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SYDENHAM TO BANKSTOWN

ENVIRONMENTAL IMPACT STATEMENT

> Volume 6 – Technical Papers

NSW GOVERNMENT

Volume 6 – Technical papers

The following technical papers informed the preparation of the Environmental Impact Statement

Volume 6

Technical Paper 8 – Hydrology, flooding and water quality assessment

Technical Paper 9 – Biodiversity assessment report

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SYDENHAM TO BANKSTOWN

ENVIRONMENTAL IMPACT STATEMENT

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

NSW GOVERNMENT

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><td>ARI (years)</td><td>AEP (%)</td></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).

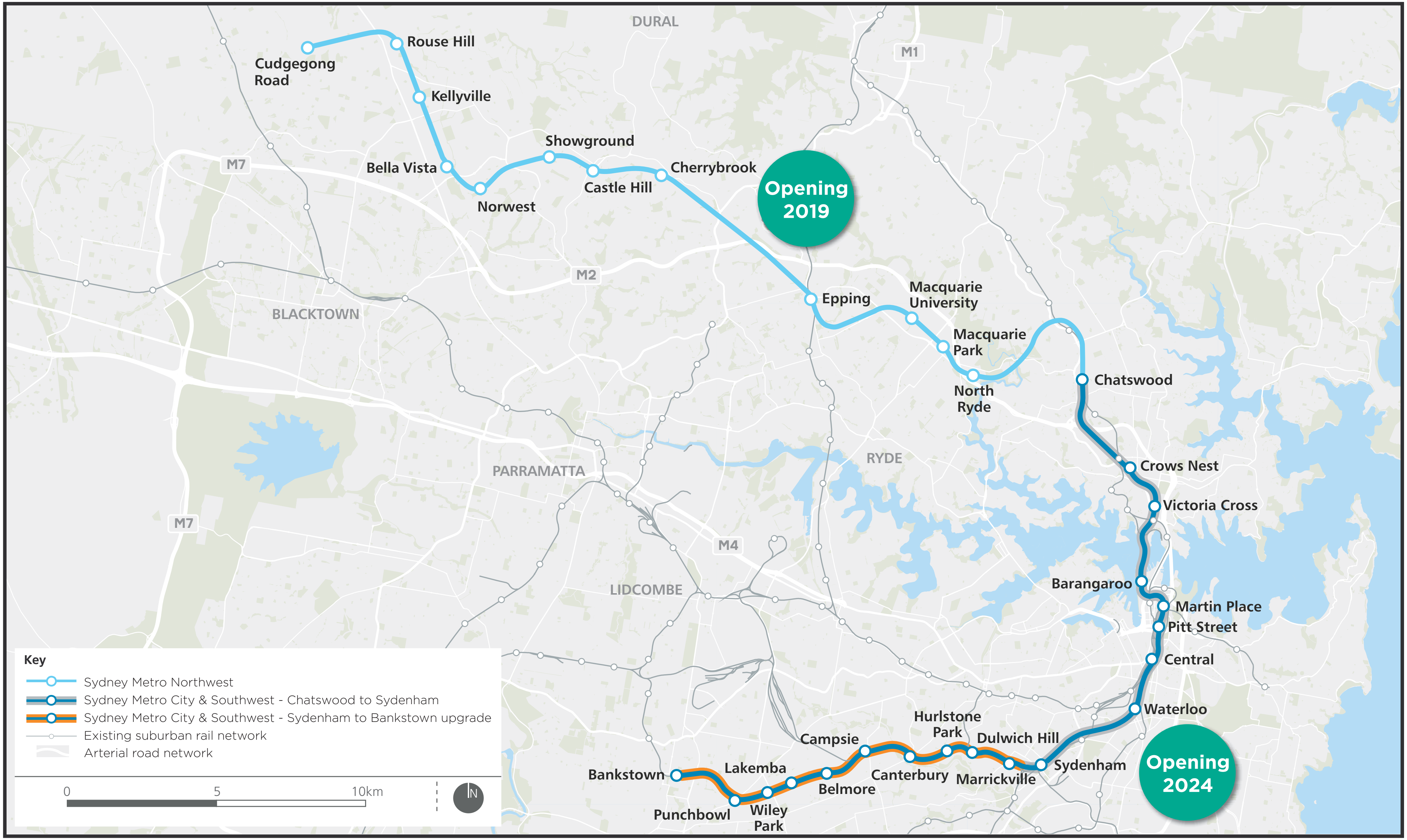
1.2 The project

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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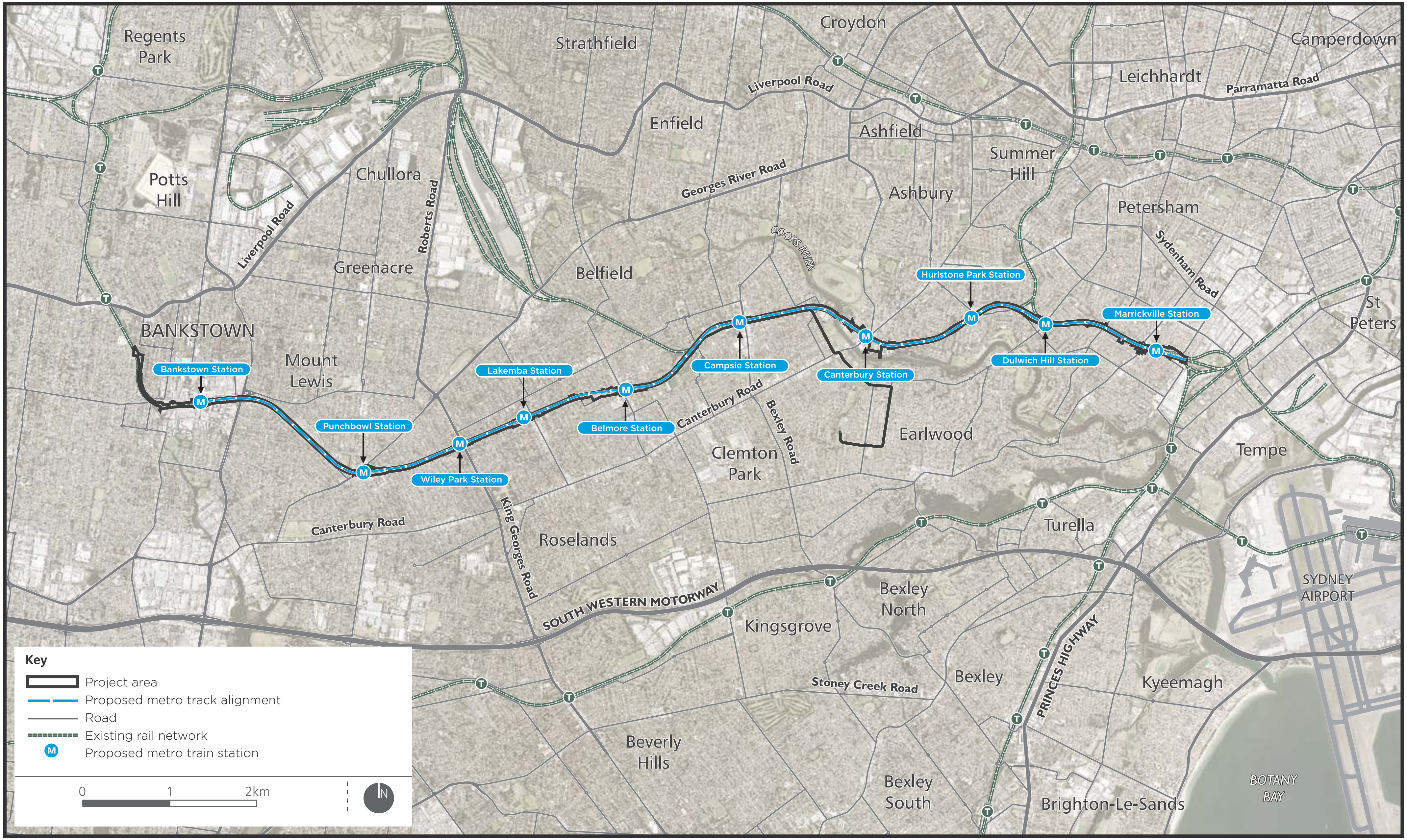
The Sydney Metro network

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 1-2 NSW 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.

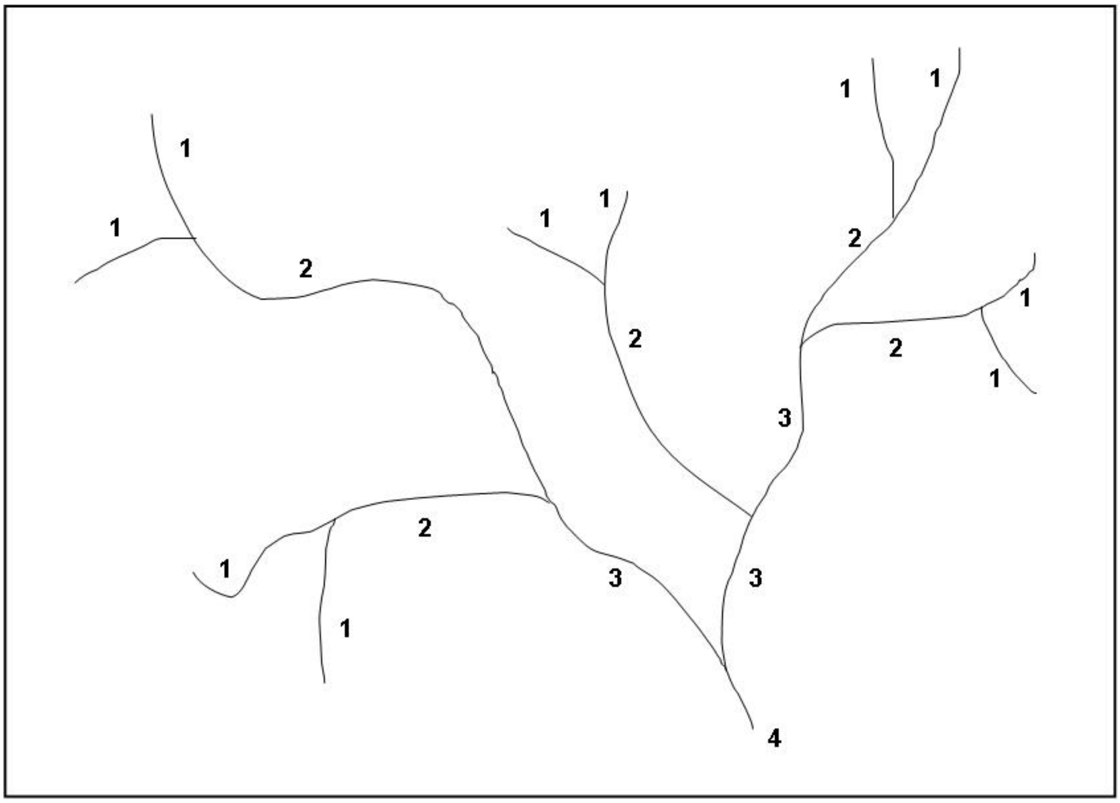


Figure 2-1 Stream order for a generic catchment

(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.

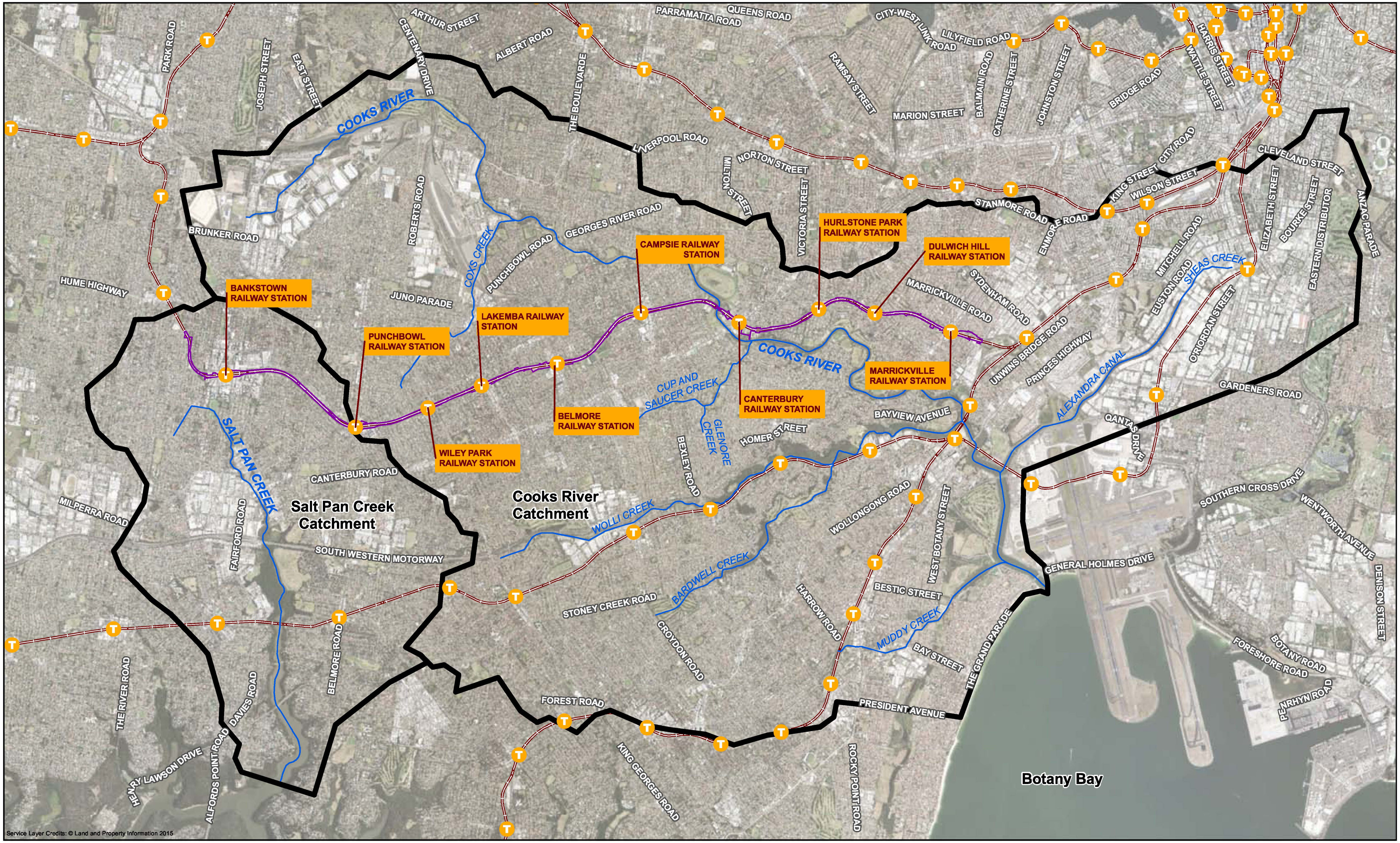
Further discussion of acid sulfate soils and their potential locations in the project area is included in EIS Chapter 19 - Soils and contamination.

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

GHD

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

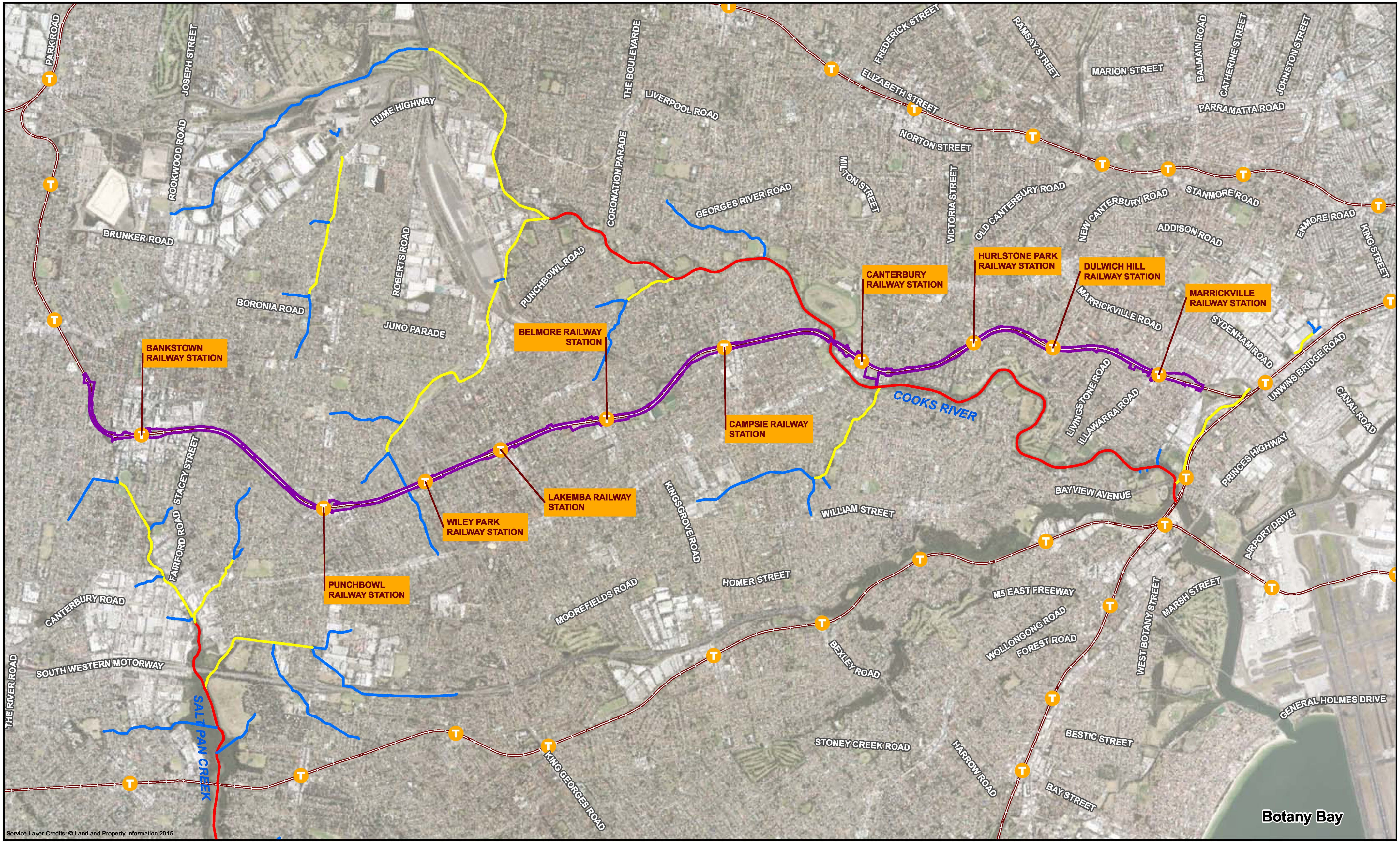
Salt Pan Creek is a tributary of the Georges River with a catchment area of around 26 kilometres squared. Around 10 per cent of the total catchment area is located north of the project area and drains beneath it to reach the downstream drainage network and the Georges River via Salt Pan Creek. The creek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

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Revision	A
Date	08 Jul 2017

GHD

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.

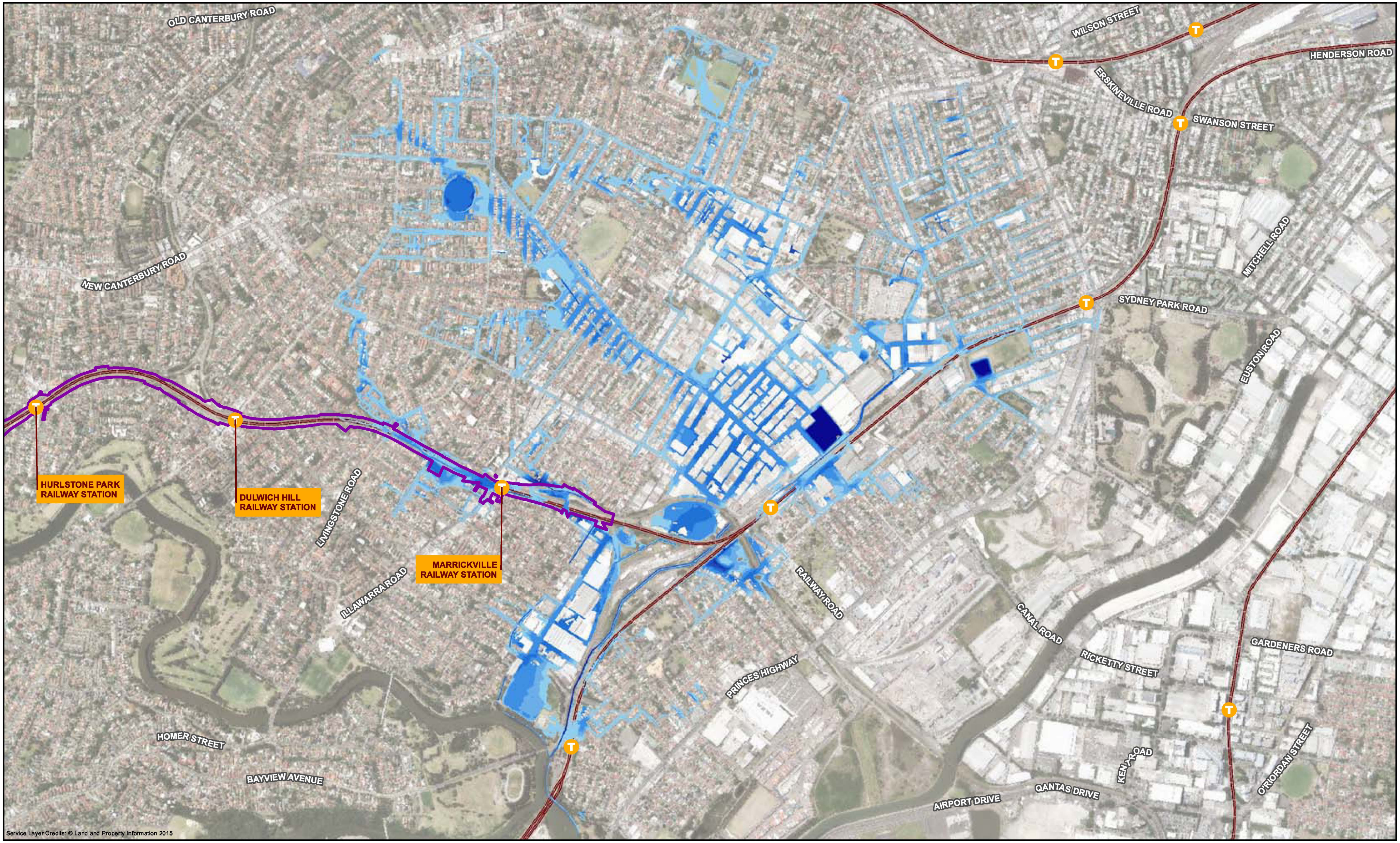
Near Marrickville Station, estimated flood water velocities are generally in the range of one metre per second to three metre per second in the project area. Peak flood velocities in the PMF are typically up to 0.5 metre per second higher than the one per cent AEP climate change event. Flood velocities 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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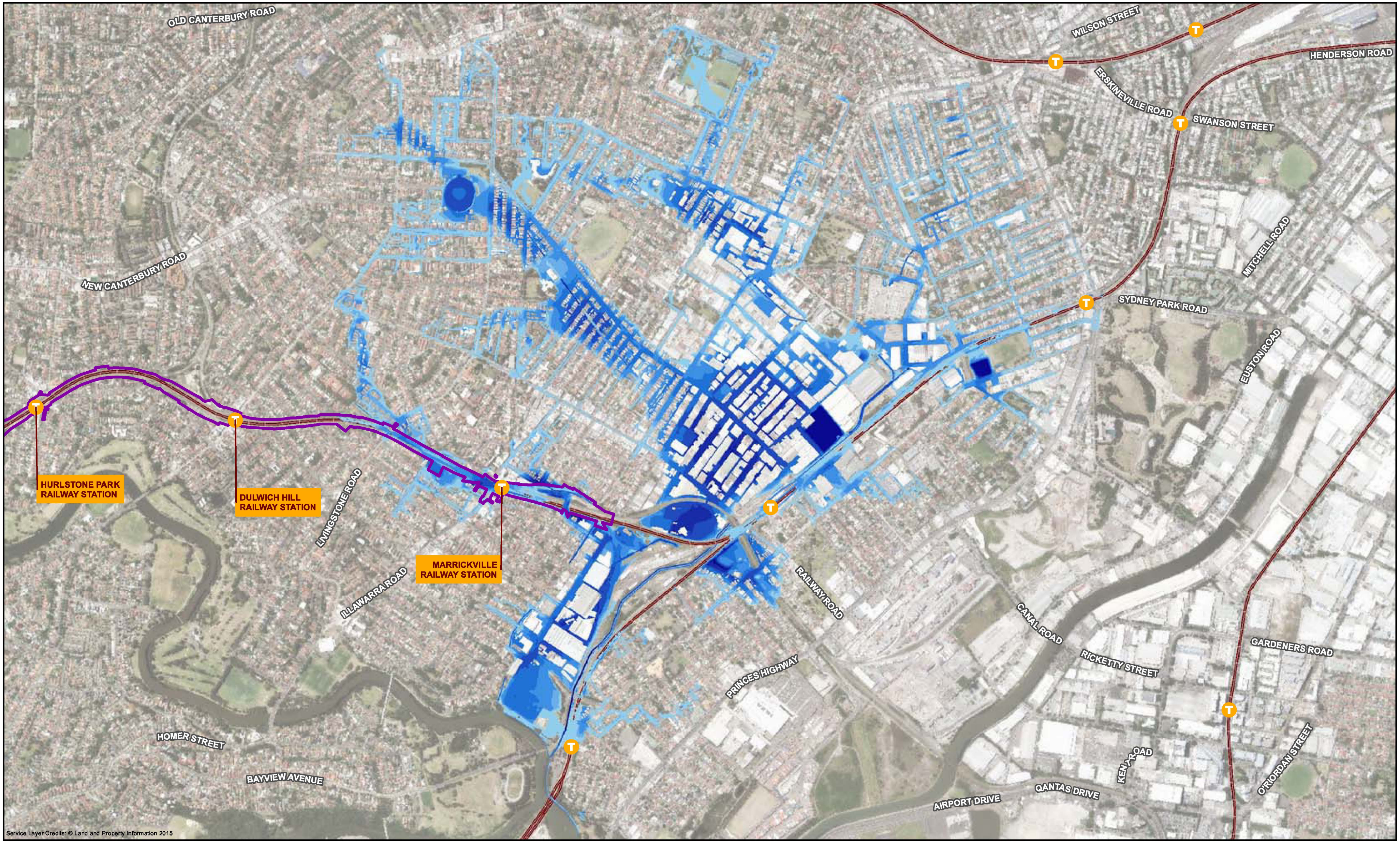
Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

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

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

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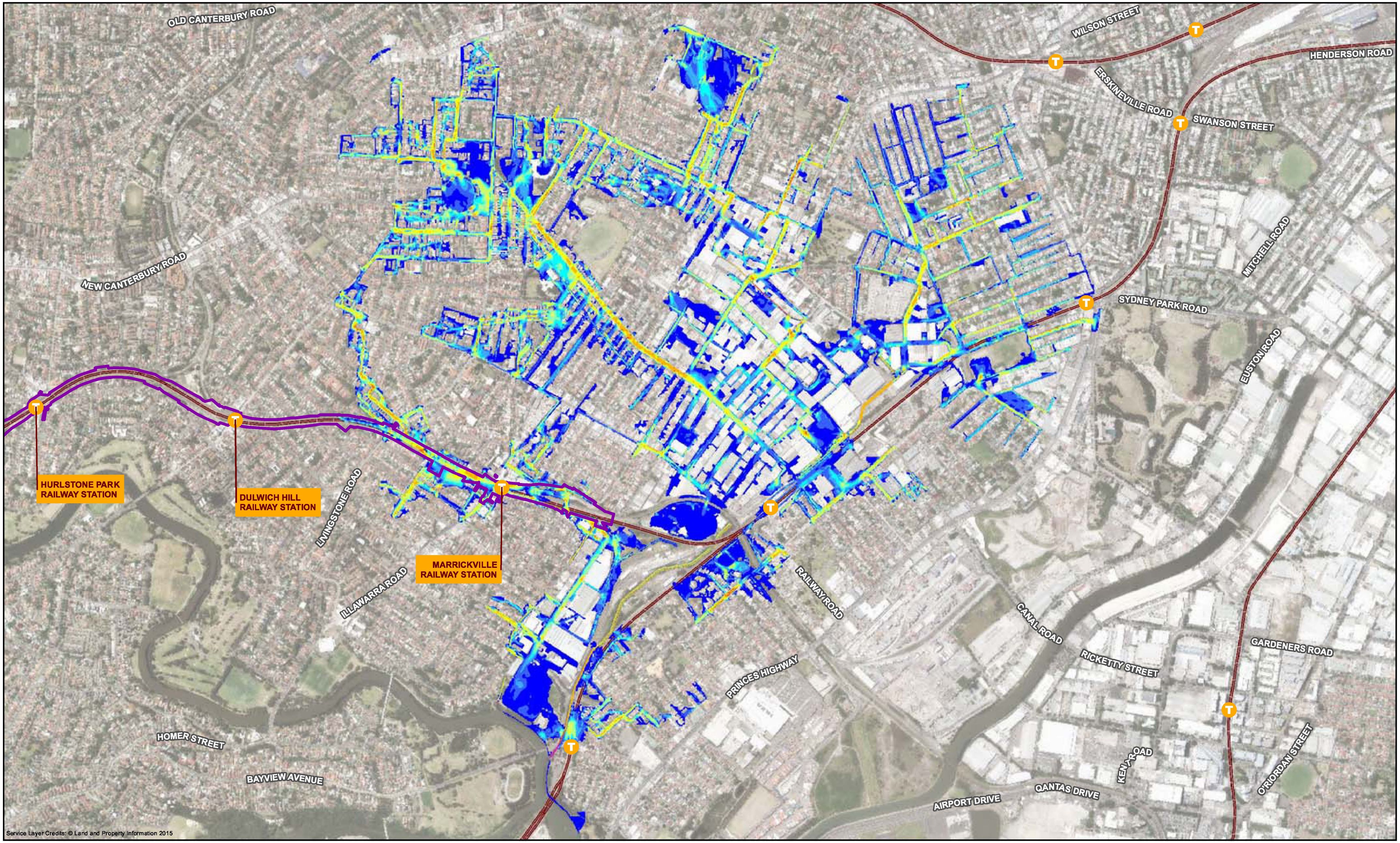
Data source: Aerial imagery - sixmaps 2016, General topo - NSW LPI DTDB 2012. Created by:afoddy



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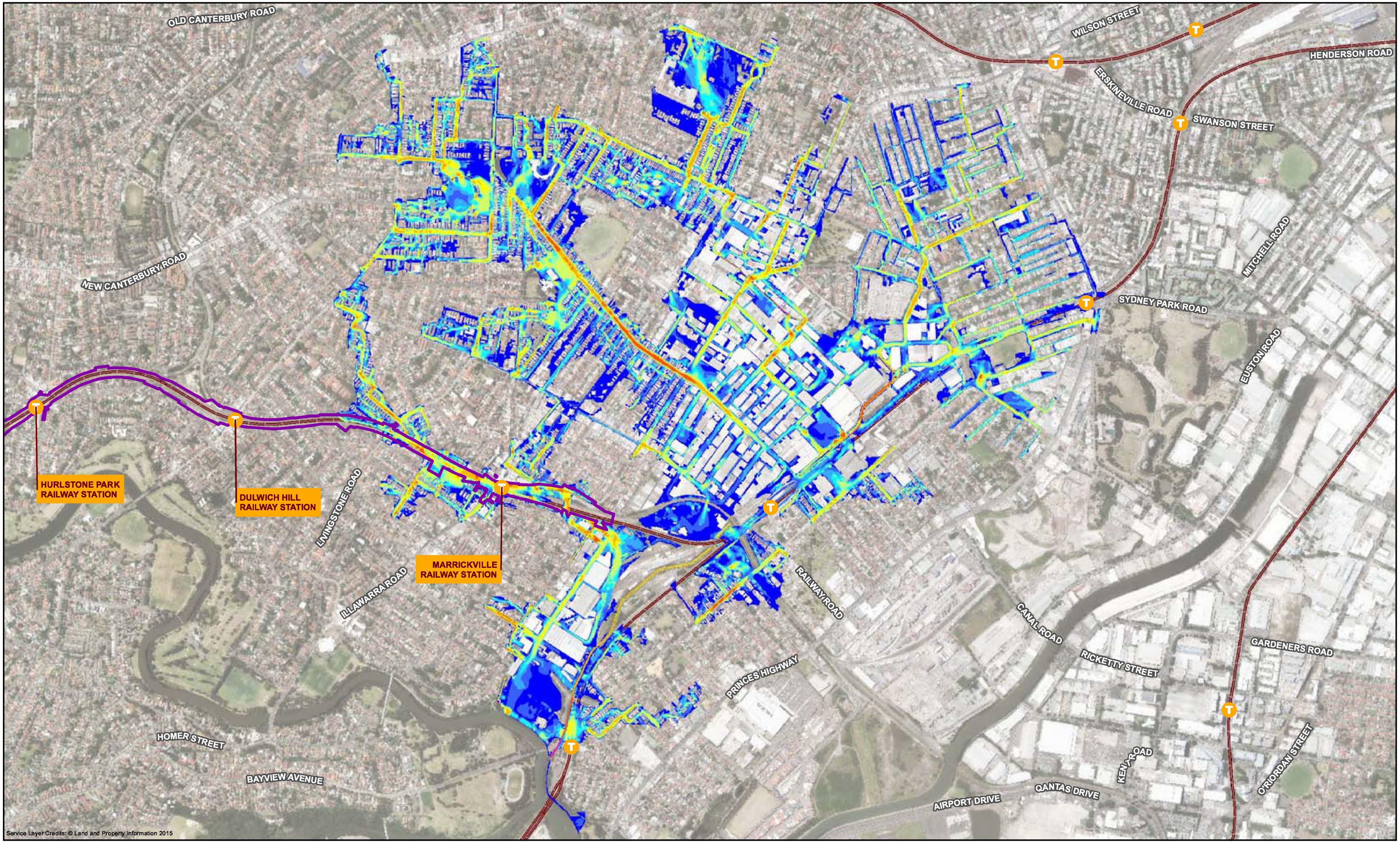
Data source: Aerial imagery - sixmaps 2016, General topo - NSW LPI DTDB 2012. Created by:afoddy



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

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Existing PMF flood velocity

Figure 3-6

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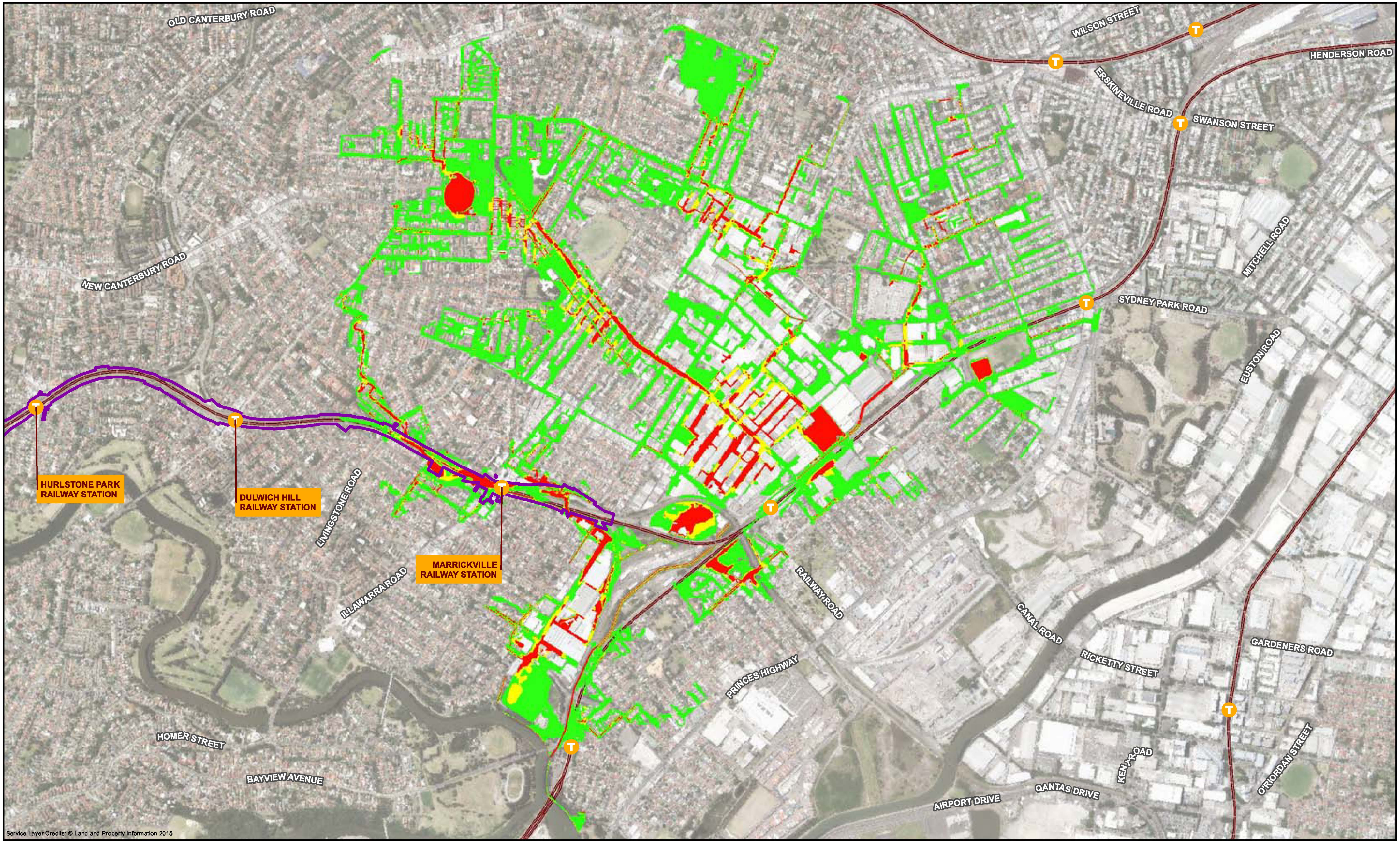
Data source: Aerial imagery - sixmaps 2016, General topo - NSW LPI DTDB 2012. Created by:afoddy

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



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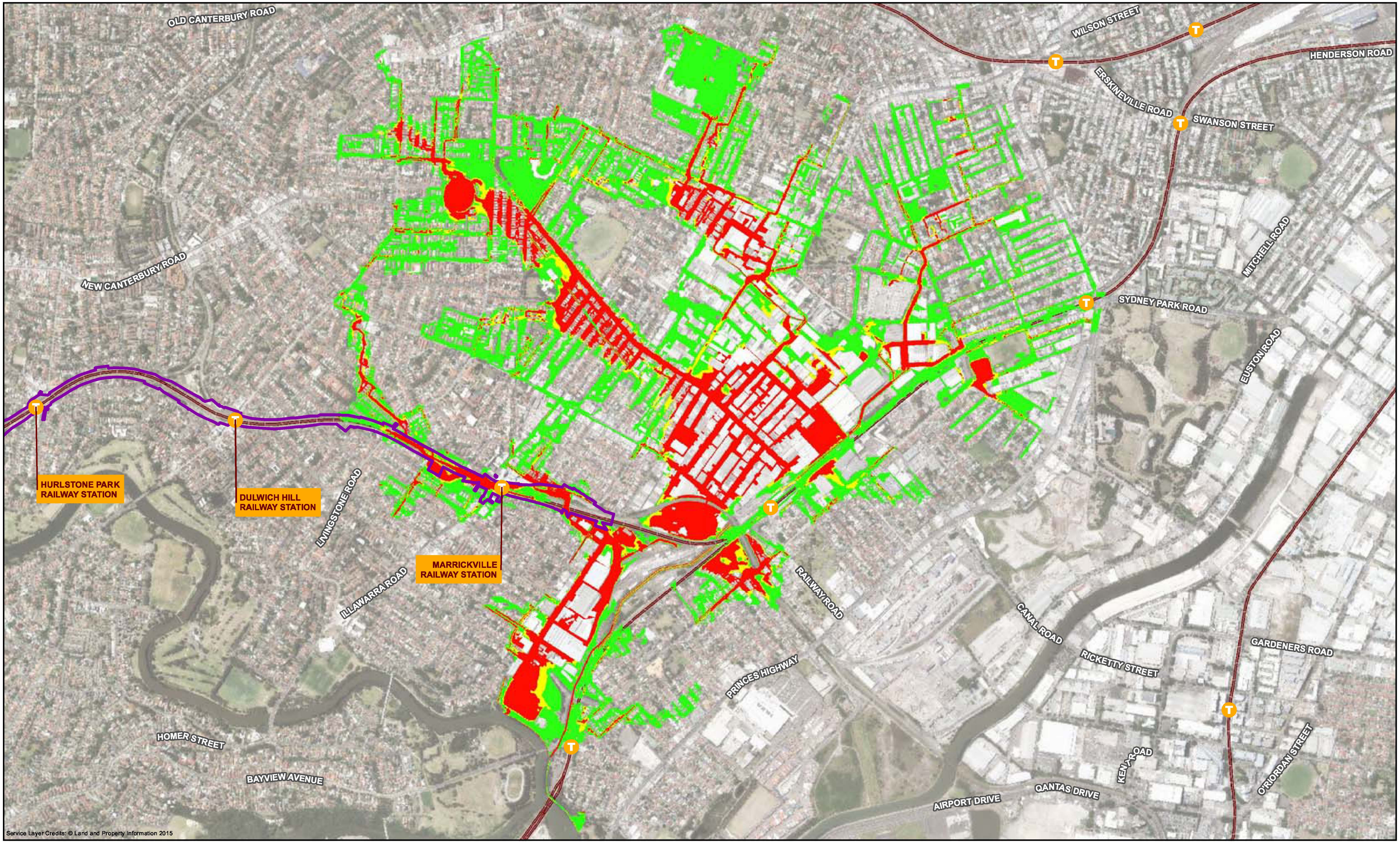
Data source: Aerial imagery - sixmaps 2016, General topo - NSW LPI DTDB 2012. Created by:afoddy



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 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

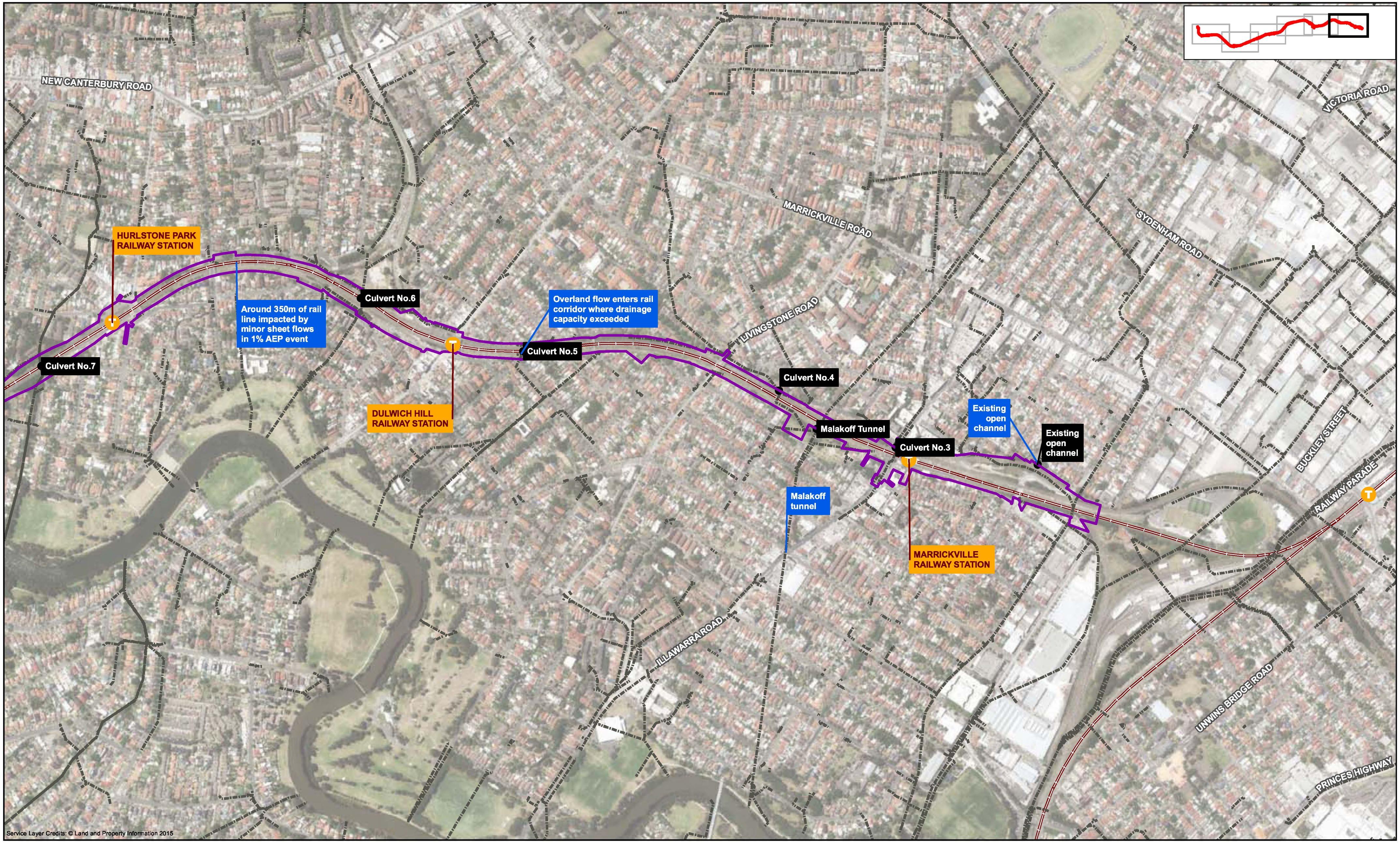
Rest of project area

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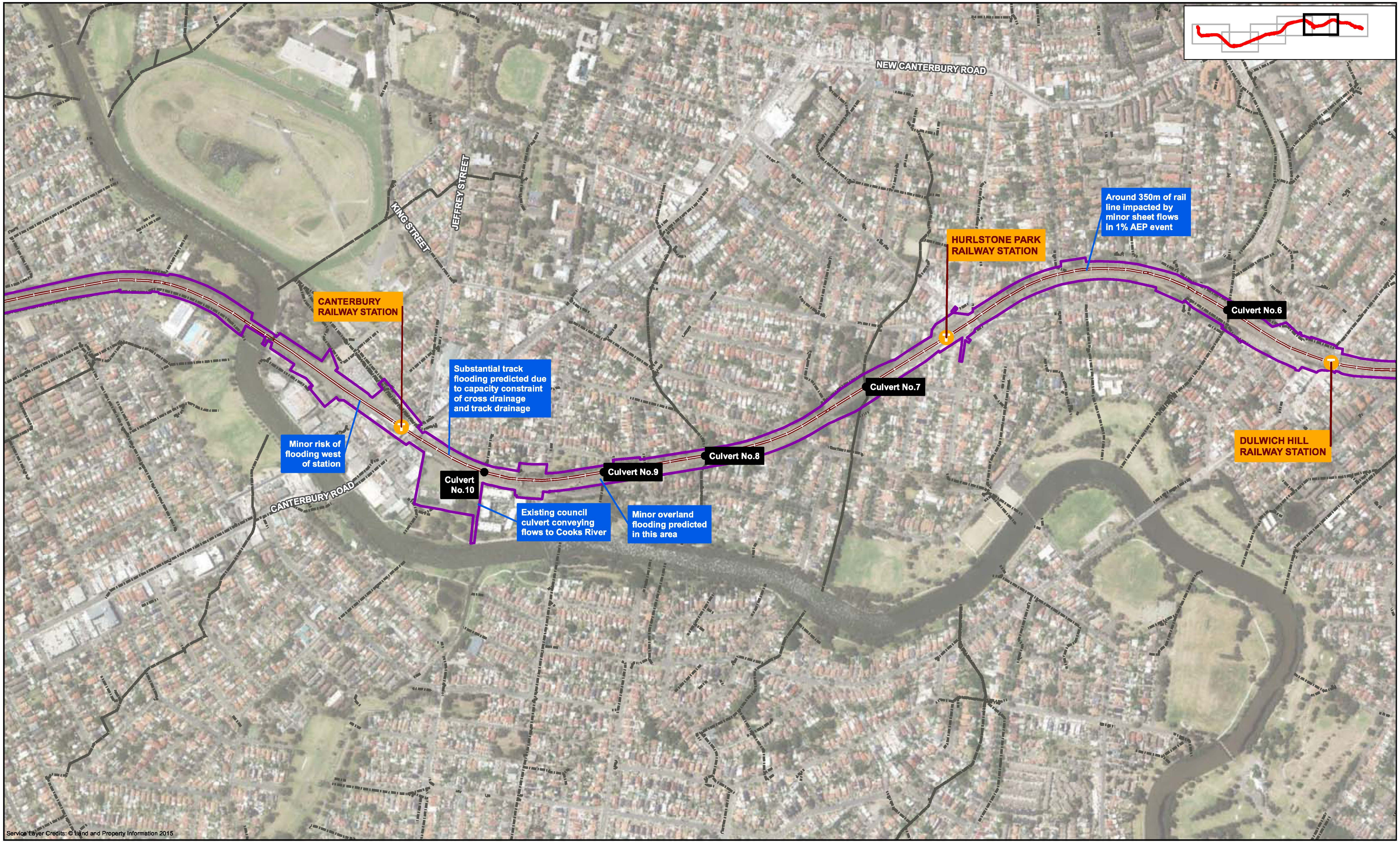
Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

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



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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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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
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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
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Grid: GDA 1994 MGA Zone 56

N

LEGEND

- Project area
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- Existing drainage

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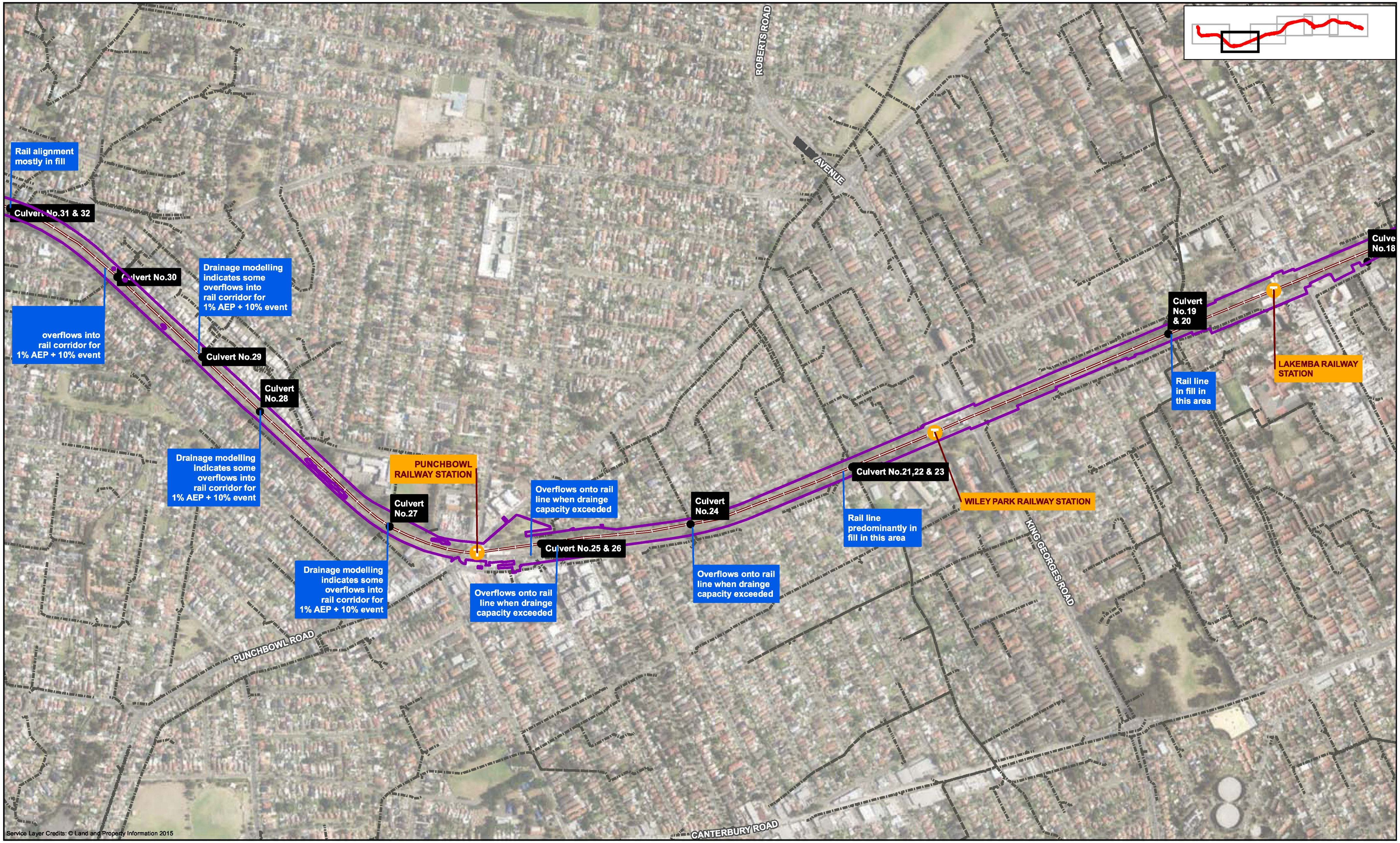
Figure 3-12

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

0 55 110 220

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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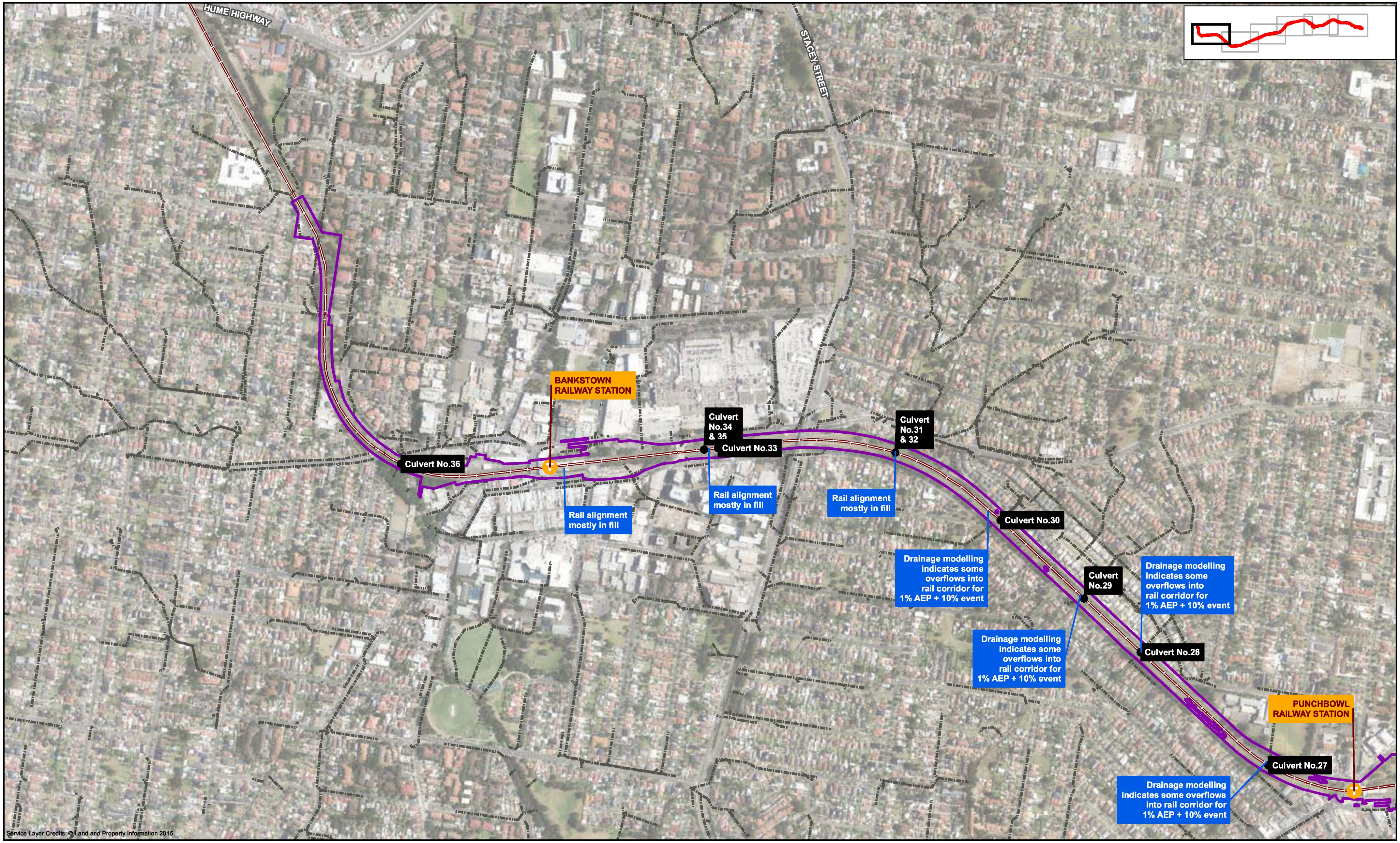
Figure 3-13

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

0 55 110 220

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.

4. Proposed drainage works

4.1 Sydney Metro design criteria

The design criteria for the project in relation to drainage and flooding was developed as part of the reference design

The reference design on which the impact assessment has been based would be refined during future design stages and the below requirements would be further addressed as necessary at that stage.

Proposed flood immunity criteria for various types of infrastructure are summarised in Table 4-1.

Table 4-1 Minimum flood immunity of metro infrastructure

Infrastructure	Minimum flood immunity	Comment
Above-ground track	1 % AEP climate change event	For mainstream flooding when measured to track formation at the edge of ballast
Above ground rail system facilities	500 mm above the 1 % AEP climate change event	Except where facilities are identified as being critical for emergency management, in which case they must be set at a minimum of the PMF
Above ground stations	1 % AEP climate change event	Subject to site specific flood risk assessment to determine impacts and emergency management in the PMF

Note: A 10 per cent increase in rainfall intensity above the one per cent AEP rainfall intensity has been included to make allowance for the future effects of climate change.

Adopted design criteria for the proposed drainage system are summarised in Table 4-2. Proposed design criteria in relation to flood impacts are provided in Table 4-3.

Table 4-2 Drainage system design criteria

Infrastructure	Design criteria	Comment
Track drainage	Capacity up to 1 % AEP climate change event where subject to overland flooding 2 % AEP + 10 % increase in rainfall intensity elsewhere, except in the Campsie and Marrickville areas, where only 5 % AEP is achievable due to existing track immunity	The existing track immunity is low in these areas due to flooding from the surrounding catchments. Achieving greater flood immunity in these areas has the potential to require major drainage upgrade works, which may alleviate flooding in the rail corridor but exacerbate downstream impacts.
	No net increase in discharge rates to downstream systems for all events up to and including the 1 % AEP event	On site detention to be provided as required.
On-site detention basin spillways	Designed to provide controlled discharge of flows for events up to and including the 1 % AEP climate change event	N/A

Infrastructure	Design criteria	Comment
Stormwater outlets	Prevention of scour up to 2 % AEP + 10 % increase in rainfall intensity	Impacts to be checked for events up to the 1 % AEP climate change event.
Stormwater inlets	Allowance in design for partial blockage	Industry practice to be adopted.
Car park drainage	Applicable council standards Effective drainage to prevent ponding of water	N/A

Table 4-3 Design criteria for flood impacts on adjoining lands

Flooding characteristic	Proposed criteria for flooding on adjoining lands
Duration of flooding	Maximum increase in time of inundation of one hour in a 1 % AEP event.
Maximum increase in flood level at properties where floor levels are already exceeded in a 1 % AEP event	10 mm
Maximum increase in flood level at properties where floor levels are not exceeded in a 1 % AEP event	50 mm
Increase in flood velocities	Identification of measures to be implemented to minimise scour and dissipate energy at locations where flood velocities are predicted to increase.

Note: Of the above criteria, only increases in flood levels and velocities have been modelled at this stage. Floor levels were not available therefore it was not possible to report against these criteria in the EIS.

Where it is not reasonable or feasible to achieve the outcomes in Table 4-3, further analysis would be undertaken at the detailed design stage to determine an acceptable flood impact for individual locations.

Proposed water quality and re-use criteria are provided in Table 4-4 and are based on the *Water Sensitive Urban Design Guideline* (Roads and Maritime Services, 2016). These guidelines were found to be more stringent than the Council guidelines reviewed which included those documented in the former Marrickville Council Development Control Plan 2011 and the Botany Bay and Catchment Water Quality Improvement Plan (Sydney Metropolitan Catchment Management Authority 2011). Relevant Sydney Water standards were also adopted where required.

It is noted that ANZECC guidelines were not adopted for the purposes of this design. However, it is intended that they will be incorporated at a later stage of the project during detailed design.

Table 4-4 Water quality design criteria

Pollutant	Pollutant reduction criteria
Suspended solids	85 % retention of the average annual load (6 months ARI)
Total Phosphorous	65 % retention of the average annual load (6 months ARI)
Total Nitrogen	45 % retention of the average annual load (6 months ARI)
Litter	Retention of litter greater than 50mm for flows up to 25 % of the 63 % AEP (1 year ARI) peak flow

Pollutant	Pollutant reduction criteria
Course sediment	Retention of sediment courser than 0.125 mm for flows up to 25 % of the 63 % AEP (1 year ARI) peak flow
Oil and grease (hydrocarbons)	In areas with concentrated hydrocarbon deposition, no visible oils for flows up to 25 % of the 63 % AEP (1 year ARI) peak flow

4.2 Drainage infrastructure

Major changes to drainage at key locations are discussed below. Numerous other amendments to track drainage and cross drainage are also proposed and are discussed in later sections. In general, changes to existing drainage in the project area would be undertaken to:

- Replace assets in poor condition
- Provide new track drainage to cater to the realigned track
- Provide new track drainage to improve existing capacity issues
- Provide new cross drainage to manage overland flooding issues
- Mitigate increases in flow rates by provision of detention basins

The proposed works include the following:

- Around 14 kilometres of new track drainage
- Six new cross drainage structures to replace assets in poor condition
- Three new cross drainage structures
- Four new detention basins of sizes between 800 cubic metres and 8,000 metres cubed
- Several new inlet structures and open channels to manage runoff from the track formation and upstream areas
- Provision of a number of water quality treatment devices along the corridor to meet water quality objectives

The proposed works are summarised in section 4.2.1 for Marrickville Station, and in section 4.2.2 for stations between Dulwich Hill and Bankstown. The locations of the proposed detention basins are shown in Figure 4-1.

4.2.1 Marrickville Station

To alleviate existing flooding of the rail corridor for events up to the five per cent AEP event, the following is proposed in the vicinity of Marrickville Station to improve collection and conveyance of stormwater runoff.

Drainage to manage stormwater from the north

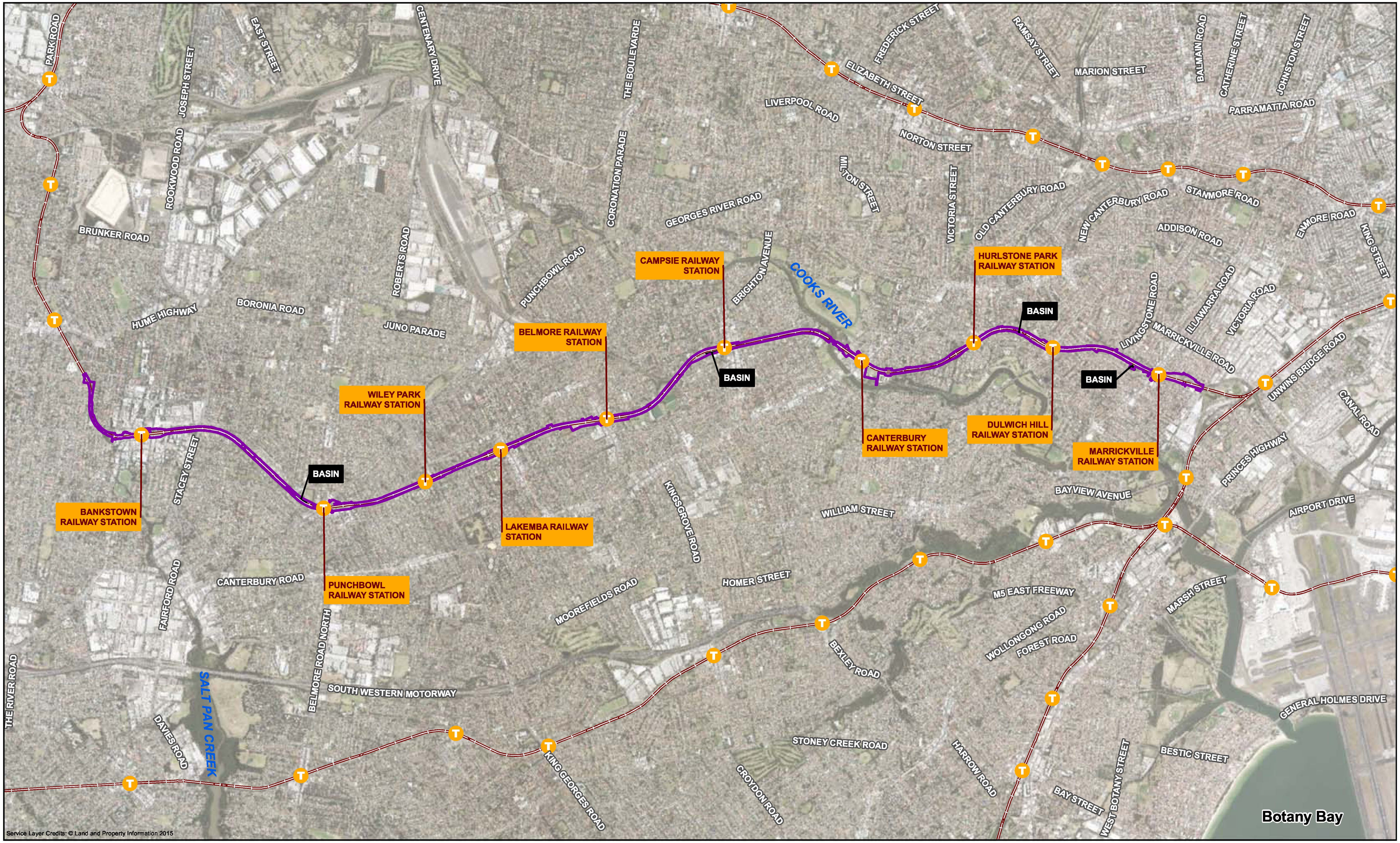
The following is proposed:

- 8,000 metres cubed underground detention basin system in McNeilly Park
- New trafficable grated inlet drains in Hollands Avenue and Livingstone Road
- Trafficable grated inlet drains in Livingstone Road and Marrickville Avenue
- New large diameter (1350 millimetre to 1650 millimetre) buried trunk stormwater system in Livingstone Road and Marrickville Avenue
- Inlet stormwater chamber in Marrickville Avenue adjacent to the rail corridor boundary

The new stormwater system external to the rail corridor would follow an alignment from the Hollands Avenue/ Livingstone Road intersection north of the rail corridor and cross beneath the rail corridor via a large inlet chamber to the north. This stormwater system would continue in an easterly direction, parallel to the cess drainage on the south side of the rail corridor in twin buried pipes placed side by side.

The most southerly of the twin pipe system will be diverted to a new 8,000 metres cubed underground detention system in McNeilly Park on the south side of the rail corridor. This detention basin manages the peak flows and discharges into the existing Malakoff Street stormwater tunnel which passes beneath McNeilly Park.

The remainder of the stormwater system from Livingstone Road continues past the proposed detention basin in McNeilly Park and is conveyed beneath Illawarra Road bridge under existing rail tracks in a large diameter buried pipe system and then diverts to the south beneath the station platform alignment.



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
Proposed Basin Location
Train station
Railway

GHD

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

Job Number	21-25273
Revision	A
Date	08 Jul 2017

Proposed Basin Locations

Figure 4-1

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

This system then crosses beneath the existing rail tracks in a northerly direction and discharges into the existing open channel adjacent to Victoria Road. The system then enters the existing closed stormwater system beneath Meeks Road bridge before finally discharging into the Western Channel which outfalls into the Cooks River.

Drainage to manage stormwater from the south

The following is proposed:

- New trafficable drains adjacent to Illawarra Road and parallel to Marrickville Station platforms.
- New drainage culverts to convey flows beneath the Marrickville Station platform.
- A series of new large stormwater drainage pipes in Station Street, conveying flows towards McNeilly Park.

4.2.2 Dulwich Hill to Bankstown

A range of drainage works are proposed in the rail corridor between Dulwich Hill and Bankstown stations. This includes detention basins and upgrades to cross drainage culverts, slotted pipe inter-track drainage, stormwater inlet pits, junction pits, cess drainage, headwalls, and other associated works.

An overview of the proposed drainage works along the alignment from Dulwich Hill to Bankstown is provided in Table 4-5.

Table 4-5 Summary of proposed drainage works from Dulwich Hill to Bankstown

Location*	Summary of existing flooding and drainage issues	Proposed drainage works
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).	• Culvert upgrades near Dulwich station. • New track drainage and local drainage upgrades. • 800 m^3 underground detention basin between Dulwich Hill and Hurlstone Park stations to mitigate increases in flow. • Culvert upgrades near Canterbury Station and provision of new 750 mm pipe to Cooks River.

Location*	Summary of existing flooding and drainage issues	Proposed drainage works
Campsie Station	• Surface water flows from south to north beneath rail corridor. • Overflows from local drainage overtop the rail corridor and flow east along rail corridor towards Campsie Station in events greater than the 10 % AEP. • West of Campsie Station is a high flood hazard area. • Overflows from local drainage into rail corridor near Belmore triangle area in events greater than 39 % AEP. • Because of the existing flooding in the rail corridor, and extensive works that would be required outside the project site to alleviate these, it is not considered practical to provide flood immunity in this area up to the 1 % event.	• New inter-track drainage. • New concrete-lined open channel to intercept overland flow from upstream. • 2,500 m^3 detention basin. • Provision of drainage standard and flood immunity to 5 % AEP level only. • New culvert to be provided in Belmore Triangle area to alleviate existing flooding.
Belmore Station	• Surface water flows from south to north beneath rail corridor. • Local drainage capacity constraints outside the rail corridor. • Rail corridor in fill and no predicted overland flow issues within the rail corridor.	• No measures proposed.
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.	• New concrete lined cess drain to be provided. • New track drainage proposed.
Wiley Park Station	• Surface water flows from south to north beneath rail corridor. • Limited cross drainage capacity however rail corridor is mostly in fill.	• New track drainage proposed.
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.	• New cess drain and track drainage in this area. • 1,700 m^3 underground detention basin underneath the Up cess area.

Location*	Summary of existing flooding and drainage issues	Proposed drainage works
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.	• New track drainage proposed.

Note: For simplicity, locations are described with reference to the nearest station

4.3 Water quality

Water quality treatment measures have been proposed to satisfy the adopted design criteria outlined in Table 1-3. The proposed measures have been modelled in MUSIC for Punchbowl Station as a test site, and extrapolated for the other stations using the results for Punchbowl as the reference. Punchbowl was adopted as the test site on the basis that it has the largest extent of proposed impervious areas.

The proposed water quality measures are summarised in Table 6-4, and consist of:

- GPTs for the treatment of litter and debris. A total of 12 GPTs (2 each for Lakemba and Wiley Park stations, and 1 each for the remaining stations).
- Rain gardens for the treatment of total phosphorus, total nitrogen and suspended solids. Rain gardens are provided for each of the stations, except for Marrickville, where it is not required.

4.4 Construction

Construction of the project would commence once all necessary approvals are obtained, and the detailed design is complete. Where possible, construction and drainage activities would be planned considering the upcoming weather forecast to minimise the risks of potential heavy rainfall and major surface runoff events.

Although planning of activities in this manner would not prevent construction during periods of potentially heavy rainfall, the risk of having disturbed construction areas or unpreparedness during heavy rainfall periods would be reduced.

4.4.1 Pre-construction works

During the early stages of construction, various preparatory works would be undertaken such as site establishment works and construction access provision. Early stage works would also include:

- Installation of environmental controls, including sediment and erosion controls
- Stormwater drainage channel protection and diversion works
- Any necessary flood mitigation measures to manage overland flows

4.4.2 Construction and maintenance access

Construction access to the rail corridor would be carefully controlled and co-ordinated to minimise disturbance and inconvenience to landholders. Access to the project area would be via existing gates along the rail corridor and from major roads, where possible.

Any new access along the corridor would be formed and stabilised. Where access crosses drainage flow paths, drainage culverts of adequate capacity would be provided across the access track to keep vehicle tyres out of the water whilst facilitating drainage.

4.4.3 Construction compounds and worksites

Construction compounds and worksites would be located both within the rail corridor and in external locations. They would be located:

- At least 50 metres from watercourses or major drainage structures unless a detailed site specific erosion and sediment control plan is implemented.
- Above the five per cent AEP flood level (1 in 20 year ARI flood level) where possible.

Indicative locations for the construction compounds are shown in Figure 4-2. Some of these are within areas identified as existing flood hazard areas. Worksite information and potential construction stage impacts resulting from these are discussed in section 5.2.2. The final construction compound and worksite locations would be selected by the construction contractor and will be included in the Construction Environmental Management Plan (CEMP) or relevant subplan.

4.4.4 Stockpiles

Stockpiles of raw materials or spoil would be located as close as practical to the work area where they are proposed to be used and to permit drainage away from the track to reduce potential flooding impacts.

4.4.5 Surface water flows

A number of proposed improvements to cross corridor drainage would occur as part of the overall construction process. In general, where new cross drainage is proposed, the new infrastructure would be installed first before decommissioning the existing infrastructure. This would minimise the potential for uncontrolled water passage through the site and into adjacent areas.

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Metres

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

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LEGEND

- Project area
- Compound Locations
- Train station
- Railway

GHD

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

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Compound Locations
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Figure 4-2

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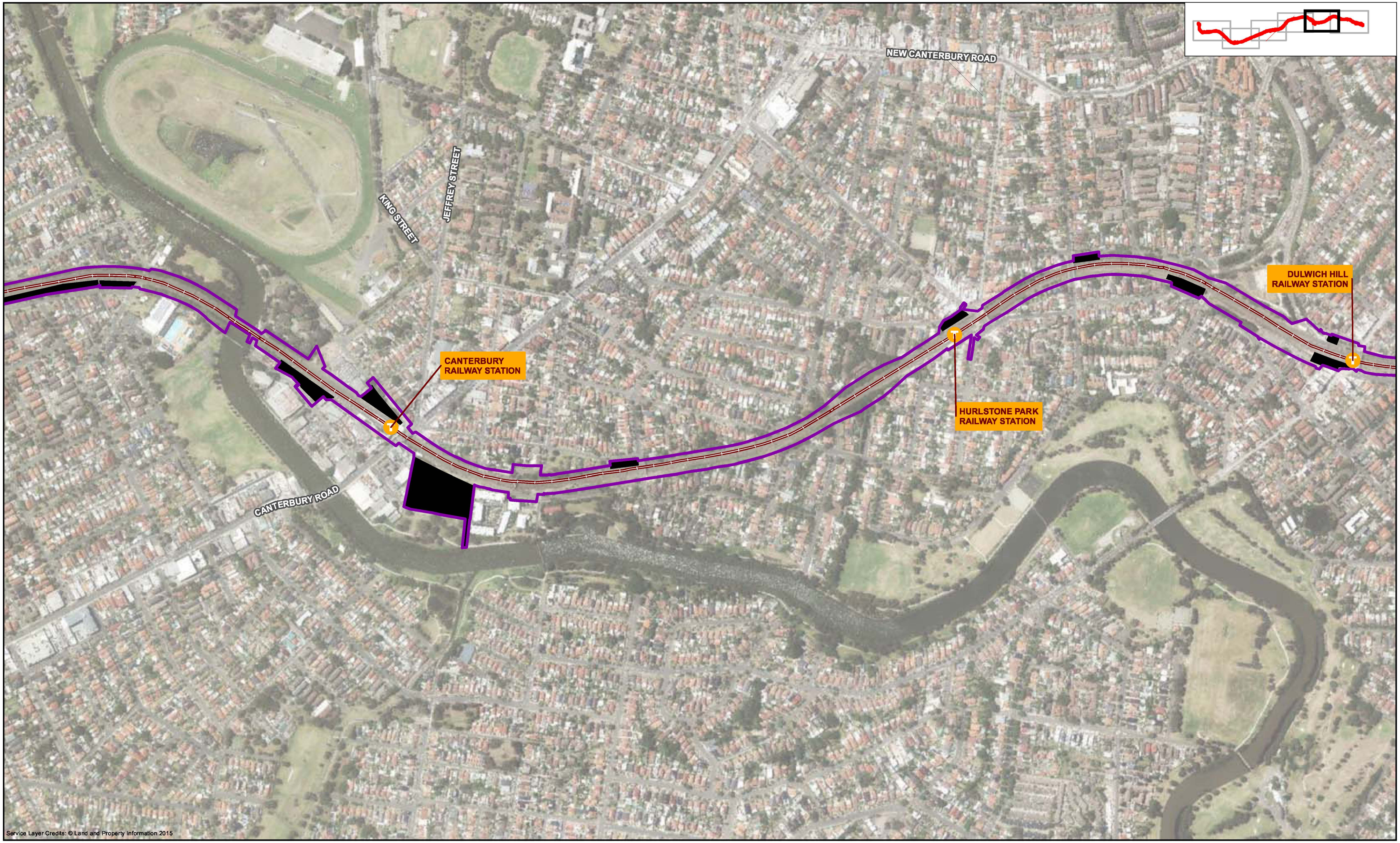
Data source: Aerial imagery - sixmaps 2016, General topo - NSW LPI DTDB 2012. Created by:afoddy



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

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LEGEND

- Project area
- Compound Locations
- Train station
- Railway

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Sydney Metro - Sydenham to Bankstown upgrade
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Figure 4-3

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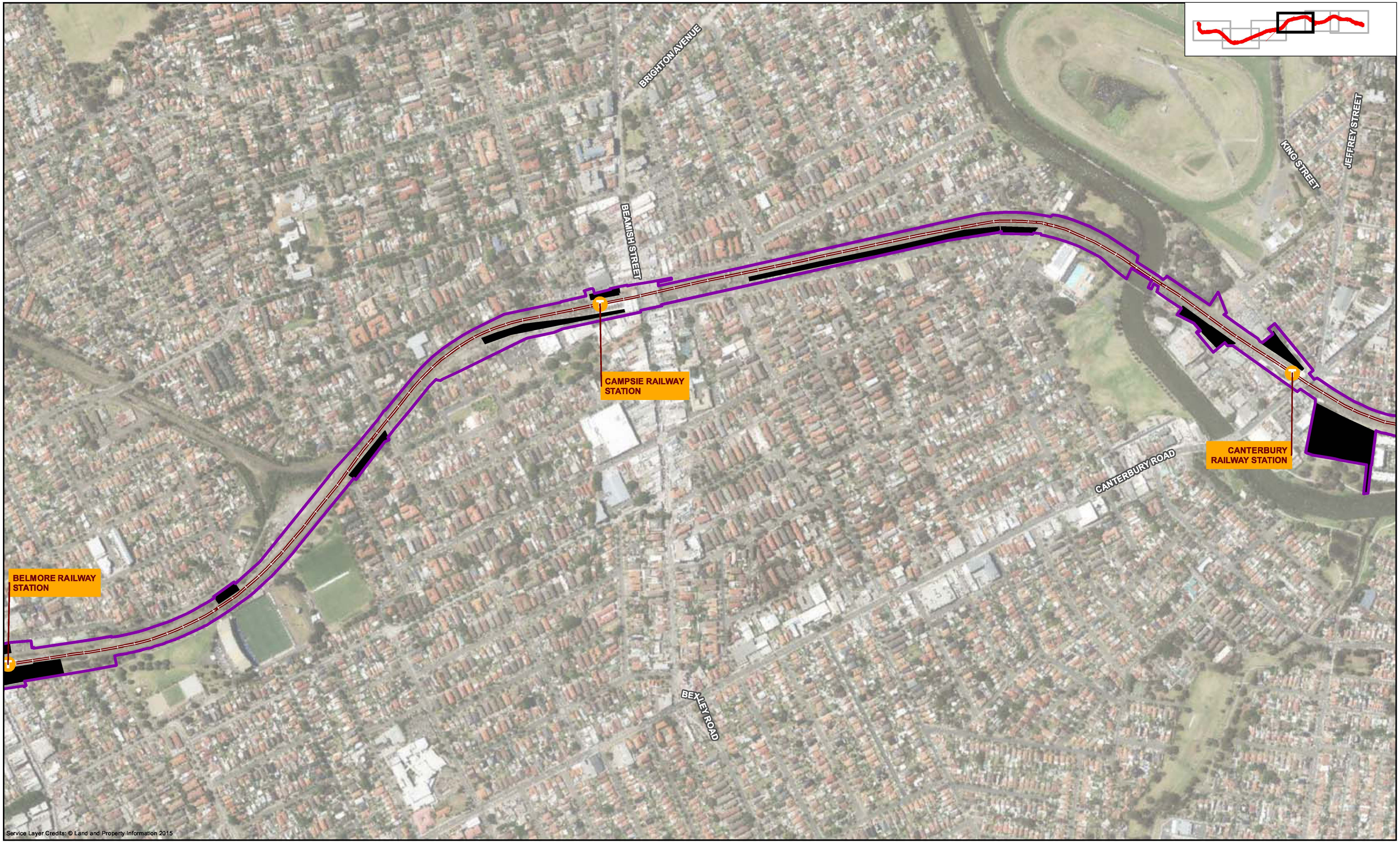

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LEGEND

- Project area
- Compound Locations
- Train station
- Railway

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Sydney Metro - Sydenham to Bankstown upgrade
Surface Water Assessment

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Figure 4-4

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Metres

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

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LEGEND

- Project area
- Compound Locations
- Train station
- Railway

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

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Compound Locations
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Figure 4-5

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

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
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Figure 4-6

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Metres

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

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LEGEND

Project area

Train station

Railway

Compound Locations

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

Compound Locations
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Figure 4-7

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

5. Construction impacts

5.1 Risk assessment

An assessment of the potential impacts and measures to avoid, mitigate or minimise them during the construction phase is provided in Table 5-1. The risks and impacts listed are discussed in the following sections.

Table 5-1 Potential construction risks and mitigation measures

Risk	Potential impacts	Measures to avoid, mitigate or minimise impacts
Hydrologic		
Impact on surface water flow in watercourses	• Changed surface flow paths across the rail corridor.	• Minimise regrading of terrain along the rail corridor. • Install appropriately sized culvert and bridge structures along the corridor.
Hydraulic issues		
Impact of raising the rail formation on flows	• Increased upstream flooding depths and extents • Increased upstream flood durations • Increased impacts on buildings • Increased impacts on adjacent infrastructure (e.g. road closures) • Additional impacts downstream of structures	• Install drainage works prior to or concurrent with rail formation construction to minimise potential adverse impacts.
Impact of conveying additional flows downstream by increasing cross drainage capacity	• Increased downstream flooding depths and extents • Increased downstream flood durations • Increased downstream impacts on buildings • Increased impacts on adjacent infrastructure (e.g. road closures)	• Provide detention basin to manage flows to existing council system. • Locate spoil mounds where they do not impact flow paths and patterns.
Working in the floodplain or flood prone areas	• Impact to construction workers working on flood prone land	• Locate construction compounds outside flooded areas, where practicable. • Prepare wet weather working and construction flood management plans.
Water quality issues		
Impact of construction activities mobilising sediment	• Pollution of receiving drainage networks and watercourses	• Locate construction compounds outside flooded areas. • Prepare wet weather working and construction flood management plans.

5.1.1 Impact of surface flow paths across the rail corridor

Surface flow paths across the rail corridor have the potential to:

- Impact on the flood immunity of the track, where the track passes through existing overland flow paths. Increases in the duration of inundation, flood levels, and flood extents may impact on the safety and operations of the metro line where design criteria and thresholds are exceeded.
- Result in changes in flow patterns, which may lead to undesired downstream flood impacts.

It is noted that the project would be designed such that rail formation overflow would not occur, except at a limited number of locations for events up to one % AEP (or five per cent AEP at Marrickville and Campsie) event, and in order to meet the flood immunity criteria.

5.1.2 Impact of raising formation levels in the project area

Raising the rail formation level could create several potential impacts:

- Increase the upstream flood level and flood extent as a result of the increased head required to pass the flow through replacement structures. Increasing the size of the replacement culverts, or providing a greater number of culverts, could reduce this impact but it would increase the potential impacts downstream of the rail corridor.
- Under existing conditions, many areas of the rail corridor overtop in relatively small design rainfall events. Raising the formation level would reduce the extent and frequency of any overtopping which could redirect flow paths or cause increases in the duration and depth of upstream flooding.

5.1.3 Impact of flow increases downstream

Where culvert capacity is to be augmented, there is potential for:

- Increasing flow depths, durations and hazard downstream of the culverts.
- Increasing load on the downstream drainage networks, some of which may be in poor condition.

5.2 Flooding and drainage outcomes

The following potential impacts on stormwater quantity and flooding are expected. A soil and water management plan (SWMP) would be required for the project area generally, with site-specific plans required at construction compounds and major worksites to manage and reduce the risk of flooding and drainage impacts associated with the works.

5.2.1 Works in the floodplain

Predicted flood extent information is available in parts of the corridor in the Marrickville and Bankstown areas. A number of work sites in these areas (refer Figure 4.2) are indicated to be partially within the floodplain including:

- The Marrickville Station construction compound, which is within the 63 per cent AEP flood extent. The compound to the east of the station is also situated near a high hazard area for the one per cent AEP event.
- The Victoria Road construction compound, also located near Marrickville Station, and also within the 63 per cent AEP flood extent. The Victoria Road compound on the southern side of the rail corridor is also situated near a high hazard area for the one per cent AEP event.

- The Campsie Station compound to the west of the station, which is situated near a high hazard area for the one per cent AEP event.
- The Canterbury Station construction compound to the east of the station, which is situated near a high hazard area for the one per cent AEP event.

Obstruction of flow paths due to the presence of construction works has the potential to:

- Redistribute flood flows and impact downstream development.
- Mobilise construction equipment or debris and cause downstream safety or water quality impacts.

The proposed location of the Marrickville and Victoria Road construction compounds within the 63 per cent AEP flood extent means that there is a 63 per cent chance that these compounds would be flooded in any year.

Due to the generally small sizes of these construction compounds, relative to the size of the floodplain, it is considered that any associated impacts are likely to be minimal.

Options to relocate these compounds or careful planning of compound layouts and management and planning of construction activities, would be considered during detailed design, if necessary, to minimise potential adverse impacts. Further review of construction compound locations beyond the Marrickville area would also be undertaken during detailed design stage to confirm that these are located above the five per cent AEP design flood event level (refer also to Section 7.1).

5.2.2 Potential for detrimental increases in the flood affectation of other properties, assets and infrastructure

During construction, there may be a need to temporarily disconnect or divert existing stormwater drainage pipes, which could result in localised modifications to existing flooding patterns, flow volumes, and velocities.

Temporary diversions would be required to transfer runoff around construction work sites. This may involve excavations and embankments, which would alter localised flow patterns. These changes would be temporary and limited to the construction phase. The landform would be restored as near as practicable to the pre-works condition following construction.

Construction would result in a small increase in impervious areas, which would have the potential to increase the volume of water flowing to watercourses. However, the change in impervious area would be negligible compared to the overall catchment area.

Temporary changes to the stormwater drainage system during construction would be subject to further design and analysis to confirm the potential impacts and to identify any required mitigation. Any flood impacts during construction are expected to be localised and relatively minor, and would be managed by implementing the measures provided in section 1. This would include, wherever possible, implementation of replacement drainage in advance of any disconnections or diversions (refer to section 7.1).

The locations of work areas and compounds within designated flood hazard areas would not result in flood affectation of other properties, assets and infrastructure (refer explanation below).

5.2.3 Consistency with Council floodplain risk management plans

Relevant plans are described in section 1. The *Salt Pan Creek Catchments Floodplain Risk Management Study and Plan* proposes drainage modifications near Wattle Street in Bankstown, which is close to the project area. Construction of the project would not prevent or compromise these proposed works. Construction works are therefore considered to be consistent with Council's floodplain risk management plans.

5.2.4 Compatibility with the flood hazard of the land

Some construction activities, work sites and compounds would be located in areas where there is an existing flood hazard. However, due to the generally small sizes of compounds and work sites relative to the size of the floodplain, minimal impacts on flood hazard would result. The layout of construction work sites and compounds would be undertaken with consideration of overland flow paths and avoid flood liable land where practicable. The location of work sites and compounds would be reviewed during construction planning to avoid, where possible, high hazard areas. Following completion of construction, no further impacts would occur.

5.2.5 Compatibility with the hydraulic functions of flow conveyance in floodways and storage areas of the land

Some areas of construction are located in areas with overland flow paths that may constitute floodways. Obstruction of flow paths and floodways due to the presence of construction works and equipment has the potential to redistribute flood flows and impact downstream properties, and/or mobilise construction equipment or debris, which could result in downstream safety or water quality impacts.

Careful review of the proposed layout of construction compounds, including siting of buildings and plant, would be undertaken where these are located within or partially within flood liable land. However, given their small size relative to the overall floodplain area, minimal impacts are expected. Following completion of construction, no further impacts would occur.

Some modifications to flood storage areas, including at McNeilly Park, are proposed. Construction flood management planning would incorporate measures to maintain the storage function of those areas in a flood event (refer also to Section 7.1).

5.2.6 Downstream velocity and scour potential

There is the potential for temporary drainage works to impact overland flow paths during construction. This could divert or concentrate flows, potentially resulting in the scouring of downstream areas, particularly where soil has been exposed during construction.

Soil and water management measures would be implemented in accordance with *the Blue Book* and *Managing Urban Stormwater: Soils and Construction, Volume 2A* (DECC, 2008), to minimise any potential impacts resulting from runoff and flooding during construction.

5.2.7 Impacts on existing emergency management arrangements

Preliminary consultation was undertaken with the NSW SES and local councils regarding existing flood evacuation routes and the potential impacts of the project. A number of roads providing access to the project area around Marrickville are subject to flooding under existing conditions (described in section 3.6.4).

With the implementation of mitigation measures provided in section 4, no impacts on existing emergency management arrangements are expected during construction. Ongoing liaison would be undertaken with relevant stakeholders during detailed design and the construction period.

5.2.8 Social and economic costs to the community

Although there would be temporary changes during construction, including installation of drainage and culvert works, there is not expected to be any social and economic costs to the community as a result of these works.

5.3 Surface water quality outcomes

The following potential impacts on stormwater quantity and flooding are expected:

- Increased erosion and sedimentation from a range of construction activities resulting in an increase in sedimentation in downstream waterways from runoff.
- Contamination of the waterways from chemical or hydrocarbon spills.

As for flooding and drainage, a SWMP would be prepared and implemented and include measures to manage and reduce the risk of water quality impacts associated with the works.

5.3.1 Erosion and sedimentation

Soil is the most likely potential contaminant that can impact water quality during the construction phase if runoff is allowed to mobilise exposed underlying soils. This can result in increased erosion and sedimentation, which is influenced by the severity of a storm event and the slope and footprint of the disturbed area.

Ground disturbance works affects all construction sites in one form or another and poses the greatest risk where they occur near waterways and steep slopes such as the existing railway embankments.

The earthworks and construction of the above ground components of the project would require the removal of existing vegetation and structures in some locations, thereby disturbing and exposing the soils. The earthworks and the movement of construction vehicles within the project area could increase erosion and sediment deposition in the waterways, particularly in proximity to inlets to the existing railway drainage or Council stormwater drainage network.

There is also the potential for the disturbance of sediments during excavation works to amend utilities including changes and additions to the existing stormwater drainage networks.

The location of existing surface water quality treatment devices in the Salt Pan Creek and Cooks River catchments downstream of the project area has not been confirmed but it is likely that devices such GPTs and bioretention basins are present. Devices such as GPTs largely treat gross pollutants such as rubbish and leaf litter and would provide very limited treatment of sediments that may be generated by the construction works. In excessive amounts, increased sediments from construction works have the potential to cause siltation of these devices, thus requiring additional maintenance. Bioretention devices or basins also retain sediments but excessive sediment loads have the potential to reduce their effectiveness.

As the construction programme will run over several years, the probability of a rainfall event occurring in excess of the minor drainage capacity is likely and appropriate flow or temporary diversion measures would be necessary. There is potential for large quantities of sediments to be directed into the stormwater network potentially resulting in siltation and blockage.

5.3.2 Potential for spills/ leaks

The release of potentially harmful chemicals and other substances in the environment may occur accidentally during construction due to spills, as a result of equipment refuelling, malfunction and maintenance, via treatment and curing processes for concrete, as a result of inappropriate storage, handling and use of the substances or from the disturbance and inappropriate handling of contaminated soils. This has the potential to impact on water quality in receiving waters downstream of the project. These contaminants could include acids and chemicals from washing processes, construction fuels, oils, lubricants, hydraulic fluids and other chemicals. Water quality and associated ecological impacts could result if these contaminants end up in the waterways and ultimately Botany Bay downstream of the works areas.

In accordance with the *Chemical Storage and Spill Response Guidelines* (Transport for NSW), spill kits would be provided at each compound and at worksites to cater for contingency events. Storage of hazardous goods, maintenance activities and refuelling activities would only be undertaken in bunded areas and away from waterways, including flood prone locations (refer also to Section 7.1.3). These locations would be identified in the soil and water management plan.

5.3.3 Demolition and construction works

There are key activities and areas within the project area that have the potential to result in downstream water quality impacts. Examples of sources of pollutants that could affect water quality from these works are as follows:

- Asbestos and other building materials
- Contaminated soils including fertilisers and pesticides
- Heavy metals
- Chemicals including hydrocarbons and fluids associated with demolition and construction processes and machinery
- Dust and airborne pollutants

Typical impacts on the waterways would be through mobilised dust, litter and other building materials being deposited or picked up by surface water runoff, waterways or stormwater management infrastructure thereby degrading the quality of the receiving environment. The transportation of building waste from the demolition and construction sites could potentially impact the quality of the waterways through inappropriate storage locations or accidental spills/material drops. Some materials that are typically found in building demolition, such as chemicals, can be easily transported from the demolition sites through off site stormwater runoff. These pollutants can be ingested by aquatic fauna and result in dead or sick marine life.

Working near watercourses or in low-lying areas introduces increased risks of contaminants being washed into the receiving stormwater network. Activities and areas which present a higher risk of impacting on the receiving waters would be outlined in the soil and water management plan, along with specific controls to reduce the risk of these impacts occurring.

5.4 Cumulative impacts

5.4.1 Council drainage works

The Salt Pan Creek Catchment Floodplain Risk Management Study and Plan proposes drainage modifications near Wattle Street in Bankstown, including formalising the overland flow path from Wattle Street to an existing rail culvert, modifications to fencing and upgrading of drainage on the upstream side of the rail corridor. Construction of Sydney Metro would not prevent the drainage upgrades by Canterbury- Bankstown Council though timing of construction would potentially need to be coordinated with the council.

5.4.2 Chatswood to Sydenham project

Construction works for the Marrickville tunnel dive structure associated with the Chatswood to Sydenham component of Sydney Metro would occur within the vicinity of the project area and is likely to be sensitive to potential cumulative impacts.

Planning, consultation and coordination work will be undertaken to ensure the planning, staging and implementation of the proposed works for both projects. In particular, the construction works would be staged to avoid or minimise the obstruction of any overland flow paths and extent of flow diversions required. Construction design criteria adopted for the project include the following:

- Increases in flood levels during events up to and including the one per cent AEP event would be minimised, particularly within private properties.
- Any increase in flow velocity for events up to and including the one per cent AEP event would not lead to scour and erosion.
- Dedicated evacuation routes would not be adversely impacted in flood events up to and including the PMF event.

On the basis of the above measures being adopted, it is not expected that there would be any significant cumulative impacts with this project.

Interface meetings between the two design teams are being undertaken and would continue during detailed design and construction to ensure that the proposed works for the two projects are well-coordinated and in order that potential cumulative impacts are minimised.

5.4.3 WestConnex

It is understood that WestConnex will drain primarily to Wolli Creek in this area, and then to the Cooks River downstream of the project. The construction impacts of the Sydenham to Bankstown project and of the WestConnex project are expected to be relatively localised and, as they are located remote from each other, the WestConnex project has a low probability to interact and impact on the water quality and flooding aspects of the Sydenham to Bankstown project during construction.

6. Operational impacts

6.1 Risk assessment

An assessment of the potential flooding risks, and measures to avoid, mitigate or minimise them during operation is provided in Table 6-1. The risks and impacts listed are discussed in the following sections.

Table 6-1 Potential impacts and mitigation measures

Risk	Potential impacts	Measures to avoid, mitigate or minimise impacts
Hydrologic		
Impact on surface flow in watercourse and flows in channels / drainage structures	• Modified surface flow volume or rate downstream of the rail corridor.	• Avoid installation of culverts that create localised surface water ponding. • Provide detention basins prior to discharge to existing drainage network where an increase in drainage capacity is proposed.
	• Changed surface flow paths across rail corridor.	• Minimise regrading of terrain along the rail corridor. • Install appropriately sized culvert along the rail corridor.
Hydraulic issues		
Impact of raising the rail formation on flows	• Increased upstream flooding depths, extents and hazard. • Increased upstream flood durations. • Increased upstream impacts on buildings. • Increased impacts on adjacent infrastructure (e.g. road closures). • Additional impacts downstream of structures.	• Provide additional inlet capacity on upstream side and drainage capacity to convey flows into Eastern Channel.
Impact of providing increased culvert / drainage capacity	• Increased downstream flooding depths, extents and hazard. • Increased downstream flood durations and reduced emergency access. • Increased downstream impacts on buildings. • Increased impacts on adjacent infrastructure (e.g. road closures). • Increased downstream velocities and scour potential.	• Provide detention basins prior to connection to existing external drainage systems. • Do not reduce watercourse flow areas. • Locate spoil mounds where they do not impact flow paths and patterns. • Increase capacity of Eastern Channel (bank raising) at key location. • Local scour protection works in unlined channels.
Impact of filling / works in flood storage areas	• Increases in flood levels, or hazard. • Changes in flow paths.	• Avoid building in flood storage areas • Provide additional capacity / mitigation if required.

Risk	Potential impacts	Measures to avoid, mitigate or minimise impacts
Flood warning and emergency management issues	• All the above items resulting in changes to duration and nature of flooding have the potential to impact flood warning and emergency evacuation.	• Implement flood warning and awareness plans.
Water quality issues		
Minor increase in hard standing areas	• Increases in pollutant generation.	• Install water quality treatment devices.
Increased flow velocities (refer hydraulic issues above)	• Increased sediment mobilisation.	• Install scour protection and control.

6.1.1 Impact of modified surface flow volume or rate downstream of the rail corridor

During operation, ongoing modification to flow volumes and rates downstream of the rail corridor could occur as a result of changes to the flow rate and/or duration of flow through culverts that are constructed for the project. This could create additional erosion either upstream or downstream of the culverts or increased local flood potential where flow conditions are modified significantly (see also below in section 6.1.2).

6.1.2 Impact of raising project area levels

Raising ground levels for the rail formation would prevent flows from overtopping the rail corridor. This could have upstream effects including:

- Increased flood depths, duration of flooding and flood hazard upstream of the culverts with potential impacts to properties and road access.
- Reducing the uncontrolled flow of water over the rail formation.

6.1.3 Impact of providing increased drainage capacity / culvert area

Increased culvert and drainage capacity would allow greater flows through the project area to the downstream areas with potential impacts including:

- Increasing flow depths, durations and hazard downstream of the culverts.
- Increased load on the downstream drainage networks, some of which may be in poor condition.
- Altered flow paths downstream where the capacity of the drainage into which the upgraded culverts are connected is overwhelmed.

6.1.4 Impact of development in flood storage areas

The location of works within areas currently acting to store floodwaters could:

- Decrease flood depths and hazard or alter overland flow paths if flood storage areas are increased.
- Increase flood depths and hazard or alter overland flow paths if flood storage areas are decreased.

6.1.5 Impact of increases in impervious areas

Increases in impervious areas could result in increased generation of surface runoff, litter and other pollutants being conveyed to receiving watercourses.

6.2 Hydrologic and hydraulic modelling results

The most flood affected parts of both the project area and surrounding study area are located in the vicinity of Marrickville Station. The key outcomes in relation to flooding in Marrickville, and between Dulwich Hill to Bankstown, are summarised in Table 6-2 and the following sections.

6.2.1 Marrickville

The key hydrologic and hydraulic outcomes in relation to flooding in the Marrickville area are summarised in Table 6-2. Mapping of the expected change in flood level, velocity and flood hazard compared to existing conditions is provided in Figure 6-1 to Figure 6-6.

Table 6-2 Design performance against flooding criteria in Marrickville

Key criteria	Marrickville	Adjacent lands	Public roads
Maximum increase in time of inundation of one hour in a 1 % AEP event	Achieved	1) No increase in flooding in the majority of the study area for 1 % AEP climate change event. 2) Reduction in flood level of up to 300mm along rail corridor west of station and between 50-150mm further to the west for 1 % AEP climate change event. 3) Reduction in flood level of between 50-100mm east of station for 1 % AEP climate change event. 4) Where there is increases in flood level, increase is 50mm or less for events up to the 1 % AEP climate change event. 5) Floor level survey and detailed analysis required to assess above-floor impacts at +- 10 mm level	1) Reduction in flood level of between 150-200mm in vicinity of Byrnes Street, O'Hara Street, and Cavey Street. 2) Reduction in flood level of between 50-100mm at southern end of Carrington Road and Richardsons Crescent, including Mackey Park and Carrington Road Industrial Park. 3) Where there is increase in flood level, increase is 50mm or less for events up to 1 % AEP climate change event.
Maximum increase of 10 mm in flood level at properties where floor levels are already exceeded in a 1 % AEP event	Floor level survey not available. Any potential flooding above-floor will be assessed during detailed design.		
Maximum increase of 50 mm in flood level at properties where floor levels are not exceeded in a 1 % AEP event	Achieved		
Increase in flood velocities - identification of mitigation measures	Many locations benefit from flood velocity decrease. Selected locations of velocity increase are generally <0.25m/s for all flood events with further development of mitigation measures to be undertaken during the next stage of design		

As shown in Figure 6.1 to Figure 6.6, the proposed drainage works outlined in section 4.2.1 would be effective at mitigating potential increases in flood level, velocity and flood hazard for the full range of flood events from the 63 per cent AEP event to the PMF event such that there would be little adverse impacts to the surrounding community.

No increase in flooding is expected in the majority of the study area for the one per cent AEP climate change event. Most of the modelled area would benefit from a reduction in flood levels of between five to 300 millimetres over the full range of flood events up to the PMF. This includes areas immediately east and west of Marrickville Station along the rail corridor, the vicinity of Byrnes Street, O’Hara Street, Cavey Street, the southern end of Carrington Road/ Richardsons Road, Mackey Park and the Carrington Road Industrial Park.

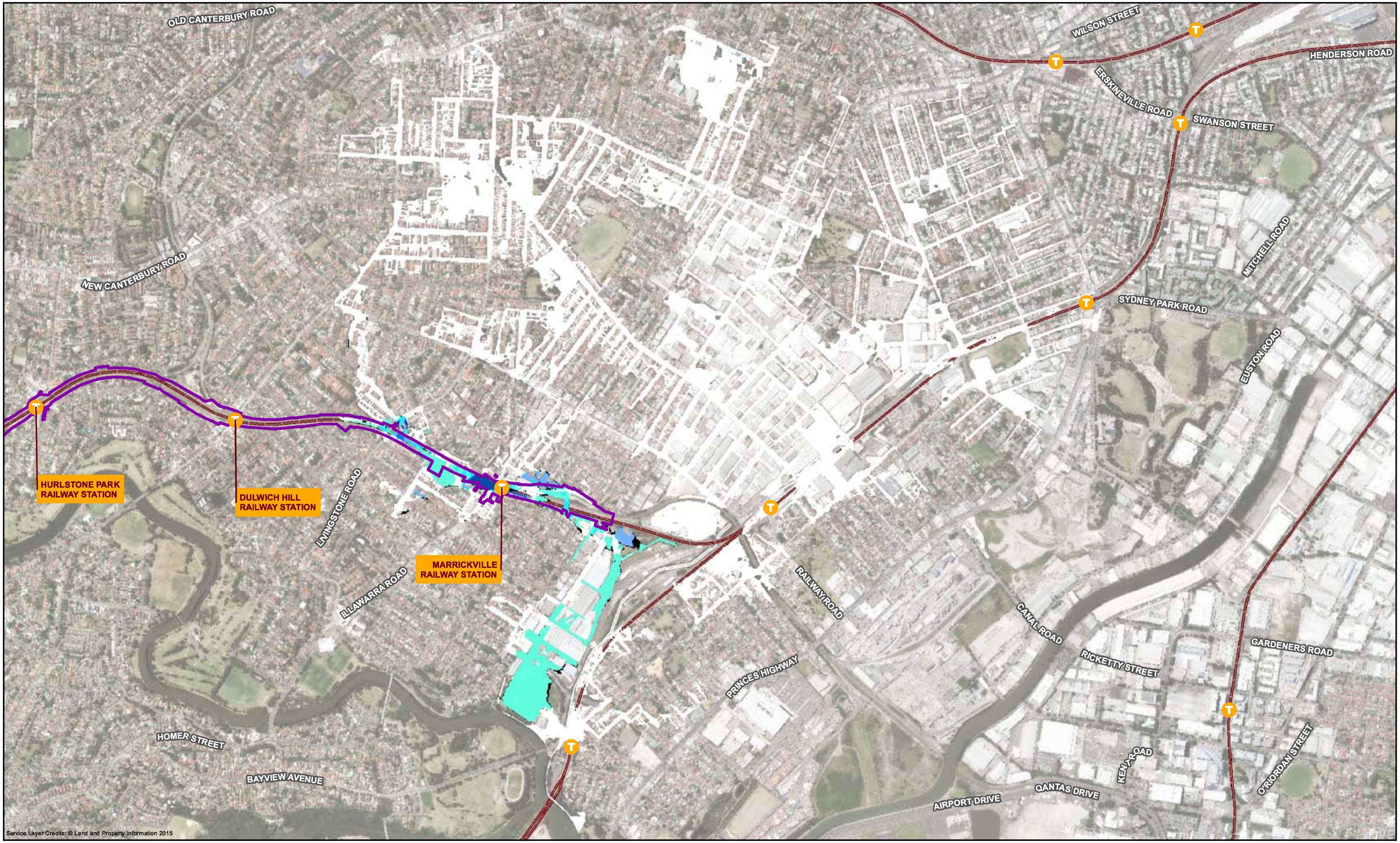
Where increases in flood levels are observed, they would be generally less than the 50 mm design criteria over the full range of flood events. The only exception is a short stretch of road along Junction Street, between Schwebel Street and Ruby Street, where increases of up to 100 mm are predicted for the 39 per cent AEP event. However, this impact is limited to the road only, and no private property would be affected.

Similarly, changes in velocities are estimated to be generally less than 0.25 metres per second at all locations for the full range of flood events. As in the case of flood levels, much of the study area would benefit from a net reduction in velocities as a result of the project.

As a result, no substantial changes in existing flood hazard are predicted with the proposed works in place.

Existing culverts within the Marrickville area include culverts no. 1 to 4 as listed in Appendix C. The post-development hydraulic results for the culverts indicate that culvert no. 3 would experience a slight increase in exit velocity for the one per cent AEP event. However, this post-development exit velocity is estimated to be only of the order of 2 metres per second, which is well within the limiting velocities for grass. On this basis, it is considered that this increase in velocity would not represent a substantial change in terms of scour and erosion potential.

Further design development would be undertaken to confirm the drainage details in the Marrickville area during detailed design.



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

Change in Flood Level (m)

- <-0.3m
- -0.3m - -0.2m
- -0.2m - -0.15m
- -0.15m - -0.1m
- -0.1m - -0.05m
- -0.05m - +0.05m
- +0.05m - +0.1m
- +0.1m - +0.15m
- +0.15m - +0.2m
- +0.2m - +0.3m
- +0.3m - +0.4m
- +0.4m - +0.5m
- > 0.5m
- Was wet now dry
- Was dry now wet

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

Job Number	21-25273
Revision	A
Date	22 May 2017

1% AEP +10% flood level change

Figure 6-1

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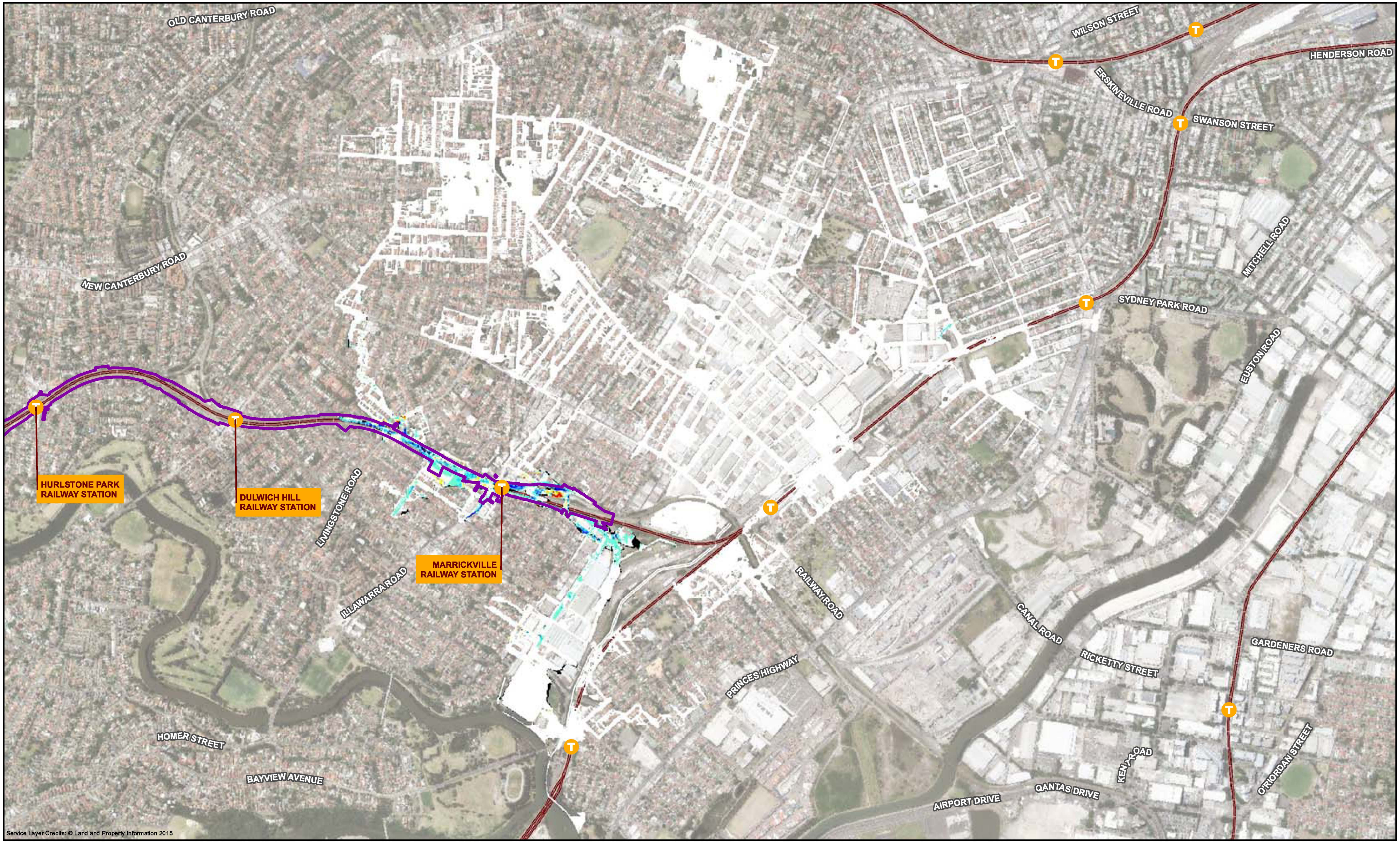
Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

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



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

Change in Flood Velocity (m/s)

- Greater than -0.5
- -0.5 to -0.4
- -0.4 to -0.3
- -0.3 to -0.2
- -0.2 to -0.1
- -0.1 to +0.1
- +0.1 to +0.2
- +0.2 to +0.3
- +0.3 to +0.4
- +0.4 to +0.5
- Greater than +0.5
- Was wet now dry
- Was dry now wet

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

Job Number	21-25273
Revision	A
Date	06 Jul 2017

1% AEP +10% velocity change

Figure 6-2

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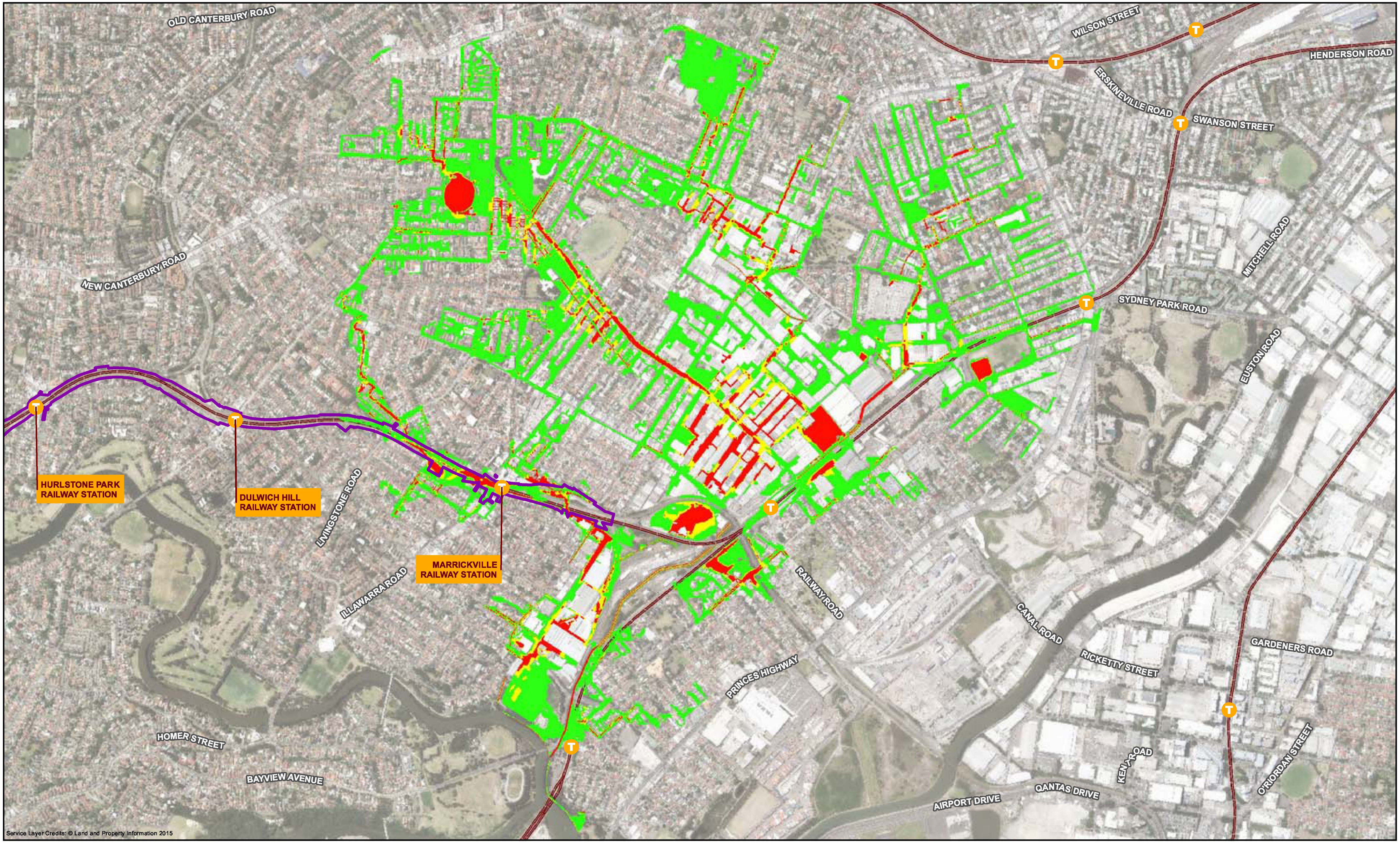
Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

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



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

Provisional Hazard Category

1 - Low Hazard

2 - Transitional Hazard

3 - High Hazard

GHD

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

Job Number	21-25273
Revision	A
Date	22 May 2017

Post-developed 1% AEP + 10% climate change provisional flood hazard

Figure 6-3

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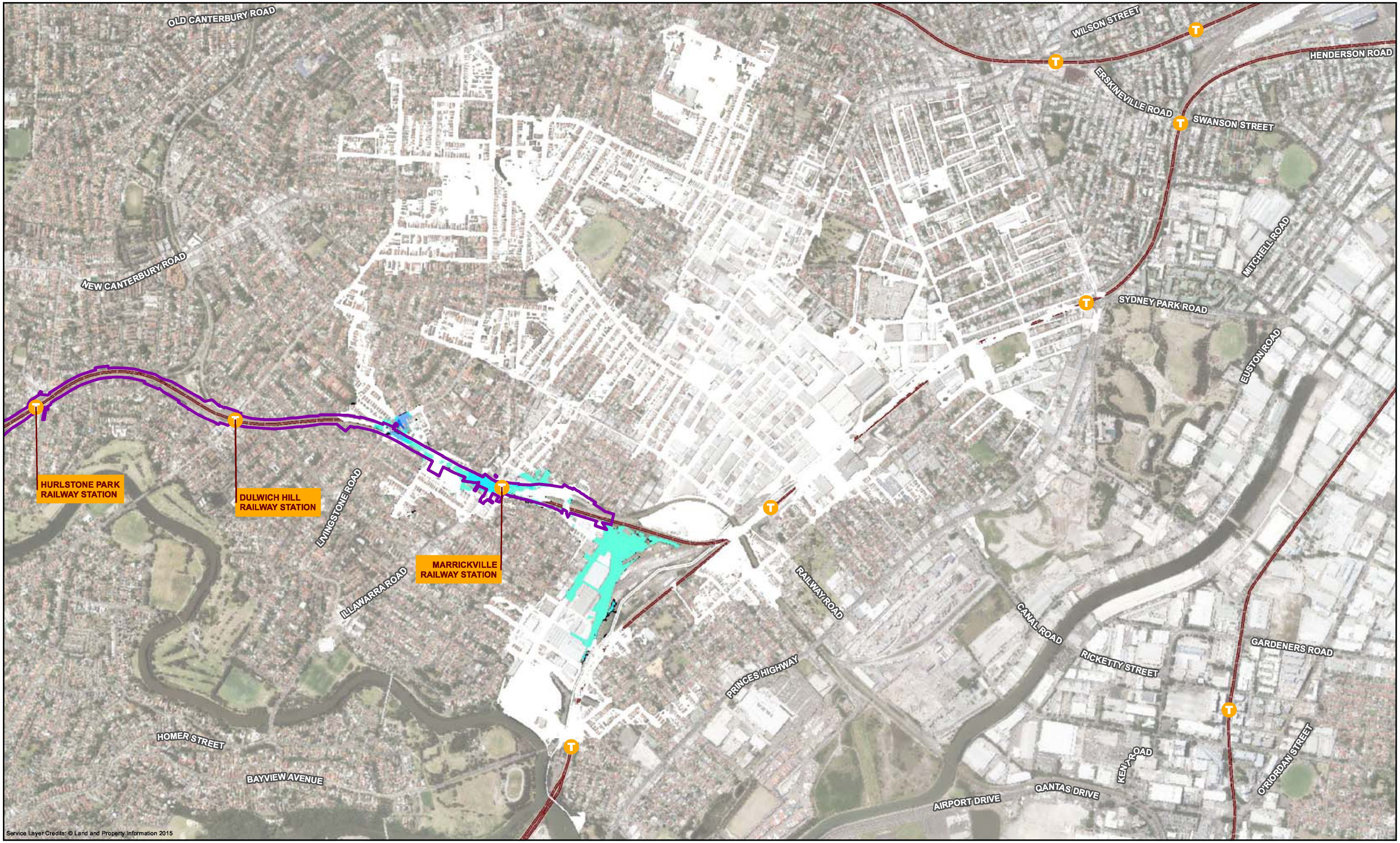
Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

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

Change in Flood Level (m)

- <-0.3m
- -0.3m - -0.2m
- -0.2m - -0.15m
- -0.15m - -0.1m
- -0.1m - -0.05m
- -0.05m - +0.05m
- +0.05m - +0.1m
- +0.1m - +0.15m
- +0.15m - +0.2m
- +0.2m - +0.3m
- +0.3m - +0.4m
- +0.4m - +0.5m
- > 0.5m
- Was wet now dry
- Was dry now wet

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

Job Number	21-25273
Revision	A
Date	22 May 2017

PMF level change

Figure 6-4

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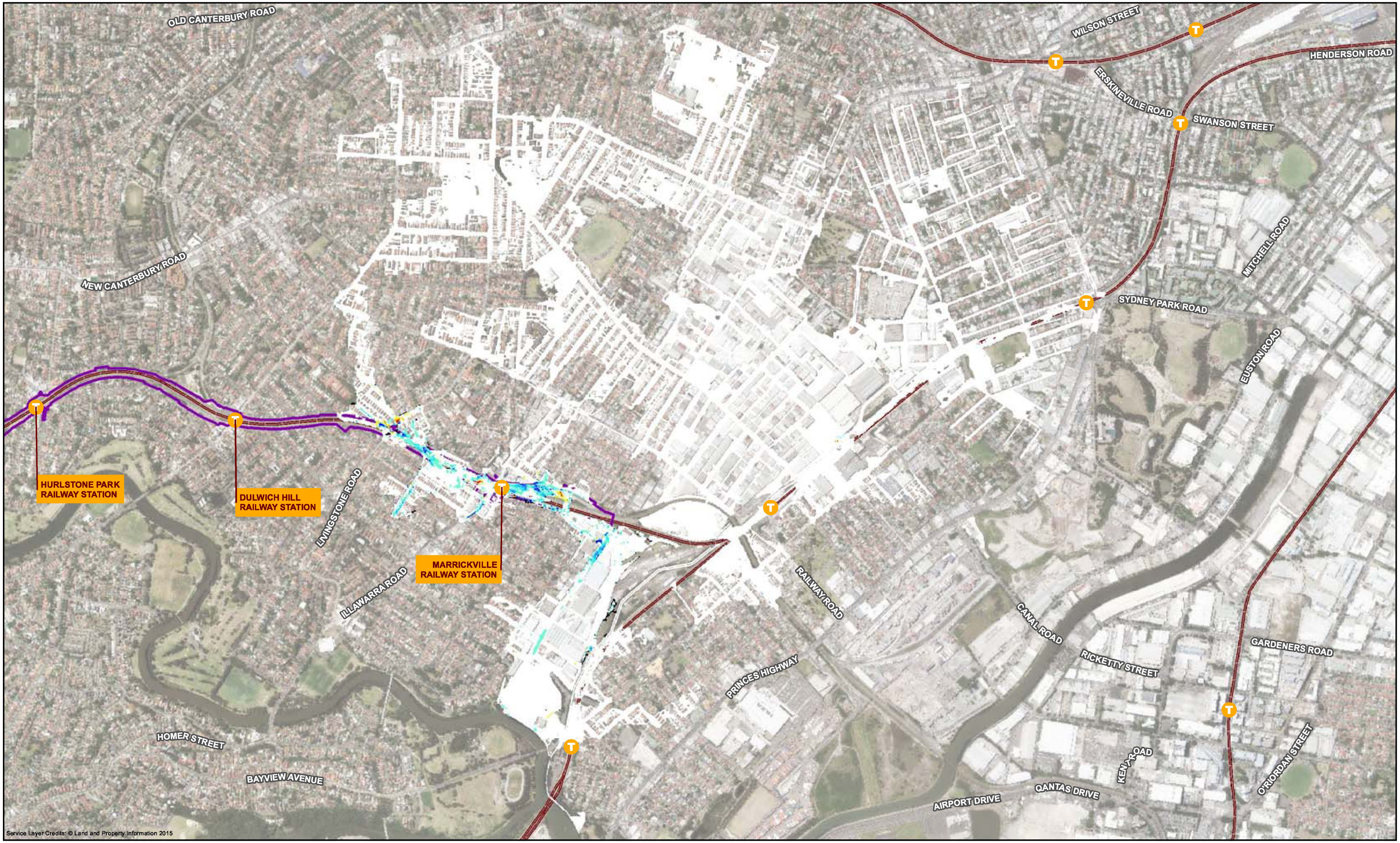
Data source: Aerial imagery - sixmaps 2016, General topo - NSW LPI DTDB 2012. Created by:afoddy



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

Change in Flood Velocity (m/s)

- Greater than -0.5
- -0.5 to -0.4
- -0.4 to -0.3
- -0.3 to -0.2
- -0.2 to -0.1
- -0.1 to +0.1
- +0.1 to +0.2
- +0.2 to +0.3
- +0.3 to +0.4
- +0.4 to +0.5
- Greater than +0.5
- Was wet now dry
- Was dry now wet

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

Job Number	21-25273
Revision	A
Date	22 May 2017

PMF velocity change

Figure 6-5

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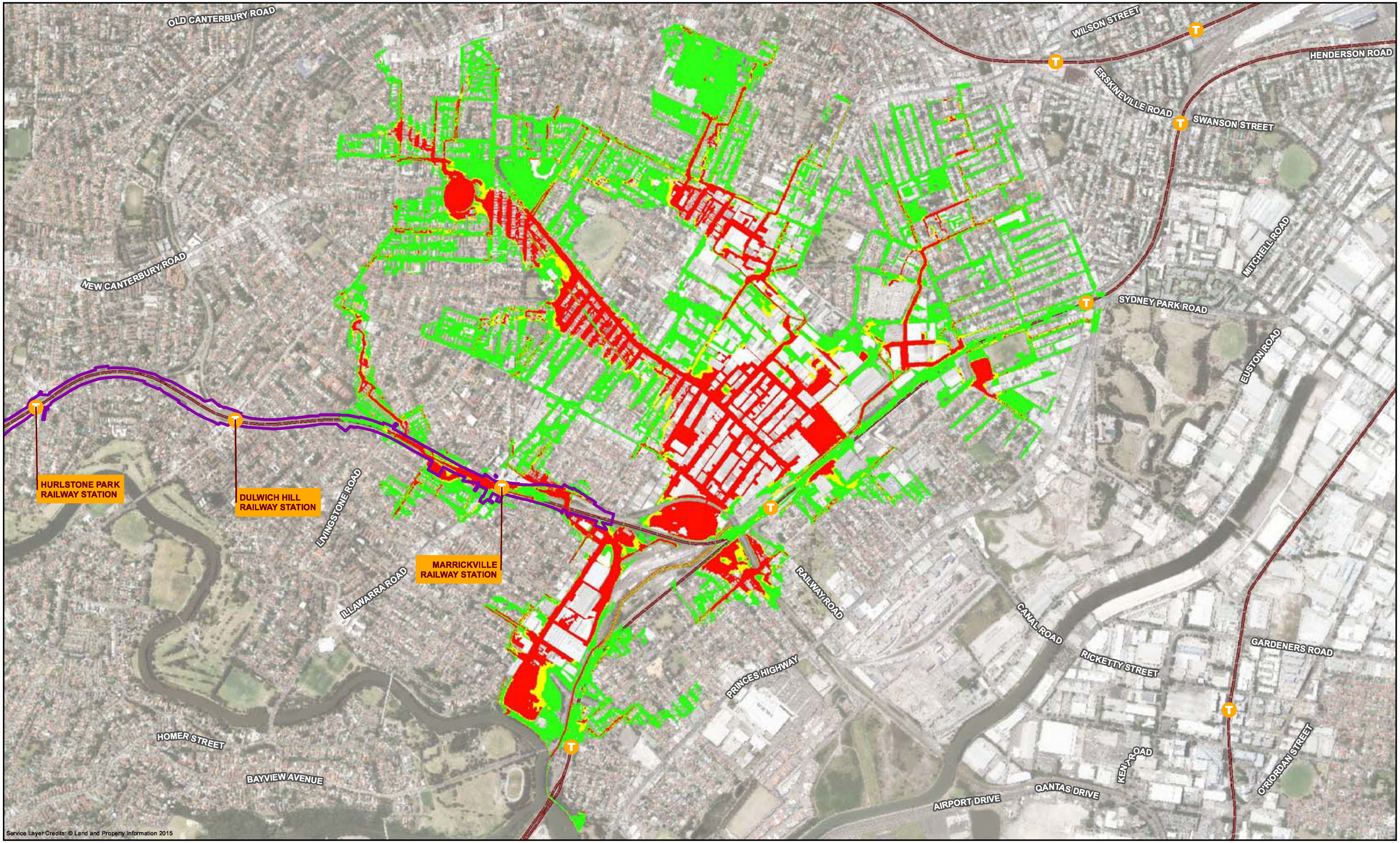
Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

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

Provisional Hazard Category

1 - Low Hazard

2 - Transitional Hazard

3 - High Hazard

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

Job Number 21-25273
Revision A
Date 22 May 2017

Post developed PMF provisional flood hazard

Figure 6-6

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

6.2.2 Dulwich Hill to Bankstown

The drainage measures outlined in section 4 include the provision of upgraded drainage infrastructure and detention basins to mitigate increases in flows to the receiving stormwater drainage network. The conclusion of the design work and modelling completed is that these measures would generally be effective at limiting downstream impacts.

In general, it was identified that peak flow rates from cross drainage structures would increase where no detention basins are proposed. It was also identified that the overall peak flow rates in the drainage systems would not increase due to differences in the timing of peak flows between the rail culverts and the wider drainage network.

Existing culverts between Dulwich Hill and Bankstown stations include culverts no. 5 to 36, as listed in Appendix C. However, of these culverts, only culverts no. 5 and 12 were identified to result in an increase in velocity with the proposed works in place. Post-development velocities for both culverts were of the order of 2 metres per second, however being less than the adopted limiting criteria of 2.5 metres per second, were not considered to be of concern.

It is noted that a number of the culverts have velocities well in excess of 2.5 metres per second under existing conditions. This includes culvert nos. 9, 13, 16, 17, 18, 24, 25, 26, 27, and 28 (refer Table 3-2 and Appendix C). At some of these locations, the velocities are up to 6 metres per second. The hydraulic results indicate that the project will not change the existing velocities at these culverts. However, in order to minimise the likelihood of scour and erosion occurring at these outlets, scour protection measures would need to be considered.

Flood modelling at the Cooks River at Canterbury Station was not undertaken as part of this project. Based on the draft *Canterbury LGA Overland Flow Study for Cooks River Catchments* (Cardno, 2015), flooding is identified to occur along the rail corridor at Canterbury Road, with flood depths of up to two metres for the five per cent AEP, one per cent AEP and PMF events. The corresponding flow velocities are estimated to be of the order of 0.2 to 0.5 metres per second. The potential impact of this project on the existing flood behaviour at Canterbury is not known however further analysis and design would be undertaken to confirm the details of design mitigation measures during detailed design.

6.3 Flooding and drainage outcomes

6.3.1 Potential for detrimental increases in the flood affectation of other properties, assets and infrastructure

As noted in section 6.2, the most flood affected parts of both the project area and surrounding study area are located in the vicinity of Marrickville Station. The key outcomes in relation to flooding in Marrickville are summarised in Table 6-2 and Figure 6-1 to Figure 6-6.

At other locations along the corridor between Marrickville and Bankstown stations, more limited modelling was undertaken to confirm that the introduction of the proposed infrastructure would not result in downstream impacts.

The conclusion of the assessment is that the proposed drainage measures would generally be effective at limiting downstream impacts. While detailed assessment of flooding at Canterbury Station was not undertaken, based on the *Draft Overland Flow Study Canterbury LGA Cooks River Catchments* (Cardno, 2016), flooding was found to occur along the rail corridor at Canterbury Road, with flood depths of up to two metres for the five per cent AEP, one per cent AEP, and PMF events.

In general, it was identified that peak flow rates from cross drainage structures would increase where no detention basins are currently proposed. It was also identified that the overall peak flow rates in the drainage systems would not increase, due to differences in the timing of peak flows between the rail culverts and the wider drainage network.

Further analysis and design would confirm the required design mitigation measures and impacts at lower risk locations.

6.3.2 Consistency with applicable Council floodplain risk management plans

As noted in section 6.2, drainage works associated with the project are compatible with local floodplain risk management plans, and would result in generally a reduction of existing flood extent and depth.

6.3.3 Compatibility with the flood hazard of the land

Results of flood modelling indicate that the project would not result in a change to existing flood hazard in or surrounding the rail corridor.

6.3.4 Compatibility with the hydraulic functions of flow conveyance in floodways and storage areas of the land

Drainage works have been designed to mitigate potential adverse impacts on more minor floodways (such as roads) in events up to the PMF.

Detention capacity in McNeilly Park (and at other locations) would be increased to cater for additional flows. Therefore, the project is considered compatible with the floodway and flood storage functions of the floodplain.

6.3.5 Downstream velocity and scour potential

At Marrickville, changes in velocities are estimated to be generally less than 0.25 metres per second at all locations for the full range of flood events. As in the case of flood levels, many of the areas would benefit from a net reduction in velocities as a result of the project.

Modelling of existing conditions indicates that approximately 10 of the existing culverts have exit velocities greater than 2.5 metres per second, which is the velocity above which scour and erosion could occur. While an increase in velocities is predicted to occur at two culverts, following implementation of the project, the level of increase is small, and the velocity would be less that the design limit.

Appropriate methods of scour protection at identified locations would be identified during detailed design.

6.3.6 Impacts of flooding on existing emergency management arrangements

Preliminary consultation was undertaken with NSW SES regarding existing flood evacuation routes and the potential impacts of the project. Roads identified to be flooded under existing conditions (refer section 3.6) which would provide access to the project area around Marrickville are also expected to be flooded once the project is operational. However, modelling results indicate no level changes are expected for storms up to and including the PMF (refer Table 6-3).

Table 6-3 Changes in emergency access route flooding during PMF event

Street	Flood level / extent of change
Marrickville Road	Negligible change in flood level
Illawarra Road	Negligible change in flood level
Schwebel Street	Negligible change in flood level
Arthur Street	Negligible change in flood level

Flood emergency management is incorporated in the design criteria for station infrastructure. Flood emergency management procedures would be incorporated in Sydney Metro's operational emergency management plans. Consideration would need to be given to flood warning and emergency management under extreme flood conditions (refer section 1).

6.3.7 Surface water flows

The proposed structures under the rail formation in some locations include increases in proposed cross drainage capacity to prevent flooding in the rail corridor.

The increased flow velocities through the culverts would potentially increase erosion immediately downstream of the culverts. The effect of this would be dependent upon site-specific soil conditions and terrain along the entire length of the rail corridor. Further design development would include consideration of potential scour and detention basins where feasible.

6.3.8 Social and economic consequences

Transport for NSW has undertaken a systematic and scientific assessment of the existing and post-development flooding situation in the project area using widely accepted design criteria utilised on other major infrastructure projects. This has included a desktop review of existing floodplain management studies by the relevant councils and consultation with the Canterbury-Bankstown and Inner West councils as well as emergency services agencies.

The above analysis indicates that there are limited adverse effects resulting from the project and an improvement in many aspects relative to existing conditions under a range of potential flood events. The impacts identified are primarily increases in velocity at a limited number of locations and in one location, an impact in flood depth (on a public road). It is considered therefore that the economic and social consequences of the proposed development are negligible.

6.4 Surface water quality outcomes

The potential operational impacts of the project include changes in the hydrologic regime leading to increased erosion and sedimentation and pollutant generation from the rail infrastructure.

Minor increases in impervious surface areas associated with the works would have the potential to result in adverse impacts on the hydrological regime in terms of increased runoff volumes and peak flows. This could lead to a range of impacts associated with increased erosion and sedimentation as well as introduction of additional quantities of other pollutants.

Discussion of the potential operational risks and impacts on water quality associated with the operation of the project is provided in the following sections.

6.4.1 Stormwater runoff

Contamination of the waterways can be caused through stormwater runoff containing typical pollutants such as oils and greases, petrochemicals and heavy metals as a result of rolling stock operations and wear. The contamination of waterways by the aforementioned pollutants can result in habitat degradation and negatively impact on the health of aquatic flora and fauna species. However by and large, the project is within the existing footprint of an existing operating railway and the potential for increase in contamination levels from these types of pollutants is expected to be very small relative to the existing situation.

As outlined in section 4.3, water quality treatment measures would be included in station precincts as a combination of GPTs and rain gardens. Table 6-4 provides details of the proposed water quality treatment measures by location, including indicative sizing.

It is noted that the proposed station impervious areas are very small relative to the total catchment area for each station ranging from only 0.02 to 1.56 per cent of their respective catchment areas. Consequently, there is very little influence on overall catchment water quality.

Table 6-4 Proposed water quality treatment measures

Location	Total station impervious area (ha)	Total catchment area (ha)	% station impervious area²	Rain garden area (m^2)	Number of GPTs
Marrickville	0.23	68	0.34	-3	1
Dulwich Hill	0.45	42	1.07	55	1
Hurlstone Park	0.10	41	0.24	15	1
Canterbury	0.23	1150	0.02	30	1
Campsie	0.61	39	1.56	75	1
Belmore	0.39	100	0.39	50	1
Lakemba	0.34	69	0.49	45	2
Wiley Park	0.16	118	0.14	20	2
Punchbowl	0.73	118	0.62	90	1
Bankstown	0.55	127	0.43	70	1

Note: 1: Hardstand area within station precinct under proposed development conditions
2: Station precinct hardstand area as a %age of catchment area
3: Marrickville Station precinct has a net reduction in impervious area of about 700 m^2 after development, and hence no raingarden is proposed.

As outlined in section 2.3.2, preliminary MUSIC modelling has been undertaken and results indicated that the proposed measures would be effective at reducing pollutant loads to the targets identified in Table 1-3 at a downstream location however:

- Treatment is not proposed within the rail corridor itself.
- The targets may not be met at each discharge point location, but would be exceeded at other locations, resulting in a net result of meeting the proposed targets within the overall catchment.

The project design team will also investigate spill containment as part of the water quality treatment train to mitigate potential spills of hazardous materials, though no specific measures were incorporated into the reference design.

Water quality outcomes been assessed against the project water quality criteria. The intention is that assessment against ANZECC guidelines would be undertaken during the detailed design.

Provision of the proposed water quality treatment measures is expected to contribute to improved water quality overall against the existing conditions, though further analysis would be required at detailed design stage to confirm this. Implementation of effective water quality treatment measures for the project would mean no adverse impacts in meeting the water quality objectives for the catchments over time.

6.4.2 Potential for spills/ leaks

The potential impacts on water quality from the operation of the rail corridor would be related to the spill of vehicle oils, lubricants, hydraulics fluids and other accidental spills including chemicals in transit through leakage.

Any such spill has the potential to pollute the downstream waterways and therefore cause detrimental effects for the riparian Botany Bay receiving environments.

As above however, the project footprint is similar to the existing condition and therefore the potential extent of any increased spills or leaks is expected to be small relative to the existing situation. There is opportunity to incorporate some spill containment capability within the water quality treatment train and this would be reviewed during design development for feasibility to incorporate into the design.

6.4.3 Erosion and sedimentation

Once the construction of a project is completed, there is a subsequent period where recently disturbed soils are susceptible to scour and erosion from stormwater runoff.

The modification of overland flow paths can cause an increase in scour of surface soil, banks or bed material and resultant sedimentation in downstream waterways. This is expected to be relevant predominantly in the vicinity of Marrickville. The potential impacts would occur in the event that appropriate reestablishment of embankments was not undertaken and poor stabilisation resulted in additional soils being mobilised and affecting water quality.

With the projected small increase in impervious area as a result of the project, there would be a comparable increase in stormwater runoff which can scour surface soil and increase sediment loading in downstream waterways.

The potential for sediment transport is influenced by factors such as severity of storm events, the slope and scale of the disturbed area and the quality of revegetation. As the disturbance area and change in impervious areas are in this case small relative to the catchment as a whole, the potential impacts would be expected to be limited in nature and less than the construction phase.

6.5 Cumulative impacts

6.5.1 Council drainage works

As noted previously, various drainage works are proposed by the Inner West and Canterbury-Bankstown councils to rectify existing flood conditions. The design has been prepared in consideration of these where details are available. Ongoing consultation with these councils during detailed design development would be undertaken to confirm the program of proposed works, where they interact with the Council's drainage network's and including any future mitigation works. Further hydraulic modelling to assess combined operational stage impacts may also be required, although given the way the project has been developed by reference to each Council's studies and works programs, it is expected that an overall improvement would result.

6.5.2 Chatswood to Sydenham project

The project adjoins the Chatswood to Sydenham component of Sydney Metro which was assessed as part of the Chatswood to Sydenham Environmental Impact Statement and subsequent modifications.

Interface and coordination meetings are being undertaken to ensure that there are no conflicts in scheduling and that potential cumulative impacts can be avoided.

Additional measures would also be reviewed during detailed design as part of that project, with the aim of further reducing flood levels in existing areas which currently flood, including any private property areas.

6.5.3 WestConnex

The WestConnex project will discharge predominantly to Wolli Creek and the Cooks River at a location downstream of the Sydenham to Bankstown project. The WestConnex project has the potential to impact on flow behaviour and proposed works in the vicinity of the Marrickville dive structure area, part of the Chatswood to Sydenham project, which is remote from the project area and therefore no cumulative impacts are expected.

6.5.4 Sydenham to Bankstown Urban Renewal Corridor

The Department of Planning and Environment are currently preparing an urban renewal plan for the Sydenham to Bankstown corridor to provide greater housing choice, more jobs and improve parks and open space. A number of different building types are being considered with medium/ high rise and high-rise buildings up to 25 stories being proposed within 400 metres of railway stations. It is assumed that all future building development would be designed in accordance with relevant Council standards and guidelines and would be subject to the DA approval process.

Considering that the proposed development corridor area is already highly urbanised, it is expected that redevelopment of the corridor would not have any significant impact in terms of increased runoff and flow velocities. On this basis, no adverse cumulative impacts are expected.

7. Recommended mitigation measures

7.1 Construction

7.1.1 Flooding and drainage

Construction phase mitigation measures would generally include:

- Temporary drainage or drainage diversions to be installed as necessary so that stormwater drainage function is not impeded during construction of new stormwater drainage lines and connections to existing stormwater network.
- Installation of on-site detention measures.

Careful review of the proposed layout of construction compounds including siting of buildings and plant would be undertaken where these are located within or partially within flood liable land and a review undertaken to locate compounds above the 5% AEP event where practical. Management procedures would be put in place to address wet weather and flooding. This would include:

- Appropriate controls to cease work in flood prone areas when a severe weather warning is issued, as once the onset of a large rainfall event occurs, the onset of flooding would be quick, as noted earlier in this report.
- Flood management plan to be incorporated into construction planning documentation during the construction of works at McNeilly Park, including appropriate controls during wet weather or forecasts of heavy rainfall.
- Identification of measures to, where feasible and reasonable, not worsen existing flooding characteristics up to and including the one per cent AEP event in the vicinity of the project. Not worsen is defined as:
  - a maximum increase flood levels of 50 millimetre in a one per cent AEP flood event
  - a maximum increase in time of inundation of one hour in a one per cent AEP flood event
  - no increase in the potential for soil erosion and scouring from any increase in flow velocity in a one per cent AEP flood event.

7.1.2 Flood event monitoring

It would be impractical to monitor the flood impacts during an individual flood event. Therefore, should a flood event occur during the construction phase, the following would be undertaken to verify the design performance and impact predictions, or to refine the design should there be a significant difference between the actual and predicted flood impacts and behaviour:

- The construction area would be inspected for damage and any required maintenance completed.
- The presence of any culvert blockages in the construction area, if present, would be recorded and cleaning undertaken as required.
- Where there is a significant variance between the predicted flood levels and the observed levels on the recently constructed stage of the works, council and local residents would be consulted to improve the understanding of the local flow and flooding behaviour.
- Any areas, and extent, of any erosion downstream of culverts would be recorded to compare to predicted values for the recently constructed stage of the works.

- The locations of any rail overtopping or damage would be recorded together with any maintenance required and form of works.
- Decisions would be made on the need to refine the design of works yet to be installed and the need to undertake required mitigation measures.
- The form and location of any implemented mitigation measures would be recorded.

7.1.3 Surface water quality

As a general guiding principle for major civil design and construction works, water quality mitigation and management measures should be implemented in accordance with the relevant requirements of:

- The Blue Book
- Managing Urban Stormwater Soils and Construction Volume 2A (DECC, 2008)
- The ANZECC guidelines
- the *Australian Guidelines for Water Quality Monitoring and Reporting* (NWQMS, 2000)
- *Australian Runoff Quality – A Guide to Water Sensitive Urban Design* (Engineers Australia, 2006)
- Other water quality criteria and guidelines identified in this report

A series of SWMPs would be prepared as part of the suite of overall CEMPs. The SWMPs would define the control and mitigation of potential surface water quality impacts during construction. The SWMP would be developed to incorporate the most appropriate or 'best practice' controls and measures in accordance with the Blue Book. The SWMP would be staged to suit the changing needs as the works progress. Due consideration would also be given to the extent of works and situation relative to the sensitivity of the surrounding environment in relation to the construction activity.

Both the CEMP and SWMP would typically include strategies such as:

- Bunding of storage areas containing hazardous goods and undertaking of refuelling activities in bunded areas
- Creation of exclusion zones to limit disturbance
- Construction staging
- Specific activity procedures for vegetation clearing and access road creation
- Diversion of run-off from upslope areas around works areas
- Surface controls to promote soil stability
- Limit run-off lengths and reduced run-off velocities within the work sites
- Installation of devices to capture and retain sediment on-site and measures to re-establish a stable groundcover as soon as practicable following the completion of construction

With appropriate strategies in place, the risk of sedimentation of the local watercourses in the vicinity of the works location would be substantially reduced.

Construction-related risks, such as earthworks, spills, and location of stockpiles and equipment, are fairly common for projects of this size and type, and would be managed in accordance with Transport for NSW or other guidelines and standards. Typical mitigation measures that would be considered and implemented where relevant include:

- Minimising disturbed areas and revegetating them as soon as practical as the works progress
- Installation of appropriate erosion control measures such as silt fencing, straw bales, check dams, temporary ground stabilisation, diversion berms or site regrading
- Diverting clean water runoff away from the works or disturbed areas wherever possible
- Installation of new temporary sediment basins as appropriate
- Providing bunded areas for storage of hazardous materials such as oils, chemicals and refuelling areas
- Protection measures where work platforms or access tracks are required in the vicinity of waterways

Management of construction work sites proposed in the flood zone would be undertaken to avoid mobilisation of sediments or other contaminants due to overland flooding (refer the following section).

7.1.4 Residual impacts

It is expected that with the appropriate mitigation measures in place, including review of the location of construction worksites and compounds relative to the floodplain, the residual potential construction impacts would be successfully managed using similar approaches to other measures employed for major infrastructure projects in Sydney.

7.2 Operation

7.2.1 Flooding and drainage

A number of drainage and flooding measures have been incorporated into the project to avoid adverse impacts on flooding outcomes in the project area and downstream. The measures are predicted to be effective in key locations for events up to and including the one per cent AEP climate change event.

The residual risks remaining would be addressed through either further design development and/or specific mitigation measures outlined below.

Further design development

The following areas were identified as requiring further analysis and attention during future design development:

- Inner West Council has requested opportunities for discharge of more flow into the Malakoff Tunnel during minor flood events to be reviewed
- Review of proposed drainage measures and conflicts with other proposed services which may result in a need for proposed drainage modifications and an increased detention basin capacity in one location
- Detailed flow calculations for smaller catchments that have not been included in the analysis to confirm drainage implications
- Confirmation of various drainage assumptions based on more detailed asset surveys

Further sensitivity analyses would be undertaken by the design team during the next stage of design development to assess the impacts of 20 per cent and 30 per cent increases in design rainfall intensity and of sea level rise, for locations potentially affected.

The drainage works would be designed in accordance with relevant design criteria and guidelines as the design progresses to ensure that identified issues are appropriately addressed.

7.2.2 Flood event monitoring

The project is designed largely to meet the flood immunity criteria of remaining flood free in events up to and including the one per cent AEP climate change event. At some locations, it is not expected to be practical to achieve flood immunity in excess of the five per cent AEP event. Flooding of the Sydney Metro tracks would therefore be expected to be a rare occurrence. However, if the rail corridor is closed due to flooding, as soon as practical after the track is considered to be safe:

- The track would be inspected and the flood levels along the length of the rail corridor would be recorded for verification against the predicted flood levels.
- The presence of any culvert blockages would be recorded.
- Where there is a significant variance between the predicted flood levels and the observed levels, consultation with nearby property owners would be undertaken to improve the understanding of the local flow and flooding behaviour.
- Any areas, and extent, of any erosion downstream of culverts would be recorded to compare to predicted values.
- The locations of any rail overtopping or damage would be recorded together with any maintenance required and form of works.
- Decisions would be made on the need to refine the design of works yet to be installed and the need to undertake required mitigation measures.
- The form and location of any implemented mitigation measures would be recorded.

Flood emergency management

The analysis undertaken by the design team has identified local flood evacuation routes which are compromised under existing conditions. However, no additional routes are affected under post-development conditions for both the one per cent AEP and PMF events, and changes in flood levels from the project are expected to be negligible.

Development of a flood warning and evacuation plan for the project would be undertaken in consultation with stakeholders including Inner West Council and the NSW SES. Such a review may also include a wider review of local flood emergency planning as well as impacts of nearby development including the WestConnex project.

Scour and velocity

A more detailed analysis including consideration of impacts to the Cooks River would need to be undertaken for a full range of flood events to confirm impacts to the Cooks River and any required mitigation measures.

7.2.3 Surface water quality

The intent of the project design with regard to water quality would be to target the minimisation of impacts on the receiving systems and implementation of the design criteria.

The preliminary modelling indicated that water quality could be managed to meet the design criteria for the project, though comparison against ANZECC guidelines was not carried out. Further design development is required to confirm treatment types and locations as well as implementation of any spill containment measures.

A water quality monitoring program would be developed to monitor water quality outcomes against the water quality objectives for the Cooks River and Salt Pan Creek. The surface water quality monitoring program would monitor key parameters, including nutrients, coliforms, sediments, hydrocarbons and heavy metals. It is expected that this would be undertaken on a monthly basis over a two year period.

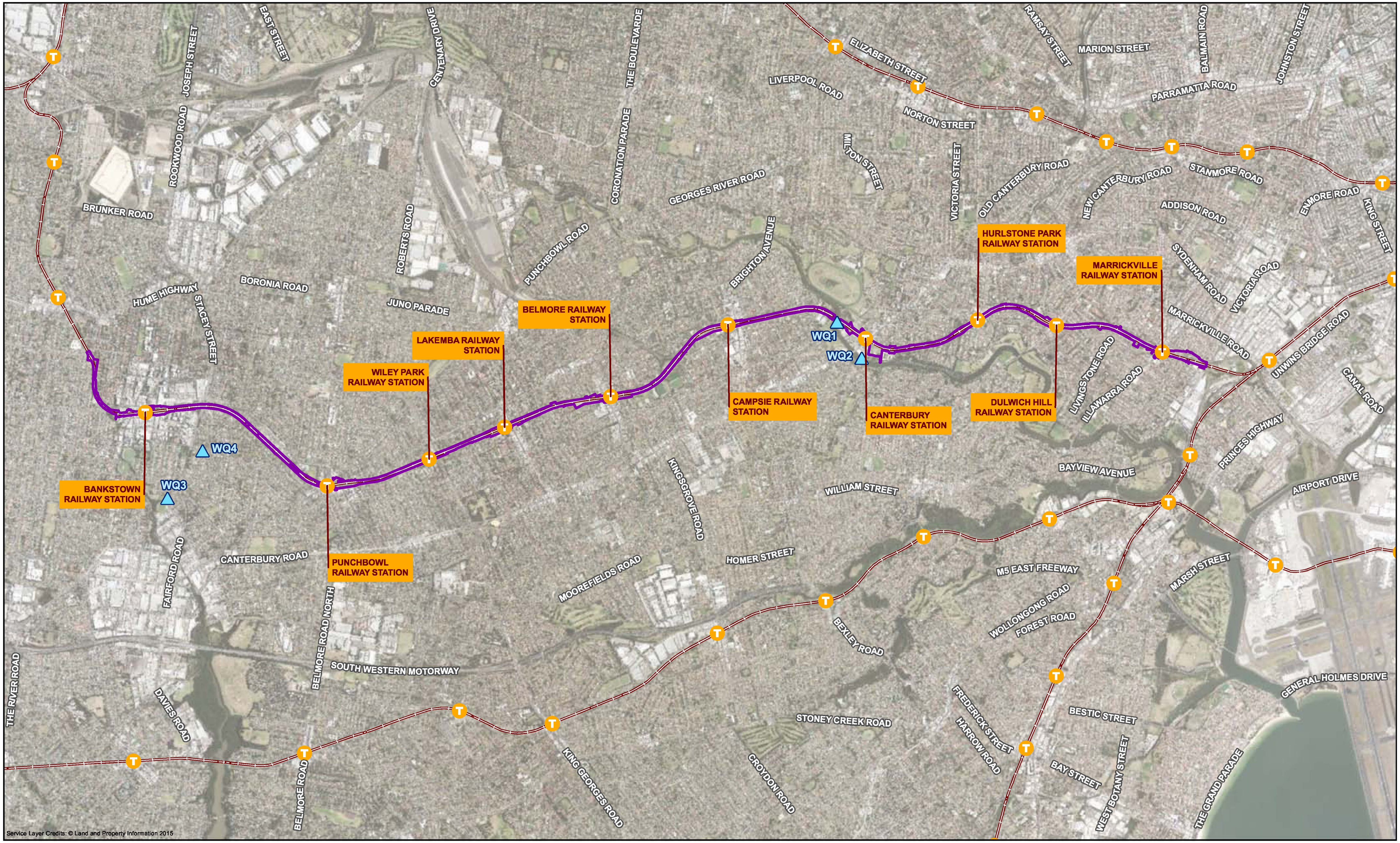
Possible indicative locations of water quality sampling points are provided in Figure 7-1. Final locations would be selected based on:

- The detailed drainage design
- Review of accessibility to sampling points
- Selection, where possible, of upstream and downstream sampling points limiting inflows from sources other than the rail corridor

Due to the extensive surface water drainage network in and surrounding the project area, as well as the linear nature of the rail corridor, identification of sampling points which effectively isolate the influence of the rail corridor may not be possible and locations should be further considered as the design develops.

7.2.4 Residual impacts

Residual impacts of the project would include increases in flood level in rare to extreme flood events of greater than the one per cent AEP climate change event. This would include impacts to surrounding properties including increased flood depth, potential flood damages during a flood event and emergency access during times of flooding.



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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
- Indicative Water Quality Montoring Locations

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

Job Number	21-25273
Revision	A
Date	08 Jul 2017

Indicative Water Quality Monitoring Locations

Figure 7-1

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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

8. Conclusion

A surface water and flooding assessment was carried out for the project.

The assessment drew on the following sources of information including:

- A desktop review of available drainage, flooding and water quality information
- Site inspections
- Analysis undertaken by the designer
- Various reference design documentation

The project area is located in a highly urbanised environment that has been substantially altered from its natural state and water quality is typical of that for urban catchments in Sydney.

Under existing conditions, the project area is subject to local flooding varying in severity due to insufficient capacity in the surrounding drainage network during large storm events and also due to insufficient drainage within the rail corridor in places. More extensive flooding currently occurs in Marrickville.

Key construction stage impacts include:

- The potential for increased sediment being discharged to downstream systems as a result of construction activities
- Flooding and overland flow issues caused by the presence of construction worksites and compounds on flood liable land

Construction impacts would be managed through implementation of SWMPs in accordance with the Blue Book and detailed planning and management of construction sites to avoid impacting overland flow paths without appropriate mitigation.

Drainage works are proposed as a component of other nearby projects and there would be a low risk of cumulative construction stage flooding and water quality impacts. Coordination with other works is proposed in order to mitigate cumulative construction impacts.

Key residual construction stage impacts include flooding to construction worksites and compounds during construction, with associated potential downstream impacts.

In the operational stage, drainage measures incorporated into the design are predicted to provide effective mitigation of major flood impacts for events up to and including the one per cent AEP climate change event.

A flood warning and evacuation plan would be developed for emergency management of flooding up to the PMF.

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.

Potential for cumulative operational impacts of Council drainage upgrade works and the project exists, however the design has been developed with consideration of known proposed measures to avoid impacts. There are opportunities for combined improvement to existing drainage issues in the project area and surrounds.

The potential for cumulative impacts with other projects, including the Chatswood to Sydenham project, WestConnex and the Sydenham to Bankstown Urban Renewal Corridor projects were identified and considered to be low.

In terms of residual operation impacts, negligible increases to flood depths along key access routes are predicted in both the one per cent AEP and PMF events, though some of these areas are already predicted to be substantially flooded under existing conditions.

The drainage design is at a reference stage and refinement of the drainage details would occur as part of the design development process. Further consideration of proposed changes against the design criteria would be undertaken at all stages to ensure that flooding, drainage and water quality impacts for a range of flood events would be managed. Further assessment of climate change impacts, including consideration of 20 per cent and 30 per cent increases in peak rainfall intensity as well as further consideration of sea level rise would also be undertaken.

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Appendices

Appendix A – Photographs

Figure A.1 Cooks River near Hurlstone Park

Figure A.2 Rail bridge over Cooks River

Figure A.3 Cooks River near rail crossing (looking upstream)

Figure A.4 Upper reaches of Salt Pan Creek

Figure A.5 Tidal reaches of Salt Pan Creek near Riverwood

Figure A.6 Wetland area near Riverwood

Figure A.7 Western Channel south east of Marrickville Station on Myrtle Street

Figure A.8 Culvert under rail corridor near Belmore Sportsground

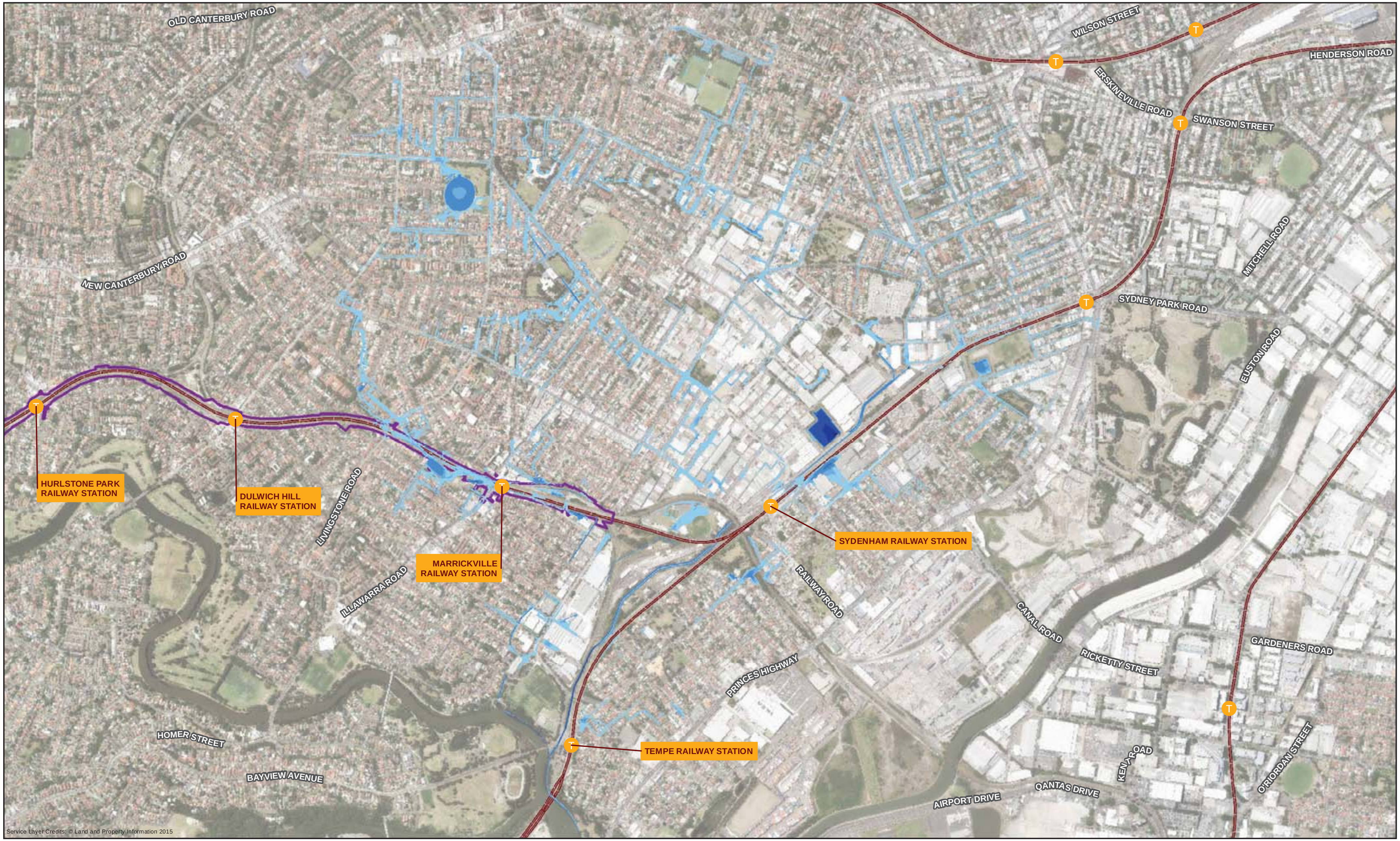
Figure A.9 Rail culvert structure west of Lakemba Station

Figure A.10 One of the culvert structures passing beneath the rail corridor at Wiley Park Station

Figure A.11 Upper reaches of Coxs Creek

Figure A.12 Confluence of Coxs Creek and Cooks River near South Strathfield

Appendix B – Flood Maps



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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

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

GHD

Transport for NSW
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Surface Water Assessment

Job Number	21-25273
Revision	A
Date	19 May 2017

Existing 63% AEP flood depth

Figure B.1

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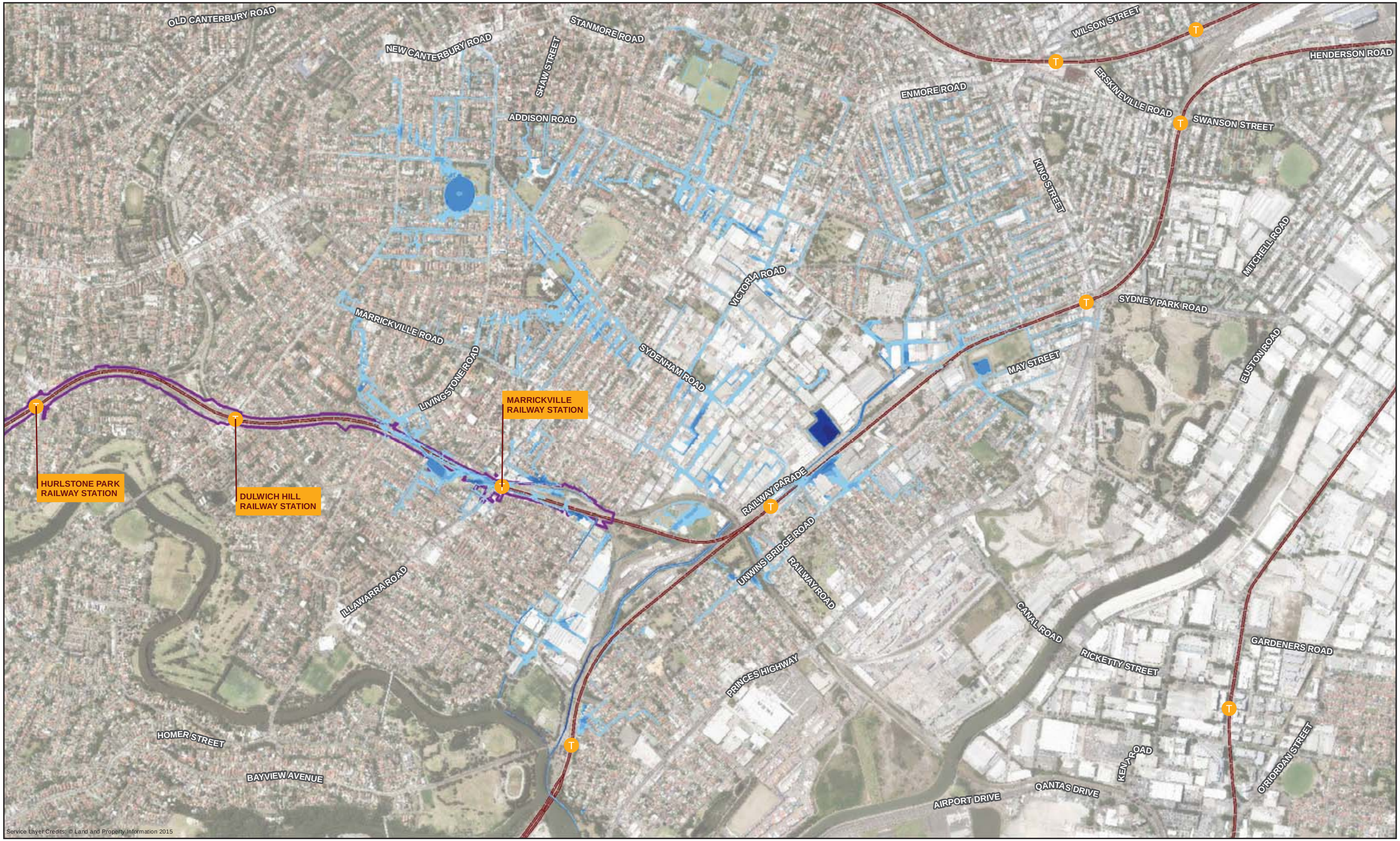
Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

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



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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

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

Job Number	21-25273
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Date	22 May 2017

Existing 39% AEP flood depth

Figure B.2

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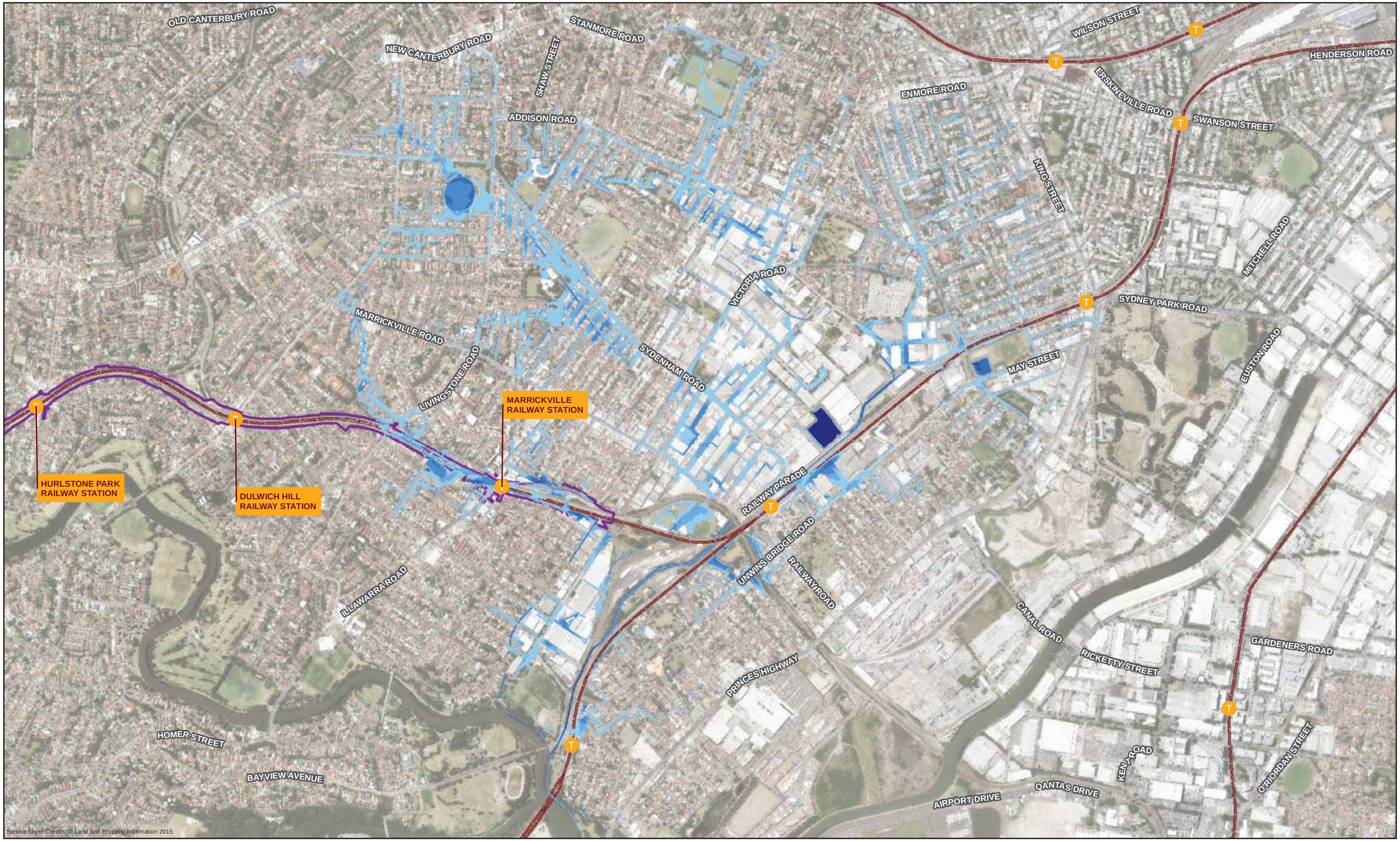
Data source: Aerial imagery - sixmaps 2016, General topo - NSW LPI DTDB 2012. Created by:afoddy



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

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

Job Number 21-25273
Revision A
Date 22 May 2017

Existing 18% AEP flood depth

Figure B.3

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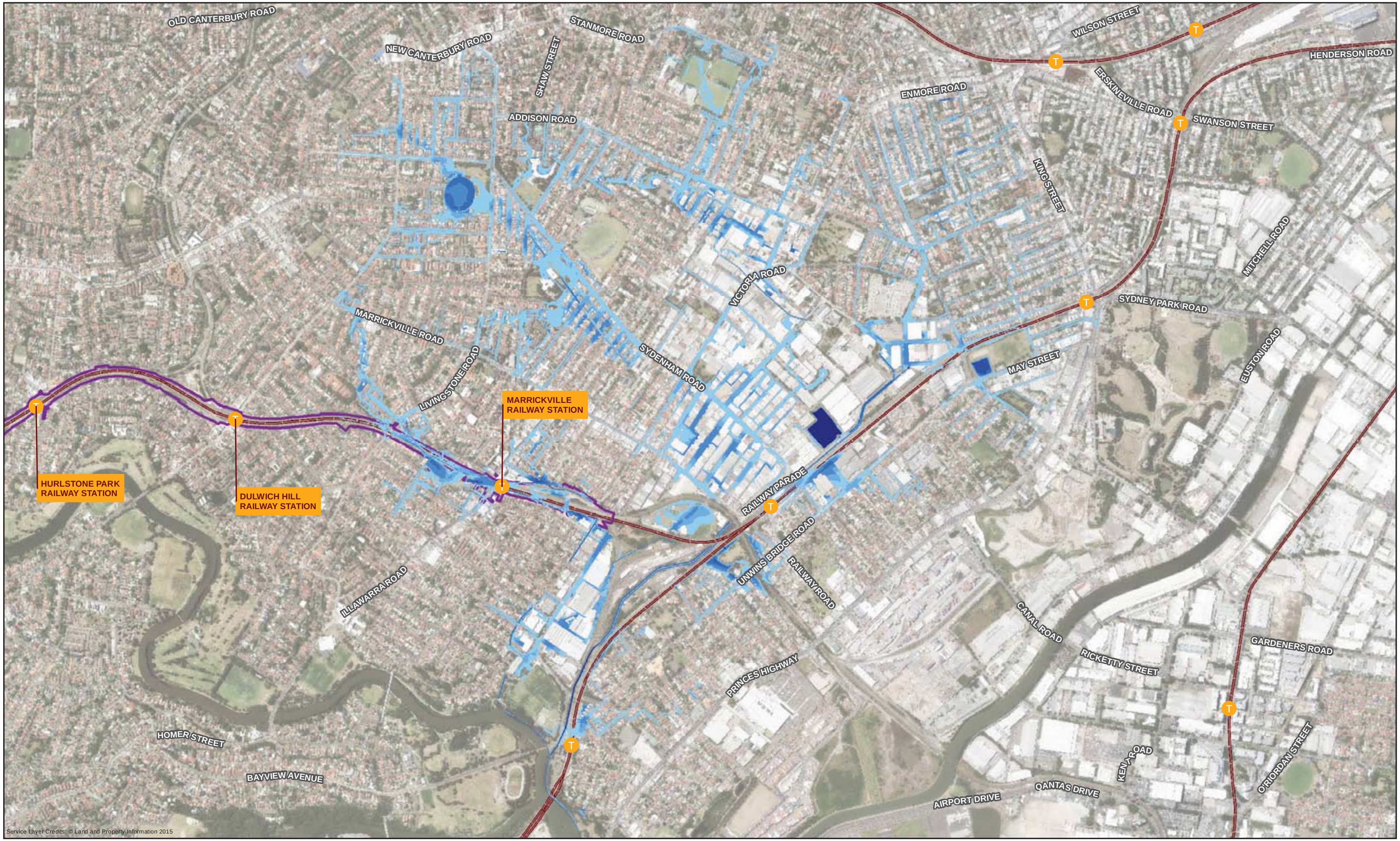
Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

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

Transport for NSW
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Surface Water Assessment

Job Number	21-25273
Revision	A
Date	22 May 2017

Existing 10% AEP flood depth

Figure B.4

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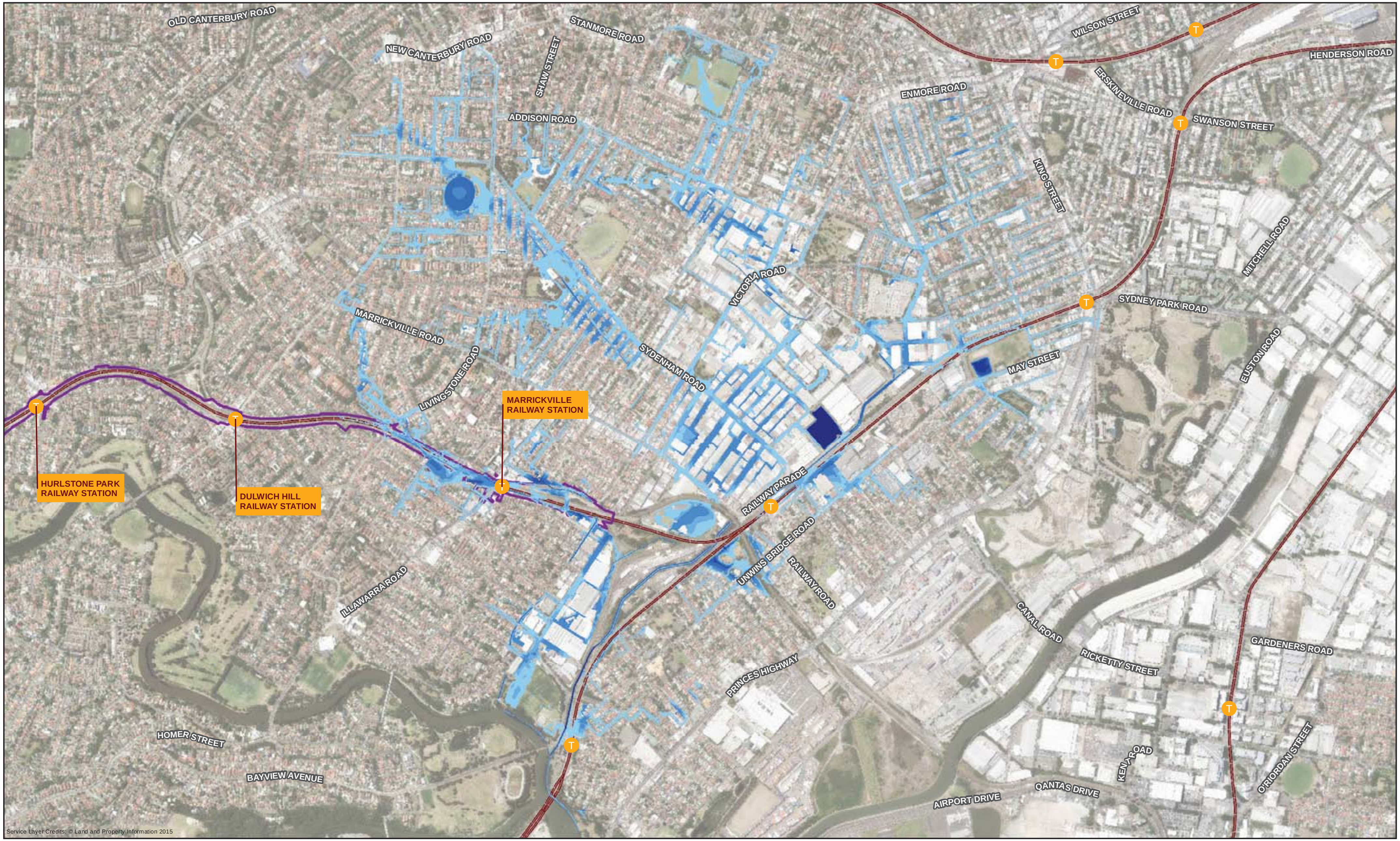
Data source: Aerial imagery - sixmaps 2016, General topo - NSW LPI DTDB 2012. Created by:afoddy



Paper Size A3

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Metres

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

N

LEGEND

Project area	**Depth (m)**	
Train station	0.00 - 0.05	0.30 - 0.50
Railway	0.05 - 0.30	0.50 - 1.00
		1.01 - 1.50

1.50 - 2.00
2.00 - 2.50
>2.50

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Surface Water Assessment

Job Number	21-25273
Revision	A
Date	22 May 2017

Existing 5% AEP flood depth

Figure B.5

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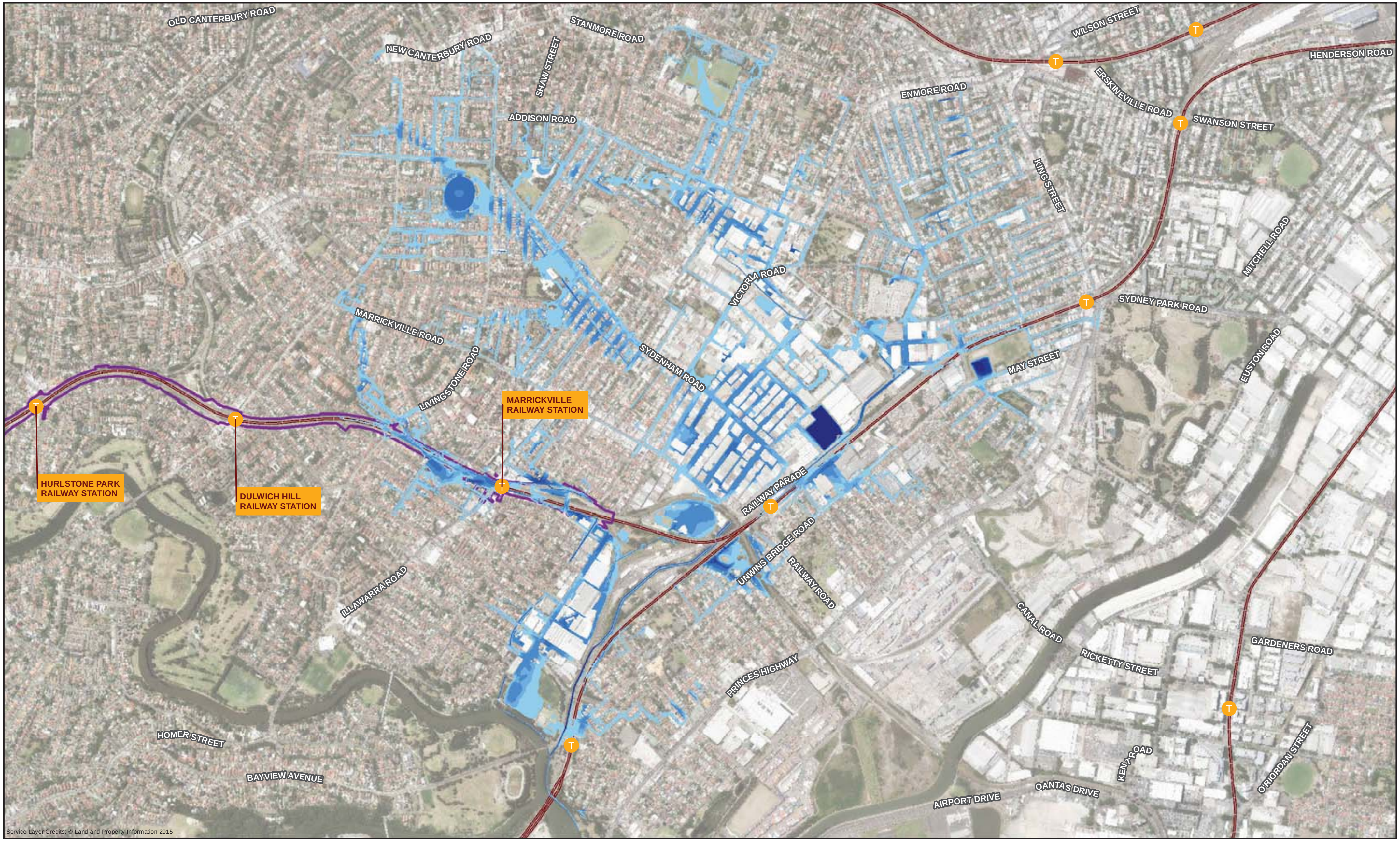

Paper Size A3

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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

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

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

Job Number	21-25273
Revision	A
Date	22 May 2017

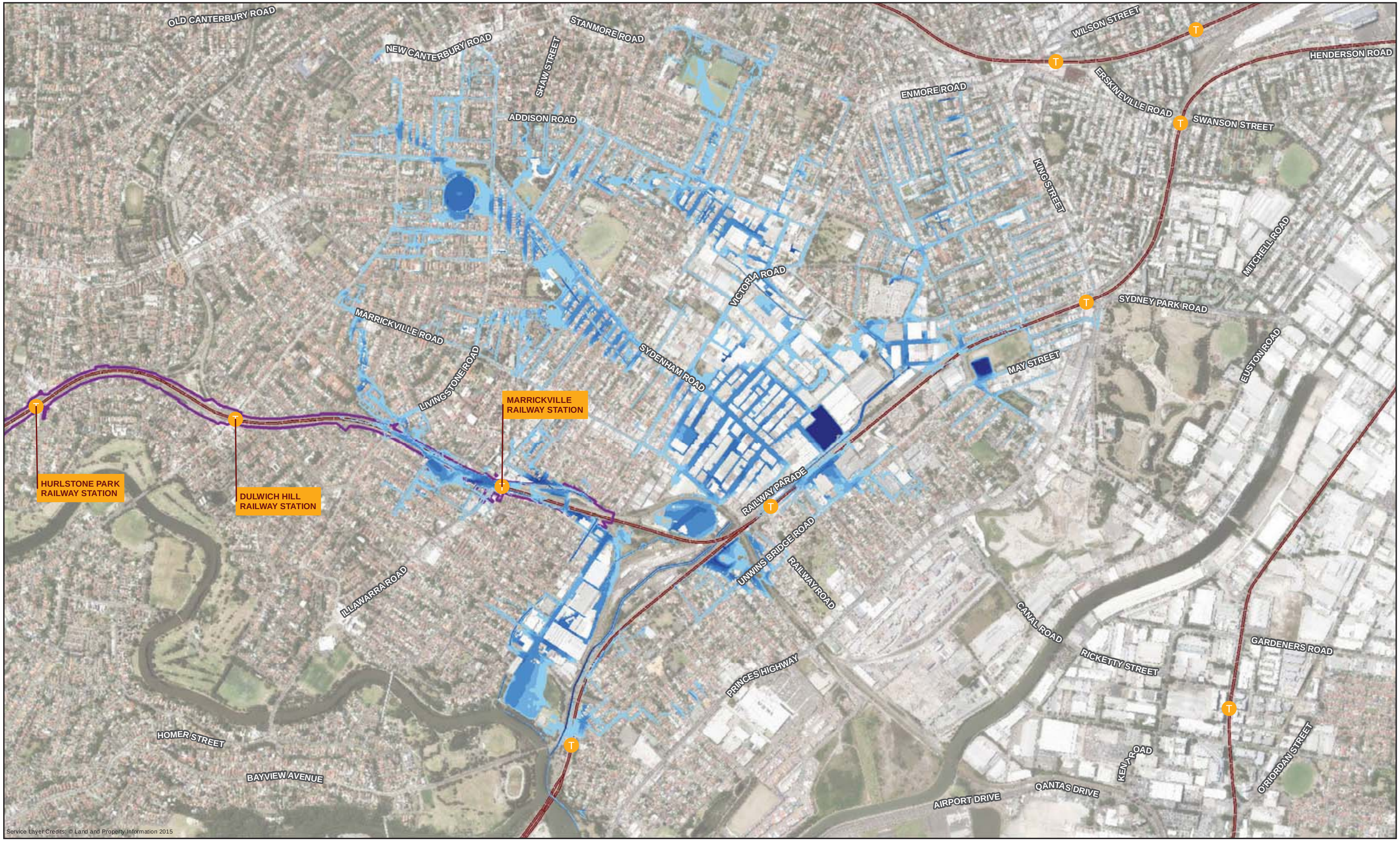
Existing 2% AEP flood depth

Figure B.6

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

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

Job Number	21-25273
Revision	A
Date	22 May 2017

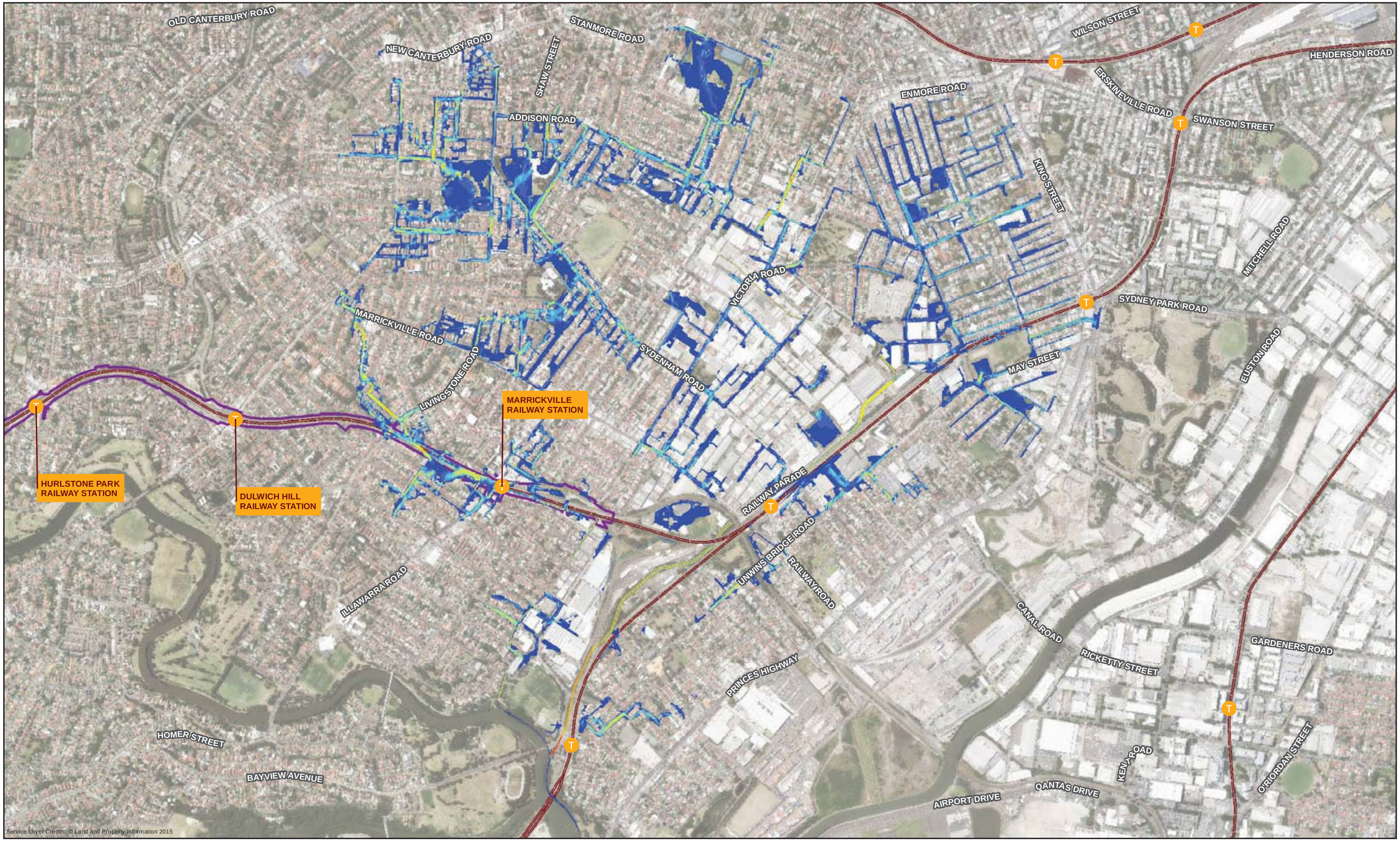
Existing 1% AEP flood depth

Figure B.7

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

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

Job Number	21-25273
Revision	A
Date	22 May 2017

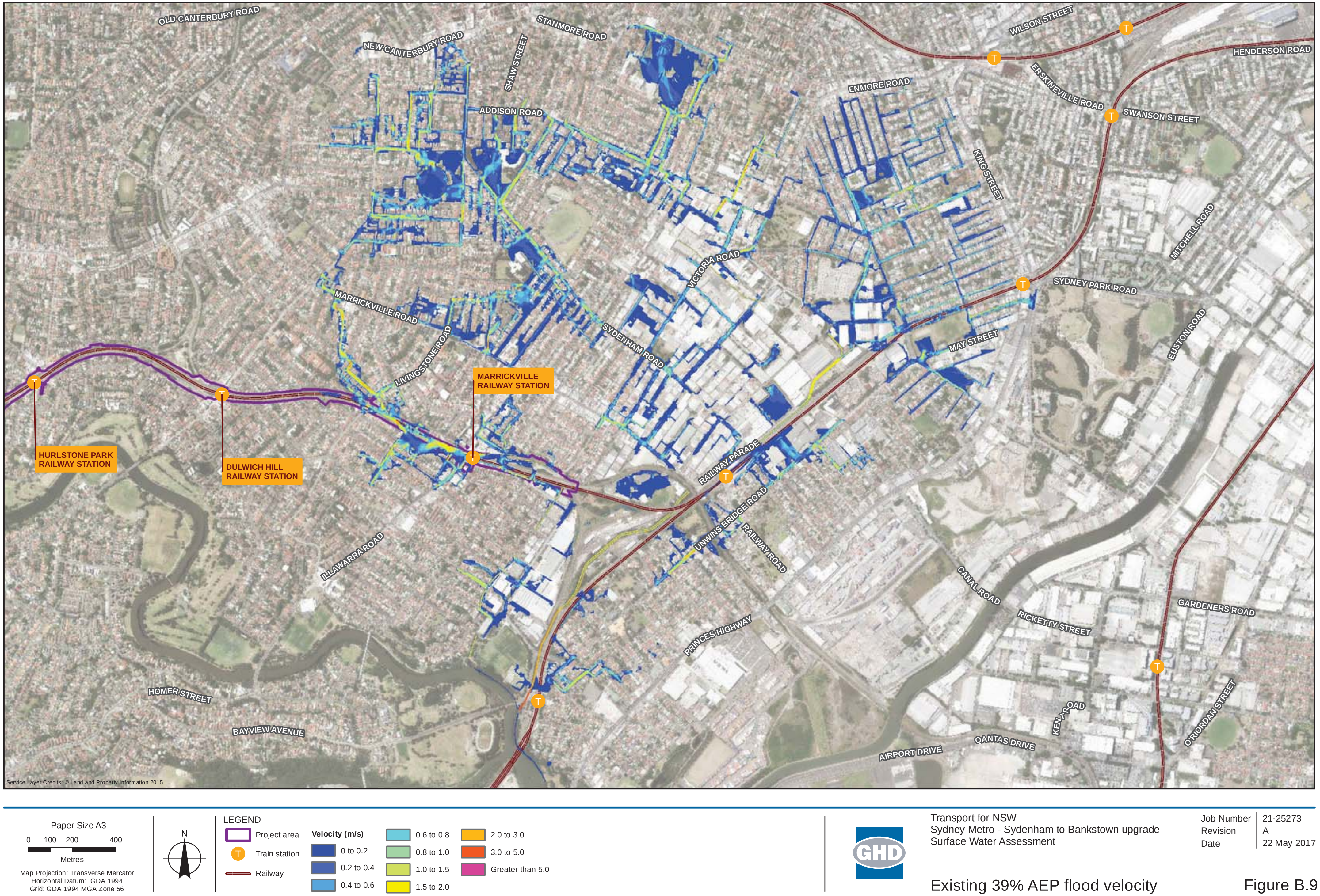
Existing 63% AEP flood velocity

Figure B.8

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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



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

Job Number	21-25273
Revision	A
Date	22 May 2017

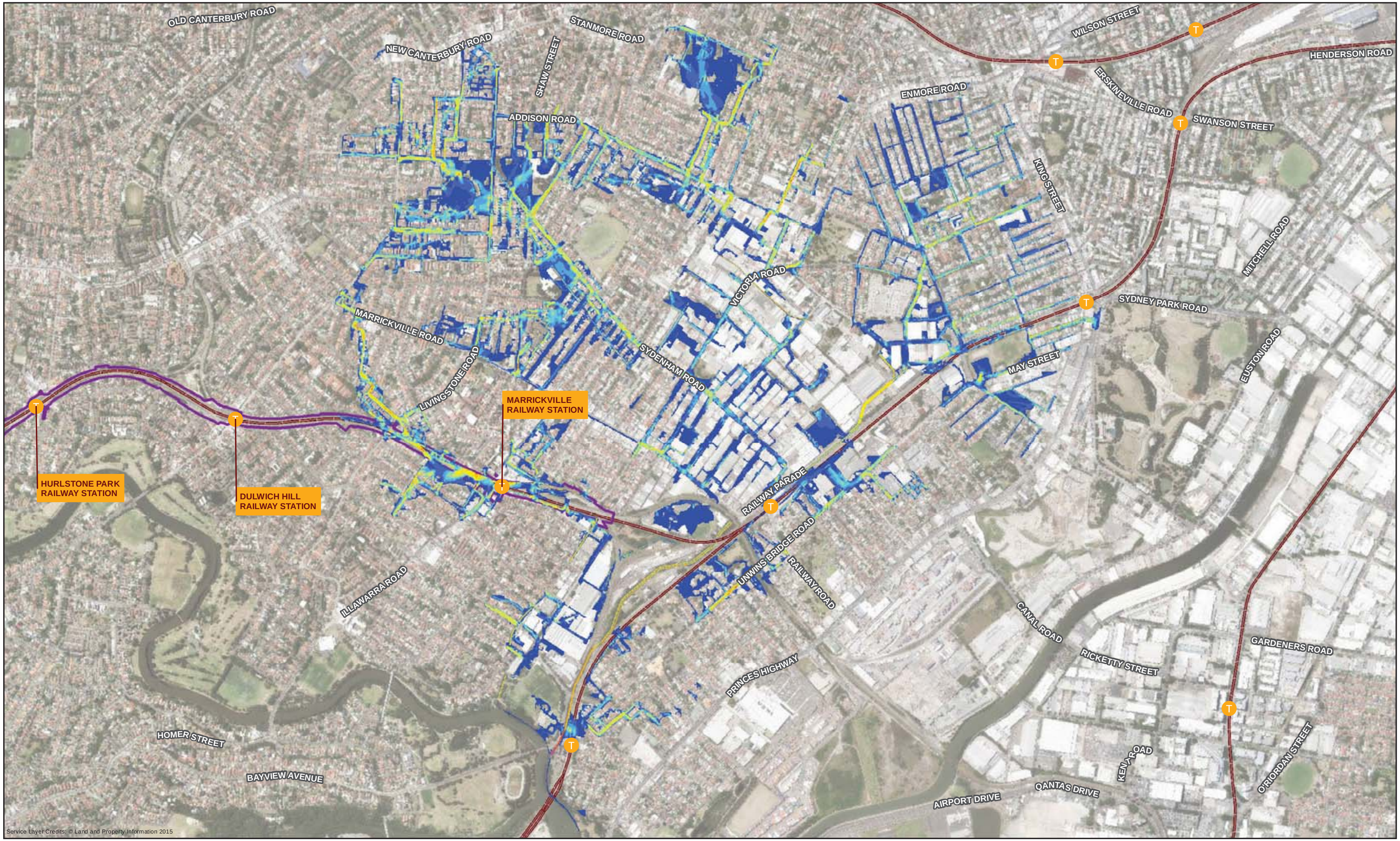
Existing 39% AEP flood velocity

Figure B.9

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

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

Job Number	21-25273
Revision	A
Date	22 May 2017

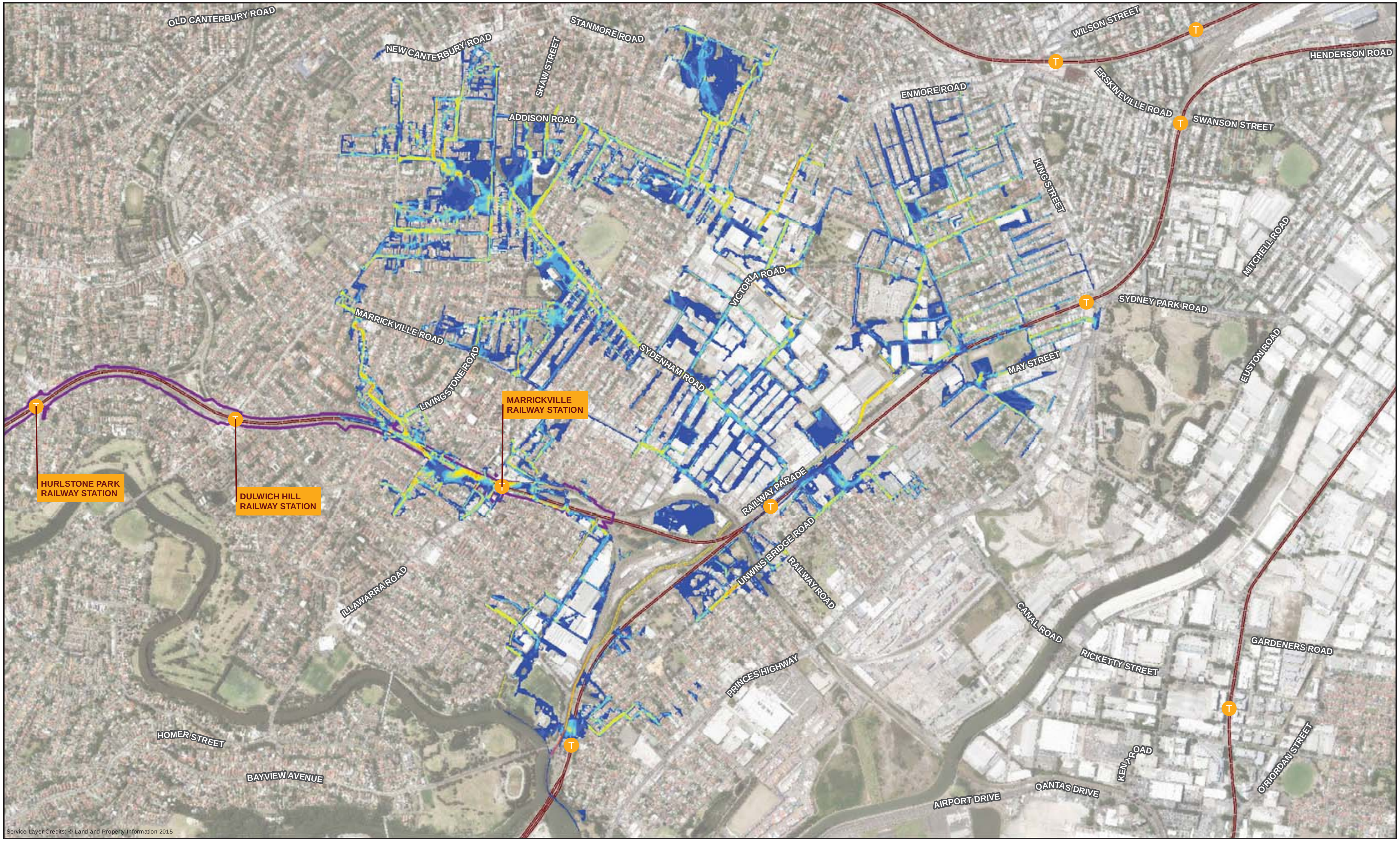
Existing 18% AEP flood velocity

Figure B.10

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

GHD

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

Job Number	21-25273
Revision	A
Date	22 May 2017

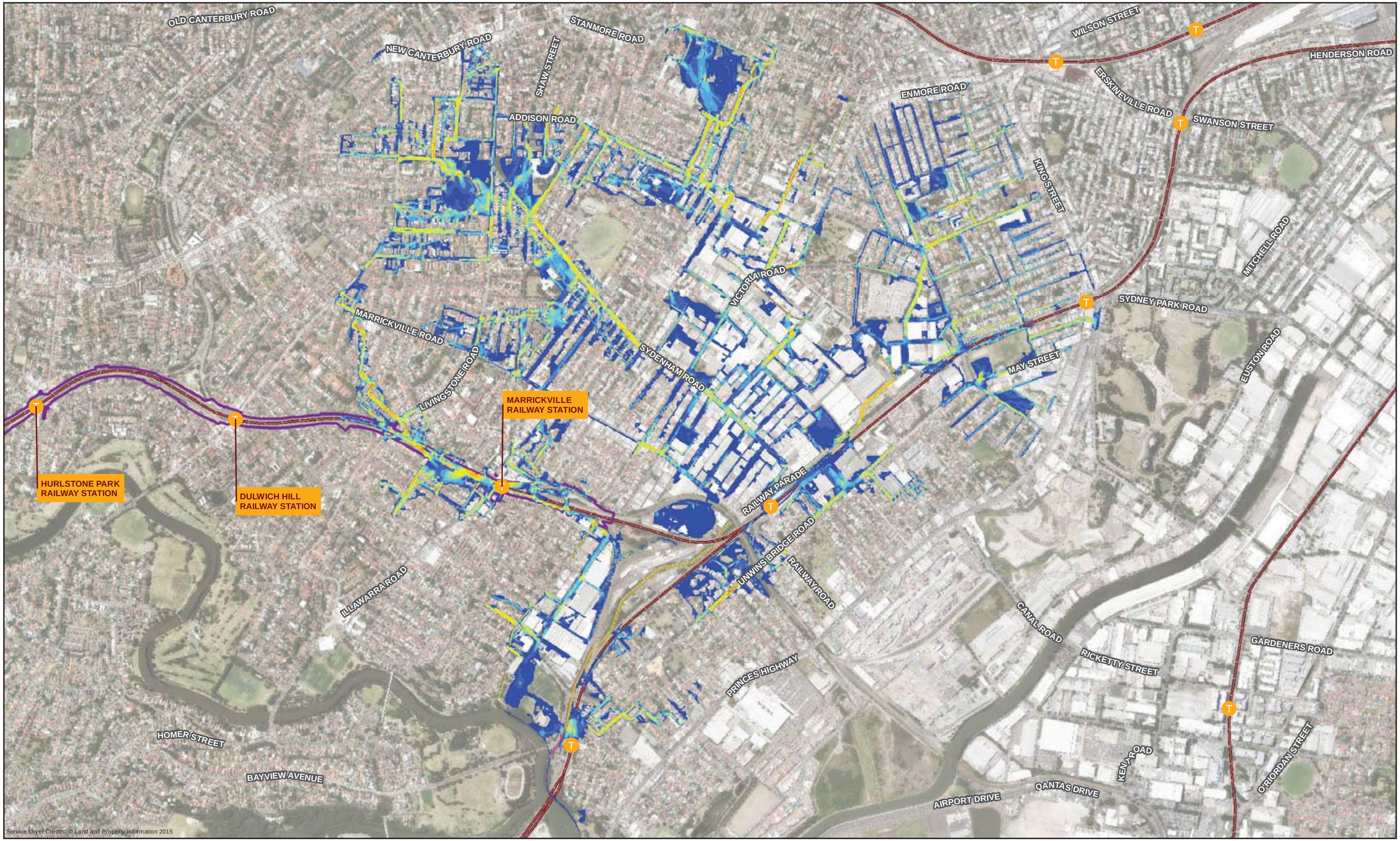
Existing 10% AEP flood velocity

Figure B.11

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

0 100 200 400

Metres

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

N

LEGEND

Project area	**Velocity (m/s)**	
Train station	0 to 0.2	1.0 to 1.5
Railway	0.2 to 0.4	1.5 to 2.0
	0.4 to 0.6	2.0 to 3.0
	0.6 to 0.8	3.0 to 5.0
	0.8 to 1.0	Greater than 5.0

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

Job Number 21-25273
Revision A
Date 22 May 2017

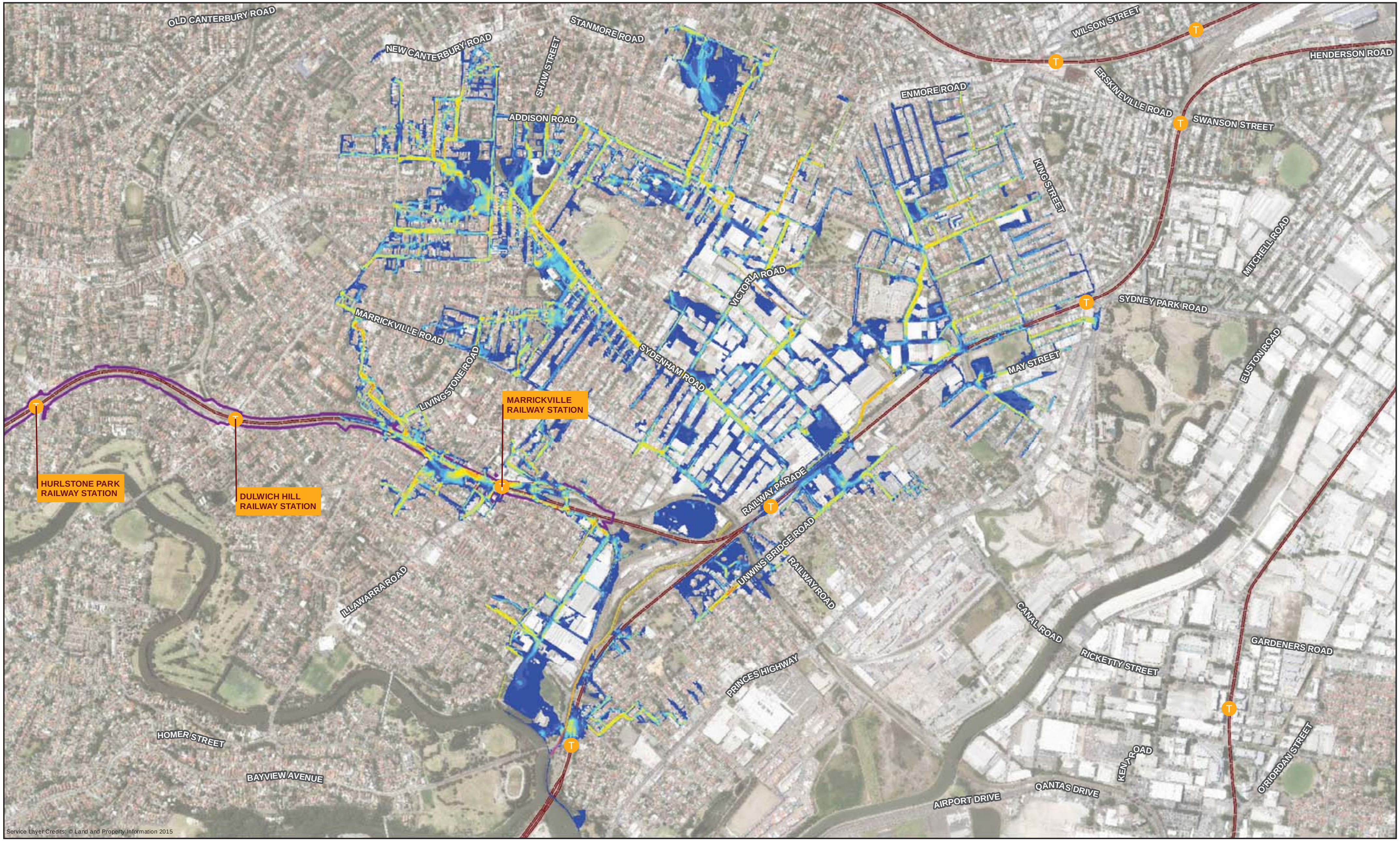
Existing 5% AEP flood velocity

Figure B.12

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

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

Job Number	21-25273
Revision	A
Date	22 May 2017

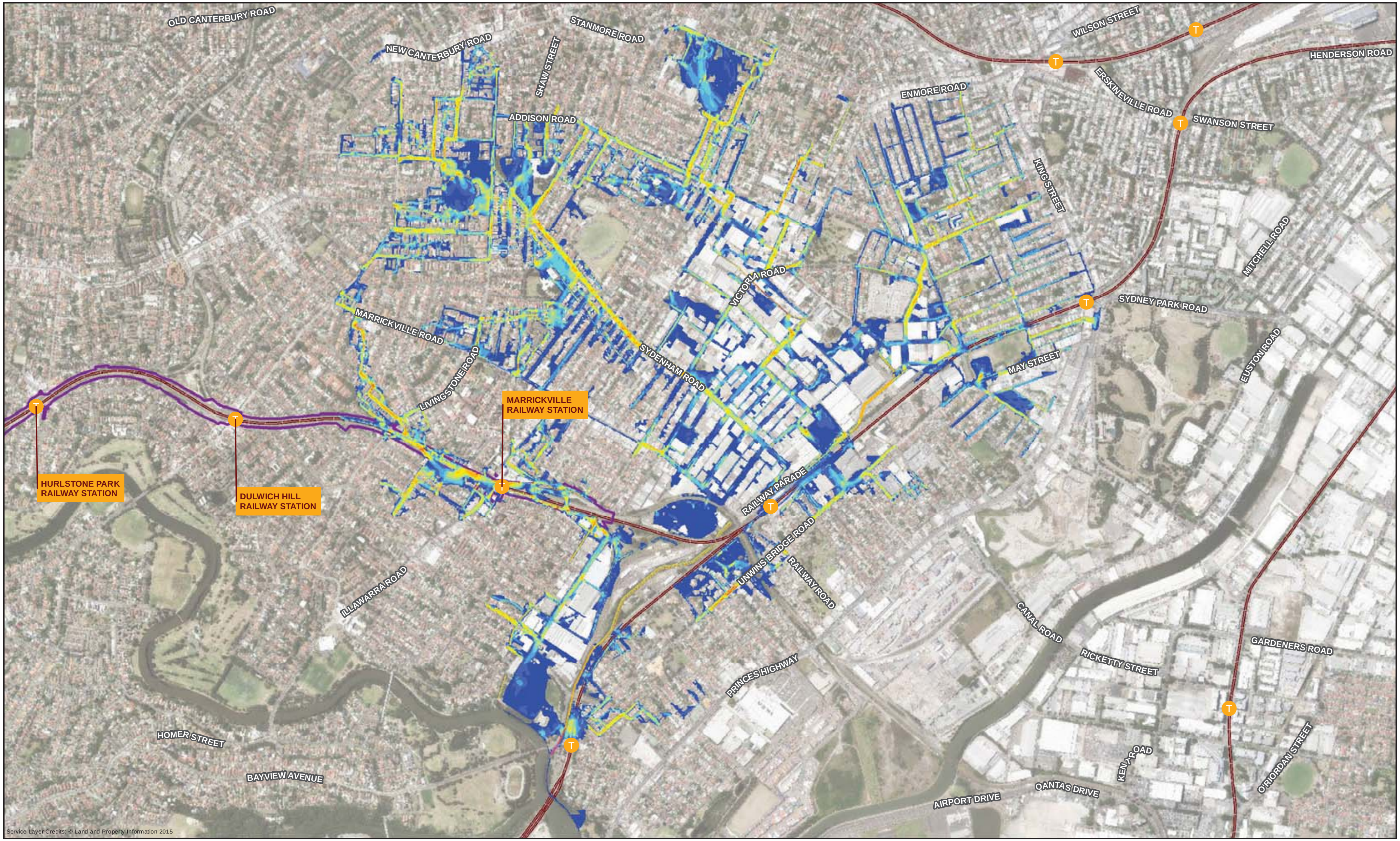
Existing 2% AEP flood velocity

Figure B.13

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

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

Job Number	21-25273
Revision	A
Date	22 May 2017

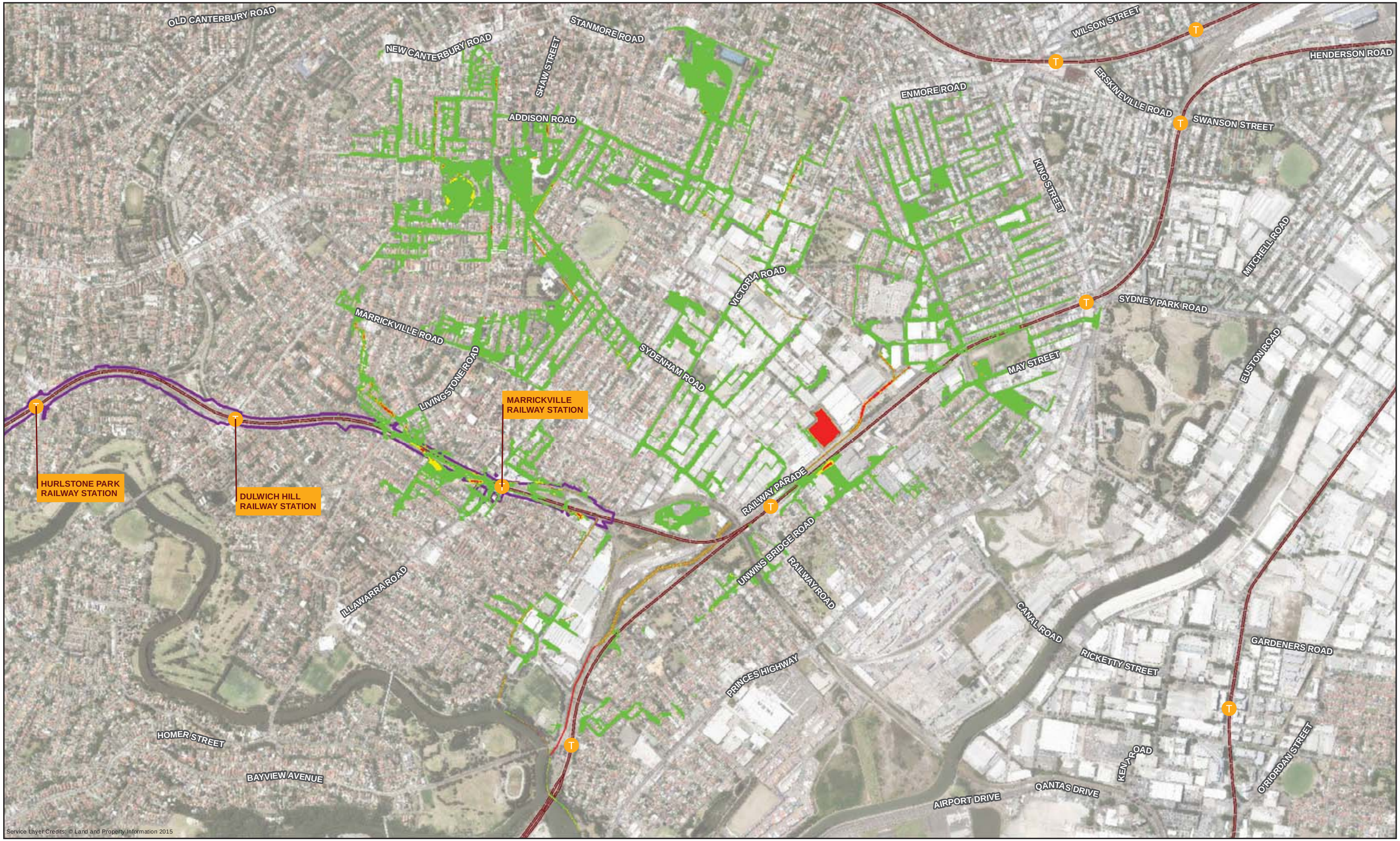
Existing 1% AEP flood velocity

Figure B.14

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

Provisional Hazard Category

1 - Low Hazard

2 - Transitional Hazard

3 - High Hazard

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

Job Number	21-25273
Revision	A
Date	22 May 2017

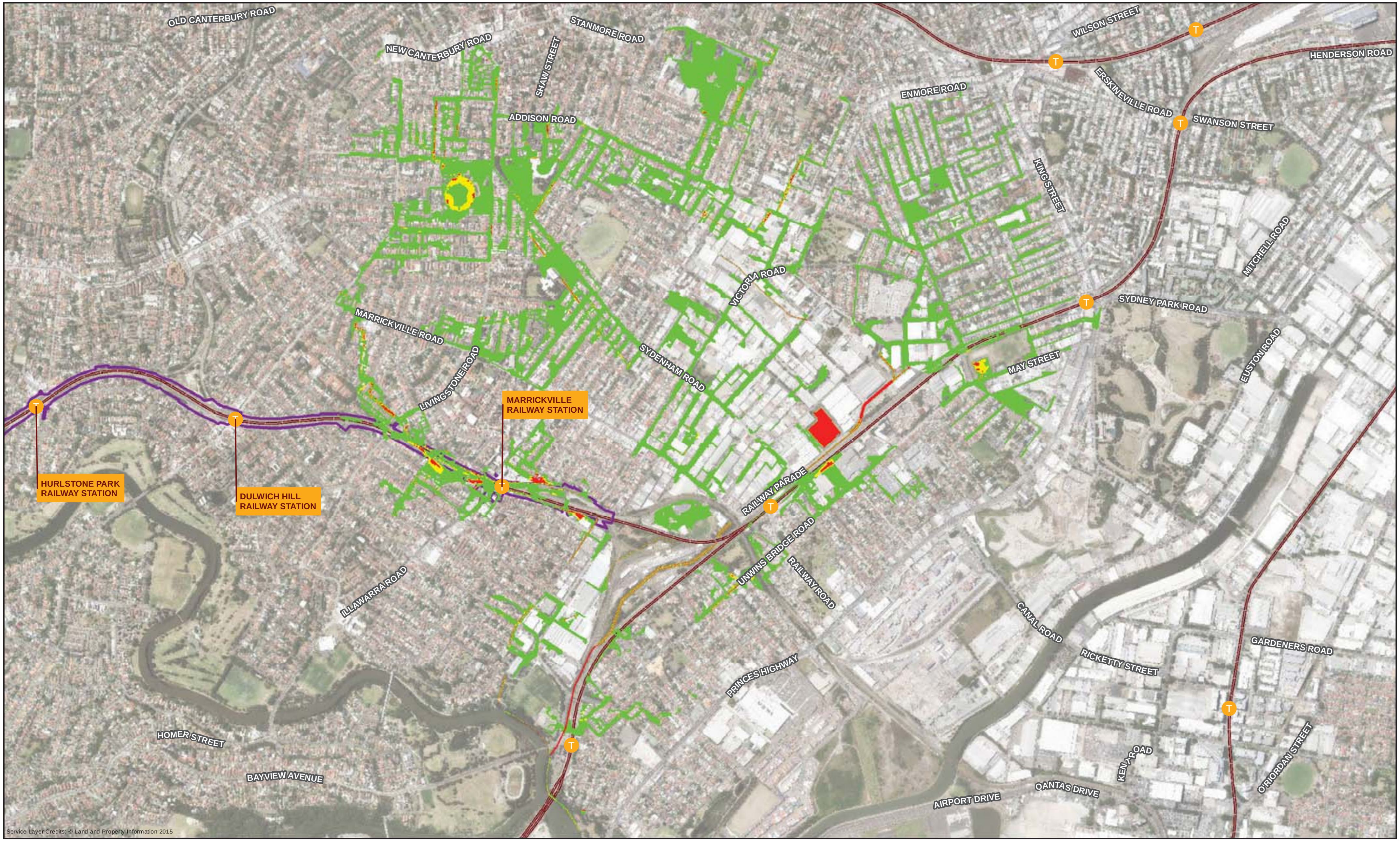
Existing 63% AEP
provisional flood hazard

Figure B.15

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

Provisional Hazard Category

1 - Low Hazard

2 - Transitional Hazard

3 - High Hazard

GHD

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

Job Number	21-25273
Revision	A
Date	22 May 2017

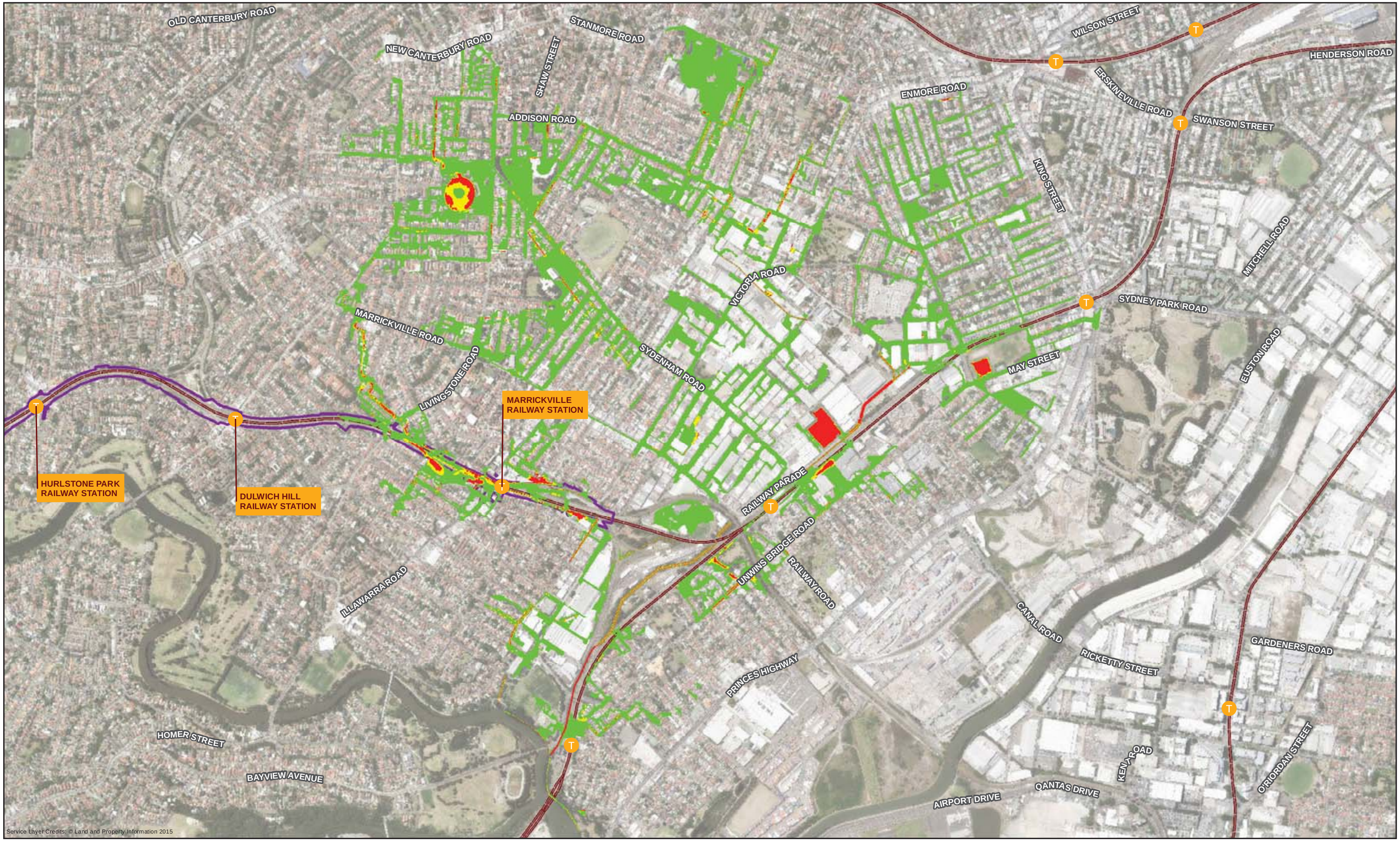
Existing 39% AEP provisional flood hazard

Figure B.16

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

0 100 200 400

Metres

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

N

LEGEND

Project area

T Train station

Railway

Provisional Hazard Category

1 - Low Hazard

2 - Transitional Hazard

3 - High Hazard

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

Job Number	21-25273
Revision	A
Date	22 May 2017

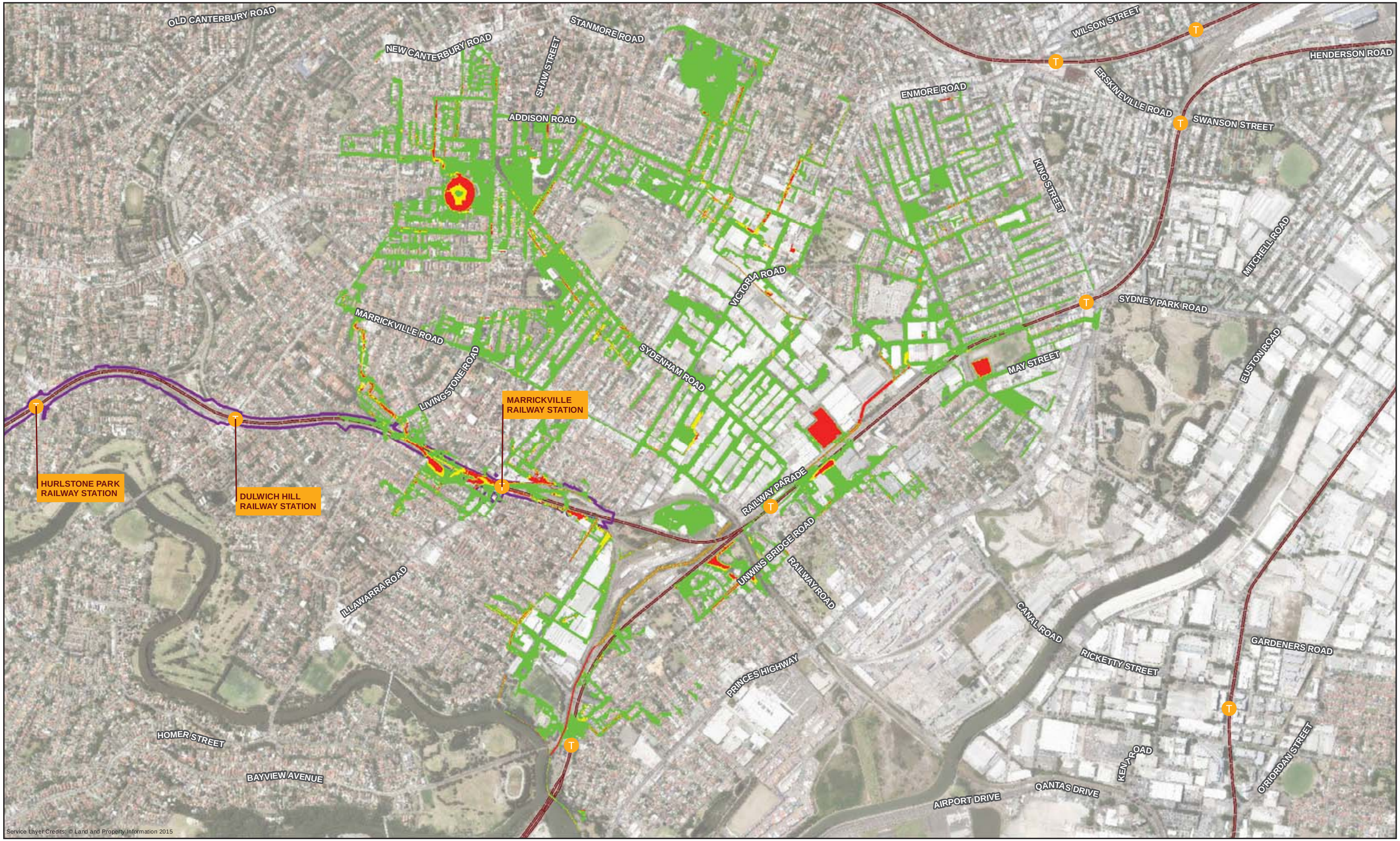
Existing 18% AEP provisional flood hazard

Figure B.17

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

Provisional Hazard Category

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

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

Job Number	21-25273
Revision	A
Date	22 May 2017

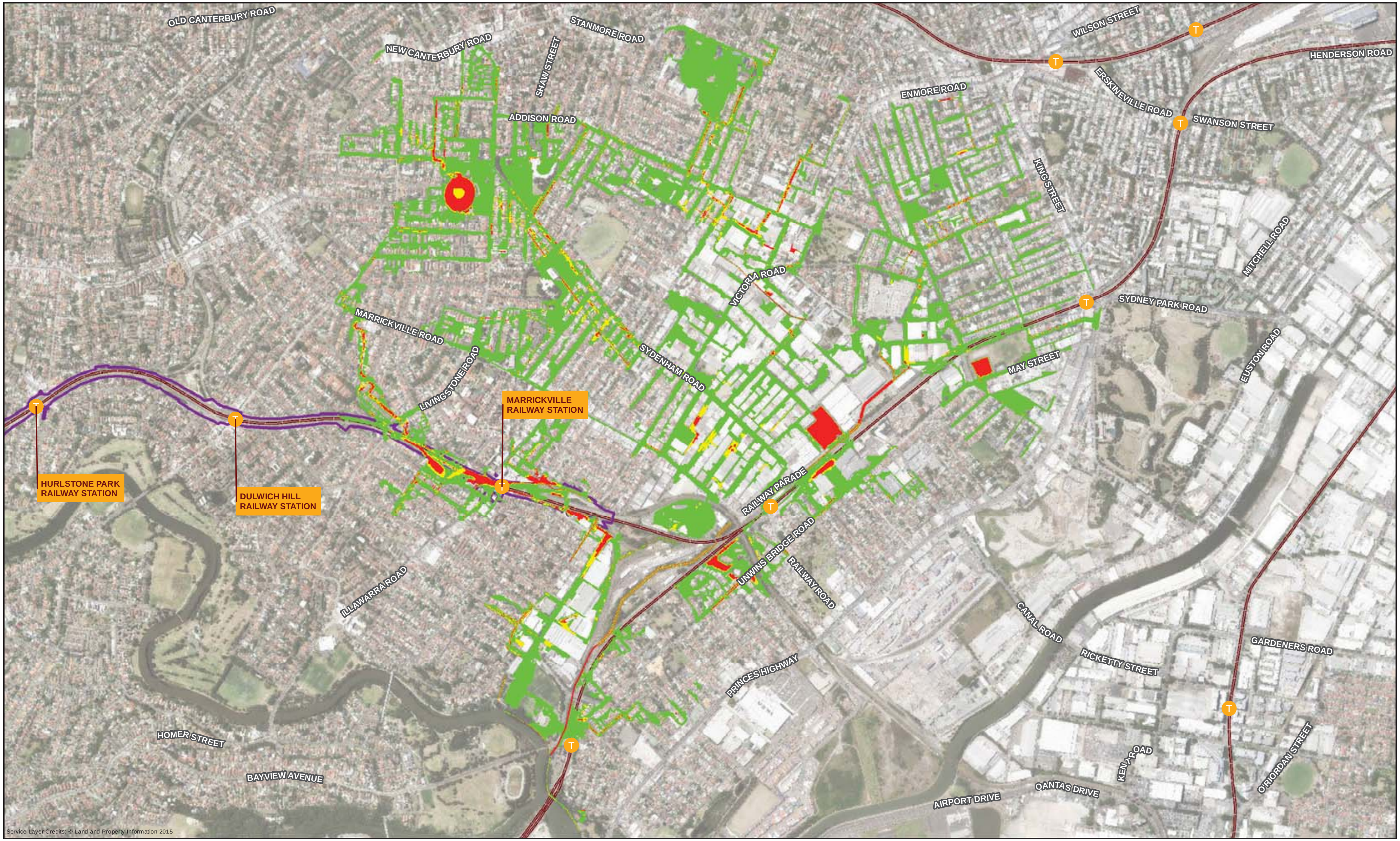
Existing 10% AEP provisional flood hazard

Figure B.18

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

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

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



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

Provisional Hazard Category

1 - Low Hazard

2 - Transitional Hazard

3 - High Hazard

GHD

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

Job Number	21-25273
Revision	A
Date	22 May 2017

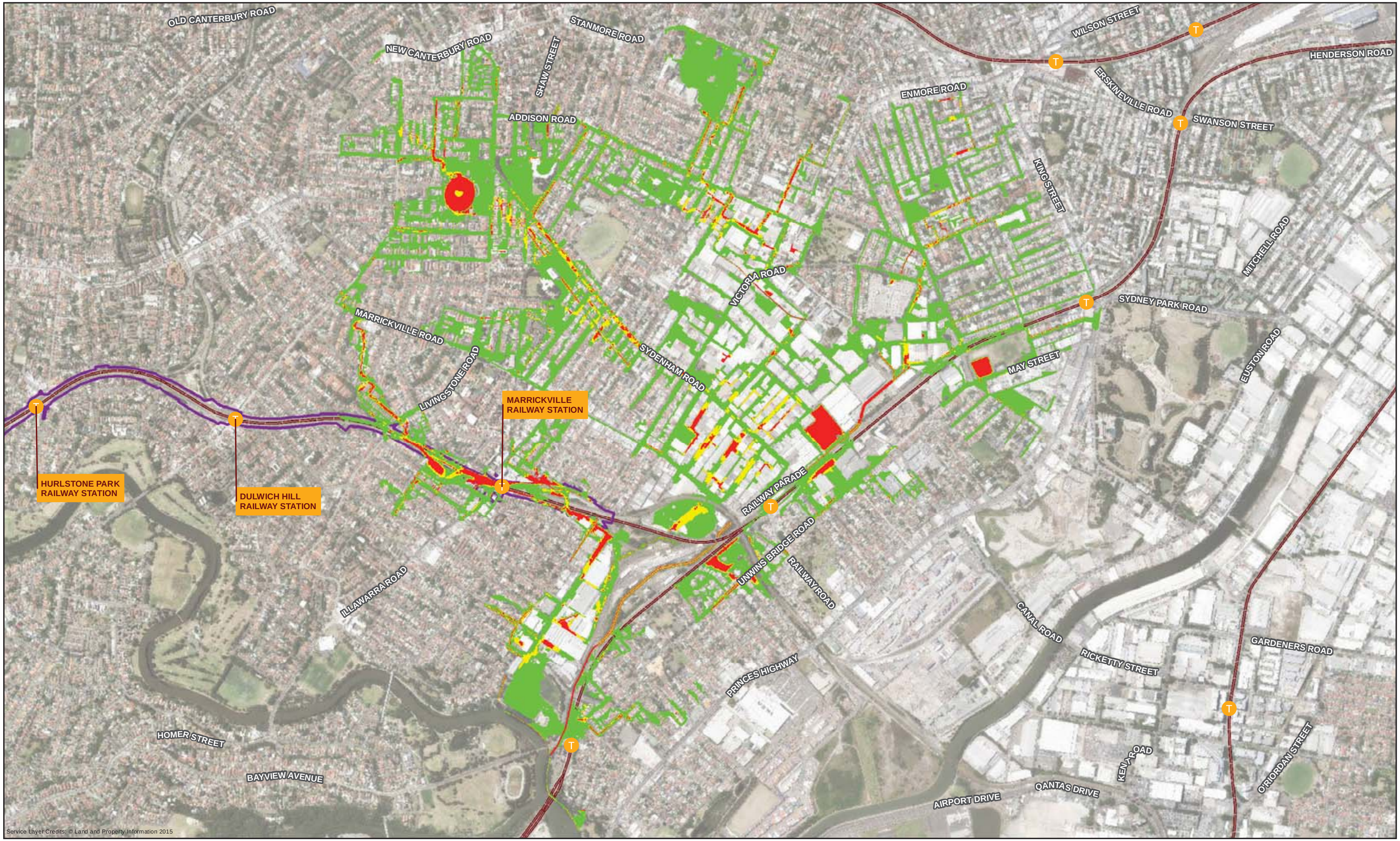
Existing 5% AEP provisional flood hazard

Figure B.19

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

Provisional Hazard Category

1 - Low Hazard

2 - Transitional Hazard

3 - High Hazard

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

Job Number	21-25273
Revision	A
Date	22 May 2017

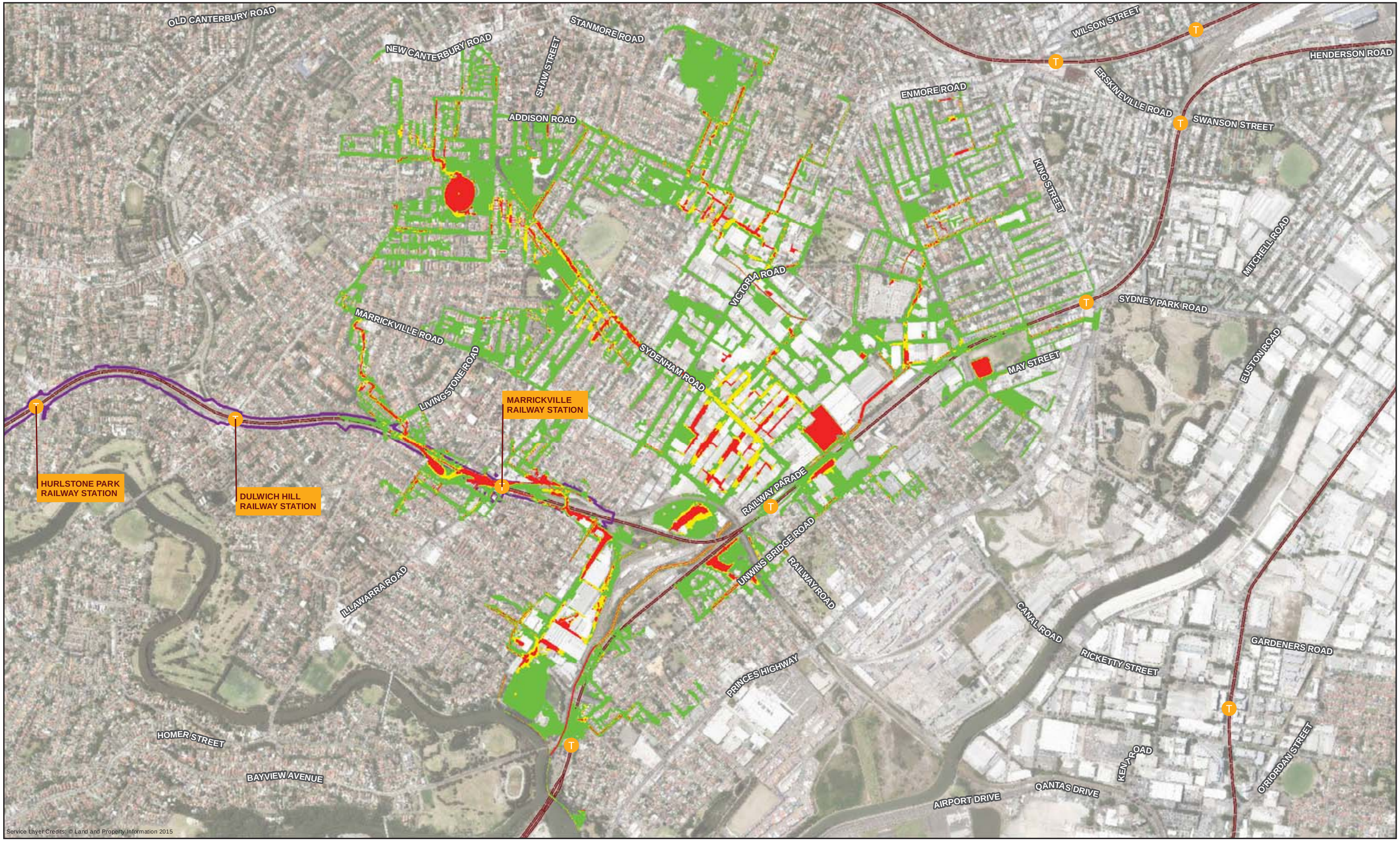
Existing 2% AEP provisional flood hazard

Figure B.20

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

Provisional Hazard Category

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

GHD

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

Job Number	21-25273
Revision	A
Date	22 May 2017

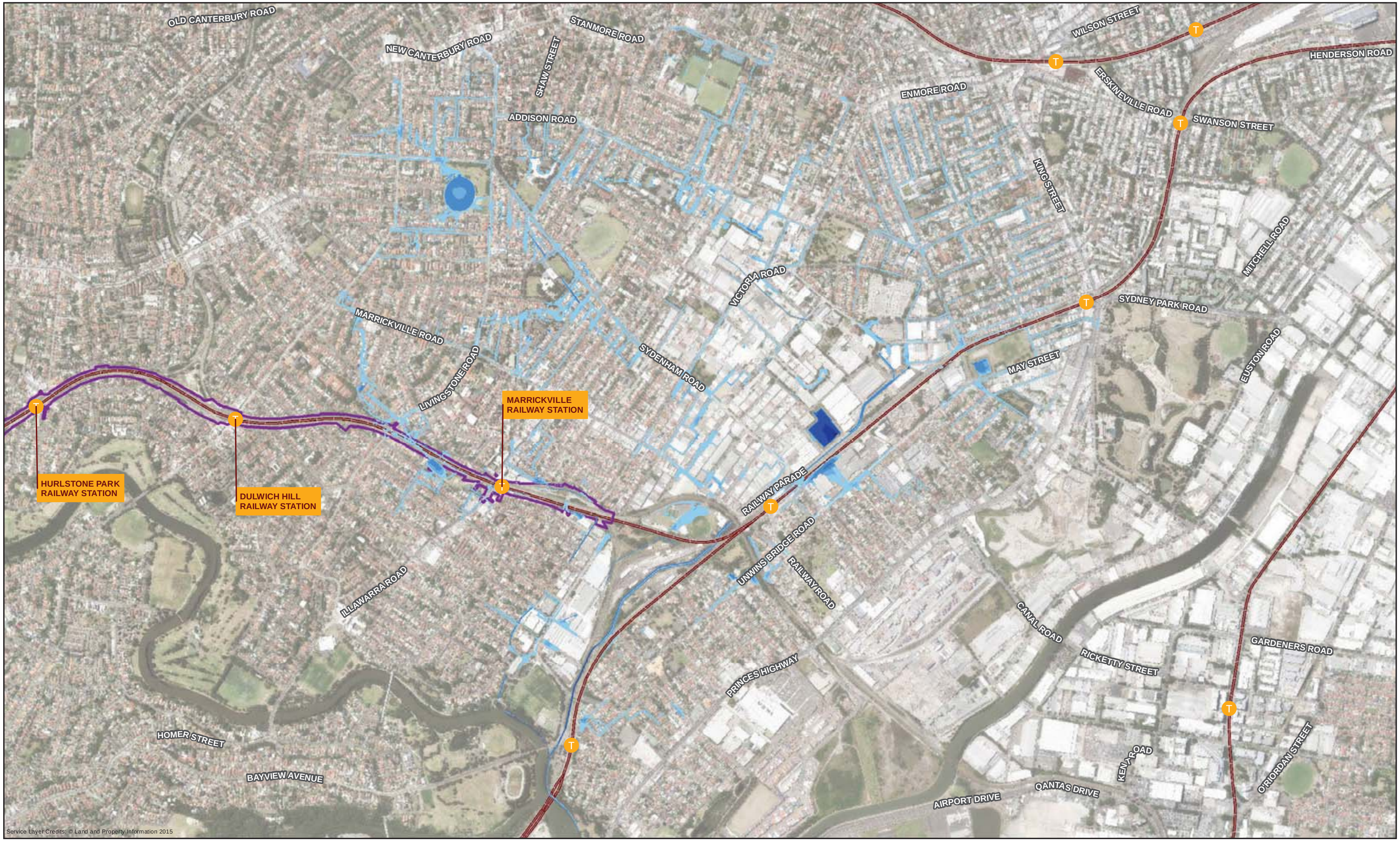
Existing 1% AEP provisional flood hazard

Figure B.21

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

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

Job Number	21-25273
Revision	A
Date	22 May 2017

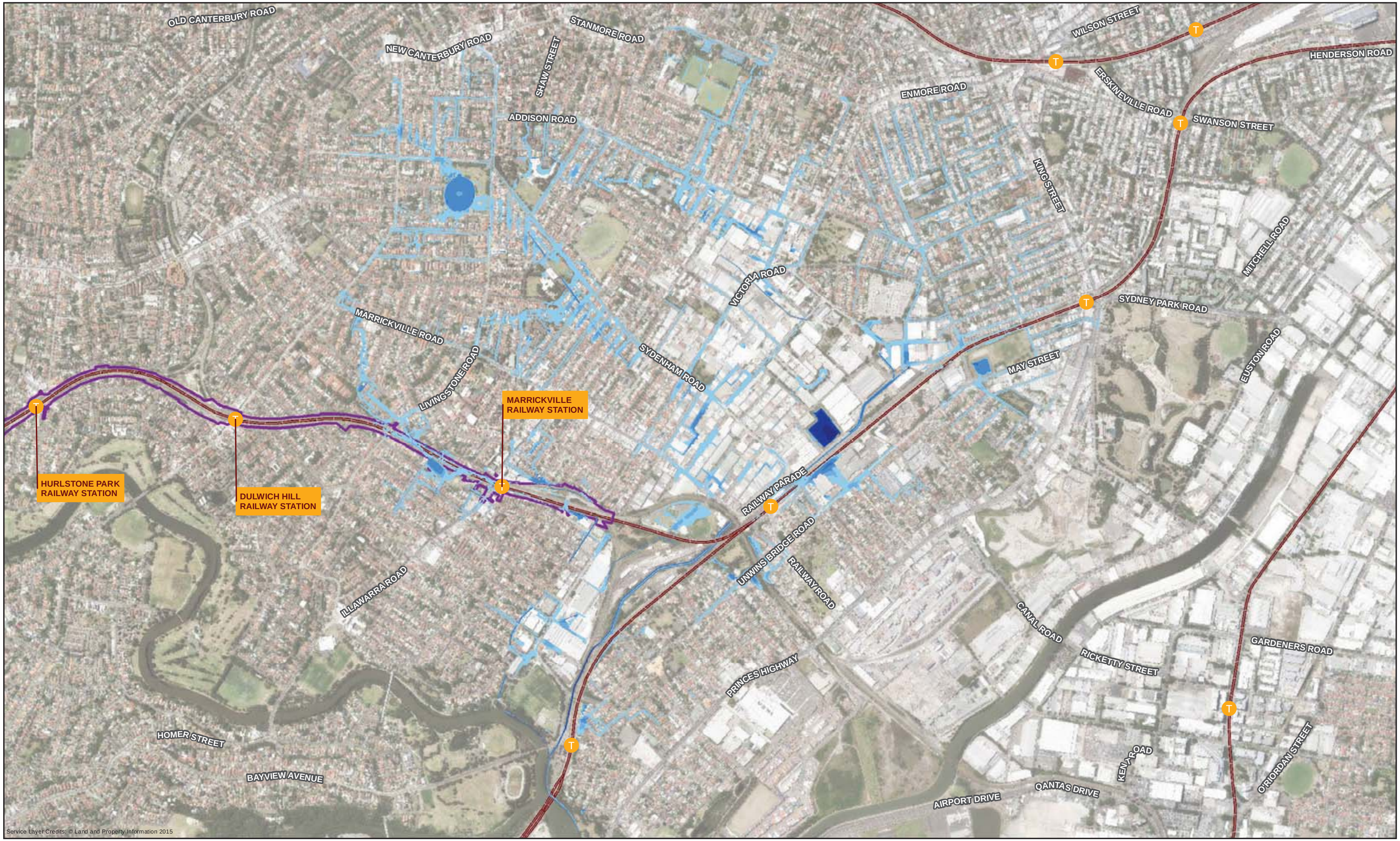
Post-developed 63% AEP flood depth

Figure B.22

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

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

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

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

Job Number	21-25273
Revision	A
Date	22 May 2017

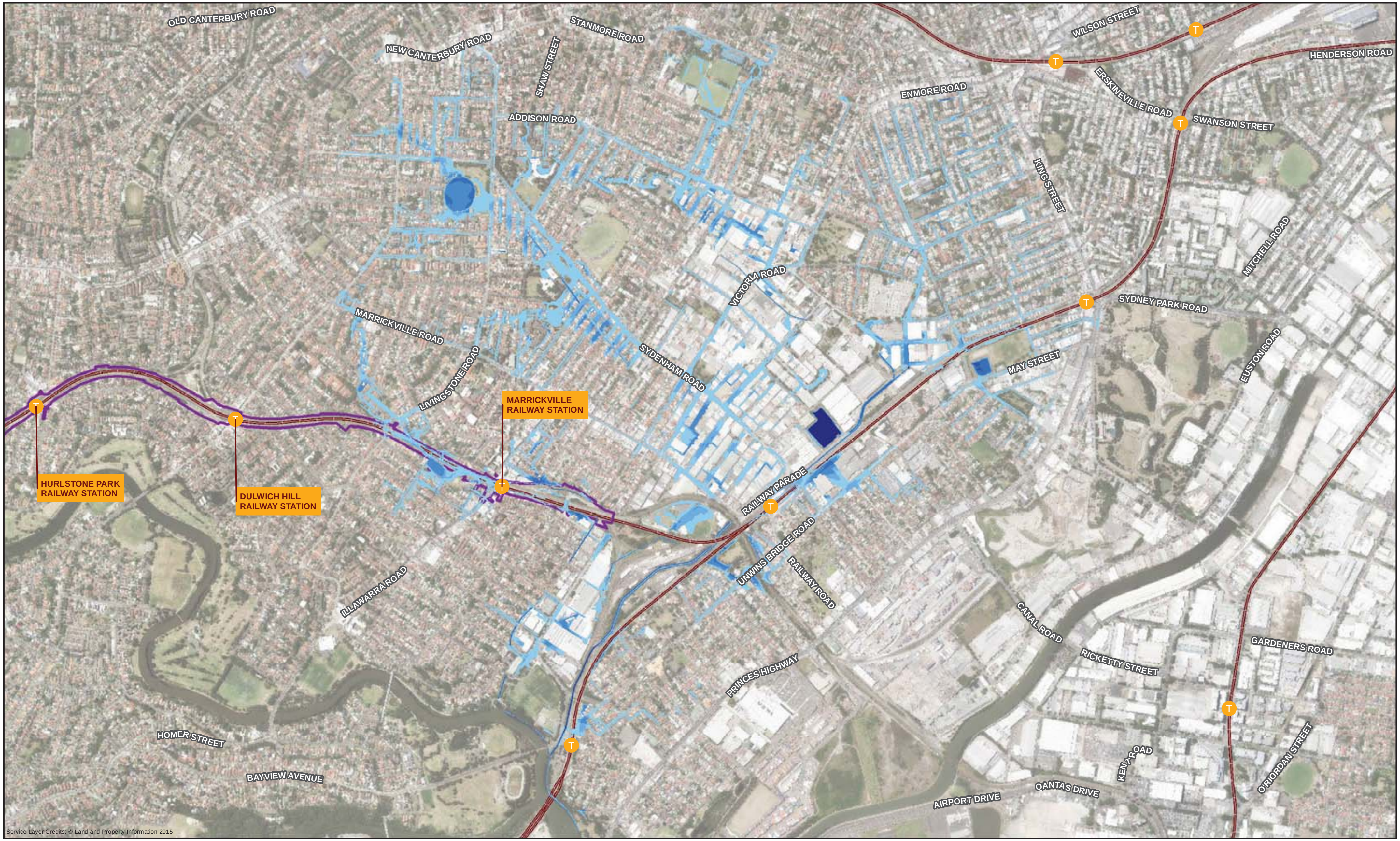
Post-developed 39% AEP flood depth

Figure B.23

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

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

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

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

Post-developed 18% AEP flood depth

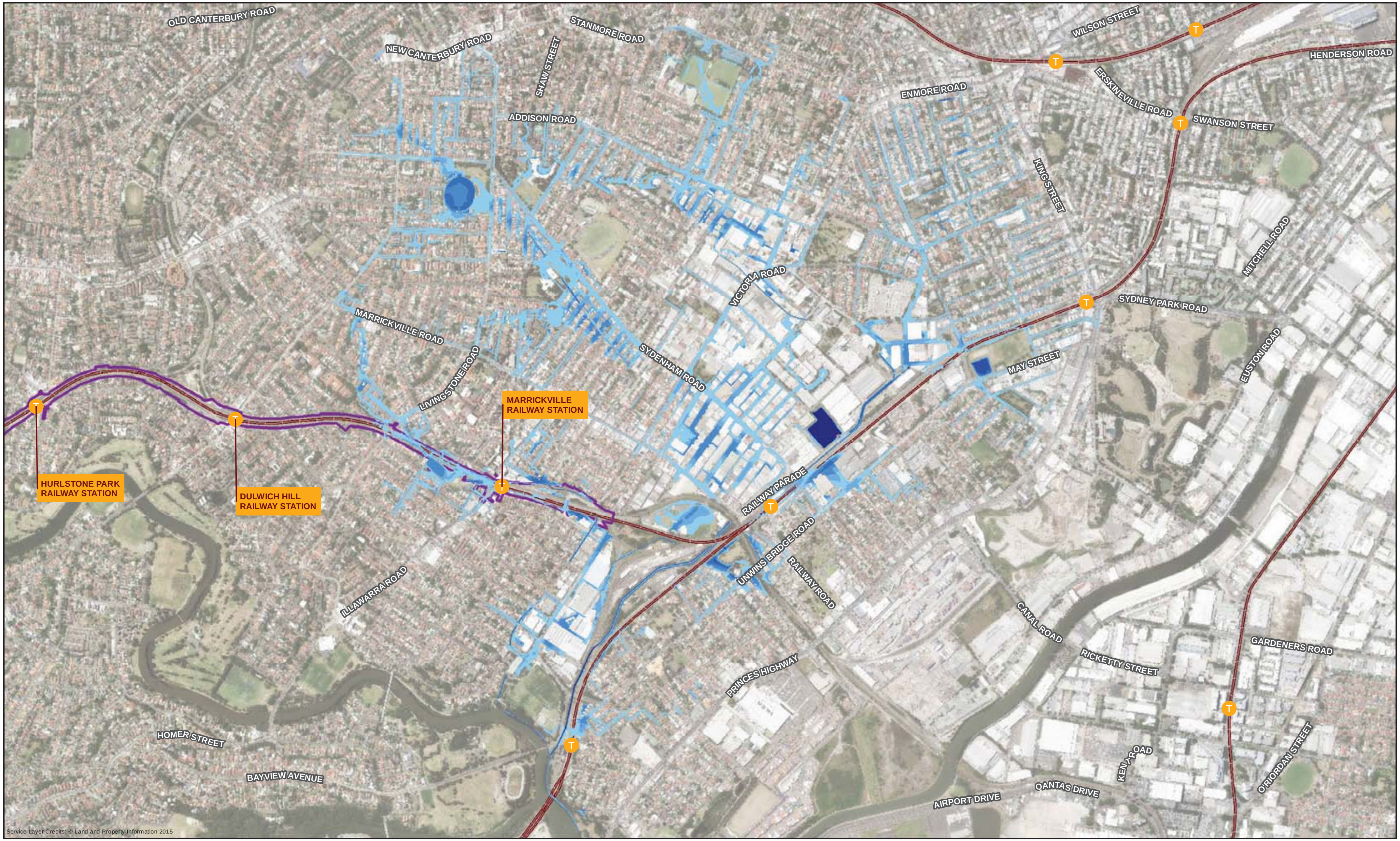
Job Number	21-25273
Revision	A
Date	22 May 2017

Figure B.24

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

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

Job Number	21-25273
Revision	A
Date	22 May 2017

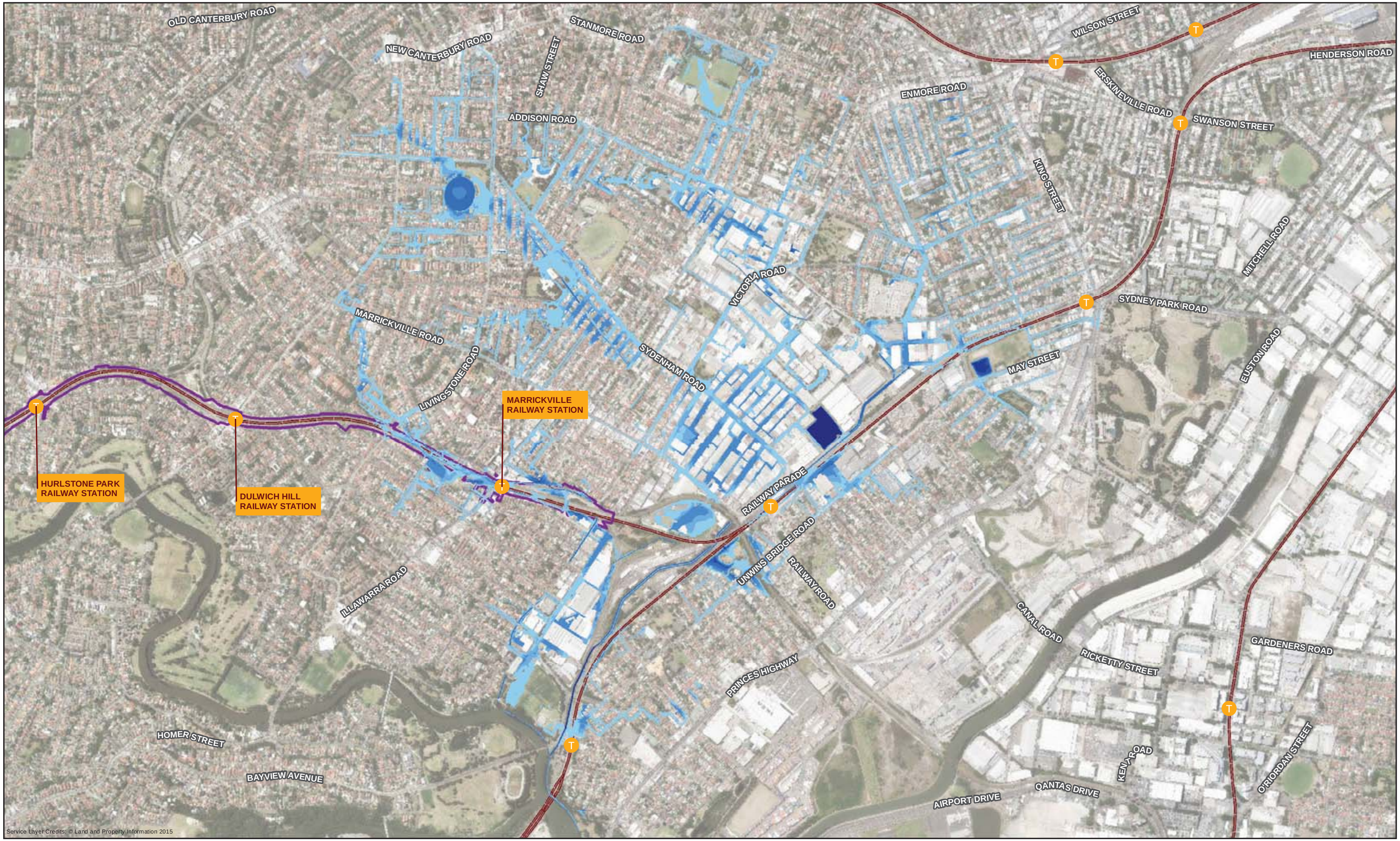
Post-developed 10% AEP flood depth

Figure B.25

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

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

Job Number	21-25273
Revision	A
Date	22 May 2017

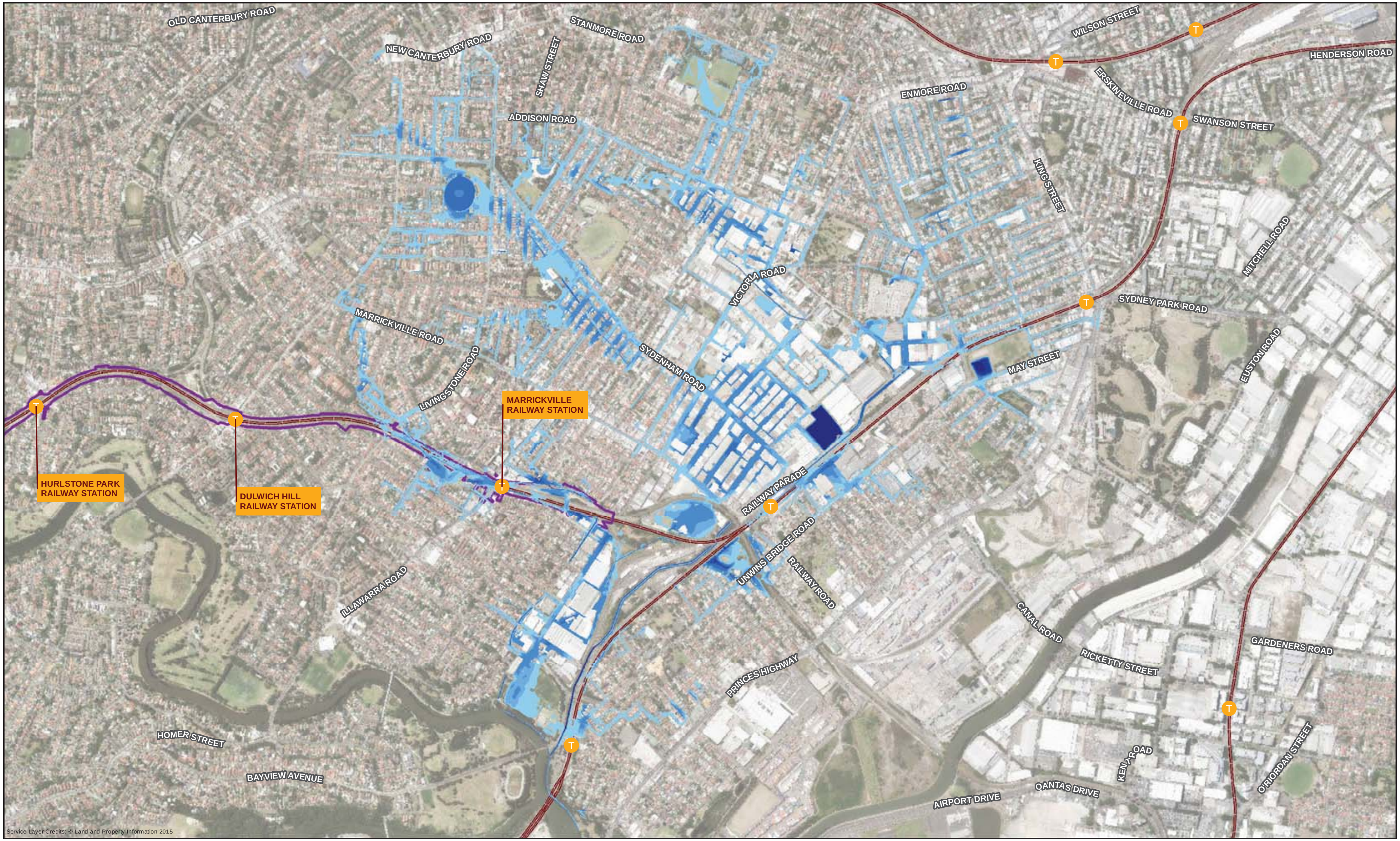
Post-developed 5%
AEP flood depth

Figure B.26

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

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

GHD

Job Number 21-25273
Revision A
Date 22 May 2017

Post-developed 2% AEP flood depth

Figure B.27

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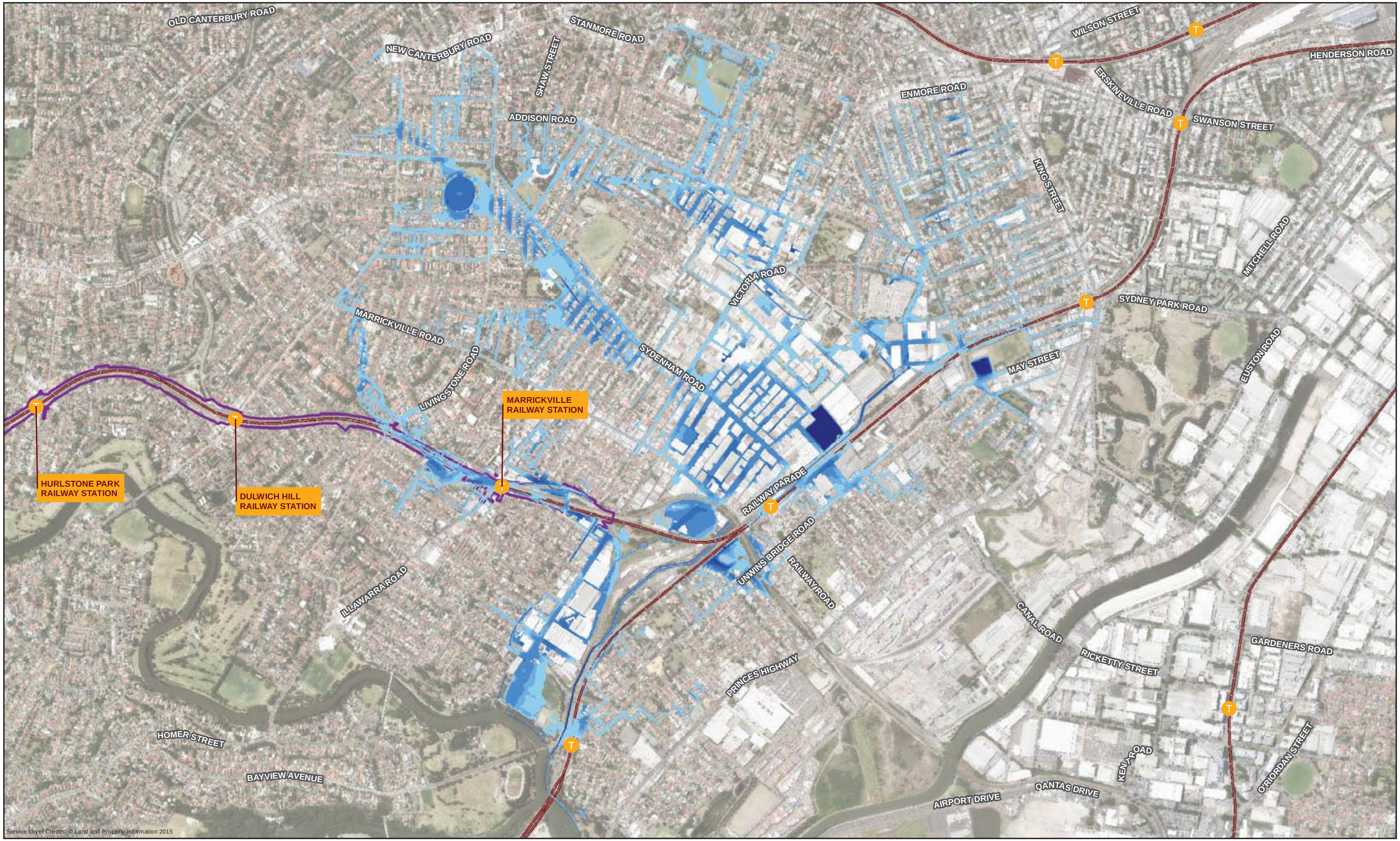
Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

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

GHD

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

Job Number	21-25273
Revision	A
Date	22 May 2017

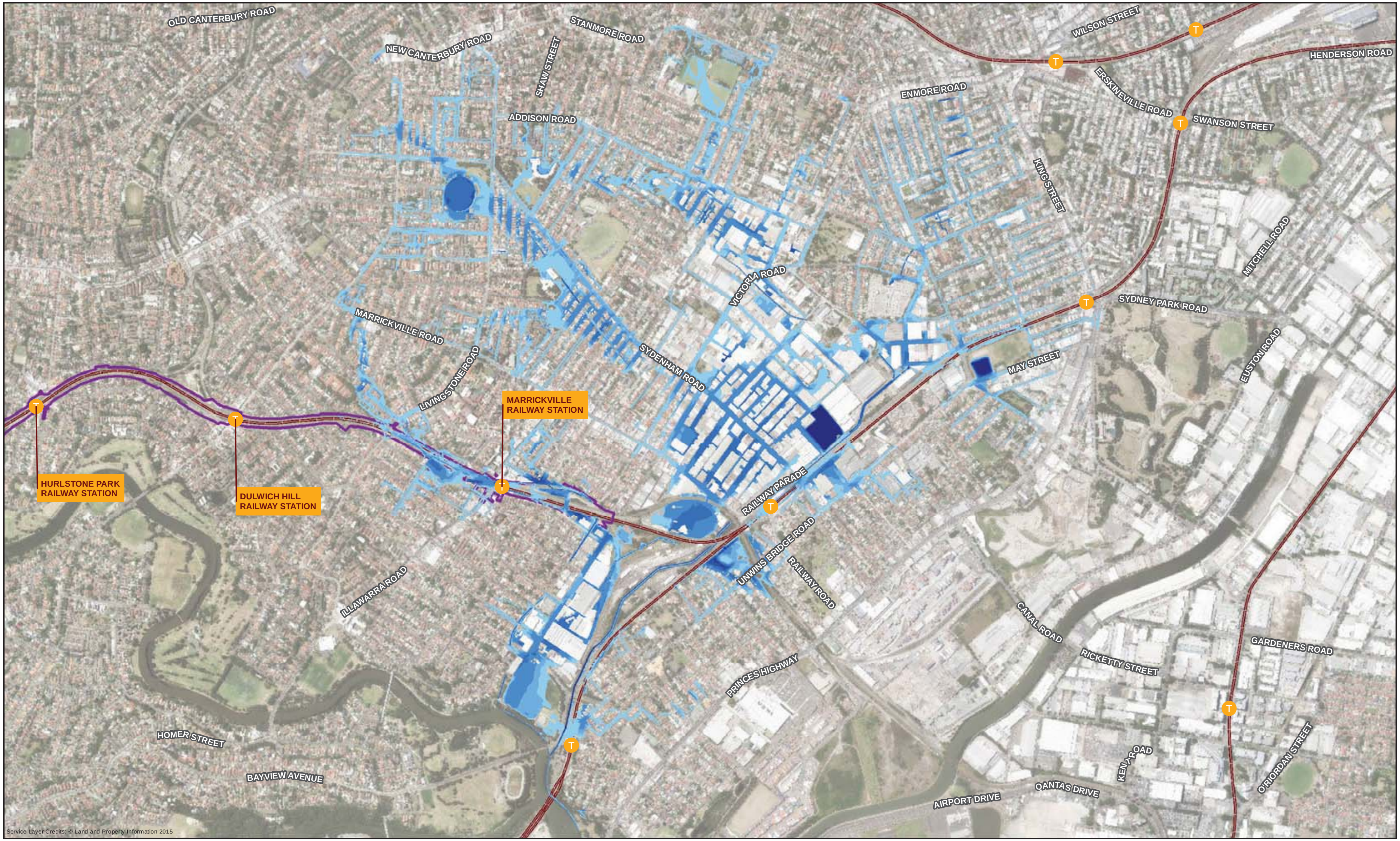
Post-developed 1% AEP flood depth

Figure B.28

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

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

Job Number	21-25273
Revision	A
Date	22 May 2017

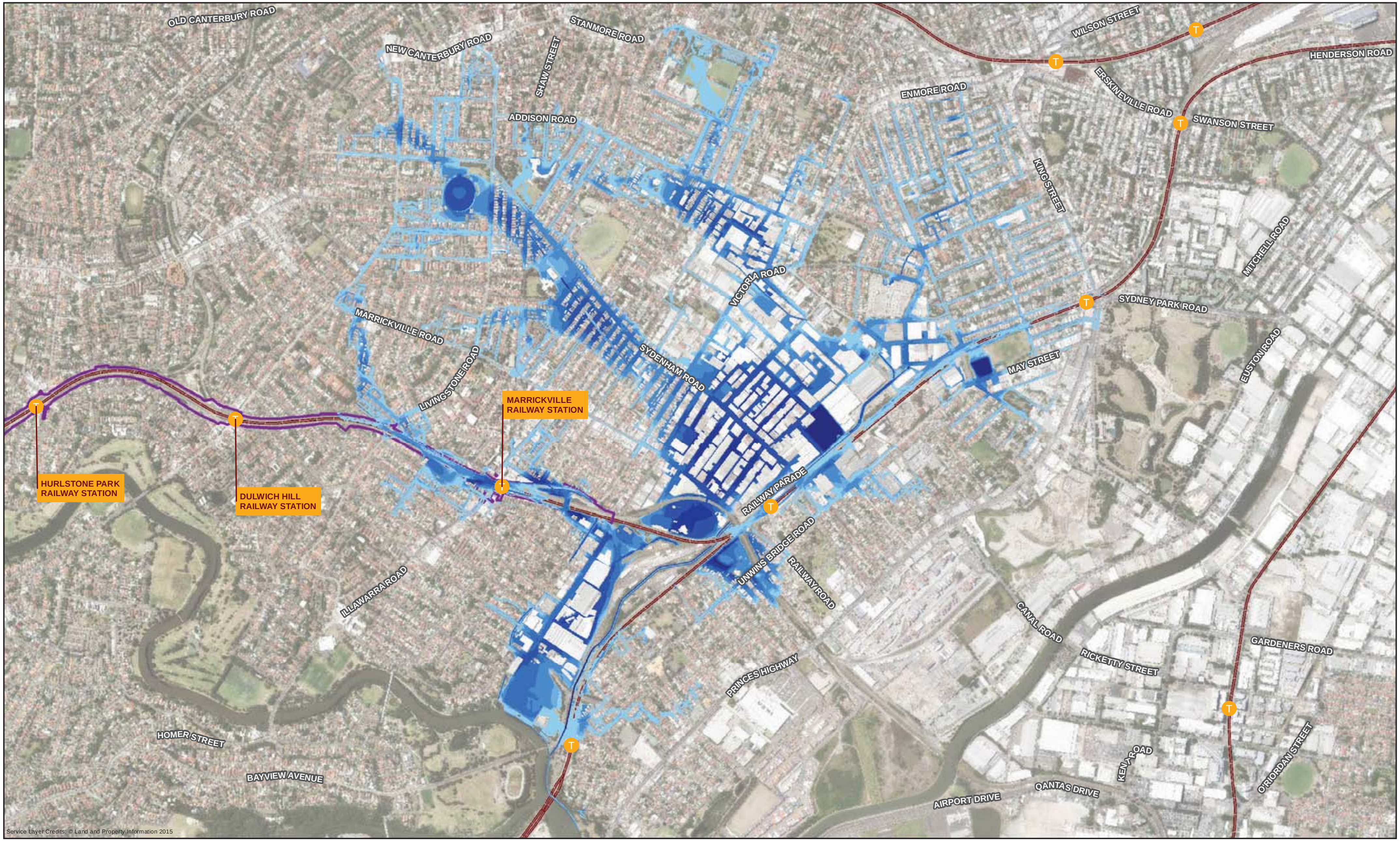
Post-developed 1% AEP + 10% climate change flood depth

Figure B.29

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

GHD

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

Job Number	21-25273
Revision	A
Date	22 May 2017

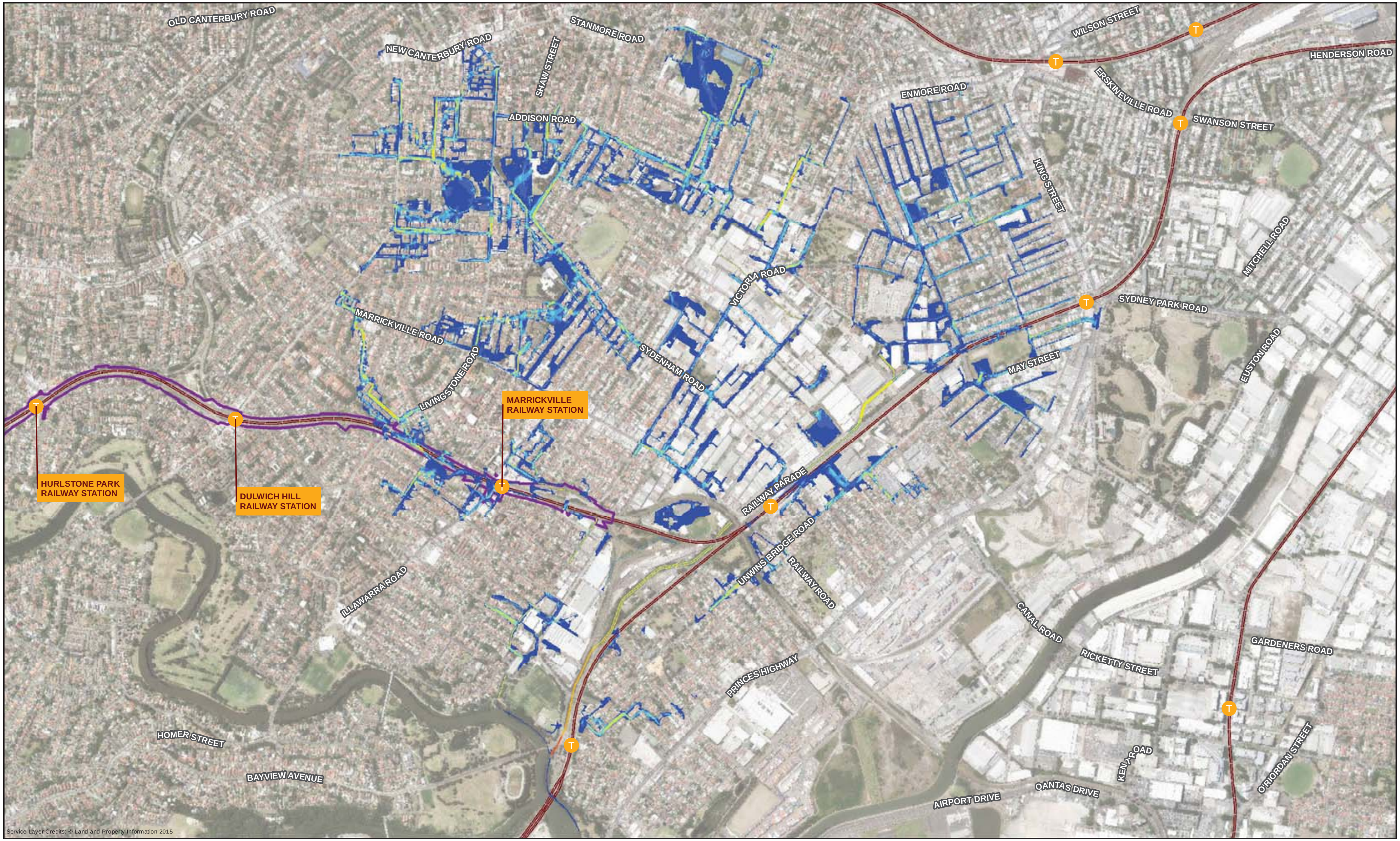
Post-developed PMF flood depth

Figure B.30

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

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

Job Number	21-25273
Revision	A
Date	22 May 2017

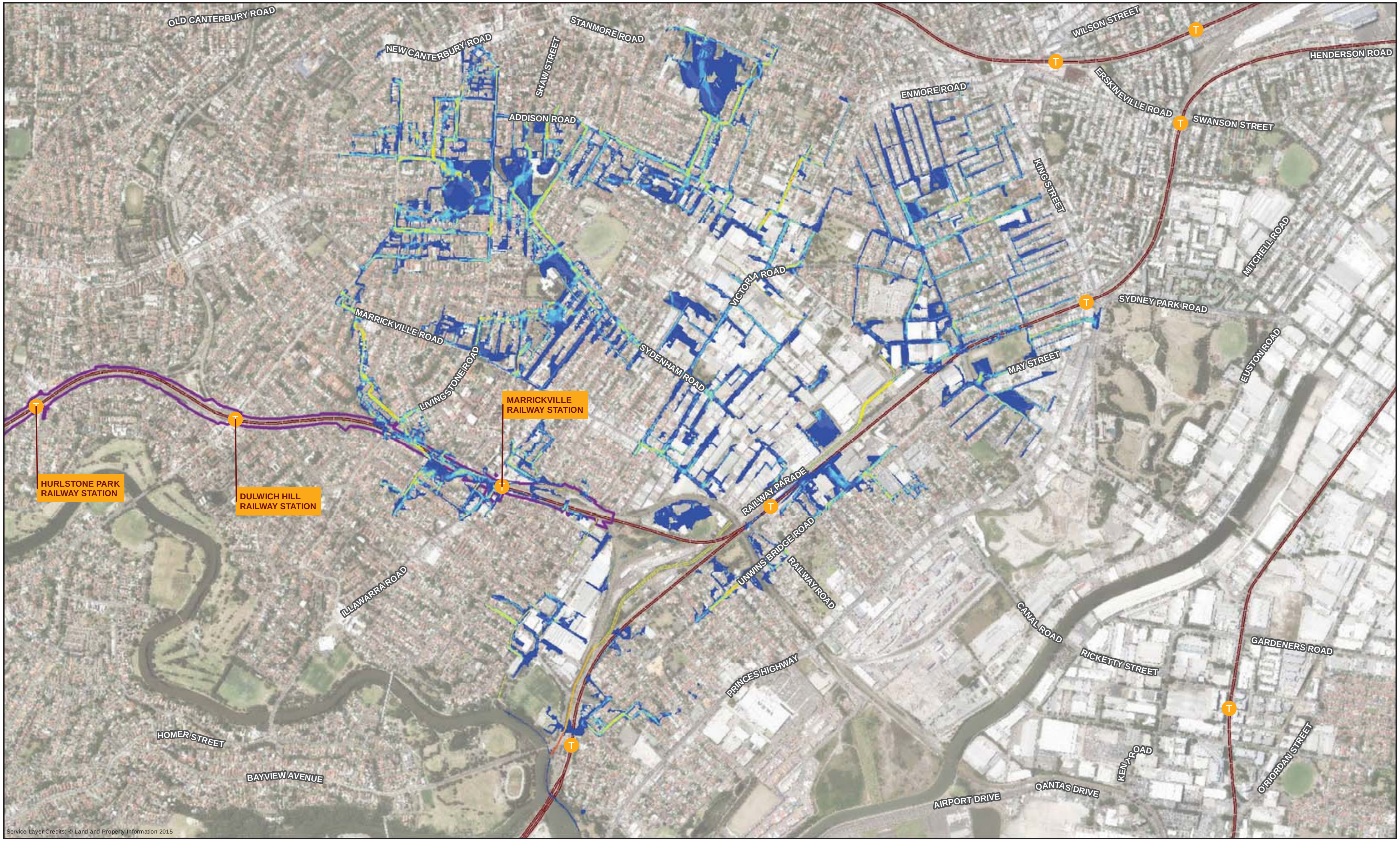
Post-developed 63% AEP flood velocity

Figure B.31

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

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

Post-developed 39% AEP flood velocity

Job Number	21-25273
Revision	A
Date	22 May 2017

Figure B.32

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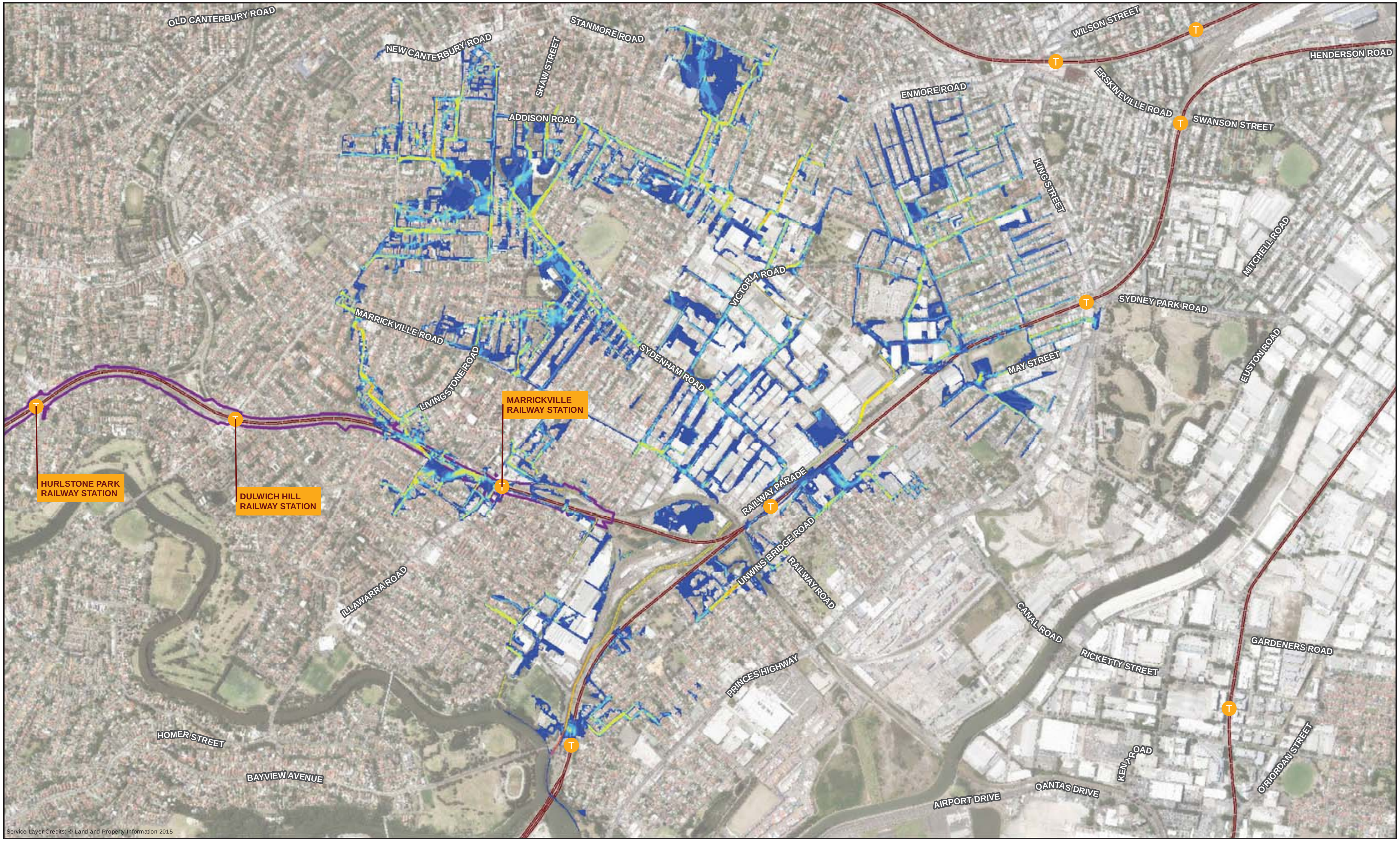
Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

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

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

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

Job Number	21-25273
Revision	A
Date	22 May 2017

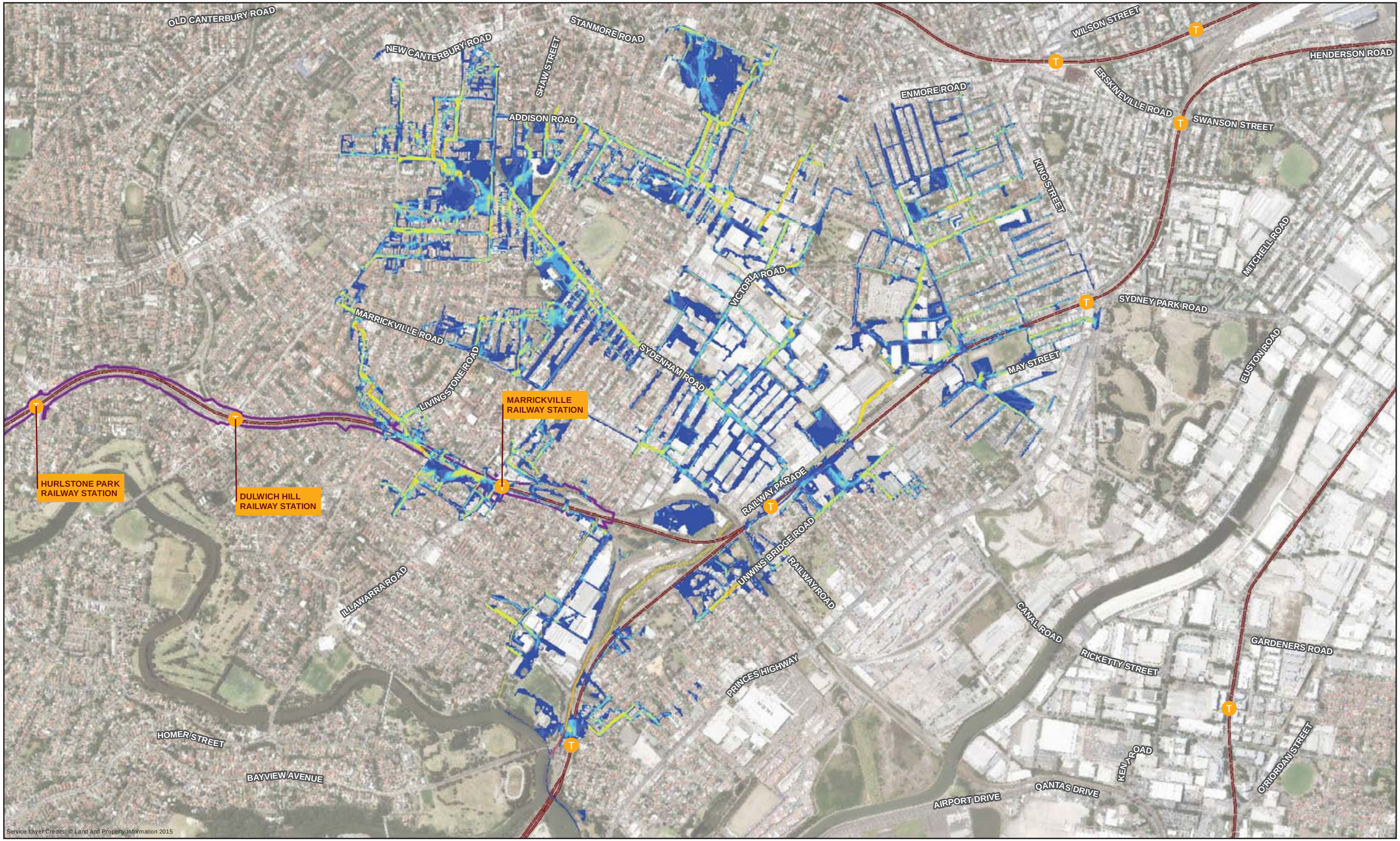
Post-developed 18% AEP flood velocity

Figure B.33

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

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

Job Number	21-25273
Revision	A
Date	22 May 2017

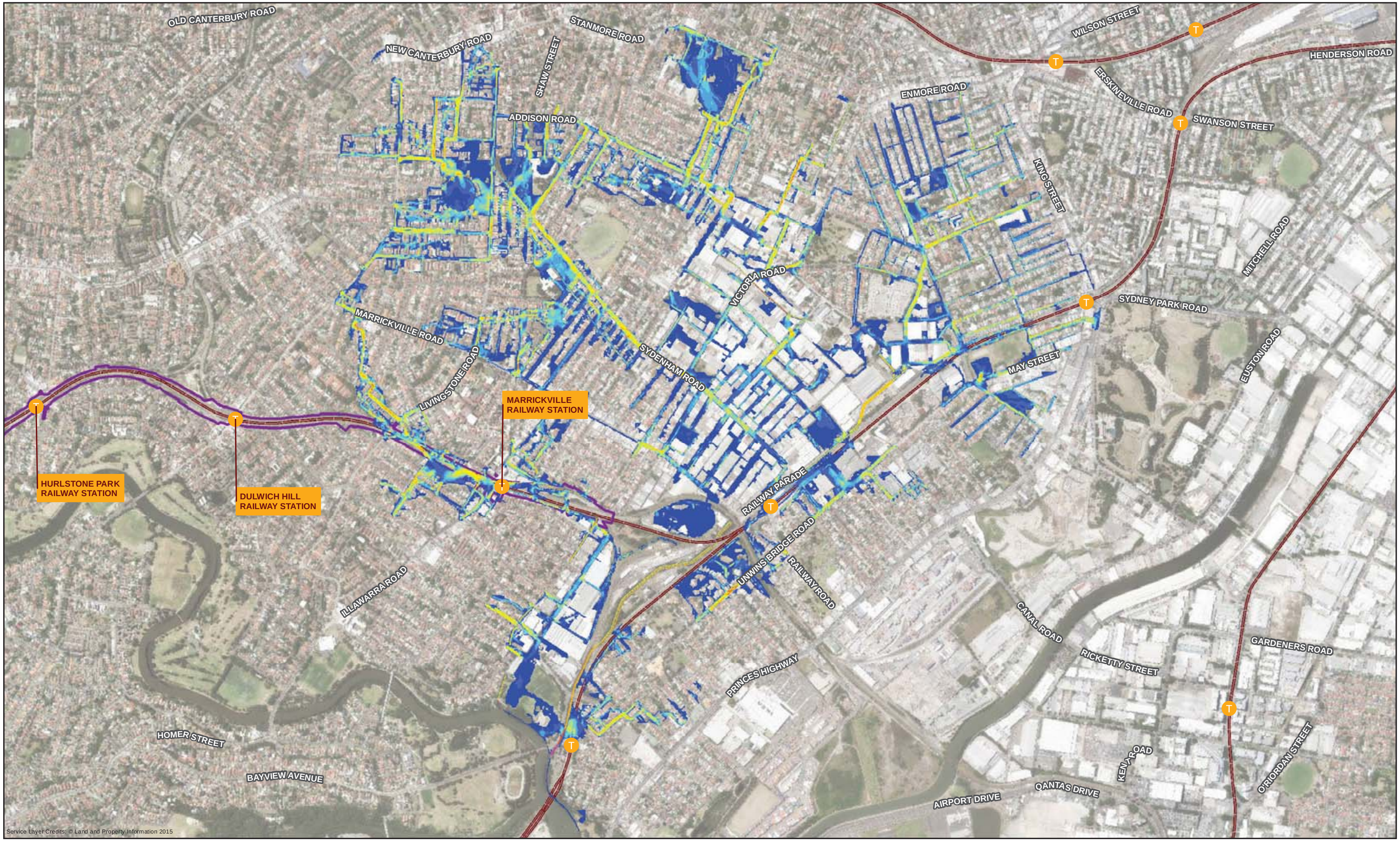
Post-developed 10% AEP flood velocity

Figure B.34

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

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

Job Number	21-25273
Revision	A
Date	22 May 2017

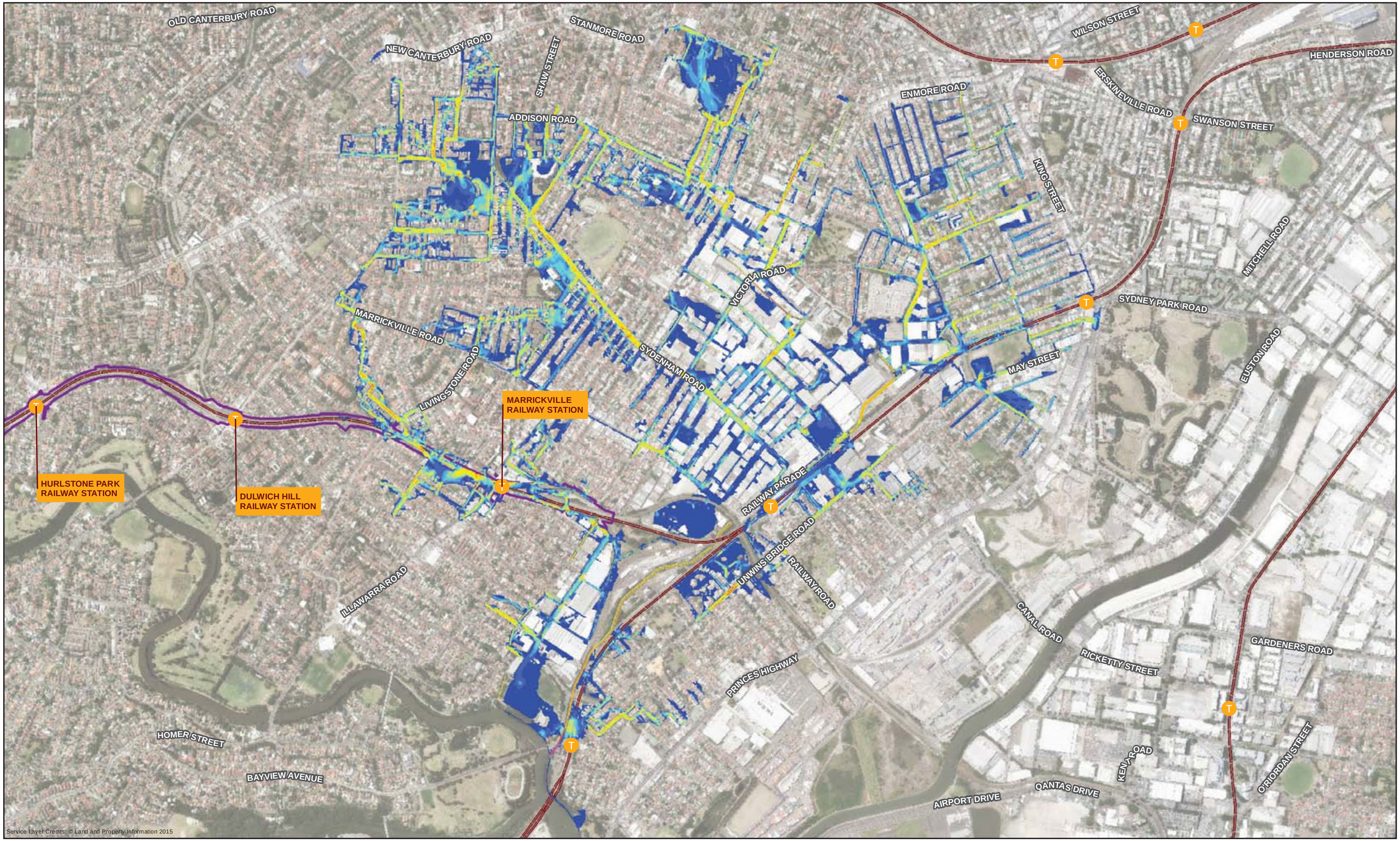
Post-developed 5% AEP flood velocity

Figure B.35

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

GHD

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

Job Number	21-25273
Revision	A
Date	22 May 2017

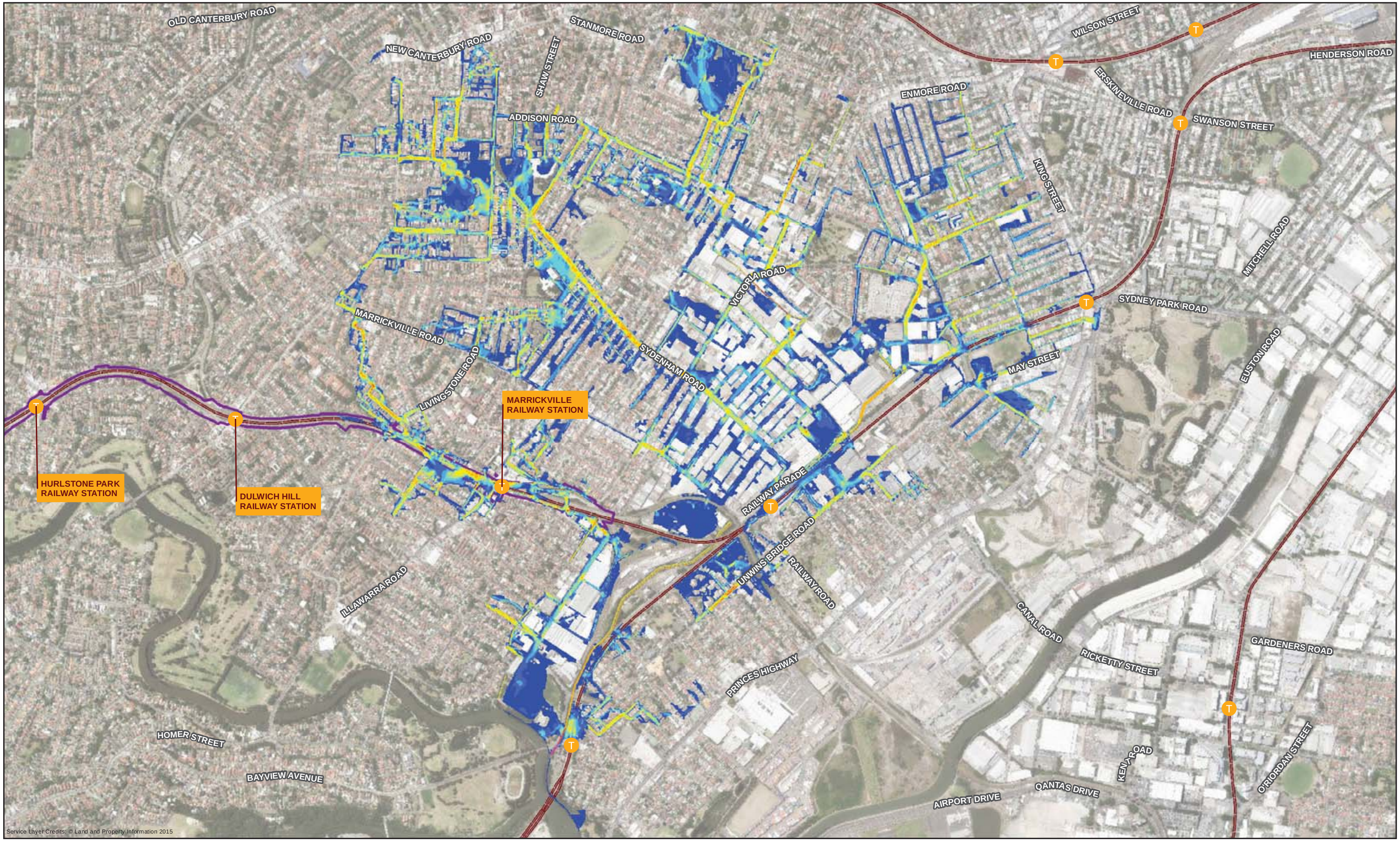
Post-developed 2% AEP flood velocity

Figure B.36

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

GHD

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

Job Number	21-25273
Revision	A
Date	22 May 2017

Post-developed 1% AEP flood velocity

Figure B.37

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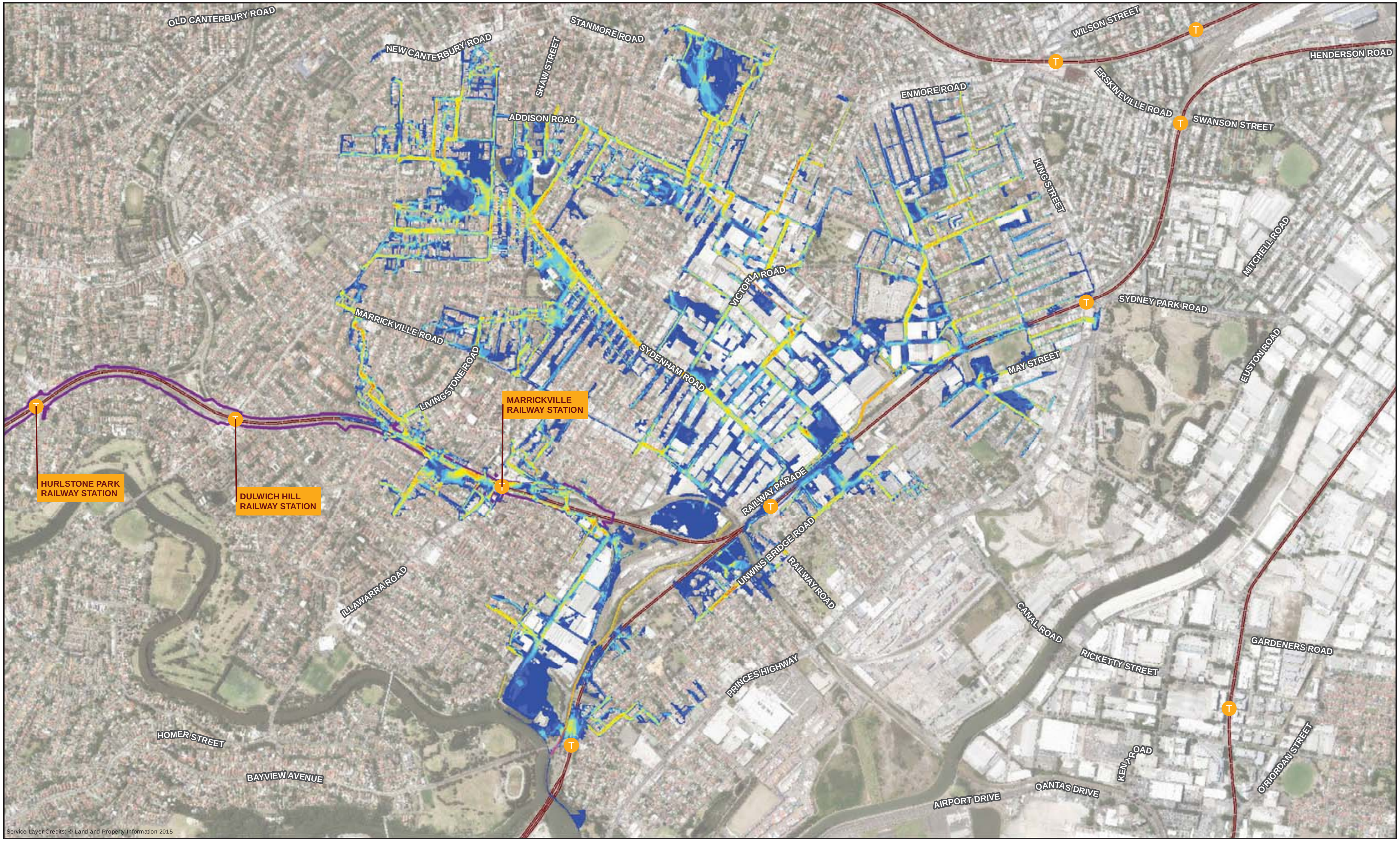
Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

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

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

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

Job Number	21-25273
Revision	A
Date	22 May 2017

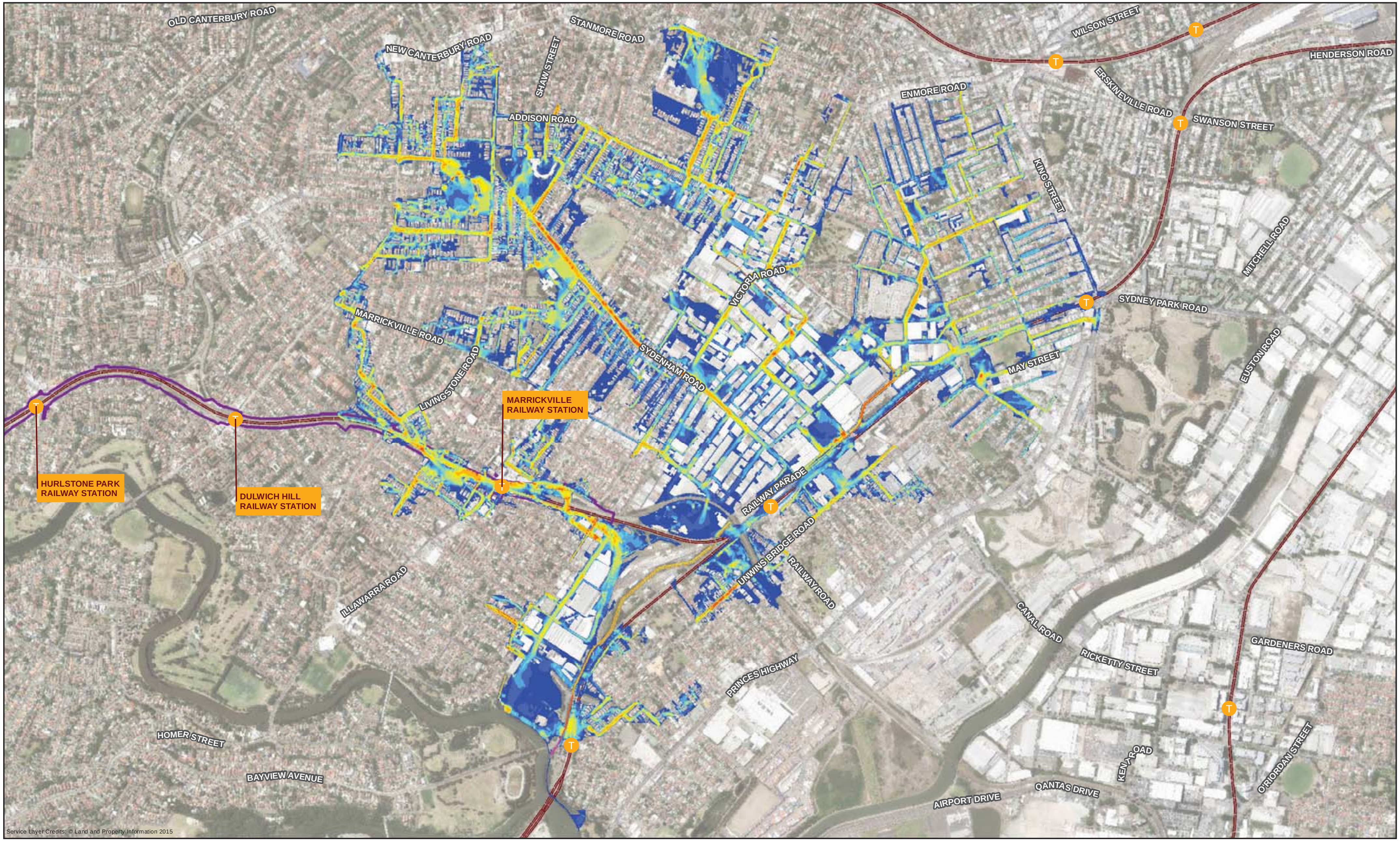
Post-developed 1% AEP + 10% climate change flood velocity

Figure B.38

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

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

Job Number	21-25273
Revision	A
Date	22 May 2017

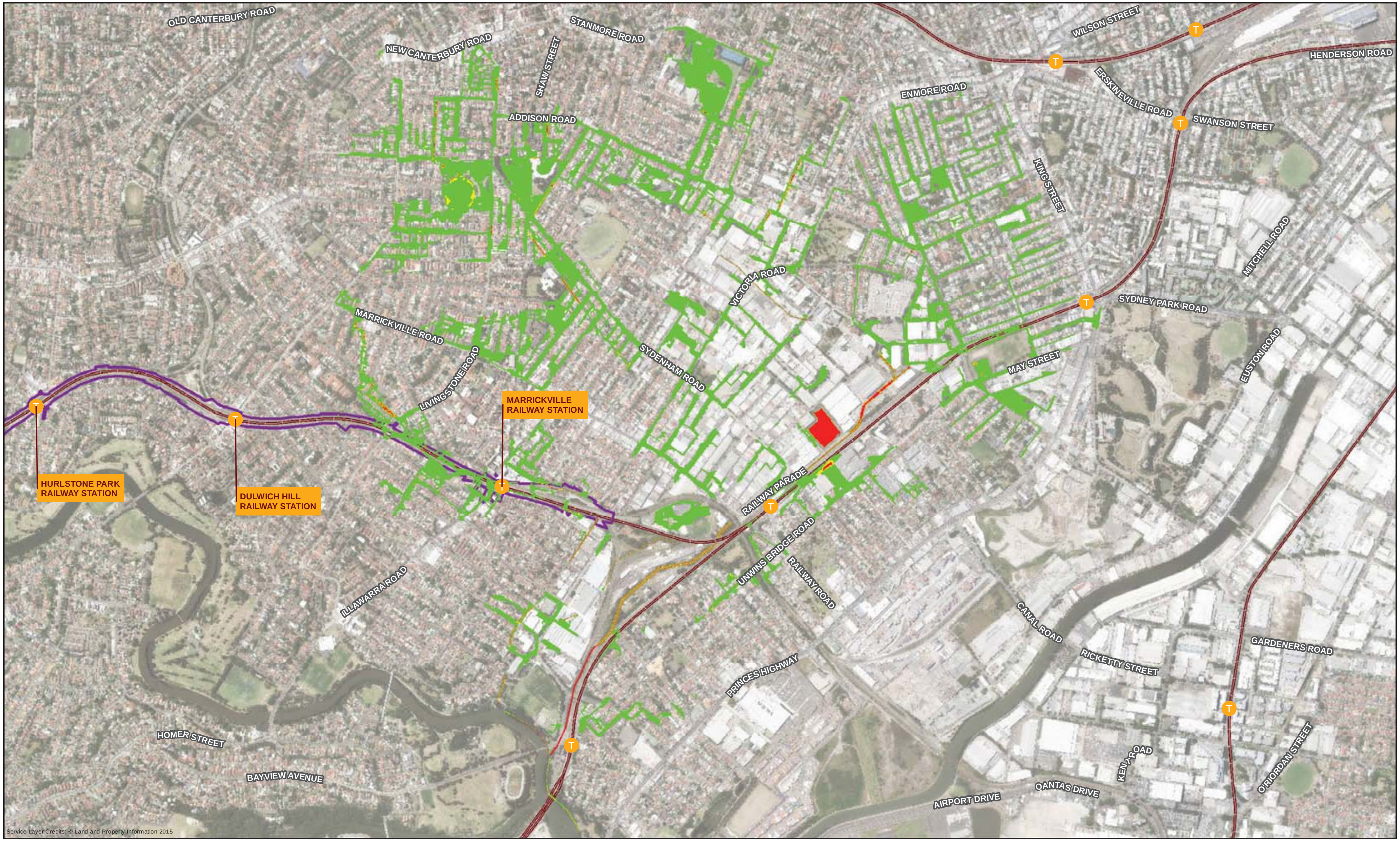
Post-developed PMF flood velocity

Figure B.39

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

Provisional Hazard Category

1 - Low Hazard

2 - Transitional Hazard

3 - High Hazard

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

Job Number	21-25273
Revision	A
Date	22 May 2017

Post-developed 63% AEP provisional flood hazard

Figure B.40

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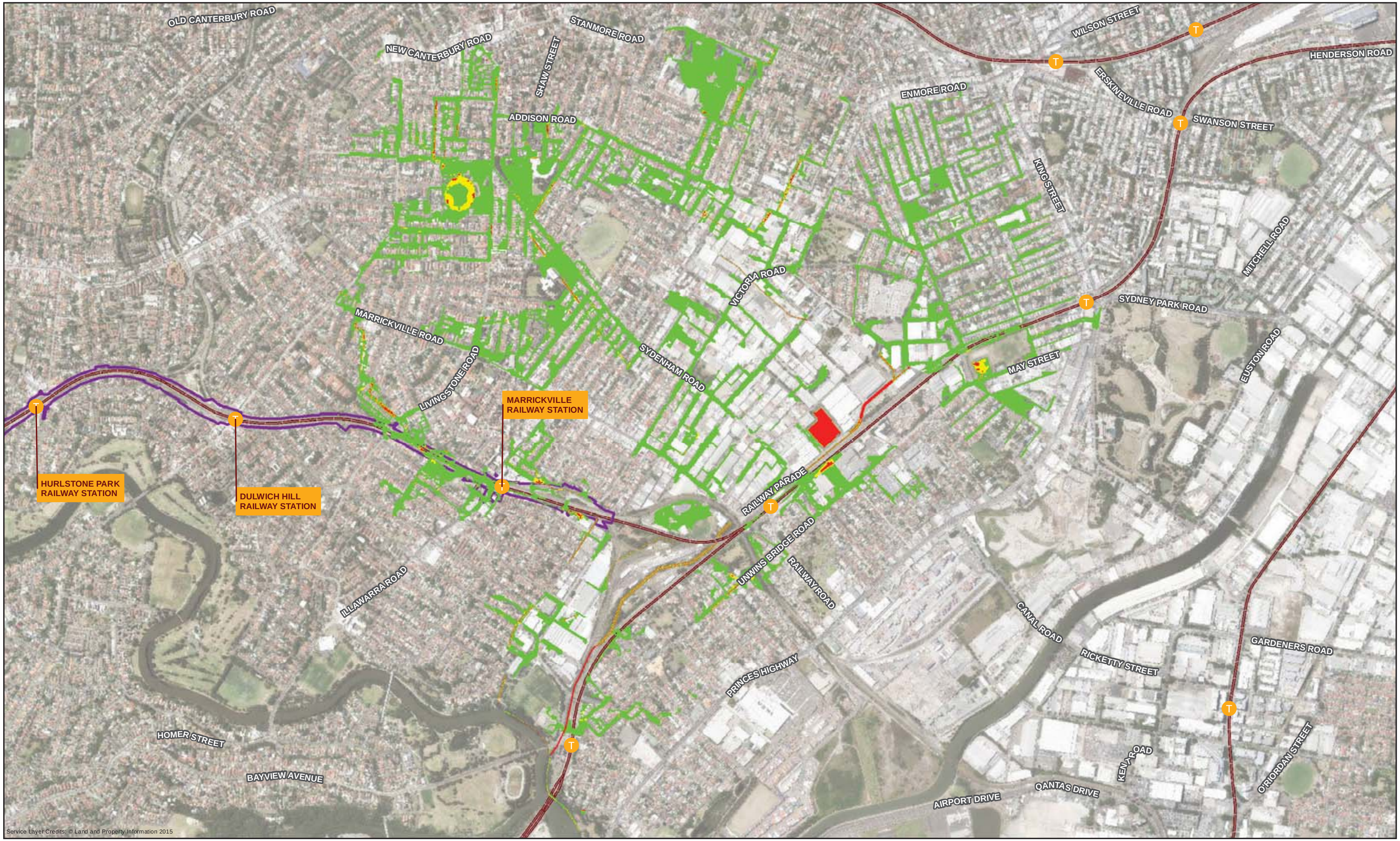
Level 15, 133 Castlereagh Street Sydney NSW 2000 **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com.au **W** www.ghd.com.au

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

Provisional Hazard Category

1 - Low Hazard

2 - Transitional Hazard

3 - High Hazard

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

Job Number	21-25273
Revision	A
Date	22 May 2017

Post-developed 39% AEP
provisional flood hazard

Figure B.41

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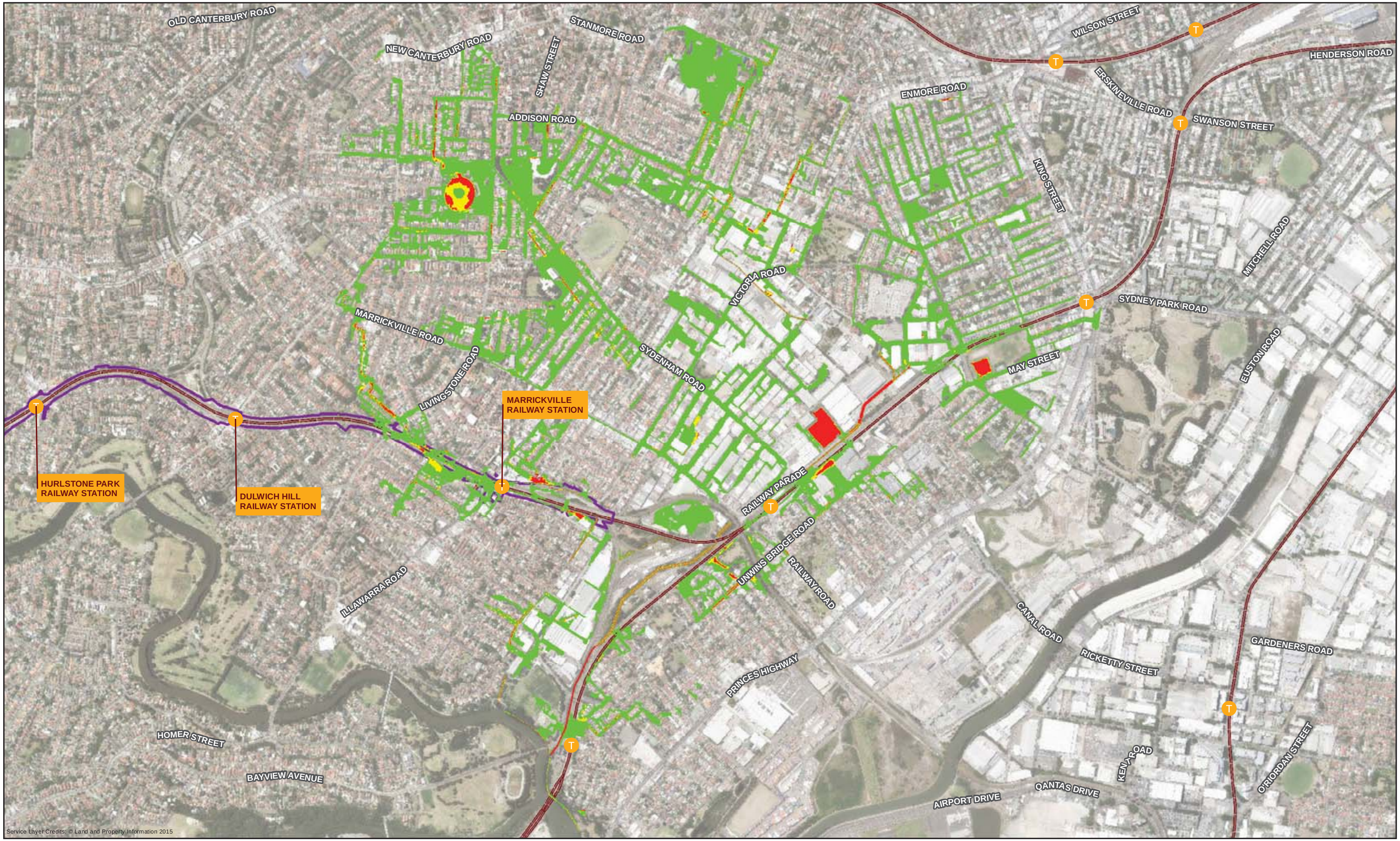
Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

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

Provisional Hazard Category

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

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

Job Number	21-25273
Revision	A
Date	22 May 2017

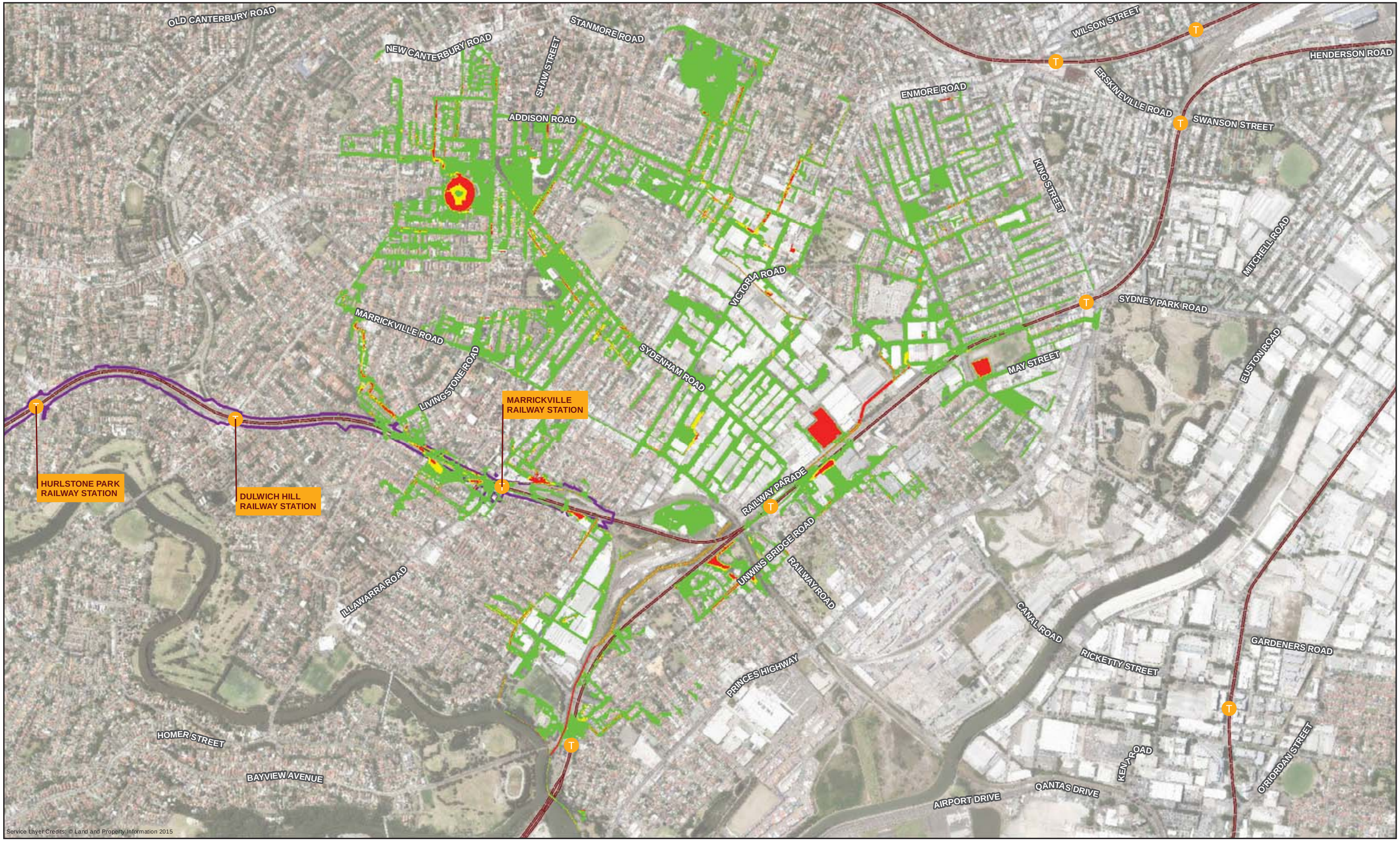
Post-developed 18% AEP provisional flood hazard

Figure B.42

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

Provisional Hazard Category

1 - Low Hazard

2 - Transitional Hazard

3 - High Hazard

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

Job Number	21-25273
Revision	A
Date	22 May 2017

Post-developed 10% AEP provisional flood hazard

Figure B.43

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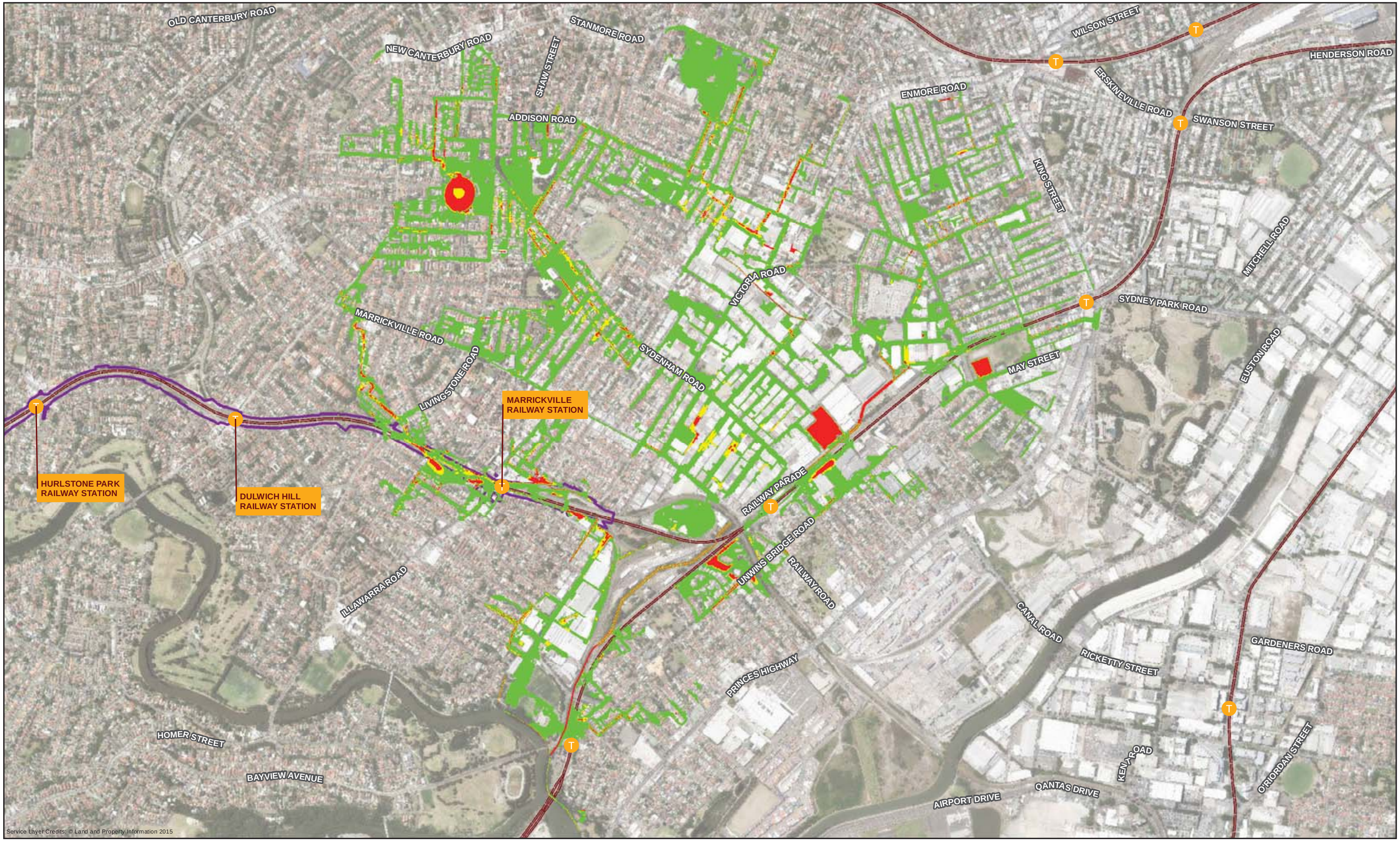
Level 15, 133 Castlereagh Street Sydney NSW 2000 **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com.au **W** www.ghd.com.au

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

Provisional Hazard Category

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

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

Job Number	21-25273
Revision	A
Date	22 May 2017

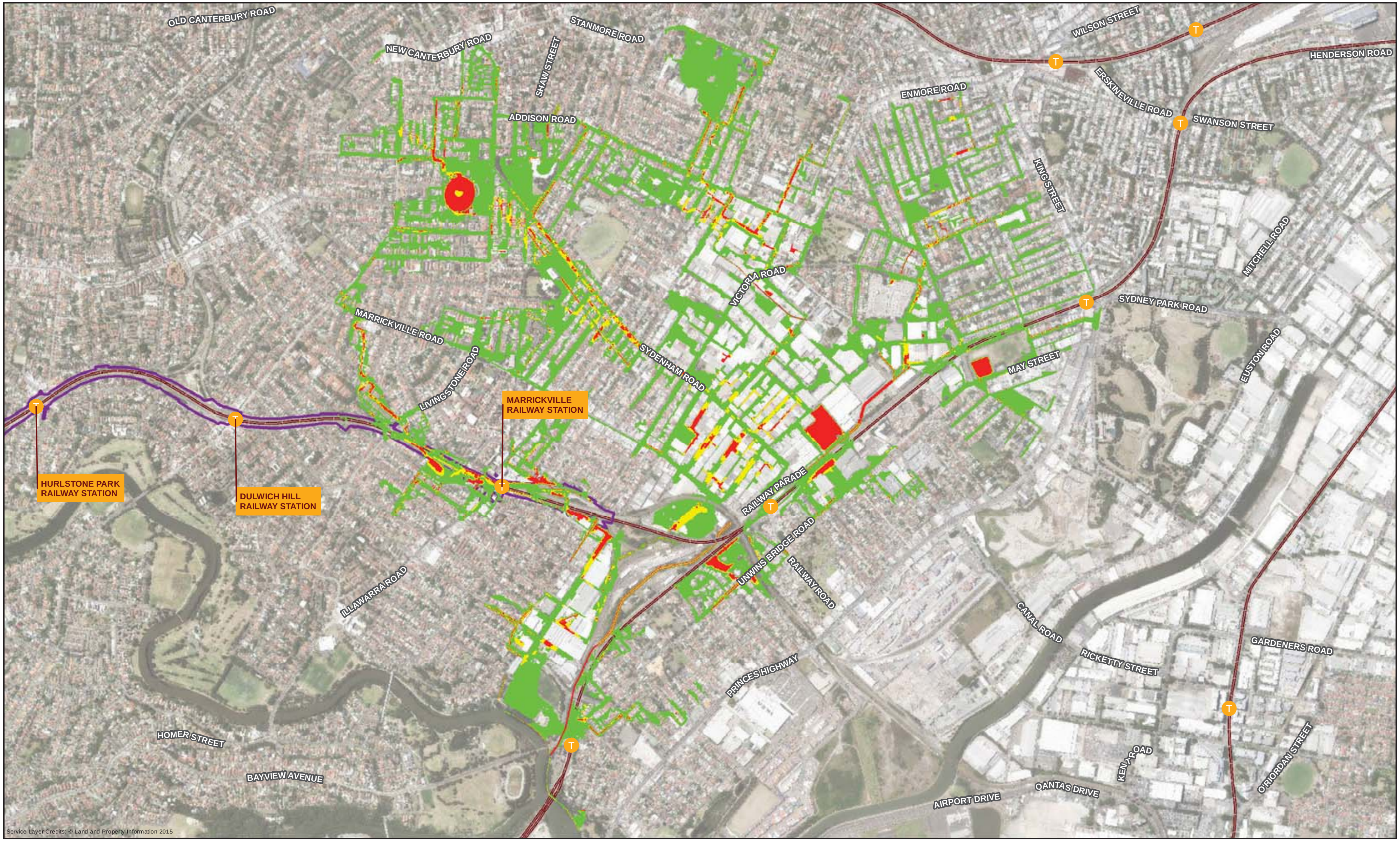
Post-developed 5% AEP provisional flood hazard

Figure B.44

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

Provisional Hazard Category

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

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

Job Number	21-25273
Revision	A
Date	22 May 2017

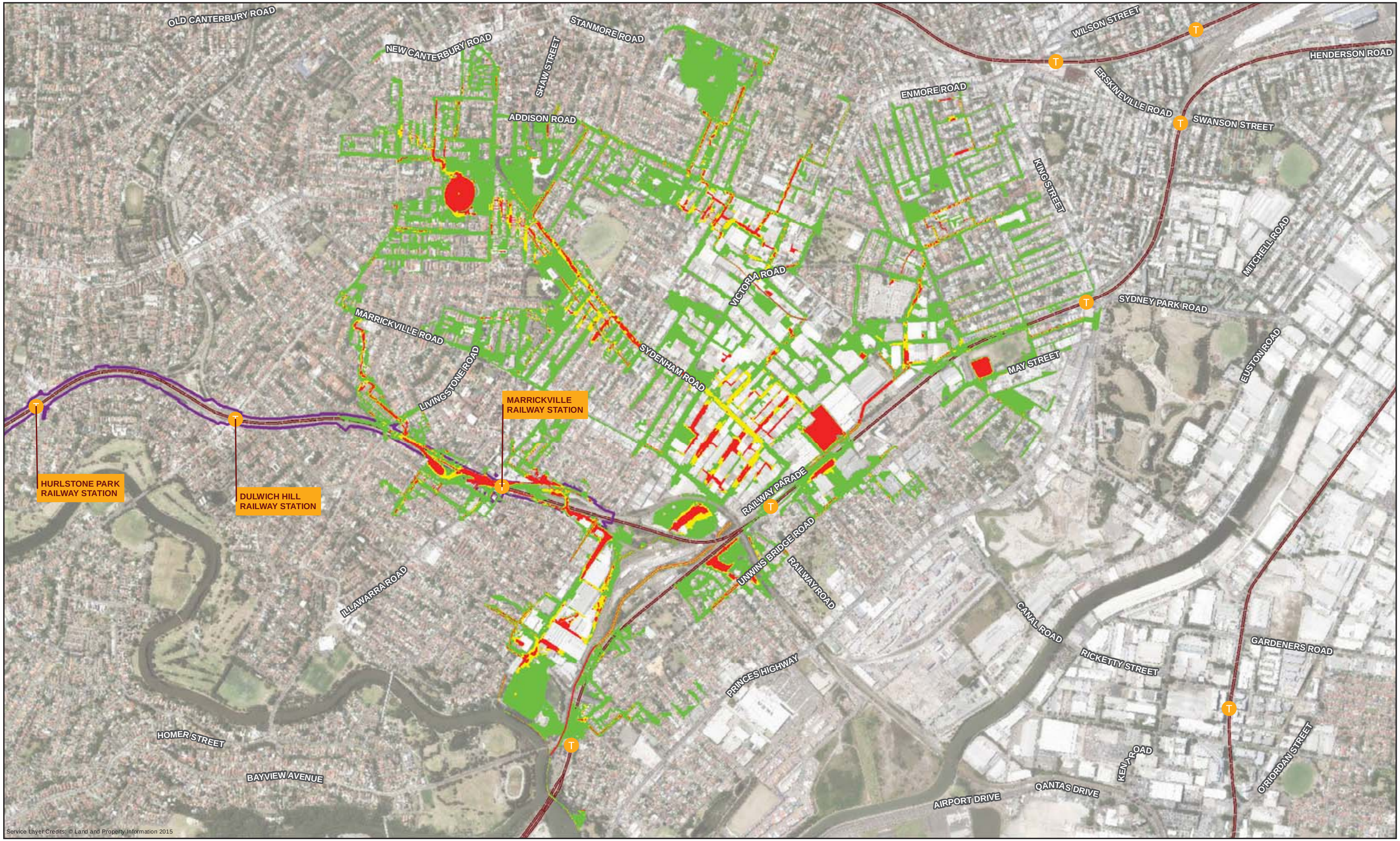
Post-developed 2% AEP provisional flood hazard

Figure B.45

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

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

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

Provisional Hazard Category

1 - Low Hazard

2 - Transitional Hazard

3 - High Hazard

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

Job Number	21-25273
Revision	A
Date	22 May 2017

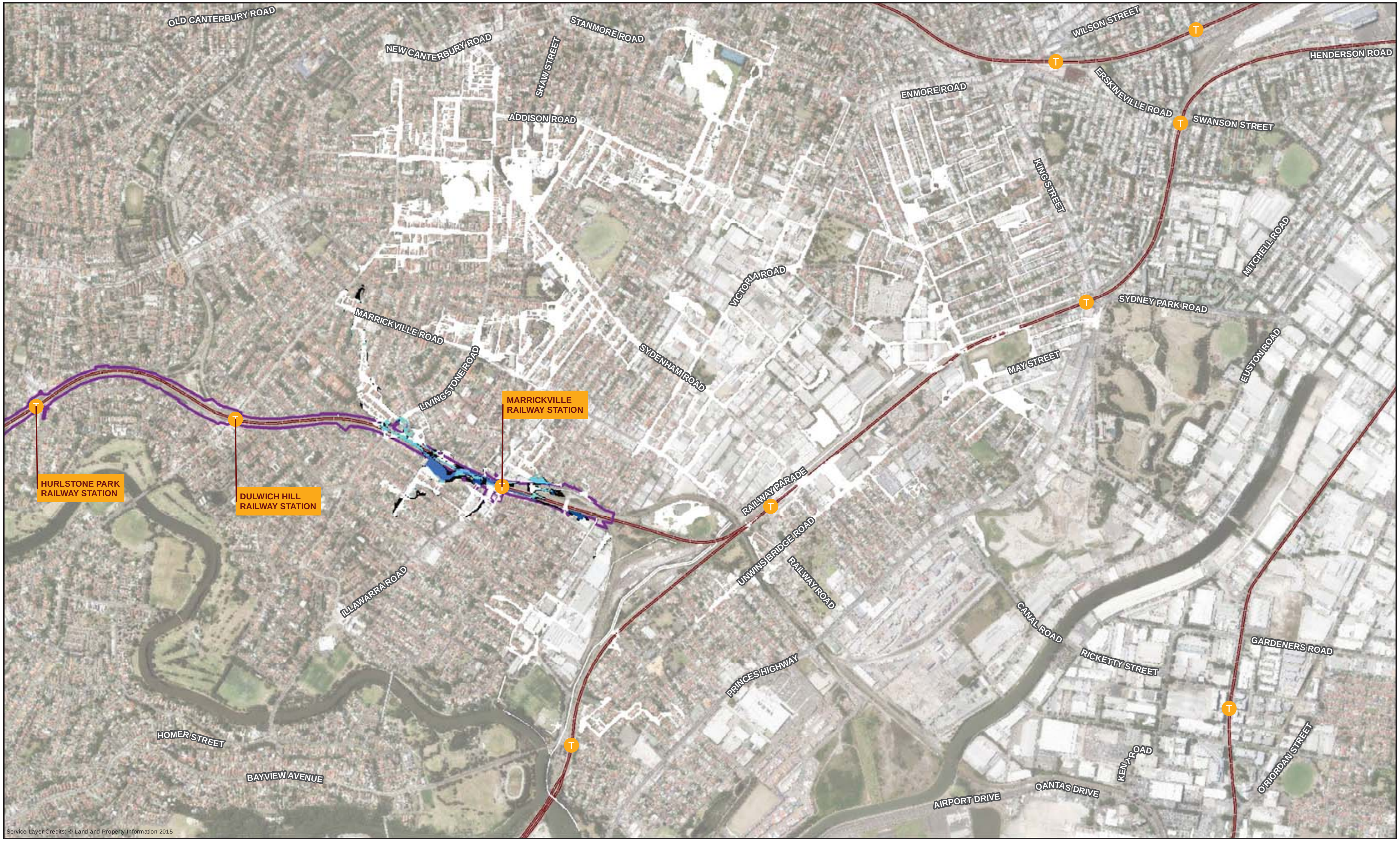
Post-developed 1%
AEP provisional flood hazard

Figure B.46

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

Change in Flood Level (m)

- <-0.3m
- -0.3m - -0.2m
- -0.2m - -0.15m
- -0.15m - -0.1m
- -0.1m - -0.05m
- -0.05m - +0.05m
- +0.05m - +0.1m
- +0.1m - +0.15m
- +0.15m - +0.2m
- +0.2m - +0.3m
- +0.3m - +0.4m
- +0.4m - +0.5m
- > 0.5m
- Was wet now dry
- Was dry now wet

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

Job Number	21-25273
Revision	A
Date	22 May 2017

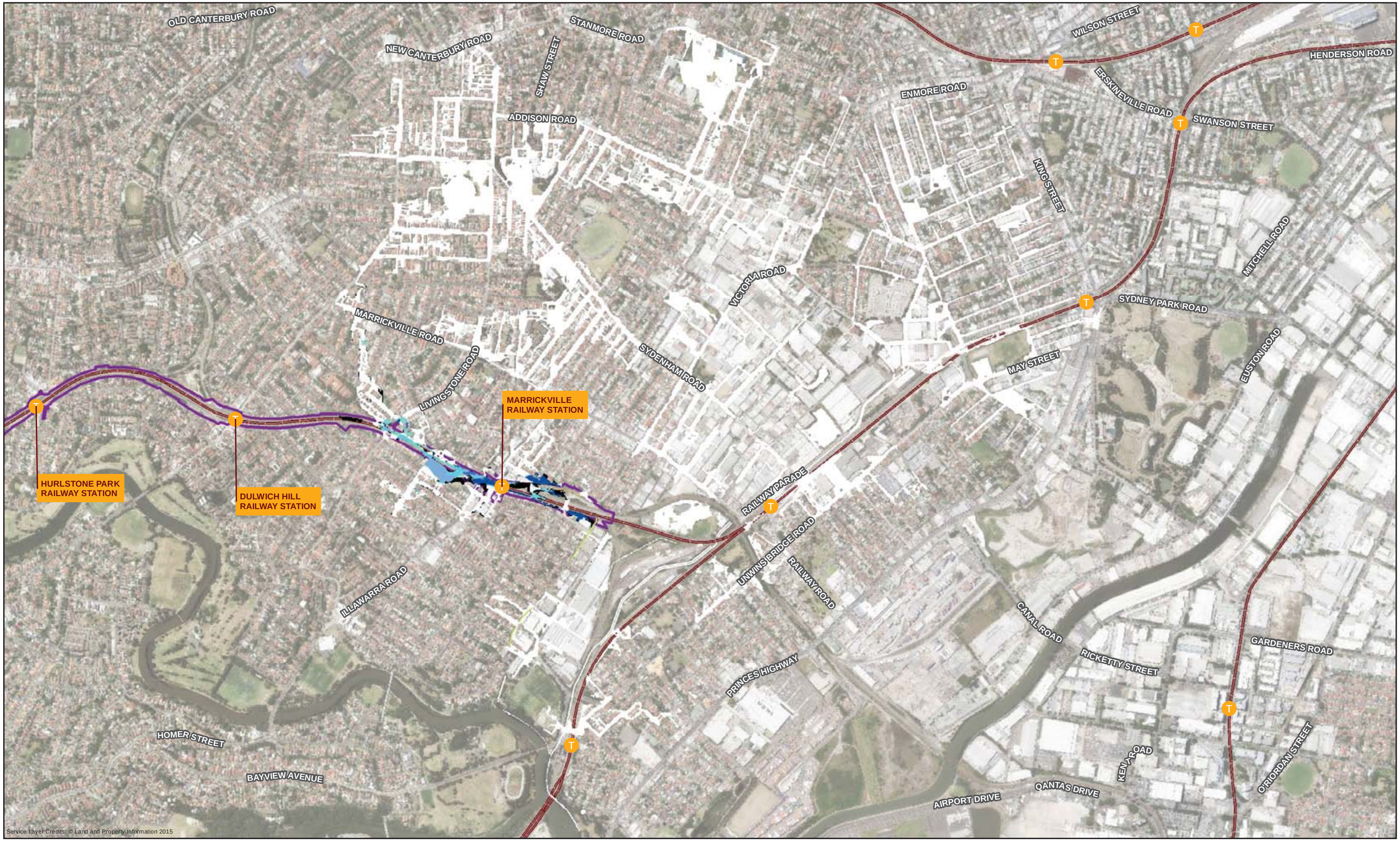
63% AEP
flood level change

Figure B.47

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

Change in Flood Level (m)

- <-0.3m
- -0.3m - -0.2m
- -0.2m - -0.15m
- -0.15m - -0.1m
- -0.1m - -0.05m
- -0.05m - +0.05m
- +0.05m - +0.1m
- +0.1m - +0.15m
- +0.15m - +0.2m
- +0.2m - +0.3m
- +0.3m - +0.4m
- +0.4m - +0.5m
- > 0.5m
- Was wet now dry
- Was dry now wet

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

39% AEP
flood level change

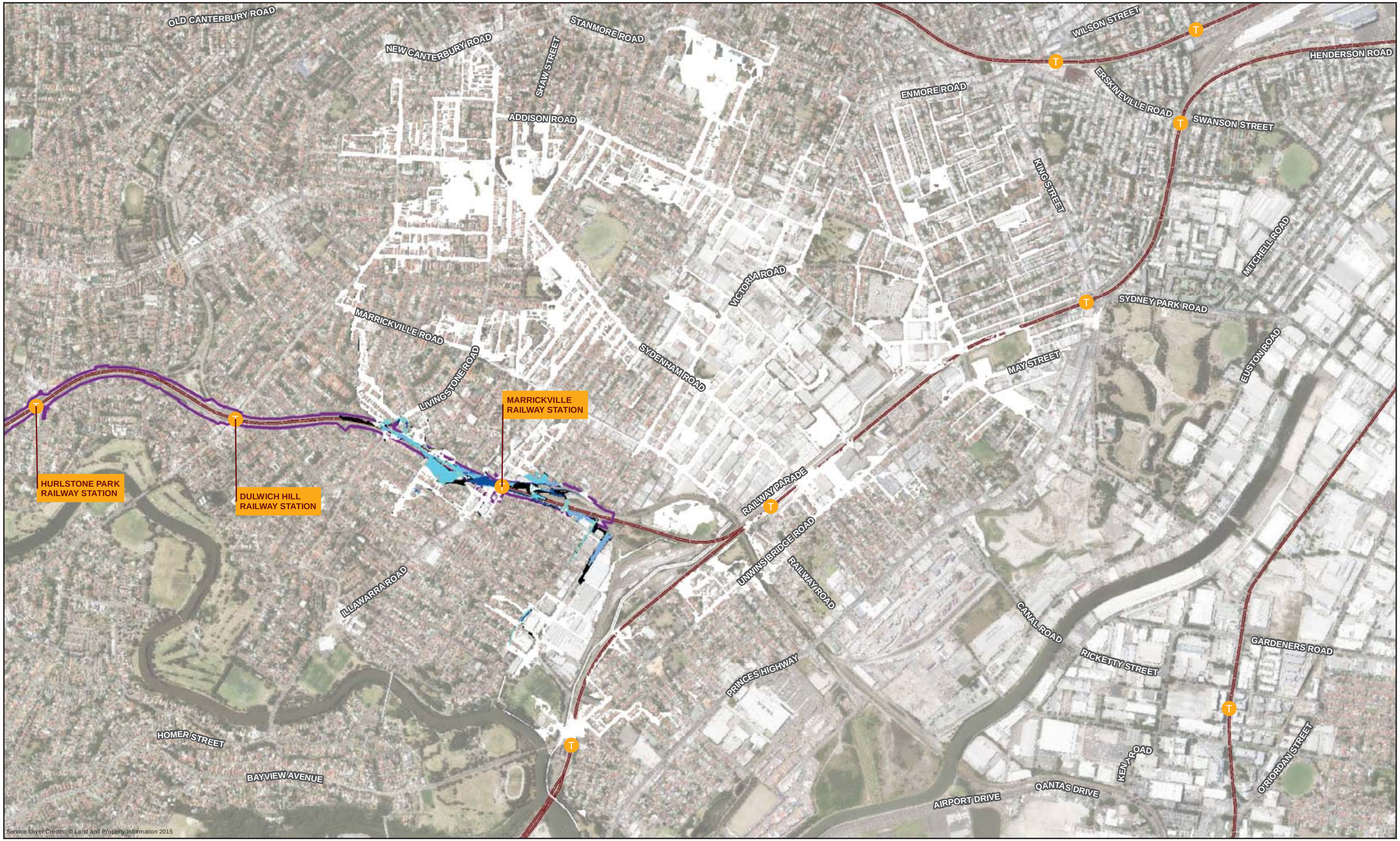
Job Number	21-25273
Revision	A
Date	22 May 2017

Figure B.48

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

Change in Flood Level (m)

- <-0.3m
- -0.3m - -0.2m
- -0.2m - -0.15m
- -0.15m - -0.1m
- -0.1m - -0.05m
- -0.05m - +0.05m
- +0.05m - +0.1m
- +0.1m - +0.15m
- +0.15m - +0.2m
- +0.2m - +0.3m
- +0.3m - +0.4m
- +0.4m - +0.5m
- > 0.5m
- Was wet now dry
- Was dry now wet

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

Job Number	21-25273
Revision	A
Date	22 May 2017

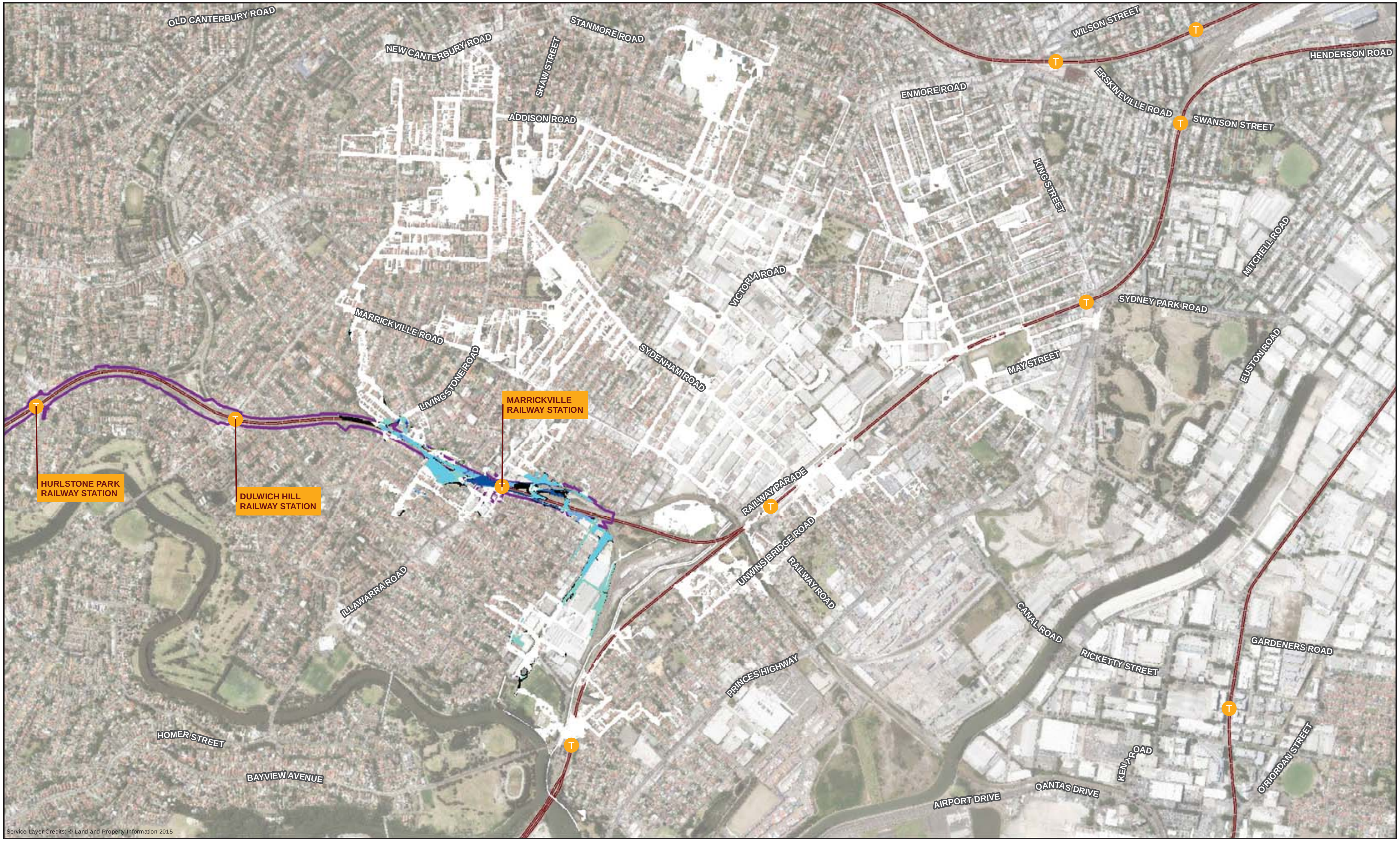
18% AEP flood level change

Figure B.49

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

Change in Flood Level (m)

- <-0.3m
- -0.3m - -0.2m
- -0.2m - -0.15m
- -0.15m - -0.1m
- -0.1m - -0.05m
- -0.05m - +0.05m
- +0.05m - +0.1m
- +0.1m - +0.15m
- +0.15m - +0.2m
- +0.2m - +0.3m
- +0.3m - +0.4m
- +0.4m - +0.5m
- > 0.5m
- Was wet now dry
- Was dry now wet

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

Job Number	21-25273
Revision	A
Date	22 May 2017

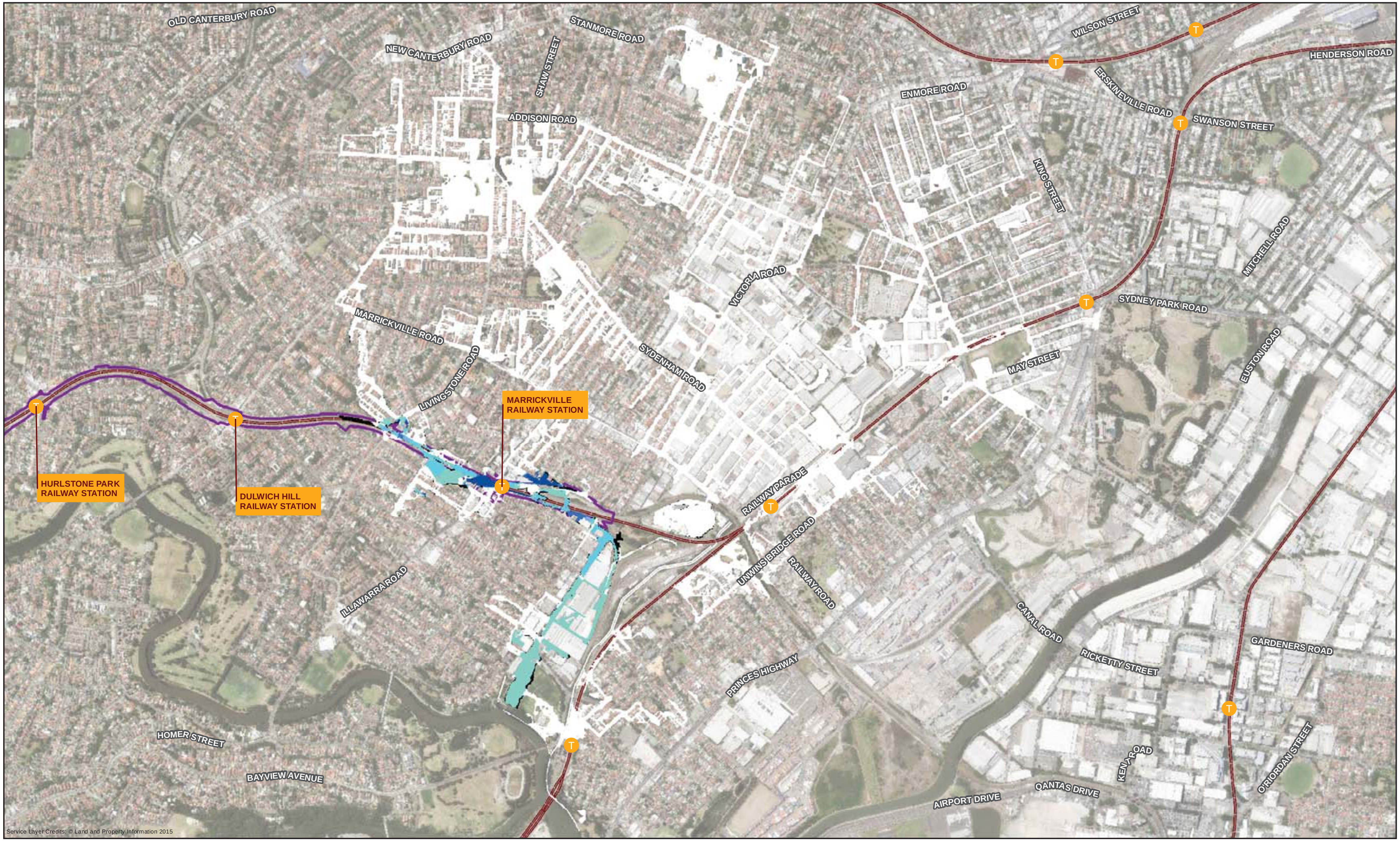
10% AEP
flood level change

Figure B.50

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

Change in Flood Level (m)

<-0.3m	-0.15m - -0.1m	+0.1m - +0.15m	+0.4m - +0.5m	Was wet now dry
-0.3m - -0.2m	-0.1m - -0.05m	+0.15m - +0.2m	> 0.5m	Was dry now wet
-0.2m - -0.15m	-0.05m - +0.05m	+0.2m - +0.3m		
	+0.05m - +0.1m	+0.3m - +0.4m		

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

Job Number 21-25273
Revision A
Date 22 May 2017

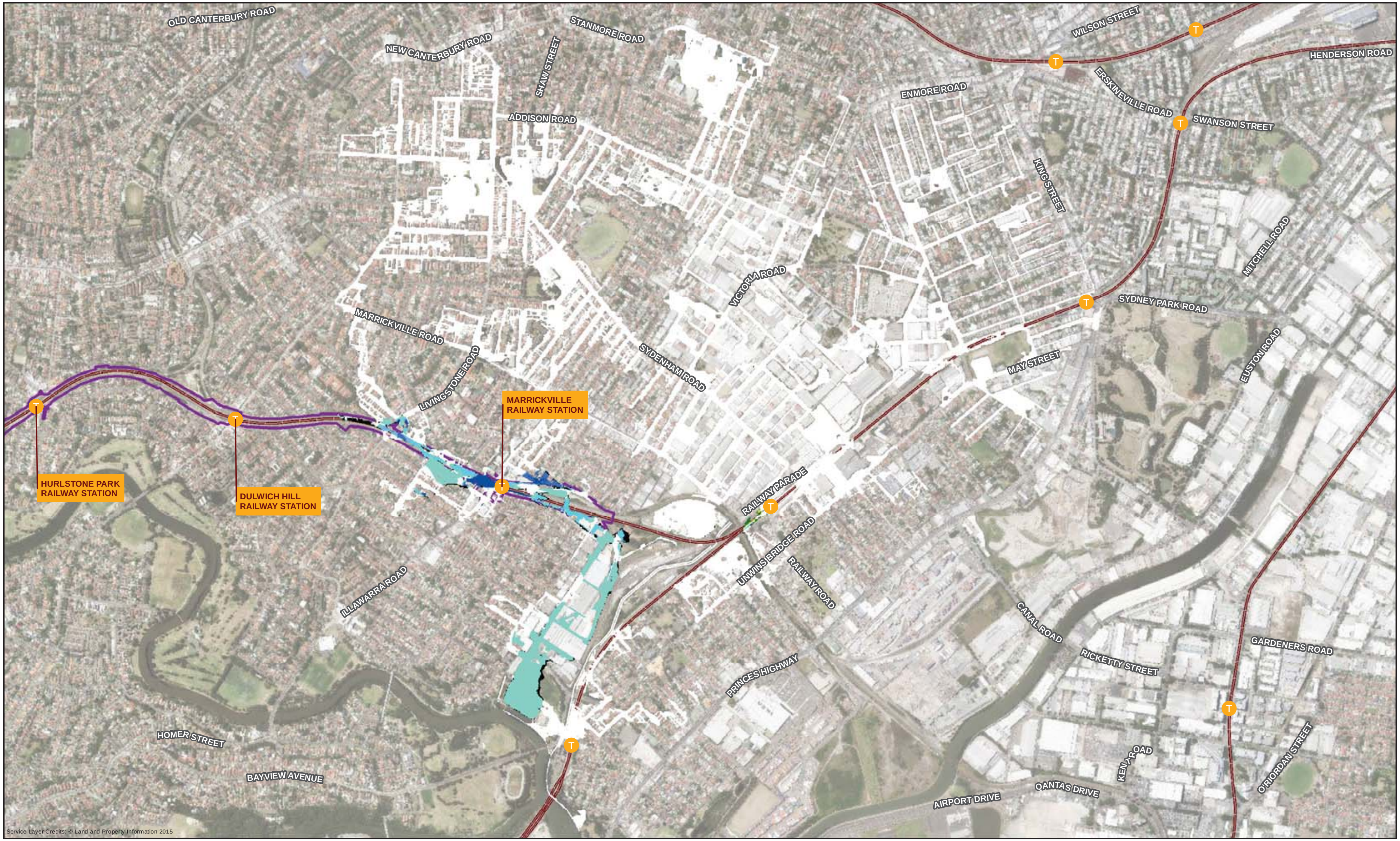
5% AEP flood level change

Figure B.51

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

Change in Flood Level (m)

- <-0.3m
- -0.3m - -0.2m
- -0.2m - -0.15m
- -0.15m - -0.1m
- -0.1m - -0.05m
- -0.05m - +0.05m
- +0.05m - +0.1m
- +0.1m - +0.15m
- +0.15m - +0.2m
- +0.2m - +0.3m
- +0.3m - +0.4m
- +0.4m - +0.5m
- > 0.5m
- Was wet now dry
- Was dry now wet

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

2% AEP flood level change

Job Number	21-25273
Revision	A
Date	22 May 2017

Figure B.52

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

Change in Flood Level (m)

- <-0.3m
- -0.3m - -0.2m
- -0.2m - -0.15m
- -0.15m - -0.1m
- -0.1m - -0.05m
- -0.05m - +0.05m
- +0.05m - +0.1m
- +0.1m - +0.15m
- +0.15m - +0.2m
- +0.2m - +0.3m
- +0.3m - +0.4m
- +0.4m - +0.5m
- > 0.5m
- Was wet now dry
- Was dry now wet

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

Job Number	21-25273
Revision	A
Date	22 May 2017

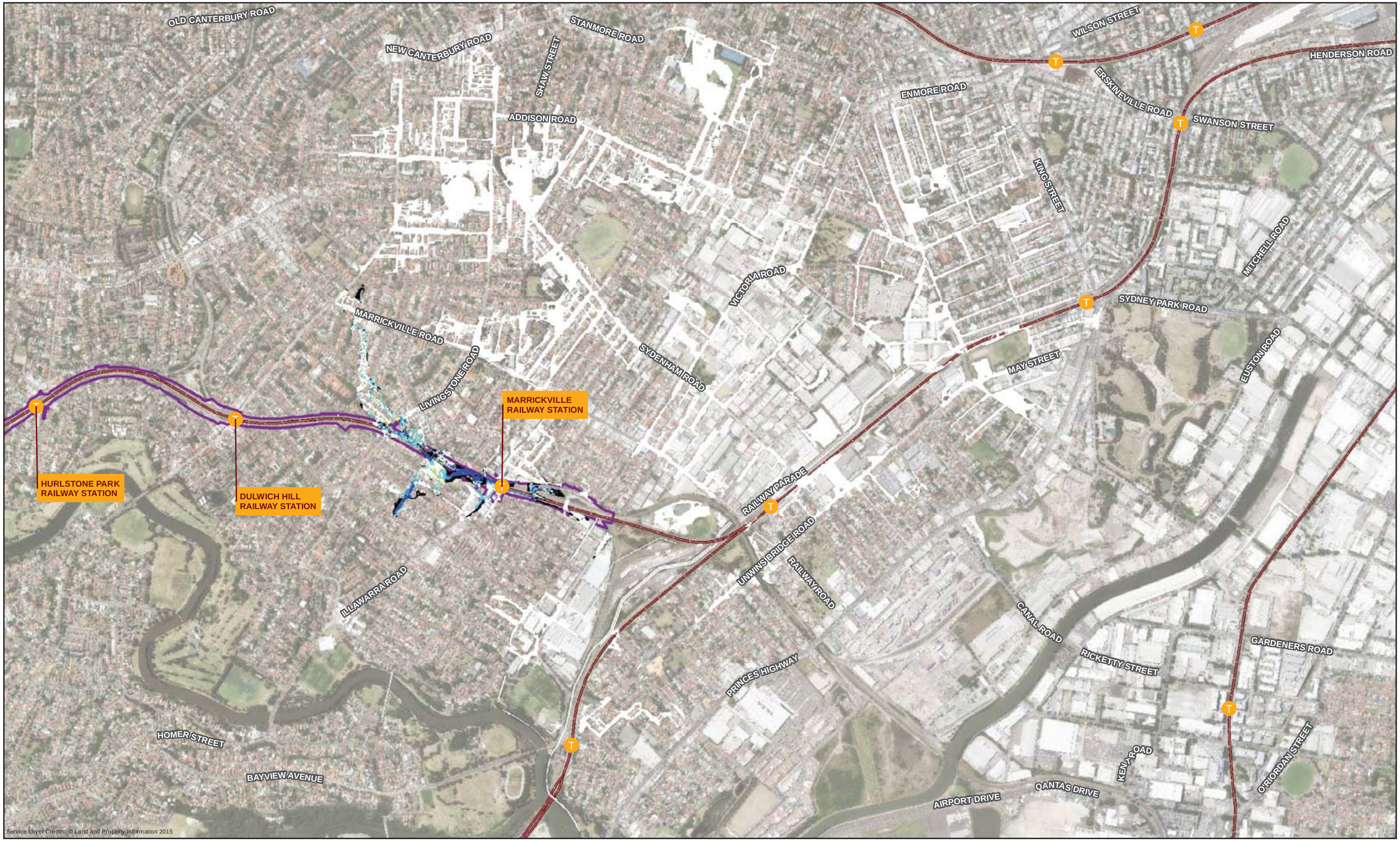
1% AEP flood level change

Figure B.53

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

Change in Flood Velocity (m/s)

- Greater than -0.5
- -0.5 to -0.4
- -0.4 to -0.3
- -0.3 to -0.2
- -0.2 to -0.1
- -0.1 to +0.1
- +0.1 to +0.2
- +0.2 to +0.3
- +0.3 to +0.4
- +0.4 to +0.5
- Greater than +0.5
- Was wet now dry
- Was dry now wet

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

Job Number	21-25273
Revision	A
Date	22 May 2017

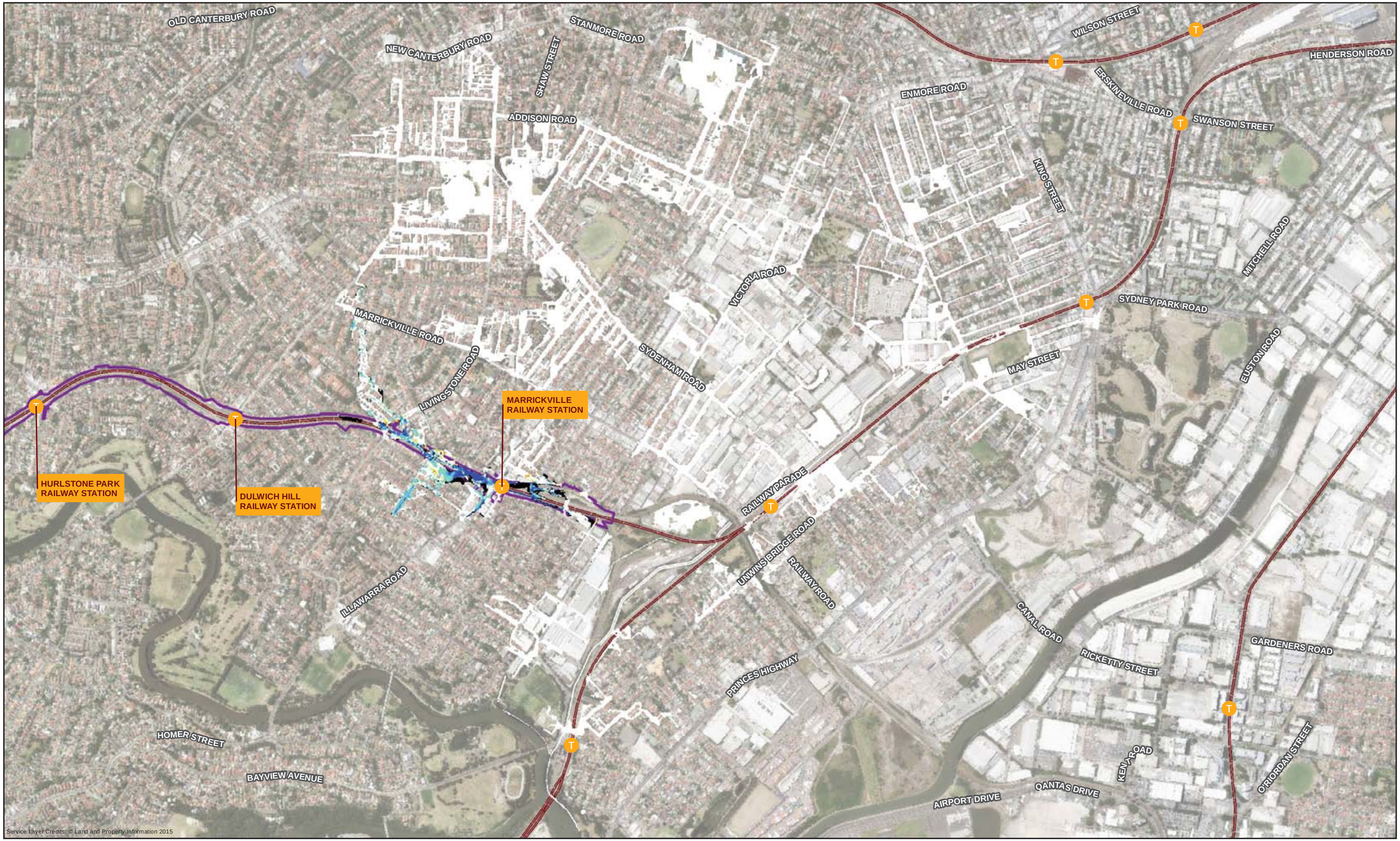
63% AEP
flood velocity change

Figure B.54

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

Change in Flood Velocity (m/s)

- Greater than -0.5
- -0.5 to -0.4
- -0.4 to -0.3
- -0.3 to -0.2
- -0.2 to -0.1
- -0.1 to +0.1
- +0.1 to +0.2
- +0.2 to +0.3
- +0.3 to +0.4
- +0.4 to +0.5
- Greater than +0.5
- Was wet now dry
- Was dry now wet

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

Job Number	21-25273
Revision	A
Date	22 May 2017

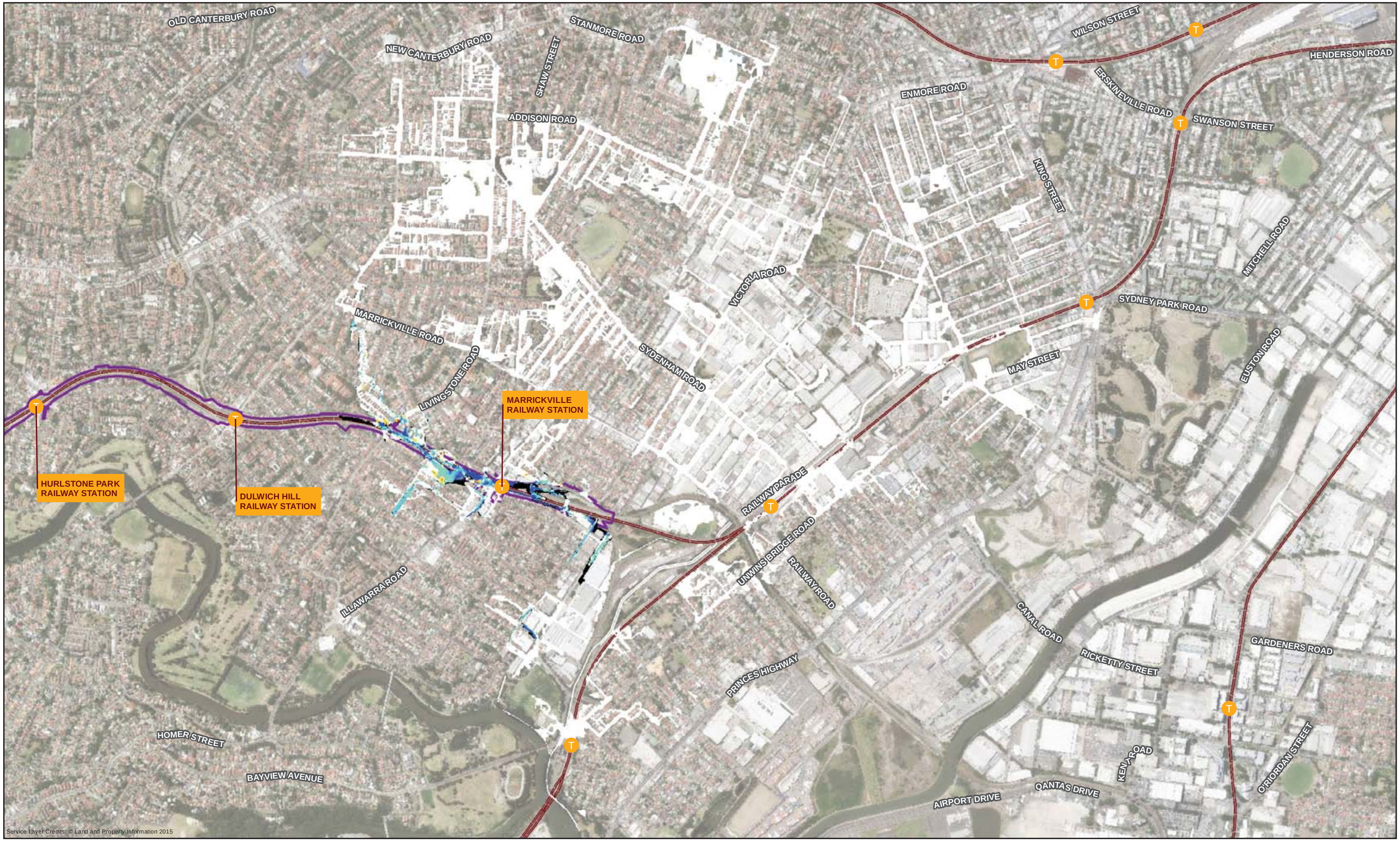
39% AEP flood velocity change

Figure B.55

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

Change in Flood Velocity (m/s)

- Greater than -0.5
- -0.5 to -0.4
- -0.4 to -0.3
- -0.3 to -0.2
- -0.2 to -0.1
- -0.1 to +0.1
- +0.1 to +0.2
- +0.2 to +0.3
- +0.3 to +0.4
- +0.4 to +0.5
- Greater than +0.5
- Was wet now dry
- Was dry now wet

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

Job Number	21-25273
Revision	A
Date	22 May 2017

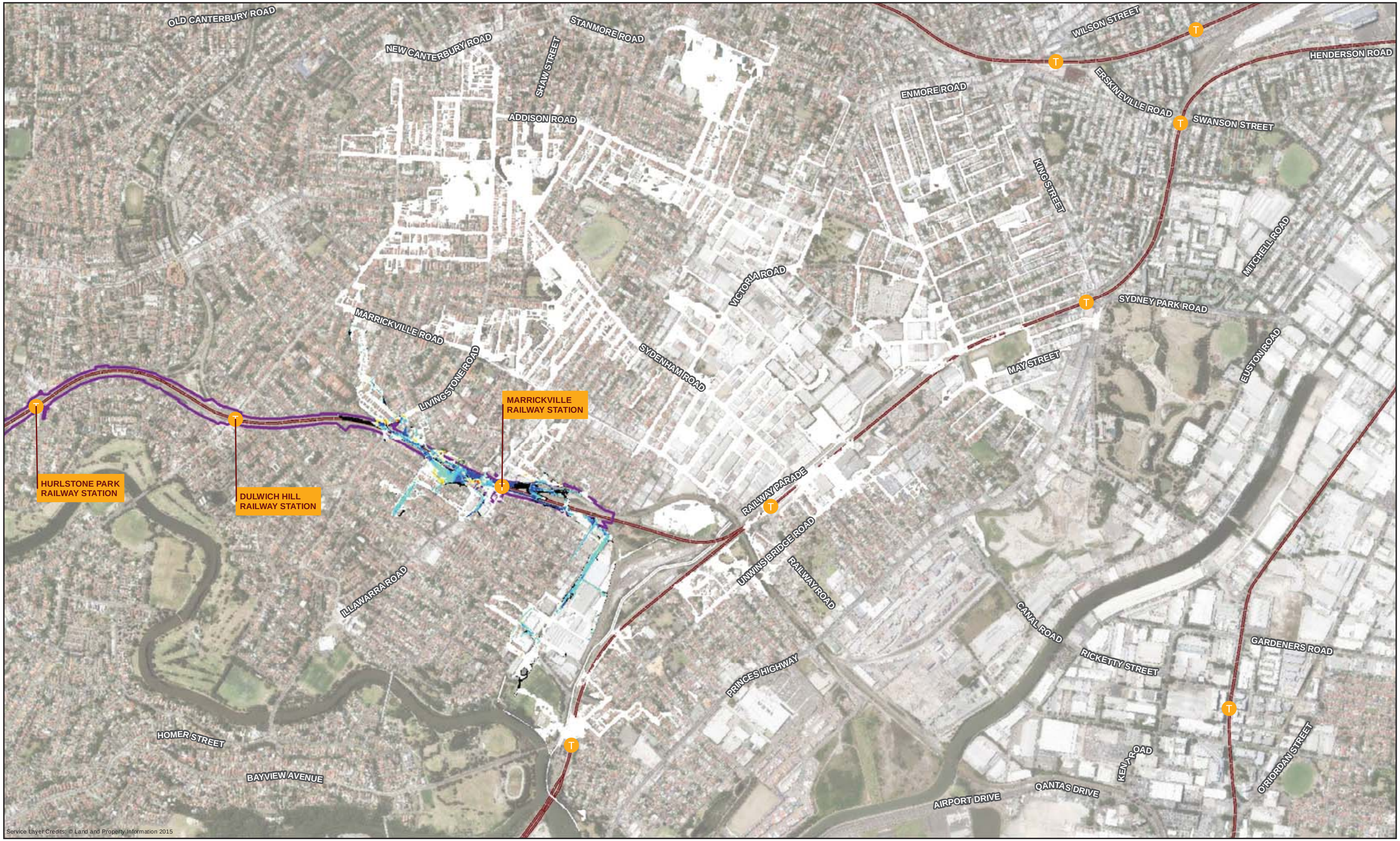
18% AEP flood velocity change

Figure B.56

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

Change in Flood Velocity (m/s)

- Greater than -0.5
- -0.5 to -0.4
- -0.4 to -0.3
- -0.3 to -0.2
- -0.2 to -0.1
- -0.1 to +0.1
- +0.1 to +0.2
- +0.2 to +0.3
- +0.3 to +0.4
- +0.4 to +0.5
- Greater than +0.5
- Was wet now dry
- Was dry now wet

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

Job Number	21-25273
Revision	A
Date	22 May 2017

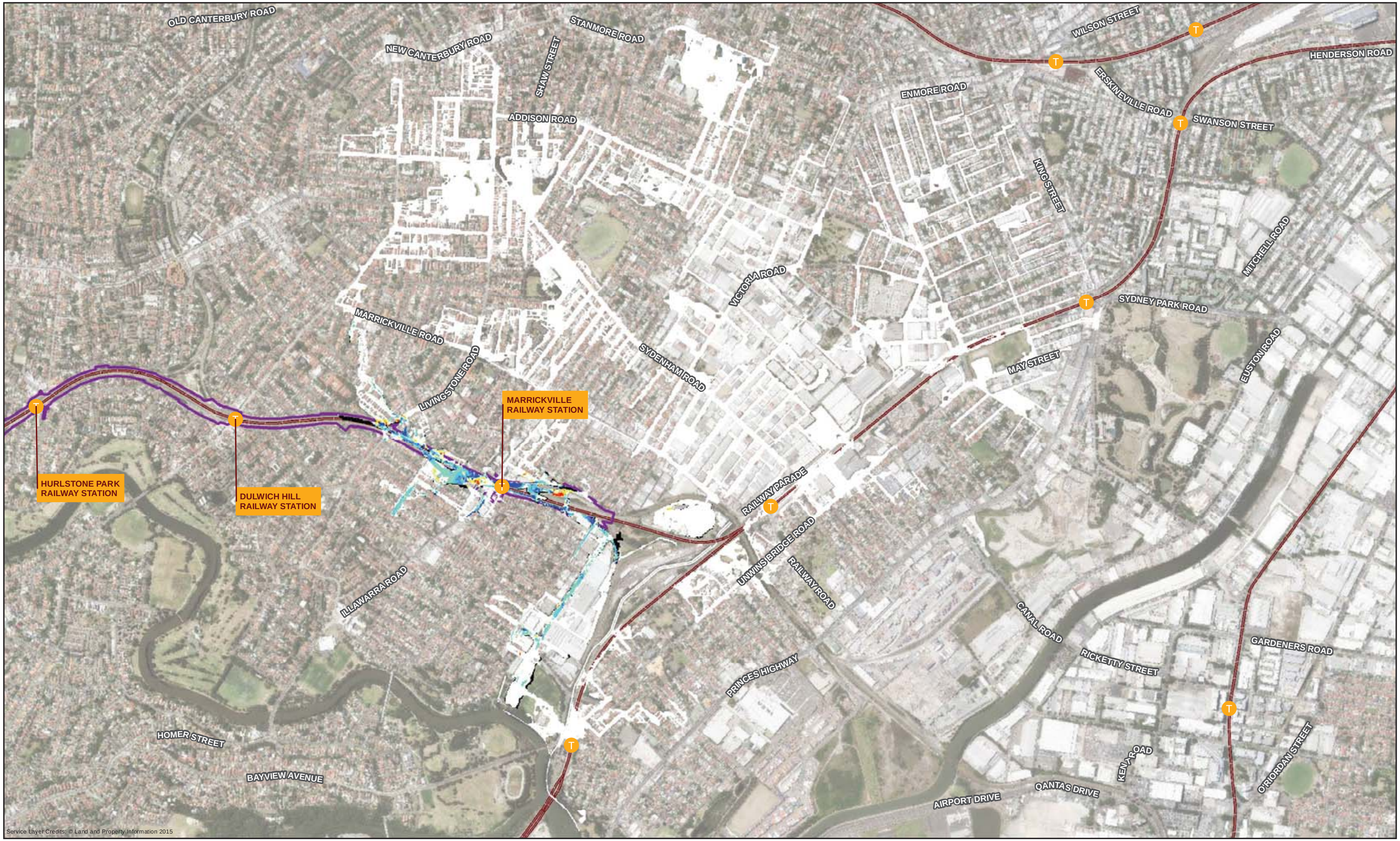
10% AEP flood velocity change

Figure B.57

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

Change in Flood Velocity (m/s)

- Greater than -0.5
- -0.5 to -0.4
- -0.4 to -0.3
- -0.3 to -0.2
- -0.2 to -0.1
- -0.1 to +0.1
- +0.1 to +0.2
- +0.2 to +0.3
- +0.3 to +0.4
- +0.4 to +0.5
- Greater than +0.5
- Was wet now dry
- Was dry now wet

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

Job Number	21-25273
Revision	A
Date	22 May 2017

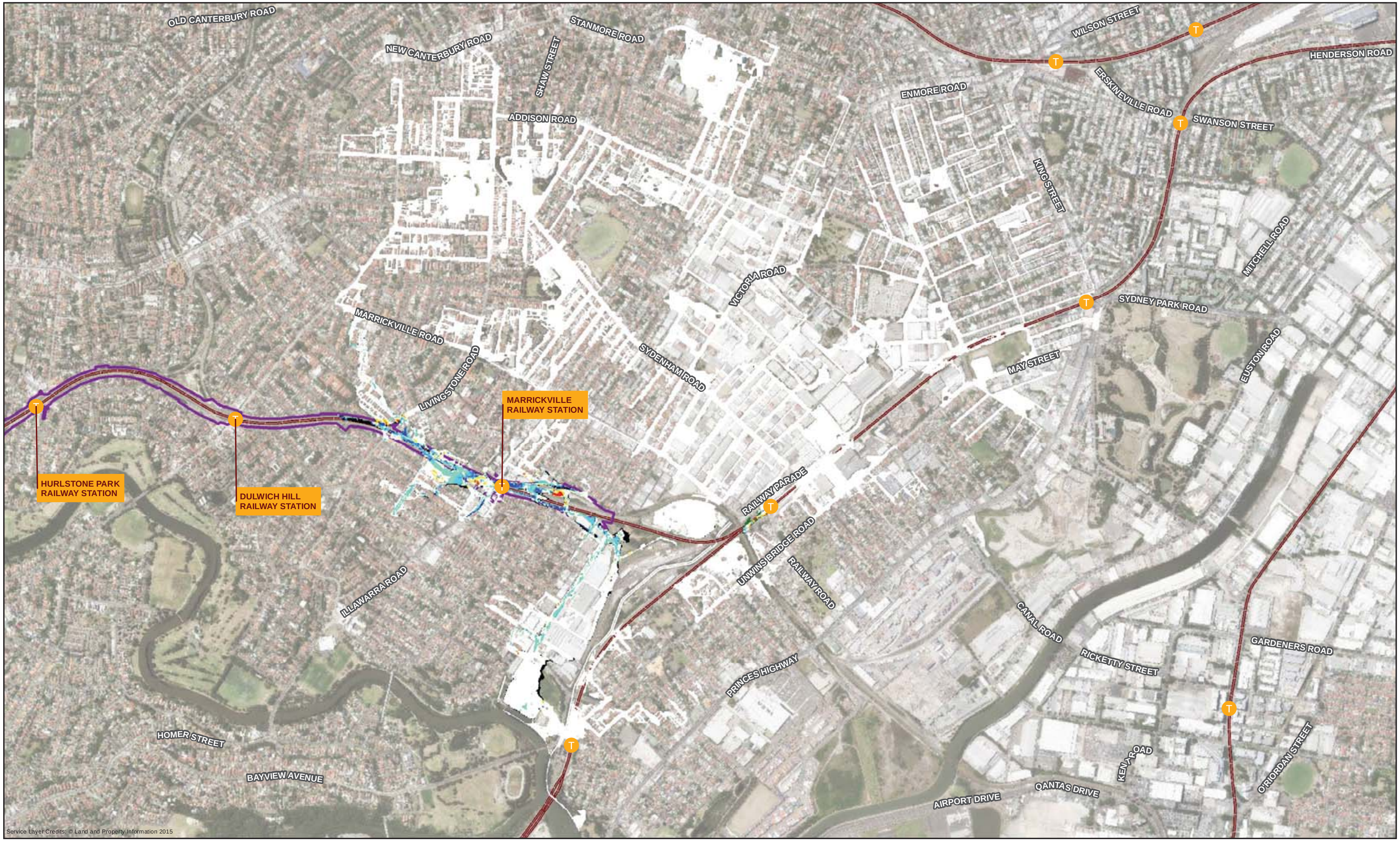
5% AEP flood velocity change

Figure B.58

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

Change in Flood Velocity (m/s)

- Greater than -0.5
- -0.5 to -0.4
- -0.4 to -0.3
- -0.3 to -0.2
- -0.2 to -0.1
- -0.1 to +0.1
- +0.1 to +0.2
- +0.2 to +0.3
- +0.3 to +0.4
- +0.4 to +0.5
- Greater than +0.5
- Was wet now dry
- Was dry now wet

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

Job Number	21-25273
Revision	A
Date	22 May 2017

2% AEP flood velocity change

Figure B.59

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

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

Change in Flood Velocity (m/s)

- Greater than -0.5
- -0.5 to -0.4
- -0.4 to -0.3
- -0.3 to -0.2
- -0.2 to -0.1
- -0.1 to +0.1
- +0.1 to +0.2
- +0.2 to +0.3
- +0.3 to +0.4
- +0.4 to +0.5
- Greater than +0.5
- Was wet now dry
- Was dry now wet

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

1% AEP flood velocity change

Job Number	21-25273
Revision	A
Date	22 May 2017

Figure B.60

G:\21\25273\GIS\Maps\Deliverables\SurfaceWaterSMA.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

Appendix C – Culverts Summary

Appendix C: Culvert Summary - comparison of design flows and velocities under existing and post-development conditions

Culvert No.	Culvert Name in Sydney Trains Chainage (Down Metro chainage)	Existing Culvert Dimensions	100 year ARI existing condition flow (m^3/s)	Existing condition velocity (m/s)	100 year ARI Post-development flow (m^3/s)	Post-development velocity (m/s)	Existing culvert capacity
1	6.183 (6.810)	Box culvert 3.0m x 1.8m					not determined
2	6.187 (6.830)	Box culvert 1.6m x 1.8m					not determined
3	6.699 (7.320)	Concrete arch culvert 1.4m x 1.8m	2.630	1.440	4.05	2.2	not determined
4	6.990 (7.600)	Circular 1.5m-dia.	3.28	1.8	3.28	1.8	not determined
5	7.665 (8.280)	Box culvert 658mmx576mm (under the ARTC tracks), 2000mmx800mm (under the ST tracks)	0.960	0.600	1.3	2	1 in 2-year ARI (both) (39% AEP)
6	8.093 (8.725)	Brick arch culvert 1.91mx1.98m	Low risk catchment, rail alignment is in fill at this location and more than 3.0m higher than the local road at the culvert location. No additional modelling has been done at concept stage.				not determined
7	9.000 (9.600)	Brick arch culvert 1.84mx1.96m	Low risk catchment, rail alignment is in fill at this location and more than 6.0m higher than the local council area at the culvert location. No additional modelling has been done at concept stage.				1 in 100 year ARI (1% AEP)
8	9.384 (10.000)	Brick arch culvert 1.525mx1.57m	Low risk catchment, rail alignment is in fill at this location and more than 5.0m higher than the local council area at the culvert location. No additional modelling has been done at concept stage.				1 in 100 year ARI (1% AEP)
9	9.617 (10.250)	Box culvert 750mmx800mm	1.270	6	1.270	6	1 in 100 year ARI +10% (1% AEP + 10% climate change)
10	9.883 South (10.500)	Box culvert 1500mmx500mm	1.500	2.500	2.2	2.2	1in 10 year ARI (10% AEP)
11	11.187 (11.800)	Circular 420mm-dia.	Long drainage culvert*				not determined
12	11.846 (12.480)	Box culvert 1.52m x 1.52m, and four cells of box culverts alongside at 870mm x 590mm each	5.800	1.900	5.71	2.5	less than 1 in 10 year ARI (10% AEP)
13	12.332 (12.950)	Box culvert 1.1mx0.7m	1.760	5.000	1.4	4.8	limited by downstream capacity of less than 1 in 2 year ARI (39% AEP)
14	12.669 (13.325)	Box culvert 1.5mx1.5m	Low risk catchment, rail alignment is in fill at this location and more than 4.0m higher than the local council area at the culvert location. No additional modelling have been done at concept stage.				1 in 2 year ARI (39% AEP)
15	12.815 (13.440)	Brick arch culvert 1.9mx1.7m	Low risk catchment, rail alignment is in fill at this location and more than 4.0m higher than the local council area at the culvert location. No additional modelling have been done at concept stage.				1 in 2 year ARI (39% AEP)
16	13.550 (14.170)	Box culvert 900mm x 900mm	3.100	3.500	3.100	3.500	Less than 1 in 5-year ARI (18% AEP)
17	14.099 (14.725)	Concrete arch culvert 0.9mx0.9m	1.750	4.800	1.750	4.800	Less than 1 in 20-year ARI (5% AEP)
18	14.171 (14.800)	Concrete arch culvert 0.9mx0.9m	2.200	4.600	2.200	4.600	not determined
19	14.725 (15.350)	Brick arch culvert 1.2mx1.2m	Low risk catchment, rail alignment is in fill at this location and more than 6.0m higher than the local road at the culvert location. No additional modelling has been done at concept stage.				Less than 1 in 5-year ARI (18% AEP)
20	14.734 (15.360)	Brick arch culvert 1.2mx1.2m	Low risk catchment, rail alignment is in fill at this location and more than 6.0m higher than the local road at the culvert location. No additional modelling has been done at concept stage.				Less than 1 in 5-year ARI (18% AEP)

21	15.558 (16.180)	Concrete arch culvert 1.4mx1.4m	Low risk catchment, rail alignment is in fill at this location and more than 6.0m higher than the local road at the culvert location. No additional modelling has been done at concept stage.				Less than 1 in 5-year ARI (18% AEP)
22	15.579 (16.200)	Concrete arch culvert 1.2mx1.2m	Low risk catchment, rail alignment is in fill at this location and more than 6.0m higher than the local road at the culvert location. No additional modelling has been done at concept stage.				Less than 1 in 5-year ARI (18% AEP)
23	15.595 (16.215)	Concrete arch culvert 1.2mx1.2m	Low risk catchment, rail alignment is in fill at this location and more than 6.0m higher than the local road at the culvert location. No additional modelling has been done at concept stage.				Less than 1 in 5-year ARI (18% AEP)
24	15.973 (16.600)	Pipe culvert 0.9m diameter	1.900	5.300	1.900	5.300	Less than 1 in 5-year ARI (18% AEP)
25	16.310 (16.925)	Pipe culvert 0.9m diameter	1.700	4.800	1.700	4.800	Less than 1 in 50-year ARI (2% AEP)
26	16.361 (16.980)	Pipe culvert 0.75m diameter	1.400	3.200	1.400	3.200	Less than 1 in 20-year ARI (5% AEP)
27	16.722 (17.350)	Pipe culvert 0.9m diameter	1.500	3.500	1.6	3.7	1 in 100 year + 10% ARI (1% AEP + 10% climate change)
28	17.139 (17.750)	Concrete arch culvert 0.9mx0.9m	3.450	5.400	3.450	5.400	1 in 100 year + 10% ARI (1% AEP + 10% climate change)
29	17.333 (17.950)	Concrete arch culvert 0.9mx0.9m	2.030	1.400	2.030	1.400	1 in 100 year + 10% ARI (1% AEP + 10% climate change)
30	17.607 (18.240)	Concrete arch culvert 0.9mx0.9m	1.130	2.000	1.130	2.000	1 in 100 year + 10% ARI (1% AEP + 10% climate change)
31	17.941 East (18.550)	Concrete arch culvert 1.2mx1.2m	Low risk catchment, rail alignment is in fill at this location and more than 2.5m higher than the local council area at the culvert location. No additional modelling has been done at concept stage.				less than 1 in 20 year ARI (5% AEP)
32	17.941 West (18.550)	Concrete arch culvert 1.2mx1.2m	Same culvert as above				less than 1 in 20 year ARI (5% AEP)
33	18.375 (19.000)	Box culvert 1000mmx950mm	Low risk catchment, rail alignment is in fill at this location and more than 2.5m higher than the local council area at the culvert location. No additional modelling has been done at concept stage.				less than 1 in 20 year ARI (5% AEP)
34	18.458 East U (19.070)	Twin box culverts (Sydney Water Culverts)	Low risk catchment, rail alignment is in fill at this location and more than 2.5m higher than the local council area at the culvert location. No additional modelling has been done at concept stage.				not determined
35	18.458 East D (19.070)						not determined
36	19.147 East (Beyond Metro chainage)	Two box culverts at 0.6m x 0.5m each	Low risk catchment, rail alignment is in fill at this location and more than 4.0 m higher than the local council area at the culvert location. No additional modelling has been done at concept stage.				not determined

Notes: The culvert locations are shown in Figures 3-9 to 3-14 in the main body of the report

* the location of this longitudinal culvert (No. 11) is not shown

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SYDENHAM TO BANKSTOWN

ENVIRONMENTAL IMPACT STATEMENT

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