Appendix D

Hydrology and Hydraulics Assessment

ROADS AND MARITIME SERVICES NSW

MEMORIAL AVENUE UPGRADE

BETWEEN OLD WINDSOR ROAD AND WINDSOR ROAD, KELLYVILLE

CONCEPT DESIGN AND REF

HYDROLOGY AND HYDRAULICS ASSESSMENT

Hyder Consulting Pty Ltd
ABN 76 104 485 289
Level 5, 141 Walker Street
Locked Bag 6503
North Sydney NSW 2060
Australia
Tel: +61 2 8907 9000
Fax: +61 2 8907 9001

ROADS AND MARITIME SERVICES NSW

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HYDROLOGY AND HYDRAULICS ASSESSMENT

Author	Ellen Hird, Ian Rath
Checker	Luiz Segundo
Approver	David Robertson
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This report has been prepared for Roads and Maritime Services NSW in accordance with the terms and conditions of appointment for Memorial Avenue Upgrade Concept Design between Old Windsor Road And Windsor Road, Kellyville dated 20th December 2013. Hyder Consulting Pty Ltd (ABN 76 104 485) cannot accept any responsibility for any use of or reliance on the contents of this report by any third party.

REVISIONS

Revision	Date	Description	Prepared By	Approved By
01	24.07.2014	Draft for RMS Review	EH, IR	

GLOSSARY OF ACRONYMS AND TERMS

Acronym	Name
2D	Two Dimensional
AEP	Annual Exceedance Probability
ALS	Airborne Laser Scanning (or Aerial Laser Survey)
ARI	Annual Recurrence Interval
ARR	Australian Rainfall and Runoff
BC	Boundary Condition
DEM	Digital Elevation Model
DDP	Design Development Plan
EM	Elizabeth Macarthur Creek (abbreviationused in the TUFLOW modelling)
EY	Exceedances per Year
FC	For Construction
Hyder	Hyder Consulting Pty Ltd
Hyder Sys	The Hyder Integrated Management System
IFD	Intensity Frequency Duration
PMF	Probable Maximum Flood
RFI	Requests for Information
RMS	Roads & Maritime Services
SC	Strangers Creek (abbreviation used in the TUFLOW modelling)
SID	Safety in Design
SIDR	Safety in Design Review
TS	Time Series
TUFLOW	A 1D/2D finite difference numerical model that simulates hydrodynamic behaviour in rivers, floodplain and urban drainage environments
UNSW	University of New South Wales
WLL	Water Level Line
XP-RAFTS	Runoff routing model

Term	Definition
Description of Services	RMS' Professional Services Contract Description of Services for Memorial Avenue and its attachments.
Project	Memorial Avenue Upgrade between Old Windsor Road And Windsor Road, Kellyville

CONTENTS

APPENDICES

1 INTRODUCTION

1.1 BACKGROUND

Hyder has been engaged by Roads and Maritime Services NSW (RMS) to undertake Concept Design and a Review of Environmental Factors (REF) for the upgrade of Memorial Avenue; a State arterial road between Old Windsor Road and Windsor Road in Kellyville. Memorial Avenue is a critical link in the growing north west of Sydney. It connects the Blacktown Local Government Area (LGA) suburbs of Glenwood, Stanhope Gardens and Parklea with The Hills Shire Council LGA suburbs of Castle Hill and Kellyville. Memorial Avenue also services residential developments in the area known as the Balmoral Road Release Area.

Memorial Avenue runs in an east-west direction connecting Old Windsor Road in the west to Windsor Road in the east and is currently a two-lane, two-way road carrying about 25,000 vehicles per day. It currently operates at a poor level of service during peak periods. This is to be addressed by the upgrade; to manage the projected traffic growth in future years based on the increased residential and commercial development in the area.

The concept design for Memorial Avenue upgrade includes two major creek crossings at Elizabeth Macarthur Creek (EM) and Strangers Creek (SC), and two minor waterway crossings. Proposed road levels will be higher than existing by about 2.0m at EMC and 2.6m at SC. Existing culverts at both of these crossings do not have 100 year ARI capacity, and overland flow currently overtops the existing roadway in large storms. Under proposed upgrade conditions these flows need to be routed through the proposed structures to mitigate the hydraulic effects of the elevated road embankment.

This assessment outlines the hydraulic modelling undertaken for each major crossing, describes the optimisation of the stormwater infrastructure, and presents outputs for the optimised configuration at each crossing.

1.2 PREVIOUS STUDIES

A hydrology and hydraulics study of the Rouse Hill Development Area (RHDA) was undertaken by GHD in 1998 using the 1D river modelling software HEC-RAS. The RHDA encapsulates the boundary of the Blacktown City Council and The Hills Shire Council and includes all, or parts, of the suburbs of Rouse Hill, Beaumont Hills, Kellyville, Kellyville Ridge, The Ponds, Stanhope Gardens, Parklea, Acacia Gardens, Glenwood and Castle Hill.

One of the criteria for approval of the RHDA was the need to regulate development to reduce the impact of flooding and flood liability on individual owners and occupiers, and to reduce private and public losses resulting from flooding. The GHD study included modelling results of pre-development, completed development and mitigation works to ensure that peak flows downstream would not be increased due to the proposed development.

SKM was commissioned by Sydney Water in 2007 to review the 1998 GHD study, and update the modelling based on the latest available information for the developed case. This resulted in a revised HEC-RAS model. The assessment included flood risk to the North West Rail Link (NWRL) project within the catchments of Strangers Creek, Caddies Creek, Second Ponds Creek and First Ponds Creek. SKM's report supported the Environmental Impact Statement for the North West Rail Link (NWRL) project. It included an assessment of the flood risks to the project within the catchments of Strangers Creek, Caddies Creek, Second Ponds Creek and First Ponds Creek. The hydrologic and hydraulic modelling was used to assess existing conditions and the impacts of the railway infrastructure on flood conditions.

Sydney Water engaged WMA Water in 2013 to produce a 2D model of the area using TUFLOW (the 'Rouse Hill Flood Study'). WMA Water's model was developed using ALS survey, and does not include the Memorial Avenue Upgrade.

Sydney Water (SW) has the responsibility of managing trunk stormwater within the vicinity of the project. This role centres on the Trunk Drainage Lands (TDL), comprising of the riparian corridor and 1% Annual Exceedence Probability (AEP) event flood-lands along the 5 main creek lines; Second Ponds Creek, Caddies Creek, Elizabeth Macarthur Creek, Strangers Creek, and Smalls Creek. WMA's Rouse Hill Flood Study was used to define the TDL based on current best practice approaches, using the SKM study as the starting point.

Part of Hyder's scope for Concept Design and preparation of the REF was to review the previous studies, check the robustness of the flood model, and update the flood model to enable the delivery team to advance the Concept Design.

1.3 PROJECT OBJECTIVES AND SCOPE

The primary objectives of the Memorial Avenue Upgrade in regards to flooding and drainage are as follows:

- Develop and design a concept design that complies with RMS Water Policy 1997; and
- Develop a water management system that complies with RMS Code of Practice for Water Management 1999.

By updating and developing the hydraulic models that define design flood behaviour based on the Concept Design, this Hydrology and Hydraulics Assessment has provided the following:

- Results of flood behaviour; design flood levels, depths, velocities, flows, and flood extents within the study area;
- Assurance that the designed road carriageways are not inundated for the 10 year Average Recurrence Interval;
- Assurance that the designed road has flood immunity for the 1% AEP;
- Drainage system achieving performance requirements set by RMS; and
- A concept design for both transverse and pavement drainage taking into consideration the findings and recommendations for previous investigations.

1.4 AVAILABLE DATA

The following information was available at commencement of Hyder's work on the Concept Design and REF for the project, and was used to develop design while ground survey being undertaken specifically for the Concept Design was underway. All the information listed was provided in electronic format:

- Ground survey completed for RMS' Strategic Concept Design which dates to approximately 2004, extending from just east of the NWRL alignment along Memorial Avenue to Windsor Road;
- Aerial Laser Survey from the NWRL project which dates to approximately 2012 and covers the alignment of the NWRL and a large area around the intersection of Memorial Avenue and Old Windsor Road;
- Base 2m contour data licenced to Hyder from Land and Property Information NSW;
- A cadastral base provided with RMS' Strategic Concept Design;

- Proposed property acquisition extents provided with RMS' Strategic Concept Design;
- Proposed road reserve locations from The Hills Shire Council's Balmoral Road Release Area (BRRA);
- Land zoning information provided by the Hills Shire Council;
- Property ownership information provided by RMS;
- An aerial photograph of the project taken from Hyder's licenced copy of NearMap;
- RMS provided 3D utility survey for the project, both in hard and electronic format. This 3D utility survey extends from east of the NWRL alignment to Windsor Road. The accuracy of information on 3D utility surveys prepared by RMS varies from Class A to Class D. A brief description of each class is as follows: Class A – utility was physically located/potholed; Class B – utility was electromagnetically located; Class C – utility was located using visible surface features, Class D – utility was plotted using Dial Before You Dig information;
- Sydney Water's HECRAS Elizabeth Creek flood model;
- University of New South Wales, Water Research Laboratory, Physical Modelling of in-stream basin control structure at Strangers Creek, Kellyville; and
- WMA's TUFLOW and XP-RAFTS models.

Detailed ground survey for the Concept Design was undertaken by Degotardi Smith and Partners, and was completed in June 2014, subsequent to commencement of Hyder's work on the project. The survey covers the area from Old Windsor Road to Windsor Road along the alignment, and includes determination of the correct location of property boundaries adjacent to the road. Detailed information at minor and major creek crossings of Memorial Avenue was included as part of this survey.

1.5 STUDY METHODOLOGY

The following approach was adopted for the hydrological and hydraulic assessment, based on Hyder's proposal for the Concept Design and REF, which was accepted by RMS:

1. Review hydraulic and hydrologic models and reports associated with the models provided by Sydney Water;
2. Develop flood models for the Concept Design using Sydney Water's TUFLOW (2D model) as the starting point;
3. Extract 100 year, 2000 year and Probable Maximum Flood (PMF) flood levels at significant waterway crossings and provide advice in regards to Concept Design configurations and drainage;
4. Undertake analysis of the preliminary sizing of structures at waterway crossings;
5. Model flooding of the proposed Concept Design and confirm size of culverts and/or bridges at waterway crossings; and
6. Prepare a Hydrology and Hydraulics Assessment outlining the methodology, analysis and results of the flood modelling.

2 EXISTING ENVIRONMENT

2.1 STUDY AREA

The study area for this Hydrology and Hydraulics Assessment is defined as the catchments of Strangers Creek and Elizabeth Macarthur Creek, both of which cross the proposed Memorial Avenue Upgrade. These creeks flow in a northerly direction and form part of the Cattai Creek catchment which eventually joins the Hawkesbury River between Richmond and Sackville. The Cattai Creek catchment and the Memorial Avenue study area is shown in **Figure 2.1**. The hydraulic study area is shown in **Figure 2.2**.

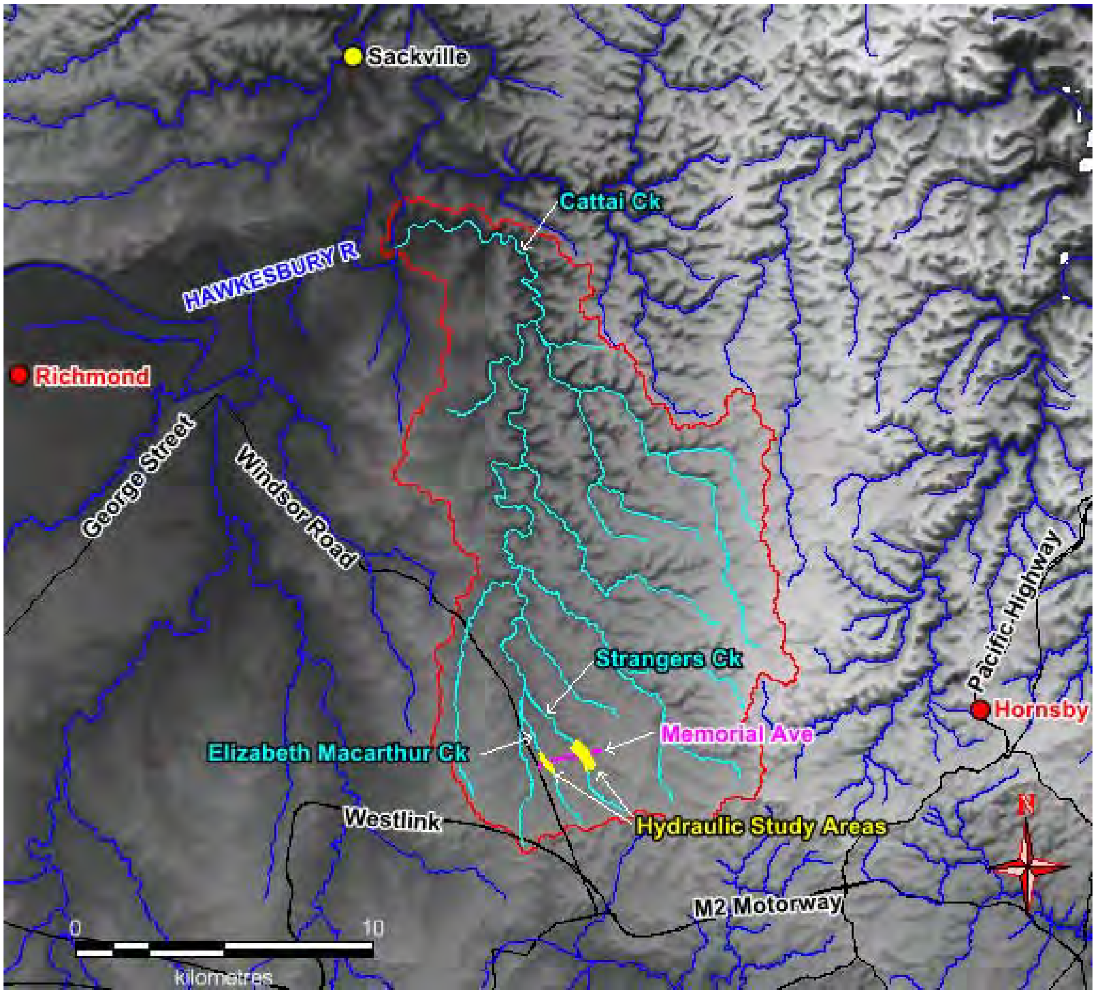

Figure 2.1 The study area in relation to the broader catchment

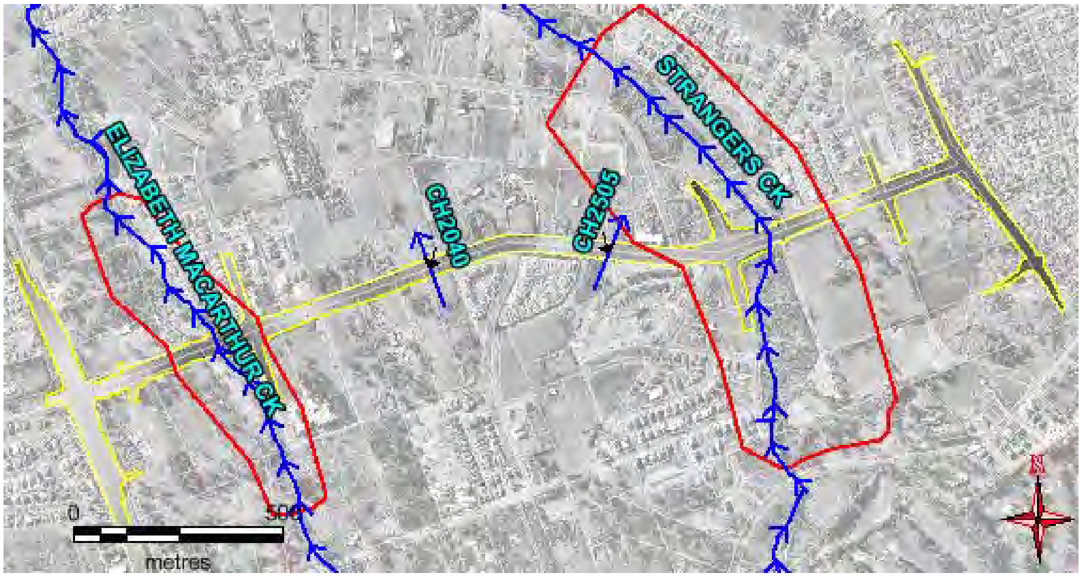

Figure 2.2 The hydraulic study areas (within the red boundaries)

2.2 ELIZABETHMACARTHUR CREEK

The catchment draining Elizabeth Macarthur Creek between Celebration Drive and Samantha Riley Drive is currently largely undeveloped. However, significant urbanisation is currently underway as part of the North West Growth Centres. A particular area of future development is the Balmoral Road Release Area. Development in the upstream catchment (south of Celebration Drive) is well established, consisting of a mixture of residential and commercial development.

The catchment area draining Elizabeth Macarthur Creek at Memorial Avenue is approximately 160 hectares.

The existing culvert structures at Memorial Avenue are three reinforced concrete box culverts each 3m wide x 0.9m high, as confirmed by the detailed ground survey(see **Figure 2.3**).

Figure 2.3 Existing culverts at Elizabeth Macarthur Creek

Elizabeth Macarthur Creek was assessed as a Class 3 fish habitat during site investigations undertaken during preparation of the ecology report prepared for the REF for this project. Fish habitat class is determined by aquatic habitat features of the waterway, which can correlate with stream order, though not in every case. DPI's minimum recommended crossing type for a Class 3 waterway is a culvert (or ford) which requires a 'minimum culvert design using the 'low flow design' procedures for fish passage.

2.3 STRANGERS CREEK

The catchment draining Strangers Creek is a highly modified system consisting of a series of ponds interconnected with drainage culverts. The catchment area upstream of Memorial Avenue is approximately 400 hectares.

The existing culvert structures at Memorial Avenue are four 1.5m diameter reinforced concrete pipes, as confirmed by the detailed ground survey (see **Figure 2.4**).

Figure 2.4 Existing culverts at Strangers Creek

There is a large stormwater detention basin upstream of the culverts with a v-notch weir outlet structure which has a significant effect on the hydraulic behaviour of the flow reaching the culverts. The weir will not be modified by the Memorial Avenue Upgrade. **Figure 2.5** shows a perspective view of the basin, and **Figure 2.6** shows the v-notch weir structure.

Figure 2.5 Perspective view of the detention basin at Strangers Creek (exaggerated vertical scale)

Figure 2.6 The v-notch weir structure basin outlet at Strangers Creek

The v-notch weir structure's vertical walls have four horizontal slots which add to the hydraulic capacity of the system. Physical testing of a model of the weir structure by UNSW showed that the hydraulic capacity of these slots is dependent on the tailwater conditions at the slots. Theoretical calculations showed that the tailwater at the slots is not a sensitive influence on their conveyance.

Figure 2-1 The horizontal slots in the v-notch weir structure

Strangers Creek was assessed as a Class 3 fish habitat during site investigations undertaken during preparation of the ecology report prepared for the REF for this project. Fish habitat class is determined by aquatic habitat features of the waterway, which can correlate with stream order, though not in every case. DPI's minimum recommended crossing type for a Class 3 waterway is a culvert (or ford) which requires a 'minimum culvert design using the 'low flow design' procedures for fish passage.

2.4 TWO MINOR CROSSINGS

There are two minor waterway crossings; at Chainage 2040, and at chainage 2505 (refer to **Figure 2.2**). Existing culvert dimensions are 1 x 450mm dia and 3 x 750mm dia respectively.

3 HYDROLOGIC AND HYDRAULIC MODELLING

3.1 HYDROLOGIC MODELLING

In previous studies of the area undertaken by GHD and SKM (described in **Section 1.2**1.2), the software package XP-RAFTS was used to set flow boundary conditions for input into the 1D HECRAS hydraulic model. XP-RAFTS is a runoff-routing model that is described in Australian Rainfall and Runoff (ARR) which is suitable for this purpose.

WMA Water's Flood Study used the XP-RAFTS model by SKM without modification, with the exception of an amendment made to reflect a change in the ultimate catchment conditions based on the latest information available.

The same XP-RAFTS flow hydrographs for ultimate catchment conditions (100 year ARI) were adopted for this working paper. 2000 year ARI and PMF hydrology was derived from the same model. A combination of total and local inflows were used as inputs into the TUFLOW hydraulic models.

3.2 HYDRAULIC MODELLING APPROACH

3.2.1 General

Hyder received a copy of the TUFLOW model prepared by WMA Water and used this in combination with ground survey for development of the Concept Design flood models. The WMA model was used as the basis of the hydraulic modelling, with the following changes:

- The model was split into two; into an EM and a SC model;
- A finer cell size was adopted (2m compared to the original 4m);
- Stormwater detention basins were converted from 1D to 2D to improve stability and flood storage characteristics;
- Inflows at the upstream edges of the models were adopted from RAFTS;
- The EM model was converted to a predominantly 2D model, with only the culverts comprising the 1D domain;
- The 1D channel elements in the SC model had duplicate storage removed;
- The v-notch weir structure in the SC model was changed to reflect UNSW testing results for flow and resultant flood level;
- Ground survey was included where available; and
- The TUFLOW release used was the most current at date of modelling (Build 2013-12-AC 64 bit).

Upstream and downstream boundary locations were chosen at location sufficiently far from the area of interest to not affect the results. This was approximately 400m each side of Memorial Avenue for the EM model, and 500m and 600m for upstream and downstream distances respectively in the SC model.

A general view of the location and extent of the two TUFLOW models is shown in **Figure 3.1**. The following sections outline some specific features of the models.

Figure 3.1 General View of the Two TUFLOW Models

3.2.2 Surface Roughness

The TUFLOW surface roughness categories and values were predominantly adopted from the WMA model. The roughness values used and their distribution are shown in **Figure 3.2**.

The roughness of the upstream reach of Elizabeth Macarthur Creek was revised to light vegetation (0.04) from WMA's value of 0.06 which Hyder considered to be too high based on aerial photographs of the area. Likewise in the Strangers Creek detention basin WMA's Mannings value of 0.08 was revised to 0.06. Velocities in the basin are low so this is not a sensitive input.

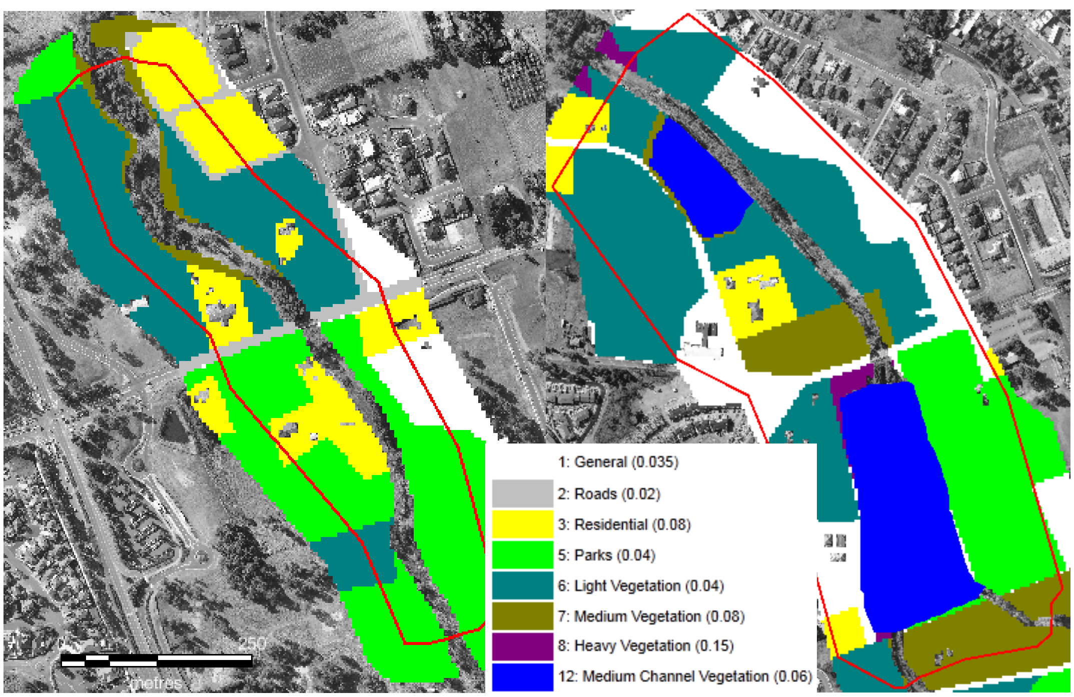

Figure 3.2 Surface roughness distribution (EM at Left, SC at Right)

3.2.3 Strangers Creek Detention Basin

In the Strangers Creek model the hydraulic characteristics of the v-notch weir structure were upgraded to match the results of the UNSW physical testing.

The upper flow limit in the physical testing was 44 cumecs which may have been considered the 100 year ARI flow peak at the time of testing. The UNSW report makes no mention of the source of the flow data, nor could any additional information be supplied by UNSW. 100 year ARI flows from the RAFTS model downstream of the basin node were approximately this value.

Investigation of the RAFTS model showed that the basin detention characteristics were overestimated by a factor of about 1.6. The basin volume was accurate, but the flood level vs flow characteristics were about 0.5m too high compared with the UNSW testing results. This is a very sensitive input because of the large storage volumes involved. **Figure 3.3** shows the discrepancy between the RAFTS basin characteristics and the UNSW testing results.

The TUFLOW model was arranged to have RAFTS 'total' hydrographs input upstream of the basin, a RAFTS 'local' hydrograph input within the basin, and the hydraulic characteristics calculated within TUFLOW via a combination of the UNSW testing results (via a TUFLOW 'Q' channel) and the basin storage defined by the terrain. The resultant 100 year ARI peak flow exiting the basin was 50.9 cumecs.

As this flow was greater than the upper limit of the UNSW testing the UNSW results were extrapolated using a curve of best fit for the v-notch and underflow slots, and a broad crested weir contribution for flows higher than the concrete wall crest. The resultant flow-depth relationship is shown in **Figure 3.4**. Zero depth is added to the v-notch invert level of 55.8m AHD to get the corresponding flood level.

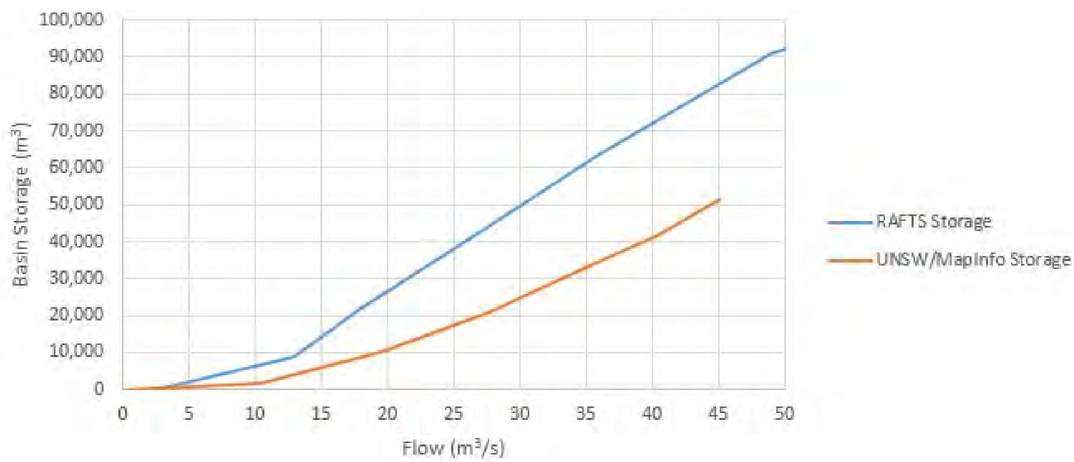

Figure 3.3 Strangers Creek Detention Basin Hydraulic Characteristics

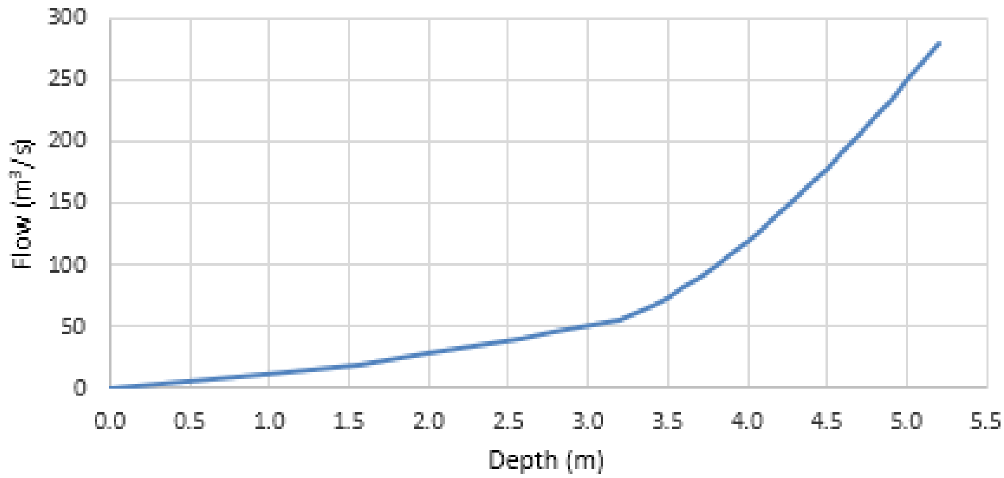

Figure 3.4 Strangers Creek Detention Basin Outlet Hydraulic Relationship

3.2.4 Base Topography and Terrain Modifiers

The base terrain was taken from the WMA terrain as ALS data was not available at time of modelling. 1D cross sections were carried across verbatim from the WMA model in the absence of ALS or ground survey data.

Some terrain modifiers (‘breaklines’) were added to ensure certain hydraulic characteristics were reflected in the output, such as the Strangers Creek high-flow earth weir of the detention basin (assumed to be at 60m AHD).

3.2.5 Other

In the EM model the hydraulic effect of guardrails was added to include some blockage (from the guardrail and debris) and friction losses. This was a more sensitive input at Elizabeth Macarthur Creek than at Strangers Creek because the valley is narrower and there is no detention basin, so the hydraulic effects of the existing road configuration potentially extends into private land whereas at Strangers Creek it does not. 50% blockage at post level was used for thrie-beam locations and 20% for w-beam.

A calculation time-step of 1 second was used (for 1D and 2D) which complies with the Courant Number recommendations outlined by the software developer.

3.3 PROPOSED BRIDGE AND CULVERT CONFIGURATIONS

3.3.1 Elizabeth Macarthur Creek

The existing culverts at Elizabeth Macarthur Creek are relatively wide but low (3 off 3.0m wide x 0.9m high). The proposed upgrade road level is approximately 2.0m higher than existing, and all flow that overtops the roadway in existing conditions must be directed through the proposed structures. Unlike Strangers Creek, there is no detention basin and there is some private property upstream of the road upgrade that could be subject to a flood level increase.

Optimisation of the EM model showed that 4 box culverts (3.0m wide x 1.8m high) are adequate to convey the 100 year ARI flow without an adverse effect.

The proposed road at Elizabeth Macarthur Creek is wider than existing, with the extra carriageway on the upstream side of the existing road (see **Figure 3.5**). Some ground shaping will be required either end of the proposed culverts to accommodate the extra culvert width and the invert levels (54.7m AHD upstream, 54.5m downstream).

Figure 3.5 Proposed Road at Elizabeth Macarthur Creek

3.3.2 Strangers Creek

RMS' Strategic Concept for the upgrade was to have triple-span twin bridge structures. Initial modelling showed that a bank of 3 box culverts (approximately 2.7m x 2.7m) would suffice hydraulically. However, a bridge was preferred to incorporate fish passage requirements of this significant creek, to minimise disturbance to the creek, and to make provision for a future cycleway being considered by The Hills Shire Council.

A single-span twin bridge structure of clear span length 16.5m is proposed. A 2H:1V spill-through batter slope is proposed for the western abutment, and space for a 4.5m wide cycleway (inclusive of 0.5m for safety railing) with vertical abutment wall for the eastern abutment (see **Figure 3.6**).

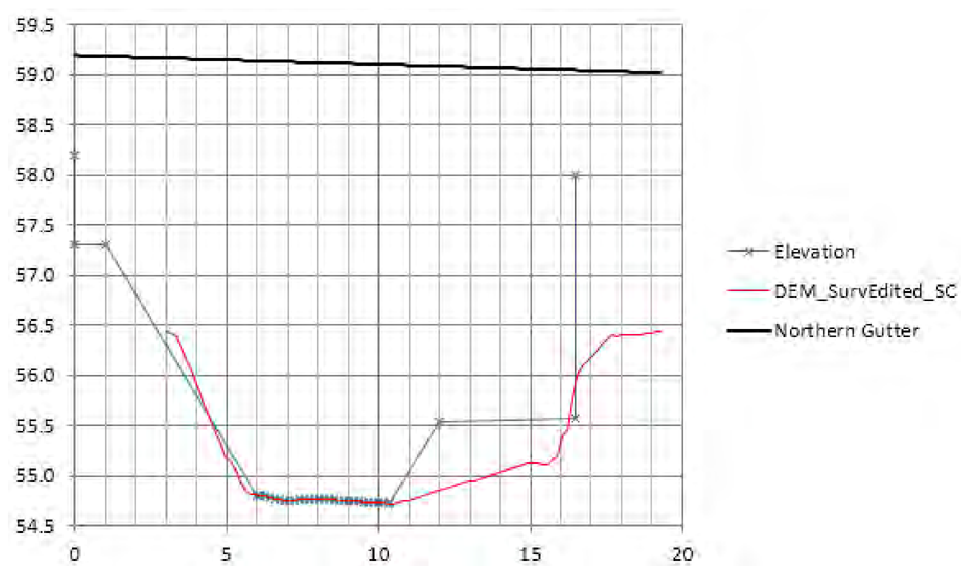

Figure 3.6 Proposed Bridge Cross Section at Strangers Creek

The proposed road at Strangers Creek is wider than existing, with the extra carriageway on the downstream side of the existing road (see **Figure 3.7**).

3.7 Proposed Road at Strangers Creek

3.3.3 Two Minor Crossings

A single 750mm diameter pipe is proposed at CH2040, and 3 x 900mm diameter pipes at CH2505.

3.4 SCENARIOS MODELLED

The following scenarios were modelled:

- Existing and proposed 100 year ARI;
- Existing and proposed PMF; and
- For the SC model only the proposed 2000 year ARI (for bridge structural information only).

4 RESULTS

4.1 ELIZABETH MACARTHUR CREEK

In the 100 year ARI event the total peak flow arriving at the roadway is about 33 cumecs. 17 cumecs passes through the culverts, the remaning 16 cumecs over the roadway. Under proposed conditions all flow passes through the culverts with slightly lower flood levels.

In the PMF the total flow arriving at the roadway is about 67 cumecs. 19 cumecs passes through the culverts, and the remaining 48 cumecs over the roadway. Under proposed conditions the flows do not overtop the road, so all 67 cumecs pass through the culverts. There is a rise in flood levels approximately 0.5m as a result.

Figure 4.1 shows a long-section view along Elizabeth Macarthur Creek of the 100 year ARI and PMF flood level results; existing and proposed conditions. The long section is taken along the red arrow line in **Figure 4.2**. Both existing condition flood profiles show the effect of the guardrails as flow overtops the road embankment. The proposed 100 year ARI profle is approximately equal with the culvert soffit showing that the 1.8m culvert height is an optimum.

The proposed PMF profile can be seen to not overtop the proposed road embankment. This produces significant hydraulic gradient between upstream and downstream ends of the proposed culvert to drive the full PMF flow through the culverts.

Downstream of the road the proposed food profile is equal to or less than the existing flood levels.

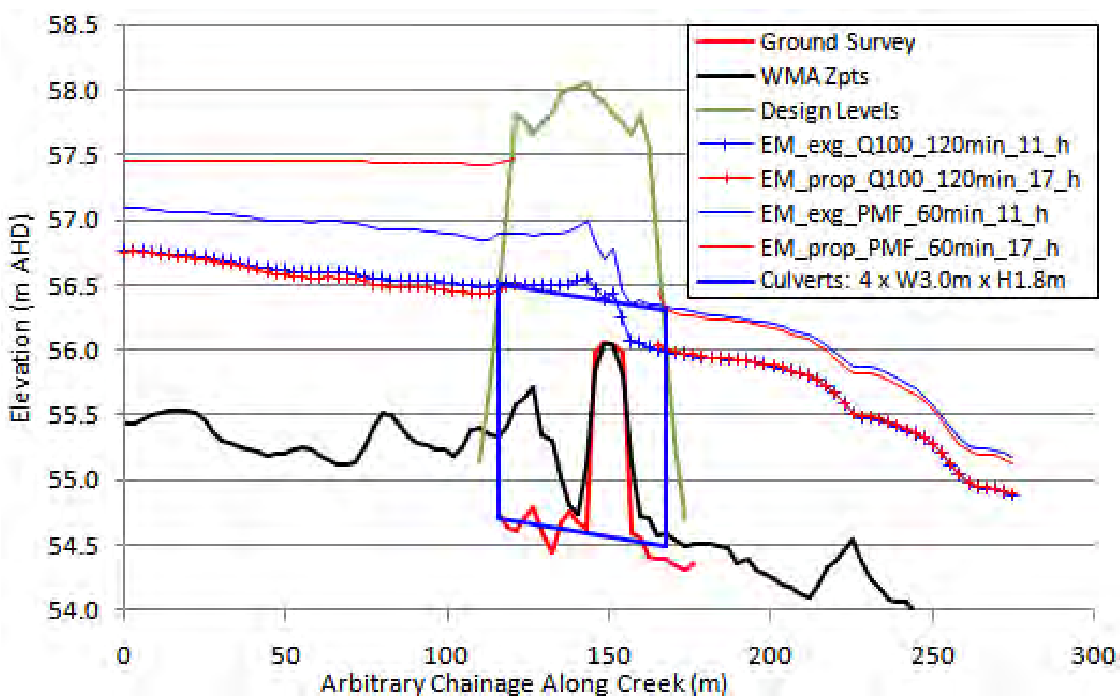

Figure 4.1 Flood analysis results along Elizabeth Macarthur Creek

Figure 4.2 shows the 100 year ARI flood extent for existing and proposed conditions. The blue outline represents existing, the red proposed. Flood levels at two arbitrary locations are given.

For more detailed information on flood levels, flood depths, velocity-depth, and provisional hydraulic hazard refer to the flood maps in **Appendix B**.

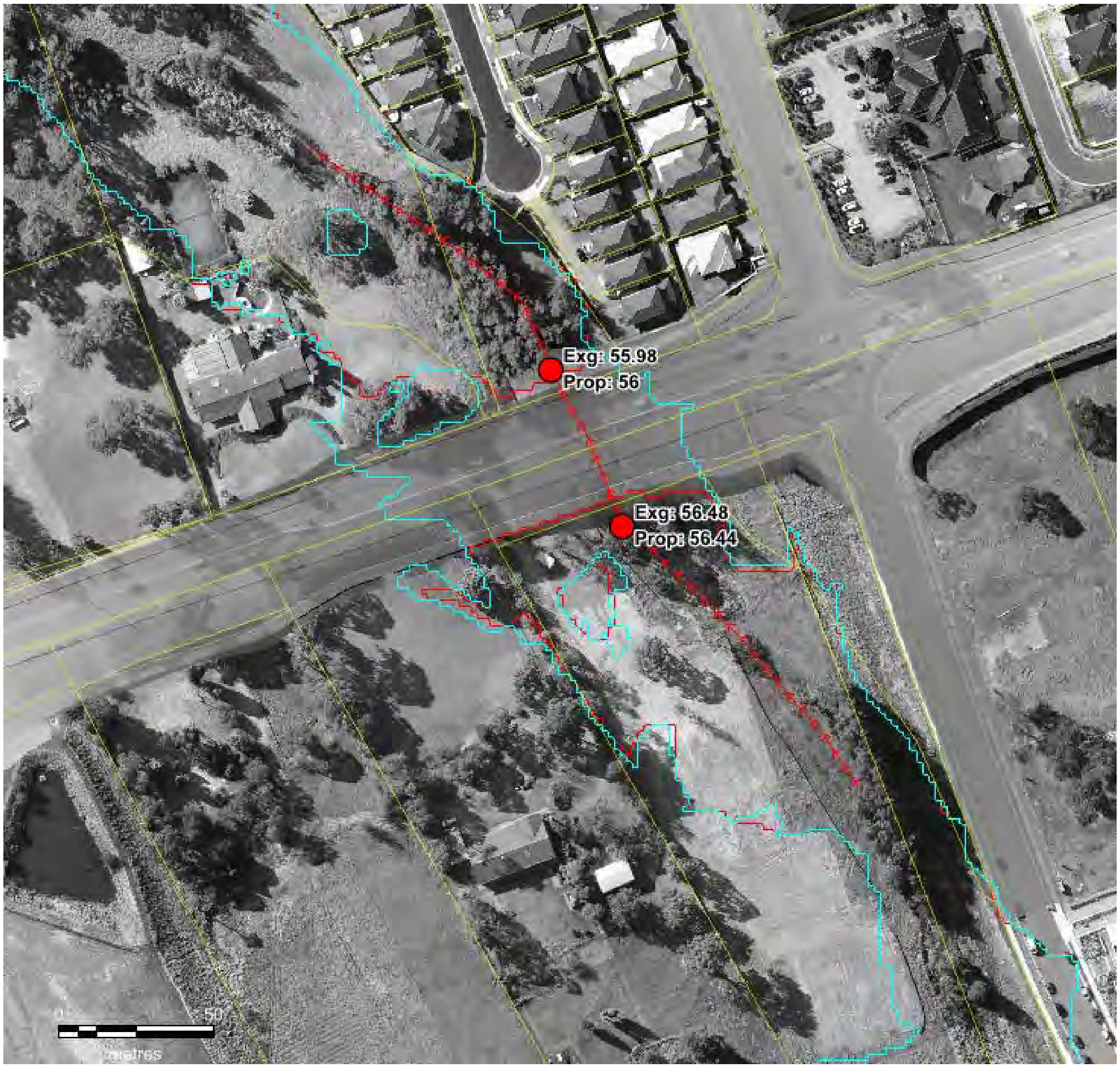

Figure 4.2 Flood extents and spot levels at Elizabeth Macarthur Creek

4.2 STRANGERS CREEK

In the 100 year ARI event the total peak flow arriving at the roadway is about 51 cumecs. 26 cumecs passes through the culverts, the remaning 25 cumecs over the roadway. Under proposed conditions all fow passes through the bridge at lower flood levels.

In the PMF the total flow arriving at the roadway is about 175 cumecs. 30 cumecs passes through the culverts, and the remaining 145 cumecs over the roadway. Under proposed conditions the flows do not overtop the road, so all 175 cumecs passes through the twin bridges. There is a rise in flood levels approximately 0.5m as a result, confined to the land between the proposed road and the v-notch weir. If any flood level rise is apparent in the detention basin due to the horizontal slots having less head differential the effect is negligible and would be confined to the basin.

Figure 4.3 shows a long-section view approximately along Strangers Creek of the 100 year ARI and PMF flood level results; existing and proposed conditions. The long section is taken along the red arrow line in **Figure 4.4**. Both existing condition flood profiles show that the proposed conditions have lower flood levels than existing between the road embankment and the v-notch weir, and no flood level increase upsteam of the v-notch weir. The v-notch weir can be seen to control flood levels, with almost a 1.5m to 2m head drop. The proposed 100 year ARI profle is well clear of the bridge soffit showing that the waterway area provided by the 16.5m clear-span bridge is larger than hydraulically required.

The proposed PMF profile can be seen to not overtop the proposed road embankment. This produces significant hydraulic gradient between upstream and downstream ends of the proposed bridge to drive the full PMF flow through the bridge. The flow seems to just reach the bridge soffit at its upstream edge.

Downstream of the road the proposed food profile is slightly higher than the existing flood levels in the 100 year ARI (maximum 40mm close to the bridge) and higher by about 150mm or less in the PMF. The main cause for this is the presence of the proposed off-ramp that will connect with Arnold Avenue confining the width of the flow. As the off-ramp elevations taper back to existing levels to the north, and the ramp curves westwards, the flow width resumes its full width and the afflux dissipates.

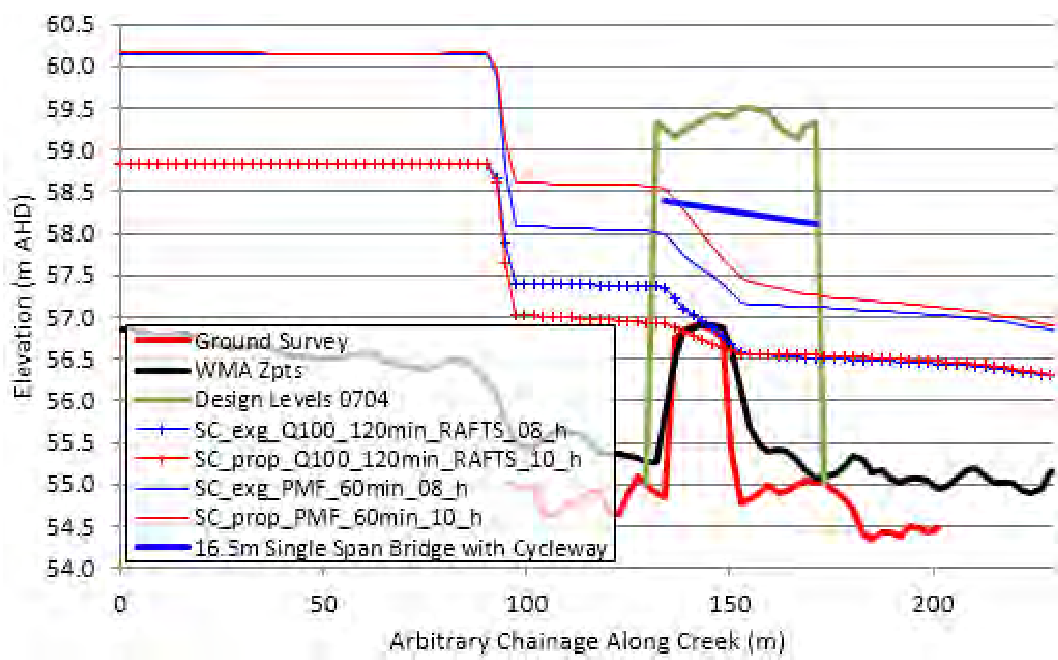

Figure 4.3 Flood analysis results along Strangers Creek

Figure 4.4 shows the 100 year ARI flood extent for existing and proposed conditions. The blue outline represents existing, the red proposed. Flood levels at two arbitrary locations are given. The confinement of the flow width downsteam (north) of the proposed road can be seen top-left of picture.

For more detailed information on flood levels, flood depths, velocity-depth, and provisional hydraulic hazard refer to the flood maps in **Appendix B**.

Figure 4.4 Flood Extents and Spot Levels at Strangers Creek

5 CONCLUSIONS

The flooding analysis outlined in this report showed that the proposed culvert configuration at Elizabeth Macarthur Creek (4 x 3.0m wide x 1.8m high box culverts) and bridge configuration at Strangers Creek (single span 16.5m clear span twin bridges with 4.5m cycleway) provided enough hydraulic capacity to produce zero afflux in 100 year ARI conditions, thus achieving the performance requirements set by RMS.

Under PMF conditions no flow overtops the proposed road at either crossing, and there is a 0.5m increase in flood levels upstream at both crossings.

At Strangers Creek the proposed bridge option caters for fish passage and the inclusion of a cycleway.

The TUFLOW models created for this analysis have been specifically set-up to predict the hydraulic impact of the road upgrade. They should not be used for another purpose without thorough knowledge of the model's set-up.

6 REFERENCES

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8. New South Wales Government Floodplain Development Manual NSW State Government, April 2005
9. Regional Environment Plan 19 –Rouse Hill Development Area gazetted 1989 (http://www.legislation.nsw.gov.au/viewtop/inforce/epi+578+1989+cd+0+N)
10. UNSW Water Research Laboratory, 2004, Physical Modelling of an In-Stream Basin Control Structure Strangers Creek, Kellyville.
11. WMA Water, 2014, 113050:RouseHill_FloodStudy.docx

APPENDIX A

MODEL MODIFICATIONS

Modifications of the WMA TUFLOW model are listed below:

- Invalid Elements Warning in Surface Modelling Software (SMS):

There were many ‘invalid elements’ picked up by the SMS program that made viewing results difficult. These were caused by Water Level lines overlapping the active 2D domain. Hyder provided a cut-down version of the TUFLOW model and edited the polygons and related boundary condition components instead of the Water level lines and points, and this largely fixed the problem, with 5 invalid elements remaining which did not affect the output.

- Flow Spike near Channel SCG005:

There was a large spike in flow at the Strangers Creek channel, especially in one of the blockage scenarios. This resulted in the blockage scenario having higher flood levels downstream than for the non-blocked scenario. The spike was about 690 cu.m/s for a catchment generating approximately 30 cu.m/s. The issue was resolved by importing flows from the RAFTS output.

- Velocity Spike near Channel W_S118:

There was a problem with the weir flow from a basin modelled with 1D elements at Strangers Creek whereby the velocity maximum was over 400m/s, and for a considerable time period. It was unclear what effect this had on nearby results therefore changing this basin to a 2D basin solved the problem. The large basin above the v-notch weir was also changed to 2D for better flood storage. This changed the basin flood profile from having a gradient with the 1D elements to being flat as expected with 2D elements. The basin flows entered into the v-notch weir 1D element with a boundary condition (SX BC) which is stable and works well where flat water is passed from 2D to 1D.

- TUFLOW Flood Routing Significantly Attenuated Flows:

The TUFLOW hydrographs were significantly attenuated compared to RAFTS. This may have been caused by double routing. The XP-RAFTS flows at the upstream ends of the cut-down TUFLOW models were used instead of the TUFLOW output.

- XP-RAFTS Basin (v-notch weir basin) Overestimated the Flood Attenuation:

There was a significant difference in the TUFLOW 2D basin performance compared with XP-RAFTS. This is because the relationship of flow vs flood level in XP-RAFTS was a highly sensitive input and was entered with values different to the UNSW v-notch weir testing. The report of this testing may not have been available to the previous modeller. It should be noted that the XP-RAFTS local inflows only were used in WMA’s TUFLOW model, so the basin attenuation was not transferred to their TUFLOW model. Caution should be used if using ‘total’ RAFTS flows downstream of the basin as they are significantly incorrect.

- Entering UNSW V-notch Weir into TUFLOW:

The new 1D Q channel worked well to enter the UNSW v-notch weir relationship. This fixes the flow/flood level relationship so the testing data can be reflected in the TUFLOW model. Caution should be used if the tailwater conditions are higher than the tailwater limits stated in the UNSW report because the Q channel fixes the flood levels as a function of flow.

Theoretical calculations using the orifice equation showed that the horizontal slots are not overly sensitive to tailwater increases, but caution should be used as the UNSW testing was capped at 44 cumecs. The UNSW report states that a hydraulic jump occurs at the orifice, and when this jump is drowned-out the flow through the slots is initially reduced until a new equilibrium is established via an increase in basin flood levels. Calculations showed that there was approximately a 3.5% flow reduction through the slots when a 360mm differential head loss was applied.

It should be noted that the flood levels in the basin under PMF conditions do not impinge on any land outside the basin other than some overtopping of the high-flow weir. No upstream land designated for any other purpose is affected.

- V-notch Weir Geometry:

The Q channel mentioned above will replace any weir geometry, but in case WMA retain their v-notch weir element it should be noted that the v-notch weir geometry was slightly out with the slope at the left side, and there was no account for the 'underflow weir' slots (maybe this was deliberate for a full-blockage scenario). It is recommended that the UNSW results be applied instead of an attempt to model this complex structure with a geometric element.

- 1D network at Elizabeth Macarthur:

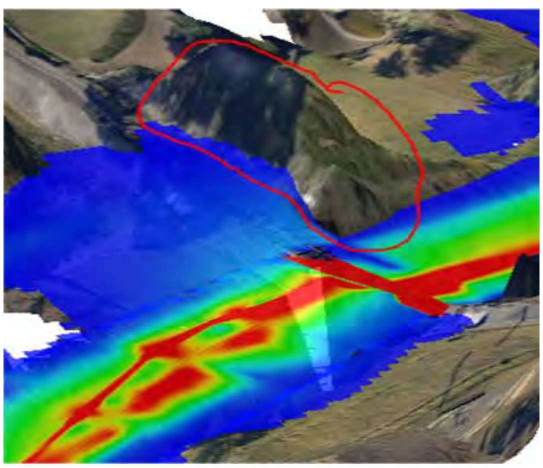
A problem with the 1D network had been carried over from the WMA model but was rectified by making the TUFLOW model predominantly 2D. The problem was in the existing model (with MWA components) when the weir flow was triggered. There was a surge of flow and velocity across the weir which may have been caused by the interaction of a high-point in the terrain with the boundary of the 1D and 2D domains. WMA had two types of weir flow; 1D where the culvert was, and 2D outside the 1D domain. There was a disjoint in the flood surface between the 2D and 1D, and it looks like the flow was affected. The interaction of the two weirs next to each other coupled with a high point in the connected 2D terrain probably created this issue.

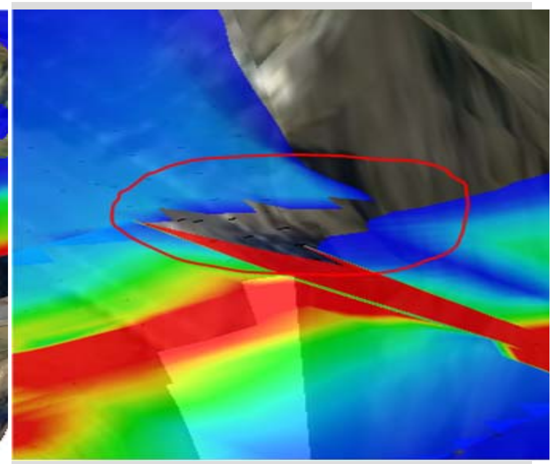
This was remodelled as a 2D-only model with culvert, so no 1D channels or boundaries of 1D/2D domains. The flood surface is now seamless and the results reliable.

WMA model at Elizabeth Macarthur Creek

WMA model at Elizabeth Macarthur Creek

Disjoint in flood surface

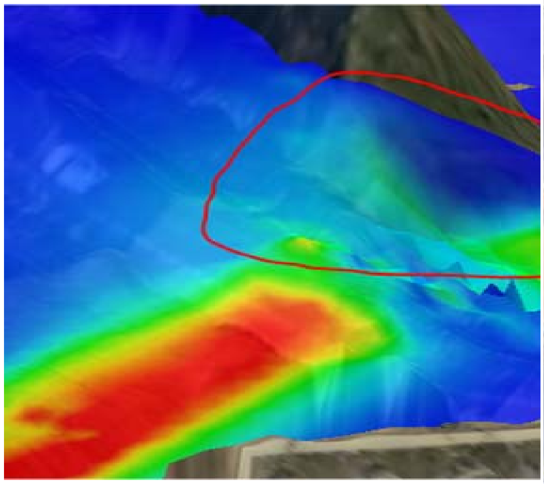
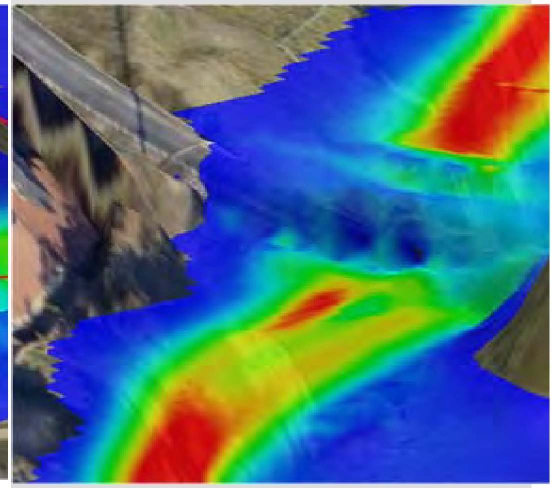




Hyder's model at Elizabeth Macarthur Creek

Hyder's model at Elizabeth Macarthur Creek

Smooth transition in flood surface

WMA model at Elizabeth Macarthur Creek	WMA model at Elizabeth Macarthur Creek Disjoint in flood surface
	

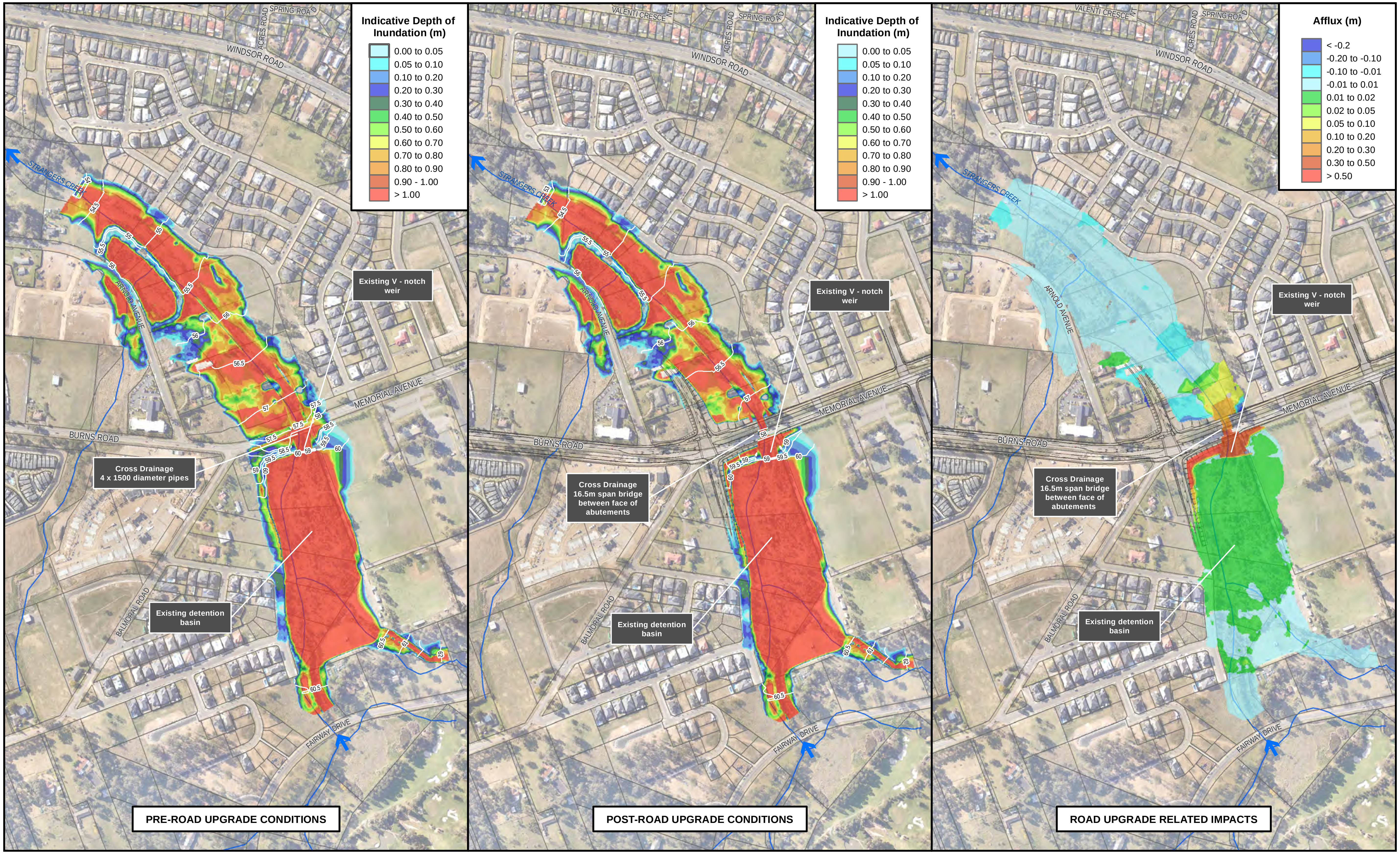
- Downstream boundary condition:

The downstream boundary condition was input into TUFLOW as a 'HQ' boundary type. This was located sufficiently downstream not to affect area of interest and positioned downstream of a local step in the flood profile from the WMA results. The HQ boundary calculates a water level versus flow along the intersecting cells given the input of water surface slope. A slope of 0.5% was used because it was a reasonable representation of the terrain slope downstream of the site and produced a stable boundary condition that did not adversely influence water levels at the area of interest.

The HQ method constituted a free-draining downstream boundary condition which simulated a no-backwater (no co-incident ARI) scenario. This allowed for the full effects of the proposed infrastructure to be isolated for the critical duration event. This was checked with the flood profile and the existing and proposed case matched the flow profile for a significant distance.

APPENDIX B

FLOOD MAPS



MEMORIAL ROAD UPGRADE
FLOOD ASSESSMENT OF PROPOSED DRAINAGE CROSSING

PMF STRANGERS CREEK FLOOD
PRE AND POST-UPGRADE CONDITIONS COMPARISON

LEGEND

- Watercourse
- Major flow directon
- Peak Water Surface Elevation Contours (at 0.5m intervals AHD)
- Lot boundary

MAP DETAILS

GDA 1994
MGA Zone 56

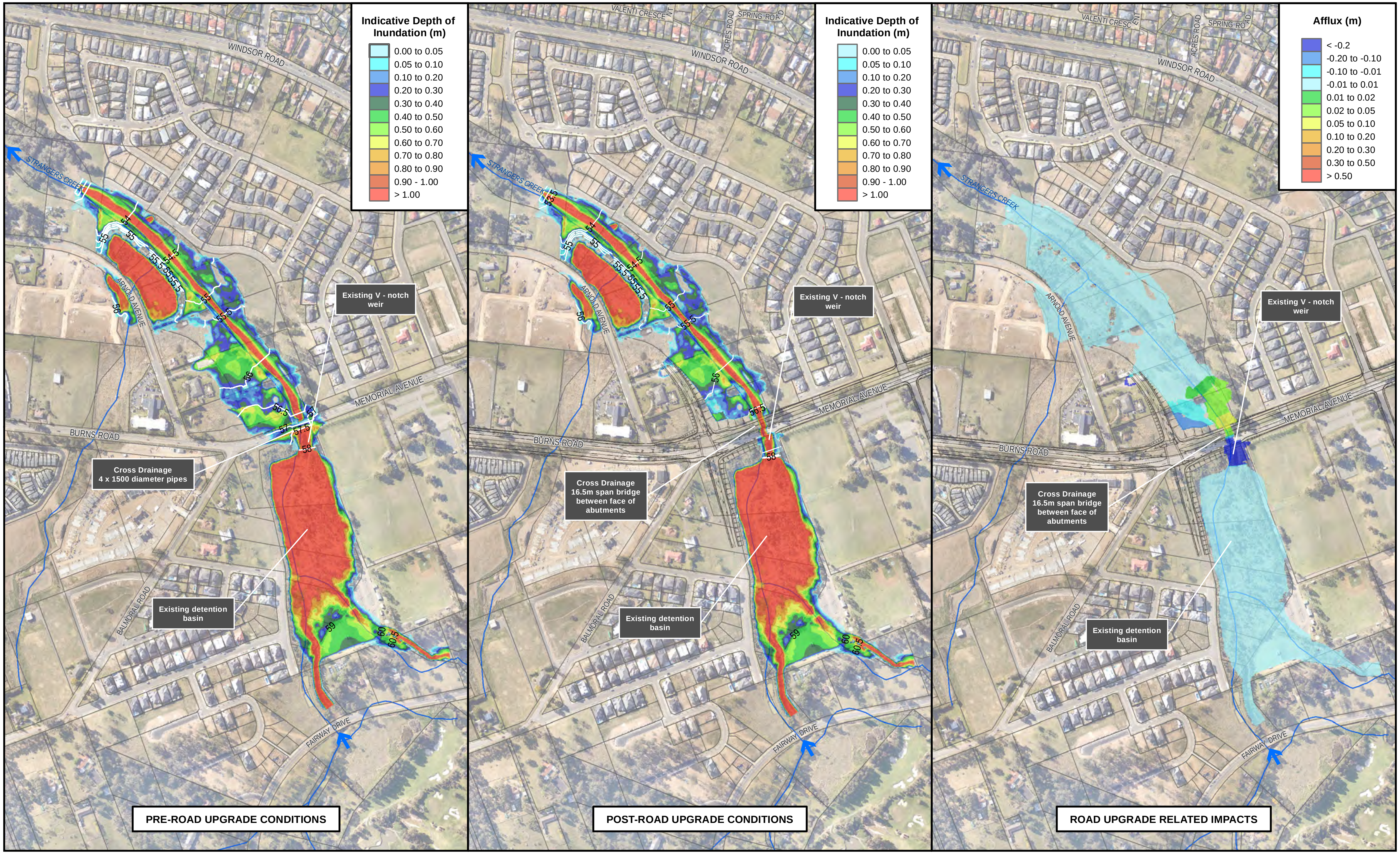
0 25 50 100 150 200 m

SYDNEY

NSW Transport Roads & Maritime Services

Hyder

MEMORIAL AVENUE



MEMORIAL ROAD UPGRADE
FLOOD ASSESSMENT OF PROPOSED DRAINAGE CROSSING

100 YEAR ARI STRANGERS CREEK FLOOD
PRE AND POST-UPGRADE CONDITIONS COMPARISON

LEGEND

- Watercourse
- Major flow directon
- Peak Water Surface Elevation Contours (at 0.5m intervals AHD)
- Lot boundary

MAP DETAILS

GDA 1994
MGA Zone 56

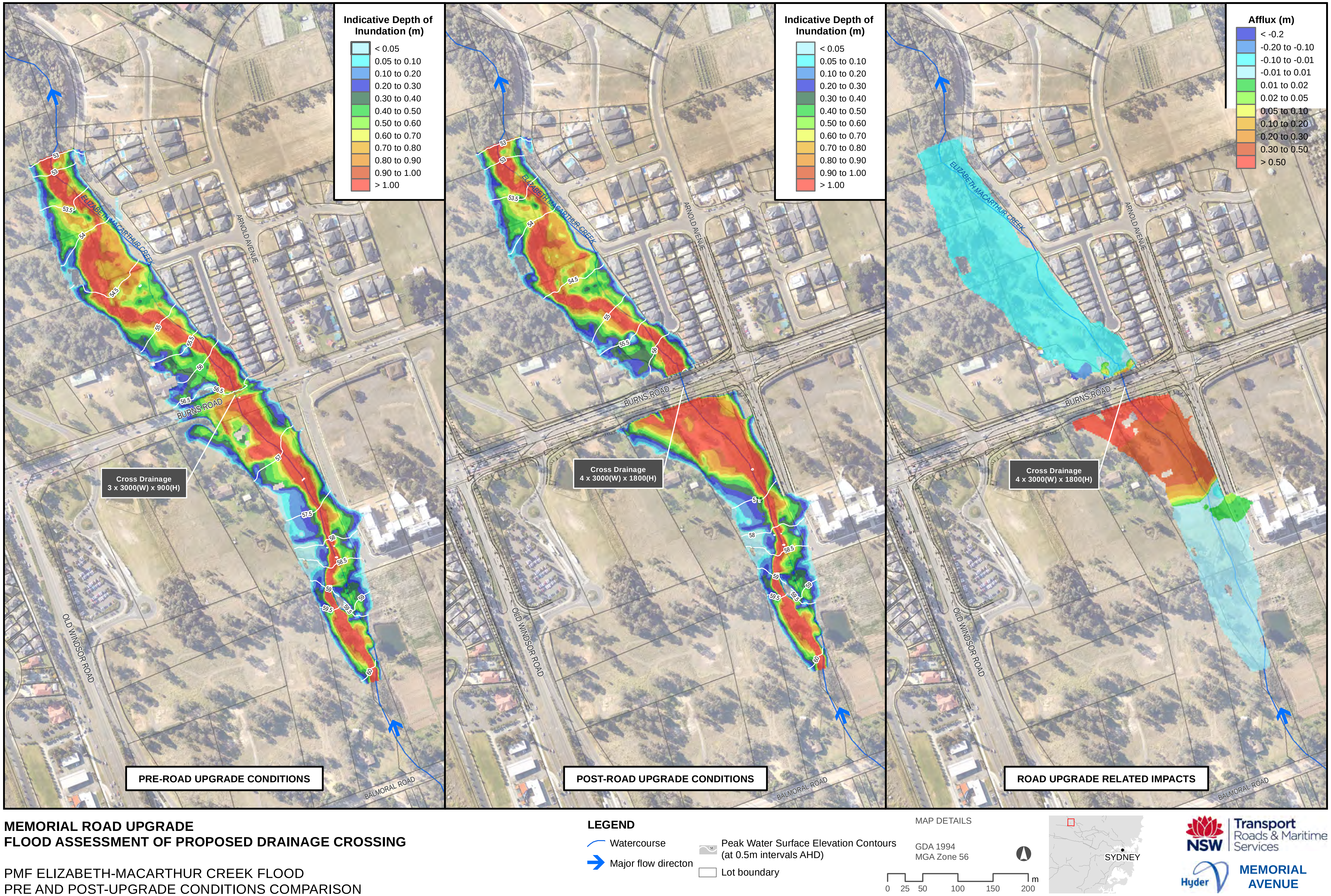
0 25 50 100 150 200 m

SYDNEY

NSW Transport Roads & Maritime Services

Hyder

MEMORIAL AVENUE



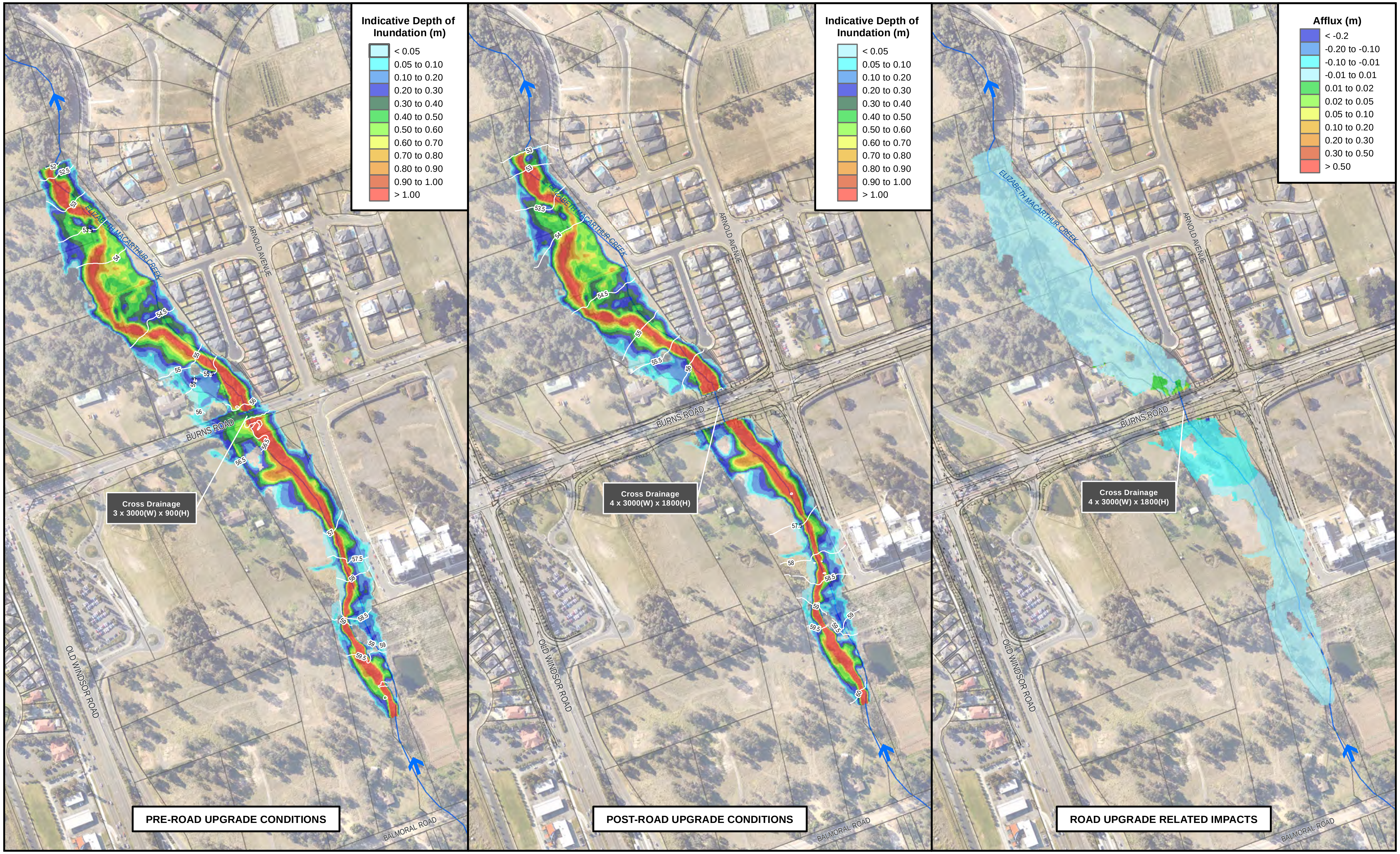
MEMORIAL ROAD UPGRADE
FLOOD ASSESSMENT OF PROPOSED DRAINAGE CROSSING

PMF ELIZABETH-MACARTHUR CREEK FLOOD
PRE AND POST-UPGRADE CONDITIONS COMPARISON

Transport Roads & Maritime Services

Hyder

MEMORIAL AVENUE



MEMORIAL ROAD UPGRADE
FLOOD ASSESSMENT OF PROPOSED DRAINAGE CROSSING

100 YEAR ARI ELIZABETH-MACARTHUR CREEK FLOOD
PRE AND POST-UPGRADE CONDITIONS COMPARISON

LEGEND

- Watercourse
- Major flow directon
- Peak Water Surface Elevation Contours (at 0.5m intervals AHD)
- Lot boundary

MAP DETAILS

GDA 1994
MGA Zone 56

0 25 50 100 150 200 m

SYDNEY

NSW Transport Roads & Maritime Services

Hyder

MEMORIAL AVENUE