastructure will be provided for non-potable uses to reduce the demand for potable mains water. Recycled water will be generated, imported and/or exported to support the Barangaroo Precinct's site wide strategy for Water Positive.

Three new gravity sewer connections are proposed Central Barangaroo which will discharge to the existing 375mm diameter Sydney Water sewer main in Hickson Road. The connections will be utilised as required to allow discharge during construction, commissioning and operation and to accommodate the required staging of the project – refer to Refer to Appendix B for indicative locations of the proposed sewer branch locations.

7. Recycled water

7.1 Recycled Water – Existing

There are no existing recycled water systems in Hickson Road or currently serving the Central Barangaroo Development.

7.2 Recycled Water – Proposed

7.2.1 Wastewater Recycling

Recycled Water will be generated, imported and/or exported in line with the overall Central Barangaroo Sustainability Strategy (CENSus).

The water will be treated in compliance with Australian Recycled Water guidelines, and recycled water infrastructure included within the design for all non-potable uses, toilet flushing and irrigation, to reduce the demand for potable mains water. Recycled Water supply infrastructure will be provided to the Public Domain for irrigation purposes.

The system will be designed and configured to support the overall IWMS for the site, with any excess Recycled Water generated available for export for offsite areas, such as the Barangaroo Reserve. Depending on rainfall, it is estimated approximately 17ML of irrigation water of appropriate quality is required annually for Barangaroo Reserve.

7.2.2 Rainwater Harvesting

The Central Barangaroo concept design includes infrastructure that captures rainfall runoff from the building roofs, podiums, and the laneways and roads that surround each building. Rainfall from building roofs will be collected and stored separately from the podium and ground level runoff. Preliminary modelling indicates that the site will be capable of harvesting and re-using up to 8ML per annum based on historical rainfall data

Collected rainwater will be stored, treated, and made available for irrigation throughout the entire development, including the public domain. Water treatment infrastructure will include filtration and disinfection apparatus, designed to ensure a fit for purpose supply in line with local, state and national regulations.

8. Electrical

8.1 Electrical Drawing

The existing Ausgrid infrastructure along Hickson Road adjacent to Central Barangaroo is within the Metro station construction zone and is the subject of current Metro relocation works. The existing Ausgrid 11kV HV cabling and associated pit and duct network have been relocated to the eastern side of the road carriageway to enable construction of the new Metro station. The existing Ausgrid substation (S6062) in Barangaroo Headland Park as well as the temporary Metro supply kiosk substations (S77751 & S77752) are being maintained in service during the relocation works.

There is an existing 16-way duct line heading south from Barangaroo Reserve towards City North Zone Substation along Hickson Road from the Ausgrid pit 29572 at the park entrance.

As part of the remediation works to South Barangaroo, the existing Ausgrid HV conduits and cabling between existing Ausgrid pits 50268 (south) and 29572 (north) will be relocated and then reinstated in their original locations on completion of remediation works

The existing Ausgrid HV pits in Hickson Road will be retained as the proposed 11kV Triplex linkage supply points for Central Barangaroo.

Provided that Metro relocation work is completed prior to commencement of the HV works for Barangaroo Central, there will be no impact on the Central Barangaroo project.

The existing Central Barangaroo Foreshore lighting and power provisions are supplied from the existing Main Switchboard in the Barangaroo Reserve adjacent to Ausgrid substation S6062.

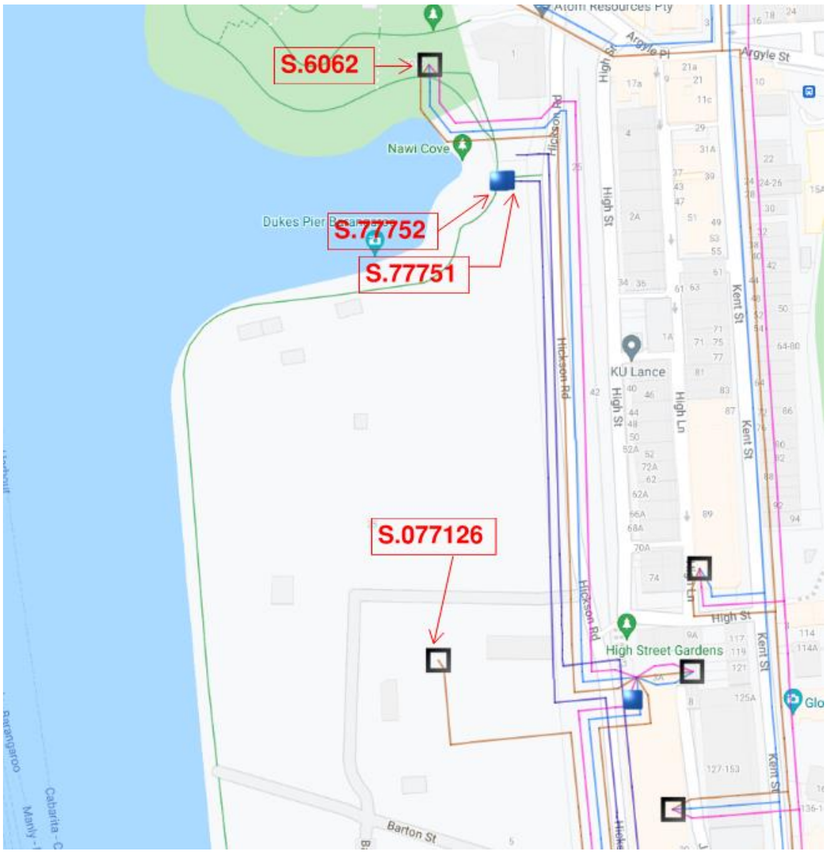


Figure 6 - Existing substations nearer the site (Ausgrid database, September 2021)

8.2 Electrical – Proposed

Electrical supply to Central Barangaroo is proposed to be connected to the existing Ausgrid 11kV network, where four CBD Triplex chamber substations are proposed to provide the necessary electrical capacity.

Ausgrid CBD electricity substations and transformers are proposed to be located within first level of the underground basement area and integrated within the buildings. Refer to the images below, indicating the four locations, at ground level, and indicative spatial area within basement 1 level.

Ausgrid owned assets will be maintained by Ausgrid and will require the establishment of lease-hold, easements and ROWs over the Public Domain and roadways for unimpeded HRV truck access to the substations from Hickson Road.

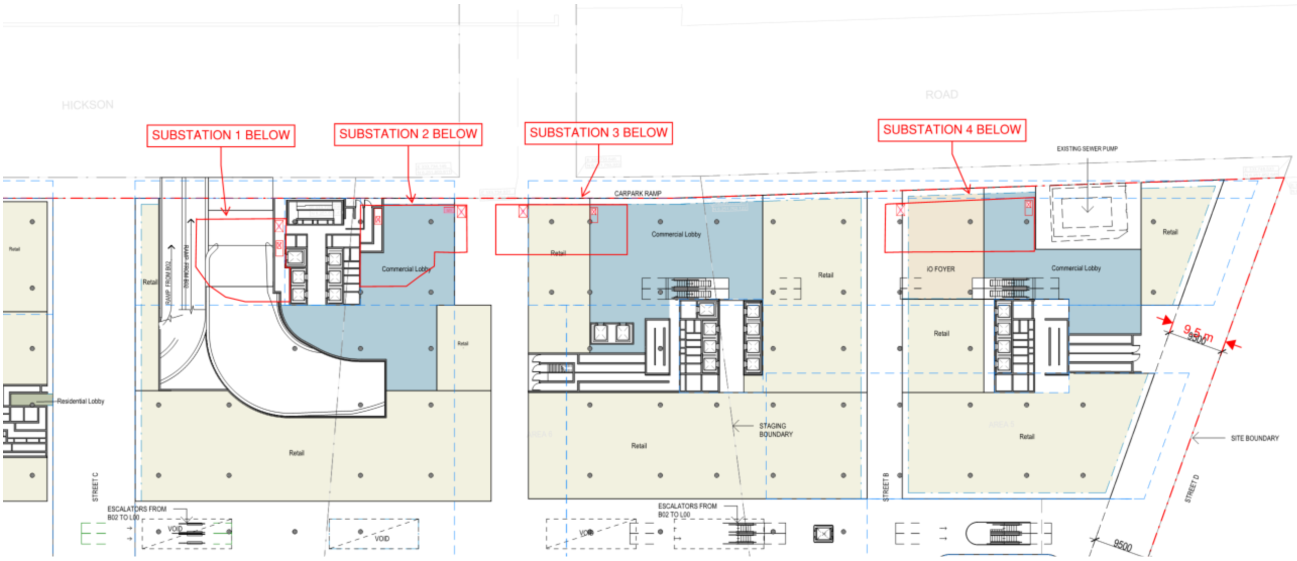


Figure 7 - Indicative substation locations (Indicative Ground Level Layout)

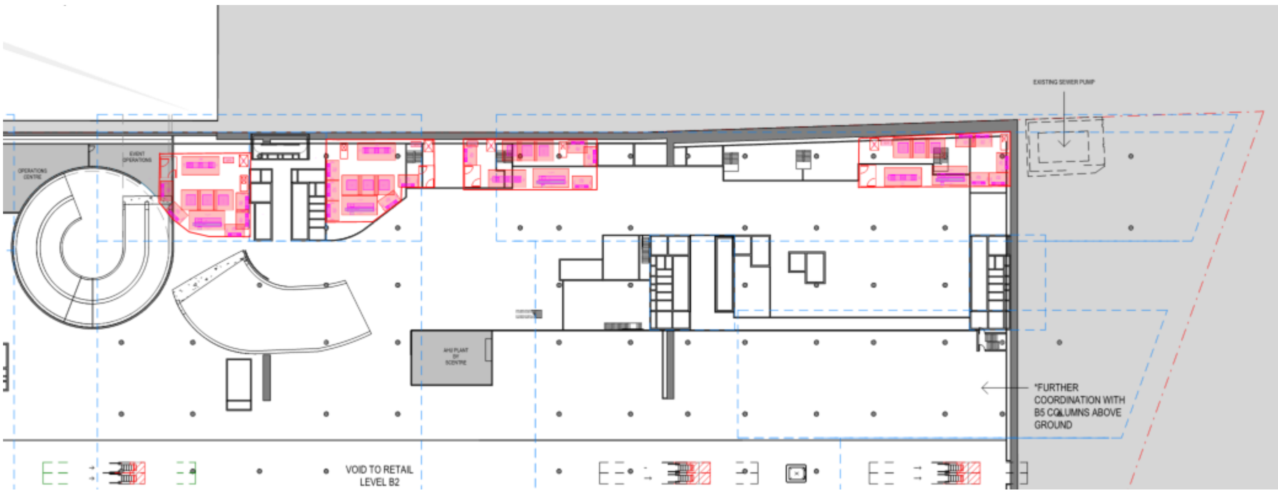


Figure 8 - Indicative substation locations (Indicative Basement 1 Layout)

The final arrangement of Ausgrid's Infrastructure will be subject to the Application for Connection to Ausgrid to commence a contestable design process to include the substations into the development. The electrical infrastructure concept will be detailed further throughout the design process, including each of the locations of all four substations.

An electrical load maximum demand assessment and planning for the HV connection point into the Ausgrid Hickson Road pits has been submitted to the electrical authority Ausgrid, and the details of the connectivity will be negotiated and agreed. Based on the currently proposed scheme, a preliminary maximum demand of 13800kVA has been calculated and submitted to Ausgrid. Updates to the maximum demand will be further coordinated with Ausgrid as the Central Barangaroo design develops. Notably, there are potentially seven HV feeders along Hickson Rd, that could provide the potential for connection of the Central Barangaroo site.

Electrical infrastructure planning to date has been based on preliminary discussions with Ausgrid for an 11kV Ausgrid supply from City North Zone Substation. There has been no consideration for integrating Central Barangaroo with the 33kV private HVC network supplying the Barangaroo South facilities.

The Public Domain will be supplied from the existing Barangaroo Reserve spare 800A supply which has a common service meter for consolidated electricity retailer billing.

On site, private embedded network cabling and Ausgrid 11kV CBD substations will be established to service the building and other site loads.

9. Telecommunication

9.1 Telecommunication – Existing

Several telecommunication service providers have existing cables adjacent to the subject site within Hickson Road. The following telecommunication services providers and their nearest located assets location are listed below:

> AARNet located within Kent Street
> NBN Co located within Kent Street
> NextGen located within Kent Street
> Optus located within Hickson Road
> UECOMM located corner of Napoleon and Kent St
> Telstra located along Hickson Road
  The Telstra Kent Street telephone exchange is also located relatively close to the site.
> Verizon located corner of Napoleon and Kent St
> Vocus located corner of Napoleon and Kent St

9.2 Telecommunication – Proposed

Sydney Metro has relocated telecommunications services within the Hickson Road Barangaroo Station Box Works area.

All telecommunication infrastructure existing within the development footprint is to be removed and capped off at the boundary.

As part of the Central Barangaroo development, the site may be supplied via NBN Co, any of the above listed existing telecommunications network provider within Hickson Road, or others Service availability and exact location of telecommunication services alignments will be detailed as design development is further progressed, subject to future planning applications and approvals.

10. Natural Gas

10.1 Natural Gas – Existing

A Dial Before You Dial (DBYD) search has identified that an existing 110mm low pressure 7kPa nylon gas main along the western side of Hickson Road.

10.1.1 TNSW Changes

A section of the existing 110mm gas line adjacent to Barangaroo Station has been decommissioned and capped off at the site footprint boundary and removed. Based on discussions with Jemena, Metro will reinstate the gas main in Hickson Road. Metro/INSW has provisioned for connection points to the gas main at Streets C & D. This is shown is Metron's Stage 3 Design drawing SMCSWSBR-MET-SBR-CE-DWG-014004

10.2 Natural Gas – Proposed

The aspiration of the precinct is to minimise the use of natural gas and maximise the use of alternative clean energy sources. To future proof the site a connection off the existing 110mm low pressure 7kPa nylon gas main service the Central Barangaroo development with a gas meter room proposed at ground level in Block 7. The gas supply will be metered and reticulated to each of the separable portions of the site in accordance with Jemena requirements.

10.2.1 Jemena and INSW Upgrades

The DBYD (14/02/2020) has identified future proposed works in Hickson Road in front of Central Barangaroo which indicates a new 32mm 7kPa Nylon gas main.

11. Chilled Water

11.1 Chilled Water – Existing

There are currently no chilled-water services or systems serving Central Barangaroo.

There is an existing centralised Harbour Heat Rejection (HHR) system which was constructed as part of the Barangaroo South development. The HHR plant and associated reticulation of chilled water within Barangaroo South is privately owned and operated and was approved in August 2013, as part of the project application for Blocks 1 to 3 basement excavation under, MP10_0023 MOD5.

11.2 Chilled Water – Proposed

As part of the Central Barangaroo development, it is proposed to construct a separate centralised HHR system to service the commercial, retail and residential developments of Central Barangaroo.

High efficiency water-cooled chillers will be located in the basement plantroom area, supplying 23MW of cooling capacity to Central Barangaroo.

It is proposed these chillers will operate in a series-counterflow arrangement, designed to maximise operating efficiencies and supply a wide range of chilled water (CHW) temperatures for different uses across the site.

Heat will be rejected from the chillers using sea water from Darling Harbour.

Six 650mm diameter condenser water pipes will reticulate in-ground between the basement central thermal plantroom and six existing pipe connections that were installed in the harbour seawall during the construction of South Barangaroo. These existing pipework connections will be lowered from their current height to enable the condenser water pumps to operate under positive suction.

Safe personnel access will be provided to the new harbour heat rejection plantroom via steps to be concealed and integrated into the wholistic landscape architectural design.

New low-velocity inlets and filters will be installed that prohibit local flora and fauna, such as fish, from entering the condenser water pipework.

Self-cleaning, high efficiency mussel filters will treat all condenser water to prevent mussel growth within the condenser pipework, pumps, and chillers.

Further details regarding the specifics of the proposed heat rejection system will be further developed and included with the relevant Stage 2 development application.

The proposed harbour heat rejection system is proposed to be standalone and shall be privately owned and operated within the Central Barangaroo precinct.

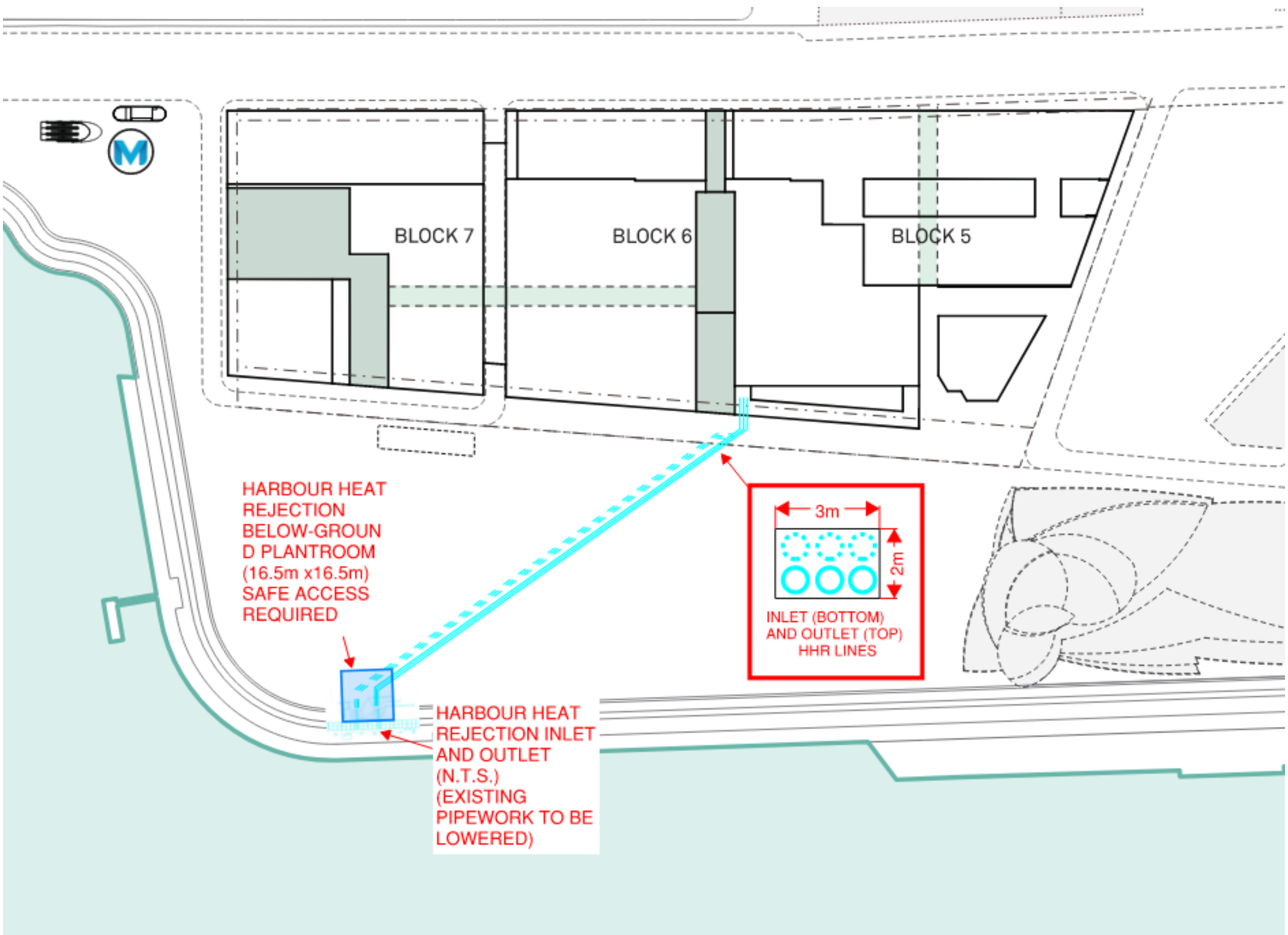


Figure 9 - Harbour Heat Rejection Pipework connection to Inlets and Outlets in Darling Harbour

12. Conclusion

This report has been prepared to outline the infrastructure strategy for the Central Barangaroo development to accompany the Section 75W Modification to the currently approved Barangaroo Concept Plan (Modification No. 9). The completed design will ensure adequate infrastructure provisions to the development.

There is commitment to undertake the necessary engagement and design arrangements with the relevant Authorities for the approval of services required to support the Central Barangaroo redevelopment. Relevant external agents, for example a Water Servicing Contractor, will be appointed as required during the detailed design of the development to support the relevant Stage 2 development applications.

ADP
Consulting : Engineering

Appendix A: Barangaroo South Flood Study

Barangaroo Station Civil Works

Hickson Road Stage 3 Design

DRAFT Report

June 2021

Barangaroo Station Civil Works
Hickson Road Stage 3 Detailed Design

Project:	Barangaroo Station Civil Works Flood Modelling Report
Project Number:	180038
Client:	Infrastructure New South Wales
Client Contact:	Peter Leong
Report Author:	Zac Richards / William Tang
Date:	18 June 2021

Prepared by: Zac Richards

Verified By: Stephen Gray

Date	Version	Description
16–June-2021	1	Draft Report for Internal Review
18–June-2021	2	Draft Report for INSW / Sydney Metro Review

Filepath: J:\180038\Admin\Report\METRON_Detailed_Design\R010621_BSCWHRS3D_Flood_Modelling_Report\R010621_BSCWHRS3D_Flood_Modelling_Report.docx

Cover Image: Infrastructure New South Wales

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EXECUTIVE SUMMARY

GRC Hydro have been commissioned by Infrastructure New South Wales (INSW) to undertake a flood assessment for the Barangaroo Station Civil Works, Hickson Road Stage 3 Design.

Flood Model Development

- Flood behaviour was assessed using an updated version of the Hickson Road Upgrade, Reference Design Flood Study (GRC Hydro 2019) flood model. Notable model changes include:
    - Updating the Reference Design applied Australian Rainfall and Runoff (ARR) 1987 methods and parameters to ARR2019 which is considered best practise;
    - Increased model resolution by reducing the grid cell size from 2 m to 1 m;
    - Updated topography in the upper catchment using LiDAR obtained in 2020;
    - Implementation of survey where available.
- Design flow estimates were compared to the Reference Design and were found to be comparable;
- Civil and stormwater design inputs were provided by METRON for inclusion in the flood model;
- Three scenarios were assessed, Pre-development conditions, 'Hickson Road North – Temporary Design' conditions, and 'Hickson Road North – Ultimate Design' conditions.
- The flood modelling assumes a design within the 'Hickson Road South' limit of works area for the 'Hickson Road North – Ultimate Design' conditions. As the design is not finalised for this region, flood model results are not provided within the 'Hickson Road South' limit of works.

Design Flood Modelling

- Flood behaviour for the 5% AEP, 1% AEP, and the PMF events were assessed;
- Climate change scenarios including increases in rainfall intensity (+10% and +RCP8.5) and ocean level rise (2100 projections) were assessed for the 1% AEP and PMF events;

Flood Impact Analysis

- Flood impact analysis was undertaken by comparing the 'Hickson Road North – Temporary Design', and 'Hickson Road North – Ultimate Design' to Pre-development Conditions;
- The 'Hickson Road North – Temporary Design' impact analysis found:
    - The 5% and 1% AEP events show reductions in the extent on flooding on Hickson Road due to increased stormwater capacity;
    - Some increases in level are noted in the area beneath the High Street sag, to the east of Hickson Road, however these are generally associated with a decrease in flood depth with little change in flood hazard;
    - A reduction in flood level for events up to and including the 1% AEP, relative to Pre-development Conditions, is expected at existing buildings at 30 and 38 Hickson Road.
    - During a PMF event, increases in flood levels, depths and hazard are expected near 30 and 38 Hickson Road. Flood level and depth increases of up to 0.4 m are noted, with potential increases in flood hazard by up to 3 categories (H1 to H4). These

impacts are not associated with the 'Hickson Road North – Temporary Design' works, and are instead due to construction of the Barangaroo Stage 1B development.

- The 'Hickson Road North – Ultimate Design' impact analysis found:
    - The 5% and 1% AEP events show reductions in the extent on flooding on Hickson Road due to increased stormwater capacity;
    - A localised area of increased flood hazard is noted beneath the High Street sag, to the east of Hickson Road, with a change from H1 to H2 categories. The increase in flood hazard to H2 is not expected to increase the flood risk as this area is not accessible to vehicles;
    - The flood impact mapping for the 1% AEP + Climate Change events (+10% rainfall and 0.9 m increase in sea level rise) shows reductions in the extent of flooding on Hickson Road due to increased pipe conveyance. Other flood impacts are similar to that presented for the 1% AEP event described above.
    - Flood levels near 25 Hickson Road are reduced for events up to an including the 1% AEP + 19.5% rainfall (RPC8.5) with 0.9 m increase in sea level rise;
    - 25 Hickson Road experiences a +0.048 m increase in flood level during the PMF;
    - Increases in flood depth and level are expected along Hickson Road, however, the limited change in flood hazard would not be considered to affect emergency vehicle access.

<u>Sydney Metro Requirements</u>

- The following Sydney Metro requirements are presented:
    - Flood mapping requirements outlined in technical memo 'SMCSWSBR-MET-SBR-IF-COR-000001';
    - PMF flood levels (considering 2100 projected sea level rise) adjacent to Sydney Metro station entrance locations are provided, as requested by METRON;
    - PMF flood characteristics were assessed for Barangaroo Reserve basement carpark entrances with the entrances found to be above the PMF (considering 2100 projected sea level rise), as requested by METRON. Mechanisms other than flooding, such as risks associated with existing stormwater reuse and internal drainage systems, may result in the ingress of water into the Barangaroo Reserve basement. <u>The assessment and management of these risks are the responsibility of Sydney Metro.</u>

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Appendix E Figures – Climate Change Conditions Flood Maps

Appendix F Figures – Hickson Road North Temporary Design, Flood Impact Maps

Appendix G Figures – Hickson Road North Ultimate Design, Flood Impact Maps

1. INTRODUCTION

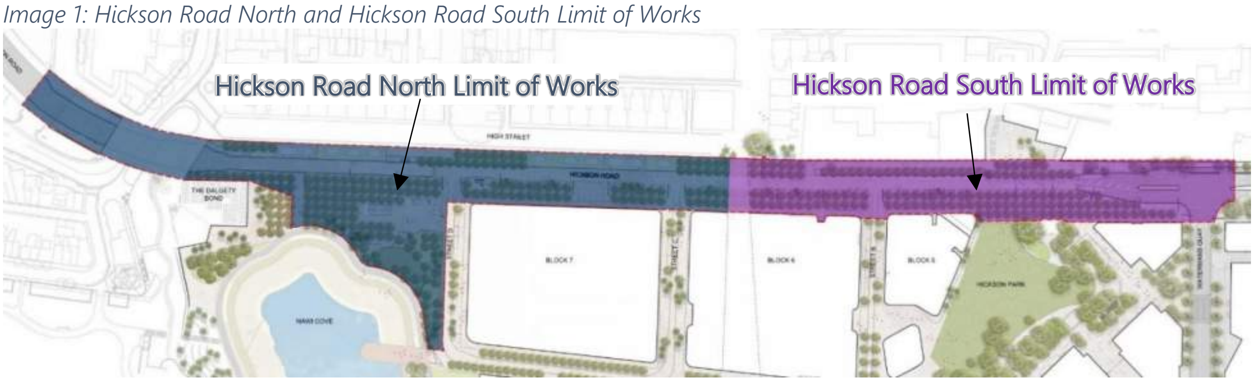
1.1 Overview

GRC Hydro was commissioned by Infrastructure New South Wales (INSW) to undertake a flood assessment for the Barangaroo Station Civil Works, Hickson Road Stage 3 Design prepared by METRON (the Designer).

The Barangaroo Station Civil Works, Hickson Road Stage 3 Design covers the area above and surrounding the Sydney Metro Barangaroo Station. The project limit of works comprises the northern portion of the 'Barangaroo Precinct', which has been divided into two areas, the 'Hickson Road North' Limit of Works and the 'Hickson Road South' Limit of Works (see Image 1).

This report (the Flood Report) and the flood modelling analysis presented herein assesses the Barangaroo Station Civil Works, Hickson Road Stage 3 Design which is situated within the 'Hickson Road North' Limit of Works area. Assessment of future works within the 'Hickson Road South' Limit of Works is not presented, as the design has not been finalised for this area.

Image 1: Hickson Road North and Hickson Road South Limit of Works



Source: Barangaroo Precinct Civil Design Report (DRAFT), Metron (June, 2021)

1.2 Description of the Project Works

The Barangaroo Station Civil Works, Hickson Road Stage 3 Design will be constructed prior to completion of the Central Barangaroo development and 'Hickson Road South' works. To facilitate construction staging, an interim design has been developed by the Designer, which aims to maintain trafficability of Hickson Road. Flood modelling has been undertaken for two development stages:

- 'Hickson Road North – Temporary Design' (called the 'Interim' design in provided design documentation, see Section 1.4), which aims to allow for the construction of Hickson Road within the 'Hickson Road North' limit of works, prior to construction of Central Barangaroo and 'Hickson Road South' works;
- 'Hickson Road North – Ultimate Design', which aims to provide future interface with the ultimate Central Barangaroo and Hickson Road South designs which are under development.

Features of the 'Hickson Road North – Ultimate Design' include:

- Barangaroo Station entrance, situated between Central Barangaroo and Nawi Cove;

- Barangaroo Station vents and emergency egress points situated in the verge between Hickson Road and the High Street wall;
- Alteration to the existing geometry of Hickson Road, with the western side of the road raised to ~3.3 mAHD (levels currently range from ~2.4 to ~2.8 mAHD) in order to better integrate with the Central Barangaroo Development and the Sydney Metro Barangaroo Station entrance;
- The western footpath situated between Hickson Road and Central Barangaroo which allows activation of Central Barangaroo by transitioning to a level of 3.45 mAHD along the Central Barangaroo boundary;
- Adjustment of Hickson Road north of Nawi Cove to suit traffic and urban design requirements;
- A cycleway bordering the eastern side of Hickson Road;
- Central Barangaroo Street D which is raised to a level of ~2.8 to ~3.4 mAHD and runs along the northern Central Barangaroo property boundary.

The 'Hickson Road North – Temporary Design':

- Batters down from the 'Hickson Road North – Ultimate Design' road levels to interface with existing ground levels at Central Barangaroo boundary;
- Provides a transition from the 'Hickson Road North – Ultimate Design' road alignment to meet existing road levels to the south of the project boundary.

1.3 Barangaroo Development Influence on Stormwater and Flooding

A summary of completed, approved and proposed works which influence stormwater and flooding outcomes for the Barangaroo Precinct include:

- The filling of land within the Barangaroo Development (Barangaroo Stage 1B and Central Barangaroo) to a level of ~3.5 mAHD to mitigate and comply with design requirements for projected future increases in sea level associated with climate change;
- Alteration to the existing geometry of Hickson Road, with the western side of the road raised to ~3.3 mAHD (levels currently range from ~2.4 to ~2.8 mAHD) to integrate with the Barangaroo Development;
- Proposed basements within the Barangaroo Stage 1B and Central Barangaroo development sites which restrict the potential for stormwater to pass through the sites to Sydney Harbour;
- Grading of Barangaroo Stage 1B, Hickson Park and Barton Street towards Hickson Road;
- Removal/diversion of existing stormwater by Sydney Metro (Tunnel Station Excavation contractor), which historically flowed through the Barangaroo Development site into Sydney Harbour;
- Raising of the Sydney Metro Barangaroo Station entrance (including vents and emergency egress points) above the level of the Probable Maximum Flood (PMF) assuming 2100 ocean level conditions;

- Positioning of the Metro Station Box under Hickson Road up to a level of 0.85 mAHD. Proposed road levels in this area are in the order of 2.5 – 3.5 mAHD. Due to vertical spatial limitations, invert level, size and available slope of stormwater is significantly constrained resulting in limited conveyance capacity.

These works and the Barangaroo Station Civil Works, Hickson Road Stage 3 Design have been incorporated into the flood model as part of the 'Hickson Road North – Ultimate Design'. A 'Pre-Development Scenario' based on pre-development catchment conditions, but inclusive of Nawi Cove and Barangaroo Reserve development (circa 2015), has also been developed. Further details of these two scenarios are presented in Sections 3.3.4 and 3.3.2 respectively.

1.4 Barangaroo Station Civil Works, Hickson Road Stage 3 Design Inputs

The following design information was provided by the Designer for inclusion in the flood model (as requested via email dated 15/6/21):

DRAINS Models (provided 1/6/2021)

1. SMCSWSBR-Redesign_Prop_North_ARR2019_Interim.drn;
2. SMCSWSBR-Redesign_Prop_North_ARR2019_Interim_100yr.drn;
3. SMCSWSBR-Redesign_Prop_North_ARR2019_Ultimate.drn;
4. SMCSWSBR-Redesign_Prop_North_ARR2019_Ultimate_100yr.drn.

Design Surfaces (provided 5/5/2021)

5. HicksonRoadUltimateDEM20210505 – '*DEM created of the ultimate design tin only up to CH 537. Includes ultimate design for western verge'*.
6. HicksonRoadInterimDEM20210505 – *'DEM created for the interim design tin only. This includes the southern transition zone south of Ch 537 and the interim design for the western verge'*.
7. HicksonRoadCombinedDEM20210505 – *'DEM created of a combined tin, with the interim tin overlaid over the ultimate design tin'*.

DRAFT Drawing Package (provided 12/5/2021)

8. SMCSWSBR-MET-SBR-CE-PKG-900005.pdf – *'Barangaroo Station Civil Works, Hickson Road Stage 3 Design'*

DRAFT Design Report (provided 15/6/2021)

9. SMCSWSBR-MET-SBR-CE-REP-000008_DRAFT.docx – *'Barangaroo Precinct Civil Design Report, Stage 3 Detailed Design, Underground Stations Design & Technical Services'*

1.5 Assumptions and Risks

Assumptions and risks for the Flood Report flood modelling assessment are listed below:

- The information provided by the Designer 'for inclusion in the flood model' (see Section 1.4) has been assessed at the direction of the Designer;

- Unless otherwise stated, all relevant assumptions and constraints outlined in the *Barangaroo Precinct Civil Design Report, Stage 3 Detailed Design, Underground Stations Design & Technical Services'* (or other similar reports) apply;
- 'Hickson Road North – Temporary Design' assumes that the Central Barangaroo site levels and drainage are as per pre-development conditions (based on the Rygate survey). Information is not available as to the current conditions of the site, and site conditions are likely to change throughout the various construction stages. This assumption is unlikely to impact on design flood behaviour for most flood events as Central Barangaroo drainage is required to discharge west towards the harbour rather than east towards Hickson Road, as agreed by Aqualand as part of the Mod9 approval. Site condition assumptions may affect flood behaviour during very rare to extreme events;
- 'Hickson Road North – Ultimate Design' assumes that the Central Barangaroo drainage and overland flows discharge west towards the harbour rather than east towards Hickson Road, as agreed by Aqualand as part of the Mod9 approval. Modelling has assumed that all flow from Central Barangaroo is discharged along the western site boundary;
- Barangaroo Stage 1B development surface has been developed from 2d lines and internal site drainage inverts have been estimated, as 3d information was not available;
- 'Hickson Road North – Ultimate Design' has been modelled in conjunction with an assumed design for 'Hickson Road South'. The assumed 'Hickson Road South' design is based on:
    - Hickson Road geometric design (SMCSWSBR-MET-SBR-CE-MOD-300301.dwg) provided 18 September 2020;
    - Updated Stormwater System at 25 Hickson Road (SBR 25 Hickson rd Updated drawings 200921) provided 21 September 2020;
    - DRAINS model (SMCSWSBR-Barangaroo_Stage3_Proposed_South_ARR2019_CoS.drn) provided 2 July 2020;
    - DRAINS model (SMCSWSBR-Barangaroo_Stage3_Proposed_North_ARR2019 - SY.drn) provided 18 September 2020;
    - Hickson Road geometric design (HicksonRoadDEM20200316.dem) provided 16 March 2020; and
    - Barangaroo Precinct Civil Design Report, Stage 3 Detailed Design (SMCSWSBR-MET-SBR-CE-REP-000008);

  The 'Hickson Road South' design has not been finalised for this area and as such flood model results for the 'Hickson Road North – Ultimate Design' are not presented south of the 'Hickson Road North' limit of works. The 'Hickson Road North' and 'Hickson Road South' areas are separate stormwater catchments, so the influence of this assumption will only affect flood behaviour during very rare to extreme events.

1.6 Scope of this Report

The Flood Report has been prepared on behalf of Infrastructure New South Wales (INSW) to present flood assessment results for the Barangaroo Station Civil Works, Hickson Road Stage 3 Design prepared by METRON (the Designer).

The scope of works covered by the Flood Report describes the flood related hydrologic and hydraulic modelling analysis for Pre-development conditions, 'Hickson Road North – Temporary Design' conditions, and 'Hickson Road North – Ultimate Design' conditions.

The flood modelling assumes a design within the 'Hickson Road South' limit of works area for the 'Hickson Road North – Ultimate Design' conditions. As the design is not finalised for this region, flood model results are not provided within the 'Hickson Road South' limit of works.

1.7 Acronyms and Terminology

Table 1 presents a list of acronyms and terminology used in the report.

Table 1: List of Acronyms and Terminology

Abbreviation	Description
1D	One-dimensional
2D	Two-dimensional
3D	Three-dimensional
AEP	Annual Exceedance Probability (see Section 1.7.1)
AHD	Australian Height Datum – national surface level datum corresponding to mean sea level
ARF	Areal Reduction Factor - is a value which can be applied to a point rainfall to give the reduced areal rainfall over a given catchment area.
ARI	Average Recurrence Interval (see Section 1.7.1)
ARR87	Australian Rainfall and Runoff, 1987 Edition – ARR is a national guideline document that is used for the estimation of design flood characteristics in Australia. ARR87 has now been superseded by ARR2019.
ARR2019	The latest revision of Australian Rainfall and Runoff.
DEM	Digital Elevation Model - is a 3D representation of a terrain's surface
GSDM	Generalised Short Duration Method – a method of calculating the PMF
Hydraulic	Term given to the study of water flow; in particular, the evaluation of flow parameters such as water level and velocity.
Hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs.
LiDAR	Light Detection and Ranging - is a remote sensing method that uses light in the form of a pulsed laser to measure ranges. This data is typically used in the creation of a DEM.
m^3/s	Cubic metres per second - a measurement of flow rate
Model	Computer model - The mathematical representation of the physical processes involved in runoff generation and flow. These models are run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
PMF	Probable Maximum Flood - The PMF is the largest flood that could conceivably occur at a particular location. The PMF defines the extent of flood prone land, that is, the floodplain. Generally, it is not physically or economically possible to provide complete protection against this event.
PMP	Probable Maximum Precipitation - the greatest possible depth of precipitation for a given duration at a particular location.
Probability	A statistical measure of the expected chance of flooding (see AEP).
SEARs	Secretary's Environmental Assessment Requirements
TUFLOW	A 1D/2D hydraulic model typically used for assessing flood behaviour

1.7.1 Adopted Probability Terminology

Event probability is often described in terms of:

- *Annual Exceedance Probability (AEP) - the probability of an event being equalled or exceeded within a year; or*
- *Average Recurrence Interval (ARI) - the average time period between occurrences equalling or exceeding a given value.*

This study has used the 'AEP' terminology when describing event probability as is recommended in Australian Rainfall and Runoff 2019 (ARR2019). The relationship between 'AEP' and 'ARI' is presented in Table 2.

Table 2: Relationship between AEP and ARI

AEP (%)	ARI (years)
20	4.48
10	10
5	20
2	50
1	100
0.2	500
0.05	2,000

The Probable Maximum Flood (PMF) is the largest flood that could conceivably occur at a particular location. The expected probability of such an event for the Hickson Road catchment is in the order of one in 10,000,000 (Generalised Short Duration Method, Bureau of Meteorology, 2003).

2. OBJECTIVES

2.1 Overview

The objective of this study is to undertake a flood assessment for the Barangaroo Station Civil Works, Hickson Road Stage 3 Design. The information and results obtained from this analysis define design flood behaviour for the Barangaroo Precinct for Pre-development conditions and 'Hickson Road North – Temporary Design' conditions. Design flood behaviour is also presented for the 'Hickson Road North' limit of works, for the 'Hickson Road North – Ultimate Design' conditions.

Flood behaviour has been examined for the 5% AEP, 1%, AEP and PMF events and to assess potential climate change effects, including sea level rise and increases in rainfall intensity.

2.2 Local Authority Requirements

Flood information is provided so that City of Sydney (CoS) requirements in the Sydney 2012 Development Control Plan (DCP), Sydney 2012 Local Environmental Plan (LEP), and Interim Floodplain Management Policy (2014) can be assessed.

The Flood Report has produced the following deliverables to assist in assessing compliance:

- Flood depth maps;
- PMF flood level contours;
- Flood hazard maps; and
- Flood depth, level and hazard impact maps.

The Sydney LEP 2012 requires that all new development adequately protects the safety of property and life, and avoids significant adverse impacts on flood behaviour and the environment. The new development must be compatible with the flood hazard of the land and not significantly adversely affect flood behaviour for other development or properties.

2.3 Sydney Metro Requirements

Sydney Metro requirements have been provided via various emails, RFIs and technical memos as outlined below:

- Sydney Metro flood mapping requirements outlined in technical memo (SMCSWSBR-MET-SBR-IF-COR-000001) provided 22nd October 2018;
- PMF flood levels adjacent to Sydney Metro station entrance locations as requested by METRON (email 30 March 2020); and
- RFI 'SMCSWSBR-MET-DRFI-000157' which requests information in relation to the flood immunity of the Barangaroo Reserve basement.

Model results are presented in Section 9 and are provided for the Designer to assess compliance.

3. FLOOD MODELLING APPROACH

3.1 Background

The flood model developed as part of the Hickson Road Upgrade, Barangaroo, Reference Design Flood Study (GRC Hydro, 2019) has been updated for the design flood modelling presented herein. The model developed for the Flood Report is referred to as the 'Design Flood Model'.

The Reference Design flood model was developed by modifying the local City of Sydney flood model developed for the:

1. City of Sydney, City Area Catchment Flood Study (BMT WBM, October 2014); and
2. City of Sydney, City Area Catchment Floodplain Risk Management Study and Plan (WMAwater, September 2016).

Various updates and amendments to the City of Sydney Flood Model were undertaken as part of the Reference Design study. Additional amendments made as part of the current study, are outlined in Sections 3.3.2 to 3.3.4.

Results of the flood modelling analysis are presented in:

- Section 4 - Pre-Development Scenario Results;
- Section 5 - Temporary Design Results;
- Section 6 - Ultimate Design Results;
- Section 7 - Climate Change Results;
- Section 8 - Flood Impact Assessment;
- Section 9 - Model results requested by Sydney Metro (see Section 2.3).

3.2 Modelling Methodology

Flood modelling was undertaken using the hydrodynamic modelling program TUFLOW. TUFLOW is a finite difference grid based 1D/2D hydrodynamic model which uses the St Venant equations in order to route flow according to gravity, momentum and roughness. TUFLOW is ideally suited to this study because it allows for 2D modelling to be dynamically linked to 1D pit and pipe systems.

The applied flood methodology is a direct-rainfall method. The direct-rainfall method directly applies rainfall to individual cells of the 2D hydraulic model. 'Traditional' flood modelling typically utilises two individual models; a hydrologic model which simulates the rainfall-runoff process of a catchment, and a hydraulic model which uses flow from the hydrologic model to produce flood behaviour such as flood levels, depths and velocities. The direct-rainfall method is particularly useful for overland flow flood modelling in urban catchments, such as that within the Barangaroo Precinct and upstream catchment. Direct rainfall method is described in Project 15 of ARR2019 and when used appropriately is best practice.

The City of Sydney Flood Model and Reference Design model used the direct-rainfall method with ARR1987 inputs. The Design Flood Model has been updated to utilise ARR2019 in line with current best practice.

3.3 Flood Model Development for Design

The flood model developed as part of the Hickson Road Upgrade, Barangaroo, Reference Design Flood Study (GRC Hydro, 2019) has been updated for the design flood modelling presented herein.

3.3.1 Application of ARR2019 Methods

The Reference Design flood model utilised ARR1987 hydrologic parameters and techniques. The Design Flood Model has updated the hydrologic approach to be consistent with ARR2019. Details of the applied methodology are detailed in Appendix A.

3.3.2 Pre-development Conditions Model Updates

The Reference Design flood model was updated with the following changes:

- The TUFLOW model version was upgraded from TUFLOW.2013-12-AA to TUFLOW.2020-10-AA and the HPC (single precision) solver was implemented;
- ARR2019 hydrologic parameters discussed in Section 3.3.1 were applied to generate design flood conditions;
- The model grid resolution was increased from a 2 m grid to a 1 m grid;
- Model topography was updated with new LiDAR captured in 2020 (Sydney202005-LID1). Survey has been used in preference to the LiDAR where available;
- Localised amendment of the LiDAR in areas of poor data quality such as under the elevated Western Distributer and near some buildings;
- Amendment of breaklines in the upper catchment areas to suit the new LiDAR dataset;
- Craig and Rhodes Survey was applied to areas of High Street, Napoleon Street, Bond Plaza and Nawi Cove near 25 Hickson Road;
- Minor amendments to terrain to smooth transition between topography from various data sets;
- Stormwater alignment, sizes and inverts reviewed to reflect Rygate survey;
- 30 Hickson Road building drainage diverted directly to the stormwater system, limited by DN225 pipe with excess flow discharged to Hickson Road to simulate failure of the building stormwater;
- Rainfall at location of the Dalgety Road and Windmill Street overpasses was removed from Hickson Road and applied to the downstream end of these crossings to avoid overestimation of rainfall on Hickson Road;
- Refinement of building footprint digitisation based on Rygate and Craig and Rhodes Survey;
- Removal of the TUFLOW 'tsoilsf' layer which was resulting in the overestimation of losses with an additional 2.5 mm/hr continuing loss applied;
- Refinement of applied Mannings and losses layers to suit site characteristics on Hickson Road and near Nawi Cove (previously pervious areas were changed to hardstand).

Pre-development Conditions model results are presented in Section 4.

3.3.3 'Hickson Road North – Temporary Design' Model Updates

The Pre-development Conditions model was modified to create the 'Hickson Road North – Temporary Design' model. Unless otherwise stated, all changes to the Pre-development model have been maintained for the Temporary Design model. Additional modifications include:

- Incorporation of Barangaroo Stage 1B stormwater and topography based on Lendlease Construction Drawings B1B CD2000010, B1B CD2000011, B1B CD2000012, B1B CD2000013A, and B1B CD2000013B;
- 'Hickson Road South' levels updated based on Craig and Rhodes Survey;
- Truncation of existing stormwater which flowed through Central Barangaroo Blocks 6 and 7 into Sydney Harbour;
- Implementation of the 'Hickson Road North – Temporary Design' stormwater as per provided information described in Section 1.4 and listed below:
  - 'SMCSWSBR-Redesign_Prop_North_ARR2019_Interim.drn',
  - 'SMCSWSBR-Redesign_Prop_North_ARR2019_Interim_100yr.drn', and
  - 'SMCSWSBR-MET-SBR-CE-PKG-900005.pdf'
- 'Hickson Road North – Temporary Design' design surface as per provided information described in Section 1.4 (HicksonRoadCombinedDEM20210505).

'Hickson Road North – Temporary Design' model results are presented in Section 5.

3.3.4 'Hickson Road North – Ultimate Design' Model Updates

The 'Hickson Road North – Temporary Design' model was modified to create the 'Hickson Road North – Ultimate Design' model. Unless otherwise stated, all changes to the 'Hickson Road North – Temporary Design' model have been maintained for the 'Hickson Road North – Ultimate Design' model. Additional modifications include:

- Raising of Central Barangaroo to a level of 3.5 mAHD. It is assumed that site drainage and overland flows are discharged west towards the Harbour rather than east towards Hickson Road, as agreed by Aqualand as part of the Mod9 approval.
- 'Hickson Road North – Ultimate Design' stormwater as per provided information described in Section 1.4 and listed below:
  - 'SMCSWSBR-Redesign_Prop_North_ARR2019_Ultimate.drn',
  - 'SMCSWSBR-Redesign_Prop_North_ARR2019_Ultimate _100yr.drn', and
  - 'SMCSWSBR-MET-SBR-CE-PKG-900005.pdf'
- 'Hickson Road North – Ultimate Design' design surface as per provided information described in Section 1.4 (HicksonRoadUltimateDEM20210505).
- The assumed 'Hickson Road South' design is based on:
  - Hickson Road geometric design (SMCSWSBR-MET-SBR-CE-MOD-300301.dwg) provided 18 September 2020;
  - Updated Stormwater System at 25 Hickson Road (SBR 25 Hickson rd Updated drawings 200921) provided 21 September 2020;
  - DRAINS model (SMCSWSBR-Barangaroo_Stage3_Proposed_South_ARR2019_CoS.drn) provided 2 July 2020;

- o DRAINS model (SMCSWSBR-Barangaroo_Stage3_Proposed_North_ARR2019 - SY.drn) provided 18 September 2020; and
- o Hickson Road geometric design (HicksonRoadDEM20200316.dem) provided 16 March 2020.

'Hickson Road North – Ultimate Design' model results are presented in Section 5. Model results for the 'Hickson Road South' limit of works are not presented as the design has not been finalised in this area.

3.3.5 Application of Hydraulic Design Parameters

The Design Flood Model has applied hydraulic parameters consistent with the DRAINS model supplied by the Designer (see Section 1.4). A summary of parameters is listed below:

- Pipe Mannings of 0.013;
- Pit loss parameter applied as a 'fixed' form loss values extracted from DRAINS model (K parameter of up to 4 for inlet structures with no through pipe);
- Inlet ratings as per DRAINS model for sag inlets. On-grade inlet ratings converted from flow/flow relationship in DRAINS to depth/flow relationship for application to the Design Flood Model;
- Inlet blockages factors applied as per City of Sydney, Sydney Streets, Technical Specification (2019) as presented in Image 2. Double 0.9 m EKI lintel inlets have been treated as 'kerb inlet <= 1.0 m' and as such higher blockage factors have been applied relative to the DRAINS model.

Image 2: Sydney Streets, Technical Specification Blockage Factors

Pit type	On grade blockage factor	Sag blockage factor
kerb inlet <= 1.0m	50%	70%
kerb inlet > 1.0m	20%	50%
V grate or grate only	90%	90%
Strip drain or other	95%	95%

3.3.6 Climate Change Modelling

The impact of climate change on flood producing rainfall and sea levels has been assessed. The assessment has applied:

- The IPCC (Intergovernmental Panel on Climate Change) greenhouse gas concentration scenarios to estimate the effect of climate change on rare rainfall events, and
- NSW Sea Level Rise Policy (DECCW, 2009) to assess potential flood impacts associated with increases in mean sea level associated with climate change.

Further details of how climate change parameters have been determined is presented in Appendix A, Section A4.3.

The climate change scenarios listed below have been adopted for assessment of the impact of climate change on design flood behaviour:

- 1% AEP Event +10% Rainfall and 0.9 m Sea Level Rise;
- 1% AEP Event with RCP8.5 (2090) Rainfall Estimates and 0.9 m Sea Level Rise;
- PMF Event with 0.9 m Sea Level Rise.

ARR2019 does not recommend increases in rainfall intensity be applied to the PMF event.

Climate change scenarios have not been assessed for the 'Hickson Road North – Temporary Design' as they are not relevant during the proposed construction timeframe.

Climate Change scenario model results are presented in Section 7.

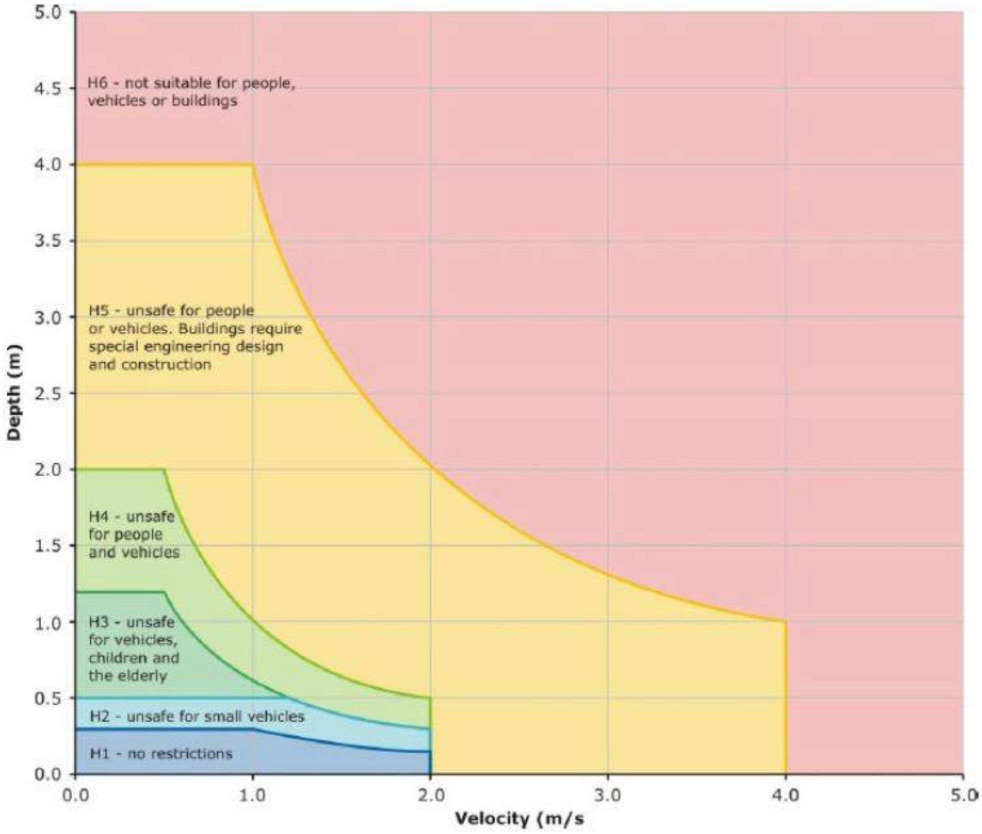
4. PRE-DEVELOPMENT SCENARIO RESULTS

Pre-development conditions model results are presented in Appendix B. Design event flood depths and hazard for the pre-development scenario model are presented in:

- Figure B 1: Pre-Development – 5% AEP Event Flood Depths and Hazard;
- Figure B 2: Pre-Development – 1% AEP Event Flood Depths and Hazard; and
- Figure B 3: Pre-Development – PMF Event Flood Depths and Hazard.

Flood hazard derived using the Australian Institute of Emergency Management approach is presented in the figures outlined above. The hazard calculation methodology considers flow hydraulic characteristics of velocity and depth (see Image 3) to determine flood hazard for various floodplain uses.

Image 3: Australian Institute of Emergency Management Flood Hazard



Examination of the flood liability of existing development at 30 and 38 Hickson Road indicates that these buildings are flooded above floor level for events as frequent as the 20% AEP event under pre-development conditions. Table 3 presents peak flood levels extracted for these existing developments, along with the building Finished Floor Levels (FFL) obtained from the Craig and Rhodes survey.

Table 3: Pre-Development Peak Flood Levels for Properties (mAHD)

Event	25 Hickson Rd FFL: 2.83 mAHD	30 Hickson Rd FFL: 2.53 mAHD	38 Hickson Rd FFL: 2.57 mAHD
20% AEP	2.760	2.554	2.667
10% AEP	2.762	2.591	2.673
5% AEP	2.765	2.654	2.68
2% AEP	2.764	2.672	2.688
1% AEP	2.768	2.682	2.693
1% AEP Event + RCP4.5 Rainfall + 0.9 m Sea Level Rise*	2.771	2.692	2.702
1% AEP Event + RCP8.5 Rainfall + 0.9 m Sea Level Rise*	2.773	2.698	2.706
PMF	2.812	2.741	2.757

* See Section 3.3.6 for explanation of climate change scenarios.

The pre-development 5% AEP event experiences shallow low hazard flooding in both the 'Hickson Road North' and 'Hickson Road South' Limit of Works. Notable areas of ponding occur near 30 and 38 Hickson Road, resulting in above floor flooding of these buildings. Ponding also occurs in the carpark of 25 Hickson Road to the south of the building. Flood depths in the kerb near these areas of interest are typically less than 0.25 m (see Figure B 1). Flood depths up to 0.35 m are experienced on Hickson Road, below the High Street sag. At this location, High Street flows overtop the High Street wall, and the pipe network surcharges.

The pre-development 1% AEP event experiences similar flood behaviour as the 5% AEP event with low hazard minor flooding (see Figure B 2) affecting Hickson Road. Above floor flooding is again noted at both 30 and 38 Hickson Road, with flood depths of up to 0.3 m noted on Hickson Road proximate to these buildings. 25 Hickson Road is not flooded above floor during this event. Flood depths up to 0.4 m are experienced on Hickson Road, below the High Street sag. Limited, localised areas of H2 hazard classification flooding area noted near the above-mentioned areas of interest.

The pre-development PMF event experiences flood depths of typically 0.3 – 0.4 m along Hickson Road. Flows of similar depth pass through much of the Barangaroo development site. Flood hazard is predominantly category H1 with areas of H2 flood hazard along the eastern side of Hickson Road (see Figure B 3).

5. TEMPORARY DESIGN RESULTS

'Hickson Road North – Temporary Design' model results are presented in Appendix C. Design event flood depths and hazard for the Temporary Design model are presented in:

- Figure C 1: Hickson Road North, Temporary Design – 5% AEP Event Flood Depths and Hazard;
- Figure C 2: Hickson Road North, Temporary Design – 1% AEP Event Flood Depths and Hazard;
- Figure C 3: Hickson Road North, Temporary Design – PMF Event Flood Depths and Hazard.

Examination of the flood liability of existing development at 30 Hickson Road indicates that this building is expected to be flooded during the 5% AEP event, however, the depth of flooding is less than Pre-development conditions. 38 Hickson Road is not expected to be flooded above floor by events up to and including the 1% AEP event. Table 4 presents peak flood levels for the 'Hickson Road North – Temporary Design' extracted for these existing developments, along with the building's Finished Floor Levels (FFL).

Table 4: 'Hickson Road North – Temporary Design' Flood Levels for Properties (mAHD)

Event	25 Hickson Rd FFL: 2.83 mAHD	30 Hickson Rd FFL: 2.53 mAHD	38 Hickson Rd FFL: 2.57 mAHD
5% AEP	2.589	2.587	2.514
1% AEP	2.604	2.666	2.554
PMF	2.797	2.847	3.049

'Hickson Road North – Temporary Design' 5% AEP event experiences negligible flooding within the 'Hickson Road North' limit of works as flows are predominantly conveyed by the stormwater system. Previous ponding in the carpark of 25 Hickson Road does not occur during this event due to the addition of proposed stormwater. Shallow low hazard flooding is noted to the east of Hickson Road in the verge between the road and the High Street wall. An area of ponding with depths of up to ~0.2 m is noted near 30 Hickson Road, whereas the extent of flooding at 38 Hickson Road is significantly reduced (see Figure C 1).

The 'Hickson Road North – Temporary Design' 1% AEP event experiences similar flood behaviour as the 5% AEP event with flooding within the 'Hickson Road North' limit of works as flows are predominantly conveyed by the stormwater system (see Figure C 2). The area beneath the High Street sag, to the east of Hickson Road, experiences flood depths of up to 0.4 m with an associated H2 flood hazard classification (which does not affect the road). The 25 Hickson Road carpark is again noted to not be flooded. Flood depths up to ~0.3 m are experienced in the kerb/gutter near 30 Hickson Road.

The 'Hickson Road North – Temporary Design' PMF results show limited flooding on Hickson Road within the 'Hickson Road North' limit of works, with a H1 flood hazard category and areas of H2 within the cycleway. H3 hazard is noted beneath the High Street sag, to the east of Hickson Road but does not affect the road or cycleway (see Figure C 3). Flood depths of up to ~0.7 m are experienced near existing development at 30 and 38 Hickson Road, with flood hazard categories of H3 and H4 noted. The increase in flood depth and hazard at this location is due to raising of the approved/constructed Barangaroo Stage 1B development. Areas surrounding the Metro Station entrance are flood free during the PMF.

6. ULTIMATE DESIGN RESULTS

'Hickson Road North – Ultimate Design' model results are presented in Appendix D. Design event flood depths and hazard for the Ultimate Design model are presented in:

- Figure D 1: Hickson Road North, Ultimate Design – 5% AEP Event Flood Depths and Hazard;
- Figure D 2: Hickson Road North, Ultimate Design – 1% AEP Event Flood Depths and Hazard; Figure D 3: Hickson Road North, Ultimate Design – PMF Event Flood Depths and Hazard.

Results are presented for the 'Hickson Road North' limit of works area only for the reasons discussed in Section 1.5.

Flood levels in the carpark at 25 Hickson Road, along with the building's Finished Floor Level (FFL), are presented in Table 5. The building is not flooded above floor until events approaching the magnitude of the PMF.

Table 5: 'Hickson Road North – Temporary Design' Flood Levels for Properties (mAHD)

Event	25 Hickson Rd FFL: 2.83 mAHD
5% AEP	2.590
1% AEP	2.606
PMF	2.860

'Hickson Road North – Ultimate Design' 5% AEP event experiences negligible flooding within the 'Hickson Road North' limit of works as flows are predominantly conveyed by the stormwater system. Previous ponding in the carpark of 25 Hickson Road does not occur during this event due to the addition of proposed stormwater. Shallow low hazard flooding is noted to the east of Hickson Road in the verge between the road and the High Street wall (see Figure D 1).

The 'Hickson Road North – Ultimate Design' 1% AEP event experiences similar flood behaviour as the 5% AEP event with flooding within the 'Hickson Road North' limit of works as flows are predominantly conveyed by the stormwater system (see Figure D 2). The area beneath the High Street sag, to the east of Hickson Road, experiences flood depths of up to ~0.4 m with an associated H2 flood hazard classification (which does not affect the road). The 25 Hickson Road carpark experiences shallow ponding (< 0.1 m depth) at proposed stormwater inlets.

The 'Hickson Road North – Ultimate Design' PMF results show H1 to H2 category flooding on Hickson Road within the 'Hickson Road North' limit of works, with flood depths of up to ~0.4 m. H2 flooding is considered unsafe for smaller vehicles, however, would not be considered to affect emergency vehicle access. The area beneath the High Street sag, to the east of Hickson Road, experiences H3 to H4 flood hazard classification, however, this does not affect the road. Areas surrounding the Metro Station entrance are flood free during the PMF (see Section 9 for further details).

7. CLIMATE CHANGE RESULTS

Climate change conditions model results are presented in Appendix D. Pre-development flood depths and hazard for expected climate change conditions are presented in:

- Figure E 1: Pre-Development – 1% AEP Event + 10% Rainfall + 0.9 m Sea Level Rise, Flood Depths and Hazard;
- Figure E 2: Pre-Development – 1% AEP Event + RCP8.5 Rainfall + 0.9 m Sea Level Rise, Flood Depths and Hazard;
- Figure E 3: Pre-Development – PMF Event + 0.9 m Sea Level Rise, Flood Depths and Hazard.

'Hickson Road North – Ultimate Design' flood depths and hazard for expected climate change conditions are presented in:

- Figure E 4: Hickson Road North, Ultimate Design – 1% AEP Event + 10% Rainfall + 0.9 m Sea Level Rise, Flood Depths and Hazard;
- Figure E 5: Hickson Road North, Ultimate Design – 1% AEP Event + RCP8.5 Rainfall + 0.9 m Sea Level Rise, Flood Depths and Hazard;
- Figure E 6: Hickson Road North, Ultimate Design – PMF Event + 0.9 m Sea Level Rise (2.4 mAHD), Flood Depths and Hazard

'Hickson Road North – Ultimate Design' results are presented for the 'Hickson Road North' limit of works area only for the reasons discussed in Section 1.5.

Flood levels in the carpark at 25 Hickson Road, along with the building's Finished Floor Level (FFL), are presented in Table 6. The building is not flooded above floor until events approaching the magnitude of the PMF.

Table 6: 25 Hickson Road Flood Levels for Climate Change Conditions (mAHD)

Event	25 Hickson Rd FFL: 2.83 mAHD	
	Pre-development Conditions	Hickson Road North – Ultimate Design
1% AEP Event + 10% Rainfall + 0.9 m Sea Level Rise*	2.771	2.612
1% AEP Event + RCP8.5 Rainfall + 0.9 m Sea Level Rise*	2.773	2.617
PMF + 0.9 m Sea Level Rise	2.813	2.887

The pre-development 1% AEP +10% rainfall & RPC8.5 events experiences similar flood behaviour as the 1% AEP event with low hazard minor flooding (see Figure E 1 and Figure E 2) affecting Hickson Road. Flooding occurs at the carpark of 25 Hickson Road, however the building is not flooded above floor during these events. Flood depths up to 0.4 m, with a H2 hazard classification, are experienced on Hickson Road, near the High Street sag.

The ‘Hickson Road North – Ultimate Design’ 1% AEP + 10% raifnall & RPC8.5 events experiences negligible flooding within the ‘Hickson Road North’ limit of works as flows are predominantly conveyed by the stormwater system. Previous ponding in the carpark of 25 Hickson Road is reduced during these events due to the addition of proposed stormwater. H3 hazard classification flooding is noted to the east of Hickson Road in the verge between the road and the High Street wall (see Figure E 4 and Figure E 5).

The PMF event with 0.9 m sea level rise exhibits similar flood depth and hazard characteristics, for both Pre-development Conditions and ‘Hickson Road North – Ultimate Design’ as the PMF event without sea level rise (see Figure E 3 and Figure E 6).

8. FLOOD IMPACT ASSESSMENT

8.1 Temporary Design Impacts

Flood depth, level and hazard impact maps that compare the 'Hickson Road North – Temporary Design' to Pre-development Conditions are presented in Appendix F, as outlined below:

- Figure F 1: Hickson Road North, Temporary Design – 5% AEP Event Flood Impact;
- Figure F 2: Hickson Road North, Temporary Design – 1% AEP Event Flood Impact;
- Figure F 3: Hickson Road North, Temporary Design – PMF Event Flood Impact.

The flood impact mapping for both the 5% and 1% AEP events shows reductions in the extent of flooding on Hickson Road due to increased pipe conveyance. Some increases in level are noted in the area beneath the High Street sag, to the east of Hickson Road, however these are generally associated with a decrease in flood depth with little change in flood hazard (see Figure F 1 and Figure F 2). A reduction in flood level for these events, relative to Pre-development Conditions, is expected at existing buildings at 30 and 38 Hickson Road. The change in flood level at existing buildings is presented in Table 7.

Table 7: Change in Flood Levels at Existing Properties for 'Hickson Road North – Temporary Design' (mAHD)

Event	25 Hickson Rd	30 Hickson Rd	38 Hickson Rd
5% AEP	-0.176	-0.067	-0.166
1% AEP	-0.164	-0.016	-0.139
PMF	-0.015	+0.106*	+0.292

* Greater increases in flood level are expected at the southern end of 30 Hickson Road.

During a PMF event, increases in flood levels, depths and hazard are expected within the 'Hickson Road South' limit of works (see Figure F 3). Flood level and depth increases of up to 0.4 m are expected, with potential increases in flood hazard of up to 3 categories (H1 to H4). These impacts are not associated with the 'Hickson Road North – Temporary Design' works, and are instead due to construction of the Barangaroo Stage 1B development.

Within the 'Hickson Road North' limit of works, increases in flood level are expected during a PMF event, however flood depths do not change significantly within the road easement. Increases in flood depth and hazard are expected to the east of Hickson Road in the verge between the road and the High Street wall, however, this area is not accessible to vehicles or pedestrians.

8.2 Ultimate Design Impacts

Flood depth, level and hazard impact maps that compare the 'Hickson Road North – Ultimate Design' to Pre-development Conditions are presented in Appendix G, as outlined below:

- Figure G 1: Hickson Road North, Ultimate Design – 5% AEP Event Flood Impact
- Figure G 2: Hickson Road North, Ultimate Design – 1% AEP Event Flood Impact

- Figure G 3: Hickson Road North, Ultimate Design – PMF Event Flood Impact
- Figure G 4: Hickson Road North, Ultimate Design – Climate Change (+10% Rainfall & 0.9 m Sea Level Rise) Flood Impact
- Figure G 5: Hickson Road North, Ultimate Design – Climate Change (RPC8.5 & 0.9 m Sea Level Rise) Flood Impact

The flood impact mapping for both the 5% and 1% AEP events shows reductions in the extent on flooding on Hickson Road due to increase pipe conveyance. Some increases in level are noted in the area beneath the High Street sag, to the east of Hickson Road, with a localised area of increased flood hazard is noted with a change for H1 to H2 categories (see Figure G 1 and Figure G 2). This area is not accessible to vehicles. A reduction in flood level for these events, relative to Pre-development Conditions, is expected at the existing buildings at 25 Hickson Road. The change in flood level at 25 Hickson Road is presented in Table 8.

Table 8: Change in Flood Levels at 25 Hickson Road for 'Hickson Road North – Ultimate Design' (mAHD)

Event	25 Hickson Rd
5% AEP	-0.175
1% AEP	-0.162
1% AEP Event + RCP4.5 Rainfall + 0.9 m Sea Level Rise*	-0.159
1% AEP Event + RCP8.5 Rainfall + 0.9 m Sea Level Rise*	-0.156
PMF	+0.048

Increases in flood levels and depths are expected within the 'Hickson Road North' limit of works area during the PMF event (see Figure G 3), which are associated with an increase in flood hazard from H1 to H2 in some areas. H2 flooding is considered unsafe for smaller vehicles, however, would not be considered to affect emergency vehicle access. Increase in flood depth and hazard are expected to the east of Hickson Road in the verge between the road and the High Street wall, however, this area is not accessible to vehicles or pedestrians.

The flood impact mapping for both the 1% AEP + 10% rainfall & RPC8.5 events shows reductions in the extent of flooding on Hickson Road due to increased pipe conveyance. Other flood impacts are similar to that presented for the 1% AEP event impact comparison, with slightly increased impacts noted in the verge between Hickson Road and the High Street wall (see Figure G 4 and Figure G 5).

9. SYDNEY METRO REQUIREMENTS

9.1 Sydney Metro Mapping Requirements

Sydney Metro flood mapping requirements were outlined in technical memo (SMCSWSBR-MET-SBR-IF-COR-000001) provided 22nd October 2018. The requested information is presented in the following maps:

- Figure E 7: Pre-Development – 1% AEP Event + 10% Rainfall + 0.9 m Sea Level Rise, Flood Depths and Hazard;
- Figure E 8: Pre-Development – PMF Event + 0.9 m Sea Level Rise, Flood Depths and Hazard;
- Figure E 9: Hickson Road North, Ultimate Design – 1% AEP Event + 10% Rainfall + 0.9 m Sea Level Rise, Flood Depths and Hazard;
- Figure E 10: Hickson Road North, Ultimate Design – PMF Event + 0.9 m Sea Level Rise, Flood Depths and Hazard;
- Figure F 4: Hickson Road North, Temporary Design – PMF Event Flood Impact;
- Figure G 6: Hickson Road North, Ultimate Design – PMF Event Flood Impact;
- Figure G 7: Hickson Road North, Ultimate Design – Climate Change (+10% Rainfall & 0.9 m Sea Level Rise) Flood Impact

9.2 Metro Station Entrance Locations

PMF flood levels adjacent to Sydney Metro station entrance locations were requested by METRON (email 30 March 2020). PMF flood levels were requested for locations A to F as per 'PMFFloodLocations.pdf' provided by METRON in the above referenced email. PMF flood levels (inclusive of 2100 sea level rise assuming a 1% AEP harbour level, i.e. 2.4 mAHD) for the requested locations are presented in Table 9.

Table 9: PMF flood levels (inclusive of 2100 sea level rise) for requested locations

Location ID	PMF flood levels with 1% AEP Harbour Level (inclusive of 2100 sea level rise) (mAHD)
A	Not flooded (3.27*)
B	Not flooded (3.37*)
C	3.04
D	3.01
E	3.40
F	3.57

* Flood level proximate to the requested location.

9.3 Barangaroo Reserve Basement Carpark

The Designer submitted RFI 'SMCSWSBR-MET-DRFI-000157' which requests information in relation to the flood immunity of the Barangaroo Reserve basement to ensure compliance with Sydney Metro SWTC requirements as outlined in the RFI and reproduced below:

(a) The Project Works must be designed, constructed and able to be operated and maintained so as to prevent flooding of the Sydney Metro City & Southwest from the Probable Maximum Flood (PMF): [SM-CSW-BZZ-SWTC-A22-635]
    i. as defined in Australian Rainfall and Runoff – A Guide to Flood Estimation, Commonwealth of Australia;
    ii. in accordance with the Department of Environment & Climate Change (DECC) Floodplain Risk Management Guideline – Practical Consideration of Climate Change, version 1 October 2007; and [SM-CSW-BZZ-SWTC-A22-637]
    iii. in accordance with DECC's Draft Seas Level Rise Policy Statement, February 2009. [SM-CSW-BZZ-SWTC-A22-638]

(b) The threshold level of all entrances, ventilation openings, tunnel portals and other openings into underground railway infrastructure must be set above the probable maximum flood (PMF) level and at least 300 mm higher (crest protection) than the surrounding finished ground level or sufficient to prevent local flash flooding entering the underground structures.

PMF flood characteristics were assessed for Barangaroo Reserve entrances to the Car Park and The Cutaway as presented in Image 4. Other entrances, such as the roof voids, do not have significant upstream catchments and are thus not considered flood prone, however rainfall entering these voids should be considered by Sydney Metro from a drainage perspective, as discussed further below.

The analysis presented herein focuses on the assessment of flooding of these two entrances due to external catchments to address point (a) above. There may be other mechanisms that result in the ingress of water into basement level 2 which could impact on the proposed Sydney Metro chilled water plant room. These mechanisms may include, but are not limited to, failure of the existing stormwater reuse system or an overwhelmed internal drainage system. Sydney Metro are advised to review pertinent civil and hydraulic design documentation for Barangaroo Reserve to ensure that Sydney Metro infrastructure is not adversely affected due to failure of the stormwater reuse system or an overwhelmed internal drainage system. In addition, Sydney Metro 'crest protection' requirements outlined in point (b) above may also need to be assessed by Sydney Metro and have not been assessed herein. Assessment of the risks associated with these two mechanisms is the responsibility of Sydney Metro and has not been assessed by GRC Hydro.

Image 4: Assessed Barangaroo Reserve Entrances

The post development scenario model results were assessed for the PMF event with a 1% AEP harbour level in conjunction with 2100 projected sea level rise (2.4 mAHD).The PMF flood levels for the two entrances are presented in Table 10 along with the entry levels obtained from the 'Barangaroo Headland Park Public Domain Main Works', 'As Built' drawing set. For both entrances, the entry level is above the PMF flood level.

Table 10: Flood Liability of Barangaroo Reserve Entrances

Location	Entry Level (mAHD)	PMF Flood Level (mAHD)	Flood Liability
Car Park Entrance	4.72	4.66	Not Flooded
The Cutaway	3.00	2.88	Not Flooded

The analysis found that the entry level for both the Car Park and The Cutaway entrances are above the PMF flood level, showing compliance with point (a) of RFI 'SMCSWSBR-MET-DRFI-000157' requirements.

<u>However, mechanisms other than flooding, such as risks associated with existing stormwater reuse and internal drainage systems, may result in the ingress of water into the Barangaroo Reserve basement. It is the responsibility of Sydney Metro to investigate/manage the potential risk to Sydney Metro infrastructure.</u>

10. CONCLUSION

GRC Hydro have been commissioned by Infrastructure New South Wales (INSW) to undertake a flood assessment for the Barangaroo Station Civil Works, Hickson Road Stage 3 Design.

Flood Model Development

- Flood behaviour was assessed using an updated version of the Hickson Road Upgrade, Reference Design Flood Study (GRC Hydro 2019) flood model. Notable model changes include:
  - Updating the Reference Design applied Australian Rainfall and Runoff (ARR) 1987 methods and parameters to ARR2019 which is considered best practise;
  - Increased model resolution by reducing the grid cell size from 2 m to 1 m;
  - Updated topography in the study area using LiDAR obtained in 2020;
  - Implementation of survey where available.
- Design flow estimates were compared to the Reference Design and were found to compare reasonably well;
- Civil and stormwater design inputs were provided by METRON for inclusion in the flood model;
- Three scenarios were assessed, Pre-development conditions, 'Hickson Road North – Temporary Design' conditions, and 'Hickson Road North – Ultimate Design' conditions.
- The flood modelling assumes a design within the 'Hickson Road South' limit of works area for the 'Hickson Road North – Ultimate Design' conditions. As the design is not finalised for this region, flood model results are not provided within the 'Hickson Road South' limit of works.

Design Flood Modelling

- Flood behaviour for the 5% AEP, 1% AEP, and the PMF events were assessed;
- Climate change scenarios including increases in rainfall intensity (+10% and RCP8.5) and ocean level rise (2100 projections) were assessed for the 1% AEP and PMF events;

Flood Impact Analysis

- Flood impact analysis was undertaken by comparing the 'Hickson Road North – Temporary Design', and 'Hickson Road North – Ultimate Design' to Pre-development Conditions:
- The 'Hickson Road North – Temporary Design' impact analysis found:
  - The 5% and 1% AEP events show reductions in the extent on flooding on Hickson Road due to increased stormwater capacity;
  - Some increases in level are noted in the area beneath the High Street sag, to the east of Hickson Road, however these are generally associated with a decrease in flood depth with little change in flood hazard;
  - A reduction in flood level for these events, relative to Pre-development Conditions, is expected at existing buildings at 30 and 38 Hickson Road.
  - During a PMF event, increases in flood levels, depths and hazard are expected near 30 and 38 Hickson Road. Flood level and depth increases of up to 0.4 m are expected, with potential increases in flood hazard by up to 3 categories (H1 to H4). These

impacts are not associated with the 'Hickson Road North – Temporary Design' works, and are instead due to construction of the Barangaroo Stage 1B development.

- The 'Hickson Road North – Ultimate Design' impact analysis found:
    - The 5% and 1% AEP events show reductions in the extent on flooding on Hickson Road due to increased stormwater capacity;
    - A localised area of increased flood hazard is noted beneath the High Street sag, to the east of Hickson Road, with a change from H1 to H2 categories. The increase in flood hazard to H2 is not expected to increase the flood risk as this area is not accessible to vehicles;
    - The flood impact mapping for both the 1% AEP + Climate Change events (+10% rainfall and 0.9 m increase in sea level rise) shows reductions in the extent of flooding on Hickson Road due to increased pipe conveyance. Other flood impacts are similar to that presented for the 1% AEP event described above.
    - Flood levels near 25 Hickson Road are reduced for events up to an including the 1% AEP + 19.5% rainfall (RPC8.5) with 0.9 m increase in sea level rise;
    - 25 Hickson Road experiences a +0.048 m increase in flood level during the PMF;
    - Increases in flood depth and level are expected along Hickson Road, however, the limited change in flood hazard would not be considered to affect emergency vehicle access.

<u>Sydney Metro Requirements</u>

- The following Sydney Metro requirements are presented:
    - Flood mapping requirements outlined in technical memo 'SMCSWSBR-MET-SBR-IF-COR-000001';
    - PMF flood levels (considering 2100 projected sea level rise) adjacent to Sydney Metro station entrance locations are provided, as requested by METRON;
    - PMF flood characteristics were assessed for Barangaroo Reserve basement carpark entrances with the entrances found to be above the PMF (considering 2100 projected sea level rise), as requested by METRON. Mechanisms other than flooding, such as risks associated with existing stormwater reuse and internal drainage systems, may result in the ingress of water into the Barangaroo Reserve basement. <u>The assessment and management of these risks are the responsibility of Sydney Metro.</u>

11. REFERENCES

Infrastructure NSW
1. Hickson Road Upgrade, Barangaroo, Reference Design Flood Study
GRC Hydro, September 2019

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2. City Area Catchment Flood Study
BMT WBM, October 2014

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3. City Area Catchment Floodplain Risk Management Study and Plan
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4. Sydney Streets Technical Specifications
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5. Barangaroo South Flood Study, Barangaroo Stage 1A and 1B
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7. SMCSWSBR-MET-SBR-IF-COR-000001 BDA – METRON Design Clarifications
22 October 2018

Bureau of Meteorology
8. The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method
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U.S. Department of Transportation Federal Highway Administration
9. Hydraulic Engineering Circular No.22, Third Edition, Urban Drainage Design Manual
September 2009

APPENDIX A – ARR2019 Flood Model Update

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A1. FLOOD MODEL DEVELOPMENT

A1.1. Background

The flood model developed as part of the Hickson Road Upgrade, Barangaroo, Reference Design Flood Study (GRC Hydro, 2019) has been updated for the design flood modelling presented herein. The flood model used for the current study is referred to as the Design Flood Model henceforth.

The Reference Design flood model was developed by modifying the local City of Sydney flood model developed as part of the:

1. City of Sydney, City Area Catchment Flood Study (BMT WBM, October 2014); and
2. City of Sydney, City Area Catchment Floodplain Risk Management Study and Plan (WMAwater, September 2016).

Additional updates/amendments were made to the Reference Design flood model as outlined in Section 3.3.2, to revise the Pre-development Conditions model. The Pre-development Conditions model was then modified to incorporate the Barangaroo Station Civil Works, Hickson Road Stage 3 Design, to develop the 'Hickson Road North – Temporary Design' and 'Hickson Road North – Ultimate Design' with the model changes discussed in Section 3.3.3 and 3.3.4.

A1.2. Australian Rainfall and Runoff Approach

The City of Sydney Flood Model and Reference Design model applied Australian Rainfall and Runoff (ARR) 1987 methods. The Design Flood Model has been updated to apply ARR2019 methodology which is now considered best practice. Hydrology, joint probability analysis and climate change analysis are presented in Sections A2, A3, and A4 respectively.

A1.3. Hydraulic Modelling Approach

Flood modelling was undertaken using the hydrodynamic modelling program TUFLOW. TUFLOW is a finite difference grid based 1D/2D hydrodynamic model which uses the St Venant equations in order to route flow according to gravity, momentum and roughness. TUFLOW is suited to this study because it allows for 2D modelling to be dynamically linked to 1D pit and pipe systems.

The applied modelling methodology implements the direct-rainfall approach to flood modelling. The direct-rainfall method directly applies rainfall to individual cells of the 2D hydraulic model. 'Traditional' flood modelling typically utilises two individual models; a hydrologic model which simulates the rainfall-runoff process of a catchment, and a hydraulic model which uses flow from the hydrologic model to produce flood behaviour such as flood levels, depths and velocities.

The direct-rainfall method is particularly useful for overland flow flood modelling in urban catchments, such as that within the Barangaroo Precinct and upstream catchment.

A2. HYDROLOGY UPDATE

A2.1. Introduction

Hydrologic analysis was updated using the methodology prescribed by ARR2019 and guidance outlined in the '*Floodplain Risk Management Guide, Incorporating 2016 Australian Rainfall and Runoff in studies*' (NSW Office of Environment and Heritage, January 2019).

A2.2. Design Rainfall

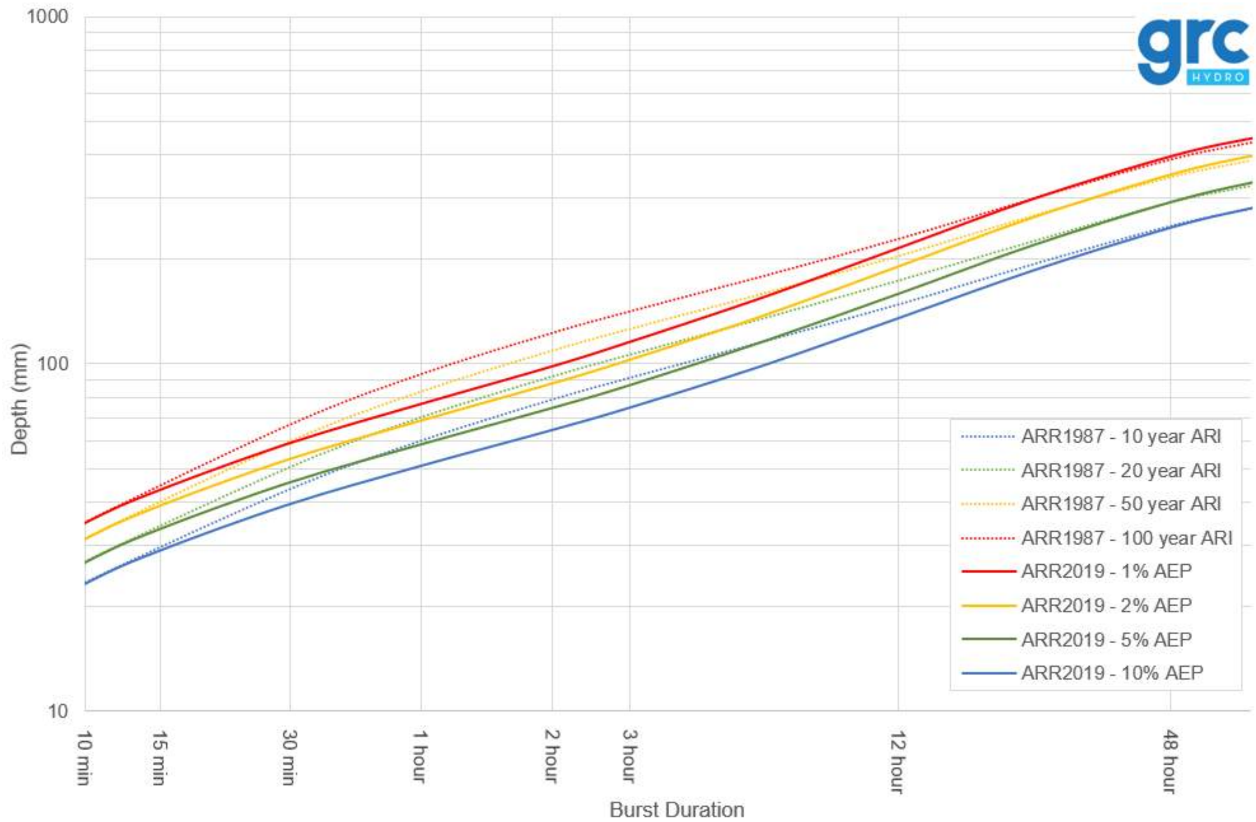
Design rainfall data was obtained from the Bureau of Meteorology (BoM) as Intensity-Frequency-Duration (IFD) data. IFD data describes rainfall depths (mm) for a range of probabilities, durations and locations. The latest revision of IFDs were provided with the release of Australian Rainfall and Runoff (ARR2016) by the Bureau of Meteorology (BoM), and aim to supersede the ARR1987 IFDs.

Due to the small catchment size, application of a design rainfall gradient is not required, and a single uniformly applied rainfall depth is appropriate for modelling of design rainfall.

A2.2.1. Comparison of ARR1987 and ARR2016 Intensity-Frequency-Duration Data

Image A 1 present a comparison of ARR1987 and ARR2016 design rainfall depths for the Barangaroo catchment. The comparison shows that ARR2016 rainfall depths have generally reduced relative to ARR1987 rainfall estimates for short durations (less than ~24 hours). The catchment's critical duration is noted to be ~25 minutes (see Section A2.3), so this reduction in design rainfall intensity is of interest for the design of stormwater infrastructure in Barangaroo.

Image A 1: Barangaroo Catchment - ARR87 and ARR2016 IFD Comparison



The tabulated difference in design rainfall estimates for ARR1987 and ARR2016 is presented in Table A 1.

Table A 1: Difference in design rainfall depths when comparing ARR1987 and ARR2016 IFDs

Duration (min)	10% AEP Event		5% AEP Event		2% AEP Event		1% AEP Event	
	(mm)	(%)	(mm)	(%)	(mm)	(%)	(mm)	(%)
30	-4.10	-9.4%	-5.00	-9.9%	-6.70	-11.2%	-7.80	-11.6%
60	-9.20	-15.3%	-11.70	-16.7%	-14.70	-17.6%	-16.80	-18.0%
120	-14.40	-18.2%	-17.60	-19.1%	-21.60	-19.7%	-24.40	-19.8%
180	-16.30	-17.8%	-19.70	-18.5%	-23.60	-18.6%	-25.90	-18.3%
360	-16.90	-14.5%	-19.60	-14.5%	-22.20	-13.9%	-23.40	-13.0%
720	-12.80	-8.6%	-15.00	-8.6%	-14.20	-6.9%	-13.20	-5.8%
1440	-7.64	-3.9%	-6.32	-2.8%	-3.80	-1.4%	0.00	0.0%

Note: a negative number indicates that ARR2016 rainfall depths are lower than ARR1987 estimates.

A2.2.2. Review of IFD Data Accuracy Based on Local Gauge Data

The '*Floodplain Risk Management Guide, Incorporating 2016 Australian Rainfall and Runoff in studies*' (NSW Office of Environment and Heritage, January 2019) recommends that, '*in NSW coastal catchments where critical storm duration is likely to be less than six hours the BoM 2016 IFD information should be checked for consistency with at-site data*'.

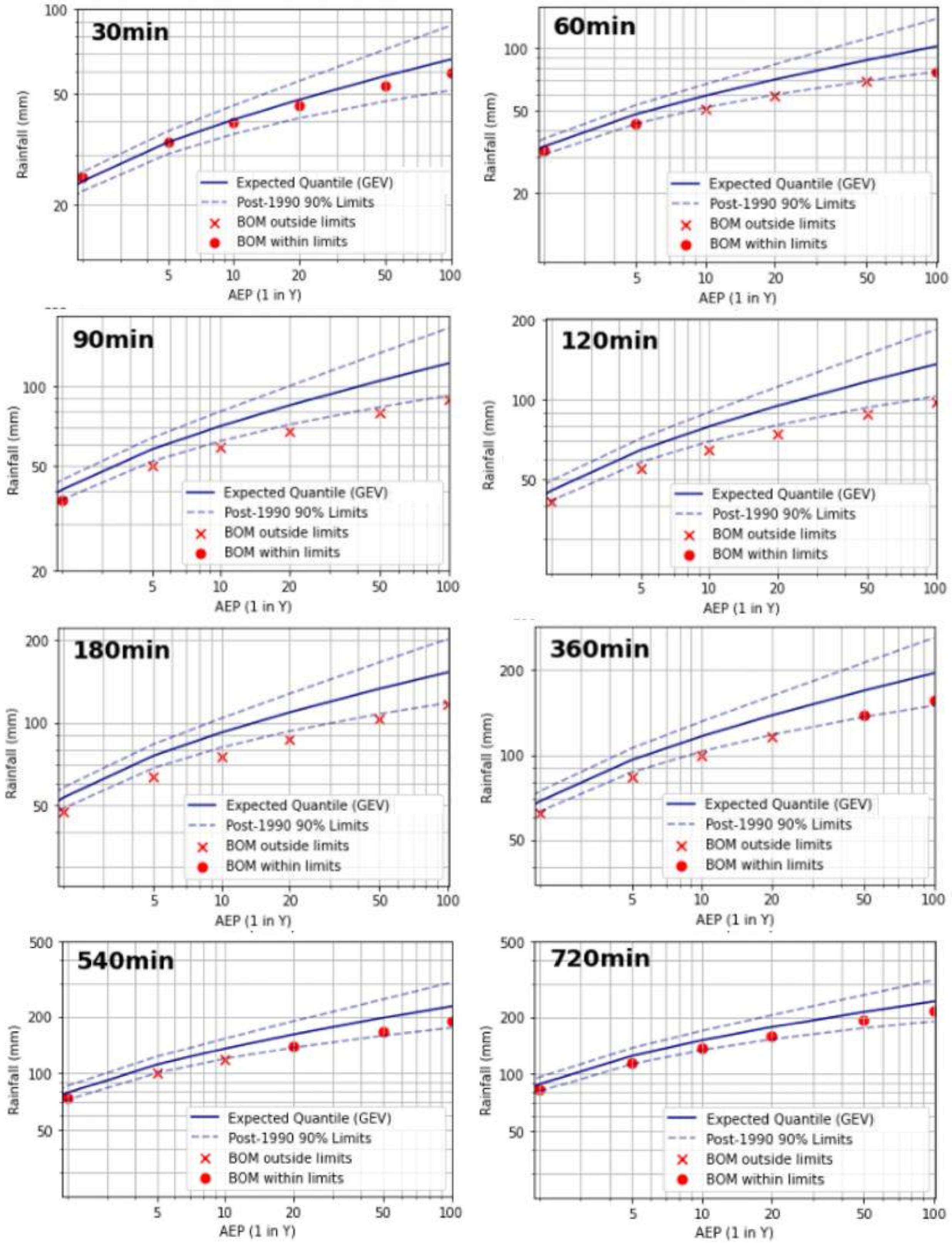
Rainfall frequency analysis of at-site data was undertaken and compared to IFD curves provided by the BOM. The analysis was undertaken for the Observatory Hill gauge (#66062) which is situated within the Barangaroo catchment and has high temporal resolution rainfall data (1 to 6 minute intervals) from January 1913. For the analysis presented herein, data was available up until January 2015 (102 years of record).

The gauge data was analysed and the annual maximum rainfall depth for various durations from 10 minutes to 72 hours was extracted to develop an annual maximum series for each duration. The rainfall frequency analysis consisted of fitting the Generalised Extreme Value distribution to the annual maximum series, using the technique of L-moments.

The results of this analysis are presented in Table A 2 with the ARR2016 IFD estimates are noted to be significantly lower ($p < 0.1$) than the at-site estimates for various durations and AEP. Short duration events, ranging between 1 and 6 hours are noted to present the most significant differences. Similar analysis found no significant difference was noted for comparison of at-site analysis to ARR87 IFDs.

Some difference between the at-site analysis and BOM IFD curves is expected due to the BOM analysis including various regression techniques such as 'Bayesian Generalised Least Squares Regression for deriving sub-daily rainfall statistics from daily rainfall values; GIS-based methods for gridding data; and an 'index rainfall procedure' for regionalisation of point data' (BOM). However, the noted significant difference for the shorter duration events is unexpected and indicates that use of the ARR2016 IFDs should be carefully considered for shorter durations. This is particularly of concern given the comparison of ARR87 and ARR2016 IFD relationships presented in Image A 1 which shows that ARR1987 estimates are significantly higher for shorter duration events and provide a better match to the at site analysis.

Table A 2: Comparison of at-site frequency analysis and ARR2019 IFDs for Observatory Hill gauge (#66062)



Further analysis was undertaken and at-site IFD curves derived and compared to both ARR1987 and ARR2016 IFDs. This comparison is presented in Image A 2 and Image A 3 for ARR2016 and ARR1987

IFDs respectively. The comparison shows that the ARR2016 design rainfall estimates are lower than the at-site frequency analysis, however, they are comparable to the ARR1987 estimates.

Significant differences are noted for short duration events which are critical for the Barangaroo catchment.

Image A 2: Comparison of ARR2016 IFD curves to at site frequency analysis for Observatory Hill (#66062)

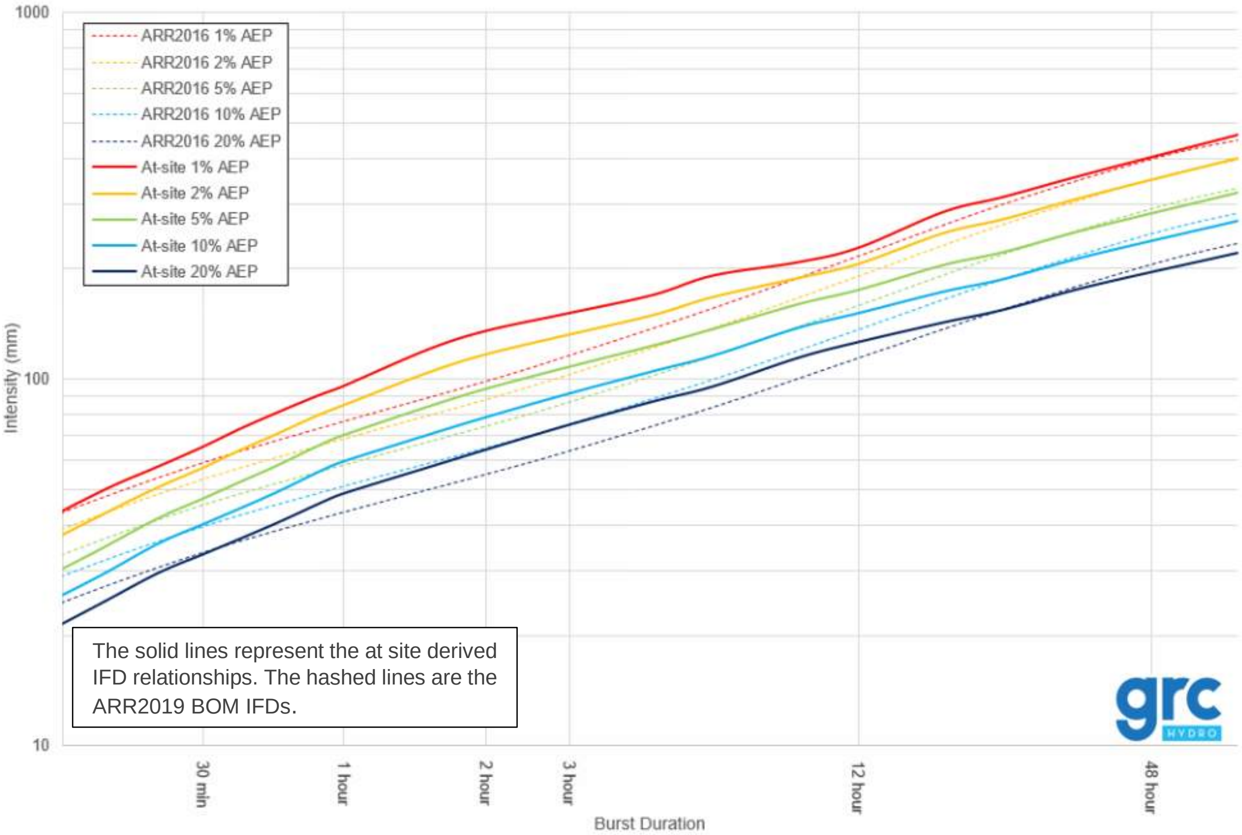
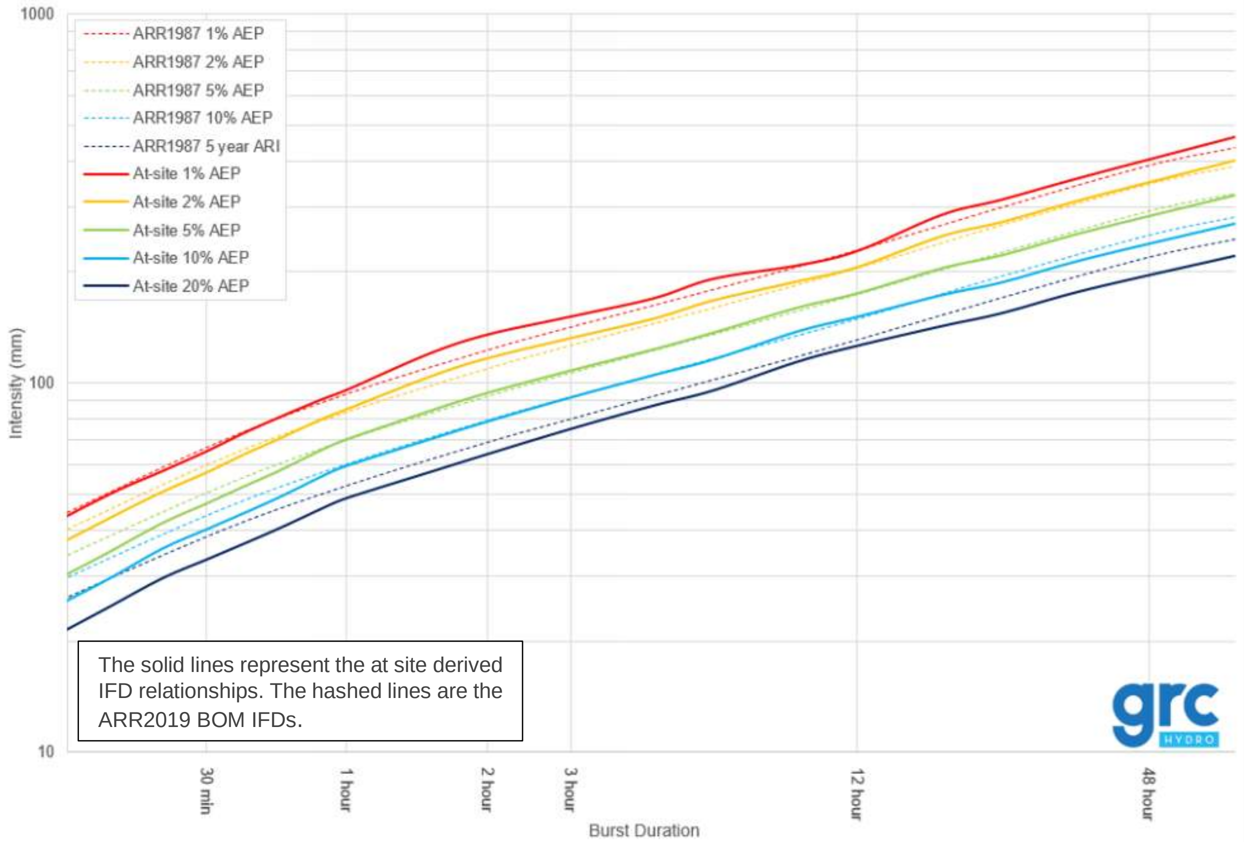


Image A 3: Comparison of ARR1987 IFD curves to at site frequency analysis for Observatory Hill (#66062)



A2.2.3. Design rainfall data selected for analysis

As per the recommendations in '*Floodplain Risk Management Guide, Incorporating 2016 Australian Rainfall and Runoff in studies*' (NSW Office of Environment and Heritage, January 2019), ARR2016 IFDs have been '*checked for consistency with at-site data*'. The analysis found a significant ($p < 0.1$) difference between ARR2016 IFDs and the at-site analysis, and that ARR2016 estimates are lower than both the at-site and ARR1987 estimates. In response to this finding, ARR2016 design rainfalls have not been applied for the current analysis.

ARR1987 design rainfall estimates have been used for the analysis presented herein and have been used in preference to the at-site analysis as they provide a smoother transition between rainfall estimates of varying duration, due to applied regionalisation techniques. Further, ARR1987 design rainfall depths have been used extensively over the past 30 years and are shown to be robust through comparison to the at-site analysis.

A2.2.4. Rainfall Temporal Patterns

Rainfall temporal patterns are used to describe how rainfall is distributed over time. ARR2019 recommends the ensemble approach to applying temporal patterns, which applies a suite of temporal patterns (typically 10) for each duration. Point temporal patterns for the 'East Coast South' region were applied to the ARR1987 design rainfall depths discussed above to develop storm bursts for application to the TUFLOW model. As 'direct rainfall' modelling methods have been applied, the temporal pattern which produced median flood level from the suite of temporal patterns was determined to be the critical storm for that duration.

A2.2.5. Areal Reduction Factors

The catchment area to Hickson Road, Barangaroo is less than 1 km^2 and accordingly, no Areal Reduction Factor has been applied to the design rainfall estimates.

A2.2.6. Rainfall Losses

The ARR2019 recommended approach to applying rainfall losses has been superseded by the '*Floodplain Risk Management Guide, Incorporating 2016 Australian Rainfall and Runoff in studies*' (NSW Office of Environment and Heritage, January 2019) which outlines a hierarchy of approaches for determining appropriate loss coefficients for implementation in design flood estimation. The hierarchy prioritises the application of calibrated losses, however, as calibrated losses are not available within the catchment or surrounding areas, use of the NSW FFA-reconciled losses obtained from the ARR Data Hub have been applied.

The Barangaroo catchment is heavily urbanised and comprised of predominately hardstand surfaces. The only significant pervious area is at Observatory Hill to the east of Kent Street. Initial and continuing losses for impervious surfaces have not been changed relative to previous studies and have been applied as 1 mm and 0 mm/hr respectively.

For pervious areas, due to the limited difference between losses for varying AEP and duration (5.7 to 9.9 mm), a single initial loss has been applied regardless of the storm event being assessed. The initial loss recommended for the 1% AEP, 2-hour duration event of 5.7 mm was applied for all storms as this was the most conservative recommended value of the events being examined. This is a reduction relative to the previous modelling which applied an initial loss of 10 mm.

Continuing losses have applied the ARR2019 recommended continuing loss of 1.6 mm/hr, multiplied by a factor of 0.4 as per the recommendations in the above reference document. The applied loss approach is acknowledged to not be recommended in urban areas, however, the applied losses are conservative relative to example analysis presented for the neighbouring Woolloomooloo catchment in Book 9, Section 6.4.5 of ARR2019.

The applied initial and continuing losses are presented in Table A 3.

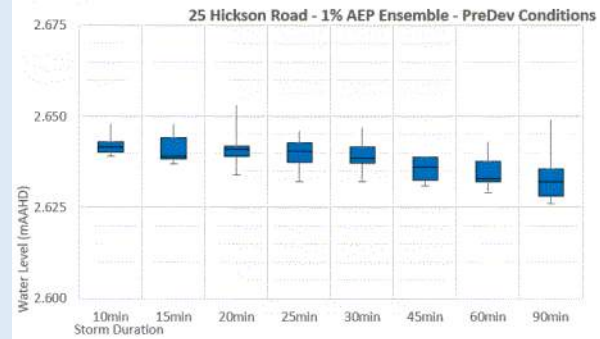
Table A 3: Applied Initial and Continuing Losses

Surface Type	Initial (mm)	Continuing (mm/hr)
Impervious	1.0	0.0
Pervious	5.6	0.64

A2.3. Critical Duration Assessment

ARR2019 recommends an ensemble approach to flood hydrology, which applies a suite of temporal patterns (typically 10) for each duration. The critical storm for each duration was determined to be the storm temporal pattern that produced the median flood level within the ensemble. The analysis focused on the critical storm event for existing development at 25, 30 and 38 Hickson Road, with the results of this analysis for the 1% AEP event presented as boxplots in Table A 4. The same analysis was undertaken for all assessed AEP storms and for both pre and post development conditions. The critical storm event was found to be consistent at the three existing developments.

Table A 4: 1% AEP Event Ensemble Results at 25, 30 and 38 Hickson Road

<table>
<tr><th>Pre-development Conditions</th><th>Post Development Conditions</th></tr>
<tr><td>


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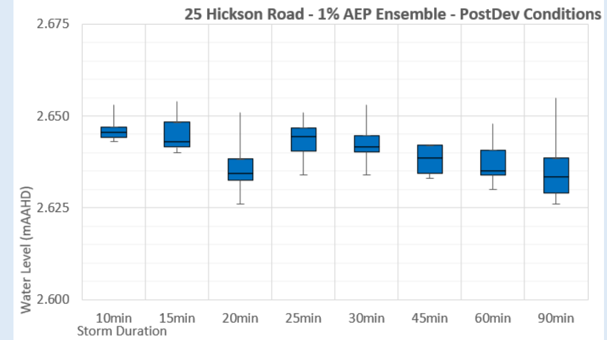

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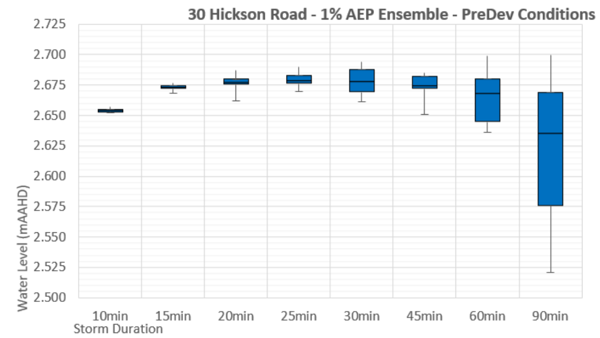

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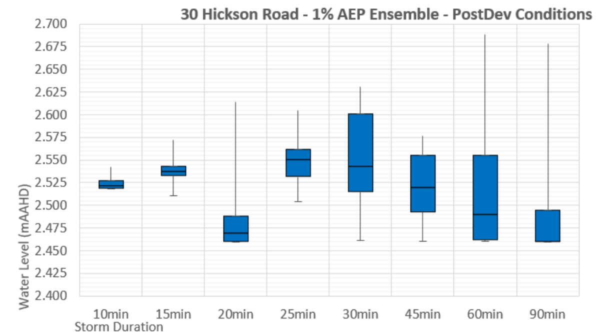

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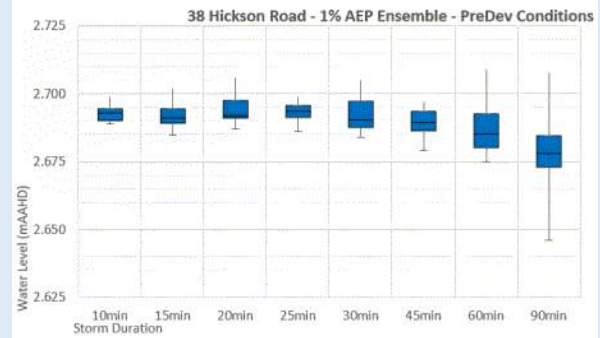

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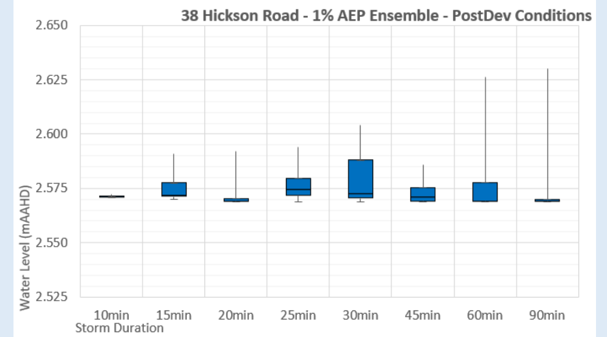

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</table>

Once the critical storm for each duration was identified, a critical duration assessment was undertaken by determining which critical storm event resulted in the highest peak flood level for each duration and AEP event.

The critical duration assessment was undertaken for both pre and post development conditions. The peak flood envelope of the critical duration for both scenarios was developed so that model results in areas not affected by future development changes were consistent.

Table A 5: Critical Storm and Duration Assessment Summary

Event (AEP)	Pre-development Duration (min)	Pre-development Critical Storm	Post Development Duration (min)	Post Development Critical Storm
20%	45	TP10	10	TP08
10%	45	TP10	10	TP08
5%	45	TP10	20	TP06
2%	20	TP07	25	TP04
1%	25	TP01	25	TP04
0.5%	25	TP01	25	TP01
0.2%	25	TP01	25	TP01
0.05%	20	TP05	20	TP04

A2.4. Comparison of Flows to Reference Design

A comparison of the current study and Reference Design peak flow estimates are presented in Table A 6. The change is peak flows is not only related to the change in applied hydrologic parameters, but also due to significant changes to the topography and hydraulic model build described in Section 3.3.2. At some locations, such as where flow overtops the High Street wall at the sag, these changes are noted to results in significant difference in flow. However, locations where model hydraulics did not change significantly, generally found flows from both models to be comparable.

Table A 6: Comparison of Current Study and Reference Design Flow for 1% AEP event

Location	Reference Design 1% AEP Flow (m^3/s)	Current Study 1% AEP Flow (m^3/s)	Difference (%)
Gas Lane (pipe and overland flow)	1.64	1.69	+3
Margaret Street east of Kent Street	0.95	1.07	+13
Erskine Street east of Sussex Street	0.96	0.81	-15
High Street near High Street stairs	0.19	0.15	-21
High Street north of High Street sag	0.31	0.32	+3
High Lane west of Kent Street	0.42	0.51	+21
Napoleon Street (pipe and overland flow)	2.01	2.20	+9
High Street sag overtopping High Street Wall (pipe and overland flow)	1.31	0.96	-27

A3. JOINT PROBABILITY ANALYSIS

A3.1. Introduction

ARR2019 notes that *'a key difference between this and earlier versions of ARR is the focus on how best to achieve "probability neutrality" between rainfall inputs and flood outputs when using rainfall-based techniques'*.

The relationship between rainfall intensity and Sydney Harbour water levels is fundamental to determining event probability at Barangaroo due to the proximity of the site to mean sea level. Stormwater conduits are frequently submerged, and elevated water levels due to tidal or storm surge conditions, can reduce stormwater capacity. Overestimating appropriate ocean level conditions for determining design flood behaviour can result in bias of the probability of the event being assessed.

The current analysis applies techniques consistent with ARR2019 and aims to achieve probability neutral outcomes by considering the joint probability of rainfall and sea level conditions.

A3.2. Guidelines and Policies

A3.2.1. NSW State Government

NSW Government guidelines for the management of joint probability considerations for flooding in coastal areas are outlined in:

- '*Flood Risk Management Guide: Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments'*, DECCW 2010 – this guideline is superseded by;
- *'Floodplain Risk Management Guide - Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways'*, NSW OEH (2015).

The 2015 guideline was developed to *'understand the interaction of catchment flooding with oceanic inundation* [and to] . . . *manage the associated flood risks to existing and future development'*. The focus of the guideline is for estuaries, with the appropriateness for application of smaller urban catchments not stated.

The guidelines recommend a series of oceanic water levels to be assumed as boundary condition according to the rarity of rainfall event being assessed. For example, the 1% AEP event is recommended to be determined by the following envelope:

- 1% AEP rainfall event with a 5% AEP ocean water level; and
- 5% AEP rainfall event with a 1% AEP ocean water level.

This approach was applied by the City of Sydney *'City Area Catchment Flood Study'* (BMT WBM, 2014), with the 1% AEP rainfall event with a 5% AEP oceanic water level found to be critical. Ocean water levels were obtained from the '*Fort Denison Sea Level Rise Vulnerability Study'* (DECCW, 2008), which provides still water levels for Fort Denison in Sydney Harbour for a range of probabilities derived via a Gumbel probability distribution.

The analysis presented in Section A3.3, provides context for this approach for small urban catchments in terms of the estimated joint probability. The analysis shows that application of this approach for a catchment such as Barangaroo, results in significant bias, and a flood event probability which is far rarer than 1% AEP.

A3.2.2. City of Sydney

The City of Sydney, Sydney Streets Technical Specifications (Section 4.7.3.5, Downstream Boundary Conditions) states '*where the impacts of a proposed network are being analysed, the downstream starting level for the hydraulic grade line shall be the . . . ocean boundary conditions consistent with the relevant City of Sydney flood study*'.

As described above, application of the OEH (2015) recommendation in the '*City Area Catchment Flood Study*' (BMT WBM, 2014) results in significant overestimation of event probability.

A3.2.3. Australian Rainfall and Runoff

The 2019 edition of Australian Rainfall and Runoff is considered best practise for design flood estimation. ARR2019 acknowledges that floods are stochastic in nature and emphasises the importance of achieving "probability neutrality" estimates, that is, a 1% AEP rainfall event should produce a 1% AEP flood event. Accordingly, the current edition of the ARR provides guidelines to best achieve probability neutrality by introducing Joint Probability analysis framework.

Details of the ARR2019 methodology are further discussed in Section A3.5.

A3.3. Joint Probability Overview

Joint probability analysis refers to the understanding of the probability of coincidence of two or more stochastic variables. For the Barangaroo catchment, there are numerous variables that may affect flood behaviour, however, the critical variables are rainfall and Sydney Harbour water levels. The dependency of these variables is key to determining the resulting probability of a specific rainfall and ocean level event coinciding.

Rainfall events are dominated by atmospheric conditions whilst oceanic water level events are dominated by astronomical tides and influenced to a lesser extent by storm surges. It is generally accepted that atmospheric conditions and astronomical tides have no correlation with each other, however, storm surges are associated to atmospheric conditions thus a dependency between rainfall event and oceanic water level event can occur.

If rainfall and ocean level events are assumed to be independent, then the joint probability of both events would be equal to the product of both probabilities, e.g. the probability of a 1% AEP rainfall event and 5% AEP ocean level event (as per NSW OEH, 2015 guidelines) happening in the same year would be equal to 0.05% AEP. Thus, to achieve flood estimates with a probability equal to the rainfall event then the ocean level event would need to be assumed equal to a mean water level.

Note that the above analysis considers the probability of two independent events occurring in the same <u>year</u>, not at the same time, as the Annual Exceedance Probability (AEP) refers to the <u>annualised</u> probability of an event (i.e. the chance of the event happening within a given year). Flood estimation at Barangaroo requires consideration of the coincided of these events, not only within the same year, but on the same day and at the same time, due to the short critical duration of the local catchments.

The joint probability of rainfall event and ocean level event happening at the same time at Barangaoo is required to be converted into hourly terms. The ARR2019 (Book 6: Chapter 5) defines the Daily Exceedance Probability (DEP) as the derived by dividing the AEP by 365 days. The same approach could be extended to derive probability in hourly terms (HEP - Hourly Exceedance Probability) by further dividing it by 24 hours. Table A 7 provides an estimate of the joint probability of both variables happening at the same time with equal AEP when both variables are assumed to be independent. The NSW OEH (2015) guidelines envelope approach (1% AEP rainfall event and 5% AEP oceanic level event) is presented in the last row, with estimated Average Recurrence Interval (ARI) of 17,520,000 years.

Table A 7: Joint Probability of Independent Events

Rainfall AEP [%]	Oceanic Level AEP [%]	Rainfall HEP [%]	Oceanic Level HEP [%]	Joint Probability HEP [%]	Joint Probability AEP [%]	Joint Probability ARI [Years]
A	B	C	D	E	F	G
Example Values	Example Values	A / (365*24)	B / (365*24)	C * D	E * (365 * 24)	1/F
20%	20%	0.00228%	0.00228%	5.21E-8%	4.57E-4%	219,000
10%	10%	0.00114%	0.00114%	1.30E-8%	1.14E-4%	876,000
5%	5%	0.00057%	0.00057%	3.26E-9%	2.85E-5%	3,504,000
2%	2%	0.00023%	0.00023%	5.21E-10%	4.57E-6%	21,900,000
1%	1%	0.00011%	0.00011%	1.30E-10%	1.14E-6%	87,600,000
1%	**5%**	**0.00011%**	**0.00057%**	**6.52E-10%**	**5.71E-6%**	**17,520,000**

It should be noted that the above analysis assumes independence of rainfall and ocean level events. To validate this assumption, correlation analysis was undertaken to determine the dependency of rainfall and ocean level events for the Barangaroo catchment.

A3.4. Correlation Analysis

Correlation analysis was performed for the tidal gauge at Fort Denison (gauge # 060370) and rainfall gauge at Sydney Observatory Hill (gauge # 066062) to determine the dependency between short duration rainfall and ocean level events. As it is generally well accepted astronomical tides do not affect meteorological conditions, the analysis is performed on storm rainfall burst depth and the tidal anomaly.

A tide anomaly is defined as the difference between the recorded ocean water level and predicted water level due to astronomical tides. The tide anomaly, like rainfall events, occurs due to meteorological conditions such as barometric pressure, and wind and wave setup.

The analysis was performed by extracting rainfall burst depths at Sydney Observatory Hill for durations of 30, 60, 90 and 120 minutes and the corresponding tidal anomaly at Fort Denison, at the time of the rainfall event. A peak over threshold series was created, with rainfall events exceeding 2EY, corresponding to the duration being assessed, included in the analysis. To account for potential lag time between rainfall and catchment response, the maximum anomaly during the period 2 hours prior and post the rainfall event was used and paired with the corresponding rainfall event. The period from 1965-2018 was used in the analysis as both rainfall and tidal data was available for these years.

The event pairs are presented in Image A 4 to Image A 7 for the 30 to 120 minute durations respectively.

Image A 4: Rainfall Depth – Tide anomaly pairs (30 minute storm duration)

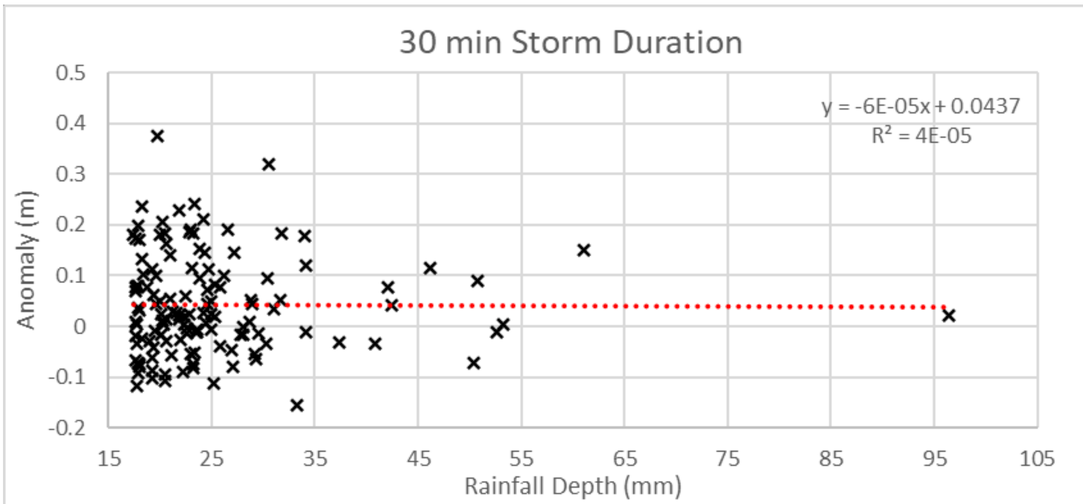


Image A 5: Rainfall Depth – Tide anomaly pairs (60 minute storm duration)

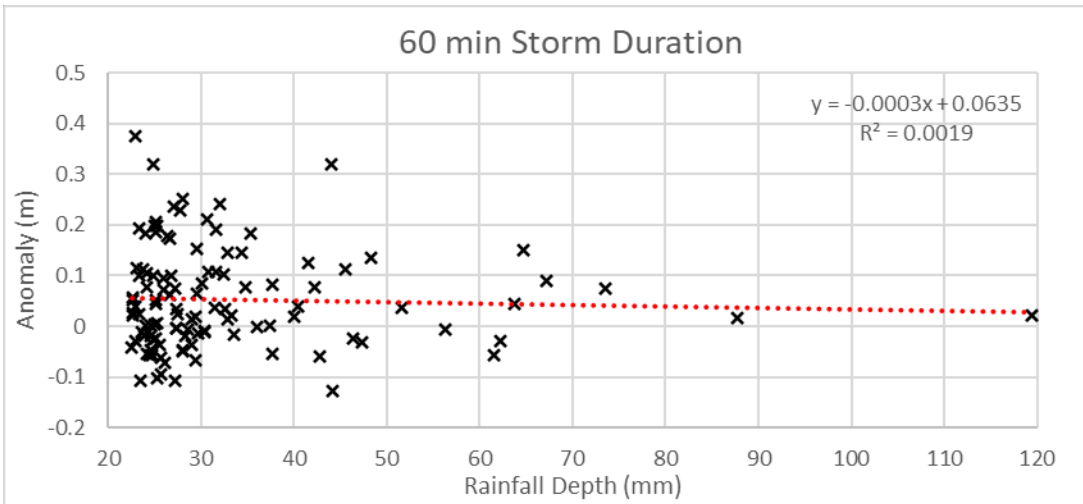


Image A 6: Rainfall Depth – Tide anomaly pairs (90 minute storm duration)

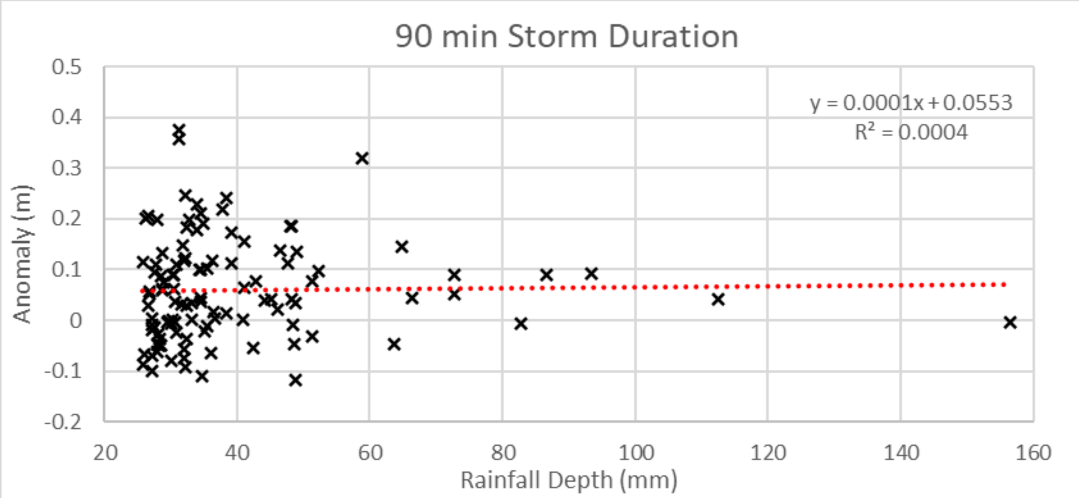
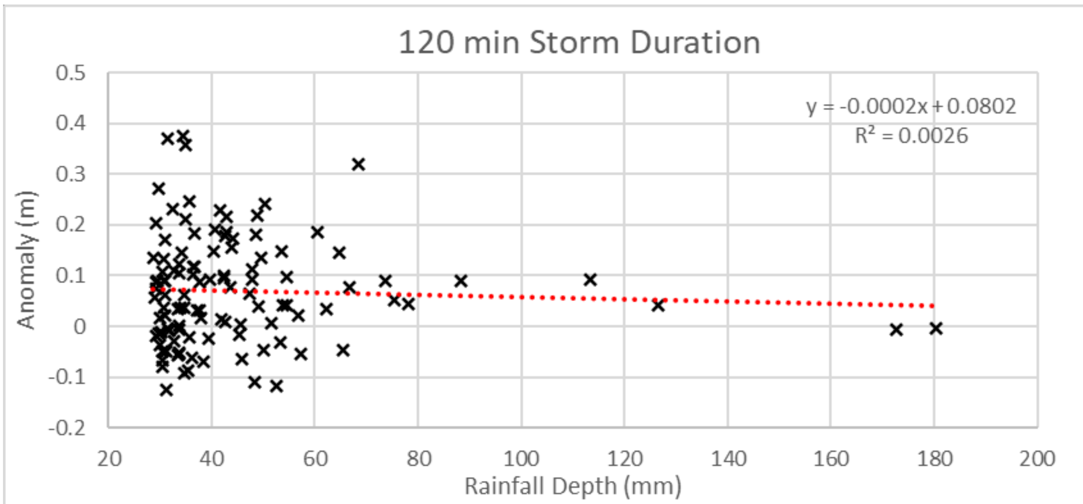


Image A 7: Rainfall Depth – Tide anomaly pairs (120 minute storm duration)



If rainfall events and tidal anomaly are indeed correlated, then it can be expected that the more intense the rainfall, the greater the anomaly, however, no clear trend is noted, with the largest rainfall events experiencing very little tidal anomaly.

Correlation coefficients of Pearson R, Kendall Tau and Spearman Rho were derived from the data pairs with the results presented in Table A 8. Interpretation of the correlation coefficient parameters are varied, but it is often agreed that degree of correlation is weak to null if Kendall's Tau is within +/-0.07 or if Spearman's Rho is within the +/-0.10 (Botsch, 2011; Akoglu, 2018; Berg, 2021)

Table A 8: Correlation Coefficients between Rainfall Burst Depth and Tide Anomaly

Storm Duration (min)	Pearson R		Kendall Tau		Spearman Rho	
	Coeff.	p-Value	Coeff.	p-Value	Coeff.	p-Value
30min	-0.05	0.60	0.04	0.51	0.07	0.47
60min	-0.01	0.94	0.02	0.80	0.03	0.78
90min	-0.04	0.65	0.02	0.76	0.03	0.76
120min	0.02	0.84	0.12	0.07	0.17	0.07

The resulting correlation coefficients are close to zero for storm durations shorter than 90 minutes, suggestive of low to null correlation between the two parameters, with a relatively high p-value when tested against the null-hypothesis of parameters being equal to zero (i.e. probability of correlation coefficient being zero is high).

Due to the low correlation, a simplified approach to achieving probability neutrality flood estimates is to assume that both variables (rainfall event and oceanic level events) are independent. Such an approach would apply the average water level of the data pairs as presented in Table A 9 which ranges from ~0.13 to 0.25 mAHD depending on duration. However, given the potential weak correlation of rainfall and ocean level events, and the sensitivity of Hickson Road stormwater system, additional analysis through application of ARR2019 bivariate logistic model was undertaken (see Section A3.5).

Table A 9: Average and maximum recorded water level for peak over threshold series

Storm Duration (min)	Average (mAHD)	Max (mAHD)
30	0.15	0.96
60	0.13	0.96
90	0.16	0.88
120	0.25	0.93

It is worth noting that for each duration, the 10 largest rainfall events to occurred between 1965 and 2018 (53 years) all occurred with a corresponding tidal anomaly of <0.15 mAHD. Table A 9 also presented the max recorded water level from the data pairs. The maximum recorded Sydney Harbour water level to occur during any rainfall event exceeding 2EY is ~0.3 m lower than the 1 year ARI oceanic water level of 1.24 mAHD (DECCW, 2008).

A3.5. ARR2019 Bivariate Logistic Model

A3.5.1. Overview

The treatment of joint probabilities of variables with complete dependency or independency is relatively straightforward as described in Section A3.3. However, as described in Section A3.4 there is potentially a degree of correlation between rainfall and ocean level events (albeit a weak one, particularly for short durations). '*Book 6: Chapter 5 – Interaction of Coastal and Catchment Flooding*' (ARR2019, Project 18) examines the degree of dependency between these two variables using a Bivariate Logistic model. The dependency of multiple probability distribution functions is expressed as the dependency parameter ‘α’. If α is equal to 0, then the two variables are said to be 100% dependant of each other (e.g. if Event ‘A’ occurs with an associated AEP of X%, then Event ‘B’ will always occur with the same AEP, at the same time). Conversely, if α is equal to 1, then it is expected that the two events always happen independently of each other (i.e. no correlation).

For correlated events, ARR2019 recommends the application of the Design Variable Method to assess interactions between coastal and catchment flooding. The method consists of:

- Extract the relevant α dependency coefficient (see Section A3.5.2);
- Running a matrix of rainfall and ocean level events of varying AEPs through a hydraulic model and tabulating the resulting water levels at a location of interest;
- Apply to above information to the ARR Bivariate Logistic model (http://p18.arr-software.org/ - beta version).

The ARR Bivariate Logistic model determines probability neutral water levels for varying AEP considering the joint probability of both variables.

A3.5.2. ‘α’ Dependency Coefficient

‘Book 6: Chapter 5’ (ARR2019, Project 18) presents derived α dependency values for rainfall and ocean level events along the Australian coastline. Figure 6.5.13 of ‘*Book 6: Chapter 5*’ has been reproduced herein as Image A 8 and presents the α values conditional to storm durations of < 12 hours, 12 to 48 hours and > 48 hours. For Sydney, the α dependency parameter is 0.95 for storm durations shorter than 12 hours, an indication of a weak dependency.

Image A 8: α Dependency Values across Australia (ARR2019 – Book 6: Chapter 5)

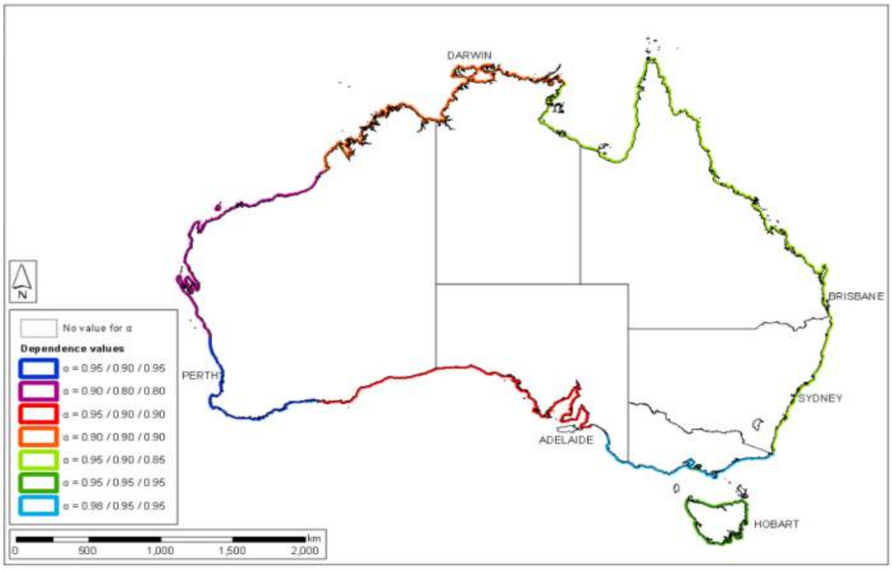
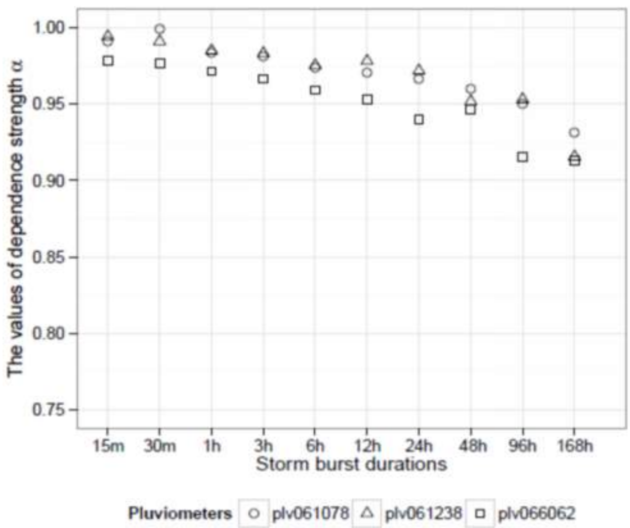


Image A 9 presents further details for Fort Denison (Sydney Harbour) and shows that for storm durations that are critical at Barangaroo (see Section A2.3), the α dependency value increases to 0.97 to 0.98, again indicating weak correlation between rainfall and ocean level events.

Image A 9: Detailed α Dependency Values at Fort Denison (ARR2019 – Project 18 Stage 3)



For the ensuing analysis, an α dependency value of 0.97 was applied.

A3.5.3. Rainfall and Ocean Level Event Matrix

The Design Variable Method described by ARR2019 requires assessment of various combinations of rainfall and ocean level events. For rainfall the 20, 10, 5, 2, 1, 0.5, 0.2 and 0.05% AEP rainfall events were assessed, in combination with Mean Sea Level (MSL), Mean High Water Springs (MHWS), and 1, 2, 5, 20, 100, 200 and 2000 years ARI ocean water level events (ARI were converted to AEP for the analysis). Ocean water levels were taken as Sydney Harbour water levels from the '*Fort Denison Sea Level Rise Vulnerability Study*' (DECCW, 2008) study, with water levels for events rarer than 100 year ARI determined via extrapolation in log-space. MSL was set as the lower boundary with a probability of 100% AEP and MHWS probability is inferred to be 99.99% AEP (24 spring tides are expected to occur in any given year, with 12 of them expected to exceed the mean which results in 12EY).

The assessment was undertaken using the critical duration and median storm discussed in Section A2.3, which were determined using Sydney Harbour water levels set at MHWS. Due to the sensitivity of stormwater at Barangaroo to ocean levels, the critical duration was reassessed for the range of ocean levels described above. To reduce the number of required model simulations, the median storm for each duration was used in the assessment. The assessment found that the critical duration for Hickson Road is relatively insensitive to ocean level, and that the determined critical durations are appropriate regardless of Sydney Harbour water levels.

The resulting water levels for the location of 25 Hickson Road, 30 Hickson Road, and 38 Hickson Road for ultimate development conditions is presented from Table A 10 to Table A 12 respectively. Due to the limited flood liability of Hickson Road near these properties under ultimate development conditions, for most storm events, where flooding has not occurred water levels are extracted as the Hydraulic Grade Line (HGL) within nearby drainage inlet structures.

Table A 10: Design Variable Method Input – Water Level Results at 25 Hickson Road (mAHD)

Rainfall Event (AEP)		Oceanic Water Level (AEP)								
		MSL	MHWS	63.21%	39.35%	18.13%	5%	1%	0.5%	0.05%
	20%	1.733	1.734	1.734	1.736	1.739	1.742	1.745	1.755	1.809
	10%	1.753	1.753	1.753	1.753	1.754	1.755	1.778	1.790	1.852
	5%	1.790	1.791	1.792	1.794	1.795	1.815	1.858	1.876	1.939
	2%	1.859	1.860	1.860	1.861	1.862	1.897	1.945	1.961	2.024
	1%	1.915	1.916	1.918	1.920	1.935	1.976	2.025	2.042	2.108
	0.5%	1.992	1.995	2.038	2.064	2.092	2.139	2.189	2.208	2.276
	0.2%	2.098	2.172	2.247	2.281	2.317	2.374	2.434	2.455	2.516
	0.05%	2.604	2.627	2.705	2.710	2.715	2.723	2.731	2.734	2.744

Note: If no flooding occurs, water levels have been extracted from the HGL at the nearest drainage inlet

Table A 11: Design Variable Method Input – Water Level Results at 30 Hickson Road (mAHD)

Rainfall Event		Oceanic Water Level								
		MSL	MHWS	1YR	2YR	5YR	20YR	100YR	200YR	2000YR
	5YR	0.958	1.122	1.684	1.721	1.759	1.819	1.880	1.901	1.974
	10YR	0.988	1.220	1.773	1.812	1.852	1.914	1.976	1.995	2.051
	20YR	1.002	1.264	1.813	1.853	1.893	1.955	2.012	2.027	2.080
	50YR	1.036	1.587	2.143	2.180	2.217	2.275	2.334	2.353	2.421
	100YR	1.179	1.816	2.338	2.375	2.412	2.459	2.491	2.501	2.535
	200YR	1.464	2.079	2.514	2.533	2.551	2.576	2.601	2.609	2.639
	500YR	1.827	2.354	2.633	2.648	2.663	2.686	2.710	2.717	2.746
	2000YR	2.769	2.917	3.039	3.046	3.053	3.064	3.075	3.079	3.091

Note: If no flooding occurs, water levels have been extracted from the HGL at the nearest drainage inlet

Table A 12: Design Variable Method Input – Water Level Results at 38 Hickson Road (mAHD)

Rainfall Event		Oceanic Water Level								
		MSL	MHWS	1YR	2YR	5YR	20YR	100YR	200YR	2000YR
	5YR	0.480	1.076	1.643	1.681	1.719	1.779	1.840	1.861	1.933
	10YR	0.548	1.166	1.726	1.766	1.806	1.867	1.929	1.949	2.010
	20YR	0.586	1.206	1.763	1.803	1.843	1.905	1.964	1.981	2.038
	50YR	0.900	1.535	2.098	2.136	2.174	2.232	2.292	2.312	2.382
	100YR	1.103	1.753	2.299	2.338	2.378	2.429	2.463	2.474	2.510
	200YR	1.385	2.018	2.487	2.507	2.526	2.553	2.579	2.588	2.618
	500YR	1.720	2.287	2.607	2.623	2.640	2.664	2.688	2.696	2.725
	2000YR	2.670	2.849	2.977	2.986	2.994	3.007	3.020	3.024	3.038

Note: If no flooding occurs, water levels have been extracted from the HGL at the nearest drainage inlet

A3.5.4. Bivariate Logistic Model Results

The matrices presented in Table A 10 to Table A 12 were applied to the ARR2019 bivariate logistical model. The software produced probability neutral design water levels for varying AEP at each location as presented in Image A 10 to Image A 12.

Image A 10: Joint Probability results at 25 Hickson Road

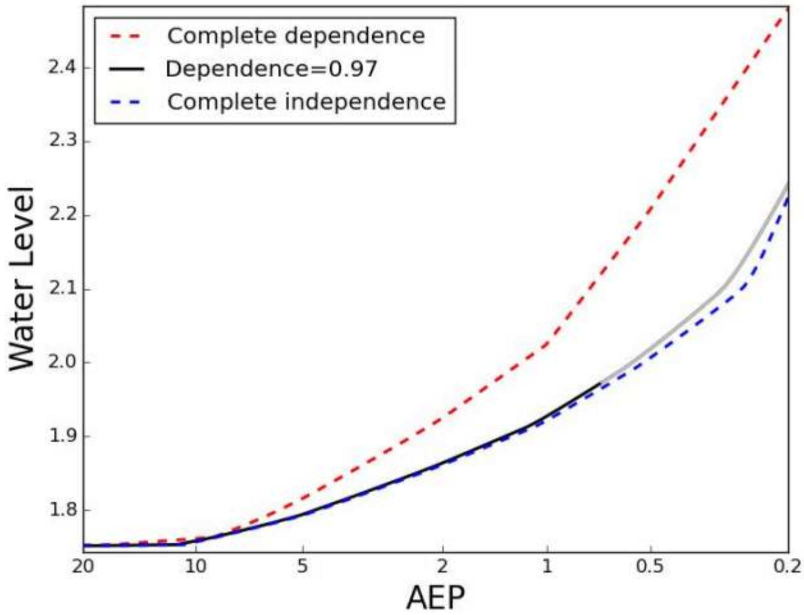


Image A 11: Joint Probability results at 30 Hickson Road

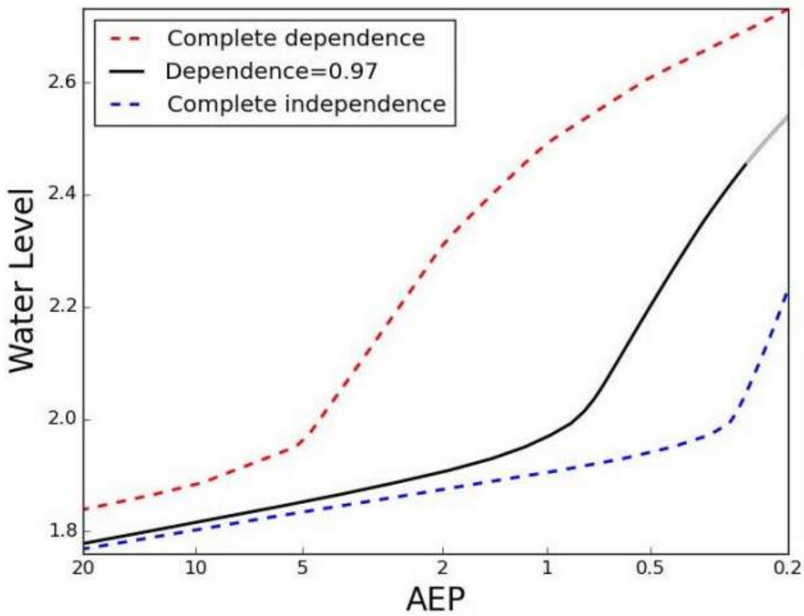
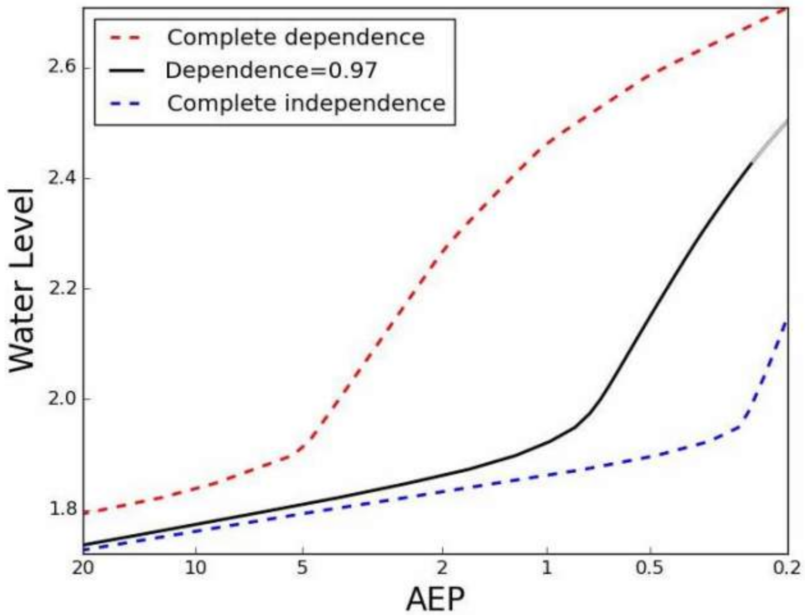


Image A 12: Joint Probability results at 38 Hickson Road



A summary of probability neutral water levels is presented in Table A 11. For 30 and 38 Hickson Road, the 1% AEP joint probability between rainfall and oceanic level events should produce a water level of 1.97 mAHD and 1.92 mAHD respectively (which is noted to be below the level of Hickson Road at ~2.6 mAHD). The Sydney Harbour water level required to achieve this water level whilst coinciding with a 1% AEP rainfall event is approximately that of the MHWS which results in water levels of 1.82 mAHD and 1.75 mAHD respectively. Application of a 1 year ARI water level would result in the overestimation of 1% AEP flood levels by ~400 mm.

Table A 13: Probability Neutral Water Level Results at AEP of interest

AEP (%)	Probability Neutral Water Level (mAHD)		
	25 Hickson Road	30 Hickson Road	38 Hickson Road
20	1.75	1.78	1.74
10	1.76	1.82	1.77
5	1.79	1.85	1.81
2	1.86	1.91	1.86
1	1.93	1.97	1.92
0.5	2.02	2.20	2.15
0.2	2.25	2.54	2.51

For context, application of the NSW OEH (2015) guidance (1% AEP rainfall with 5% AEP ocean level) results in an estimated event probability of ~0.2% AEP (500 year ARI).

Following the same approach for 25 Hickson Road, application of an assumed Sydney Harbour water level of a 2 year ARI would be required to produce probability neutral estimates, however, it should be noted that the difference in water level assuming MSL is only 20 mm. Similar outcomes were noted for more frequent events (e.g. for a 20% AEP event at 38 Hickson Road, the assumed Sydney

Harbour water level would need to be rarer than 5 year ARI), which is an illogical outcome, indicating a potential issues with the approach.

A3.6. Applied Design Tailwater Levels

The current best practice for flood estimates as provided by the latest edition of ARR2019 emphasises the importance of achieving probability neutrality in the flood estimates.

The analysis provided herein describes how current guidance provided by NSW DPIE (NSW OEH, 2015) and adopted by Council, is no longer considered 'best practice', results in significant bias, and a flood event probability which is far rarer than the applied rainfall.

Correlation analysis of rainfall and ocean water level events found the two variables to be independent or very weakly correlated for the short storm durations critical at Barangaroo. *'Book 6: Chapter 5'* (ARR2019, Project 18) presents a similar finding with α dependency coefficient of 0.97 – 0.98 indicating weak correlation.

Application of the ARR2019 bivariate logistical model was undertaken with results indicating use of the Mean High Water Springs (MHWS) tide levels offer a simple assumption which achieves estimates close to probability neutrality. Some of the results from the analysis were found to be illogical, so direct application of the approach for Barangaroo was found to be inappropriate.

Design flood analysis has therefore implemented a tailwater conditions of 0.625 mAHD which corresponds to the Mean High Water Spring tide level (MHWS). Correlation analysis (Section A3.4) found that for all events exceeding 2EY rainfall intensities over a 50 year period, the MHWS tide level was only exceeded 10% of the time and by a maximum of ~330 mm (~0.96 mAHD).

Further, application of MHWS as the oceanic boundary conditions is consistent with that applied for stormwater design for the Barangaroo South and Stage 1B developments (Cardno).

For the PMF, the 1% AEP Sydney Harbour water level from the '*Fort Denison Sea Level Rise Vulnerability Study*' (DECCW, 2008) has been applied as the oceanic boundary.

A4. CLIMATE CHANGE ANALYSIS

A4.1. Climate Change Impacts on Rainfall

The impact of climate change on flood producing rainfall and resultant flooding has been assessed. The assessment used the IPCC (Intergovernmental Panel on Climate Change) greenhouse gas concentration scenarios to estimate the effect of climate change on rare rainfall events. There are four IPCC greenhouse gas concentration projections named RCP 2.5, 4.5, 6.0 and 8.5, with the RCP 2.5 being the most optimistic and 8.5 the least optimistic. The ARR2019 methodology recommends the use of RCP 4.5 and 8.5 scenarios, and their projected increase in precipitation intensity were obtained from the ARR Data Hub and shown in Table A 14 for the 2090 planning horizon.

Table A 14: Climate Change Factors – Percentage Increase in Rainfall Intensity in 2090

Year	RCP 4.5	RCP 8.5
2090	+9.5 %	+19.7%

The IPCC recommendations indicate, under a relatively low emissions scenario (RCP 4.5), that rainfall intensity is expected to increase by 9.5% in Barangaroo by 2090. The significance of this percentage is measured by comparing it to the range of design flood events. The results of this assessment are shown in Table A 15, which lists the total rainfall depth for the 5%, 2%, 1%, 0.5% and 0.2% AEP events (for the critical duration at Barangaroo, i.e. 25 minutes) and then compares those events with the increased rainfall caused by two emissions scenarios – RCP 4.5 and RCP 8.5.

Table A 15: Comparison between Design Rainfall and Projected Climate Change Rainfall Intensity

AEP	Total Rainfall Depth (mm)		
	IFD	2090 RCP 4.5	2090 RCP 8.5
	25 minutes	+9.5%	+19.7%
5%	45.5	49.8	54.5
2%	53.9	59.0	64.5
1%	60.1	65.8	71.9
0.5%	66.6	72.9	79.7
0.2%	74.5	81.6	89.2

The table shows that, the 1% AEP flood event will increase to a magnitude close to the present day 0.5% AEP event under the 2090 RCP 4.5 scenario. Under the 2090 RCP 8.5 scenario, the 1% AEP storm event will be equivalent to a present-day event between 0.5% and 0.2% AEP.

<u>To meet Sydney Metro requirements outlined in Section 9.1, the RPC4.5 emissions scenario increase of 9.5% has been rounded up to 10%. This scenario is referenced to as '+10% Rainfall'.</u>

A4.2. Climate Change Impacts on Sea Level

Sea level rise guidelines outlined in the NSW Sea Level Rise Policy (DECCW, 2009) have been adopted to assess potential flood impacts associated with increases in mean sea level associated with climate change. The Policy set the benchmarks for a projected rise in sea level for 2050 and 2100 planning horizons of 0.4 m and 0.9 m respectively.

Sea level rise estimates have been revised by more recent IPCC estimates with the mean estimate of climate models for the 2100 planning horizon expected to be ~0.5 m for Sydney. However, due to the sensitivity of the Barangaroo stormwater system to Sydney Harbour water levels, the NSW Sea Level Rise Policy (DECCW, 2009) estimates have been used.

A4.3. Adopted Climate Change Scenarios

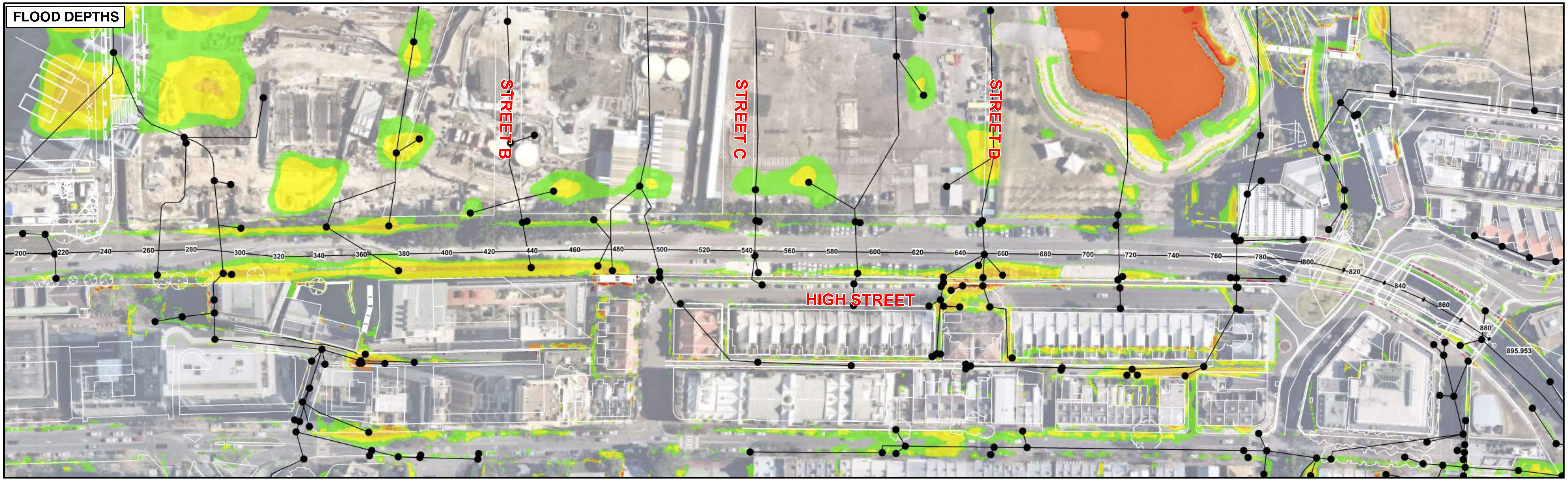
The climate change scenarios listed below have been adopted for assessment of the impact of climate change on design flood behaviour:

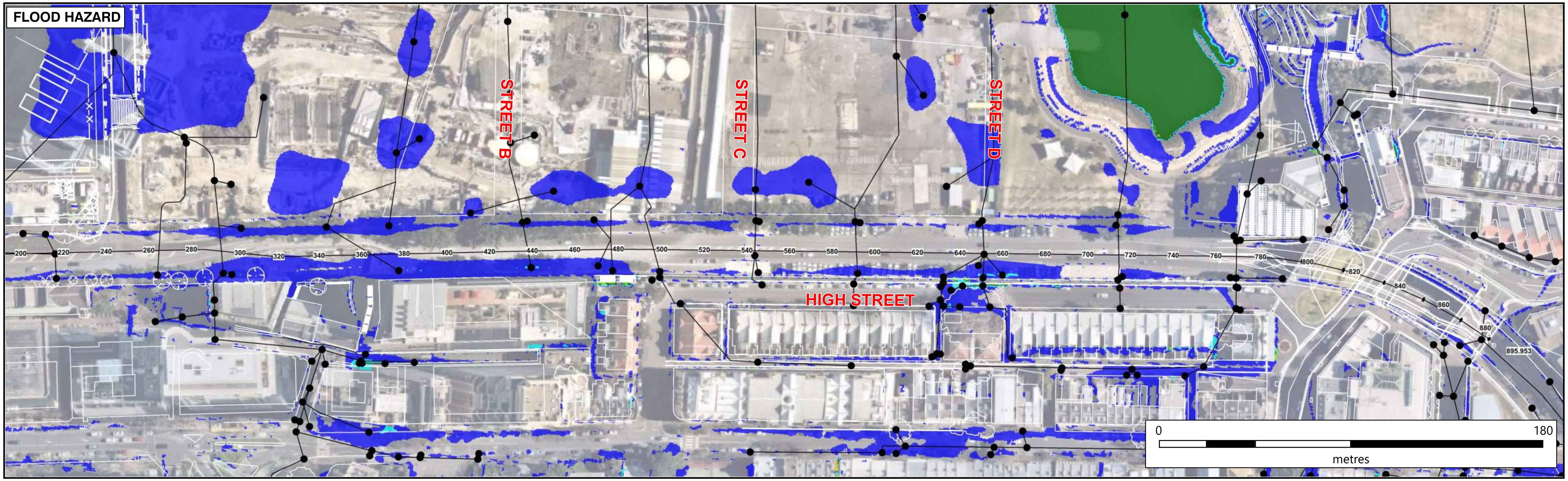
- 1% AEP Event +10% Rainfall and 0.9 m Sea Level Rise;
- 1% AEP Event + RCP8.5 (2090) Rainfall Estimates with 0.9 m Sea Level Rise;
- PMF Event with 0.9 m Sea Level Rise.

ARR2019 does not recommend increases in rainfall intensity be applied to the PMF event.

The climate change scenarios have not been assessed for the 'Hickson Road North – Temporary Design' as they are not relevant during the proposed construction timeframe.

Appendix B – Pre-Development Conditions, Flood Maps





Existing Pit
Existing Pipe

Flood Depth (m)

0.0 to 0.05	0.2 to 0.3	1.0 to 1.5
0.05 to 0.1	0.3 to 0.5	1.5 to 2.0
0.1 to 0.2	0.5 to 1.0	> 2.0

Flood Hazard Category (AEM)

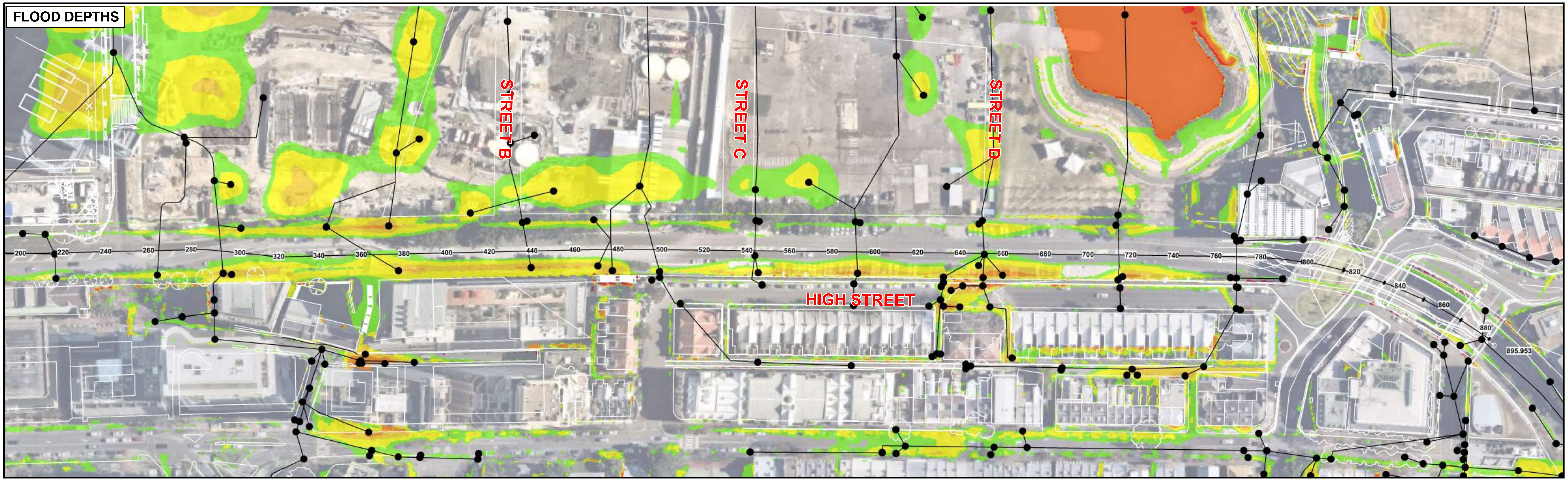
H1	H4
H2	H5
H3	H6

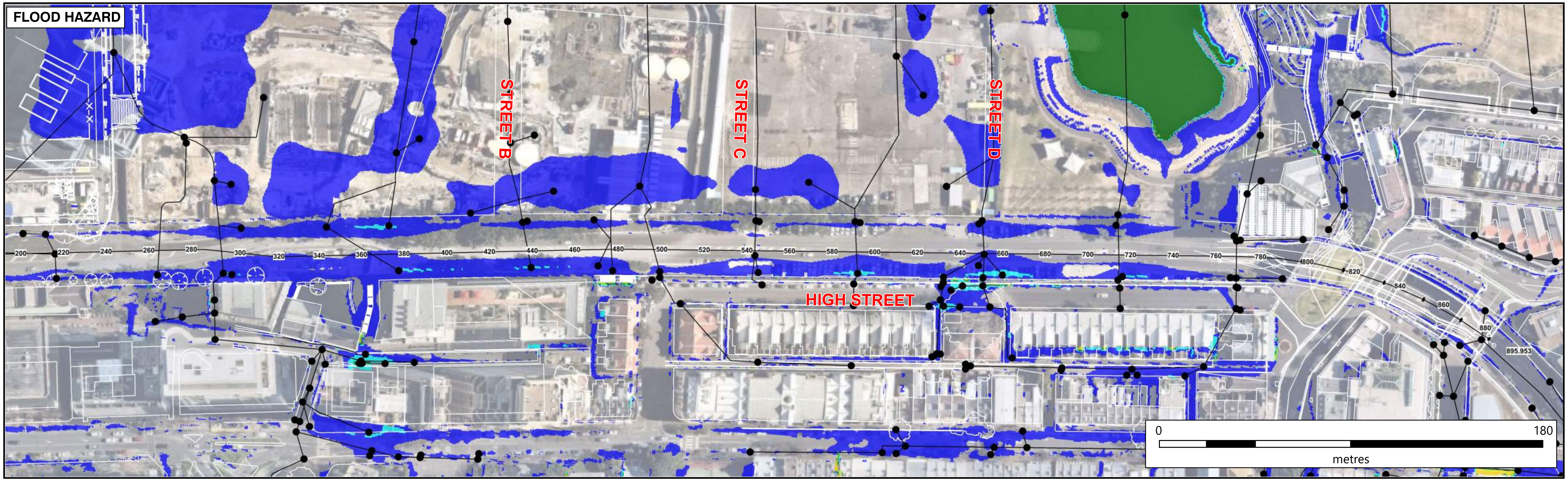
W N S E

Flood model results presented on this map have been prepared for INSW in accordance with the terms of the engagement and should not be used for any other purpose

grc HYDRO

TITLE : **PRE-DEVELOPMENT CONDITIONS - FLOOD DEPTHS AND HAZARD**	EVENT: **5% AEP**	PROJECT: **Barangaroo Station Civil Works Hickson Road Stage 3 Design**	PROJECT No.**180038**	DATE: **June 2021**	FIGURE NUMBER: **B1**





Existing Pit
Existing Pipe

Flood Depth (m)

0.0 to 0.05	0.2 to 0.3	1.0 to 1.5
0.05 to 0.1	0.3 to 0.5	1.5 to 2.0
0.1 to 0.2	0.5 to 1.0	> 2.0

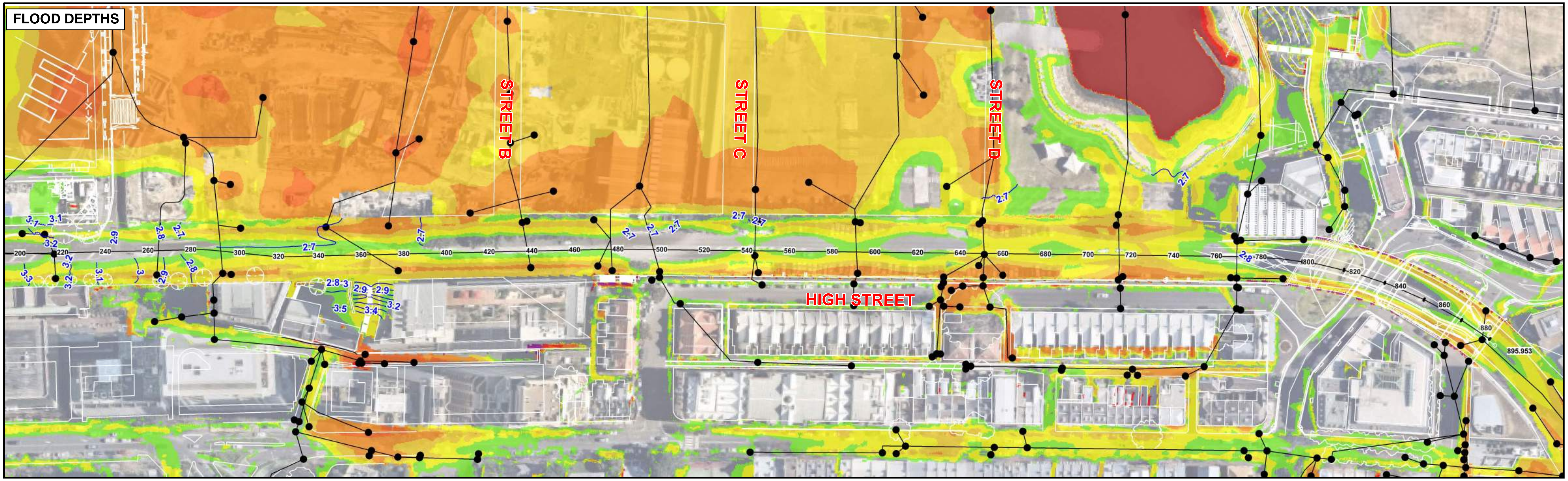
Flood Hazard Category (AEM)

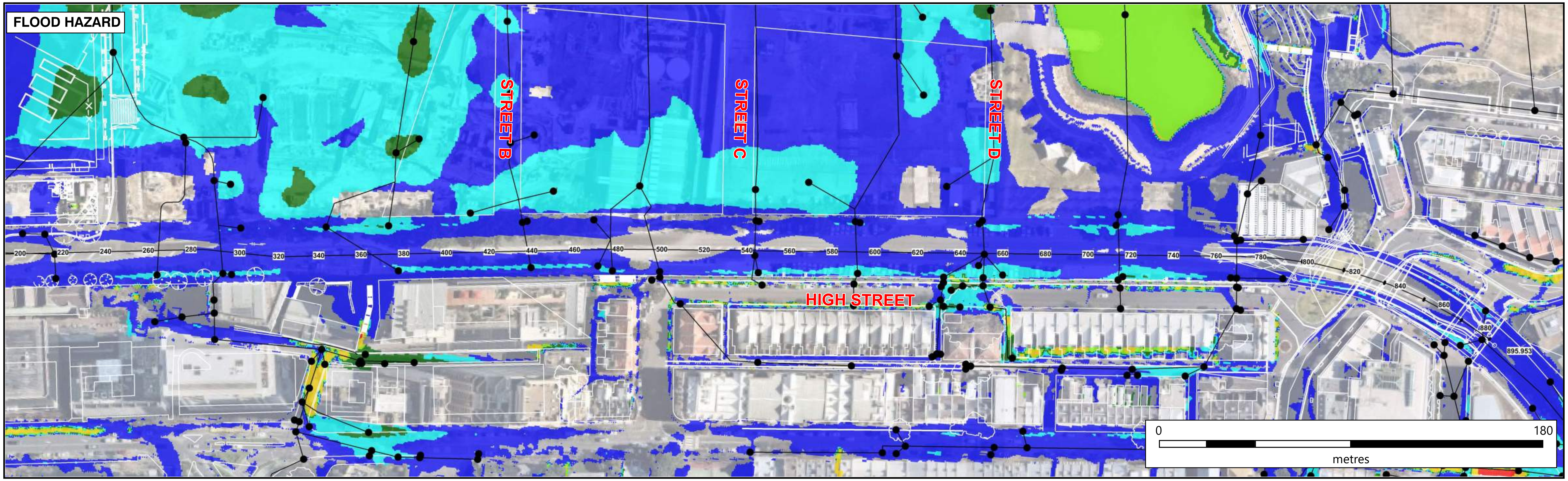
H1	H4
H2	H5
H3	H6

Flood model results presented on this map have been prepared for INSW in accordance with the terms of the engagement and should not be used for any other purpose

grc HYDRO

TITLE : **PRE-DEVELOPMENT CONDITIONS - FLOOD DEPTHS AND HAZARD**	EVENT: **1% AEP**	PROJECT: **Barangaroo Station Civil Works Hickson Road Stage 3 Design**	PROJECT No.**180038**	DATE: **June 2021**	FIGURE NUMBER: **B2**





- Existing Pit
- Existing Pipe

Flood Depth (m)

0.0 to 0.05	0.2 to 0.3
0.05 to 0.1	0.3 to 0.5
0.1 to 0.2	0.5 to 1.0
1.0 to 1.5	1.5 to 2.0
> 2.0	

Flood Hazard Category (AEM)

H1, H2, H3, H4, H5, H6

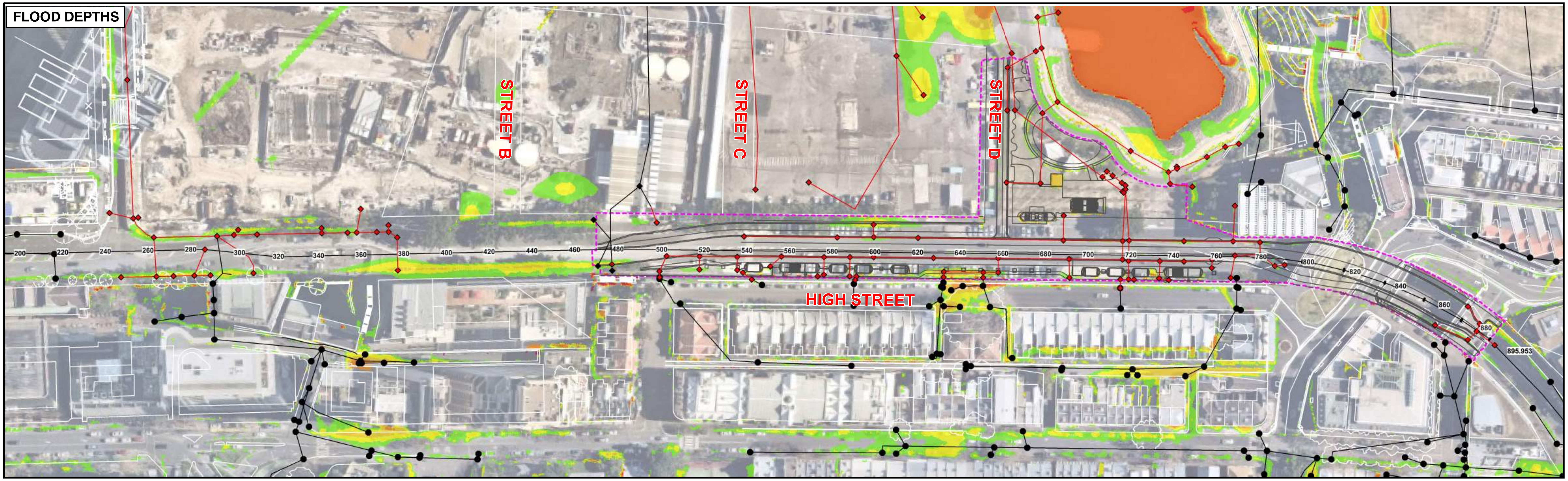
Peak Water Level (mAHD)
Contour Spacing = 0.1m

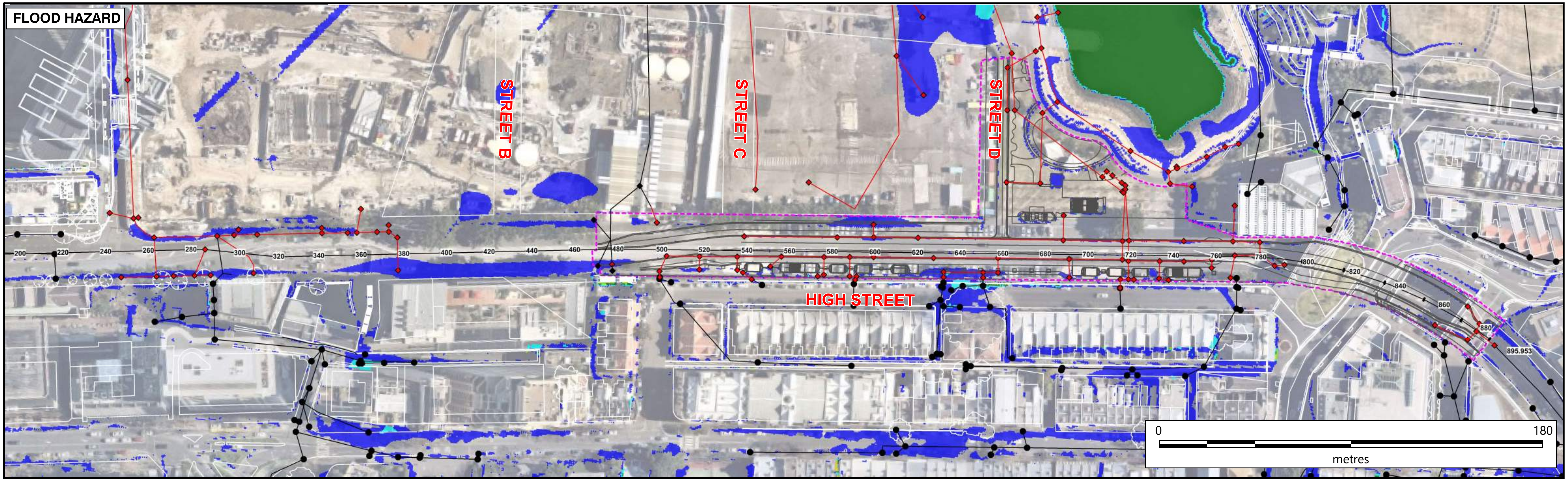
Flood model results presented on this map have been prepared for INSW in accordance with the terms of the engagement and should not be used for any other purpose

grc HYDRO

TITLE : PRE-DEVELOPMENT CONDITIONS - FLOOD DEPTHS AND HAZARD	EVENT: PMF	PROJECT: Barangaroo Station Civil Works Hickson Road Stage 3 Design	PROJECT No.180038	DATE: June 2021	FIGURE NUMBER: B3

Appendix C – Hickson Road North Temporary Design, Flood Maps





Proposed Pit
Proposed Pipe
Existing Pit
Existing Pipe
Hickson Road North, Temporary Design - Extent of Works

Flood Depth (m)

0 to 0.05	0.2 to 0.3	1.0 to 1.5
0.05 to 0.1	0.3 to 0.5	1.5 to 2.0
0.1 to 0.2	0.5 to 1.0	> 2.0

Flood Hazard Category (AEM)

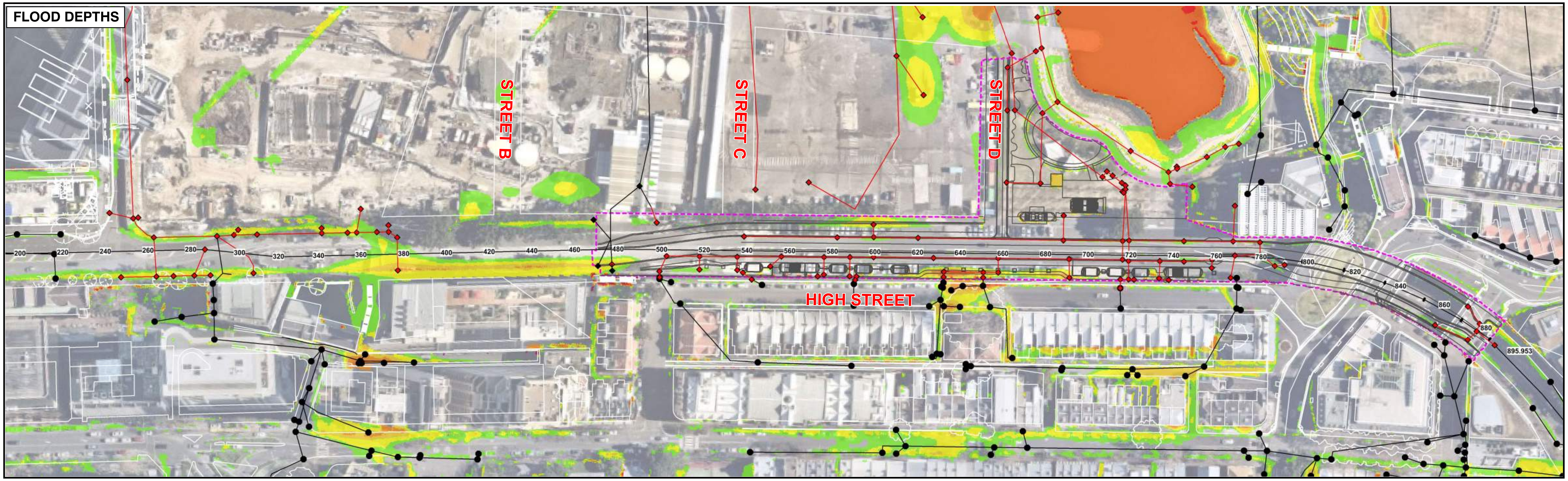
H1	H4
H2	H5
H3	H6

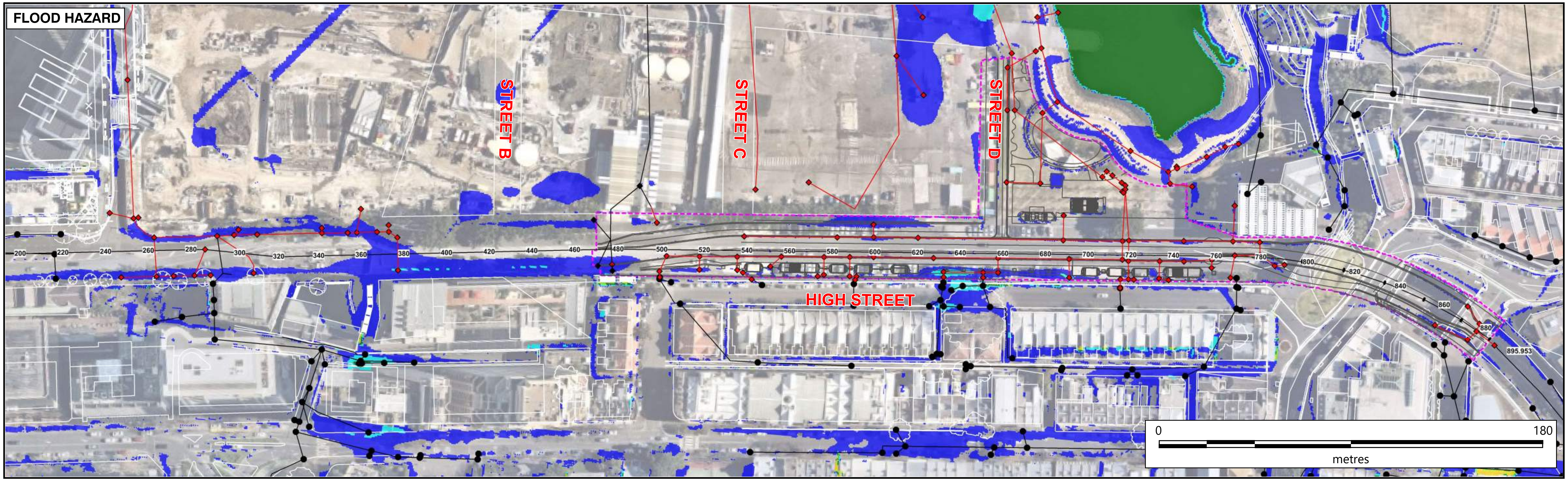
W N E S

Flood model results presented on this map have been prepared for INSW in accordance with the terms of the engagement and should not be used for any other purpose

grc HYDRO

TITLE : HICKSON ROAD NORTH, TEMPORARY DESIGN - FLOOD DEPTHS AND HAZARD	EVENT: 5% AEP	PROJECT: Barangaroo Station Civil Works Hickson Road Stage 3 Design	PROJECT No.180038	DATE: June 2021	FIGURE NUMBER: C1





Proposed Pit
Proposed Pipe
Existing Pit
Existing Pipe
Hickson Road North, Temporary Design - Extent of Works

Flood Depth (m)

0 to 0.05	0.2 to 0.3
0.05 to 0.1	0.3 to 0.5
0.1 to 0.2	0.5 to 1.0
1.0 to 1.5	
1.5 to 2.0	
> 2.0	

Flood Hazard Category (AEM)

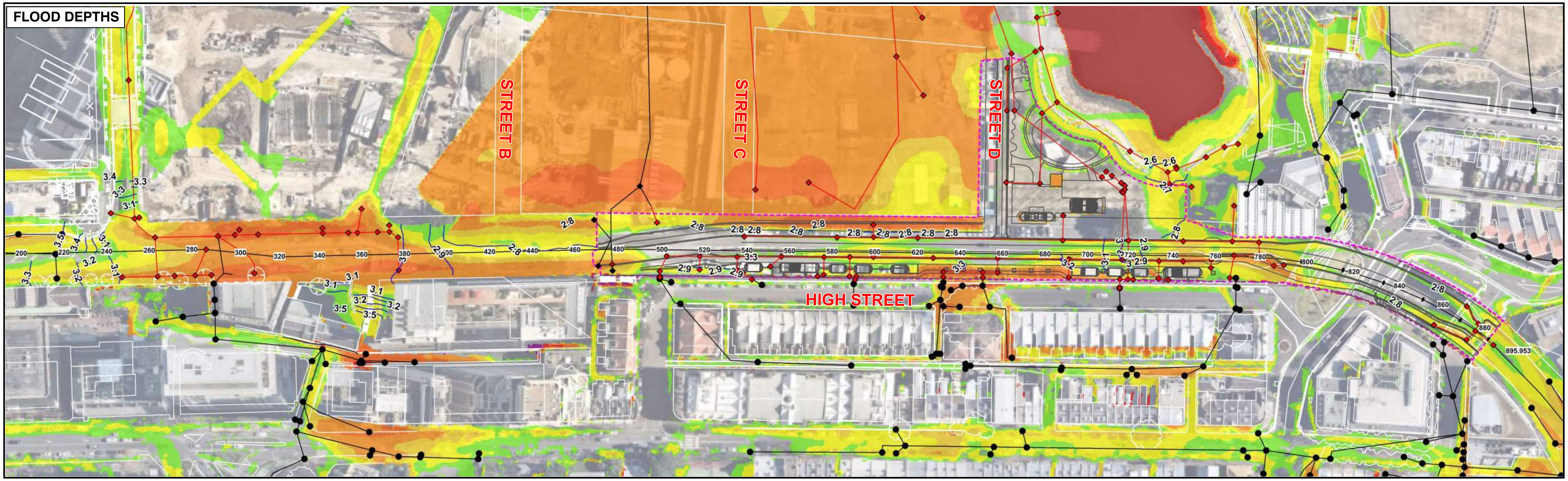
H1 H4
H2 H5
H3 H6

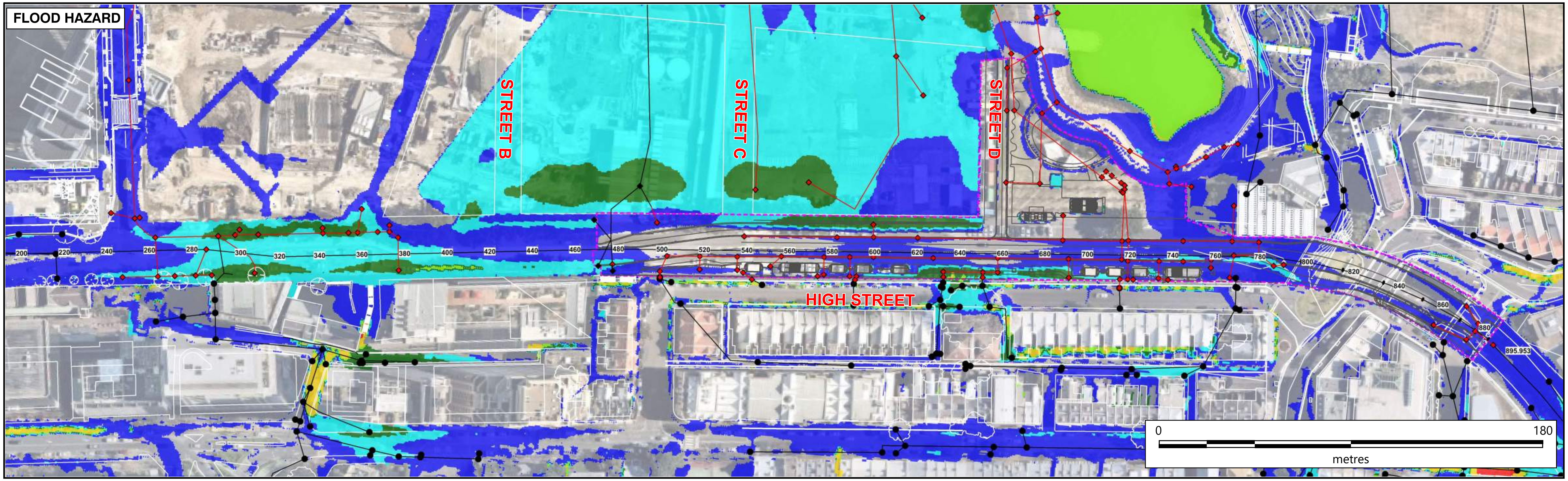
W N E S

Flood model results presented on this map have been prepared for INSW in accordance with the terms of the engagement and should not be used for any other purpose

grc HYDRO

TITLE : **HICKSON ROAD NORTH, TEMPORARY DESIGN - FLOOD DEPTHS AND HAZARD**	EVENT: **1% AEP**	PROJECT: **Barangaroo Station Civil Works Hickson Road Stage 3 Design**	PROJECT No.**180038**	DATE: **June 2021**	FIGURE NUMBER: **C2**





Proposed Pit
Proposed Pipe
Existing Pit
Existing Pipe
Hickson Road North, Temporary Design - Extent of Works

Flood Depth (m)

0 to 0.05	0.2 to 0.3	1.0 to 1.5
0.05 to 0.1	0.3 to 0.5	1.5 to 2.0
0.1 to 0.2	0.5 to 1.0	> 2.0

Flood Hazard Category (AEM)

H1	H4
H2	H5
H3	H6

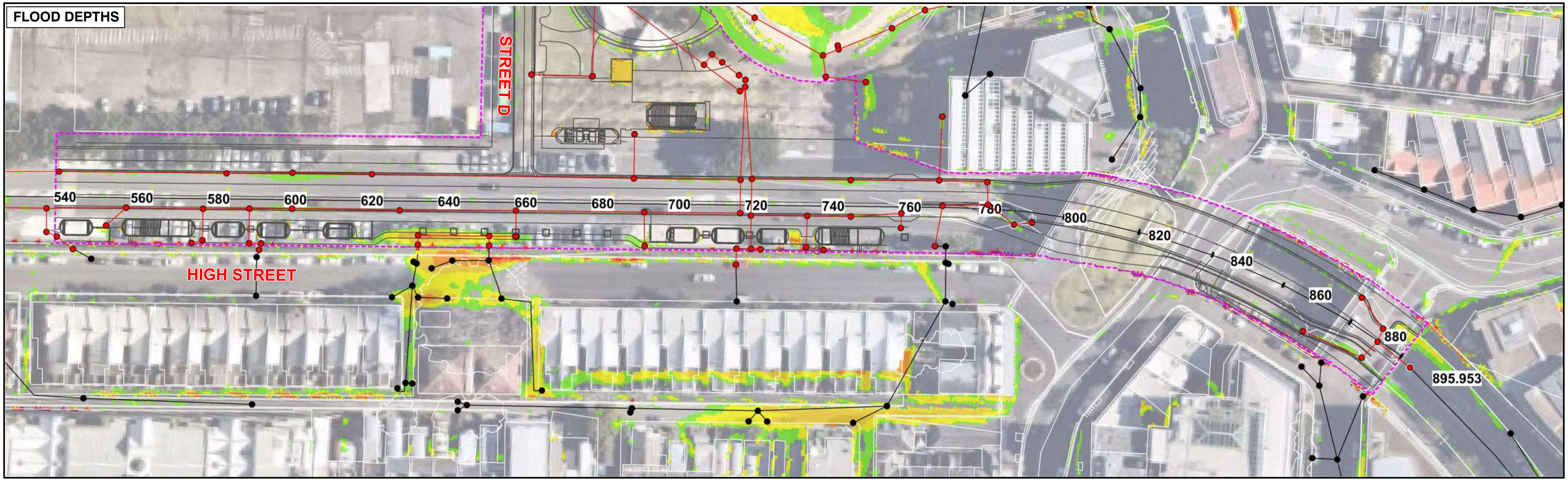
Peak Water Level (mAHD) Contour Spacing = 0.1m

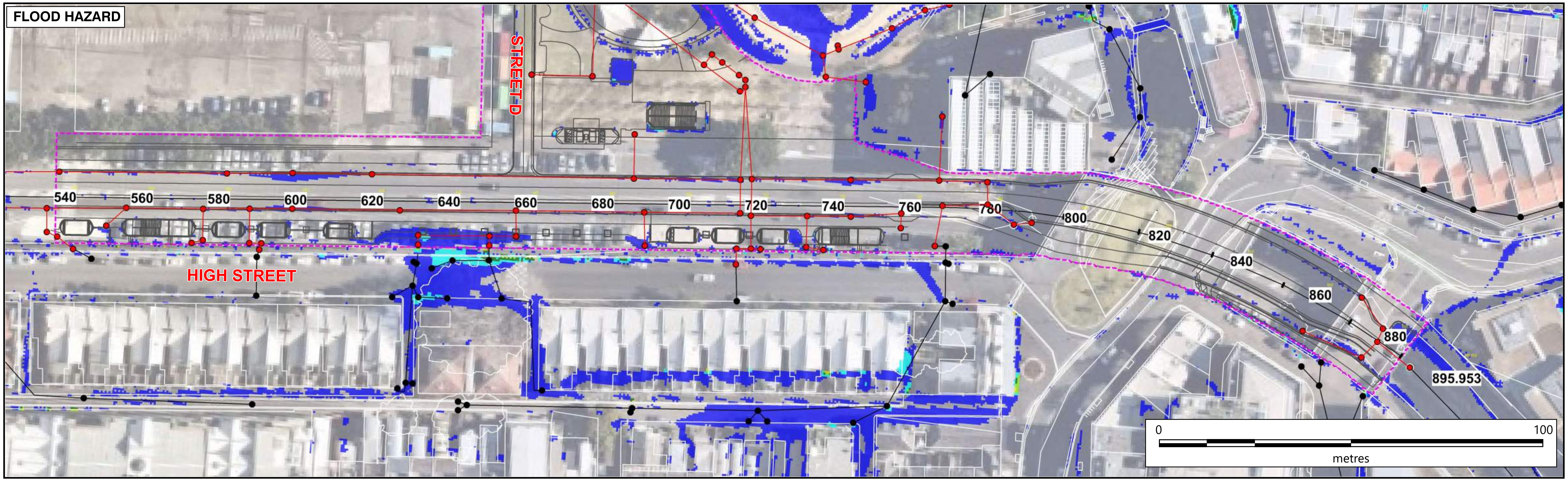
Flood model results presented on this map have been prepared for INSW in accordance with the terms of the engagement and should not be used for any other purpose

grc HYDRO

TITLE : **HICKSON ROAD NORTH, TEMPORARY DESIGN - FLOOD DEPTHS AND HAZARD**	EVENT: **PMF**	PROJECT: **Barangaroo Station Civil Works Hickson Road Stage 3 Design**	PROJECT No. **180038**	DATE: **June 2021**	FIGURE NUMBER: **C3**

Appendix D – Hickson Road North Ultimate Design, Flood Maps





- Proposed Pit
- Proposed Pipe
- Existing Pit
- Existing Pipe
- Hickson Road North, Ultimate Design - Extent of Works

Flood Depth (m)

0.0 to 0.05	
0.05 to 0.1	
0.1 to 0.2	
0.2 to 0.3	
0.3 to 0.5	
0.5 to 1.0	
1.0 to 1.5	
1.5 to 2	
> 2.0	

Flood Hazard Category (AEM)

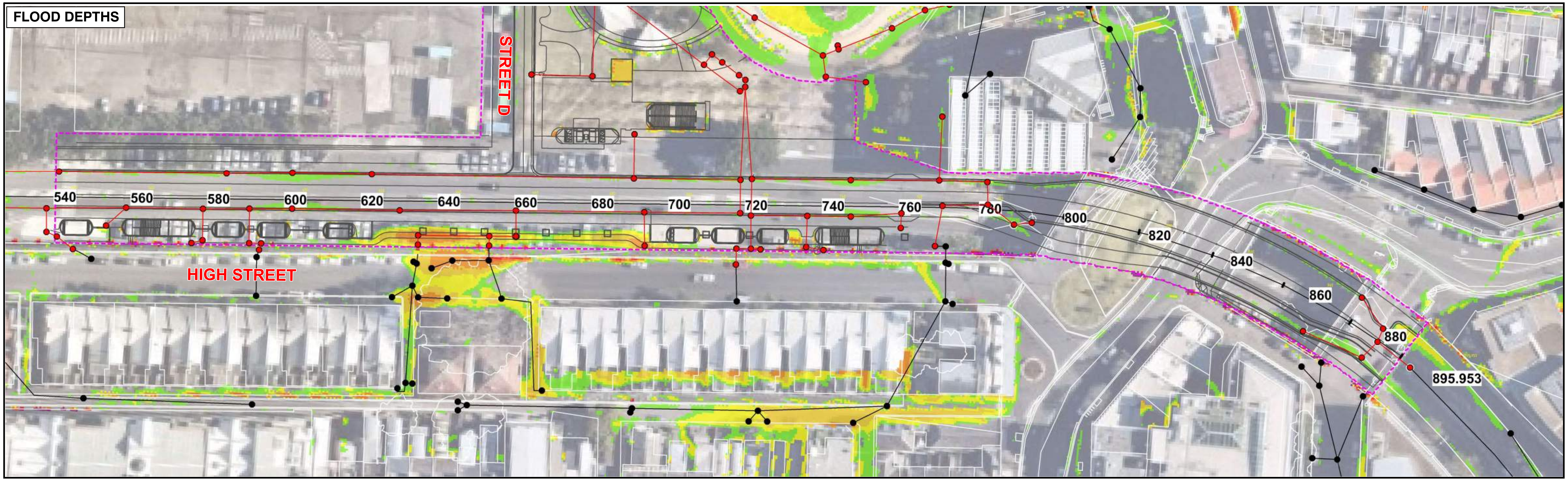
H2	H4
H2	H5
H3	H6

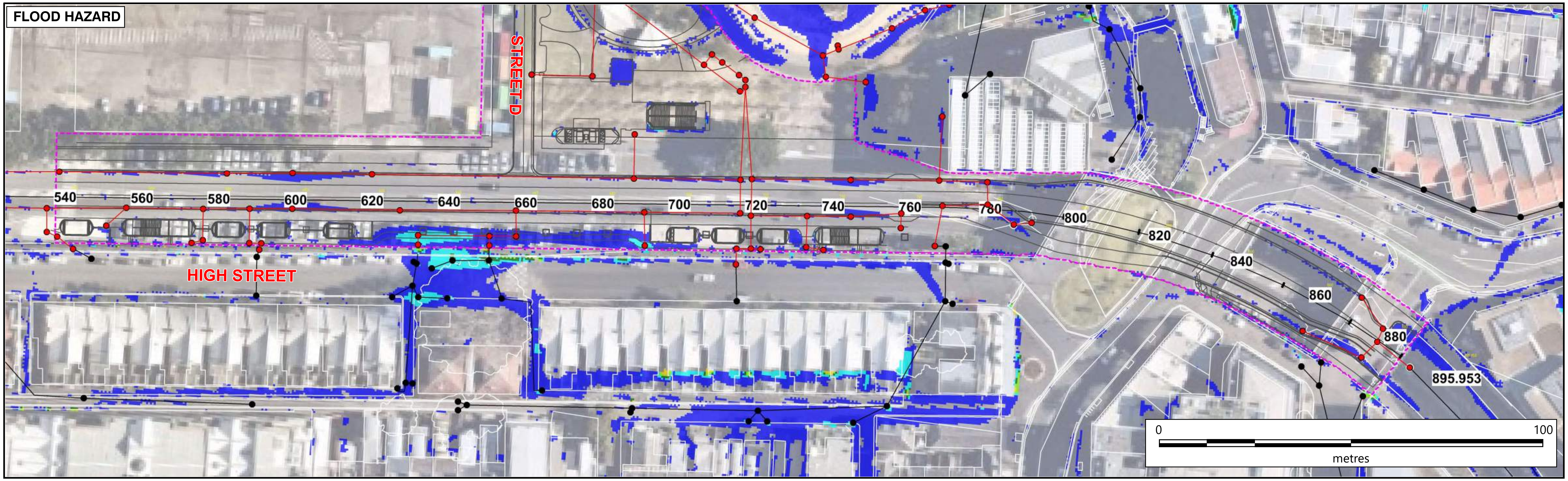
N E S W

Flood model results presented on this map have been prepared for INSW in accordance with the terms of the engagement and should not be used for any other purpose

grc HYDRO

TITLE : **HICKSON ROAD NORTH, ULTIMATE DESIGN - FLOOD DEPTHS AND HAZARD**	EVENT: **5% AEP**	PROJECT: **Barangaroo Station Civil Works Hickson Road Stage 3 Design**	PROJECT No.**180038**	DATE: **June 2021**	FIGURE NUMBER: **D1**





Proposed Pit
Proposed Pipe
Existing Pit
Existing Pipe
Hickson Road North, Ultimate Design - Extent of Works

Flood Depth (m)

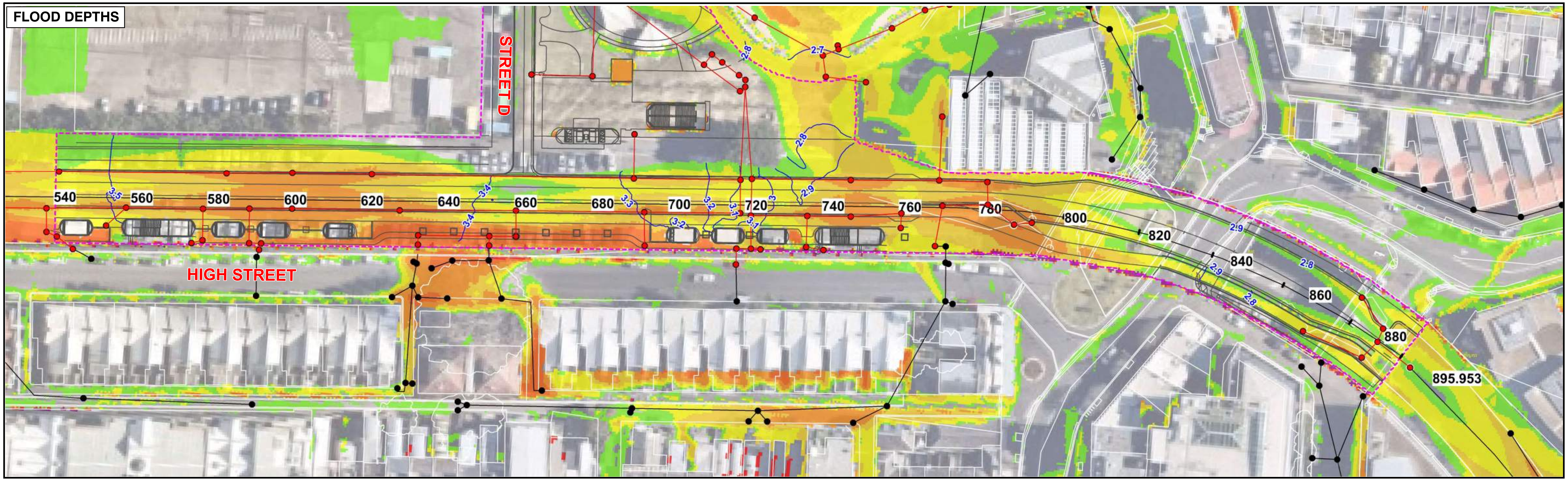
- 0.0 to 0.05
- 0.05 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2
- > 2.0

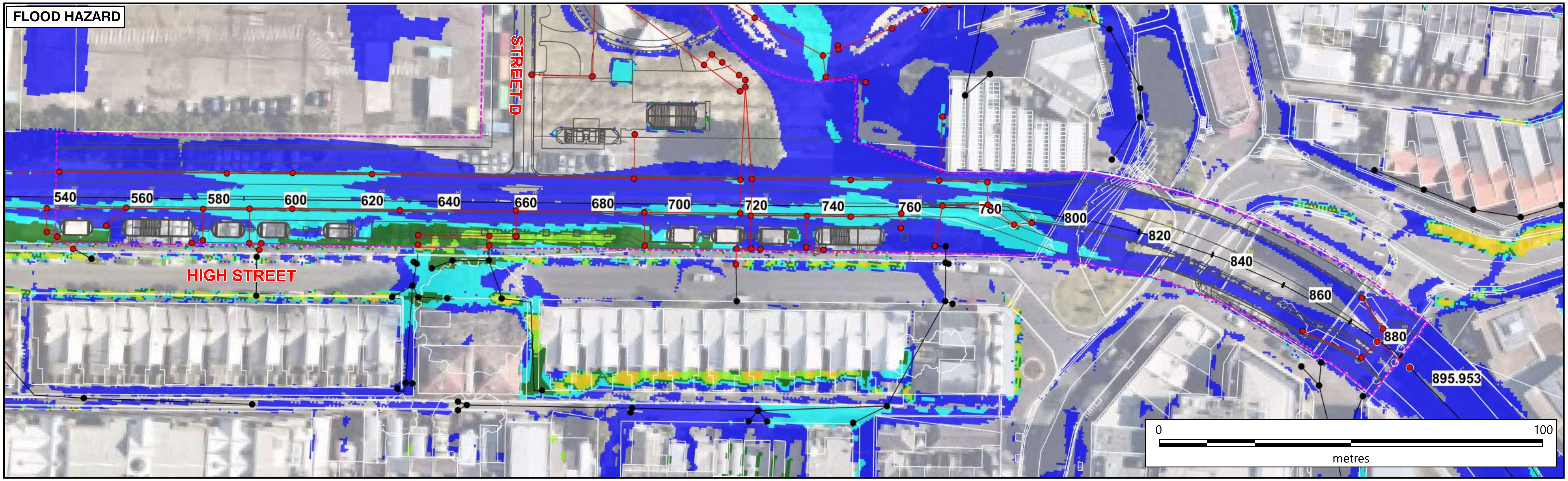
Flood Hazard Category (AEM)

- H2
- H2
- H3
- H4
- H5
- H6

Flood model results presented on this map have been prepared for INSW in accordance with the terms of the engagement and should not be used for any other purpose

TITLE : HICKSON ROAD NORTH, ULTIMATE DESIGN - FLOOD DEPTHS AND HAZARD	EVENT: 1% AEP	PROJECT: Barangaroo Station Civil Works Hickson Road Stage 3 Design	PROJECT No.180038	DATE: June 2021	FIGURE NUMBER: D2





Proposed Pit
Proposed Pipe
Existing Pit
Existing Pipe
Hickson Road North, Ultimate Design - Extent of Works

Flood Depth (m)

0.0 to 0.05	0.2 to 0.3	1.0 to 1.5
0.05 to 0.1	0.3 to 0.5	1.5 to 2
0.1 to 0.2	0.5 to 1.0	> 2.0

Flood Hazard Category (AEM)

H2	H4
H2	H5
H3	H6

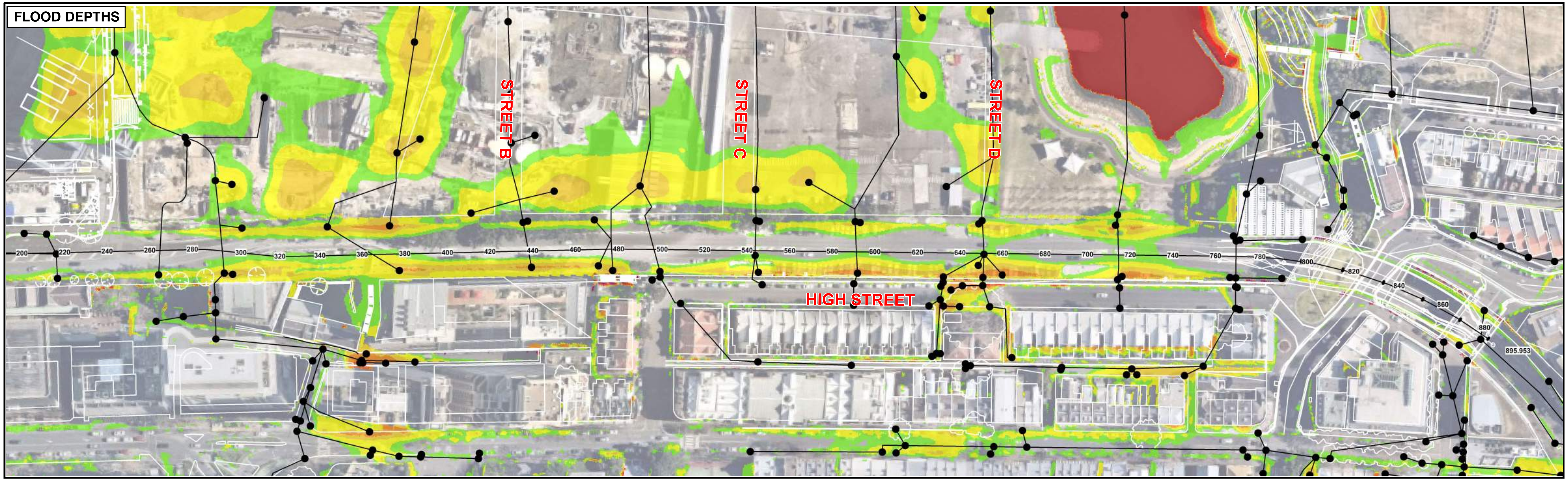
Peak Water Level (mAHD)
Contour Spacing = 0.1m

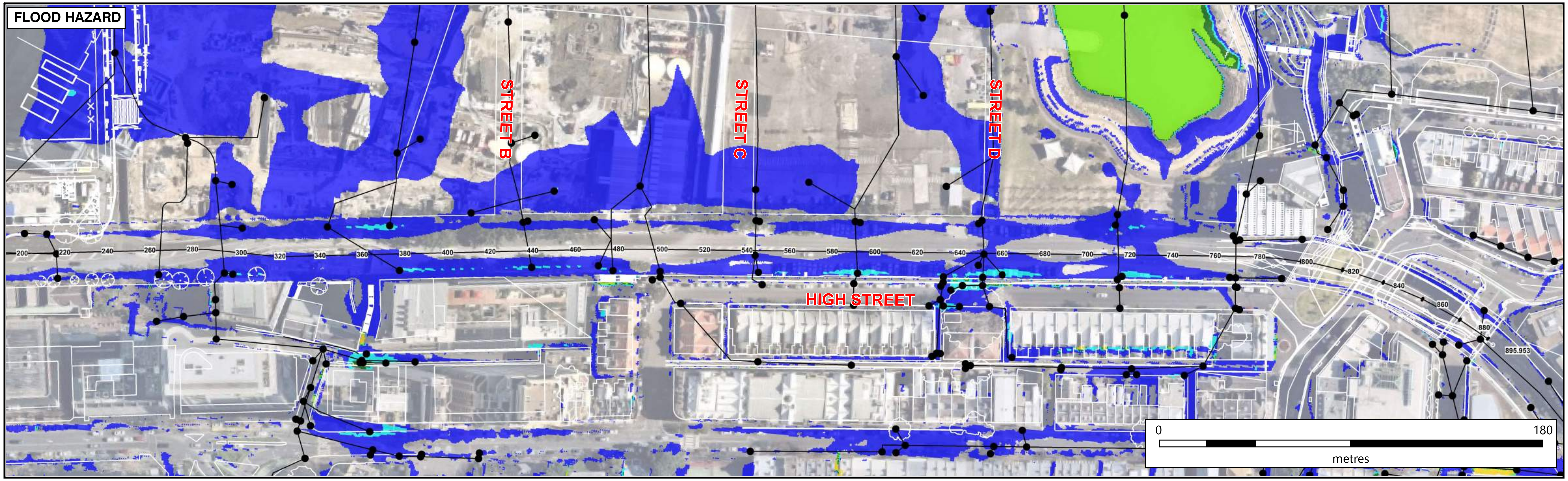
Flood model results presented on this map have been prepared for INSW in accordance with the terms of the engagement and should not be used for any other purpose

grc HYDRO

TITLE : HICKSON ROAD NORTH, ULTIMATE DESIGN - FLOOD DEPTHS AND HAZARD	EVENT: PMF	PROJECT: Barangaroo Station Civil Works Hickson Road Stage 3 Design	PROJECT No.180038	DATE: June 2021	FIGURE NUMBER: D3

Appendix E – Climate Change Conditions Flood Maps





Existing Pit
Existing Pipe

Flood Depth (m)

0.0 to 0.05	0.2 to 0.3
0.05 to 0.1	0.3 to 0.5
0.1 to 0.2	0.5 to 1.0
1.0 to 1.5	
1.5 to 2.0	
> 2.0	

Flood Hazard Category (AEM)

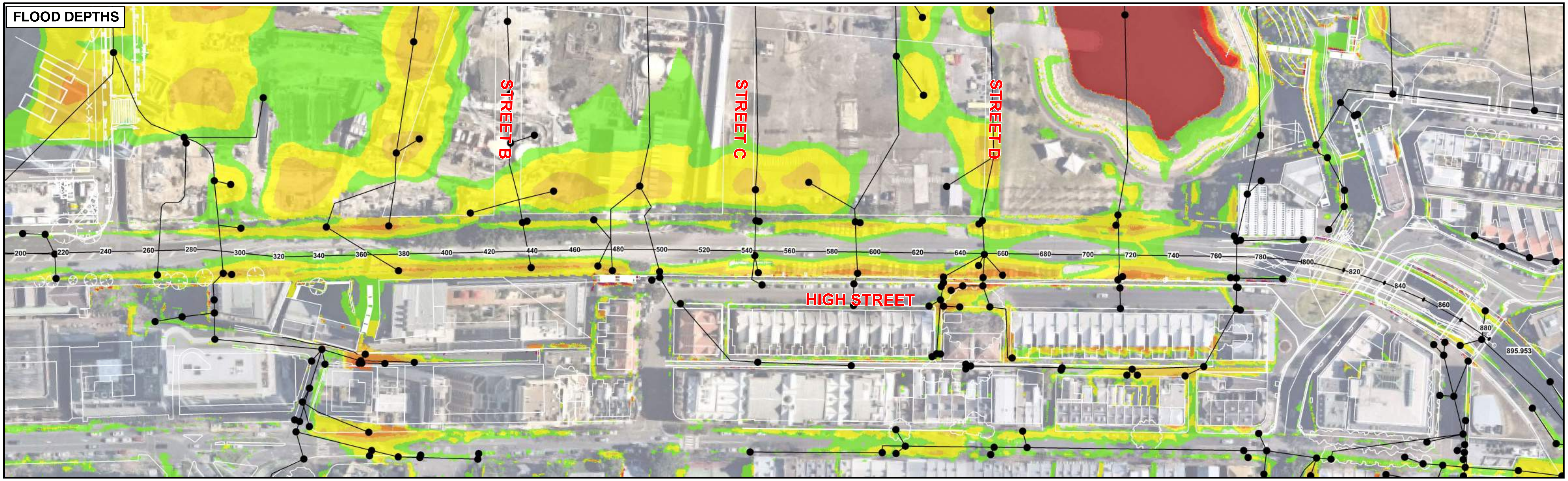
H1	H4
H2	H5
H3	H6

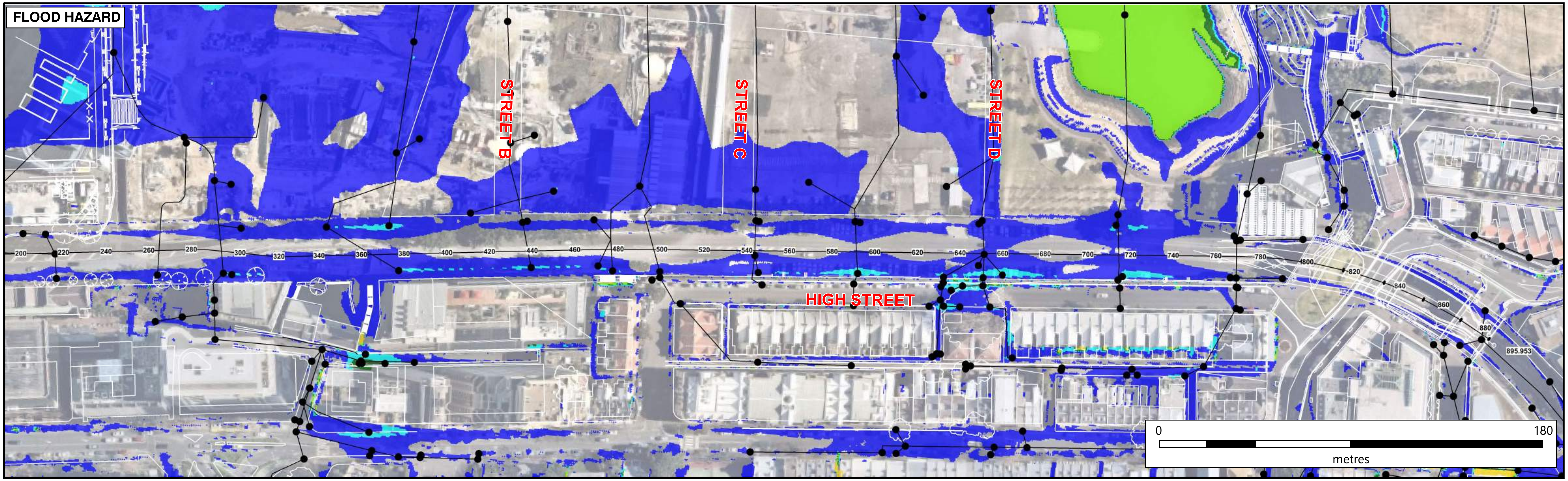
N S E W

Flood model results presented on this map have been prepared for INSW in accordance with the terms of the engagement and should not be used for any other purpose

grc HYDRO

TITLE : PRE-DEVELOPMENT CONDITIONS - FLOOD DEPTHS AND HAZARD	EVENT: 1% AEP Event + 10% Rainfall + 0.9 m Sea Level Rise	PROJECT: Barangaroo Station Civil Works Hickson Road Stage 3 Design	PROJECT No.180038	DATE: June 2021	FIGURE NUMBER: E1





● Existing Pit
— Existing Pipe

Flood Depth (m)

0.0 to 0.05	
0.05 to 0.1	
0.1 to 0.2	
0.2 to 0.3	
0.3 to 0.5	
0.5 to 1.0	
1.0 to 1.5	
1.5 to 2.0	
> 2.0	

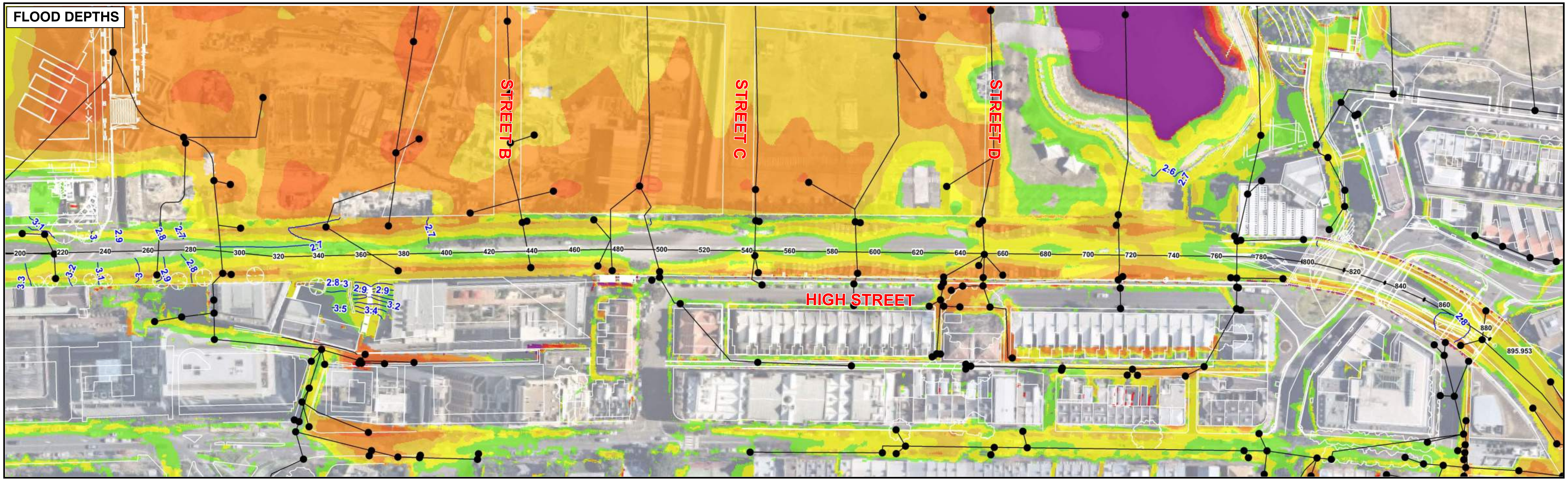
Flood Hazard Category (AEM)

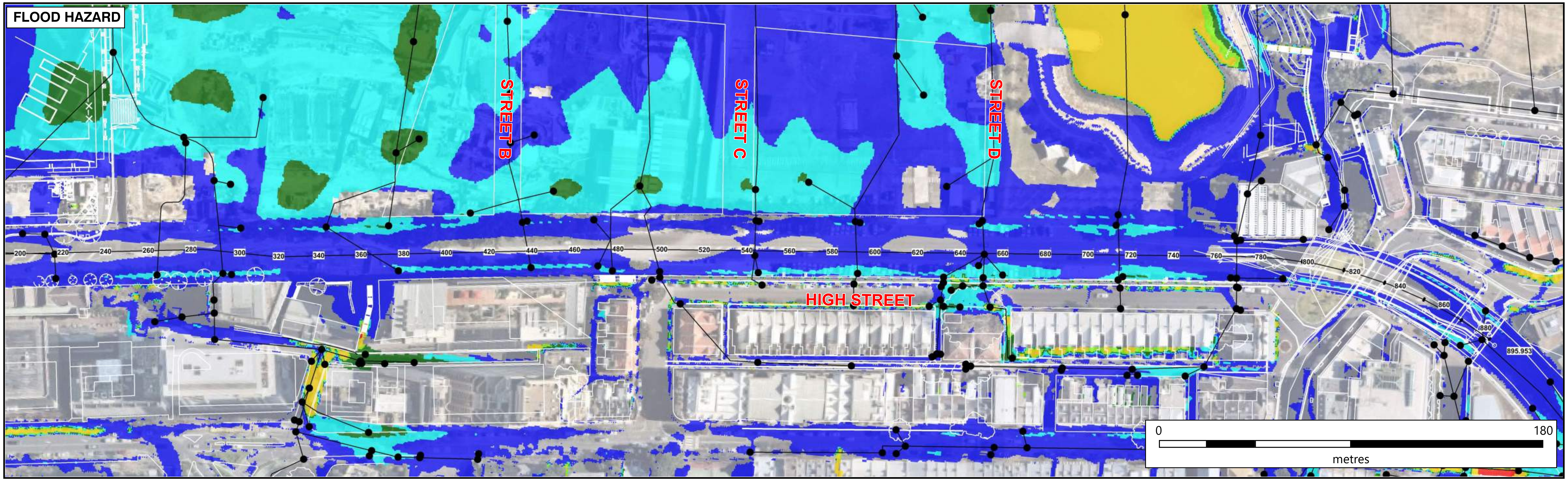
H1, H2, H3, H4, H5, H6

Flood model results presented on this map have been prepared for INSW in accordance with the terms of the engagement and should not be used for any other purpose

grc HYDRO

TITLE:	PRE-DEVELOPMENT CONDITIONS - FLOOD DEPTHS AND HAZARD
EVENT:	1% AEP Event + RCP8.5 Rainfall + 0.9 m Sea Level
PROJECT:	Barangaroo Station Civil Works Hickson Road Stage 3 Design
PROJECT No.	180038
DATE:	June 2021
FIGURE NUMBER:	E2





● Existing Pit
—— Existing Pipe

Flood Depth (m)

0.0 to 0.05	0.2 to 0.3	1.0 to 1.5
0.05 to 0.1	0.3 to 0.5	1.5 to 2.0
0.1 to 0.2	0.5 to 1.0	> 2.0

Flood Hazard Category (AEM)

H1	H4
H2	H5
H3	H6

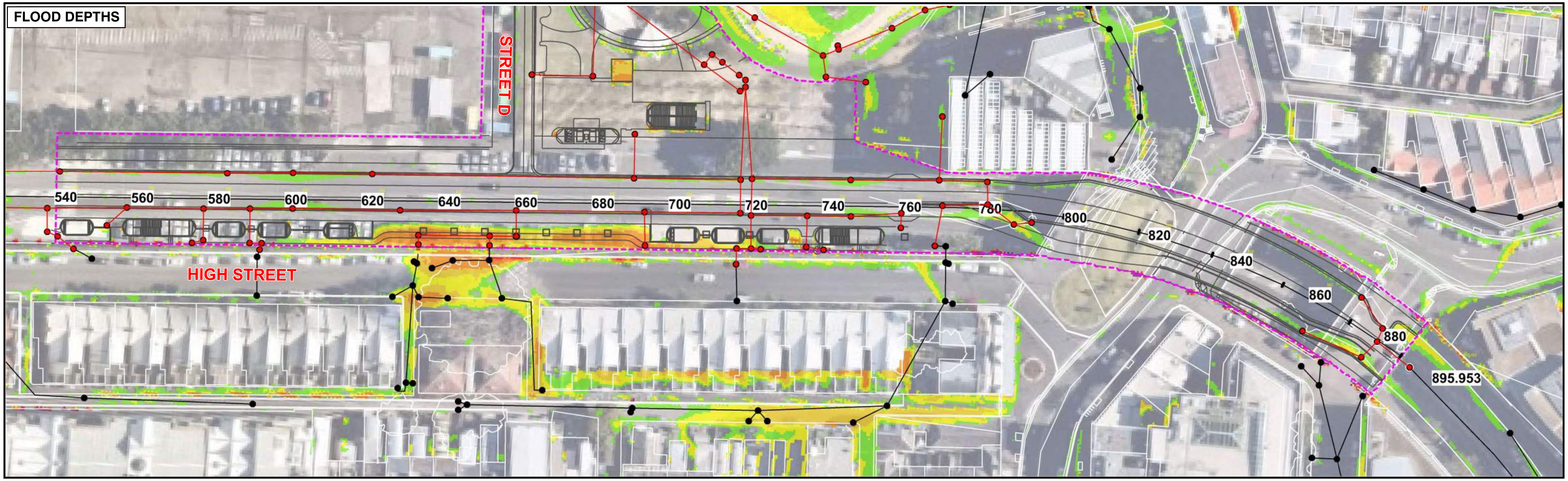
Peak Water Level (mAHD)
Contour Spacing = 0.1m

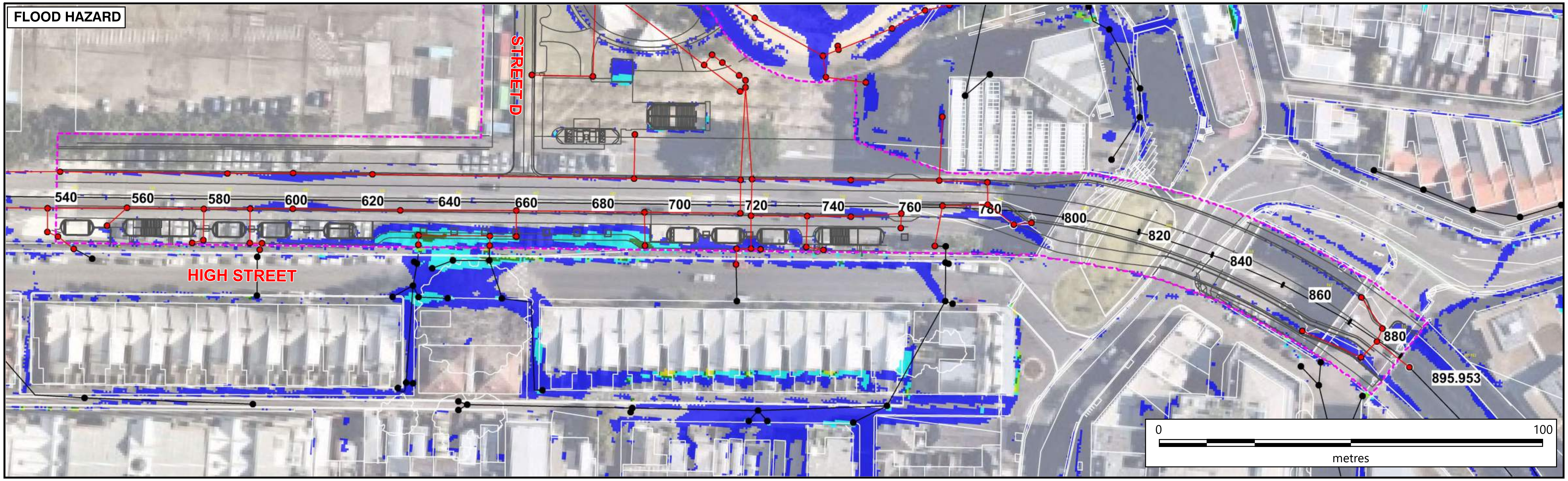
W N E S

Flood model results presented on this map have been prepared for INSW in accordance with the terms of the engagement and should not be used for any other purpose

grc HYDRO

TITLE : **PRE-DEVELOPMENT CONDITIONS - FLOOD DEPTHS AND HAZARD**	EVENT: **PMF Event + 0.9 m Sea Level Rise**	PROJECT: **Barangaroo Station Civil Works Hickson Road Stage 3 Design**	PROJECT No. **180038**	DATE: **June 2021**	FIGURE NUMBER: **E3**





- Proposed Pit
- Proposed Pipe
- Existing Pit
- Existing Pipe
- Hickson Road North, Ultimate Design - Extent of Works

Flood Depth (m)

0.0 to 0.05	0.2 to 0.3	1.0 to 1.5
0.05 to 0.1	0.3 to 0.5	1.5 to 2
0.1 to 0.2	0.5 to 1.0	> 2.0

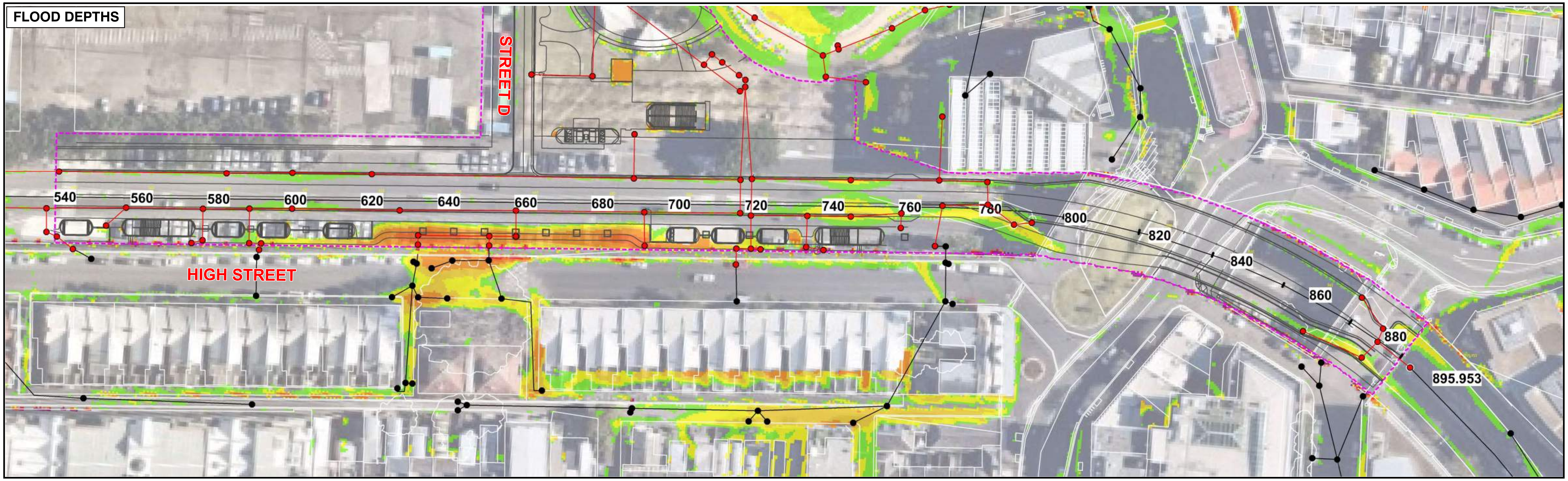
Flood Hazard Category (AEM)

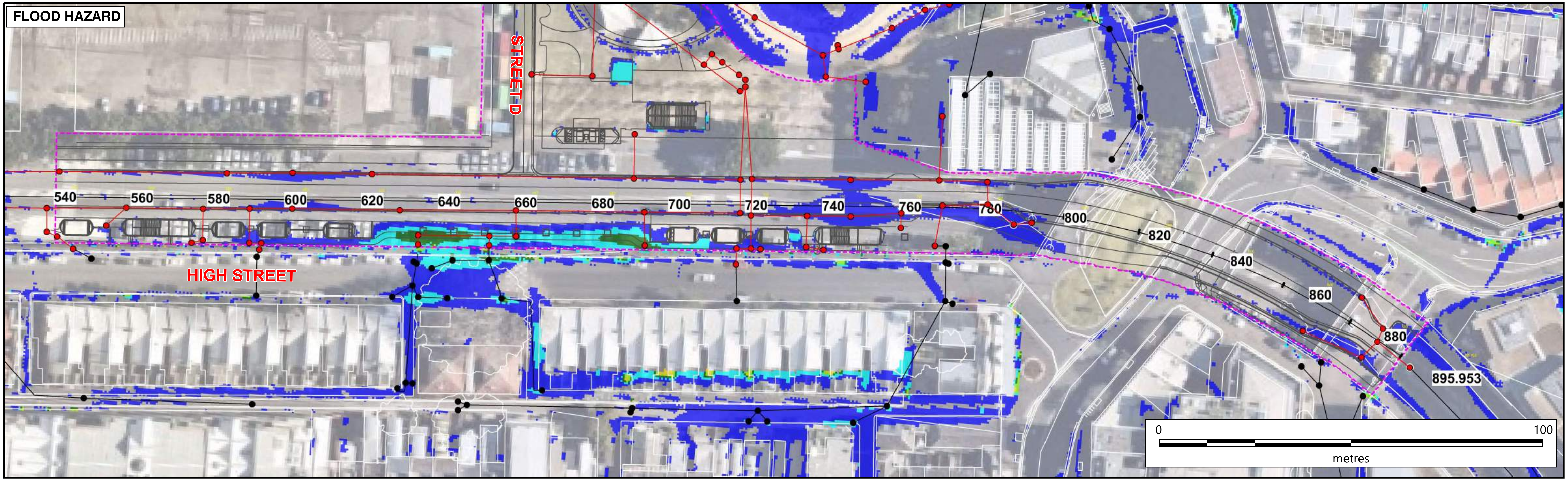
H2	H4
H2	H5
H3	H6

W N E S

Flood model results presented on this map have been prepared for INSW in accordance with the terms of the engagement and should not be used for any other purpose

TITLE : HICKSON ROAD NORTH, ULTIMATE DESIGN - FLOOD DEPTHS AND HAZARD	EVENT: 1% AEP Event + 10% Rainfall + 0.9 m Sea Level	PROJECT: Barangaroo Station Civil Works Hickson Road Stage 3 Design	PROJECT No.180038	DATE: June 2021	FIGURE NUMBER: E4





Proposed Pit
Proposed Pipe
Existing Pit
Existing Pipe
Hickson Road North, Ultimate Design - Extent of Works

Flood Depth (m)

0.0 to 0.05	0.2 to 0.3	1.0 to 1.5
0.05 to 0.1	0.3 to 0.5	1.5 to 2
0.1 to 0.2	0.5 to 1.0	> 2.0

Flood Hazard Category (AEM)

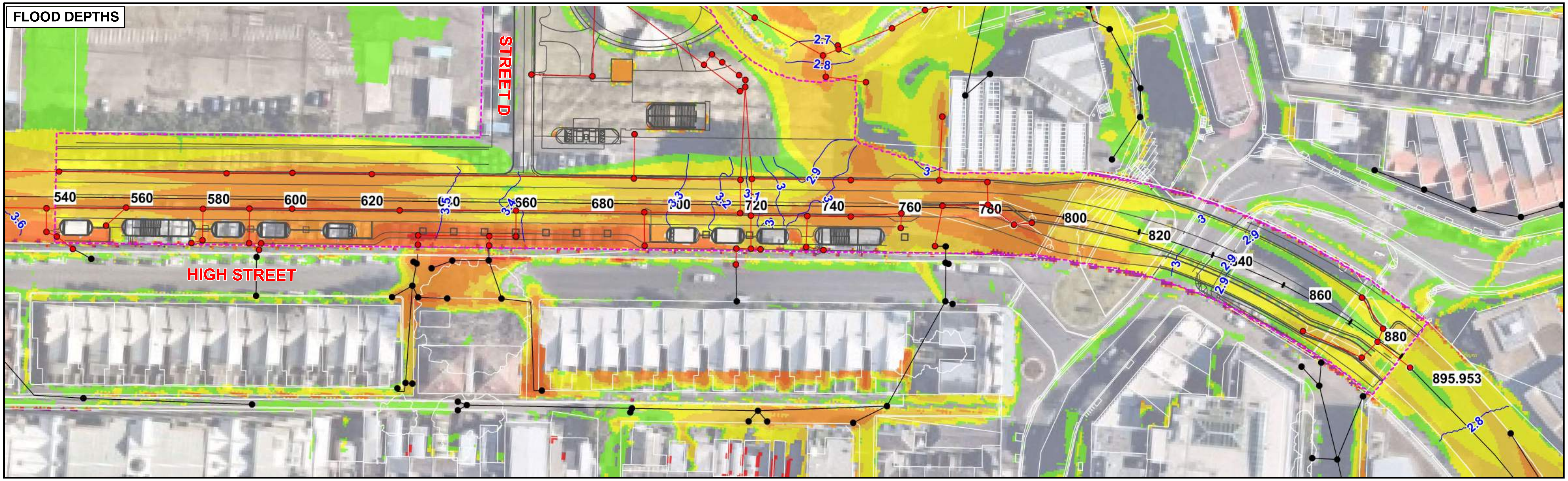
H2	H4
H2	H5
H3	H6

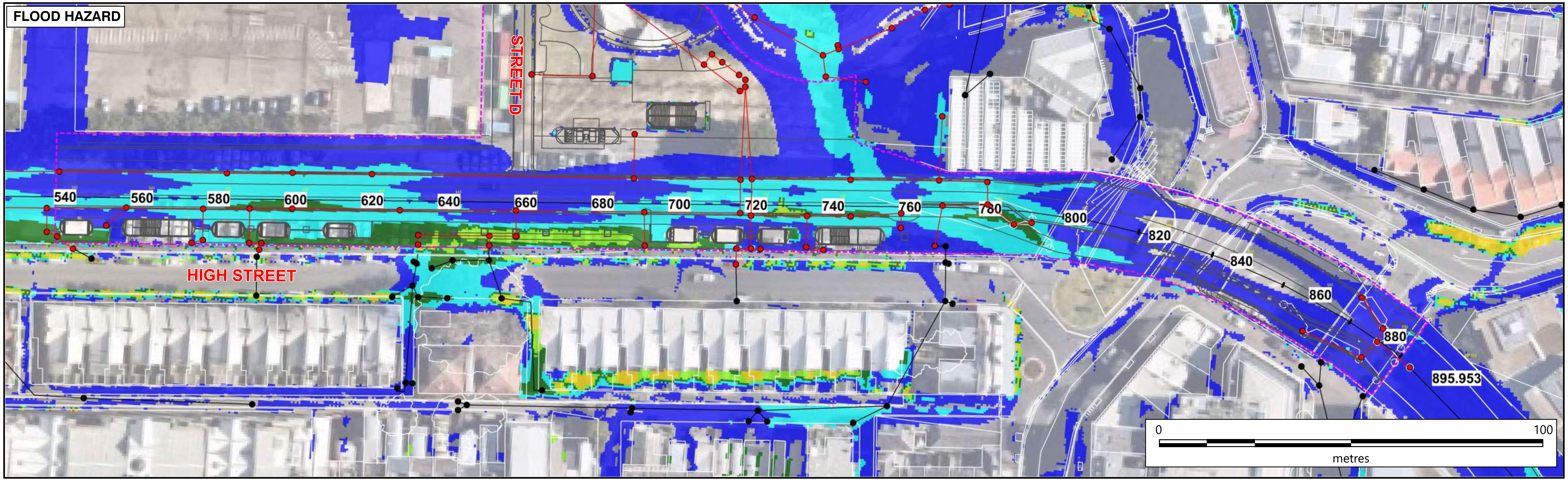
W S N E

Flood model results presented on this map have been prepared for INSW in accordance with the terms of the engagement and should not be used for any other purpose

grc HYDRO

TITLE : HICKSON ROAD NORTH, ULTIMATE DESIGN - FLOOD DEPTHS AND HAZARD	EVENT: 1% AEP Event + RCP8.5 Rainfall + 0.9 m Sea Level	PROJECT: Barangaroo Station Civil Works Hickson Road Stage 3 Design	PROJECT No.180038	DATE: June 2021	FIGURE NUMBER: E5





Proposed Pit
Proposed Pipe
Existing Pit
Existing Pipe
Hickson Road North, Ultimate Design - Extent of Works

Flood Depth (m)

0.0 to 0.05	0.2 to 0.3
0.05 to 0.1	0.3 to 0.5
0.1 to 0.2	0.5 to 1.0
1.0 to 1.5	1.5 to 2
> 2.0	

Flood Hazard Category (AEM)

H2, H2, H3, H4, H5, H6

Peak Water Level (mAHD)
Contour Spacing = 0.1m

Flood model results presented on this map have been prepared for INSW in accordance with the terms of the engagement and should not be used for any other purpose

grc HYDRO

TITLE : HICKSON ROAD NORTH, ULTIMATE DESIGN - FLOOD DEPTHS AND HAZARD	EVENT: PMF Event + 0.9 m Sea Level Rise	PROJECT: Barangaroo Station Civil Works Hickson Road Stage 3 Design	PROJECT No.180038	DATE: June 2021	FIGURE NUMBER: E6

Appendix F – Hickson Road North Temporary Design, Flood Impact Maps

Proposed Pit
Proposed Pipe
Existing Pit
Existing Pipe
Hickson Road North, Temporary Design - Extent of Works

Flood Depth/Level Impact (m)

- < -0.01
- No Difference
- 0.01 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.4
- 0.4 to 0.5
- 0.5 to 0.6
- 0.6 to 0.7
- 0.7 to 0.8
- 0.8 to 0.9
- 0.9 to 1.0
- > 1.0
- Newly Flooded
- No Longer Flooded

Flood Hazard Impact

- Decreased by 3+ categories
- Decreased by 2 categories
- Decreased by 1 categories
- No Difference
- Increased by 1 categories
- Increased by 2 categories
- Increased by 3+ categories
- Newly Flooded
- No Longer Flooded

W N S E

Flood model results presented on this map have been prepared for INSW in accordance with the terms of the engagement and should not be used for any other purpose

grc HYDRO

TITLE : HICKSON ROAD NORTH, TEMPORARY DESIGN - FLOOD IMPACTS	EVENT: 5% AEP	PROJECT: Barangaroo Station Civil Works Hickson Road Stage 3 Design	PROJECT No. 180038	DATE: June 2021	FIGURE NUMBER: F1

Proposed Pit
Proposed Pipe
Existing Pit
Existing Pipe
Hickson Road North, Temporary Design - Extent of Works

Flood Depth/Level Impact (m)

- < -0.01
- No Difference
- 0.01 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.4
- 0.4 to 0.5
- 0.5 to 0.6
- 0.6 to 0.7
- 0.7 to 0.8
- 0.8 to 0.9
- 0.9 to 1.0
- > 1.0
- Newly Flooded
- No Longer Flooded

Flood Hazard Impact

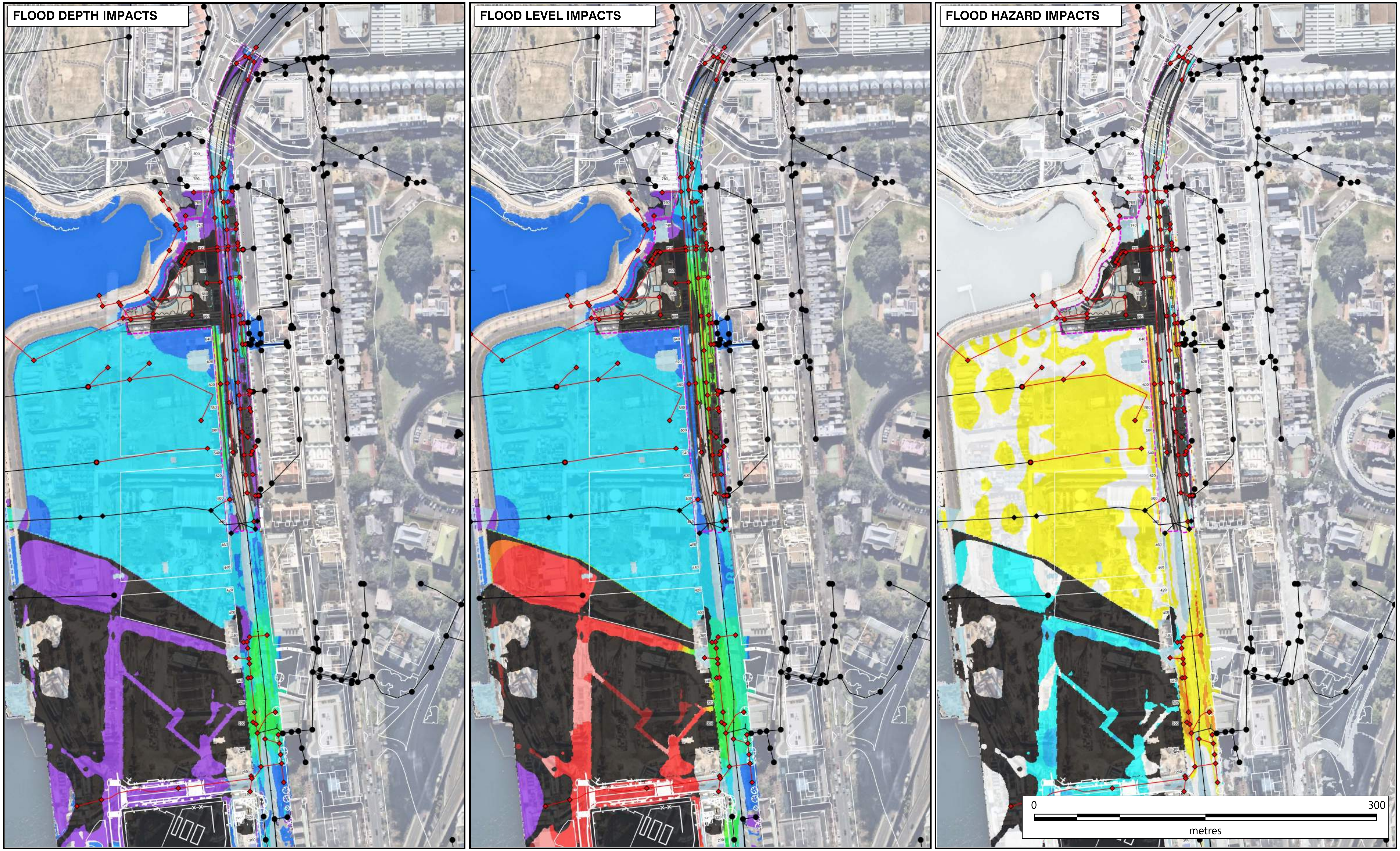
- Decreased by 3+ categories
- Decreased by 2 categories
- Decreased by 1 categories
- No Difference
- Increased by 1 categories
- Increased by 2 categories
- Increased by 3+ categories
- Newly Flooded
- No Longer Flooded

W
N
S
E

Flood model results presented on this map have been prepared for INSW in accordance with the terms of the engagement and should not be used for any other purpose

grc HYDRO

TITLE : HICKSON ROAD NORTH, TEMPORARY DESIGN - FLOOD IMPACTS	EVENT: 1% AEP	PROJECT: Barangaroo Station Civil Works Hickson Road Stage 3 Design	PROJECT No. 180038	DATE: June 2021	FIGURE NUMBER: F2



- Proposed Pit
- Proposed Pipe
- Existing Pit
- Existing Pipe
- Hickson Road North, Temporary Design - Extent of Works

Flood Depth/Level Impact (m)

- < -0.01
- No Difference
- 0.01 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.4
- 0.4 to 0.5
- 0.5 to 0.6
- 0.6 to 0.7
- 0.7 to 0.8
- 0.8 to 0.9
- 0.9 to 1.0
- > 1.0
- Newly Flooded
- No Longer Flooded

Flood Hazard Impact

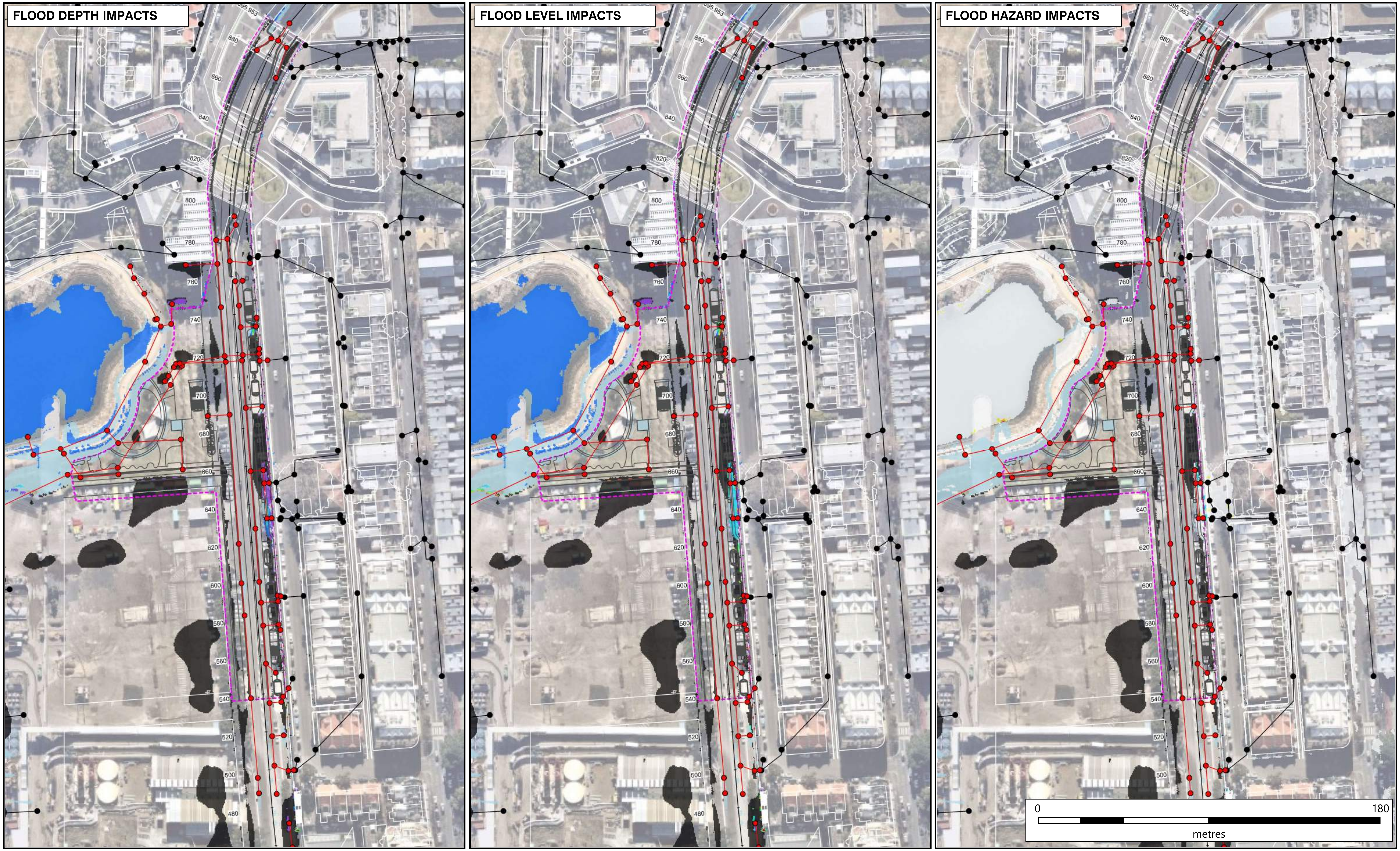
- Decreased by 3+ categories
- Decreased by 2 categories
- Decreased by 1 categories
- No Difference
- Increased by 1 categories
- Increased by 2 categories
- Increased by 3+ categories
- Newly Flooded
- No Longer Flooded

Flood model results presented on this map have been prepared for INSW in accordance with the terms of the engagement and should not be used for any other purpose

grc HYDRO

TITLE : **HICKSON ROAD NORTH, TEMPORARY DESIGN - FLOOD IMPACTS**	EVENT: **PMF**	PROJECT: **Barangaroo Station Civil Works Hickson Road Stage 3 Design**	PROJECT No.**180038**	DATE: **June 2021**	FIGURE NUMBER: **F3**

Appendix G – Hickson Road North Ultimate Design, Flood Impact Maps



Proposed Pit
Proposed Pipe
Existing Pit
Existing Pipe
Hickson Road North, Ultimate Design - Extent of Works

Flood Depth/Level Impact (m)

< -0.01	0.2 to 0.3	0.6 to 0.7	> 1.0
No Difference	0.3 to 0.4	0.7 to 0.8	Newly Flooded
0.01 to 0.1	0.4 to 0.5	0.8 to 0.9	No Longer Flooded
0.1 to 0.2	0.5 to 0.6	0.9 to 1.0	

Flood Hazard Impact

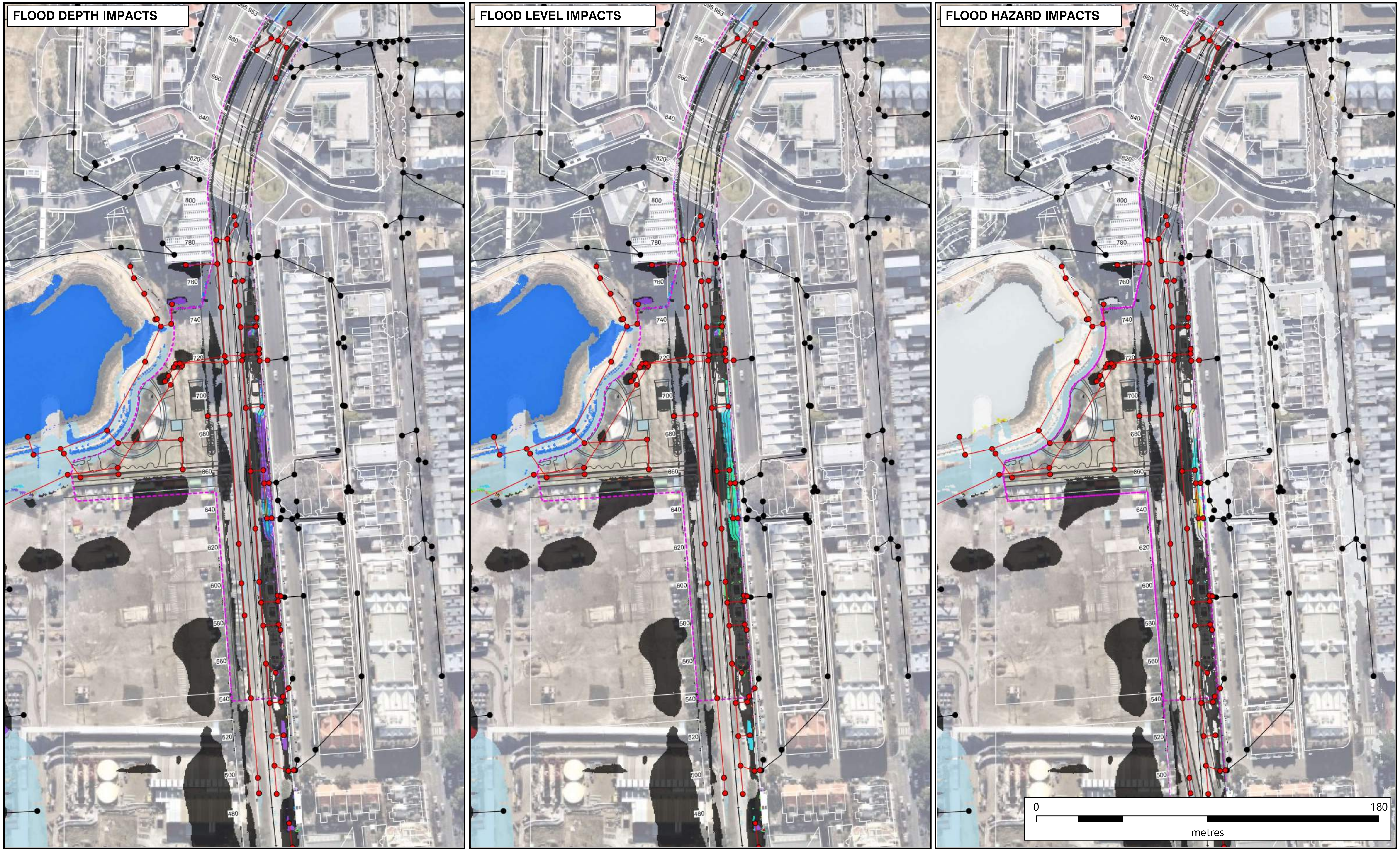
Decreased by 3+ categories	Increased by 1 categories	
Decreased by 2 categories	Increased by 2 categories	
Decreased by 1 categories	Increased by 3+ categories	
No Difference	Newly Flooded	No Longer Flooded

W S E N

Flood model results presented on this map have been prepared for INSW in accordance with the terms of the engagement and should not be used for any other purpose

grc HYDRO

TITLE : **HICKSON ROAD NORTH, ULTIMATE DESIGN - FLOOD IMPACTS**	EVENT: **5% AEP**	PROJECT: **Barangaroo Station Civil Works Hickson Road Stage 3 Design**	PROJECT No. **180038**	DATE: **June 2021**	FIGURE NUMBER: **G1**



Proposed Pit
Proposed Pipe
Existing Pit
Existing Pipe
Hickson Road North, Ultimate Design - Extent of Works

Flood Depth/Level Impact (m)

- < -0.01
- No Difference
- 0.01 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.4
- 0.4 to 0.5
- 0.5 to 0.6
- 0.6 to 0.7
- 0.7 to 0.8
- 0.8 to 0.9
- 0.9 to 1.0
- > 1.0
- Newly Flooded
- No Longer Flooded

Flood Hazard Impact

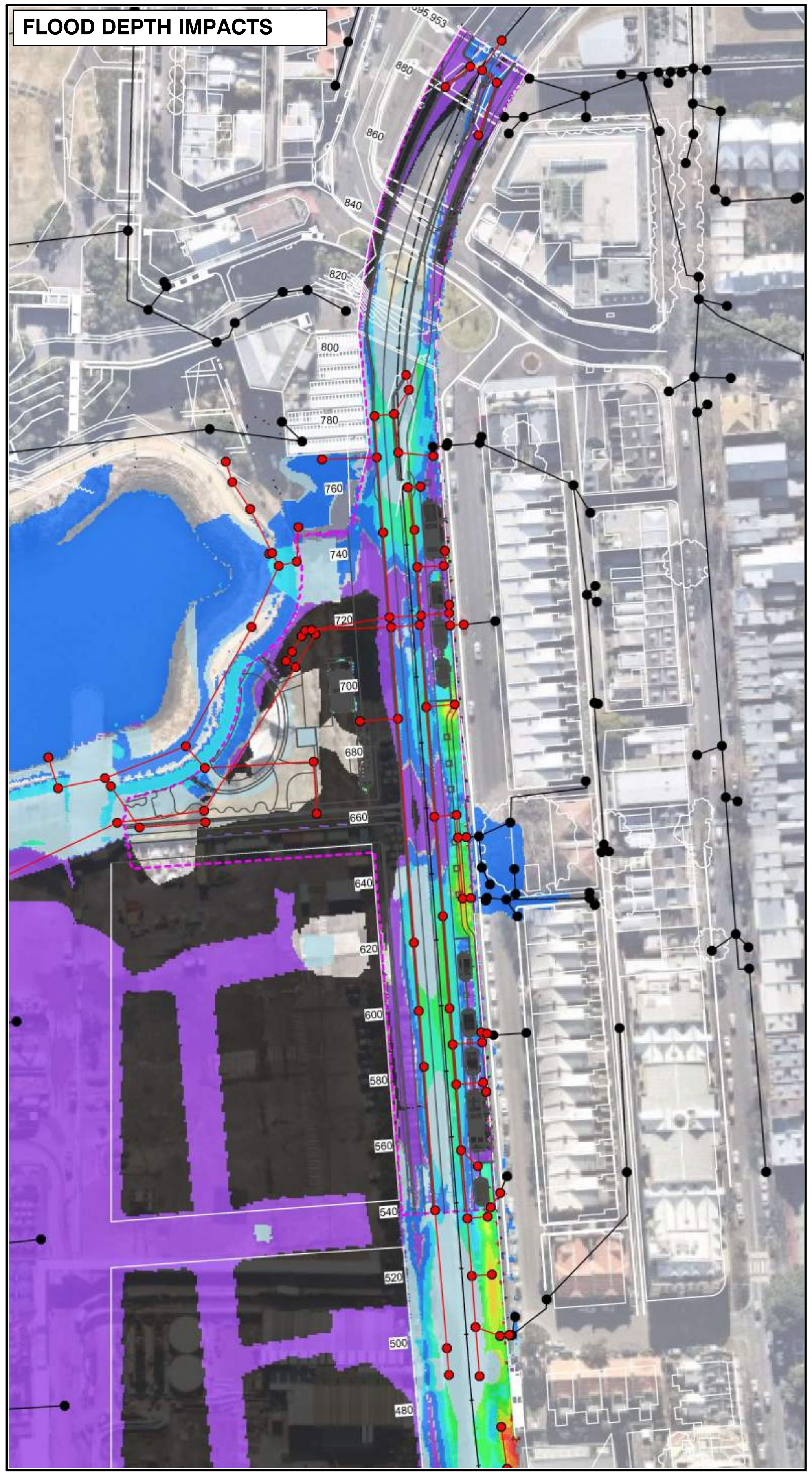
- Decreased by 3+ categories
- Decreased by 2 categories
- Decreased by 1 categories
- No Difference
- Increased by 1 categories
- Increased by 2 categories
- Increased by 3+ categories
- Newly Flooded
- No Longer Flooded

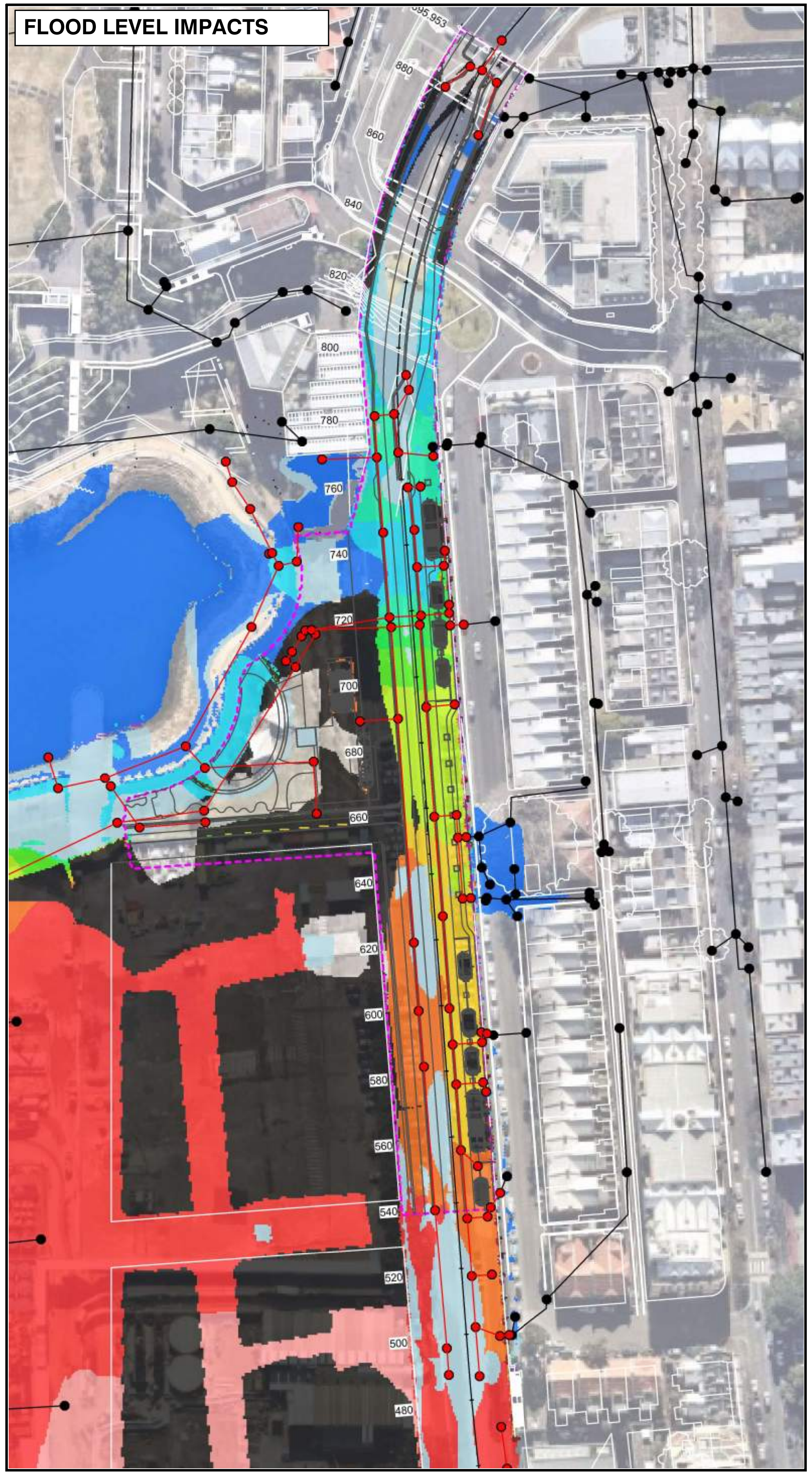
W S N E

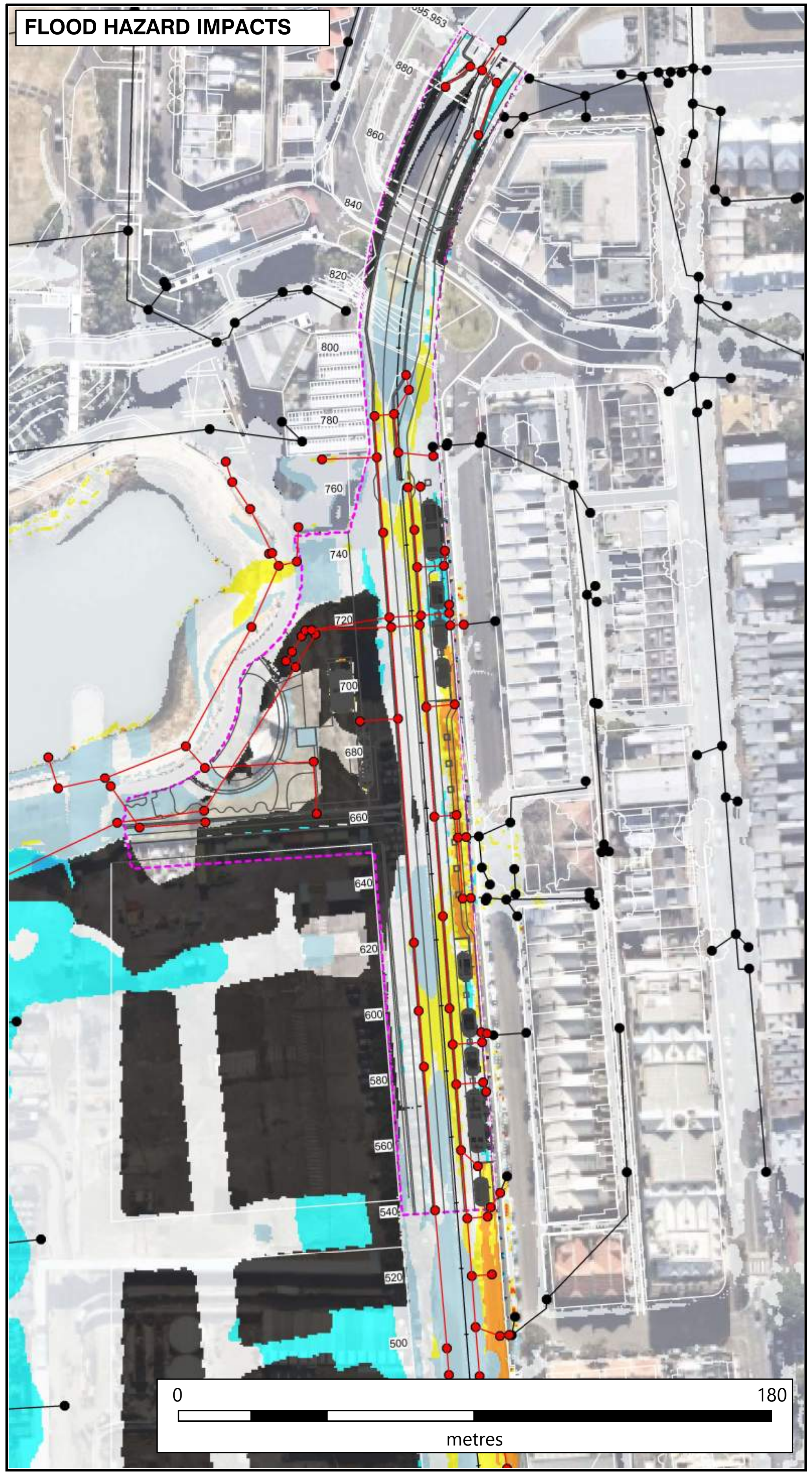
Flood model results presented on this map have been prepared for INSW in accordance with the terms of the engagement and should not be used for any other purpose

grc HYDRO

TITLE : **HICKSON ROAD NORTH, ULTIMATE DESIGN - FLOOD IMPACTS**	EVENT: **1% AEP**	PROJECT: **Barangaroo Station Civil Works Hickson Road Stage 3 Design**	PROJECT No.**180038**	DATE: **June 2021**	FIGURE NUMBER: **G2**







Proposed Pit
Proposed Pipe
Existing Pit
Existing Pipe
Hickson Road North, Ultimate Design - Extent of Works

Flood Depth/Level Impact (m)

- < -0.01
- No Difference
- 0.01 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.4
- 0.4 to 0.5
- 0.5 to 0.6
- 0.6 to 0.7
- 0.7 to 0.8
- 0.8 to 0.9
- 0.9 to 1.0
- > 1.0
- Newly Flooded
- No Longer Flooded

Flood Hazard Impact

- Decreased by 3+ categories
- Decreased by 2 categories
- Decreased by 1 categories
- No Difference
- Increased by 1 categories
- Increased by 2 categories
- Increased by 3+ categories
- Newly Flooded
- No Longer Flooded

W S N E

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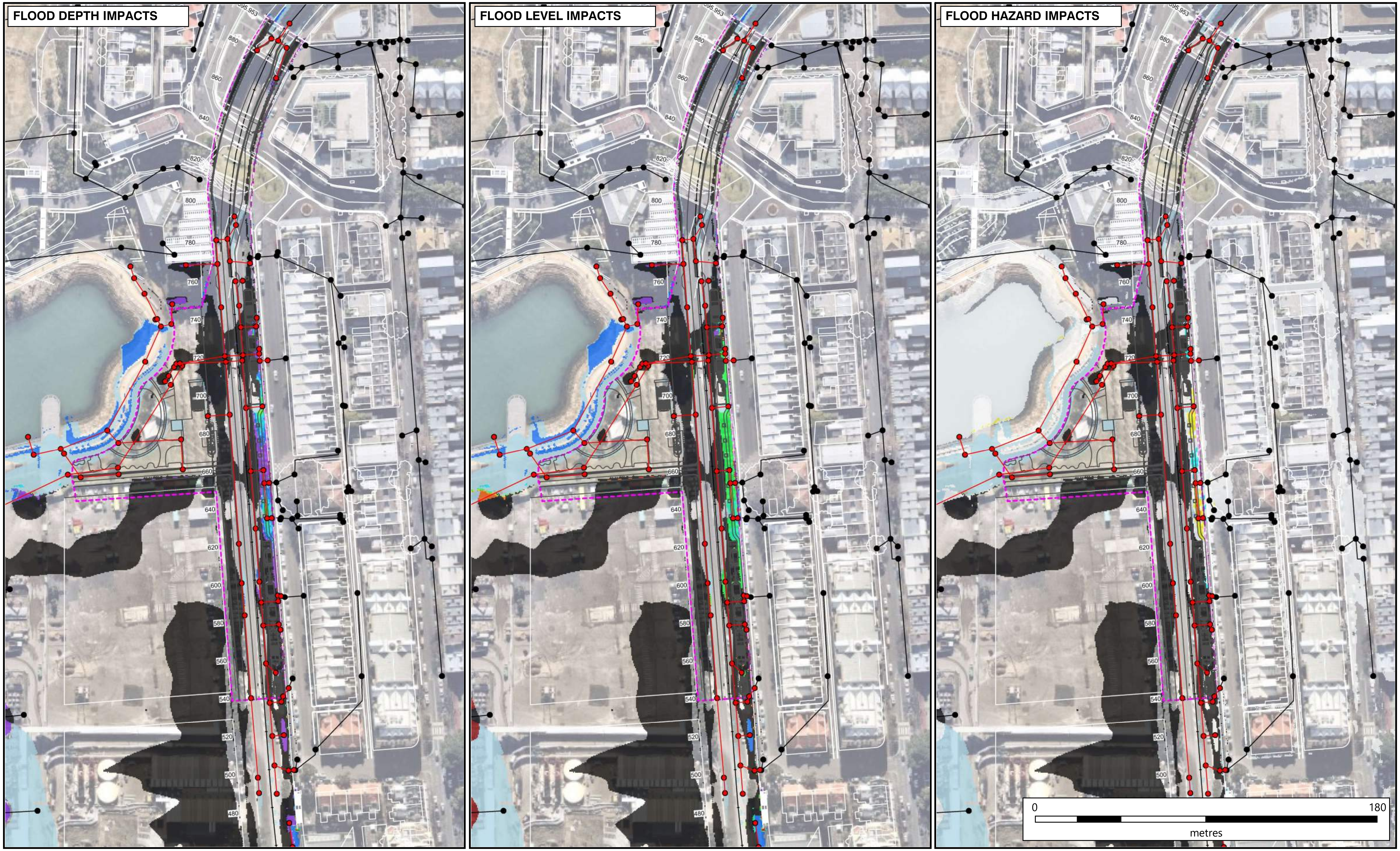
grc HYDRO

TITLE : **HICKSON ROAD NORTH, ULTIMATE DESIGN - FLOOD IMPACTS**	EVENT: **PMF**	PROJECT: **Barangaroo Station Civil Works Hickson Road Stage 3 Design**	PROJECT No.**180038**	DATE: **June 2021**	FIGURE NUMBER: **G3**



Proposed Pit
Proposed Pipe
Existing Pit
Existing Pipe
Hickson Road North, Ultimate Design - Extent of Works

Flood Depth/Level Impact (m)

< -0.01	0.2 to 0.3	0.6 to 0.7	> 1.0
No Difference	0.3 to 0.4	0.7 to 0.8	Newly Flooded
0.01 to 0.1	0.4 to 0.5	0.8 to 0.9	No Longer Flooded
0.1 to 0.2	0.5 to 0.6	0.9 to 1.0	

Flood Hazard Impact

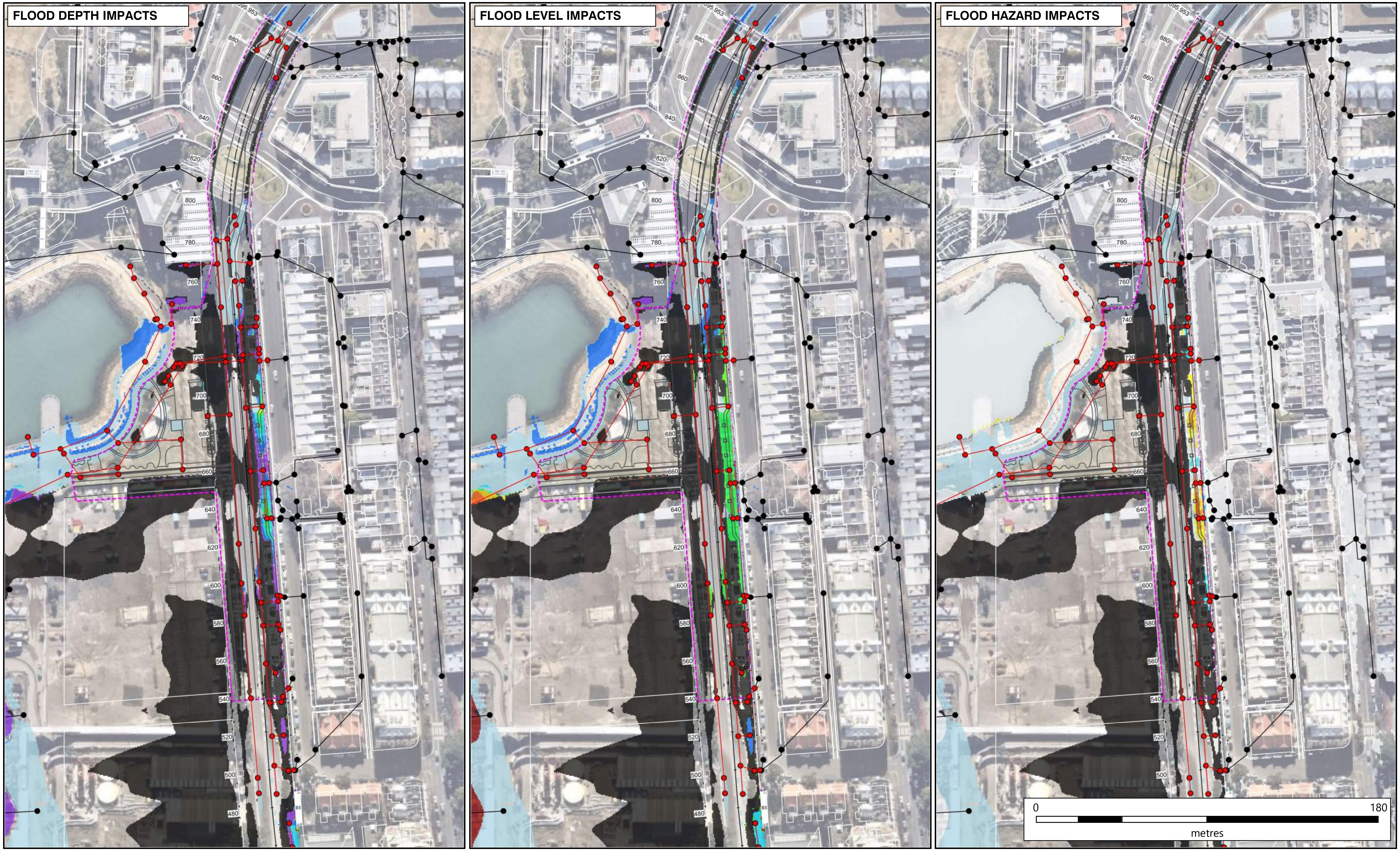
Decreased by 3+ categories	Increased by 1 categories	
Decreased by 2 categories	Increased by 2 categories	
Decreased by 1 categories	Increased by 3+ categories	
No Difference	Newly Flooded	No Longer Flooded

W S N E

Flood model results presented on this map have been prepared for INSW in accordance with the terms of the engagement and should not be used for any other purpose

grc HYDRO

TITLE : **HICKSON ROAD NORTH, ULTIMATE DESIGN - FLOOD IMPACTS**	EVENT: **1% AEP Event + 10% Rainfall + 0.9 m Sea Level**	PROJECT: **Barangaroo Station Civil Works Hickson Road Stage 3 Design**	PROJECT No. **180038**	DATE: **June 2021**	FIGURE NUMBER: **G4**



Proposed Pit
Proposed Pipe
Existing Pit
Existing Pipe
Hickson Road North, Ultimate Design - Extent of Works

Flood Depth/Level Impact (m)

- < -0.01
- No Difference
- 0.01 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.4
- 0.4 to 0.5
- 0.5 to 0.6
- 0.6 to 0.7
- 0.7 to 0.8
- 0.8 to 0.9
- 0.9 to 1.0
- > 1.0
- Newly Flooded
- No Longer Flooded

Flood Hazard Impact

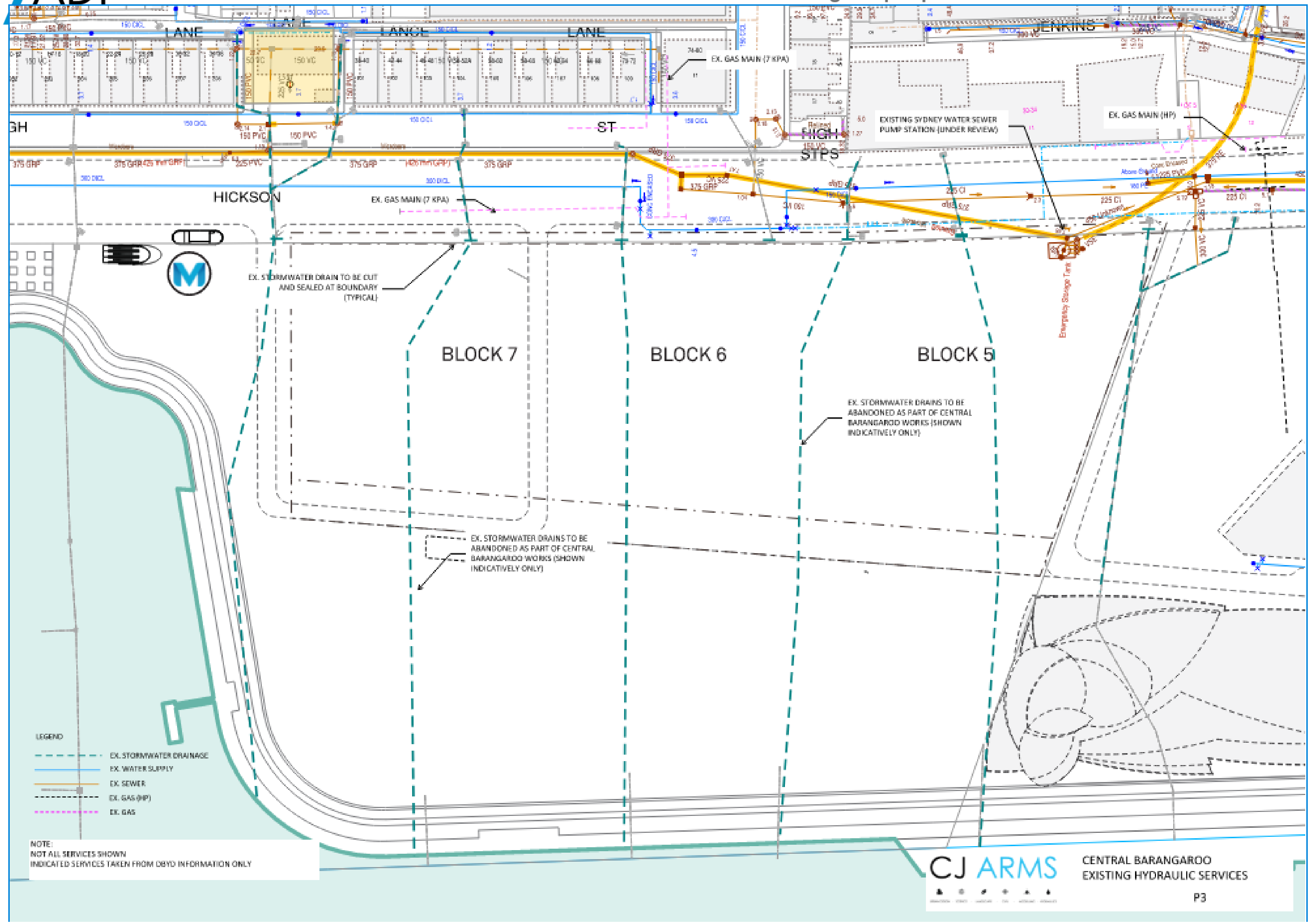
- Decreased by 3+ categories
- Decreased by 2 categories
- Decreased by 1 categories
- No Difference
- Increased by 1 categories
- Increased by 2 categories
- Increased by 3+ categories
- Newly Flooded
- No Longer Flooded

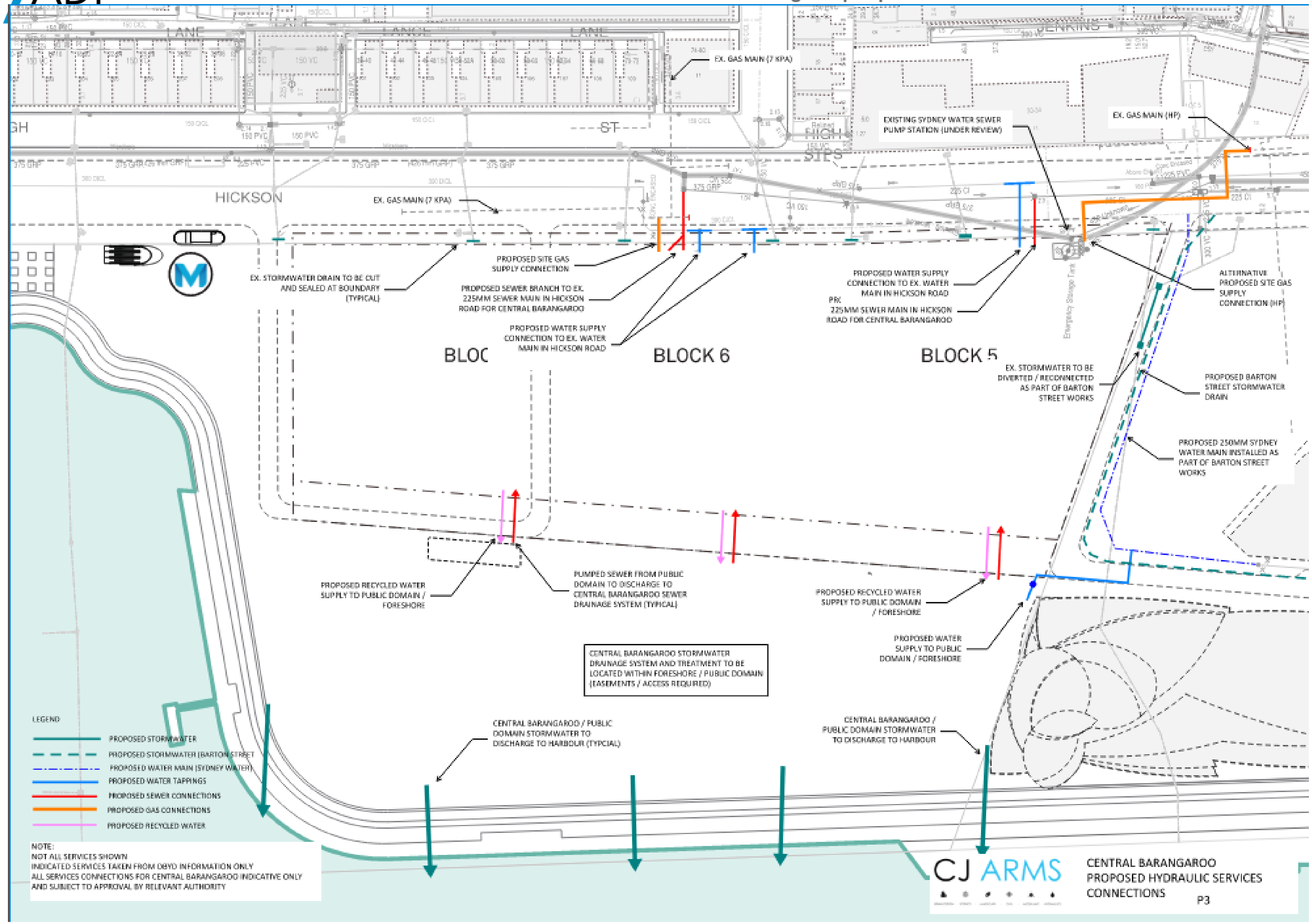
N S E W

Flood model results presented on this map have been prepared for INSW in accordance with the terms of the engagement and should not be used for any other purpose

TITLE : **HICKSON ROAD NORTH, ULTIMATE DESIGN - FLOOD IMPACTS**	EVENT: **1% AEP Event + RCP8.5 Rainfall + 0.9 m Sea Level**	PROJECT: **Barangaroo Station Civil Works Hickson Road Stage 3 Design**	PROJECT No. **180038**	DATE: **June 2021**	FIGURE NUMBER: **G5**

Appendix B: Infrastructure Plans, Existing and Proposed


HICKSON
ST
HIGH
STPS
JENKINS
LANE
BLOCK 7
BLOCK 6
BLOCK 5
EX. GAS MAIN (7 KPA)
EX. GAS MAIN (HP)
EXISTING SYDNEY WATER SEWER PUMP STATION (UNDER REVIEW)
EX. STORMWATER DRAIN TO BE CUT AND SEALED AT BOUNDARY (TYPICAL)
EX. STORMWATER DRAINS TO BE ABANDONED AS PART OF CENTRAL BARANGAROO WORKS (SHOWN INDICATIVELY ONLY)
EX. STORMWATER DRAINS TO BE ABANDONED AS PART OF CENTRAL BARANGAROO WORKS (SHOWN INDICATIVELY ONLY)
LEGEND
EX. STORMWATER DRAINAGE
EX. WATER SUPPLY
EX. SEWER
EX. GAS (HP)
EX. GAS
NOTE:
NOT ALL SERVICES SHOWN
INDICATED SERVICES TAKEN FROM DBYD INFORMATION ONLY
CJ ARMS
CENTRAL BARANGAROO
EXISTING HYDRAULIC SERVICES
P3


HICKSON
EX. GAS MAIN (7 KPA)
EX. GAS MAIN (7 KPA)
EXISTING SYDNEY WATER SEWER PUMP STATION (UNDER REVIEW)
EX. GAS MAIN (HP)
EX. STORMWATER DRAIN TO BE CUT AND SEALED AT BOUNDARY (TYPICAL)
PROPOSED SITE GAS SUPPLY CONNECTION
PROPOSED SEWER BRANCH TO EX. 225MM SEWER MAIN IN HICKSON ROAD FOR CENTRAL BARANGAROO
PROPOSED WATER SUPPLY CONNECTION TO EX. WATER MAIN IN HICKSON ROAD
PROPOSED WATER SUPPLY CONNECTION TO EX. WATER MAIN IN HICKSON ROAD
225MM SEWER MAIN IN HICKSON ROAD FOR CENTRAL BARANGAROO
ALTERNATIVE PROPOSED SITE GAS SUPPLY CONNECTION (HP)
BLOCK 6
BLOCK 5
EX. STORMWATER TO BE DIVERTED / RECONNECTED AS PART OF BARTON STREET WORKS
PROPOSED BARTON STREET STORMWATER DRAIN
PROPOSED 250MM SYDNEY WATER MAIN INSTALLED AS PART OF BARTON STREET WORKS
PROPOSED RECYCLED WATER SUPPLY TO PUBLIC DOMAIN / FORESHORE
PUMPED SEWER FROM PUBLIC DOMAIN TO DISCHARGE TO CENTRAL BARANGAROO SEWER DRAINAGE SYSTEM (TYPICAL)
PROPOSED RECYCLED WATER SUPPLY TO PUBLIC DOMAIN / FORESHORE
PROPOSED WATER SUPPLY TO PUBLIC DOMAIN / FORESHORE
CENTRAL BARANGAROO STORMWATER DRAINAGE SYSTEM AND TREATMENT TO BE LOCATED WITHIN FORESHORE / PUBLIC DOMAIN (EASEMENTS / ACCESS REQUIRED)
CENTRAL BARANGAROO / PUBLIC DOMAIN STORMWATER TO DISCHARGE TO HARBOUR (TYPCIAL)
CENTRAL BARANGAROO / PUBLIC DOMAIN STORMWATER TO DISCHARGE TO HARBOUR
LEGEND
PROPOSED STORMWATER
PROPOSED STORMWATER (BARTON STREET)
PROPOSED WATER MAIN (SYDNEY WATER)
PROPOSED WATER TAPPINGS
PROPOSED SEWER CONNECTIONS
PROPOSED GAS CONNECTIONS
PROPOSED RECYCLED WATER
NOTE:
NOT ALL SERVICES SHOWN
INDICATED SERVICES TAKEN FROM DBYD INFORMATION ONLY
ALL SERVICES CONNECTIONS FOR CENTRAL BARANGAROO INDICATIVE ONLY AND SUBJECT TO APPROVAL BY RELEVANT AUTHORITY
CJ ARMS
CENTRAL BARANGAROO
PROPOSED HYDRAULIC SERVICES
CONNECTIONS
P3

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