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SYDENHAM TO BANKSTOWN

ENVIRONMENTAL IMPACT STATEMENT

> Technical Paper 8 - Hydrology, flooding and water quality assessment

NSW GOVERNMENT

GHD

Transport for NSW

Sydney Metro City & Southwest

Sydenham to Bankstown upgrade

Environmental Impact Statement

Technical Paper 8 – Hydrology, Flooding and Water Quality

August 2017

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Executive summary

Transport for NSW ('the proponent') is seeking approval to construct and operate the Sydenham to Bankstown upgrade component of Sydney Metro City & Southwest (the 'project'). The project involves upgrading the existing rail corridor (from about 800 metres west of Sydenham Station in Marrickville, to about one kilometre west of Bankstown Station in Bankstown), the 10 existing stations within the corridor, and areas surrounding the rail corridor

This Hydrology, Flooding and Water Quality Technical Paper has been prepared in accordance with the Secretary's Environmental Assessment Requirements (SEARs) to describe the surface water environment present at the study area, assess impacts of the project on surface water quality, hydrology and flooding and identify mitigation measures to manage the project impact.

The assessment was based on a desktop review of available information regarding surface water, site visits and analysis and modelling undertaken by the designers for the project.

The project area from Marrickville to Punchbowl Station is located in the surface water catchment of the Cooks River and its tributaries which drain to Botany Bay. A smaller component of the project from Punchbowl Station to Bankstown Station drains to Salt Pan Creek via the stormwater drainage network. Salt Pan Creek drains to the Georges River which also discharges to Botany Bay.

Land use in the catchments of Salt Pan Creek and the Cooks River is highly modified from its natural state through the majority of the catchment including in the project area. In the lower reaches and estuary areas downstream of the project area there remain areas of each of the catchments that are closer to their natural state. The majority of the project area is located within the rail corridor, which has been cleared and substantially modified through earthworks and construction.

A technical report prepared by the designers identified the presence of existing drainage and flooding issues within the project area. Local flooding was generally found to be caused by a insufficient drainage within the rail corridor or insufficient capacity in the local stormwater drainage network. There are existing flooding problems within the rail corridor near Marrickville Station. Flooding is caused by overland flows which exceed the capacity of the stormwater drainage network.

According to recent studies undertaken by the NSW Government, water quality in Salt Pan Creek is considered "good". Water quality near the outlet of the Cooks River in Botany Bay is also rated as "good", however the Cooks River has been identified as a source of pollutants in the bay indicating less favourable water quality.

The reference design includes changes to existing drainage as part of the project to replace assets in poor condition and provide new or improved track drainage and cross drainage structures. Major works include the provision of a number of detention basins to mitigate increases in peak flow rates. Provision of water quality treatment devices in the form of rain gardens and gross pollutant traps is also proposed.

Key construction stage impacts include the potential for increased sediment being discharged to downstream systems, flooding and overland flow from construction worksites and compounds on flood-liable land.

To mitigate these impacts, erosion and sediment control measures would be implemented during construction in accordance with the Construction Environemtnal Management Plan. A surface water monitoring framework would be implemented to monitor surface water quality in the vicinity of the project.

Construction impacts would be managed through the implementation of a soil and water management plan(s) in accordance with the *Managing urban stormawater soild and construction- Volume 1 (Landom, 2004)* and detailed planning and management of construction sites to avoid any adverse impacts.

With drainage works also being undertaken as part of other nearby projects, there is a risk of cumulative construction stage flooding and water quality impacts. Coordination with these other works will be important to mitigate potential cumulative impacts.

Flood mitigation and drainage measures proposed as part of project are predicted to provide effective mitigation of flood impacts for the full range of events from the 63 per cent Annual Exceedance Probability (one-year average recurrence interval) event to the probable maximum flood (PMF) event. Flood mapping undertaken for the project indicates that at most locations, there would be a reduction in flood depth and extent. Further, where there are increases, the post-development flood levels would generally not increase by more than 50 millimetres above existing levels, which satisfies the design limit adopted for the project.

A flood warning and evacuation plan would also be developed with consideration of emergency management of flooding for events up to and including the PMF.

Operational water quality impacts would be managed through implementation of water sensitive urban design measures. A water quality monitoring program would be developed to monitor water quality outcomes against long-term water quality objectives.

The proposed drainage works have taken into account the Inner City and Canterbury- Bankstown council's own drainage plans to ensure that there are no conflicts and that no cumulative impacts would occur during the operational phase. Consultation and coordination with these councils would continue throughout the different phases of the project. The opportunity exists for some of the proposed works to be brought forward, which would be beneficial in mitigating some existing drainage issues in the project area and surrounds.

Potential cumulative impacts from other projects, including the Chatswood to Sydenham project, WestConnex, and the Sydenham to Bankstown Urban Renewal Corridor projects were identified, but were not considered to be an issue for this project.

Glossary and abbreviations

<table>
<tr><th>Term</th><th>Definition</th></tr>
<tr><td>Annual exceedance probability (AEP)</td><td>The annual exceedance probability is a measure of the frequency of a rainfall event. It is the probability that a given rainfall total, accumulated over a given duration, will be exceeded in any one year. A one % AEP event is a rainfall event with a one % chance of being exceeded in magnitude in any year.
The current Australian Rainfall and Runoff Guideline (Commonwealth of Australia, 2016) recommends the use of AEP terminology whereas historically, the term average recurrence interval (ARI) was used. Where reference documents have used ARI, this has been converted to an equivalent AEP using the information below (Bureau of Meteorology, 2016).
<table>
<tr><th>ARI (years)</th><th>AEP (%)</th></tr>
<tr><td>1</td><td>63</td></tr>
<tr><td>2</td><td>39</td></tr>
<tr><td>5</td><td>18</td></tr>
<tr><td>10</td><td>10</td></tr>
<tr><td>20</td><td>5</td></tr>
<tr><td>50</td><td>2</td></tr>
<tr><td>100</td><td>1</td></tr>
</table>
</td></tr>
<tr><td>Afflux</td><td>With reference to flooding, afflux refers to the predicted change, usually in flood levels, between two scenarios. It is frequently used as a measure of the change in flood levels between an existing scenario and a proposed scenario.</td></tr>
<tr><td>Australian Height Datum (AHD)</td><td>A common reference level used in Australia which is approximately equivalent to the height above sea level.</td></tr>
<tr><td>Average recurrence interval (ARI)</td><td>The average recurrence interval is a measure of the frequency of a rainfall event. It is the expected average value of the periods between exceedances of a given rainfall total accumulated over a given duration eg. 1 in 100 years.
However, this sometimes resulted in the term being misinterpreted as implying that the associated magnitude is only exceeded at regular intervals, and that it was referring to the elapsed time to the next exceedance. In fact, the periods between events of a similar magnitude are random and unpredictable.
For these reasons, the annual exceedance probability (AEP) is now the preferred terminology.</td></tr>
<tr><td>Blue Book</td><td>Managing Urban Stormwater: Soils and Construction Handbook (see References in Section 9)</td></tr>
<tr><td>Catchment</td><td>The area drained by a stream or body of water or the area of land from which water is collected.</td></tr>
<tr><td>Climate change event</td><td>In this report, the 1 % AEP climate change event is a 1 % AEP event including a 10 % increase in peak rainfall intensity to incorporate the possible future effects of climate change.</td></tr>
<tr><td>Datum</td><td>A level surface used as a reference in measuring elevations.</td></tr>
</table>

Term	Definition
Discharge	Quantity of water per unit of time flowing in a stream, for example cubic meters per second or megalitres per day.
Erosion	A natural process where wind or water detaches a soil particle and provides energy to move the particle.
Flood	For the purposes of this report, a flood is defined as the inundation of normally dry land by water which escapes from, is released from, is unable to enter, or overflows from the normal confines of a natural body of water or watercourse such as rivers, creeks or lakes, or any altered or modified body of water, including dams, canals, reservoirs and stormwater channels.
Flood immunity	Flood immunity has been used in this report to describe the minimum AEP above which infrastructure must be set. So the flood level of a building required to have a flood immunity of the 1 % AEP must be set at a level above the 1 % AEP flood.
Flood liable land	Land which is within the extent of the probable maximum flood and therefore prone to flooding. See probable maximum flood.
Floodplain	The area of land subject to inundation by floods up to and including the probable maximum flood.
Floodway	The area of the floodplain where a significant portion of flow is conveyed during floods. Usually aligned with naturally defined channels.
Formation	A fundamental unit used in the classification of rock or soil sequences, generally comprising a body with distinctive physical and chemical features.
Geomorphology	Scientific study of landforms, their evolution and the processes that shape them. In this report, geomorphology relates to the form and structure of watercourses.
Groundwater	Subsurface water stored in pores of soil or rocks.
Hazard	The potential or capacity of a known or potential risk to cause adverse effects. See also Flood Hazard, which has a particular definition in the NSW Floodplain Development Manual and is described in this report
Hydraulics	The physics of channel and floodplain flow relating to depth, velocity and turbulence.
Hydrology	The study of rainfall and surface water runoff processes.
Impervious	In the context of this report, impervious surfaces are surfaces non-permeable to water. These include areas such as paved surfaces or rooves.
Infiltration	The downward movement of water into soil and rock, which is largely governed by the structural condition of the soil, the nature of the soil surface (including presence of vegetation) and the antecedent moisture content of the soil.
Landform	A specific feature of the landscape or the general shape of the land.
LPI	NSW Land and Property Information
Meteorology	The science concerned with the processes and phenomena of the atmosphere, especially as a means of forecasting the weather.
Overbank	The portion of the flow that extends over the top of watercourse banks.

Term	Definition
Overland flow path	The path that water can follow if it leaves the confines of the main flow channel. Overland flow paths can occur through private property or along roads. Water travelling along overland flow paths, often referred to as 'overland flows', may either re-enter the main channel or may be diverted to another watercourse.
Permeability	The capacity of a porous medium to transmit water.
Probable maximum flood (PMF)	The probable maximum flood is the maximum flood which can theoretically occur based on the worst combination of the probable maximum precipitation and flood-producing catchment conditions that are reasonably possible at a given location.
Project area	The term 'project area' is used throughout this document to refer to the area where the project would be undertaken, including the existing rail corridor (from about one kilometre north-east of Sydenham Station to about one kilometre west of Bankstown Station), at the 11 existing stations within the corridor, and the area surrounding the rail corridor.
Riparian	Pertaining to, or situated on, the bank of a river or other water body.
Risk	The chance of something happening that will have an impact measured in terms of likelihood and consequence.
Risk assessment	Systematic process of evaluating potential risks of harmful effects on the environment from exposure to hazards associated with a particular product or activity.
Runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
Salinity	The total soluble mineral content of water or soil (dissolved solids); concentrations of total salts are expressed as milligrams per litre (equivalent to parts per million).
Sediment	Material of varying sizes that has been or is being moved from its site of origin by the action of wind, water or gravity.
Stream order	Stream classification system, where order 1 is for headwater (new) streams at the top of a catchment. Order number increases downstream using a defined methodology relating to the branching of streams.
Study area	The study area for this report includes the catchments of Salt Pan Creek and the Cooks River as shown on the figures. See also 'project area'.
Surface water	Water that is derived from precipitation or pumped from underground and may be stored in dams, rivers, creeks and drainage lines.
Topography	Representation of the features and configuration of land surfaces.
Watercourse	Generic term used to refer to rivers, streams and creeks.
Water quality	Chemical, physical and biological characteristics of water. Also the degree (or lack) of contamination.
Water sharing plan	A legal document prepared under the *Water Management Act 2000* (NSW) that establishes rules for sharing water between the environmental needs of the river or aquifer and water users and also different types of water use.

Term	Definition
Water table	The surface of saturation in an unconfined aquifer, or the level at which pressure of the water is equal to atmospheric pressure.

1. Introduction

1.1 Overview

1.1.1 Project background

The New South Wales (NSW) Government is implementing *Sydney's Rail Future* (Transport for NSW, 2012a), a plan to transform and modernise Sydney's rail network so that it can grow with the city's population and meet the needs of rail customers into the future.

Sydney Metro is a new standalone rail network identified in *Sydney's Rail Future*, providing 66 kilometres of metro rail line and 31 metro stations. The NSW Government is currently delivering the first two stages of Sydney Metro, shown in Figure 1-1, which consist of Sydney Metro Northwest (between Rouse Hill and Chatswood) and Sydney Metro City & Southwest (between Chatswood and Bankstown).

Sydney Metro Northwest is currently under construction. Sydney Metro Northwest services will start in the first half of 2019, with a metro train running every four minutes in the peak period. Services will operate between a new station at Cudgegong Road (beyond Rouse Hill) and Chatswood Station.

Sydney Metro City & Southwest will extend the Sydney Metro system beyond Chatswood to Bankstown, delivering about 30 kilometres of additional metro rail, a new crossing beneath Sydney Harbour, new railway stations in the lower North Shore and Sydney central business district (CBD), and the upgrade of existing stations from Marrickville to Bankstown. City & Southwest trains would run between Sydenham and Bankstown stations in each direction, at least every four minutes in peak periods, averaging around 15 trains per hour.

Sydney Metro City & Southwest comprises two core components (shown in Figure 1-1):

- The Chatswood to Sydenham project
- The Sydenham to Bankstown upgrade ('the project' and the subject of this document).

1.1.2 The project for which approval is sought

Transport for NSW is seeking approval to construct and operate the Sydenham to Bankstown upgrade component of Sydney Metro City & Southwest (the project).

The project involves upgrading 10 existing stations west of Sydenham (Marrickville to Bankstown inclusive), and a 13 kilometre long section of the Sydney Trains T3 Bankstown Line, between west of Sydenham Station and west of Bankstown Station, to improve accessibility for customers and meet the standards required for metro operations. The project would enable Sydney Metro to operate beyond Sydenham, to Bankstown.

A key element of the project is upgrading stations along the corridor from Marrickville to Bankstown, to allow better access for more people by providing new concourses, level platforms, and lifts at stations. These upgrades aim to provide a better, more convenient, and safer experience for public transport customers, by delivering:

- Stations that are accessible to people with a disability or limited mobility, the elderly, people with prams, and people travelling with luggage.
- Upgraded station buildings and facilities for all transport modes that meet the needs of a growing population.
- Interchanges that support an integrated transport network and allow seamless transfers between different modes for all customers.

The project is subject to assessment and approval by the NSW Minister for Planning under Part 5.1 of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act).

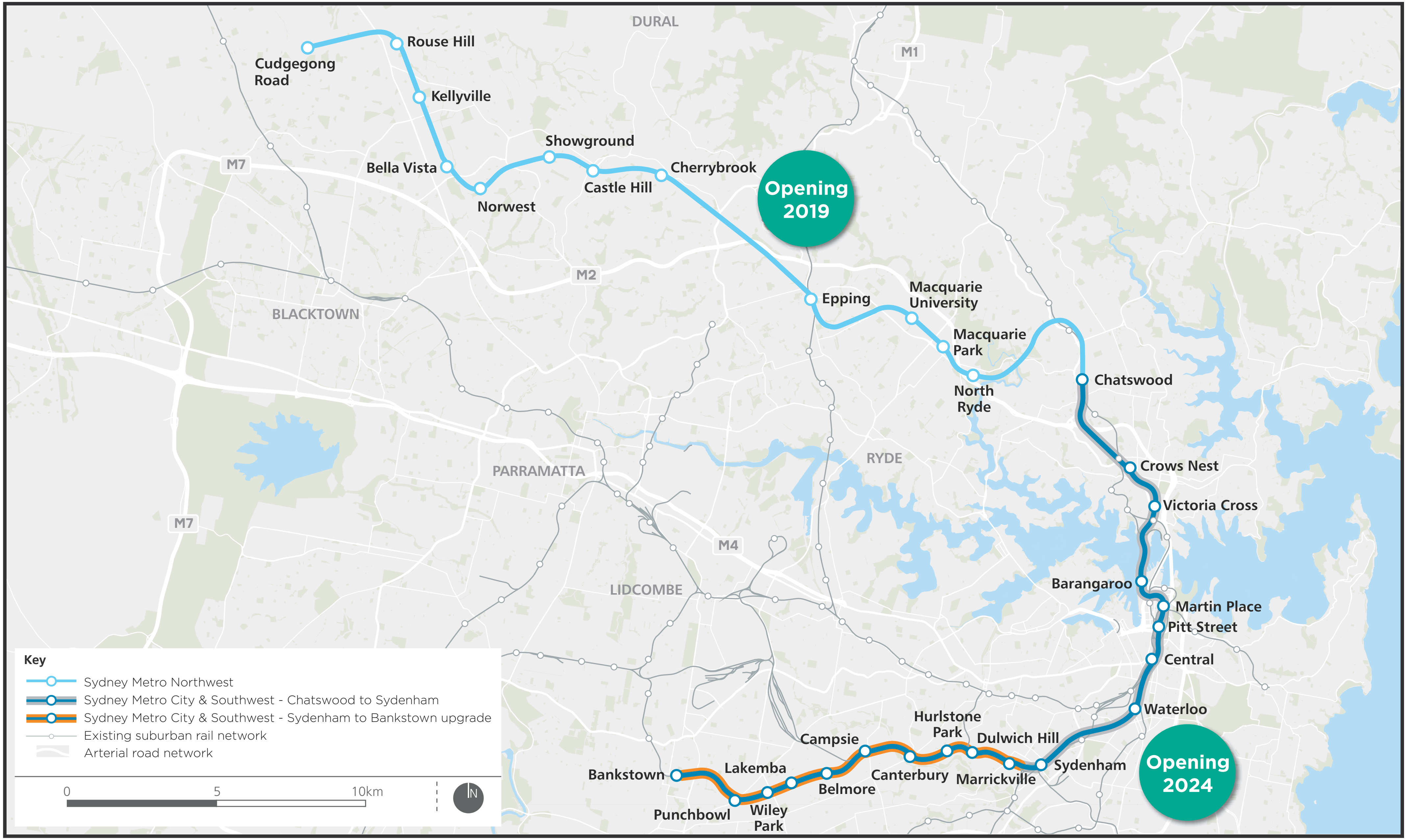
1.2 The project

1.2.1 Location

The location of the project is shown in Figure 1-2.

The key elements of the project are located mainly within the existing rail corridor, from about 800 metres west of Sydenham Station in Marrickville, to about one kilometre west of Bankstown Station in Bankstown. The project is located in the Inner West and Canterbury-Bankstown local government areas.

The term ‘project area’ is used throughout this document to refer to the area where the physical works for the project would be undertaken. This area encompasses the existing rail corridor (as described above), the 10 existing stations within the corridor, and areas surrounding the rail corridor as shown in Figure 1-2.



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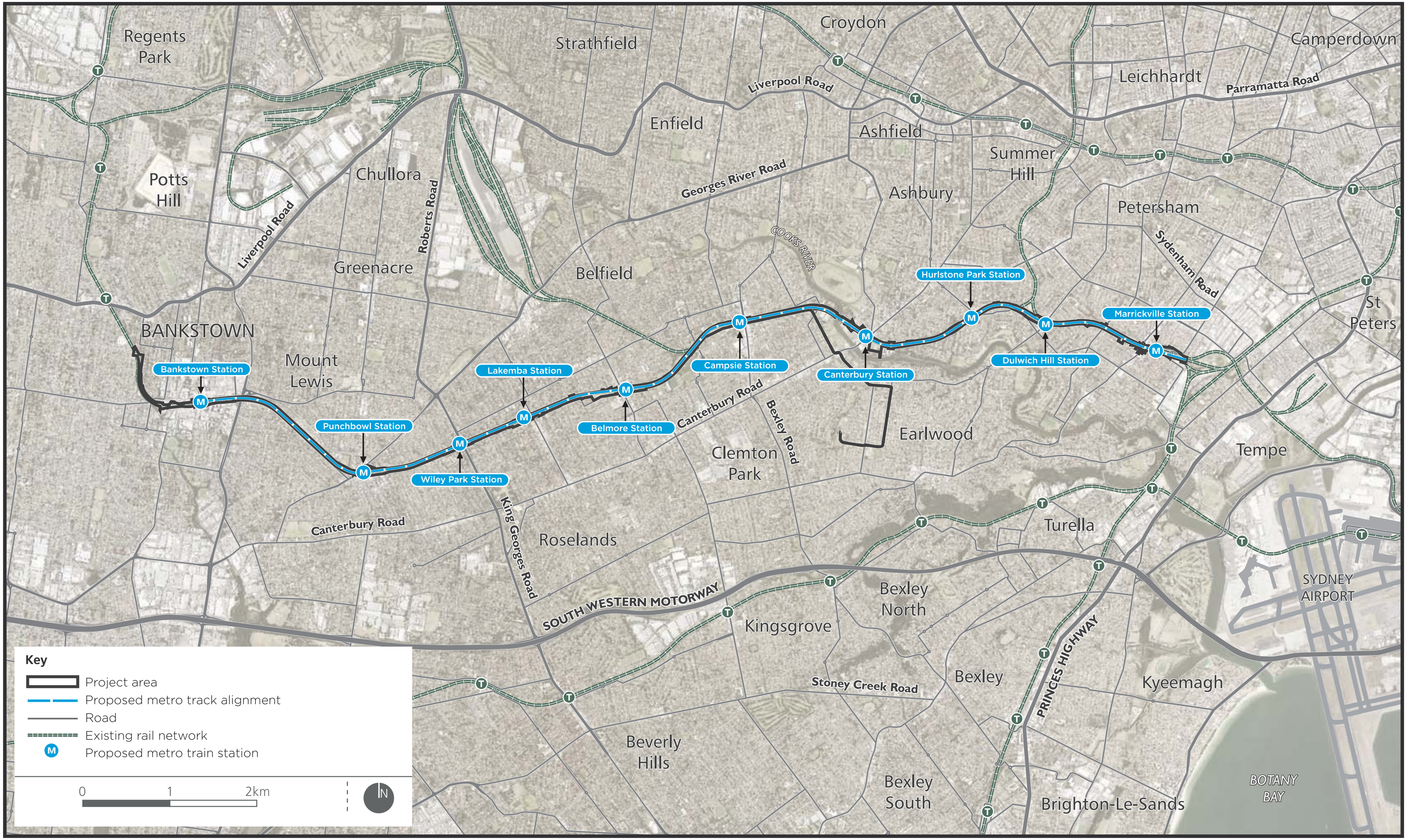
The Sydney Metro network

FIGURE 1.1



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Overview of the project

FIGURE 1.2

1.2.2 Key features

The key features of the project are summarised below and are shown in Figure 1-2.

Works to upgrade access at stations

The project includes upgrading the 10 stations from Marrickville to Bankstown as required, to meet legislative requirements for accessible public transport, including the requirements of the *Disability Discrimination Act 1992* and the *Disability Standard for Accessible Public Transport 2002*. The proposed works include:

- Works to platforms to address accessibility issues, including levelling and straightening platforms.
- New station concourse and station entrance locations, including:
  - new stairs and ramps
  - new or relocated lifts
- Provision of additional station facilities as required, including signage and canopies.

Works would also be undertaken in the areas around the stations to better integrate with other modes of transport, improve travel paths, and meet statutory accessibility requirements. This would include provision of pedestrian, cyclist, and other transport interchange facilities; as well as works to the public domain, including landscaping.

Works to convert stations and the rail line to Sydney Metro standards

Station works

In addition to the station upgrades to improve accessibility, works to meet the standards required for metro services would be carried out, including:

- Installation of platform screen doors
- Provision of operational facilities, such as station services buildings

Track and rail system facility works

Upgrading the track and rail systems to enable operation of metro services would include:

- Track works where required along the rail corridor, including upgrading tracks and adjusting alignments, between west of Sydenham Station and west of Bankstown Station.
- New turnback facilities and track crossovers.
- Installing Sydney Metro rail systems and adjusting existing Sydney Trains rail systems.
- Overhead wiring adjustments.

Other works

Other works proposed to support Sydney Metro operations include:

- Upgrading existing bridges and underpasses across the rail corridor
- Installation of security measures, including fencing
- Installation of noise barriers where required
- Modifications to corridor access gates and tracks
- Augmenting the existing power supply, including new traction substations and provision of new feeder cables
- Utility and rail system protection and relocation works

- Drainage works to reduce flooding and manage stormwater.

Active transport corridor and surrounding development

The project would also provide for:

- Parts of an active transport corridor where located within the station areas or surplus rail corridor land, to facilitate walking and cycling connections to each station and between Marrickville and Bankstown.
- Enabling works to support future development at Campsie Station (future development would be subject to a separate approvals process).

Temporary works during construction

During construction, the project would involve:

- Provision of temporary facilities to support construction, including construction compounds and work sites.
- Implementation of alternative transport arrangements for rail customers during possession periods and/or station closures, guided by the Temporary Transport Strategy.

1.2.3 Timing

Construction

Construction of the project would commence once all necessary approvals are obtained (anticipated to be in 2018), and would take about five years to complete.

The T3 Bankstown Line would remain operational for the majority of the construction period. However, to ensure the station and infrastructure upgrade works are completed as efficiently and safely as possible and to accommodate works that cannot be undertaken when trains are operating, it would be necessary to undertake some work during rail possession periods, when trains are not operating. It is anticipated that these rail possession periods would comprise the routine weekend maintenance possessions, together with some longer possessions during periods of reduced patronage such as school holidays.

A final, longer possession of about three to six months would also be required. This would involve full closure of the line to enable conversion to metro operations. This would include works such as the installation of new signalling, communication systems, and platform screen doors.

During each possession period, alternative transport arrangements would be implemented to ensure that customers can continue to reach their destinations.

Operation

Sydney Metro City & Southwest would be fully operational by 2024, with the opportunity of operation commencing in two phases. Initially, Sydney Metro Northwest services would be extended by the City & Southwest project, and would operate from Chatswood Station to Sydenham Station. Some months later, metro operations would extend from Sydenham Station to Bankstown Station, with both phases planned to be completed before the end of 2024. The opportunity for phased opening of the project would enable metro trains to operate from Cudgegong Road Station to Sydenham Station prior to the final conversion of the T3 Bankstown Line to metro operations.

Once the project is operational, Sydney Trains services would no longer operate along the T3 Bankstown Line between Sydenham and Bankstown stations. Customers would be able to interchange with Sydney Trains services at Sydenham and Bankstown stations. Sydney Trains services to and from Bankstown to Liverpool and Lidcombe stations would not be affected.

1.3 Purpose and scope of this report

This report has been prepared to support the Environmental Impact Statement for the project. The Environmental Impact Statement has been prepared to accompany the application for approval of the project, and addresses the environmental assessment requirements of the Secretary of the Department of Planning and Environment ('the Secretary's environmental assessment requirements').

This report documents:

- An assessment of the existing surface water environment with respect to surface water quality, surface water drainage and flooding.
- Potential surface water impacts as a result of the project.
- Potential control measures and criteria to mitigate project impacts for both the construction and operational stages and measures to mitigate residual impact.

1.4 Secretary's environmental assessment requirements

The Secretary's environmental assessment requirements relating to surface water quality and hydrology, and where these requirements are addressed in this report, are outlined in Table 1-1.

Table 1-1 Secretary's environmental assessment requirements – flooding, water hydrology and water quality

Key issue	Requirement	Where addressed?
6. Flooding and Hydrology	1. The Proponent must assess and model (where appropriate), taking into account relevant Council-adopted flood models or latest flood data available from Councils, the impacts on flood behaviour during construction and operation for flood events ranging from the 1 % AEP up to the probable maximum flood (taking into account sea level rise and storm intensity due to climate change) including:	Refer Appendix B and below
	(a) detrimental increases in the potential flood affectation of other properties, assets and infrastructure;	Section 5.2 Sections 6.2 and 6.3
	(b) consistency (or inconsistency) with applicable Council floodplain risk management plans;	Sections 5.2.3 and 6.3.2
	(c) compatibility with the flood hazard of the land;	Sections 5.2.4 and 6.3.3
	(d) compatibility with the hydraulic functions of flow conveyance in flood ways and storage areas of the land;	Sections 5.2.5 and 6.3.4
	(e) downstream velocity and scour potential;	Sections 5.2.6 and 6.3.5
	(f) impacts the development may have upon existing community emergency management arrangements for flooding. These matters must be discussed with the State Emergency Services and Council; and	Section 5.2.7 and section 6.3.6

Key issue	Requirement	Where addressed?
	(g) any impacts the development may have on the social and economic costs to the community as a consequence of flooding.	Sections 5.2.8 and 6.3.8
	2. The Proponent must 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 project, including stream orders, as per the FBA.	Sections 3.4 to 3.6 Groundwater resources are discussed in Chapter 20 of the EIS
	3. The Proponent must assess (and model if appropriate) the impact of the construction and operation of the project and any ancillary facilities (both built elements and discharges) on surface and groundwater hydrology in accordance with the current guidelines, including: (a) minimising the effects of proposed stormwater and wastewater management during construction and operation 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; and	Section 5.2 Section 6.2
	(b) water take (direct or passive) from surface and groundwater sources with estimates of annual volumes during construction and operation.	Water extraction from groundwater or surface water sources is not proposed
	4. The Proponent must identify any requirements for baseline monitoring of hydrological attributes.	Section 7.2.3
15. Water Quality	4. The Proponent must: (a) state the ambient NSW Water Quality Objectives (NSW WQO) and environmental values for the receiving waters relevant to the project, including the indicators and associated trigger values or criteria for the identified environmental values;	Section 1.5.2
	(b) identify pollutants that may be introduced into the water cycle and describe the nature 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	Section 3.7 Section 5.3 Section 6.4
	(c) identify the rainfall event that the water quality protection measures will be designed to cope with	Section 4.1
	(d) assess the significance of any identified impacts including consideration of the relevant ambient water quality outcomes	Sections 5.3 and 6.4.1
	(e) demonstrate how construction and operation of the project will, to the extent that the project can influence, ensure that:	Section 6.4.1

Key issue	Requirement	Where addressed?
	• where the NSW WQOs for receiving waters are currently being met they will continue to be protected; and • where the NSW WQOs are not currently being met, activities will work toward their achievement over time	
	(f) justify, if required, why the WQOs cannot be maintained or achieved over time	Section 6.4.1
	(g) demonstrate that all practical measures to avoid or minimise water pollution and protect human health and the environment from harm are investigated and implemented	Section 6.4.1
	(h) identify sensitive receiving environments (which may include estuarine and marine waters downstream) and develop a strategy to avoid or minimise impacts on these environments; and	Sections 1.1, 3.4 and 3.5 Section 1.3 Section 1
	(i) identify indicative monitoring locations, monitoring frequency and indicators of surface water quality.	Section 7.2.3

1.5 Relevant legislation and guidelines

The following legislation and guidelines are relevant to this technical report:

1.5.1 Water Management Act 2000

The *Water Management Act 2000*, is administered by Water NSW and is progressively being implemented throughout NSW to manage water resources, superseding the *Water Act 1912*. The aim of the Water Management Act is to ensure that water resources are conserved and properly managed for sustainable use benefiting both present and future generations. It is also intended to provide formal means for the protection and enhancement of the environmental qualities of waterways and their in-stream uses as well as to provide for protection of catchment conditions. Fresh water sources throughout NSW are managed by water sharing plans (WSPs) under the Water Management Act.

Principles of the Water Management Act relating to drainage and floodplain management include the need to avoid or minimise land degradation including soil erosion, compaction, geomorphic instability and waterlogging.

1.5.2 Guidelines and standards

Key guidelines referenced in the assessment include:

- The Floodplain Development Manual- the management of flood liable land, (NSW Government, 2005) (the Floodplain Development Manual)
- Managing Urban Stormwater: Soils and Construction Volume 1, (Landcom, 2004) (the Blue Book)
- National Water Quality Management Strategy, (ANZECC and ARMCANZ, 1994)
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ, 2000) (the ANZECC guidelines)
- Australian Rainfall and Runoff, (Commonwealth Government of Australia, 2016)
- Australian Rainfall and Runoff, (Engineers Australia, 1987)
- Australian Runoff Quality, (Engineers Australia, 2006)

- Water Sensitive Urban Design Guideline, (Roads and maritime Services, 2006)

A detailed list of reference material is provided in Section 8.

NSW Floodplain Development Manual

The Floodplain Development Manual concerns the management of flood-prone land within NSW. It provides guidelines in relation to the management of flood liable lands, including any development that has the potential to influence flooding, particularly in relation to increasing the flood risk to people and infrastructure. Activities of the project which have the potential to increase flood risk through, for example, increasing stormwater runoff would be subject to consideration under the Floodplain Development Manual.

Australian Rainfall and Runoff

Australian Rainfall and Runoff (Commonwealth of Australia, 2016) is the primary technical publication for hydrological estimates and design considerations. The draft consultation issue was finalised in November 2016 and was the result of a number of years' of updates to the previous version of Australian Rainfall and Runoff (Engineers Australia, 1987). The technical analysis and development of the original hydrologic and hydraulic models for the Sydenham to Bankstown upgrade was commenced prior to finalisation of ARR 2016 and is therefore largely based on the Engineers Australia version (1987).

Managing Urban Stormwater – Soils and Construction Volume 1

The principles for the management of stormwater are documented in the Blue Book.

National Water Quality Management Strategy

Since 1992, the *National Water Quality Management Strategy* (NWQMS) has been developed by the Australian and New Zealand Governments in cooperation with state and territory governments. The NWQMS aims to protect the nation's water resources, by improving water quality while supporting the businesses, industry, environment and communities that depend on water for their continued development. The NWQMS consists of three major elements: policy, process and guidelines. The main policy objective of the NWQMS is to achieve sustainable use of water resources, by protecting and enhancing their quality, while maintaining economic and social development. The process strives to form a nationally consistent approach to water quality management through the development of high-status national guidelines. The guidelines provide the point of reference when issues are being determined on a case-by-case basis. These include guidance on regulatory and market-based approaches to managing water quality as well as regional water quality criteria. The ANZECC guidelines are relevant to this assessment.

ANZECC Guidelines

In 2000, the former Australian and New Zealand Environment and Conservation Council (ANZECC) released the ANZECC guidelines to provide a nationally consistent approach to water quality management based on the principle of ecological sustainable development of water resources. The guidelines contain a set of tools for the assessment and management of water quality across a range of water resource types based on designated environmental values. The objective of the ANZECC, relevant to the project, is to maintain and enhance the 'ecological integrity' of freshwater and marine ecosystems, including biological diversity, relative abundance and ecological processes. The framework categorises ecosystems on a three point scale from high conservation and ecological value to highly disturbed systems. Indicators include biological indicators, physical and chemical stressors, toxicant and sediments.

Water Quality Objectives

The *NSW Water Quality and River Flow Objectives* provide water quality objectives for the Cooks River and Georges River catchments, for the protection of the following within waterways affected by urban development, or estuaries:

- Aquatic ecosystems
- Visual amenity
- Secondary contact recreation
- Primary contact recreation

Waterways affected by urban development are defined as streams within urban areas, which are frequently substantially modified and generally carry poor quality stormwater. The majority of waterways within the project area meet this definition, with the exception of the Cooks River, which meets the definition of an estuary, as it is dominated by saline conditions.

The water quality objectives for the receiving watercourses for the study area are provided in Table 1-2, together with default trigger values for various indicators drawn from ANZECC on how the stated water quality objectives may be achieved or maintained. These water quality objectives have been extracted from NSW OEH website (DECCW, 2006a and 2006b.

Table 1-2NSW water quality objectives

Water quality objective	Indicators	Associated trigger values or criteria	Catchments to which it applies
Aquatic ecosystems			
Maintaining or improving the ecological condition of waterbodies and their riparian zones over the long term	Total phosphorus	Lowland rivers: 0.025 mg/L for rivers flowing to the coast Estuaries: 0.03 mg/L	Cooks River Georges River (Salt Pan Creek)
	Total nitrogen	Lowland rivers: 0.350 mg/L for rivers flowing to the coast Estuaries: 0.300 mg/L	
	Chlorophyll-a	Lowland rivers: 0.005 mg/L. Estuaries: 0.004 mg/L.	
	Turbidity	Lowland rivers: 6–50 NTU Estuaries: 0.5–10 NTU	
	Salinity (electrical conductivity)	Lowland rivers: 125–2200 µS/cm	
	Dissolved oxygen	Lowland rivers: 85–110 % Estuaries: 80–110 %	
	pH	Lowland rivers: 6.5–8.5 Estuaries: 7.0–8.5	

Water quality objective	Indicators	Associated trigger values or criteria	Catchments to which it applies
Visual amenity			
Maintain aesthetic qualities of waters	Visual clarity and colour	Natural visual clarity should not be reduced by more than 20 % Natural hue of water should not be changed by more than 10 points on the Munsell Scale Natural reflectance of water should not be changed by more than 50 %	Cooks River Georges River (Salt Pan Creek)
	Surface film and debris	Oils and petrochemicals should not be noticeable as a visible form 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			
Maintain or improve water quality for activities such as boating and wading, where this is a low probability of water being swallowed	Faecal coliforms	Median bacterial content in fresh and marine waters of < 1000 faecal coliforms per 100 mL, with 4 out of 5 samples < 4000/100 mL (minimum of 5 samples taken at regular intervals not exceeding one month)	Cooks River Georges River (Salt Pan Creek)
	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	Large numbers of midges and aquatic worms are undesirable and as per visual amenity guidelines	

Water quality objective	Indicators	Associated trigger values or criteria	Catchments to which it applies
	Chemical contaminants	Waters containing chemicals that are either toxic or irritating to the skin or mucous membranes are unsuitable for recreation	
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 mm diameter black disc should be able to be sighted horizontally from a distance of more than 1.6 m (approximately 6 NTU)	Cooks River Georges River (Salt Pan Creek)
	Faecal coliforms	Beachwatch considers waters are unsuitable for swimming if: the median faecal coliform density exceeds 150 colony forming units per 100 millilitres (cfu/100mL) for five samples taken at regular intervals not exceeding one month, or the second highest sample contains equal to or greater than 600 cfu/100mL (faecal coliforms) for five samples taken at regular intervals not exceeding one month ANZECC 2000 Guidelines recommend: Median over bathing season of < 150 faecal coliforms per 100 mL, with 4 out of 5 samples < 600/100 mL (minimum of 5 samples taken at regular intervals not exceeding one month)	
	Enterococci	Beachwatch considers waters are unsuitable for swimming if: the median enterococci density exceeds 35 cfu/100mL for five samples taken at regular intervals not exceeding one month, or the second highest sample contains equal	

Water quality objective	Indicators	Associated trigger values or criteria	Catchments to which it applies
		to or greater than 100 cfu/100mL (enterococci) for five samples taken at regular intervals not exceeding one month. 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)	
	Algae & blue-green algae	< 15 000 cells/mL	
	Nuisance organisms	Use visual amenity guidelines.	
		Large numbers of midges and aquatic worms are undesirable.	
	pH	5.0-9.0	
	Temperature	15°-35°C for prolonged exposure.	
	Chemical contaminants	Waters containing chemicals that are either toxic or irritating to the skin or mucus membranes are unsuitable for recreation	
Aquatic foods (cooked)			
Refers to 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	Cooks River
	Faecal coliforms	Guideline in water for shellfish: The median faecal coliform concentration should not exceed 14 MPN/100mL; with no	

Water quality objective	Indicators	Associated trigger values or criteria	Catchments to which it applies
		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	
	Toxicants (as applied to aquaculture activities)	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) PCBs: less than 2 µgm/L	
	Physio-chemical indicators (as applied to aquaculture activities)	Suspended solids: less than 0.040 mg/L (freshwater) Temperature: less than 2 degrees Celsius change over one hour	

Water Sensitive Urban Design Guideline Rail

The design criteria for water quality adopted in the reference design were the *Water Sensitive Urban Design Guideline Rail* which are provided in Table 1-3. Detailed water quality design criteria are provided in Table 4-4.

Table 1-3 Water quality and water re-use requirements

Water quality and use	Design requirements
Water quality	Water Sensitive Urban Design (WSUD) measures will be included in station precincts, stabling facilities and car parks. The design will address local council standards and Sydney Metro sustainability guidelines.
Water re-use	All on-grade car park stormwater drainage will be captured, treated in WSUD bio-swales, stored where possible and re-used.

Other Transport for NSW guidelines adopted in the ongoing design development on the project include:

- Water Discharge and Reuse Guideline
- Environmental Incident Classification and Reporting
- Chemical Storage and Spill Response Guidelines
- Concrete Washout Guideline

2. Assessment methodology

2.1 Overview

This study of surface water quality, drainage and flooding involved a desktop review of design information provided by Transport for NSW and a site visit. The project reference design report included operational flood modelling results, drawings and preliminary construction information.

The focus of this technical study is the rail corridor between Marrickville and Bankstown. The desktop review however incorporated a high level consideration of a wider study area which included the catchments of Salt Pan Creek and the Cooks River.

2.2 Desktop review and site visit

The following activities were undertaken to provide information for the impact assessment:

- Collation and review of background information, previous reports and project information including:
  - flood studies and floodplain risk management studies
  - existing and proposed water quality data and water quality treatment measures
  - existing and future flooding conditions
  - existing cross drainage location and capacity data, including Dial Before You Dig data
- A site visit in June 2016 to inspect accessible culverts, drains, flow paths and surrounding development

2.3 Impact assessment

The following tasks were undertaken:

- Consideration of the location of the project area in the context of surrounding and upstream catchment areas and potential influence of downstream waterways.
- Identification of construction activities likely to impact on surface water quality, drainage and flooding.
- Review of the reference design and activities likely to cause an impact on water quality, drainage and flooding.
- Identification and assessment of impacts on water quality with respect to potential increases or decreases in pollutant loading both at construction stage and during operation.
- Identification and assessment of potential impacts through changes in surface water quantity with respect to increases or decreases in stormwater runoff and the sensitivity of the downstream waters both at construction stage and during operation.
- Identification of potential impacts of changes in the flood regime and potential increases or decreases in flood risk to downstream areas.
- Broad assessment of the likely change in flood storage and potential flood flow paths to be expected as a result of the project.
- Consideration of the likely impacts of climate change on the project.

2.3.1 Flood modelling

The design team undertook hydraulic modelling to design the track drainage and to set track formation levels to meet the design criteria. The full range of flood events ranging from the 63 per cent annual exceedance probability (AEP) event to the probable maximum flood (PMF) event were modelled. This was undertaken for both the existing and post-development conditions, and the results were used to assess the potential impacts on flood behaviour, including flood depths, velocities and hazard.

At key locations, assessment of flood impacts to adjoining lands was undertaken, including at Marrickville Station. The relevant findings of this assessment are discussed in this report and were used to inform the impact assessment. A summary of the flooding and drainage modelling undertaken by the design team is provided in Table 2-1.

Table 2-1 Drainage and flood modelling undertaken

Location	Events modelled	Modelling approach	Results available for EIS
Marrickville Station	**Existing case:** 63 %, 39 %, 18 %, 10 %, 5 %, 2 %, 1 % AEPs and 1 % AEP + 10 % increase for climate change and PMF **Post-developed case:** 63 %, 39 %, 18 %, 10 %, 5 %, 2 %, 1 % AEPs and 1 % AEP + 10 % increase for climate change and PMF	TUFLOW	Key peak flood results were available in GIS format. Mapping of flood depths, velocities, and hazard are presented in this report.
Dulwich Hill to Bankstown	**Post-developed case (key locations):** 2 % AEP including 10 % increase in rainfall intensity; 1 % AEP including 10 % increase in rainfall intensity	1D modelling using 12D drainage module and DRAINS	No flood mapping data or model results were available as this part of the corridor was generally considered to present a lower flooding risk than the Marrickville area. Discussion of key outcomes is provided in this report.

Note: The AEPs quoted in the above table have been converted from equivalent ARIs – refer glossary

The designers undertook sensitivity tests at selected locations to assess the likely influence of sea level rise on the project. The findings were that there was no impact on flood parameters at these locations, however further assessment would be undertaken during detailed design to confirm this preliminary conclusion.

2.3.2 Water quality modelling

The design team undertook limited water quality modelling for the rail corridor between Dulwich Hill and Bankstown using the Model for Urban Stormwater Conceptualisation (MUSIC) computer software.

A test site, Punchbowl Station, was trialled to assess the potential effect of increases in impervious areas on pollutant generation and retention rates. Punchbowl Station was chosen on the basis that it had one of the largest impervious area increases of the stations considered. The results indicated that the provision of a gross pollutant trap (GPT), coupled with either a bio-retention swale or rain garden, would generally suffice in achieving the percentage pollutant retention target adopted for the project.

No further details of the water quality modelling or assessment against the ANZECC guidelines were available.

2.4 Mitigation measures

Mitigation measures were identified with the aim of reducing potential adverse impacts on the environment. This included:

- Identification of measures and controls to mitigate impacts on surface water quality and flooding
- Broad assessment of the expected residual impacts on surface water following implementation of measures and controls

2.5 Stream order mapping

GIS data and aerial imagery was used to identify and map the stream order of watercourses in the study area. Mapping was completed for all stream lines identified on the New South Wales Land and Property Information (LPI) hydrolines layer.

Stream ordering followed the Strahler stream classification system where watercourses are given an 'order' according to the number of additional tributaries associated with each watercourse (Strahler, 1952). Figure 2-1 indicates the Strahler stream ordering process for a generic catchment. Numbering begins at the top of a catchment with headwater ('new') flow paths being assigned the number one.

Where two flow paths of order one join, the section downstream of the junction is referred to as a second order stream. Where two second order streams join, the watercourse downstream of the junction is referred to as a third order stream, and so on. Where a lower order stream (e.g. first order) joins a higher order stream (e.g. third order), the area downstream of the junction will retain the higher stream order.

In New South Wales, stream orders are relevant as indicators when determining the quality or class of fish habitat.

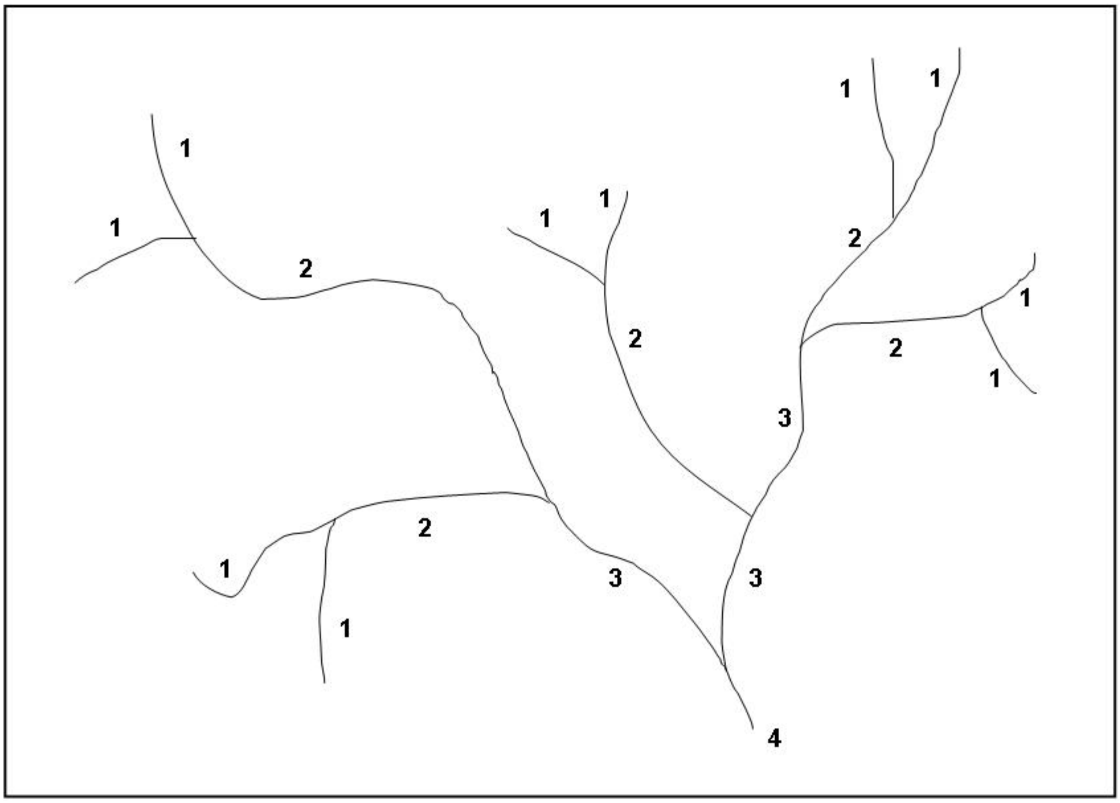


Figure 2-1 Stream order for a generic catchment

(using Strahler method, 1952)

2.6 Referenced data sources

The following key project documents and information were used in this assessment. Additional background data used to inform the existing environment analysis is documented in Section 3.6.1.

Table 2-2 Key project reference documents

Document Reference	Description	Date
Various design documents	Corridor layouts, drainage and flooding information	September 2016 – February 2017
Various documents pertaining to construction	Construction compound schedule GIS database of construction compound and worksite locations GIS locations of vehicle haulage routes	Various
Various email correspondence	Notes regarding proposed drainage at Livingstone Road north, Marrickville (detention basin) and near Canterbury (culvert upgrades)	Various
Flood modelling results	Peak flood modelling results in the Marrickville area	May 2017

3. Existing environment

3.1 Regional drainage catchments

The study area for this technical paper is shown in Figure 3-1 and incorporates the drainage catchments of Salt Pan Creek and the Cooks River.

The rail corridor from Marrickville to Punchbowl Station drains to the Cooks River and its tributaries. The elevated corridor from around Punchbowl Station to Bankstown Station drains to Salt Pan Creek, a tributary of the Georges River.

The project area, being largely developed and urbanised, is mostly impervious. Pervious areas are generally limited to pocket parks and landscaped areas around stations. The wider study area has also been highly modified from its natural state by various forms of urban development and transport infrastructure.

The project area traverses the Inner West and Canterbury-Bankstown local government areas (LGAs) between Marrickville and Bankstown.

3.2 Topography

The elevation of the rail corridor varies greatly along its length, being around 3.5 metres Australian height datum (AHD) at its lowest point near Sydenham Station, approximately 23 metres AHD near Bankstown Station, and a maximum elevation near Wiley Park Station at around 36 metres AHD.

The track is located on or near to a localised ridge line from Punchbowl Station to Bankstown Station. East of Punchbowl Station, the natural topography varies through to a large rail bridge crossing over the Cooks River. Between the rail bridge crossing and Marrickville Station, the track again meanders over a series of gullies and ridges. The rail corridor at Marrickville Station is in low-lying terrain and is particularly flood prone (refer to section 3.6.4 for further discussion of key flood prone areas and existing flood behaviour).

3.3 Acid sulfate soils

Acid sulfate soils are generally widespread among the low-lying estuarine floodplains and coastal lowlands of NSW. Other locations where acid sulphate soils may be encountered are in areas of fill where sediments from low-lying areas have been used to reclaim or fill land.

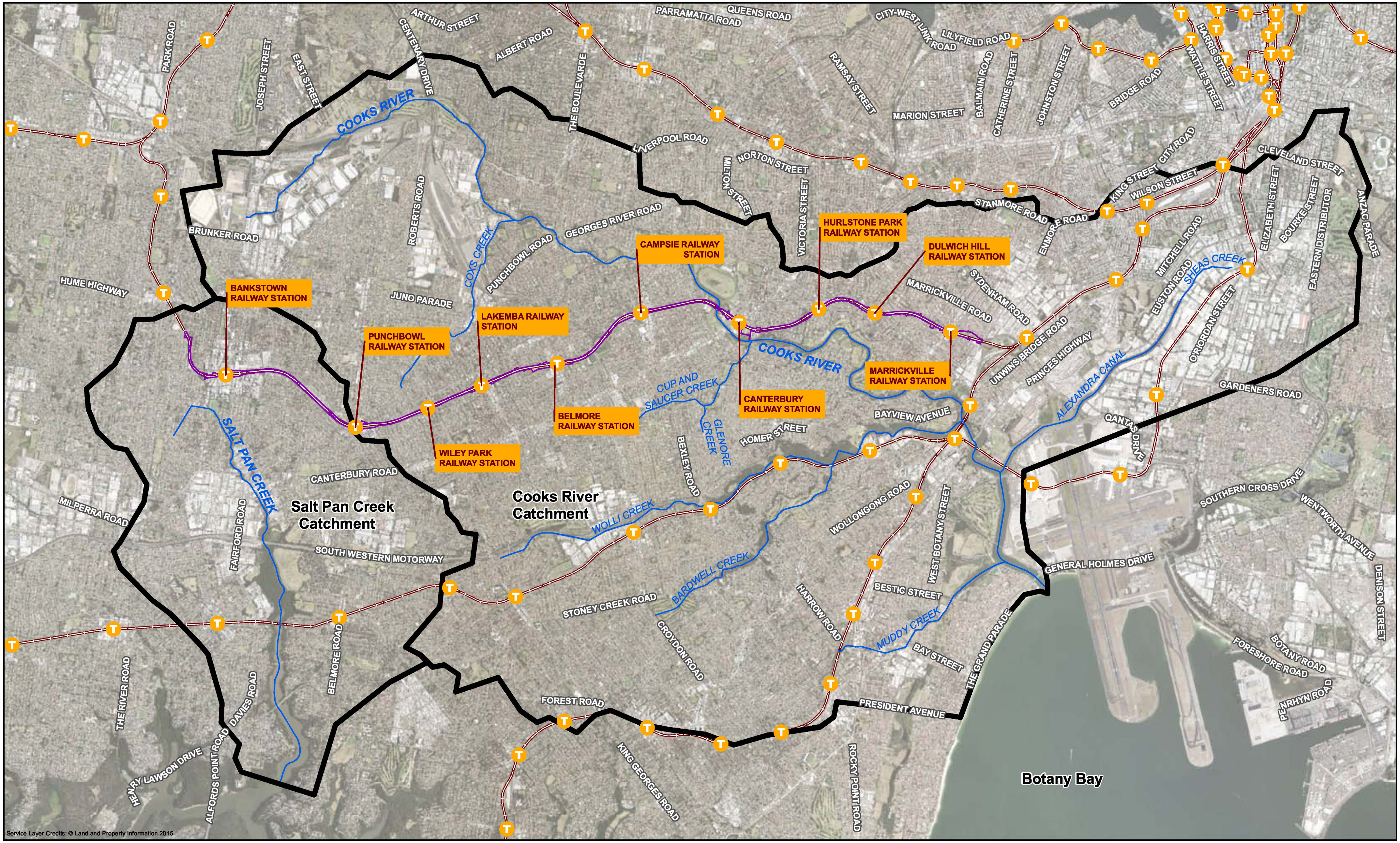
Further discussion of acid sulfate soils and their potential locations in the project area is included in EIS Chapter 19 - Soils and contamination.

3.4 Cooks River

3.4.1 Overview

The Cooks River discharges to Botany Bay at Tempe adjacent to Sydney Airport. The catchment area is around 102 kilometres squared. The watercourse is tidally influenced as far as South Enfield. Botany Bay is around 3.5 kilometres from the south extent of the project area near Tempe.

The land use of the Cooks River catchment is highly urbanised, with development being largely residential. Areas of parkland, as well as commercial and industrial development are also present. The proportion of parkland and open space within the catchment as a whole is relatively low and is concentrated along the foreshore areas. This includes wetlands, bushland and riparian vegetation which are of ecological and recreational value, according to the *Cooks River Alliance Management Plan 2014 (*Cooks River Alliance, 2014) (Figure A.1 in Appendix A). Management of the river is shared amongst several local councils and also Sydney Water Corporation.



Paper Size A3

0 350 700 1,400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Project area
- Train station
- Railway
- Regional surface water catchments
- Watercourses

Transport for NSW
Sydney Metro - Sydenham to Bankstown upgrade
Surface Water Assessment

Job Number	21-25273
Revision	A
Date	08 Jul 2017

Surface water overview **Figure 3-1**

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Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

Data source: Aerial imagery - sixmaps 2016, General topo - NSW LPI DTDB 2012. Created by:afoddy

The Cooks River was historically a natural watercourse but some reaches were replaced with concrete lined channels or concrete side walls commencing in the 1940s. The upper reaches are concrete lined, with a mix of concrete and unlined channels further downstream. Sydney Water Corporation has undertaken progressive channel naturalisation works at three locations to restore a more natural creek in areas where the concrete sections had deteriorated. Additionally, the former Sydney Metropolitan Catchment Management Authority, in consultation with local councils, undertook a number of wetland remediation projects along the Cooks River between 2008 and 2012.

The Cooks River is a third order stream at the rail crossing near Canterbury Station (refer Figure 3-2).

3.4.2 Tributaries

Significant tributaries of the Cooks River include, from upstream to downstream:

- Coxs Creek
- Cup and Saucer Creek
- Wolli Creek
- Alexandra Canal
- Muddy Creek
- Eastern Channel
- Western Channel

3.5 Salt Pan Creek

3.5.1 Overview

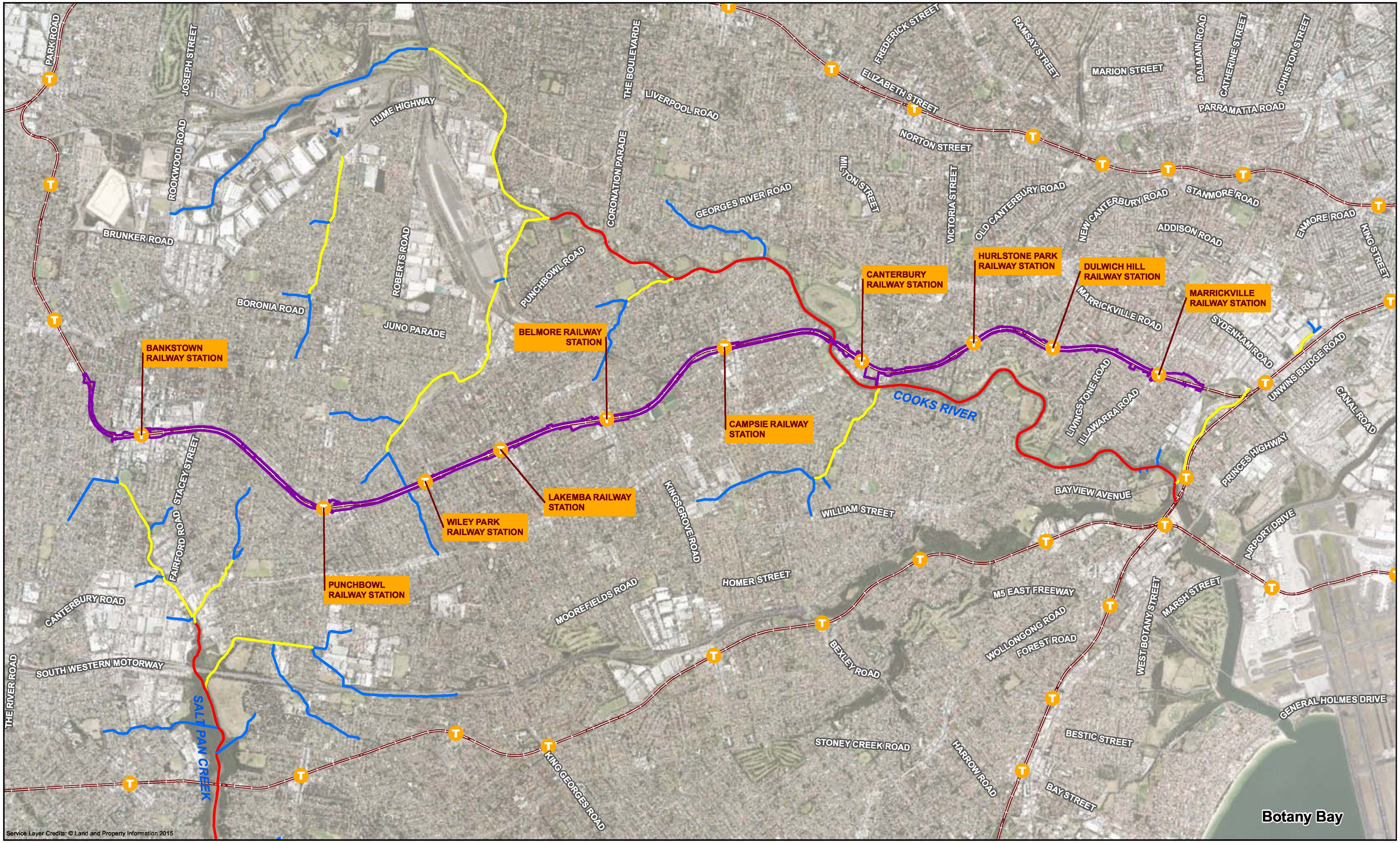
Salt Pan Creek is a tributary of the Georges River with a catchment area of around 26 kilometres squared. Around 10 per cent of the total catchment area is located north of the project area and drains beneath it to reach the downstream drainage network and the Georges River via Salt Pan Creek. The creek is tidally influenced until a short distance upstream of Fairford Road.

The catchment is heavily developed in the upper reaches near the rail corridor and residences are located along the channel in many places. The upper reaches of the creek, where in open channel, are highly modified (Figure A.4 in Appendix A) and generally concrete lined with limited vegetation until Canterbury Road.

According to the *Salt Pan Creek Corridor Masterplan Report* (Bankstown City Council, 2006), in the past, a number of wetlands were filled in for urban development or landfill purposes. Some wetlands and saltmarsh areas still remain along the creek (Figure A.5 in Appendix A). There are also a number of public reserves and passive and active recreation areas in the catchment.

3.5.2 Tributaries

Tributaries are not recognised by name on available mapping. A number of unnamed urban channel tributaries drain to the upper reaches of the creek. The tributaries of Salt Pan Creek downstream of the project area are first order streams (refer Figure 3-2).



Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Project area
- Train station
- Railway

Strahler stream order

- 1
- 2
- 3

Transport for NSW
Sydney Metro - Sydenham to Bankstown upgrade
Surface Water Assessment

Job Number	21-25273
Revision	A
Date	08 Jul 2017

Strahler stream order

Figure 3-2

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Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

Data source: Aerial imagery - sixmaps 2016, General topo - NSW LPI DTDB 2012. Created by:afoddy

3.6 Existing flood behaviour

This section provides a summary of a number of local flood studies which describe existing flooding and drainage issues in the catchments, including the rail corridor, and an overview of floodplain risk management.

3.6.1 Background information sources

In addition to the project documents referenced in Section 2.6, the following flood studies were reviewed to provide background on the existing flood regime within the project and study areas:

- *Cooks River Flood Study*, Sydney Water Corporation, 2009
- *Cooks River Floodplain Risk Management Study and Plan*, (WMA Water and Storm Consulting, 2015)
- *Marrickville Valley Flood Study*, (WMA Water and Storm Consulting, 2013)
- *Salt Pan Creek Stormwater Catchment Study 2007 Report including 2009 Addendum*, (Bewsher Consulting and BMT WBM, 2011)
- *Salt Pan Creek Catchments Floodplain Risk Management Study and Plan* (Bewsher Consulting, 2013
- *Draft Overland Flow Study Canterbury LGA Cooks River Catchments*, (Cardno, 2016)

These studies were used as inputs for the design team and their flood modelling work.

3.6.2 Catchment flood behaviour

The Salt Pan Creek and Cooks River catchments are typical of many urbanised catchments in that the predominance of impervious surfaces means that rainfall is quickly converted into surface water runoff. This rainfall runoff response means that floods may develop quickly following the onset of intense rainfall events, with little advance warning. Figures summarising existing flooding conditions for Marrickville and its surrounds are provided in Figure 3-3 to Figure 3-8. Further details of existing flooding conditions within the project area are provided in section 3.6.4.

Cooks River catchment

The *Cooks River Flood Study*, assessed flooding for the Cooks River and significant tributaries, including the Eastern Channel downstream of the rail corridor. The local stormwater drainage network was not assessed in detail by this study. Flood maps indicate the rail corridor itself would not be inundated at the main crossing of the Cooks River.

The Marrickville Valley Flood Study provides more details of predicted flooding conditions and incorporates analysis of the existing drainage network as well as flooding from the rivers and creeks.

Stormwater runoff from Moyes Street and Greenbank Street, Marrickville on the south side of the rail corridor, in excess of the capacity of the underground drainage network, flows into McNeilly Park and then into the rail corridor and towards Marrickville Station from the west.

Flooding of the rail corridor in the vicinity of Marrickville Station is predicted in events as frequent as a 39 per cent AEP (more frequent events were not assessed). Flood depths are estimated to be up to one metre in a one per cent AEP event near the Illawarra Road bridge. Flooding was also predicted in the precinct around Marrickville Station.

The Malakoff Street drainage tunnel is a significant drainage asset which conveys stormwater from the Malakoff Street area, under the railway, through McNeilly Park and to the Cooks River.

Marrickville Oval (located outside the project area) was identified as an important flood storage location, acting as a detention basin during flood events. McNeilly Park, near Marrickville Station, also acts a flood storage area during flood events.

Flood hazard maps indicate areas of high hydraulic hazard particularly to the west of Marrickville Station and along a number of public roads, including some used for emergency access, including:

- Railway Parade
- Sydenham Road
- Marrickville Road
- Illawarra Road
- Schwebel Street
- Arthur Street

The *Draft Overland Flow Study Canterbury LGA Cooks River Catchments* shows flooding of the rail corridor east of Canterbury Station occurs in the five per cent AEP event. This study also indicates that the flood hazard is generally low in the catchment, although frequent smaller areas of transitional and high hazard also exist.

Salt Pan Creek catchment

The *Salt Pan Creek Stormwater Catchment Study 2007 Report including 2009 Addendum* investigated flooding in the upper reaches of Salt Pan Creek. The report provides flood depths for a range of flood events up to the PMF. Because of the urbanised nature of the catchment, runoff would occur quite quickly following the onset of a rainfall event, with little time available to prepare for flooding.

The report identifies flooding behaviour in the vicinity of Bankstown Station and indicates potential flooding of the rail corridor in a one per cent AEP event at several locations. In events as frequent as a 63 per cent AEP event, flood maps indicate ponding on the northern side of the rail corridor adjacent to Marion Street near the intersection with Bungalow Crescent, Bankstown.

In a one per cent AEP event, additional flooding and surface ponding from the local drainage network would also occur near the rail corridor on Olympic Parade and short sections of North Terrace and South Terrace.

Provisional flood hazard information is available in the *Salt Pan Creek Catchments Floodplain Risk Management Study and Plan*. There are limited areas of high flood risk identified, primarily they occur north of the rail corridor and overflow across the corridor at a few locations of generally moderate hazard.

3.6.3 Corridor drainage

Surface water from the stations and surrounds is conveyed into the local drainage network, into trunk drainage systems and then to the downstream waterways. The pathways from the local drainage network to the receiving waterways for each station are outlined in Table 3-1.

Table 3-1 Project area and receiving waterways

Project area section	Pathway to receiving waters from local drainage network
Marrickville	Western Channel / Eastern Channel → Cooks River → Botany Bay
Dulwich Hill	Cooks River → Botany Bay
Hurlstone Park	Cooks River → Botany Bay
Canterbury	Cooks River → Botany Bay
Campsie	Cooks River → Botany Bay
Belmore	Cooks River → Botany Bay
Lakemba	Coxs Creek → Cooks River → Botany Bay
Wiley Park	Coxs Creek → Cooks River → Botany Bay
Punchbowl	Coxs Creek → Cooks River → Botany Bay
Bankstown	Salt Pan Creek → Georges River → Botany Bay
Rail corridor between stations	The project area between stations also drains to Botany Bay via the Cooks River or Salt Pan Creek. Significant drainage structures identified in the project area are discussed in the sections below.

There are more than 40 cross corridor drainage culverts larger than 450 millimetres within the project area. A summary of these culverts is provided in Appendix C while the locations are shown in Figure 3.9 to Figure 3.14. The capacities of these culverts vary and are estimated to range from about the 39 per cent AEP event to the one per cent AEP event.

There is also drainage in the form of track and cess drainage which conveys stormwater flows along the rail corridor and connects to the local drainage network.

Where the local drainage network upstream of the rail corridor has limited capacity, it overflows during flood events and overflows are directed into the rail corridor in some places.

In some locations within the rail corridor, there is insufficient existing drainage to capture overflows from the external catchments. This means that any water from external catchments has the potential to flow as sheet flow into the rail corridor. Photographs of various drainage structures taken during the site visit are included in Appendix A.

Existing culverts where the one per cent AEP exit velocities are considered to be relatively high are shown on Figure 3-9 to Figure 3-14. For the purposes of this project, an upper velocity limit of 2.5 metres per second was adopted, above which scour and erosion of most grasses may occur. Under existing conditions, 10 of the above culverts have velocities greater than 2.5 metres per second. Details of these 10 culverts are provided in Table 3-2.

Table 3-2 Summary of culverts with existing velocities >2.5 metres per second

Culvert No.	Dimensions	1 %AEP Discharge (m3/s)	1 % AEP Velocity (m/s)	Existing Capacity (AEP)
9	Box 0.75 x 0.8m	1.27	6	>1 % AEP
13	Box 1.1m x 0.7 m	1.76	5	< 39 % AEP
16	Box 0.9m x 0.9m	3.1	3.5	< 39 % AEP
17	Arch 0.9m x 0.9m	1.75	4.8	< 5 % AEP
18	Arch 0.9m x 0.9m	2.2	4.6	Not available
24	0.9m diameter	1.9	5.3	< 18 % AEP
25	0.9m diameter	1.7	4.8	< 2 % AEP
26	0.75m diameter	1.4	3.2	< 5 % AEP
27	0.9m diameter	1.5	3.5	> 1 % AEP
28	Arch 0.9m x 0.9m	3.45	5.4	> 1 % AEP

Note: Culvert numbers correspond to those shown on Figures 3-9 to 3-14

3.6.4 Existing flooding conditions within the project area

This section provides additional details regarding existing flooding and drainage issues specific to the project area. The most severely flood affected part of the project area is in the rail corridor near Marrickville Station. Other areas of the rail corridor of moderate or high flood risk are to the west of Campsie Station and east of Canterbury Station. A summary of the identified flooding issues for the project area are provided on Figure 3-9 to Figure 3-14.

Marrickville Station

The alignment of the rail corridor to the west of Illawarra Road was constructed on a historic creek. Sydney Water Corporation trunk drainage receives runoff from a catchment to the north west and south west of Marrickville Station. At the rail corridor, the drainage passes into an open channel and runs from west to east along the north side of the rail corridor before joining with the Western Channel east of the station. The Western Channel then conveys stormwater in a north-south direction towards the Cooks River (Figure A.7 in Appendix A). Stormwater drainage from the south side of the rail corridor connects into the Western Channel through a 1500 millimetres x 900 millimetres culvert crossing the rail corridor.

Flooding of the rail tracks is caused in part from subcatchments north-west of Livingstone Road. These drain through Hollands Avenue, Marrickville Avenue and then to Livingstone Road. Overland flow then enters the rail corridor directly from Marrickville Avenue and at a second location, between the Livingstone Road and Illawarra Road overbridges.

From the southern side of the rail corridor, there is some overflow onto the tracks between Moyes Street and Illawarra Road, though the flows are attenuated where they pass through McNeilly Park before reaching the rail corridor.

Mapping in Appendix B indicates that flooding of the rail corridor in the vicinity of Marrickville Station is predicted in events as frequent as a 39 per cent AEP. Flood maps in Figure 3-3 and Figure 3-4 indicate flood depths up to one metre in a one per cent AEP event near the Illawarra Road bridge.

Near Marrickville Station, estimated flood water velocities are generally in the range of one metre per second to three metre per second in the project area. Peak flood velocities in the PMF are typically up to 0.5 metre per second higher than the one per cent AEP climate change event. Flood velocities for the one per cent AEP and PMF respectively are shown in Figure 3-5 and Figure 3-6.

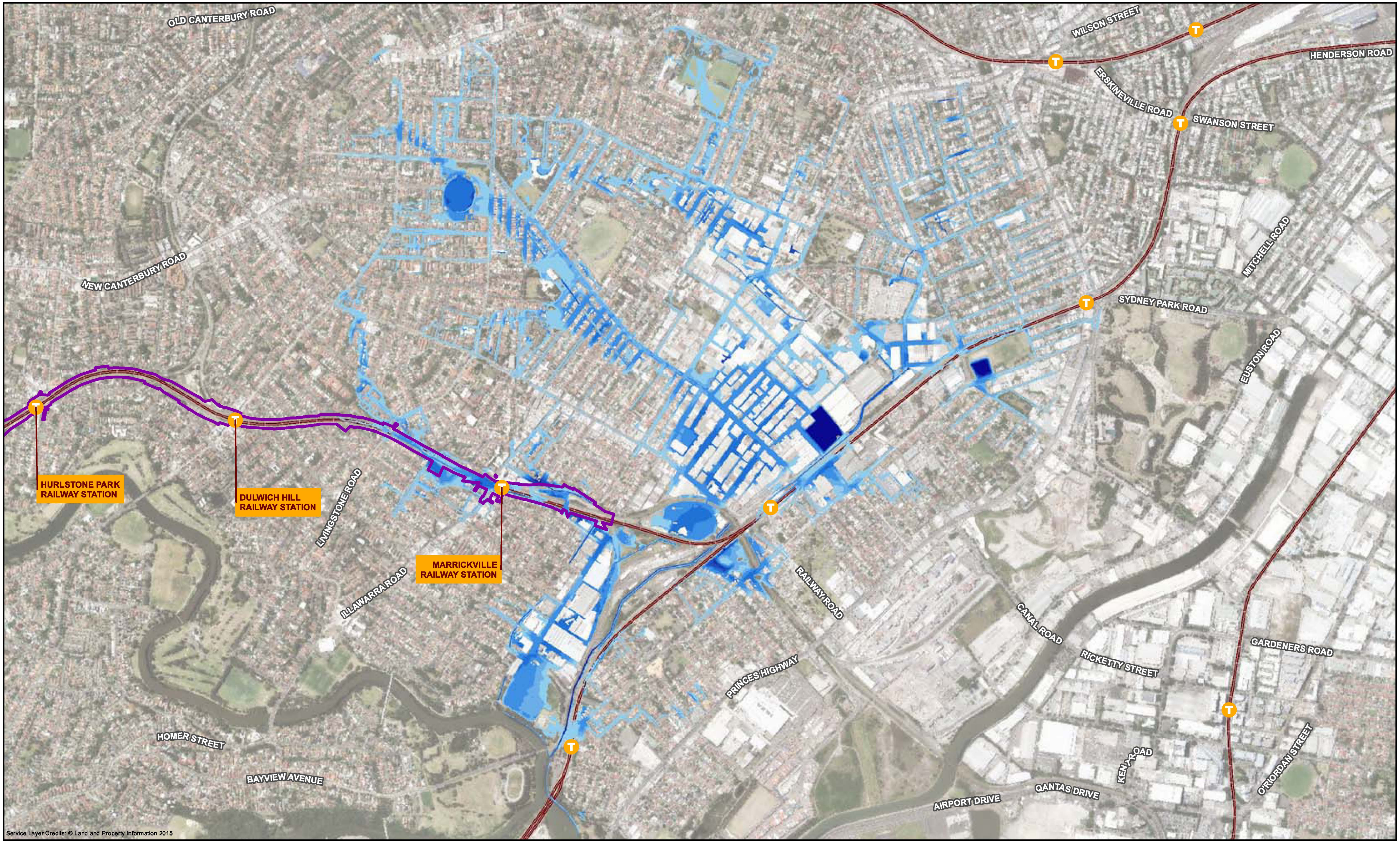
Provisional[1] flood hazard based on the hydraulic hazard definitions in the Floodplain Development Manual were assessed. The Floodplain Development Manual classifies the floodplain into low or high hazard based on the product (multiple) of the velocity and depth of floodwater on the basis that they are the two key hydraulic components of hazard. A third “transitional” area which exists between areas of low and high hazard is also defined[2].

Figure 3-7 and Figure 3-8 show the provisional flood hazard classifications for the one per cent AEP and PMF respectively. In the one per cent AEP climate change event, high flood hazard areas include those to the west and east of Marrickville Station within the rail corridor. The situation is generally similar in the PMF event.

---

[1] Provisional flood hazard is based on hydraulic parameters (velocity-depth product) alone. “True” flood hazard is based on a review of the provisional hazard taking into account factors other than hydraulics. The provisional flood hazard from the NSW Floodplain Development Manual has been used in this report in lieu of flood hazard information based on the new ARR 2016 guidelines being available.

[2] ARR 2016 provides revised and refined categories of flood hazard. Mapping was not available for the new classifications for this EIS.



Paper Size A3

0 100 200 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Project area
- Train station
- Railway

Depth (m)

- 0.00 - 0.05
- 0.05 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.01 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- >2.50

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Existing 1% AEP + 10% climate change flood depth

Figure 3-3

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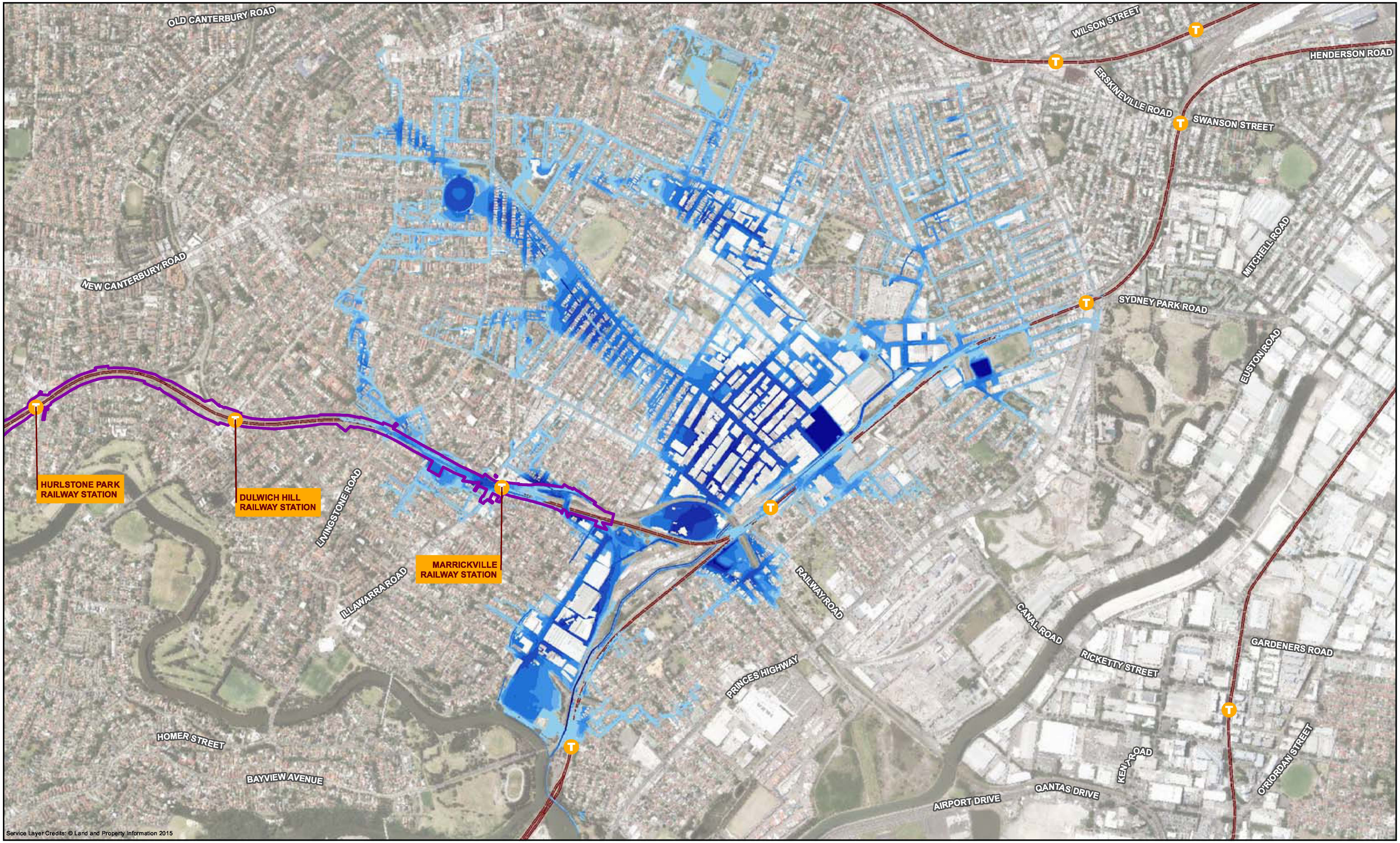
Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

Data source: Aerial imagery - sixmaps 2016, General topo - NSW LPI DTDB 2012. Created by:afoddy



Paper Size A3

0 100 200 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project area

Train station

Railway

Depth (m)

- 0.00 - 0.05
- 0.05 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.01 - 1.50
- 1.50 - 2.00
- 2.00 - 2.50
- >2.50

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Existing PMF flood depth

Figure 3-4

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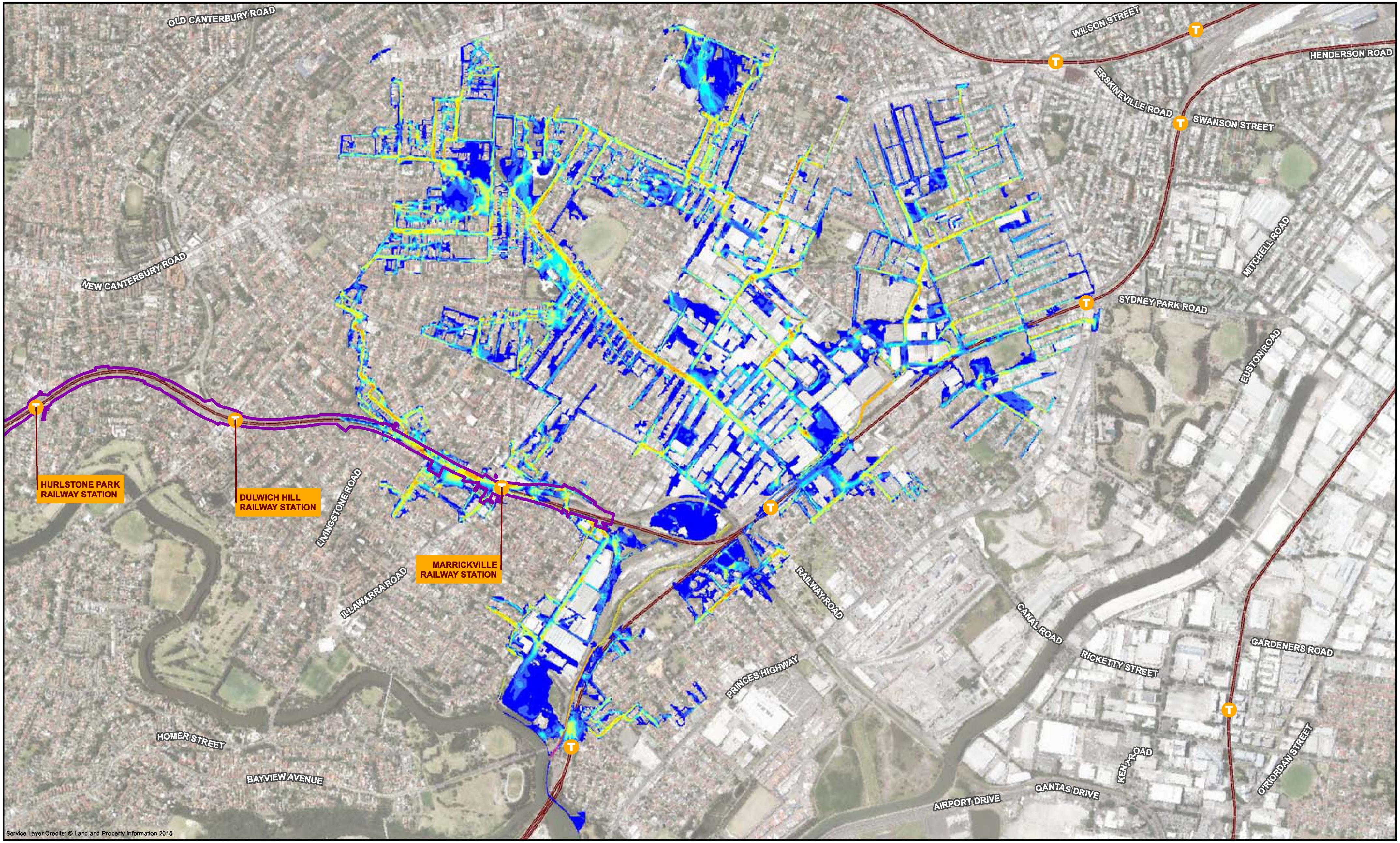
Data source: Aerial imagery - sixmaps 2016, General topo - NSW LPI DTDB 2012. Created by:afoddy



Paper Size A3

0 100 200 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Project area
- Train station
- Railway

Velocity (m/s)

- 0 to 0.2
- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 3.0
- 3.0 to 5.0
- Greater than 5.0

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Existing 1% AEP + 10% climate change flood velocity

Figure 3-5

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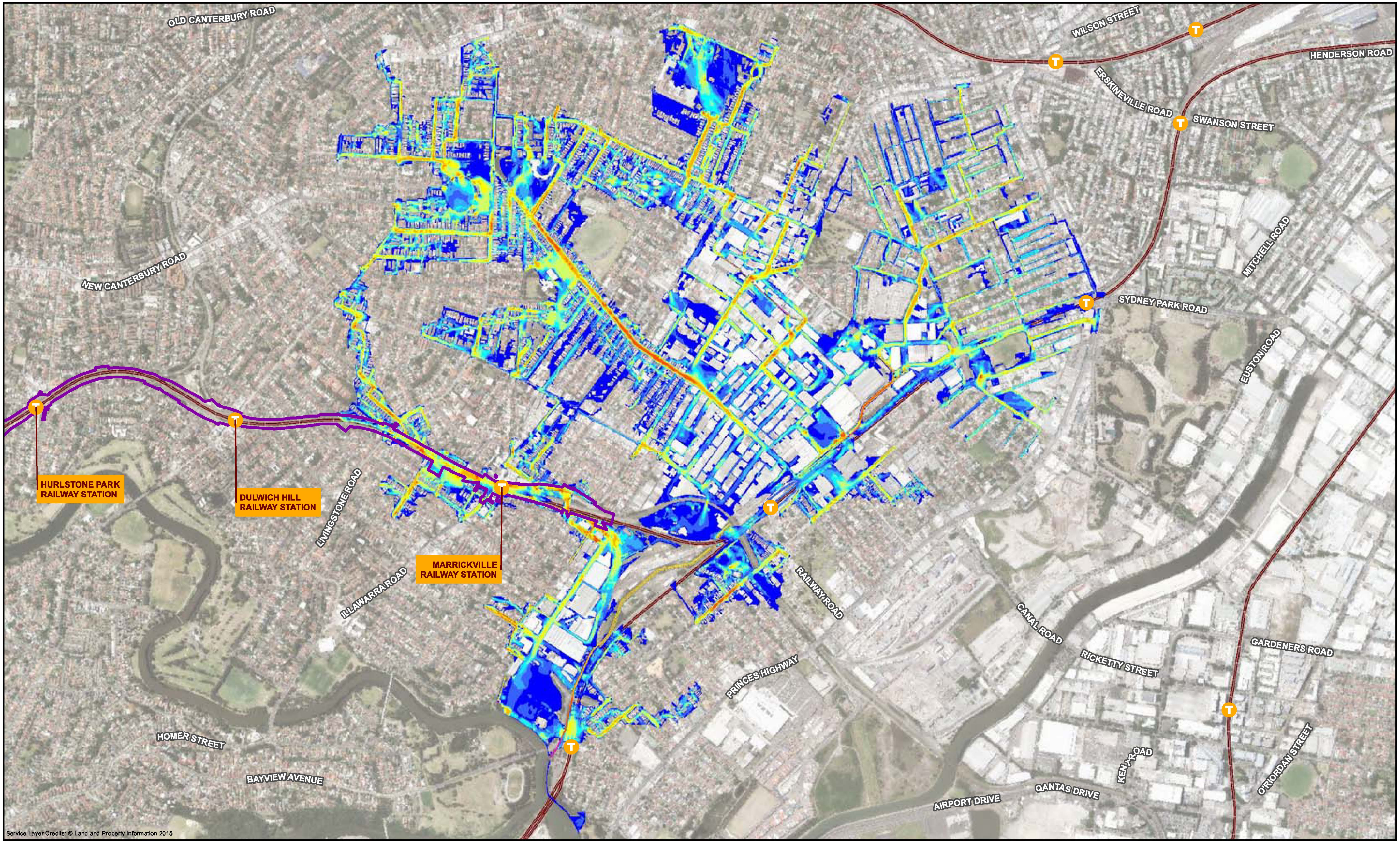

Paper Size A3

0 100 200 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Project area
- Train station
- Railway

Velocity (m/s)

- 0 to 0.2
- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 3.0
- 3.0 to 5.0
- Greater than 5.0

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Existing PMF flood velocity

Figure 3-6

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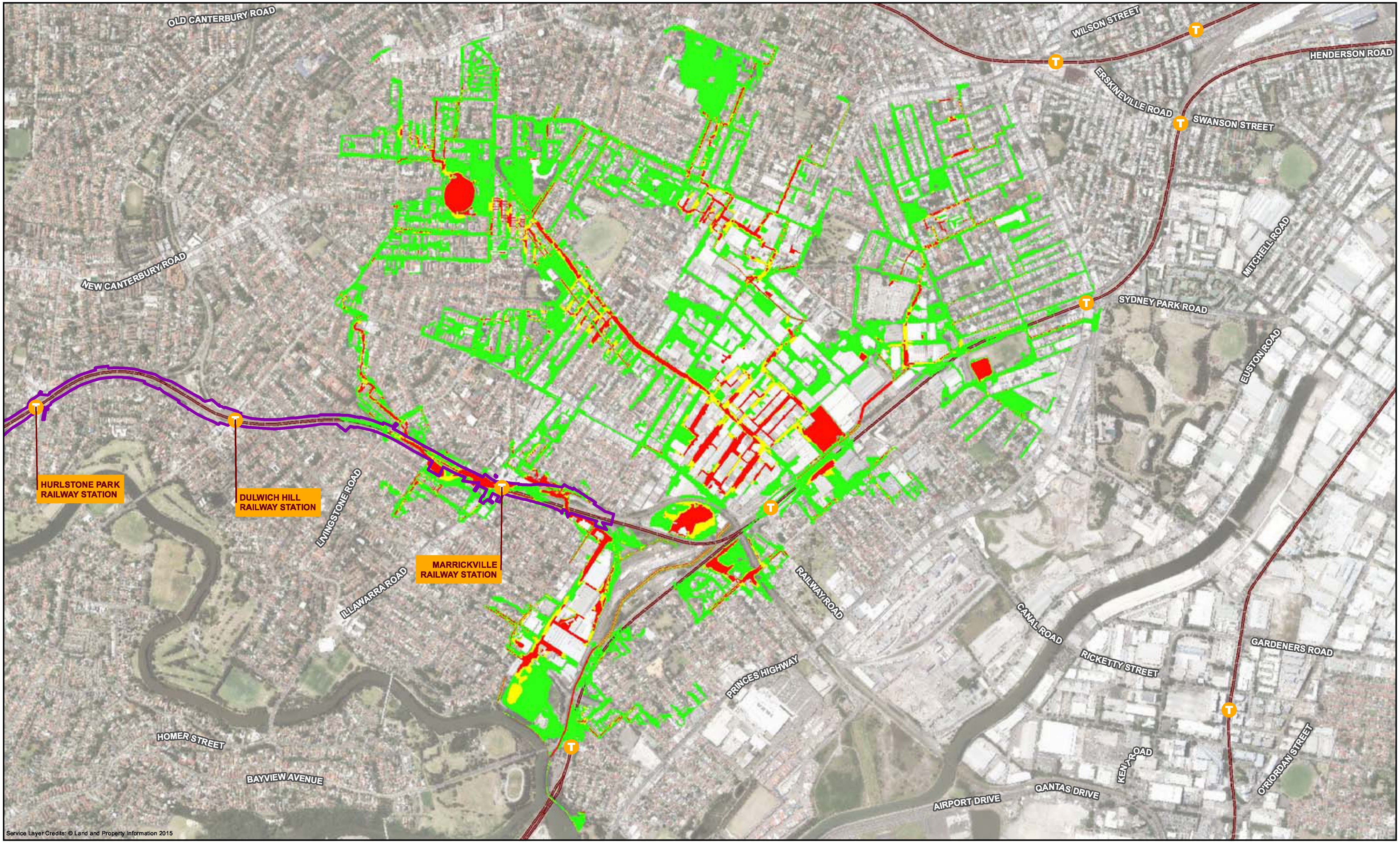
Data source: Aerial imagery - sixmaps 2016, General topo - NSW LPI DTDB 2012. Created by:afoddy



Paper Size A3

0 100 200 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Project area
- Train station
- Railway

Preliminary Hazard Category

- 1 - Low Hazard
- 2 - Transitional Hazard
- 3 - High Hazard

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Existing 1% AEP + 10% climate change provisional flood hazard

Figure 3-7

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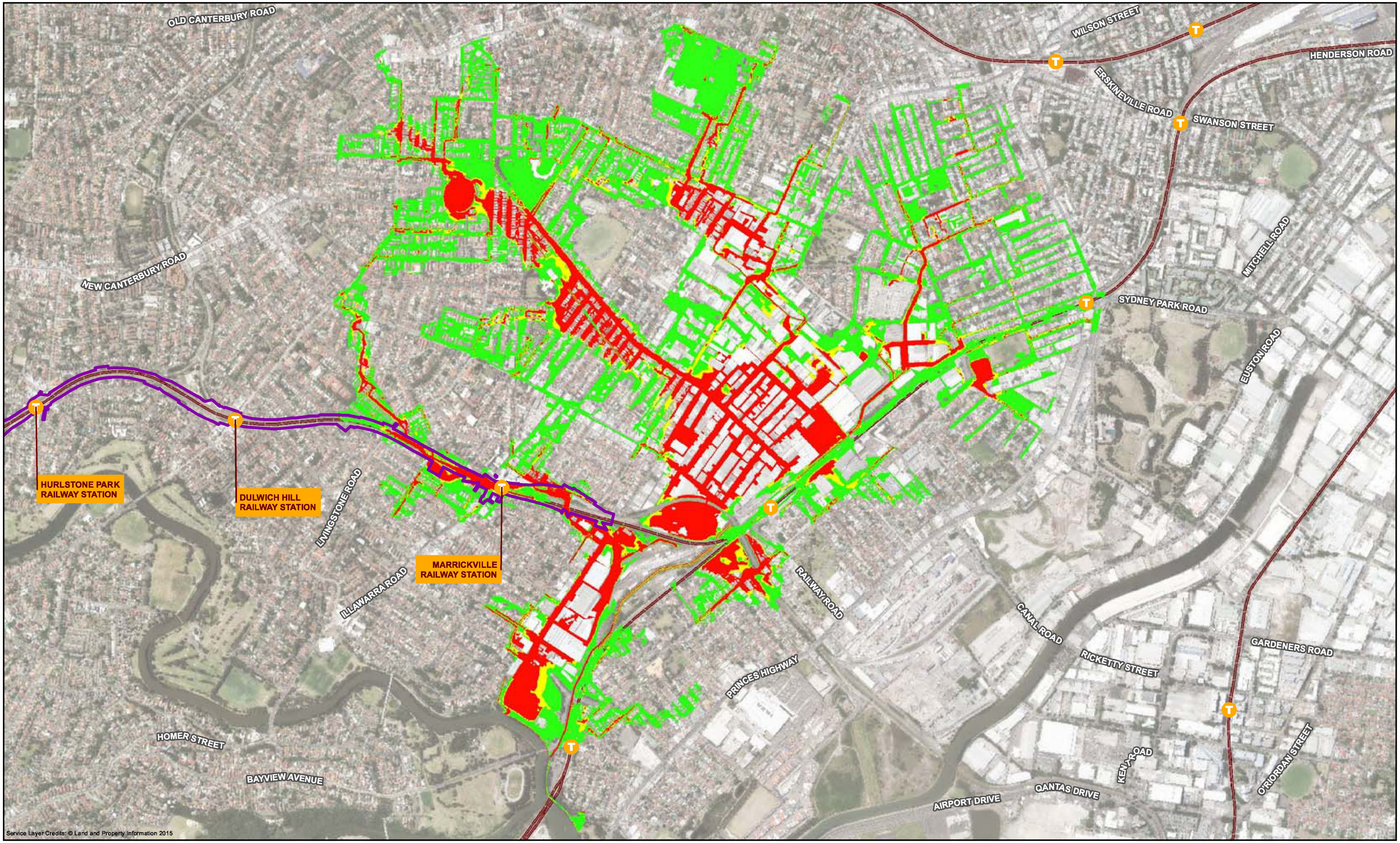

Paper Size A3

0 100 200 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

Project area

Train station

Railway

Preliminary Hazard Category

1 - Low Hazard

2 - Transitional Hazard

3 - High Hazard

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Existing PMF provisional hazard

Figure 3-8

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Data source: Aerial imagery - sixmaps 2016, General topo - NSW LPI DTDB 2012. Created by:afoddy

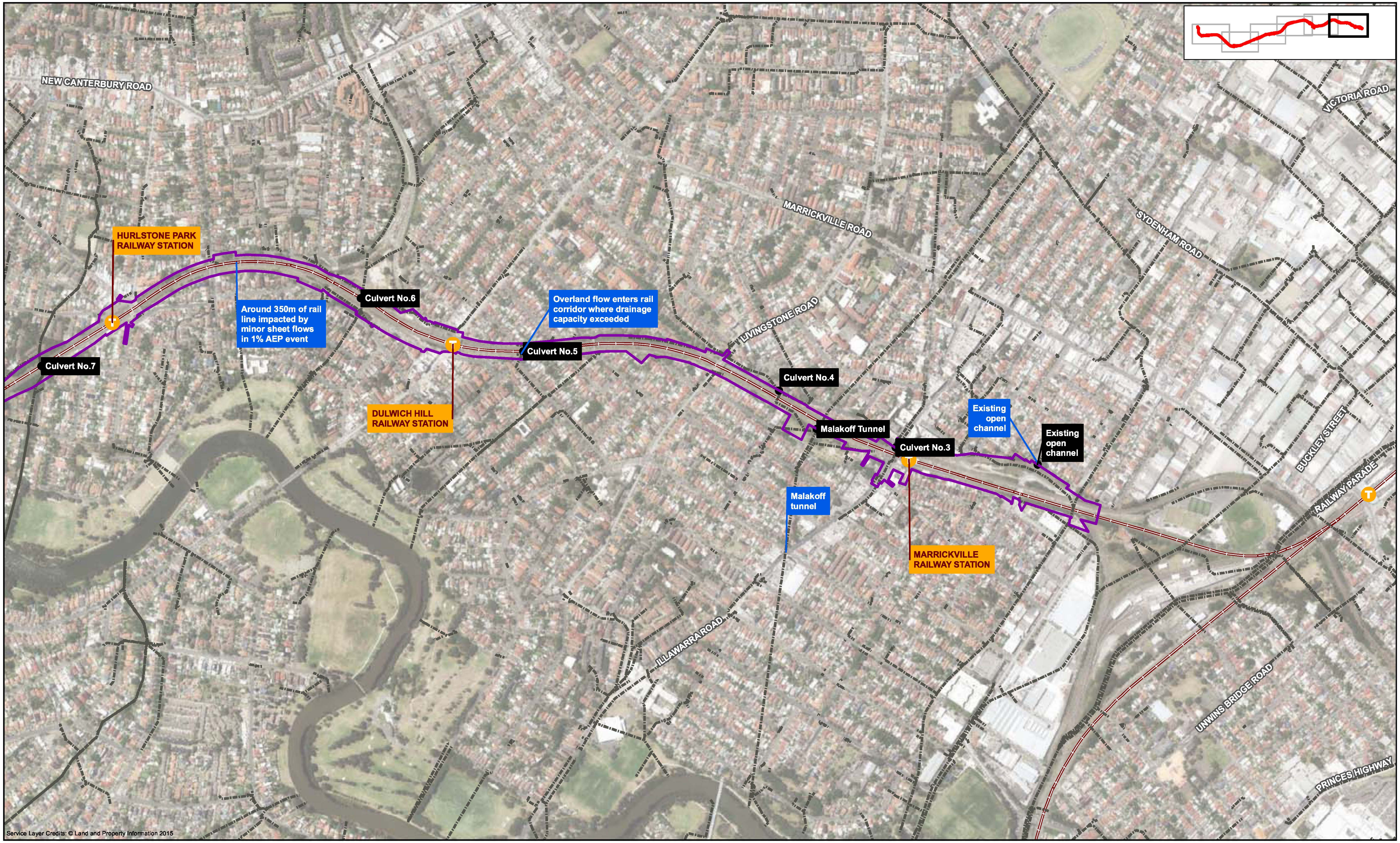
Rest of project area

In the remainder of the project area, between Dulwich Hill and Bankstown stations, existing flooding concerns are considered more minor. High flood risk areas occur within the rail corridor to the west of Campsie Station and east of Canterbury Station but are more localised. Smaller sections of low flood hazard also occur. A summary of existing drainage and flooding concerns in the remainder of the project area is provided in Table 3-3.

Table 3-3 Summary of existing flooding and drainage conditions – rest of project area

Location	Summary of existing flooding and drainage issues	Figure reference
Dulwich Hill Station to Canterbury Station	• Surface water flows from north to south beneath rail corridor. • Some locations of overland flooding into the rail corridor when the existing cross drainage capacity is exceeded (refer figures). • Substantial overland flooding east of Canterbury Station (high flood hazard area) due to insufficient track and cross drainage. • Minor overland flooding potential west of Canterbury Station (low flood hazard area).	Figure 3-9 Figure 3-10
Campsie Station	• Surface water flows from south to north beneath rail corridor. • Overflows from local drainage enter the rail corridor and flow east towards Campsie Station in events greater than the 10 % AEP . • West of Campsie Station is a high flood hazard area. • Overflows from local drainage enter the rail corridor near Belmore triangle area in events greater than 39 % AEP.	Figure 3-11
Belmore Station	• Surface water flows from south to north beneath rail corridor. • Local drainage capacity constraints outside the rail corridor. • Rail alignment in fill and no predicted overland flow issues within the rail corridor.	Figure 3-12
Lakemba Station	• Surface water flows from south to north beneath rail corridor. • East of station, risk of flooding in rail corridor for 5 % AEP and greater. • West of station, limited cross drainage capacity however rail corridor is in fill.	Figure 3-12
Wiley Park Station	• Surface water flows from south to north beneath rail corridor. • Limited cross drainage capacity however rail corridor is mostly in fill.	Figure 3-13

Location	Summary of existing flooding and drainage issues	Figure reference
Punchbowl Station	• Surface water flows from south to north beneath rail corridor. • East of the station there are a number of culvert crossings present with varying capacities. • Potential for overflows into the rail corridor. • West of the station drainage modelling indicates overflows into the rail corridor at a number of locations for 1 % AEP climate change event.	Figure 3-13
Bankstown Station	• Rail corridor mostly in fill with limited potential for flooding of tracks except in large (infrequent) events. • An area of medium flood risk hazard to the east of the station.	Figure 3-14



Paper Size A3

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Project area
- Train station
- Railway
- Existing drainage

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Figure 3-9

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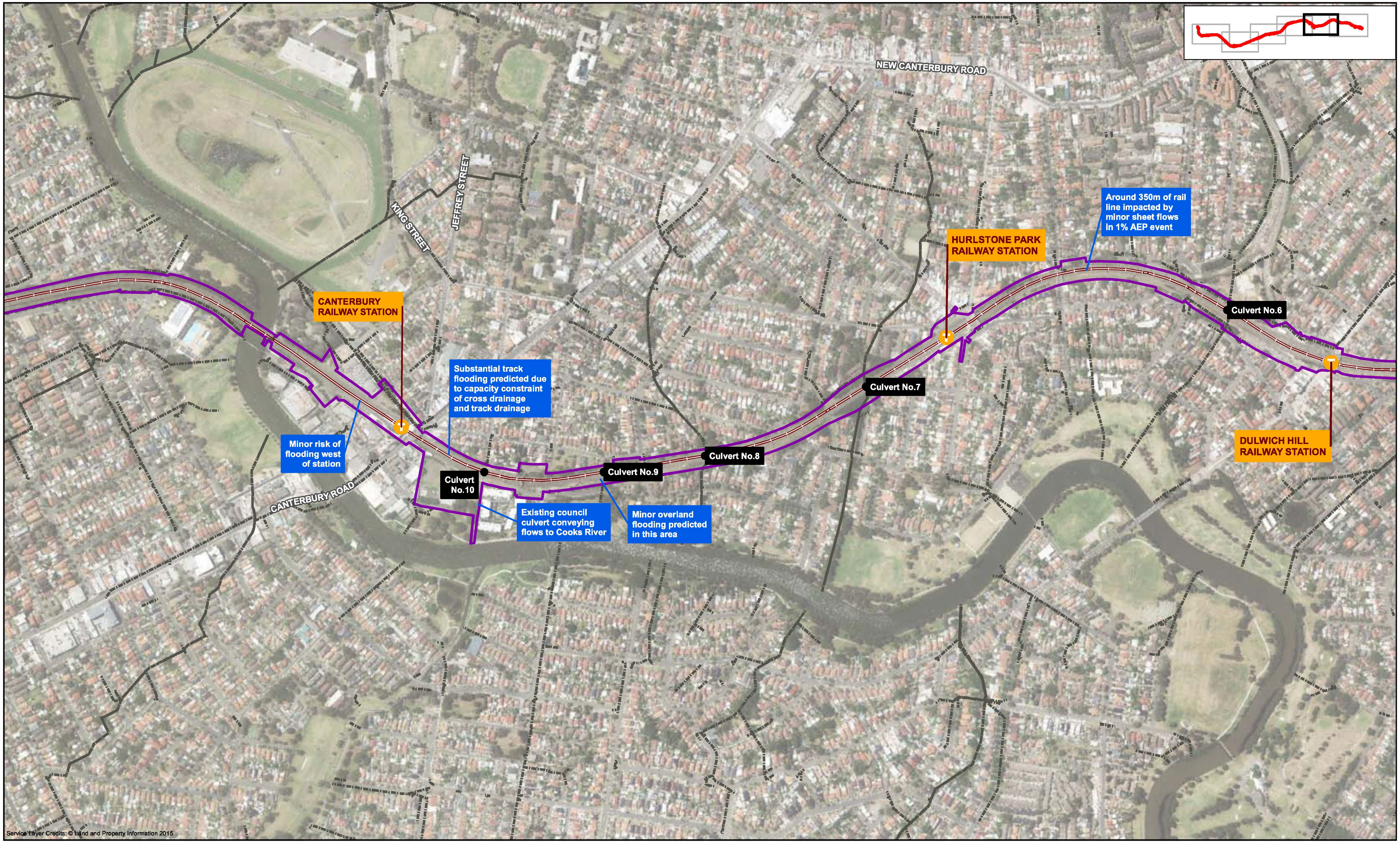

Paper Size A3

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Project area
- Train station
- Railway
- Existing drainage

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Figure 3-10

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Data source: Aerial imagery - sixmaps 2016, General topo - NSW LPI DTDB 2012. Created by:afoddy

Paper Size A3

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
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N

LEGEND

- Project area
- Train station
- Railway
- Existing drainage

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Figure 3-11

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Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

Data source: Aerial imagery - sixmaps 2016, General topo - NSW LPI DTDB 2012. Created by:afoddy

Paper Size A3

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND
- Project area
- Train station
- Railway
- Existing drainage

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Figure 3-12

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Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

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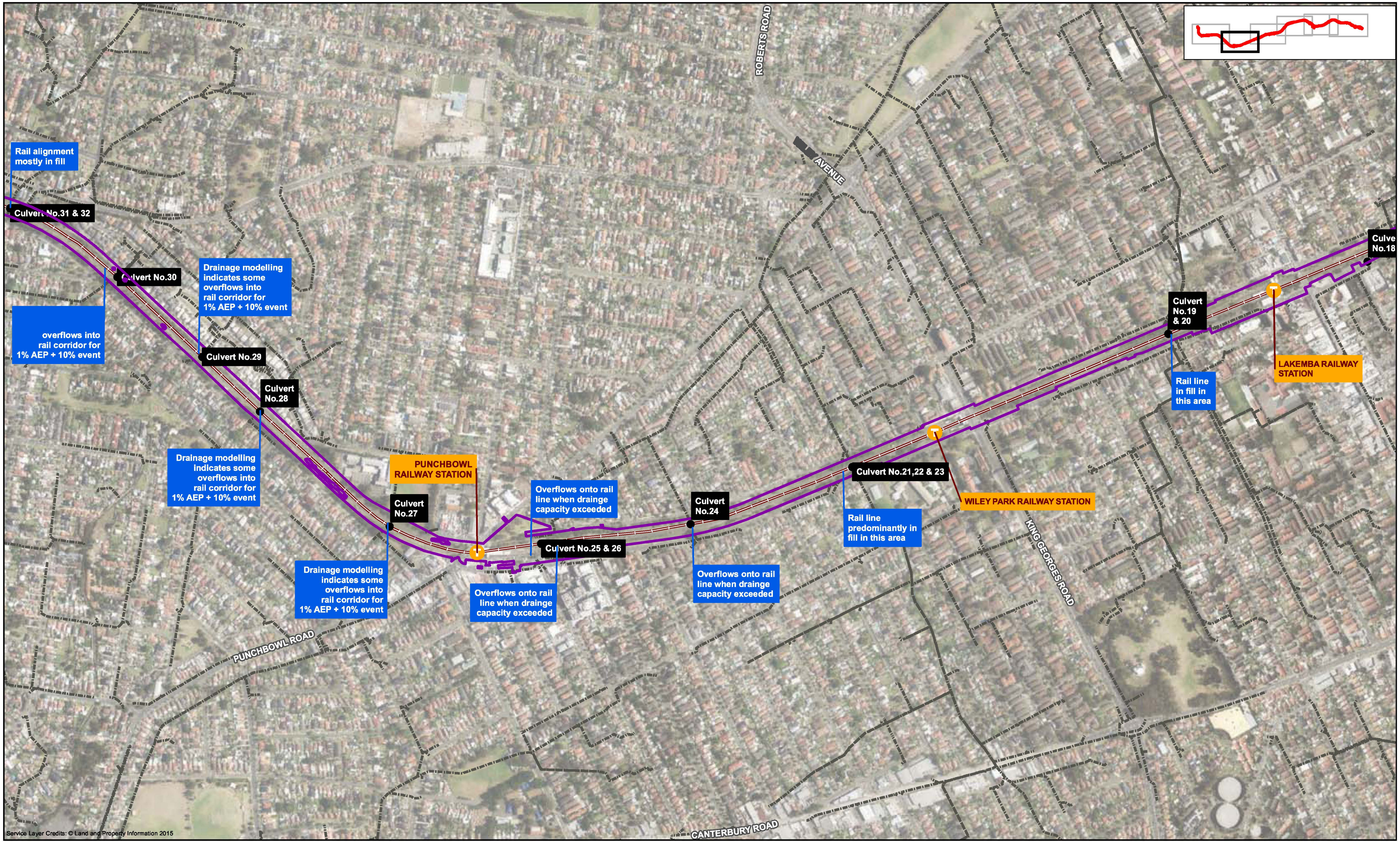

Paper Size A3

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Project area
- Train station
- Railway
- Existing drainage

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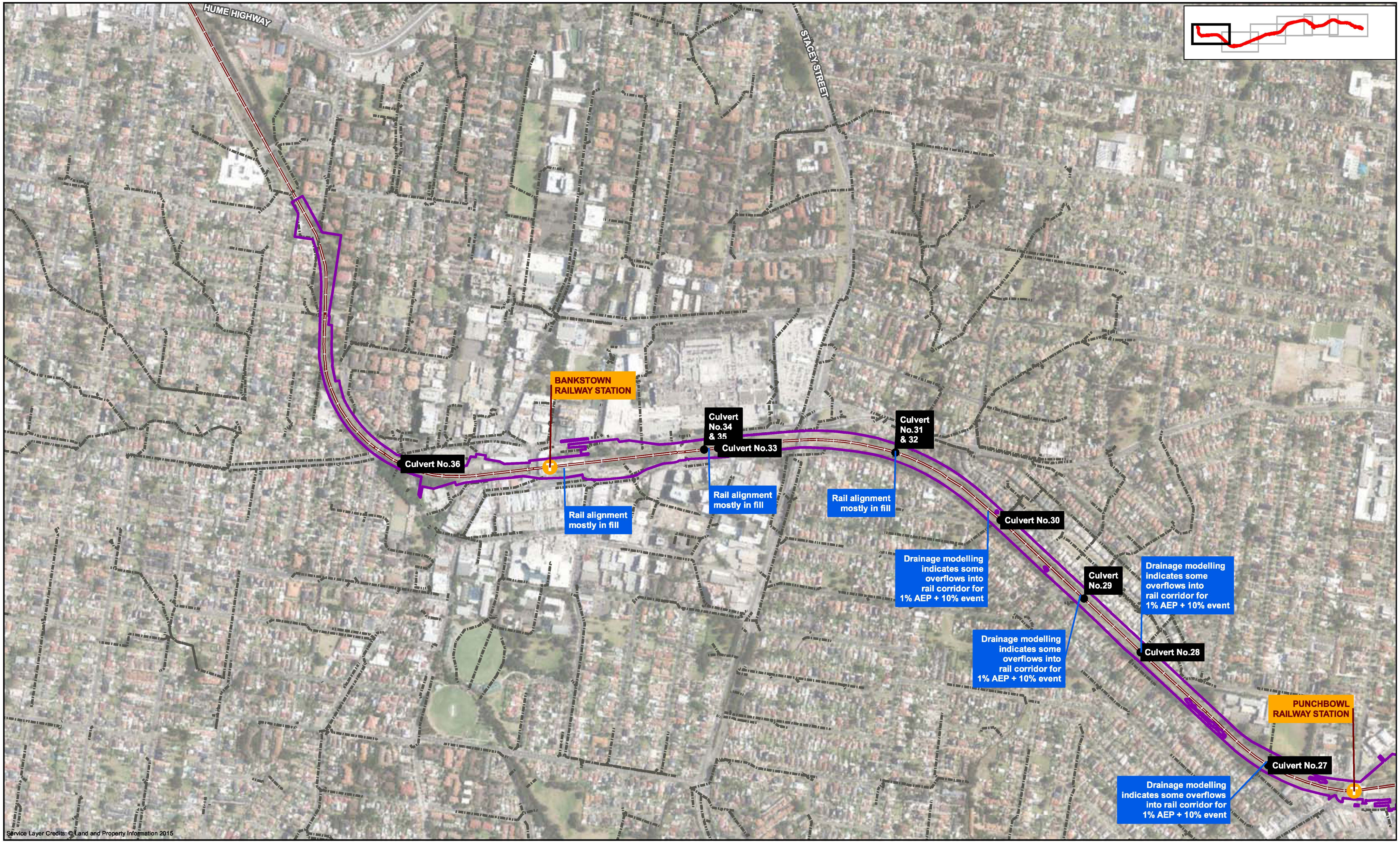
Figure 3-13

G:\21\25273\GIS\Maps\Deliverables\21_25273_Z004_Local_Drainage_DDP.mxd

Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

Data source: Aerial imagery - sixmaps 2016, General topo - NSW LPI DTDB 2012. Created by:afoddy



Paper Size A3

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Project area
- Train station
- Railway
- Existing drainage

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Figure 3-14

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Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

Data source: Aerial imagery - sixmaps 2016, General topo - NSW LPI DTDB 2012. Created by:afoddy

3.6.5 Flood risk management

Cooks River catchment

The Cooks River Flood Study investigated the flood behaviour within the catchment for a range of events. *The Cooks River Floodplain Risk Management Study and Plan* discussed a number of potential floodplain management measures. However, no specific measures were recommended or incorporated within the project area from either of the above studies.

Salt Pan Creek Catchment

The Salt Pan Creek Catchments Floodplain Risk Management Study and Plan (Bewsher Consulting, 2013) provides floodplain management options to address known flooding issues in the catchment.

The plan identified the need for mitigation works associated with the Wattle Street railway culvert at Bankstown. These were mainly aimed at reducing flood risk to the properties upstream of the rail corridor. The works include culvert upgrade or flow diversion and formalisation of the flow path to upstream of the rail corridor. The status of these works is unknown.

The plan also identified drainage issues in the Bankstown CBD and noted that works have previously been undertaken at the rail corridor to amplify the box culvert crossing near the rail corridor and to formalise an overland flow path downstream of the rail corridor underpass (West Terrace). Recommendations for further works were made as part of the plan and include improvement of the overland flow path near the rail corridor underpass.

3.6.6 Emergency management

The applicable emergency management plan for the study area is the *South West Metropolitan Emergency Management District Disaster Plan* (NSW Government, 2012). Local Flood Plans (LFP) are subordinate plans of the Local Disaster Plan. LFPs outline the roles and responsibilities for the NSW State Emergency Service (SES) and other agencies during flood events in relation to flood preparation, management and recovery. No currently published flood plans for the area are available on the NSW SES Floodsafe webpage. The floodplain risk management studies in the area indicate that a LFP was available for Marrickville but that it considered flooding from the Cooks River only.

Flood emergency management is incorporated into design criteria for Sydney Metro station infrastructure. Flood emergency management procedures would be incorporated in Sydney Metro operational emergency management plans.

The project team has held preliminary discussions with the NSW SES who identified Unwins Bridge Road in the Marrickville area as being a key evacuation route in advance of a flood event, although it was noted that in recent flood history, the flood events that have occurred have been of the order of a maximum of the 20 per cent AEP event.

3.7 Water quality

Typical surface pollutants from the existing project area, including the rail corridor, stations, car parks and ancillary facilities could include:

- Oils and hydrocarbons
- Heavy metals
- Chemicals from spills or inappropriate waste disposal
- Sediments

- Gross pollutants including litter and debris
- Nitrogen
- Phosphorous

No existing water quality treatment measures within the project area were identified in the desktop research or site visit.

3.7.1 Cooks River catchment

Historically poor water quality in the Cooks River means that it has been considered unfit for contact by humans (Cooks River Alliance, 2014). Sewage overflow, illegal dumping and litter by both the public and businesses have been quoted as the main sources of pollution in the catchment.

An ongoing plan of management for the Cooks River is in place. The plan targets, amongst other objectives, the improvement of water quality.

Further downstream in the Cooks River Estuary at Botany Bay, water quality is monitored as part of the NSW Government's State of the Beaches programme. The *State of the Beaches 2015-2016 Sydney Region* (NSW OEH, 2016) report graded the beach at Kyeemagh Baths, the beach most relevant to the study area, as good, indicating that water quality was suitable for swimming most of the time. The report noted that swimming suitability was affected from time to time by upstream sources, including from the Cooks River.

The Cooks River Water Quality and River Flow Objectives (DECCW, 2006a) states that tidal patterns in the estuary at Botany Bay significantly influence water quality, flow regimes in the Cooks River are already significantly altered, and that a return to pristine aquatic ecosystems is unlikely. However it notes that improvements in water quality should still be targeted.

3.7.2 Salt Pan Creek catchment

Heavy development in the Salt Pan Creek catchment, including construction effects and litter, as well as other influences such as sewer overflows and a landfill operation, have resulted in historically poor water quality in the creek. The water quality was designated D- ("poor") in 2009-2010. However water quality has improved in the ensuing years through the efforts of local councils and others. The most recently available report, the *2015-2016 River Health Report Card for the Georges River (GRCCC, 2016)*, identified the overall water quality health of Salt Pan Creek as "good" (A-). It is understood that water quality treatment devices in the form of trash racks and GPTs have been installed in the catchment together with the implementation of a public education program, amongst other controls.

The *State of the Beaches 2015-2016 Sydney Region* (NSW OEH, 2016) report graded the majority of the beaches of the Lower Georges River as being good, meaning that water was appropriate for swimming most of the time.