HAWKESBURY-NEPEAN VALLEY FLOOD EVACUATION ROAD RESILIENCE PROGRAM
IMPROVEMENTS ON THE NORTHERN ROAD AND LONDONDERRY ROAD FLOOD EVACUATION ROUTES

REVIEW OF ENVIRONMENTAL FACTORS

TECHNICAL PAPER: FLOODING

July 2024

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TABLE OF CONTENTS

Page No.

Continued over page

TABLE OF CONTENTS (Cont'd)

LIST OF FIGURES

LIST OF ANNEXURES

A. Concept layouts showing proposed scope of drainage improvements

B. Table summarising drainage related works associated with drainage improvements and road shoulder widening

C. Figures showing the layout of hydrologic and hydraulic models

D. Figures showing patterns of mainstream flooding and major overland flow under pre-proposal conditions for design storms with AEPs of 20%, 5% and 0.05%

E. Figures showing maximum flow velocities and durations of inundation under pre-proposal conditions for storms with AEPs of 10% and 1%

F. Figures showing patterns of mainstream flooding and major overland flow under post-proposal conditions for storms with AEPs of 20%, 5% and 0.05%

G. Figures showing the impact of the proposal on flood behaviour for storms with AEPs of 20%, 5% and 0.05%

H. Figures showing maximum flow velocities and durations of inundation under post-proposal conditions as well as the impact of the proposal on maximum flow velocities and durations of inundation for storms with AEPs of 10% and 1%

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

The technical 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 technical paper 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).
BoM	Bureau of Meteorology.
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).
CEMP	Construction Environmental Management Plan.
Construction footprint	The area required for the construction of the proposal.
Construction ancillary sites	The key sites containing ancillary facilities to support the construction of the proposed drainage improvements and road shoulder widening associated with the proposal. Ancillary facilities would include, but are not limited to, storage of plant, equipment and materials, and/or construction site offices and parking.
Cumulative impact	The combined impacts of the proposal on a matter with other relevant future projects.
DCP	Development control plan.

Term	Meaning
DECC	Department of Environment and Climate Change (now DPE EES).
DECCW	Department of Environment, Climate Change and Water (now DPE EES).
Detailed design	The detailed design of the proposal, including construction methodology. This term represents the next phase of proposal development and will further develop the design and construction methodology of the proposal considering the performance outcomes and mitigation measures as recommended in the REF.
DIPNR	Department of Infrastructure, Planning and Natural Resources (now DPE EES).
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]).
DPIE	Department of Planning and Environment.
DPE EES	Department of Planning and Environment – Environment Energy and Science.
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.
Embankment	An earthen structure where the road (or other infrastructure) is located above the natural surface.
Erosion	A natural process where wind or water detaches a soil particle and provides energy to move the particle.
FDM	*Floodplain Development Manual* (Department of Planning, Infrastructure and Natural Resources (DIPNR) 2005).
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.

Term	Meaning
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).
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.
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.
FRMM	*Floodplain Risk Management Manual* (Department of Planning and Environment (DPE) 2023a).
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.
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.
IFD	Intensity-Frequency-Duration.
Impact	Influence or effect exerted by a proposal, project or other activity on the natural, built and community environment.

Term	Meaning
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.
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.
Mainstream 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.
Operational footprint	The area that would be occupied by permanent components of the proposal.
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).

Term	Meaning
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-proposal conditions	Conditions (within the study area) prior to the construction of the State Project component of the Hawkesbury-Nepean Valley Evacuation Road Resilience Program. This includes details of projects that are presently under construction or will be constructed prior to the State Project component of the Hawkesbury-Nepean Valley Evacuation Road Resilience Program.
Proponent	Transport for NSW
Proposal	The construction and operation of the State Project component of the Hawkesbury-Nepean Valley Flood Evacuation Road Resilience Program.
PRM	Probabilistic rational method.
Probability	A statistical measure of the expected chance of flooding (see annual exceedance probability).
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.
NSW SES	NSW State Emergency Services.
Spoil	Surplus excavated material.
Stage	Equivalent to water level (measured with reference to a specified datum).
Stockpile	Temporarily stored materials such as soil, sand, gravel and spoil/waste.
Surcharge	Overflow from a creek, waterbody, overland flow or drainage system.

ES1 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 Hawkesbury-Nepean Valley Flood Evacuation Road Resilience Program – Improvements on The Northern Road and Londonderry Road flood evacuation routes (**proposal**).

The proposal would involve drainage improvements and road shoulder widening along The Northern Road and Londonderry Road flood evacuation routes, which comprise the state roads component of the Hawkesbury-Nepean Valley Flood Evacuation Road Resilience Program (**Program**) (The Northern Road and Londonderry Road are collectively referred to as the 'state roads'). The Program is aimed at improving the flood resilience of the Hawkesbury-Nepean Valley by reducing existing impediments to vehicular movements.

This report has been prepared to support the Review of Environmental Factors (**REF**) for the proposal. **Sections 1** to **3** provide background to the proposal and the overarching Program, as well as the approach that was adopted in carrying out 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 proposal and also the impact that the proposal would have on flood behaviour.

Existing environment

The roads that comprise the proposal are identified in the *Hawkesbury Nepean Valley Flood Emergency Plan* (NSW SES, 2020) as key flood evacuation routes for sections of the Hawkesbury-Nepean River floodplain. The proposal traverses both semi-rural and urbanised portions of the Rickabys Creek, South Creek, Penrith Lakes and Boundary Creek catchments, all of which form part of the much larger Hawkesbury-Nepean River catchment. The investigation found that the stormwater drainage systems that control runoff from the catchments draining to the proposal are typically of limited capacity. As a result, there are sections of the proposal that are presently impacted by mainstream flooding and major overland flow due to local catchment runoff during periods of heavy rainfall.

Section 4 contains a brief description of the characteristics of the catchments that drain to the proposal corridor, as well as a description of the nature of local catchment flooding under present day (or pre-proposal) conditions for design storms with AEPs between 20% and 0.2%, as well as the Probable Maximum Flood (**PMF**).

Impacts during construction

Impact of flooding on construction activities associated with the proposal

Table 5.1 in **Section 5.1** provides a summary of the assessed flood risk at each construction work area and their associated activities, while **Figure 5.1** (12 sheets) shows the extent to which floods of varying magnitude affect each construction work area.

The assessment found that a number of the construction work areas would be affected by flooding during storms as frequent as 20% AEP. Inundation of these construction work areas by flooding has the potential to:

- cause damage to the proposed 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 broad outline of potential measures aimed at mitigating the impact of flooding on the construction of the proposal is provided in **Chapter 7**.

Figure 5.1 (12 sheets) also shows the location of ten construction ancillary sites (denoted ancillary sites 1 to 10) that are proposed to support construction activities across the construction work areas. Each ancillary site 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. **Table 5.1** provides a summary of the ancillary sites within each construction work area.

Site facilities located in areas exposed to high flood depths and/or velocities pose a safety risk to construction personnel. It is noted that the depth and velocity of flooding across each of the proposed ancillary sites during a 1% AEP design storm event typically corresponds to a hazard vulnerability classification[1] of H1, which is generally considered safe for persons and vehicles.

Impact of construction activities associated with the proposal on flood behaviour

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 would involve works within the floodplain that would need to be managed, the assessment found that the greatest potential for adverse impacts on flood behaviour is associated with the replacement or extension of existing transverse drainage structures.

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 (i.e. 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. Further details on the range of measures which will be considered to mitigate the potential construction related impacts of the project are outlined in **Chapter 7**.

[1] The hazard vulnerability classification of flooding was determined using the thresholds set out in Table 6.7.4 of Chapter 7 of Book 6 of ARR 2019.

Impacts during operation

Impact of flooding on the proposal

At locations where both drainage improvements and road shoulder widening are proposed

The assessment found that of the thirteen (13) locations where both drainage improvements and road shoulder widening are proposed a 0.2% AEP level of flood immunity would be provided to both the outbound travel lane and widened shoulder.

At locations where road shoulder widening is proposed in the absence of drainage improvements

The assessment found that of the thirty-seven (37) locations where road shoulder widening is proposed in the absence of drainage improvements:[2]

i. the outbound travel lane would:
    a. not be flooded at seventeen (17) locations
    b. have a hazard vulnerability classification of H1 at twenty (20) locations, which is generally considered to be safe for persons and vehicles.

ii. the outbound shoulder would:
    a. not be flooded at fifteen (15) locations
    b. have a hazard vulnerability classification of H1 at twenty (20) locations
    c. have a hazard vulnerability classification of H2 at two location (transverse drainage structures TNR01 and LNR08), which is generally considered to be unsafe for small vehicles.

At transverse drainage structure TNR01, the hazard vulnerability classification of H2 along the outbound shoulder is due to the depth of inundation exceeding 0.3 metres (occurring to a maximum of 0.32 metres). The extent of the widened shoulder where ponding depths exceed 0.3 metres occurs over a length of about 70 metres but encroaches into the widened shoulder to a maximum width of 1 metre. The duration of time that depths exceed 0.3 metre during a 0.2% AEP design storm would be less than 30 minutes.

In order to reduce the hazard vulnerability classification along the outbound shoulder, it would be necessary to reduce the depth of inundation by either increasing the capacity of transverse drainage structure TNR01 or raising the level of the outbound shoulder by reducing the crossfall of the road. It is noted that increasing the capacity of transverse drainage structure TNR01 would in turn require the construction of a channel through properties located in The Northern Road and Bennetts Road to control the increase in flow discharging from the transverse drainage structure. This drainage channel would require the acquisition of an easement and would therefore be subject to consultation with the affected property owners.

At transverse drainage structure LNR08, the hazard vulnerability classification of H2 along the outbound shoulder is also due to the depth of inundation exceeding 0.3 metres (occurring to a maximum of 0.38 metres). The extent of the widened shoulder where ponding depths exceed 0.3 metres occurs over a length of about 90 metres and encroaches into the widened shoulder to a maximum width of 2.5 metres. The duration of time that depths exceed 0.3 metre during a 0.2% AEP design storm would be approximately 1 hour.

[2] Includes the section of Londonderry Road that drains to transverse drainage structures LNR08 and LNR09, parts of which do not require widening as the existing shoulder width is adequate for vehicles.

The investigation found that there is limited scope to reduce the hazardous nature of flooding to the section of Londonderry Road adjacent to transverse drainage structure LNR08 by increasing the capacity of the drainage system due to the low lying nature of the road, as well as the impact that the any proposed increase in capacity could potentially have on flood behaviour in areas downstream of the structure. In order to reduce the hazardous nature of flooding, it is likely to be necessary to raise the level of Londonderry Road at transverse drainage structure LNR08, noting that this would exacerbate flooding in adjoining properties due to the displacement of floodwater that presently ponds in the road corridor.

Impact of the proposal on flood behaviour

Storms up to 1% AEP in intensity

Table 6.2 at the end of **Chapter 6** of this technical paper contains a summary of the impact that the proposal would have on flood behaviour during storms up to 1% AEP in magnitude. **Table 6.2** also shows those locations where impacts exceed the criteria that were established for the assessment of flood related impacts of the proposal, the details of which are set out in **Section 2.2.3** of this technical paper.

Table 6.2 shows that:

i. There are eleven (11) locations where increases in either the depth, velocity or duration of inundation exceed the limits that are set out in **Section 2.2.3** of this technical paper.

ii. Of the eleven (11) locations identified in item i, there are:

   a. Seven locations (transverse drainage structures TNR06, TNR14a/14b, TNR20, LNR04, LNR10, LNR12 and LNR15) where the exceedance is due to an increase in the duration of inundation. At each of these locations, the impacts are confined to existing drainage paths or watercourses that would experience prolonged inundation during frequent rainfall events under pre-proposal conditions. On this basis, the increases in duration of inundation during rare storm events would not result in an increase in the long-term wetting up of land. The affected areas also do not contain any existing buildings, property improvements or access driveways. For these reasons, the increase in the duration of inundations at these locations are not considered to represent a significant impact on the affected properties.

   b. One location (transverse drainage structure TNR11) where the exceedance is due to an increase in the duration of inundation over the access driveway to No. 407 The Northern Road, Londonderry. During a 1% AEP design storm event, the duration of inundation to the access driveway would be increased from 0.9 hours (pre-proposal conditions) to 2.4 hours (post-proposal conditions). This increase in the duration of inundation can be mitigated through further development of the proposed culvert crossing of the driveway and downstream channel works during detailed design. This impact can be addressed through further development of the concept road design and its associated table drain and culvert crossing under the driveway, which would discharge to the outlet of transverse drainage structure TNR11.

   c. One location (transverse drainage structure TNR05) where the exceedance is due to an increase in peak flow velocities over an area to the west (downstream) of the transverse drainage structure within No. 1 Carrington Road. During a 1% AEP design storm event, peak flow velocities over the affected area would be increased

from between 0.9 and 1.1 m/s (pre-proposal conditions) to 1.3 m/s (post-proposal conditions). While the increases in peak flow velocities are relatively localised, they occur over an area of embankment that is relatively steep that would therefore be susceptible to scour as a result of an increase in flow velocities.

Subject to further development of the proposed drainage improvements during detailed design, should any residual impacts on scour potential remain, then the provision of scour protection in the form of rock riprap lining to the affected area would be a feasible solution. This would be subject to consultation and agreement with the affected property owner.

d. One location (transverse drainage structure TNR01) where the exceedance is due to an increase in the depth and duration of inundation, as well as an increase in peak flow velocities within properties that are located to the west (downstream) of the transverse drainage structure. The affected area includes three buildings within No. 49-51 The Northern Road, where floor level survey has confirmed that the increase in peak flood levels would lead to an increase in above-floor inundation during storms with AEPs between 10% and 1%. The affected area also includes a number of buildings within No. 60-62 Bennett Road where floor level survey would be required to confirm whether the increase in peak flood levels would lead to an increase in above-floor inundation.

   Plate 6.1 in **Section 6.2.1** of this technical paper shows the arrangement of a potential measure that could be implemented to mitigate the impacts described above. This measure would involve the construction of a grassed lined channel that would run from the outlet of transverse drainage structure TNR01, primarily through No. 49-51 The Northern Road and No. 60-62 Bennett Road, to the inlet of the existing transverse drainage in Bennett Road. This mitigation option would be subject to consultation with the affected property owners and would require the acquisition of a drainage easement to contain the proposed channel.

e. One location (transverse drainage structures TNR13 and TNR14a/14b) where the exceedance is due to an increase in the depth of inundation within a RU4 zoned rural residential property that is located to the west (downstream) of The Northern Road (No. 2 Thomas Road), as well as an undeveloped parcel of land that is located to the east (upstream) of The Northern Road (No. 175-209 Spinks Road).[3]

   During a 1% AEP design storm, depths of inundation within No. 2 Thomas Road would be increased by a maximum of 0.21 metres on an existing depth of about 0.2 metres, while depths of inundation within No. 175-209 Spinks Road would be increased by a maximum of 0.17 metres on an existing depth of about 0.3 metres. In both cases, the affected area is confined to heavily vegetated areas of the property.

   While it would be feasible to mitigate the increase in peak flood levels to the east (upstream) of The Northern Road by increasing the capacity of transverse drainage structures TNR13 and TNR14a/14b, this would lead to further increases in peak flood levels to the west (downstream).

[3] While the exceedance at transverse drainage structure TNR13 is also due to an increase in the duration of inundation, it is not considered to result in a significant wetting up of land or impact on development within the affected property for the same reasons as those set out in item ii.a.

While it would also be feasible to mitigate the increase in peak flood levels to both the east (upstream) and west (downstream) of The Northern Road by installing a series of high flow culverts between transverse drainage structure TNR13 and TNR14a, this would require the level of the road to be further raised to accommodate these culverts, which in turn would increase the footprint of the proposed works and require the acquisition of additional land to the east of the road corridor within No. 175-209 Spinks Road).[4]

The increase in peak flood levels to the west (downstream) of transverse drainage structure TNR13 could be managed by the provision of a grass-lined channel that would run for approximately 40 metres through the north-east corner of No. 2 Thomas Road and a further 200 metres along the road reserve of Thomas Road. **Plate 6.2** in **Section 6.2.1** of this technical paper shows an indicative alignment of the grass-lined channel, which would be subject to consultation and agreement with the affected property owner.

Storms greater than 1% AEP in intensity

The assessment has also considered the impact of the proposal on flood behaviour during storms greater than 1% AEP up to the PMF. The assessment found that during the PMF, the greatest impacts on flood behaviour attributable to the proposal occur upstream of locations where road raising is proposed as part of the drainage improvement works at transverse drainage structures TNR11, TNR13, TNR14a, TNR14b, TNR15, TNR16, TNR19 and TNR20.

At each of the locations identified above, the assessment found that the impact of the proposal on flood behaviour during the PMF is not considered to have a significant impact on critical infrastructure or vulnerable development. The changes in flood behaviour during the PMF are also not considered to result in a significant increase in the hazardous nature of flooding in existing development.

Potential impact of future climate change on flood behaviour

A sensitivity analysis has been carried out in order to gain an understanding of the potential impact of future climate change on flooding to the designated flood evacuation routes. The impact that the proposal would have on flood behaviour in areas outside the road corridors under future climate change conditions has also been assessed as part of the present investigation.

Impact of future climate change on flooding to the designated flood evacuation routes

Table 6.3 at the end of **Chapter 6** of this technical paper provides a comparison of the hazard vulnerability classification of the outbound travel lane and shoulder during a 0.2% AEP storm event under current climatic and potential future climate change conditions.

Table 6.3 shows that the hazard vulnerability classification of flooding would be the same under current climatic and future climate change conditions except at:

i. five (5) locations along the outbound travel lane, where flooding would be increased from not flooded (current climatic conditions) to a hazard vulnerability classification of H1 (future climate change conditions) (refer to transverse drainage structures TNR26, TNR34, TNR35, LNR12 and CR35c);

[4] This is based on advice provided by the Concept Design PSC during an interface meeting that was held on 28 February 2024.

ii. seven (7) locations along the outbound shoulder, where flooding would be increased from "not flooded" (current climatic conditions) to a hazard vulnerability classification of H1 (future climate change conditions) (refer to transverse drainage structures TNR05, TNR13, TNR34, TNR35, TNR36, LNR12 and CR35c)

iii. one location along the outbound shoulder, where flooding would be increased from a hazard vulnerability classification of H1 (current climatic conditions) to a hazard vulnerability classification of H2 (future climate change conditions) (refer to transverse drainage structure TNR37).

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

Table 6.4 at the end of **Chapter 6** of this technical paper provides a comparison of the impact that the proposed drainage improvements and road shoulder widening would have on the depth and extent of inundation in areas outside the road corridor during a 1% AEP storm event under current climatic and potential future climate change conditions.

Table 6.4 shows that the locations where the afflux limits are exceeded would be the same under current climatic and future climate change conditions, with the exception of:

i. transverse drainage structure TNR22, where the increases in depths of inundation are within afflux limits under current climatic conditions, but would exceed the afflux limits under future climate change conditions, and

ii. transverse drainage structures LNR10 and LNR11, where the increases in depths of inundation are within the afflux limits under current climatic conditions, but would require floor level survey to confirm or otherwise exceedance of the afflux limits under future climate change conditions.

Management of impacts

Chapter 7 sets out the approach that will be adopted during the detailed design phase to manage the flood risks to the proposal 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 **Chapter 5** 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. **Table 7.1** in **Chapter 7** 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 **Table 7.1** in **Chapter 7**. 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
- minimising the potential for an increase in scour and erosion in areas downstream of the proposal.

1 INTRODUCTION

1.1 Background

1.1.1 Hawkesbury-Nepean Valley Flood Evacuation Road Resilience Program

The Hawkesbury-Nepean Valley Flood Evacuation Road Resilience Program (**the Program**) comprises a series of works relating to drainage improvements, road shoulder widening and pinch point improvements that are aimed at improving the flood resilience of the Hawkesbury-Nepean Valley by reducing existing impediments to vehicular movements along designated flood evacuation routes. **Figure 1.1** over the page shows the extent of the drainage improvements and road shoulder widening that comprise the Program.

While the majority of the drainage improvements and road shoulder widening are located along the regional flood evacuation routes which are identified in the *Hawkesbury Nepean Valley Flood Emergency Plan* (NSW SES, 2020), some are located along flood evacuation routes within defined flood evacuation sectors and sub-sectors. For ease of reference, the regional and sector based flood evacuation routes that form the basis of the program are collectively referred to in this report as the designated flood evacuation routes.

A strategic business case for the program was prepared in 2019 and received Infrastructure NSW (now NSW Reconstruction Authority (**NSW RA**)) Gate 1 Clearance in 2021. Transport for NSW (**Transport**) is now progressing the concept design and environmental assessment of the program.

1.1.2 Scope of the Program

The scope of the Program has been divided into two separate projects covering drainage improvements, road shoulder widening and pinch point improvements along what are mostly state roads (**State project**) and regional or local roads (**Regional/Local Project**), with separate concurrent concept designs and environmental assessments to be delivered for each project. **Figure 1.1** shows the extent of drainage improvements and road shoulder widening that fall under the state and Regional/Local Projects.

The State Project is located within the local government areas (**LGAs**) of Penrith City Council and Hawkesbury City Council, and comprises drainage improvements and road shoulder widening on the following flood evacuation routes that are identified in NSW SES, 2020:

- the section of The Northern Road regional flood evacuation route to the north of the Great Western Highway
- Londonderry Road regional flood evacuation route.

The Regional/Local Project is located within the LGAs of Penrith City Council, Hawkesbury City Council, Blacktown City Council and The Hills Shire Council, and comprises drainage improvements, road shoulder widening and pinch point improvements along the following flood evacuation routes that are identified in NSW SES, 2020:

- Llandilo Road regional flood evacuation route
- the section of the Castlereagh Road regional flood evacuation route to the north of Borrowdale Way
- Pitt Town Road regional flood evacuation route

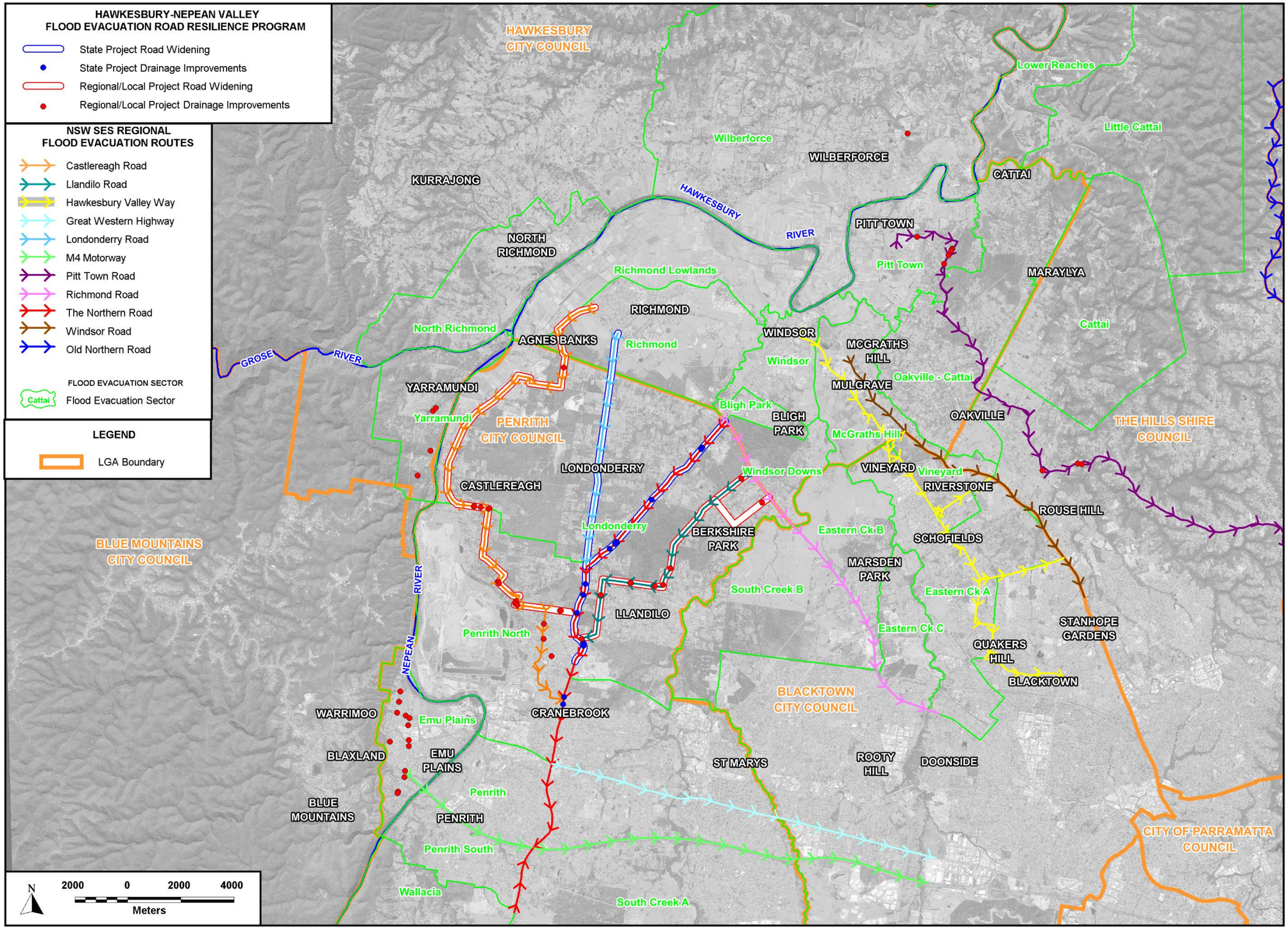

Figure 1.1 Location plan

- the section of Hawkesbury Valley Way regional flood evacuation route where it runs along Bandon Road between Wallace Road and Windsor Road in Vineyard
- Fourth Road and St Marys Road within the Londonderry sector (**Londonderry sector flood evacuation route**)
- Vincent Road[5] and Borrowdale Way within the Penrith North sector (**Penrith North sector flood evacuation route**)
- Springwood Road within the Yarramundi sector (**Yarramundi sector flood evacuation route**)
- Wedmore Road, Palomino Road, Old Bathurst Road, Koloona Drive, Russell Street and Leonay Parade within the Emu Plains sector (**Emu Plains sector flood evacuation route**)
- Sackville Road within the Wilberforce sector (**Wilberforce sector flood evacuation route**).

1.2 Purpose of this technical paper

This technical report has been prepared to support and inform the Review of Environmental Factors (**REF**) being prepared by Transport under Division 5.1 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) for the State Project (**the proposal**). The purpose of the technical paper is to document the potential flooding impacts from the construction and operation of the proposal. The technical paper:

- describes the existing environment with respect to flood behaviour
- assesses the impacts of constructing and operating the proposal on existing flood behaviour, as well as the impact that flooding could have on the construction and operation of the proposal
- recommends measures to mitigate the identifiable flood related impacts that are attributable to the proposal.

1.3 Proposal overview

Figure 1.2 over the page shows the extent of the proposal area, which comprises the area required to construct and operate the following scope of proposed works:

- The Northern Road between the intersection with Richmond Road/Blacktown Road, Bligh Park in the north and Borrowdale Way, Cranebrook in the south
- Londonderry Road from 270 metres south of the existing Southee Road, Hobartville to the intersection with The Northern Road, Llandilo excluding approximately 270 metres north and 300 metres south of the existing intersection at The Driftway, Londonderry
- The Northern Road (Route A9) from approximately 130 metres north of Andrews Road in Cranebrook southwards to Boomerang Place in Cambridge Gardens (noting that Route A9 is known as Richmond Road south of Andrews Road)

[5] While Vincent Road is located within the regional/local project, the scope of drainage improvements that are proposed to alleviate flooding at a transverse drainage structure at its eastern end (denoted transverse drainage structure CR35c) have been incorporated into the state project due to their proximity to The Northern Road.

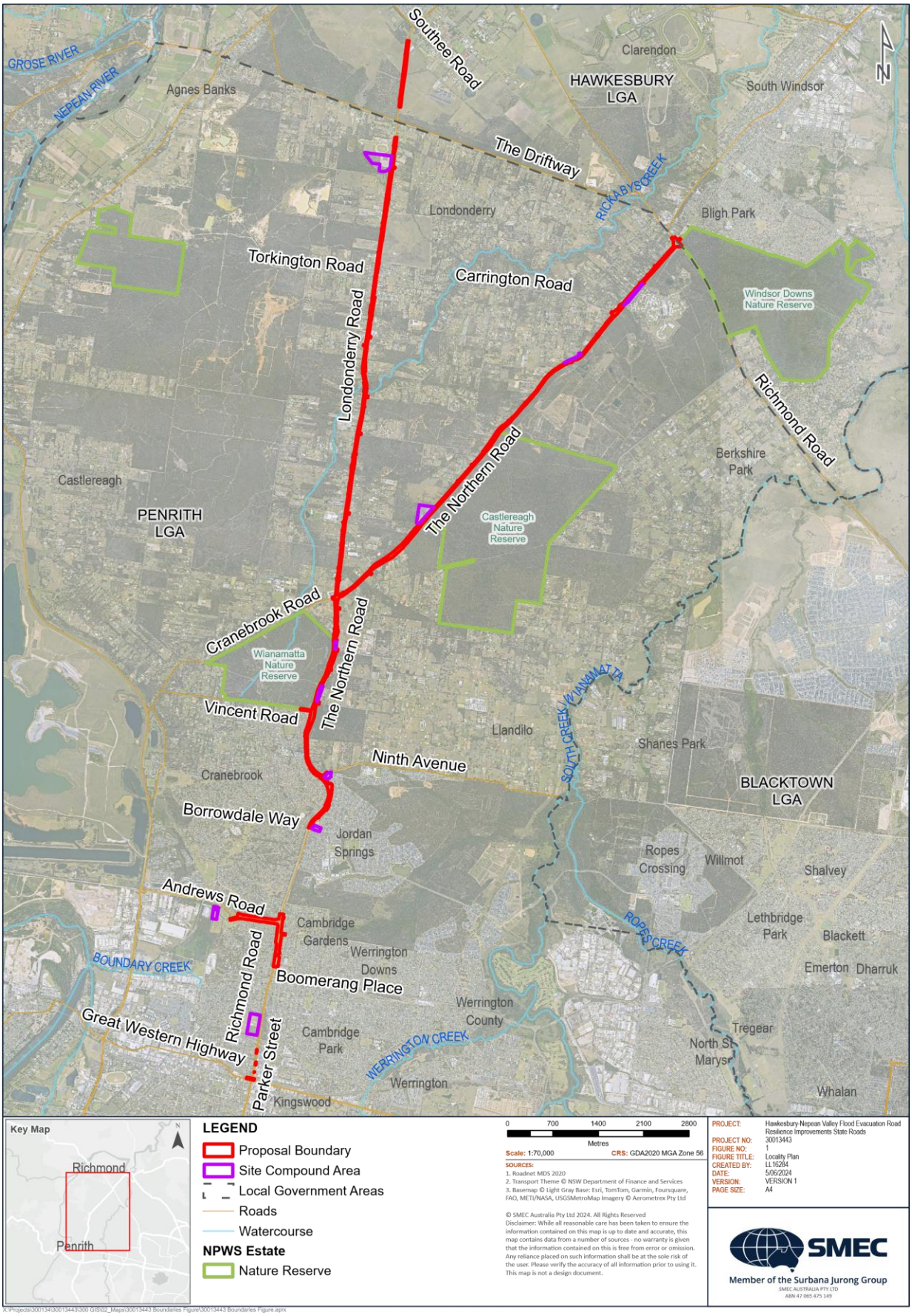

Figure 1.2 – Proposal area

- Andrews Road in Cranebrook from The Northern Road to the Andrews Road Baseball Complex west of Greygums Road in Cranebrook
- Vincent Road in Cranebrook for approximately 70 metres west of The Northern Road
- Identified areas within The Northern Road (Route A9) between Gascoigne Street and Great Western Highway, Kingswood for the installation of flood evacuation signage (noting that Route A9 is known as Parker Street between Coreen Avenue in Penrith and Maxwell Street in South Penrith).

The proposal area includes a buffer from the outer edge of the designed works to facilitate construction work. The buffer is generally 10 metres in width, but is reduced to 6 metres or less in specific areas to minimise impacts on sensitive areas.

Key features of the proposal include:

- Widening of the southbound shoulder pavement of the following roads over an approximate length of 20 kilometres in total to provide a second outbound trafficable lane reserved for use during emergency flood evacuations. This would include culvert and drainage extensions to accommodate a wider road corridor, and connecting drainage along:
    - Londonderry Road between 270m south of Southee Road and The Northern Road in Londonderry
    - The Northern Road between Richmond Road/ Blacktown Road and Borrowdale Way in Londonderry, Berkshire Park, Cranebrook, Llandilo, and Jordan Springs
- Drainage improvements such as upgrades to culverts, drainage channels, drains, and pit and pipe networks at identified locations to improve resilience in localised flooding events. Work would include:
    - Culvert upgrades, and associated drainage channel works:
        - Along sections of The Northern Road associated with raising of low points as outlined below
        - On Carrington Road at the intersection with The Northern Road, Londonderry
        - At two locations on The Northern Road approximately 50 metres and 130 metres north of the intersection of Carrington Road, Londonderry
        - On The Northern Road approximately 250 metres north of Toorah Road, Londonderry
        - On Vincent Road at the intersection with The Northern Road, Cranebrook
        - On Fifth Avenue at the intersection with The Northern Road, Llandilo.
    - New roadside drainage channels (including vegetated and concrete of various widths):
        - Along Londonderry Road (adjacent to the southbound shoulder), from a location 270 metres south of Southee Road, Hobartville to the intersection with The Northern Road, Llandilo
        - Along The Northern Road (adjacent to the southbound shoulder), from the intersection with Blacktown Road/Richmond Road, Berkshire Park south to Ninth Avenue, Llandilo

        - Along The Northern Road (adjacent to the northbound shoulder), at road raising areas (described in further detail below)
    - Underground drainage network upgrades:
        - Along The Northern Road (southbound), Cleeve Place and Star Crescent, Cambridge Gardens from Trinity Drive to Boomerang Place, including approximately 60 metres along Trinity Drive, Cambridge Gardens
        - Along The Northern Road (northbound), Cranebrook from approximately 115 metres north of Andrews Road in Cranebrook to Trinity Drive in Cambridge Gardens, including new drainage crossings underneath The Northern Road
        - Along Andrews Road from The Northern Road up to the Andrews Road Baseball Complex in Cranebrook
- Raising of low points along sections of The Northern Road, affecting all road lanes:
    - From a location approximately 120 metres north of Whitegates Road, Londonderry and heading northwards over a 345 metre length
    - From a location immediately north of Spinks Road, Llandilo and heading northwards over a 920 metre length
    - From a location approximately 435 metres south of Fifth Avenue, Llandilo to a location approximately 270 metres north of Fifth Avenue, Llandilo
    - From a location approximately 105 metres south of Vincent Road, Cranebrook to a location approximately 185 metres north of Vincent Road, Cranebrook
    - From a location approximately 365 metres south of Ninth Avenue, Cranebrook to a location approximately 50 metres south of Ninth Avenue, Cranebrook
- Extending, replacing or adding new culverts at selected locations along Londonderry Road and The Northern Road to maintain property access (e.g. driveways) as required
- Realigning The Northern Road in Cranebrook (within the road corridor) from approximately 330 metres north of Seventh Avenue, Llandilo to approximately 280 metres south of Vincent Road, Cranebrook to reduce project impacts on adjacent sensitive receivers and improve road safety
- Adjusting the following intersections to facilitate a secondary outbound lane for drivers to use during a flood evacuation event:
    - The Northern Road and Richmond Road in Berkshire Park
    - Londonderry Road and The Northern Road in Cranebrook
    - The Northern Road and Vincent Road in Cranebrook
    - The Northern Road and Ninth Avenue in Jordan Springs
- Installing new signage to be displayed during emergency flood evacuations to facilitate a second left turn at the existing Parker Street/Great Western Highway intersection in Penrith under traffic control
- Adjustments as required to connect Londonderry Road and The Northern Road to local roadways, side roads and access roads
- Relocation and/or adjustments of various road furniture (such as signage, road safety barriers, street lighting, kerb and island adjustment etc) throughout the Proposal area.

- Relocation of bus stops at:
    - The Northern Road (northbound) approximately 30 metres south of Vincent Road, to relocate the bus stop approximately 130 metres to the south
    - The Northern Road (southbound) approximately 210 metres south of Ninth Avenue, to relocate the bus stop approximately 20 metres to the north
- Utility and driveway adjustments as required within the proposal area
- Landscaping as required
- Provision of temporary ancillary facilities to support the construction works including office and staff amenities, site compound and laydown areas. The proposal area includes ancillary facility sites at the following locations, subject to property owner agreement:
    - Road reserve adjacent to the Francis Greenway John Moroney Correctional Complex, Berkshire Park (site 1)
    - Road reserve adjacent to 245 The Northern Road, Berkshire Park (site 2)
    - 557 The Northern Road, Berkshire Park (site 3)
    - Road reserve adjacent to 107 Fifth Avenue, Llandilo (site 4)
    - Road reserve adjacent to 902 The Northern Road, Llandilo (site 5)
    - 1042 The Northern Road, Llandilo (site 6)
    - Council reserve, Greenwood Parkway, Jordan Springs (site 7)
    - Part of the Richmond Race Club, Londonderry Road, Londonderry (site 8)
    - Council reserve, Andrews Road, Penrith (site 9)
    - Council reserve, Parker Street, Penrith (site 10).

Due to the minor nature of the works associated with the installation of new signage to be displayed during emergency flood evacuations, they have been excluded from the flood assessment presented in this technical paper.

The scope of drainage improvements that comprise the proposal are shown on the concept layouts that are contained in **Annexure A** of this technical paper, while **Table B1** in **Annexure B** of this technical paper contains a summary of proposed works at each transverse drainage structure along the proposal and identifies whether the works are proposed for the purpose of drainage improvements and/or road shoulder widening.

1.4 Structure of this technical paper

The structure and content of this flooding technical paper is as follows:

- **Chapter 1** provides an introduction to this technical paper (this chapter)
- **Chapter 2** provides an overview of the regulatory context for the assessment, including an overview of the flood related legislation, policy and guidelines that apply to the proposal
- **Chapter 3** sets out the methodology that has been adopted in the definition of flood behaviour in the vicinity of the proposal and also the impact that the proposal 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.
- **Chapter 4** describes the existing environment as it relates to flooding, including a brief description of the catchments within which the proposal is located and which form the study area for the assessment. The chapter provides a description of flood behaviour in the vicinity of the proposal under present day (i.e. pre-proposal) conditions.
- **Chapter 5** describes the potential flood risks to the proposal and its impact on flood behaviour during its construction.
- **Chapter 6** describes the potential flood risks to the proposal and its impact on flood behaviour during the operation of the proposal. The chapter also presents the findings of an assessment of the potential impact of future climate change on flood behaviour.
- **Chapter 7** provides recommended mitigation and management measures to avoid, minimise and manage any potential flood related risks and impacts associated with the construction and operation of the proposal.
- **Chapter 8** contains a list of references cited in this paper.
- **Annexure A** contains a series of concept layouts showing the proposed scope of drainage improvements that comprise the proposal.
- **Annexure B** contains a table summarising drainage related works associated with drainage improvements and road shoulder widening that comprise the proposal.
- **Annexure C** contains a series of figures that show the layout of the hydrologic and hydraulic models that were developed in order to define flood behaviour in the vicinity of the proposal.
- **Annexures D** and **E** contains a series of figures that show additional flood model results under pre-proposal conditions.
- **Annexures F** , **G** and **H** contains a series of figures that show additional flood model results under post-proposal conditions.

The figures that are referred to in **Chapters 4**, **5** and **6** are located after **Chapter 8** of this technical paper.

2 LEGISLATIVE AND POLICY CONTEXT

This chapter summarises the legislation, guidelines and policies governing the approach to the flooding assessment. Relevant commonwealth, state and local government legislation, guidelines and policies are discussed in **Sections 2.1**, **2.2** and **2.3**, respectively.

2.1 Commonwealth guidelines

2.1.1 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 those that comprise the Hawkesbury-Nepean Valley Road Resilience Program are planned, designed, constructed and operated in a manner that best manages flood risk.

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 in 2019 (ARR 2019) (Geoscience Australia (GA) 2019). The hydrologic and hydraulic models (collectively referred to as 'flood models') that were relied upon for the present investigation were developed using the procedures set out in ARR 2019.

ARR 2019 includes:

- procedures for the derivation of design rainfall intensities, temporal rainfall distributions and rainfall losses for application to hydrologic models that define the rainfall runoff process
- guidance on the development of hydraulic models, including the procedures for the derivation of blockage factors to apply to hydraulic structures, that define how runoff is conveyed in waterways and across the land
- guidance on how design rainfall intensities could be impacted by future climate change.

In regards to the last dot point, ARR 2019 contains a series of tables that are available through the *ARR 2019 Data Hub* of projected temperature increase and corresponding increase in rainfall intensity with varying representative concentration pathway (**RCP**)[6] and projection date. The values have been derived based on an analysis of the predicted temperature increase from global climate models across each of the eight Natural Resource Management (**NRM**) clusters set out in the Commonwealth Science Industrial Research Organisation's (CSIRO's) *Future Climates Tool* website.

Based on a projection date of 2090, ARR 2019 shows that:

- for a RCP of 4.5, the predicted rise in temperature is 1.9^{o}C, which corresponds to an increase in rainfall intensity of 9.5 per cent across the study area
- for a RCP of 8.5, the predicted rise in temperature is 3.7^{o}C, which corresponds to an increase in rainfall intensity of 19.7 per cent across the study area.

Section 3.7 describes the approach that was adopted to assess the impact of future climate change on flood behaviour using the predicted increases in rainfall intensities that are set out in ARR 2019.

[6] RCPs are a measure of greenhouse gas concentration trajectories and are used to described different climate futures that are considered possible depending on the level of emissions. The RCPs are named according to the radiative forcing values (W m-2) in the year 2100 relative to pre-industrial values.

2.2 State legislation, policies and guidelines

2.2.1 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.

Under Section 9.1(2) of the EP&A Act, the Minister for Planning has issued a number of directions to relevant planning authorities that apply to planning proposals lodged with the Department of Planning and Environment on or after the date the particular direction was issued and commenced. *Direction 4.1 - Flood Prone Land* (Direction 4.1) (previously issued in July 2021 as Direction 4.3) applies to all councils that contain flood prone land within their LGA.

While not applicable to the proposal under Division 5.1 of the EP&A Act, Direction 4.1 sets out the approach to establishing flood-related planning controls for surrounding development and has therefore been taken into consideration when assessing the impact of the proposal on existing flood risk as well as the future development potential for land outside the proposal footprint. For planning proposals under Part 3 of the EP&A Act, Direction 4.1 requires that:

A planning proposal must include provisions that give effect to and are consistent with:

(a) the NSW Flood Prone Land Policy,

(b) the principles of the Floodplain Development Manual 2005,

(c) the Considering flooding in land use planning guideline 2021, and

(d) any adopted flood study and/or floodplain risk management plan prepared in accordance with the principles of the Floodplain Development Manual 2005 and adopted by the relevant council.

A planning proposal must not rezone land within the flood planning area from Recreation, Rural, Special Purpose or Environmental Protection Zones to a Residential, Business, Industrial or Special Purpose Zones.

A planning proposal must not contain provisions that apply to the flood planning area which:

(a) permit development in floodway areas,

(b) permit development that will result in significant flood impacts to other properties,

(c) permit development for the purposes of residential accommodation in high hazard areas,

(d) permit a significant increase in the development and/or dwelling density of that land,

(e) permit development for the purpose of centre-based childcare facilities, hostels, boarding houses, group homes, hospitals, residential care facilities, respite day care centres and seniors housing in areas where the occupants of the development cannot effectively evacuate,

(f) permit development to be carried out without development consent except for the purposes of exempt development or agriculture. Dams, drainage canals, levees, still require development consent,

(g) are likely to result in a significantly increased requirement for government spending on emergency management services, flood mitigation and emergency response

measures, which can include but are not limited to the provision of road infrastructure, flood mitigation infrastructure and utilities, or

(h) permit hazardous industries or hazardous storage establishments where hazardous materials cannot be effectively contained during the occurrence of a flood event.

A planning proposal must not contain provisions that apply to areas between the flood planning area and probable maximum flood to which Special Flood Considerations apply which:

(a) permit development in floodway areas,

(b) permit development that will result in significant flood impacts to other properties,

(c) permit a significant increase in the dwelling density of that land,

(d) permit the development of centre-based childcare facilities, hostels, boarding houses, group homes, hospitals, residential care facilities, respite day care centres and seniors housing in areas where the occupants of the development cannot effectively evacuate,

(e) are likely to affect the safe occupation of and efficient evacuation of the lot, or

(f) are likely to result in a significantly increased requirement for government spending on emergency management services, and flood mitigation and emergency response measures, which can include but not limited to road infrastructure, flood mitigation infrastructure and utilities.

For the purposes of preparing a planning proposal, the flood planning area must be consistent with the principles of the Floodplain Development Manual 2005 or as otherwise determined by a Floodplain Risk Management Study or Plan adopted by the relevant council.

Direction 4.1 also states that a planning proposal may be inconsistent with the terms of this direction only if the planning proposal authority can satisfy the Secretary of the Department of Planning and Environment (or their nominee) that:

(a) the planning proposal is in accordance with a floodplain risk management study or plan adopted by the relevant Council in accordance with the principles and guidelines of the Floodplain Development Manual 2005, or

(b) where there is no council adopted floodplain risk management study or plan, the planning proposal is consistent with the flood study adopted by the council prepared in accordance with the principles of the Floodplain Development Manual 2005 or

(c) the planning proposal is supported by a flood and risk impact assessment accepted by the relevant planning authority and is prepared in accordance with the principles of the Floodplain Development Manual 2005 and consistent with the relevant planning authorities' requirements, or

(d) the provisions of the planning proposal that are inconsistent are of minor significance as determined by the relevant planning authority.

2.2.2 Floodplain risk management manual

The *Floodplain Risk Management Manual* (FRMM) (Department of Planning and Environment (DPE) 2023a) 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 FRMM 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 FRMM promotes the concept that proposed developments be treated on their merit rather than through the imposition of rigid and prescriptive criteria. The FRMM replaces the Floodplain Development Manual (**FMD**) (Department of Infrastructure, Planning and Natural Resources (DIPNR), 2005).

The merits-based approach set out in the FRMM has been adopted when establishing the flood related criteria against which the proposal has been assessed. In accordance with the FRMM, the hydraulic and hazard categorisation of the floodplain was considered when assessing the impact that the proposal could have on existing flood behaviour, as well as the impact of flooding to the proposal and its users.

2.2.3 Guideline on development controls on flood prone land

In July 2021 the NSW Government issued Planning Circular PS 21-006 *Considering flooding in land use planning: guidance and statutory requirements*. The circular provides advice on a package of changes regarding how land use planning considers flooding and flood-related constraints. The package includes:

- an amendment to clause 7A of Schedule 4 to the *Environmental Planning and Assessment Regulation 2000* (the Regulation)
- a revised local planning direction regarding flooding issued under section 9.1 of the *Environmental Planning and Assessment Act 1979* (EP&A Act)
- two local environmental plan clauses which introduce flood related development controls
- a new guideline: *Considering Flooding in Land Use Planning (2021)* (the guideline)
- revoking the *Guideline on Development Controls on Low Flood Risk Areas (2007)*.

In March 2024, the NSW Government issued Planning Circular PS 24-001 *Update on addressing flood risk in planning* as a supplement to Planning Circular PS21-006 by providing additional information to planning authorities in relation to addressing flood risk in land use planning and development assessment under the EP&A Act. Planning Circular PS 24-001 outlines existing flood-related planning policies and provides further information and advice on their application in planning. The circular also provides updates on flood-related policy initiatives underway, including action taken in response to the independent expert inquiry into the flood events experienced in NSW in early 2022.

While not applicable to the proposal under Division 5.1 of the EP&A Act, Planning Circulars PS 21-006 and PS 24-001 001 set out the approach to establishing flood-related planning controls for surrounding development under Part 3 of the EP&A Act and are therefore an important consideration in assessing the impact of the proposal on existing flood risk, as well as the future development potential of land outside the proposal footprint.

The guideline supports the principles of the FDM (now FRMM) and provides advice to councils on land-use planning on flood prone land. It provides councils with greater flexibility in defining the areas to which flood-related development controls apply, with consideration of defined flood events, freeboards, low-probability/high-consequence flooding and emergency management

considerations. The guideline and the FDM (now FRMM) state that a defined flood event (DFE) of 1% AEP, or a historic flood of similar scale, plus a freeboard should generally be used as the minimum level for setting residential flood planning levels (FPL). Choosing different DFEs and freeboards requires justification based on a merits-based assessment that is consistent with the floodplain risk management process and principles of the FDM (now FRMM). Special flood considerations apply to sensitive and hazardous development in areas between the flood planning area (FPA) and the PMF and to land that may cause a particular risk to life and other safety considerations that require additional controls. These controls relate to the management of risk to life and the risk of hazardous industry/hazardous storage establishments to the community and the environment in the event of a flood.

A similar merits-based approach to that described in the guideline has been adopted in the assessment of the impacts that the proposal 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 proposal on the existing environment. Consistent with the guideline, the assessment that is presented in this technical paper has taken into consideration floods larger than the 1% AEP event, up to the PMF.

2.2.4 Flood risk management guideline on climate change

Scientific evidence shows that climate change is expected to lead to an increase in flood producing rainfall intensities and sea levels. The significance of these effects on flood behaviour would vary depending on geographic location and local topographic conditions. Given the location and elevation of the proposal and the watercourses that it crosses, future sea level rise would not impact on flood behaviour in its vicinity. Consideration of flood behaviour under future climate change has therefore focused on potential increases in rainfall intensities.

The *Flood risk management guideline FB01 - Understanding and managing flood risk* (DPE, 2023b) provides guidance on how the impact of future climate change can be considered in flood risk management decisions. DPE, 2023b recognises that research into the scale to which climate change is expected to impact flood-producing rainfall events is ongoing and therefore advice on how it is considered will need to be updated over time. DPE, 2023b recommends that current advice be based on the projected increases in rainfall intensity with varying RCP and projection date that are set out on ARR 2019, the details of which are summarised in **Section 2.1.1**.

Based on the recommendations set out in DPE, 2023b, the following approach has been adopted in order to assess the potential impact of future climate change on flood behaviour in the vicinity of the proposal corridor:

- An increase in design rainfall intensities of 20 per cent has been adopted in the assessment of future climate change conditions based on an RCP of 8.5 and a projection date of 2090.
- The 0.05% AEP event has been adopted as being analogous to a 20 per cent increase in rainfall intensity on the 0.2% AEP due to future climate change, and the 0.2% AEP event be adopted as being analogous to an increase in rainfall intensity of 20 per cent on the 1% AEP event.[7]

[7] Based on inspection of design rainfall intensities across the Hawkesbury-Nepean Valley.

2.2.5 Hawkesbury-Nepean Valley Flood Emergency Plan

The Hawkesbury-Nepean Valley Flood Emergency Plan (NSW SES, 2020) sets out the emergency management arrangements for flooding in the Hawkesbury-Nepean Valley. NSW SES, 2020 contains a brief overview of existing flood behaviour and associated risks to the social, built, economic and natural environments within the Hawkesbury-Nepean Valley, and sets out the preparedness measures, the process for carrying out response operations and the coordination of immediate recovery measures from flooding. A description of existing flood behaviour in the Hawkesbury-Nepean Valley is presented in **Section 4.1** of this technical paper.

The aim of the drainage improvements and road shoulder widening works is to reduce existing impediments to vehicular movements along the designated flood evacuation routes that comprise the proposal, which are identified in NSW SES, 2020 as key evacuation routes for the Hawkesbury-Nepean Valley during flood events.

2.3 Council policies and guidelines

2.3.1 Local environmental plans

As mentioned, the proposal is located in the local government areas of Penrith City Council and Hawkesbury City Council. The *Penrith Local Environmental Plan 2010* and the *Hawkesbury Local Environmental Plan 2012* both contain flood planning clauses that apply to the determination of a Part 4 development application by a consent authority under the EP&A Act. While not applicable to the proposal under Division 5.1 of the EP&A Act, the flood planning clauses in the respective LEPs have been taken into consideration in establishing the approach to assessing the impact of the proposal on flood behaviour.

In May 2021, the NSW Government issued the Standard Instrument (Local Environmental Plans) Amendment (Flood Planning) Order 2021 that sets out changes to the flood planning related clauses of the LEPs of the respective councils that took effect on 14 July 2021. The updates to the above flood planning clause under the Standard Instrument (Local Environmental Plans) Amendment (Flood Planning) Order 2021 are aimed at supporting better management of flood risk and building greater resilience in communities located on floodplains during floods greater than 1% AEP up to the PMF. The assessment that is presented in this technical paper has taken into consideration floods larger than the 1% AEP event, up to the PMF and is therefore considered to be consistent with the NSW Government's floodplain risk management objectives.

Penrith City Council and Hawkesbury City Council have both prepared Development Control Plans (DCPs) (respectively denoted the *Penrith Development Control Plan 2014* and the *Hawkesbury Development Control Plan 2023*) to guide development in accordance with their respective LEPs. As with the flood planning clauses of the LEPs for each council, the requirements set out in their respective DCPs are not applicable to the proposal under Division 5.1 of the EP&A Act. However, the flood related requirements of the respective DCPs have been taken into consideration in establishing the approach to assessing the impact of the proposal on existing flood behaviour.

3 METHODOLOGY

This chapter describes the methodology that was used to undertake the flooding assessment for the proposal.

3.1 Key tasks

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

- Review of available data and existing flood studies of the catchments within which the proposal is located
- 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 figures showing flood behaviour under present day (i.e. pre-proposal) conditions for design floods with AEPs of 10%, 5%, 1%, 0.2% and 0.05%, as well as the PMF
- Assessment of the impact of the proposal (both during its construction and operation) on flood behaviour for the aforementioned design flood events
- Assessment of the potential impact future climate change would have on flood behaviour under operational conditions, as well as the impact of the proposal on flood behaviour under future climate change conditions
- Identification of measures that should be applied to manage the risk of flooding to the proposal and its impact on existing flood behaviour.

The following sections of this paper set out the methodology which was adopted in the assessment of flood behaviour under pre-proposal conditions, and during both the construction and operational phases of the proposal.

3.2 Study area

For the purpose of the flooding assessment, the study area comprised the following catchments within which the proposal is located:

- Rickabys Creek
- South Creek
- Penrith Lakes
- Boundary Creek
- Peachtree Creek

Each of the catchments listed above form part of the larger Hawkesbury – Nepean River catchment. The extent of each catchment draining to the proposal corridor is mapped in **Section 4.2**, which also contains a description of the key drainage features in the vicinity of the proposal.

3.3 Summary of adopted assessment criteria and standards

The following section sets out the flood related assessment criteria and standards that have been established for the proposal with due consideration of the policies and guidelines set out in **Section 2** of this technical paper.

3.3.1 Criteria adopted in the identification and scoping of drainage improvements

This section sets out the criteria that have been adopted in the identification and scoping of drainage improvements, the details of which have been developed in consultation with Penrith City Council, Hawkesbury City Council, NSW RA and NSW SES.

Adopted Threshold Criteria for identifying locations for drainage improvements

The criteria that have been adopted in the identification of locations requiring drainage improvements (denoted herein as "the Threshold Criteria") were originally developed as part of a flooding investigation that was carried out to support the strategic business case for the Program, the findings of which were presented in a report entitled *Hawkesbury Nepean Valley Designated Flood Evacuation Route Upgrades - Flooding and Drainage Investigation* (Lyall and Associates, 2019).

As part of Lyall and Associates, 2019, it was determined that the drainage improvement requirements would need to be designed to provide a minimum 0.2% (1 in 500) AEP level of flood immunity from local catchment flooding in order to be consistent with the improvement objectives for flood evacuation routes set out in *"Hawkesbury Nepean Flood Plan"* (NSW SES, 2020) and *"Managing Flood Risk Through Planning Opportunities – Guidance on Land Use Planning in Flood Prone Areas"* (Hawkesbury-Nepean Floodplain Management Steering Committee, 2006).

Based on subsequent discussions with Transport, NSW RA and NSW SES, it was agreed that flooding that exceeded the following Threshold Criteria during a 0.2% AEP local catchment storm event would be intolerable for vehicular movements and were therefore adopted in the identification of locations requiring drainage improvements:

a) a depth of flooding over the centreline of the road of greater than 0.1 metres for a period of more than one hour; or

b) a hazard vulnerability classification on the outbound trafficable lane(s) of the road of H2[8] or greater based on the general flood hazard vulnerability curves set out in ARR 2019.

The above criteria have subsequently been endorsed through the governance of the Program, with close engagement with the relevant local councils.

An investigation was carried during the initial phase of the concept design to confirm those locations along the designated flood evacuation routes that comprise the State Project where flooding exceeds the Threshold Criteria set out above, and hence where drainage improvements are required to meet the objective of the Program. This investigation has informed the locations of drainage improvements that comprise the proposal.

[8] A hazard vulnerability classification of H2 defines the combination of depth of velocity of floodwater that would be unsafe for small vehicles.

Flood immunity criteria for scoping drainage improvements

The following set of criteria (in order of priority) that were originally established as part of Lyall and Associates, 2019 were adopted for assessing the scope of the drainage improvements as part of the proposal:

- First order criterion – Drainage improvements to provide a 0.2% AEP level of flood immunity against local catchment flooding to the outbound trafficable lane(s).
- Second order criterion – Limit flooding to less than the Threshold Criteria for the identification of locations requiring drainage improvements that are set out in the preceding section.
- Third order criterion – As far as practicable, maximise the level of flood immunity to the outbound trafficable lanes.

An assessment of the level of flood immunity achieved by the proposed drainage improvements under the proposal against the criteria set out above is presented in **Section 6.1.1** of this technical paper.

3.3.2 Criteria adopted in assessing the impact of the proposal on flood behaviour

For road and drainage works of the nature proposed under the proposal it is not reasonable or feasible to design the works in a way that results in no change in flood behaviour within surrounding areas. For this reason, a set of criteria have been established against which the proposal has been assessed. The following criteria are consistent with the merits-based approach that is set out in the FRMM and have been established in consultation with NSW RA, NSW SES and relevant councils for assessing the impact of the proposed works on flood behaviour. The following criteria are also consistent with the afflux limits set out in the NSW Department of Planning and Environment's draft *State Significant Infrastructure Template Conditions of Approval (Linear Infrastructure)* (February 2022) for critical state significant infrastructure.

For storms up to 1% AEP in intensity

Where reasonable and feasible the proposal is to be designed to limit impacts on flood behaviour in areas outside the proposal corridor for design storms up to an including the 1% AEP flood event, to the following:

a) a maximum increase in inundation time of one hour;

b) a maximum increase of 10 mm in above-floor inundation to habitable rooms where floor levels are currently exceeded;

c) no above-floor inundation of habitable rooms which are currently not inundated;

d) a maximum increase of 50 mm in inundation of land zoned as residential, industrial or commercial;

e) a maximum increase of 100 mm in inundation of land zoned as rural, primary production, environment zone or public recreation;

f) no significant increase in the flood hazard or risk to life; and

g) maximum relative increase in velocity of 10%, where the resulting velocity is greater than 1.0 m/s, unless adequate scour protection measures are implemented and/or the velocity increases do not exacerbate erosion as demonstrated through site-specific risk of scour or geomorphological assessments.

Where the requirements set out in clauses (d), (e) and (g) cannot be met, consultation would be carried out with the affected land owner to discuss any residual flood impacts and alternative mitigation measures.

An assessment of the impact of the proposal on flood behaviour against the criteria set out above is presented in **Section 6.2.1** of this technical paper.

Storms greater than 1% AEP in intensity

In accordance with the FRMM, changes in flood behaviour during storms greater than 1% AEP in intensity are to also be assessed in order to identify impacts on critical infrastructure (such as hospitals), 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 proposed modification.

An assessment of the impact of the proposal on flood behaviour during storms greater than 1% AEP in intensity is presented in **Section 6.2.2** of this technical paper.

3.3.3 Consideration of the potential impact of future climate change on flood behaviour

The following approach has been adopted in order to assess the potential impact of future climate change on flood behaviour:

- An increase in design rainfall intensities of 20 per cent has been adopted in the assessment of future climate change conditions based on an RCP of 8.5 and a projection date of 2090.
- The 0.05% AEP event has been adopted as being analogous to a 20 per cent increase in rainfall intensity on the 0.2% AEP due to future climate change, while the 0.2% AEP event has been adopted as being analogous to an increase in rainfall intensity of 20 per cent on the 1% AEP event.[9]
- The potential impact of future climate change on flooding to the designated flood evacuation routes has been based on a comparison of flood behaviour during a 0.05% AEP and 0.2% AEP event under post-proposal conditions.
- The potential impact that the proposal could have on flood behaviour under future climate change has been based on comparing their effect on pre-proposal flood behaviour during a 0.2% AEP event against those during a 1% AEP event.

An assessment of the potential impact of future climate change on flood behaviour is presented in **Section 6.3** of this technical paper.

3.3.4 Blockage potential in transverse drainage structures

The design of transverse drainage structures has included an allowance for partial blockage based on blockage factors that have been calculated using the procedures set out in ARR 2019. ARR 2019 recommends that the adopted blockage factor be based on:

- the average length of the largest 10% of debris arriving at the structure (termed the "L_{10} value") relative to its clear opening width;
- the availability, mobility and transportability of the debris; and
- the magnitude of the flood event.

[9] Based on inspection of design rainfall intensities across the Hawkesbury-Nepean Valley.

The calculation of blockage factors using the ARR 2019 procedures involved the following tasks:

1. An L_{10} value of 1.5 metres was adopted for urban and rural debris source areas in accordance with recommendations set out in ARR 2019. In the absence of any guidance in ARR 2019 of an appropriate L_{10} value for heavily vegetated areas, a value of 2 metres was adopted on the basis that it would be expected to be larger than that for urban and rural catchments. Based on a review of flood behaviour along the designated flood evacuation routes within heavily vegetated areas, it was considered unrealistic for the L_{10} value to be significantly larger than 2 metres given the depth, velocity and width of overland flow approaching the road corridor.
2. An assessment was made of the availability, mobility and transportability of the debris using descriptions set out in Tables 6.6.1, 6.6.2 and 6.6.3 of ARR 2019 in order to derive a 1% AEP debris potential classification of either high, medium or low at each transverse drainage structure using Table 6.6.4 of ARR 2019. The 1% AEP debris potential classifications were adjusted using Table 6.6.5 of ARR 2019 in order to derive a set of 0.2% AEP debris potential classifications.
3. The opening width of each transverse drainage structure was compared to the adopted L_{10} value and a blockage factor was calculated for the 1% and 0.2% AEP debris potential classifications using Table 6.6.6 of ARR 2019.
4. One limitation of the blockage factors set out in Table 6.6.6 of ARR 2019 is that for a high debris potential classification and a clear opening width that is just below the L_{10} value, the adopted blockage factor is 100%, compared with a blockage factor of 20% for a clear opening width that is just above the L_{10} value. For example, for a high debris potential classification and an adopted L_{10} value of 2 metres, a 100% blockage factor would apply to a 1.8 metres wide x 1.2 metres high box culvert compared with a blockage factor of 20% for a 2.1 metres wide x 1.2 metres high box culvert. This is not considered to be a realistic reflection of the relative difference in blockage potential of a culvert of these sizes.

   In order to address the above limitation for a high debris potential classification the following approach was adopted:

   i. A lower bound L_{10} value of 1.2 metres was adopted, while the previously adopted values of 1.5 metres for urban and rural debris source areas, and 2 metres for heavily vegetated areas were adopted as upper bound values[10].

   ii. For clear opening widths:

      a. below the lower bound L_{10} value a blockage factor of 100% was adopted,

      b. above the upper bound L_{10} value a blockage factor of 20% was adopted, and

      c. between the lower and upper bound L_{10} values the adopted blockage factor was derived based on interpolation between 100% and 20%.

[10] The lower bound L_{10} value of 1.2 m was adopted based on guidance set out in *Review of Conduit Blockage Policy – Summary Report* (Wollongong City Council (WCC), 2016), which was subsequently incorporated by WCC into an update of the *Wollongong Development Control Plan 2009* (WCC, 2020).

3.3.5 Impact of flooding during the construction of the proposal

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 technical paper identifies the risks associated with each construction activity such that informed decisions can be made on how flooding to the proposal is managed during its construction.

Similarly, the impact that the construction of the proposal could have on flood behaviour need to be considered 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 technical paper identifies the potential impacts associated with the proposal such that informed decisions can be made on how the impact of the proposal on flood behaviour during its construction are managed.

3.4 Definition of flood behaviour under pre-proposal conditions

A set of hydrologic and hydraulic models (collectively referred to as flood models) were used to define flood behaviour in the vicinity of the proposal under present day (i.e. pre-proposal) conditions in order to:

i. assess the impact of flooding to the designated flood evacuation routes and to identify those locations where drainage improvements are required to improve their resilience to local catchment flooding based on the Threshold Criteria[11]

ii. establish baseline conditions against which the impact that the proposal would have on flood behaviour are assessed.

The flood models that were used to define flood behaviour under present day (ie. pre-proposal) conditions were based on a set of models that were originally developed as part of Lyall and Associates, 2019.

In developing the flood models as part of Lyall and Associates, 2019, it was recognised that the adoption of a consistent modelling approach across all locations that comprise the program was important in ensuring that there was consistency in the assessment of drainage improvement requirements. A set of hydrologic models were developed of the catchments draining to the designated flood evacuation routes using the DRAINS rainfall-runoff software. These models were used to generate a series of design discharge hydrographs that were applied as inflows to a set of hydraulic models that were developed using the TUFLOW two-dimensional software.

Due to the timing of the investigations that were carried out as part of Lyall and Associates, 2019, the procedures, inputs and parameters for the derivation of design rainfall intensities, storm temporal patterns and rainfall losses were based on those set out in ARR 1987. For the purpose of the present investigation, the flood models that were developed as part of Lyall and Associates, 2019 have been updated to incorporate the procedures set out in ARR 2019.

[11] The assessment under item i. was carried out during the initial phase of the concept design to confirm those locations along the designated flood evacuation routes that comprise the state project where drainage improvements are required, and thus inform the scope of the proposal.

The following sections of this technical paper provide a brief description of the DRAINS hydrologic and TUFLOW hydraulic models that were originally developed as part of Lyall and Associates, 2019, as well as the updates that have been made for the purpose of the present investigation.

3.4.1 Hydrologic modelling

Model layout

Two DRAINS hydrologic models were developed to define the rainfall runoff process within the following catchments that contribute flow to the drainage systems along the proposal:

- Rickabys Creek and South Creek (referred to as the Rickabys Creek DRAINS model)
- Penrith Lakes and Boundary Creek (referred to as the Cranebrook DRAINS model)

Figure C.01 (8 sheets) in **Annexure C** of this technical paper shows the layout of the sub-catchments which comprise the Rickabys Creek and Cranebrook DRAINS Models.

The ILSAX and RAFTS sub-models within the DRAINS software were adopted as part of Lyall and Associates, 2019 as they are best suited to simulate the rainfall-runoff process in urban and rural/semi-rural areas, respectively. In updating the DRAINS models for the Stormwater/Flood Modelling PSC, the ILSAX sub-model was converted to an Initial Loss-Continuing Loss Model (**IL-CL**) in accordance with the recommended approach set out in ARR 2019. **Figure C.01** (8 sheets) also shows the sub-catchments where the RAFTS and IL-CL sub-models were applied to the Rickabys Creek and Cranebrook DRAINS Models.

Sub-catchment boundaries in the Rickabys Creek and Cranebrook DRAINS models were digitised based on contour information derived from the available LiDAR survey data, while sub-catchment slopes used as input to the IL-CL and RAFTS sub-models were derived using the average sub-catchment slope and vector averaged slope approaches, respectively. Aerial photography and site observations were used to assess the degree of urbanisation that is present in each sub-catchment.

Design storms and rainfall losses

As noted, the procedures set out in ARR 2019 were used to derive the design rainfall intensities, temporal patterns and losses that were used in the the Rickabys Creek and Cranebrook DRAINS models. Estimates of Probable Maximum Precipitation (PMP) were derived using the Generalised Short Duration Method (GSDM) as described in *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short -Duration Method* (Bureau of Meteorology (BoM), 2003).

Model parameters

Parameters that influence the routing of runoff within the model were based on those contained in the DRAINS models that were developed as part of Lyall and Associates, 2019, which comprised:

i. within the RAFTS sub-model:
    - a storage routing coefficient multiplier (Bx factor) of 1.0, and
    - PERN values ranging between 0.04 and 0.1, with a value at the lower end reflecting grassed areas and a value at the upper end reflecting dense bushland

ii. within the IL-CL sub-model:
    - a retardance coefficient of 0.02 for impervious areas and 0.06 to 0.07 for pervious areas was applied to the routing of runoff using the kinematic wave formula.

The adopted model parameters in the Rickabys Creek and Cranebrook DRAINS Models are consistent with those in the DRAINS hydrologic model that was developed as part of the *Cranebrook Overland Flow Flood Study* (Lyall and Associates, 2022). It is noted that as part of Lyall and Associates, 2022, the DRAINS hydrologic and TUFLOW hydraulic models that were developed as part of that study were jointly calibrated based on comparison to flooding that was observed during storm events that occurred in February 2012, January 2016 and February 2020.

The Rickabys Creek and Cranebrook DRAINS models were run for design storms with AEPs of 20%, 10%, 5%, 2%, 1%, 0.2% and 0.05%, as well as the PMF in order to generate a set of flow hydrographs that were applied as inflow boundaries to the TUFLOW hydraulic models.

3.4.2 Hydraulic Modelling

Model layout

Table 3.1 over the page lists the four TUFLOW models that were developed to define flooding patterns along the designated flood evacuation routes that comprise the proposal, the extent of which are shown on **Figure C.02** (12 sheets) in **Annexure C**.

Given the interrelated nature of the proposal and the regional/local project that comprise the overall program, the extent of each TUFLOW model has been established to cover sections of the adjoining projects to enable their combined impact on flood behaviour to be assessed. **Table 3.1** also shows the designated flood evacuation routes that comprise the regional/local project that are contained within each TUFLOW model.

Each of the TUFLOW models incorporate a grid spacing of 2 metres as it provides an appropriate level of definition of features that influence the passage of flow over the natural surface (e.g. roads, buildings and drainage paths), whilst maintaining a reasonable simulation run time.

The grid elevations in the TUFLOW models that were developed as part of Lyall and Associates, 2019 were based on LiDAR survey data that were captured between 2011 and 2017, together with available ground survey along the road corridors. For the present investigation, the grid elevations in the TUFLOW models were updated based on LiDAR survey data that were captured between 2019 and 2020, together with an updated data set of ground survey along the road corridors that has been collated for the purpose of the concept design.

Ridge and gully lines were added to the TUFLOW models where the grid spacing was considered too coarse to accurately represent important topographic features that influence the passage of overland flow. This included ridge lines along the centreline of roads and gully lines along the inverts of watercourses and minor drainage lines.

The footprints of individual buildings located in close proximity to the road corridors were digitised and assigned a high hydraulic roughness value that accounted for their blocking effect on flow while maintaining storage in the TUFLOW models.

Details of the existing transverse drainage that are located along the road corridors were incorporated into the TUFLOW models using a combination of detailed survey that was collected by Transport and GIS based data obtained from Penrith City Council. Details of several minor drainage lines that are located in adjacent urban areas were also included in the TUFLOW models using GIS based data that was obtained from Penrith City Council.

While a 50 per cent blockage factor was applied to the inlet of all transverse drainage culvert structures along the designated flood evacuation routes as part of Lyall and Associates, 2019, for the present investigation, design blockage factors were calculated at each individual transverse drainage culvert structure based on the approach that is described in **Section 3.3.4** of this technical paper.

TABLE 3.1
TUFLOW HYDRAULIC MODELS

TUFLOW Model	Source of Inflow Boundaries	Flood Evacuation Routes and Corresponding Project under the Program
Berkshire Park North TUFLOW Model [BPN]	Rickabys Creek DRAINS Model	The Northern Road regional flood evacuation route (state project) Richmond Road regional flood evacuation route (state project) (1) Llandilo Road regional flood evacuation route (regional/local project) Londonderry sector flood evacuation route (St Marys Road and Fourth Road) (regional/local project)
Londonderry TUFLOW Model [LR]	Rickabys Creek DRAINS Model Rickabys Creek HPC TUFLOW Model	Londonderry Road regional flood evacuation route (state project) Castlereagh Road regional flood evacuation route (regional/local project)
Llandilo North TUFLOW Model [MNR]	Rickabys Creek DRAINS Model	The Northern Road regional flood evacuation route (state project) Llandilo Road regional flood evacuation route (regional/local project) Castlereagh Road regional flood evacuation route (regional/local project) Londonderry sector flood evacuation route (Fifth Road) (regional/local project) Penrith North sector flood evacuation route (Vincent Road) (state project)
Cranebrook TUFLOW Model [CB]	Cranebrook DRAINS Model	The Northern Road regional flood evacuation route (state project) Castlereagh Road regional flood evacuation route (regional/local project) Penrith North sector flood evacuation route (Borrowdale Way) (regional/local project)

1. While the Richmond Road regional flood evacuation route was included in the flood assessment under the state project, it does not form part of the proposal as the assessment found that flooding does not exceed the threshold criteria that was adopted in the identification of locations of drainage improvement works that are set out in **Section 3.3.1**.

Model boundary conditions

The discharge hydrographs that were generated by the Rickabys Creek and Cranebrook DRAINS models were applied to the aforementioned TUFLOW models as both external and internal inflow boundaries. **Figure C.02** (12 sheets) in **Annexure C** shows the location where inflows were input to the four TUFLOW models that cover the designated flood evacuation routes that comprise the proposal.

As part of Lyall and Associates, 2019, a TUFLOW Heavily Parallelised Computation model was developed of the Rickabys Creek floodplain (Rickabys Creek HPC TUFLOW Model) in order to derive a set of external inflow hydrographs to the Londonderry TUFLOW Model that accounted for the attenuating effect that routing along Rickabys Creek and its tributaries has on flow.

Figure C.02, sheet 1 in **Annexure C** shows the extent of the Rickabys Creek HPC TUFLOW Model, which comprised a grid spacing of 6 metres to provide an appropriate level of definition for routing of flow whilst maintaining a reasonable simulation run time. The discharge hydrographs that were generated by the Rickabys Creek DRAINS model were applied as both external and internal inflow boundaries to the Rickabys Creek HPC TUFLOW Model. Discharge hydrographs were then extracted from the Rickabys Creek HPC TUFLOW Model for use as external inflow boundaries to the Londonderry TUFLOW Model.

The downstream boundary of each of the TUFLOW models comprise either a normal depth calculation or a fixed tailwater level reflecting low flow conditions in the downstream watercourse. The model extents have been selected to ensure the boundary is located a sufficient distance downstream to prevent any influence on flood behaviour within the vicinity of the designated flood evacuation routes.

The adopted downstream boundary conditions are based on the scenario whereby local catchment flooding occurs in the absence of elevated tailwater levels due to Hawkesbury-Nepean River flooding. This scenario reflects the purpose of the drainage improvements, which is to improve the resilience of the designated flood evacuation routes from local catchment flooding in order to maximise the time that is available for people to evacuate an area prior to it being impacted by riverine type flooding.

A sensitivity analysis was undertaken to assess the impact that coincident flooding on the Hawkesbury-Nepean River would have on local catchment flood behaviour along the designated flood evacuation routes. For this purpose, it was assumed that a 0.2% AEP local catchment storm occurred coincident with a 5% AEP Hawkesbury-Nepean River flood.[12] Based on an inspection of the 5% AEP flood extent due to Hawkesbury-Nepean River flooding that was obtained from NSW RA, no locations were identified along the designated flood evacuation routes that comprise the proposal that would be sensitive to a Hawkesbury-Nepean River flood of this magnitude.

Model Parameters

The main physical parameter represented in TUFLOW is hydraulic roughness, which is required for each of the various types of surfaces comprising the overland flow paths in the two-dimensional domain, as well as for the culverts and pipes that were incorporated in the model as one-dimensional elements. In addition to the energy lost by bed friction, obstructions to flow also dissipate energy by forcing water to change direction and velocity, and by forming eddies. Hydraulic modelling traditionally represents all of these effects via the surface roughness parameter known as “Mannings n”.

Hydraulic roughness values adopted for design purposes were selected based on site inspection, past experience and values contained in the engineering literature such as *Australian Rainfall & Runoff Project 15 Report – Two Dimensional Modelling in Urban and Rural Floodplains* (IEAust, 2012) (refer **Table 3.2** over the page).

[12] This combination of local catchment storm and Hawkesbury-Nepean River flood is consistent with that adopted in Lyall and Associates, 2022.

Model validation

Results generated by the TUFLOW models were validated based on comparison with those derived as part of Lyall and Associates, 2022. As part of this model validation, peak 1% AEP flood levels generated by the TUFLOW models were compared to those based on Lyall and Associates, 2022 at eleven locations along the designated flood evacuation routes that comprise the proposal and regional/local project. The comparison found that peak 1% AEP flood levels generated by the TUFLOW models matched closely (within plus 0.06 metres and minus 0.03 metres) with the corresponding results based on Lyall and Associates, 2022.

TABLE 3.2
"BEST ESTIMATE" OF HYDRAULIC ROUGHNESS VALUES
ADOPTED FOR TUFLOW MODELLING

Surface Treatment	Manning's n Value
Reinforced concrete pipes and box culverts	0.015
Roads	0.02
Inbank area of creeks and watercourses (including wetlands)	0.03 – 0.08
Grass and cleared pasture land	0.03 - 0.045
Light vegetation (including scrub, trees and shrubs)	0.05 – 0.09
Allotments	0.1
Dense vegetation	0.12
Buildings	10

3.5 Assessment of construction related impacts

A qualitative assessment was made of the construction related issues associated with flooding along the proposal based on indicative construction areas and activities as provided in the current design. The locations of surface earthworks, upgrades to transverse drainage structures and construction ancillary sites were overlaid onto the indicative flood extents for events with AEPs of 20%, 10%, 5%, 1% and 0.2%, 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 based on an understanding of flood behaviour under pre-proposal conditions during a 1% AEP event.[13] Consideration was also given to the potential for localised overland flooding to occur in construction areas.

Chapter 5 of this technical paper 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 proposal footprint.

[13] While the 1% AEP event has been adopted for the purpose of the preliminary assessment, as per the assessment criteria set out in **Section 3.3.5**, 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.

3.6 Assessment of operational related impacts

The structure of the flood models that were originally developed to define flood behaviour under present day (i.e. pre-proposal conditions) were adjusted to incorporate details of the proposed drainage improvements and road shoulder widening works.

The Rickabys Creek and Cranebrook DRAINS Models were adjusted to reflect the increase in runoff from the widened road shoulder in order to generate a revised set of inflow hydrographs to apply to the TUFLOW models representing operational (i.e. post-proposal) conditions.

In order to assess the impact of the program as a whole, the proposed drainage improvements and road shoulder widening works for both the proposal and the regional/local project were incorporated into the four TUFLOW models representing post-proposal conditions.

For the purpose of the flood assessment, details of the proposed drainage improvements and road shoulder widening were based on a developed concept design, noting that the assessed design of the proposal would be subject to further development during detailed design.

The results of modelling a range of flood events with AEPs of between 20% and 0.05%, as well as the PMF were used to prepare a series of figures showing flooding patterns under operational conditions and afflux diagrams[14] showing the impact that the proposal would have on flood behaviour.

Sections 6.1 and **6.2** of this technical paper respectively deal with the impact that flooding could have on the proposal, as well as the impact that the works associated with the proposal could have on flood behaviour.

3.7 Impact of future climate change on flood behaviour

A sensitivity analysis was carried out in order to gain an understanding of the potential impact of future climate change on flood patterns along the designated flood evacuation routes. The impact that the proposed drainage improvements and road shoulder widening works would have on flood behaviour in areas outside the proposal corridor under future climate change conditions has also been assessed as part of the present investigation.

As noted in **Section 2.2.4**, the sensitivity analysis comprised the assessment of:

a) The potential impact of future climate change on flooding to the designated flood evacuation routes based on a comparison of flood behaviour under post-proposal conditions for storms with AEPs of 0.2% and 0.05%; and

b) the potential impact that the proposed drainage improvements and road shoulder widening work would have on flood behaviour under future climate change based on comparing their impact on present day flood behaviour during a 1% AEP design storm event, against those during a 0.2% AEP design storm event.

Section 6.3 of this technical paper presents the findings of an assessment of the impact that future climate change could have on flooding to the proposal, as well as the impact that the proposal could have on flood behaviour under future climate change conditions.

[14] 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-proposal conditions.

4 EXISTING ENVIRONMENT

This chapter of the technical paper contains a brief description of the Hawkesbury-Nepean River system, as well as the nature of riverine type flooding in the vicinity of the proposal. Also contained in this chapter is a brief description of the existing drainage systems that control local catchment runoff in the vicinity of the designated flood evacuation routes that comprise the proposal.

This chapter also contains a description of the nature of both mainstream flooding and major overland flow (collectively referred to in this technical paper as "local catchment flooding") along the designated flood evacuation routes that comprise the proposal, including a comparison against the Threshold Criteria.

4.1 Hawkesbury-Nepean River system

The following discussion on the Hawkesbury-Nepean River system has been paraphrased from NSW SES, 2020.

The Hawkesbury-Nepean catchment is around 22,500 km^2 in size, stretching from Goulburn in the south to Singleton in the north-west. The Hawkesbury-Nepean River is about 470 km long. It flows generally in a north-easterly direction from its source near Goulburn, until eventually discharging to the Pacific Ocean north of Sydney at Broken Bay. **Plate 1** over the page has been taken from NSW SES, 2020 and shows the extent of the Hawkesbury-Nepean River Basin.

The Hawkesbury and Nepean Rivers are the same river, with the Nepean forming the upper portion, and the Hawkesbury the lower portion of the river system. The junction between the Hawkesbury and Nepean rivers is located at Yarramundi, where the Gross River joins the system.

Within the Hawkesbury-Nepean catchment the major flood risk areas are located on the floodplains and tributaries between Wallacia and Spencer. There are four main identifiable floodplains within the Hawkesbury-Nepean Valley area. These are the:

- Wallacia Floodplain;
- Penrith / Emu Plains / Castlereagh Floodplain;
- Richmond / Windsor / Wilberforce Floodplain; and
- Lower Hawkesbury Floodplain

Plate 2 two pages over shows the extent of each of the four floodplains listed above (as defined by the extent of the PMF). The designated flood evacuation routes that form the basis of the proposal service parts of the Penrith / Emu Plains / Castlereagh and Richmond / Windsor / Wilberforce floodplains. The following section of this technical paper briefly describe the nature of riverine type flooding across these two areas.

Plate 1 – Hawkesbury – Nepean River Basin (Source: NSW SES, 2020)

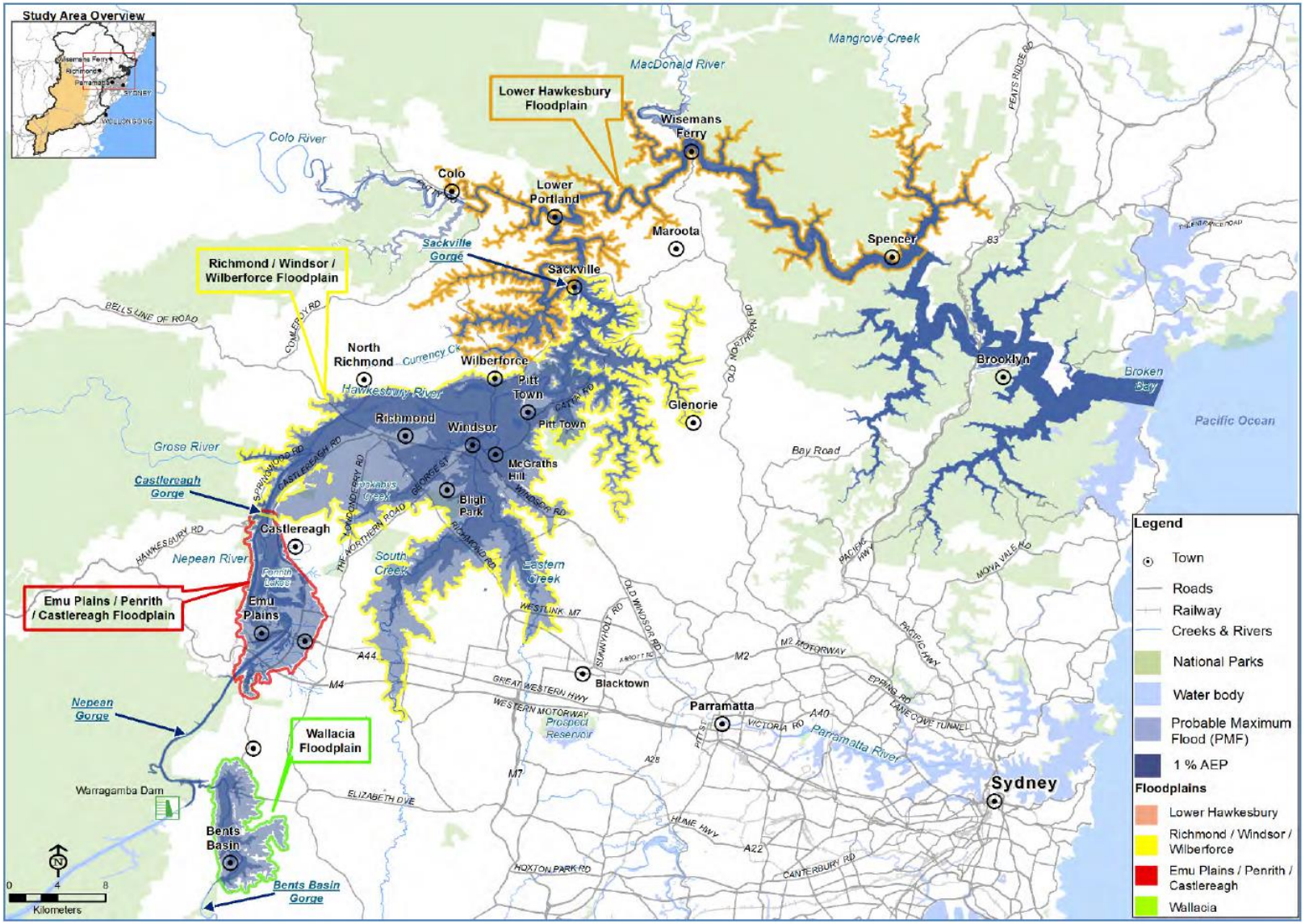

Plate 2 – Hawkesbury – Nepean Floodplains (Source: NSW SES, 2020)

4.1.1 Flooding on the Emu Plains / Penrith / Castlereagh Floodplain

While the presence of natural levee banks along the reach of the Nepean River near Penrith and Leonay prevent the breakout of floodwater during floods up to 1% AEP in magnitude, flooding can occur in several areas due to floodwater backing up the local creek system.

Floodwater can isolate parts of the communities of Emu Plains including Emu Heights, Leonay, Central and East Emu Plains, North Penrith and the Peach Tree Creek area creating 'flood islands'. Depending on the size of the flood, these islands can gradually become completely submerged by floodwater. During the PMF event, most of Emu Plains, the Penrith Lakes area and parts of Penrith would be flooded. Design peak flood levels on the Emu Plains / Penrith / Castlereagh Floodplain at Penrith are set out in **Table 4.1**.

It is understood that the Bureau of Meteorology (**BoM**) can currently provide about eight hours advance warning time of impending flooding on the Emu Plains / Penrith / Castlereagh Floodplain.

TABLE 4.1
DESIGN PEAK FLOOD LEVELS AT PENRITH AND WINDSOR
HAWKESBURY-NEPEAN RIVER FLOODING ONLY
(m AHD)

Design Flood Event (% AEP)	Penrith (Victoria Bridge)	Windsor (Windsor bridge)
20	19.6	9.9
10	21.3	11.9
5	23.3	13.7
2	24.8	16.1
1	25.8	17.3
0.5	26.5	18.4
0.2	27.1	19.6
0.1	27.5	20.6
PMF	32.8	26.4

Source: NSW SES, 2020

4.1.2 Flooding on the Richmond / Windsor / Wilberforce Floodplain

The natural constriction that is present at the location where the Hawkesbury River enters the Sackville Gorge has a marked influence on flood behaviour on the Richmond / Windsor / Wilberforce Floodplain, whereby floodwater cannot discharge to the downstream reach of the river system at the same rate as it enters onto the floodplain. As a result, floodwater is forced to back up and temporarily pond over a large area. Design peak flood levels on the Richmond / Windsor / Wilberforce Floodplain at Windsor are set out in **Table 4.1**.

Low lying farming areas including Richmond Lowlands, Cornwallis, Pitt Town Bottoms and areas along Rickabys Creek and South Creek are initially flooded. Depending on the size of the flood,

areas that are normally hills or rises in the landscape can be surrounded by floodwater and become isolated 'flood islands'. These areas, several of which can be totally inundated during rare to extreme flood events, include the townships of McGraths Hill, Pitt Town, Windsor, Bligh Park and parts of Richmond.

It is understood that BoM can currently provide about fifteen hours advance warning time of impending flooding on the Richmond / Windsor / Wilberforce Floodplain.

4.2 Description of existing local drainage system

As noted in **Section 3.2**, the proposal is located within the following catchments:

- Rickabys Creek
- South Creek
- Penrith Lakes
- Boundary Creek
- Peachtree Creek

Figure 4.1, sheet 1 shows the extent of each of the above catchments in the vicinity of the proposal corridor.

The following section of the report provides a brief description of the existing drainage systems that control local catchment runoff along the proposal corridor. **Table 4.2** at the end of this chapter lists the existing transverse drainage structures that are located along the proposal. **Figure 4.1** (12 sheets) shows the extent of the catchments which contribute to flow in the existing transverse drainage that are located along the proposal, as well as the layout of the existing drainage system in their immediate vicinity.

4.2.1 The Northern Road regional flood evacuation route

The section of The Northern Road regional flood evacuation route that forms part of the scope of the present investigation comprises the following sections of road corridor:

- The Northern Road between Richmond Road and Andrews Road in the suburbs of Berkshire Park, Londonderry, Llandilo, Cranebrook, Jordan Springs and Cambridge Gardens
- Richmond Road between Andrews Road and Coreen Avenue in the suburb of Penrith
- Parker Street between Coreen Avenue and the Great Western Highway in the suburb of Penrith.

The section of The Northern Road regional flood evacuation route between Richmond Road and Llandilo Road lies within the Rickabys Creek catchment (refer transverse drainage structures TNR01 to TNR23 on **Figure 4.1**, sheets 2, 3, 4, 5, 6 and 7), while the section which runs between Llandilo Road and Coreen Avenue drain to either Penrith Lakes to the west or South Creek to the east (refer transverse drainage structures TNR24 to TNR38 on **Figure 4.1**, sheets 6, 7, 8 and 9). The section of the The Northern Road regional flood evacuation route between Coreen Avenue and The Great Western Highway drains to either Boundary Creek to the west or Peachtree Creek to the south (refer transverse drainage structures TNR39 to TNR43 on **Figure 4.1**, sheet 9).

4.2.2 Londonderry Road regional flood evacuation route

The section of the Londonderry Road regional flood evacuation route that forms part of the scope of the present investigation runs between Southee Road and The Northern Road in the suburbs of Richmond and Londonderry, and is located within the Rickabys Creek catchment.

Londonderry Road crosses the main arm of Rickabys Creek between Spencer Road and Cherrybrook Chase via a relatively large transverse drainage structure that comprises 3 off 3600 x 2400 RCBCs, 8 off 3600 x 1500 RCBCs and 10 off 3600 x 1200 RCBCs (refer transverse drainage structure LNR12 on **Figure 4.1**, sheet 4).

4.2.3 Penrith North Sector flood evacuation route (Vincent Road)

While Vincent Road in Llandilo is located within the regional/local project, the scope of drainage improvements that are proposed to alleviate flooding at a transverse drainage structure at its eastern end (denoted transverse drainage structure CR35c) have been incorporated into the proposal due to their proximity to The Northern Road. **Figure 4.1**, sheet 7 shows the location of existing transverse drainage structure CR35c.

Transverse drainage structure CR35c discharges to transverse drainage structure TNR22 which crosses The Northern Road immediately to its north. The structures drain to a tributary of Rickabys Creek that runs in a northerly direction to the east of The Northern Road.

TABLE 4.2
EXISTING TRANSVERSE DRAINAGE ALONG THE DESIGNATED FLOOD EVACUATION ROUTES THAT COMPRISE THE PROPOSAL

Designated Flood Evacuation Route	Transverse Drainage Structure Identifier (1)	Catchment Area (hectares) (2)	Structure Type and Dimensions (3)
The Northern Road Regional Flood Evacuation Route	TNR01a	9.3	1 off 1800x600 RCBC
	TNR01	36.8	2 off 450 RCPs
	TNR02	18.0	1 off 375 RCP
	TNR03	1.0	1 off 600 RCP
	TNR04	404.4	3 off 1200 RCP's
	TNR05	12.9	1 off 600 RCP
	TNR06	7.7	1 off 600 RCP
	TNR07	13.1	2 off 450 RCPs
	TNR08	1.4	1 off 450 RCP
	TNR09	4.4	1 off 750 RCP
	TNR10	17.5	2 off 600 RCPs
	TNR11	237.3	3 off 2400x900 RCBCs
	TNR12	6.3	1 off 600 RCP
	TNR13	60.7	2 off 1200x600 RCBCs

Designated Flood Evacuation Route	Transverse Drainage Structure Identifier [(1)]	Catchment Area (hectares) [(2)]	Structure Type and Dimensions [(3)]
The Northern Road Regional Flood Evacuation Route	TNR14a	0.76	2 off 600 RCPs
	TNR14b	184.2	1 off 900 RCP
	TNR15	2.5	1 off 600 RCP
	TNR16	98.7	3 off 900 RCPs
	TNR17	6.4	1 off 450 RCP
	TNR18	4.0	2 off 450 RCPs
	TNR19	14.0	1 off 1200 x450 RCBC
	TNR20	58.2	2 off 1200x600 RCBCs
	TNR21	137.9	2 off 2200x1050 RCBCs
	TNR22	4.9	2 off 375 RCPs
	TNR22b	4.1	1 off 375 RCP
	TNR23	19.0	1 off 1800x600 RCBC
	TNR24	1.8	1 off 600 RCP
	TNR25	0.98	1 off 450 RCP
	TNR26	5.3	1 off 450 RCP
	TNR27	1.5	1 off 450 RCP
	TNR28	2.9	2 off 450 RCP
	TNR29	4.2	1 off 600x300 RCBC
	TNR30	15.9	1 off 1050 RCP
	TNR31	14.4	1 off 450 RCP
	TNR32	1.1	1 off 1600X800 RCBC
	TNR33	4.7	1 off 600 RCP
	TNR34	14.7	1 off 1200 RCP
	TNR35	16.9	1 off 900x450 RCBC
	TNR36	3.0	No existing structure (discharges to TNR35)
	TNR37	1.5	1 off 450 RCP
	TNR38	2.0	1 off 525 RCP
	TNR39	0.45	1 off 450 RCP
	TNR40	1.3	1 off 375 RCP
	TNR41	3.3	1 off 600 RCP
	TNR42	1.1	1 off 375 RCP

Designated Flood Evacuation Route	Transverse Drainage Structure Identifier [1]	Catchment Area (hectares) [2]	Structure Type and Dimensions [3]
The Northern Road Regional Flood Evacuation Route	TNR43	0.96	1 off 375 RCP
Londonderry Road Regional Flood Evacuation Route	LNR01	138.7	4 off 2400 x 1200 RCBCs
	LNR02	2.8	1 off 600x300 RCBC
	LNR03	0.20	1 off 900x300 RCBC
	LNR04	458.8	1 off 3600x1800 RCBCs & 3 off 3600x1200 RCBCs
	LNR05	8.0	1 off 375 RCP
	LNR06	Combined with LNR05	1 off 375 RCP
	LNR07	7.9	2 off 3600x600 RCBCs
	LNR08	29.7	1 off 1050 RCP
	LNR09	2.4	1 off 450 RCP
	LNR10	2,844	4 off 3600x2400 RCBCs & 4 off 3600x1200 RCBCs & 2 off 3600x1500 RCBCs & 5 off 3600x2100 RCBCs
	LNR11	Combined with LNR10	4 off 3600x1200 RCBCs & 3 off 3600x1500 RCBCs
	LNR12	1,680	3 off 3600x2400 RCBCs & 8 off 3600x1500 RCBCs & 10 off 3600x1200 RCBCs
	LNR13	Combined with LNR12	2 off 525 RCPs
	LNR14	14.4	1 off 600 RCP
	LNR15	507.8	3 off 3600x1200 RCBCs & 2 off 3600x1500 RCBCs & 6 off 3600x1050 RCBCs
	LNR16	12.2	1 off 450 RCP
	LNR17	8.1	2 off 1200x600 RCBCs
Penrith North Sector Flood Evacuation Route (Vincent Road)	CR35c[4]	3.0	1 off 1200x150 RCBC

1. Refer to **Figure 4.1** (12 sheets) for locations of transverse drainage structures.
2. Catchment areas are indicative as in some locations runoff distributes across multiple transverse drainage structures.
3. RCP = Reinforced Concrete Pipe RCBC = Reinforced Concrete Box Culvert
4. While transverse drainage structure CR35c on Vincent Road is located within the regional/local project, the scope of drainage improvements that are proposed to alleviate flooding at this location have been incorporated into the proposal due to their proximity to The Northern Road.

4.3 Description of existing flood behaviour

The following section of this technical paper provides a brief description of patterns of both mainstream flooding and major overland flow along the designated flood evacuation routes that comprise the proposal.

The following figures are also referred to in the following discussion:

- **Figures 4.2**, **4.3**, **4.4** and **4.5** (12 sheets each) show the indicative extent and depth of inundation in the vicinity of the designated flood evacuation routes that comprise the proposal for local catchment floods with AEPs of 10%, 1% and 0.2%, as well as the PMF event, respectively.
- **Figures 4.6** and **4.7** (12 sheets each) show the hazard vulnerability classification in the vicinity of the designated flood evacuation routes that comprise the proposal for local catchment floods with AEPs of 1% and 0.2%, respectively.
- **Annexure D** contains a series of figures that show the indicative extent and depth of inundation in the vicinity of the designated flood evacuation routes that comprise the proposal for local catchment floods with AEPs of 20%, 5% and 0.05%.
- **Annexure E** contains a series of figures showing maximum flow velocities and durations of inundation in the vicinity of the designated flood evacuation routes that comprise the proposal for local catchment floods with AEPs of 10% and 1%. These data have principally been used to assess the impact that the proposed drainage improvements and road shoulder widening works would have on flow velocities (and hence scour potential) and durations of inundation.

Flood behaviour has been defined using the hydrologic and hydraulic models that are described in **Section 3.4**.

4.3.1 The Northern Road regional flood evacuation route

Up to 0.2% AEP

Between Richmond Road and Carrington Road in Londonderry and Berkshire Park

While the section of The Northern Road adjacent to transverse drainage structure TNR01a is not impacted by mainstream flooding or major overland flow during storms up to 5% AEP in intensity, it will be inundated by runoff that surcharges the local pavement drainage system. During a 1% AEP design storm event, flow in excess of the capacity of transverse drainage structure TNR01a will discharge onto the adjacent section of The Northern Road where it will pond to a maximum depth of about 0.1 metres to the south of its intersection with Richmond Road, increasing to 0.2 metres during a 0.2% AEP design storm event.

The section of The Northern Road adjacent to transverse drainage structures TNR01, TNR02 and TNR03 would be inundated by floodwater during storms more frequent than 20% AEP.

During a 10% AEP design storm event, the section of The Northern Road extending to the north and south of transverse drainage structure TNR01 over a total distance of about 140 metres is inundated by floodwater, increasing to about 160 and 170 metres during a 1% and 0.2% AEP design storm event, respectively. During these design storm event depths of inundation would be less than 0.05 metres along the northbound travel lanes and 0.2 metres along the southbound travel lane (i.e. the latter comprising the outbound lane for flood evacuation purposes).

During a 10% AEP design storm event, the section of The Northern Road extending north and south of the entry to the John Morony Correctional Complex will be inundated over a length of about 170 metres due to flow that surcharges transverse drainage structures TNR02 and TNR03. The extent of inundation along The Northern Road would increase to about 180 and 270 metres during design storms with AEPs of 1% and 0.2%, respectively. During each of these design storm events, depths of inundation would be less than 0.05 metres along the northbound travel lanes and 0.2 metres along the southbound travel lane (i.e. the latter comprising the outbound lane for flood evacuation purposes).

During a 10% AEP design storm event a short section of The Northern Road to the south of transverse drainage structure TNR05 would be inundated by flow that surcharges the adjacent drainage channel. During design storms with AEPs of 1% and 0.2% the section of The Northern Road between transverse drainage structures TNR04 and TNR05 will be inundated over to a maximum depth of about 0.3 metres.

Between Carrington Road and Whitegates Road in Londonderry and Berkshire Park

The section of The Northern Road adjacent to transverse drainage structure TNR06 is not impacted by floodwaters during storms up to 5% AEP in intensity. During design storms with AEPs of 1% and 0.2% the section of The Northern Road extending about 120 metres north of transverse drainage structure TNR06 is inundated by floodwater. Depths of inundation are less than 0.05 metres along the northbound travel lanes and 0.2 metres along the southbound travel lane (i.e. the outbound lane during flood evacuation).

The section of The Northern Road adjacent to transverse drainage structure TNR07 is not impacted by mainstream flooding or major overland flow during a 0.2% AEP design storm event, noting that flow in excess of the capacity of the transverse drainage structure discharges in a northerly direction toward transverse drainage structure TNR06 rather than overtop the road at this location.

The section of The Northern Road adjacent to transverse drainage structure TNR08 is not impacted by floodwaters during storms up to 10% AEP in intensity. During design storms with AEPs of 1% and 0.2%, a relatively short length of less than 40 metres of The Northern Road adjacent to transverse drainage structure TNR08 is inundated by floodwater, albeit to relatively shallow depths that are typically less than 0.05 metres.

The section of The Northern Road adjacent to transverse drainage structures TNR09 and TNR10 is not impacted by mainstream flooding or major overland flow during a 0.2% AEP design storm event, noting that flow in excess of the capacity of these transverse drainage structures discharges in a southerly direction toward transverse drainage structure TNR11 rather than overtop the road at this location.

The section of The Northern Road adjacent to transverse drainage structure TNR11 is overtopped by floodwaters during storms more frequent than 20% AEP. During a 1% AEP design storm event, the section of The Northern Road adjacent to transverse drainage structure TNR11 will be inundated over a length of about 120 metres and to a maximum depth of 0.3 metres, increasing to a length of 140 metres and a maximum depth of 0.4 metres during a 0.2% AEP design storm event.

Between Whitegates Road and Londonderry Road in Londonderry, Berkshire Park and Llandilo

The section of The Northern Road adjacent to transverse drainage structure TNR12 is not impacted by mainstream flooding or major overland flow during a 0.2% AEP design storm event, noting that flow in excess of the capacity of this transverse drainage structure discharges in a northerly direction toward transverse drainage structure TNR12 rather than overtop the road at this location.

Flow in excess of the capacity of transverse drainage structure TNR13 discharges toward transverse drainage structures TNR14a and TNR14b where the adjacent section of road is overtopped by floodwaters during storms more frequent than 20% AEP. During a 1% AEP design storm event, the section of The Northern Road adjacent to transverse drainage structures TNR14a and TNR14b will be inundated over a length of about 120 metres and to a maximum depth of 0.25 metres, with only a slightly grater depth and extent of inundation occurring during a 0.2% AEP design storm event.

The section of The Northern Road adjacent to transverse drainage structures TNR15 and TNR16 is overtopped by floodwaters during storms more frequent than 20% AEP. During a 1% AEP design storm event, the section of The Northern Road adjacent to transverse drainage structures TNR15 and TNR16 will be inundated over a length of about 210 metres and to a maximum depth of 0.2 metres, increasing to a maximum depth of 0.25 metres during a 0.2% AEP design storm event.

The section of The Northern Road adjacent to transverse drainage structure TNR17 is not impacted by floodwaters during storms up to 5% AEP in intensity. During design storms with AEPs of 1% and 0.2%, a relatively short length of less than 40 metres of The Northern Road adjacent to transverse drainage structure TNR17 is inundated by floodwater, albeit to relatively shallow depths that are typically less than 0.05 metres.

Between Londonderry Road and Andromeda Drive in Cranebrook and Llandilo

The section of The Northern Road where it runs between transverse drainage structures TNR18, TNR19, TNR20 and TNR21 is generally not impacted by floodwaters during a 20% AEP design storm event, with the exception of a 60 metre length immediately north of transverse drainage structure TNR20 where depths of inundation would be less than 0.05 m. During a 1% AEP design storm event, the section of The Northern Road between transverse drainage structures TNR18 and TNR21 would be inundated over a length of about 580 metres and to a maximum depth of 0.2 metres, increasing to a maximum depth of 0.25 metres over a similar extent during a 0.2% AEP design storm event.

The section of The Northern Road adjacent to transverse drainage structures TNR22 and TNR22b is overtopped by floodwaters during storms more frequent than 20% AEP. During design storms with AEPs of 1% and 0.2%, the section of The Northern Road adjacent to transverse drainage structure TNR22 will be inundated over a length of about 120 metres, but to a maximum depth that is less than 0.1 metres, while the section of The Northern Road adjacent to transverse drainage structure TNR22b will be inundated over a length of about 40 metres, but to a maximum depth that is less than 0.05 metres.

Between Andromeda Drive and Borrowdale Way in Cranebrook and Jordan Springs

The northbound carriageway of The Northern Road will be inundated by flow in excess of the capacity of transverse drainage structure TNR23 during storms more frequent than 20% AEP. During a 1% AEP design storm event, overland flow that is conveyed along the northbound carriageway toward transverse drainage structure TNR24 will occur to a maximum depth of 0.3 metres, increasing to 0.4 metres during a 0.2% AEP design storm event.

The section of The Northern Road between transverse drainage structures TNR24 and TNR25 will be inundated by floodwaters during storms more frequent than 20% AEP. During a 0.2% AEP design storm event, The Northern Road will be overtopped over a length of about 80 metres, where the depth of inundation along the northbound and southbound carriageway will occur to a maximum

of 0.8 and 0.5 metres, respectively (the latter comprising the outbound lane for flood evacuation purposes).

The section of The Northern Road adjacent to transverse drainage structure TNR26 is not impacted by mainstream flooding or major overland flow during a 1% AEP design storm event, noting that flow in excess of the capacity of the transverse drainage structure discharges in a northerly direction toward transverse drainage structure TNR25 rather than overtop the road at this location.

Sections of The Northern Road less than 100 metres in length that are located adjacent to transverse drainage structures TNR27 and TNR28 will be inundated by floodwater during design storms with AEPs of 1% and 0.2%, albeit to a relatively shallow depths that are less than 0.05 metres.

The section of The Northern Road adjacent to transverse drainage structure TNR29 is not impacted by mainstream flooding or major overland flow during a 1% AEP design storm event, noting that flow in excess of the capacity of the transverse drainage structure discharges in a southerly direction toward transverse drainage structure TNR30 rather than overtop the road at this location. During a 0.2% AEP design storm event a 30 metre length of The Northern Road adjacent to transverse drainage structure TNR29 is inundated by floodwaters to relatively shallow depths that are less than 0.05 metres.

Between Borrowdale Way and Sherringham Road in Cranebrook and Jordan Springs

The section of The Northern Road adjacent to transverse drainage structure TNR30 is overtopped by floodwater during a 10% AEP design storm event. During design storms with AEPs of 1% and 0.2%, the section of The Northern Road adjacent to transverse drainage structure TNR30 will be inundated over a length of about 60 metres but to a maximum depth that is less than 0.1 metres.

The section of The Northern Road adjacent to transverse drainage structures TNR31 and TNR32 is overtopped by floodwater during a 10% AEP design storm event. During design storms with AEPs of 1% and 0.2%, the section of The Northern Road adjacent to transverse drainage structures TNR31 and TNR32 will be inundated over a length of about 80 metres but to a maximum depth of 0.1 metres.

Between Sherringham Road and Dunheved Road in Cranebrook, Penrith and Cambridge Gardens

The section of The Northern Road adjacent to transverse drainage structures TNR33 and TNR34 is overtopped by floodwater during storms more frequent than 20% AEP. During design storms with AEPs of 1% and 0.2%, the section of The Northern Road adjacent to transverse drainage structures TNR33 and TNR34 will be inundated over a length of about 210 metres. Depths of inundation are greatest adjacent to transverse drainage structure TNR34 where they occur to a maximum of 0.2 metres during a 1% AEP design storm event, increasing to 0.4 m during a 0.2% AEP design storm event.

Flow in excess of the capacity of the drainage system at transverse drainage structures TNR36 and TNR37 discharges in a northerly direction toward transverse drainage structure TNR35, where floodwater will overtop The Northern Road during storms more frequent than 20% AEP. During a 1% AEP design storm event, the section of The Northern Road adjacent to transverse drainage structure TNR35 will be inundated over a length of about 80 metres and to a maximum depth 0.5 metres, increasing to a maximum depth of 0.6 metres during a 0.2% AEP design storm event.

Between Denheved Road and Great Western Highway in Penrith, Kingswood and Cambridge Park

While the section of The Northern Road adjacent to transverse drainage structure TNR38 is not impacted by mainstream flooding or major overland flow during storms up to 10% AEP in intensity, it will be inundated by runoff that surcharges the local pavement drainage system. During a 1% AEP design storm event, flow in excess of the capacity of transverse drainage structure TNR38 will discharge onto the adjacent section of The Northern Road where it will pond to a maximum depth of about 0.3 and 0.1 metres in the northbound and southbound carriageways, respectively. During a 0.2% AEP design storm event depth of inundation will be increased to a maximum depth of about 0.4 and 0.1 metres in the northbound and southbound carriageways, respectively (the latter comprising the outbound lane for flood evacuation purposes).

While the section of The Northern Road adjacent to transverse drainage structure TNR39 is not impacted by mainstream flooding or major overland flow during storms up to 10% AEP in intensity, it will be inundated by runoff that surcharges the local pavement drainage system. During a 1% AEP design storm event, flow in excess of the capacity of transverse drainage structure TNR39 will discharge onto the adjacent section of The Northern Road where it will pond to a maximum depth of about 0.2 and 0.1 metres in the northbound and southbound carriageways, respectively (the latter comprising the outbound lane for flood evacuation purposes). Similar depths of inundation would also occur during a 0.2% AEP design storm event.

The section of The Northern Road where it runs between transverse drainage structures TNR40 and TNR43 will be inundated to relatively shallow depths due to flow that surcharges the road drainage system. During design storms with AEPs of 1% and 0.2%, the greatest depth of inundation occurs at transverse drainage structure TNR41 to a maximum of 0.2 metres.

PMF

While widespread flooding occurs along significant lengths of The Northern Road regional flood evacuation route, the depth of overtopping across the centreline of the road is typically less than 0.3 metres, except at the following locations:

- At transverse drainage structures TNR04 and TNR05 where the depth of overtopping across the centreline of the road will occur to a maximum of 0.9 metres.
- At transverse drainage structure TNR11 where the depth of overtopping across the centreline of the road will occur to a maximum of 1.1 metres.
- At transverse drainage structures TNR14a and TNR14b where the depth of overtopping across the centreline of the road will occur to a maximum of 1.2 metres.
- At transverse drainage structures TNR15 and TNR16 where the depth of overtopping across the centreline of the road will occur to a maximum of 0.8 metres.
- At transverse drainage structures TNR20 and TNR21 where the depth of overtopping across the centreline of the road will occur to a maximum of 0.8 metres.
- At transverse drainage structures TNR23, TNR24 and TNR25 where the depth of overtopping across the centreline of the road will occur to a maximum of 0.8 metres.

4.3.2 Londonderry Road regional flood evacuation route

Up to 0.2% AEP

Between Southee Road and Reynolds Road in Richmond and Londonderry

While the section of Londonderry Road where it runs between Southee Road and The Driftway, is not impacted by mainstream flooding or major overland flow during storms up to 0.2% AEP in intensity, a 100 metre length of road to the north of transverse drainage structure LNR01 will be inundated by runoff that surcharges the adjacent table drain to relatively shallow depths.

Similarly, while the section of Londonderry Road where it runs between The Driftway and Reynolds Road is not impacted by mainstream flooding or major overland flow during storms up to 0.2% AEP in intensity, sections of road to the north and south of transverse drainage structure LNR03 will be inundated by runoff that surcharges the adjacent table drain to a maximum depth of 0.25 metres.

Between Reynolds Road and Kenmare Road in Londonderry

The section of Londonderry Road adjacent to transverse drainage structures LNR04, LNR05, LNR06 and LNR07 is not impacted by floodwaters during storms up to 0.2% AEP in intensity.

The section of Londonderry Road where it runs between transverse drainage structures LNR08 and LNR09 is inundated by flow that surcharges the associated drainage systems during storms more frequent than 20% AEP. The greatest depth of inundation occurs immediately north of transverse drainage structure LNR08 where both the northbound and southbound travel lanes will be inundated to a depth of 0.4 metres during a 0.2% AEP design storm event (the latter comprising the outbound lane for flood evacuation purposes).

Between Kenmare Road and Cherrybrook Chase in Londonderry

The section of Londonderry Road where it crosses a tributary of Rickabys Creek at transverse drainage structures LNR10 and LNR11 is not impacted by floodwaters during storms up to 0.2% AEP in intensity.

The section of Londonderry Road where it crosses Rickabys Creek at transverse drainage structure LNR12 is not impacted by floodwater during storms up to 1% AEP in intensity. During a 0.2% AEP design storm event, flow that surcharges the inlet to transverse drainage structure LNR12 will overtop the section of Londonderry Road adjacent to transverse drainage structure LNR13 over a length of about 100 metres and to a maximum depth of about 0.1 metres.

While the section of Londonderry Road where it runs between Cherrybrook Chase and Whitegates Road is not impacted by mainstream flooding or major overland flow during storms up to 0.2% AEP in intensity, a section of the southbound carriageway to the south of transverse drainage structure LNR13 will be inundated by runoff that surcharges the adjacent table drain to relatively shallow depths.

Between Cherrybrook Chase and The Northern Road in Londonderry

A 30 metre length of Londonderry Road to the south of transverse drainage structure LNR14 will be inundated by floodwater during a 5% AEP design storm event, albeit to relatively shallow depths of less than 0.05 metres. Similar depths of inundation will occur during a 0.2% AEP design storm event over a 90 metre length of road.

The section of Londonderry Road where it runs between transverse drainage structures LNR15 and LNR16 will be inundated by flow that surcharges the adjacent table drains during storms more frequent than 20% AEP. During a 0.2% AEP design storm event, depths of inundation along the road are typically less than 0.1 metres except at the intersection with Thomas Road where depths occur to a maximum of 0.2 metres.

The section of Londonderry Road adjacent to transverse drainage structure LNR17 is not impacted by floodwater during storms up to 1% AEP in intensity. During a 0.2% AEP design storm event, flow that surcharges the inlet to transverse drainage structure LNR17 will overtop the adjacent section of road over a length of about 60 metres and to a maximum depth of about 0.1 metres.

PMF

While widespread flooding occurs along significant lengths of the Londonderry Road regional flood evacuation route, the depth of overtopping across the centreline of the road is typically less than 0.3 metres, except at the following locations:

- At transverse drainage structure LNR04 where the depth of overtopping across the centreline of the road will occur to a maximum of 0.6 metres.
- At transverse drainage structure LNR08 where the depth of overtopping across the centreline of the road will occur to a maximum of 1.6 metres.
- At transverse drainage structure LNR09 where the depth of overtopping across the centreline of the road will occur to a maximum of 1.9 metres.
- At transverse drainage structures LNR10 and LNR11 where the depth of overtopping across the centreline of the road will occur to a maximum of 0.9 metres.
- At transverse drainage structures LNR12 and LNR13 where the depth of overtopping across the centreline of the road will occur to a maximum of 1.8 metres.
- At transverse drainage structure LNR15 where the depth of overtopping across the centreline of the road will occur to a maximum of 1 metre.

4.3.3 Penrith North Sector flood evacuation route (Vincent Road)

Up to 0.2% AEP

The section of Vincent Road to the west of its intersection with The Northern Road will be inundated by floodwater that surcharges the inlet to transverse drainage structure CR35c during storms more frequent than 20% AEP. During a 1% AEP design storm event, a 30 metre length of Vincent Road to the west of its intersection with The Northern Road will be inundated to a maximum depth of 0.5 metres, increasing to 0.6 metres during a 0.2% AEP design storm event.

PMF

During the PMF event, a 40 metre length of Vincent Road to the west of its intersection with The Northern Road will be inundated to a maximum depth of 0.7 metres.

4.4 Comparison of existing flood behaviour against the adopted Threshold Criteria for flooding along the designated flood evacuation routes

As noted in **Section 3.3.1**, an investigation was carried out during the initial phase of the concept design to confirm those locations along the designated flood evacuation routes that comprise the State Project where flooding during a 0.2% AEP design storm exceeds the Threshold Criteria. This investigation was used to inform the identification of locations where drainage improvements are required to meet the objective of the Program. This section provides a summary of the key findings of this investigation as they relate to the designated flood evacuation routes that comprise the proposal.[15]

4.4.1 The Northern Road regional flood evacuation route

With the exception of transverse drainage structures TNR07, TNR26 and TNR29, flooding will occur to The Northern Road regional flood evacuation route at all other transverse drainage structures to varying degrees. Based on a comparison of flood behaviour at these other transverse drainage structures against the Threshold Criteria, it is noted that:

- The duration of overtopping and hazard vulnerability classification of flooding to the outbound travel lanes does not exceed the Threshold Criteria, meaning drainage improvements are not required at transverse drainage structures TNR01a, TNR01, TNR02, TNR03, TNR06, TNR08, TNR09, TNR10, TNR12, TNR13, TNR16, TNR17, TNR18, TNR20, TNR22, TNR22b, TNR23, TNR27, TNR28, TNR30, TNR31, TNR32, TNR33, TNR37, TNR38, TNR39, TNR40, TNR41, TNR42 and TNR43.
- Both the duration of overtopping and hazard vulnerability classification of flooding to the outbound travel lane exceeds the Threshold Criteria meaning drainage improvements are required at transverse drainage structures TNR04, TNR11, TNR14a, TNR14b, TNR15, TNR24 and TNR25.
- The duration of overtopping, and not the hazard vulnerability classification of flooding to the outbound travel lane exceeds the Threshold Criteria, meaning drainage improvements are required at transverse drainage structures TNR05 and TNR19.
- The hazard vulnerability classification of flooding to the outbound travel lanes, and not the duration of overtopping exceeds the Threshold Criteria, meaning drainage improvements are required at transverse drainage structures TNR21, TNR34, TNR35 and TNR36.

4.4.2 Londonderry Road regional flood evacuation route

With the exception of transverse drainage structures LNR01, LNR04, LNR05, LNR06, LNR07, LNR10, LNR11, LNR12 and LNR14, flooding will occur to Londonderry Road regional flood evacuation route at all other transverse drainage structures to varying degrees. Based on a comparison of flood behaviour at these other transverse drainage structures against the Threshold Criteria, it is noted that:

- The duration of overtopping and hazard vulnerability classification of flooding to the outbound travel lanes does not exceed the Threshold Criteria, meaning drainage improvements are not required at transverse drainage structures LNR02, LNR03, LNR09, LNR13, LNR15, LNR16 and LNR17.

[15] While the flood assessment that has been carried out for the State Project component of the Program also included the section of the Richmond Road regional flood evacuation route to the north of South Creek, no drainage improvements are proposed along that section of road as the assessment found that flood behaviour during a 0.2% AEP design storm does not exceed the adopted Threshold Criteria.

- The duration of overtopping, and not the hazard vulnerability classification of flooding to the outbound travel lane exceeds the Threshold Criteria, meaning drainage improvements are required at transverse drainage structure LNR08.

4.4.3 Penrith North Sector flood evacuation route (Vincent Road)

At transverse drainage structure CR35c on Vincent Road the duration of overtopping, as well as the hazard vulnerability classification of flooding to the outbound travel lane exceed the Threshold Criteria meaning drainage improvements are required at this location.

4.4.4 Summary of locations where existing flood behaviour exceeds the adopted Threshold Criteria for flooding along the designated flood evacuation routes

The assessment that is presented in the preceding sections of this technical paper shows that flood behaviour during a 0.2% AEP design storm exceeds the Threshold Criteria at the following locations:

i. transverse drainage structures TNR04, TNR05, TNR11, TNR14a, TNR14b, TNR15, TNR19, TNR21, TNR24, TNR25, TNR34, TNR35 and TNR36 (13 in total) that are located on The Northern Road regional flood evacuation route,

ii. transverse drainage structure LNR08 that is located on the Londonderry Road regional flood evacuation route, and

iii. transverse drainage structure CR35c that is located on Vincent Road, which forms part of the Penrith North sector flood evacuation route.

Of the transverse drainage structures listed above, an initial investigation into the drainage improvement requirements found that there is limited scope to further improve the level of flooding to the section of Londonderry Road adjacent to transverse drainage structure LNR08 by increasing the capacity of the drainage system due to the low-lying nature of the road, as well as the impact that any proposed increase in capacity could potentially have on flood behaviour in areas downstream the structure. For example, the initial investigation found that the scope of upgrades to the drainage system that are shown on **Plate 4.1** over the page would have the following effect on local catchment flooding for a 0.2% AEP design storm event:

i. the depth of overtopping across the centreline of the road would be reduced from 0.2 metres (pre-proposal conditions) to 0.18 metres (post-proposal conditions)

ii. the period of time that the depth of flooding over the centreline of the road exceeds 0.1 metres would be reduced from about 1.2 hours (pre-proposal conditions) to about 0.5 hours (post-proposal conditions)

iii. the hazard vulnerability classification of the outbound travel lane would be H1[16], which is considered safe for all vehicle types

iv. the hazard vulnerability classification of the road shoulder would be H2, which is considered to be unsafe for small vehicles due to the depth of inundation exceeding 0.3 metres (occurring to a maximum of 0.36 metres) over a 80 metre length of the widened shoulder.[17]

v. the period of time that the hazard vulnerability classification of the widened shoulder exceeds H1 would be reduced from about 1 hour (pre-proposal conditions) to about 0.5 hours (post-proposal conditions).

[16] The hazard vulnerability classification of flooding was determined using the threshold values for depth and velocity that are set out in Table 6.7.4 of Chapter 7 of Book 6 of ARR 2019.

[17] A depth of 0.3 m is the limiting still-water depth for a hazard vulnerability classification of H1.

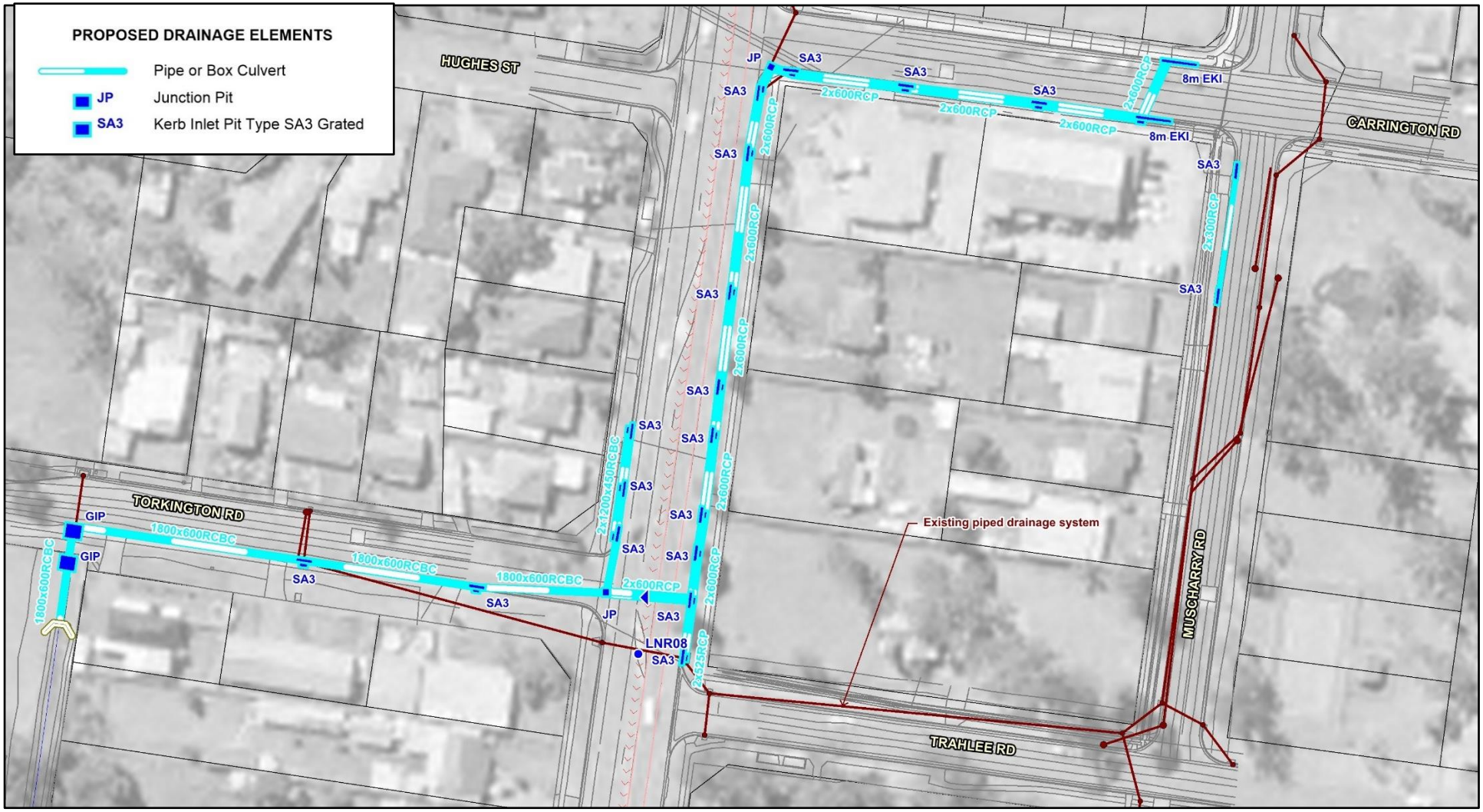

Plate 4.1 – Scope of drainage improvements that formed the basis of initial investigations at transverse drainage structure LNR08 on Londonderry Road

Given the relatively minor benefit that the scope of upgrades set out in **Plate 4.1** would have in reducing flooding along Londonderry Road, it was decided not to include this scope of drainage improvements in the proposal.

During detailed design, further investigations will be carried into the provision of additional inlet capacity along the section of Londonderry Road at transverse drainage structure LNR08, with the aim of draining the area more quickly and thereby reducing the period of time that Londonderry Road is inundated to depths that would impede vehicle movements.

5 CONSTRUCTION IMPACT ASSESSMENT

This chapter provides an assessment of the flood risk associated with the construction of the proposal, as well as an overview of the potential impacts that the proposed construction activities could have on flood behaviour. For the purpose of this assessment, the construction footprint has been split into the following areas of work (labelled work area (WA) 1 to 5 in this technical paper for ease of reference):

- Londonderry Road north work area (WA4), which is located between Southee Road and The Driftway
- The Northern Road north work area (WA1), which is located between Richmond Road and Londonderry Road
- The Northern Road mid work area (WA2), which is located between Londonderry Road and Borrowdale Way
- The Northern Road south work area (WA3), which is located between Andrews Road and Boomerang Place
- Londonderry Road south work area (WA5), which is located between The Driftway and The Northern Road.

This chapter also provides an assessment of the flood risks associated with the ten construction related ancillary sites (denoted ancillary sites 1 to 10) that are identified in Section 3.4 of the REF.

Figure 5.1 (12 sheets) shows the locations of the work areas and ancillary sites that are referred to in this technical paper.

5.1 Potential flood risks at work areas

Without the implementation of appropriate management measures, the inundation of the work areas by floodwater has the potential to:

- cause damage to the proposed works and delays in construction programming
- pose a safety risk to construction workers
- impact the downstream waterways through the transport of sediments and construction materials by floodwater
- obstruct the passage of floodwater and overland flow, which in turn could exacerbate flooding conditions in areas located outside the construction footprint.

Table 5.1 at the end of this chapter provides a summary of the assessed flood risk at each work area and their associated activities, while **Figure 5.1** (12 sheets) shows the extent to which floods of varying magnitude affect each work area across the extent of the proposal.

Construction related ancillary sites

Figure 5.1 (12 sheets) shows the location of the ten construction ancillary sites that are proposed to support construction across the work areas. Each ancillary site 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. **Table 5.1** provides a summary of the ancillary sites within each work area.

Site facilities located on the floodplain, particularly in areas of high flood depth and/or velocity, pose a safety risk to construction personnel. The depth and velocity of flooding across each of the proposed ancillary sites during a 1% AEP design storm event typically corresponds to a hazard vulnerability classification[18] of H1 (generally safe for persons and vehicles).

Spoil management and material storage areas

The construction of the proposal would generate spoil, some of which would need to be temporarily stored in stockpile areas for reuse on site or disposed of according to the procedures set out in Section 3 of the REF. It would also be necessary to temporarily store precast drainage components (such as pits, pipes, box culvert and headwalls) and imported material required to construct road embankments and the pavement of the widened road shoulder.

Stored drainage components and stockpiled material 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.

There are areas within each construction work area and ancillary site that would be suitable for the temporary storage of construction materials. The locations within each construction work area and ancillary site where materials would be stored would be subject to detailed design and construction planning.

Earthworks

Earthworks will be required across all the work areas in order to construct the road shoulder widening and drainage improvement works. This would include excavation to the foundation level of the new road pavement and installing fill material to raise or widen road embankments.

All work areas cross existing drainage lines, overland flowpaths and watercourses where earthworks required to construct the road shoulder widening and drainage improvement works will be susceptible to inundation by floodwaters to varying degrees. Areas of inundation within each work area are described in **Table 5.1**.

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. A broad outline of potential mitigation measures is provided in **Section 7**.

5.2 Potential impacts of construction activities on flood behaviour

Construction activities have the potential to exacerbate flooding conditions when compared to both existing and operational conditions. This is because construction activities typically impose a larger footprint on the floodplain due to the need to provide temporary structures, such as ancillary sites outside the operational footprint which would be removed following the completion of construction activities. The upgrade or extension of existing transverse drainage structures would also require the temporary diversion of existing drainage lines that also have the potential to impact on flood behaviour should a storm event occurring during the construction of these works.

[18] The hazard vulnerability classification of flooding was determined using the thresholds set out in Table 6.7.4 of Chapter 7 of Book 6 of ARR 2019.

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

The assessment found that:

i. Site facilities and stored materials located over the northern portion of ancillary facility site 1 have the potential to obstruct the conveyance of flow that discharges from the John Morony Correctional Complex toward The Northern Road.

ii. Site facilities and stored materials over the northern portion of ancillary site 9 have the potential to displace floodwaters that presently pond across the site during storms more frequent than 20% AEP.

iii. The construction of drainage improvements and road shoulder widening within all five work areas have the potential to obstruct the conveyance of flow in the drainage lines, watercourses and overland flowpaths that cross each area. The greatest potential for impacts on flood behaviour during construction is likely to be associated with the replacement or extension of existing transverse drainage structures.

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. **Section 7** outlines a range of potential measures that are aimed at mitigating the potential impact of the proposal on flood behaviour during its construction.

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

Construction work area	Ancillary site / other areas	Threshold of flooding[1]	Proposed construction activities[2]			Assessment of Flood Affectation	Potential impacts of construction activities on flood behaviour
			Site facilities[3]	Spoil & material storage[4]	Earthworks[5]		
The Northern Road north work area (WA1)	Ancillary site 1 Road reserve at John Morony Correctional Complex	More frequent than 20% AEP	✓	✓	x	• Refer to **Figure 5.1**, sheet 2. • The northern portion of the site would be frequently inundated by flow that discharges from the drainage system within the John Morony Correctional Complex. • During a 1% AEP design storm event, flow discharging from the John Morony Correctional Complex will inundate the northern portion of the site over a 180 m length and to a maximum depth of 0.3 m.	• Site facilities and materials located over the northern portion of the site have the potential to obstruct the conveyance of flow that discharges from the John Morony Correctional Complex toward The Northern Road.
	Ancillary site 2 Road reserve south of Leitch Avenue	More frequent than 20% AEP	✓	✓	x	• Refer to **Figure 5.1**, sheets 3 and 4. • A 7 m wide channel that runs across the northern portion of the site controls flow discharging from transverse drainage structure TNR07. • With the exception of a localised area in the vicinity of the abovementioned channel, the remainder of the site is not impacted by mainstream flooding or major overland flow during storms up to 1% AEP in magnitude.	• Activities within the site would have a minor impact on flood behaviour provided its layout is configured to prevent any temporary works that encroach into the channel that controls flow discharging from transverse drainage structure TNR07.
	Ancillary site 3 Northern Auto Wreckers	More frequent than 20% AEP	✓	✓	x	• Refer to **Figure 5.1**, sheet 5. • An overland flow path runs through the central portion of the site, where depths of inundation up to 0.2 m occur during a 1% AEP design storm event.	• Activities within the site would have only a minor impact on flood behaviour provided its layout is configured to prevent any temporary works that obstruct the

Construction work area	Ancillary site / other areas	Threshold of flooding[1]	Proposed construction activities[2]			Assessment of Flood Affectation	Potential impacts of construction activities on flood behaviour
			Site facilities[3]	Spoil & material storage[4]	Earthworks[5]		
The Northern Road north work area (WA1)							overland flow path that runs through its central portion.
	Other areas within WA1	More frequent than 20% AEP	x	✓	✓	• Refer to **Figure 5.1**, sheets 2 to 5. • A number of local drainage lines and tributaries of Rickabys Creek drain to and through the Northern Road north work area via transverse drainage structures that are located along the existing road. The work area would be inundated by runoff that is conveyed in these local drainage lines and tributaries during frequent rainfall events. • During a 1% AEP event, The Northern Road north work area would be inundated by floodwaters at a number of locations, including: o over a length of about 100 m and to a maximum depth of about 0.3 m in the vicinity of transverse drainage structure TNR01a o over a length of about 540 m and to a maximum depth of more than 1 m in the vicinity of transverse drainage structures TNR01, TNR02 and TNR03 o over a length of about 640 m and to a maximum depth of more than 3 m along the edge of the road corridor in the vicinity of transverse drainage structures TNR04, TNR05 and TNR06	• Construction activities within The Northern Road north work area have the potential to obstruct the conveyance of flow in the local drainage lines and tributaries that cross the corridor. • The greatest potential for impacts on flood behaviour during construction is likely to be associated with the replacement or extension of existing transverse drainage structures that control runoff in the local drainage lines and tributaries that cross the corridor.

Construction work area	Ancillary site / other areas	Threshold of flooding[1]	Proposed construction activities[2]			Assessment of Flood Affectation	Potential impacts of construction activities on flood behaviour
			Site facilities[3]	Spoil & material storage[4]	Earthworks[5]		
The Northern Road north work area (WA1)						○ over a length of about 280 m and to a maximum depth of about 0.8 m in the vicinity of transverse drainage structure TNR07 ○ over a length of about 80 m and to a maximum depth of about 0.4 m in the vicinity of transverse drainage structure TNR08 ○ over a length of about 410 m and to a maximum depth of more than 1 m in the vicinity of transverse drainage structures TNR09, TNR10 and TNR11 ○ over a 1,700 m length extending north and south of transverse drainage structure TNR12 but confined to a narrow corridor along the eastern side of the existing road where depths of inundation occur to a maximum of 0.4 m. ○ over a length of about 400 m and to a maximum depth of more than 1 m in the vicinity of transverse drainage structures TNR13, TNR14a and TNR14b ○ over a length of about 260 m and to a maximum depth of more than 1 m in the vicinity of transverse drainage structures TNR15 and TNR16 ○ over a length of about 100 m and to a maximum depth of about 1 m in the vicinity of transverse drainage structure TNR17	

Construction work area	Ancillary site / other areas	Threshold of flooding[1]	Proposed construction activities[2]			Assessment of Flood Affectation	Potential impacts of construction activities on flood behaviour
			Site facilities[3]	Spoil & material storage[4]	Earthworks[5]		
The Northern Road mid work area (WA2)	Ancillary site 4 Road reserve north of Fifth Avenue	Between 20% and 10% AEP	✓	✓	x	• Refer to **Figure 5.1**, sheet 6. • A relatively localised area in the northern portion of the site is inundated by floodwater that ponds at the inlet to transverse drainage structure TNR19, where depths of inundation would be a maximum of 0.3 m.	• While site facilities and stored materials located in the northern portion of the site have the potential to displace floodwater that ponds at the inlet to transverse drainage structure TNR19, impacts on flood behaviour are likely to be minor given the extent of flooding relative to the extent of the ancillary facilities.
	Ancillary site 5 Road reserve north of Seventh Avenue	Not flooded	✓	✓	x	• Refer to **Figure 5.1**, sheet 6. • The site is not impacted by mainstream flooding or major overland flow during storms up to 1% AEP in magnitude.	• Activities within the site would have no impact on mainstream flooding or major overland flow during storms up to 1% AEP in magnitude.
	Ancillary site 6 Open space at Ninth Avenue	Between 0.05% AEP and PMF	✓	✓	x	• Refer to **Figure 5.1**, sheet 6. • The site is not impacted by mainstream flooding or major overland flow during storms up to 1% AEP in magnitude.	• Activities within the site would have no impact on mainstream flooding or major overland flow during storms up to 1% AEP in magnitude.
	Ancillary site 7 The Northern Road Oval	Between 5% and 1% AEP	✓	✓	x	• Refer to **Figure 5.1**, sheet 8. • During a 1% AEP design storm event, a relatively localised area along the southern portion of the site will be inundated by floodwaters that surcharge Greenwood Parkway, albeit to relatively shallow depths.	• Activities within the site would have no impact on mainstream flooding or major overland flow during storms up to 1% AEP in magnitude.

Construction work area	Ancillary site / other areas	Threshold of flooding[1]	Proposed construction activities[2]			Assessment of Flood Affectation	Potential impacts of construction activities on flood behaviour
			Site facilities[3]	Spoil & material storage[4]	Earthworks[5]		
The Northern Road mid work area (WA2)	Other areas within WA2	More frequent than 20% AEP	x	✓	✓	• Refer to **Figure 5.1**, sheets 5 to 8. • A number of local drainage lines and tributaries of Rickabys Creek and South Creek drain to and through The Northern Road mid work area via transverse drainage structures that are located along the existing road. The construction work area would be inundated by runoff that is conveyed in these local drainage lines and tributaries during frequent rainfall events. • During a 1% AEP event, The Northern Road mid work area would be inundated by floodwater at a number of locations, including: o over a length of about 800 m and to a maximum depth of more than 1 m in the vicinity of transverse drainage structures TNR18, TNR19, TNR20 and TNR21 o over a length of about 340 m and to a maximum depth of about 1 m in the vicinity of transverse drainage structures TNR22, TNR22b and CR35c o over a length of about 630 m and to a maximum depth of more than 1 m in the vicinity of transverse drainage structures TNR23, TNR24, TNR25 and TNR26 o over a length of about 340 m to the north and south of transverse drainage structure TNR27, but mainly confined to a narrow corridor along the western side	• Construction activities within The Northern Road mid work area have the potential to obstruct the conveyance of flow in the local drainage lines and tributaries that cross the corridor. • The greatest potential for impacts on flood behaviour during construction is likely to be associated with the replacement or extension of existing transverse drainage structures that control runoff in the local drainage lines and tributaries that cross the corridor.

Construction work area	Ancillary site / other areas	Threshold of flooding[1]	Proposed construction activities[2]			Assessment of Flood Affectation	Potential impacts of construction activities on flood behaviour
			Site facilities[3]	Spoil & material storage[4]	Earthworks[5]		
The Northern Road mid work area (WA2)						of the existing road where depths of inundation will occur to a maximum of 0.2 m ○ over a length of about 100 m and to a maximum depth of more than 1 m in the vicinity of transverse drainage structure TNR28.	
The Northern Road south work area (WA3)	Ancillary site 9 Andrews Road Baseball Complex	More frequent than 20% AEP	✓	✓	x	• Refer to **Figure 5.1**, sheet 8. • During a 20% AEP design storm event, northern portion of the site will be inundated over a relatively localised area along a drainage swale where depths of inundation will occur to a maximum of 0.3 m. • During a 1% AEP design storm event, the majority of the site will be inundated by floodwaters. Depths of inundation across the northern portion of the site will occur to a maximum of 0.7 m.	• Site facilities and stored materials within the site have the potential to displace floodwater, noting that the greatest potential to result in adverse impacts on flood behaviour would be associated with activities within the northern portion of the site.
	Ancillary site 10 Parker Street Oval	More frequent than 20% AEP	✓	✓	x	• Refer to **Figure 5.1**, sheet 9. • During a 1% AEP design storm event, the site would be inundated by floodwater around its northern perimeter, albeit to relatively shallow depths that are typically less than 0.1 m.	• While site facilities and stored materials located in the northern portion of the site have the potential to displace floodwater, impacts on flood behaviour are likely to be minor given the extent of flooding relative to the extent of the ancillary facilities.

Construction work area	Ancillary site / other areas	Threshold of flooding[1]	Proposed construction activities[2]			Assessment of Flood Affectation	Potential impacts of construction activities on flood behaviour
			Site facilities[3]	Spoil & material storage[4]	Earthworks[5]		
The Northern Road south work area (WA3)	Other areas within WA3	More frequent than 20% AEP	x	✓	✓	• Refer to **Figure 5.1**, sheets 8 and 9. • The road corridors that comprise the Northern Road south work area act as overland flowpaths to convey flows in excess of the capacity of the road drainage system. • During a 1% AEP event, The Northern Road south work area would be inundated by floodwater at a number of locations, including: o over a length of about 90 m and to a maximum depth of about 0.6 m in the vicinity of transverse drainage structure TNR34 o over a length of about 610 m and to a maximum depth of about 0.8 m in the vicinity of transverse drainage structures TNR35, TNR36 and TNR37 o over a length of about 650 m and to a maximum depth of about 0.6 m along Andrews Road.	• Construction activities within The Northern Road south work area have the potential to obstruct the conveyance of overland flow along the road corridor.
Londonderry Road north work area (WA4)	Areas within WA4	More frequent than 20% AEP	x	✓	✓	• Refer to **Figure 5.1**, sheets 10 and 11. • During a 1% AEP event, the Londonderry Road north work area would be inundated over the following areas: o within the inbank area of the drainage channels that are located upstream and downstream of transverse drainage structure LNR01, where depths would exceed 1.5 m. o along the table drains that are located either side of the existing road to the north of transverse drainage	• Construction activities within the Londonderry Road north work area have the potential to obstruct the conveyance of flow in the drainage channels and table drains that control runoff within the road corridor. • The greatest potential for impacts on flood behaviour during construction is likely to be

Construction work area	Ancillary site / other areas	Threshold of flooding[1]	Proposed construction activities[2]			Assessment of Flood Affectation	Potential impacts of construction activities on flood behaviour
			Site facilities[3]	Spoil & material storage[4]	Earthworks[5]		
Londonderry Road north work area (WA4)						○ structure TNR01 where depths of inundation would occur to a maximum of 0.2 m ○ along the table drain that is located along the eastern side of the existing road to the north and south of transverse drainage structure TNR02 where depths of inundation would occur to a maximum of 0.2 m.	associated with the extension of existing transverse drainage structure LNR02.
Londonderry Road south work area (WA5)	Ancillary site 8 Adjacent to Richmond Greyhound Racing Club	Between 0.05% AEP and PMF	✓	✓	x	• Refer to **Figure 5.1**, sheet 11. • While the site is not impacted by mainstream flooding or major overland flow, a series of drainage swales that control local catchment runoff run in a southerly direction through the site where they discharge to a water storage dam located to the south of the site.	• Subject to the inclusion of appropriate drainage controls to manage local catchment runoff, activities within the site would have a minimal effect on flood behaviour.
	Other areas within WA5	More frequent than 20% AEP	x	✓	✓	• Refer to **Figure 5.1**, sheets 4, 5, 11 and 12. • A number of local drainage lines, as well as Rickabys Creek and two of its tributaries, drain to and through the Londonderry Road south work area via transverse drainage structures that are located along the existing road. The construction work area would be inundated by runoff that is conveyed in these local drainage lines and watercourses during frequent rainfall events. • During a 1% AEP event, the Londonderry Road south work area would be inundated by floodwater at a number of locations, including:	• Construction activities within the Londonderry Road south work area have the potential to obstruct the conveyance of flow in the local drainage lines and watercourses that cross the corridor. • The greatest potential for impacts on flood behaviour during construction is likely to be associated with the replacement or extension of existing transverse drainage structures that control

Construction work area	Ancillary site / other areas	Threshold of flooding[1]	Proposed construction activities[2]			Assessment of Flood Affectation	Potential impacts of construction activities on flood behaviour
			Site facilities[3]	Spoil & material storage[4]	Earthworks[5]		
Londonderry Road south work area (WA5)						○ over a length of about 600 m to the north and south of transverse drainage structure LNR02, but mainly confined to the table drains that runs either side of the existing road where depths of inundation occur to a maximum of 0.4 m ○ over a length of about 330 m in the vicinity of transverse drainage structures LNR04, LNR05 and LNR06, but mainly confined to areas either side of the existing road where depths of inundation occur to a maximum of about 1.5 m ○ locally at the inlet and outlet to transverse drainage structure LNR07 where depths occur to a maximum of 0.7 m ○ over a length of about 550 m and to a maximum depth of about 0.4 m in the vicinity of transverse drainage structures LNR08 and LNR09 ○ over a length of about 170 m in the vicinity of transverse drainage structures LNR10 and LNR11, but mainly confined to areas either side of the existing road where depths of inundation occur to a maximum of about 2 m ○ over a length of about 100 m in the vicinity of transverse drainage structures LNR12 and LNR13, but mainly confined to areas either side of the existing road where depths of inundation occur to a maximum of about 3 m	runoff in the local drainage lines and watercourses that cross the corridor.

Construction work area	Ancillary site / other areas	Threshold of flooding[1]	Proposed construction activities[2]			Assessment of Flood Affectation	Potential impacts of construction activities on flood behaviour
			Site facilities[3]	Spoil & material storage[4]	Earthworks[5]		
Londonderry Road south work area (WA5)						○ over a length of about 100 m and to a maximum depth of about 0.9 m in the vicinity of transverse drainage structure LNR14 ○ over a length of about 140 m in the vicinity of transverse drainage structure LNR15, but mainly confined to areas either side of the existing road where depths of inundation occur to a maximum of about 2 m ○ over a length of about 870 m to the north and south of transverse drainage structure LNR16 where depths of inundation will occur to a maximum of 1 m at the inlet and outlet of the transverse drainage structure, but are typically less than 0.2 m across the remainder of this section of road corridor ○ locally at the inlet and outlet to transverse drainage structure LNR17 where depths occur to a maximum of 0.6 m.	

1. The assessed threshold of flooding is based on pre-proposal conditions. Refer **Figure 5.1** (12 sheets) for flood extent mapping under pre-proposal conditions.
2. Refer to **Section 5.1** for a description of flood risks associated with each construction activity.
3. Site facilities include construction compounds, support facilities and workforce accommodation, which include site offices, staff amenities, storage of materials and parking.
4. Spoil management includes stockpiling and treatment of excavated material.
5. Earthworks includes construction of drainage channels and trenching for pipes and box culverts.

6 OPERATIONAL IMPACT ASSESSMENT

This section provides an assessment of the impact that flooding would have on the designated flood evacuation routes that comprise the proposal following the construction of the proposed drainage improvements and road shoulder widening. This section also presents the findings of an assessment of the impact that the proposed drainage improvements and road shoulder widening would have on flood behaviour in areas outside the proposal corridor.

The scope of drainage improvements that formed the basis of the assessment are shown on the concept layouts that are contained in **Annexure A** of this technical paper, while **Table B1** in **Annexure B** of this technical paper contains a summary of proposed works at each transverse drainage structure along the proposal and identifies whether the works are proposed for the purpose of drainage improvements and/or road shoulder widening.[19]

When developing the scope of drainage improvements it was identified that it would be necessary to raise several sections of road in order to achieve the minimum cover and/or flood immunity requirements for the proposal. Locations where road raising is required are set out in **Table B1** in **Annexure B**, while their extents are shown on the concept layouts that are contained in **Annexure A**.

The following figures show flooding patterns and impacts under operational conditions (i.e. conditions following the construction of the proposal) and should be referred to when reading the following sections of this report:

- **Figures 6.1**, **6.2**, **6.3** and **6.4** (12 sheets each) respectively show the indicative extent and depth of inundation under operational conditions resulting from local catchment flooding of this technical paper for design storms with AEPs of 10%, 1% and 0.2%, as well as the PMF. **Annexure F** contains a series of figures showing corresponding results for design storms with AEPs of 20%, 5% and 0.05%.
- **Figures 6.5**, **6.6**, **6.7** and **6.8** (12 sheets each) respectively show the impact that the proposal would have on flood behaviour in terms of changes in peak flood levels for design storms with AEPs of 10%, 1% and 0.2%, as well as the PMF[20]. **Annexure G** of this technical paper contains a series of figures showing corresponding results for design storms with AEPs of 20%, 5% and 0.05%.
- **Annexure H** of this technical paper contains a set of figures that show maximum flow velocities and durations of inundation under operational conditions for design storms with AEPs of 10% and 1%, as well as the impact that the proposal would have in terms of changes in maximum flow velocities and durations of inundation for the same design storm events.

[19] There are a number of locations where upgrades to transverse drainage structures are proposed as part of the scope of drainage improvements at another location. An example of this is at transverse drainage structure TNR16, which is proposed to be upgraded for the purpose of drainage improvements at transverse drainage structure TNR15.

[20] 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”.

6.1 Impact of flooding to the designated flood evacuation routes under operational conditions

An assessment was carried out into the impact of flooding to the designated flood evacuation routes under post-proposal conditions in terms of:

a) the level of flood immunity achieved at those locations where drainage improvements are proposed (refer **Section 6.1.1** of this technical paper)

b) the impact of the proposed road shoulder widening on the hazard vulnerability classification of the outbound travel lane and widened shoulder at locations where drainage improvements have not been identified as being required (refer **Section 6.1.2** of this technical paper).

Table 6.1 contains a summary of flood behaviour along the outbound travel lanes under pre- and post-proposal (ie. operational) conditions and should be referred to when reading the following sections of the technical paper.

6.1.1 At those locations where drainage improvements are proposed

Table 6.1 shows that of the fourteen (14) locations where drainage improvements are proposed, a 0.2% AEP level of flood immunity would be provided to both the outbound travel lane and widened shoulder.

6.1.2 At those locations where road shoulder widening is proposed in the absence of drainage improvements

Table 6.1 shows that of the thirty-seven (37) locations where road shoulder widening is proposed in the absence of drainage improvements:

i. the outbound travel lane would:
    a. not be flooded at seventeen (17) locations
    b. have a hazard vulnerability classification of H1 at nineteen (20) locations.

ii. the outbound shoulder would:
    a. not be flooded at fifteen (15) locations
    b. have a hazard vulnerability classification of H1 at twenty (20) locations
    c. have a hazard vulnerability classification of H2 at two locations (transverse drainage structures TNR01 and LNR08), which is generally considered to be unsafe for small vehicles and exceeds the Threshold Criteria.

At transverse drainage structure TNR01, the hazard vulnerability classification of H2 along the outbound shoulder is due to the depth of inundation exceeding 0.3 metres (occurring to a maximum of 0.32 metres). The extent of the widened shoulder where ponding depths exceed 0.3 metres occurs over a length of about 70 metres but encroaches into the widened shoulder to a maximum width of 1 metre. The duration of time that depths exceed 0.3 metre during a 0.2% AEP design storm would be less than 30 minutes.

In order to reduce the hazard vulnerability classification along the outbound shoulder, it would be necessary to reduce the depth of inundation by either increasing the capacity of transverse drainage structure TNR01 or raising the level of the outbound shoulder by reducing the crossfall of the road. It is noted that increasing the capacity of transverse drainage structure TNR01 would in turn require the construction of a channel through properties located in The Northern Road and

Bennetts Road to control the increase in flow discharging from the transverse drainage structure. This drainage channel would require the acquisition of an easement and would therefore be subject to consultation with the affected property owners.

At transverse drainage structure LNR08, the hazard vulnerability classification of H2 along the outbound shoulder is also due to the depth of inundation exceeding 0.3 metres (occurring to a maximum of 0.38 metres). The extent of the widened shoulder where ponding depths exceed 0.3 metres occurs over a length of about 90 metres and encroaches into the widened shoulder to a maximum width of 2.5 metres. The duration of time that depths exceed 0.3 metre during a 0.2% AEP design storm would be approximately 1 hour.

The investigation found that there is limited scope to reduce the hazardous nature of flooding to the section of Londonderry Road adjacent to transverse drainage structure LNR08 by increasing the capacity of the drainage system due to the low-lying nature of the road, as well as the impact that any proposed increase in capacity could potentially have on flood behaviour in areas downstream of the structure. In order to reduce the hazardous nature of flooding, it is likely to be necessary to raise the level of Londonderry Road at transverse drainage structure LNR08, noting that this would exacerbate flooding in adjoining properties due to the displacement of floodwater that presently ponds in the road corridor.

6.2 Impact of the proposed drainage improvements and road shoulder widening on flood behaviour

6.2.1 Storms up to 1% AEP in intensity

Table 6.2 at the end of this chapter contains a summary of the impact that the proposal would have on flood behaviour during storms up to 1% AEP in magnitude. **Table 6.2** also shows those locations where impacts exceed the limits set out in **Section 2.2.3** of this report.

Table 6.2 shows that:

iii. There are eleven (11) locations where increases in either the depth, velocity or duration of inundation exceed the limits that are set out in **Section 2.2.3** of this report.

iv. Of the eleven (11) locations identified in item i, there are:

   a. Seven locations (transverse drainage structures TNR06, TNR14a/14b, TNR20, LNR04, LNR10, LNR12 and LNR15) where the exceedance is due to an increase in the duration of inundation. At each of these locations, the impacts are confined to existing drainage paths or watercourses that would experience prolonged inundation during frequent rainfall events under pre-proposal conditions. On this basis, the increases in duration of inundation during rare storm events would not result in an increase in the long-term wetting up of land. The affected areas also do not contain any existing buildings, property improvements or access driveways. For these reasons, the increases in the duration of inundation at these locations are not considered to represent a significant impact on the affected properties.

   b. One location (transverse drainage structure TNR11) where the exceedance is due to an increase in the duration of inundation over the access driveway to No. 407 The Northern Road, Londonderry. During a 1% AEP design storm event, the duration of inundation to the access driveway would be increased from 0.9 hours (pre-proposal conditions) to 2.4 hours (post-proposal conditions). This increase in the duration of inundation can be mitigated through further development of the proposed culvert crossing of the driveway and downstream channel works during

detailed design. This impact can be addressed through further development of the concept road design and its associated table drain and culvert crossing under the driveway, which would discharge to the outlet of transverse drainage structure TNR11.

c. One location (transverse drainage structure TNR05) where the exceedance is due to an increase in peak flow velocities over an area to the west (downstream) of the transverse drainage structure within No. 1 Carrington Road. During a 1% AEP design storm event, peak flow velocities over the affected area would be increased from between 0.9 and 1.1 m/s (pre-proposal conditions) to 1.3 m/s (post-proposal conditions). While the increases in peak flow velocities are relatively localised, they occur over an area of embankment that is relatively steep that would therefore be susceptible to scour as a result of an increase in flow velocities.

   Subject to further development of the proposed drainage improvements during detailed design, should any residual impacts on scour potential remain, then the provision of scour protection in the form of rock riprap lining to the affected area would be a feasible solution. This would be subject to consultation and agreement with the affected property owner.

d. One location (transverse drainage structure TNR01) where the exceedance is due to an increase in the depth and duration of inundation, as well as an increase in peak flow velocities within properties that are located to the west (downstream) of the transverse drainage structure. The affected area includes three buildings within No. 49-51 The Northern Road, where floor level survey has confirmed that the increase in peak flood levels would lead to an increase in above-floor inundation during storms with AEPs between 10% and 1%. The affected area also includes a number of buildings within No. 60-62 Bennett Road where floor level survey would be required to confirm whether the increase in peak flood levels would lead to an increase in above-floor inundation.

   Plate 6.1 over the page shows the arrangement of a potential measure that could be implemented to mitigate the impacts described above. This measure would involve the construction of a grassed lined channel that would run from the outlet of transverse drainage structure TNR01, primarily through No. 49-51 The Northern Road and No. 60-62 Bennett Road, to the inlet of the existing transverse drainage in Bennett Road. This mitigation option would be subject to consultation with the affected property owners and would require the acquisition of a drainage easement to contain the proposed channel.

e. One location (transverse drainage structures TNR13 and TNR14a/14b) where the exceedance is due to an increase in the depth of inundation within a RU4 zoned rural residential property that is located to the west (downstream) of The Northern Road (No. 2 Thomas Road), as well as an undeveloped parcel of land that is located to the east (upstream) of The Northern Road (No. 175-209 Spinks Road).[21]

   During a 1% AEP design storm, depths of inundation within No. 2 Thomas Road would be increased by a maximum of 0.21 metres on an existing depth of about 0.2 metres, while depths of inundation within No. 175-209 Spinks Road would be increased by a maximum of 0.17 metres on an existing depth of about 0.3 metres.

[21] While the exceedance at transverse drainage structure TNR13 is also due to an increase in the duration of inundation, it is not considered to result in a significant wetting up of land or impact on development within the affected property for the same reasons as those set out in item ii.a.

In both cases, the affected area is confined to heavily vegetated areas of the property.

While it would be feasible to mitigate the increase in peak flood levels to the east (upstream) of The Northern Road by increasing the capacity of transverse drainage structures TNR13 and TNR14a/14b, this would lead to further increases in peak flood levels to the west (downstream).

While it would also be feasible to mitigate the increase in peak flood levels to both the east (upstream) and west (downstream) of The Northern Road by installing a series of high flow culverts between transverse drainage structures TNR13 and TNR14a, this would require the level of The Northern Road to be further raised to accommodate these culvert, which in turn would increase the footprint of the proposed works and require the acquisition of additional land to the east of the road corridor within No. 175-209 Spinks Road).[22]

The increase in peak flood levels to the west (downstream) of transverse drainage structure TNR13 could be managed by the provision of a grass-lined channel that would run for approximately 40 metres through the north-east corner of No. 2 Thomas Road and a further 200 metres along the road reserve of Thomas Road. **Plate 6.2** over the page shows an indicative alignment of the grass-lined channel, which would be subject to consultation and agreement with the affected property owner.

Plate 6.1 – Alignment of potential flood mitigation channel downstream of transverse drainage structure TNR01

[22] This is based on advice provided by the Concept Design PSC during an interface meeting that was held on 28 February 2024.

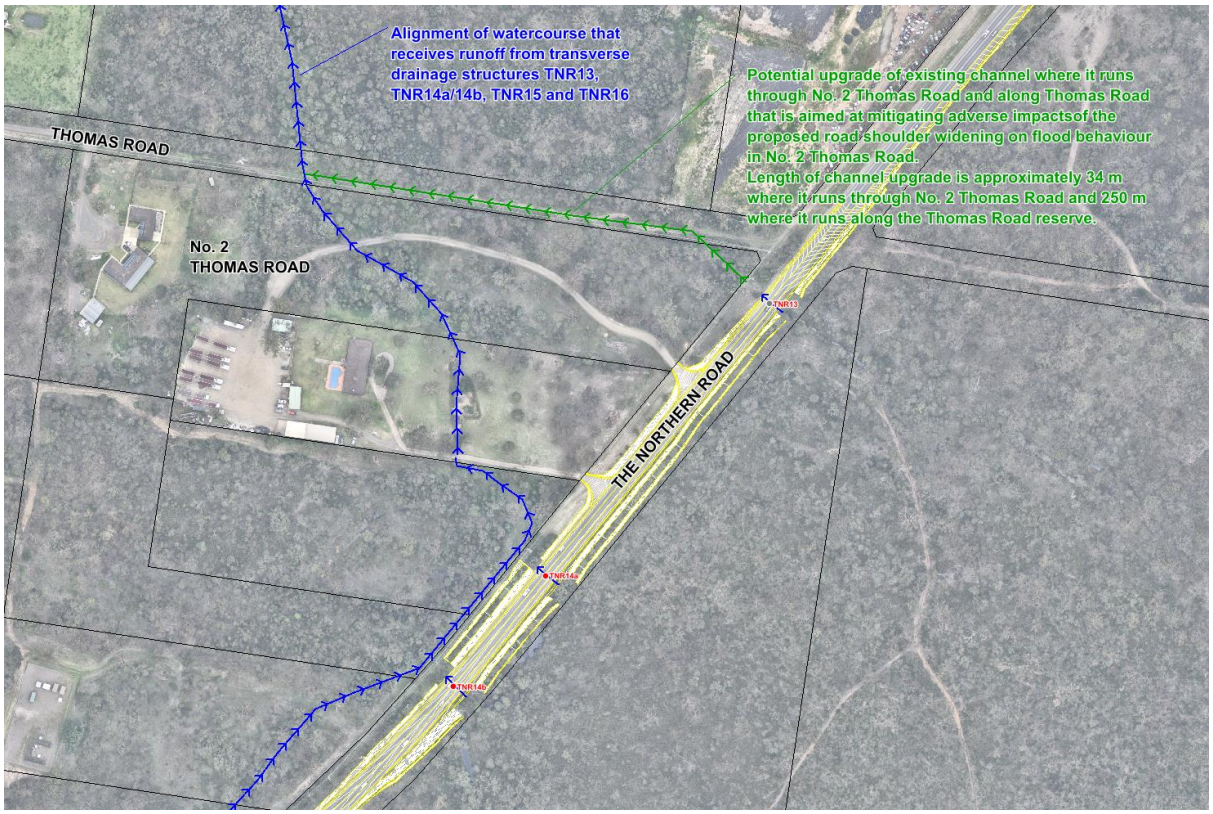

Plate 6.2 – Alignment of potential flood mitigation channel downstream of transverse drainage structure TNR13

6.2.2 Storms greater than 1% AEP in intensity

As noted in **Section 3.3.2**, the assessment has also considered the impact of the proposal on flood behaviour during storms greater than 1% AEP up to the PMF. The assessment found that during the PMF, the greatest impacts on flood behaviour attributable to the proposal occur upstream of the following locations where road raising is proposed as part of the drainage improvement works:

i. TNR11, where depths of inundation will be increased by a maximum of 0.5 metres on an existing depth of more than 1.5 metres (refer Figure 6.9, sheet 4). The affected area is located within the Castlereagh Nature Reserve.

ii. TNR13, where depths of inundation would be increased by a maximum of 0.2 metres on an existing depth of more than 1 metre (refer Figure 6.9, sheet 5). The affected area is located within an undeveloped parcel of land that is zoned RU4 (rural residential).

iii. TNR14a and TNR14b, where depths of inundation will be increased by a maximum of 0.2 metres on an existing depth of more than 1.5 metres (refer Figure 6.9, sheet 5). The affected area extends across an undeveloped parcel of land that is zoned RU4 (rural residential), as well as the front yard of a RU4 zoned rural residential property.

iv. TNR15 and TNR16, where depths of inundation will be increased by a maximum of 0.5 metres on an existing depth of more than 1.5 metres (refer Figure 6.9, sheet 5). The affected area extends across three RU4 zoned rural residential properties and includes three buildings within the southernmost rural residential property where depths of inundation will be increased by a maximum of 0.1 metres on an existing depth of about 0.6 metres.

v. TNR19 and TNR20, where depths of inundation will be increased by a maximum of 0.4 metres on an existing depth of more than 1.5 metres (refer Figure 6.9, sheet 6). The affected area extends across three RU4 zoned rural residential properties that include Cherrybrook Village, which provides supported hostel accommodation. At the entry to Cherrybrook Village, depths of inundation will be increased from 1.1 metres (pre-proposal conditions) to 1.4 metres (post-proposal conditions). The affected area does not extend to buildings located within the Cherrywood Village.

The impact of the proposal on flood behaviour during the PMF is not considered to have a significant impact on critical infrastructure or vulnerable development (such as Cherrybrook Village). The changes in flood behaviour during the PMF are also not considered to result in a significant increase in the hazardous nature of flooding in existing development.

6.3 Potential impact of future climate change on flood behaviour

A sensitivity analysis has been carried out in order to gain an understanding of the potential impact of future climate change on flooding to the designated flood evacuation routes. The impact that the proposal would have on flood behaviour in areas outside the road corridors under future climate change conditions has also been assessed as part of the present investigation.

As noted in **Section 3.7**, the sensitivity analysis comprised the assessment of:

a) the impact of future climate change on flooding to the designated flood evacuation routes based on a comparison of flood behaviour under post-proposal conditions for storms with AEPs of 0.2% and 0.05%; and

b) the impact that the proposal would have on flood behaviour under future climate change based on comparing its impact on flood behaviour for a 0.2% AEP storm event against those for a 1% AEP storm event.

6.3.1 Potential impact of future climate change on flooding to the proposal

Table 6.3 at the end of this chapter provides a comparison of the hazard vulnerability classification of the outbound travel lane and shoulder during a 0.2% AEP storm event under current climatic and potential future climate change conditions. **Table 6.3** shows that the hazard vulnerability classification of flooding would be the same under current climatic and future climate change conditions except at:

i. five (5) locations along the outbound travel lane, where flooding would be increased from not flooded (current climatic conditions) to a hazard vulnerability classification of H1 (future climate change conditions) (refer to transverse drainage structures TNR26, TNR34, TNR35, LNR12 and CR35c)

ii. seven (7) locations along the outbound shoulder, where flooding would be increased from “not flooded” (current climatic conditions) to a hazard vulnerability classification of H1 (future climate change conditions) (refer to transverse drainage structures TNR05, TNR13, TNR34, TNR35, TNR36, LNR12 and CR35c)

iii. one location along the outbound shoulder, where flooding would be increased from a hazard vulnerability classification of H1 (current climatic conditions) to a hazard vulnerability classification of H2 (future climate change conditions) (refer to transverse drainage structure TNR37).

6.3.2 Potential impact of the proposal on flood behaviour under future climate change conditions

Table 6.4 at the end of this chapter provides a comparison of the impact that the proposal would have on the depth and extent of inundation in areas outside the proposal corridor during a 1% AEP storm event under current climatic and potential future climate change conditions. **Table 6.4** shows that the locations where the afflux limits are exceeded would be the same under current climatic and future climate change conditions, with the exception of:

i. transverse drainage structure TNR22, where the increases in depths of inundation are within afflux limits under current climatic conditions, but would exceed the afflux limits under future climate change conditions, and

ii. transverse drainage structures LNR10 and LNR11, where the increases in depths of inundation are within the afflux limits under current climatic conditions, but would require floor level survey to confirm or otherwise exceedance of the afflux limits under future climate change conditions.

TABLE 6.1
HAZARD VULNERABILITY CLASSIFICATION OF THE OUTBOUND TRAVEL LANE AND WIDENED SHOULDER UNDER PRE- AND POST-PROPOSAL CONDITIONS - 0.2% AEP DESIGN STORM

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Criterion Level Achieved by Drainage Improvements[1]	Hazard Vulnerability Classification[2,3]		
				Pre-Proposal Conditions	Post-Proposal (ie. Operational) Conditions	
				Outbound Travel Lane	Outbound Travel Lane	Widened Shoulder
The Northern Road regional flood evacuation route	TNR01a	Shoulder widening		H1	H1	H1
	TNR01	Shoulder widening		H1	H1	H2
	TNR02	Shoulder widening		H1	H1	H1
	TNR03	Shoulder widening		H1	H1	H1
	TNR04	Drainage improvements and shoulder widening	1st	H2	Not flooded	Not flooded
	TNR05	Drainage improvements and shoulder widening	1st	H1	Not flooded	Not flooded
	TNR06	Shoulder widening		H1	H1	H1
	TNR07	Shoulder widening		Not flooded	Not flooded	H1
	TNR08	Shoulder widening		H1	Not flooded	H1
	TNR09	Shoulder widening		H1	Not flooded	Not flooded
	TNR10	Shoulder widening		H1	H1	H1
	TNR11	Drainage improvements and shoulder widening	1st	H2	Not flooded	Not flooded

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Criterion Level Achieved by Drainage Improvements[1]	Hazard Vulnerability Classification[2,3]		
				Pre-Proposal Conditions	Post-Proposal (ie. Operational) Conditions	
				Outbound Travel Lane	Outbound Travel Lane	Widened Shoulder
The Northern Road regional flood evacuation route	TNR12	Shoulder widening		H1	H1	H1
	TNR13	Drainage improvements (for TNR14a and TNR14b) and shoulder widening		H1	Not flooded	Not flooded
	TNR14a	Drainage improvements and shoulder widening	1st	H2	Not flooded	Not flooded
	TNR14b	Drainage improvements and shoulder widening	1st	H2	Not flooded	Not flooded
	TNR15	Drainage improvements and shoulder widening	1st	H2	Not flooded	Not flooded
	TNR16	Shoulder widening		H1	Not flooded	Not flooded
	TNR17	Shoulder widening		H1	H1	H1
	TNR18	Drainage improvements (for TNR19) and shoulder widening		H1	Not flooded	Not flooded
	TNR19	Drainage improvements and shoulder widening	1st	H1	Not flooded	Not flooded
	TNR20	Drainage improvements (for TNR19) and shoulder widening		H1	Not flooded	Not flooded
	TNR21	Drainage improvements and shoulder widening	1st	H2	Not flooded	Not flooded
	TNR22	Drainage improvements (for CR35c) and shoulder widening		H1	H1	H1

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Criterion Level Achieved by Drainage Improvements[1]	Hazard Vulnerability Classification[2,3]		
				Pre-Proposal Conditions	Post-Proposal (ie. Operational) Conditions	
				Outbound Travel Lane	Outbound Travel Lane	Widened Shoulder
The Northern Road regional flood evacuation route	TNR22b	Shoulder widening		H1	Not flooded	Not flooded
	TNR23	Drainage improvements (for TNR24) and shoulder widening		H1	H1	H1
	TNR24	Drainage improvements and shoulder widening	1st	H2	Not flooded	Not flooded
	TNR25	Drainage improvements and shoulder widening	1st	H2	Not flooded	Not flooded
	TNR26	Shoulder widening		Not flooded	Not flooded	Not flooded
	TNR27	Shoulder widening		H1	H1	H1
	TNR28	Shoulder widening		H1	H1	H1
	TNR29	None		Not flooded	Not flooded	Not flooded[4]
	TNR30	None		H1	H1	H1[4]
	TNR31	None		H1	H1	H1[4]
	TNR32	None		H1	H1	H1[4]
	TNR33	None		H1	H1	H1[4]
	TNR34	Drainage improvements	1st	H2	Not flooded	Not flooded
	TNR35	Drainage improvements	1st	H3	Not flooded	Not flooded

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Criterion Level Achieved by Drainage Improvements[1]	Hazard Vulnerability Classification[2,3]		
				Pre-Proposal Conditions	Post-Proposal (ie. Operational) Conditions	
				Outbound Travel Lane	Outbound Travel Lane	Widened Shoulder
The Northern Road regional flood evacuation route	TNR36	Drainage improvements	1st	H2	Not flooded	Not flooded
	TNR37	None		H1	H1	H1[4]
	TNR38	None		H1	H1	H1[4]
	TNR39	None		H1	H1	H1[4]
	TNR40	None		H1	H1	H1[4]
	TNR41	None		H1	H1	H1[4]
	TNR42	None		H1	H1	H1[4]
	TNR43	None		H1	H1	H1[4]
Londonderry Road regional flood evacuation route	LNR01	Shoulder widening		Not flooded	Not flooded	Not flooded
	LNR02	Shoulder widening		H1	H1	H1
	LNR03	Shoulder widening		H1	H1	H1
	LNR04	Shoulder widening		Not flooded	Not flooded	Not flooded
	LNR05	Shoulder widening		Not flooded	Not flooded	Not flooded
	LNR06	Shoulder widening		Not flooded	Not flooded	Not flooded
	LNR07	Shoulder widening		Not flooded	Not flooded	Not flooded
	LNR08	Shoulder widening[5]	-	H1	H1	H2

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Criterion Level Achieved by Drainage Improvements[1]	Hazard Vulnerability Classification[2,3]		
				Pre-Proposal Conditions	Post-Proposal (ie. Operational) Conditions	
				Outbound Travel Lane	Outbound Travel Lane	Widened Shoulder
Londonderry Road regional flood evacuation route	LNR09	Shoulder widening[5]		H1	H1	H1
	LNR10	Shoulder widening		Not flooded	Not flooded	Not flooded
	LNR11	Shoulder widening		Not flooded	Not flooded	Not flooded
	LNR12	Shoulder widening		Not flooded	Not flooded	Not flooded
	LNR13	Shoulder widening		H1	H1	H1
	LNR14	Shoulder widening		Not flooded	Not flooded	Not flooded
	LNR15	Shoulder widening		H1	H1	H1
	LNR16	Shoulder widening		H1	H1	H1
	LNR17	Shoulder widening		H1	H1	H1
Penrith North Sector flood evacuation route	CR35c	Drainage improvements and shoulder widening	1st	H2	Not flooded	Not flooded

1. Refer to **Section 3.3.1** for a description of each of the criterion levels adopted in the assessment of proposed drainage improvements.
2. The hazard vulnerability classifications were derived using the thresholds set out in Table 6.7.4 of Chapter 7 of Book 6 of ARR 2019. A hazard vulnerability classification of:
    - H1 is generally considered safe for vehicles, people and buildings
    - H2 is generally considered unsafe for small vehicles
    - H3 is generally considered unsafe for vehicles, children and the elderly.
3. Cells highlighted in orange indicate locations where the hazard vulnerability classification exceeds H1, which is the limit set out in the Threshold Criteria.
4. Results presented are for the outside travel lane as The Northern Road comprises two outbound travel lanes at this location.
5. Shoulder widening is proposed for that part of Londonderry Road draining to transverse drainage structures LNR08 and LNR09 where the existing shoulder width is inadequate for traffic.

TABLE 6.2
IMPACT OF THE PROPOSED DRAINAGE IMPROVEMENTS AND ROAD SHOULDER WIDENING ON FLOOD BEHAVIOUR DURING STORMS UP TO 1% AEP IN INTENSITY

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Impact of Proposed Works on Flood Behaviour	Compliance with Adopted Afflux Criteria	Comments/Recommendations
The Northern Road regional flood evacuation route	TNR01a	Shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* There would be no significant change in peak flood levels upstream and downstream of the proposal corridor at transverse drainage structure TNR01a during storms with AEPs between 10% and 1%.	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of the proposal corridor at TNR01a would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation Changes in the duration of inundation in areas upstream and downstream of transverse drainage structure TNR01a would be less than one hour during storms with AEPs of 10% and 1%.	Yes	
	TNR01	Shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* There would be an increase in the depth of inundation over an area to the west (downstream) of transverse drainage structure TNR01. During a 10% AEP design storm event, depths of inundation would be increased by a maximum of 0.06 m in seven RU4 zoned rural residential properties, increasing to a maximum of 0.07 m over the same number of properties during a 5% AEP design storm event. During a 1% AEP design storm event, depths of inundation would be increased by a maximum of 0.06 m in four RU4 zoned rural residential properties. The affected area includes three buildings within No. 49-51 The Northern Road where floor level survey has confirmed that the increase in peak flood levels would lead to an increase in above-floor inundation during storms with AEPs between 10% and 1%. The affected area also includes a number of buildings within No. 60-62 Bennett Road where floor level survey would be required to confirm whether the increase in peak flood levels would lead to an increase in above-floor inundation. During storms with AEPs between 10% and 1% there would either be no change or a slight reduction on peak flood levels in areas to the east (upstream) of transverse drainage structure TNR01.	No	One option to mitigate the increase in the depth and duration of inundation, as well as the increase in peak flow velocities within properties to the west (downstream) of The Northern Road would involve the construction of a grass-lined channel that would run from the outlet of transverse drainage structure TNR01, primarily through No. 49-51 The Northern Road and No. 60-62 Bennet Road, to the inlet of the existing transverse drainage in Bennett Road. This mitigation option would be subject to consultation with the affected property owners and would require the acquisition of a drainage easement to contain the proposed channel.
			Changes in Peak Flow Velocities During a 1% AEP design storm event, there would be an increase in peak flow velocities over a localised area of the property that is located immediately west (downstream) of the outlet to transverse drainage structure TNR01, from 0.9 m/s (pre-proposal conditions) to 1.3 m/s (post-proposal conditions).	No	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, there would be an increase in the duration of inundation by more than one hour over five RU4 zoned rural residential properties that are located to the west (downstream) of transverse drainage structure TNR01.	No	

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Impact of Proposed Works on Flood Behaviour	Compliance with Adopted Afflux Criteria	Comments/Recommendations
The Northern Road regional flood evacuation route	TNR02	Shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* There would be either no change or a slight reduction in peak flood levels upstream and downstream of The Northern Road at transverse drainage structure TNR02 during storms with AEPs between 10% and 1%.	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of TNR02 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of The Northern Road at transverse drainage structure TNR02 would be less than one hour.	Yes	
	TNR03	Shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* There would be either no change or a slight reduction in peak flood levels upstream and downstream of The Northern Road at transverse drainage structure TNR03 during storms with AEPs between 10% and 1%.	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of TNR03 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of The Northern Road at transverse drainage structure TNR03 would be less than one hour.	Yes	
	TNR04	Drainage improvements and shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* Peak 5% and 1% AEP flood levels would be increased within two rural residential properties (zoned RU4 small lot primary production) that are located immediately west (downstream) of the outlet to transverse drainage structure TNR04 by a maximum of 0.04 m on existing depths that exceed 1 m. During a 10% AEP design storm event, flood levels would be increased by a maximum of 0.02 m on existing depths that exceed 1 m, but would extend over nine rural residential properties (zoned RU4 small lot primary production) that are located west (downstream) of the outlet to transverse drainage structure TNR04. The affected area does not contain any existing buildings and the maximum increase in peak flood levels is within the 0.1 m limit for the type of land impacted (primary production).	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of TNR04 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Impact of Proposed Works on Flood Behaviour	Compliance with Adopted Afflux Criteria	Comments/Recommendations
The Northern Road regional flood evacuation route			*Changes in the Duration of Inundation* During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of The Northern Road at transverse drainage structure TNR04 would be less than one hour.	Yes	
	TNR05	Drainage improvements and shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* During a 1% AEP design storm event, there would be an increase in the depth of flow along the drainage line that runs through a single RU4 zoned rural residential property that is located to the west (downstream) of transverse drainage structure TNR05 by a maximum of 0.06 m. The affected area does not contain any existing buildings and the maximum increase in peak flood levels is within the 0.1 m limit for this land use type.	Yes	While the increases in peak flow velocities to the west (downstream) of transverse drainage structure TNR05 are relatively localised, they occur over an area of embankment that is relatively steep and therefore would be susceptible to scour as a result of an increase in flow velocities.  Subject to further development of the proposed drainage improvements during detailed design, should any residual impacts on scour potential remain, then the provision of scour protection in the form of rock riprap lining to the affected area may be a feasible solution. This would be subject to consultation and agreement with the affected property owner of No. 1 Carrington Road.
			Changes in Peak Flow Velocities During a 1% AEP design storm event. there would be an increase in peak flow velocities over two relatively localised areas of the drainage line that runs through a single RU4 zoned rural residential property that is located to the west (downstream) of transverse drainage structure TNR05 (No. 1 Carrington Road). Peak flow velocities would be increased from between 0.9 and 1.1 m/s (pre-proposal conditions) to 1.3 m/s (post-proposal conditions).	No	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of The Northern Road at transverse drainage structure TNR05 would be less than one hour.	Yes	
	TNR06	Shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* During storms with AEPs of between 10% and 1% AEP, there would be no change in peak flood levels to the west (downstream) of The Northern Road at transverse drainage structure TNR06. During a 5% and 1% AEP design storm event, there would be an increase in peak flood levels on C2 zoned land that lies to the east (upstream) of The Northern Road, about 300 m to the north of transverse drainage structure TNR06, by a maximum of 0.05 m. The impacted area does not contain any existing buildings and the maximum increase in peak flood levels is within the 0.1 m limit for this land use type.	Yes	As increases in the duration of inundation to the north of transverse drainage structure TNR06 are confined to the inbank area of an existing drainage line, it is not considered to result in an increase in the wetting up of land given that the impacted area would be inundated during frequent storm events.
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of TNR06 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Impact of Proposed Works on Flood Behaviour	Compliance with Adopted Afflux Criteria	Comments/Recommendations
The Northern Road regional flood evacuation route			*Changes in the Duration of Inundation* During a 1% AEP design storm event, the duration of inundation would be increased by more than one hour along a localised section of an existing drainage line that is located to the east (upstream) of The Northern Road, about 300 m to the north of transverse drainage structure TNR06.	No	
	TNR07	Shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* During storms with AEPs of 10% and 1% AEP, there would be no change in peak flood levels to the west (downstream) of The Northern Road at transverse drainage structure TNR07. During a 5% and 1% AEP storm event, there would be an increase in peak flood levels by a maximum of 0.03 m over an area of C2 zoned nature reserve to the east (upstream) of The Northern Road, about 50 m to the north of transverse drainage structure TNR07. The impacted area does not contain any existing buildings and the maximum increase in peak flood levels is within the 0.1 m limit for this land use.	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of TNR07 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of The Northern Road at transverse drainage structure TNR07 would be less than one hour.	Yes	
	TNR08	Shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* There would be no change in peak 10% and 1% AEP flood levels upstream or downstream of The Northern Road at transverse drainage structure TNR08.	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of TNR08 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of The Northern Road at transverse drainage structure TNR08 would be less than one hour.	Yes	
	TNR09	Shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* There would either be no change or a slight reduction in peak flood levels upstream and downstream of The Northern Road at transverse drainage structure TNR09 during storms with AEPs between 10% and 1%.	Yes	

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Impact of Proposed Works on Flood Behaviour	Compliance with Adopted Afflux Criteria	Comments/Recommendations
The Northern Road regional flood evacuation route			*Changes in Peak Flow Velocities* During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of TNR09 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of The Northern Road at transverse drainage structure TNR08 would be less than one hour.	Yes	
	TNR10	Shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* There would be no change in peak 10% and 1% AEP flood levels upstream or downstream of The Northern Road at transverse drainage structure TNR10.	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of transverse drainage structure TNR10 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of The Northern Road at transverse drainage structure TNR10 would be less than one hour.	Yes	
	TNR11	Drainage improvements and shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* During storms with AEPs between 10% and 1%, peak flood levels would be increased by a maximum of 0.05 m, but typically less than 0.02 m in three RU4 zoned rural residential properties that are located to the west (downstream) of transverse drainage structure TNR11. The impacted area does not contain any existing buildings and the maximum increase in peak flood levels is within the 0.1 m limit for this land use type. During storms with AEPs between 10% and 1%, there would either be no change or a slight reduction in peak flood levels upstream of The Northern Road at transverse drainage structure TNR11.	Yes	Yes Increases in the duration of inundation at the driveway of the rural residential property to the west (downstream) of transverse drainage structure TNR11 (No. 407 The Northern Road) is caused by the obstruction to overland flow by the proposed driveway access adjustments which form part of the concept road design. This impact can be addressed through further development of the concept road design and its associated table drain and culvert crossing under the driveway, which would discharge to the outlet of transverse drainage structure TNR11.
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of transverse drainage structure TNR11 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During a 1% AEP design storm event, the duration of inundation would be increased by more than one hour at the driveway access to the rural residential property that is located immediately west (downstream) of transverse drainage structure TNR11 (No. 407 The Northern Road). The duration of inundation to the access driveway would be increased from 0.9 hours (pre-proposal conditions) to 2.4 hours (post-proposal conditions).	No	

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Impact of Proposed Works on Flood Behaviour	Compliance with Adopted Afflux Criteria	Comments/Recommendations
The Northern Road regional flood evacuation route	TNR12	Shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* During storms with AEPs between 10% and 1%, there would either be no change or a slight reduction in peak flood levels upstream and downstream of The Northern Road at transverse drainage structure TNR12.	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of TNR12 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of The Northern Road at transverse drainage structure TNR12 would be less than one hour.	Yes	
	TNR13	Drainage improvements (for TNR14a and TNR14b) and shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* Peak flood levels would be increased within an area of a single RU4 zoned rural residential property that is located immediately to the west (downstream) of transverse drainage structure TNR13 (No. 2 Thomas Road). During a 10% AEP design storm, peak flood levels would be increased by a maximum of 0.03 m on an existing depth of less than 0.1 m, increasing to 0.09 m on an existing depth of about 0.1 m during a 5% AEP storm event and 0.21 m on an existing depth of about 0.2 m during a 1% AEP storm event. While the affected area does not contain any existing buildings, the maximum increase in peak flood levels exceeds the 0.1 m limit for this land use type. During a 1% AEP design storm, peak flood levels would also be increased over an area to the east (upstream) of The Northern Road between transverse drainage structures TNR13 and TNR14a/14b. The affected area is located within an undeveloped parcel of RU4 (rural residential) zoned land (No. 175-209 Spinks Road). Depths of inundation adjacent to transverse drainage structure TNR13 would be increased by a maximum of 0.17 m on an existing depth of about 0.3 m. While the affected area does not contain any existing buildings, the maximum increase in peak flood levels exceeds the 0.1 m limit for this land use type.	No	While it would be feasible to mitigate the increase in peak flood levels to the east (upstream) of transverse drainage structure TNR13 by increasing its capacity, this would lead to further increases in peak flood levels to the west (downstream). While it would also be feasible to mitigate the increase in peak flood levels to both the east (upstream) and west (downstream) of transverse drainage structure TNR13 by installing a series of high flow culverts to its south, this would require the level of The Northern Road to be further raised, which in turn would increase the footprint of the proposed works, which would likely require the acquisition of additional land to the east of the road corridor. The increase in peak flood levels to the west (downstream) of transverse drainage structure TNR13 could be managed by the provision of a channel that would run for approximately 40 m through the north-east corner of No. 2 Thomas Road and a further 200 m along the road reserve of Thomas Road. This arrangement would be subject to consultation and agreement with the affected property owner. While the changes in duration of inundation under post-proposal conditions are not considered to result in a net increase in the wetting up of land, the provision of the aforementioned channel through No. 2 Thomas Road would also reduce the duration of inundation in areas of the property to the west (downstream) of transverse drainage structure TNR13.
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of transverse drainage structure TNR13 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During a 10% AEP design storm, there would either be no change or a reduction in the duration of inundation in areas to the east (upstream) and west (downstream) of transverse drainage structure TNR13. During a 1% AEP design storm, there would be localised increases in the duration of inundation of more than one hour, and conversely localised reductions of more than one hour in areas to the west (downstream) of transverse drainage structure TNR13. These changes can be attributed to a redistribution of overland flow discharging from the road corridor during this	No	

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Impact of Proposed Works on Flood Behaviour	Compliance with Adopted Afflux Criteria	Comments/Recommendations
The Northern Road regional flood evacuation route			storm event and are not considered to result in a net increase in the wetting up of land within the property.		
	TNR14a & TNR14b	Drainage improvements and shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* Peak 10% AEP flood levels would be increased by a maximum of 0.07 m within four RU4 zoned residential properties that are located to the west (downstream) of transverse drainage structures TNR14a and TNR14b, increasing to 0.09 m during design storms with AEPs of 5% and 1%. The affected area does not contain any existing buildings and the maximum increase in peak flood levels is within the 0.1 m limit for this land use type. There would be a slight reduction in peak 10% and 5% AEP flood levels to the east (upstream) of The Northern Road at transverse drainage structures TNR14a and TNR14b. During a 1% AEP design storm, peak flood levels would be increased over an area to the east (upstream) of The Northern Road between transverse drainage structures TNR13 and TNR14a/14b. The affected area is located within an undeveloped parcel of RU4 (rural residential) zoned land (No. 175-209 Spinks Road). Depths of inundation adjacent to transverse drainage structures TNR14a/14b would be increased by a maximum of 0.12 m on an existing depth of more than about 0.4 m. While the affected area does not contain any existing buildings, the maximum increase in peak flood levels exceeds the 0.1 m limit for this land use type.	No	In order to mitigate the increase in peak flood levels to the east (upstream) of The Northern Road without exacerbating flooding to the west, it is likely to be necessary to install a series of high flow culverts between transverse drainage structures TNR13 and TNR14a. As noted above, this would require the level of The Northern Road to be further raised, which in turn would increase the footprint of the proposed works and require the acquisition of additional land to the east of the road corridor. Changes in the duration of inundation that are observed to occur during a 10% and 1% AEP storm event are not considered to result in an increase in the wetting up of land given that the impacted areas are mainly confined to the existing drainage lines downstream of transverse drainage structures TNR14a and TNR14b that would also be inundated during more frequent events. Furthermore, the increase in duration of inundation along these existing drainage lines is offset by a reduction in the duration of inundation to other areas as a result of flow no longer overtopping the road and discharging into the properties over a broader extent.
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of the proposed works would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, there would be localised areas within the four aforementioned rural residential properties where there would be an increase in the duration of inundation of more than one hour, and conversely there would also be comparatively larger areas within the same four properties where there would be a reduction in the duration of inundation by more than one hour. These changes can be attributed to a redistribution of flow discharging from the road corridor during these storm events. Under pre-proposal conditions the majority of flow surcharges the inlet of the transverse drainage structures and overtops the road where it discharges into the properties over a relatively wide area. In comparison, no overtopping of the road occurs under post-project conditions and so a larger portion of the flow would discharge toward the drainage lines located downstream of transverse drainage structures TNR14a and TNR14b.	No	

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Impact of Proposed Works on Flood Behaviour	Compliance with Adopted Afflux Criteria	Comments/Recommendations
The Northern Road regional flood evacuation route	TNR15 & TNR16	Drainage improvements and shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* During a 1% AEP storm event, peak flood levels would be increased over an area to the west (downstream) of transverse drainage structures TNR15 and TNR16 within two RU4 zoned rural residential properties. Depths of inundation within the affected properties would be increased by a maximum of 0.1 m on existing depths of about 0.3 m. The impacted area within each lot does not contain any existing buildings and the maximum increase in peak flood level is within the 0.1 m limit for this land use type. There would also be a localised increase in peak 1% AEP flood levels within two RU4 zoned rural residential properties that are located immediately east (upstream) of transverse drainage structure TNR16. Depths of inundation within the affected properties would be increased by a maximum of 0.02 m over an area where the existing depth of inundation is typically more than 0.5 m. The affected area does not contain any buildings and the maximum increase in peak flood levels is within the 0.1 m limit for this land use type. Changes in peak flood levels during a 10% and 5% AEP storm event would be similar to those described above for a 1% AEP storm event, but would occur over a smaller extent.	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of TNR15 and TNR16 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of The Northern Road at transverse drainage structure TNR15 and TNR16 would be less than one hour.	Yes	
	TNR17	Shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* During storms with AEPs of 10% and 5%, peak flood levels within two RU4 zoned rural residential properties that are located immediately east (upstream) of transverse drainage structure TNR17 would be increased by a maximum of 0.03 m. The affected area does not contain any buildings and the maximum increase in peak flood levels is within the 0.1 m limit for this land use. There would be no change in peak 1% AEP flood levels upstream or downstream of The Northern Road at transverse drainage structure TNR17.	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of TNR15 and TNR16 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of The Northern Road at transverse drainage structure TNR17 would be less than one hour.	Yes	

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Impact of Proposed Works on Flood Behaviour	Compliance with Adopted Afflux Criteria	Comments/Recommendations
The Northern Road regional flood evacuation route	TNR18	Drainage improvements (for TNR19) and shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* Peak flood levels to the west (downstream) of transverse drainage structure TNR18 would be increased within three RU4 zoned rural residential properties. During storms with AEPs of 10% and 5%, increases in the depth of inundation within the affected properties would occur to a maximum of 0.03 m. During a 1% AEP storm event, increases in the depth of inundation would occur to a maximum of 0.05 m. The affected area within each property does not contain any existing buildings and the maximum increase in peak flood level is within the 0.1 m limit for this land use type.	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of TNR18 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of The Northern Road at transverse drainage structure TNR18 would be less than one hour.	Yes	
	TNR19	Drainage improvements and shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* Peak flood levels would be increased within a localised area of the C2 zoned Wianamatta Nature Reserve that is located to the west (downstream) of transverse drainage structure TNR19. During a 10% AEP design storm event, depths of inundation would be increased by a maximum of 0.02 m, increasing to 0.08 m during storms with AEPs of 5% and 1%. The affected area does not contain any existing buildings and the maximum increase in peak flood level is within the 0.1 m limit for this land use type.	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of TNR19 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of The Northern Road at transverse drainage structure TNR19 would be less than one hour.	Yes	
	TNR20	Drainage improvements (for TNR19) and shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* Peak flood levels would be increased within an area of the C2 zoned Wianamatta Nature Reserve that is located to the west (downstream) of transverse drainage structure TNR20. During storms with AEPs of 10% and 5%, peak flood levels would be increased by a maximum of 0.06 m, increasing to 0.08 m during a 1% AEP design storm event. The impacted area does not contain any existing buildings and the maximum increase in peak flood level is within the 0.1 m limit for this land use type.	Yes	As increases in the duration of inundation are confined to the main drainage path downstream of transverse drainage structure TNR20, it is not considered to result in an increase in the wetting up of land given that the impacted area would be inundated during frequent storm events.

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Impact of Proposed Works on Flood Behaviour	Compliance with Adopted Afflux Criteria	Comments/Recommendations
The Northern Road regional flood evacuation route			*Changes in Peak Flow Velocities* During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of TNR20 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During a 1% AEP design storm event there would be increases in the duration of inundation in areas to the west (downstream) of transverse drainage structure TNR20 by more than one hour. The affected areas would be confined to the main drainage path downstream of transverse drainage structure TNR20 that would be inundated during frequent rainfall events.	No	
	TNR21	Drainage improvements and shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* Peak 1% AEP flood levels would be increased within an area of the C2 zoned Wianamatta Nature Reserve that is located to the west (downstream) of transverse drainage structure TNR21 by a maximum of 0.06 m, which is within the 0.1 m limit for this land use type. No existing buildings are located within the affected area. During storms with AEPs of 10% and 5%, there would be either no change or a slight reduction in peak flood levels upstream and downstream of The Northern Road at transverse drainage structure TNR21.	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of TNR21 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of The Northern Road at transverse drainage structure TNR21 would be less than one hour.	Yes	
	TNR22	Drainage improvements (for CR35c) and shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* There would be a localised increase in peak flood levels immediately east (downstream) of transverse drainage structure TNR21 within an undeveloped parcel of land that is zoned RU4. During a 10% AEP design storm event, peak flood levels would be increased by a maximum of 0.05 m, increasing to 0.07 m and 0.10 m during a 5% and 1% AEP design storm event, respectively. No existing buildings are located within the affected area and the maximum increase in peak flood level is within the 0.1 m limit for this land use type.	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of TNR22 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Impact of Proposed Works on Flood Behaviour	Compliance with Adopted Afflux Criteria	Comments/Recommendations
The Northern Road regional flood evacuation route			*Changes in the Duration of Inundation* During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of The Northern Road at transverse drainage structure TNR22 would be less than one hour.	Yes	
	TNR22b	Shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* There would be a localised increase in peak flood levels to the east (downstream) of transverse drainage structure TNR22b within an undeveloped parcel of land that is zoned RU4. During storms with AEPs of 10% and 5%, peak flood levels would be increased by a maximum of 0.03 m, increasing to 0.05 m during a 1% AEP design storm event. No existing buildings are located within the affected area.	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of TNR22b would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of The Northern Road at transverse drainage structure TNR22b would be less than one hour.	Yes	
	TNR23	Drainage improvements (for TNR24) and shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* During a 1% AEP storm, peak flood levels would be increased within seven RU4 zoned rural properties that are located to the north-east (downstream) of transverse drainage structure TNR23. Depths of inundation within the affected properties would be increased by a maximum of: i. 0.07 m within the southernmost property; and ii. 0.03 m across the other six properties. The affected area within each property does not contain any existing buildings and the maximum increase in peak flood level is within the 0.1 m limit for this land use type. There would also be an increase in peak 1% AEP flood levels within a parcel of land that is located immediately north-east (downstream) of transverse drainage structure TNR23 by a maximum of 0.09 m. While the parcel of land is zoned RU4 (small lot primary production), it presently contains a stormwater detention basin. The increase in peak flood levels would have only a minor impact on the performance of the stormwater detention basin. During storms with AEPs of 10% and 5%, increases in peak flood levels outside the road corridor would be confined to the stormwater detention basin that is located to the north-east (downstream) of transverse drainage structure TNR23, where depths of inundation would be increased by 0.05 m and 0.08 m, respectively.	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of TNR23 would be less than 10 per cent, or	Yes	

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Impact of Proposed Works on Flood Behaviour	Compliance with Adopted Afflux Criteria	Comments/Recommendations
The Northern Road regional flood evacuation route			would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.		
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of The Northern Road at transverse drainage structure TNR23 would be less than one hour.	Yes	
	TNR24 & TNR25	Drainage improvements and shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* During storms with AEPs between 10% and 1%, peak flood levels would be increased within areas to the east (downstream) of The Northern Road. While depths of inundation would be increased by a maximum of 0.03 m, impacts would be confined to the C2 zoned Wianamatta Nature Reserve.	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of transverse drainage structures TNR24 and TNR25 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of The Northern Road at transverse drainage structures TNR24 and TNR25 would be less than one hour.	Yes	
	TNR26	Shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* There would be no change in peak 10% and 1% AEP flood levels upstream or downstream of The Northern Road at transverse drainage structure TNR26.	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of transverse drainage structure TNR26 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of The Northern Road at transverse drainage structure TNR26 would be less than one hour.	Yes	
	TNR27	Shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* There would be no change in peak 10% and 1% AEP flood levels upstream or downstream of The Northern Road at transverse drainage structure TNR27.	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of transverse drainage structure TNR27 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Impact of Proposed Works on Flood Behaviour	Compliance with Adopted Afflux Criteria	Comments/Recommendations
The Northern Road regional flood evacuation route			*Changes in the Duration of Inundation* During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of The Northern Road at transverse drainage structure TNR27 would be less than one hour.	Yes	
	TNR28	Shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* There would be no change in peak 10% and 1% AEP flood levels upstream or downstream of The Northern Road at transverse drainage structure TNR28.	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of transverse drainage structure TNR28 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of The Northern Road at transverse drainage structure TNR28 would be less than one hour.	Yes	
	TNR34, TNR 35 & TNR36	Drainage improvements	*Changes in Peak Flood Levels and Depths and Extents of Inundation* The upgrade of the drainage system associated with transverse drainage structures TNR34, TNR35 and TNR36 would generally lead to either no change or a reduction in depths of inundation in areas outside the extent of the proposed works. The exception is an area of RE1 zoned open space to the south of Andrews Road where depths of inundation would be increased by a maximum of 0.08 m on an existing depth of 0.1 m during a 1% AEP storm.	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of The Northern Road at transverse drainage structures TNR34, TNR35 and TNR36 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of The Northern Road at transverse drainage structures TNR34, TNR35 and TNR36 would be less than one hour.	Yes	
Londonderry Road regional flood evacuation route	LNR01	Shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* During storms with AEPs of 10% and 1%, there would be either no change or a slight reduction in peak flood levels upstream and downstream of Londonderry Road at transverse drainage structure LNR01.	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of transverse drainage structure LNR01 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Impact of Proposed Works on Flood Behaviour	Compliance with Adopted Afflux Criteria	Comments/Recommendations
Londonderry Road regional flood evacuation route			*Changes in the Duration of Inundation* During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of transverse drainage structure LNR01 would be less than one hour.	Yes	
	LNR02	Shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* During a 1% AEP storm event, there would be an increase in the depth and extent of inundation over a significant area of SP1 (education agriculture) zoned land to the north-east of Londonderry Road that forms part of the Western Sydney University. Depths of inundation would be increased by a maximum of 0.09 m on existing depths that are less than 0.1 m. The increase in the depth of inundation is within the limits for this type of land use.	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of transverse drainage structure LNR02 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of transverse drainage structure LNR02 would be less than one hour.	Yes	
	LNR03	Shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* There would be no change in peak flood levels upstream and downstream of Londonderry Road at transverse drainage structure LNR03 during storms with AEPs of 10% and 1%.	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of transverse drainage structure LNR03 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of Londonderry Road at transverse drainage structure LNR03 would be less than one hour.	Yes	
	LNR04, LNR05 & LNR06	Shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* During storms with AEPs between 10% and 1%, depths of inundation would be increased by a maximum of 0.05 m within a relatively localised area of two RU4 zoned rural residential properties that are located to the east (downstream) of Londonderry Road at transverse drainage structure LNR04. The affected area does not contain any buildings and the maximum increase is within the 0.1 m limit for this land use type.	Yes	As increases in the duration of inundation are confined to a local drainage depression, it is not considered to result in an increase in the wetting up of land given that the impacted area would be inundated during frequent storm events.

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Impact of Proposed Works on Flood Behaviour	Compliance with Adopted Afflux Criteria	Comments/Recommendations
Londonderry Road regional flood evacuation route			*Changes in Peak Flow Velocities* During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of transverse drainage structures LNR04, LNR05 and LNR06 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During a 10% AEP design storm event, there would an increase in the duration of inundation by more than one hour along a local drainage depression that runs along the common boundary of two RU4 zoned rural residential properties that are located to the east (downstream) of Londonderry Road and south of transverse drainage structure LNR04.	No	
	LNR07	Shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* There would be no change in peak flood levels upstream and downstream of Londonderry Road at transverse drainage structure LNR07 during storms with AEPs of 10% and 1%.	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of transverse drainage structure LNR07 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of Londonderry Road at transverse drainage structure LNR07 would be less than one hour.	Yes	
	LNR08	Shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* There would either be no change or a slight reduction in peak flood levels upstream and downstream of Londonderry Road at transverse drainage structure LNR08 during storms with AEPs of 10% and 1%.	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of transverse drainage structure LNR08 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, there would typically be a reduction in the duration of inundation within properties located to the east (upstream) and west (downstream) of Londonderry Road at transverse drainage structure LNR08 would be less than one hour.	Yes	
	LNR09	Shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* There would be no change in peak flood levels upstream and downstream of Londonderry Road at transverse drainage structure LNR09 during storms with AEPs of 10% and 1%.	Yes	

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Impact of Proposed Works on Flood Behaviour	Compliance with Adopted Afflux Criteria	Comments/Recommendations
Londonderry Road regional flood evacuation route			*Changes in Peak Flow Velocities* During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of transverse drainage structure LNR09 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of Londonderry Road at transverse drainage structure LNR09 would be less than one hour.	Yes	
	LNR10 & LNR11	Shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* There would be a relatively localised increase in peak 1% AEP flood levels by a maximum of 0.02 m within two RU4 zoned rural residential properties that are located to the west (upstream) of transverse drainage structure LNR11. No buildings are located within the affected area and the increase is within the 0.1 m limit for this land use type.	Yes	As increases in the duration of inundation along the watercourse to the east (downstream) of transverse drainage structure LNR10 is confined to its inbank area, it is not considered to result in an increase in the wetting up of land given that the impacted area would be inundated during frequent storm events.
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of transverse drainage structures LNR10 and LNR11 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During a 10% AEP design storm event, there would be an increase in the duration of inundation by more than one hour over an area of land to the east of the outlet to transverse drainage structure LNR10 within a RU4 zoned rural residential property. The affected area is confined to the inbank area of the watercourse downstream of the transverse drainage structure.	No	
	LNR12 & LNR13	Shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* During storms with AEPs between 10% and 1% there would be an increase in peak flood levels by a maximum of 0.03 m within two RU4 zoned rural residential properties that are located to the east (downstream) of transverse drainage structure LNR12. The affected area does not contain any existing buildings and the maximum increase is within the 0.1 m limit for this land use type.	Yes	The increase in the duration of inundation within the rural residential property is due to flow that surcharges the drainage channel that is proposed to run along the toe of the adjacent section of road embankment. The increase in the duration of inundation is considered to be a minor relative impact when the existing duration of inundation is taken into consideration. Should it be required, it is expected that the increase in the duration of inundation that is described above can be mitigated by providing a bund along the eastern side of the drainage channel that is proposed to run along the toe of the section of road embankment to the north of the outlet to transverse drainage structure LNR12. As increases in the duration of inundation along the section of Rickabys Creek to the east (downstream) of transverse drainage structure LNR12 is confined to its inbank area, it is not considered to result in an increase in the wetting up of land given that the creek would be inundated during frequent storm events.
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of transverse drainage structures LNR12 and LNR13 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, there would be a relatively localised increase in the duration of inundation by more than one hour over an area of land to the north of the outlet to transverse drainage structure LNR12 within a single RU4 zoned rural residential property. During a 1% AEP storm event the duration of inundation would be increased from 12.2 hours (pre-proposal	No	

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Impact of Proposed Works on Flood Behaviour	Compliance with Adopted Afflux Criteria	Comments/Recommendations
Londonderry Road regional flood evacuation route			conditions) to 13.4 hours (post-proposal conditions). Similar relative increases in the duration of inundation would occur during a 10% AEP storm event. While the TUFLOW model results also show increases in the duration of inundation by more than one hour to the east of the outlet to transverse drainage structure LNR12, it is noted that these increases are confined to the inbank area of Rickabys Creek.		
	LNR14	Shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* There would either be no change or a slight reduction in peak flood levels upstream and downstream of Londonderry Road at transverse drainage structure LNR14 during storms with AEPs of 10% and 1%.	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of transverse drainage structure LNR14 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of Londonderry Road at transverse drainage structure LNR14 would be less than one hour.	Yes	
	LNR15	Shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* Peak 1% AEP flood levels would be increased by a maximum of 0.03 m within one RU4 zoned rural property that is located to the east (upstream) and two RU4 zoned rural properties that are located to the west (downstream) of Londonderry Road at transverse drainage structure LNR015. During storms with AEPs of 10% and 5% increases in peak flood levels would occur over a similar area, but to a maximum of 0.05 m. No buildings are located within the impacted area and the maximum increase in peak flood levels is within the 0.1 m limit for this land use type.	Yes	As increases in the duration of inundation are confined to a local drainage depression, it is not considered to result in an increase in the wetting up of land given that the impacted area would be inundated during frequent storm events.
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of transverse drainage structure LNR15 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During a 10% AEP design storm event, there would an increase in the duration of inundation by more than one hour along a local drainage depression that runs through a single RU4 zoned rural residential property that is located to the east (upstream) of Londonderry Road and south of transverse drainage structure LNR15.	No	
	LNR16	Shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* During storms with AEPs of 10% and 1%, there would either be no change or a slight reduction in peak flood levels upstream and downstream of Londonderry Road.	Yes	

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Impact of Proposed Works on Flood Behaviour	Compliance with Adopted Afflux Criteria	Comments/Recommendations
Londonderry Road regional flood evacuation route			*Changes in Peak Flow Velocities* During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of transverse drainage structure LNR16 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of Londonderry Road at transverse drainage structure LNR16 would be less than one hour.	Yes	
	LNR17	Shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* There would be no change in peak flood levels upstream and downstream of Londonderry Road at transverse drainage structure LNR17 during storms with AEPs of 10% and 1%.	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of transverse drainage structure LNR17 would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of Londonderry Road at transverse drainage structure LNR17 would be less than one hour.	Yes	
Penrith North Sector flood evacuation route	CR35c	Drainage improvements and shoulder widening	*Changes in Peak Flood Levels and Depths and Extents of Inundation* There would be no change in peak flood levels upstream and downstream of Vincent Road at transverse drainage structure CR35c during storms with AEPs of 10% and 1%.	Yes	
			Changes in Peak Flow Velocities During storms with AEPs of 10% and 1%, changes in peak flow velocities in areas upstream and downstream of transverse drainage structure CR35c would be less than 10 per cent, or would result in peak flow velocities under post-proposal conditions that are less than 1 m/s.	Yes	
			Changes in the Duration of Inundation During storms with AEPs of 10% and 1%, changes in the duration of inundation in areas upstream and downstream of Vincent Road at transverse drainage structure CR35c would be less than one hour.	Yes	

TABLE 6.3
COMPARISON OF HAZARD VULNERABILITY CLASSIFICATION OF FLOODING ALONG DESIGNATED FLOOD EVACUATION ROUTES UNDER CURRENT AND POTENTIAL FUTURE CLIMATIC CONDITIONS – 0.2% AEP DESIGN STORM

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Hazard Vulnerability Classification			
			Current Climatic Conditions		Potential Future Climatic Conditions[1,2]	
			Outbound Travel Lane	Outbound Shoulder	Outbound Travel Lane	Outbound Shoulder
The Northern Road Regional Flood Evacuation Route	TNR01a	Shoulder widening	H1	H1	H1	H1
	TNR01	Shoulder widening	H1	H2	H1	H2
	TNR02	Shoulder widening	H1	H1	H1	H1
	TNR03	Shoulder widening	H1	H1	H1	H1
	TNR04	Drainage improvements and shoulder widening	Not flooded	Not flooded	Not flooded	Not flooded
	TNR05	Drainage improvements and shoulder widening	Not flooded	Not flooded	Not flooded	H1
	TNR06	Shoulder widening	H1	H1	H1	H1
	TNR07	Shoulder widening	Not flooded	H1	Not flooded	H1
	TNR08	Shoulder widening	Not flooded	H1	Not flooded	H1
	TNR09	Shoulder widening	Not flooded	Not flooded	Not flooded	Not flooded
	TNR10	Shoulder widening	H1	H1	H1	H1
	TNR11	Drainage improvements and shoulder widening	Not flooded	Not flooded	Not flooded	Not flooded
	TNR12	Shoulder widening	H1	H1	H1	H1

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Hazard Vulnerability Classification			
			Current Climatic Conditions		Potential Future Climatic Conditions[1,2]	
			Outbound Travel Lane	Outbound Shoulder	Outbound Travel Lane	Outbound Shoulder
The Northern Road Regional Flood Evacuation Route	TNR13	Drainage improvements (for TNR14a and TNR14b) and shoulder widening	Not flooded	Not flooded	Not flooded	H1
	TNR14a	Drainage improvements and shoulder widening	Not flooded	Not flooded	Not flooded	Not flooded
	TNR14b	Drainage improvements and shoulder widening	Not flooded	Not flooded	Not flooded	Not flooded
	TNR15	Drainage improvements and shoulder widening	Not flooded	Not flooded	Not flooded	Not flooded
	TNR16	Shoulder widening	Not flooded	Not flooded	Not flooded	Not flooded
	TNR17	Shoulder widening	H1	H1	H1	H1
	TNR18	Drainage improvements (for TNR19) and shoulder widening	Not flooded	Not flooded	Not flooded	Not flooded
	TNR19	Drainage improvements and shoulder widening	Not flooded	Not flooded	Not flooded	Not flooded
	TNR20	Drainage improvements (for TNR19) and shoulder widening	Not flooded	Not flooded	Not flooded	Not flooded
	TNR21	Drainage improvements and shoulder widening	Not flooded	Not flooded	Not flooded	Not flooded
	TNR22	Drainage improvements (for CR35c) and shoulder widening	H1	H1	H1	H1
	TNR22b	Shoulder widening	Not flooded	Not flooded	Not flooded	Not flooded
	TNR23	Drainage improvements (for TNR24) and shoulder widening	H1	H1	H1	H1
	TNR24	Drainage improvements and shoulder widening	Not flooded	Not flooded	Not flooded	Not flooded

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Hazard Vulnerability Classification			
			Current Climatic Conditions		Potential Future Climatic Conditions[1,2]	
			Outbound Travel Lane	Outbound Shoulder	Outbound Travel Lane	Outbound Shoulder
The Northern Road Regional Flood Evacuation Route	TNR25	Drainage improvements and shoulder widening	Not flooded	Not flooded	Not flooded	Not flooded
	TNR26	Shoulder widening	Not flooded	Not flooded	H1	Not flooded
	TNR27	Shoulder widening	H1	H1	H1	H1
	TNR28	Shoulder widening	H1	H1	H1	H1
	TNR29	None	Not flooded	Not flooded[3]	Not flooded	Not flooded[3]
	TNR30	None	H1	H1[3]	H1	H1[3]
	TNR31	None	H1	H1[3]	H1	H1[3]
	TNR32	None	H1	H1[3]	H1	H1[3]
	TNR33	None	H1	H1[3]	H1	H1[3]
	TNR34	Drainage improvements	Not flooded	Not flooded[3]	H1	H1[3]
	TNR35	Drainage improvements	Not flooded	Not flooded[3]	H1	H1[3]
	TNR36	Drainage improvements	Not flooded	Not flooded[3]	Not flooded	H1[3]
	TNR37	None	H1	H1[3]	H1	H2[3]
	TNR38	None	H1	H1[3]	H1	H1[3]
	TNR39	None	H1	H1[3]	H1	H1[3]
	TNR40	None	H1	H1[3]	H1	H1[3]

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Hazard Vulnerability Classification			
			Current Climatic Conditions		Potential Future Climatic Conditions[1,2]	
			Outbound Travel Lane	Outbound Shoulder	Outbound Travel Lane	Outbound Shoulder
The Northern Road Regional Flood Evacuation Route	TNR41	None	H1	H1[3]	H1	H1[3]
	TNR42	None	H1	H1[3]	H1	H1[3]
	TNR43	None	H1	H1[3]	H1	H1[3]
Londonderry Road Regional Flood Evacuation Route	LNR01	Shoulder widening	Not flooded	Not flooded	Not flooded	Not flooded
	LNR02	Shoulder widening	H1	H1	H1	H1
	LNR03	Shoulder widening	H1	H1	H1	H1
	LNR04	Shoulder widening	Not flooded	Not flooded	Not flooded	Not flooded
	LNR05	Shoulder widening	Not flooded	Not flooded	Not flooded	Not flooded
	LNR06	Shoulder widening	Not flooded	Not flooded	Not flooded	Not flooded
	LNR07	Shoulder widening	Not flooded	Not flooded	Not flooded	Not flooded
	LNR08	Shoulder widening	H1	H2	H1	H2
	LNR09	Shoulder widening	H1	H1	H1	H1
	LNR10	Shoulder widening	Not flooded	Not flooded	Not flooded	Not flooded
	LNR11	Shoulder widening	Not flooded	Not flooded	Not flooded	Not flooded
	LNR12	Shoulder widening	Not flooded	Not flooded	H1	H1
	LNR13	Shoulder widening	H1	H1	H1	H1
	LNR14	Shoulder widening	Not flooded	Not flooded	Not flooded	Not flooded

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Hazard Vulnerability Classification			
			Current Climatic Conditions		Potential Future Climatic Conditions[1,2]	
			Outbound Travel Lane	Outbound Shoulder	Outbound Travel Lane	Outbound Shoulder
Londonderry Road Regional Flood Evacuation Route	LNR15	Shoulder widening	H1	H1	H1	H1
	LNR16	Shoulder widening	H1	H1	H1	H1
	LNR17	Shoulder widening	H1	H1	H1	H1
Penrith North Sector Flood Evacuation Route (Vincent Road)	CR35c[4]	Drainage improvements and shoulder widening	Not flooded	Not flooded	H1	H1

1. As noted in **Section 3.3.3**, the 0.05% AEP event was adopted as being analogous to an increase in 0.2% AEP design rainfall intensities under future climate change.
2. Cells shaded in orange denote an increase in the hazard vulnerability classification of the outbound travel lane or widened shoulder when compared to current climatic conditions.
3. Results presented are for the outside travel lane as The Northern Road comprises two outbound travel lanes at this location.

TABLE 6.4
COMPARISON OF IMPACT OF PROPOSED DRAINAGE IMPROVEMENTS AND ROAD SHOULDER WIDENING ON FLOOD BEHAVIOUR UNDER CURRENT AND POTENTIAL FUTURE CLIMATIC CONDITIONS – 1% AEP DESIGN STORM

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Impact of Proposed Works on Flood Behaviour			
			Current Climatic Conditions		Potential Future Climatic Conditions[1]	
			Description	Compliance with Afflux Limits	Description	Compliance with Afflux Limits[2]
The Northern Road Regional Flood Evacuation Route	TNR01a	Shoulder widening	There would be no change in peak flood levels upstream and downstream of The Northern Road at transverse drainage structure TNR01a.	Yes	Changes in peak flood levels would be consistent with those described for current climatic conditions.	Yes
	TNR01	Shoulder widening	There would be an increase in the depth of inundation over an area to the west (downstream) of transverse drainage structure TNR01 by a maximum of 0.06 m in four RU4 zoned rural residential properties. The affected area includes three buildings within No. 49-51 The Northern Road where floor level survey has confirmed that the increase in peak flood levels would lead to an increase in above-floor inundation during storms with AEPs between 10% and 1%. The affected area also includes a number of buildings within No. 60-62 Bennett Road where floor level survey would be required to confirm whether the increase in peak flood levels would lead to an increase in above-floor inundation.	No	Peak flood levels downstream of transverse drainage structure TNR01 would be increase by a similar amount and over a similar extent as those described for current climatic conditions.	No
	TNR02	Shoulder widening	There would be either no change or a slight reduction in peak flood levels upstream and downstream of The Northern Road at transverse drainage structure TNR02.	Yes	Changes in peak flood levels would be consistent with those described for current climatic conditions.	Yes
	TNR03	Shoulder widening	There would be either no change or a slight reduction in peak flood levels upstream and downstream of The Northern Road at transverse drainage structure TNR03.	Yes	Peak flood levels to the west (downstream) of transverse drainage structure TNR03 would be increased by a maximum of 0.03 m within the front yard of a RU4 zoned rural residential property. The area impacted does not contain any existing buildings and the maximum increase in peak flood levels is within the 0.1 m limit relating to current climatic conditions for this land use type. There would be no change in peak flood levels upstream The Northern Road at transverse drainage structure TNR03.	Yes
	TNR04	Drainage improvements and shoulder widening	Peak flood levels to the west (downstream) of transverse drainage structure TNR04 would be increased by a maximum of 0.04 m on existing depths that exceed 1 m within two RU4 zoned rural residential properties. The impacted area does not contain any existing buildings and the maximum increase in peak flood levels is within the 0.1 m limit for this land use type.	Yes	Peak flood levels to the west (downstream) of transverse drainage structure TNR04 would be increased by a maximum of 0.1 m within two RU4 zoned rural residential properties that are located immediately west (downstream) of the outlet to transverse drainage structure TNR04. The impacted area does not contain any existing buildings and the maximum increase in peak flood levels is within the 0.1 m limit relating to current climatic conditions for this land use type.	Yes
	TNR05	Drainage improvements and shoulder widening	There would be an increase in the depth of flow along the drainage line that runs through a single RU4 zoned rural residential property that is located to the west (downstream) of transverse drainage structure TNR05. Peak flood levels along the drainage line would be increased by a maximum of 0.06 m. The impacted area does not contain any existing buildings and the maximum increase in peak flood levels is within the 0.1 m limit for this land use type.	Yes	Peak flood levels to the west (downstream) of transverse drainage structure TNR05 would be increased by the same amount and over a similar extent as under current climatic conditions.	Yes

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Impact of Proposed Works on Flood Behaviour			
			Current Climatic Conditions		Potential Future Climatic Conditions[1]	
			Description	Compliance with Afflux Limits	Description	Compliance with Afflux Limits[2]
The Northern Road Regional Flood Evacuation Route	TNR06	Shoulder widening	There would be no change in peak flood levels to the west (downstream) of The Northern Road at transverse drainage structure TNR06. There would be an increase in peak flood levels on C2 (environmental conservation) zoned land that is located to the east (upstream) of The Northern Road, about 300 m to the north of transverse drainage structure TNR06, by a maximum of 0.05 m. The impacted area does not contain any existing buildings and the maximum increase in peak flood levels is within the 0.1 m limit for this land use type.	Yes	Changes in peak flood levels would be consistent with those under current climatic conditions.	Yes
	TNR07	Shoulder widening	There would be no change in peak flood levels to the west (downstream) of The Northern Road at transverse drainage structure TNR07. There would be an increase in peak flood levels over an area to the east (upstream) of The Northern Road, about 50 m to the north of transverse drainage structure TNR06 by a maximum of 0.03 m. The area impacted land does not contain any existing buildings and the maximum increase in peak flood levels is within the 0.1 m limit for the type of land impacted (environmental conservation).	Yes	Changes in peak flood levels would be consistent with those under current climatic conditions.	Yes
	TNR08	Shoulder widening	There would be no change in peak flood levels upstream or downstream of The Northern Road at transverse drainage structure TNR08.	Yes	Changes in peak flood levels would be consistent with those under current climatic conditions.	Yes
	TNR09	Shoulder widening	There would either be no change or a slight reduction in peak flood levels upstream and downstream of The Northern Road at transverse drainage structure TNR09.	Yes	Changes in peak flood levels would be consistent with those under current climatic conditions.	Yes
	TNR10	Shoulder widening	There would be no change in peak flood levels upstream or downstream of The Northern Road at transverse drainage structure TNR10.	Yes	Changes in peak flood levels would be consistent with those under current climatic conditions.	Yes
	TNR11	Drainage improvements and shoulder widening	Peak flood levels would be increased in an area to the west (downstream) of The Northern Road within two RU4 zoned rural residential properties by a maximum of 0.05 m but typically less than 0.04 m. The impacted area does not contain any existing buildings and the maximum increase in peak flood levels is within the 0.1 m limit for this land use type. There would either be no change or a slight reduction in peak flood levels upstream of The Northern Road at transverse drainage structure TNR11.	Yes	Peak flood levels would be increased within the two RU4 zoned rural residential properties to the west (downstream) of The Northern Road by a maximum of 0.07 m, which is slightly more than that under current climatic conditions. The impacted area does not contain any existing buildings. There would either be no change or a slight reduction in peak flood levels upstream of The Northern Road at transverse drainage structure TNR11.	Yes
	TNR12	Shoulder widening	There would either be no change or a slight reduction in peak flood levels upstream and downstream of The Northern Road at transverse drainage structure TNR12.	Yes	Changes in peak flood levels would be consistent with those under current climatic conditions.	Yes
	TNR13	Drainage improvements (for TNR14a and TNR14b) and shoulder widening	Peak flood levels would be increased within a single RU4 zoned rural residential property that is located immediately to the west (downstream) of transverse drainage structure TNR13 by a maximum of 0.21 m. While the impacted area does not contain any	No	Peak flood levels to the west (downstream) of transverse drainage structure TNR13 would be increased by a maximum of 0.55 m over a similar area as that under current climatic conditions.	No

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Impact of Proposed Works on Flood Behaviour			
			Current Climatic Conditions		Potential Future Climatic Conditions[1]	
			Description	Compliance with Afflux Limits	Description	Compliance with Afflux Limits[2]
The Northern Road Regional Flood Evacuation Route			existing buildings, the maximum increase in peak flood levels exceeds the 0.1 m limit for this land use type. Peak flood levels would also be increased within a single RU4 zoned rural residential property that is located immediately to the east (upstream) of transverse drainage structure TNR13 by a maximum of 0.17 m. While the impacted area does not contain any existing buildings, the maximum increase in peak flood levels exceeds the 0.1 m limit for this land use type.		Peak flood levels to the east (upstream) of transverse drainage structure TNR13 would be increased by a maximum of 0.31 m over a slightly larger area when compared to current climatic conditions.	
	TNR14a & TNR14b	Drainage improvements and shoulder widening	Peak flood levels would be increased by a maximum of 0.09 m within four RU4 zoned rural residential properties that are located to the west (downstream) of transverse drainage structures TNR14a and TNR14b. Peak flood levels would be increased by a maximum of 0.12 m on existing depths of more than 0.4 m to the east (upstream) of The Northern Road at transverse drainage structures TNR14a and TNR14b. The affected area is located within an undeveloped parcel of land that is zoned RU4 (rural residential).	No	Peak flood levels to the west (downstream) of transverse drainage structures TNR14a and TNR14b would be increased by a maximum of 0.05 m over a similar area as that under current climatic conditions. Peak flood levels to the east (upstream) of transverse drainage structures TNR14a and TNR14b would be increased by a maximum of 0.3 m over a slightly larger area when compared to current climatic conditions.	No
	TNR15 & TNR16	Drainage improvements and shoulder widening	Peak flood levels would be increased over an area to the west (downstream) of transverse drainage structures TNR15 and TNR16 within two RU4 zoned rural residential properties. Depths of inundation within the affected properties would be increased by a maximum of 0.1 m on existing depths of about 0.3 m. The impacted area within each lot does not contain any existing buildings and the maximum increase in peak flood level is within the 0.1 m limit for this land use type. There would also be a localised increase in peak flood levels within two RU4 zoned rural residential properties that are located immediately east (upstream) of transverse drainage structure TNR16. Depths of inundation within the affected properties would be increased by a maximum of 0.02 m over an area where the existing depth of inundation is typically more than 0.5 m. The affected area does not contain any buildings and the maximum increase in peak flood levels is within the 0.1 m limit for this land use type.	Yes	Changes in peak flood levels to the west (downstream) of transverse drainage structures TNR15 and TNR16 would be consistent with those under current climatic conditions. Peak flood levels to the east (upstream) of transverse drainage structure TNR16 would be increased by a maximum of 0.05 m and over a slightly larger extent within two RU4 zoned rural residential properties when compared to current climatic conditions. The impacted area does not contain any buildings.	Yes
	TNR17	Shoulder widening	There would be no change in peak 1% AEP flood levels upstream or downstream of The Northern Road at transverse drainage structure TNR17	Yes	Changes in peak flood levels would be consistent with those under current climatic conditions.	Yes
	TNR18	Drainage improvements (for TNR19) and shoulder widening	Peak flood levels to the west (downstream) of transverse drainage structure TNR18 would be increased within three RU4 zoned rural residential properties. Increases in the depth of inundation would occur to a maximum of 0.05 m. The area of impact within each property does not contain any existing buildings and the maximum increase in peak flood level is within the 0.1 m limit for this land use type.	Yes	Peak flood levels to the west (downstream) of transverse drainage structure TNR18 would be increased by a maximum of 0.09 m, but over a smaller extent when compared to current climatic conditions that includes two RU4 zoned rural residential properties.	Yes

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Impact of Proposed Works on Flood Behaviour			
			Current Climatic Conditions		Potential Future Climatic Conditions[1]	
			Description	Compliance with Afflux Limits	Description	Compliance with Afflux Limits[2]
The Northern Road Regional Flood Evacuation Route	TNR19	Drainage improvements and shoulder widening	Peak flood levels would be increased within a localised area of the C2 zoned Wianamatta Nature Reserve that is located to the west (downstream) of transverse drainage structure TNR19. Depths of inundation would be increased by a maximum of 0.08 m, which is within the 0.1 m limit for this land use type. No existing buildings are located within the impacted area.	Yes	Changes in peak flood levels would be consistent with those under current climatic conditions.	Yes
	TNR20	Drainage improvements (for TNR19) and shoulder widening	Peak flood levels would be increased within an area of the C2 zoned Wianamatta Nature Reserve that is located to the west (downstream) of transverse drainage structure TNR20. Peak flood levels would be increased by a maximum of 0.08 m, which is within the 0.1 m limit for this land use type. No existing buildings are located within the impacted area.	Yes	Peak flood levels to the west (downstream) of transverse drainage structure TNR20 would be increased by a maximum of 0.10 m over a similar extent as that under current climatic conditions.	Yes
	TNR21	Drainage improvements and shoulder widening	Peak flood levels would be increased within an area of the Wianamatta Nature Reserve that is located to the west (downstream) of transverse drainage structure TNR21 by a maximum of 0.06 m, which is within the 0.1 m limit for this type of land (environmental conservation). No existing buildings are located within the impacted area.	Yes	Peak flood levels would be increased within an area of the C2 zoned Wianamatta Nature Reserve that is located to the west (downstream) of transverse drainage structure TNR21 by a maximum of 0.07 m compared with 0.08 m under current climatic conditions. No existing buildings are located within the impacted area.	Yes
	TNR22	Drainage improvements (for CR35c) and shoulder widening	There would be a localised increase in peak flood levels to the east (downstream) of transverse drainage structure TNR22 within a vacant parcel of RU4 zoned land. Peak flood levels would be increased by a maximum of 0.10 m, which is within the 0.1 m limit for this land use type. No existing buildings are located within the impacted area.	Yes	There would be a localised increase in peak flood levels to the east (downstream) of transverse drainage structure TNR22 within a vacant parcel of RU4 zoned land. Peak flood levels would be increased by a maximum of 0.13 m, compared with 0.1 m under current climatic conditions. No existing buildings are located within the impacted area.	No
	TNR22b	Shoulder widening	There would be a localised increase in peak flood levels to the east (downstream) of transverse drainage structure TNR22b within an undeveloped parcel of land that is zoned RU4 (small lot primary production). Peak flood levels would be increased by a maximum of 0.05 m, which is within the 0.1 m limit for this land use type. No existing buildings are located within the impacted area.	Yes	There would be an increase in peak flood levels to the east (downstream) of transverse drainage structure TNR22b within a vacant parcel of RU4 zoned land over a larger extent when compared to current climatic conditions. Peak flood levels would be increased by a maximum of 0.07 m (compared with 0.05 m under current climatic conditions). No existing buildings are located within the impacted area.	Yes
	TNR23	Drainage improvements (for TNR24) and shoulder widening	Peak flood levels would be increased within seven RU4 zoned rural residential properties that are located to the north-east (downstream) of transverse drainage structure TNR23. Depths of inundation within the affected properties would be increased by a maximum of: i. 0.07 m within the southernmost property; and ii. 0.03 m across the other six properties. The impacted area within each property does not contain any existing buildings and the maximum increase in peak flood level is within the 0.1 m limit for this land use type. There would also be an increase in peak 1% AEP flood levels within a parcel of land that is located immediately north-east (downstream) of transverse drainage structure TNR23 by a maximum of 0.09 m.	Yes	Changes in peak flood levels would be similar to those under current climatic conditions.	Yes

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Impact of Proposed Works on Flood Behaviour			
			Current Climatic Conditions		Potential Future Climatic Conditions[1]	
			Description	Compliance with Afflux Limits	Description	Compliance with Afflux Limits[2]
The Northern Road Regional Flood Evacuation Route			While the parcel of land is zoned RU4, it presently contains a stormwater detention basin. The increase in peak flood levels would have only a minor impact on the performance of the stormwater detention basin.			
	TNR24 & TNR25	Drainage improvements and shoulder widening	Peak flood levels would be increased within areas to the east (downstream) of The Northern Road. While depths of inundation would be increased by a maximum of 0.03 m, impacts would be confined to the C2 zoned Wianamatta Regional Park.	Yes	Changes in peak flood levels would be consistent with those under current climatic conditions.	Yes
	TNR26	Shoulder widening	There would be no change in peak flood levels upstream or downstream of The Northern Road at transverse drainage structure TNR26.	Yes	Changes in peak flood levels would be consistent with those under current climatic conditions.	Yes
	TNR27	Shoulder widening	There would be no change in peak flood levels upstream or downstream of The Northern Road at transverse drainage structure TNR27.	Yes	Changes in peak flood levels would be consistent with those under current climatic conditions.	Yes
	TNR28	Shoulder widening	There would be no change in peak flood levels upstream or downstream of The Northern Road at transverse drainage structure TNR28.	Yes	Changes in peak flood levels would be consistent with those under current climatic conditions.	Yes
	TNR34, TNR35 & TNR36	Drainage improvements	The upgrade of the drainage system associated with transverse drainage structures TNR34, TNR35 and TNR36 would generally lead to either no change or a reduction in depths of inundation, with the exception of an area of open space reserve to the south of Andrews Road. Depths of inundation within the area of RE1 zoned open space would be increased by a maximum of 0.08 m on an existing depth of 0.1 m.	Yes	Changes in peak flood levels would be consistent with those under current climatic conditions.	Yes
Londonderry Road Regional Flood Evacuation Route	LNR01	Shoulder widening	There would be either no change or a slight reduction in peak flood levels upstream and downstream of Londonderry Road at transverse drainage structure LNR01.	Yes	Changes in peak flood levels would be consistent with those under current climatic conditions.	Yes
	LNR02	Shoulder widening	There would be an increase in the depth and extent of inundation over a significant area of SP1(Education Agriculture) zoned land to the north-east of Londonderry Road and The Driftway. Depths of inundation would be increased by a maximum of 0.09 m on existing depths that are less than 0.1 m. The increase in the depth of inundation is within the limits for this land use type.	Yes	Changes in peak flood levels would be similar to those that are described for current climatic conditions.	Yes
	LNR03	Shoulder widening	There would be no change in peak flood levels upstream and downstream of Londonderry Road at transverse drainage structure LNR03.	Yes	Changes in peak flood levels would be consistent with those under current climatic conditions.	Yes
	LNR04, LNR05 & LNR06	Shoulder widening	Depths of inundation would be increased by a maximum of 0.05 m within a relatively localised area of two RU4 zoned rural residential properties that are located to the east (downstream) of Londonderry Road at transverse drainage structure LNR04. The affected area does not contain any buildings and the maximum increase is within the 0.1 m limit for this land use type.	Yes	Changes in peak flood levels would be consistent with those under current climatic conditions.	Yes
	LNR07	Shoulder widening	There would be no change in peak flood levels upstream and downstream of Londonderry Road at transverse drainage structure LNR07.	Yes	Changes in peak flood levels would be consistent with those under current climatic conditions.	Yes

Designated Flood Evacuation Route	Transverse Drainage Structure	Proposed Works	Impact of Proposed Works on Flood Behaviour			
			Current Climatic Conditions		Potential Future Climatic Conditions[1]	
			Description	Compliance with Afflux Limits	Description	Compliance with Afflux Limits[2]
Londonderry Road Regional Flood Evacuation Route	LNR08	Shoulder widening	There would either be no change or a slight reduction in peak flood levels upstream and downstream of Londonderry Road at transverse drainage structure LNR08.	Yes	Changes in peak flood levels would be consistent with those under current climatic conditions.	Yes
	LNR09	Shoulder widening	There would be no change in peak flood levels upstream and downstream of Londonderry Road at transverse drainage structure LNR09.	Yes	Changes in peak flood levels would be consistent with those under current climatic conditions.	Yes
	LNR10 & LNR11	Shoulder widening	There would be a relatively localised increase in peak flood levels by a maximum of 0.02 m within two RU4 zoned rural residential properties that are located to the west (upstream) of transverse drainage structure LNR11. No buildings are located within the impacted area.	Yes	Peak flood levels to the west (upstream) of transverse drainage structure LNR11would also be increased by a maximum of 0.02 m but would occur over a larger area compared to that under current climatic conditions. The affected area includes two buildings where floor level survey would be required to confirm whether the increase in peak flood levels would results in an increase in above floor inundation.	Dependant on floor level survey
	LNR12 & LNR13	Shoulder widening	There would be an increase in peak flood levels by a maximum of 0.03 m within two RU4 zoned rural residential properties that are located to the east (downstream) of transverse drainage structure LNR12. The affected area does not contain any existing buildings and the maximum increase is within the 0.1 m limit for this land use type.	Yes	Changes in peak flood levels would be consistent with those under current climatic conditions.	Yes
	LNR14	Shoulder widening	There would either be no change or a slight reduction in peak flood levels upstream and downstream of Londonderry Road at transverse drainage structure LNR14.	Yes	Changes in peak flood levels would be consistent with those under current climatic conditions.	Yes
	LNR15	Shoulder widening	Peak flood levels would be increased by a maximum of 0.03 m within one RU4 zoned rural property that is located to the east (upstream) and two RU4 zoned rural properties that are located to the west (downstream) of Londonderry Road at transverse drainage structure LNR015. No buildings are located within the impacted area and the maximum increase in peak flood levels is within the 0.1 m limit for this land use type.	Yes	Changes in peak flood levels would be consistent with those under current climatic conditions.	Yes
	LNR16	Shoulder widening	There would either be no change or a slight reduction in peak flood levels upstream and downstream of Londonderry Road.	Yes	Changes in peak flood levels would be consistent with those under current climatic conditions.	Yes
	LNR17	Shoulder widening	There would be no change in peak flood levels upstream and downstream of Londonderry Road at transverse drainage structure LNR17.	Yes	Changes in peak flood levels would be consistent with those under current climatic conditions.	Yes
Penrith North Sector Flood Evacuation Route (Vincent Road)	CR35c[4]	Drainage improvements and shoulder widening	There would be no change in peak flood levels upstream and downstream of Vincent Road at transverse drainage structure CR35c.	Yes	Changes in peak flood levels would be consistent with those under current climatic conditions.	Yes

1. As noted in **Section 3.3.3**, the 0.2% AEP event was adopted as being analogous to an increase in 1% AEP design rainfall intensities under future climate change conditions.
2. Based on comparison to the afflux limits relating to current climatic conditions that have been established for the Program.

7 MANAGEMENT OF IMPACTS

The assessment of flood impacts associated with the proposal has provided an understanding of the scale and nature of the flood risk to the proposal, 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 proposal that will build on the flood assessment presented in this technical 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 proposal, 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 measures to be implemented during the construction of the proposal in order to prepare for a flood, as well as the procedures that will need to be implemented during a flood.
- The identification of design and flood mitigation measures that will be implemented to manage the risk of flooding to the designated flood evacuation routes and not worsen existing flooding characteristics in areas outside the proposal corridor during construction and operation, including erosion and scour.

The flood assessment that will be undertaken during the detailed design phase of the proposal will be undertaken in consultation with Transport, NSW RA, NSW SES, relevant councils and affected property owners.

Table 7.1 sets out the measures that would be implemented to manage flood related impacts during the construction and operation of the proposal.

TABLE 7.1
FLOODING RELATED MITIGATION AND MANAGEMENT MEASURES

ID	Mitigation and management measure	Applicable area
Construction – flooding		
FL01	Detailed construction planning would consider flood risk at work areas and associated ancillary sites, including: • reviewing construction site layouts and staging construction activities in order to avoid or minimise obstruction of overland flow paths and limiting the extent of flow diversion required • designing the layout of construction facilities and implementing stormwater management controls during their establishment in order to manage the impact of flooding on construction personnel, equipment and materials. • identifying and applying measures to not worsen flood impacts on the community and on other property and infrastructure during construction up to and including	All

	the 1% AEP flood event where reasonable and feasible. Where warranted by the scale and nature of the proposed works this would include flood modelling and assessment to assess the extent of potential impacts and therefore the scope of mitigation measures that may be required • measures to mitigate alterations to local runoff conditions due to construction activities.	
FL02	Spoil stockpiles would be located in areas which are not subject to frequent inundation by floodwater, ideally outside the 10% AEP flood extent. The exact level of flood risk accepted at stockpile sites would depend on the duration of stockpiling operations, the type of material stored, the nature of the receiving drainage lines and also the extent to which it would impact flooding conditions in adjacent development.	All
FL03	Construction facilities would be located outside high flood hazard areas based on a 1% AEP flood.	Ancillary sites
FL04	Flood emergency management measures for construction of the proposal would be prepared and incorporated into relevant environmental and/or safety management documentation. This would include: • contingency planning for construction facilities that are located in areas that are inundated by mainstream flooding during a 1% AEP event • for construction facilities located within the floodplain the identification of how flood related risks to personal safety and damage to construction facilities and equipment will be managed • procedures to monitor accurate and timely weather data, and disseminate warnings to construction personnel of impending flood producing rain	All
Operation – flooding		
FL05	The impact of the proposal on flood behaviour would be confirmed during detailed design. This would include consideration of future climate change.	All
FL06	The proposal would be designed to minimise adverse flood related impacts on: i. surrounding development for storms up to 1% AEP in intensity ii. critical infrastructure, vulnerable development or increases in risk to life due to a significant increase in flood hazard for floods up to the PMF.	All
FL07	The proposed drainage improvements and road shoulder widening associated with the proposal would be designed to manage adverse impacts on the receiving drainage lines as a result of changes in the depth, velocity, extent and duration of flow during storms up to 1% AEP in intensity.	All

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