ARTC

BOTANY RAIL DUPLICATION

TECHNICAL REPORT

Technical Report 6 –
Flooding Impact Assessment

BOTANY RAIL DUPLICATION
ENVIRONMENTAL IMPACT STATEMENT

TECHNICAL WORKING PAPER:
FLOODING

FINAL REPORT

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NOTE ON FLOOD FREQUENCY TERMINOLOGY

The frequency of flood events is generally referred to in terms of their Annual Exceedance Probability (AEP) or Average Recurrence Interval (ARI). For example, for a flood magnitude having five per cent AEP, there is a five per cent probability (or 1 in 20 chance) that there would be floods of greater magnitude each year. As another example, for a flood having a 20 year ARI, there would be floods of equal or greater magnitude once in twenty years on average. The approximate correspondence between these two systems is:

Annual Exceedance Probability (AEP) per cent	Average Recurrence Interval (ARI) years
0.2	500
0.5	200
1	100
5	20
10	10
20	5
50	2
1 EY[(1)]	1
2 EY[(1)]	0.5

1. Floods more frequent than 50% AEP are expressed in terms of the number of exceedances per year (EY).

In this technical working paper the frequency of flood events generated by runoff from the catchments within the study area (ie catchment flooding) is referred to in terms of their AEP, for example a 1% AEP flood.

The frequencies of peak water levels derived from ocean flooding are also referred to in terms of their AEP; for example, a 1% AEP peak ocean water level.

The technical working paper also refers to the Probable Maximum Flood (PMF). This flood occurs as a result of the probable maximum precipitation (PMP) on the catchments within the study area. The PMP is the result of the optimum combination of the available moisture in the atmosphere and the efficiency of the storm mechanism as regards rainfall production. The PMP is used to estimate PMF discharges using a catchment hydrologic model that simulates the conversion of rainfall to runoff. The PMF is defined as the upper limiting value of floods that could reasonably be expected to occur and defines the extent of flood prone land (i.e. the floodplain).

GLOSSARY OF TERMS AND ABBREVIATIONS

Term	Meaning
AEP	Annual exceedance probability. The chance of a rainfall or a flood event exceeding a nominated level in any one year, usually expressed as a percentage. For example, if a peak flood level has an AEP of five per cent, it means that there is a five per cent chance (that is one-in-20 chance) of being exceeded in any one year. The frequency of floods is generally referred to in terms of their AEP or ARI. In this report the frequency of floods generated by runoff from the study catchments is referred to in terms of their AEP, for example a 1% AEP flood.
Afflux	Increase/decrease in water level resulting from a change in conditions. The change may relate to the watercourse, floodplain, flow rate, tailwater level, etc.
AHD	Australian height datum. A common national surface level datum approximately corresponding to mean sea level.
ARI	Average recurrence interval. An indicator used to describe the frequency of a rainfall or a flood event, expressed as an average interval in years between events of a given magnitude. For example, over a long period of say 200 years, a flood equivalent to or greater than a 20 year ARI event would occur 10 times. A 20 year ARI flood has a one-in-5 chance of occurrence in any one year. See also AEP.
ARR 1987	Australian Rainfall and Runoff (Institute of Engineers Australia (IEAust) 1987).
ARR 2019	Australian Rainfall and Runoff (Geosciences Australia (GA) 2019).
ARTC	Australian Rail Track Corporation (the proponent).
Ballast	Material such as crushed rock or stone used to provide a foundation for a railway track. Ballast usually provides the bed on which railway sleepers are laid, transmits the load from train movements and restrains the track from movement.
BoM	Bureau of Meteorology.
Botany Line	A dedicated freight rail line (operated by ARTC) that forms part of the Metropolitan Freight Network. The line extends from near Marrickville Station to Port Botany.
Box culvert	A culvert of rectangular cross section.
Catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
Climate change	A change in the state of the climate that can be identified (for example by statistical tests) by changes in the mean and/or variability of its properties, and that persists for an extended period of time, typically decades or longer (IPCC 2007).
Climate projection	A climate projection is the simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases and aerosols, generally derived using climate models. Climate projections are distinguished from climate predictions by their dependence on the emission/concentration/radiative forcing scenario used, which in turn is based on assumptions concerning, for example, future socio-economic and technological developments that may or may not be realised (IPCC 2007).

Term	Meaning
Construction ancillary facilities	Temporary facilities during construction that include, but are not limited to, construction work areas, sediment basins, temporary water treatment plants, pre-cast yards and material stockpiles, laydown areas, parking, maintenance workshops and offices, and construction compounds.
Construction compound	An area used as the base for construction activities, usually for the storage of plant, equipment and materials, and/or construction site offices and worker facilities.
CEMP	Construction Environmental Management Plan.
DCP	Development control plan.
DECC	Department of Environment and Climate Change (now OEH).
DECCW	Department of Environment, Climate Change and Water (now OEH).
Detailed design	The stage of design where project elements are design in detail, suitable for construction.
DIPNR	Department of Infrastructure, Planning and Natural Resources (now OEH).
Discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving (e.g. metres per second [m/s]).
DoP	Department of Planning (now DPE).
DPE	Department of Planning and Environment (formerly DoP).
DSC	Dam Safety Committee.
Drainage	Natural or artificial means for the interception and removal of surface or subsurface water.
DRAINS	A computer simulation program which converts rainfall patterns to stormwater runoff and generates discharge hydrographs. These hydrographs can then be routed through networks of piped drainage systems, culverts, storages and open channels using the DRAINS software to calculate hydraulic grade lines and analyse the magnitude of overflows. Alternatively, discharge hydrographs generated by DRAINS can be used as inflows to alternative hydraulic models (such as the TUFLOW two-dimensional hydraulic modelling software) to calculate water surface levels and flooding patterns.
Earthworks	All operations involving the loosening, excavating, placing, shaping and compacting of soil or rock.
Emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
EIS	Environmental Impact Statement.
Embankment	An earthen structure where the rail (or other infrastructure) is located above the natural surface.
Existing rail corridor	The corridor within which the existing rail infrastructure is located. In the study area, the existing rail corridor is the Botany Line.
FDM	_Floodplain Development Manual_ (Department of Planning, Infrastructure and Natural Resources (DIPNR) 2005).

Term	Meaning
Fill	The material placed in an embankment.
Flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunamis.
Flood affectation	The extent to which a property or area of land is affected by flooding.
Flood fringe area	The remaining area of flood prone land after floodway and flood storage areas have been defined.
Flood immunity	Relates to the level at which a particular structure would be clear of a certain flood event.
Flood prone land	Land susceptible to flooding by the Probable Maximum Flood. Note that the flood prone land is synonymous with flood liable land.
Flood storage area	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
Floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event (i.e. flood prone land).
Floodplain Risk Management Plan	A management plan developed in accordance with the principles and guidelines in the *Floodplain Development Manual* (FDM), (DIPNR 2005). Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
Floodway area	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
Flow velocity	A measure of how fast how fast water is moving, for example, metres per second (m/s).
Formation	The earthworks/material on which the ballast, sleepers and tracks are laid.
FPA	Flood Planning Area. The area of land below the Flood Planning Level and thus subject to flood planning controls.
FPLs	Flood Planning Levels. The combination of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans.

Term	Meaning
Freeboard	A factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. It is usually expressed as the difference in height between the adopted Flood Planning Level and the peak height of the flood used to determine the Flood Planning Level. Freeboard provides a factor of safety to compensate for uncertainties in the estimation of flood levels across the floodplain, such as wave action, localised hydraulic behaviour and impacts that are specific event related, such as levee and embankment settlement, and other effects such as "greenhouse" and climate change. Freeboard is included in the Flood Planning Level.
GSDM	Generalised Short Duration Method. A method prescribed by BoM for estimating the Probable Maximum Precipitation for catchments up to 1,000 square kilometres in area.
Hazard	A source of potential harm or a situation with a potential to cause loss. In relation to the *NSW Floodplain Development Manual* (FDM), (DIPNR, 2005) the hazard is flooding which has the potential to cause damage to the community.
HHWSS	Highest High Water Solstice Spring. The tide level reached on average once or twice per year.
Hydraulics	The term given to the study of water flow in waterways, in particular the evaluation of flow parameters such as water level and velocity.
Hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
Hydrology	The term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of discharge hydrographs for a range of floods.
Hyetograph	A graph which shows how rainfall intensities or depths vary with time during a storm burst. A design hyetograph shows the distribution of rainfall over a design storm burst.
IFD	Intensity-Frequency-Duration.
Impact	Influence or effect exerted by a project or other activity on the natural, built and community environment.
Inbank area	The area of a creek or watercourse below its top of bank levels.
Inundation	The spreading of a flood over an area.
IPCC	Intergovernmental Panel on Climate Change.
LGA	Local government area.
LiDAR	Light detection and ranging. A form of aerial survey used to measure ground elevations.
Local drainage	Smaller scale drainage systems in urban areas. Commonly defined as areas where the depth of inundation along overland flow paths is less than 150 millimetres during a 1% AEP storm.
m	Metres. Used to define a length.
m AHD	Metres above Australian Height Datum . Used to define an elevation above Australian Height Datum.

Term	Meaning
m^2	Square metres. Used to define an area.
m^3	Cubic metres. Used to define a volume.
m^3/s	Cubic metres per second. Used to quantify a flowrate.
Main stream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
Major overland flow	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam. Also referred to as overland flooding.
Mathematical/ computer models	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
Merits based approach	The merits based approach weighs social, economic and environmental impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well-being of the State's rivers and floodplains.
OEH	Office of Environment and Heritage (formerly DECCW).
Overland flooding	Refer major overland flow.
Peak discharge	The maximum discharge occurring during a flood event.
Peak flood level	The maximum water level occurring during a flood event.
PMF	Probable maximum flood. The flood that occurs as a result of the Probable Maximum Precipitation (PMP) on a study catchment. The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically feasible to provide complete protection against this event. The PMF defines the extent of flood prone land (i.e. the floodplain).
PMP	Probable maximum precipitation. The PMP is the result of the optimum combination of the available moisture in the atmosphere and the efficiency of the storm mechanism as regards rainfall production. The PMP is used to estimate PMF discharges using a catchment hydrologic model which simulates the conversion of rainfall to runoff.
Pre-project conditions	Conditions (within the study area) prior to the construction of the Botany Rail Duplication project. This includes details of projects that are presently under construction or will be constructed prior to the Botany Rail Duplication project (such as the Airport East and Airport North projects).
PRM	Probabilistic rational method.
Probability	A statistical measure of the expected chance of flooding (see annual exceedance probability).

Term	Meaning
Project site	The area that would be directly affected by construction (also known as the construction footprint). It includes the location of operational project infrastructure, the area that would be directly disturbed by the movement of construction plant and machinery, and the location of the storage areas/compounds etc, that would be used to construct that infrastructure.
Project	The construction and operation of the Botany Rail Duplication.
RCBC	Reinforced Concrete Box Culvert.
RCP	Reinforced Concrete Pipe.
Representative Concentration Pathway	A greenhouse gas concentration trajectory adopted by the Intergovernmental Panel on Climate Change.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the *NSW Floodplain Development Manual* (DIPNR 2005) it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
RL	Reduced level. The reduced level is the vertical distance between an elevation and an adopted datum plane such as the Australian Height Datum (AHD).
Runoff	The amount of rainfall which actually ends up as stream flow, also known as rainfall excess.
Scour	The erosion of material by the action of flowing water.
SEARs	Secretary's Environmental Assessment Requirements and specifications for an environmental assessment prepared by the Secretary of the NSW Department of Planning and Environment under section 115Y of the Environmental Planning and Assessment Act 1979 (NSW).
SES	NSW State Emergency Services.
Spoil	Surplus excavated material.
Stage	Equivalent to water level (measured with reference to a specified datum).
State significant infrastructure	Major transport and services infrastructure considered to have State significance as a result of size, economic value or potential impacts.
Stockpile	Temporarily stored materials such as soil, sand, gravel and spoil/waste.
Study area	The study area is defined as the wider area including and surrounding the project site, with the potential to be directly or indirectly affected by the project (e.g. by noise and vibration, visual or traffic impacts). The actual size and extent of the study area varies according to the nature and requirements of each assessment and the relative potential for impacts but which is sufficient to allow for a complete assessment of the proposed project impacts to be undertaken.
Surcharge	Overflow from a creek, waterbody, overland flow or drainage system.
Surface water	Water flowing or held in streams, rivers and other water bodies in the landscape.
Water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
Waterway	Any flowing stream of water, whether natural or artificially regulated (not necessarily permanent).

S1 EXECUTIVE SUMMARY

Overview

This report deals with the findings of an investigation which was undertaken to assess flood related issues associated with the construction and operation of the Botany Rail Duplication project (project).

This report has been prepared to support the Environmental Impact Statement (EIS) for the project. **Sections 1** to **3** provide details of the background to the assessment. An outline is provided of relevant government legislation, policies and guidelines that were taken into consideration in the assessment. Details are also provided of the methodology that was adopted in the definition of flood behaviour in the vicinity of the project and also the impact the project would have on flood behaviour.

Existing environment

The project traverses highly urbanised portions of the Alexandra Canal and Mill Stream catchments. The investigation found that the stormwater drainage systems that control runoff from these catchments are typically of limited capacity. As a result, there are sections of the existing rail corridor that are presently impacted by major overland flow during periods of heavy rainfall.

Section 4 contains a brief description of the characteristics of the catchments through which the project runs, as well as a description of the nature of mainstream flooding and major overland flow under present day (or pre-project) conditions for events ranging between 50% and 0.2% Annual Exceedance Probability (AEP), as well as the Probable Maximum Flood (PMF). Mainstream flooding and major overland flow have been collectively termed ‘flooding’ within this report.

Impacts during construction

Table 5.1 in **Section 5.1** provides a summary of the assessed flood risk at each construction work area and their associated activities. **Figure 5.1** (3 sheets) shows the extent to which floods of varying magnitude affect each construction work area, while **Figure 5.2** (6 sheets) shows the provisional flood hazard and preliminary hydraulic categorisation of the floodplain in the vicinity of each construction work area and compound for a 1% AEP flood event.

The assessment found that a number of the construction work areas would be affected by flooding during storms as frequent as 50% AEP. Inundation of these construction sites by flooding has the potential to:

- cause damage to the project works and delays in construction programming
- pose a safety risk to construction workers
- detrimentally impact the downstream waterways through the transport of sediments and construction materials by floodwaters
- obstruct the passage of floodwater and overland flow through the provision of temporary measures such as site sheds, stockpiles and temporary fencing, which in turn could exacerbate flooding conditions in existing development located outside the construction footprint.

A qualitative assessment was undertaken of the potential impacts construction activities could have on flood behaviour, the key findings of which are summarised in **Table 5.1**. While all construction work areas will involve works within the floodplain that will need to be managed, the assessment found that the greatest potential for adverse impacts on flood behaviour is associated with the impact that the construction of the Mill Stream bridge with its construction compound (C5), proposed crane pads (CP4) and temporary piling platforms could have on the conveyance of flow in Mill Stream. The works also have the potential to increase flow velocities and therefore scour and erosion potential in Mill Stream.

There is also the potential for all construction activities to impact local catchment runoff, which would require appropriate local stormwater management controls to be implemented during the construction phase of the project.

While the findings of the assessment provide an indication of the potential impacts of construction activities on flood behaviour, further investigation would need to be undertaken during detailed design as layouts and staging diagrams are further developed. Consideration would also need to be given to setting an appropriate hydrologic standard (ie design flood event) for mitigating the impacts of construction activities on flood behaviour, taking into account their temporary nature and therefore the likelihood of a flood of a given AEP occurring during the construction period.

Measures aimed at mitigating the impacts of construction activities on flood behaviour will be developed further during the detailed design phase and included in the Construction Environment Management Plan (CEMP) for the project. Further details on the range of measures which will be considered to mitigate the potential construction related impacts of the project are outlined in **Section 6.2**.

Impacts during operation

Inundation of the project by floodwater during its operation has the potential to cause damage to infrastructure, impact on the operation of the rail line and pose a safety risk to rail users and staff. The project also has the potential to exacerbate flooding conditions in adjacent development. An assessment was undertaken of the flood risk to the project in its as-built form, as well as the impact it would have on the characteristics of flooding in adjacent areas.

Table 5.2 provides details of the project components that formed the basis of the assessment of flood behaviour within the Alexandra Canal and Mill Stream catchments, while **Figure 5.3** (3 sheets) shows the general design arrangement including key flooding and drainage related features. The assessed design would be subject to further development during the detailed design stage, which would also consider measures to further reduce the impact of flooding to the project and surrounding areas.

Potential flood risk to the project

Table 5.3 provides a summary of the assessed flood risk to the project. A recommended level of flood protection to each project element has been identified based on the adopted criteria outlined in **Section 3.3**.

Impact of the project on flood behaviour

The assessment found that once constructed, the project would generally have only a minor impact on flood behaviour (refer **Tables 5.4**, **5.5** and **5.6** for a summary of key findings). The following residual flood impacts have been identified on existing infrastructure:

1. Peak 1% AEP flood levels upstream of Mill Stream bridge would be increased by a maximum of 0.1 metres, which would also lead to an increase in the rate and therefore depth of flow that surcharges the western bank of Mill Stream and is conveyed along the travel lanes of Southern Cross Drive and Botany Road. The increase in peak flood levels upstream of the rail corridor will also lead to an increase in the frequency with which flow surcharges the western bank of Mill Stream onto the travel lanes of Southern Cross Drive, from about a 1% AEP event under pre-project conditions, to about a 2% AEP event under post-project conditions (ie twice as frequent).

   The design of the Mill Stream bridge would be further refined during detailed design to mitigate the impact of the project on the increased rate and frequency of flow that discharges onto Southern Cross Drive. This would involve one or both of the following:

   - Increasing the length of the western span to reduce the encroachment of the western abutment on the floodway of Mill Stream.
   - Providing a retaining wall along the southern side of the rail line to the west of Mill Stream to reduce the encroachment of the rail embankment on the floodway of Mill Stream.

2. During a 1% AEP event there would be an increase in peak flood levels upstream of the inlet to the 1,050 millimetre diameter pipe that crosses the rail corridor at Myrtle Street which would also lead to the following impacts in adjoining development:

   - Peak flood levels in a multi-unit development at 104 Bay Street would be increased by a maximum of 0.02 metres. Impacts would occur in the northern portion of the development over an area that includes several units that front Myrtle Street.
   - Peak flood levels in a multi-unit development at 15 Begonia Street would be increased by a maximum of 0.02 metres. Impacts would occur in the northeastern portion of the development, adjacent to the entry to a basement carpark from Myrtle Street.

   Subject to further flood assessment during detailed design it will be necessary to collect detailed ground survey within the multi-unit developments at 104 Bay Street and 15 Begonia Street, including floor levels of units and the level of entry points to units and basement carparks.

   The survey would be used to confirm the potential for an increase in above floor inundation to units as well as an increase in the frequency, rate and volume of flow into basement carparks. The survey would also assist in developing a scope of works that would be aimed at mitigating the impact of the project on:

   - An increase in above floor inundation to units for all events up to 1% AEP.
   - An increase in the frequency, rate and volume of flow into basement carparks for all events up to the PMF.

   This scope of works may include:

   - Refinement of the drainage design to reduce the magnitude of flow that is diverted toward the inlet to the 1,050 millimetre diameter pipe that crosses the rail corridor at Myrtle Street.
   - Provision of oversized channels along the northern side of the rail corridor between Myrtle Street and Lord Street to provide temporary floodplain storage to offset the displacement caused by the widened rail embankment.

The investigation found that while the current design would result in an increase in velocities in Mill Stream that have the potential to increase scour and erosion, these impacts are expected to be mitigated through the implementation of measures in the detailed design to reduce the encroachment of the proposed works on the floodway of Mill Stream. Potential measures are outlined under Item 1 above.

Subject to the incorporation of the above mitigation measures during the detailed design, then the nature of the changes in flooding patterns attributable to the project would not have a significant impact on the Flood Planning Area or the future development potential of land located outside the project boundary. The changes in flooding patterns would also not result in a significant change to the flood hazard, existing flood emergency response procedures, or the social and economic costs of flooding.

The project would generally have a minor impact on flow behaviour in the drainage systems downstream of the proposed drainage outlets that would control runoff from the rail corridor. While the investigation found that there would be a slight increase in the depth of inundation along Qantas Drive and an adjoining portion of Sydney Airport due to an increase in flow that surcharges the drainage system downstream of the rail corridor, impacts would be confined to an area that would be upgraded as part of the Sydney Gateway Road project.

The assessment found that the project would have only a minor impact on the extent and duration of inundation of flooding within Mill Stream.

Impact of climate change on flood behaviour

Projected changes in the intensity of flood producing rainfall and to a lesser degree a rise in sea level have the potential to impact on the characteristics of flooding in the vicinity of the project. The potential impacts of future climate change on flooding were assessed in accordance with the recommended procedures set out in the *Floodplain Risk Management Guideline – Practical Considerations of Climate Change* (NSW Department of Environment and Climate Change (DECC) 2007). **Table 3.2** in **Section 3.7.1** summarises the two scenarios comprising a combination of design storm rainfalls and sea level conditions which were used to assess the potential impact of future climate change on the characteristics of flooding in the vicinity of the project.

Future climate change has the potential to increase the frequency and depth of inundation to the duplicated section of rail and the new corridor access roads. For example, during a 1% AEP event a section of the northern track between O'Riordan Street and General Holmes Drive would be inundated to a depth of 0.4 metres above the toe of ballast under the upper bound estimate of future climate change, whereas the ballast would not be inundated under current climatic conditions. The depth of inundation to the ballast would be increased to a section of southern track between O'Riordan Street and General Holmes Drive and a section of the northern track between Southern Cross Drive and Banksia Street.

While flooding under future climate change conditions would increase the depth and frequency of inundation to the ballast below the duplicated rail line, the depth of inundation in a 1% AEP event would still be a minimum 0.25 metres below the top of rail level. Raising the level of the rail line in order to reduce the depth of inundation to the ballast would be constrained by the level of the existing rail line and is also likely to result in adverse impacts on flood behaviour in areas outside the rail corridor.

The investigation found that future climate change would not impact on the Mill Stream bridge as there would be a minimum 0.5 metres of clearance between the underside of the existing and new bridges over Mill Stream and the peak 1% AEP flood level under both future climate change scenarios.

Cumulative impacts

The assessment found that due to the relatively localised and minor nature of the project related flood impacts there would be either minor or no cumulative impacts associated with it and other major projects in its vicinity during its construction and operation.

Management of impacts

Section 6 sets out the approach that will be adopted during the detailed design phase to manage the flood risk to the project as well as the impact it would have on flood behaviour through:

- documenting procedures and measures that are aimed at managing the risk of flooding to the project, as well as the potential for adverse impacts on existing flood behaviour within its vicinity
- identifying appropriate design standards for managing the flood risk during the construction and operational phases of the project
- including procedures aimed at reducing the flooding threat to human safety and infrastructure
- including controls that are aimed at mitigating the impact of the project (during construction and operation) on flood behaviour.

While the findings of the assessment presented in **Section 5.1** provide an indication of the potential impact construction activities would have on flood behaviour, further investigations will need to be undertaken during detailed design with the benefit of more detailed site layouts and staging diagrams. **Section 6.2** contains a range of potential measures which could be implemented in order to reduce the impact of construction activities on flood behaviour.

The assessment of flood behaviour during the operation of the project has provided an understanding of the scale and nature of the flood risk to the project infrastructure, as well as its impact on flooding in surrounding areas. A broad outline of measures which would need to be implemented during the detailed design phase in order to manage the project related flood risks and impacts are outlined in **Section 6.3**. The design of the project would need to incorporate measures that are aimed at:

- minimising adverse impacts on surrounding development for flood up to 1% AEP event; assessment would also be made of impacts during floods up to the PMF in the context of impacts on critical infrastructure and flood hazard
- mitigating impacts on flood behaviour in properties where existing buildings would experience above-floor inundation during floods up to the 1% AEP event, or where there is the ingress of floodwater into basement carparks during events up to the PMF
- minimising the potential for an increase in scour and erosion in areas downstream of the project, including Mill Stream.

1 INTRODUCTION

1.1 Overview

1.1.1 Background

Australian Rail Track Corporation (ARTC) proposes to construct and operate a new second track within the existing Botany Line rail corridor between Mascot and Botany, in the Bayside local government area (LGA). The Botany Rail Duplication ('the project') would increase freight rail capacity to and from Sydney Airport and Port Botany. The location of the project is shown in **Figure 1.1**.

The project is State significant infrastructure in accordance with Division 5.2 of the NSW Environmental Planning and Assessment Act 1979 (EP&A Act). As State significant infrastructure, the project needs approval from the NSW Minister for Planning and Public Spaces.

This report has been prepared to accompany the environmental impact statement (EIS) to support the application for approval of the project, and address the Secretary of the Department of Planning and Environment's environmental assessment requirements (the SEARs), issued on 21 December 2018.

1.1.2 Overview of the project

The project would involve:

- track duplication – constructing a new track predominantly within the rail corridor for a distance of about three kilometres
- track realignment (slewing) and upgrading – moving some sections of track sideways (slewing) and upgrading some sections of track to improve the alignment of both tracks and minimise impacts to adjoining land uses
- new crossovers – constructing new rail crossovers to maintain and improve access at two locations (totalling four new crossovers)
- bridge works – constructing new bridge structures at Mill Stream, Southern Cross Drive, O'Riordan Street and Robey Street (adjacent to the existing bridges), and re-constructing the existing bridge structures at Robey Street and O'Riordan Street
- embankment/retaining structures – construction of a new embankment and retaining structures adjacent to Qantas Drive between Robey and O'Riordan streets and a new embankment between the Mill Stream and Botany Road bridges.

Further information on the key elements of the project is provided in the EIS.

Ancillary work would include bi-directional signalling upgrades, drainage work and protecting/relocating utilities.

Subject to approval of the project, construction is planned to start at the end of 2020, and is expected to take about three years for the main construction works to be undertaken. Construction is expected to be completed in late 2023 with commissioning activities undertaken in early 2024.

It is anticipated that some features of the project would be constructed while the existing rail line continues to operate. Other features of the project would need to be constructed during programmed weekend rail possession periods when rail services along the line cease to operate.

The project would operate as part of the existing Botany Line and would continue to be managed by ARTC. ARTC is not responsible for the operation of rolling stock. Train services are currently, and would continue to be, provided by a variety of operators. Following the completion of works, the existing functionality of surrounding infrastructure would be restored.

Key features of the project are shown on **Figure 1.2**.

Figure 1.1 – Location of the project

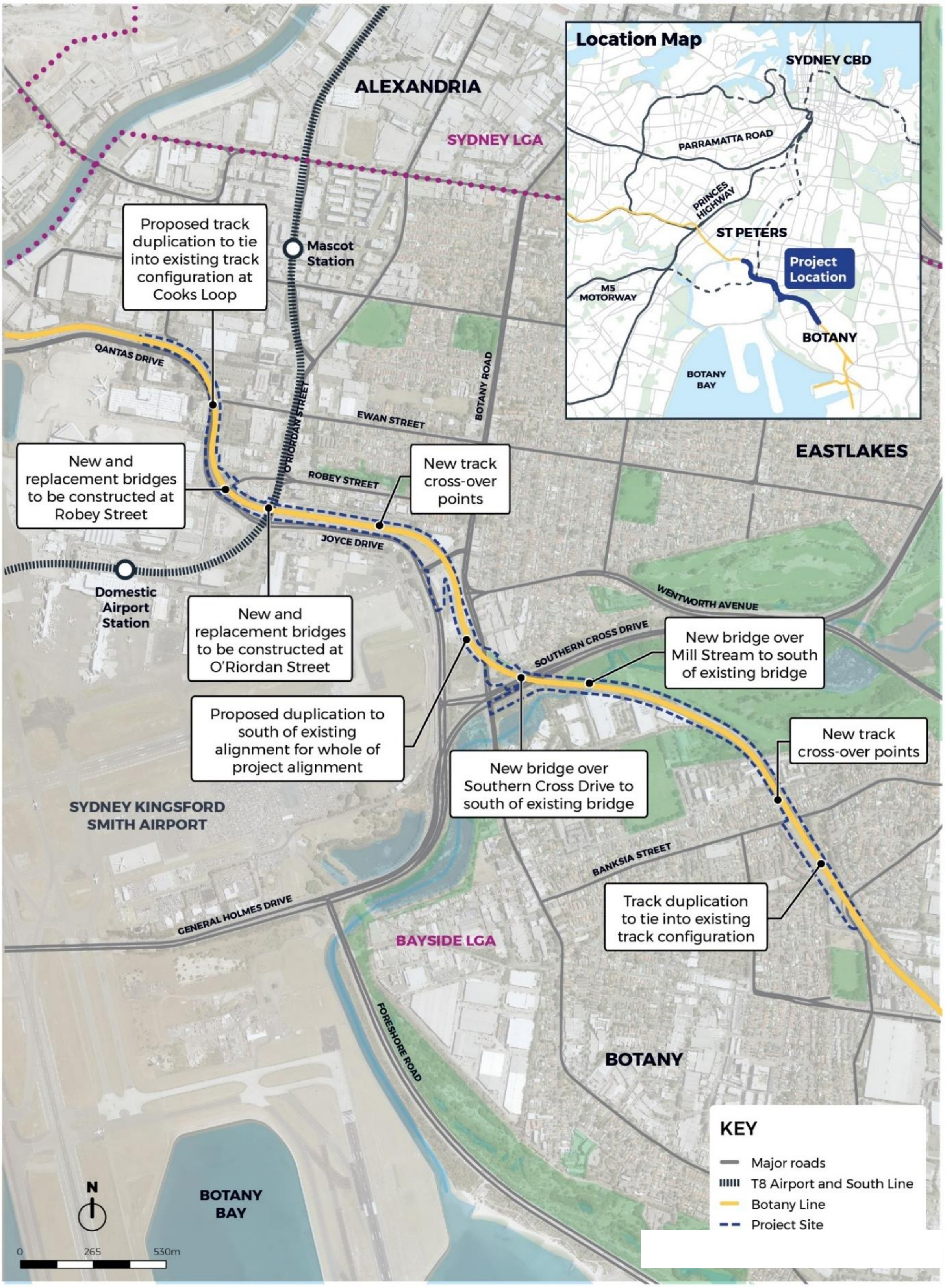

Figure 1.2 – Botany Rail Duplication project overview

1.2 Purpose and scope of this report

The purpose of this report is to assess the potential flooding impacts from the operation and construction of the project. This flooding assessment addresses the relevant SEARs for the EIS, as outlined in **Table 2.1**.

The report:

- describes the existing environment with respect to flood behaviour
- assesses the impacts of constructing and operating the proposal on flood behaviour
- recommends measures to mitigate the flood related impacts identified.

1.3 Structure of this report

The structure of the report is outlined below:

- **Section 1** provides a brief overview of the project and the purpose of this report.
- **Section 2** sets out the relevant government legislation, policies and guidelines that were taken into consideration during the assessment. The chapter also sets out the flooding and drainage related SEARs which were issued by the NSW Department of Planning and Environment (DPE) for the preparation of the EIS.
- **Section 3** sets out the methodology that has been adopted in the definition of flood behaviour in the vicinity of the project and also the impact the project would have on flood behaviour. The chapter also contains a summary of the criteria and standards that have been adopted for the assessment based on consideration of the relevant government legislation, policies and guidelines.
- **Section 4** contains a brief description of the catchments through which the project runs. This chapter of the technical working paper also provides a description of flood behaviour in the vicinity of the project under present day (i.e. pre-project) conditions.
- **Section 5** deals with the flood risks to the project and its impact on flood behaviour during the construction and operation of the project. The chapter also presents the findings of an assessment of the potential impact of future climate change on flood behaviour, as well as the impact that a partial blockage of major hydraulic structures would have on flood behaviour in the vicinity of the project. The chapter also describes the potential cumulative impacts on flooding patterns that would result from the project in combination with other projects in its vicinity.
- **Section 6** outlines potential measures to mitigate the construction and operational (i.e. post-construction) related impacts of the project on flooding conditions in adjacent development and to manage the risk of flooding to the project.
- **Section 7** summarises the key findings of the assessment.
- **Section 8** contains a list of references cited in this technical working paper.
- **Annexure A** of this technical working paper contains background to the development and testing of the hydrologic and hydraulic models (collectively referred to as 'flood models') that were used to define flood behaviour in the vicinity of the project.
- **Annexure B** contains a series of figures which show flooding patterns for design storms with annual exceedance probabilities (AEPs) of 50%, 5%, 2%, 0.5% and 0.2%. **Annexure B** also contains a series of figures that show the extent of land which is located

below the peak 1% AEP flood level plus 0.5 metres (defined in the Rockdale LEP 2011 (RCC 2011) as the Flood Planning Area[1]), as well as provisional flood hazard and preliminary hydraulic categories for a 1% AEP flood.

The scales on figures referred to in this technical working paper are applicable when printed at A3 size. The figures referred to in **Sections 4** and **5** of this technical working paper are located after **Section 8** of this technical working paper.

[1] The *Botany Bay Local Environmental Plan 2013* which applies to land on which the project is located does not include a "flood planning" clause. For the purpose of this report it has therefore been assumed that the Flood Planning Level in the vicinity of the project is equal to the peak 1% AEP flood level plus an allowance of 0.5 metres for freeboard, and that the Flood Planning Area (FPA) is the area of land located at or below the FPL. This is consistent with the definition of the FPL and FPA that was adopted by the former Rockdale City Council in *Rockdale Local Environment Plan 2011*, which now forms part of Bayside Council.

2 LEGISLATIVE AND POLICY CONTEXT

This section summarises the legislation, guidelines and/or policies driving the approach to the assessment. Relevant commonwealth, state and local government policies and guidelines are discussed in **Sections 2.1.1**, **2.1.2** and **2.1.3**, respectively. **Section 2.2** lists the SEARs requirements relevant to flooding and identifies where they have been addressed in this report.

2.1 Relevant legislation, policies and guidelines

2.1.1 Commonwealth guidelines

Australian Rainfall and Runoff

Australian Rainfall and Runoff (ARR) is a national guideline for the estimation of design flood characteristics in Australia. The application of the procedures, inputs and parameters set out in ARR is an important component in the provision of reliable and robust estimates of design flood behaviour to ensure that projects such as the Botany Rail Duplication are designed in a manner that manages the impact of flooding.

The third edition of ARR was released in 1987 (ARR 1987) (Institute of Engineers Australia (IEAust) 1987), while a fourth edition of ARR was issued during the course of the present investigation (ARR 2019) (Geoscience Australia (GA) 2019).

Due to the timing of the release of ARR 2019, hydrologic modelling that has been undertaken to support the flood assessment for the project was based on the procedures set out in ARR 1987, which is also consistent with the approach adopted for previous flood studies in the study area. Given the recent release of ARR 2019, a comparison has been made in the vicinity of the project in order to assess the potential changes that the adoption of the procedures set out in ARR 2019 would have on predicted flood behaviour. **Annexure A** of this technical working paper contains further details of the hydrologic modelling that was undertaken as part of the flood assessment, as well as a comparison of the procedures set out in ARR 1987 and ARR 2019.

2.1.2 State legislation, policies and guidelines

Floodplain development manual

The _Floodplain Development Manual_ (FDM) (DIPNR 2005) incorporates the NSW Government's Flood Prone Land Policy, the primary objectives of which are to reduce the impact of flooding and flood liability on owners and occupiers of flood prone property and to reduce public and private losses resulting from floods, whilst also recognising the benefits of use, occupation and development of flood prone land.

The FDM forms the NSW Government's primary technical guidance for the development of sustainable strategies to support human occupation and use of the floodplain, and promotes strategic consideration of key issues including safety to people, management of potential damage to property and infrastructure and management of cumulative impacts of development. Importantly, The FDM promotes the concept that proposed developments be treated on their merit rather than through the imposition of rigid and prescriptive criteria.

Flood and floodplain risk management studies undertaken by local councils as part of the NSW Government's Floodplain Management Program are carried out in accordance with the merits based approach promoted by the FDM. A similar merits based approach has been adopted in the assessment of the impacts the project would have on existing flood behaviour and also in the development of a range of potential measures which would be aimed at mitigating the impact of the project on the existing environment. In accordance with the FDM, the hydraulic and hazard categorisation of the floodplain was also considered when assessing the impact of the project on existing flood behaviour as well as the impact of flooding to the project and its users.

Guideline on development controls on low risk flood areas

In January 2007 the NSW Government issued Planning Circular PS 07-003 *New guideline and changes to section 117 direction and EP&A Regulation on flood prone land* which provided an overview of its new guideline to the FDM titled *Guideline on Development Controls on Low Flood Risk Areas*. More specifically, the circular provided advice on a package of changes concerning flood-related development controls on residential development on land subject to events above the 1% AEP flood and up to the Probable Maximum Flood (PMF) (i.e. land that is affected by flooding during events that are greater than 1% AEP in magnitude). These areas are sometimes known as low flood risk areas.

Guideline on Development Controls on Low Flood Risk Areas confirmed that unless there are exceptional circumstances, councils should adopt the 1% AEP flood as the basis for deriving the Flood Planning Level (FPL) for residential development. In proposing a case for exceptional circumstances, a council would need to demonstrate that a different FPL was required for the management of residential development due to local flood behaviour, flood history, associated flood hazards or a particular historic flood. The guideline also notes that unless there are exceptional circumstances, councils should not impose flood related development controls on residential development on land above the residential FPL (low flood risk areas). However, the guideline does acknowledge that controls may need to apply to critical infrastructure (such as hospitals and airports) and consideration given to evacuation routes and vulnerable developments (such as aged care facilities and schools) in areas above the 1% AEP flood.

Based on the above requirements, the assessment of the impacts the project would have on existing flood behaviour and also the future development potential of flood affected land outside the project corridor relates to:

- all storms with AEPs up to 1% in intensity in the case of residential type development (and by default commercial and industrial type development)
- storms with AEPs greater than 1% in intensity in the case of critical infrastructure (such as hospitals) and vulnerable developments (such as aged care facilities and schools).

Environmental Planning and Assessment Act 1979

The Environmental Planning and Assessment Act 1979 (EP&A Act) and associated regulations set out the system of environmental planning and assessment for the state of New South Wales.

In July 2009 the NSW Minister for Planning issued a list of directions to local councils under section 117(2) of the EP&A Act. *Direction 4.3 - Flood Prone Land* applies to all councils that contain flood prone land within their LGA and requires that:

- A draft Local Environmental Plan (LEP) shall include provisions that give effect to and are consistent with the NSW Flood Prone Land Policy and the principles of the FDM (including the Guideline on Development Controls on Low Flood Risk Areas).
- A draft LEP shall not rezone land within the Flood Planning Areas from Special Use, Special Purpose, Recreation, Rural or Environmental Protection Zones to a Residential, Business, Industrial, Special Use or Special Purpose Zone.

- A draft LEP shall not contain provisions that apply to the Flood Planning Areas which:
  - Permit development in floodway areas
  - Permit development that will result in significant flood impacts to other properties
  - Permit a significant increase in the development of that land
  - Are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services or
  - Permit development to be carried out without development consent except for the purposes of agriculture (not including dams, drainage canals, levees, buildings or structures in floodways or high hazard areas), roads or exempt development.
- A draft LEP must not impose flood related development controls above the residential FPL for residential development on land, unless a council provides adequate justification for those controls to the satisfaction of the Director-General (or an officer of the Department nominated by the Director-General).
- For the purposes of a draft LEP, a council must not determine a FPL that is inconsistent with the FDM (including the Guideline on Development Controls on Low Flood Risk Areas) unless a council provides adequate justification for the proposed departure from that Manual to the satisfaction of the Director-General (or an officer of the Department nominated by the Director-General).

The above requirements and how they have been considered in the assessment are similar those outlined in the preceding section for *Guideline on Development Controls on Low Flood Risk Areas*.

Floodplain risk management guidelines

Scientific evidence shows that climate change is expected to lead to sea level rise and an increase in flood producing rainfall intensities. The significance of these effects on flood behaviour would vary depending on geographic location and local topographic conditions. Climate change impacts on flood producing rainfall events show a trend for larger scale storms and increased depths of rainfall. Future impacts on sea levels are likely to result in a continuation of the rise in levels which has been observed over the last 20 years.

The NSW Government's *Floodplain Risk Management Guideline: Practical Considerations of Climate Change* (DECC 2007) recommends that until more work is completed in relation to the climate change impacts on rainfall intensities, sensitivity analyses should be undertaken based on increases in rainfall intensities of between 10 and 30 per cent. Under current climatic conditions, increasing the 1% AEP design rainfall intensities by 10 per cent would produce about a 0.5% AEP flood; and increasing those rainfalls by 30 per cent would produce about a 0.2% AEP flood. On current projections the increase in rainfalls within the design life of the project is likely to be around 10 per cent, with the higher value of 30 per cent representing an upper limit.

Based on the recommendations set out in DECC 2007 the 0.5% AEP and 0.2% AEP design storms were adopted as being analogous to an increase in 1% AEP design rainfall intensities of 10 and 30 per cent respectively, for assessing the impact future climate change could have on flooding conditions in the vicinity of the project. This range of potential increases also encompasses the values given in ARR 2019, which suggests a potential increase in rainfall intensities of between 9.1% and 18.6% by 2090 for Representative Concentration Pathways of between 4.5 and 8.5.

Climate Change 2007: The Physical Science Basis. Summary for Policymakers (Intergovernmental Panel on Climate Change (IPCC) 2007)) includes trends that indicate that average global sea level rise (not including ice flow melt) may be between 0.18 to 0.59 metres by between 2090 and 2100. Adding to this the ice flow melt uncertainty of up to 0.2 metres gives an adjusted global range of 0.18 to 0.79 metres.

IPCC 2007 and recent CSIRO modelling (see for example *Projected Changes in Climatological Forcing Conditions for Coastal Erosion in NSW* (McInnes et al 2007)) indicates that mean sea levels along the NSW coast are expected to rise by more than the global mean. Combining the relevant global and local information indicates that sea level rise on the NSW coast is expected to be in the range of 0.18 to 0.91 metres by between 2090 and 2100.

In its *Floodplain Risk Management Guideline: Practical Considerations of Climate Change* (DECC 2007), the NSW Government recommended sensitivity analyses be undertaken to assess the potential impact of sea level rise in the range 0.18 to 0.91 metres, dependent on the relevant project time horizon.

In 2009 the NSW Government released its *Sea Level Rise Policy Statement* (NSW Government 2009) which supported adaptation to projected sea level rise impacts. The policy statement included sea level rise planning benchmarks for use in assessing potential impacts of projected sea level rise in coastal areas, including flood risk and coastal hazard assessment. These benchmarks were a projected rise in sea level (relative to 1990 mean sea level) of 0.4 metres by 2050 and 0.9 metres by 2100, based on work carried out by the IPCC and CSIRO. In its *Flood Risk Management Guide: Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments* (DECCW 2010), the NSW Government recommended that these benchmark rises should be used to assess the sensitivity of flood behaviour to future sea level rise.

In 2012 the NSW Government announced its *Stage 1 Coastal Management Reforms* (NSW Government 2012). As part of these reforms, the NSW Government no longer recommends state-wide sea level rise benchmarks, with local councils now having the flexibility to consider local conditions when determining local future hazards.

In the absence of a formal State Government policy on sea level rise benchmarks, the previously recommended rises in sea level of 0.4 metres by 2050 and 0.9 metres by 2100 have been adopted for assessing the impact future climate change could have on flooding conditions in the vicinity of the project.

2.1.3 Council policies and guidelines

Flood planning controls

The project is located in the former Botany Bay (now Bayside) local government area. The *Botany Bay Local Environmental Plan 2013*, which still applies to land located in the former Botany Bay local government area, does not include a "flood planning" clause. As a result, the FPL has not been defined for development located in the vicinity of the project.

For the purpose of this report it has been assumed that the FPL in the vicinity of the project is equal to the peak 1% AEP flood level plus an allowance of 0.5 metres for freeboard. This is consistent with the definition of the FPL that was adopted by the former Rockdale City Council, which now forms part of Bayside Council.

Drainage related standards

Bayside Council relies on the *Botany Development Control Plan 2013* to guide development in the former Botany Bay local government area in accordance with *Botany Bay Local Environmental Plan 2013*. These requirements include the provision of on-site detention in order to mitigate an increase in the quantity of runoff discharging into Council's receiving drainage system as a result of future development.

Notwithstanding the above council requirements, there would be a general requirement of the project to manage adverse changes to existing flow behaviour, should they occur. The assessment of flooding patterns under pre- and post-project conditions is presented in **Sections 4** and **5** of this report.

2.2 Secretary's environmental assessment requirements

The SEARs relevant to the flood assessment, together with a reference to where they are addressed in this report, are outlined in **Table 2.1**.

TABLE 2.1
SEARS RELEVANT TO THIS ASSESSMENT

Requirements	Where addressed in this report
General SEARs	
3. Assessment of Key Issues Key issue impacts are assessed objectively and thoroughly to provide confidence that the project will be constructed and operated within acceptable levels of impact.	
2. For each key issue the proponent must:	
a) describe the biophysical and socio-economic environment, as far as it is relevant to that issue;	**Section 4** contains a brief description of the catchments through which the project runs, as well as a description of flood behaviour in the vicinity of the project under pre-project conditions.
b) describe the legislative and policy context, as far as it is relevant to the issue;	**Section 2** sets out the relevant government legislation, policies and guidelines that were taken into consideration during the assessment.
c) identify, describe and quantify (if possible) the impacts associated with the issue, including the likelihood and consequence (including worst case scenario) of the impact (comprehensive risk assessment), and the cumulative impacts;	**Section 5** deals with the flood risks to the project and its impact on flood behaviour during the construction and operation of the project for a range of events up to the PMF. The chapter also presents the findings of an assessment of the potential impact of future climate change on flood behaviour, as well as the impact that a partial blockage of major hydraulic structures would have on flood behaviour in the vicinity of the project. The chapter also describes the potential cumulative impacts on flood behaviour that would result from the project in combination with other projects.

Requirements	**Where addressed in this report**
d) demonstrate how options within the project potentially affect the impacts relevant to the issue;	**Table 5.2** provides an overview of the key flood and drainage related features of the current design that formed the basis of the assessment. **Tables 5.4**, **5.5** and **5.6** provide a summary of the impacts that the project would have on flood behaviour, as well as options that would be developed further during detailed design that are aimed at mitigating residual impacts.
e) demonstrate how potential impacts have been avoided (through design, or construction or operation methodologies);	**Section 3.3** sets out the assessment criteria and standards that have been established to manage the risk of flooding to the project and the impact it would have on flood behaviour. **Sections 5.1** and **5.2** present the findings of an assessment of flood risks to the project and its impact on flood behaviour, while **Section 6** sets out requirements for the management of flood risks and impacts during future stages of the project.
f) detail how likely impacts that have not been avoided through design will be minimised, and the predicted effectiveness of these measures (against performance criteria where relevant); and;	**Tables 5.4**, **5.5** and **5.6** provide a summary of the impacts that the project would have on flood behaviour and identifies measures that will be developed further during detailed design that are aimed at mitigating residual impacts.
g) detail how any residual impacts will be managed or offset, and the approach and effectiveness of these measures.	**Sections 6.2** and **6.3** set out the requirements for managing residual impacts of the project on flood behaviour during the construction and operational phases of the project.
Key Issue SEARs	
6. Flooding The project minimises adverse impacts on existing flooding characteristics. Construction and operation of the project avoids or minimises the risk of, and adverse impacts from, infrastructure flooding, flooding hazards, or dam failure.	
1. The Proponent must assess and (model where required) the impacts on flood behaviour during construction and operation for a full range of flood events up to the probable maximum flood (taking into account sea level rise and storm intensity due to climate change) including:	**Section 3** sets out the approach that was adopted to assess the impact the project would have on flood behaviour during both its construction and operation. **Section 3.4** describes the methodology that was used to model flood behaviour under pre-project conditions, while **Sections 3.5** and **3.6** describe the methodology adopted to assess the impact of the project on flood behaviour during its construction and operation, respectively. **Section 3.7** sets out the approach that was adopted to assess the impact that future climate change would have on flood behaviour. **Sections 5.1** and **5.2** present the findings of the assessment of impacts during the construction and operation of the project, respectively.
a) any increases in the potential flood affectation of other properties, assets and infrastructure;	**Sections 5.1.2** and **5.2.1** present the findings of an assessment of the potential impacts on flood behaviour during the construction and operational phases of the project, respectively.

Requirements	Where addressed in this report
b) consistency (or inconsistency) with applicable Council floodplain risk management plans and Rural Floodplain Management Plans;	**Section 5.2.2** presents the findings of a review of the project in terms of its consistency with council floodplain risk management plans.
c) compatibility with the flood hazard of the land	**Section 4.3** describes the existing flood behaviour in the vicinity of the project, including an overview of the provisional flood hazard for a 1% AEP flood. **Section 5.2.2** includes discussion on the findings of the assessment in terms of the impact the project would have on the hazard categorisation of the floodplain.
d) compatibility with the hydraulic functions of flow conveyance in flood ways and storage areas of the land;	**Section 4.3** describes the existing flood behaviour in the vicinity of the project, including an overview of the hydraulic categories for a 1% AEP flood. **Section 5.2.1** and **Table 5.3** includes discussion on the findings of the assessment in terms of the impact the project would have on the hydraulic functions of flow conveyance and floodplain storage.
e) adverse effects to beneficial inundation of the floodplain environment, on, adjacent to or downstream of the project;	Given the largely urbanised nature of the floodplain, this requirement would be mainly relevant to Mill Stream. **Table 5.6** presents the findings of an assessment of more general impacts of the project on changes in the extent and duration of inundation including impacts to Mill Stream. A summary of key findings is provided in **Section 5.2.1**.
f) downstream velocity and scour potential;	**Section 5.2.1** and **Table 5.4** presents the findings of an assessment of the impact the project would have on flood behaviour, including changes in flow, flow velocity and scour potential.
g) 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 5.2.2** presents the findings of a review of the project in terms of its impact on the emergency management arrangements and measures for managing flood risk that are set out in the _Mascot, Rosebery and Eastlakes Floodplain Risk Management Study & Plan_ (Royal Haskoning DHV (RH DHV) 2017). Consultation has been undertaken with State Emergency Services and Bayside Council during the preparation of the EIS, details of which are set out in Section 4.2.1 of Chapter 4 (Consultation) of the EIS. **Section 6.1** sets out recommendations for further consultation with State Emergency Services and relevant councils during the detailed design phase of the project.
h) any impacts the development may have on the social and economic costs to the community as consequence of flooding.	**Section 5.2.1** and **5.2.2** present the findings of an assessment of the impact the project would have on flood behaviour, including consideration of social impacts (such as impacts on emergency response arrangements and flood risk to persons) and economic impacts (such as the potential for increases in flood damages in adjacent development).
2. The assessment should take into consideration any flood studies undertaken by local government councils and State government agencies.	**Section 3.4** contains details of previous flood studies that were considered as part of the present investigation.

Requirements	Where addressed in this report
3. The EIS must include maps illustrating the following features relevant to flooding as described in the NSW Floodplain Development Manual (2005):	Figures containing maps of features relevant to flooding are listed below.
a) flood prone land;	**Figure 4.5** (3 sheets) shows the extent of flood prone land in the vicinity of the project (i.e. the extent of land that is susceptible to flooding during a Probable Maximum Flood (PMF) event).
b) flood planning areas and any areas below the flood planning level;	**Figure B.6** (3 sheets) in **Annexure B** shows the extent of land which is located below the 1% AEP flood level plus 0.5 m, which is defined in the Rockdale Local Environmental Plan 2011 (RCC 2011) as the Flood Planning Level.
c) hydraulic categorisation (floodways and flood storage areas); and	**Figure B.7** (3 sheets) in **Annexure B** shows a preliminary hydraulic categorisation of the 1% AEP design flood into floodway, flood storage and flood fringe areas.
d) flood hazard.	**Figure B.8** (3 sheets) in **Annexure B** shows a provisional hazard categorisation of the 1% AEP design flood into high and low hazard.
7. Water - Hydrology Long term impacts on surface water and groundwater hydrology (including drawdown, flow rates and volumes) are minimised. The environmental values of nearby, connected and affected water sources, groundwater and dependent ecological systems including estuarine and marine water (if applicable) are maintained (where values are achieved) or improved and maintained (where values are not achieved). Sustainable use of water resources.	
1. 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.	**Section 4.2** describes the catchments within the study area, while **Section 4.3** provides an overview of the flooding patterns in the vicinity of the project under present day (i.e. pre-project) conditions. **Figures 4.1** and **4.2** contain maps that shows the extent of each catchment within the study area. Refer **Technical Working Paper: Groundwater** and **Technical Working Paper: Surface water quality** of the EIS for further details of the existing groundwater and surface water regimes, respectively.
2. 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:	**Section 3** describes the methodology that was used to define flood behaviour under present day (i.e. pre-project) conditions and to assess the impact of the project on flood behaviour during its construction and operation. Refer **Technical Working Paper 8** (Surface water quality) and **Technical Working Paper 7** (Groundwater) of the EIS for further details of the assessment of the impact of the construction and operation of the project on surface water and groundwater hydrology, respectively.

Requirements	Where addressed in this report
a) Natural processes within rivers, wetlands, estuaries, marine waters and floodplains that affect the health of the fluvial, riparian, estuarine or marine system and landscape health (such as modified discharge volumes, durations and velocities), aquatic connectivity and access to habitat for spawning and refuge;	**Section 5.2.1** contains an assessment of the impact the project would have on flooding patterns, including changes in flow velocities and the duration of inundation during a flood event. Refer **Technical Working Paper: Surface water quality** and **Technical Working Paper: Biodiversity** of the EIS for further details of the assessment of impacts on natural processes within rivers, wetlands and floodplains that are crossed by the project.
b) impacts from any permanent and temporary interruption of groundwater flow, including the extent of drawdown, barriers to flows, implications for groundwater dependent surface flows, ecosystems and species, groundwater users and the potential for settlement;	Not addressed in this report. Refer **Technical Working Paper: Groundwater** of the EIS.
c) 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 5.1.2** and **Table 5.1** include a summary of the potential impact that the construction of the project would have on flow velocities during a flood event. **Section 5.2.1** and **Tables 6.4** and **6.5** present the findings of an assessment of the impact that the operation of the project would have on flow velocities, as well as the duration of inundation during a flood event. Refer **Technical Working Paper: Surface water quality** of the EIS for further assessment of the impact of the project on the surface water attributes, including volumes.
d) water take (direct or passive) from all surface and groundwater sources with estimates of annual volumes during construction and operation.	Not addressed in this report. Refer **Technical Working Paper: Groundwater** and **Technical Working Paper: Surface water quality** of the EIS for an assessment of water take from groundwater and surface water sources, respectively.
3. The Proponent must identify any requirements for baseline monitoring of hydrological attributes.	Not addressed in this report. Refer **Technical Working Paper: Surface water quality** of the EIS for identified requirements for baseline monitoring of surface water related hydrologic attributes, respectively.
4. The assessment must include details of proposed surface and groundwater monitoring.	Not addressed in this report. Refer **Technical Working Paper: Groundwater** and **Technical Working Paper: Surface water quality** of the EIS for details of the proposed groundwater and surface water monitoring, respectively.

3 METHODOLOGY

This section describes the methodology used to undertake the flooding assessment.

3.1 Study area

The project is located within the following two catchments:

- Alexandra Canal
- Mill Stream

Each catchment is mapped and described in **Section 4.2**. Alexandra Canal forms part of the larger Cooks River catchment, while the Cooks River and Mill Stream both drain to Botany Bay.

3.2 Key tasks

The key tasks comprising the flood assessment were broadly as follows:

- Review of available data and existing flood studies within the catchments that are crossed by the project
- Development of a set of hydrologic and hydraulic models (collectively referred to as 'flood models') of the catchments that are located within the study area
- Flood modelling and preparation of exhibits showing flood behaviour under present day (ie pre-project) conditions for design floods with AEPs of 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2%, as well as the PMF
- Assessment of the potential impact the project (both during its construction and operation) would have on flood behaviour for the aforementioned design flood events
- Assessment of the impact future climate change would have on flood behaviour under operational conditions
- Assessment of the impact a partial blockage of major hydraulic structures would have on flood behaviour under operational conditions
- Assessment of potential measures which aim to mitigate the risk of flooding to the project and its impact on existing flood behaviour.

The followings sections of this report set out the methodology which was adopted in the assessment of flood behaviour under pre-project conditions and during both the construction and operational phases of the project.

3.3 Summary of adopted assessment criteria and standards

Table 3.1 sets out the flood related assessment criteria and standards that have been established for the project with due consideration of the policies and guidelines outlined in the preceding sections of this report.

In accordance with the FDM, the hydrologic standards adopted are based on matching the level of protection to the likelihood and consequence of flooding. A merits based approach has been adopted in the assessment of the impacts the project would have on existing flood behaviour and also in the development of a range of potential measures which are aimed at mitigating its impact on the existing environment.

TABLE 3.1
SUMMARY OF ADOPTED ASSESSMENT CRITERIA AND STANDARDS

Aspect	Requirement
Flood risks to the project	
Impact of flooding on proposed construction activities	• Construction related flood risks need to be evaluated in the context of the construction period in order to set requirements that are commensurate to the period of time that the risk exposure occurs. To this end, this report identifies the risks associated with each construction activity such that informed decisions can be made on the flood criteria that are set as part of the Construction Environmental Management Plan (CEMP) for the project.
Duplication of the existing rail line	• As a minimum, the modification and duplication of the existing rail line are to be configured to ensure the existing level of flood immunity (ie the magnitude of flood that does not cause inundation to the track and its ballast layer) is not reduced by the project. • Ideally, the modification and duplication of the existing rail line is to provide a minimum 1% AEP level of flood immunity in accordance with ARTC standards.
Bridge waterway crossings	• Bridge waterway crossings are to provide a minimum clearance of 0.5 metres between the underside of the bridge structure and the 1% AEP flood level.
System and control network	• Rail location cabinets (LOCs) for housing communications, power and signalling equipment for the system and control network would be located a minimum 0.5 metres above the 1% AEP flood level in accordance with ARTC standards.
New corridor access roads	• A 10% AEP level of flood immunity would be adopted for new access roads. • Consideration is to also be given to the flood risk to ARTC staff during larger floods (e.g. 1% AEP event) as a result of high hazard flooding conditions.
Impact of future climate change on flooding to the project	• The assessment of the potential impact future climate change could have on flood behaviour in the vicinity of the project was based on: o Increases in 1% AEP design rainfall intensities ranging between 10 and 30 per cent in accordance with the NSW Government's *Floodplain Risk Management Guideline: Practical Considerations of Climate Change* (DECC 2007)[1] o Rises in sea level of 0.4 metres by 2050 and 0.9 metres by 2100 based on the NSW Government's *Sea Level Rise Policy Statement* (NSW Government 2009)
Impact of the project on flood behaviour	
Impact of construction activities on flood behaviour	• Construction related flood impacts need to be evaluated in the context of the construction period in order to set requirements that are commensurate to the period of time that the exposure to the potential impacts occurs. To this end, this report identifies the potential impacts associated with each construction activity such that informed decisions can be made on the flood criteria that are set as part of the CEMP for the project.
Impact of project on flood behaviour in existing development	• Floods up to 1% AEP in magnitude are to be considered in the assessment of measures that are required to mitigate any adverse impacts on flood behaviour attributable to the project. • Changes in flood behaviour under larger floods up to the PMF event are also to be assessed in order to identify impacts on critical infrastructure (such as hospitals) and vulnerable development (such as aged care facilities and schools), as well as to identify potentially significant changes in flood hazard as a result of the project.

Aspect	Requirement
Impact of the project on flood behaviour under future climate change conditions	• The assessment of the impact the project would have on flood behaviour under future climate change conditions was based on assessing the effect of the project on pre-project flood behaviour during a 0.5 % and 0.2 % AEP event.[1]

1. For the purpose of this assessment the 0.5% and 0.2% AEP events were adopted as being analogous to increases in 1% AEP design rainfall intensities of 10 and 30 per cent, respectively.

3.4 Definition of pre-project flooding and drainage patterns

In order to define the nature of flooding in the vicinity of the project it was necessary to develop a set of computer-based flood models. Both the RAFTS and DRAINS rainfall-runoff modelling software packages were used to generate design discharge hydrographs for input to the hydraulic model, while flooding patterns in the vicinity of the project were defined using the TUFLOW two-dimensional (in plan) hydraulic modelling software.

Annexure A of this technical working paper contains background to the development and testing of the RAFTS, DRAINS and TUFLOW models (collectively referred to as 'flood models') that were used to define flood behaviour in the vicinity of the project.

Coincident catchment and ocean flooding conditions were assessed in order to derive design flood envelopes. Site specific ocean level data was used to define peak ocean water levels for ocean floods ranging between 20% (1 in 5) and 1% (1 in 100) AEP (as opposed to the simplistic approach of adopting the default storm tide hydrographs recommended in OEH's guideline *Flood Risk Management Guide: Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments* (DECCW 2010)). An estimate of the peak storm tide level which would be reached for an extreme ocean flood event was also derived by extrapolation of the site specific data. **Section A4.5** in **Annexure A** of this technical working paper contains further background to the derivation of storm tide hydrographs which were used for defining design flood levels.

Results from the TUFLOW model were compared to peak flood levels presented in the *Mascot, Rosebery and Eastlakes Flood Study* (WMAwater 2015) and the *Airport Flood Study* (AECOM 2018).

Flood behaviour in the vicinity of the project was defined for a range of events with AEPs of between 50% and 0.2%, as well as the PMF. Figures were prepared for each event showing the indicative extent and depth of inundation, as well as the direction and relative velocity of flow. Figures were also prepared showing the hydraulic and hazard categorisation during a 1% AEP event, which were defined using the procedures set out in the *Floodplain Development Manual* (DIPNR, 2005).

A description of flood behaviour in the vicinity of the project under pre-project conditions is presented in **Section 4.3**, while a summary of the figures that show flooding behaviour under pre-project conditions is contained in **Section 4.3.1**.

3.5 Assessment of construction related impacts

A qualitative assessment was made of the construction related issues associated with flooding along the rail corridor based on indicative construction areas and activities as provided in the current design. The locations of surface works, construction compounds, materials storage and crane pads were overlaid onto the indicative flood extents for events with AEPs of 50%, 10%, 5% and 1%, as well as the PMF. This provided an understanding of the likelihood that flooding could occur in the vicinity of construction activities.

The potential flood risk to construction activities, as well as their impact on existing flood behaviour were assessed using the hydraulic and hazard categorisation of flooding that were defined for pre-project conditions during a 1% AEP event. [2] Consideration was also given to the potential for localised overland flooding to occur in areas of proposed construction.

Section 5.1 of this report deals with the impact that flooding could have on construction activities. It also includes an assessment of the impact that construction activities could have on flood behaviour external to the project footprint.

3.6 Assessment of operational related impacts

The structure of the TUFLOW model that was originally developed to define flood behaviour under pre-project conditions was adjusted to incorporate details of the project under operational conditions. The results of modelling a range of events with AEPs of between 50% and 0.2%, as well as the PMF were used to prepare a series of figures showing flooding patterns under operational conditions and afflux diagrams[3] showing the impact the project would have on flood behaviour.

Details of the current design arrangements that were incorporated into the hydraulic models used to define flood behaviour in the vicinity of the project are summarised in **Table 5.2**, while a discussion on the impacts that the project would have on flood behaviour during its operation is contained in **Section 5.2.1**.

3.7 Impact of future climate change on flood behaviour

The following sections describe the approach that was adopted to assess the potential impact of future climate change on flooding to the project, as well as the impact that the project may have on flood behaviour under future climate change conditions. The findings of this assessment are contained in **Section 5.2.3** of this technical working paper.

[2] While the 1% AEP event has been adopted for the purpose of the preliminary assessment, as per the design criteria set out in **Table 3.1**, the management of flood impacts during the construction of the project will need to consider the period of risk exposure in establishing an appropriate flood standard.

[3] Afflux is an increase in peak flood levels caused by a change in floodplain or catchment conditions. A positive afflux represents an increase and conversely a negative afflux represents a decrease in peak flood levels when compared to pre-project conditions.

3.7.1 Impact of future climate change on flooding to the project

Based on the adopted assessment criteria set out in **Table 3.1**, the following scenarios were adopted as being representative of the likely lower and upper estimates of future climate change related impacts over the design life of the project:

- Scenario 1 – based on an assumed 10 per cent increase in currently adopted design rainfall intensities, together with a rise in sea level of 0.4 metres.
- Scenario 2 – based on an assumed 30 per cent increase in currently adopted design rainfall intensities, together with a rise in sea level of 0.9 metres.

Table 3.2 shows the combination of catchment and coincident storm tide conditions that were used to define the 1% AEP design flood envelopes under Scenario 1 and 2 climatic conditions.

TABLE 3.2
DERIVATION OF DESIGN FLOOD ENVELOPES FOR ASSESSMENT OF POTENTIAL CLIMATE CHANGE IMPACTS – 1% AEP EVENT

Scenario	Local catchment flood	Downstream boundary condition in Botany Bay(1,2)
Current Conditions	1% AEP	5% AEP peak storm tide level [1.63 m AHD]
Scenario 1	Based on 1% AEP rainfall intensities increased by 10%(3)	5% AEP peak storm tide level plus 0.4 m [2.03 m AHD]
Scenario 2	Based on 1% AEP rainfall intensities increased by 30%(3)	5% AEP peak storm tide level plus 0.9 m [2.53 m AHD]

1 Values in [ ] relate to adopted peak storm tide level.
2 All values include 0.25 m increase to allow for additional storm related components such as wind stress and wave action.
3 Design rainfall intensities for the 0.5% and 0.2% AEP events were adopted as being analogous to the 1% AEP design rainfall intensities increased by 10 per cent and 30 per cent, respectively.

3.7.2 Impact of the project on flood behaviour under future climate change conditions

The predicted impact that the project may have on flood behaviour under potential future climate change conditions was based on assessing its effect on pre-project flood behaviour during a 0.5% and 0.2% AEP event as proxies for assessing the sensitivity to an increase in rainfall intensity on the 1% AEP event due to future climate change.

3.8 Impact of a partial blockage of major hydraulic structures on flood behaviour

The assessment of the impact that a partial blockage of major hydraulic structures may have on flood behaviour was based on guidance provided in ARR 2019, as well as *AR&R Revision Projects – Project 11 – Blockage of Hydraulic Structures* (IEAust 2013).

In regards culvert structures, IEAust 2013 recommends the adoption of a 20 per cent blockage factor where the height of a culvert is less than three metres or its width is less than five metres, while ARR 2019 recommends that the adopted blockage factor be based on the size of the largest 10% of debris relative to the size of the waterway opening; the availability, mobility and transportability of the debris; and the magnitude of the flood event.

With due consideration to these guidelines, the structure of the hydraulic model was adjusted to include a 20 per cent blockage factor which was applied to all transverse drainage culvert structures along the rail corridor (ie culvert structures that convey runoff from the catchments upstream of the rail corridor).

The impact an accumulation of debris on existing and proposed bridge structures over Mill Stream was also assessed given the potential impact on flood behaviour in the vicinity of the project. The impact a one metre thick raft of debris lodged beneath the underside of the existing bridge structures, in combination with a four metre wide raft of debris lodged on the upstream side of each pier over the full height of the clear opening, was assessed as part of the investigation. The findings of the blockage related impact assessment are contained in **Section 5.2.4**.

4 EXISTING ENVIRONMENT

4.1 Overview

The following catchments contribute runoff to the existing drainage systems and waterways that are located within the project footprint (refer **Figure 4.1**):

- Alexandra Canal
- Mill Stream

Alexandra Canal forms part of the larger Cooks River catchment. Both the Cooks River and Mill Stream drain to Botany Bay. Each system is described separately in **Section 4.2** with information regarding the source of flows in the existing drainage lines that cross the rail corridor, while **Section 4.3** provides a description of the nature of main stream flooding and major overland flow in the vicinity of the project under present day (ie pre-project) conditions. Main stream flooding and major overland flow have collectively been termed 'flooding' within this report.

4.2 Catchment description

4.2.1 Alexandra Canal

Alexandra Canal is a major tributary of the Cooks River. The original creek was widened in the late 1800's over about a four kilometre length to form the Alexandra Canal. The size of the catchment draining to the canal increases from about 6.6 square kilometres (660 hectares) at its northern (upstream) end near Sydney Park Road, to about 17.7 square kilometres (1,770 hectares) at its confluence with the Cooks River. **Figure 4.1** shows the extent of the catchment which drains to Alexandra Canal upstream of its confluence with the Cooks River.

The Alexandra Canal catchment is located within the suburbs of Alexandria, Rosebery, Tempe, Erskineville, Beaconsfield, Zetland, Waterloo, Redfern, Newtown, Eveleigh, Surry Hills and Moore Park.

Land use within the catchment comprises medium and high density residential, commercial and industrial development. More significant areas of open space include Sydney Park, Moore Park Playing Fields, Moore Park golf course, The Australian golf course and Alexandria Park.

Figure 4.2, sheet 2 shows that the section of the project footprint between Lancastrian Road and a location about 160 metres east of O'Riordan Street is located within the Alexandra Canal catchment. The existing drainage along the rail corridor generally comprises informal open drains and overland flowpaths that convey runoff to the receiving drainage lines. Existing drainage lines in the vicinity of the project footprint comprise the following:

- A Sydney Water owned trunk drainage line comprising box culvert and concrete lined channel sections runs in an easterly direction from John Curtin Reserve, across O'Riordan Street and along the northern side of the existing rail corridor and ultimately discharges into Alexandra Canal to the north of the rail line. The trunk drainage line controls runoff from a significant portion of the suburb of Mascot to the north of the existing rail corridor.
- A 525 millimetre diameter piped drainage line crosses the existing rail corridor at King Street where it runs in a westerly direction along Qantas Drive and discharges into a trunk drainage line at Lancastrian Road. The trunk drainage line continues in a westerly

direction across Qantas Drive and the rail line where it discharges into Alexandra Canal via two 1,500 millimetre diameter pipes.

- A series of piped drainage lines with diameters between 300 and 750 millimetres run in a westerly direction across the existing rail corridor and adjacent section of Qantas Drive between Ewan Street and O'Riordan Street where they discharge into a pond that is located within the northern portion of Sydney Airport (denoted "Northern pond 1" on **Figure 4.2**, sheet 2). Northern pond 1 drains across Airport Drive via seven 1050 millimetre diameter pipes into a second pond that is located on the southern bank of Alexandra Canal (denoted "Northern pond 2" on **Figure 4.2**, sheet 2).[4] The piped drainage lines control runoff from Qantas Drive and the existing rail corridor, as well as the urbanised catchment to its north.

4.2.2 Mill Stream

The Mill Stream catchment extends from Centennial Park in the north to its outlet into Botany Bay in the south. The catchment draining to Mill Stream is about 20 square kilometres (2,000 hectares) at Foreshore Drive. The upper reach of the catchment is located within the Randwick City Council, City of Sydney and Waverley LGAs, while the lower reach is located within the Bayside Council LGA. The catchment includes the suburbs of Centennial Park, Queens Park, Kensington, Randwick, Kingsford, Daceyville, Eastlakes, Rosebery, Mascot, Pagewood and Botany.

Land use within the catchment predominantly comprises medium and high density residential and commercial development. More significant areas of development are located within the Entertainment Quarter, the University of New South Wales and the town centres of Randwick and Kingsford. Areas of open space include Centennial Park and Randwick Racecourse in the upper reaches of the catchment, and The Lakes, Eastlake and Bonnie Doon golf courses in the lower reaches of the catchment.

Mill Stream comprises a vegetated channel where it runs in a southerly direction through Eastlake golf course from Gardeners Road and feeds a series of interconnected freshwater ponds that are referred to as the Botany Wetlands. The section of Botany Wetlands between Eastlake golf course and Botany Road is owned and maintained by Sydney Water under the *Plan of Management – Botany Wetlands 2018 – 2028* (Sydney Water 2018).

Wentworth Avenue, the Botany Line, Botany Road and Foreshore Drive are located on bridge structures where they cross Mill Stream and the ponds that form the Botany Wetlands.

A weir structure is located 120 metres downstream of Botany Road that controls water levels in the section of watercourse extending to the Botany Line, while a second weir structure that is located upstream of Foreshore Drive controls water levels in the section of watercourse extending to the first weir.

Mill Stream comprises a man-made channel where it runs along the eastern side of Sydney Airport from Foreshore Drive to its outlet into Botany Bay.

Figure 4.2, sheets 2 and 3 show that the section of the project footprint between a location about 160 metres east of O'Riordan Street and Stephen Road is located within the Mill Stream catchment. The existing drainage along the rail corridor generally comprises informal open drains

[4] Northern pond 1 and 2 are collectively referred to as 'the Northern ponds'.

and overland flowpaths that convey runoff to the receiving drainage lines. Existing drainage lines in the vicinity of the project footprint comprise the following:

- A 2,400 millimetre wide by 1,800 millimetre high box culvert which crosses the existing rail corridor to the south of General Holmes Drive where it discharges into a concrete lined channel. The box culvert controls runoff from the urbanised portions of the suburbs of Mascot and Eastlakes to the east of O'Riordan Street. The concrete lined channel, which is denoted 'Ascot Drain' on **Figure 4.2**, sheets 2 and 3, runs for about 600 metres and discharges into Mill Stream to the south of Southern Cross Drive.
- Two piped drainage lines comprising 525 and 1,200 millimetre diameter pipes cross the existing rail corridor to the north of General Holmes Drive where they discharge into an 1,800 millimetre diameter pipe that runs in a southerly direction along the western side of the rail corridor. The 1,800 millimetre diameter pipe discharges into the aforementioned 2,400 millimetre wide by 1,800 millimetre high box culvert to the south of General Holmes Drive.
- Two piped drainage lines comprising 1,200 and 1,500 millimetre diameter pipes that have been constructed as part of the Airport East project cross the existing rail corridor between Wentworth Avenue and Bronti Street where they discharge into Ascot Drain on its eastern bank.
- A vegetated channel that runs along the eastern side of the existing rail line between Banksia Street and Myrtle Street controls runoff from the urbanised catchment to its east. Piped drainage lines discharge into the channel on its eastern bank at Banksia Street and Bay Street. The channel discharges into a 1,050 millimetre diameter pipe that crosses the rail corridor at Myrtle Street where it runs in a southwesterly direction and ultimately discharges into Mill Stream to the north of Foreshore Drive.

4.3 Description of existing flooding and drainage behaviour

4.3.1 General

The following sections of the report provide a brief description of patterns of both main stream flooding and major overland flow under pre-project conditions. The following figures are also referred to in the following discussion:

- **Figures 4.3, 4.4** and **4.5** (3 sheets each) show the indicative extent and depth of inundation in the vicinity of the project footprint for a 10% and 1% AEP event, as well as the PMF event, respectively.
- **Annexure B** contains a series of figures that show patterns of main stream flooding and major overland flow in the vicinity of the project for 50%, 5%, 2%, 0.5% and 0.2% AEP events. **Annexure B** also contains a series of figures that show the extent of land which is located below the 1% AEP flood level plus 0.5 metres, as well as the preliminary hydraulic categorisation and provisional hazard of land for a 1% AEP storm event.

4.3.2 Alexandra Canal

For the purpose of describing existing flood behaviour in the Alexandra Canal catchment, the following discussion has been limited to major overland flow in the vicinity of the section of the project corridor that runs between Lancastrian Road and O'Riordan Street.

During a 10% AEP event, flooding to the concrete lined channel that runs along the northern side of the rail corridor to the west of the Lancastrian Bridge would be mainly confined to its inbank area (ie the area of the channel below its top of bank levels). During a 2% AEP event, floodwater would surcharge the southern bank of the channel but would still be about 0.4 metres below the level of the adjacent rail line, reducing to 0.3 metres in a 1% AEP event. Floodwater that surcharges the channel would overtop the rail line to a depth of 0.6 metres during the PMF.

Flow that surcharges the stormwater drainage system in King Street during a 10% AEP event would pond in a low point that is located at its western end to a maximum depth of about 0.2 metres. During a 2% and 1% AEP event flow that ponds at the low point in King Street would discharge in a northerly direction along the western side of the rail corridor to a maximum depth of about 0.2 metres, increasing to 0.3 metres in the PMF.

During a 10% AEP event, flow that surcharges the stormwater drainage system in Ewan Street will pond in a low point that is located adjacent to the rail corridor to a maximum depth of about 0.9 metres. Flow that surcharges the drainage system would pond to a maximum depth of 1.1 metres during a 2% AEP event, which would still be about 1.8 metres below the level of the adjacent rail line. The depth of ponding would increase to 1.3 and 2.0 metres during a 1% AEP event and the PMF, respectively. The depth of ponding during events greater than about a 10% AEP event would be sufficient to result in hazardous flooding conditions to persons and property.

The rail line is on an elevated bridge structure where it crosses the low points in Robey Street and O'Riordan Street (denoted 'Robey Street Underpass' and 'O'Riordan Street Underpass' on **Figure 4.4**, sheet 2). While the rail line is not impacted by flooding up to the PMF, flow in excess of the capacity of the stormwater drainage system will pond at the low points in the Robey and O'Riordan Street Underpasses to between 0.7 and 0.9 metres during a 10% AEP event, and between 0.9 and 1.1 metres during a 1% AEP event. Similar depths of ponding would also occur at the low point in Qantas Drive that is located to the west of Robey Street (denoted 'Qantas Drive Sag' on **Figure 4.4**, sheet 2).

Flow surcharges the low point at Qantas Drive sag during a 10% AEP design storm where it discharges in a southerly direction into an adjoining carpark within Sydney Airport. Depths of inundation in the carpark occur to a maximum of 0.6 metres during a 10% AEP design storm, increasing to a maximum of 0.9 metres during a 1% AEP design storm.

During a 1% AEP event the depth of ponding at the Robey Street Underpass will result in flow discharging into the basement carpark of the Stamford Plaza Sydney Airport (Stamford Plaza) via the entrance that is located immediately to its east.

During a PMF event the depth of ponding at the O'Riordan Street Underpass will result in flow discharging into the basement carpark of the Stamford Plaza via a second entrance that is located immediately to its north.

Flooding was reported at the Robey Street Underpass during a storm that occurred on 7 September 2018. A photo that was taken during the storm indicated that the depth of ponding at the low point could have been in the order of 0.2 to 0.3 metres. An analysis of the rainfall that was recorded at Sydney Airport during this event is provided in **Section C1** of **Annexure C** of this technical working paper, which shows that for durations of between 30 minutes and 6 hours the storm was equivalent to less than a 1 Exceedance per Year (**EY**) event (i.e. its intensity was less than that of a storm that occurs once every year on average).

Flooding has also recently been reported at the low point in the O'Riordan Street Underpass during a storm that occurred on 28 November 2018. A video taken of the flooding to the underpass indicates that the depth of ponding at the low point could have been in the order of 0.5 metres. An analysis of the rainfall that was recorded at Sydney Airport during this event is also provided in **Section C2** of **Annexure C** of this technical working paper, which shows that for durations of between 30 minutes and 6 hours the storm was equivalent to a 1 EY event or less (i.e. its intensity was equal to or less than that of a storm that occurs once every year on average).

4.3.3 Mill Stream

For the purpose of describing existing flood behaviour in the Mill Stream catchment, the following discussion has been divided into:

- Main stream flooding along the main arm of **Mill Stream**.
- Major overland flow in the vicinity of the rail corridor where it runs between O'Riordan Street and Southern Cross Drive to the **west of Mill Stream**.
- Major overland flow in the vicinity of the rail corridor where it runs between Lord Street and Stephen Road to the **east of Mill Stream**.

Mill Stream:

i. The peak 1% AEP flood level at the bridge that spans Mill Stream (denoted Mill Stream bridge on **Figure 4.4**, sheet 3) is RL 6.0 metres AHD, which is about 1.5 metres below the underside of the bridge.

ii. Southern Cross Drive where it runs under the rail line to the west of Botany Road acts as an overland flowpath to convey flows that surcharge the section of Mill Stream within the Lakes Golf Club during events greater than about 2% AEP. During a 1% AEP event overland flow that is conveyed along Southern Cross Drive collects at the low point in Botany Road between Wentworth Avenue and Southern Cross Drive.

iii. A section of rail line about 220 metres to the east of the Mill Stream bridge would be inundated by overland flow that surcharges Mill Stream and discharges through the southern portion of the Lakes Golf Club during events greater than about 10% AEP. During a 2% AEP event the track ballast layer would be inundated to a maximum depth of 0.3 metres, increasing to 0.5 metres and 1.0 metre during a 1% AEP event and the PMF, respectively.

West of Mill Stream:

i. Flow that surcharges the drainage system in Baxter Road will collect at the low point that is located about 260 metres west of Botany Road where it would pond to a maximum depth of about 0.5 metres during a 10% AEP event, increasing to 1.1 metres during a 1% AEP event and 2.3 metres during the PMF. While the extent of inundation in a 1% AEP event would encroach onto the rail corridor it would not inundate the track or its ballast layer, whereas in the PMF the track would be overtopped to a maximum depth of 1.0 metre above top of rail level.

ii. A section of the existing track that is located 140 metres to the north of General Holmes Drive is impacted by local catchment runoff that collects at the low point in the rail corridor along its southern boundary. During a 10% AEP event, runoff that collects at the low point will overtop the track where it will discharge in a northerly direction toward Baxter Road.

iii. The rail underpass at Wentworth Avenue (denoted 'Wentworth Avenue Underpass' on **Figure 4.3**, sheet 3) that has been constructed as part of the Airport East project would be inundated by floodwater to a depth of about 0.5 metres during a 10% AEP event, increasing to 0.9 metres during a 1% AEP event and 2.4 metres during a PMF. While the design of the Airport East project includes a 6 metre by 6 metre inlet structure on the corner of Botany Road and Wentworth Avenue to intercept flow that surcharges the low point in Botany Lane, the results of the present investigation show that a significant portion of this surcharge flow will bypass the inlet pit to its east and west, where a portion of the flow will discharge to the Wentworth Avenue Underpass.

iv. During a 1% AEP event, a 150 metre length of Botany Road between Wentworth Avenue and Southern Cross Drive would be inundated by floodwater, including the section of road that runs under the rail line to the south of Bronti Street. Flooding occurs to a maximum depth of about 0.6 metres due to surcharge of the stormwater drainage system that crosses Botany Road between Wentworth Avenue and Bronti Street, as well as overland flow that is conveyed along Southern Cross Drive due to surcharge of Mill Stream.

East of Mill Stream:

i. Flow that surcharges the stormwater drainage system in Banksia Street will collect at its low point to the north of the rail corridor before discharging into the rail corridor. The depth of ponding in Banksia Street will occur to a maximum of 0.4 metres during a 10% AEP event, increasing to about 0.5 metres during a 1% AEP event. While the majority of flow that discharges into the rail corridor is conveyed along the vegetated channel that runs along its eastern side, during a 1% AEP event a portion of this flow will overtop the adjacent section of rail line, albeit to relatively shallow depths of 0.1 metres or less.

ii. Flow that surcharges the stormwater drainage system in Bay Street will collect at its low point to the north of the rail corridor before discharging into the vegetated channel that runs along the eastern side of the rail line during events more frequent than 50% AEP. The depth of ponding in Bay Street will occur to a maximum of 0.5 metres during a 10% AEP event, increasing to about 0.8 metres during a 1% AEP event. Flow that discharges into the rail corridor during a 1% AEP event combines with flow that originates in Banksia Street and is conveyed along the vegetated channel.

iii. Flow in the vegetated channel that runs along the eastern side of the rail line from Banksia Street would surcharge the inlet to the 1,050 millimetre piped drainage line where it crosses the rail corridor at Myrtle Street during events greater than about 10% AEP. Flow that surcharges the inlet of the 1,050 millimetre piped drainage line would discharge in a northerly direction toward the Eastlake golf course and combine with flow that surcharges Mill Stream.

iv. A section of the existing rail line that is located 150 metres to the north of Myrtle Street is impacted by local catchment runoff that collects at the low point in the rail corridor along its northern boundary. During a 10% AEP event, runoff that collects at the low point will overtop the rail line where it will discharge in a westerly direction toward Mill Stream.

5 IMPACT ASSESSMENT

This chapter deals with the flood risks to the project and its impact on flood behaviour during the construction and operation of the project. The chapter also describes the potential cumulative impacts on flooding patterns that would result from the project in combination with other projects in its vicinity.

5.1 Impacts during construction

This section provides an assessment of the flood risk associated with the construction of the project. For the purpose of this assessment the project corridor has been split into the following five areas of work that are identified in Chapter 7 (Construction) of the EIS (labelled work area (WA) 1 to 5 in this report for ease of reference):

- Cooks Loop work area (Lancastrian Road to Robey Street) (WA1)
- Robey Street to General Holmes Drive work area (WA2)
- General Holmes Drive to Botany Road work area (WA3)
- Botany Road to Southern Cross Drive work area (WA4)
- Southern Cross Drive to Banksia Street work area (WA5)

This section also provides an assessment of the flood risks associated with the six construction compounds (denoted C1 to C6), the eight material laydown and storage areas (denote MS1 to MS8) and four crane pads (denoted CP1 to CP4) that are identified within the construction work areas in Chapter 7 (Construction) of the EIS.

Figure 5.1 (3 sheets) shows the locations of the construction work areas, compounds, laydown and storage areas and crane pads that are referred to in this report.

This section also provides an overview of the potential impacts that the proposed construction activities could have on flood behaviour.

5.1.1 Potential flood risks at construction work areas

Without the implementation of appropriate management measures, the inundation of the construction work areas and their associated construction compounds by floodwater has the potential to:

- cause damage to the project works and delays in construction programming
- pose a safety risk to construction workers
- detrimentally impact the downstream waterways through the transport of sediments and construction materials by floodwaters
- obstruct the passage of floodwater and overland flow through ancillary works such as site sheds, stockpiles and some types of temporary fencing, which in turn could exacerbate flooding conditions in existing development located outside the construction footprint.

Table 5.1 at the end of this section provides a summary of the assessed flood risk at each construction work area and their associated activities. **Figure 5.1** (3 sheets) shows the extent to which floods of varying magnitude affect each construction work area, while **Figure 5.2** (6 sheets) shows the provisional flood hazard and preliminary hydraulic categorisation of the floodplain in the vicinity of each construction work area and compound for a 1% AEP flood event. Further details of each construction work area and its associated compounds is provided in Chapter 7 (Construction) of the EIS.

Construction compounds

Figure 5.1 (3 sheets) shows the location of six construction compounds (denoted C1 to C6) that are proposed to support construction across the work areas. Each construction compound would contain a range of site facilities that would include offices, staff amenities, parking and storage areas for plant, equipment and materials, as well as fencing and security facilities. **Table 5.1** provides a summary of the construction compounds within each work area.

The flood affectation of the six construction compounds can be summarised as follows:

- The northern portion of the King Street compound (C1) would be inundated by flow that surcharges the drainage system in King Street during events larger than 10% AEP.
- The Joyce Drive compound (C2) would be inundated along its western side due to flow that surcharges the drainage system in Robey Street and collects at the low point in the Robey Street Underpass during a 10% AEP event. Minor inundation would also occur along the eastern side of the compound due to flow that surcharges the drainage system in Joyce Drive during the same event.
- The General Holmes Drive compound (C3) is located on land that typically lies above the 1% AEP flood level, with the exception of localised flooding that occurs as a result of surcharge of the trunk drainage line that runs through the northern portion of the compound.
- The portion of the Botany Road compound (C4) to the north of Southern Cross Drive is located on land that lies above the 1% AEP flood level. The portion of the Botany Road compound (C4) that is located between the northbound and southbound carriageways of Southern Cross Drive would be inundated by overland flow that is conveyed along the roadway during a 1% AEP event as a result of flow that surcharge the section of Mill Stream within the Lakes Golf Club.
- The Mill Stream compound (C5) would be impacted by floodwater that surcharges the eastern bank of Mill Stream during a 10% AEP event. The extent of inundation would be confined to the western quarter of the site for events up to 1% AEP in magnitude.
- The Banksia Street compound (C6) is located on land that typically lies above the 1% AEP flood level with the exception of localised inundation that occurs along its middle portion due to surcharge of the cess drain that runs along its eastern side.

Site facilities located on the floodplain, particularly in areas of high hazard, pose a safety risk to construction personnel. It would therefore be necessary to locate site facilities outside high hazard areas with safe evacuation routes. All six construction compounds include land that is located outside areas of high hazard during a 1% AEP event that would be suitable for site facilities with the provision of appropriate flood mitigation measures and emergency response procedures.

Material laydown and storage areas

Figure 5.1 (3 sheets) shows the potential location of eight material storage areas (denoted MS1 to MS8). Construction compounds C3, C4 and C6 would also include areas for storage of materials and stockpiling. The areas would mainly be used for the storage of materials and equipment. The construction of the project would generate spoil which may also need to be temporarily stored in stockpile areas for reuse on site or haulage to an appropriately licensed facility.

Stored equipment and stockpiles located on the floodplain have the potential to obstruct floodwater and alter flooding patterns. Inundation of stockpile areas by floodwater can also lead to significant quantities of material being washed into the receiving drainage lines and waterways.

While all of the potential material storage areas are affected by flooding to varying degrees (refer **Table 5.1**), there would typically be areas outside the 10% AEP flood extent that could be used to stockpile material. The exceptions to this are:

- The material storage area at Qantas Drive to the north of Robey Street (MS1), which would be inundated to a depth of 0.3 metres over more than half of its area during a 10% AEP event.
- The material storage area at the western end of McBurney Street (MS4), which would be inundated to a depth of 0.1 to 0.2 metres over the majority of its area during a 50% AEP event.

The larger material storage areas may be located at General Holmes Drive (material storage area MS3) and at the Banksia Street compound (C6). Both of these areas are located outside the 1% AEP flood extent.

Earthworks

Earthworks will be required across all the construction work areas, which would include excavation to excavate formation subgrade and fill to expand embankments and support new retaining walls and bridge abutments.

The flood affectation of the proposed earthworks within each work area can be summarised as follows:

- The earthworks within the Cooks Loop work area (WA1) is located on land that typically lies above the 1% AEP flood with the exception of:
    - an area along its eastern side that would be impacted by overland flow that surcharges the drainage system in King Street during events greater than 10% AEP
    - an area along its western side that would be impacted by local catchment runoff that runs between the existing rail line and adjacent billboards.
- The earthworks within the Robey Street to General Holmes Drive work area (WA2) is located on land that typically lies above the 1% AEP flood, with the exception of an area to the north of General Holmes Drive that would be impacted by local catchment runoff that ponds along either side of the rail corridor.
- Minor earthworks proposed within the General Holmes Drive to Botany Road work area (WA3) would be located outside the 1% AEP flood extent.
- The earthworks within the Botany Road to Southern Cross Drive work area (WA4) would be located outside the 1% AEP extent.
- The earthworks within the Southern Cross Drive to Banksia Street work area (WA5) would be inundated during a 50% AEP event.

The inundation of the earthworks by floodwater has the potential to cause scour of disturbed surfaces and the transport of sediment and construction materials into the receiving waterways. It would therefore be necessary to plan, implement and maintain measures which are aimed at managing the diversion of floodwater either through or around the construction areas.

Bridge construction

The following six bridge structures are proposed to be constructed as part of the project:

- Robey Street bridge (comprising two bridges)
- O'Riordan Street bridge (comprising two bridges)
- Southern Cross Drive bridge
- Mill Stream bridge

The existing Botany Road bridge would be retained as part of the project and may involve some minor remediation works to the abutments, headstock and deck as required.

Figure 5.1 (3 sheets) shows the potential extent of temporary crane pads that would be provided at each of the four proposed bridge structures to support cranes that are required to install various bridge components including precast sections and beams (denoted CP1 to CP4).

The temporary crane pads at the Robey Street and O'Riordan Street bridges (CP1 and CP2) are located in areas that are impacted by overland flow during storms as frequent as 50% AEP, while the temporary crane pads at the Southern Cross Drive construction compound (CP3) are located in areas that are impacted by overland flow during a 1% AEP event. The temporary crane pads at Mill Stream bridge are located in areas that are impacted by mainstream flooding from Mill Stream during a 50% AEP event. Where feasible, the temporary crane pads would be located in areas that minimise the impact of flooding.

In order to construct the central pier for the Mill Stream bridge it will be necessary to install a temporary piling platform that would likely be located across part of the main channel of Mill Stream in an area that would be frequently inundated by flow. It would therefore be necessary to design and construct the temporary piling platform to manage the potential for scour and transport of material into Mill Stream, whilst also maintaining a passage for the conveyance of floodwater through the construction site.

5.1.2 Potential impacts of construction activities on flood behaviour

Construction activities have the potential to exacerbate flooding conditions when compared to both pre-project and operational conditions. This is because the construction activities typically impose a larger footprint on the floodplain due to the need to provide temporary structures, such as construction compounds, outside the operational project footprint which would be removed following the completion of construction activities.

A qualitative assessment was undertaken of the potential impacts that construction activities could have on flood behaviour, the key findings of which are summarised in **Table 5.1**.

While all construction work areas will involve works within the floodplain that will need to be managed, the assessment found that the greatest potential for adverse impacts on flood behaviour is due to the impact that the construction of the Mill Stream bridge and its associated Mill Stream construction compound (C5), proposed temporary crane pads (CP4) and temporary piling platforms could have on the conveyance of flow in Mill Stream. The works also have the potential to increase flow velocities and therefore scour and erosion potential in Mill Stream.

While the proposed temporary crane pads for the construction of the Robey Street and O'Riordan Street bridges (CP1 and CP2) have the potential to obstruct overland flow that is conveyed along the roadways, the temporary crane pads would only be in place during a short term rail possession period of around 48 hours. As a result, the potential for the pads to impact on flood behaviour would be managed by monitoring weather warnings to ensure that the works are not carried out should a weather warning be issued of impending flood producing rain.

There is also the potential for all construction activities to impact local catchment runoff, which would require appropriate local stormwater management controls to be implemented during the construction phase of the project.

While the findings of the assessment provide an indication of the potential impacts of construction activities on flood behaviour, further investigation would need to be undertaken during detailed design, as layouts and staging diagrams are further developed. Consideration would also need to be given to setting an appropriate hydrologic standard for mitigating the impacts of construction activities on flood behaviour, taking into account their temporary nature and therefore the likelihood of a flood of a given AEP occurring during the construction period.

Measures aimed at mitigating the impacts of construction activities on flood behaviour will be developed further during the detailed design phase and included in the Construction Environment Management Plan (CEMP) for the project. Further details on the range of measures which will be implemented to mitigate the potential construction related impacts of the project are outlined in **Section 6.2**.

TABLE 5.1
SUMMARY OF ASSESSED FLOOD RISKS AND POTENTIAL IMPACTS AT PROPOSED CONSTRUCTION WORK AREAS

Construction work area	Compounds / other areas[1]	Threshold of flooding[2]	Proposed construction activities[3]				Description of existing flood behaviour (pre-mitigation)	Potential impacts of construction activities on flood behaviour
			Site facilities[4]	Material storage and stockpiling[5]	Earthworks[6]	Bridge construction[7]		
Cooks Loop work area (WA1) (refer **Figure 5.1**, sheet 2)	King Street compound (C1)	2% AEP	✓	x	x	x	During a 2% AEP event more than half of the compound would be inundated by flow that surcharges the drainage system in King Street and discharges onto the rail corridor. Should a 1% AEP event occur during the construction phase of the project, then flow that surcharges the aforementioned drainage system would inundate the majority of the compound to a maximum depth of 0.1 m.	Site facilities and perimeter fencing have the potential to obstruct the conveyance of overland flow from King Street should a flood event equivalent to or greater than 2% AEP in magnitude occur during the construction phase of the project.
	Material storage area at Qantas Drive north of Robey Street (MS1)	10% AEP	x	✓	x	x	During a 10% AEP event the majority of the compound would be inundated by flow that collects at the low point in Qantas Drive to its south. Should a 1% AEP event occur during the construction phase of the project, then the compound would be inundated to a maximum depth of 0.7 m.	The storage of materials and stockpiling within this area has the potential to displace floodwater that discharges onto the site from Qantas Drive should a flood equivalent to or greater than 10% AEP in magnitude occur during the construction phase of the project.
	Other areas within WA1	More frequent than 50% AEP	x	✓	✓	x	The southern portion of the work area between the existing rail line	Construction activities within the southern portion of the work area

Construction work area	Compounds / other areas[1]	Threshold of flooding[2]	Proposed construction activities[3]				Description of existing flood behaviour (pre-mitigation)	Potential impacts of construction activities on flood behaviour
			Site facilities[4]	Material storage and stockpiling[5]	Earthworks[6]	Bridge construction[7]		
Cooks Loop work area (WA1) (refer **Figure 5.1**, sheet 2)							and Qantas Drive is inundated by overland flow that collects at the low point in Qantas Drive during events more frequent than 50% AEP. Should a 1% AEP event occur during the construction phase of the project, then the southern portion of the work area would be inundated to a maximum depth of 0.9 m.	between the existing rail line and Qantas Drive have the potential to displace floodwaters that discharge onto the site from Qantas Drive during events more frequent than 50% AEP.
Robey Street to General Holmes Drive work area (WA2) (refer **Figure 5.1**, sheet 2)	Joyce Drive compound (C2)	10% AEP	✓	x	x	x	During a 10% AEP event the northern portion of the site would be inundated by flow that surcharges the drainage systems in Qantas Drive and the Robey Street Underpass, albeit to relative shallow depths of less than 0.1 m. Should a 1% AEP event occur during the construction phase of the project, then about a half of the compound along its northern side would be inundated to a maximum depth of 0.4 m by flow that collects at the Robey Street Underpass.	While facilities located within the compound have the potential to displace floodwater that collects at the Robey Street Underpass, impacts on flood behaviour for events up to 1% AEP are likely to be minor given the extent and depth of inundation across the compound under pre-project conditions.
	Material storage area at Qantas Drive west of	1% AEP	✓	x	x	x	Should a 1% AEP event occur during the construction phase of the project, then a relatively localised area along	The potential impact of storing materials and stockpiling on flood behaviour for events up to 1% AEP

Construction work area	Compounds / other areas[1]	Threshold of flooding[2]	Proposed construction activities[3]: Site facilities[4]	Material storage and stockpiling[5]	Earthworks[6]	Bridge construction[7]	Description of existing flood behaviour (pre-mitigation)	Potential impacts of construction activities on flood behaviour
Robey Street to General Holmes Drive work area (WA2) (refer **Figure 5.1**, sheet 2)	O'Riordan Street (MS2)						the southern side of the material storage area would be inundated, albeit to relatively shallows depths of less than 0.1 m.	are likely to be minor given the depth and extent of inundation under pre-pre-project conditions.
	Material storage area at Joyce Drive west of General Holmes Drive (MS3)	0.2% AEP	x	✓	x	x	The material storage area is located on land that lies above the 1% AEP flood level.	The storage of materials and stockpiling in this area is not expected to impact on flood behaviour for events up to 1% AEP.
	Crane pads for Robey Street bridge (CP1)	More frequent than 50% AEP	x	x	x	✓	The area where the crane pads are proposed to be located is inundated by overland flow that surcharges the drainage system in Robey Street during events more frequent than 50% AEP. Should a 1% AEP event occur during the construction phase of the project, then the area where the crane pads are proposed to be located would be inundated to a maximum depth of 0.9 m.	The crane pads have the potential to obstruct the conveyance of overland flow and displace floodwater that collects at the Robey Street underpass during events more frequent that 50% AEP, leading to an increase in depth of inundation in the adjacent roadway and the potential for flooding to adjacent development. As the crane pads would only be in place during a short term rail possession of about 48 hours, their potential impact on flood behaviour can be managed by monitoring weather warnings to ensure that the works are not carried out should a weather warning be issued of

Construction work area	Compounds / other areas(1)	Threshold of flooding(2)	Proposed construction activities(3)				Description of existing flood behaviour (pre-mitigation)	Potential impacts of construction activities on flood behaviour
			Site facilities(4)	Material storage and stockpiling(5)	Earthworks(6)	Bridge construction(7)		
Robey Street to General Holmes Drive work area (WA2) (refer **Figure 5.1**, sheet 2)								impending flood producing rain.
	Crane pads for O'Riordan Street bridge (CP2)	More frequent than 50% AEP	x	x	x	✓	The area where the crane pads are proposed to be located is inundated by overland flow that surcharges the drainage system in O'Riordan Street during events more frequent than 50% AEP. Should a 1% AEP event occur during the construction phase of the project, then the area where the crane pads are proposed to be located would be inundated to a maximum depth of 0.8 m.	The crane pads have the potential to obstruct the conveyance of overland flow and displace floodwater that collects at the Robey Street underpass during events more frequent that 50% AEP. As the crane pads would only be in place during a short term rail possession of about 48 hours, their potential impact on flood behaviour can be managed by monitoring weather warnings to ensure that the works are not carried out should a weather warning be issued of impending flood producing rain.
	Other areas within WA2	More frequent than 50% AEP	x	✓	✓	x	An area to the north of General Holmes Drive is impacted by local catchment runoff that ponds either side of the existing rail line during events as frequent as 50% AEP.	Activities within the area to the north of General Holmes Drive has the potential to displace runoff that ponds within the rail corridor.

Construction work area	Compounds / other areas[(1)]	Threshold of flooding[(2)]	Proposed construction activities[(3)]				Description of existing flood behaviour (pre-mitigation)	Potential impacts of construction activities on flood behaviour
			Site facilities[(4)]	Material storage and stockpiling[(5)]	Earthworks[(6)]	Bridge construction[(7)]		
General Holmes Drive to Botany Road work area (WA3) (refer **Figure 5.1**, sheet 3)	General Holmes Drive compound (C3)	10% AEP	✓	x	x	x	During a 10% AEP event a localised area would be inundated by flow that surcharges the trunk drainage line that runs through the northern portion of the compound. Should a 1% AEP event occur during the construction phase of the project, then inundation would occur to a maximum depth of 0.1 m due to flow that surcharges the aforementioned trunk drainage line.	The potential impact of facilities located within the compound on flood behaviour for events up to 1% AEP are likely to be minor given the depth and extent of inundation under pre-project conditions.
	Other areas within WA3	50% AEP	x	✓	✓	x	The Wentworth Avenue Underpass that is being constructed as part of the Airport East project would be inundated by floodwater to a depth of about 0.2 m during a 50% AEP event, increasing to 0.5 m during a 10% AEP event and 0.9 metres during a 1% AEP event.	No construction works are anticipated within this work area that would impact on flood behaviour at the Wentworth Avenue Underpass for events up to 1% AEP.
Botany Road to Southern Cross Drive work area (WA4) (refer **Figure 5.1**, sheet 3)	Botany Road compound (C4)	1% AEP	✓	✓	x	x	Should a 1% AEP event occur during the construction phase of the project, then a relatively localised area along the southern side of the compound would be inundated by flow that discharges from Southern Cross Drive to a maximum depth of 0.2 m.	The potential impact of facilities located within the compound on flood behaviour for events up to 1% AEP are likely to be minor given the depth and extent of inundation under pre-project conditions.

Construction work area	Compounds / other areas[1]	Threshold of flooding[2]	Proposed construction activities[3]				Description of existing flood behaviour (pre-mitigation)	Potential impacts of construction activities on flood behaviour
			Site facilities[4]	Material storage and stockpiling[5]	Earthworks[6]	Bridge construction[7]		
Botany Road to Southern Cross Drive work area (WA4) (refer **Figure 5.1**, sheet 3)	Material storage area at western end of McBurney Avenue (MS4)	More frequent than 50% AEP	x	✓	x	x	During a 50% AEP event the majority of the area would be inundated to a depth of 0.1 to 0.2 m. Should a 1% AEP event occur during the construction phase of the project, then the area would be inundated to a depth of 0.2 to 0.3 m.	The storage of materials and stockpiling within this area has the potential to displace floodwater that ponds within the area for events up to 1% AEP, leading to an increase in the depth of inundation in the adjacent roadway and the potential for flooding to adjacent development. It would therefore be necessary to maintain an overland flowpath through the area between McBurney Avenue and Botany Road.
	Material storage area between carriageways of Southern Cross Drive (MS5)	1% AEP	x	✓	x	x	Should a 1% AEP event occur during the construction phase of the project, then the majority of the material storage area would be inundated by flow that is conveyed along Southern Cross Drive to a maximum depth of 0.2 m.	The storage of materials and stockpiling in this area has the potential to divert overland flow onto the adjoining section of Southern Cross Drive should a 1% AEP event occur during the construction phase of the project.
	Material storage area west of Southern Cross Drive (MS6)	1% AEP	x	✓	x	x	Should a 1% AEP event occur during the construction phase of the project, then the middle portion of the material storage area would be inundated by flow that is conveyed along Southern Cross Drive to a maximum depth of 0.2 m.	The storage of materials and stockpiling in this area has the potential to obstruct the conveyance of overland flow that discharges from Southern Cross Drive toward Mill Stream should a 1% AEP event occur during the construction phase of the project.

Construction work area	Compounds / other areas[1]	Threshold of flooding[2]	Proposed construction activities[3]				Description of existing flood behaviour (pre-mitigation)	Potential impacts of construction activities on flood behaviour
			Site facilities[4]	Material storage and stockpiling[5]	Earthworks[6]	Bridge construction[7]		
Botany Road to Southern Cross Drive work area (WA4) (refer **Figure 5.1**, sheet 3)	Crane pads for Southern Cross Drive bridge (CP3)	1% AEP	x	x	x	✓	Should a 1% AEP event occur during the construction phase of the project, then the area where the crane pads are proposed to be located would be inundated to a maximum depth of 0.4 m.	The crane pads have the potential to obstruct the conveyance of overland flow that discharges from Southern Cross Drive toward Mill Stream should a 1% AEP event occur during the construction phase of the project.
	Other areas within WA4		x	✓	✓	x	The section of Botany Road where it runs under the existing rail line would be inundated by overland flow to a maximum depth of 0.1 m during a 50% AEP event, increasing to 0.3 m during a 1% AEP event.	No construction works are anticipated within this work area that would impact on flood behaviour along the section of Botany Road that runs under the existing rail line for events up to 1% AEP.
Southern Cross Drive to Banksia Street work area (WA5) (refer **Figure 5.1**, sheet 4)	Mill Stream compound (C5)	10% AEP	✓	x	x	x	The compound would be impacted by floodwater that surcharges the eastern bank of Mill Stream during a 10% AEP event. Should a 1% AEP event occur during the construction phase of the project, about one quarter of the compound on its western side would be inundated to a maximum depth of about 1 metre.	Facilities located within the western quarter of the compound have the potential to obstruct the conveyance of floodwaters in Mill Stream should a flood event equivalent to or greater than 10% AEP in magnitude occur during the construction phase of the project. This in turn may impact on the extent and depth of inundation and flow velocities in Mill Stream.
	Banksia Street compound (C6)	10% AEP	✓	✓	x	x	During a 10% AEP event a localised area along its middle portion would be inundated by flow that surcharges the cess drain that runs along the	The potential impact of facilities located within the compound on flood behaviour for events up to 1% AEP are likely to be minor given

Construction work area	Compounds / other areas[1]	Threshold of flooding[2]	Proposed construction activities[3]				Description of existing flood behaviour (pre-mitigation)	Potential impacts of construction activities on flood behaviour
			Site facilities[4]	Material storage and stockpiling[5]	Earthworks[6]	Bridge construction[7]		
Southern Cross Drive to Banksia Street work area (WA5) (refer **Figure 5.1**, sheet 4)							western side of the existing rail line. Should a 1% AEP event occur during the construction phase of the project, then inundation would occur to a maximum of 0.1 m due to flow that surcharges the aforementioned cess drain.	the depth and extent of inundation under pre-project conditions.
	Material storage area east of Mill Stream (MS7)	2% AEP	x	✓	x	x	During a 2% AEP event a localised area along its middle portion would be inundated by flow that surcharges the section of Mill Stream that runs through the Lakes golf course and discharges across the existing rail line. Should a 1% AEP event occur during the construction phase of the project, then inundation would occur to a maximum depth of 0.2 m due to flow that surcharges the aforementioned cess drain.	The potential impact of storing materials and stockpiling on flood behaviour for events up to 1% AEP are likely to be minor given the depth and extent of inundation under pre-project conditions.
	Material storage area west of Myrtle Street (MS8)	More frequent than 50% AEP	x	✓	x	x	During a 50% AEP event the western portion of the material storage area would be inundated by local catchment runoff to a maximum depth of 0.2 m. Should a 1% AEP event occur during	While the storage of materials and stockpiling within this area has the potential to displace floodwater that ponds within the area for events up to 1% AEP, impacts would likely be confined to a localised area of the

Construction work area	**Compounds / other areas**[1]	**Threshold of flooding**[2]	**Proposed construction activities**[3]				**Description of existing flood behaviour (pre-mitigation)**	**Potential impacts of construction activities on flood behaviour**
			Site facilities[4]	**Material storage and stockpiling**[5]	**Earthworks**[6]	**Bridge construction**[7]		
Southern Cross Drive to Banksia Street work area (WA5) (refer **Figure 5.1**, sheet 4)							the construction phase of the project, then inundation would occur over the western half of the area to a maximum depth of 0.6 m due to flow that surcharges the aforementioned cess drain.	Eastlake golf course.
	Crane pads for Mill Stream bridge (CP4)	Less than 50% AEP	x	x	x	✓	The area where the crane pads are proposed to be located is inundated by flow that surcharges the main channel of Mill Stream during events more frequent than 50% AEP. Should a 1% AEP event occur during the construction phase of the project, then the area where the crane pads are proposed to be located would be inundated to a maximum depth of 1 m.	The crane pads have the potential to obstruct the conveyance of flow in Mill Stream during events more frequent that 50% AEP. This in turn may impact on the extent and depth of inundation and flow velocities in Mill Stream.
	Temporary piling platform for Mill Stream bridge	Less than 50% AEP	x	x	x	✓	The temporary piling platform to construct the central pier for the Mill Stream bridge is likely to encroach on the main channel of Mill Stream, in an area that experiences frequent inundation. Should a 1% AEP event occur during the construction phase of the project, then flow in the main channel of Mill	The temporary piling platform has the potential to obstruct the conveyance of flow in Mill Stream during events more frequent that 50% AEP. This in turn may impact on the extent and depth of inundation and flow velocities in Mill Stream.

Construction work area	Compounds / other areas[1]	Threshold of flooding[2]	Proposed construction activities[3]				Description of existing flood behaviour (pre-mitigation)	Potential impacts of construction activities on flood behaviour
			Site facilities[4]	Material storage and stockpiling[5]	Earthworks[6]	Bridge construction[7]		
Southern Cross Drive to Banksia Street work area (WA5) (refer **Figure 5.1**, sheet 4)							Stream would occur to a depth of 1 to 2 m and a velocity of 2 to 3 m/s.	
	Other areas within WA5	Less than 50% AEP	x	✓	✓	x	An area within the work area about 260 m east of Mill Stream is impacted by local catchment runoff during events as frequent as 50% AEP. A channel that is located along the eastern side of the work area conveys runoff that discharges from the drainage systems in Banksia Street and Bay Street. Flow along the channel would occur to a maximum depth of 1.5 m during a 1% AEP event.	Activities within the work area have the potential to displace local catchment runoff that ponds within the rail corridor to the west of Mill Stream and obstruct flow that is conveyed along the channel that runs along the western side of the work area.

Notes:

1. Refer **Figure 5.1** (3 sheets) for location of construction compounds and other facilities.
2. The assessed threshold of flooding is based on pre-project conditions. Refer **Figure 5.1** (3 sheets) for flood extent mapping under pre-project conditions.
3. Refer to **Section 5.1.1** for a description of flood risks associated with construction compounds and other activities.
4. Site facilities include offices, staff amenities, parking and storage areas for plant, equipment and materials.
5. Material storage and stockpiling includes stockpiling and treatment of excavated material.
6. Earthworks includes construction of rail line and drainage works.
7. Bridges include working pads for support cranes to install various bridge components.

5.2 Impacts during operation

This section provides an assessment of the flood risk to the project and the impact it would have on flood behaviour during operation if appropriate mitigation measures are not incorporated into its design. The assessment has been based on the current design for the project. The findings of an assessment into the potential impacts of future climate change and impacts of a partial blockage of major hydraulic structures on flood behaviour under operational conditions are also presented.

5.2.1 Potential flood risk to the project and its impact on flood behaviour

Inundation of the project by floodwater during its operation has the potential to cause damage to infrastructure, impact on train movements and pose a safety risk to rail users. The project also has the potential to exacerbate flooding and drainage conditions in adjacent development by obstructing or diverting floodwater, displacing floodplain storage or altering runoff behaviour from the rail corridor. An assessment was undertaken of the flood risk to the project in its as-built form, as well as the impact it would have on the characteristics of flooding in adjacent areas.

Table 5.2 provides details of the project components that formed the basis of the assessment of flood behaviour within the Alexandra Canal and Mill Stream catchments, while **Figure 5.3** (3 sheets) shows the general design arrangement including key flooding and drainage related features. The assessed design would be subject to further development during the detailed design stage, which would also consider measures to further reduce the impact of flooding to the project and surrounding areas.

Potential flood risk to the project

Table 5.3 provides a summary of the assessed flood risk to the project. A recommended level of flood protection to each project element has been identified based on the adopted criteria outlined in **Section 3.3**. The assessment found that:

- The proposed duplication would provide a level of flood immunity of about 10% AEP to both the existing and new rail tracks, which is slightly greater than that of the existing rail track. Inundation of the track or its ballast would occur at the following locations during a 1% AEP event:
    - A section of the southern track to the west of General Holmes Drive would be inundated to a depth of 0.3 metres above the toe of ballast, which is about 0.5 metres below the top of rail level. This is the result of local catchment runoff that ponds along the edge of the rail corridor due to higher ground to its south.
    - A section of the northern track to the west of Myrtle Street would be inundated to a depth of 0.4 m above the toe of ballast, which is about 0.4 metres below the top of rail level. This is due to flow that surcharges the inlet to the 1,050 mm diameter piped drainage line that crosses the rail corridor at Myrtle Street.
- The proposed bridge over Mill Stream would provide more than 0.5 metres of freeboard between the underside of the bridge structure and the peak 1% AEP flood level.
- The new corridor access roads would provide a 10% AEP level of flood immunity with the exception of a section of road about 140 metres west of Myrtle Street which would be inundated to a maximum depth of 0.3 metres due to local catchment runoff that ponds along the northern side of the rail corridor. Further development of the design of the

corridor access road would be carried out during detailed design to provide a 10% AEP level of flood immunity at this location. This may involve:

- Raising the section of access road above the 10% AEP flood level.
- Provision of channels either side of the access road to offset the displacement of ponded runoff caused by the raised level of the road.

A flood risk assessment of rail location cabinets for housing communications, power and signalling equipment would be undertaken during the detailed design once details of their specific locations are known. If required, these structures can be located on elevated platforms to locate them a minimum 0.5 metres above the peak 1% AEP flood level.

Impact of the project on flood behaviour

An assessment was carried out into the impact the project would have on flood behaviour due to changes in flow conveyance and flood storage across the floodplain. The findings of the assessment are summarised in **Tables 5.4, 5.5** and **5.6** in terms of changes to peak flood levels and depths, peak flows and velocities, and the extent and duration of inundation, respectively. The following figures showing flood patterns and impacts under operational conditions should be referred to when reading **Tables 5.4, 5.5** and **5.6** and the following discussion:

- **Figure 5.3** (3 sheets) shows flooding patterns under operational conditions during a 10% AEP event, while **Figure 5.4** (3 sheets) shows the impact that the project would have on flood behaviour in terms of changes in peak 10% AEP flood levels[5]. Corresponding results for a 1% AEP event and the PMF are provided in **Figures 5.5** to **5.8** (3 sheets each), while **Figures B.9** to **B.18** in **Annexure B** show flooding patterns and impacts under operational conditions during storms with AEPs of 50%, 5%, 0.5% and 0.2%.
- **Figure B.19** in **Annexure B** shows peak flow velocities under pre-project conditions during a 10% AEP event, while **Figure B.20** shows the impact that the project would have in terms of changes in peak flow velocities during a 10% AEP event. Corresponding results for a 1% AEP event are provided in **Figures B.21** and **B.22** in **Annexure B**.
- **Figure B.23** in **Annexure B** shows the duration of inundation under pre-project conditions during a 20% AEP storm of two hour duration, while **Figure B.24** shows the impact that the project would have in terms of changes in the duration of inundation for this design storm event. Corresponding results for a 1% AEP storm of two hour duration are provided in **Figures B.25** and **B.26** in **Annexure B**.

The assessment found that once constructed, the project would generally have only a minor impact on flood behaviour for floods up to the PMF event, with the exception of the following residual flood impacts that have been identified on existing infrastructure:

1. Peak 1% AEP flood levels upstream of Mill Stream bridge would be increased by a maximum of 0.1 metres, which would also lead to an increase in the rate and therefore depth of flow that surcharges the western bank of Mill Stream and is conveyed along the travel lanes of Southern Cross Drive and Botany Road. The increase in peak flood levels

[5] Changes in peak flood levels are denoted on the figure as "afflux". An afflux of plus or minus 0.01 metres is considered to be within the order of accuracy of the flood model. The figure also shows changes in the extent of inundation that could be caused by the construction of the project. A reduction in the extent of inundation is denoted "Land rendered flood free", while an increase in the extent of inundation is denoted "Additional area of land flooded".

upstream of Mill Stream will also lead to an increase in the frequency with which flow surcharges the western bank of Mill Stream onto the travel lanes of Southern Cross Drive, from about a 1% AEP event under pre-project conditions, to about a 2% AEP event under post-project conditions (ie twice more frequent).

The design of the Mill Stream bridge would be further refined during the detailed design to mitigate the impact of the project on an increase in the rate and frequency of flow that discharges onto Southern Cross Drive as a result of an increase in flood levels in Mill Stream. This would involve one or both of the following:

- Increasing the length of the western span to reduce the encroachment of the western abutment on the floodway of Mill Stream.
- Providing a retaining wall along the southern side of the rail line to the west of Mill Stream to reduce the encroachment of the rail embankment on the floodway of Mill Stream.

2. During a 1% AEP event there would be an increase in peak flood levels upstream of the inlet to the 1,050 millimetre diameter pipe that crosses the rail corridor at Myrtle Street which would also lead to the following impacts in adjoining development:
   - Peak flood levels in a multi-unit development at 104 Bay Street[6] would be increased by a maximum of 0.02 metres. Impacts would occur in the northern portion of the development over an area that includes several units that front Myrtle Street.
   - Peak flood levels in a multi-unit development at 15 Begonia Street[6] would be increased by a maximum of 0.02 metres. Impacts would occur in the northeastern portion of the development, adjacent to the entry to basement carparking from Myrtle Street.

   Subject to further design development and flood assessment during detailed design it may be necessary to collect detailed ground survey within the multi-unit developments at 104 Bay Street and 15 Begonia Street, including floor levels of units and the level of entry points to units and basement carparking.

   The survey would be used to confirm:

   - the potential for an increase in above-floor inundation and therefore the economic cost of flood related damages to units, as well as
   - an increase in the frequency, rate and volume of flow into basement carparks, which has the potential to increase the economic costs of flood related damages to buildings, vehicles and other stored material as well as social costs related to a potential increase in flood risk to persons.

   The survey would also assist in developing a scope of works that would be aimed at mitigating the impact of the project on:

   - an increase in above-floor inundation to units for all events up to 1% AEP [7]

[6] Property addresses have been obtained from Bayside Council's online property mapping system at http://maps.bayside.nsw.gov.au/Intramaps80/?module=Property.

[7] A change in depth of inundation of plus or minus 0.01 metres is considered to be within the order of accuracy of the flood model and would therefore be considered to be no change in above floor inundation in the context of this requirement.

- an increase in the frequency, rate and volume of flow into basement carparks for all events up to the PMF.

This scope of works may include:

- refinement of the drainage design to reduce the magnitude of flow that is diverted toward the inlet to the 1,050 millimetre diameter pipe that crosses the rail corridor at Myrtle Street
- provision of an oversized open channel or closed system box culvert along the northern side of the rail corridor between Myrtle Street and Bay Street to provide temporary floodplain storage to offset the displacement caused by the slightly widened rail embankment within the current design,
- minimising changes in existing ground levels along the northern side of the rail corridor between Banksia Street and Myrtle Street in order to minimise changes to flood behaviour.

The investigation found that while the current design would result in an increase in flow velocities in Mill Stream that have the potential to increase scour and erosion, the implementation of measures in the detailed design to reduce the encroachment of the proposed works on the floodway of Mill Stream as discussed above would aim to reduce the likelihood of this potential impact. . Potential measures are outlined under Item 1 above.

The project would generally have a minor impact on flow behaviour (ie flow depths and velocities) in the drainage systems downstream of the proposed drainage outlets that would control runoff from the project corridor (denoted **drainage outlets DO1** to **DO14** on **Figure 5.4**, sheets 2 and 3). The exception is downstream of **drainage outlet DO3** where the depth of flow along Qantas Drive would be increased by a maximum of 0.03 metres during a 10% AEP event on existing depths that are typically less than 0.05 metres. Similar increases in depth would also occur during a 1% AEP event which would also result in an increase in the depth of inundation within an area of Sydney Airport immediately west of Qantas Drive. The impacts are located in an area of Qantas Drive that would be upgraded as part of the Sydney Gateway Road Project, while the impacts within Sydney Airport are located in an area that would be acquired as part of the Sydney Gateway Road Project. Measures that could be incorporated into the detailed design to mitigate this impact, should it be required, include:

- refinement of the track drainage design to minimise the change in catchment area draining to **drainage outlet DO3**
- provision of drainage measures aimed at attenuating the rate of runoff discharging from the rail corridor, such as oversized channels and culverts to provide temporary storage of runoff.

The assessment found that the project would have only a minor impact on the extent and duration of inundation of flooding within Mill Stream, including any adverse effects to the beneficial inundation of the floodplain environment.

5.2.2 Consistency with council and state government flood plans and policies

Mascot, Rosebery and Eastlakes Floodplain Risk Management Study & Plan (RH DHV 2017) contains a draft floodplain risk management plan that defines the hazard categorisation of the floodplain and sets out general, non-structural and location specific structural measures with varying priority rankings to manage the flood risk associated with development within the Mascot, Rosebery and Eastlakes areas, as well as a portion of Pagewood. The study area for RH DHV 2017 covers a portion of the Alexandra Canal and Mill Stream catchments that include the project footprint for the Botany Rail Duplication.

General non-structural measures set out in RH DHV 2017 include the development of emergency response measures, such as the preparation of a Local Flood Plan in collaboration with NSW SES, and improved flood awareness, such as the implementation of a community flood education program. Structural measures include the provision of detention basins and the upgrade of stormwater drainage infrastructure.

The findings of the assessment presented in **Section 5.2.1** of this technical working paper show that subject to the provision of suitable mitigation measures during detailed design, the project would have only a minor impact on peak 1% AEP flood levels and flow velocities within areas outside the project footprint (ie the study area for RH DHV 2017). Increases in PMF levels are also considered minor in terms of the relative increase in flood hazard and changes in the extent of inundation. As a result, it is considered that the project would have no significant impact on the extent of the floodplain or its hazard categorisation.

Subject to the provision of measures during detailed design that mitigate the impact of the project on an increase in flow that surcharges the western bank of Mill Stream onto Southern Cross Drive, then it is also considered that the project would have no significant impact on emergency access during times of flood and therefore the emergency response arrangements that would be developed as part of any future Local Flood Plan for the area.

Given the extent of works that are proposed as part of the project and the relatively minor nature of their impact on flood behaviour, it is also considered that the project would not preclude or limit any of the measures identified in the draft floodplain risk management plan that is contained in RH DHV 2017.

5.2.3 Impact of future climate change on flood behaviour

Impact of flood behaviour under future climate change conditions on the project

Peak flood levels at key locations along the project for current climate conditions, as well as for the assessed future climate change scenarios set out in **Table 3.1**, are shown in **Table 5.7** at the end of this chapter.

While the climate change scenarios include an allowance for sea level rise, due to the location of the proposed works on the Alexandra Canal and Mill Stream floodplains the impact of climate change on flooding behaviour is primarily due to an increase in rainfall intensities.

Potential impacts of future climate change on flooding to the key elements of the project for a storm with an AEP of 1% can be summarised as follows:

Rail duplication:

- The proposed rail duplication is located above the 1% AEP flood level under both future climate change scenarios, with the exception of the following locations:
    - A section of the southern track between O'Riordan Street and General Holmes Drive would be inundated to a depth of 0.35 and 0.42 metres above the toe of ballast under future climate change Scenarios 1 and 2 respectively, in comparison to a depth of 0.3 metres under current climatic conditions. Under future climate

change conditions the depth of inundation would still be a minimum 0.38 metres below the top of rail level.

  - A section of the northern track between O'Riordan Street and General Holmes Drive would be inundated to a depth of 0.20 and 0.41 metres above the toe of ballast under future climate change Scenarios 1 and 2 respectively, whereas the ballast would not be inundated under current climatic conditions. Under future climate change conditions the depth of inundation would still be a minimum 0.39 metres below the top of rail level.
  - A section of the northern track between Southern Cross Drive and Banksia Street would be inundated to a depth of 0.47 and 0.55 metres above the toe of ballast under future climate change Scenarios 1 and 2 respectively, in comparison to a depth of 0.4 metres under current climatic conditions. Under future climate change conditions the depth of inundation would still be a minimum 0.25 metres below the top of rail level.

- While flooding under future climate change conditions would increase the depth of inundation to the ballast below the duplicated rail line, the depth of inundation would still be a minimum 0.25 metres below the top of rail level and is therefore unlikely to impede train operations during a 1% AEP event. The increase in the frequency and depth of inundation of the ballast is likely to increase the rate of deterioration and therefore maintenance requirements of the track.
- Raising the level of the rail line in order to reduce the depth of inundation to the ballast would be constrained by the level of the existing rail line and is also likely to result in adverse impacts on flood behaviour in areas outside the rail corridor.

Bridge waterway crossings:

- There would be a minimum 0.5 metres of clearance between the underside of the existing and new bridges over Mill Stream and the 1% AEP flood level under both future climate change scenarios. As a result, climate change would not impact on flooding to the rail track at Mill Stream bridge during a 1% AEP event.

New corridor access roads:

- The new corridor access road would be impacted during a 1% AEP event at the following locations:
  - A section of the new corridor access road to the west of General Holmes Drive would be inundated to a depth of 0.05 and 0.37 metres under future climate change Scenarios 1 and 2 respectively, whereas the access road would not be inundated under current climatic conditions.
  - The western end of the corridor access road between Botany Road and Southern Cross Drive would be inundated to a depth of 0.49 and 0.64 metres under future climate change Scenarios 1 and 2 respectively, in comparison to a depth of 0.06 metres under current climatic conditions.
  - A section of corridor access road about 140 metres to the west of Myrtle Street would be inundated to a depth of 0.81 and 0.95 metres under future climate change Scenarios 1 and 2 respectively, in comparison to a depth of 0.60 metres under current climatic conditions.

- While the assessment of flood impacts has been based on the 1% AEP event, it is noted that future climate change has the potential to increase the frequency of inundation to access roads that are designed for a 10% AEP level of flood immunity. For example, should rainfall intensities under current climate conditions be increased by 10 per cent, then a rainfall event with a 10% (1 in 10) AEP under current climatic conditions would be equivalent to a rainfall event with a 20% (1 in 5) AEP under future climate change conditions. As a result, the access roads would be inundated twice as frequent under future climate change conditions.

Impact of the project on flood behaviour under future climate change conditions

As noted in **Section 3.7.2**, the 0.5% and 0.2% AEP events were adopted as proxies for assessing the sensitivity to an increase in 1% AEP design rainfall intensities of between 10% and 30% due to future climate change. **Figure 5.6** shows the impact of the project on flood behaviour during a 1% AEP event under current climatic conditions, while **Figures B.16** and **B.18** in **Annexure B** show the impact that the project would on flood behaviour during a 0.5% and 0.2% AEP event.

Comparison of **Figures B.16** and **B.18** with **Figure 5.6** shows that there will be relatively minor increases in flood impacts attributable to the project under both the lower and upper bound future climate change scenarios.

5.2.4 Impact of a partial blockage of major hydraulic structures on flood behaviour

Table 5.8 shows the impact a partial blockage of major hydraulic structures would have on peak flood levels at key locations along the project. The assessment showed that a partial blockage of major hydraulic structures would result in:

- An increase in peak 1% AEP flood levels upstream of the Mill Stream bridge by a maximum of 0.03 metres. As a result, there would be an increase in the rate and depth of flow that surcharges the western bank of Mill Stream onto Southern Cross Drive. The resulting peak flood level would still be more than 1 metre below the underside of the existing and new bridge structures at Mill Stream.
- An increase in peak 1% AEP flood level upstream of the inlet to the 1,050 millimetre diameter pipe that crosses the rail corridor at Myrtle Street by 0.01 metres, which would have a negligible impact on flooding to the rail line.

TABLE 5.2
ASSESSED DESIGN ARRANGEMENT

Catchment	Project component	Assessed design arrangement

Alexandra Canal	Lancastrian Road to O'Riordan Street	• Refer **Figure 5.3**, sheet 2.
		• Realignment of the existing rail line between Lancastrian Road and King Street.
		• Duplication of the existing rail line between King Street and O'Riordan Street with a new track to the south of the existing track. The existing track between King Street and O'Riordan Street would also be realigned to accommodate the new track.
		• Replacement of the existing bridges at Robey Street and O'Riordan Street with two new single span bridges at each location. One bridge would be constructed in the position of the existing bridge while the other would be located to its south.
		• Provision of a new access road along the northern side of the rail line between Coleman Street and a location 20 m to the west of Ewan Street.
		• A track drainage system would be provided to control runoff from the realigned and duplicated section of rail. The track drainage system would comprise cess drains and piped drainage lines that would connect into the following existing drainage systems:
		  ○ An existing cess drain that runs along the southern side of the rail line at Lancastrian Road (refer **Drainage outlet DO1** on **Figure 5.3**, sheet 2).
		  ○ An open channel that comprises the Sydney Water owned trunk drainage line where it runs along the northern side of the rail corridor to the west of Lancastrian bridge (refer **Drainage outlet DO2** on **Figure 5.3**, sheet 2).
		  ○ Existing piped drainage lines in Qantas Drive adjacent to King Street and Ewan Street (refer **Drainage outlets DO3** and **DO4** on **Figure 5.3**, sheet 2).
		  ○ An existing piped drainage line on the eastern side of Robey Street (refer **Drainage outlet DO5** on **Figure 5.3**, sheet 2).
		  ○ An existing piped drainage line in Qantas Drive to the east of O'Riordan Street (refer **Drainage outlet DO6** on **Figure 5.3**, sheet 2).
		The proposed connections into the existing drainage systems would be confirmed during detailed design.

Mill Stream	O'Riordan Street to Southern Cross Drive	• Refer **Figure 5.3**, sheets 2 and 3. • Duplication of the existing rail line between O'Riordan Street and Southern Cross Drive with a new track to the south of the existing track. Sections of the existing track would also be realigned to accommodate the new track. • Minor remediation works may be undertaken at Botany Road bridge. • A new two-span bridge at Southern Cross Drive adjacent the existing bridge. • Provision of the following sections of new corridor access roads:

Catchment	Project component	Assessed design arrangement
Mill Stream		○ Along the northern side of the rail line between General Holmes Drive and a location 235 m west of General Holmes Drive. ○ Along the southern side of the rail line between Botany Road bridge and the bridge over Southern Cross Drive. • A track drainage system would be provided to control runoff from the realigned and duplicated sections of rail. The track drainage system would comprise cess drains that would connect into the following existing drainage systems: ○ Existing piped drainage lines that cross the rail corridor to the west of General Holmes Drive (refer **Drainage outlets DO7** and **DO8** on **Figure 5.3**, sheet 2). ○ Piped drainage lines that cross the rail corridor to the east of General Holmes Drive and discharge into Ascot Drain (refer **Drainage outlets DO9** and **D10** on **Figure 5.3**, sheets 2 and 3). ○ An existing piped drainage line in Botany Road to the south of the rail corridor (refer **Drainage outlet DO11** on **Figure 5.3**, sheet 3). The proposed connections into the existing drainage systems would be confirmed during detailed design.
	Southern Cross Drive to Banksia Street	• Refer **Figure 5.3**, sheet 3. • Duplication of the existing rail line between Southern Cross Drive and Banksia Street with a new track to the south of the existing track. Sections of the existing track would also be realigned to accommodate the new track. • The existing bridge over Mill Stream would be retained and a new two span bridge would be constructed to its south to accommodate the new track. The central pier for the new two span bridge would be located on the western bank of Mill Stream. • Track drainage would be provided that would comprise: ○ Cess drains to control runoff from the duplicated section of rail between Southern Cross Drive and Mill Stream that would discharge into Mill Stream via a piped drainage outlet on its western bank (refer **Drainage outlet DO12** on **Figure 5.3**, sheet 3). ○ A piped drainage line would control runoff from the realigned and duplicated section of rail between Mill Stream and Myrtle Street that would discharge into Mill Stream via a piped drainage outlet on its eastern bank (refer **Drainage outlet DO13** on **Figure 5.3**, sheet 3). ○ Cess drains would be provided to control runoff from the duplicated section of rail between Myrtle Street and Banksia Street that would discharge into an existing piped drainage line that runs in a southerly direction across the rail corridor at Myrtle Street (refer **Drainage outlet DO14** on **Figure 5.3**, sheet 3). The proposed connections into the existing drainage systems would be confirmed during detailed design. • The existing channel that runs along the eastern side of the rail corridor between Banksia Street and Myrtle Street would be maintained and realigned where required to accommodate the proposed track duplication.

TABLE 5.3
SUMMARY OF FLOOD RISKS TO THE PROJECT

Project Element	Recommended level of flood protection	Location	Peak flood level (m AHD)[1]			Assessed flood risk
			10% AEP	1% AEP	PMF	
Duplication of existing rail line	As a minimum, maintain the existing level of flood immunity to the rail line and ideally provide 1% AEP level of flood immunity where feasible based on site constraints	Lancastrian Road to O'Riordan Street	Varies	Varies	Varies	**Figure 5.3**, sheet 2 and **Figure 5.5**, sheet 2 show operational flooding patterns during a 10% and 1% AEP event, respectively. The section of track between Lancastrian Road and O'Riordan Street is located above the 1% AEP flood level.
		O'Riordan Street to General Holmes Drive	Varies	Varies	Varies	**Figure 5.3**, sheet 2 and **Figure 5.5**, sheet 2 show operational flooding patterns during a 10% and 1% AEP event, respectively. The section of rail line between O'Riordan Street and General Holmes Drive would have a level of flood immunity of about 10% AEP, which is slightly greater than that under pre-project conditions. During a 1% AEP event the southern track would be inundated to a depth of 0.3 m above the toe of ballast, which is about 0.5 m below the top of rail level. This is the result of local catchment runoff that ponds along the edge of the rail corridor due to higher ground to its south.
		General Holmes Drive to Southern Cross Drive	Varies	Varies	Varies	**Figure 5.3**, sheets 2 and 3, and **Figure 5.5**, sheets 2 and 3, show operational flooding patterns during a 10% and 1% AEP event, respectively. The section of track and its ballast between General Holmes Drive and Southern Cross Drive is located above the 1% AEP flood level.
		Southern Cross Drive to Banksia Street	8.5[2]	8.8[2]	9.4[2]	**Figure 5.3**, sheet 2 and **Figure 5.5**, sheet 2 show operational flooding patterns during a 10% and 1% AEP event, respectively. The section of rail track between Southern Cross Drive and Banksia Street would have a level of flood immunity of about 10% AEP, which is slightly greater than that under pre-project conditions. During a 1% AEP event the northern track would be inundated to a depth of 0.4 m above the toe of ballast, which is about 0.4 m below the top of rail level. This is due to flow that surcharges the inlet to the 1,050 mm diameter piped drainage line that crosses the rail corridor at Myrtle Street.

Project Element	Recommended level of flood protection	Location	Peak flood level (m AHD)[1]			Assessed flood risk
			10% AEP	1% AEP	PMF	
Bridge waterway crossings	A minimum clearance of 0.5 m between the underside of the new bridge and the 1% AEP flood level	Mill Stream bridge	5.2	6.0	7.5	**Figure 5.3**, sheet 3 and **Figure 5.5**, sheet 3 show operational flooding patterns during a 10% and 1% AEP event, respectively. The underside of the both the existing and new bridges over Mill Stream are located more than 0.5 m above the peak 1% AEP flood level.
New corridor access roads	As a minimum provide a 10% AEP level of flood immunity and low provisional flood hazard during a 1% AEP event	Coleman Street to 20 m west of Ewan Street	Varies	Varies	Varies	**Figure 5.3**, sheet 2 and **Figure 5.5**, sheet 2 show operational flooding patterns during a 10% and 1% AEP event, respectively. The new corridor access road is located above the 10% AEP flood level and outside areas of high hazard during a 1% AEP event.
		General Holmes Drive to 235 m west of General Holmes Drive	Varies	Varies	Varies	**Figure 5.3**, sheet 2 and **Figure 5.5**, sheet 2 show operational flooding patterns during a 10% and 1% AEP event, respectively. The new corridor access road is located above the 10% AEP flood level and outside areas of high hazard during a 1% AEP event.
		Botany Road bridge to Southern Cross Drive bridge	Varies	Varies	Varies	**Figure 5.3**, sheet 3 and **Figure 5.5** sheet 3 show operational flooding patterns during a 10% and 1% AEP event, respectively. The new corridor access road is located above the 10% AEP flood level and outside areas of high hazard during a 1% AEP event.
		Mill Stream to Banksia Street	Varies	Varies	Varies	**Figure 5.3**, sheet 3 and **Figure 5.5** sheet 3 show operational flooding patterns during a 10% and 1% AEP event, respectively. Based on the current design, a section of corridor access road about 140 m north of Myrtle Street would be inundated to a maximum depth of 0.3 m during a 10% AEP event due to local catchment runoff that ponds along the northern side of the rail corridor. Further development of the design of the corridor access road would be carried out during detailed design to provide a 10% AEP level of flood immunity. This may involve: • Raising the section of access road above the 10% AEP flood level. • Provision of channels either side of the access road to offset the displacement of ponded runoff caused by the raised level of the road.

1. Peak flood levels are based on current climatic conditions and no blockage to major hydraulic structures. Refer **Sections 5.2.3** and **5.2.4** for an assessment of the impact of future climate change and a partial blockage of major hydraulic structures on peak flood levels at key locations along the length of the project.
2. Peak flood levels are quoted at the inlet to the 1,050 mm diameter piped drainage line that crosses the rail corridor at Myrtle Street.

TABLE 5.4
SUMMARY OF IMPACTS OF THE PROJECT ON FLOOD BEHAVIOUR - CHANGES IN PEAK FLOOD LEVELS AND DEPTHS

Catchment	Changes in peak flood levels and depths

Alexandra Canal	• The upgrade of the drainage system along the rail corridor will generally result in a reduction in overland flow and therefore the depth and extent of inundation along the section of Qantas Drive that runs under Lancastrian Bridge.
	• During a 10% AEP event there would be an increase in the depth of flow along Qantas Drive due to flow that surcharges the piped drainage system that is located between King Street and Ewan Street. The depth of flow along Qantas Drive would be increased by a maximum of 0.03 m on existing depths that are typically less than 0.05 m. Similar increases in depth would also occur during a 1% AEP event which would also result in an increase in the depth of inundation within an area of Sydney Airport immediately west of Qantas Drive. The impacts are located in an area of Qantas Drive that would be upgraded as part of the Sydney Gateway Road Project, while the impacts within Sydney Airport are located in an area that would be acquired as part of the Sydney Gateway Road Project. Measures that could be incorporated into the detailed design to mitigate this impact, should it be required, include:
	  ○ refinement of the track drainage design to minimise the change in catchment area draining to drainage outlet **DO3**
	  ○ provision of drainage measures aimed at attenuating the rate of runoff discharging from the rail corridor, such as oversized channels and culverts to provide temporary storage of runoff.
	• During a 1% AEP event a section of Qantas Drive to the east of O'Riordan Street would be inundated due to surcharge of the existing piped drainage system, albeit to relatively shallow depths of less than 0.05 m.
	• During the PMF there would be minor changes in peak flood levels as a result of the project.

Mill Stream	• Mill Stream:
	  ○ While peak 10% AEP flood levels upstream of Mill Stream bridge would be increased by a maximum of 0.14 m, impacts would be largely confined to an area of reserve between Mill Stream and Southern Cross Drive that is owned by Sydney Water where existing depths of inundation range between 0.6 and 1.2 m.
	  ○ Peak 1% AEP flood levels upstream of Mill Stream bridge would be increased by a maximum of 0.10 m, which would also lead to an increase in the rate and therefore depth of flow that surcharges the western bank of Mill Stream and is conveyed along Southern Cross Drive. The depth of overland flow along Southern Cross Drive will be increased by a maximum of 0.08 m on existing depths of between 0.2 m and 0.4 m, while the depth of overland flow at the low point in Botany Road to the north of Southern Cross Drive will be increased by a maximum of 0.14 m on an existing depth of 0.2 m.
	  ○ The increase in peak flood levels upstream of Mill Stream will also lead to an increase in the frequency with which flow surcharges the western bank of Mill Stream onto Southern Cross Drive, from about a 1% AEP event under pre-project conditions, to about a 2% AEP event under post-project conditions.
	  ○ The design of the Mill Stream bridge would be further refined during the detailed design to mitigate the impact of the project on an increase in the rate and frequency of flow that discharges onto Southern Cross Drive as a result of an increase in flood levels in Mill Stream. This

Catchment	Changes in peak flood levels and depths
Mill Stream	would involve one or both of the following: ○ Increasing the length of the western span to reduce the encroachment of the western abutment on the floodway of Mill Stream. ○ Providing a retaining wall along the southern side of the rail line to the west of Mill Stream to reduce the encroachment of the rail embankment on the floodway of Mill Stream. ○ During the PMF there would be an increase in peak flood levels along Mill Stream and the section of Southern Cross Drive to its west by a maximum of 0.08 m, which is considered minor relative to the existing depth of inundation of 1 to 3 m. There would be no significant increase in the extent of inundation during a PMF event. • West of Mill Stream: ○ The upgrade of the drainage system along the section of rail corridor to the west of General Holmes Drive would result in a reduction in overland flow and therefore the depth and extent of inundation in an adjacent area of carparking type development between Baxter Road and the rail corridor. ○ The depth of inundation along Southern Cross Drive and the section of Botany Road to its north will be increased during events that result in surcharge of the western bank of Mill Stream onto Southern Cross Drive. Refer to the description of impacts above for Mill Stream. • East of Mill Stream: ○ The upgrade of the drainage system along the section of rail corridor between Mill Stream and Lord Street would result in a reduction in the depth and extent of inundation within the section of the Eastlake golf course to its north. There would also be a reduction in overland flow that discharges from the rail corridor and therefore the depth and extent of inundation in an area of industrial development to the south of the rail corridor. ○ The upgrade of the drainage system along the rail corridor between Banksia Street and Myrtle Street would result in either no change or a slight reduction in the depth of inundation along the sections of Banksia Street and Bay Street to the north of the rail corridor. There would also be a reduction in flow that discharges from the rail corridor into the section of Banksia Street to the south of the rail corridor, resulting in a reduction in the depth of inundation along the road. ○ During a 1% AEP event there would be an increase in peak flood levels upstream of the inlet to the 1,050 mm diameter pipe that crosses the rail corridor at Myrtle Street which would also lead to the following impacts in adjoining development: ▪ The depth of inundation in the road reserve of Myrtle Street would be increased by a maximum of 0.03 m, which is considered minor relative to existing depths of inundation of up to 1 m and the nature of the areas that would be impacted by the project. ▪ The depth of inundation in an area of Eastlake golf course to the north of the rail corridor would be increased by a maximum of 0.08 m, which is considered minor relative to existing depths of inundation of up to 0.5 m and the nature of the areas impacted. ▪ Peak flood levels in a multi-unit development at 104 Bay Street would be increased by a maximum of 0.02 m. Impacts would occur in the northern portion of the property over an area that includes several units that front Myrtle Street. ▪ Peak flood levels in a multi-unit development at 15 Begonia Street would be increased by a maximum of 0.02 m. Impacts would

Catchment	Changes in peak flood levels and depths
Mill Stream	occur in the northeastern portion of the property, adjacent to the entry to a basement carpark. Subject to further design development and assessment during detailed design it may be necessary to collect detailed survey within the multi-unit developments at 104 Bay Street and 15 Begonia Street, including floor levels of units and the level of entry points to units and basement carparks. The survey would be used to confirm the potential for an increase in above-floor inundation to residential units, as well as an increase in the rate and volume of flow into basement carparks. The survey would also assist in developing the scope of works that would be required to mitigate the impact that the project would otherwise have on these multi-unit developments. This scope of works may include: ▪ refinement of the drainage design to reduce the magnitude of flow that is diverted toward the inlet to the 1,050 mm diameter pipe that crosses the rail corridor at Myrtle Street ▪ provision of an oversized open channel or closed system box culvert along the northern side of the rail corridor between Myrtle Street and Bay Street to provide temporary floodplain storage to offset the displacement caused by the slightly widened rail embankment within the current design ▪ minimising changes in existing ground levels along the northern side of the rail corridor between Banksia Street and Myrtle Street in order to minimise changes to flood behaviour. ○ During the PMF there would be an increase in peak flood levels in an area of Eastlake golf course to the east of Mill Stream by a maximum of 0.25 m, which is considered minor relative to the existing depth of inundation of 1 m and the nature of the area that would be impacted by the project. There would be no significant increase in the extent of inundation during a PMF event.

TABLE 5.5
SUMMARY OF IMPACTS OF THE PROJECT ON FLOOD BEHAVIOUR - CHANGES IN PEAK FLOWS AND VELOCITIES

Catchment	Changes in peak flows and velocities
Alexandra Canal	• **Figure B.22**, sheet 2 in **Annexure B** shows that there would be increases in peak 1% AEP flow velocities along a section of Qantas Drive between King Street and Ewan Street, as well as an area of Sydney Airport immediately west of Qantas Drive. Increases would be confined to areas of road and carpark where scour potential would be low. The change in velocity would have a minor impact on the existing flood hazard as maximum flow velocities would be less than 0.5 m/s on depth of flow of 0.05 m. • There would be minor changes in flow behaviour downstream of drainage outlets DO1, DO2 and DO5. • During a 10% AEP event there would be an increase in the rate of surcharge of the drainage system in Qantas Drive downstream of drainage outlets DO3 and DO4, which is due to an increase in the rate of runoff from the rail corridor that occurs as a result of the increase in impervious area and the more efficient drainage system. During a 1% AEP event the increase in surcharge in Qantas Drive will also lead to an increase in the depth of inundation in an adjacent area of Sydney Airport. The impacts are located in an area of Qantas Drive that would be upgraded as part of the Sydney Gateway Road Project, while the impacts within Sydney Airport are located in an area that would be acquired as part of the Sydney Gateway Road Project. • During a 1% AEP event a section of Qantas Drive to the east of O'Riordan Street would be inundated due to surcharge of the drainage system downstream of drainage outlet DO6. This surcharge, which does not occur under pre-project conditions, is the result of an increase in the rate of runoff from the rail corridor due to the increase in impervious area and the more efficient drainage system.
Mill Stream	Mill Stream: • **Figure B.22**, sheet 3 in **Annexure B** shows that there would be increases in peak 1% AEP flow velocities downstream of the proposed Mill Stream bridge. Maximum flow velocities would be increased by up to 0.9 m/s, while the area impact would extend over a distance of 120 m downstream of the proposed bridge. The increase in flow velocities would increase the potential for scour to occur in Mill Stream. **Table 5.4** outlines measures that would be incorporated into the detailed design of the Mill Stream bridge that are aimed at mitigating its impact on the conveyance of flow in Mill Stream that would also reduce its impact on flow velocities. • While proposed drainage outlets DO12 and DO13 would have a minor impact on flow behaviour in Mill Stream, there is the potential for a localised increase in scour potential due to the concentrated discharge of runoff from the new drainage outlets. During detailed design scour protection and energy dissipation measures would be incorporated into the design of the drainage outlets to manage localised increases in flow velocity. • **Figure B.22**, sheet 3 in **Annexure B** shows that 1% AEP flow velocities along Southern Cross Drive and Botany Road would be increased by a maximum of by 0.5 m/s due to an increase in flow that surcharges the western bank of Mill Stream onto Southern Cross Drive. The increase in velocity and depth of flow along the road would increase the hazardous nature of flooding. **Table 5.4** outlines measures that would be incorporated into the detailed design of the Mill Stream bridge that are aimed at mitigating its impact on the conveyance of flow in Mill Stream. These measures would also reduce the impact the project would have on the rate of flow that surcharges the western bank of Mill Stream onto Southern Cross Drive.

<table>
<tr><th>Catchment</th><th>Changes in peak flows and velocities</th></tr>
<tr><td>Mill Stream</td><td>West of Mill Stream:
There would typically be only minor changes in flow velocities in areas of the catchment to the west of Mill Stream, with the exception of those along Southern Cross Drive and Botany Road (refer to the description of impacts above for Mill Stream).
There would be minor changes in flow behaviour downstream of drainage outlet DO14.
East of Mill Stream:
Figure B.22, sheet 3 in Annexure B shows the following changes in peak flow velocities during a 1% AEP event:
An area within the Eastlake golf course where flow velocities would be increased by 0.3 m/s on an existing velocity of 0.3 m/s. The increase in flow velocity is due to the upgrade of the drainage system in the rail corridor, which leads to a reduction in the build up of flow in the adjoining area of golf course. Increases in flow velocities would be confined to a vegetated area of the golf course where the resulting velocities would have a low potential for scour.
Sections of Bay Street and Banksia Street to the north of the rail corridor where flow velocities would be increased by up to 0.2 m/s and 0.4 m/s, respectively. These increases in flow velocity are due to the upgrade of the drainage system in the rail corridor, which leads to a reduction in the build up of flow in the adjacent sections of road. Increases in flow velocities are confined to areas of road where there is low scour potential, while the combination of increases in flow velocity and a reduction in flood depths has only a minor impact on the existing flood hazard.
There would be minor changes in flow behaviour downstream of drainage outlets DO7 to DO11.</td></tr>
</table>

TABLE 5.6
SUMMARY OF IMPACTS OF THE PROJECT ON FLOOD BEHAVIOUR - CHANGES IN THE EXTENT AND DURATION OF INUNDATION

Catchment	Changes in the extent and duration of flooding
Alexandra Canal	• During a 1% AEP event there would be a reduction in the extent of inundation along a section of Qantas Drive adjacent the Lancastrian Bridge, while conversely there would be an increase in the extent of inundation along a section of Qantas Drive and adjoining area of Sydney Airport opposite Ewan Street. There would also be a relatively localised increase in the extent of inundation along a section of Qantas Drive to the east of O'Riordan Street. Across the remainder of the Alexandra Canal catchment there would be relatively minor changes in the extent of inundation for all events up to the PMF. • There would be relatively minor changes in the duration of inundation across the Alexandra Canal catchment as a result of the project.
Mill Stream	Mill Stream: • There would be minor changes in the extent and duration of inundation along the main arm of Mill Stream. • During a 1% AEP event there would be an increase in both the extent and duration of inundation along Southern Cross Drive, Botany Road and an area of undeveloped land to the west of Botany Road. The increase in the extent and duration of inundation, which would impede vehicular movements, is due to an increase in flow that surcharges the western bank of Mill Stream onto Southern Cross Drive. **Table 5.4** outlines measures that would be incorporated into the detailed design of the Mill Stream bridge that are aimed at mitigating its impact on the conveyance of flow in Mill Stream. These measures would also reduce the impact that the project would have on the rate of flow that surcharges the western bank of Mill Stream onto Southern Cross Drive. West of Mill Stream: • The upgrade of the drainage system along the section of rail corridor to the west of General Holmes Drive would result in a reduction in the extent of inundation in an adjacent area of carparking type development between Baxter Road and the rail corridor. • The extent of inundation along Southern Cross Drive and the section of Botany Road to its north would be increased during events that result in surcharge of the western bank of Mill Stream onto Southern Cross Drive. Refer to the description of impacts above for Mill Stream. East of Mill Stream: • During a 1% AEP event there would be an increase in the extent and duration of inundation in an area of the Eastlake golf course to the north of the rail corridor between Myrtle Street and Lord Street, while conversely areas within the Eastlake golf course to the north and south of the affected area would experience a reduction in the extent and duration of inundation. • The upgrade of the drainage system along the rail corridor between Banksia Street and Myrtle Street would result in either no change or a slight reduction in the extent and duration of inundation along the sections of Banksia Street and Bay Street to the north of the rail corridor. There would also be a reduction in flow that discharges from the rail corridor into the section of Banksia Street to the south of the rail corridor, resulting in a reduction in the extent and duration of inundation along the road.

TABLE 5.7
SUMMARY OF PEAK 1% AEP FLOOD LEVELS – CURRENT AND FUTURE CLIMATE CHANGE CONDITIONS(1)

Project Element	Location	Current conditions(2)	Scenario 1(3)	Scenario 2(3)	Potential impacts of future climate change on flood behaviour
Duplication of existing rail line	Lancastrian Road to O'Riordan Street	5.63	5.66 *[0.03]*	5.71 *[0.08]*	The section of rail line between Lancastrian Road and O'Riordan Street is located above the 1% AEP flood level under both future climate change scenarios.
	O'Riordan Street to General Holmes Drive (Southern track)	5.80	5.85 *[0.05]*	5.92 *[0.12]*	The southern track would be inundated to a depth of between 0.35 m and 0.42 m above the ballast, in comparison to a depth of 0.30 m under current climatic conditions. The depth of inundation under future climate change would still be a minimum 0.38 m below the top of rail level.
	O'Riordan Street to General Holmes Drive (Northern track)	5.36	5.60 *[0.24]*	5.91 *[0.55]*	The northern track would be inundated to a depth of between 0.20 m and 0.41 m above the ballast, whereas the ballast would not be inundated under current climatic conditions. Under future climate change Scenario 2 the depth of inundation would still be 0.39 m below the top of rail level.
	General Holmes Drive to Southern Cross Drive	6.55	6.56 *[0.01]*	6.57 *[0.02]*	The section of rail line between General Holmes Drive to Southern Cross Drive is located above the 1% AEP flood level under both future climate change scenarios.
	Southern Cross Drive to Banksia Street	8.75	8.82 [0.07]	8.90 *[0.15]*	The northern track would be inundated to a depth of between 0.47 m and 0.55 m above the ballast, in comparison to a depth of 0.40 m under current climatic conditions. The depth of inundation under future climate change conditions would still be a minimum 0.25 m below the top of rail level.
Bridge waterway crossings	Mill Stream bridge	6.00	6.13 *[0.13]*	6.25 *[0.25]*	The underside of the both the existing and new bridges over Mill Stream would be located more than 0.5 m above the peak 1% AEP flood level under both future climate change scenarios.
New corridor access roads	Coleman Street to 20 m west of Ewan Street	5.08	5.17 *[0.09]*	5.27 *[0.19]*	The new corridor access road is located above the 1% AEP flood level under both future climate change scenarios.
	General Holmes Drive to 235 m west of General Holmes Drive	4.97	5.29 *[0.32]*	5.61 *[0.64]*	The new corridor access road would be inundated to a depth of between 0.05 m and 0.37 m, whereas the access road would not be inundated under current climatic conditions.

Project Element	Location	Current conditions(2)	Scenario 1(3)	Scenario 2(3)	Potential impacts of future climate change on flood behaviour
	Botany Road bridge to Southern Cross Drive bridge	5.02	5.45 _[0.43]_	5.60 _[0.58]_	The western end of the new corridor access road at its connection to Botany Road would be inundated to a depth of between 0.49 m and 0.64 m, in comparison to a depth of 0.06 m under current climatic conditions.
	Mill Stream to Banksia Street	8.48	8.69 _[0.21]_	8.83 _[0.35]_	The low point in the access road about 140 m north of Myrtle Street would be inundated to a depth of between 0.81 m and 0.95 m, in comparison to a depth of 0.60 m under current climatic conditions.

1. Peak flood levels quoted to two decimal places for ease of comparison only. Adopted peak flood levels for design purposes should be rounded off to the nearest 0.1 m.
2. Where applicable peak flood levels are quoted at the location with the smallest freeboard or greatest depth of inundation.
3. Values in brackets represent the increase in peak flood level relative to current climatic conditions.

TABLE 5.8
IMPACT OF A PARTIAL BLOCKAGE OF MAJOR HYDRAULIC STRUCTURES ON PEAK 1% AEP FLOOD LEVELS(1)

Project Element	Location	With blockage(2)	Without blockage(3)	Potential impacts of blockage on flood behaviour
Duplication of existing rail line	Lancastrian Road to O'Riordan Street	5.63	5.63 *[0.00]*	Flood behaviour is not affected by a partial blockage of major hydraulic structures.
	O'Riordan Street to General Holmes Drive (Southern track)	5.80	5.80 *[0.00]*	Flood behaviour is not affected by a partial blockage of major hydraulic structures.
	O'Riordan Street to General Holmes Drive (Northern track)	5.36	5.36 *[0.00]*	Flood behaviour is not affected by a partial blockage of major hydraulic structures.
	General Holmes Drive to Southern Cross Drive	6.55	6.55 *[0.00]*	Flood behaviour is not affected by a partial blockage of major hydraulic structures.
	Southern Cross Drive to Banksia Street	8.75	8.76 *[0.01]*	Minor increase in peak 1% AEP flood level at the inlet to the 1,050 mm diameter pipe that crosses the rail corridor at Myrtle Street.
Bridge waterway crossings	Mill Stream bridge	6.00	6.03 *[0.03]*	Minor increase in peak 1% AEP flood level at Mill Stream bridge.
New corridor access roads	Coleman Street to 20 m west of Ewan Street	5.08	5.08 *[0.00]*	Flood behaviour is not affected by a partial blockage of major hydraulic structures.
	General Holmes Drive to 235 m west of General Holmes Drive	4.97	4.97 *[0.00]*	Flood behaviour is not affected by a partial blockage of major hydraulic structures.
	Botany Road bridge to Southern Cross Drive bridge	5.02	5.02 *[0.00]*	Flood behaviour is not affected by a partial blockage of major hydraulic structures.
	Mill Stream to Banksia Street	8.48	8.48 *[0.00]*	Flood behaviour is not affected by a partial blockage of major hydraulic structures.

1. Peak flood levels quoted to two decimal places for ease of comparison only. Adopted peak flood levels for design purposes should be rounded off to the nearest 0.1 m.
2. Where applicable, peak flood levels are quoted at the location with the smallest freeboard or greatest depth of inundation.
3. Values in brackets represent the increase in peak flood level relative to current climatic conditions.

5.3 Cumulative impacts

This section presents the findings of an assessment of the potential impacts the project would have on flood behaviour in combination with the following other projects in its vicinity:

- Sydney Gateway Road project
- Qantas Flight Training Centre
- WestConnex Stage 2 (New M5)
- WestConnex Stage 3 (M4-M5 Link)
- F6 Extension Stage 1
- Airport East
- Airport North
- Future Airport Hotel
- Mascot Intersections

The assessment was based on impacts during the operation of the project only, given the short term nature of exposure to potential flood impacts during its construction together with the general requirement to manage adverse impacts on the existing development. Furthermore, the assessment presented in **Section 5.1.2** found that the greatest potential for impacts associated with the construction of the project would be as a result of the construction of the Mill Stream bridge, which is located in an area of the Mill Stream floodplain that is remote from the other projects listed above.

The findings of the assessment of potential cumulative impacts on flood behaviour are summarised below.

Sydney Gateway Road project:

- The future Sydney Gateway Road project would involve the upgrade of the section of Qantas Drive to the south of the rail corridor within the Alexandra Canal catchment that, in combination with the project, has the potential for cumulative impacts on flood behaviour.
- While subject to future design development and environmental approvals, the Sydney Gateway Road project is likely to include surface earthworks and widening of the existing section of Qantas Drive between O'Riordan Street and Lancastrian Road, which may impact on flow behaviour in the drainage systems that run across Qantas Drive and through Sydney Airport between O'Riordan Street and Lancastrian Road.
- Given the minor nature of impacts on flow behaviour in the drainage systems that run through Sydney Airport that are attributable to the project, it is expected that the cumulative impacts of it in combination with the Sydney Gateway Road project would also be minor in nature.

Qantas Flight Training Centre

- The future Qantas Flight Training Centre project would involve the construction of a new flight training centre and ancillary facilities to replace the existing facility located within Sydney Airport that would be impacted by the Sydney Gateway Road project. The new flight training centre would be located on land that is located to the east of the rail corridor, north of King Street.

- The potential cumulative impact of the project in combination with the Qantas Flight Training Centre project is considered to be minor on the basis that:
  - The land on which the new Qantas Flight Training Centre is proposed to be located contains a significant portion of impervious surface comprising existing carparking and buildings. As a result, changes in runoff behaviour attributable to the new flight training centre would be expected to be minor.
  - Given the minor nature of impacts that are attributable to the project on flow behaviour in the drainage systems that control runoff from the section of rail corridor to the north of King Street, it is expected that the cumulative impacts of it in combination with the Qantas Flight Training Centre project would also be minor in nature.

New M5 Motorway:

- The New M5 Motorway project involves the construction of a new interchange at St Peters with local road connections at Canal Road and Campbell Road within the Alexandra Canal catchment.
- There would be no cumulative impacts on flood behaviour as the New M5 Motorway is located in an area of the Alexandra Canal catchment that is remote from the project.

M4-M5 Link:

- There would be no cumulative impacts on flood behaviour as the M4-M5 Link project is located in adjacent valleys that are remote from the project.

F6 Extension Stage 1:

- There would be no cumulative impacts on flood behaviour as the F6 Extension Stage 1 project is located in adjacent valleys that are remote from the project.

Airport East:

- The Airport East project involves the upgrade of Botany Road, General Holmes Drive and Joyce Drive, as well as the replacement of the existing General Holmes Drive rail level crossing with a road underpass linking General Holmes Drive, Botany Road and Wentworth Avenue. The proposed works are located within the Mill Stream catchment.
- Given the minor nature of impacts that are attributable to the project on flood behaviour in the drainage systems that control runoff from the section of rail corridor in the vicinity of Joyce Drive, General Holmes Drive and Botany Road, it is expected that the cumulative impacts of it in combination with the Airport East project would also be minor in nature.

Airport North:

- The Airport North project involves the widening of O'Riordan Street between Bourke Road and Robey Street and the upgrade of the southern sections of Robey Street and O'Riordan Street at their connection with Qantas Drive. The proposed works are located within the Alexandra Canal catchment.

- Given the minor nature of impacts that are attributable to the project on flow behaviour in the drainage systems that control runoff from the section of rail corridor in the vicinity of Robey Street and O'Riordan Street, it is expected that the cumulative impacts of it in combination with the Airport North project would also be minor in nature.

Future Airport Hotel:

- The Future Airport Hotel project would involve the construction of a new hotel on Qantas Drive between Seventh Street and Ninth Street, which are located opposite Robey Street and O'Riordan Street within the Alexandra Canal catchment.
- Given the minor nature of impacts that are attributable to the project on flow behaviour in the drainage systems that control runoff from the section of rail corridor in the vicinity of Robey Street and O'Riordan Street, it is expected that the cumulative impacts of it in combination with the Future Airport Hotel project would also be minor in nature.

Mascot Intersections:

- The future Mascot Intersections project would involve the upgrade of the following intersections within the Alexandra Canal catchment to manage traffic flow and improve safety:
    - Gardeners Road and O'Riordan Street
    - Gardeners Road and Botany Road
    - Kent Road and Ricketty Street
    - Coward Street and Kent Road
    - Bourke Street and Coward Street.
- There would be no cumulative impacts on flood behaviour as the Mascot Intersections project is located in an area of the Alexandra Canal catchment that is remote from the project.

6 MANAGEMENT OF IMPACTS

6.1 Approach

The assessment of flood impacts associated with the project has provided an understanding of the scale and nature of the flood risk to the project, as well as the increased flood risks on the surrounding environment during its construction and operation. Further assessment will be undertaken during the detailed design phase of the project that will build on the flood assessment presented in this technical working paper and will be based on further design development and flood modelling where required. The approach to this further flood assessment will be based on:

- The identification of flood risks to the project, including the consideration of local drainage characteristics and a partial blockage of waterway structures on flood behaviour.
- The identification of potential flood impacts on the existing environment and future development potential of land, including the collection of floor level survey where required to confirm whether there would be an increase in the frequency and depth of above-floor inundation to existing residential, commercial and industrial buildings.
- The identification of design and flood mitigation measures that will be implemented to manage the risk of flooding to proposed operations and not worsen existing flooding characteristics during construction and operation, including erosion and scour.
- The identification of measures to be implemented during the construction of the project in order to prepare for a flood, as well as the procedures that will need to be implemented during a flood.

The flood assessment during the detailed design phase will be undertaken in consultation with Transport for NSW, Sydney Water, SES and relevant councils.

The following sections outline measures which will be considered to manage the flood risks and impacts during the construction and operational phases of the project.

6.2 Management of construction impacts

A broad outline of measures which will be considered for incorporation into the CEMP in order to manage construction related flood risks and impacts are outlined below.

Earthworks

- Surface earthworks within all five work areas (WA1 to WA5) are affected by main stream flooding, major overland flow or local catchment runoff to varying degrees. Flow that currently discharges onto the land proposed for project earthworks has the potential to cause scouring of disturbed surfaces, as well as the transport of sediment and construction materials. It will therefore be necessary to plan, implement and maintain measures which are aimed at:
  - intercepting flow from areas upstream of the project and diverting it in a controlled manner whether through or around the construction sites
  - implementing construction practices that minimise the potential for scour through stabilisation of disturbed surfaces.

Spoil management

- Spoil stockpiles will need to be located in areas that are not subject to frequent inundation by floodwater and ideally outside the 1% AEP flood extent. The CEMP will define the flood immunity criteria for stockpiles proposed to be located in areas that are inundated during a 1% AEP event. These criteria will be based on the duration of stockpiling operations, the type of material stored, the nature of the receiving drainage lines and also the extent to which the stockpile would impact flooding conditions in adjacent areas. The frequency at which each construction site is impacted by flooding is summarised in **Table 5.1**.

Site facilities and flood emergency management

- As a minimum, site facilities are to be located outside high flood hazard areas based on a 1% AEP flood and ideally outside the 1% AEP flood extent.
- For site facilities located within the floodplain, the CEMP is to identify how risks to personal safety and damage to construction facilities and equipment will be managed.
- The CEMP will need to include details of:
  - the procedure to monitor accurate and timely weather data, and disseminate warnings to construction personnel of impending flood producing rain
  - an evacuation plan for construction personnel should a severe weather warning be issued.

Management of adverse flood impacts on existing development

- The CEMP will need to include details and procedures to manage the potential for proposed construction activities to adversely impact on flood behaviour in adjacent development.
- A more detailed assessment of the impact that construction activities would have on flood behaviour, as well as the scope of measures which will be required to mitigate those impacts, will need to be undertaken during the detailed design phase, with the benefit of more refined construction plans and details by the preferred construction contractor.
- Subject to the outcomes of further design development and flood assessment during the detailed design phase, a floor level survey may need to be undertaken of affected properties (i.e. in properties where there is a potential increase in flood levels) to determine whether construction activities will increase flood damages in adjacent development and if mitigation measures are required.
- The layout of the construction compounds, material storage areas, as well as temporary crane pads and piling platforms will need to be designed to:
  - Limit the extent of works located in floodway areas
  - Divert overland flow either through or around work areas in a controlled manner
  - Minimise adverse impacts on flood behaviour in adjacent development.
- Measures to manage residual flood impacts may include:
  - staging construction to limit the extent and duration of temporary works on the floodplain

  - ensuring construction equipment and materials are removed from floodplain areas at the completion of each work activity or should a weather warning be issued of impending flood producing rain
  - providing temporary flood protection to properties identified as being at risk of adverse flood impacts during any stage of construction of the project
  - developing flood emergency response procedures to remove temporary works during periods of heavy rainfall.

6.3 Management of operational impacts

A broad outline of measures which will be considered during the detailed design phase in order to manage operational related flood risks and impacts are outlined below.

Rail duplication

- As a minimum, the modification and duplication of the existing rail line is to be configured to ensure the existing level of flood immunity is not reduced by the project.
- Measures to improve the existing level of flood immunity and ideally provide a 1% AEP level of flood immunity are to be further investigated during detailed design.

New bridge over Mill Stream

- The new bridge crossing over Mill Stream is to provide a minimum freeboard of 0.5 metres between the underside of the bridge structure and the peak 1% AEP flood level.

System and control network

- Rail location cabinets (LOCs) for housing communications, power and signalling equipment for the system and control network would be located a minimum 0.5 metres above the peak 1% AEP flood level in accordance with ARTC standards.

New corridor access roads

- A 10% AEP level of flood immunity is to be provided to the new access roads.

Management of adverse flood impacts on the existing environment

- A detailed hydrologic and hydraulic (flood) assessment of the impacts of the project on flood behaviour and the associated measures which are required to mitigate those impacts will be undertaken during detailed design.
- Works within the floodplain would be designed to minimise adverse impacts on surrounding development for flooding up to the 1% AEP event in magnitude. Assessment would also be made of impacts during floods up to the PMF in the context of impacts on critical infrastructure and flood hazards.
- Subject to the flood assessment during detailed design a detailed ground survey (including floor levels and entry levels to buildings and basement carparks) may need to be undertaken in affected areas to determine whether the project would increase flood damages in adjacent development (i.e. in properties where there is a potential for increases in peak flood levels for events up to 1% AEP in magnitude) or increase the flood hazard to basement carparks (i.e. in basement carparks where there is a potential

for increases in the frequency, rate and volume of flow into basement carparks for events up to the PMF).

- The design of the project would need to incorporate measures that are aimed at mitigating the impact of the project on flood behaviour in properties where existing buildings would experience above-floor inundation during floods up to the 1% AEP event, or where there is the ingress of floodwater to basement carparks during storms up to the PMF.
- Localised increases in flow velocities at the outlets to upgraded, relocated or new stormwater drainage systems would be mitigated through the provision of scour protection and energy dissipation measures.

7 CONCLUSION

This report has documented the findings of a flooding assessment that has been carried out to support the EIS for the Botany Rail Duplication project. Baseline conditions with respect to existing flood behaviour were established and the nature and extent of the potential impacts associated with the proposed works identified. The potential impacts associated with both the construction and operational phases of the project were considered as part of the assessment.

The assessment of flood risks to the project and its impact on the surrounding environment, as well as the development of appropriate flood standards and mitigation measures has been carried out in accordance with the requirements of the SEARs issued by DPE, the *Floodplain Development Manual* (DIPNR 2005) and other relevant Commonwealth, state and local government guidelines.

Flood risks to the project during construction

Table 5.1 presents a summary of the construction related flood risks at the five proposed construction work areas and their associated construction compounds and activities. The assessment found that all proposed construction work areas have the potential to be impacted by flooding or local catchment runoff to some degree. It would therefore be necessary to develop a measures to deal with the flooding and stormwater related issues that are specific to each construction work area that would be incorporated into the CEMP for the project. The CEMP would need to include procedures that are aimed at reducing the risks to human safety and damage to infrastructure that would be associated with heavy rainfall or a flood event were they to occur during the construction period.

Impacts of the project construction on existing flood behaviour

A qualitative assessment of the impacts that the construction works areas could have on flooding (refer **Table 5.1** which summarises the key findings of the investigation) identified that the greatest potential for adverse impacts on flood behaviour is due to the impact that the construction of the Mill Stream bridge and its associated Mill Stream construction compound (C5), temporary crane pads (CP4) and temporary piling platforms could have on the conveyance of flow in Mill Stream. The works also have the potential to increase flow velocities and therefore scour and erosion potential in Mill Stream.

There is also the potential for all the construction work areas to impact local catchment runoff, requiring appropriate local stormwater management controls to be implemented during the construction phase of the project. The CEMP would therefore need to include details and procedures to manage the risk of adverse flood impacts being experienced in adjacent development during the construction period.

Flood risks to the project during operation

Section 3.3 sets out the recommended level of flood protection associated with the key elements of the project based on consideration of the consequences of flooding in accordance with the *Floodplain Development Manual* and current ARTC standards. **Table 5.3** sets out the operational related flood risks associated with key elements of the project.

The investigation found that the modification and duplication of the existing rail line would maintain and in some areas improve on the existing level of flood immunity. Measures to further improve the level of flood immunity and ideally provide a 1% AEP level of flood immunity would be further investigated during detailed design.

Impacts of the project operation on existing flood behaviour

The investigation found that once constructed, the project would generally have only a minor impact on flood behaviour in adjacent development for floods up to the PMF (refer **Tables 5.3**, **5.4** and **5.5** for a summary of key findings). Based on the assessment of the current design the following residual flood impacts have been identified on existing infrastructure:

1. There would be an increase in peak flood levels upstream of Mill Stream bridge which in turn would lead to an increase in the frequency and rate of flow that surcharges the western bank of Mill Stream and is conveyed along Southern Cross Drive and Botany Road.

   The design of the Mill Stream bridge would be further refined during the detailed design to reduce the encroachment of the proposed works on the floodway of Mill Stream in order to mitigate the impact the project would have on the rate and frequency of flow that discharges onto Southern Cross Drive.

2. During a 1% AEP event there would be an increase in peak flood levels upstream of the inlet to the 1,050 millimetre diameter pipe that crosses the rail corridor at Myrtle Street which would also lead to the following impacts in adjoining development:

   - Peak flood levels in a multi-unit development at 104 Bay Street would be increased by a maximum of 0.02 metres. Impacts would occur in the northern portion of the development over an area that includes several units that front Myrtle Street.
   - Peak flood levels in a multi-unit development at 15 Begonia Street would be increased by a maximum of 0.02 metres. Impacts would occur in the northeastern portion of the development, adjacent to the entry to a basement carpark from Myrtle Street.

   Measures would be incorporated into the detailed design that are aimed at mitigating the impact of the project on an increase in above-floor inundation to properties for all events up to 1% AEP, and an increase in the frequency, rate and volume of flow into basement carparks for all events up to the PMF.

The nature and extent of the project related impacts and also the scope of the required mitigation measures would be subject to further flood assessment which would be undertaken during the detailed design phase. Subject to this further flood assessment, detailed ground survey may be required in affected developments to confirm the extent to which the proposed works would increase flood damages and flood hazards in affected development and therefore to design the scope of measures that may be required to mitigate any unacceptable impacts of the project on flooding.

The investigation found that while the current design would increase the potential for scour and erosion in Mill Stream, these impacts are expected to be mitigated through the implementation of measures which are aimed at reducing the encroachment of the proposed works on the floodway of Mill Stream (refer Item 1 above).

Subject to the incorporation of the mitigation measures during the detailed design as outlined in Items 1 and 2 above, the project would have only a minor impact on peak 1% AEP flood levels and flow velocities within areas outside the project footprint. Increases in PMF levels are also considered minor in terms of the relative increase in flood hazard and changes in the extent of inundation. As a result, it is considered that the project would have no significant impact on the extent of the floodplain or its hazard categorisation. It is also considered that the project would have no significant impact on emergency access during times of flood and therefore the emergency response arrangements that would be developed as part of any future Local Flood Plan for the area. Nor would the changes in flooding patterns result in a significant change to the Flood Planning Area or the future development potential of land located outside the project footprint, or the social and economic costs of flooding.

The project would generally have a minor impact on flow behaviour in the drainage systems would control runoff from the project corridor. While the investigation found that there would be a slight increase in the depth of inundation in Qantas Drive and an adjoining portion of Sydney Airport due to an increase in flow that surcharges the drainage system downstream of the rail corridor, impacts would be confined to an area that would be upgraded as part of the Sydney Gateway Road project.

The assessment found that the project would have only a minor impact on the extent and duration of inundation of flooding within Mill Stream.

Impact of future climate change on flood behaviour

Future climate change has the potential to increase the frequency and depth of inundation to the modified and duplicated sections of rail. For example, during a 1% AEP event a section of the northern track between O'Riordan Street and General Holmes Drive would be inundated to a depth of 0.4 metres above the toe of ballast under upper bound estimate of future climate change, whereas the ballast would not be inundated under current climatic conditions. The depth of inundation to the ballast would be increased to a section of southern track between O'Riordan Street and General Holmes Drive and a section of the northern track between Southern Cross Drive and Banksia Street.

While flooding under future climate change conditions would increase the depth and frequency of inundation to the ballast below the duplicated rail line, the depth of inundation would still be a minimum 0.25 metres below the top of rail level. Raising the level of the rail line in order to reduce the depth of inundation to the ballast would be constrained by the level of the existing rail line and is also likely to result in adverse impacts on flood behaviour in areas outside the rail corridor.

Cumulative impacts

The assessment found that due to the relatively localised and minor nature of the project related flood impacts there would be either minor or no cumulative impacts associated with it and other major projects in its vicinity.

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