West

Major civil construction between The Bays and Sydney CBD

Environmental Impact Statement 2021

Technical Paper 9

Hydrology, flooding and water quality

Project:	Sydney Metro West
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Mott MacDonald Australia Pty Ltd

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Executive summary

Sydney Metro, Australia's biggest public transport program, is aiming to deliver an integrated transport system that meets the needs of customers now and those in the future, with its delivery critical to keeping Sydney moving. The Sydney metro program includes the Metro North West Line (which opened in May 2019), Sydney Metro City & Southwest (which is currently under construction and due to open in 2024), Sydney Metro West (this proposal) and Sydney Metro Greater West (which is currently in the final stages of planning).

The planning process for Sydney Metro West is being assessed as a staged infrastructure application under section 5.20 of the *Environment Planning and Assessment Act 1979* (EP&A Act).

The Sydney Metro West Concept and major civil construction work for Sydney Metro West between Westmead and The Bays (Stage 1 of the planning approval process for Sydney Metro West), application number SSI-10038, were approved on 11 March 2021.

The Concept includes:

- Construction and operation of new passenger rail infrastructure between Westmead and the central business district of Sydney, including:
  - Tunnels, stations (including surrounding areas) and associated rail facilities
  - Stabling and maintenance facilities (including associated underground and overground connections to tunnels)
- Modification of existing rail infrastructure (including stations and surrounding areas)
- Ancillary development.

Major civil construction work for Sydney Metro West between Westmead and The Bays includes:

- Tunnel excavation including tunnel support activities between Westmead and The Bays
- Station excavation for new metro stations at Westmead, Parramatta, Sydney Olympic Park, North Strathfield, Burwood North, Five Dock and The Bays
- Shaft excavation for services facilities
- Civil work for the stabling and maintenance facility at Clyde.

Stage 2 (this Proposal) of the planning approval process includes all major civil construction work including station excavation and tunnelling between The Bays and Hunter Street Station (Sydney CBD).

Future planning applications for Sydney Metro West will include tunnel fit-out, station building fit-out and operation of the line between Westmead and Hunter Street Station (Sydney CBD).

This hydrology, flooding and water quality assessment

This technical paper has been prepared to support the Environmental Impact Statement by identifying and assessing the potential impacts of the Proposal during construction, in relation to hydrology, flooding and water quality. In doing so, this technical paper responds directly to the Secretary's Environmental Assessment Requirements.

The Secretary's Environmental Assessment Requirements issued by the NSW Department of Planning, Industry and Environment require a hydrology, flooding and water quality assessment to support the Environmental Impact Statement being prepared for the Proposal. This technical paper addresses the relevant flooding, hydrology and water quality requirements in the Secretary's Environmental Assessment Requirements and provides an assessment of potential impacts to the Sydney Harbour catchment and receiving waterways, flood behaviour, waterway conditions and water quality during construction of the Proposal.

The assessment undertaken in this technical paper has considered a range of potential flood events. Cumulative impacts have been assessed to determine potential changes to Sydney Harbour catchment as a result of the Proposal occurring alongside other projects and projected future land use changes. Furthermore, appropriate performance outcomes and proposed mitigation and management measures have been identified.

Assessment methodology

Through a review of existing catchment flood studies and adaption of associated hydraulic models, an understanding of baseline flood characteristics along the Proposal alignment has been developed. The hydraulic models have been updated to gain a greater understanding of potential impacts the Proposal may have on flood behaviour and to ensure components of the Proposal, such as drainage structures and construction works, are designed to minimise flood impacts.

Existing literature, monitoring data and previous assessments completed for the *Sydney Metro West Environmental Impact Statement – Westmead to The Bays and Sydney CBD* (Sydney Metro, 2020) have been reviewed to develop an understanding of the existing water quality of the Proposal area. The assessment has identified the pollutants and contaminants which may impact water quality as a result of construction and developed mitigation measures to minimise the impact, reviewing their performance against the relevant guidelines and water quality objectives.

Existing conditions

The Proposal footprint lies entirely within the Sydney Harbour catchment and flows generally in a northerly direction to White Bay in the lower estuary of Sydney Harbour.

All the station construction sites are impacted by the 1% AEP and PMF events to varying degrees. The sites are typically within low hazard areas except for Hunter Street Station (Sydney CBD) construction sites which has a high hazard mapping on Hunter Street.

Existing water quality within the Proposal area is generally poor due to the heavily urbanised state of the surrounding environment.

Potential construction impacts

As the Proposal largely involves tunnel excavation, the predicted changes to flood behaviour during construction are likely to be minimal. Localised changes to overland flows are limited in their scale to the immediate vicinity of the construction sites, and due to the temporary nature of the impacts are considered minor. Impacts are not inconsistent with relevant council floodplain management plans. Flood protection levels have been estimated for all station sites for design purposes and will continue to be refined as the designs progress.

The construction of the Proposal has the potential to impact the water quality of surrounding environments including White Bay and Sydney Harbour. Potential impacts on the water quality are generally associated with demolition works, earth works and concrete activities which may disturb and/or spread sources of pollutants, generate soils and waste materials, soil erosion and discharge of concrete dust/slurries. These sources can be conveyed to nearby waterbodies resulting in elevated levels of pollution, increased turbidity, reduce dissolved oxygen and increased nutrients and heavy metals, severely impacting the water quality.

Proposed management and mitigation measure

Management and mitigation measures have been proposed for the construction phase of this Proposal along with a number of relevant measures previously recommended (Sydney Metro, 2020 and Sydney Metro, 2020a). These would be documented and implemented as part of a project Construction Environmental Management Framework and include measures to manage residual risks associated with threats to personal safety during construction should high hazard flood events occur, particularly in relation to the roads immediately adjacent to the Hunter Street Station (Sydney CBD) construction sites.

Additional flood mitigation measures include addressing the blockage of local flow paths at The Bays construction site and reviewing any existing emergency evacuation plans along with all mitigation measures to maintain a consistent approach to emergency evacuation throughout the construction period at all the construction sites encompassed by this proposal. An additional mitigation measure has been proposed to address the Secretary's Environmental Assessment Requirement regarding the identification of the rainfall event that will be the design basis for the water quality protection measures.

These measures along with those recommended in Technical Paper 7 will address the Secretary's Environmental Assessment Requirements associated with hydrology, flooding and water quality impacts by this Proposal.

Residual impacts following the implementation of mitigation measures are expected to be restricted to localised changes of overland flowpaths limited in scale to the immediate vicinity of the construction site. These are considered to be minor due to the temporary nature of construction. Impacts on receiving waterbodies around the Proposal would be minimised by the application of design standards as well as management measures throughout the life of the construction of the Proposal.

TERMINOLOGY

<table>
<tr><th>Term</th><th>Definition</th></tr>
<tr><td>AHD</td><td>Australian Height Datum. A common national surface level datum approximately corresponding to mean sea level.</td></tr>
<tr><td>Annual Exceedance Probability (AEP)</td><td>The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. In this study AEP has been used consistently to define the probability of occurrence of flooding. The following relationships between AEP and ARI applies to this study (Ball et al, 2019).
<table>
<tr><th>Frequency Descriptor</th><th>EY</th><th>AEP (%)</th><th>AEP (1 in x)</th><th>ARI</th></tr>
<tr><td rowspan="6">Very frequent</td><td>12</td><td></td><td></td><td></td></tr>
<tr><td>6</td><td>99.75</td><td>1.002</td><td>0.17</td></tr>
<tr><td>4</td><td>98.17</td><td>1.02</td><td>0.25</td></tr>
<tr><td>3</td><td>95.02</td><td>1.05</td><td>0.33</td></tr>
<tr><td>2</td><td>86.47</td><td>1.16</td><td>0.50</td></tr>
<tr><td>1</td><td>63.2</td><td>1.58</td><td>1.00</td></tr>
<tr><td rowspan="5">Frequent</td><td>0.69</td><td>50.00</td><td>2</td><td>1.44</td></tr>
<tr><td>0.5</td><td>39.35</td><td>2.54</td><td>2.00</td></tr>
<tr><td>0.22</td><td>20.00</td><td>5</td><td>4.48</td></tr>
<tr><td>0.2</td><td>18.13</td><td>5.52</td><td>5.00</td></tr>
<tr><td>0.11</td><td>10.00</td><td>10.00</td><td>9.49</td></tr>
<tr><td rowspan="3">Infrequent</td><td>0.05</td><td>5.00</td><td>20</td><td>20.0</td></tr>
<tr><td>0.02</td><td>2.00</td><td>50</td><td>50.0</td></tr>
<tr><td>0.01</td><td>1.00</td><td>100</td><td>100</td></tr>
<tr><td rowspan="4">Rare</td><td>0.005</td><td>0.50</td><td>200</td><td>200</td></tr>
<tr><td>0.002</td><td>0.20</td><td>500</td><td>500</td></tr>
<tr><td>0.001</td><td>0.10</td><td>1000</td><td>1000</td></tr>
<tr><td>0.0005</td><td>0.05</td><td>2000</td><td>2000</td></tr>
<tr><td rowspan="5">Extremely Rare</td><td>0.0002</td><td>0.02</td><td>5000</td><td>5000</td></tr>
<tr><td></td><td></td><td rowspan="4">↓</td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>Extreme</td><td></td><td></td><td>PMP</td><td></td></tr>
</table>
</td></tr>
<tr><td>ARR</td><td>Australian Rainfall and Runoff (ARR) is a national guideline document used for the estimation of design flood characteristics in Australia. Reference is made to either ARR1987 (3rd edition) or ARR2019 (4th edition) as specified.</td></tr>
</table>

Term	Definition
Average Recurrence Interval (ARI)	The long-term average number of years between the occurrences of a flood as big as or larger than the selected event. For example, floods with a discharge as great as or greater than the 20-year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event. Also refer to Average Exceedance Probability (AEP), which is the industry standard terminology for definition of design flood events.
Catchment	The land area draining through the mainstream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
Exceedances per year (EY)	The number of times an event is likely to occur or be exceeded within any given year.
Flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. Existing flood risk: the risk a community is exposed to due to its location on the floodplain. Future flood risk: the risk a community may be exposed to due to new development on the floodplain. Continuing flood risk: the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
Hydrology	The study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
Probable Maximum Flood (PMF)	The largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The probable maximum flood defines the extent of flood prone land, that is, the floodplain.
SOBEK	SOBEK is a computer program used to study the effects of dam breaks, river floods, dike breaches, urban flooding. The hydrodynamic 1D/2D simulation engine allows the combined simulation of pipe, river-, channel- and overland flow through an implicit coupling of 1D and 2D flow equations.

Term	Definition
TUFLOW	TUFLOW is a computer program which is used to simulate free-surface flow for flood and tidal wave propagation. It provides coupled 1D and 2D hydraulic solutions using a powerful and robust computation. The engine has seamless interfacing with GIS and is widely used across Australia.

1 Introduction

1.1 Sydney Metro West

Sydney Metro West will double rail capacity between Greater Parramatta and the Sydney CBD, transforming Sydney for generations to come.

The once-in-a-century infrastructure investment will have a target travel time of about 20 minutes between Parramatta and the Sydney CBD, link new communities to rail services and support employment growth and housing supply.

Stations have been confirmed at Westmead, Parramatta, Sydney Olympic Park, North Strathfield, Burwood North, Five Dock, The Bays, Pyrmont and Hunter Street (Sydney CBD). The main elements of Sydney Metro West are shown in Figure 1-1.

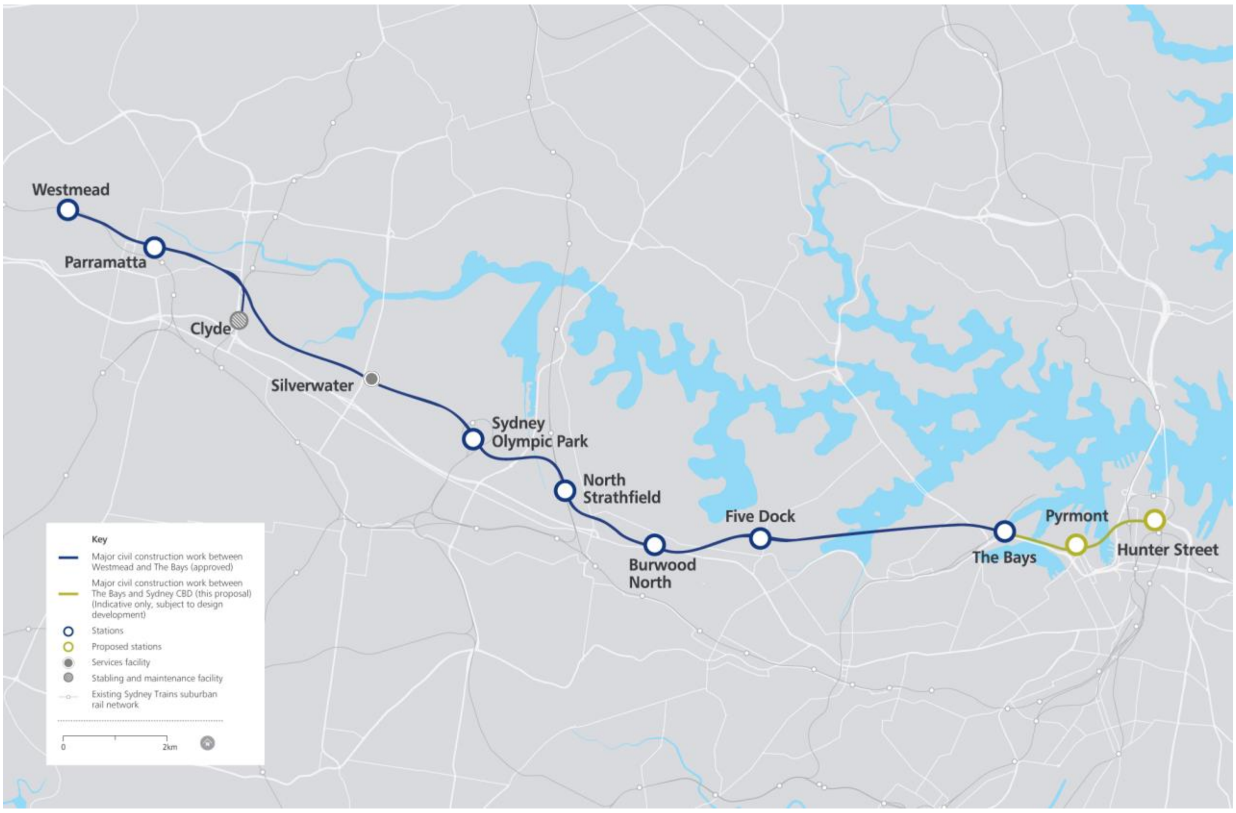

Figure 1-1 Sydney Metro West

The planning process for Sydney Metro West is being assessed as a staged infrastructure application under section 5.20 of the *Environment Planning and Assessment Act 1979* (EP&A Act).

The Sydney Metro West Concept and major civil construction work for Sydney Metro West between Westmead and The Bays (Stage 1 of the planning approval process for Sydney Metro West), application number SSI-10038, were approved on 11 March 2021.

The Concept includes:

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  - Tunnels, stations (including surrounding areas) and associated rail facilities
  - Stabling and maintenance facilities (including associated underground and overground connections to tunnels)
- Modification of existing rail infrastructure (including stations and surrounding areas)
- Ancillary development.

Major civil construction work for Sydney Metro West between Westmead and The Bays (Stage 1) includes:

- Tunnel excavation including tunnel support activities between Westmead and The Bays
- Station excavation for new metro stations at Westmead, Parramatta, Sydney Olympic Park, North Strathfield, Burwood North, Five Dock and The Bays
- Shaft excavation for services facilities
- Civil work for the stabling and maintenance facility at Clyde.

Stage 2 (this Proposal) of the planning approval process includes all major civil construction work including station excavation and tunnelling between The Bays and Hunter Street Station (Sydney CBD).

Future planning applications for Sydney Metro West will include tunnel fit-out, station building and fit-out and operation of the line between Westmead and Hunter Street Station (Sydney CBD).

1.2 Overview of the Proposal

This Proposal would be located largely underground in twin tunnels. Indicative locations of the proposed alignment and stations are shown in Figure 1-2.

Figure 1-2 Overview of Sydney Metro West between The Bays and Sydney CBD

The proposed major civil construction work between The Bays and Hunter Street Station (Sydney CBD) would include:

- Enabling work such as demolition, utility supply to construction sites, utility adjustments, and modifications to the existing transport network
- Tunnel excavation including tunnel support activities
- Station excavation for new metro stations at Pyrmont and at Hunter Street, in the Sydney CBD.

Components of this Proposal are subject to further design, and changes may be made during the ongoing design which take into account the outcomes of community and stakeholder engagement and environmental field investigations.

The surface construction work at station and shaft excavation sites are temporary, taking approximately three years.

The Proposal is further described in Chapter 5 (Project description) of the Stage 2 Environmental Impact Statement.

It is important to note that The Bays Station construction site has already been approved as part of the *Sydney Metro West Environmental Impact Statement – Westmead to The Bays and Sydney CBD* (Sydney Metro, 2020). This included the use of the site to:

- Carry out the excavation of The Bays Station
- Launch and support two tunnel boring machines for the drive west to the Sydney Olympic Park metro station construction site.

The Bays Station construction site is being established under the existing approval. This technical report only assesses the proposed use of the eastern and southern part of The Bays Station construction site to launch and support two tunnel boring machines for the drive east to the proposed Pyrmont and Hunter Street Station (Sydney CBD) construction sites. There would be minimal surface ground disturbance associated with this work.

1.3 Purpose and scope of this Technical Paper

This Hydrology, Flooding and Water Quality Technical Paper is one of a number of Technical Papers that form part of the Stage 2 Environmental Impact Statement for major civil construction work between The Bays and Hunter Street Station (Sydney CBD). The purpose of this Technical Paper is to identify and assess the potential impacts of the Proposal in relation to Hydrology, Flooding and Water Quality. It responds directly to the Secretary's Environmental Assessment Requirements outlined in section 1.3.1.

The objectives of this Technical Paper include:

- Characterise existing flooding behaviour and identify flood risks during construction
- Assess hydrology, flooding and water quality impacts which could occur during this Proposal
- Identify mitigation measures for this Proposal.

1.3.1 Secretary's Environmental Assessment Requirements

The Secretary's Environmental Assessment Requirements for Stage 2 were issued on 7 July 2021. The response to the Secretary's Environmental Assessment Requirements for hydrology is split across technical papers 7 and 9. The requirements specific to surface water hydrology, flooding and water quality impacts, and where these requirements are assessed in this Technical Paper, are outlined in Table 1-1.

In support of seeking the Secretary's Environmental Assessment Requirements, the *Sydney Metro West Scoping Report – Major civil construction from The Bays to Sydney CBD* (Sydney Metro, 2021) identified a number of investigations and further assessments relevant to this Technical Paper. How this Technical Paper addresses these matters is provided in Table 1-2.

Table 1-1 Secretary's Environmental Assessment Requirements – Water

Secretary's environmental assessment requirements	Where addressed
Flooding	
1. Flood management objectives must be clearly identified and justified to address the characteristics of the environment and relevant legislative, management and guidance requirements.	Refer to Table 3-2

Secretary's environmental assessment requirements	Where addressed
2. Flood behaviour during construction including: (a) potential flood affectation of other properties, assets and infrastructure; (b) consistency (or inconsistency) with applicable Council floodplain risk management plans; (c) compatibility with the flood hazard of the land; and (d) compatibility with the hydraulic functions of flow conveyance in flood ways and storage areas of the land.	Refer to section 5.1
3. Identify measures to achieve the flood management objectives.	Refer to section 6
Water - Hydrology	
1. Describe (and map) the existing hydrological regime for any surface and groundwater resource (including reliance by users and for ecological purposes) likely to be impacted by the Proposal, including stream orders, as per the Framework for Biodiversity Assessment (FBA).	Refer to section 3.4 and section 4
2. Provide a water balance for ground and surface water including the proposed intake and discharge locations, volume, frequency and duration.	Refer to section 5.2.2 and section 5.3
3. Surface and groundwater hydrology impacts of the Proposal in accordance with the current guidelines, including: (a) impacts from any permanent and temporary interruption of groundwater flow, including the extent of drawdown, barriers to flows, implications for groundwater dependent surface flows, groundwater users and the potential for settlement; and (b) minimising the effects of proposed stormwater and wastewater management during construction on natural hydrological attributes (such as volumes, flow rates, management methods and re-use options) and on the conveyance capacity of existing stormwater systems where discharges are proposed through such systems.	Refer to section 5.1, Technical Paper 7 Hydrogeology section 5 and section 5.1.3
4. Identify any requirements for baseline monitoring of hydrological attributes.	Refer to Technical Paper 7 Hydrogeology section 5 and section 6
Water – quality	
1. Surface and groundwater quality impacts including:	

Secretary’s environmental assessment requirements	Where addressed
(a) identifying and estimating the discharge water quality and degree of impact that any discharge(s) may have on the receiving environment, including consideration of all pollutants that pose a risk of non-trivial harm to human health and the environment;	Refer to section 4.7 and section 5.1.3
(b) identifying the rainfall event that the water quality protection measures will be designed to cope with; and	Refer to Table 6-2
(c) assessing the significance of any identified impacts including consideration of the relevant ambient water quality outcomes	Refer to section 5.2 for construction impacts. Section 5.2.3 assesses the impact of the Proposal against the WQOs.
2. Demonstrating how the project will ensure that:	Refer to section 4.8, section 5.2.2, section 5.2.3 and section 6.3
(a) where the NSW Water Quality Objectives (WQOs) for receiving waters are currently being met they will continue to be protected;	
(b) where the NSW WQOs are not currently being met, activities will work toward their enhancement over time; and	
(c) justify, if required, why the WQOs cannot be maintained or achieved over time.	

Table 1-2 Investigations and further assessments identified in Scoping Report – Water

Investigations and further assessments	How addressed
The assessment of hydrology and flooding impacts will include:	
• Review of relevant existing flood study reports and description of flood behaviour for the existing conditions	Refer to section 4.10
• Identification and assessment of potential impacts on stormwater quantity	Refer to section 5.1.3

Investigations and further assessments	How addressed
• Broad assessment of the potential change in stormwater runoff (increase or decrease) including consideration of changes to flooding behaviour in response to climate change (sea level rise and rainfall intensity)[1]	Refer to section 5.1
• Identification of potential impacts as a result of changes in surface water quantity, with respect to increases or decreases in stormwater runoff and the sensitivity of the downstream waters	Refer to section 5.1
• Identification of any potential changes to flood levels (including flood affectation of other properties, assets and infrastructure), discharges, velocities, duration of flood inundation and flood hazards for the five per cent and one per cent Annual Exceedance Probability flood events, and the probable maximum flood	Refer to section 5.1
• A review of consistency with applicable Council Floodplain Risk Management Study	Refer to section 5.1
• A review of compatibility with flood hazard and hydraulic functions of the land	Refer to section 5.1
• Identification of appropriate mitigation and management measures	Refer to section 6

1.4 Structure of this Technical Paper

The structure of this Technical Paper is outlined below:

- Section 2 presents relevant legislative and policy context to this Proposal
- Section 3 documents the assessment methodology for the impact assessment
- Section 4 details the existing environment
- Section 5 provides an assessment of the potential impacts of this Proposal during construction, including cumulative impacts
- Section 6 identifies mitigation and management measures.

[1] Consideration of climate change impacts will be detailed in the report *Sydney Metro West Westmead to Sydney CBD Environmental Impact Statement – Rail infrastructure, stations, precincts and operations Technical Paper 9 Hydrology, Flooding and Water Quality (Mott Macdonald, 2021)*

2 Legislative and policy context

This section presents the relevant legislative, policy context and guidelines as it pertains to this stage of the environmental impact assessment.

2.1 Commonwealth legislation and policy

2.1.1 National Water Quality Management Strategy

The *National Water Quality Management Strategy* (NWQMS) is the adopted national approach to protecting and improving water quality in Australia. It consists of a number of guideline documents, with specific documents relating to the protection of surface water and groundwater resources.

The primary document relevant to the assessment of groundwater risks for the study area is the *Guidelines for Groundwater Quality Protection in Australia* (Australian Government, 2013). This document sets out a high-level risk-based approach to protecting or improving groundwater quality for a range of groundwater beneficial uses (called ‘environmental values’). The beneficial uses are as follows:

- Aquatic ecosystems, comprising the animals, plants and micro-organisms that live in water, and the physical and chemical environment and climatic conditions with which they interact
- Primary industries, including irrigation and general water users, stock drinking water, aquaculture and human consumption of aquatic foods
- Recreation and aesthetic values, including recreational activities such as swimming and boating, and the aesthetic appeal of waterbodies
- Drinking water, which is required to be safe to use and aesthetically pleasing
- Industrial water, such as water used for industrial processes including cooling towers, process water or wash water
- Cultural and spiritual values, which may relate to a range of uses and issues of a water source, particularly for indigenous people, including spiritual relationships, sacred sites, customary use, the plants and animals associated with water, drinking water or recreational activities.

Each beneficial use has a unique set of water quality criteria designed to protect the environmental value of the groundwater resource. For the purposes of this assessment, ‘environmental values’ pertaining to aquatic ecosystems, primary industries, industrial water, and cultural values are considered potentially applicable. ‘Environmental values’ pertaining to drinking water are not applicable as the groundwater quality is generally not suitable for drinking water due to poor groundwater quality. The majority of creeks that pass beneath at depth of the proposed underground activities, may be fed by groundwater baseflow at times and have been identified as having visual amenity values. A few have also been identified as having primary or secondary contact recreation (e.g. White Bay).

Cultural values are not considered applicable as groundwater-related Aboriginal cultural heritage sites have not been identified in the vicinity of the study area. There are no high priority culturally significant sites listed in the schedule of the Water Sharing Plan.

The Australian and New Zealand Governments and Australian state and territory governments are part of the NWQMS. Refer to Technical Paper 7 (Jacobs, 2020a) for more information.

2.1.2 The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018)

The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG 2018) is a key guideline within the NWQMS that is used to identify catchment and waterway specific water quality management goals. These guidelines are an updated version of the previous guidelines, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ, 2000).

The ANZG (2018) guidelines provide a process for assessing existing water quality condition and developing water quality objectives to sustain current or likely future environmental values for water resources. Guideline trigger values for water quality indicators are provided for different environmental values as generic starting points for assessing water quality where site specific information is not available.

The guideline trigger values are used to evaluate the existing water quality conditions against long term water quality goals. It should be noted that the trigger values have not been designed for direct application in activities such as discharge consents, recycled water quality or stormwater quality. These guideline trigger values are provided for various levels of protection of waterways which are considered when describing the existing water quality and key indicators of concern. The level of protection applied in this assessment when assessing ambient water quality is for slightly disturbed to moderately disturbed ecosystems. The ANZG (2018) guidelines provide updated databases to derive guideline values for toxicants and sediments in aquaculture and aquatic foods, physical and chemical stressors and for guideline values for agricultural water users. These databases and values have not been updated for all regions of Australia and in some regions, the values as used in the previous ANZECC/ARMCANZ ANZECC (2000) guidelines still apply.

The Proposal environmental values, based on ANZG (2018) guideline trigger values for the selected toxicants, would be for the protection of 95 per cent of species (or 99 per cent species protection for toxicants that bioaccumulate unless other discharge criteria are agreed with relevant authorities) in slightly disturbed to moderately disturbed systems. For physical and chemical stressors, the ANZG (2018) guidelines are the same as the ANZECC/ARMCANZ ANZECC (2000) and provide guideline trigger values for slightly disturbed ecosystems in estuaries in south-east Australia as shown in Table 2-1.

Table 2-1 ANZG 2018 guideline water quality trigger values for physical and chemical stressors for slightly disturbed estuarine ecosystems in south-east NSW

Parameter	Trigger value or criteria
Chlorophyll-a (µg/L)	4 µg/L
Total Phosphorous (TP) (µg/L)	30 µg/L
Filterable Reactive Phosphorus (FRP) (µg/L)	5 µg/L
Total Nitrogen (TN) (µg/L)	300 µg/L

Parameter	Trigger value or criteria
Oxides of nitrogen (NOx) (µg/L)	15 µg/L
Ammonia (NH4) (µg/L)	15 µg/L
Dissolved Oxygen (DO)	80% - 110%
Turbidity (NTU)	0.5 to 10
pH	7-8.5
Oils, petroleum and hydrocarbons	Oils and petrochemicals should not be noticeable as a visible film on the water, nor should they be detectable by odour

2.2 NSW legislation and policies

2.2.1 Water Act 1912, Water Management Act 2000 and Water Management Regulation 2018

Water resources in NSW are administered under the *Water Act 1912* and the *Water Management Act 2000* by the NSW Department of Planning, Industry and Environment. The *Water Management Act 2000* governs the issue of water access licences and approvals for those water sources (rivers, lakes, estuaries and groundwater) in NSW where Water Sharing Plans have commenced. The Water Sharing Plan for the study area has commenced, and the area is therefore governed under the *Water Management Act 2000.*

In accordance with section 5.23(1) of the *Environmental Planning & Assessment Act 1979*, the following approvals, which may have otherwise been required, would not be required for approved State significant infrastructure:

- Water use approval under section 89 of the *Water Management Act 2000*
- Water management work approval (including a water supply works approval) under section 90 of the *Water Management Act 2000*
- Activity approval under section 91 of the *Water Management Act 2000*.

2.2.2 Water sharing plans

Water sharing plans, following the introduction of the *Water Management Act 2000*, provide the basis for equitable sharing of surface water and groundwater between water users, including the environment.

The majority of NSW is now covered by Water Sharing Plans. If an activity leads to a take from a groundwater or surface water source covered by a Water Sharing Plan, then an approval and / or licence is required. In general, the *Water Management Act 2000* requires:

- A water access licence to take water
- A water supply works approval to construct a work
- A water use approval to use the water.

This Proposal would be located within the Sydney Basin Central Groundwater Source. The Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011 (the Water Sharing Plan) applies to the Sydney Basin Central Groundwater Source.

The Water Sharing Plan contains provisions for allocation of water to construction projects through a volume of ‘unassigned water’ or through the ability to purchase an entitlement where groundwater is available under the long-term average annual extraction limit (LTAAEL).

The LTAAEL for the Sydney Basin Central is 45,915 megalitres per year, which is 25 per cent of the estimated annual recharge for the area. Under the Water Sharing Plan, there are currently 120 groundwater access licences, with a total licensed volume of 2,592 megalitres per year. As such there is up to 43,323 megalitres per year of water available under the LTAAEL.

The Sydney Basin Central Groundwater Source is declared a Less Productive Groundwater Source by the NSW Office of Water (now WaterNSW). Therefore, Less Productive Minimal Impact Considerations of the NSW Aquifer Interference Policy apply with respect to Porous and Fractured Rock Water Sources.

2.2.3 Protection of the Environment Operations Act 1997

Section 120 of the *Protection of the Environment Operations Act 1997* (POEO Act) prohibits the pollution of waters by any person. Under section 122, holding an environment protection licence is a defence against accidental pollution of watercourses.

2.2.4 NSW Aquifer Interference Policy

The *NSW Aquifer Interference Policy* (Office of Water, 2012) is a component of the *Strategic Regional Land Use Policy* and was introduced in September 2012. The *NSW Aquifer Interference Policy* defines the regime for protecting and managing impacts of aquifer interference activities on NSW’s water resources and strikes a balance between the water needs of towns, farmers, industry and the environment. It clarifies the requirements for obtaining groundwater extraction licences and the assessment process under the *Water Management Act 2000.*

The *Water Management Act 2000* defines a number of aquifer interference activities including penetration of, interference with, and obstruction of water flow within, an aquifer. Taking and disposing of groundwater from an aquifer are also defined as being aquifer interference activities.

The *NSW Aquifer Interference Policy* requires that for an aquifer interference activity to meet the minimal impact considerations, any change in groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity.

Groundwater along the corridor is likely to be used by aquatic ecosystems, and primary industries to account for small-scale domestic use of groundwater.

However, this varies locally depending on ambient groundwater conditions. The *NSW Aquifer Interference Policy* also provides a framework for assessing the impacts of aquifer interference activities on water resources. To assess potential impacts, groundwater sources are categorised as either highly productive or less productive, with sub-categories for alluvial, coastal sands, porous rock, and fractured rock aquifers. For each category, there are a number of prescribed minimal impact considerations relating to water table and groundwater pressure drawdown, and changes to groundwater and surface water quality. These are briefly discussed in later sections with references containing further detail for the relevant groundwater sources potentially impacted by this stage of works. This is addressed in Technical Paper 7 Hydrogeology.

2.2.5 Groundwater Dependent Ecosystem Policy

This Proposal has the potential to impact Groundwater Dependent Ecosystems by reducing the potential groundwater that is accessible to those ecosystems.

The *NSW State Groundwater Dependent Ecosystems Policy* (Department of Land and Water Conservation, 2002) implements the *Water Management Act 2000* by providing guidance on the protection and management of Groundwater Dependent Ecosystems. It sets out management objectives and principles to:

- Ensure that the most vulnerable and valuable ecosystems are protected
- Manage groundwater extraction within defined limits thereby providing groundwater flow sufficient to sustain ecological processes and maintain biodiversity
- Ensure that sufficient groundwater of suitable quality is available to ecosystems when needed
- Ensure that the precautionary principle is applied to protect groundwater dependent ecosystems, particularly the dynamics of flow and availability and the species reliant on these attributes
- Ensure that land use activities aim to minimise adverse impacts on groundwater dependent ecosystems.

2.2.6 Flood Prone Land Policy

The *Flood Prone Land Policy* and the accompanying *Floodplain Development Manual* (NSW Government, 2005) guide development on flood prone land apply across the state. The key objectives of this policy are to identify potential hazards and risks, reduce the impact of flooding and flood liability on owners and occupiers of flood prone property, and to reduce public and private losses resulting from floods. This policy also recognises the benefits of the use, occupation and development of flood prone land.

Pursuant to this, Councils will have commissioned floodplain management studies and plans that determine flood planning levels and areas along with hydraulic and hazard categorisation for proposed development within these catchments and their boundaries. Such relevant studies and plans have been identified across the study area and are discussed in further detail in later sections of this report.

The assessment of potential flooding impacts of this study on existing flood regimes has been conducted in accordance with the requirements of the *Floodplain Development Manual*. The assessment and management of potential flooding impacts would follow the guidelines from the *Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (Australian Institute for Disaster Resilience, 2017).

It is noted that during 2020 the Department of Planning, Infrastructure and Environment undertook consultation[2] on revisions to this policy to build greater resilience in people and communities within floodplains by requiring the full range of flood events to be considered

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[2] https://www.planningportal.nsw.gov.au/flood-prone-land-package

when undertaking strategic land use planning. Changes to Local Environmental Plan (LEP) will follow in due course. LEP relevant to this study are listed in section 2.3.

2.2.7 NSW Water Quality Objectives

The NSW Government has developed Sydney Harbour and Parramatta River Water Quality and River Flow Objectives that are consistent with the *National Water Quality Management Strategy*, and in particular, with the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG, 2018). The Sydney Harbour water quality objectives relate to fresh and estuarine surface waters. Surface and groundwater quality must therefore be maintained to a level that does not degrade any receiving surface water environments.

Table 2-2 Environmental values for the study area and associated water quality indicators, trigger values and criteria

Water quality objective	Indicators	Associated trigger values or criteria
Aquatic ecosystems		
Maintaining or improving the ecological condition of waterbodies and their riparian zones over the long term	Total phosphorus	Estuaries - 30µg/L
	Total nitrogen	Estuaries - 300µg/L
	Chlorophyll-a	Estuaries - 4µg/L
	Turbidity	Estuaries - 0.5 - 10 NTU
	Dissolved oxygen	Estuaries - 80 – 100 per cent
	pH	Estuaries - 7.0 - 8.5
	Chemical contaminants or toxicants	As per ANZG – Online Platform
Visual amenity		
Maintaining the aesthetic quality of waters	Visual clarity and colour	Natural visual clarity should not be reduced by more than 20 per cent. Natural hue of the water should not be changed by more than 10 points on the Munsell Scale. The natural reflectance of the water should not be changed by more than 50 per cent.

Water quality objective	Indicators	Associated trigger values or criteria
	Surface films and debris	Oils and petrochemicals should not be noticeable as a visible film on the water, nor should they be detectable by odour. Waters should be free from floating debris and litter.
	Nuisance organisms	Macrophytes, phytoplankton scums, filamentous algal mats, blue-green algae, sewage fungus and leeches should not be present in unsightly amounts.
Secondary contact recreation		
Maintaining or improving water quality for activities such as boating and wading, where there is a low probability of water being swallowed	Enterococci	Median bacterial content in fresh and marine waters of < 230 enterococci per 100 mL (maximum number in any one sample: 450-700 organisms/100 mL).
	Algae & blue-green algae	< 15 000 cells/mL
	Nuisance organisms	Use visual amenity guidelines. Large numbers of midges and aquatic worms are undesirable.
	Chemical contaminants	Waters containing chemicals that are either toxic or irritating to the skin or mucous membranes are unsuitable for recreation. Toxic substances should not exceed values in the ANZG Guidelines.
	Visual clarity and colour	Use visual amenity guidelines
	Surface films	Use visual amenity guidelines
Primary contact recreation		

Water quality objective	Indicators	Associated trigger values or criteria
Maintaining or improving water quality for activities such as swimming in which there is a high probability of water being swallowed	Turbidity	A 200 millimetre diameter black disc should be able to be sighted horizontally from a distance of more than 1.6 metres (approximately 6 NTU).
	Enterococci	NHMRC (2008) microbial assessment based on 95th percentile of enterococci (cfu/100 mL): Category A – Less than 40. No illness seen in most epidemiological studies Category B – Between 41-200. Upper level is above the threshold of illness transmission reported in most studies. Category C – Between 201-500. Represents a substantial elevation in the probability of adverse health outcomes. Category D – Greater than 500. Above this level there may be a significant risk of high levels of illness transmission. ANZECC/ARMCANZ (2000) guidelines recommend: • Median over bathing season of <35 enterococci per 100 mL (maximum number in any one sample: 60-100 organisms/100 mL
	Protozoans	Pathogenic free-living protozoans should be absent from bodies of fresh water. (Note, it is not necessary to analyse water for these pathogens unless temperature is greater than 24 degrees Celsius).
	Algae & blue-green algae	NHMRC (2008) suitability for coastal and estuarine recreational waterbodies should not contain:

Water quality objective	Indicators	Associated trigger values or criteria
		≥ 10 cells/mL *Karenia brevis* and/or have *Lyngbya majuscula* and/or *Pfiesteria* present in high numbers
	pH	6.5-8.5
	Temperature	16°-34°C
	Chemical Contaminants	Waters containing chemicals that are either toxic or irritating to the skin or mucus membranes are unsuitable for recreation. Toxic substances should not exceed the concentrations provided in ANZG (2018).
	Visual clarity and colour	Use visual amenity guidelines
	Surface films	Use visual amenity guidelines
Aquatic foods (cooked)		
Protecting water quality so that it is suitable for the production of aquatic foods for human consumption and aquaculture activities.	Algae & blue-green algae	No guideline is directly applicable, but toxins present in blue-green algae may accumulate in other aquatic organisms.
Note: At the time of developing the catchment water quality objectives, consumption of aquatic foods was nominated for protection. However due to contamination, particularly dioxins, current recommendations by the Department of Primary Industries is that no fish or crustaceans caught west of the Sydney Harbour Bridge should be eaten (Department of Primary Industries, n.d.).	Faecal coliforms	Guideline in water for shellfish: The median faecal coliform concentration should not exceed 14 MPN/100mL; with no more than 10 per cent of the samples exceeding 43 MPN/100 mL. Standard in edible tissue: Fish destined for human consumption should not exceed a limit of 2.3 MPN E Coli /g of flesh with a standard plate count of 100,000 organisms /g.

Water quality objective	Indicators	Associated trigger values or criteria
	Toxicants	Metals: • Copper: less than 5 µgm/L • Mercury: less than 1 µgm/L • Zinc: less than 5 µgm/L Organochlorines: • Chlordane: less than 0.004 µgm/L (saltwater production) • PCB's: less than 2 µgm/L.
	Physio-chemical indicators	Suspended solids: less than 40 micrograms per litre for saltwater production and less than 75 micrograms per litre for Brackish conditions. Temperature: less than 2 degrees Celsius change over one hour.

2.3 Planning controls

The following planning controls are within the study area:

- Leichardt Local Environmental Plan 2013
- Sydney Local Environmental Plan 2012
- Sydney Local Environmental Plan 2005
- Sydney Regional Environmental Plan (Sydney Harbour Catchment) 2005
- Sydney Harbour Foreshore Area Development Control Plan 2005
- Sydney Regional Environmental Plan No 26 - City West.

2.4 Relevant best practice guidelines

In addition to the legislation and policy arrangements outlined previously, the assessment has been undertaken generally in accordance with the following key guidelines as applicable.

2.4.1 Australian rainfall and runoff

Australian Rainfall and Runoff (ARR) is a national guideline document used for the estimation of design flood characteristics in Australia. Since 1958 there have been four editions with the 3rd edition published in 1987 (ARR1987) and the 4th edition published in 2019 (ARR2019) being the relevant guidelines applicable to this study.

Notable differences between these versions include:

- Intensity Frequency Duration (IFD) now uses BoM and other agency gauges rather than only BoM rainfall gauges with approximately 30 years of additional recorded rainfall data and updated statistical techniques to derive the design rainfalls
- Areal Reduction Factors (ARF) was based on USA data and was not available for long durations, now based on Australian data
- Losses now include national advice for rural and urban catchments
- Baseflow now provides Australia wide advice including for ungauged catchments
- Temporal Patterns now based on historic records, multi pattern for each design quantile and complete storms, with pre burst considered
- At site Flood Frequency analysis for gauged and ungauged catchments use Bayesian of L moments and Regional Flood Frequency rather than Probable Rational Method in some states
- Hydrograph Estimation Methods previously used Simple Design Event but now uses ensemble and Monte Carlo
- Interaction of Coastal and River Flooding was not previously considered
- Blockage was not previously considered
- Safety Design Criteria was not previously considered.

The guidelines require practitioners to apply their judgement about the appropriateness of a method to their particular situation and associated local data. Further guidance (OEH, 2019) suggests that there are some situations where the 1987 IFDs may continue to be more appropriate.

For clarity it is noted that:

- ARR1999/2001 are reprints of ARR1987 with updates to the chapter on the estimation of extreme to large floods and reformatting of the chapters into books
- ARR2019 is the culmination of the implementation of ARR2016 following practitioner feedback and the finalisation of Book 9 Runoff in Urban Areas.

2.4.2 Australian Disaster Resilience Handbook Collection

The *Australian Disaster Resilience Handbook Collection* is a series of guidelines providing authoritative knowledge about disaster resilience and is hosted by the Australian Institute for Disaster Resilience (AIDR).

Of particular relevance to this study, is the guideline on managing the floodplain and flood hazard definition. Flood hazard mapping, where the flood hazard is rated thematically based on the flooding depth and velocity at any one time during a flood event, has traditionally been undertaken based on the definition in the *Floodplain Development Manual*. More recently, a comprehensive approach to defining hazard with six classifications (H1 – H6) has been adopted (AIDR, 2017b), see section 7 below for reference. Figure 2-1 is also sourced from the guideline.

The combined hazard curves relate to the vulnerability of the community and allow more of a breakdown as compared to the *Floodplain Development Manual* which was limited to definitions of high/medium and low flood hazard conditions with little differentiation between the susceptibility of different members of the community and of different types of assets and property.

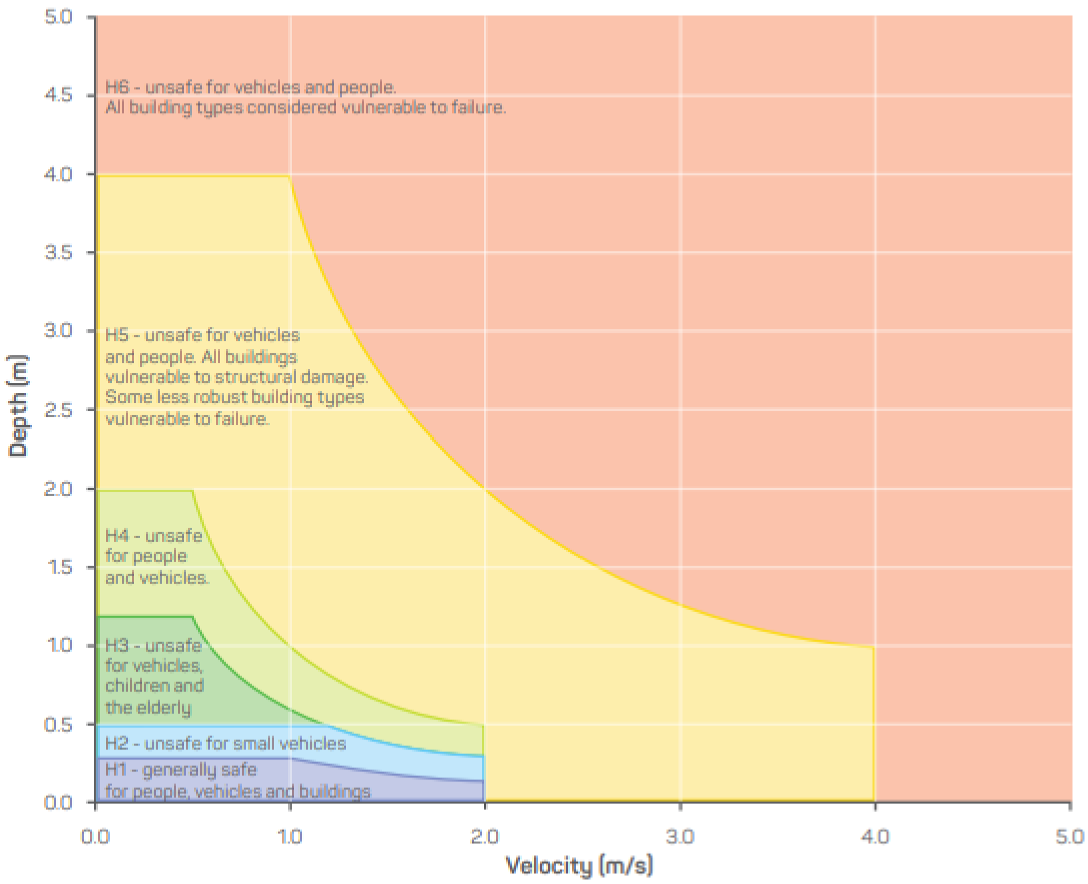

Figure 2-1 Thresholds for people stability in floods

The hazard conditions shown in the figure are defined below:

- H1: Generally safe for vehicles, people and buildings
- H2: Unsafe for small vehicles
- H3: Unsafe for vehicles, children and the elderly
- H4: Unsafe for vehicles and people
- H5: Unsafe for vehicles and people. All building types vulnerable to structural damage. Some less robust building types vulnerable to failure
- H6: Unsafe for vehicles and people. All building types considered vulnerable to failure.

2.4.3 Australian Groundwater Modelling Guidelines

The *Australian Groundwater Modelling Guidelines* (SKM & NCGRT, 2012) provide a point of reference and a consistent approach to groundwater flow and solute transport models in Australia. They also detail the approach to model the interaction between surface water and groundwater bodies. Further discussion of these guidelines is included in Technical Paper 7.

2.4.4 Managing urban stormwater series

The soils and construction series provide guidance on how to reduce the impacts of land disturbance on waterways by better management of soil erosion and sediment control. This series, commonly referred to as the 'Blue Book', includes the following publications:

- Managing Urban Stormwater: Soils and Construction – Volume 1, 4th edition
- Managing Urban Stormwater: Soils and Construction – Volume 2A, Installation of services
- Managing Urban Stormwater: Soils and Construction – Volume 2B, Waste landfills
- Managing Urban Stormwater: Soils and construction – Volume 2C, Unsealed roads
- Managing Urban Stormwater: Soils and construction – Volume 2D, Main road construction
- Managing Urban Stormwater: Soils and Construction – Volume 2E, Mines and quarries.

Erosion and sediment measures would be implemented at all construction sites in accordance with the principles and requirements in Managing Urban Stormwater – Soils and Construction, Volumes 1 (Landcom, 2004) and 2D (Department of Environment and Climate Change NSW, 2008).

3 Assessment methodology

3.1 Methodology overview

The methodology adopted to assess the impact of the Proposal is outlined below. This approach has been developed in line with relevant legislation and guidelines and with reference to the Secretary's Environmental Assessment Requirements.

3.2 Study area

The study area is located within the Sydney Harbour catchment, which includes the Parramatta River catchment, as indicated in Figure 3-1.

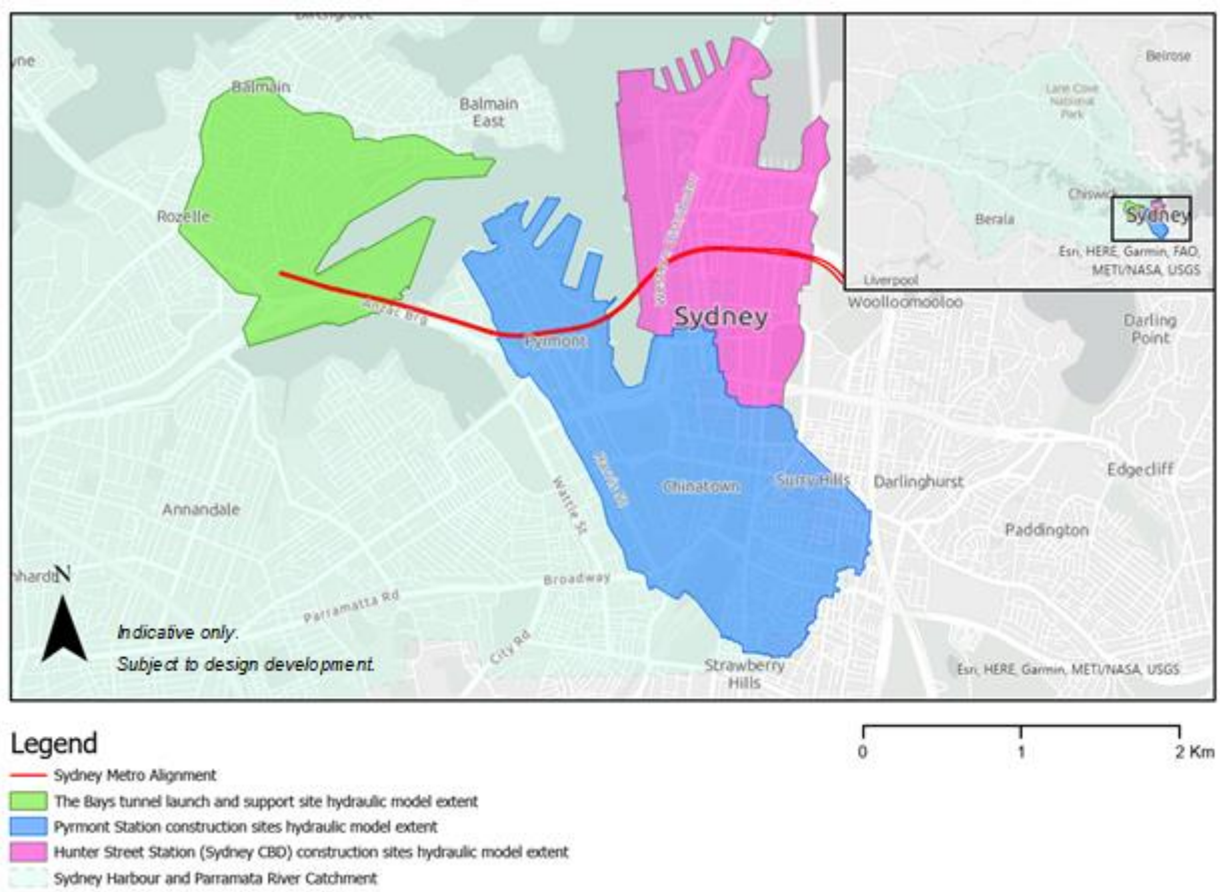

Figure 3-1 Study area

The Bays Station tunnel launch and support site subcatchment drains to White Bay in the lower estuary of Sydney Harbour. The subcatchment for the Pyrmont Station construction sites drains to Pyrmont Bay and Blackwattle Bay, whilst the subcatchment for the Hunter Street Station (Sydney CBD) construction sites drains to Sydney Cove. Table 3-1 lists the watercourses crossed by the Proposal tunnel alignment.

Table 3-1 Watercourses relevant to this Proposal

Construction Site	Watercourse	Receiving Waters
The Bays tunnel launch and support site	White Bay	Sydney Harbour
Pyrmont Station construction sites	Sydney Harbour (Pyrmont Bay and Blackwattle Bay)	Sydney Harbour
Hunter Street Station (Sydney CBD) construction sites	Sydney Harbour (Sydney Cove)	Sydney Harbour

For the purposes of the hydrology, flooding and water quality assessment, the study area extends beyond the Proposal's construction footprint for each construction site to take all potential impacts into consideration in the vicinity of the construction sites and on downstream watercourses.

3.3 Hydrology and flooding

The following methodology has been used to develop an understanding of the existing flood behaviour in the study area and to assess potential construction phase flood impacts and potential cumulative flood impacts.

As noted earlier in section 1.1 and section 1.2, this Proposal includes all major civil construction work including station excavation and tunnelling between The Bays and Hunter Street Station (Sydney CBD). Consequently, the baseline scenario for the hydrology and flooding assessment at The Bays Station tunnel launch and support site is the same scenario as the proposal end state for Stage 1 of the planning approval process.

Key steps in the hydrology and flooding assessment methodology are shown in Figure 3-2.

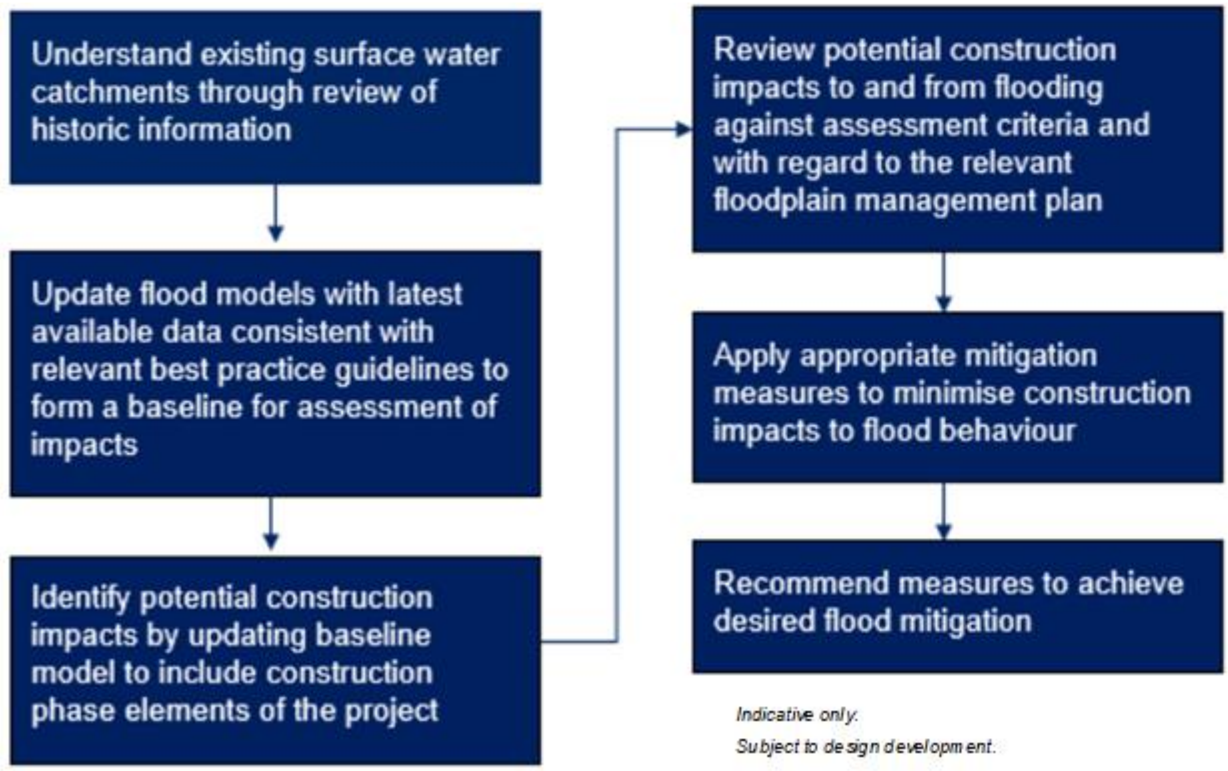

Figure 3-2 Hydrology and flooding assessment methodology

The hydrology and flooding assessment was undertaken based on the key tasks shown in Table 3-2.

Table 3-2 Hydrology and flooding assessment methodology

Key tasks in hydrology and flooding assessment methodology
Desktop review
Desktop review of publicly available flood study reports and models from local council(s) and other sources was undertaken to characterise existing flooding conditions at all construction sites and the surrounding areas. Factors considered include: • Topography in the vicinity of the sites and presence of flow paths and watercourses • Flood hazard • Flood depths and levels. In these studies, hydrological assessment has been incorporated directly into the hydraulic models, rather than employing a separate hydrological model to derive flow hydrographs. Along with topographic information and model parameters reflecting the catchment and watercourse, flood behaviour including flood levels, flood extents, flood velocities and the duration of inundation in the catchment and watercourse can be predicted. Hydraulic models from relevant studies have been adapted as outlined later in this table for use in this study.

Key tasks in hydrology and flooding assessment methodology
Hydrology and flood models
Assessment of the potential impacts of this Proposal on flooding that consider events up to the Probable Maximum Flood (PMF) which focuses on: • Potential increases in flood risk and flood affectation on adjacent properties and assets as well as potential impacts to any emergency management arrangements • Land use compatibility in relation to flood hazard • Compatibility with council floodplain risk management in terms of safe velocities and depths for pedestrians and vehicles • Where required mitigation and management measures have been identified. • Quantitative assessments have been undertaken for each site associated with proposal. Typically, these have been based on council flood models which have been validated and updated with construction information around each site. These models apply rainfall directly to the digital elevation model (DEM) therefore no flow hydrographs need to be derived separately. Additional information on the parameters for the hydrology (rain-on-grid) aspect of the hydraulic models is contained later in this table under Scenario Assessment. This level of assessment is appropriate for each construction site given the general low level of flood exposure in addition to the low risk of significant flooding impacts due to the works associated with this Proposal. The flooding assessment is based on the alignment model Version 4.1 from The Bays to Sydney CBD North Environmental Impact Statement – Stage 2 Constructability Report (Sydney Metro, 2021). The flood models were developed from the following source of information: • The Bays Station tunnel launch and support site was based on the *Leichhardt Floodplain Risk Management Study and Plan* (Cardno, 2017) and the *Leichhardt Flood Study* (Cardno, 2015b) • Pyrmont Station was based on the *Darling Harbour Catchment Flood Study* (BMT WBM, 2014b), *Darling Harbour Catchment Floodplain Risk Management Study* (WMA Water, 2016c) and the *Darling Harbour Catchment Floodplain Risk Management Plan* (WMA Water, 2016d) • Hunter Street Station (Sydney CBD) construction sites was based on the *City Area Catchment Flood Study* (BMT WBM, 2014a), *City Area Catchment Floodplain Risk Management Study* (WMA Water, 2016a) and the *City Area Catchment Floodplain Risk Management Plan* (WMA Water, 2016b)
Scenario assessment
A TUFLOW one dimensional/two dimensional hydraulic model has been developed for the proposal to convert rainfall runoff rates into flow depths and velocities for both the existing environment scenario (no proposal) and proposal design scenarios. The model has been prepared to assess the full range of probable flood events. This includes the 1% AEP and PMF. The 5%AEP is a more frequent event than the 1% AEP so will be similar/slightly shallower than 1% AEP and therefore has not been focussed on.

Key tasks in hydrology and flooding assessment methodology
Calibration and validation: A key phase of building a suitable hydraulic model for the proposal is the process of model calibration and validation. This is required to ensure the adopted model adequately predicts flood behaviour. Calibration involves utilising historic flood event data (referred to as observed data) to change model inputs to get the model to replicate the historic flood event. Validation then involves checking the model inputs against another historic event. Where historic data are available this is the recommended method for checking that the model inputs are suitable. It is noted that as these are existing studies any calibration and validation have been undertaken previously when the models were originally developed. Assumptions and constraints: The Australian Rainfall and Runoff Datahub (ARR Datahub) was the source of hydrological modelling parameters used to update the models. ARR Datahub produces a large list of hydrological input parameters. However, as they are linked to the geographical location and the date of access to the ARR Datahub this information has been tabulated below to allow for reproducibility.

Parameter	The Bays tunnel and launch site	Pyrmont Station	Hunter Street Station (Sydney CBD)
Latitude	151.178	151.192	151.216
Longitude	-33.867	-33.869	-33.855
Access date	March 2021	June 2021	June 2021

It is noted that Intensity-Frequency-Duration (IFD) design rainfall data associated with ARR2019 is typically 20-30 per cent lower than for ARR1987 for some storm burst durations across the Sydney region (Rahman et al, 2017). Although the IFDs derived by BOM in 2016 use a much larger and longer dataset than those from 1987 and support a broad-scale national approach, local factors may not be adequately represented (WMAwater, 2018). Consequently, it will be explored in greater detail as the design progresses.

There were no changes to the council models used for Hunter Street Station (Sydney CBD) and Pyrmont stations regarding boundary conditions or the DEM.

The boundary condition for The Bays Station tunnel launch and support site modelling has been based on the *Fort Denison Vulnerability Study* (Watson et al, 2008). A tail water level of 1.45 mAHD was adopted. Further details are included in The Bays Station model conversion document attached in Appendix A. The DEM was sourced from Geoscience Australia 2021 with the latest LiDAR data for this area as at June 2020.

It is assumed that any current re-development of the proposed station catchment areas outside the construction sites would not increase the flood risk to the sites and that adequate controls would be provided by any future development to mitigate potential flood impacts. Any potential impacts from current re-development will be considered for the permanent works in subsequent Environmental Impact Statements.

This assessment does not include the detailed design of construction site drainage systems, however it is acknowledged that this will be required as the proposal progresses. An aspect of this will be

Key tasks in hydrology and flooding assessment methodology
appreciation of the limits of any existing local stormwater capacity which the construction site drainage system interacts with in the context of relevant design criteria and project approvals.
Flooding criteria
The flood management objectives relevant to this Proposal are set out below: • Excavations for stations would be protected from floodwater inflows. Where feasible the protection level would be above the probable maximum flood or at least 0.5 metres above the 1% AEP flood level, whichever is the greater. • Where it is not feasible or reasonable to meet the criteria, additional controls would be required to manage any potential inflows • Minimise increases in flood levels due to the proposal during flood events up to and including the 1% AEP • Dedicated evacuation routes would not be adversely impacted in flood events up to and including the probable maximum flood. The flood events which will be presented for each assessment include 1% AEP and PMF.
Impact assessment
Construction impacts were assessed quantitatively using the scenarios outlined previously as the basis of the assessment. The cumulative impact assessment has followed a qualitative approach based on a review of major developments proposed in the study area (refer to section 5.4 for further details). These assessments are based on the information and outcomes from available flooding studies only at the time of the assessment. A number of studies are ongoing and may result in new or updated information, which may affect further assessment outcomes of this study. Flood maps have been developed for each site with flood hazard categories in accordance with the Australian Institute of Disaster Resilience (2017b) Guideline 7-3.
Proposed management and mitigation measures
Management plans are identified through the Construction Environmental Management Framework (CEMF) and industry guidelines to manage the impacts of the proposal and to set monitoring programs and have been developed and discussed in section 6.

3.4 Waterways and stream ordering

The Secretary's Environmental Assessment Requirements include a requirement to describe and map the existing surface water hydrological regime likely to be impacted by this Proposal including stream orders in accordance with the Framework for Biodiversity Assessment (FBA). The FBA requires the application of the Strahler stream ordering system to determine the stream order of waterways. This approach is consistent with the requirements outlined in the Biodiversity Assessment Method Order 2020 under the *Biodiversity Conservation Act 2016*.

There are no applicable waterways crossed by the Proposal tunnel alignment therefore a steam order assessment was not undertaken. Jacobs (2020c) contains details of stream order with an associated map for Whites and Johnstons Creeks which discharge to nearby Rozelle Bay south of The Bays Station tunnel launch and support site. It is noted that the Beattie Street Stormwater Channel No 15 is contained within The Bays Station tunnel launch and support site hydraulic model, however it is not crossed by the Proposal tunnel alignment.

3.5 Water quality

The following methodology has been used to understand the existing water quality environment in the study area and to assess potential construction phase water quality impacts. Key steps in the water quality assessment are shown in Figure 3-3.

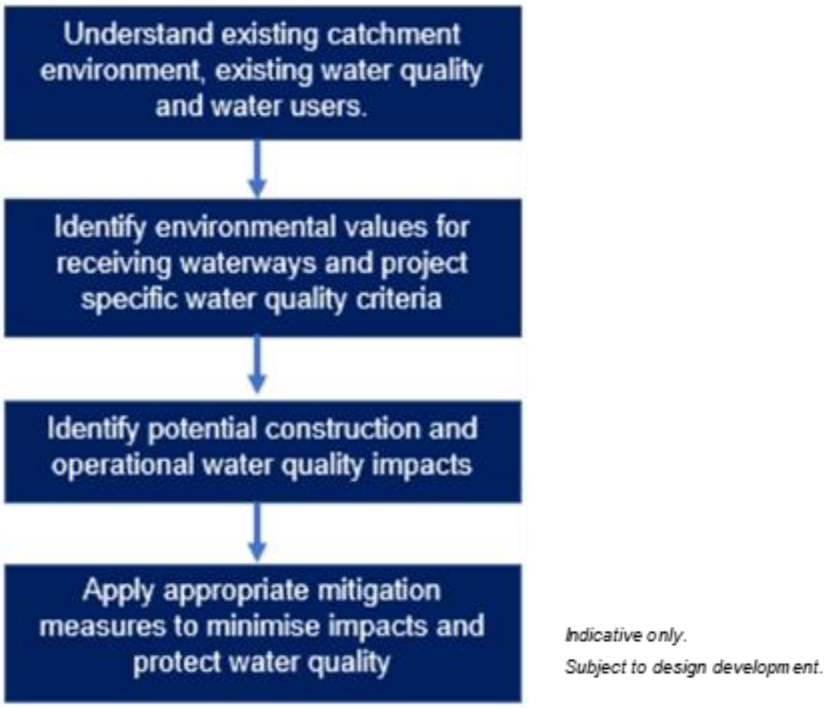

Figure 3-3: Water quality assessment methodology

3.5.1 Existing water quality environment

Available water quality studies and assessments were reviewed to understand the baseline surface water quality conditions for this Proposal. An overview of the existing baseline is provided in section 4.8.

The ANZG (2018) water quality guidelines provide the associated water quality indicators and guideline trigger values (refer to section 2.1.2) and the *Sydney Harbour and Parramatta River Water Quality and River Flow Objectives* (refer to section 2.2.7) provide the values for the catchment.

While the guideline trigger values are adopted for this Proposal, site specific water quality trigger values should be considered for the proposal based on a monitoring program carried out during pre-construction and construction of the Proposal.

3.5.2 Impact assessment

An assessment of the potential water quality impacts from the Proposal has been carried out in section 5.1.3 and considers:

- Water Quality and Objectives (WQO's) in line with the *Sydney Harbour and Parramatta River Water Quality and River Flow Objectives* (NSW Department of Environment, Climate Change and Water, 2006)
- The potential pollutants and impacts to the water quality environment from construction activities
- Appropriate and feasible mitigation measures which can be readily implemented on site to minimise impacts to the water quality environment.

The potential water quality impacts during the construction phase are based on current understanding of the likely construction approach and methods.

3.5.3 Water quality mitigation measures

The mitigation measures are identified for construction of the Proposal to minimise and manage potential impacts to waterways. Surface water issues would be managed in accordance with Sydney Metro's Construction Environmental Management Framework (CEMF) which describes the environmental management, monitoring and reporting approach during construction. Specifically, the CEMF outlines the requirements the construction contractor must address in developing the Construction Environmental Management Plan (CEMP), sub-plans, and other supporting documents for each environmental aspect. Specific sub-plans to be developed from the CEMF include:

- Soil and Water Management Plan
- Stormwater and Flooding Management Plan
- Progressive Erosion and Sediment Control Plan.

Key supporting guidelines to inform the development of these plans:

- *Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia*, Handbook 7, Australian Institute for Disaster Resilience, 2017
- *Managing Urban Stormwater – Soils and Construction*, Landcom, 2004.

4 Existing environment

4.1 Catchment and land uses

The Proposal is located entirely within the Sydney Harbour catchment. The water flows from all stations would drain to Sydney Harbour. The catchment is highly urbanised and altered from its natural state. Catchment areas draining to flow paths and watercourses in the vicinity of the construction sites are a mixture of low, medium and high density residential, commercial and industrial land uses, with some parklands and open spaces. The catchment areas also include several main rail and road transport corridors (e.g. Western Distributor and Cross City Tunnel). These land uses influence the water quality, quantity and speed of flows within the catchment.

The Bays Station tunnel launch and support site forms part of a major overland flow path which drains an area to the north west into White Bay. White Bay is a concrete lined, enclosed embayment located in south-western reaches of Sydney Harbour and is near Blackwattle Bay, Cockle Bay, Johnston Bay, Rozelle Bay and Jones Bay. The upstream catchment is a high-density residential area.

Pyrmont is a heavily developed suburb, west of the Sydney CBD. This area was once a vital component of Sydney's industrial waterfront being home to shipyards, factories and wharves.

The area around Hunter Street Station (Sydney CBD) is heavily urbanised with very little greenspace remaining.

4.2 Climate and rainfall

The study area experiences a temperate climate with a monthly average maximum temperature range of 17 to 26°C, and a monthly average minimum range of 8.1 to 18.9°C. Annual average rainfall total for Observatory Hill (within 2.5km of all sites) is 1211mm/year with the monthly variation as indicated in the Bureau of Meteorology extract in Figure 4-1.

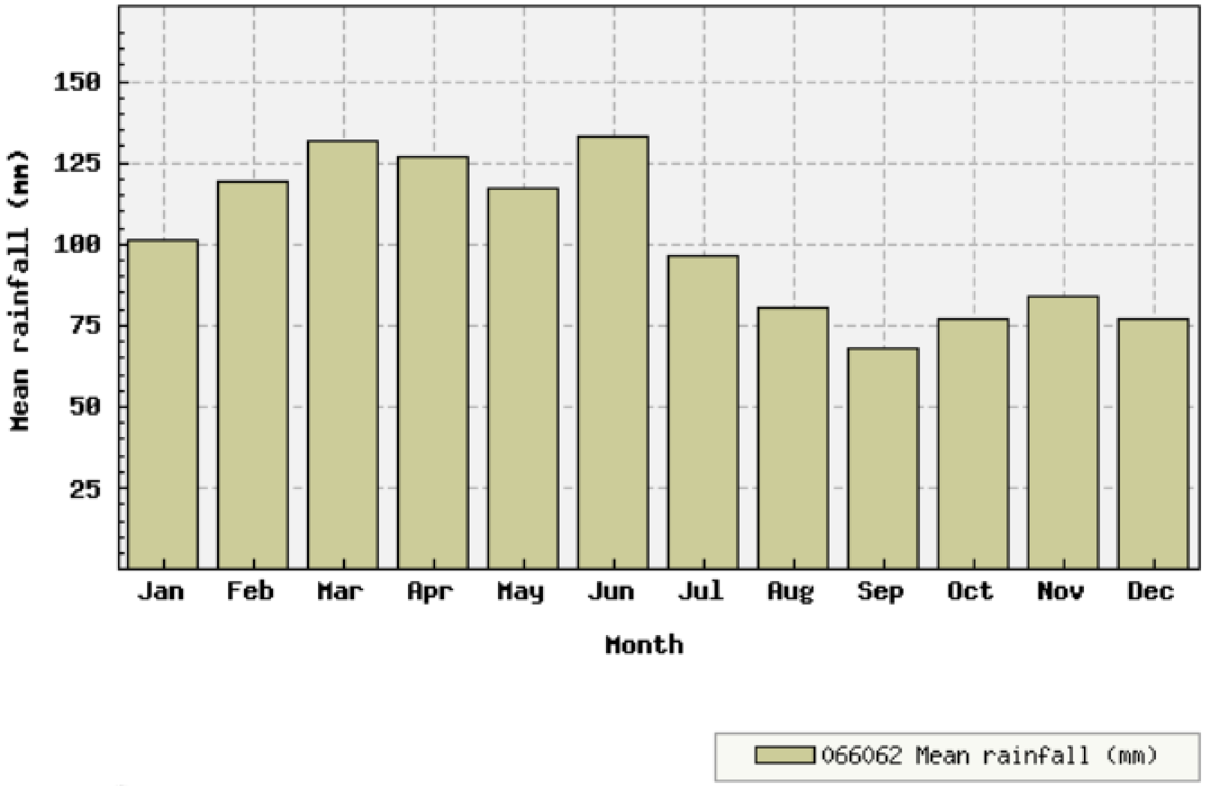

Figure 4-1 Observatory Hill Rainfall Station

4.3 Existing topography

The topography along the Proposal alignment between The Bays tunnel launch and support site and Pyrmont Station construction sites is primarily at sea level, increasing toward the Hunter Street Station (Sydney CBD) construction sites up to 22 metres AHD. The topography associated with these areas is further outlined in Table 4-1 and Table 4-2.

Table 4-1 Topography for the Proposal

Location	Topography
The Bays	Terrain disturbed by human activity. Local relief is usually less than 2 metres, but occasionally up to 10 metres. Most areas of disturbed ground have been levelled to slopes of less than 3 per cent. In terraced cut and fill areas, short rises may be steeper than 30 per cent. Microtopography may be hummocky due to truck dumping of fill material. Disturbed areas are often landscaped and artificially drained. Landform elements include berms, cut faces, embankments, mounds, pits and trenches.
Pyrmont to Sydney CBD	Undulating to rolling low hills with local relief (20–80 metres) and slopes of 10–25 per cent. Side slopes with narrow to wide outcropping sandstone rock benches (10 –100 metres), often forming broken scarps of less than 5 metres.

Table 4-2 Topography of the construction sites

Construction site	Topography
The Bays tunnel launch and support site	The Bays tunnel launch and support site is situated within The Bays Station construction site (Jacobs, 2020b) on a low-lying former dockland site. There is a section of lower land immediately to the west (the former White Bay PowerStation site) which forms part of a major overland flow path that drains an area stretching north-west towards Rozelle. The site is generally flat land with little to no slope around White Bay. It has an elevation typically around three to four metres AHD with some low-lying sections along White Bay (one metre AHD) and a small section of higher land associated with the Victoria Road embankment in the south-east of the site.
Pyrmont Station construction sites	The Pyrmont Station construction sites are situated in urban areas occupied by commercial properties. Generally slopes west to east, eventually draining to Pyrmont Bay. From inspection of LiDAR survey elevations on Pyrmont Bridge Road and Edward Street appear to be approximately 14 to 15 metres AHD whereas Union Street is approximately 10 metres AHD. Results from the TUFLOW modelling suggest flows from Pyrmont Bridge Road (on the western construction site) travel west through local roads.
Hunter Street Station (Sydney CBD)	The Hunter Street (Sydney CBD) Station construction sites are situated in urban areas, occupied by commercial properties and current construction activity, which fall towards Pitt Street from south to north and runs between the two sites. These disturbed areas are often landscaped and artificially drained. The landform elements present in the area include berms, cut faces, embankments, mounds, pits and trenches.

4.4 Soils and geology

The expected geology along the Proposal alignment generally comprises of Hawkesbury Sandstone bedrock. The Middle-Triassic Hawkesbury Sandstone was deposited in a fluvial paleo-environment, likely to have been a braided river setting, and as such it is highly stratified. It is ubiquitous across the Sydney Basin and can be up to 300 metres thick. Hawkesbury Sandstone is often described as medium to coarse grained and consists of three main depositional environments: massive sandstone facies, cross-bedded or sheet facies, and shale/siltstone interbedded facies.

The Soil Landscapes of Sydney 1:100,000 Sheet (Tille et al., 2009) and Penrith 1:100,000 Sheet (Hazelton et al., 2010) identifies the footprint of the Proposal within the Gymea and Disturbed Terrain soil landscapes, as shown in Figure 4-2 and described in Table 4-3.

Table 4-3 Soil units

Soil unit	Description
Disturbed terrain	The original soil has been completely disturbed, removed or buried. Fill may include soil, rock, building and waste material with a cap of sandy loam. Soil may by strongly acidic to strongly alkaline. The soil is typically of low fertility, low wet strength, low availability water capability, high permeability, localised toxicity/acidity and/or alkalinity, with a potential mass movement hazard.
Gymea	Shallow to moderately deep (30 centimetres to 100 centimetres) soils. Localised steep slopes, high soil erosion hazards, shallow highly permeable soil and very low soil fertility

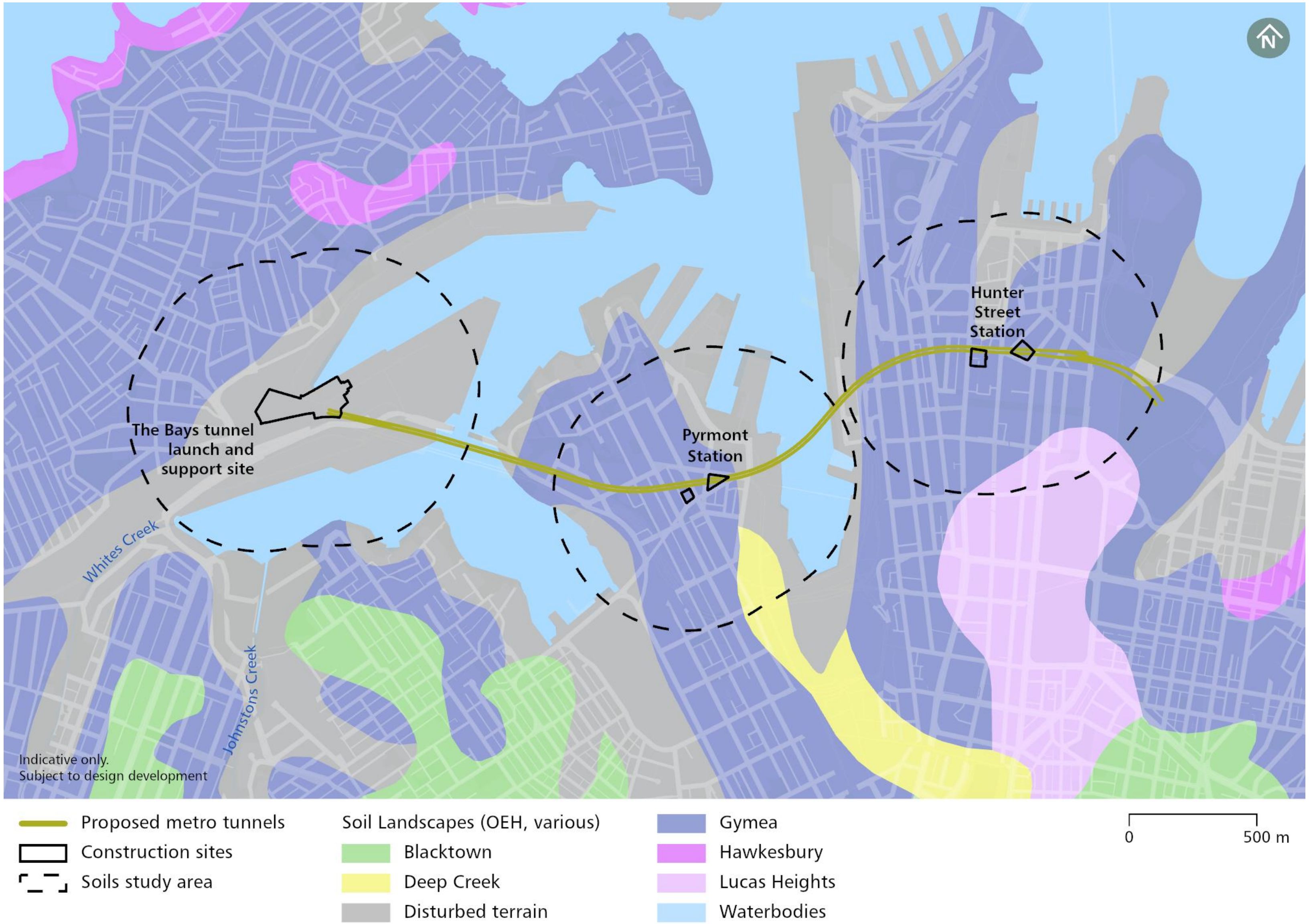

Figure 4-2 Soil landscapes

4.5 Acid sulfate soils and contaminated lands

Review of the Department of Planning, Industry and Environment (DPIE) acid sulfate soil (ASS) risk data indicates the following:

- The Bays tunnel launch and support site – entire proposal area is classified as disturbed terrain. Acid sulfate soil is likely to occur below natural ground surface.
- Pyrmont Station construction sites – land east of the proposed east entry is classified as disturbed terrain. Acid sulfate soils are likely to occur below natural ground surface in the north-east portion of the proposed Pyrmont Station eastern construction site.
- Hunter Street Station (Sydney CBD) construction sites – acid sulfate soils are not likely to occur within the construction area.

A number of known and potential contamination sources (areas of environmental interest - AEIs) or areas of specific geological conditions have been identified within and/or adjacent to the proposal (Mott Macdonald, 2020b). To understand the potential interaction of construction activities with potential contaminations, sites have been placed into five categories of potential impact (very low, low, moderate, high and very high). The findings of the assessment are detailed below:

- The Bays tunnel launch and support site - Soils, groundwater and vapour within / beneath the site have been assigned a moderate to high potential impact associated with the historical activities carried out on the site (power station and land reclamation) and reported contamination. AEI with a moderate to high potential impact include former White Bay Power Station, land reclamation (historical use of potentially contaminated fill), ASS and saline soils.
- Pyrmont Station construction sites - Groundwater beneath the Pyrmont Station construction sites have been assigned a moderate potential impact associated with general historical activities carried out in the surrounding area and surface and reported elevated concentrations of metals in groundwater from previous investigations. AEI with a moderate to high potential impact include general historical commercial and industrial use (including rail yards), ASS and saline soils.
- Hunter Street Station (Sydney CBD) construction sites - Groundwater beneath the Hunter Street Station (Sydney CBD) construction sites have been assigned a moderate to high potential impact associated with historical activities carried out in the surrounding area (gasworks and commercial land use) and known/potential contamination at these sites. AEI with a moderate to high potential impact include the former gasworks at Millers Point.

4.6 Salinity

Potential changes that could occur to the groundwater system due to the construction of the tunnel and station excavations may cause salinity impacts. Salinity impacts may include locally severe salt scalding across landscape elements, damage to buildings and infrastructure, fluvial and sheet erosion, high in-stream salinity, localised water-logging, flood hazard, and a potential decline in water quality.

The spatial information system, eSPADE, (2021) presents public soil and land information from the NSW Soil and Land Information System, as shown in Figure 4-3. The overall salinity hazard has been identified as ‘moderate’ for The Bays tunnel launch and support site, and waterfront areas in the vicinity of Pyrmont Station and Hunter Street Station (Sydney CBD) construction sites. The overall salinity hazard for the areas of Pyrmont Station and Hunter Street Station (Sydney CBD) construction site which are not immediately adjacent to the water are identified as ‘very low risk’. Refer to Technical Report 7 for the further detail on the salinity hazard for this Proposal.

The NSW Department of Primary Industries (Winkler et al, 2012) reports very high salinity hazard along the coastal fringe of Sydney Harbour. Whereas, very low salinity hazard is reported for Sydney CBD.

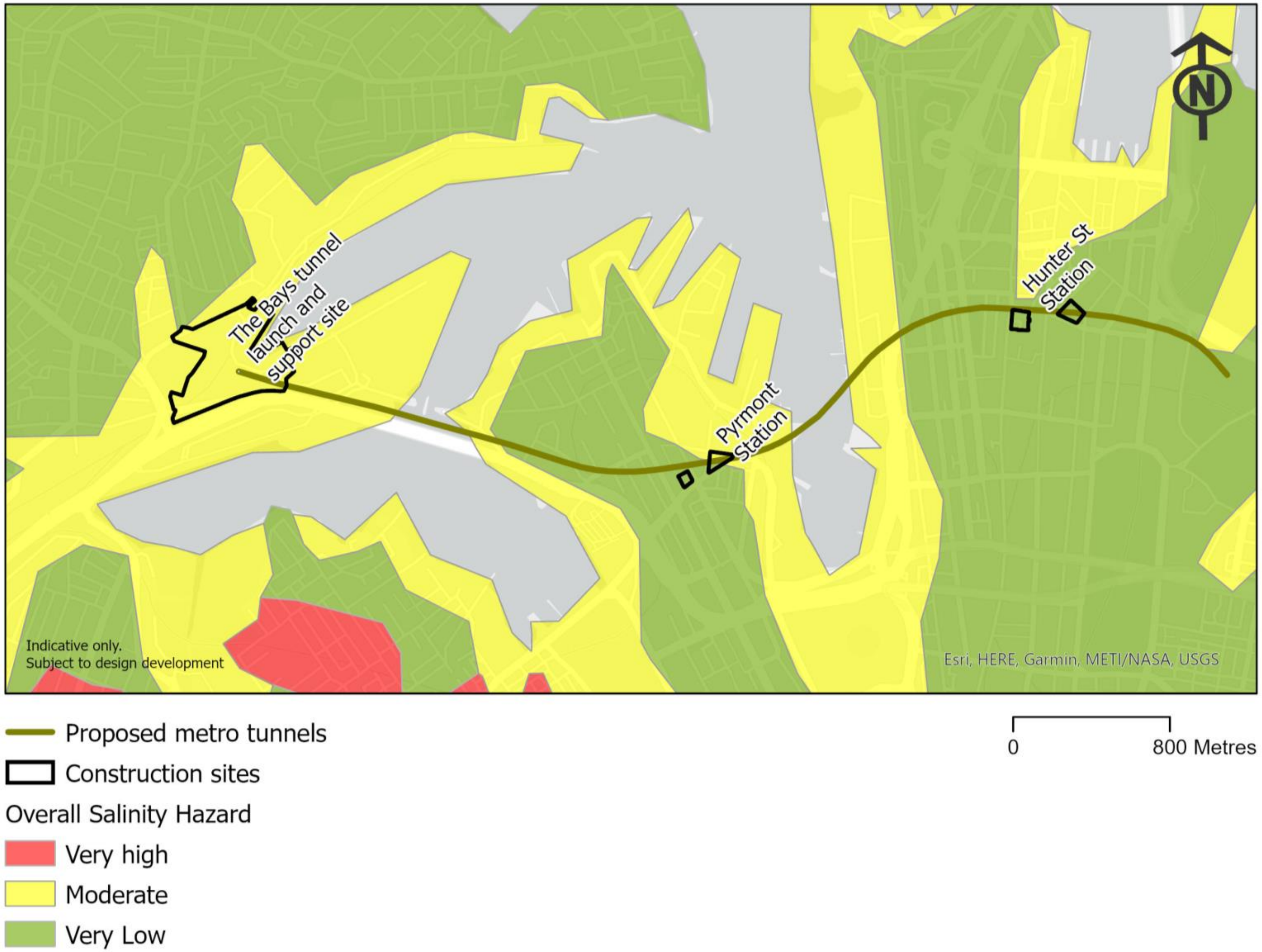

Figure 4-3 Salinity hazard

4.7 Groundwater interactions and groundwater quality

4.7.1 Groundwater

Groundwater is known to occur in the soil profile and within the fractured/porous rock along the alignment. Site investigations for Sydney Metro West included the installation of groundwater monitoring infrastructure at 65 locations (56 groundwater monitoring wells, and nine single vibrating-wire piezometers). Between The Bays Station and Hunter Street Station (Sydney CBD) construction sites, 14 groundwater monitoring wells, and two single vibrating-wire piezometers have been installed and the data collected has been used to assess current groundwater conditions (Golder, 2020).

The data indicated that there is generally hydraulic connection between the soil and rock aquifers. At some locations a perched water table may be present within the soils, due to a separation caused by the low vertical conductivity of the soil profile.

Groundwater levels of the monitoring points are generally shallow and tend to mimic topography where groundwater levels are higher on hills and shallower at creeks and bays. Table 4-4 presents typical groundwater levels in metres AHD in the vicinity of the alignment.

Groundwater flow is from areas of higher ground towards creeks or drainage lines and the harbour where it discharges. The groundwater system along the alignment is considered to be impacted by existing basements, tunnels and shafts. Recharge to the groundwater system is also considered highly modified due to the large number of impervious surfaces, leaking pipes and irrigation of gardens parks and ovals.

Table 4-4 Groundwater levels in the vicinity of construction sites

Construction site	Typical groundwater level in the vicinity of the construction site (mAHD)
The Bays tunnel launch and support sites	0.8 (SMW_BH066&067)
Pyrmont Station construction sites	-2.4 (SMW_BN052)
Hunter Street Station (Sydney CBD) construction sites	2.9 (SMW_ENV101) -5.5 (SMW_ENV100)

4.7.2 Surface water-groundwater interaction

Interaction between groundwater and surface water along the alignment is generally expected to be limited due to the widespread impervious surfaces across the catchment

Sections of the alignment are located adjacent to waterbodies, including at The Bays and Pyrmont, and the alignment passes under bays of Sydney Harbour in two locations (Johnston's Bay and Cockle Bay). The presence of these waterbodies can have an effect on the hydrogeological environment around and along the alignment.

Table 4-5 lists the waterbodies identified in proximity to construction sites associated with this Proposal which have the potential for groundwater interaction. However, where portions of these waterbodies are lined (e.g. White Bay), they are considered to have a limited connection with the groundwater system.

Table 4-5: Waterbodies within proximity to this Proposal construction sites

Construction Site	Watercourse	Receiving Waters
The Bays Station	White Bay	Sydney Harbour
Pyrmont Station	Sydney Harbour (Pyrmont Bay, Blackwattle Bay and Cockle Bay)	Sydney Harbour
Hunter Street Station (Sydney CBD)	Sydney Harbour (Sydney Cove)	Sydney Harbour

4.7.3 Groundwater quality

The Golder-Douglas monitoring data (2021 and 2021a) for The Bays showed groundwater exceeding the ANZG (2018) trigger levels for 95 per cent protection of aquatic ecosystems at a number of groundwater wells. Ammonia and heavy metal parameters exceeded this protection level at 20 per cent of the samples tested. Concentrations exceeded the trigger levels for cobalt, manganese and zinc at the majority of the monitoring well locations.

Pyrmont station construction sites had one monitoring well within 500 metres which provided groundwater quality data. Concentrations exceeded the trigger levels for cobalt, iron and Manganese.

One monitoring well is located within the Hunter Street Station (Sydney CBD) construction site; however, no data had been collected at this location and therefore no analysis on the groundwater parameters can be carried out.

4.8 Surface water quality

4.8.1 NSW Water Quality Objectives

The Bays tunnel launch and support site drains to White Bay in the lower estuary of Sydney Harbour. The catchment for Pyrmont Station construction sites drain into Pyrmont Bay and Blackwattle Bay, and Hunter Street Station (Sydney CBD) construction sites drain into Sydney Cove.

The bays of Sydney Harbour represent a significant recreational, scenic and economic resource for the people of Sydney. The *NSW Water Quality and River Flow Objectives* provide a number of environmental objectives for Sydney Harbour:

- Aquatic ecosystems – Maintaining or improving the ecological condition of waterbodies and their riparian zones over the long term
- Visual amenity – Aesthetic qualities of waters
- Primary contact recreation – Maintaining or improving water quality for activities such as swimming in which there is a high probability of water being swallowed
- Secondary contact recreation – Maintaining or improving water quality for activities such as boating and wading, where there is a low probability of water being swallowed
- Aquatic foods (cooked) – Protecting water quality so that it is suitable for the production of aquatic foods for human consumption and aquaculture activities.

Table 4-6 shows the environmental objectives assigned to the watercourses relevant to this Proposal.

Table 4-6 Assigned environmental values for watercourses and receiving waters

Watercourse and/or receiving waters	Environmental Value				
	Aquatic ecosystems	Visual amenity	Primary contact recreation	Secondary contact recreation	Aquatic foods (cooked)
White Bay	●	●	●	●	
Blackwattle Bay, Cockle Bay and Pyrmont Bay and Sydney Cove	●	●	●	●	●

4.8.2 Sensitive receiving environments

Sydney Harbour is identified as a sensitive receiving environment due to the presence of numerous *State Environmental Planning Policy (Coastal Management) 2018* Coastal Wetlands, Type 1 (highly sensitive) Key Fish Habitat and potential habitat for threatened aquatic species and protected aquatic vegetation.

Although the entire Sydney Harbour catchment is mapped as Key Fish Habitat and classified as Type 1 Key Fish Habitat, the bays in the vicinity of this proposal are unlikely to contain significant aquatic habitat due to being heavily modified and are therefore not considered Key Fish Habitat in accordance with the *Policy and guidelines for fish habitat conservation and management – Update 2013* (NSW Department of Primary Industries, 2013). No threatened species listed under the *Fisheries Management Act 1994* have potential habitat within the relevant areas of Sydney Harbour.

Coastal wetlands, as defined by the Coastal Management SEPP, are greater than 500 metres away from all discharge-receiving bays.

4.8.3 Current water quality impacts

The water quality of Sydney Harbour is influenced by several factors including (Freewater et al, 2015):

- Current and historical land uses
- Wastewater overflows and leachate from contaminated and/or reclaimed land
- Urbanisation of the catchments and subsequent reduction in permeable area, increase in run-off
- Illegal dumping
- Contaminants entering the Sydney Harbour via stormwater including:
  - Sediments (e.g. soil erosion)

- Pathogens (e.g. bacteria from leaking septic tanks) and animal faeces
- Gross pollutants (e.g. litter)
- Toxicants (e.g. pesticides, accidental spills or deliberate dumping)
- Nutrients (e.g. wastewater overflows, fertilizers, detergents and animal faeces)
- Oils and lubricants from road and boat-based pollutants
- Organic matter (e.g. leaf litter)
- Anti-fouling paints, disposal or overflow of sewerage and galley wastes from boats.

4.8.4 Current water quality status

As part of *Sydney Metro West Environmental Impact Statement – Westmead to The Bays and Sydney CBD* (Sydney Metro, 2020), a review of available water quality data close to The Bays was undertaken and assessed against the ANZG (2018) water quality guidelines. White Bay was characterised by elevated nutrient and heavy metal concentrations and high turbidity.

A parliamentary briefing paper from 2015 assessed water quality at a number of Sydney Harbour sites, including Blackwattle Bay, against the ANZECC/ARMCANZ (2000) guidelines. Blackwattle Bay was identified as having elevated levels of the following parameters:

- Total nitrogen
- Total phosphorus
- Chlorophyll-a
- Enterococci.

The *Water Quality Improvement Plan for Sydney Harbour Catchment* (2015) summarised that:

- Over 50 per cent of sediments exceed the Interim Sediment Guideline – high concentrations for lead
- 100 per cent of sediments exceed trigger values
- The highest levels of contamination are found in the upper reaches of harbour embayments.

Hedge *et al*. (2014) determined that sediments over the majority of the harbour exceeded the trigger concentrations.

Pinto *et al.* (2015) reviewed a total of 200 studies on Sydney Harbour and found the waterbody to suffer from metal concentrations in sediments and seaweeds amongst the highest recorded worldwide, along with high organic contamination.

As all four bays referred to earlier in section 4.8.1, lie within two kilometres of each other and are inherently interconnected, water quality is likely to be reasonably consistent between the bays, allowing the limited available data (including exceedances of Water Quality Objectives parameters) sufficient to conclude that the receiving waters are generally in a poor condition.

4.9 Existing drainage network and flooding conditions

The existing drainage across each construction site are described in Table 4-7 below.

Table 4-7 Drainage in the vicinity of construction sites

Construction site	Drainage
The Bays tunnel launch and support site	There is limited existing drainage on the site, being limited to small drainage lines to service the current Port Access Road. The area around the former White Bay Power Station site acts as a trapped low point with little fall or existing drainage to drain the area. The largest drainage infrastructure is a large culvert that runs parallel to Robert Street and discharges to White Bay north of the site.
Pyrmont Station construction sites	Existing drainage arrangements have been identified with trunk drainage channel/culverts visible to the north of the Pyrmont Station eastern construction site, which are presumed to run under Edward Street. There appears to be a local minor drainage pipe which runs under the same construction site and across the intersection of Union Street and Edward Street to connect into the trunk line.
Hunter Street Station (Sydney CBD) construction sites	Existing drainage arrangements have been identified within the sites and surrounds. Both Hunter Street Station (Sydney CBD) construction sites have underground drainage networks in the adjacent road reserve generally following existing kerb lines and eventually connecting into Pitt Street where flows eventually discharge to Sydney Cove. The Hunter Street Station (Sydney CBD) eastern construction site also has local stormwater drainage (0.375 metres diameter) which could pick up additional construction site runoff if required.

4.10 Existing flood conditions

4.10.1 Previous reports

A number of flood studies and floodplain management studies have been carried out across the catchment which define design flood behaviour and provide sustainable flood management strategies to support social and economic development within the catchment. These are listed in Table 3-2 and are considered sufficient for this assessment as these studies encompassed the areas of interest, were recent and had been used by the relevant council as the basis for their floodplain management plans.

These existing studies are substantially based on methods and data associated with ARR1987. As outlined in section 2.4, there are a range of improvements incorporated into ARR2019 which support a view that generally these methods should be applied in the assessments required for this Proposal.

4.10.2 Modelling

The existing environment flood conditions at and surrounding each construction site are described in this section. The assessment focusses on the 1% AEP flood event and PMF, as these events are the key events for flood planning and flood protection aspects.

There are four potential causes of flooding which are summarised below:

- **Intense rainfall**: Local flooding may be caused by intense rainfall falling directly onto sites or adjacent to sites during storm events, which are not adequately managed by the provided drainage systems. This may cause nuisance flooding and disruption due to localised ponding of water and runoff within sites. This type of issue is broadly referred to as “drainage issues” in this assessment

- **Overland flooding:** Occurs when local catchment runoff exceeds the capacity of existing drainage systems, with excess flows being conveyed on surface flow paths and ponding in low points. Development which is present in or adjacent to these flow paths and low points may be impacted by floodwaters. In this assessment, overland flooding has been broadly characterised as being “minor” in nature (expected shallow depths and/or relatively low velocity) or “major” (high depths and/or high velocity, typically in main flow paths and which may be classified as high hazard). Overland flooding is typically caused by short duration, intense rainfall resulting in rapid rise in flood flows with little or no warning time
- **Mainstream flooding:** Occurs due to floodwaters in rivers, creeks and canals rising out of these watercourses and inundating the broader floodplain above bank level. Mainstream flooding may be caused by prolonged heavy rainfall, providing some warning time for rising floodwaters particularly in large catchments. Although of short duration, intense rainfall storms over tributary catchments may result in flash flooding in some of the tributary channels.
- **Coastal inundation:** Generally, results from elevated ocean levels caused by storm surge due to low pressure weather systems and/or highest astronomical tides (i.e. “king tides”). These two mechanisms are independent of each other but may coincide and reinforce each other during a coastal inundation event.

Table 4-8 indicates the causes of flooding that can be expected at the construction sites within this Proposal.

Table 4-8 Existing flooding conditions at proposed construction sites

Construction site	Cause of flooding			
	Coastal Inundation	Intense Rainfall	Mainstream flooding	Overland flooding
The Bays tunnel launch and support site	Yes	Yes	N/A	Yes (major)
Pyrmont Station	N/A	Yes	N/A	Yes (minor)
Hunter Street Station (Sydney CBD)	N/A	Yes	N/A	Yes (minor to major)

4.10.3 The Bays tunnel launch and support site

The Bays tunnel launch and support site is bounded by White Bay to its north-east, Robert Street to the north, the White Bay Power Station site to the west and the Anzac Bridge Access Road to the south. Surrounding land use includes commercial properties on the northern side of Robert Street and docklands on the north eastern side of the construction site. Measures which prevent overland flow from entering the station box will have been implemented in Stage 1 of this planning process. The Bays tunnel launch and support site has the potential to be impacted by coastal inundation.

There is a major overland flow path to the existing box culvert under Robert and Mullens Street intersection. Upstream and downstream flood levels are controlled by the existing culvert in Robert Street which ultimately discharges to the port. It appears that the existing culvert does not have sufficient capacity to convey the peak flows for the 1% AEP event. As White Bay Power Station, situated downstream of the culvert headwall, is approximately 1.5 metres lower than the construction site, significant ponding occurs in the vicinity of the construction site.

Based on the modelling undertaken, The Bays tunnel launch and support site would be partially impacted during the 1% AEP flood event and mostly affected during the PMF as a result of significant overland flood flows originating from the gully extending up into Rozelle, Beattie Street Stormwater Channel No 15. There is also a local catchment within the site to the south of the proposed construction area which discharges toward the construction site which is not part of this stormwater drainage scheme.

Flood depths of up to 0.4 metres would occur in the 1% AEP event in the western side of the construction site, adjoining the former White Bay Power Station. Depths of up to 0.5 metres would occur at the site vehicle entry point off Robert Street at the northern corner of the construction site, while depths of up to 1.4 metres would occur at the centre of the construction site, on the southern side of the station box. Peak 1% AEP flood levels are about 3.2 metres AHD at the western extent of the station box and 4.4 metres AHD on the southern side of the station box.

In the PMF event, flood depths of up to one metre would occur in the western areas of the construction site, adjoining the former White Bay Power Station site. Depths of up to 1.2 metres would occur at the proposed site vehicle entry point off Robert Street at the northern corner of the site, while depths of up to 1.6 metres would occur on the southern side of the station box. Depths of 1.0 to 1.3 metres would occur in the eastern areas of the construction site. Peak PMF levels vary from about 4.2 to 4.7 metres AHD across the site.

Preliminary flood depth mapping and flood hazard mapping is presented in Appendix B. Definitions for the hazard categories are outlined in section 2.4.2. At the southern side of the station box, the ponded flood depth of up to 1.6 metres results in a H4 hazard category (unsafe for people and vehicles). The remaining portion of the construction site is generally low hazard in the 1% AEP event, which is safe for vehicles, people and buildings. There are localised areas of H3 hazard category (unsafe for vehicles, children and the elderly) within existing drainage channels and ponded areas. In the PMF event, there are significant areas of H3 and H4 at the west and south of the construction site, primarily as a result of a combination of ponded flood depth.

Buildings and property which are adjacent to The Bays Station construction site are subject to flooding in both the 1% AEP and PMF scenarios with a range of hazard categories.

4.10.4 Pyrmont Station construction sites

The Pyrmont Station construction sites are both situated north of Pyrmont Bridge Road, one north of Paternoster Row and south of Pyrmont Street (Pyrmont Station western construction site) and the other south of Union Street and east of Edward Street (Pyrmont Station eastern construction site). The surrounding land use mainly consists of commercial properties.

Flood depths and levels at the construction sites are outlined below for each Pyrmont Station construction site. It is noted that existing building footprints have been included and represent areas of the model which do not contribute to the flood storage volume.

- **Pyrmont Station western construction site:** Flood depths up to 0.1 metres would occur in the 1% AEP on Pyrmont Bridge Road, this appears to be the worst-case flooding, with the other streets experiencing maximum depths of 0.09 metres. Similarly, in the PMF event flood depths up to 0.12 metres would occur on Pyrmont Bridge Road, whilst the remainder of the surrounding roads would be inundated by less than 0.1 metres. The above flood depths are attributed to a critical duration of 90mins for both the 1% AEP & PMF. The construction site would generally experience inundation with shallow flood depths in both events. The Pyrmont Station western construction site would also be affected by the PMF event with a shallow depth of water against the existing buildings.

  Flood levels around the site would vary from 14.5mAHD to 15.5mAHD owing to the terrain. The difference between the peak 1% AEP and peak PMF flood scenarios is the extent of the surrounding roads which would be flooded, with the PMF covering the full road width around this site. Flooding within the site would be more extensive in the PMF when compared to the 1% AEP event.

- **Pyrmont Station eastern construction site:** Flood depths up to 0.3 metres would occur in the 1% AEP event on the northern side of the construction site on Union Street. Depths of up to 0.06 metres would occur along Pyrmont Bridge Road, while depths of up to 0.03 metres would occur on Edward Street. Flood depths outside Union Street are considered relatively minor. In the PMF event, maximum flood depths of 0.4 metres would occur on Union Street. This appears to be the worst-case flooding for the PMF, with the other streets would experience shallower inundation of up to 0.08 metres. The critical duration for the eastern site is also 90mins however there would be pockets of deeper flood depths around the site perimeter due to sag points along Union Street causing water to pond.

  The construction site would be partially impacted during the 1% AEP flood event and mostly affected during the PMF as a result of significant overland flood flows originating from Pyrmont Bridge Road.

  Flood levels through and around the site would vary from 8mAHD to 15mAHD owing to the terrain. The difference between the peak 1% AEP and peak PMF flood scenarios is the extent of the surrounding roads which would be flooded, with the PMF covering the full road width around this site.

Preliminary flood depth mapping and flood hazard mapping is presented in Appendix B. The flood hazard is generally within the H1 category (generally safe for vehicles, people and buildings) across the sites in the 1% AEP event. In the PMF event, there are localised areas of H5[3] category hazard (at the north eastern areas of Pyrmont Station eastern construction site). This appears to be caused by the blocking off of an existing overland flow path from Pyrmont Bridge Road to Edward Street which subsequently causes the water to be redirected to Union Street from Pyrmont Bridge Road.

Some buildings and properties adjacent to both construction sites are subject to flooding in both the 1% AEP and PMF scenarios with low hazard categories.

4.10.5 Hunter Street Station (Sydney CBD) construction sites

There are two Hunter Street Station (Sydney CBD) construction sites which are situated in the following locations:

- **Hunter Street Station (Sydney CBD) western construction site**: Hunter Street to the north, Pitt Street to the east and George Street to the west

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[3] Unsafe for vehicles and people. All building types vulnerable to structural damage. Some less robust building types vulnerable to failure.

- **Hunter Street Station (Sydney CBD) eastern construction site**: Situated on the corner of O'Connell and Hunter Street and Bligh Street to the south.

As these sites are located within the CBD the majority of the surrounding land use consists of commercial properties.

Flood depths and levels at the construction sites are outlined below for each Hunter Street Station (Sydney CBD) construction site. It is noted that existing building footprints have been included and represent areas of the model which do not contribute to the flood storage volume.

- **Hunter Street Station (Sydney CBD) western construction site**: Flood depths up to 0.6 metres would occur in the 1% AEP at the north eastern portion of the site between the northern site boundary and Hunter Street. Outside of the northern boundary, there would be flood depths up to 0.25 metres between the western boundary and George Street. A similar trend is seen in the PMF, with the worst-case flooding occurring at 90mins at the northern boundary with depths up to 1 metre. The western boundary would be inundated up to 0.4 metres in the PMF. The above flood depths are attributed to a critical duration of 90mins for both the 1% AEP & PMF.

  This construction site would be impacted during flood events with depth of water against existing building increasing with the rarity of the event particularly in close proximity to Hamilton Street.

  Flood levels through and around the site would vary from 11mAHD to 14mAHD owing to the terrain. The difference between the peak 1% AEP and peak PMF flood scenarios is the extent of the surrounding roads which would be flooded, with the PMF covering the full road width around this site, and the depth of inundation.

- **Hunter Street Station (Sydney CBD) eastern construction site**: Flood depths up to 0.25 metres would occur in the 1% AEP between the southern boundary and Bligh Street, elsewhere Hunter Street would be inundated up to 0.24 metres and O'Connell Street with less than 0.1 metres. In the PMF both Hunter Street and the southern portion of the site would receive flood depths up to 0.3 metres. Flood depths up to 0.15 metres would occur on O'Connell Street. The critical duration for the eastern site is also 90mins, however the site has lower flood depths around the site perimeter due to adjacent roads being higher than those around the western construction site.

  This construction site would be impacted during flood events with depth of water against existing building increasing with the rarity of the event particularly with proximity to Pitt Street.

  Flood levels through and around the site would vary from 11.5mAHD to 19mAHD owing to the terrain. The difference between the peak 1% AEP and peak PMF flood scenarios is the extent of the surrounding roads which would be flooded, with the PMF covering the full road width around this site, and the depth of inundation.

Preliminary flood depth mapping and flood hazard mapping is presented in Appendix B. The flood hazard for the sites is outlined below:

- **Hunter Street Station (Sydney CBD) western construction site:** In the 1% AEP event the northern portion of the site along Hunter Street is predominantly showing H5 & H6 hazard along with a short section of George Street. The remainder of the site surrounds appear to be within the low H1 hazard category (generally safe for vehicles, people and buildings). As expected, the PMF is generally showing higher hazard categories of H5 & H6 with pockets of low hazard H1

- **Hunter Street Station (Sydney CBD) eastern construction sites**: In both the 1% AEP event and PMF Hunter Street appears to be within high hazard categories H5 & H6 whereas O'Connell and Bligh Street are both within the H1 hazard category.

Some buildings and properties adjacent to both construction sites are subject to inundation from flooding in both the 1% AEP and PMF scenarios with varying hazard categories. Pitt and Hunter Street experience high hazard flooding with the extent of high hazard flooding increasing considerably for the PMF event.

5 Assessment of construction impacts

5.1 Hydrology and flooding

This section describes the hydrology and flooding impact of the proposal on the surrounding environment within the study area in the context of Secretary's Environmental Assessment Requirements outlined in Table 1-1 and particularly in relation to the elements of water – hydrology and flooding.

5.1.1 Surface water hydrology

Stormwater and wastewater drainage into Sydney Harbour is not anticipated to result in any significant hydrological impacts due to the existing high capacity of Sydney Harbour. As the catchments of the construction sites are highly urbanised and developed with widespread impervious surfaces, the amount of impervious area would not be significantly increased by construction of the proposal. Wastewater would be treated and reused where practicable. As a result, changes to the conveyance capacity of existing stormwater systems would be minimised.

5.1.2 Flooding

Physical features associated with this proposal may temporarily impact on flooding behaviour during construction due to the features obstructing and redirecting overland flood flows, resulting in increases in flood depths and flow velocities.

Key features of this Proposal that may have an impact on flooding include:

- Temporary flood protection measures (e.g. retaining walls) around the excavations (e.g. shafts)
- Permanent flood protection measures (e.g. retaining walls) around the dive structure, including fill embankment formations and modifications to current site grading
- Temporary noise barriers, acoustic sheds (proposed at some sites), site hoardings
- Temporary material stockpiles
- Temporary and permanent drainage and flow diversion works
- Paving of currently pervious areas, resulting in increased runoff volumes during flood events
- Formalised drainage speeding up runoff rates for local site drainage which may increase peak flows downstream.

The majority of construction sites have existing building coverage which influence flood behaviour. However, changes to flooding behaviour around the construction sites will occur with the removal of these buildings. The alteration of the built form or the provision of new structures surrounding the entire site (e.g. hoardings) could change existing flow paths through the construction site.

The modelling outlined in this section indicates that the overall risk of flooding impacts from this proposal is considered low and the magnitude of impacts negligible. Whilst Hunter Street Station (Sydney CBD) and The Bays construction sites and to a lesser extent Pyrmont Station construction sites are affected by major overland flow paths, the proposed changes to those sites do not significantly alter flooding impacts on neighbouring sites.

Flooding may also cause impacts on the construction sites themselves. The risks and impacts of flooding to the construction sites may range from minor, such as nuisance drainage problems, to more severe, including damage to the sites and construction facilities, ingress of significant volumes of floodwater into excavated voids and the tunnels underground, or construction materials and spoil being washed into nearby drainage lines and waterways. This will require further consideration as the proposal progresses particularly at the Pyrmont Station and Hunter Street Station (Sydney CBD) construction sites where higher hazard categories are expected in adjacent streets. The proposal locates The Bays Station tunnel launch and support site in the lower portion of the catchment of Beattie Street Stormwater Channel No 15. Consequently, it is affected by a major flood flow path. These risks are considered manageable as surface works associated with this Proposal will only require a portion of The Bays Station construction site.

Where required, flood protection levels (estimated from the interpretation of available flood study information) that are consistent with design criteria are identified in Table 3-2. The risks of flooding on the construction sites and the potential impacts at each site to adjacent properties are summarised in Table 5-1. A comparison of the existing flooding conditions in the vicinity of the proposal construction sites and the potential flood impacts of the proposal is shown in Appendix B and Appendix C.

Table 5-1 Potential Construction Impacts on Flooding

Construction site	Proposed works with potential to cause impacts	Discussion
The Bays tunnel launch and support site	Acoustic sheds covering parts of the excavated void (or other acoustic measures) Temporary material stockpiles	Surface works associated with this Proposal are limited to the temporary support activities necessary for the tunnelling works. As indicated in section 4.10.3, overland flow in excess of the capacity of existing drainage passes through the site. Activities within the site have the potential to impact local overland flooding with a loss of flood plain storage and blocking of the flow path. Detailed construction planning recommended in the mitigation measures of Table 6 2 will be required to address local flood risks within the site whilst works are being undertaken. As these works are limited in scale it is expected that they would not impact on flooding beyond the site. Construction planning will be used to ensure this is the case. Consequently, the Proposal is not expected to increase flood levels or hazard associated with neighbouring buildings and properties. An existing internal road within the construction site is currently being constructed under a separate planning approval. Final road levels may influence flooding at the site if they are considerably different to what has been modelled to date.

Construction site	Proposed works with potential to cause impacts	Discussion
		Overland flows during the 1% AEP or greater flood event may present a risk to the construction site and facilities which would be managed through detailed construction planning and the integration of flood mitigation measures into the Stage 1 construction works. Floodwater ingress into the station excavation could occur due to overland flooding or coastal inundation. Direct intense rainfall onto site may cause nuisance flooding and drainage issues. The flood protection level and feasible and reasonable protection based on the flood risks would be reviewed during detailed construction planning. The flood protection level varies across the site and is required to be the greater of the PMF level and of the 1% AEP flood level plus 0.5 metres freeboard, and ranges from 4.2 to 4.7 metres AHD. Consideration of the protection level would also be required to account for coastal inundation (estimated at a minimum level of around 2.11 metres AHD which includes allowances for wind and wave effects). These results are not inconsistent with the Inner West Council's Leichhardt Floodplain Risk Management Plan (the plan), noting the different hazard categories that have been mapped. The hazard mapping is compatible with the proposed usage of the site (i.e. low). The plan recommends an option for upgrade works proposing a new pipe network or duplication of existing pipe network parallel to Robert Street and eventually draining into White Bay, although these works are not ranked particularly high in the multicriteria analysis. Should these works proceed at the same time there is the potential for conflict.
Pyrmont Station construction sites	Shaft excavation and associated flood protection measures Potential modifications to current site grading and filling of the site Acoustic sheds covering the excavated void (or other acoustic measures)	As indicated in section 4.10.4, the Pyrmont Station eastern construction site is partially affected by overland flooding in the 1% AEP and PMF events and the Pyrmont Station western construction site is also affected by the PMF event with a shallow depth of water against the existing buildings. Therefore, flood protection measures would be required to prevent overland flow entering the shafts. Appendix C contains the preliminary flood depth mapping and flood hazard mapping representing this scenario. The relative difference in flood storage volume in the vicinity of the Proposal between the existing and proposed scenarios is negligeable. Consequently,

Construction site	Proposed works with potential to cause impacts	Discussion
	Temporary material stockpiles Site/noise hoardings around site boundary Power supply arrangements	the Proposal is not expected to increase flood levels, duration of inundation or flood hazard associated with neighbouring buildings and properties. Floodwater ingress into the excavation shafts could occur due to overland flooding. Direct intense rainfall onto site may cause nuisance flooding and drainage issues. The flood protection level and the implementation of feasible and reasonable protection measures based on the flood risks would be reviewed during detailed construction planning. The flood protection level varies across the site and is required to be the greater of the PMF level and of the 1% AEP flood level plus 0.5 metres freeboard relative to the water level (flood depth plus ground level). The estimated flood protection level for the two sites are as follows: • Pyrmont Station eastern construction site: 15.5m AHD • Pyrmont Station western construction site: 16m AHD at the station entrance. These results are not inconsistent with the City of Sydney Council's Darling Harbour Catchment Floodplain Risk Management Study (the plan), noting the different hazard categories that have been mapped and the resolution of the mapping. The hazard mapping is compatible with the proposed usage of the site (i.e. low) however as mentioned earlier in section 5.1 higher hazard categories are expected in adjacent streets. There are no high or medium priority options recommended in the plan which would result in works near either construction site. An underground power supply route is proposed from a substation located in Harris Street to this construction site. It is anticipated this will be located within the road reserve. Installation is expected to be via open trench except where traversing major infrastructure or constraints which would necessitate the use of trenchless boring methods. The scale of these particular works is such that they would not have an adverse impact on rare or extreme flooding. Local impacts associated with frequent events would

Construction site	Proposed works with potential to cause impacts	Discussion
		be addressed through mitigation measures indicated in Table 6-2.
Hunter Street Station (Sydney CBD) construction sites	Shaft excavation and associated flood protection measures Potential modifications to current site grading and filling of the site Acoustic shed partially covering excavated void at Hunter Street Station eastern construction site (or other acoustic measures) Temporary material stockpiles Site/noise hoardings around site boundary Power supply arrangements	As indicated in section 4.10.5, the Hunter Street Station (Sydney CBD) construction sites are at risk of being affected by flood inundation. Therefore, flood protection measures would be required to prevent overland flow entering the shafts. Appendix C contains the preliminary flood depth mapping and flood hazard mapping representing this scenario. The relative difference in flood storage volume in the vicinity of the Proposal between the existing and proposed scenarios is negligeable. Consequently, the Proposal is not expected to increase flood levels, duration of inundation or flood hazard associated with neighbouring buildings and properties. Floodwater ingress into the excavation shafts could occur due to overland flooding. Direct intense rainfall onto site may cause nuisance flooding and drainage issues. The flood protection level and the implementation of feasible and reasonable protection measures based on the flood risks would be reviewed during detailed construction planning. The flood protection level varies across the site and is required to be the greater of the PMF level and of the 1% AEP flood level plus 0.5 metres freeboard relative to the water level (flood depth plus ground level). The estimated flood protection levels for the two sites are as follows: • Hunter Street Station (Sydney CBD) eastern construction site: 13.5m AHD at the station entrance • Hunter Street Station (Sydney CBD) western construction site: 14.5m AHD These results are not inconsistent with the City of Sydney Council's City Area Catchment Floodplain Risk Management Plan (the plan), noting the different hazard categories that have been mapped. The hazard mapping is compatible with the proposed usage of the site with mitigation measures (i.e. low). However as noted in section 5.1, Hunter Street itself is of high hazard during a PMF and also mapped as a floodway, and sections of Hunter Street are high

Construction site	Proposed works with potential to cause impacts	Discussion
		hazard during the 1% AEP. There are no high or medium priority options recommended in the plan which would result in works near the sites. The power supply arrangements are proposed to be provided through the existing Sydney Metro City & Southwest power supply arrangements. Therefore, it is expected that limited works in close proximity to the Hunter Street Station (Sydney CBD) construction sites is the extent of works that would be required to access this supply. The scale of these particular works is such that they would not have an adverse impact on rare or extreme flooding. Local impacts associated with frequent events would be addressed through mitigation measures indicated in Table 6-2.

5.1.3 Climate change adaption

The assessment of this proposal has highlighted the major civil construction work impacts between The Bays and Sydney CBD, the climate change impacts of the proposal would potentially be realised at a time when the Sydney Metro West project is operational. Climate change is anticipated to have potential direct and indirect impacts on the Sydney Metro West project. It is anticipated that impacts due to sea level rise at the Hunter Street Station (Sydney CBD) and Pyrmont Station construction sites would be very limited due to their distance from nearby bays. At The Bays tunnel launch and support site the majority of potential impacts due to sea level rise are expected to be addressed as part of the approved Concept and major civil construction work for Sydney Metro West between Westmead and The Bays. The adoption of additional climate change allowances would be considered during detailed design, including alternative or additional flood control measures

The Construction Environmental Management Framework includes a requirement for the development and implementation of Stormwater and Flooding Management Plans for the proposal's construction sites. These plans would identify the appropriate design standard for flood mitigation based on the duration of construction, proposed activities and flood risks. The identification of flood risks and consequently a suitable and appropriate mitigation strategy requires assessment which is likely to be impacted by climate change in the following aspects:

- Rainfall Intensity Frequency Duration (IFD) relationships
- Rainfall temporal patterns
- Continuous rainfall sequences
- Antecedent conditions
- Compounded extremes of sea level rise and increased rainfall intensity.

Consequently, the Stormwater and Flooding Management Plans would incorporate the impact of climate change which for a construction timeframe of approximately 10 years, which would be to the year 2030. Relevant best practice guidelines outlined in section 2.4 would be the basis of this assessment including an appropriate rainfall intensity uplift which would be incorporated into the appropriate design standard for flood mitigation.

5.2 Surface water quality

5.2.1 Release of pollutants

The construction of the Proposal has the potential to further degrade the water quality of Sydney Harbour and the bays due to the release of pollutants. The following pollutants could be released directly or conveyed by stormwater flow or, in some cases, wind:

- Sediment from soil excavation, movement and storage and stormwater runoff through disturbed sites
- Chemicals, fuels and hydrocarbons from use, refuelling and maintenance of equipment and construction machinery
- Concrete slurry and wastewater – from mobile concrete batching plants
- Contaminants related to previous land uses or acid sulfate soils mobilised during civil works
- Gross pollutants such as paper and plastic packaging and materials from material use on construction sites and general construction staff litter.

Without appropriate mitigation measures the construction works could further degrade the water quality of Sydney Harbour, hinder long term achievement of the *NSW Water Quality and River Flow Objectives*, and impact marine ecology. The likelihood and magnitude of risks would vary depending on the stage of construction, the area of disturbance and occurrence of high rainfall or wind weather events. In accordance with the Sydney Metro CEMF, soil and water mitigation and management measures, including progressive erosion and sediment control would be implemented at all construction sites, which would limit the impact of the construction works on water quality.

The mitigation measures in section 6 would be implemented to manage potential impacts to water quality which would be low and temporary, with no long term impacts expected. A summary of potential impacts to surface water quality from surface work is provided in Table 5-2. Surface construction work would generally be carried out in highly modified and urban environments and would not be located within or near waterways.

Table 5-2 Potential construction impacts on water quality

Construction works	Potential impacts
Demolition works	The removal of existing buildings and structures would be required for the proposal. Demolition work has the potential to disturb and/or spread sources of pollutants that could affect water quality. Demolition could also generate dust and airborne pollutants. These pollutants once mobilised could potentially enter stormwater runoff and be distributed to downstream receiving watercourses via the drainage network.
Earthworks and stockpiling	Exposure of soils during earthworks (including stripping of topsoil, excavation, removal of existing paved areas, stockpiling and transport of materials), could result in temporary soil erosion and off-site movement of sediments by wind and/or stormwater into receiving waterbodies. If sediments enter waterbodies, they could directly and indirectly impact on the aquatic environment by increasing turbidity, reducing dissolved oxygen levels, and increasing the concentration of nutrients and heavy metals, which are bound to sediments.

Construction works	Potential impacts
Construction of power supply routes	The construction of power supply routes would be carried out for Pyrmont Station construction sites. Routes would be constructed using open trenching and underboring methods and has the potential to increase the risk of temporary erosion and sedimentation, particularly in areas near watercourses.
Discharges from construction water treatment plants	Discharge of large volumes of treated wastewater at all proposal construction sites via the local stormwater network has the potential to increase soil erosion through scour and increase the turbidity of downstream watercourses.
Removal of vegetation	The removal of vegetation has the potential to increase the risk of erosion and sedimentation. As described in Chapter 18 (Biodiversity) of the Environmental Impact Statement, limited vegetation would be cleared as part of the proposal.
Accidental spills	Accidental spills or leaks could occur from the maintenance or re-fuelling of construction plant and equipment machinery at construction sites, or from vehicle/truck incidents travelling to and from construction sites. Contaminants could potentially be transported downstream to receiving waters via drainage infrastructure.
Disturbance of contaminated land	Potential disturbance of contaminated soils, groundwater, or acid sulfate soils during construction of the proposal could result in the mobilisation of contamination or acid sulfate soils by stormwater runoff and subsequent transportation to downstream watercourses, potentially increasing contaminant concentrations in the receiving environment. There are isolated areas of potential acid sulfate soils which could potentially affect surrounding watercourses if not managed appropriately (refer to Chapter 15 (Soils and surface water quality) of the Environmental Impact Statement)).
Concrete activities	Concreting activities during the proposal could result in the discharge of concrete dust, concrete slurries or washout water to downstream waterways. This could potentially increase the alkalinity and pH of downstream waterways which can be harmful to aquatic life. Concrete solids contained in the discharge also have the potential to clog stormwater pipes and cause flooding.

5.2.2 Water treatment plant discharges

During the construction of the Proposal, works would result in wastewater being generated from the following sources:

- Water used in the tunnel boring machine process
- Groundwater ingress
- Rainfall runoff into tunnel portals and excavations
- Machinery wash down runoff.

Water volumes generated during the construction of this Proposal would vary based on construction works both above and below the ground surface, the amount of groundwater infiltrating into the tunnels and the length of tunnels that have been excavated. Groundwater ingress is expected to be the main contributor to wastewater volumes. The re-use of wastewater would be maximised during construction works (e.g. dust suppression and tunnelling activities) and any surplus wastewater would be discharged to the local stormwater system. Estimated volumes of construction wastewater are included in Table 5-3.

Temporary water treatment plants would be constructed at each construction site as described in Table 5-3 to treat the wastewater generated. Wastewater treatment plants would be configured so that treated water does not negatively impact the water quality of the receiving waterbody, as further described in section 5.2.3.

Table 5-3 Construction wastewater treatment plants

Wastewater treatment plant location	Indicative capacity (litres per second)	Discharge location	Receiving waterbody
The Bays tunnel launch and support site	30	Local stormwater infrastructure	White Bay
Pyrmont Station construction sites	30	Local stormwater infrastructure	Blackwattle Bay, Cockle Bay and Pyrmont Bay
Hunter Street Station (Sydney CBD) construction sites	30	Local stormwater infrastructure	Sydney Cove

5.2.3 Impacts on NSW Water Quality Objectives

The Water Quality Objectives relevant to this proposal and the potential impacts as a result of construction work are described in Table 5-4. In summary, the proposal would not impact any Water Quality Objectives.

Standard erosion and sediment control measures would be implemented for all surface work areas to minimise pollutant loading to the downstream waterbodies during construction. Wastewater would be tested and treated at construction wastewater treatment plants prior to reuse or discharge. Wastewater treatment plants would be configured so that treated water is compliant with the ANZECC/ ARMCANZ (2000) and ANZG (2018) guidelines, which would either maintain or improve the water quality of surface waterways and the marine environment. The proposal will work towards enhancement of water quality objectives. Runoff from construction work would be designed to meet the standards outlined in *Managing Urban Stormwater – Soils and Construction, Volume 1* (Landcom 2004) and Volume 2D (NSW Department of Environment, Climate Change and Water 2008). Discharges from the wastewater treatment plants would be monitored to ensure compliance with any discharge criteria in an environment protection licence(s) issued for the proposal. As such, the impacts on the water quality of the catchment would be negligible.

Table 5-4: Water Quality Objectives

Water quality objective	Indicators	Associated trigger values or criteria	Construction impacts
Aquatic ecosystems			
Maintaining or improving the ecological condition of waterbodies and their riparian zones over the long term	Total phosphorus	Estuaries - 30µg/L	With the implementation of these mitigation measures, pollutant loading to the receiving waterbodies would be minimised and the existing water quality maintained, as a minimum, or improved.
	Total nitrogen	Estuaries - 300µg/L	Therefore, the Proposal would not negatively impact the aquatic ecosystems of Sydney Harbour.
	Chlorophyll-a	Estuaries - 4µg/L	
	Turbidity	Estuaries - 0.5 - 10 NTU	
	Dissolved oxygen	Estuaries - 80 - 100%	
	pH	Estuaries - 7.0 - 8.5	

Water quality objective	Indicators	Associated trigger values or criteria	Construction impacts
	Chemical contaminants or toxicants	Set by ANZG – online platform	
	Temperature	As per table 3.3.1 ANZECC/ ARMCANZ (2000)	
Visual Amenity			
Maintaining the aesthetic quality of waters	Visual clarity and colour	Natural visual clarity should not be reduced by more than 20%. Natural hue of the water should not be changed by more than 10 points on the Munsell Scale. The natural reflectance of the water should not be changed by more than 50%.	With the implementation of these mitigation measures, pollutant loading to the receiving waterbodies would be minimised and the existing water quality maintained, as a minimum, or improved. Therefore, the Proposal would not negatively impact the aquatic ecosystems of Sydney Harbour.
	Surface films and debris	Oils and petrochemicals should not be noticeable as a visible film on the water, nor should they be detectable by odor. Waters should be free from floating debris and litter.	

Water quality objective	Indicators	Associated trigger values or criteria	Construction impacts
	Nuisance organisms	Macrophytes, phytoplankton scums, filamentous algal mats, blue-green algae, sewage fungus and leeches should not be present in unsightly amounts.	
Primary Contact Recreation			
Maintaining or improving water quality for activities such as swimming in which there is a high probability of water being swallowed	Turbidity	A 200 millimetre diameter black disc should be able to be sighted horizontally from a distance of more than 1.6 metres (approximately 6 NTU).	With the implementation of these mitigation measures, pollutant loading to the receiving waterbodies would be minimised and the existing water quality maintained, as a minimum, or improved. Therefore, the Proposal would not negatively impact the aquatic ecosystems of Sydney Harbour.

Water quality objective	Indicators	Associated trigger values or criteria	Construction impacts
	Enterococci	NHMRC (2008) microbial assessment based on 95th percentile of enterococci (cfu/100 mL): Category A – Less than 40. No illness seen in most epidemiological studies Category B – Between 41-200. Upper level is above the threshold of illness transmission reported in most studies. Category C – Between 201-500. Represents a substantial elevation in the probability of adverse health outcomes. Category D – Greater than 500. Above this level there may be a significant risk of high levels of illness transmission. ANZECC 2000 guidelines recommend: Median over bathing season of < 35 enterococci per 100 mL (maximum number in any one sample: 60-100 organisms/100 mL).	
	Protozoans	Pathogenic free-living protozoans should be absent from bodies of fresh water. (Note, it is not necessary to analyse water for these pathogens unless temperature is greater than 24 degrees Celsius).	

Water quality objective	Indicators	Associated trigger values or criteria	Construction impacts
	Algae & blue-green algae	NHMRC (2008) suitability for coastal and estuarine recreational waterbodies should not contain: ≥ 10 cells/mL Karenia brevis and/or have Lyngbya majuscula and/or Pfiesteria present in high numbers	
	pH	6.5-8.5	
	Temperature	16°-34°C	
	Chemical Contaminants	Waters containing chemicals that are either toxic or irritating to the skin or mucus membranes are unsuitable for recreation. Toxic substances should not exceed the concentrations provided in the ANZG (2018).	
Secondary Contact Recreation			
Maintaining or improving water quality for activities such as boating and wading, where there is a low probability of water being swallowed	Enterococci	Median bacterial content in fresh and marine waters of < 230 enterococci per 100 mL (maximum number in any one sample: 450-700 organisms/100 mL).	With the implementation of these mitigation measures, pollutant loading to the receiving waterbodies would be minimised and the existing water quality maintained, as a minimum, or improved.

Water quality objective	Indicators	Associated trigger values or criteria	Construction impacts
	Algae & blue-green algae	< 15 000 cells/mL	Therefore, the Proposal would not negatively impact the aquatic ecosystems of Sydney Harbour.
	Nuisance organisms	Large numbers of midges and aquatic worms are undesirable.	
	Chemical contaminants	Set by ANZG (2018) – online platform	
Aquatic Foods (cooked)			
Protecting water quality so that it is suitable for the production of aquatic foods for human consumption and aquaculture activities. Note: At the time of developing the catchment water quality objectives, consumption of aquatic foods was nominated for protection. However due to contamination, particularly dioxins, current recommendations by the Department of Primary Industries is that no fish or crustaceans caught west of the Sydney Harbour Bridge should be eaten (Department of Primary Industries, n.d.).	Algae & blue-green algae	No guideline is directly applicable, but toxins present in blue-green algae may accumulate in other aquatic organisms.	With the implementation of these mitigation measures, pollutant loading to the receiving waterbodies would be minimised and the existing water quality maintained, as a minimum, or improved. Therefore, the Proposal would not negatively impact the aquatic ecosystems of Sydney Harbour.
	Faecal coliforms	Guideline in water for shellfish: The median faecal coliform concentration should not exceed 14 MPN/100mL; with no more than 10% of the samples exceeding 43 MPN/100 mL. Standard in edible tissue: Fish destined for human consumption should not exceed a limit of 2.3 MPN E Coli /g of flesh with a standard plate count of 100,000 organisms /g.	

Water quality objective	Indicators	Associated trigger values or criteria	Construction impacts
	Toxicants	Metals: Copper: less than 5µgm/L Mercury: less than 1µgm/L Zinc: less than 5µgm/L Organochlorines: Chlordane: less than 0.004 µgm/L (saltwater production) PCB's: less than 2 µgm/L.	
	Physio-chemical indicators	Suspended solids: less than 40 micrograms per litre for saltwater production and less than 75 micrograms per litre for brackish conditions. Temperature: less than 2 degrees Celsius change over one hour.	

5.3 Water balance for this Proposal

The indicative water balance for the construction of this Proposal based on average groundwater inflows, and the estimated treated discharge quantities are shown in Table 5-5. Non-potable water uses would include dust suppression, plant wash-down, tunnelling activities and rock bolting. Some demand activities are consumptive such as water used in the offices which would be discharged to the sewerage network. There would also be minor losses in the system due to evaporation. The remainder would be treated and either re-used or discharged at the proposed discharge locations listed in Table 5-3.

Table 5-5 Indicative water balance for this Proposal

Activity	Type	Amount (ML / year) Totals	Supply / Demand
Supply			
Recycled potable water to meet non-potable demand	Non-potable	11	65
Ground-water inflow that can be used and/or recycled	Non-potable	19	
Sydney Water (mains supply)	Potable	35	
Demand			
Construction activities (including stations, cross over caverns and tunnels)	Non-potable	130	165
	Potable	35	
Losses via consumption			
Consumed by construction activities	Non-potable	165	165
Water required from other sources			
Make up water can include recycled water from other sources if available, else potable Sydney Water	Non-potable		100

The water balance excludes The Bays Station tunnel launch and support site as that has been previously considered as part of the approved concept and major civil construction work for Sydney Metro West between Westmead and The Bays.

5.4 Cumulative impacts

Cumulative impacts are impacts that result from the successive, incremental, or combined effects of an activity or project when added to other past, current, planned, or reasonably anticipated future impacts (Department of Planning and Environment, 2017). Work covered by this Proposal has the possibility of interacting with a number of other projects along the planned corridor or at proposed construction sites.

A qualitative assessment has been undertaken. Key projects to be considered are described below.

Cumulative water quality impacts are not likely as the proposed construction site mitigation measures would be implemented and wastewater treated so that all discharges from the construction site would maintain the existing water quality.

5.4.1 Sydney Metro West existing approval

The Sydney Metro West Concept and major civil construction work for Sydney Metro West between Westmead and The Bays (Stage 1 of the planning approval for Sydney Metro West) were approved on 11 March 2021. As part of this work, The Bays tunnel launch and support site would initially be occupied by the Contractor undertaking construction work (tunnelling westbound) under the existing approval.

This part of the site would be vacated by the tunnelling contractor (for the tunnelling westbound) at approximately the end of the first quarter 2023. The Contractor for this Proposal would undertake enabling work, crossover excavations and prepare for the tunnel boring machine launch from the end of the first quarter 2023. The site would, therefore, be in use for an extended period, from the second quarter, 2023 to approximately the end of the fourth quarter, 2025. In addition, proposed work at The Bays tunnel launch and support site would occur concurrently with the approved tunnelling work westwards from The Bays to Sydney Olympic Park, for a period of approximately six months.

Other than use of the construction site, there would also be concurrent tunnelling for the two proposals. The tunnelling west from this site as part of the existing approval would be carried out between mid-2022 and mid-2024. The tunnelling east as part of this Proposal would be carried out between early 2024 and early 2025. This concurrent tunnelling does not have the potential to have cumulative impacts on flooding and hydrology, as The Bays Station box and any relevant flood protection measures would be constructed by others prior to works associated with the Proposal commencing. The Bays Station box would be used to set up the tunnel boring machine from The Bays to Sydney CBD.

5.4.2 M4-M5 Link (Rozelle Interchange)

The M4-M5 Link component of WestConnex involves the construction and operation of twin tunnels between the New M4 at Haberfield and the New M5 at St Peters, with an interchange at Rozelle and tunnel connection to Victoria Road at Iron Cove.

The Rozelle Interchange is currently under construction to the south and south west of The Bays construction site and has an influence on local overland flooding in the vicinity of the Rozelle Interchange construction site. While the majority of runoff from the Rozelle Interchange and local flooding impacted by the Rozelle Interchange is in the Rozelle Bay catchment, some local impacts are encountered in overland flows draining to White Bay.

These impacts are likely very localised and comprise water level and velocity changes as a result of the modifications to topography and provision of temporary overland flow diversion and erosion and sediment control measures as part of the construction plan for Rozelle

Interchange. As these impacts are on the periphery of The Bays construction site they are not anticipated to impact works in the main areas of use in the site. Cumulative impacts are not expected in the 1% AEP event.

5.4.3 Sydney Metro City & Southwest Martin Place metro station

The Sydney Metro City & Southwest Project involves the construction and operation of a 15.5 km metro line from Chatswood, under Sydney Harbour and through Sydney's CBD out to Sydenham. This is an approved project with a construction period from 2017 until 2024. Components of the project relevant to this assessment include the White Bay truck marshalling yard and tunnelling/construction of stations at Barangaroo and Martin Place.

The Sydney Metro City & Southwest Project, application number SSI-7400, were approved on 9 January 2017 with a number of subsequent modifications. Relevant Secretary's Environmental Assessment Requirements for this project require that

- Changes to overland flow diversions during construction would meet the following criteria:
  - Increases in flood levels during events up to and including the 100-year average recurrence interval would be minimised particularly within private properties
  - Any increase in flow velocity for events up to and including a 100-year average recurrence interval event would not increase the potential for soil erosion and scouring ·
  - Dedicated evacuation routes would not be adversely impacted in flood events up to and including the probable maximum flood
- There would be no additional private properties affected by flooding up to and including the 100-year average recurrence interval event during operation
- The performance of the downstream drainage network would be maintained during operation.

This Proposal was not specifically considered in the cumulative assessment (Sydney Metro, 2016). The Hunter Street Station (Sydney CBD) eastern construction site is 50 metres to the south-east of Martin Place Station. Hunter Street is a floodway from below the location of the Hunter Street Station (Sydney CBD) eastern construction site to at least the intersection with Castlereagh Street (WMAwater, 2016b).

It is understood by Sydney Metro that the development of the Martin Place Station does not cause increased flood levels at either of the Hunter Street Station (Sydney CBD) construction sites. Additionally, it is anticipated that construction of the Martin Place Station will be well advanced with a building on the footprint. However, there may be a potential impact on the Martin Place Station as there would be a 10 metre rise of the adit connection to the Hunter Street Station (Sydney CBD) eastern construction site.

5.4.4 The new Sydney Fish Market

The project involves building a new Sydney Fish Market which will be set within an improved public domain including the creation of a waterfront promenade. The site is located at the head of Blackwattle Bay between Pyrmont Peninsula and Glebe Peninsula. This is an approved project with a construction period from 2020 until 2024.

The project is 1km to the south-east of the Bays tunnel launch and support site and 500 m to the south-west of the Pyrmont Station construction site. However, it is not hydraulically connected to either The Bays tunnel launch and support site or the Pyrmont Station construction sites therefore no cumulative impacts are expected in up to the 1% AEP event.

5.4.5 Western Harbour Tunnel and Warringah Freeway Upgrade

The Western Harbour Tunnel and Warringah Freeway Upgrade project form part of the Western Harbour Tunnel and Beaches Link Program and comprise a new motorway tunnel connection across Sydney Harbour, and an upgrade of the Warringah Freeway to integrate the new motorway infrastructure with the existing road network, with a connection to the Beaches Link and Gore Hill Freeway Connection project. This is an approved project with a construction period from 2023 until 2024.

Components of the proposal relevant to this assessment include construction activities at White Bay. However, it is not hydraulically connected to The Bays tunnel launch and support site therefore no cumulative impacts are expected in up to the 1% AEP event.

5.4.6 Cockle Bay Wharf mixed use development

A State Significant Development Application was approved by the NSW Independent Planning Commission on 13 May 2019 for the Concept Proposal and Stage 1 works which includes demolition work.

The current Proposal would include:

- Construction of a landbridge across part of the Western Distributor
- The design, construction and use of a 43 storey mixed-use development
- At least 6500 m^2 of publicly accessible open space
- Site interface works
- Subdivision.

The project is approximately 500 metres south-west of the Pyrmont Station construction sites and 700 metres south-west of the Hunter Street Station (Sydney CBD) construction site. However, it is not hydraulically connected to any of these construction sites therefore no cumulative impacts are expected in up to the 1% AEP event.

5.4.7 50-52 Phillip Street New Hotel

The proposal involves the delivery of a new landmark hotel building in Sydney's CBD with approximately 330 rooms throughout the 47 storey development. Construction is likely to extend across 2.5 years and commencement of demolition and construction is not expected before 2023.

This project is 300 metres to the north-east of the Hunter Street Station (Sydney CBD) construction site and effectively a different sub-catchment of the same catchment draining to Sydney Cove. This site is located in an area of the catchment which in rare events drains directly to Sydney Cove via Phillip Street (WMAwater, 2016a). Consequently, cumulative impacts are not expected in up to the 1% AEP event.

5.4.8 One Sydney Harbour

One Sydney Harbour is a skyscraper complex under construction in Sydney which includes 808 apartments in three towers. The project is part of the major urban renewal precinct of Barangaroo.

The Hunter Street Station (Sydney CBD) construction site is 550 metres to the north-west. However, it is not hydraulically connected therefore no cumulative impacts are expected in up to the 1% AEP event.

5.4.9 Sydney Metro - Martin Place Over Station Development

The project includes two over station development commercial towers above the northern and southern entrances of the yet to be constructed Martin Place Metro Station. The Concept Proposal is intended to be delivered as a single, integrated project along with the delivery of rail, station, concourse infrastructure and public domain works associated with the Martin Place Metro Station. The construction of the different elements is likely to be staged so as not to interrupt the Metro construction program.

Although, the Hunter Street Station (Sydney CBD) construction site is 50 metres to the south-east, this project coincides with Martin Place Station as outlined in section 5.4.3. No additional cumulative impacts are expected as a result of this project in up to the 1% AEP event.

5.4.10 111 &121 Castlereagh/65-77 Market Street, Sydney

The project involves the retention and alteration of the existing retail/commercial building on the site and the construction of a 22 storey residential tower above with a total height of 32 storeys. The development accommodates retail and commercial uses within the existing building, 101 residential apartments within the tower and 108 car parking spaces within the basement. The proposal is Integrated Development under the Roads Act 1993.

The Hunter Street Station (Sydney CBD) construction site is 550 metres to the south. However, it is not hydraulically connected therefore no cumulative impacts are expected in up to the 1% AEP event.

5.4.11 Summary of cumulative impact

The named developments in the above sections have been considered in a qualitative analysis. The potential for cumulative impacts on flooding are considered unlikely at the Pyrmont Station construction sites and at The Bays tunnel launch and support site and possible at the Hunter Street Station (Sydney CBD) eastern construction site without mitigation.

6 Proposed management and mitigation measures

6.1 Approach to the management and mitigation

Mitigation and management measures are proposed where appropriate to minimise impacts to water quality, limit flooding impacts of this Proposal on surrounding properties and on the construction sites. These are provided in Table 6-2.

Details of the groundwater management and mitigation measures are outlined in Technical Paper 7 (Mott MacDonald, 2021a).

As detailed in the CEMF, described in Chapter 27 (Synthesis of the Environmental Impact Statement) and Appendix D of the *Sydney Metro West Environmental Impact Statement – Westmead to The Bays and Sydney CBD* (Sydney Metro, 2020), a number of plans will be required to manage the relevant impacts including:

- A Soil and Water Management Plan
- Progressive Erosion and Sediment Control Plans
- Stormwater and Flooding Management Plans.

The Soil and Water Management Plan must be prepared and is required to include at least the following:

- The surface water and flooding mitigation measures as detailed in the environmental approval documentation
- Details of construction activities and their locations, which have the potential to impact on water courses, storage facilities, stormwater flows, and groundwater
- Surface water and ground water impact assessment criteria consistent with the principles of the ANZG (2018) guidelines for 95 per cent species protection level (or 99 per cent species protection for toxicants that bioaccumulate).
- Management measures to be used to minimise surface and groundwater impacts, including identification of water treatment measures and discharge points, details of how spoil and fill material required by the project will be sourced, handled, stockpiled, reused and managed; erosion and sediment control measures; salinity control measures and the consideration of flood events
- A contingency plan, consistent with the NSW Acid Sulfate Soils Manual (EPA 1998), to deal with the unexpected discovery of actual or potential acid sulfate soils, including procedures for the investigation, handling, treatment and management of such soils and water seepage
- A description of how the effectiveness of these actions and measures would be monitored during the proposed works, clearly indicating how often this monitoring would be undertaken, the locations where monitoring would take place, how the results of the monitoring would be recorded and reported, and, if any exceedance of the criteria is detected how any non-compliance can be rectified
- The requirements of any applicable licence conditions
- Procedures for the development and implementation of Progressive Erosion and Sediment Control Plans

- Identification of locations where site specific Stormwater and Flooding Management Plans are required.

Progressive Erosion and Sediment Control Plans will be required at all active worksites and must be undertaken in accordance with Landcom (2004).

Stormwater and Flooding Management Plans will be required for the relevant construction sites. These plans will identify the appropriate design standard for flood mitigation based on the duration of construction, proposed activities and flood risks. The plan will develop procedures to ensure that threats to human safety and damage to infrastructure are not exacerbated during the construction period where there is residual risk of flooding, after mitigation, discussed further in section 6.4. This residual risk would occur at the The Bays tunnel launch and support site, the Pyrmont Station and the Hunter Street Station (Sydney CBD) construction sites during a 1% AEP flood event and up to the PMF.

6.2 Performance outcomes

The desired performance outcomes associated with the Secretary's Environmental Assessment Requirements for this proposal are summarised in the Table 6-1 below for hydrology, flooding and water quality. The performance objectives in the table are from the key areas of flooding, soils and contamination, hydrology and water quality respectively.

Table 6-1: Summary of performance outcomes

Reference	Desired performance outcome
PO 1	The Proposal minimises adverse impacts on existing flooding characteristics. Construction of the Proposal avoids or minimises the risk of, and adverse impacts from, infrastructure flooding or flooding hazards.
PO 2	The environmental values of land, including soils, subsoils and landforms, are protected. Risks arising from the disturbance and excavation of land and disposal of soil are minimised, including disturbance to acid sulfate soils and site contamination.
PO 3	Long term impacts on surface water and groundwater hydrology (including drawdown, flow rates and volumes) are minimised. The environmental values of nearby, connected and affected water sources, groundwater and dependent ecological systems including estuarine and marine water (if applicable) are maintained (where values are achieved) or improved and maintained (where values are not achieved). Sustainable use of water resources.
PO 4	The project is designed, constructed and operated to protect the NSW Water Quality Objectives (WQOs) where they are currently being achieved, and contribute towards achievement of the Water Quality Objectives over time where they are currently not being achieved, including downstream of the project to the extent of the project impact including estuarine and marine waters (if applicable).

6.3 Proposed mitigation measures

The mitigation measures that would be implemented to address potential hydrology, flooding and water quality impacts associated with this Proposal are listed in Table 6-2. These mitigation measures include earlier identified measures from the *Sydney Metro West Environmental Impact Statement – Westmead to The Bays and Sydney CBD* (Sydney Metro, 2020) for the same locations.

Table 6-2: Summary of potential impacts and management measures

Reference	Impact/Issue	Mitigation measure	Applicable location(s)
HF 1	Overland flows disturbed by construction activities including temporary finished surface changes resulting in changes to flood conditions	Detailed construction planning would consider flood risk at construction sites. This would include: • Identification of measures to not worsen flood impacts on the community and on other property and infrastructure during construction up to and including the 1% AEP flood event • Provide flood-proofing to excavations at risk of flooding or coastal inundation during construction, where reasonable and feasible, such as raised entry into shafts and/or pump-out facilities to minimise ingress of floodwaters into shafts and the dive structure • Review of site layout and staging of construction activities to avoid or minimise obstruction of overland flow paths, address loss of flood plain storage and limit the extent of flow diversion required. This includes design of site hoardings to minimise disruption to flow paths (if possible). Not worsen is defined as: • A maximum increase in flood levels of 50mm in a 1% AEP flood event • A maximum increase in time of inundation on one hour in a 1% AEP flood event • No increase in potential soil erosion and scouring from any increase inflow velocity in a 1% AEP flood event.	The Bays tunnel launch and support site, Pyrmont Station, Hunter Street Station (Sydney CBD)

Reference	Impact/Issue	Mitigation measure	Applicable location(s)
HF 2	Staging of earthworks and location of site entry and exit locations within overland flow paths disturbing existing stormwater flows.	Drainage at construction sites would be designed, where feasible and reasonable, to mitigate potential alterations to local runoff conditions due to construction sites.	Hunter Street Station (Sydney CBD), Pyrmont Station, The Bays tunnel launch and support sites, Power supply arrangements
HF 3	Loss of floodplain storage and obstructions to shallow overland flow causing localised changes to flood levels.	Detailed construction planning for The Bays tunnel launch and support site construction would aim to minimise changes to existing levels in relation to potential impacts on flood behaviour, along the north-western side of site adjacent to low-lying property, to minimise reduction in floodplain storage and blockage to local overland flow path.	The Bays tunnel launch and support site
HF 4	Changes to the local road environment and site access locations potentially impacting direct evacuation route from the site and adjacent public road areas.	Construction planning regarding flooding matters would be carried out in consultation with the NSW State Emergency Service and the relevant local council.	Hunter Street Station (Sydney CBD), Pyrmont Station, The Bays tunnel launch and support site, Power supply arrangements
HF 5	Potential cumulative impacts of concurrent construction activities causes worsening of local flooding conditions.	Detailed construction planning for The Bays tunnel launch and support site construction site would aim to avoid conflicts with the potential construction of flood mitigation works in Robert Street, in consultation with Inner West Council.	The Bays tunnel launch and support site

Reference	Impact/Issue	Mitigation measure	Applicable location(s)
HF 6	Potential cumulative impacts	To ensure flood protection on the bottom of the adit between Hunter Street station construction site and the Sydney Metro – City & Southwest Martin Place metro station site, appropriate flood protection would be implemented.	Hunter Street Station (Sydney CBD)
SSWQ1	Acid sulfate soils	Prior to ground disturbance in areas of potential acid sulfate soil occurrence, testing would be carried out to determine the presence of actual and/or potential acid sulfate soils. If acid sulfate soils are encountered, they would be managed in accordance with the Acid Sulfate Soil Manual (ASSMAC, 1998)	Pyrmont Station and The Bays tunnel launch and support site
SSWQ2	Soil salinity	Prior to ground disturbance in high probability salinity areas, testing would be carried out to determine the presence of saline soils. If salinity is encountered, excavated soils would not be reused or would be managed in accordance with Book 4 Dryland Salinity: Productive Use of Saline Land and Water (NSW DECC, 2008). Erosion controls would be implemented in accordance with the 'Blue Book' (Landcom, 2004)	The Bays tunnel launch and support site
SSWQ3	Erosion and sedimentation	Erosion and sediment measures would be implemented at all construction sites in accordance with the principles and requirements in Managing Urban Stormwater – Soils and Construction, Volume 1 (Landcom, 2004) and Volume 2D (NSW Department of Environment, Climate Change and Water 2008), commonly referred to as the 'Blue Book', to ensure water quality is not adversely affected at receiving waters to a minimum set by the 80th percentile 5 day rainfall event. Additionally, any water collected from construction sites would be appropriately treated and discharged to avoid any potential contamination or local stormwater impacts. Temporary sediment basins would be designed in accordance with Managing Urban Stormwater: Soils and Construction and Managing Urban Stormwater, Volume 2D: Main Road Construction (DECC, 2008).	Hunter Street Station (Sydney CBD), Pyrmont Station, The Bays tunnel launch and support site

Reference	Impact/Issue	Mitigation measure	Applicable location(s)
SSWQ4	Working in low lying areas	Works in waterbodies and surrounding low lying areas would be carried out in accordance with progressive erosion and sediment control plans	The Bays tunnel launch and support site
SSWQ5	Wastewater discharge	The water treatment plants would be designed with the aim of treating wastewater to a level as close as practicable to the ANZECC (2000), ANZG (2018) and draft ANZG (2020) default guidelines for 95 per cent species protection and 99 per cent species protection for toxicants that bioaccumulate unless other discharge criteria are agreed with relevant authorities.	Hunter Street Station (Sydney CBD), Pyrmont Station, The Bays tunnel launch and support site
SSWQ6	Water quality monitoring	A surface water monitoring program would be implemented to observe any changes in surface water quality that may be attributable to construction and inform appropriate management responses. The program would be developed in consultation with the EPA and relevant councils. The program would consider monitoring being undertaken as part of other infrastructure projects. Monitoring would occur during pre-construction and during construction at all waterways with the potential to be impacted. Monitoring would include sampling for key indicators of concern.	Hunter Street Station (Sydney CBD), Pyrmont Station, The Bays tunnel launch and support site
SSWQ7	Local stormwater capacity	Further design development would confirm the local stormwater system capacity to receive construction water treatment plant inflows. In the event there is a stormwater infrastructure capacity issue with existing infrastructure, mitigation measures such as storage detention to control water outflow during wet weather events would be implemented.	Hunter Street Station (Sydney CBD), Pyrmont Station, The Bays tunnel launch and support site

6.4 Residual impacts

Localised changes to overland flows are limited in their scale to the immediate vicinity of the construction site and due to the temporary nature of the impacts are considered minor.

Application of design standards as well as management measures throughout the life of the construction of the Proposal would minimise impacts to the receiving waterbodies around the proposal.

6.5 Interactions between mitigation measures

Mitigation measures in other chapters that are relevant to the management of potential impacts include:

- Chapter 14 (Groundwater and ground movement), specifically measures which address groundwater levels and the migration of contaminants through groundwater
- Chapter 16 (Contamination), specifically measures which address the disturbance of contaminated land during construction.

Together, these measures would minimise the potential impacts of this Proposal. There are no mitigation measures identified in the assessment of other environmental aspects that are likely to affect the assessment of hydrology, flooding and water quality impacts.

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Appendix A – The Bays Station Model Conversion

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1 Introduction

This appendix report describes the conversion of an existing SOBEK[1] numerical model to TUFLOW numerical model for use in the flood impact assessment at The Bays tunnel launch and support site.

[1] Refer to glossary in main report for definitions

2 TUFLOW model development

Multiple SOBEK models were developed for the entire former Leichhardt Local Government Area as part of the Leichhardt Flood Study (Cardno, 2015). A SOBEK model developed for the White Bay catchment has been converted to a TUFLOW model for the Sydney Metro West flood impact assessment in the vicinity of the Bays Station.

The following components of the SOBEK model have been extracted to build a base TUFLOW model which then has been updated in accordance with Australia Rainfall & Runoff 2019 (ARR2019):

- Digital Elevation Model (DEM)
- Rainfall
- Rainfall losses for ARR2019
- 1D network
- Surface roughness.

2 Digital Elevation Model

A 1m resolution Airborne Laser Scanning (ALS) data captured in August 2006 was used for Council's flood study. Buildings in the SOBEK model were assumed to completely block overland flow and were modelled as raised blocks.

The DEM data used in Council's flood study has been replaced by the latest LiDAR DEM data (June 2020) obtained from Elevation Foundation Spatial Data and topographic survey including the design surface of Port Access Relocation Works for the flood assessment for Stage 2.

There is a major overland flow path on the western side of Mullens Street. There are numerous properties constructed across the flow path. Buildings which obstruct the major flow path cause significant ponding of water in streets and properties. As buildings upstream of the Bays Station attenuate the flows and reduce the potential flooding downstream, the built up area footprints in the TUFLOW model have been represented as a high roughness.

2.1 Rainfall

The Cardno SOBEK model was developed in accordance with Australia Rainfall & Runoff 1987 (ARR1987)[2]. Due to software limitation of SOBEK on applying rainfall losses, the losses were subtracted from the design rainfall to derive rainfall-excess hyetographs. A TUFLOW model with the exact same rainfall depth (rainfall excess) as the council's model has been developed to compare the results from two different modelling software packages.

In order to determine flood protection levels and potential impacts, a TUFLOW model with the latest LiDAR data has been developed with the 2016 design rainfall data in accordance with ARR2019.

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[2] Cardno 2015 report references the 1999 reprint of ARR1987 which was largely the same however the chapter on the estimation of extreme to large floods has been updated.

2.2 Rainfall Losses

According to NSW Specific Data Info from ARR Datahub, the storm losses applicable for the study area are:

- Initial Loss: Probability Burst Initial Loss as per Table A1
- Continuing Loss: Rural default ARR Datahub continuing losses with a multiplication factor of 0.4 (0.4 x 1.8 = 0.72 mm/hr)
- Initial Loss for indirectly connected areas (ICA): Probability Burst Initial Loss as per Table 4 with a multiplication factor of 0.6
- Continuing Loss for indirectly connected areas (ICA): Rural default ARR Datahub continuing losses with a multiplication factor of 0.6 (0.6 x 0.72 = 0.432 mm/hr).

Table A1 Probability Neutral Initial Losses

Duration (mins)	50%	20%	10%	5%	2%	1%
60	11.6	7.8	8.9	8.5	8.2	6.4
90	11.9	8.3	9.5	9.5	9.4	6.5
120	13.3	8.9	9.9	9.7	9.4	5.7
180	13.3	9.7	10.7	10.2	8.8	4.5
270	13.2	9.2	9.6	9.1	8.9	3.8
360	13	8.8	8.6	7.9	9	3
540	15.7	10.9	10.6	9.4	10.5	3.1
720	18.3	13	12.7	10.9	12.1	3.2
1080	18.6	13.6	14.4	12	12.4	3.9
1440	21.6	16.4	16.5	14.2	14.9	4.4
1800	23.2	17.7	17.6	15	15.8	5.3
2160	24.7	19	18.6	15.8	16.7	6.3
2880	27.7	22.4	21.7	23.1	19.9	9.5

PMF losses indicated in Table A2 have been adopted in accordance with ARR2019 (Book 8, Section 4.3.5, Table 8.4.1).

Table A2 Recommended Loss Rates for Urban Catchments for PMF

Area Class	Storm Initial Loss (mm)	Burst Initial Loss (mm)	Continuing Loss (mm/hr)
Effective Impervious	1	0	0
Other	At the lower range of values adopted for rural catchments		
Pervious	As for rural catchments		

2.3 One dimensional network

A pit and pipe network model in the SOBEK 1D model has been converted to TUFLOW 1D GIS layers. The following properties have been directly converted:

- Pit surface and invert levels
- Pipe sizes, roughness and invert levels.

Minor adjustments have been made on the pit and pipe locations to account for SOBEK's different 1D modelling approach to TUFLOW. As SOBEK calculates pit inlet rating curves using an 'orifice node', the node type 'R' has been specified in the TUFLOW model. The plan width and height of pits have been assigned to each node based on the plan areas specified in the SOBEK model.

The drainage design for Port Access Relocation Works has been included in the base TUFLOW model for the EIS.

A review of available aerial imagery indicates there are additional drainage network within the Bays site which were not included in the Sobek model and not available at the time of reporting. A review of available information to determine existing culvert structures on site will be undertaken and the TUFLOW model will be subsequently updated. If no information is available at the structure locations, assumed culvert configurations will be included in the model. There is a large culvert on the downstream side of Robert Street to the north of The Bays site. Available information will be reviewed to determine the size of the structure which will be included in updated modelling.

During rare and extreme events, such as the 1% and PMF events assessed as part of this study, the stormwater would typically exceed the capacity of the stormwater network. Therefore, blockage on the inlets was not considered as part of this study.

A considerable portion of stormwater discharges past The Bays Station Construction Site via an underground stormwater pipe located on the upstream site of Robert Street. A blockage assessment of the main trunk drainage structure which collects stormwater from the open drain upstream of Robert Street was undertaken. The existing pipe is 1/ 4.93 x 1.37m culvert which discharges from the open drain located to the north of the White Bay Power Station to White Bay.

The blockage analysis considered the debris availability, debris mobility and transportability. Upstream of the open drain, stormwater enters the stormwater network through numerous stormwater inlets along the kerb and channel drainage within the catchment. No detailed information was available to confirm all stormwater inlet structures. The inlet height of such inlets is typically less than 150mm therefore debris entering the drainage system by this means would be limited by this constriction. Any debris that would enter the stormwater system would not typically cause blockage to the large trunk drainage.

Other avenues for debris to enter the stormwater network would be directly into the open drain immediately upstream of the culvert entrance under Robert Street. A 15% blockage factor has been applied to the culvert to test the sensitivity of the blockage on the flood levels in the vicinity of the subject site. This represents a bottom up blockage of an area of approximately 1m^2, which is considered appropriate for debris that could enter the drain. The change in flood level between the no blockage scenario and the 15% blockage scenario is presented in Figure A1. The blockage will cause additional flood water to discharge from the open drain onto Rover Street, increasing flood levels on the road and around the White Bay Power Station by up to 75mm in a 1% AEP design flood event. The discharge into the pipe decreases from 11.4 m^3/s to 9.8 m^3/s. There were no considerable differences in water level within the subject site and it is considered unlikely the large culvert will become blocked by debris from the catchment. The no blockage scenario has been adopted as a basis for the hydraulic modelling.

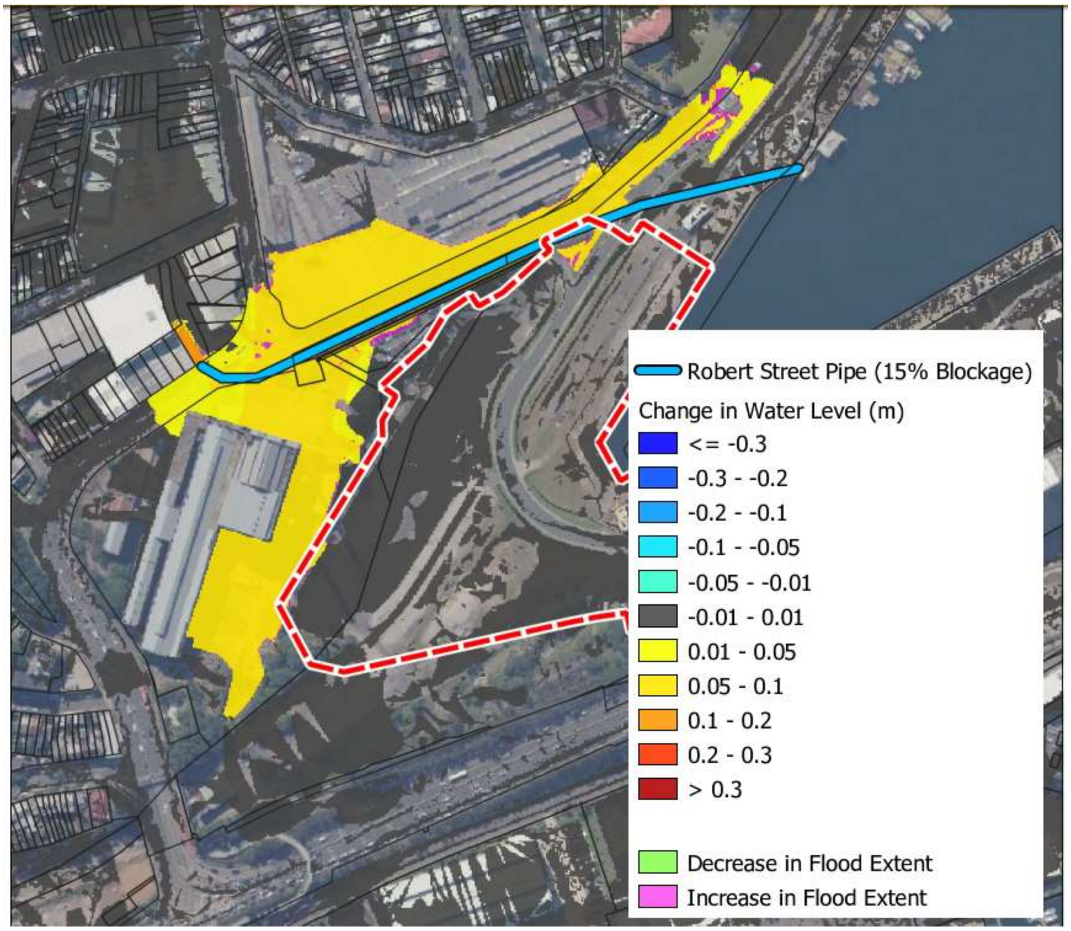


Figure A1 Trunk drainage blockage water level difference map

2.4 Surface roughness

The raster grid file with the surface roughness has been converted to GIS polygons. In the Sobek model the, structures were included in the DEM as raised structures. In the TUFLOW the buildings were not blocked in the DEM. To represent the blockage from structures the built-up areas have been modelled as a high roughness. This Manning's 'n' roughness value of 0.1 has been adopted to represent the buildings, backyards, fences and other obstructions through the built-up areas. This was considered an appropriate value, particularly considering the direct-rainfall methodology which includes rainfall directly onto existing structures. Adopting a higher roughness may better represent the overland flooding blockage, while over attenuating the rainfall that falls directly on the buildings. Commercial properties which represented a large blockage were modelled with a roughness of 0.15 and hardstand areas with a value of 0.015 and the White Bay Power Station as a solid blockage.

Minor updates have been made where the aerial image shows significant changes in land use near the project site, relative to the existing data in Leichhardt Flood Study modelling.

A sensitivity analysis was undertaken to check the effect an increased roughness on the residential and built up areas would have on flood levels in the vicinity of the subject site. The Manning's 'n' roughness for the built-up areas was increased from 0.1 to 0.5. The increased roughness resulted to higher flood levels within the upper catchment in the areas of the built-up areas. The attenuation from the additional flood storage and reduced velocity also resulted in reduced flood levels on Robert Street by up to 330mm and around the White Bay Power station by up to 215mm. The higher roughness significantly reduces flood levels around the site. The adopted Manning's 'n' value of 0.1 was considered appropriate and has been adopted as a basis for the hydraulic modelling.

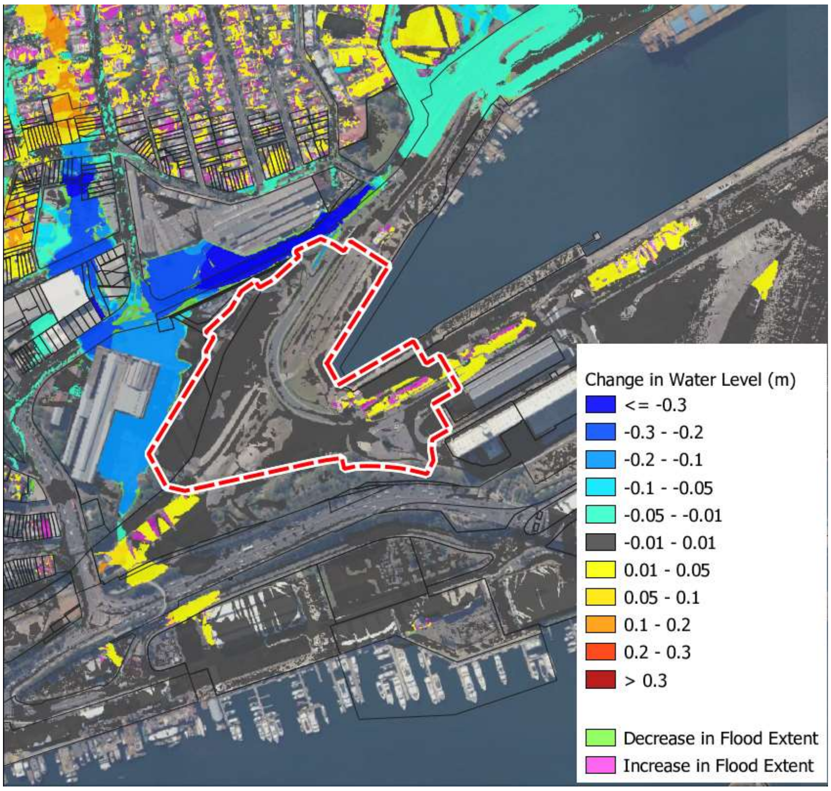


Figure A2 Built up area Manning's 'n' roughness sensitivity map

2.5 Boundary condition

The water level of 1 m AHD for Sydney Harbour was adopted for all design storm events for the Council flood study. The water level at Sydney Harbour has been revised based on the Fort Denison Vulnerability Study (Watson et al, 2008) shown in Table A3.

Table A3 Extreme Water Levels for Fort Denison

Return Period [years]	Extreme Water Levels [m, AHD]
10	1.345
25	1.382
50	1.415
100	1.435

The updated TUFLOW model has adopted the Fort Denison water levels for the analysis. The 100-year return period was adopted as 1.45 mAHD, which was also adopted for the Probable Maximum Flood. For the 100-year climate change assessment, a sensitivity analysis was undertaken to include estimated sea level rise of 0.66m.

3 TUFLOW model results

The TUFLOW model developed using the same model input parameters from the SOBEK model was run for the 1% AEP 30, 60 and 90 minute critical durations specified in the flood study to compare the results.

Peak flood levels produced from the TUFLOW model are generally 150 mm higher than the flood levels from SOBEK model where the flows are restricted by buildings. Figure A3 shows the depth differences upstream of the project site where red denotes the flood levels from SOBEK which are higher than TUFLOW.

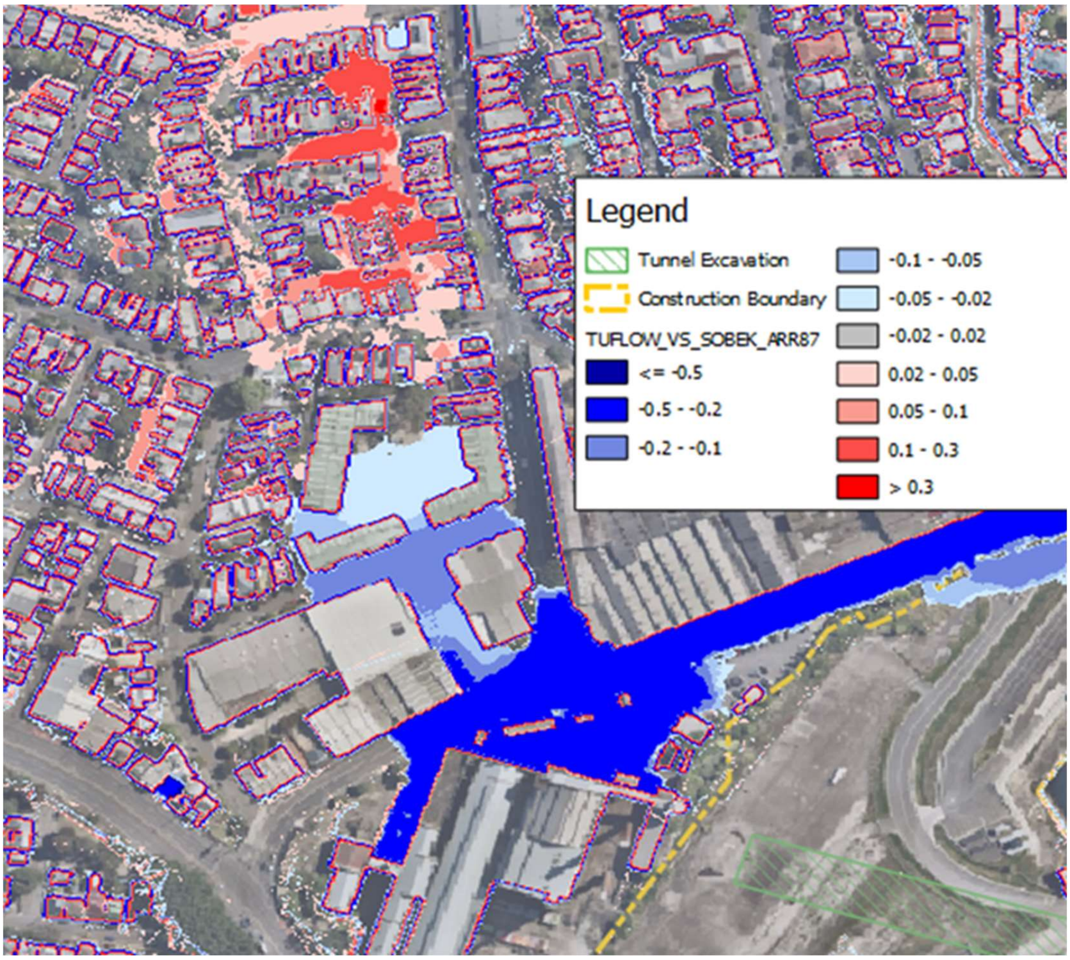


Figure A3 Difference map

It was found that the existing box culvert under Robert Street (Sydney Water asset) modelled in the SOBEK model conveyed significantly less flows than the TUFLOW model. It appears that the 1D channel modelled in the SOBEK model only conveys the immediate upstream pipe flows and does not take additional overland flows coming from Parsons Street. The 1D channel has been deleted in the TUFLOW model.

Further site investigation will be required to confirm that there is no obstruction in the flow path entering the channel to validate the latest LiDAR data and TUFLOW modelling approach. This will include undertaking a blockage assessment as discussed previously.

The peak flowrates in the vicinity of the intersection have been summarised in Table A4.

Table A4 Recommended Loss Rates for Urban Catchments for PMF

Location	SOBEK Peak Flows (m3/s)	TUFLOW Peak Flows (m3/s)	Type of flow
Robert St N - Upstream of existing culvert	9.2	6.25	2D Overland
	7.8	10.23	Pipe
2D Channel - Upstream of Robert St	17	16.44	SOBEK - 1D + 2D TUFLOW - 2D
Box culvert under Robert St	7.67	13.81	Pipe

3.1 Critical Duration Assessment for ARR2019

Critical duration assessment has been undertaken for 1% AEP and PMF design storms using a 2.5 m cell size. Ten temporal patterns have been run for each storm duration up to 540 minutes for 1% AEP and 180 minutes for PMF. As it was not practical to run a total of 130 simulations, the following storm events that produce the closest peak flows to the average in the vicinity of the project site have been selected:

- 1% AEP, 15 min, Temporal Pattern 08
- 1% AEP, 45 min, Temporal Pattern 02
- 1% AEP, 540 min, Temporal Pattern 04
- PMF, 30 min, Temporal Pattern AS66
- PMF, 60 min, Temporal Pattern TO98
- PMF, 90 min, Temporal Pattern BR97.

The critical durations adopted in the council's flood study for the 1% AEP are 30, 60 and 90 minute storm events. As the low-lying floodplain area adjacent to the White Bays Power Station requires longer duration to fill up the flood storage area, a 540 minute storm has been included for the EIS.

4 TUFLOW – SOBEK comparison

4.1 Results

The following model scenarios have been assessed to validate the base model used for the EIS:

- Scenario 1: Legacy DEM data (SOBEK, buildings modelled as raised blocks) with ARR1987 procedures (1% AEP)
- Scenario 2: Legacy DEM data (SOBEK, buildings modelled as raised blocks) with ARR2019 procedures (1% AEP)
- Scenario 3: Latest DEM data (2020, without buildings as raised blocks) with ARR2019 procedures (1% AEP).

4.2 Scenario 1 vs Scenario 2

In general, the Scenario 1 flood model produces considerably higher flood levels than the Scenario 2 model due to the following reasons upstream of the project site:

- The rainfall intensity from the ARR1987 IFD data is up to 22.5% higher than the latest IFD data for ARR2019. Refer to Table 5
- The Council model does not allow continuing losses.

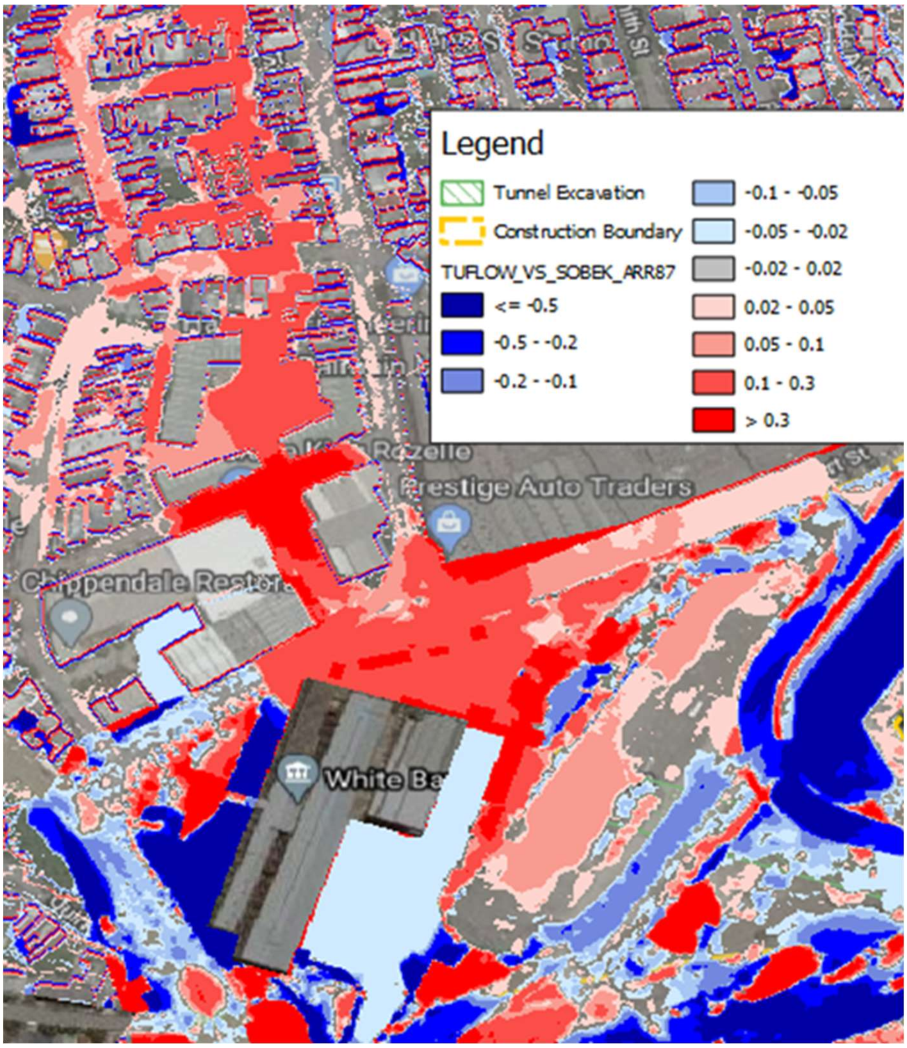


Figure A4 Difference map

The red in Figure A4 denotes the area where the flood levels for Scenario 1 are higher than Scenario 2.

Table A5 IFD comparison for 1% AEP

Duration	IFD (mm/hr) (1987)	IFD (mm/hr) (2016)	Change (%)
5 mins	266	251	-5.64%
6 mins	250	239	-4.40%
10 mins	209	201	-3.83%
20 mins	160	144	-10.00%
30 mins	133	114	-14.29%
1 hour	92.8	73.4	-20.91%
2 hours	60.8	47.1	-22.53%
3 hours	46.6	36.8	-21.03%
6 hours	29.3	25	-14.68%
12 hours	18.6	17.5	-5.91%
24 hours	12.1	12.3	1.65%
48 hours	7.81	8.19	4.87%
72 hours	5.81	6.17	6.20%

4.3 Scenario 2 vs Scenario 3

The Scenario 2 flood model produces generally lower flood levels than the Scenario 3 model as there are no buildings in the major flow path which attenuates flows upstream.

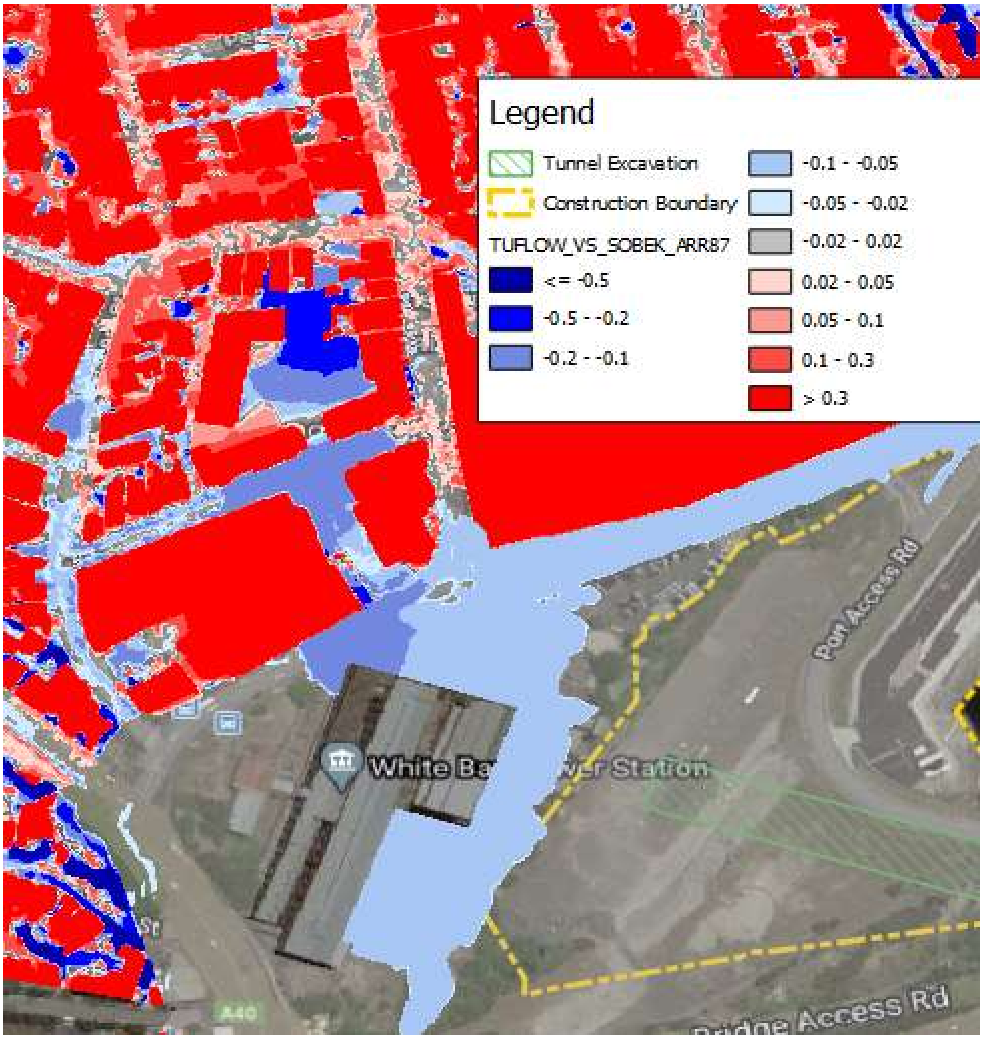


Figure A5 Difference map

The blue in Figure A5 denotes the area where the flood levels for Scenario 2 are lower than Scenario 3. It is noted that the difference in flood levels have been taken from the top of the buildings to the surface levels to the LiDAR data.

As the Scenario 3 model produces the flood levels between Scenario 1 and 2, it has been adopted as the base case scenario model for the EIS.

4.4 Recommendation

Scenario 3 model is adopted as the base case model for the EIS.

5 References

Babister, M., Trim, A., Testoni, I. and Retallick, M. 2016. The Australian Rainfall & Runoff Datahub, 37th Hydrology and Water Resources Symposium Queenstown NZ

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) (2019) Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia

Cardno (2015) Leichhardt Flood Study. Prepared for Leichhardt City Council (now Inner West Council)

Geoscience Australia. (2021). Elevation Information System (ELVIS), accessed April 2021, https://elevation.fsdf.org.au/

Pilgrim, D. H. (Editor-in-chief) (1999) Australian Rainfall and Runoff: A Guide to Flood Estimation Vol. 1 reprinted

Watson P.J and Lord, D.B. (2008) Fort Denison Sea Level Rise Vulnerability Study. Prepared by the Coastal Unit, NSW Department of Environment and Climate Change

Appendix B – Existing environment flood maps

The Bays tunnel launch and support site flood maps

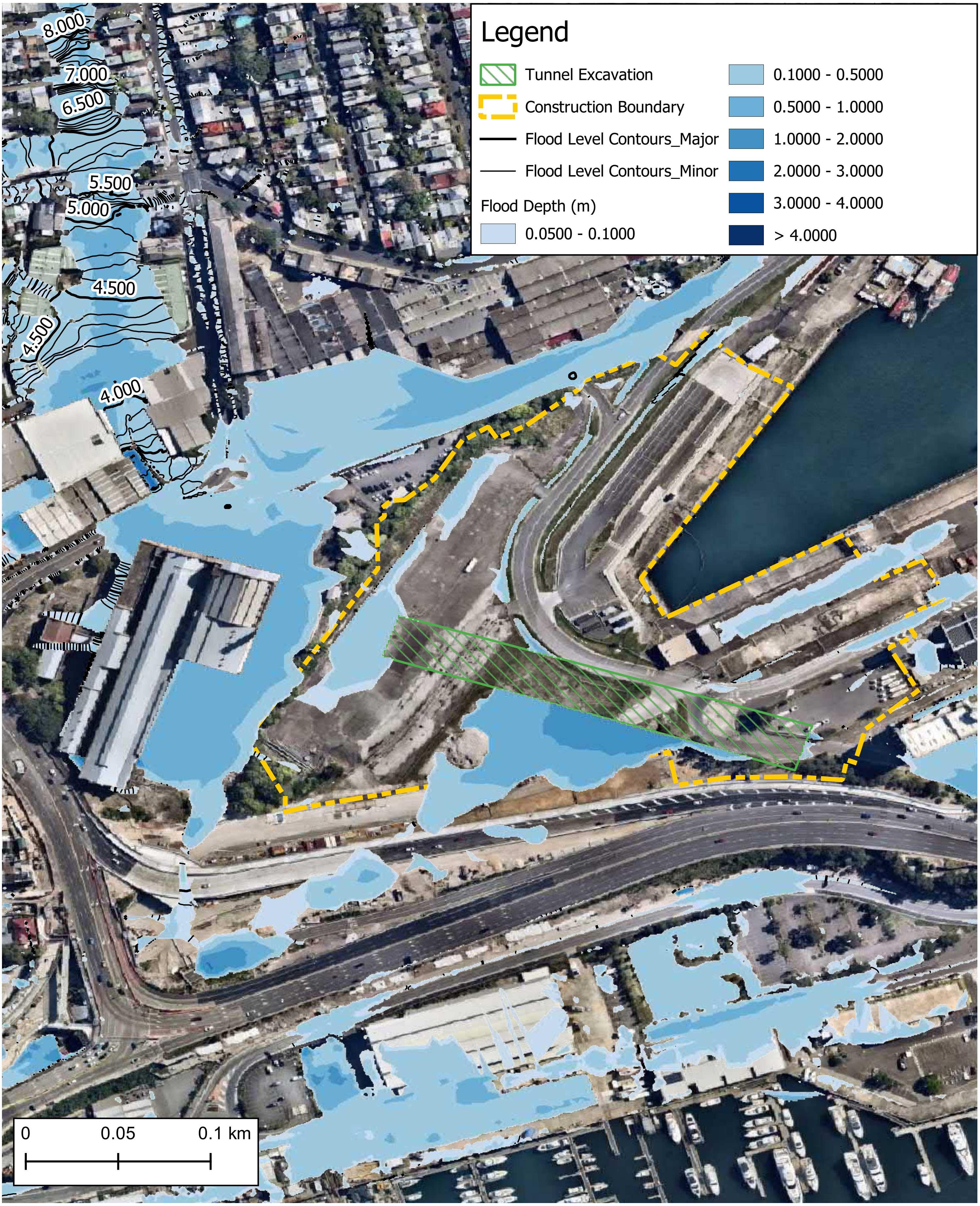
Figure B-1 1% AEP Baseline Stage Depth
Figure B-2 PMF Baseline Depth
Figure B-3 1% AEP Baseline Hazard
Figure B-4 PMF Baseline Hazard

Pyrmont Station flood maps

Figure B-5 1% AEP Baseline Stage Depth
Figure B-6 PMF Baseline Depth
Figure B-7 1% AEP Baseline Hazard
Figure B-8 PMF Baseline Hazard

Hunter Street Station (Sydney CBD) flood maps

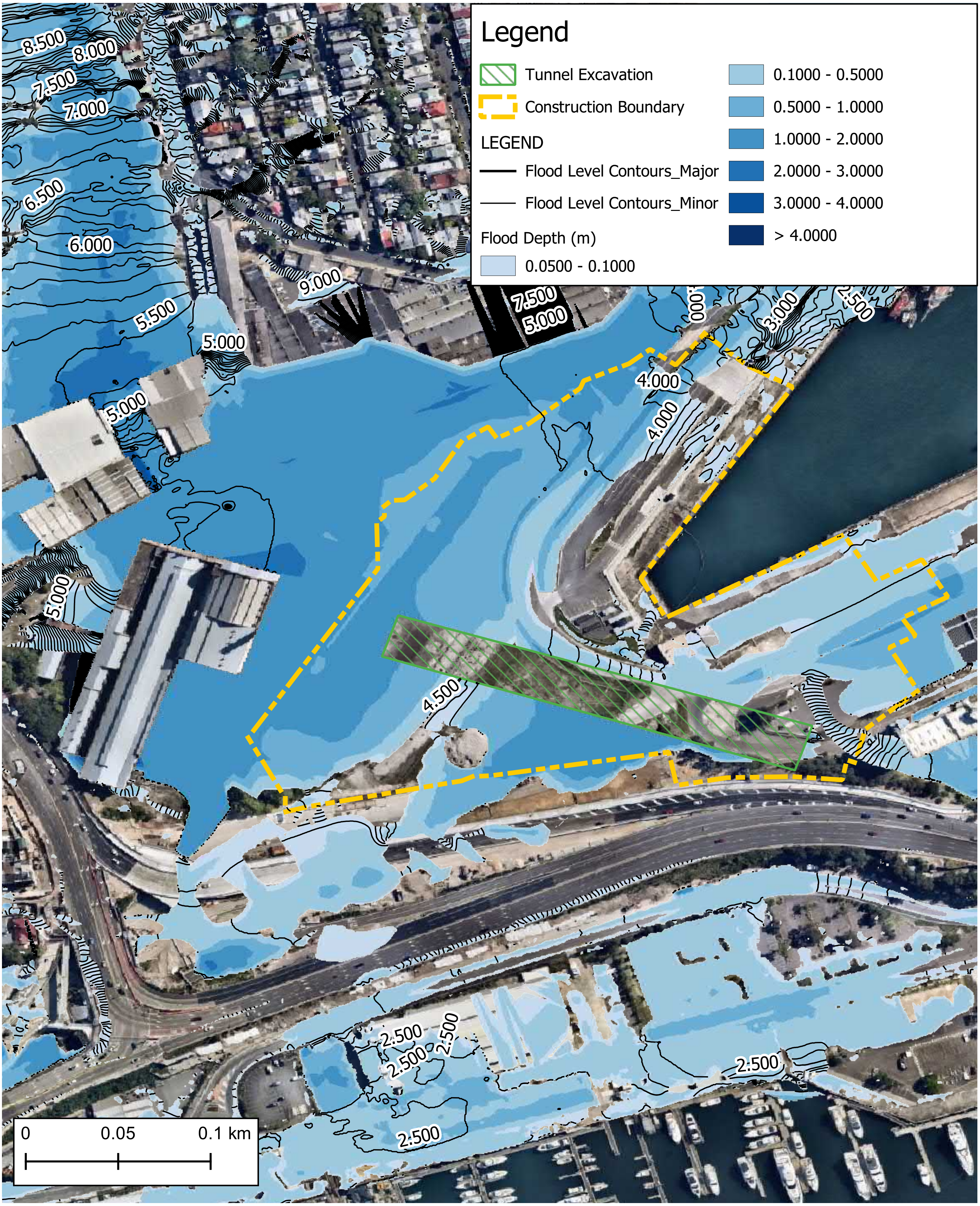
Figure B-9 1% AEP Baseline Stage Depth
Figure B-10 PMF Baseline Depth
Figure B-11 1% AEP Baseline Hazard
Figure B-12 PMF Baseline Hazard



TITLE	
Figure B-1 1% AEP Baseline Stage Depth	NSW GOVERNMENT / sydney METRO
PROJECT EDS-SWM-The Bays	

Date	Drawn	Check	Approved	Scale	Rev
27/05/2021	MK	JM	DF	1 : 2000	1

TBY_CST_100y_d_MAX_cd0.05.asc



TITLE

Figure B-2

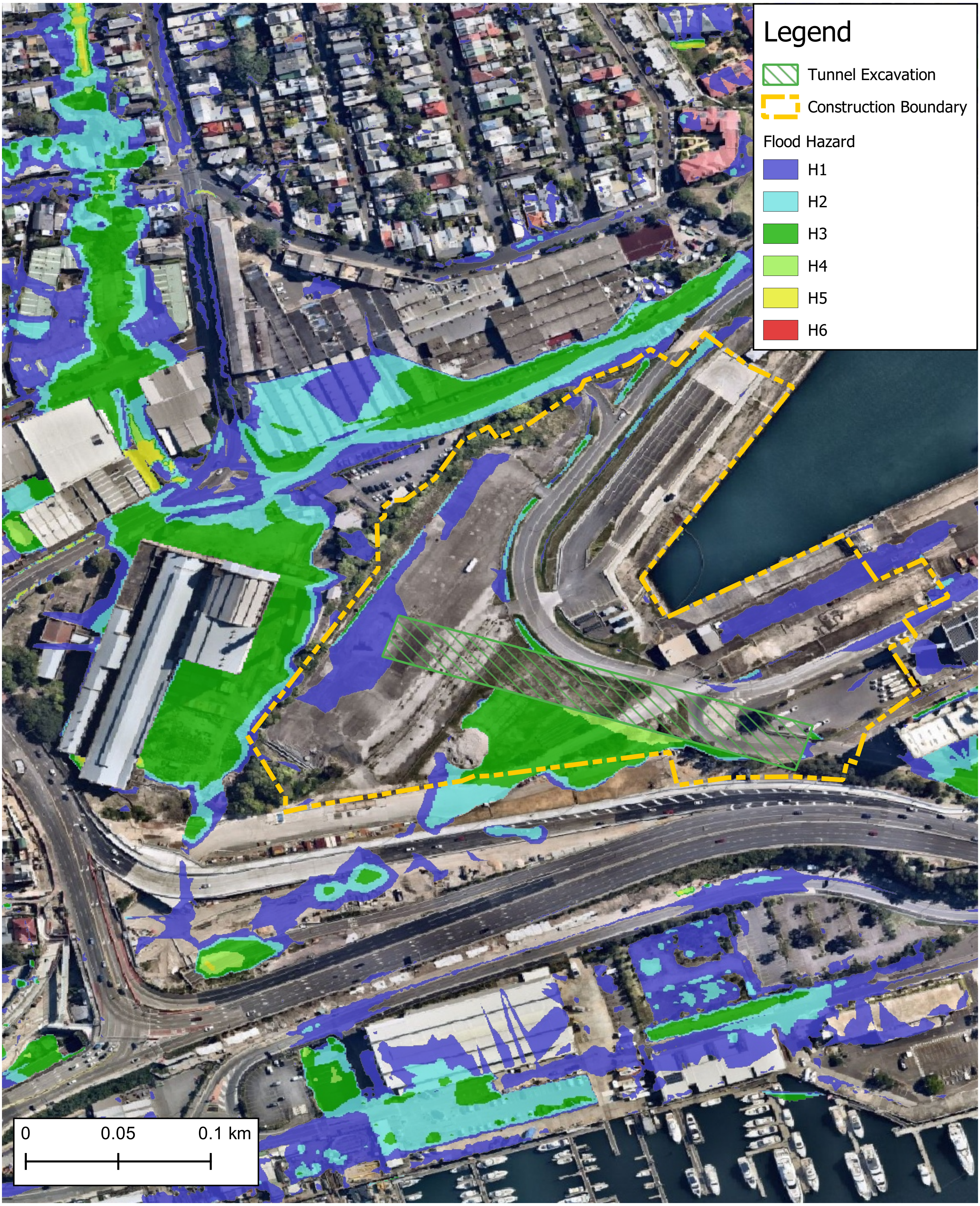
PMF Baseline Stage Depth

PROJECT

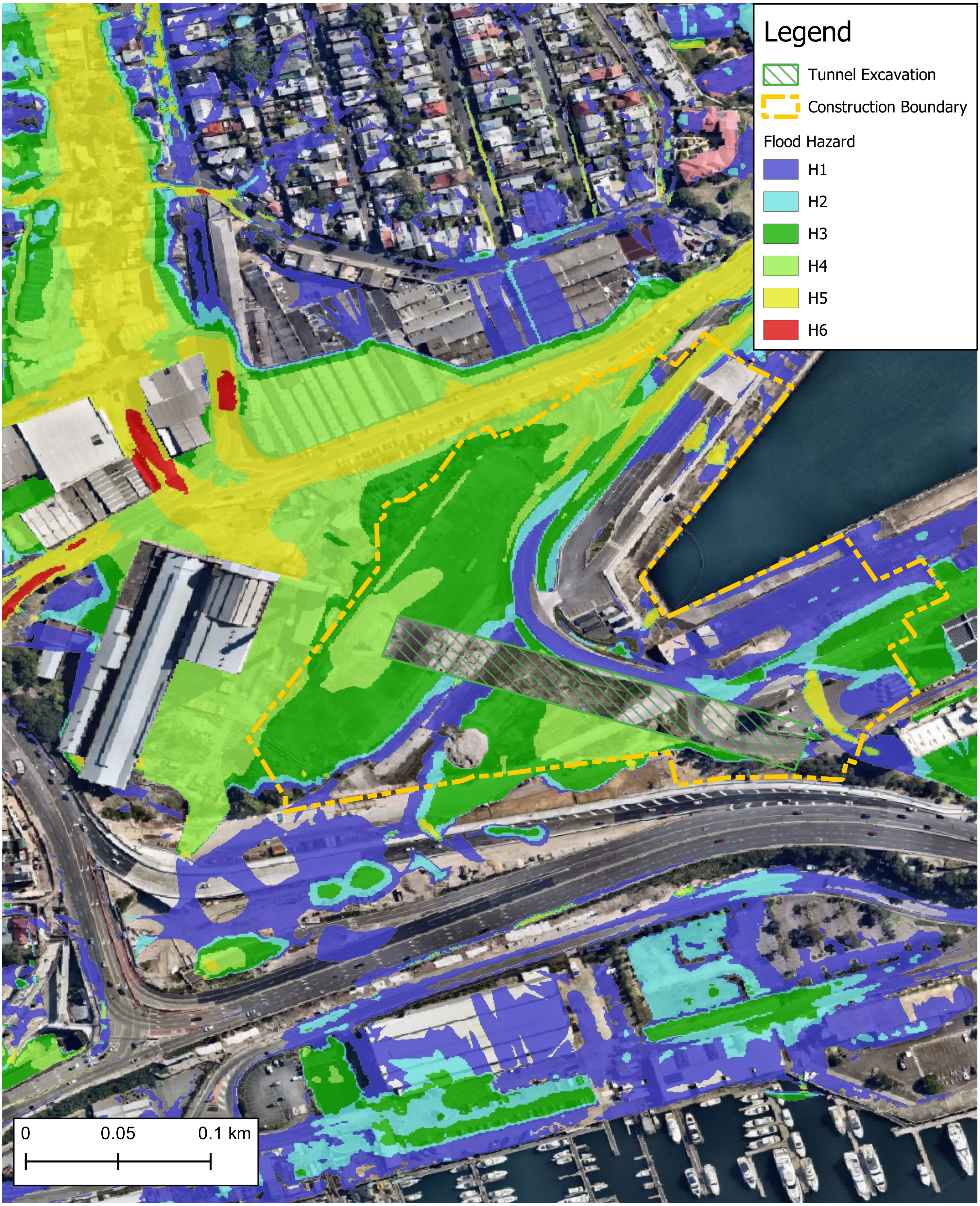
EDS-SWM-The Bays

NSW GOVERNMENT | sydney METRO

Date	Drawn	Check	Approved	Scale	Rev
27/05/2021	MK	JM	DF	1 : 2000	1



TITLE Figure B-3 1% AEP Baseline Stage Hazard PROJECT EDS-SWM-The Bays					
Date 31/05/2021	Drawn MK	Check JM	Approved DF	Scale 1 : 2000	Rev 1



TITLE

Figure B-4

PMF Baseline Stage Hazard

PROJECT

EDS-SWM-The Bays

NSW GOVERNMENT | sydney METRO

Date	Drawn	Check	Approved	Scale	Rev
31/05/2021	MK	JM	DF	1 : 2000	1

Legend

- Construction Hoarding
- Pyrmont Construction Site

Existing Flood Depth 1% AEP

- <= 0.010
- 0.010 - 0.050
- 0.050 - 0.100
- 0.100 - 0.500
- 0.500 - 1.000
- 1.000 - 2.000
- 2.000 - 3.000
- 3.000 - 4.000
- > 4.000

- Flood Level Contours_Major
- Flood Level Contours_Minor

TITLE

Figure B-5
1% AEP Baseline Stage Depth

PROJECT

EDS-SWM- Pyrmont Station

0 0.1 0.2 km

Date	Drawn	Check	Approved	Scale	Rev
16/06/2021	SH	FH	JM	1 : 2500	1

Legend

- Construction Hoarding
- Pyrmont Construction Site

Existing Flood Depth PMF

- <= 0.010
- 0.010 - 0.050
- 0.050 - 0.100
- 0.100 - 0.500
- 0.500 - 1.000
- 1.000 - 2.000
- 2.000 - 3.000
- 3.000 - 4.000
- > 4.000

- Flood Level Contours_Minor
- Flood Level Contours_Major

TITLE

Figure B-6
PMF Baseline Depth

PROJECT

EDS-SWM- Pyrmont Station

0 0.1 0.2 km

NSW GOVERNMENT

sydney METRO

Date	Drawn	Check	Approved	Scale	Rev
16/06/2021	SH	FH	JM	1 : 2500	1

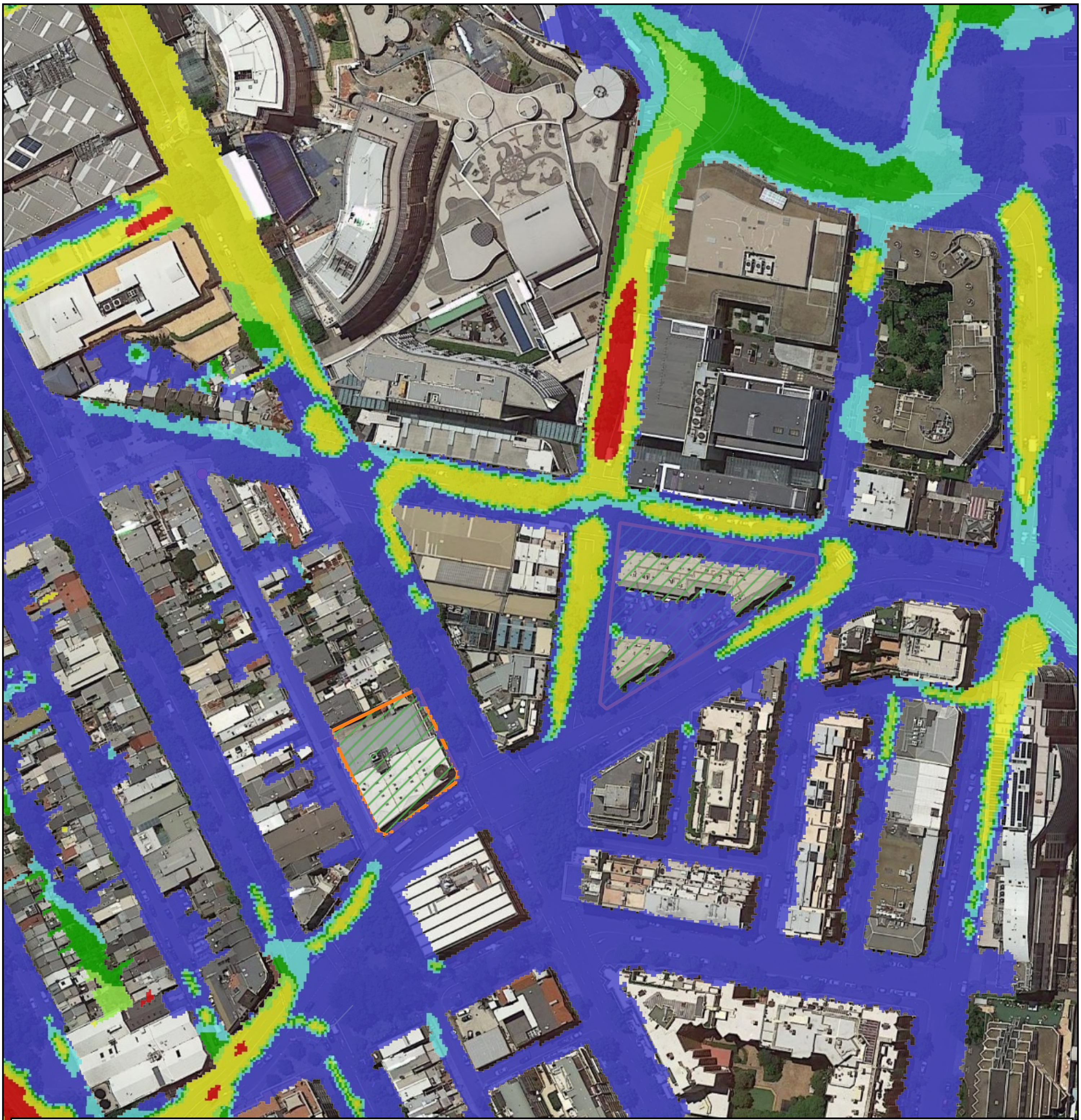
TITLE

Figure B-7
1% AEP Baseline Hazard

PROJECT
Proposed Scenario
EDS-SWM- Pyrmont Station

0 0.1 0.2 km

Date	Drawn	Check	Approved	Scale	Rev
16/06/2021	SH	FH	JM	1 : 2500	1



Legend

Construction Hoarding

Pyrmont Construction Site

Existing Flood Hazard PMF

H1

H2

H3

H4

H5

H6

TITLE

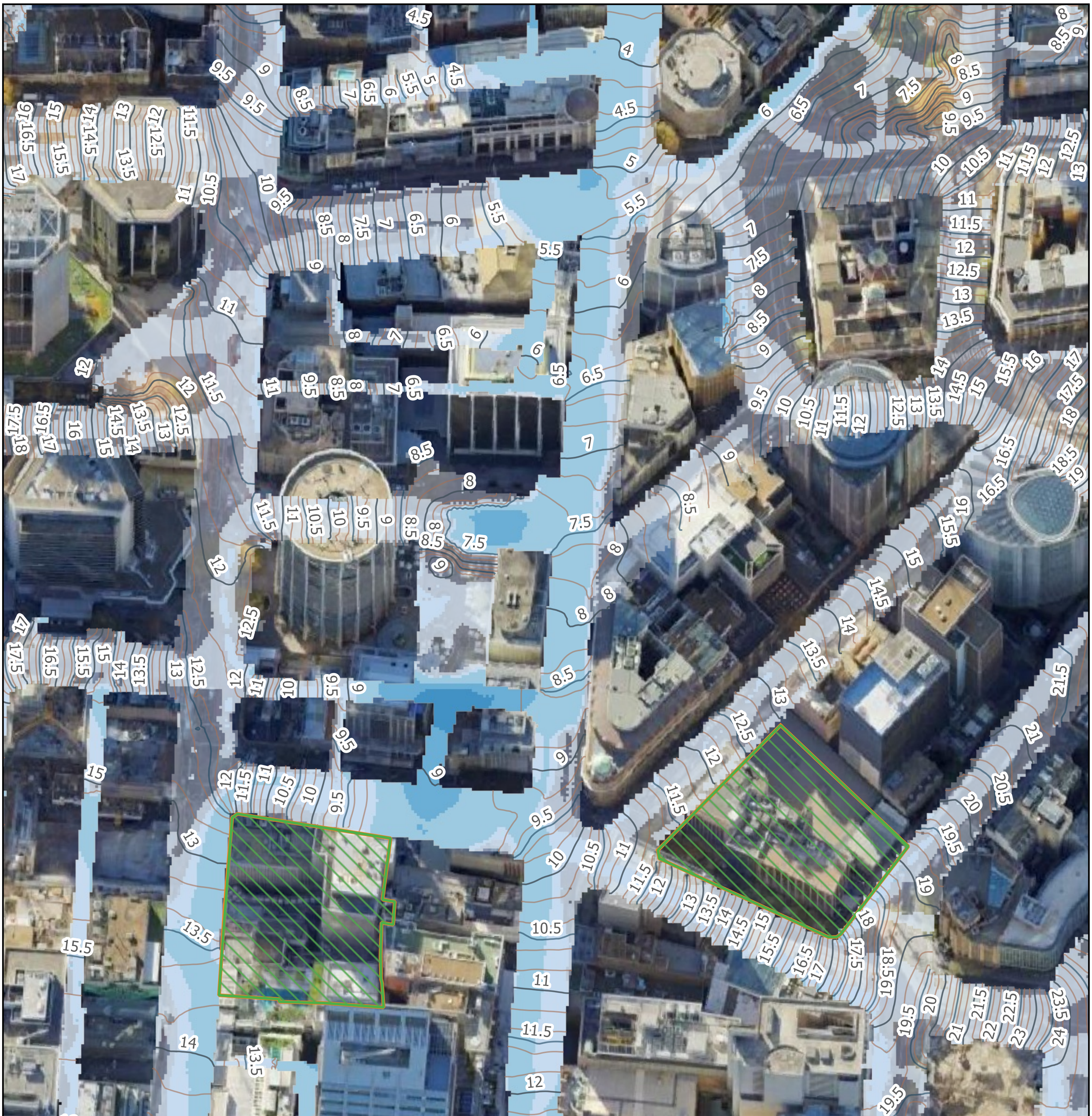
Figure B-8
PMF Baseline Hazard

PROJECT

EDS-SWM- Pyrmont Station

0 0.1 0.2 km

Date	Drawn	Check	Approved	Scale	Rev
16/06/2021	SH	FH	JM	1 : 2500	1



Legend

- Construction Hoarding
- Hunter Street Construction Site

Existing Flood Depth 1% AEP

- <= 0.010
- 0.010 - 0.050
- 0.050 - 0.100
- 0.100 - 0.500
- 0.500 - 1.000
- 1.000 - 2.000
- 2.000 - 3.000
- 3.000 - 4.000
- > 4.000
- Flood Level Contours_Minor
- Flood Level Contours_Major

TITLE

Figure B-9

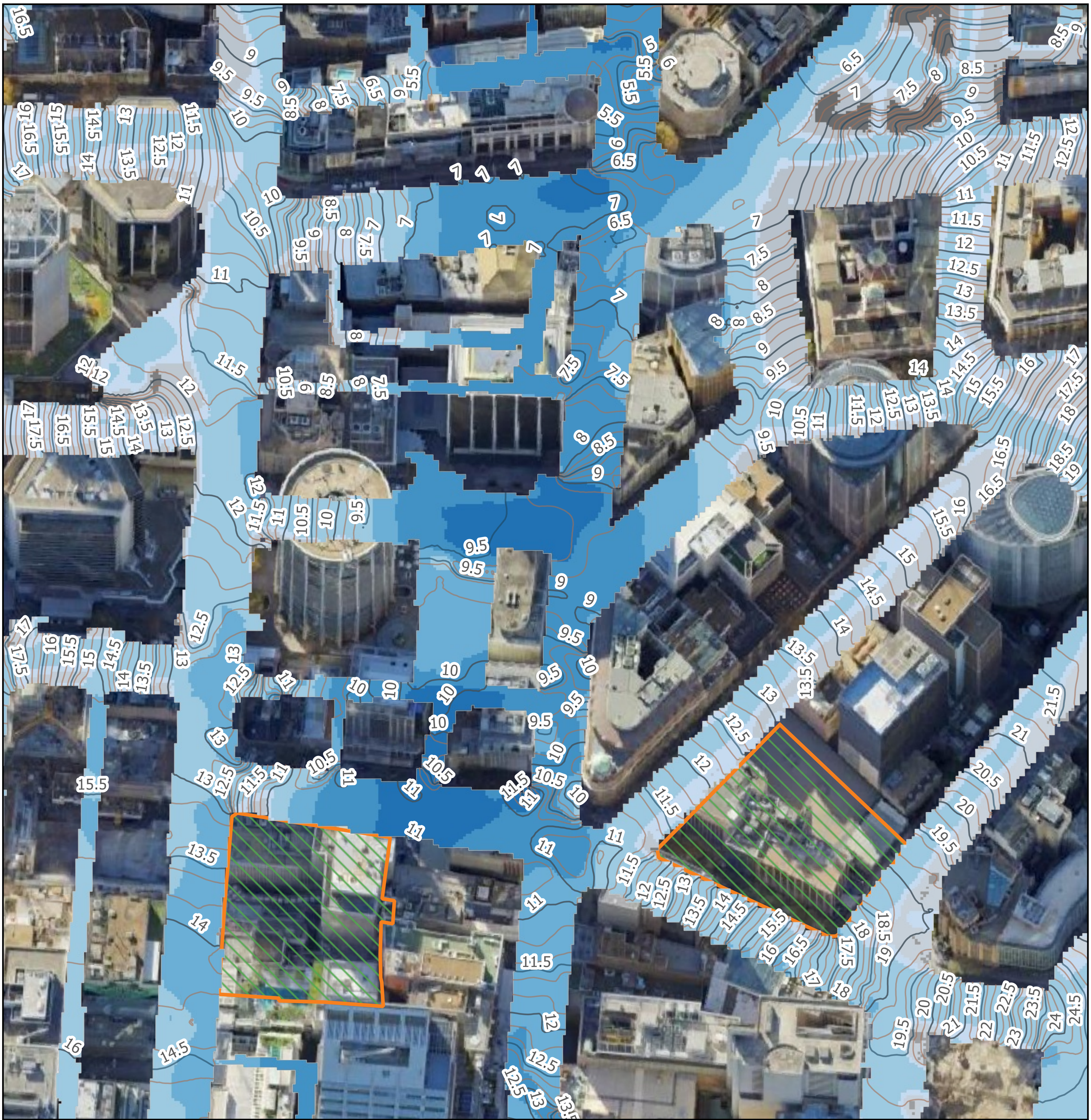
1% AEP Baseline Stage Depth

PROJECT

EDS-SWM- Hunter Street

0 25 50 m

Date	Drawn	Check	Approved	Scale	Rev
16/06/2021	SH	FH	JM	1 : 2000	1



Legend

Construction Hoarding

Hunter Street Construction Site

Existing Flood Depth PMF

- <= 0.010
- 0.010 - 0.050
- 0.050 - 0.100
- 0.100 - 0.500
- 0.500 - 1.000
- 1.000 - 2.000
- 2.000 - 3.000
- 3.000 - 4.000
- > 4.000

Flood Level Contours_Major

Flood Level Contours_Minor

TITLE

Figure B-10
PMF Baseline Depth

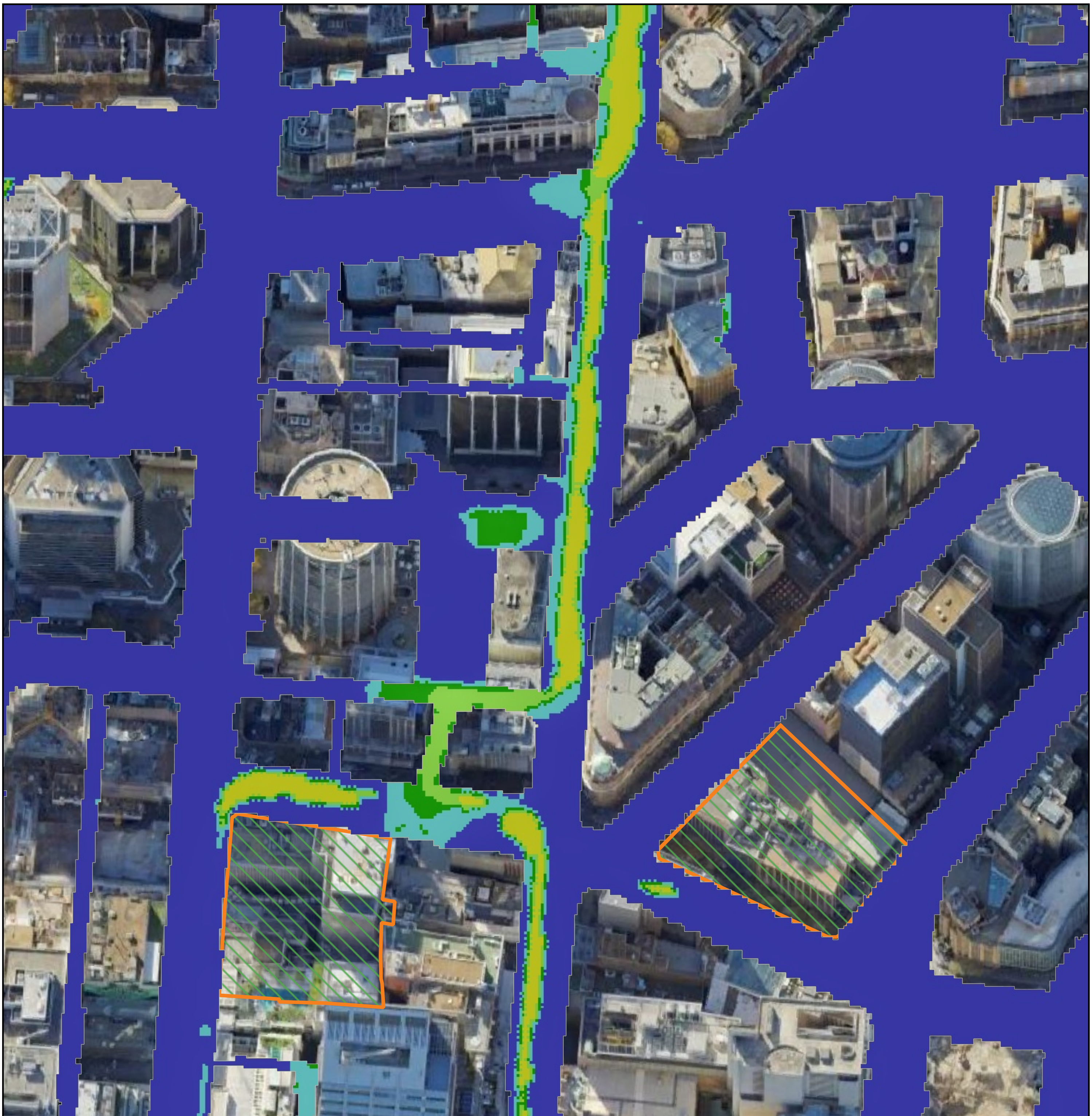
PROJECT

EDS-SWM-Hunter Street

NSW GOVERNMENT | sydney METRO

0 25 50 m

Date	Drawn	Check	Approved	Scale	Rev
17/06/2021	SH	FH	JM	1 : 2000	1



Legend

Construction Hoarding

Hunter Street Construction Site

Existing Flood Hazard 1% AEP

H1

H2

H3

H4

H5

H6

TITLE

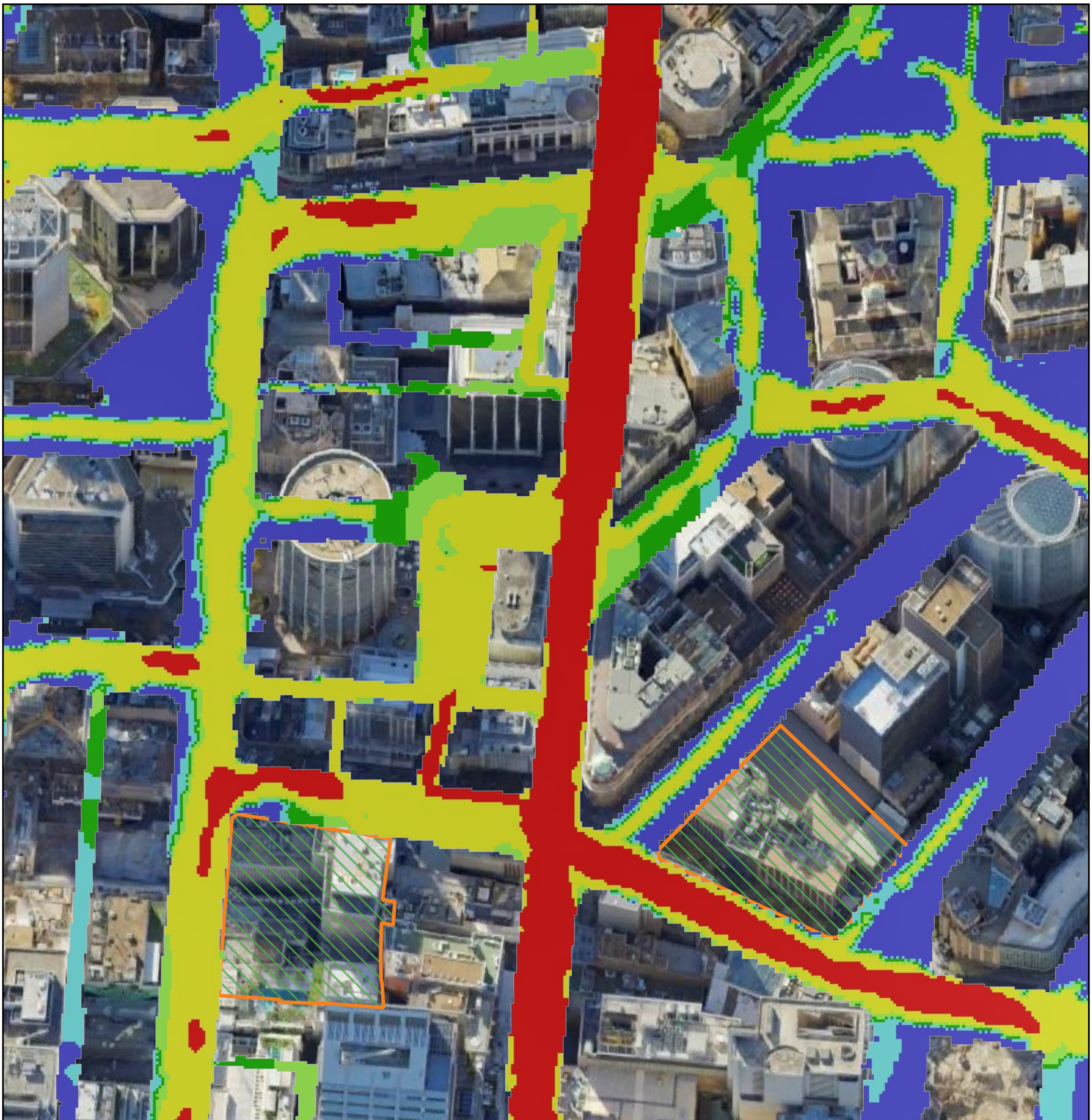
Figure B-11
1% AEP Baseline Hazard

PROJECT

EDS-SWM- Hunter Street

0 25 50 m

Date	Drawn	Check	Approved	Scale	Rev
16/06/2021	SH	FH	JM	1 : 2000	1



Legend

Construction Hoarding		H2		H5
Hunter Street Construction Site		H3		H6
Existing Flood Hazard PMF		H4		
H1				

TITLE

Figure B-12
PMF Baseline Hazard

PROJECT

EDS-SWM-Hunter Street

0 25 50 m

Date	Drawn	Check	Approved	Scale	Rev
17/06/2021	SH	FH	JM	1 : 2000	1