Appendix C – Addendum Hydrology and Flooding Assessment Report

Albion Park Rail bypass

September 2017

NSW GOVERNMENT

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ROADS AND MARITIME SERVICES

ALBION PARK RAIL BYPASS

Addendum Hydrology and Flooding Assessment Report

Technical Paper

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Revision 10

REVISIONS

Revision	Date	Description	Prepared By	Approved By
01	09/02/2017	Issue for RMS review	RH	KR
02	09/03/2017	2nd Draft	RH	TM
03	31/03/2017	3rd Draft	RH	TM
04	24/04/2017	4th Draft	RH	KR
05	10/05/2017	5th Draft	RH	KR
06	29/05/2017	6th Draft	RH	KR
07	13/06/2017	Final Draft for RMS sign off	RH	KR
08	19/06/2017	Final Report	RH	KR
09	01/09/2017	1st Revised Draft	RH	KR
10	07/09/2017	Revised Report	RJ	KR

CONTENTS

APPENDICES

GLOSSARY

AHD	Australian Height Datum
Afflux	The increase in flood levels, e.g. due to the restriction of flows.
Attenuation	Reduction of flows, e.g. by providing flood storage.
Average Recurrence Interval (ARI)	The average period between occurrences equalling or exceeding a given value. For example, a 20 year ARI flood would occur on average once every 20 years.
Annual Exceedance Probability (AEP)	The probability of an event occurring or being exceeded within a year. For example, a 5% AEP flood would have a 5% chance of occurring in any year. An approximate conversion between ARI and AEP is provided below:
Catchment	The land area draining through the main stream, as well as tributary streams, to a particular site location. It always relates to an area upstream of a specific location.
Conveyance	The transport of flood water downstream.
Discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second. Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving, for example metres per second.
EIS	Environmental Impact Statement
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 tsunami.
Floodplain	Area of land that is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
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.

AEP	ARI
63.2 %	1 year
39.3 %	2 year
18.1 %	5 year
10 %	10 year
5 %	20 year
2 %	50 year
1 %	100 year
0.5 %	200 year
0.2 %	500 year

GLOSSARY

Hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
Intensity Frequency Duration (IFD)	Describes rainfall in terms of intensity (typically mm/hr), frequency (eg ARI) and duration of the storm.
Probable maximum flood (PMF)	The largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain.
Rainfall intensity	The amount of rainfall that falls per unit time, usually measured in millimetres per hour (mm/hr).
Reinforced concrete pipe (RCP)	A type of pipe culvert consisting of concrete reinforced with steel. For example a 1200 RCP is a reinforced concrete pipe 1200 mm in diameter.
Reinforced concrete box culvert (RCBC)	A type of box culvert consisting of concrete reinforced with steel. For example, a 2400W x 1200H RCBC is a reinforced concrete box culvert 2400 mm wide and 1200 mm high.
SPIR	Submissions and Preferred Infrastructure Report.
Scour	Erosion by mechanical action of water, typically of soil.

1 INTRODUCTION

NSW Roads and Maritime Services (Roads and Maritime) propose to build a 9.8 kilometre extension of the Princes Motorway between Yallah and Oak Flats that would bypass Albion Park Rail (**Figure 1-1**). Key features of the project include:

- Two lanes in each direction divided by a median (with capacity to upgrade to three lanes in each direction in future)
- Three interchanges provided at Yallah, Albion Park and Oak Flats would connect the local road network with the motorway
- Bridges to carry the motorway over Duck Creek, Macquarie Rivulet and Frazers Creek
- Bridges to carry the motorway over the Princes Highway and Tongarra Road
- A bridge to carry the motorway over the South Coast Rail Line
- Improved pedestrian and cycle connections
- Improvements to directly impacted sporting facilities at the Croom Regional Sporting Complex and changes to the southern access.

An Environmental Impact Statement (EIS) was prepared by Roads and Maritime to assess the potential impacts of the proposal. The EIS was publicly exhibited by the Department of Planning and Environment between 28 October and 27 November 2015.

Following the EIS display, a review of the design was undertaken in response to feedback following stakeholder consultation. As a result of this review process, Roads and Maritime has refined a number of aspects of the project as exhibited in the EIS. Design refinements have been developed to minimise EIS impacts where possible and in response to:

- Consultation with the community during the EIS exhibition period
- Submissions received during and following the EIS exhibition period
- Landowner discussions during property acquisition and adjustment
- Further concept design review of the EIS design.

The key design refinements proposed include:

- Reconfiguration of the interchange at Albion Park to minimise the impact on agricultural land and allow northbound traffic to exit the motorway onto Tongarra Road
- Reduction in the project footprint within agricultural land
- Some refinements to intersection arrangements in response to further detailed traffic modelling.

Roads and Maritime has prepared a Submissions and Preferred Infrastructure Report (SPIR) to respond to issues raised in submissions received during the exhibition of the EIS. It also describes and assesses the proposed design refinements. This report forms an appendix to the SPIR and details the additional hydrology and flooding investigations undertaken as part of this process.

Figure 1-1 The Albion Park Rail Bypass Project

2 ASSESSMENT METHODOLOGY

2.1 OVERVIEW

Much of the project traverses flood affected areas. Flooding is therefore a substantial constraint and the design requires a number of bridges and culverts. The motorway elevation and configuration of the watercourse crossings has required careful optimisation to ensure that a high level of flood immunity is achieved, while mitigating flooding impacts to an acceptable level. It is noted that the flood impacts of the project are being compared to flooding under current conditions including the existing infrastructure.

2.2 ASSESSMENT CRITERIA

The Hyder Cardno Joint Venture (HCJV) and Roads and Maritime developed assessment criteria for the project through review of local issues and past project experience. The assessment criteria relate to flood immunity, flood impacts, and flooding and drainage design. The assessment criteria used for the revised design is unchanged from that used in the EIS (refer to Chapter 8 of the Albion Park Rail bypass environmental impact statement and Technical Paper 3 – Hydrology and Flooding, 2015).

The desirable flood immunity for the project has been set as the 100 year ARI event (refer to section 3.2.1 of technical report 3). It is noted in the Hydrology and Flooding Assessment EIS Technical Paper that this has been achieved for the motorway with the exception of the low point south of the Duck Creek bridge where 50 year ARI immunity is achieved.

The design has been revised as part of the SPIR and 100 year ARI immunity is achieved on the motorway with the exception of the low point south of the Duck Creek bridge where 50 year ARI immunity is achieved. This level of immunity will be carried through in the detailed design.

The flood impact criteria used for this project is consistent with other large Roads and Maritime highway projects in flood prone areas. Impacts will be further reviewed as part of the detailed design and management measures have been developed to minimise impacts of the project.

2.3 MODELLING APPROACH

This project used catchment-wide flood models provided by Shellharbour City Council and Wollongong City Council for the three main project catchments. Moving from north to south, the three main catchments are Duck Creek, Macquarie Rivulet and Horsley Creek. These flood models form the base case for the hydrological and hydraulic assessments.

The Macquarie Rivulet Flood Study is currently in preparation, and a draft report was exhibited by Shellharbour City Council in July 2016 after the EIS was issued for public exhibition. In 2014, an advance copy of the Macquarie Rivulet flood model was made available to Roads and Maritime for the EIS. The model represented the most comprehensive flood model available at the time for this catchment.

After the flood model was provided to Roads and Maritime for the EIS, some changes were made by Shellharbour Council to the Council flood model for the issue of the draft Macquarie Rivulet Flood Study. These changes include:

- Changes to rainfall data
- Changes to rainfall loss rates
- Changes to culvert blockage assumptions

- Changes to tailwater assumptions for Lake Illawarra

All of these changes to the model mean that the results of the 2016 draft Macquarie Rivulet Flood Study are different to the results from the preliminary Macquarie Rivulet flood model provided to Roads and Maritime for the EIS in 2014. A comparison of the two models undertaken by the HCJV found that flow rates and flood levels for a range of design storm events between the 5 year ARI and 100 year ARI are lower in the July 2016 draft flood model compared to the model used in the EIS. In events greater than the 100 year ARI, the 2016 draft flood model predicts higher flow rates and flood levels.

The flood model used for this assessment has therefore not changed and is the same as used in the EIS. This is justified because:

- It is a conservative approach due to the higher flow rates and flood levels in the design storm events
- It allows for a like-for-like comparison of impacts from the revised design compared to the EIS design
- The Macquarie Rivulet flood model has not yet been finalised.

The impacts and immunity of the design have been developed based on the Macquarie Rivulet flood model used in the EIS. As a sensitivity test, the revised design has been analysed in the 2016 draft Macquarie Rivulet flood model to determine the impacts in the 20 year ARI and 100 year ARI events if the draft model was to be used.

3 ASSESSMENT OF OPERATIONAL IMPACTS

3.1 BROOKS CREEK

The northern-most portion of the project lies in the Brooks Creek catchment, however the impact of hydrology and flooding associated with this catchment was not considered during the EIS.

Flooding in the Brooks Creek catchment was not initially considered as the LEP corridor and preferred concept design adopted for the EIS did not extend into this catchment. Following development of the concept to 80 per cent design stage, the project footprint was extended into the Brooks Creek catchment by approximately 500 metres to facilitate the northbound entry ramp. Based on the Mullet and Brooks Creek Catchment Flood Study prepared by engineering consultants BMT-WBM for Wollongong City Council, this section of the existing Motorway is not predicted to be impacted by flooding from Brooks Creek in events up to the probable maximum flood (PMF).

An extract from the Mullet and Brooks Creek Flood Study (BMT-WBM, 2010) showing the existing PMF extent adjacent to the existing Motorway is shown in **Figure 3-1**.

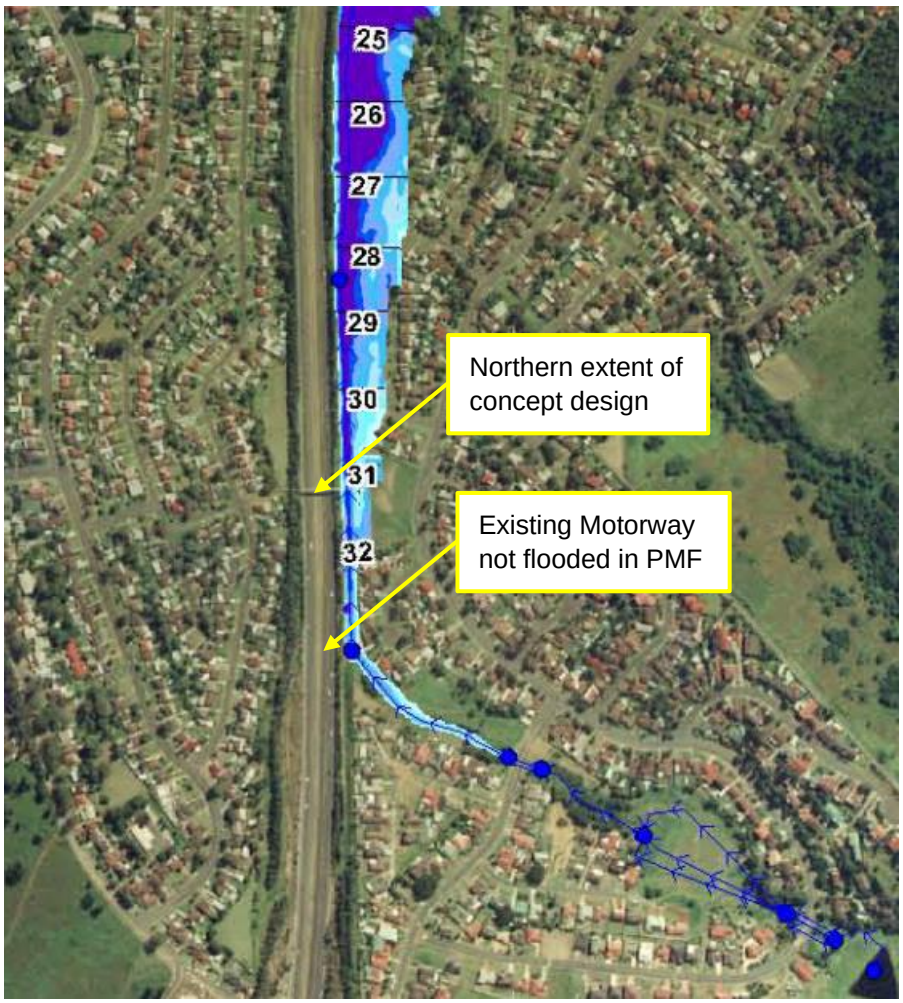


Figure 3-1 Extract from Wollongong City Council Mullet and Brooks Creek Flood Study

Within the Brooks Creek catchment, two culverts convey flow under the existing Motorway in an easterly direction towards Brooks Creek. The northern catchment is 10.7ha and the southern catchment is 4.6ha at the motorway. Refer to **Figure 3-2**. It is noted that there are no proposed works on the Princes Motorway Southbound in the area adjacent to Brooks Creek.

The culvert crossing within the northern catchment (Catchment A) conveys flows from a pit in a low point west of the existing Motorway to a headwall outlet to the east of the existing Motorway. The motorway is being widened to the west by approximately three metres at this location to cater for the new northbound entry ramp. The proposed entry ramp does not impact on the inlet pit at this location and the existing drainage infrastructure at this location would remain. The capacity of the existing culvert would be unchanged and the level of flood immunity on the motorway at this location would be unchanged from the existing condition.

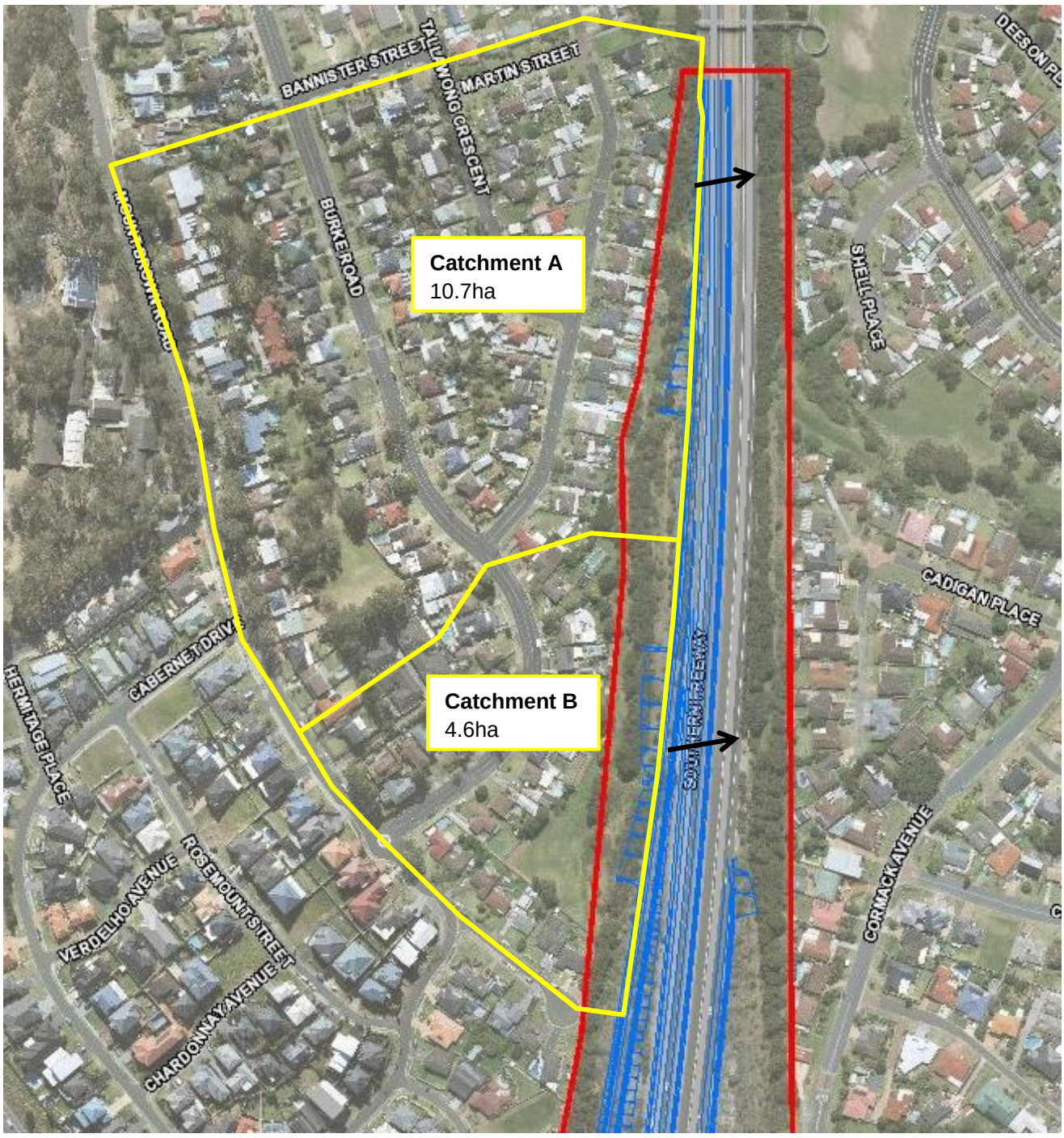


Figure 3-2 Existing Culvert Crossings in Brooks Creek Catchment

The culvert crossing under the existing Motorway conveys stormwater flows from the southern catchment (Catchment B) to the east. The culvert consists of an inlet 15 metres west of the Motorway and a grated inlet five metres west of the Motorway, with an outlet to the east of the existing Motorway. At present, the flow of water into the culvert is controlled by an earthen mound located between the culvert inlet and the Motorway. The mound is approximately 1.6 metres higher than the bottom of the pipe, and prevents flooding of the Motorway by directing flows into the culvert.

The motorway is proposed to be widened to the west by approximately 15 metres at this location to cater for the new northbound entry ramp. These widening works would impact on the existing culvert inlet. It is proposed to construct a new inlet with a raised grate and a new culvert to connect to the existing grated inlet. It is proposed to construct an earthen mound between the new inlet and the motorway to ensure that the capacity of the culvert crossing is unchanged from the current situation. With this design, the flood immunity of the motorway would remain consistent with the existing conditions and there would be no changes to flooding upstream and downstream of the motorway.

3.2 DUCK CREEK

There are no changes to the design which impact on flooding within the Duck Creek floodplain. The flood impacts and performance against criteria within the Duck Creek catchment for the project are as per the EIS.

It is noted that Wollongong City Council have recently revised their blockage policy, which generally has lower blockage values when compared to the previous Wollongong City Council blockage policy. The flood impacts and performance against criteria presented in the EIS within the Duck Creek catchment are based on the previous (more conservative) Wollongong City Council blockage policy and has not been re-assessed with the new blockage policy. An analysis of the project with the new blockage policy would generally result in lower flood levels upstream of bridges and culverts.

The motorway achieves 100 year Average Recurrence Interval (ARI) flood immunity (which means the road level is higher than the 100 year ARI flood level) for the full extent of the project with the exception of a low point south of the Duck Creek Bridge, where the project uses the existing bridge. At this location two of the three northbound lanes would be flooded in the 100 year ARI event, but the motorway would remain trafficable to emergency vehicles.

3.3 MACQUARIE RIVULET

3.3.1 DESIGN

A summary of the changes to the transverse drainage design for the revised design compared to the EIS design are provided along with results at each location for the Macquarie Rivulet catchment in **Table 3-1**. The transverse drainage structure locations are shown in **Figure 3-3**. It is noted that the bridge openings are measured between the toe of the abutments unless noted otherwise.

Table 3-1 Changes to the Transverse Drainage Design Approach – Macquarie Rivulet Catchment

Transverse Drainage Structure	Design (Operational Activity)	Comments
M1a	Culvert opening as per EIS.	Culverts is (1x) 1800 RCP.
M1 CH 18650	Bridge opening as per EIS.	Bridge has 200 m opening
M2 CH 19600	Bridge opening as per EIS (150 m), abutments shifted north 50 m to reduce impacts.	The bridge now spans deeper water within the floodplain which improves the conveyance under the bridge.
M2e (New)	A new culvert has been provided in the design to allow flood water to cross under the motorway during a flood.	This culvert allows water to flow between the floodplain to the west of the motorway and the floodplain to the east of the motorway.
M2a M2b M2c M2d (New) CH 20600	The Albion Park interchange has been changed to reduce the footprint and the northbound exit ramp has been moved to Tongarra Road. Due to the adjustments to the interchange, culvert M2a, which is under the northbound entry ramp, has been resized to (3x) 1200H x 3000W RCBC which is a reduction from the EIS design which was (5x) 1200H x 3000W RCBC. The two culverts under the motorway to the east of M2a (M2b and M2c) have been removed and an additional (4x) 1200H x 3000W culvert (M2d) has been included in the design under the southbound exit ramp to the west of the motorway. The adjustments to the culverts at this location cater for the changes to the motorway and ramp alignment and ensure that the level of immunity and impacts in this area meet the design criteria.	The northbound entry ramp and southbound exit ramp are not flooded in the 100 year ARI event.
M3 CH 21000	Bridge opening as per EIS.	Bridge has 90 m opening.
M4 CH 21200	Culvert opening as per EIS.	Culverts are (3x) 2400H x 3000W RCBC.
Tongarra Road CH 21450	The revised design is similar to the EIS at Tongarra Road with the addition of a new northbound exit ramp which connects to Tongarra Road.	The new northbound exit ramp achieves 5 year ARI immunity. This ramp connects to Tongarra Road where the immunity is increased from 2 year ARI to 5 year ARI as a result of the project. In the 10 year ARI event, Tongarra Road would be flooded at the intersection with the northbound exit ramp and at the existing low point to the west of the northbound exit ramp.
M5 CH 22100	Bridge, culvert opening and creek diversion as per EIS.	Bridge is 65 m span, culverts are (4x) 2100 RCP and creek diversion is 30 m wide at the bridge.

3.3.2 FLOOD IMMUNITY

The motorway achieves 100 year ARI flood immunity (which means the road level is higher than the 100 year ARI flood level) for the full extent of the project, with the exception of a low point south of the Duck Creek Bridge, where the project uses the existing bridge. The flood immunity of local roads is expected to remain the same with the exception of Tongarra Road where flood immunity in improved from the 2 year ARI event to the 5 year ARI event.

3.3.3 FLOOD IMPACTS

Flood impacts are generally less across the floodplain in the revised design when compared to the impacts of the EIS design.

Flood Level

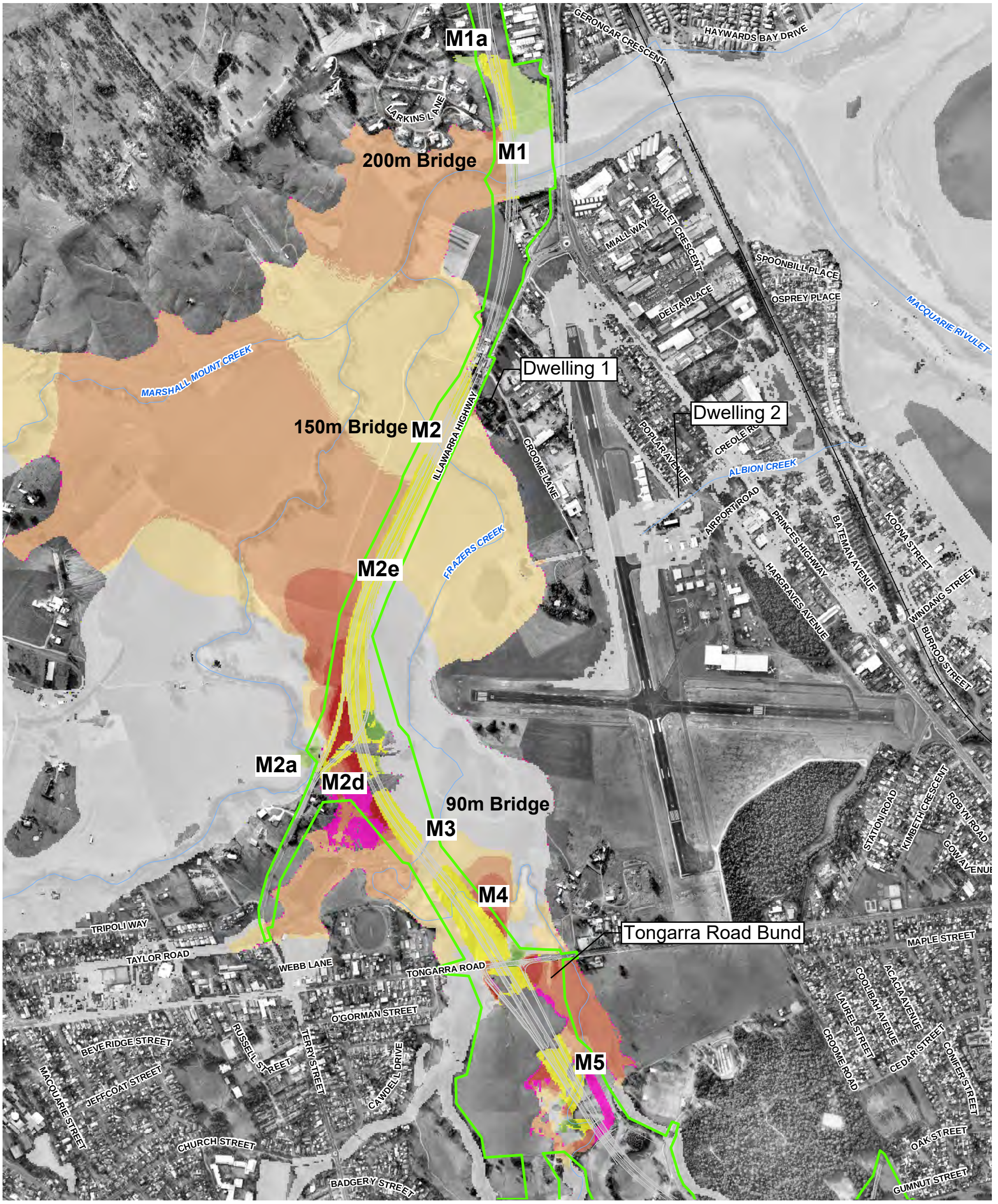
Changes in flood levels is illustrated in **Figure 3-3** and **Figure 3-4** for the 20 year ARI and 100 year ARI design storm events (respectively). Flood maps for all of the events modelled are included in **Appendix A**.

A summary of flood level changes in the Macquarie Rivulet catchment for the range of flood events modelled is provided in **Table 3-2**. Changes in flood level from the design presented in the EIS are shown and changes in water level from the revised design presented in the SPIR are shown in **bold**.

Table 3-2 Change in Water Levels – Macquarie Rivulet

Location		10 year ARI	20 year ARI	50 year ARI	100 year ARI	200 year ARI	500 year ARI	PMF
Macquarie Rivulet (M1), upstream of motorway at project boundary	EIS	+0.08m	+0.10m	+0.10m	+0.12m	+0.14m	+0.22m	+0.33m
	SPIR	**+0.07m**	**+0.08m**	**+0.09m**	**+0.10m**	**+0.11m**	**+0.19m**	**+0.38m**
Macquarie Rivulet (M1), downstream of motorway at project boundary	EIS	-0.02m	+0.00m	+0.01m	+0.01m	+0.00m	-0.07m	-0.52m
	SPIR	**-0.02m**	**-0.01m**	**-0.01m**	**+0.00m**	**+0.00m**	**-0.05m**	**-0.52m**
Confluence of Macquarie Rivulet and Frazers Creek	EIS	+0.04m	+0.06m	+0.08m	+0.09m	+0.11m	+0.16m	+0.24m
	SPIR	**+0.04m**	**+0.05m**	**+0.06m**	**+0.08m**	**+0.08m**	**+0.13m**	**+0.24m**
Frazers Creek (M2), upstream of motorway at project boundary	EIS	+0.04m	+0.05m	+0.06m	+0.07m	+0.08m	+0.11m	+0.06m
	SPIR	**+0.02m**	**+0.03m**	**+0.04m**	**+0.05m**	**+0.05m**	**+0.08m**	**+0.05m**
Frazers Creek (M2), downstream of motorway at project boundary	EIS	+0.04m	+0.05m	+0.07m	+0.09m	+0.10m	+0.15m	+0.21m
	SPIR	**+0.03m**	**+0.04m**	**+0.05m**	**+0.07m**	**+0.07m**	**+0.11m**	**+0.20m**
West of Albion Park interchange	EIS	+0.06m	+0.09m	+0.14m	+0.21m	+0.24m	+0.31m	+0.35m
	SPIR	**+0.00m**	**+0.01m**	**+0.04m**	**+0.11m**	**+0.14m**	**+0.25m**	**+0.32m**
East of Albion Park interchange	EIS	+0.03m	+0.03m	+0.05m	+0.06m	+0.07m	+0.09m	+0.02m
	SPIR	**+0.00m**	**+0.02m**	**+0.03m**	**+0.04m**	**+0.04m**	**+0.07m**	**+0.03m**
Frazers Creek (M3),	EIS	+0.07m	+0.06m	+0.01m	-0.01m	-0.01m	-0.02m	-0.06m

Location		10 year ARI	20 year ARI	50 year ARI	100 year ARI	200 year ARI	500 year ARI	PMF
upstream of motorway at project boundary	**SPIR**	**+0.05m**	**+0.05m**	**+0.01m**	**-0.01m**	**-0.01m**	**-0.02m**	**-0.04m**
Frazers Creek (M3), downstream of motorway at project boundary	EIS	+0.08m	+0.07m	+0.04m	+0.05m	+0.05m	+0.07m	+0.01m
	SPIR	**+0.03m**	**+0.02m**	**+0.03m**	**+0.03m**	**+0.04m**	**+0.06m**	**+0.02m**
Frazers Creek (M4), upstream of motorway at project boundary	EIS	+0.15m	+0.16m	+0.19m	+0.07m	+0.08m	+0.09m	+0.03m
	SPIR	**+0.17m**	**+0.17m**	**+0.19m**	**+0.04m**	**+0.05m**	**+0.07m**	**+0.03m**
Frazers Creek (M4), downstream of motorway at project boundary	EIS	+0.03m	+0.03m	+0.04m	-0.01m	-0.01m	-0.01m	-0.05m
	SPIR	**+0.02m**	**+0.04m**	**+0.01m**	**+0.00m**	**-0.01m**	**-0.01m**	**-0.03m**
Frazers Creek, upstream of Tongarra Road at project boundary	EIS	+0.19m	+0.22m	+0.22m	+0.19m	+0.15m	+0.04m	-0.09m
	SPIR	**+0.20m**	**+0.22m**	**+0.22m**	**+0.19m**	**+0.12m**	**+0.03m**	**-0.10m**
Frazers Creek, downstream of Tongarra Road at project boundary	EIS	+0.02m	+0.06m	+0.03m	+0.03m	+0.03m	+0.02m	+0.01m
	SPIR	**+0.03m**	**+0.06m**	**+0.03m**	**+0.03m**	**+0.01m**	**+0.02m**	**-0.03m**
Tributary west of Motorway, upstream of Tongarra Road at project boundary	EIS	+0.00m	-0.01m	-0.01m	-0.01m	-0.01m	-0.01m	-0.05m
	SPIR	**+0.00m**	**+0.01m**	**+0.02m**	**-0.01m**	**-0.01m**	**-0.01m**	**-0.03m**
Tributary west of Motorway, downstream of Tongarra Road at project boundary	EIS	+0.00m	+0.00m	+0.01m	-0.01m	-0.01m	-0.01m	-0.05m
	SPIR	**+0.01m**	**+0.02m**	**+0.01m**	**+0.00m**	**-0.01m**	**-0.01m**	**-0.03m**



LEGEND

Site Boundary	> 0.4	-0.05 to -0.02
Concept Design	0.25 to 0.4	-0.1 to -0.05
Major Watercourses	0.1 to 0.25	-0.25 to -0.1
Railway	0.05 to 0.1	-0.4 to -0.25
Change in Water Level (m)	0.02 to 0.05	< -0.4
Newly Flooded	-0.02 to 0.02	No Longer Flooded

MACQUARIE RIVULET 20 YEAR ARI CHANGE IN WATER LEVEL

ALBION PARK RAIL BYPASS
NSW ROADS AND MARITIME SERVICES

1:12,500 @ A3

0 90 180 360
Metres

COORDINATE SYSTEM:
GDA 1994 MGA ZONE 56

REVISION NUMBER: 03
AUTHOR: CL

DATE: JUNE 9, 2017

Transport Roads & Maritime Services

Hyder Cardno JOINT VENTURE

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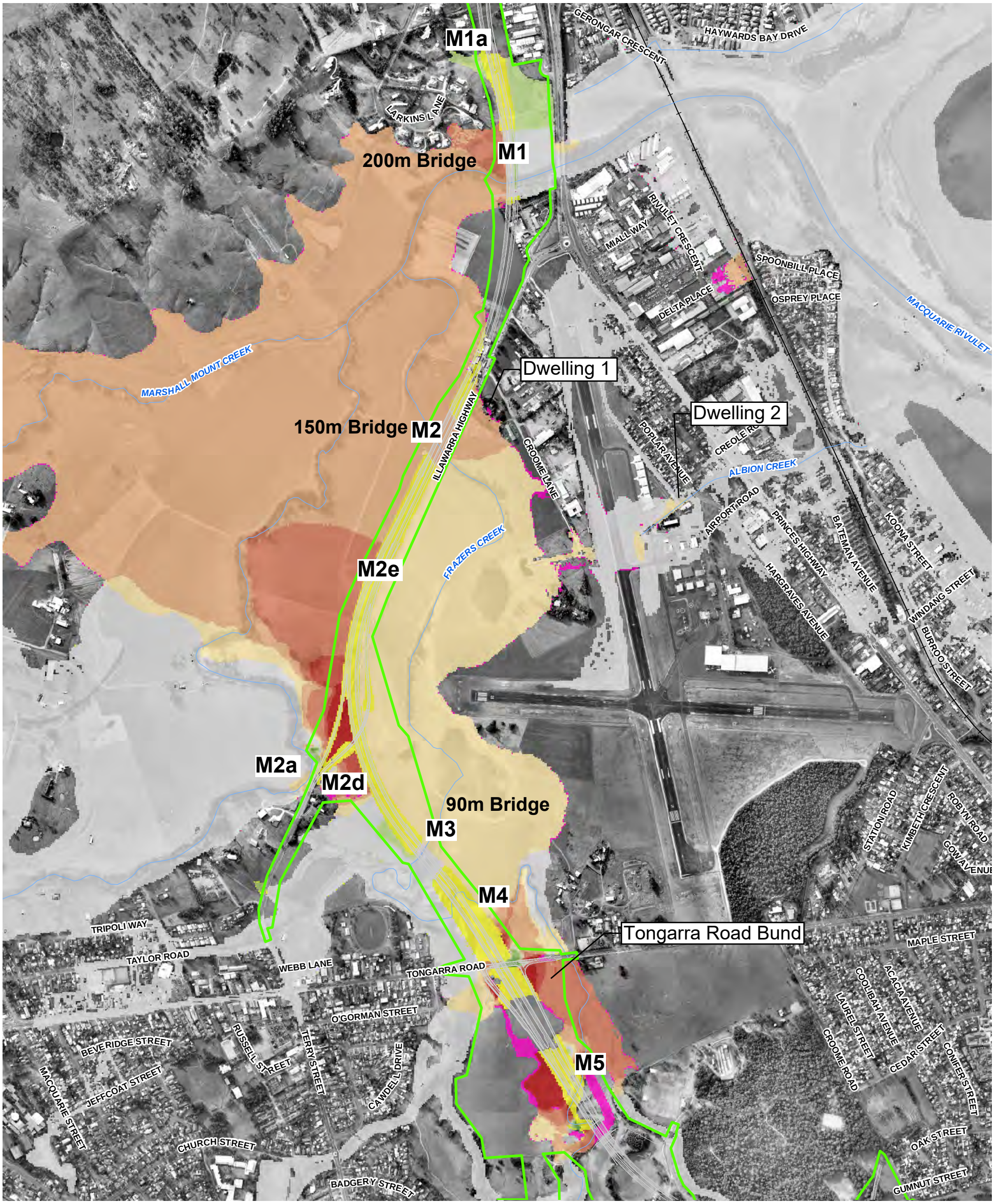
Figure 3-3



LEGEND

- Site Boundary
- Concept Design
- Major Watercourses
- Railway
- **Change in Water Level (m)**
- Newly Flooded
- > 0.4
- 0.25 to 0.4
- 0.1 to 0.25
- 0.05 to 0.1
- 0.02 to 0.05
- -0.02 to 0.02
- -0.05 to -0.02
- -0.1 to -0.05
- -0.25 to -0.1
- -0.4 to -0.25
- < -0.4
- No Longer Flooded

MACQUARIE RIVULET 100 YEAR ARI CHANGE IN WATER LEVEL

ALBION PARK RAIL BYPASS
NSW ROADS AND MARITIME SERVICES

1:12,500 @ A3

0 90 180 360
Metres

COORDINATE SYSTEM:
GDA 1994 MGA ZONE 56

REVISION NUMBER: 03
AUTHOR: CL

DATE: JUNE 9, 2017

Transport Roads & Maritime Services

Hyder Cardno JOINT VENTURE

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Figure 3-4

Velocity

Some increases in the velocity of flood flows are predicted within the floodplain between the main alignment and the Illawarra Regional Airport. This is due to the alignment directing the flow in the north-south direction and reducing flow in the east-west direction. The change in flow velocity is relatively minor, with velocities remaining below 1m/s across the majority of the Macquarie Rivulet floodplain.

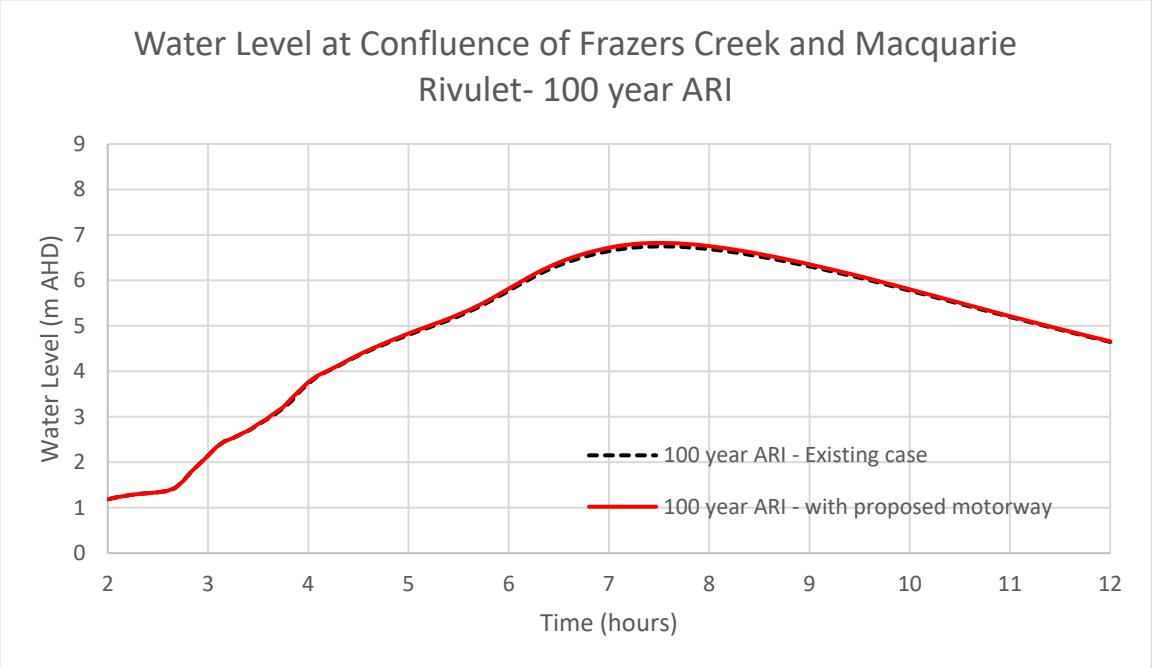
When comparing the locations affected by flow velocities of over 1m/s under the existing condition and with the proposed works, velocities are decreased in some locations, and in others are increased by up to 20%. This is within the project design criteria. Increases in velocity greater than 20% occur at the inlet and outlet of culverts and at bridge crossings. An increase in velocity is expected at these structures due to the contraction of flow. Scour protection measures for structures would be designed at the detailed design phase.

Flood velocity maps for the Macquarie Rivulet for the revised design are provided in **Appendix A** for the full range of storm events modelled.

Duration

Flood duration within the Macquarie Rivulet catchment is not substantially changed as a result of the project.

The flood level at the confluence of Frazers Creek and Macquarie Rivulet during a nine hour 100 year ARI event is presented in the following chart. This graph demonstrates that flood waters would rise and fall in a similar manner in the existing case and in the proposed case. For example, in the existing case flood waters are greater than five metres AHD for six hours and five minutes during the nine hour 100 year ARI event. In the proposed case this is increased by five minutes to six hours and ten minutes.



Direction

In major (less frequent) storms, some changes in flow direction are predicted within the Macquarie Rivulet floodplain. This is due to the road embankment, which crosses the floodplain at the location of the existing Illawarra Highway. In minor (frequent) storms, existing flow paths are maintained, with the exception of the proposed watercourse diversion at location M5.

The direction of flow within the Macquarie Rivulet floodplain is influenced by the timing of flows from Frazers Creek and Macquarie Rivulet. In the existing 100 year ARI event, water from Frazers Creek flows northwest across the floodplain prior to the peak of flooding in the Macquarie Rivulet. A few hours later the flow from Macquarie Rivulet peaks and flows north across the floodplain. Due to existing hydraulic constraints which limit outflow to Lake Illawarra, water in Frazers Creek flows upstream for a period of time, before draining downstream. This flood behaviour is predicted to continue with the revised design.

Impacts to Watercourses

For the majority of watercourses, the direction and velocity of flows is not expected to change considerably from the existing condition for the design flood events modelled for the revised design. The main risk of bed and / or bank instability would be associated with the adjustment of Frazers Creek at location M5 and adjacent to the bridge over the Macquarie Rivulet (Bridge M1), which may require piers within the watercourse. At these locations there is a risk of scour of the bed and bank erosion, resulting in a decline in water quality and sedimentation of the watercourse. An assessment of the bed and bank stability and the potential for scour would be undertaken as part of the detailed design, and appropriate scour protection works incorporated into the design to reduce the potential for scour to occur.

3.3.4 PERFORMANCE AGAINST CRITERIA

The following flood immunities and changes in water levels have been achieved for the revised design in accordance with the design criteria:

- 100 year ARI immunity achieved on the motorway within the Macquarie Rivulet catchment
- 100 year ARI immunity achieved on Albion Park interchange northbound entry ramp and southbound exit ramp.
- 100 year ARI increase in water level at Dwelling 2 is 20 millimetres (see **Figure 3-4**) which is less that the 54 millimetres impact presented in the EIS
- 10 year ARI immunity is achieved on the southbound entry ramp. This ramp connects to Tongarra Road where the immunity is increased from 2 year ARI to 5 year ARI as a result of the project
- 5 year ARI immunity is achieved on the northbound exit ramp. This ramp connects to Tongarra Road where the immunity is increased from 2 year ARI to 5 year ARI as a result of the project
- In the 100 year ARI event, increases in flood levels in agricultural land are below 250 millimetres with the exception of an area of 0.88 hectares that has impacts up to 400 millimetres in the 100 year ARI event, which is within the design criteria. This 0.88 hectare area is on private agricultural land to the west of the northbound entry ramp at the Albion Park interchange. The existing 100 year ARI flooding ranges from 0.13 metres to 1.40 metres and increases to a range of 0.45 metres to 1.7 metres within this area.
- In the 20 year ARI event, increases in flood levels in agricultural land are below 250 millimetres with the exception of an area of 0.47 hectares that has impacts up to 400 millimetres, which is within the design criteria.
- Flood velocities within the Macquarie Rivulet floodplain are not substantially changed as a result of the project.
- 100 year ARI increase in water level at Dwelling 1 (see **Figure 3-4**) of 35 millimetres compared to 83 millimetres in the EIS

- The project still results in increased flooding over the floor of Dwelling 1, however this is within the design criteria and is less than the impacts presented in the EIS. The proposed impacts can still be mitigated using the mitigation methods proposed in the EIS.

3.3.5 FLOOD RESULTS WITH 2016 DRAFT MODEL

As discussed in **Section 2.3**, the Macquarie Rivulet flood model used for the EIS was used in the assessment of the revised design. As a sensitivity test, the revised design was analysed using the 2016 draft Macquarie Rivulet flood model. Due to the lower rainfall used in this model, the flood levels are lower across the floodplain and the impacts due to the revised design is lower compared to the impacts predicted by the flood model used in the EIS.

The 2016 draft flood model predicts that the project would result in the water level at Dwelling 1 increasing by 51 millimetres from 6.65 metres AHD to 6.70 metres AHD in the 100 year ARI, which is lower than the floor level of 6.84 metres AHD. The impacts predicted by the 2016 draft model at Dwelling 1 are lower compared to the impacts predicted by the model used in the EIS. The draft model predicts that the revised design would result in no changes in water level at Dwelling 2 and therefore no flood impact at this location.

Maps showing change in flood levels predicted by the 2016 draft Macquarie Rivulet flood model are included in **Appendix B**.

3.4 HORSLEY CREEK

There are no changes to the design which impacts on flooding within the Horsley Creek floodplain. The flood impacts and performance against criteria within the Horsley Creek catchment are as per the EIS.

3.5 POTENTIAL FUTURE SCENARIOS

3.5.1 CLIMATE CHANGE

A climate change assessment was undertaken to assess the flood immunity of the project under a future climate change scenario in accordance with the design criteria. The assessment adopted a 20% increase in rainfall intensity and a 0.91m increase in water levels at Lake Illawarra under a future climate change scenario. These values are consistent with the values used in the climate change assessment undertaken by WBM-BMT for the Duck Creek Flood Study and with parameters typically adopted for the assessment of climate change in flood studies. Climate change predictions are based on mid-range estimates provided in the Floodplain Risk Management Guideline titled *Practical Consideration of Climate Change* (DECC, 2007).

In the Duck Creek and Horsley Creek catchments, the projected increase in rainfall intensity is the primary cause of flood impacts on the alignment, while the increase in Lake Illawarra water levels does not substantially impact flooding for the proposed alignment. In the Macquarie Rivulet catchment, the increase in Lake Illawarra water levels and the increase in rainfall intensity combine to result in increased flooding at the location of the proposed alignment, in the climate change scenario.

For all catchments, the motorway achieves 20 year ARI flood immunity under the climate change scenario. Refer to climate change and land use change map in **Appendix A**.

Proxy Assessment

In accordance with the requirements of the Secretary's Environmental Assessment Requirements, the effect of the proposal (including fill) on existing flood behaviour was modelled for the range of design events, with the use of the 200 year ARI and 500 year ARI design flood events as proxies for assessing sensitivity to an increase in rainfall intensity due to climate change and land use change scenarios.

It is expected that increases in rainfall intensities will occur under climate change conditions. The 200 year ARI and 500 year ARI events are therefore used to assess the flood immunity of the project under a potential future climate change scenario. For the 200 year ARI event, this is roughly equivalent to a 10-15% increase in rainfall intensity when compared to the existing condition (i.e. no climate change) 100 year ARI flood event. For the 500 year ARI event, this is roughly equivalent to a 25-30% increase in rainfall intensity when compared to the existing condition 100 year ARI flood event.

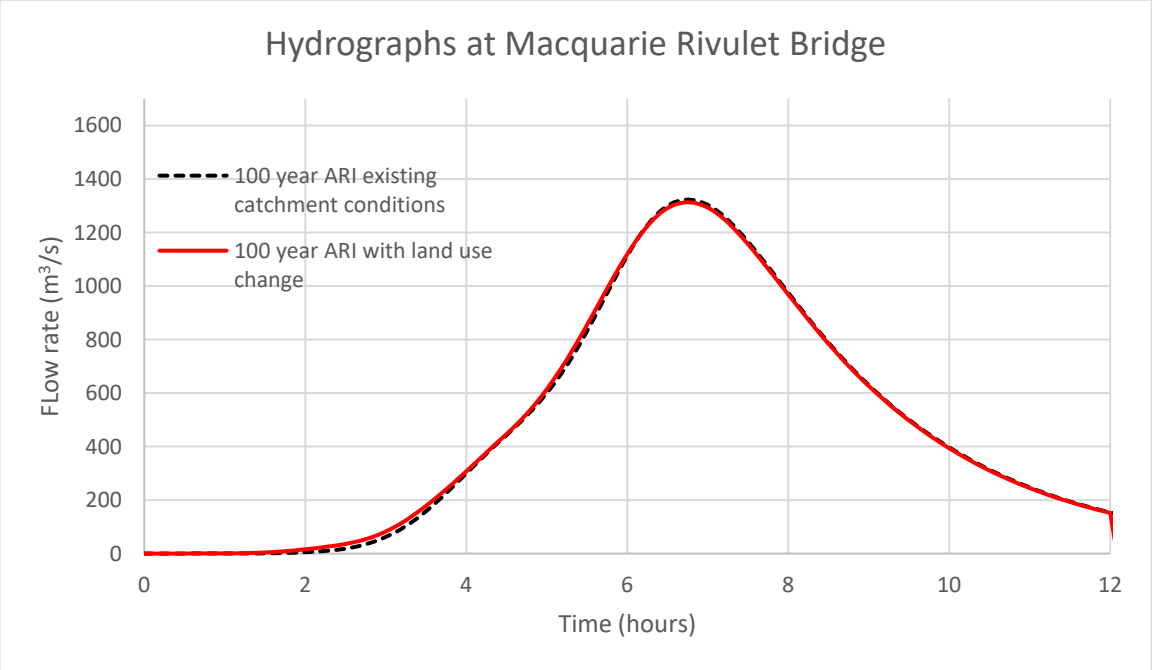
In the 200 year ARI flood event, the motorway is flooded at the Duck Creek Bridge by 0.56m, however, the rest of the motorway is not predicted to flood. In the 500 year ARI flood event, the motorway is flooded at the Duck Creek Bridge by 0.91m and between the Macquarie Rivulet and Frazers Creek bridges by 0.27m.

The motorway is not designed to achieve flood immunity in the 200 or 500 year ARI events, and is predicted to be flooded in these events. When comparing the existing and proposed conditions, the impacts are predicted to be greater when compared to the impacts in the 100 year ARI event. Water level change maps and depth maps for the 200 and 500 year ARI events are included in **Appendix A**.

3.5.2 LAND USE CHANGE

A number of major urban development projects are anticipated within the catchments, generally upstream of the alignment. Hydrological impacts associated with these developments (i.e. increase in impervious area, resulting in increased runoff volumes) were estimated in the EIS based on current zoning plans, which were used to create a land use change scenario hydrological model.

The hydrological model was updated to include the effects of the predicted land use change. The 100 year ARI flow rate within Macquarie Rivulet at the location of the proposed motorway is shown in the following graph and has been based on the revised design. While the timing of flows changes slightly (e.g. at the start of the storm, runoff occurs quicker), this graphs illustrates that future development within the Macquarie Rivulet catchment results in no substantial change in peak flow rate in the 100 year ARI event.



The results of the land use change analysis show that peak flows within the Macquarie Rivulet are not predicted to change substantially due to the cumulative impacts of the project and future development areas within the catchment. The future land use changes do not have any major impact on peak runoff rates and is not predicted to contribute to an accumulation of flooding impacts when considered in conjunction with the project. The cumulative impacts of the proposed motorway and land use change (as modelled) is therefore likely to be no worse than the impacts of the motorway as presented.

It is noted that dry catchment conditions (Initial loss greater than 0mm) was assumed for the existing scenario in assessing the impacts of land use change. Losses used were 20mm for initial loss and 2-2.5mm/hr continuing loss. The land use change assessment is therefore fully accounts for the increase in impervious area.

4 ASSESSMENT OF CONSTRUCTION IMPACTS

4.1 RELEVANT CONSTRUCTION ACTIVITIES

The construction related activities listed in the EIS are still relevant as there are not proposed to be any different construction activities as a result of the design changes that weren't already addressed in the EIS.

4.2 CONSTRUCTION RELATED IMPACTS

The construction related flooding impacts are unchanged from the EIS.

4.3 MANAGEMENT OF CONSTRUCTION RELATED IMPACTS

There are no changes to the measures proposed in the EIS for the management of construction related impacts.

5 EMERGENCY MANAGEMENT, EVACUATION AND ACCESS

The revised design does not result in any changes to the assessment of emergency management, evacuation and access provided in the EIS.

Parts of Albion Park are very prone to flooding in minor storm events and Albion Park can be isolated in minor storm events due to roads being inundated. The project offers significant improvements to some evacuation routes during floods due to improved flood immunity. **Figure 5-1** shows the level of service of the project in existing and proposed conditions.

5.1 FLOOD IMMUNITY

The motorway achieves 100 year ARI immunity for the extent of the project with the exception of the low point south of the Duck Creek bridge. At this location, two of the three northbound lanes would be flooded in the 100 year ARI event. The flood immunity achieved at different locations of the Motorway are shown in **Figure 5-2**.

10 year ARI immunity is achieved on the central interchange southbound entry ramp. This ramp connects to Tongarra Road where the immunity is increased from 2 year ARI to 5 year ARI as a result of the project. 5 year ARI immunity is achieved on the central interchange northbound exit ramp. This ramp also connects to Tongarra Road where the immunity is increased from 2 year ARI to 5 year ARI as a result of the project. 100 year ARI immunity is achieved on the remainder of the new motorway ramps.

It is noted that the flood immunity criteria adopted for the project is based on comparing the flood levels and the motorway levels and does not account for freeboard. The revised design is generally achieved 0.5m freeboard to the 20 year ARI flood levels. The flood levels, and freeboard achieved at the critical points along the motorway are summarised in **Table 5-1**.

Table 5-1 Freeboard Details

Location	20 year ARI Flood Level	100 year ARI Flood Level	Edge of Lane Level	Freeboard to 20 year ARI Level	Freeboard to 100 year ARI Level
Duck Creek Bridge, low point	8.55	9.52	9.267	0.72m	nil
South of Macquarie Rivulet Bridge, low point	6.07	6.87	7.014	0.94m	0.14m
Central Interchange, low point	6.23	7	7.93	1.70m	0.93m
South of Tongarra Rd, low point	10.05	10.98	13.135	3.09m	2.16m
Green Meadows Basin, low point	24.21	24.51	24.657	0.45m	0.15m

5.2 STOCK MOVEMENT

A dairy farm currently operates adjacent to the Illawarra Highway within the Macquarie Rivulet catchment. The dairy currently has access across the Illawarra Highway, which allows cattle to be moved to high ground to the west of the Highway and the diary to continue operation during a flood. The alignment of the project would require that the current diary infrastructure be removed and reduces the area of high ground available for cattle to shelter during a flood. In a 20 year ARI event, the area of flood free land between the Illawarra Highway and Macquarie Rivulet is reduced from 7.6 hectares to 3.6 hectares (up from 3.3 hectares in the EIS) as a result of the project. It is noted that this reduction in flood free area is primarily due to the land required for the project, not due to changes in the flood extent. The diary would no longer occupy its current location and the need for a flood refuge for stock has a reduced benefit in this location as it would not be located next to the dairy. Access under the motorway to the high ground is provided at Frazers Creek under the bridge at this location. This access utilises the existing Illawarra Highway crossing of Frazers Creek and would be severed due to minor flooding multiple times a year and for durations greater than a day.

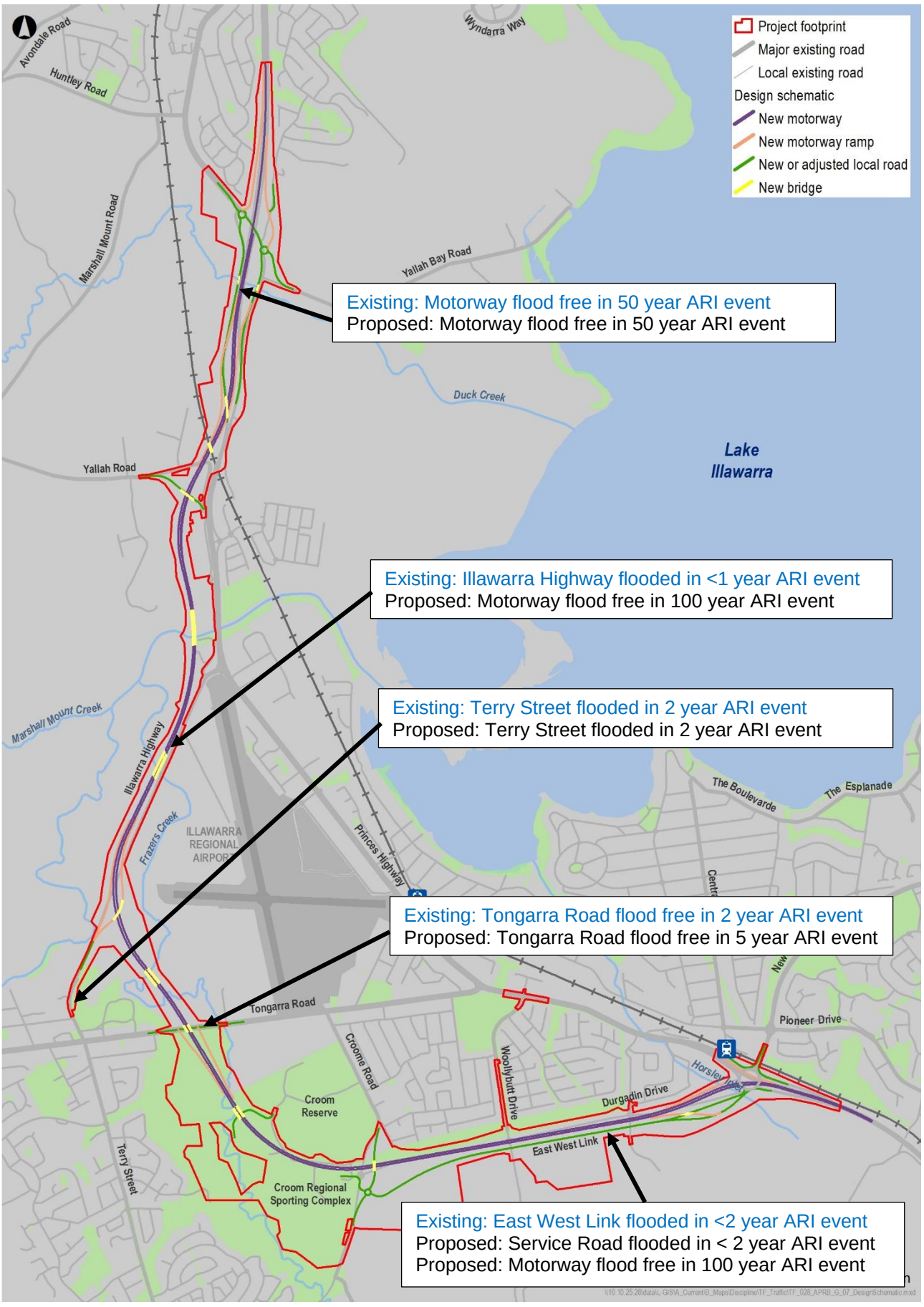


Figure 5-1 Existing and Proposed Flood Access

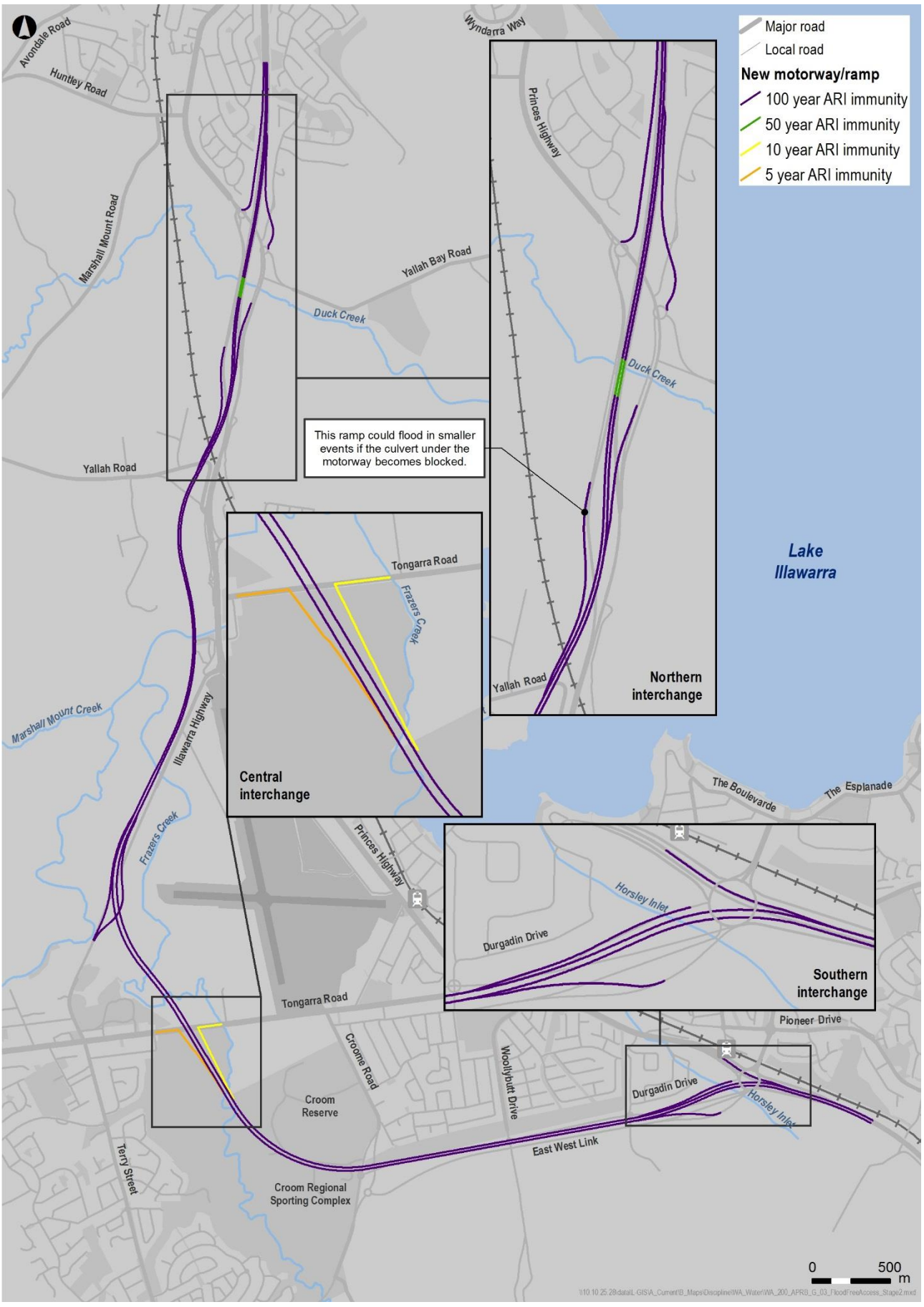


Figure 5-2 Flood Immunity on Motorway

6 CHANGES TO MITIGATION MEASURES

Flood modelling has been undertaken iteratively throughout the progression of the design to identify impacts to hydrology and flooding and to ensure these impacts are minimised or eliminated where possible.

6.1 FLOOD CONVEYANCE

Initially, flood modelling was undertaken to reflect numerous design options with various alignment and interchange configurations. Once selected, the preferred option was continually refined to minimise increases to flood levels while achieving a high level of flood immunity. This was achieved primarily through refinement of the bridge locations, bridge spans and culvert sizes, and also through optimisation of elements such as embankment slopes and the vertical alignment.

Changes to flood conveyance structures in the revised concept design compared to the EIS design are shown in **Table 6-1**. Structures removed as part of the revised design are shown with a ~~strikethrough~~ and new structures are shown in **bold**.

Table 6-1 Summary of Flood Structures

Transverse Drainage Structure	Description	Sizing (bridge sizes represent the toe to toe measurement between bridge abutments)	Comments
D1 CH 16320	Duck Creek	45 m bridge	No change
D2 CH 16830	Duck Creek tributary	6x 900 mm RCP culverts	No change
D3 CH 17050	Duck Creek tributary	1x 2100 mm RCP culvert	No change
D5 CH 17750	Duck Creek tributary	(2x) 1200H x 2400W RCBC under the Yallah Road upgrade	No change
M1 CH 18650	Macquarie Rivulet	200 m bridge opening (measured at the toe of abutment)	No change
M2e	**Floodplain**	**(3x) 3000H x 3000W RCBC under motorway**	
M2 CH 19600	Frazers Creek	150 m bridge opening (measured at the toe of the abutment)	Shifted 50 m north
M2a ~~M2b~~ ~~M2c~~ **M2d** CH 20600	Floodplain	~~(5x)~~ **(3x)** 1200H x 3000W RCBC culvert under ramp ~~(2x) 1200H x 3000W RCBC culvert under motorway~~ ~~(2x) 1200H x 3000W RCBC culvert under motorway~~ **(4x) 1200H x 3000W RCBC culvert under ramp**	Revised to cater for adjustments to Albion Park interchange
M3 CH 21000	Frazers Creek	90 m bridge opening (measured at the toe of abutment)	No change

Transverse Drainage Structure	Description	Sizing (bridge sizes represent the toe to toe measurement between bridge abutments)	Comments
M4 CH 21200	Frazers Creek	(3x) 2400H x 3000W RCBC culvert	No change
M5 CH 22100	Frazers Creek	65 m bridge opening over 30 m wide creek diversion (4x) 2100 mm RCP culverts 200 m north of the proposed bridge	No change
H1a H1b H1c H1d CH 23100	Horsley Creek tributary	(1x) 1200H x 1500W RCBC under service road (1x) 1200H x 3000W RCBC under service road (1x) 1500H x 3000W RCBC under motorway (1x) 1500H x 3000W RCBC under Croome Road New detention basin	No change
H2 H3 H4 H5 CH 24000 – CH 24700	Green Meadows Basin	1x 900 RCP 1x 900 RCP 1200 RCP culvert 1350 RCP culvert Three sets of (2x) 1500H x 3300W RCBC) at spillway	No change
H6 CH25500	Horsley Creek	(1x) 1800H x 3600W RCBC culvert	No change

6.2 POST EIS MITIGATIONS

In addition to the mitigation measures incorporated into the design, the mitigation and management measures listed in **Table 6-2** would be implemented to avoid, minimise or manage impacts of the project on hydrology and flooding. The mitigation measures presented below supersede the mitigation measures presented in the Hydrology and Flooding Technical Report and the EIS.

Table 6-2 Management of Impacts Relating to Hydrology and Flooding

Issue	ID No.	Environmental management measure	Responsibility	Timing
Impacts on flood behaviour during construction	HF01	Temporary works will consider flood impacts during construction including flood duration as well as warning and response times. Should construction staging require a temporary departure from the design (e.g. higher embankments for preloading, temporary diversions or temporary crossings), flood impacts will be assessed utilising the proposed design before finalising the approach.	Contractor	Construction
	HF02	Where stockpiles are to be located in the floodplain, they will be located and sized to ensure that temporary impacts are not greater than those specified in the design criteria.	Contractor	Construction
Impact of flooding on construction activities	HF03	For ancillary sites with flood immunity of less than 20 year ARI, a flood contingency plan will be prepared. This plan will consider likelihood of flooding, evacuation routes, warning times, and potential impacts from the site flooding. It will include, but not be limited to: ▪ Any monitoring requirements to ensure advance notice of a flood event ▪ Procedures to be implemented in the event of a flood ▪ Details of the required training and staff inductions.	Contractor	Construction
Bed and bank stability during construction	HF04	Temporary watercourse crossings will be designed to minimise impacts on hydrology, aquatic habitat and fauna by: ▪ Maintaining low-flow conditions ▪ Being designed with consideration of the potential for flooding during construction ▪ Be removed and the area rehabilitated following completion of construction. These crossings will not be used for Class 1 waterways, and will take into consideration the requirements of the Policy and guidelines for fish habitat conservation and management (NSW Department of Primary Industries, 2013).	Contractor	Construction

Issue	ID No.	Environmental management measure	Responsibility	Timing
Bed and bank stability during construction	SW01	Industry standard erosion and sediment controls will be designed and implemented in accordance with the following specifications and guidelines: ▪ Managing Urban Stormwater: Soils and Construction (Landcom, 2004) ▪ Roads and Maritime's Erosion and Sedimentation Management Procedure (PN143) ▪ Roads and Maritime's Soil and Water Management Specification (G38) ▪ The NSW Office of Water's guidelines for Controlled Activities ▪ Volume 2D Main Road Construction published (DECC, 2008). These controls will be established before the start of construction and maintained in effective working order for the duration of the construction period until the site is restored.	Contractor	Construction
	SW02	The construction environmental management plan will include a construction soil and water quality management plan to manage potential impacts on soils and receiving watercourses, to include, but not be limited to: o Objectives and targets for soil and water quality management o Information on the relevant statutory and other requirements relating to soils and water quality, including any permits or licences required for the project o Details of any consultation requirements under the Plan o An overview of the existing environment and potential impacts related to the construction works o Measures to manage impacts of the project including in relation to: o Soils, erosion and sedimentation o Stockpile management o Spoil and fill management o Surface water quality o Groundwater levels o Discharges from sedimentation basins, acid sulfate soil treatment areas and groundwater de-watering	Contractor	Construction

Issue	ID No.	Environmental management measure	Responsibility	Timing
		○ Acid sulfate soils and contaminated lands ○ Significant weather events (such as heavy rainfall or flooding) ○ Re-fuelling of vehicles and other equipment and accidental spills ○ Unexpected finds such as asbestos or contaminated fill ▪ A surface water quality monitoring program that as a minimum addresses the requirements of the project Environment Protection Licence ▪ Auditing and reporting requirements ▪ Site inductions and training for construction personnel in the implementation of the Plan. The strategy will be prepared in accordance with the relevant industry standard guidelines and procedures.		
Frazers Creek adjustment	HF05	The Frazers Creek adjustment shall be designed and constructed in a way that mimics natural flow conditions, creates habitat for aquatic animals, and incorporates locally native riparian vegetation, in accordance with the requirements of the Policy and guidelines for fish habitat conservation and management (NSW Department of Primary Industries, 2013) in consultation with NSW Fisheries and the NSW Office of Water.	Contractor	Detailed design
Operational phase impacts on flood behaviour	HF06	The potential negative flood impacts on Properties 1, 2 (Dwelling 1) and 3 (Dwelling 2) will be reviewed during the detailed design by flood modelling to seek to further avoid or minimise impacts. If the properties are still impacted, and if mitigation is required, investigation into site-specific flood management measures will be undertaken in consultation with the landowner.	Roads and Maritime / Contractor	Detailed design
Bed and bank stability during the operational phase	HF07	A geomorphological assessment will be undertaken at the detailed design phase for all watercourses, with an aim to minimise changes to natural stream flow and velocity. This assessment will consider impacts on stream geomorphology from regular stream flows as a result of increased flow velocities, changes to direction of flow and instream structures.	Contractor	Detailed design
	HF08	The detailed design of bridges and culverts will consider the requirement for fish passage and scour protection under the Policy and Guidelines for Fish Habitat Conservation and Management (NSW Department of Primary Industries, 2013) and the NSW Office of Water guidelines for Controlled Activities.	Contractor	Detailed design

Issue	ID No.	Environmental management measure	Responsibility	Timing
Reconfiguration of Green Meadows detention basin	HF09	A dam break assessment will be undertaken to assess the risk associated with the Green Meadows Basin.	Contractor	Detailed design
Flood access	HF10	Consultation would be undertaken where access to farms is to be temporarily impacted during construction. Property access will be maintained or alternative arrangements made in consultation with the affected landowners.	Contractor	Construction
Emergency access and evacuation during construction	HF11	Consultation would be undertaken with the emergency services and the SES once the construction staging and program has been developed, to discuss any potential impacts on emergency access and flood evacuation, and (if required) alternative access / egress routes during construction.	Roads and Maritime	Construction

7 CONCLUSION

This hydrology and flooding assessment has provided detail on how the revised design would impact on flooding and has compared the proposed impacts to the impacts predicted for the EIS design. In summary:

- Extension of one culvert in Brooks Creek can be done in a way to maintain the existing flood immunity at that location
- Impacts in Duck Creek are unchanged from the EIS
- Impacts within Macquarie Rivulet are generally slightly less than impacts predicted from the EIS design
- Impacts within Macquarie Rivulet are within the design criteria
- Within the Macquarie Rivulet, the motorway achieves 100 year ARI immunity
- Impacts in Horsley Creek are unchanged from the EIS.

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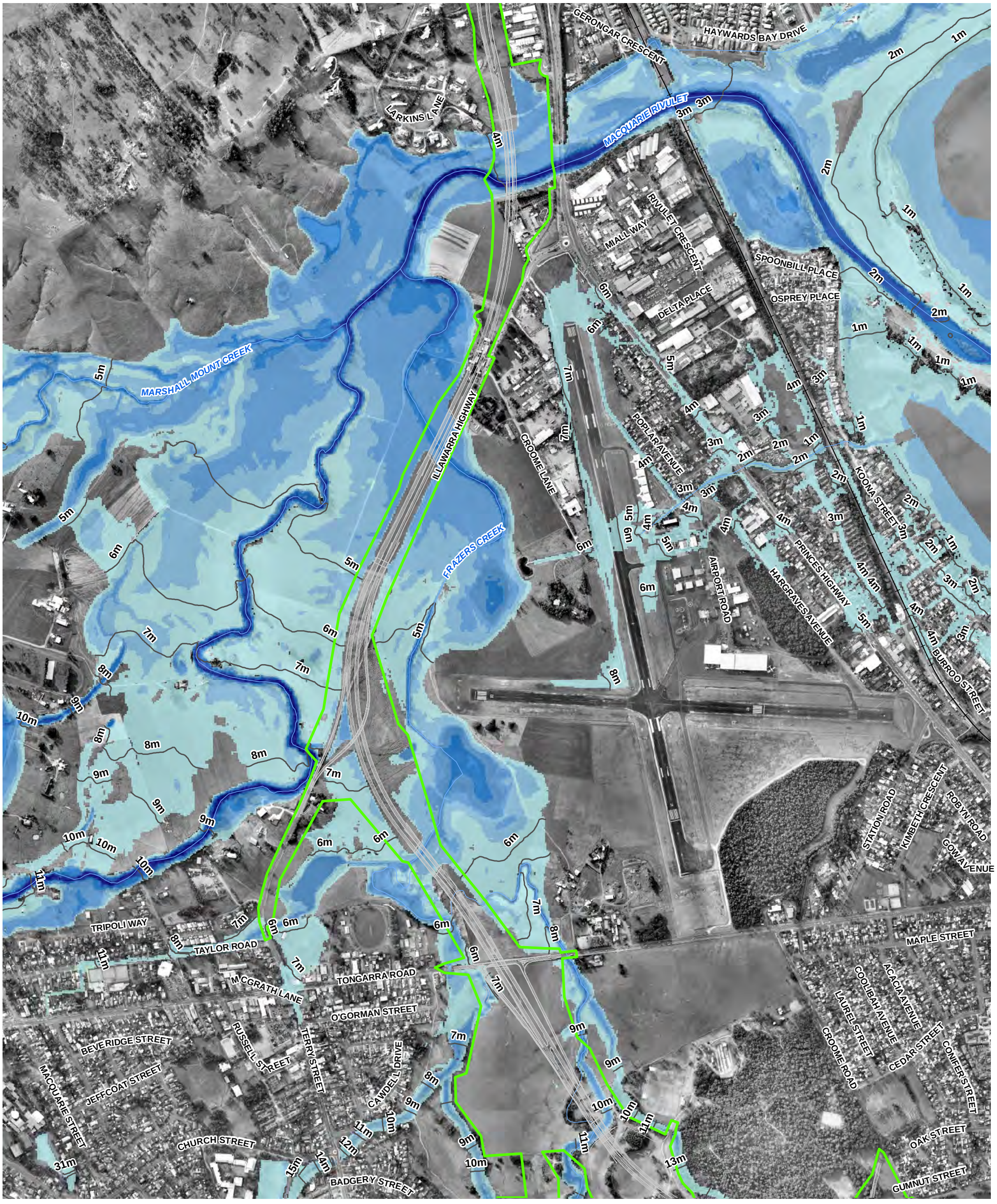
APPENDIX A

FLOOD MAPS



LEGEND

- Site Boundary
- Concept Design
- Major Watercourses
- Railway
- 1m Flood Contours

Flood Depth (m)

- 0 - 0.5
- 0.5 - 1
- 1 - 2
- 2 -3
- 3 - 4
- 4 - 5
- >5

1:12,500 @ A3

0 90 180 360
Metres

MACQUARIE RIVULET 2 YEAR ARI FLOOD DEPTH – WITH PROPOSED BYPASS

ALBION PARK RAIL BYPASS
NSW ROADS AND MARITIME SERVICES

COORDINATE SYSTEM:
GDA 1994 MGA ZONE 56

REVISION NUMBER: 03
AUTHOR: CL

DATE: JUNE 9, 2017

Transport Roads & Maritime Services

Hyder Cardno JOINT VENTURE

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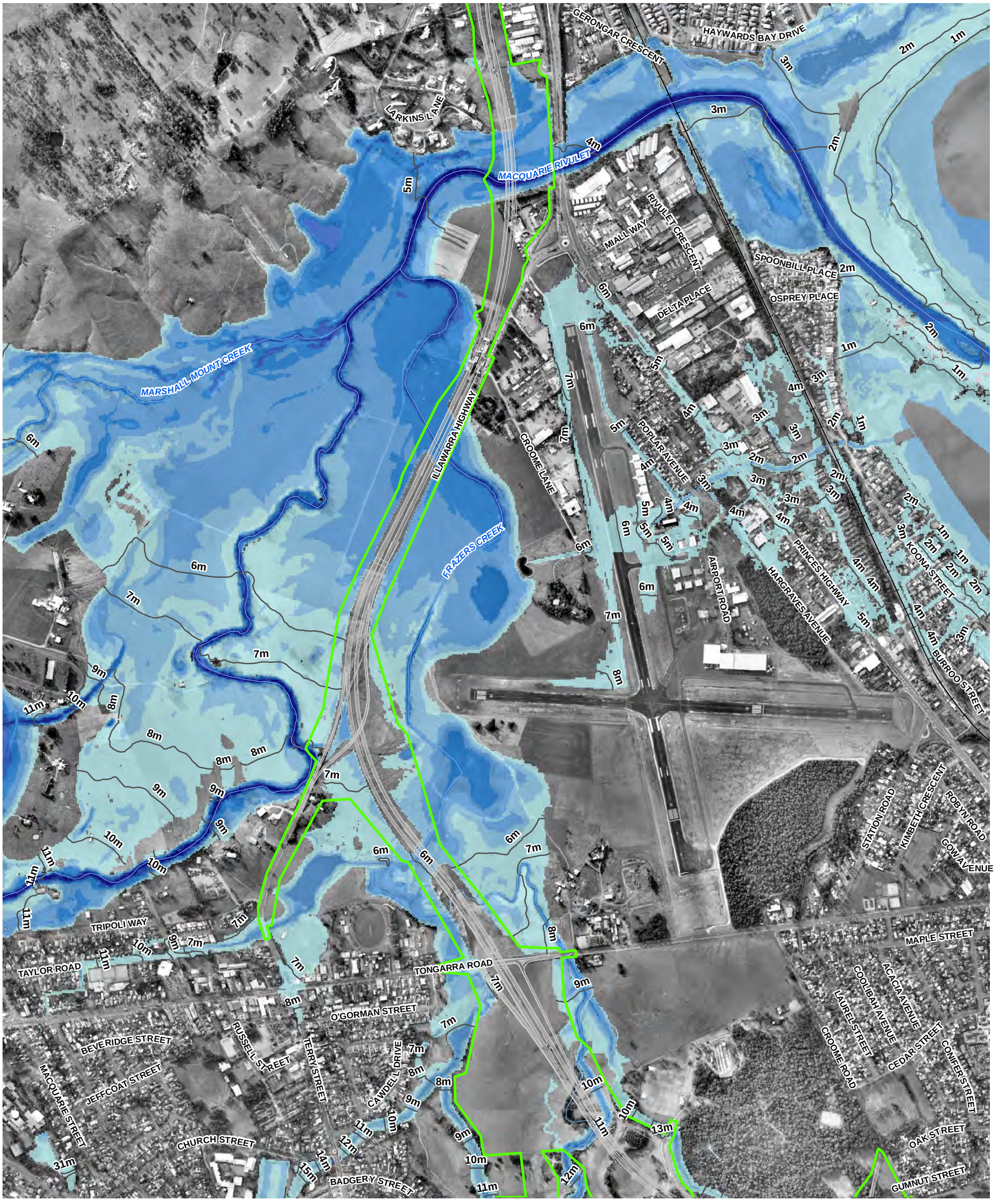

LEGEND

- Site Boundary
- Concept Design
- Major Watercourses
- Railway
- 1m Flood Contours

Flood Depth (m)

- 0 - 0.5
- 0.5 - 1
- 1 - 2
- 2 -3
- 3 - 4
- 4 - 5
- >5

1:12,500 @ A3

0 90 180 360
Metres

MACQUARIE RIVULET 5 YEAR ARI FLOOD DEPTH – WITH PROPOSED BYPASS

ALBION PARK RAIL BYPASS
NSW ROADS AND MARITIME SERVICES

COORDINATE SYSTEM:
GDA 1994 MGA ZONE 56

REVISION NUMBER: 03
AUTHOR: CL

DATE: JUNE 9, 2017

Transport Roads & Maritime Services

Hyder Cardno JOINT VENTURE

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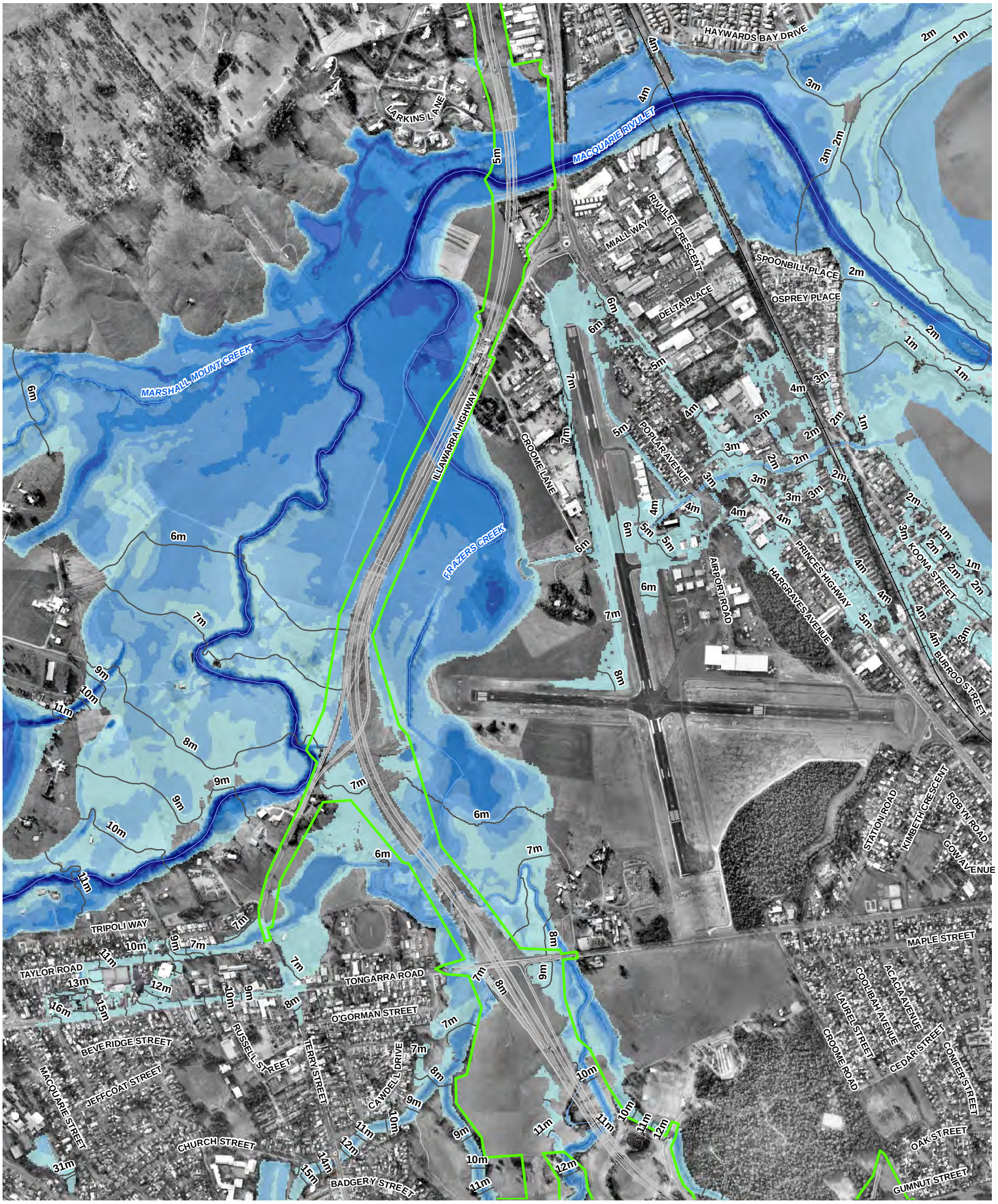


LEGEND

- Site Boundary
- Concept Design
- Major Watercourses
- Railway
- 1m Flood Contours

Flood Depth (m)

- 0 - 0.5
- 0.5 - 1
- 1 - 2
- 2 -3
- 3 - 4
- 4 - 5
- >5

1:12,500 @ A3

0 90 180 360
Metres

MACQUARIE RIVULET 10 YEAR ARI FLOOD DEPTH – WITH PROPOSED BYPASS

ALBION PARK RAIL BYPASS
NSW ROADS AND MARITIME SERVICES

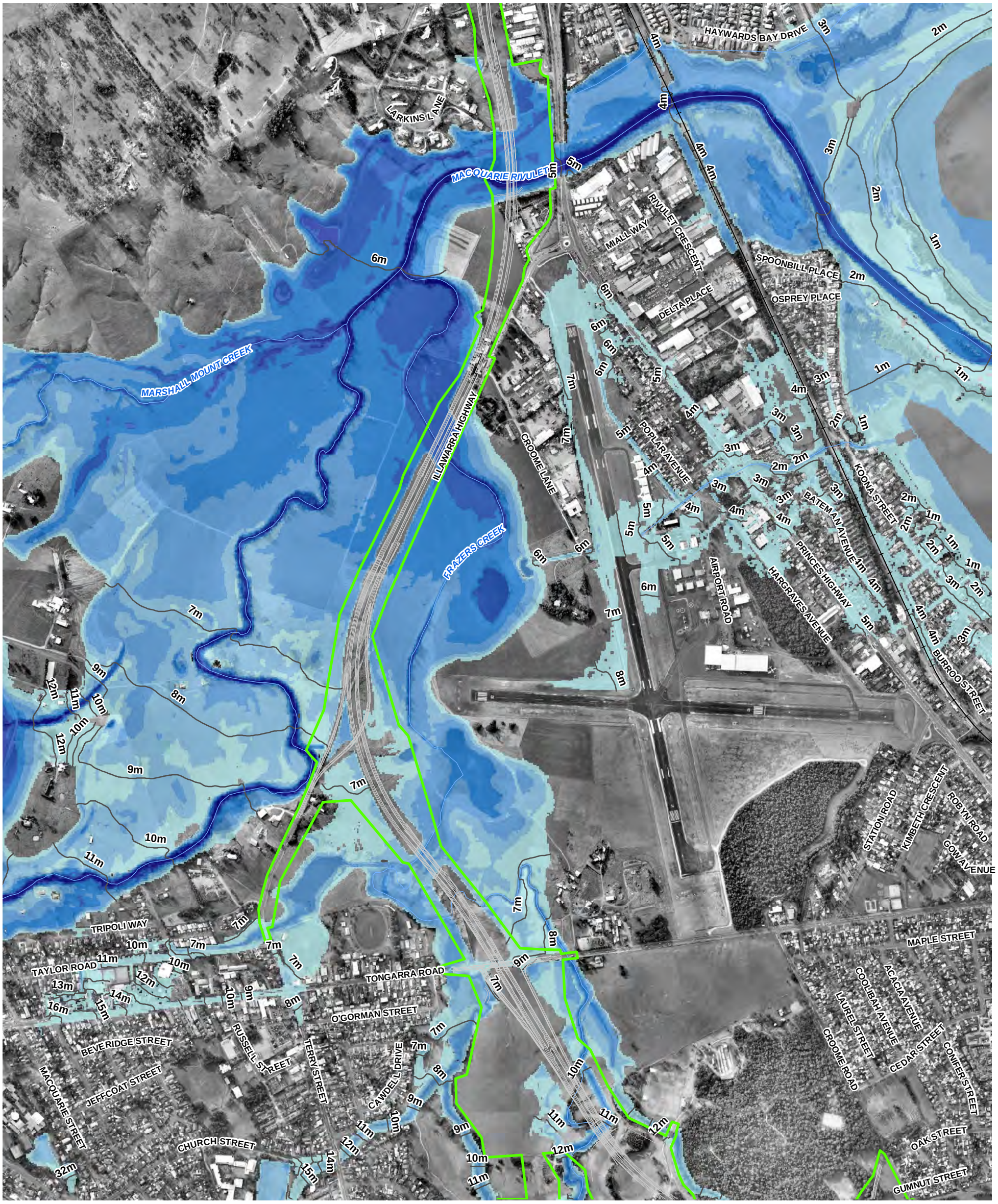
COORDINATE SYSTEM:
GDA 1994 MGA ZONE 56

REVISION NUMBER: 03
AUTHOR: CL

DATE: JUNE 9, 2017

Transport Roads & Maritime Services

Hyder Cardno JOINT VENTURE



LEGEND

- Site Boundary
- Concept Design
- Major Watercourses
- Railway
- 1m Flood Contours

Flood Depth (m)

- 0 - 0.5
- 0.5 - 1
- 1 - 2
- 2 -3
- 3 - 4
- 4 - 5
- >5

1:12,500 @ A3

0 90 180 360
Metres

MACQUARIE RIVULET 20 YEAR ARI FLOOD DEPTH – WITH PROPOSED BYPASS

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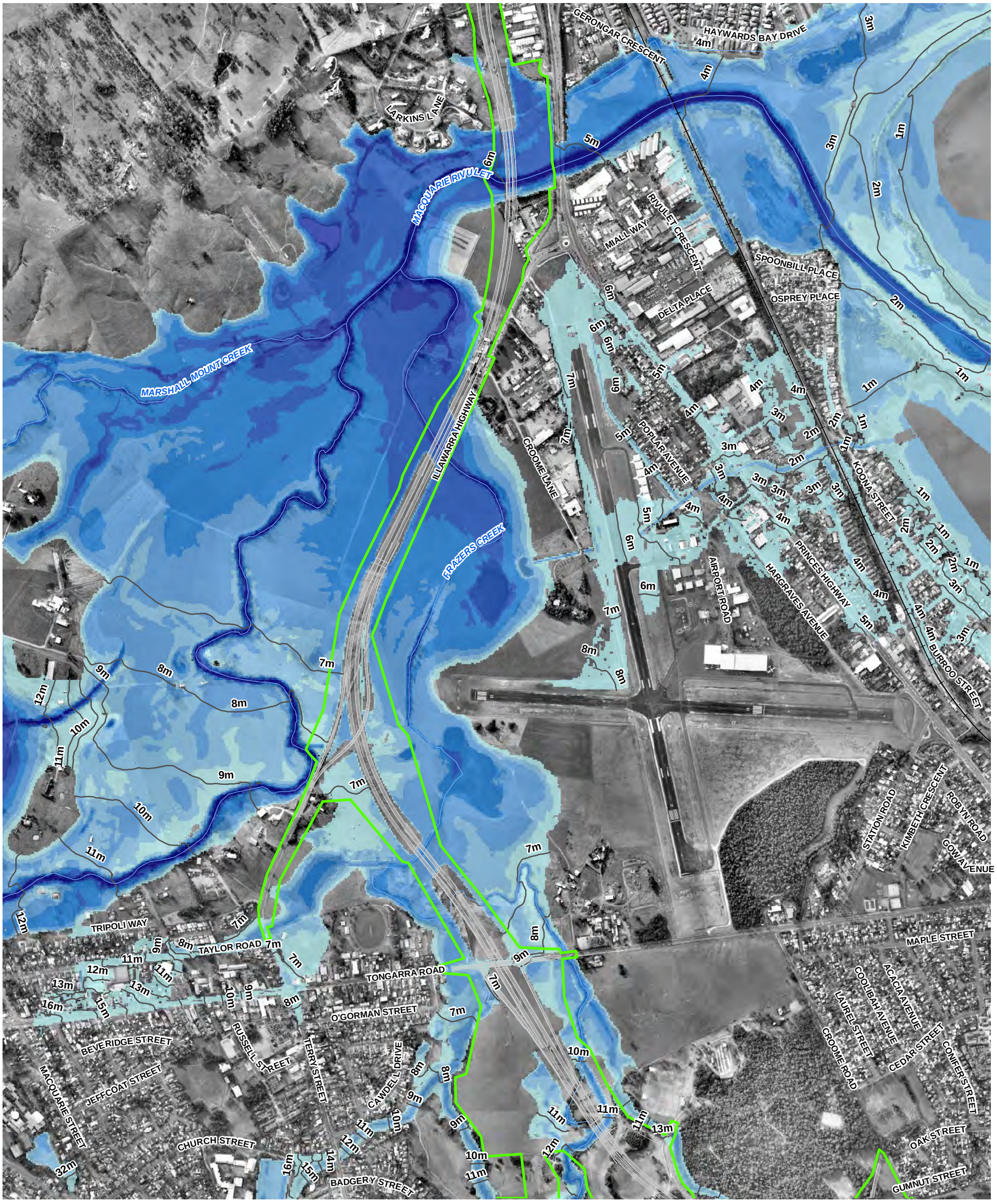

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- 2 -3
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- >5

1:12,500 @ A3

0 90 180 360
Metres

MACQUARIE RIVULET 50 YEAR ARI FLOOD DEPTH – WITH PROPOSED BYPASS

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LEGEND

- Site Boundary
- Concept Design
- Major Watercourses
- Railway
- 1m Flood Contours

Flood Depth (m)

- 0 - 0.5
- 0.5 - 1
- 1 - 2
- 2 -3
- 3 - 4
- 4 - 5
- >5

1:12,500 @ A3

0 90 180 360
Metres

MACQUARIE RIVULET 100 YEAR ARI FLOOD DEPTH - WITH PROPOSED BYPASS

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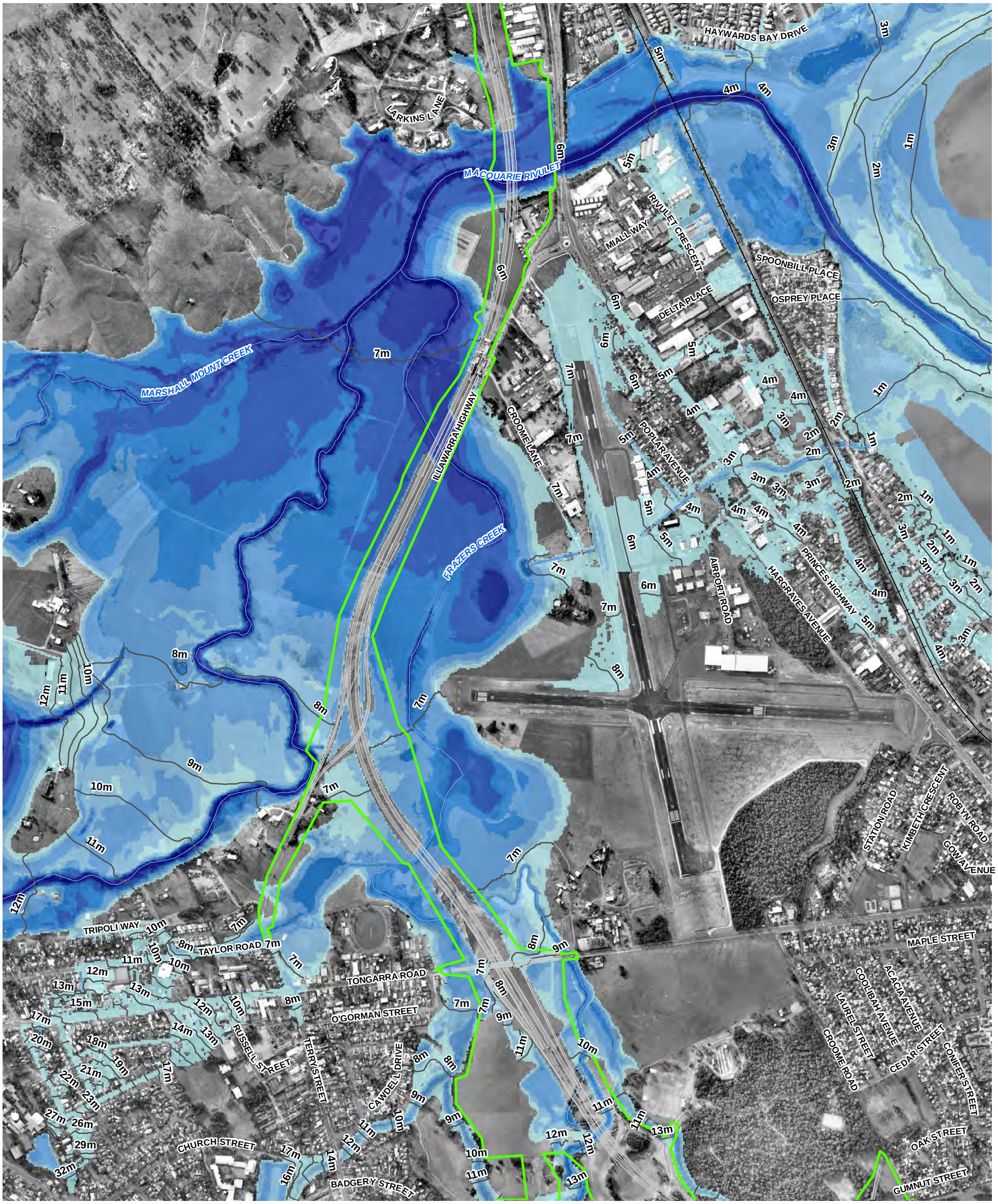

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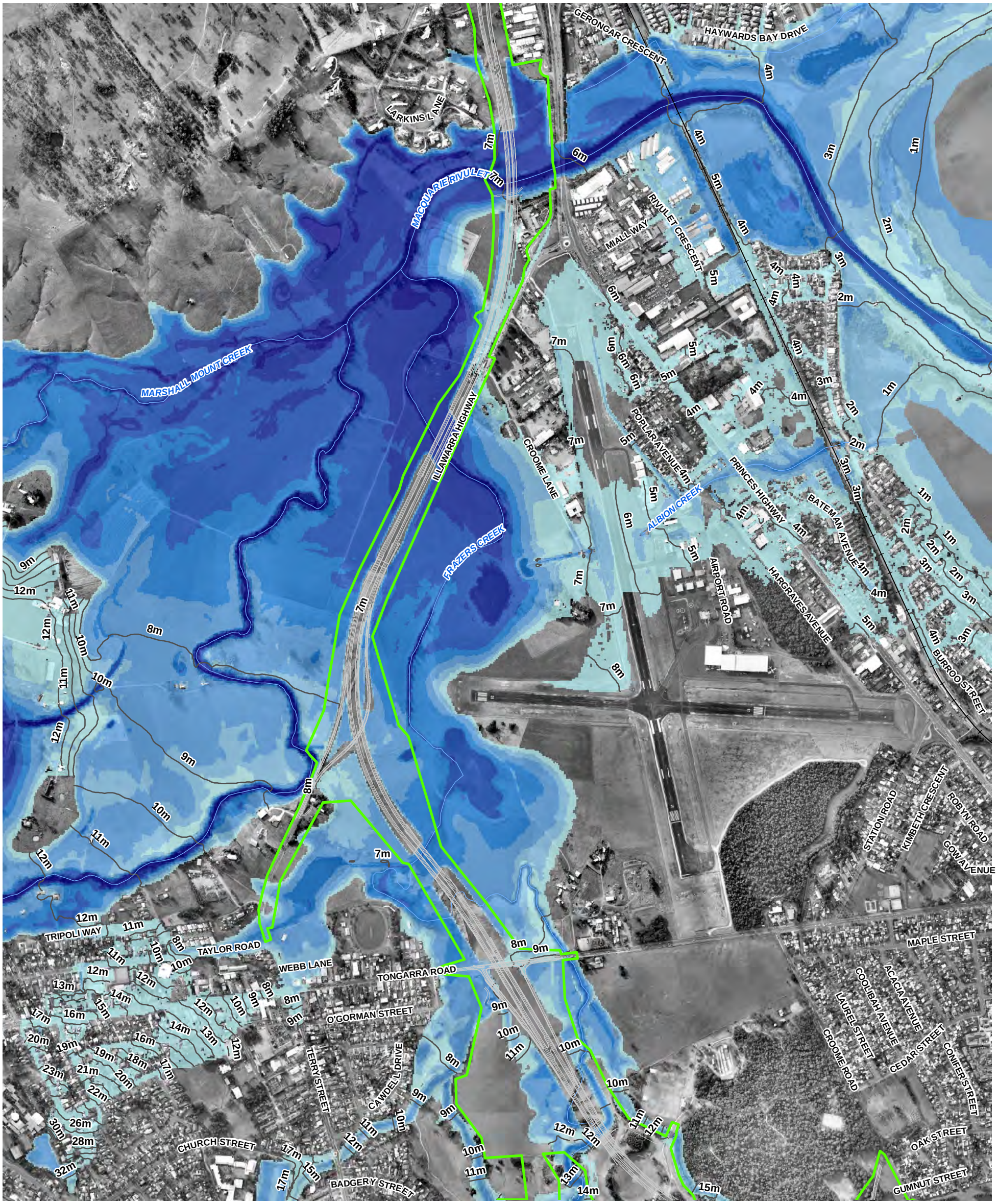

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- 4 - 5
- >5

1:12,500 @ A3

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Metres

MACQUARIE RIVULET 500 YEAR ARI FLOOD DEPTH – WITH PROPOSED BYPASS

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