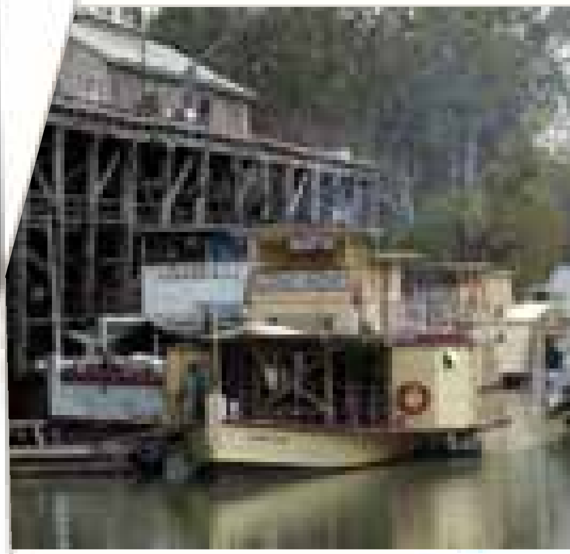
Echuca-Moama Bridge Scoping Study

Investigation of the Mid West 2 Alignments

LJ5748 / RM2397



Prepared for
VicRoads

January 2013

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Document Information

Prepared for	VicRoads
Project Name	Investigation of the Mid West 2 Alignments
File Reference	LJ5748_RM2397_Final_v1.0.docx
Job Reference	LJ5748 / RM2397
Date	January 2013

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Document Control

Version	Date	Author	Author Initials	Reviewer	Reviewer Initials
0.1	Nov 2012	Heath Sommerville	HCS	Rob Swan	RCS
1.0	Jan 2013	Heath Sommerville	HCS	Rob Swan	RCS

Cover Image: Echuca Wharf with paddle steamers taken from advancetourism.com.au

Executive Summary

Cardno has undertaken a detailed assessment of additional structure alignments for the proposed Echuca-Moama bridge crossing. These alignments are denoted the 'Mid West 2' alignments. This report defines six proposed alignments and outlines the approach undertaken to determine the specific hydraulic structures (bridges, culvers etc) required to ensure that the peak flood depths for the Campaspe and Murray Rivers are not increased above acceptable levels (set by the North Central CMA). This report outlines the detailed modelling of the designed alignments and extends upon the preliminary assessment of the proposed options (March 2012).

The preliminary and detailed analysis was undertaken using the 5%, 2%, 1% and 0.5% Annual Exceedence Probability (AEP) flood events. These events were developed based on the hydrological analysis from the Moama-Echuca Flood Study (SKM, 1997). The analysis in that report was based on a Flood Frequency Analysis (FFA) with over 100 years of data (1865-1996), and tested using a one-dimensional (1D) hydraulic model (MIKE11). The key hydrological flow rates and level at the Echuca Wharf gauge are summarised in Table i for the events used in this analysis.

Table i Design Flows and Levels as per SKM's findings in the Moama-Echuca Flood Study

Design ARI (Years)	Estimated Murray Rating Curve Flow (m^3/s)	Design Peak Levels at Echuca Wharf (m AHD)
10	1,055	94.45
20	1,195	94.85
50	1,343	95.20
100	1,431	95.45
200	1,505	95.60

The floodplain behaviour at Echuca is complicated by the confluence of the Campaspe and Murray Rivers and as such a range of hydrological events must be simulated. Details of these scenarios are summarised in Section 6. The three scenarios used for the hydrology included:

- **Scenario 1**: Murray River inflows from the estimated rating-curve flows at the Echuca Wharf gauge, with a tailwater level set to achieve the design flood-level at the Echuca Wharf gauge. A low flow was added for the Campaspe River based on the design flow hydrographs in SKM's report.
- **Scenario 2**: A tailwater level set at the design flood-level at the downstream boundary of the model (taken from the SKM report, approximately 12 km downstream of the proposed works) with Murray River inflows set to achieve the design flood-level at the Echuca Gauge. A low flow was added for the Campaspe River based on the design flow hydrographs in SKM's report.
- **Scenario 3**: High (design) flow in the Campaspe with a low flow in the Murray, using a tailwater condition set at the design flood-level at the downstream boundary of the model (taken from the SKM report, approximately 12 km downstream of the proposed works). Scenario 3 was not undertaken for the 200 year event, as it was not required in the scope of the study.

The preliminary assessment extended upon the works completed by Cardno in 2009 on the Mid West alignment which is shown in Figure i as the 'Alignment from the 2009 Assessment'. As a result of the 2009 study VicRoads proposed additional alignments, these options are denoted as the 'Mid West 2' alignments. The six preliminary alignments for Mid West 2 are shown in Figure i. Each of the proposed alignments was set above the 1% AEP flood event with a minimum of 300 mm freeboard to ensure there was no overtopping of the alignments.

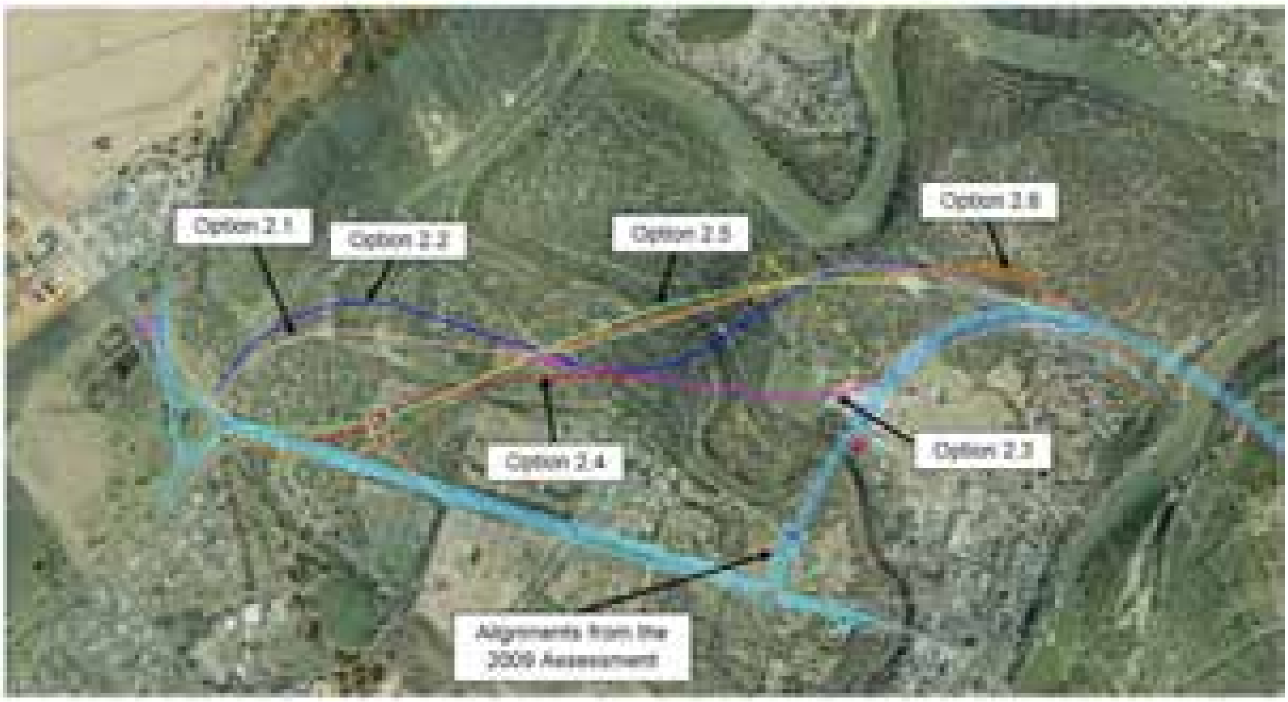

Figure i Proposed alignments for the Mid West 2 Echuca-Moama bridge crossing

A preliminary analysis was undertaken on the six proposed options (details of the preliminary assessment have been summarised in Section 8). From this assessment four options were selected to progress to a detail design phase. The selected options included:

- Option 2.1 (denoted as '2A' for the detailed assessment)
- Option 2.3 (denoted as '2B' for the detailed assessment)
- Option 2.5 (denoted as '2C' for the detailed assessment)
- Option 2.4 (denoted as '2D' for the detailed assessment)

The detailed analysis of the four selected options involved a detailed design of each of the alignments which was undertaken by SKM. The detailed design was used to develop a trial and error approach to establish the required mitigation (i.e. bridge opening widths and culverts) within the structure to ensure that the North Central CMA's criteria to maintain peak flood depths at no greater than 2.5 cm above existing were maintained. The required mitigation lengths are summarised in Table ii for the detailed alignments.

Table ii Summary of the required mitigation for the detailed design alignments

Alignment	Bridge Length (m)	Culverts width (m)	Total Mitigation Width (m)
2A	2,055	-	**2,055**
2B	1,715	-	**1,715**
2C	2,150	240 (80 x 3m x 2.4m)	**2,390**
2D	1,840	240 (80 x 3m x 2.4m)	**2,080**

Within this report the recommended option has been based on using the required bridge length openings and culvert width as a proxy for increased costs for the bridge construction. This is based on the knowledge that building the elevated structure and culverts is more expensive than constructing raised embankments.

Alignment 2B provides the shortest length of mitigation to achieve the objectives for the proposed Echuca-Moama bridge and is therefore the recommended alignment from this study. It should be noted that only alignments 2A and 2B had detailed drainage plans developed.

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Glossary

Annual Exceedence Probability (AEP)	Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded; it would occur quite often and would be relatively small. A 1% AEP flood has a low probability of occurrence or being exceeded; it would be fairly rare but it would be relatively large.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Recurrence Interval (ARI)	The average or expected value of the period between exceedences of a given discharge or event. A 1 in 100 year ARI event would occur, on average, once every 100 years.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Design flood	A significant event to be considered in the design process; various works within the floodplain may have different design events e.g. some roads may be designed to be overtopped in the 1 in 1 year or 100% AEP flood event.
Development	The erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
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 overland runoff before entering a watercourse and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Geographical information systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.

Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff, pipe and overland stream flow.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a more detailed explanation see Annual Exceedence Probability.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. For this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Topography	A surface which defines the ground level of a chosen area.

1 Introduction

Cardno has undertaken a detailed assessment of additional proposed alignments for the Echuca-Moama bridge crossing. These alignments are denoted the 'Mid West 2' alignments. This report defines the six proposed alignments and outlines the approach undertaken to determine the specific hydraulic structures (bridges, culvers etc) required to ensure that the peak flood depths for the Campaspe and Murray Rivers are not increased above acceptable levels. This report outlines the detailed modelling of the designed alignments and extends upon the preliminary assessment of the proposed options (March 2012).

This report includes all relevant background information from previous reports as required so that the document has the capacity to act as a standalone document.

Cardno was commissioned by VicRoads to undertake a detailed assessment of the hydrology surrounding the proposed Echuca-Moama bridge alignment. This assessment formed the report of the *Detailed Hydrology Study for the Echuca-Moama Bridge Planning Study* ["the 2009 Study"] (Cardno, 2009). This was followed by an addendum report ["the Addendum"] (Cardno, 2010) to assess additional modelling that was required due to additional information becoming available. This report is a stand-alone document that incorporates the required information regarding the hydrology and model setup from the 2009 Study and the Addendum and leads on to the assessment of the additional Mid West 2 bridge alignments.

The 2009 Study examined various options for the Echuca-Moama proposed bridge alignment flood mitigation options for the Murray River and Campaspe River (Warren Street) crossings. Overall there were three options considered for the Murray River crossing and seven options explored for the Campaspe River crossing and Warren Street. The 2009 Study developed these options so that the flood afflux criteria were at acceptable levels via flood mitigation structures. Each option was subject to a basic economic analysis.

The purpose of the 2009 study was to develop a model alignment that met the balance between meeting the flood afflux criteria, the VicRoads guidelines and the economic constraints for the proposed structure. The addendum report was required due to additional information that was required to be examined, including:

- The inclusion of the Moama levee bank system on the northern side of the Murray River.
- Extending the model upstream along the Murray River to encapsulate the additional levee banks.
- Assessing the 0.5% AEP (1 in 200 year ARI) event for the Murray River flows.
- Exploring modification of existing options for the orientation of the Murray River and Campaspe River sections of the proposed bridge to aid the final design.

This report includes the relevant information from the 2009 Study and Addendum as required so that the document has the capacity to act as a standalone document.

1.1 Relevant Legislation, Policy and Guidelines

The following legislation, policy and guidelines have been considered during this study:

- Victorian Flood Management Strategy (State Flood Policy Committee, 1998)
- State Planning Policy Framework as part of Victoria Planning Provisions
- A planning guide for land liable to flooding in rural Victoria (RWC, 1989)
- A guide to Floodplain Management in Country Victoria (RWC, 1987)
- Water Act 1989 (Vic)
- Floodplain Development Manual (NSW Government, 2005)
- Water Management Act 2000 (NSW).
- Murray Local Environmental Plan (LEP) (2010).

A more detailed outline of the legislation and policy framework is outlined in Table 1.1.

Table 1.1 Relevant policies and framework

Policy/Strategy	Clause	Objective
State Planning Policy Framework (SPPF)	15.01 Protection of catchments, waterways and groundwater.	To assist in the protection and, where possible, restoration of catchments, waterways, water bodies, groundwater, and the marine environment.
	15.02 Floodplain Management	To assist the protection of: • Life, property and community infrastructure from flood hazard. • The natural flood carrying capacity of rivers, streams and floodways. • The flood storage function of floodplains and waterways. • Floodplain areas of environmental significance.
	15.09 Conservation of native flora and fauna	To assist the protection and conservation of biodiversity, including native vegetation retention and provision of habitats for native plants and animals and control of pest plants and animals.
Murray Local Environmental Plan 2010 (LEP)	7.1 Biodiversity (Terrestrial)	The objective of this clause is to maintain terrestrial biodiversity, including: • protecting native flora and fauna, • protecting the ecological processes necessary for their continued existence, and • encouraging the recovery of native flora and fauna, and their habitats.
	7.2 Riparian Land and Waterways	The objective of this clause is to protect and maintain: • water quality within waterways, • stability of the bed and banks of waterways, • aquatic and riparian habitats, and • ecological processes within waterways and riparian areas.
	7.3 Wetlands	The objective of this clause is to ensure that natural wetlands are preserved and protected from the impacts of development.
	7.5 Flood planning	The objectives of this clause are as follows: • to minimise the flood risk to life and property associated with the use of land, • to allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change, • to avoid significant adverse impacts on flood behaviour and the environment.

	7.6 Development on river front areas	The objectives of this clause are as follows: • to support natural riverine processes, including migration of the river channel, • to protect and improve the bed and bank stability of rivers, • to maintain or improve the water quality of rivers, • to protect the amenity, scenic landscape values, cultural heritage of rivers and public access to riverine corridors, • to conserve and protect riverine corridors, including wildlife habitat.
	7.7 Development on riverbeds and banks	The objectives of this clause are as follows: • to manage and maintain the quality of water in rivers, • to protect the environmental values, scenic amenity and cultural heritage of rivers, • to protect the stability of the bed and bank of rivers, • to limit the impact of structures in rivers on natural riverine processes and navigability of rivers.
Campaspe Shire Municipal Strategic Statement (MSS)	21.04 Flooding	The catchments of the various rivers and streams within the municipality include areas of flood prone land, where flooding has historically caused substantial damage to the built environment. Floods are naturally occurring events and the inherent functions of the floodplains to convey and store floodwater should be recognised and preserved to minimise the deterioration of environmental values, mitigation of downstream flooding and maintain floodplain production, assets and communities. Sound floodplain management in the municipality is the critical means by which the economic, social and environmental risks associated with floodplain use and development can be managed. This level of management is provided by seven “local floodplain development plans (LFDP)” which have been prepared by the respective CMA’s to provide a performance-based approach for decision making that reflects local issues and best practice in floodplain management.

	44.04 Land Subject to Inundation Overlay	To implement the State Planning Policy Framework and the Local Planning Policy Framework, including the Municipal Strategic Statement and local planning policies. To identify land in a flood storage or flood fringe area affected by the 1 in 100 year flood or any other area determined by the floodplain management authority. To ensure that development maintains the free passage and temporary storage of floodwaters, minimises flood damage, is compatible with the flood hazard and local drainage conditions and will not cause any significant rise in flood level or flow velocity. To reflect any declaration under Division 4 of Part 10 of the Water Act, 1989 where a declaration has been made. To protect water quality in accordance with the provisions of relevant State Environment Protection Policies, particularly in accordance with Clauses 33 and 35 of the State Environment Protection Policy (Waters of Victoria). To ensure that development maintains or improves river and wetland health, waterway protection and flood plain health.

2 Scope of Works

The purpose of this report is to outline the detailed assessment of the selected Mid West 2 proposed crossing of the Echuca-Moama floodplain. The Mid West 2 alignments were developed following the previous 2009 investigation and were subject to a preliminary investigation in March 2012. The detailed assessment aims to extend the investigation from a concept alignment to a full design of the alignments such that increases to the flood depths within the floodplain are maintained within acceptable levels. Acceptable levels have been set by the North Central Catchment Management Authority (North Central CMA) as being no greater than 2.5 cm when compared to existing conditions.

The preliminary proposed alignments are shown in Figure 2-1. For the proposed Mid West 2 alignments there were six (6) alignment options initially proposed. In the preliminary investigation in March 2012 this set of six options was reduced to four for the detailed design options. The details of the preliminary assessment have been included in Section 7.

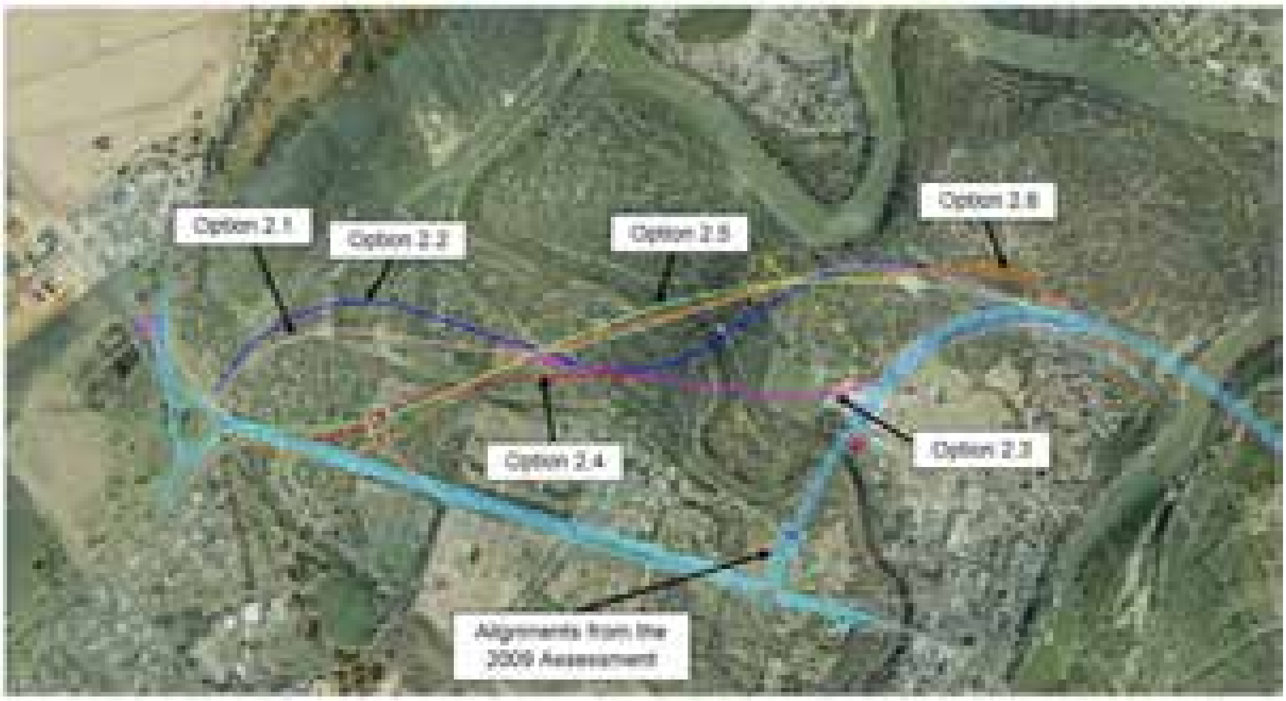

Figure 2-1 Proposed alignments for the Mid West 2 Echuca-Moama bridge crossing

From the six options four were selected due to the similarities between the options and to minimise the costs for the investigation. From the six options the following were selected for the detailed assessment:

- Option 2.1 (denoted as '2A' for the detailed assessment)
- Option 2.3 (denoted as '2B' for the detailed assessment)
- Option 2.5 (denoted as '2C' for the detailed assessment)
- Option 2.4 (denoted as '2D' for the detailed assessment)

Options 2A, 2B, 2C and 2D are detailed design options that include the full road width, batter slopes, full abutments widths as well as the required runoff and sedimentation infrastructure. The setup of these alignments is summarised in Section 5.

3 Background

There are three major highways that intersect at Echuca-Moama; the Northern Highway and the Murray Valley Highway in Victoria and the Cobb Highway in New South Wales. These highways are all significant transport routes. The existing Murray River bridge structure is narrow with one lane in each direction and has little capacity to cater for the long-term traffic needs of the region (VicRoads Study Brief, 2008). The existing bridge is unable to provide a suitable level of service for the increasing volume of traffic in the area during peak tourist events. The existing bridge also requires extensive rehabilitation which would result in partial closure of the bridge while work is being carried out. The second Murray River crossing will act as an alternative access between Echuca and Moama and relieve congestion on the existing bridge.

3.1 Murray River Options

In the 2009 Study three options were considered to span the Murray River floodplain. Each of these options was denoted ‘a’, ‘b’ and ‘c’. A summary of the options and their relative performance and costs is shown in Table 3-1.

Initially, all options provided for a 545 m bridge length over the Murray River with the following assumptions:

- The existing bridge (Warren Street Bridge) would be retained,
- The proposed bridge over the Murray River would be a cantilever bridge, with a 95 m span between the main piers on the banks of the Murray.
- Neither of the bridges would have significant piers in the main river channel.
- Piers on the proposed bridge would be aligned with the direction of floodplain flow,
- Spans between bridge piers in the floodplain would be approximately 20 m in length, with the span between bridge piers larger for the proposed Murray River Bridge. The Murray River itself would be spanned by a 95m section of bridge, with no bridge piers in the main river channel.
- Bridge piers in the floodplain would have an average width of 1 m,
- The pier dimension perpendicular to the road centreline would be no greater than 5 m,

Option ‘a’ was the mitigation option explored with only the 545 m bridge span utilised, there was no additional bridge span included. This option required 50 culverts at 3.6 m x 3 m (w x h) to mitigate the afflux upstream of the bridge structure on the Murray River.

Option ‘b’ explored the required additional bridge width to mitigate the flood afflux assuming that no additional drainage was included aside from the existing infrastructure. This option found that the 545 m bridge span would have to be extended by 185 m to achieve appropriate flood afflux.

Option ‘c’ was a compromise between these two options with a partial bridge extension of 105 m with 12 culverts of 3.6 m x 3 m (w x h) included under the roadway to manage flood afflux. Ultimately **Option ‘c’ was the recommended** option due to this option having the best hydraulic performance and only a marginal additional economic cost over Option ‘a’.

Table 3-1 Murray Floodplain Mitigation Summary

Description	Murray Floodplain Options		
	a	b	c
Bridge Span (m)	545	730	650
Culverts (No. x w x h) (m)	50 x 3.6 x 3	Local drainage only	12 x 3.6 x 3
Hydraulic Performance (Acceptable Afflux)	Fair	Poor	Good
Total Supply Cost Mitigation Works (incl. 30% contingency) ($ mill)	$ 4.21 mill	$6.01 mill	$4.45 mill

3.2 Mid West Alignment

Seven vertical alignments were considered in the 2009 study for the Campaspe floodplain. VicRoads provided the vertical alignments for options 1, 2 and 3 vertical options for Warren Street before modelling occurred, effectively setting the elevation for each. The vertical elevations for options 4, 5, 6 and 7 were set from existing flood levels with appropriate road freeboard. The alignments all followed the same path and this is shown in Figure 2-1. The seven vertical options along Warren Street can be described as follows:

- **Option 1**: The road gradeline is relatively even along the length of Warren Street from the Murray Valley Highway to the existing bridge over the Campaspe River. The road gradeline is set at just below the 5% AEP flood level.

- **Option 2**: The road gradeline is effectively the same as Option 1 between the Murray Valley Highway and the new link road intersection with Warren Street. Between this intersection and the existing bridge over the Campaspe River, the road gradeline is raised to approximately the 1% AEP flood level with no freeboard.

- **Option 3**: The road gradeline is relatively even along the length of Warren Street from the Murray Valley Highway to the existing bridge over the Campaspe River. The road gradeline is set at approximately 2 m above the 1% AEP flood level (> 97.5 m AHD).

- **Option 4**: The road gradeline is relatively even along the length of Warren Street from the Murray Valley Highway to the existing bridge over the Campaspe River. The road gradeline is set at the 5% AEP flood level plus an additional 300 mm freeboard.

- **Option 5**: The road gradeline is relatively even along the length of Warren Street from the Murray Valley Highway to the existing bridge over the Campaspe River. The road gradeline is set at the 2% AEP flood level plus an additional 300 mm freeboard.

- **Option 6**: The road gradeline is set to the 5% AEP flood level plus 300 mm freeboard between the Murray Valley Highway and the new link road intersection with Warren Street. Between this intersection and the existing bridge over the Campaspe River, the road gradeline is raised to approximately the 1% AEP flood level. The slope of the transition from the 1% AEP road grade level to the 5% AEP road grade level with freeboard was approximately 1:40 (V:H).

- **Option 7**: The road gradeline is set to the 2% AEP flood level plus 300 mm freeboard between the Murray Valley Highway and the new link road intersection with Warren Street. Between this intersection and the existing bridge over the Campaspe River, the road gradeline is raised to approximately the 1% AEP flood level. The slope of the transition from the 1% AEP road grade level to the 2% AEP road grade level with freeboard was approximately 1:75 (V:H).

Seven options were examined initially in the 2009 Study for the Campaspe floodplain and each option is described in Table 3-2. Each option sets the Warren Street road at a height to provide a designated level of protection. The 2009 Study developed incorporated flood mitigation structures in order to mitigate the flood afflux to acceptable levels.

Table 3-2 Descriptions of the Mid West alignment mitigation scenarios

Option	Protection to the west of the junction	Protection to the east of the junction*	Scenario description
Option 1	< 5% AEP	< 5% AEP	Road gradeline at a constant level just below the 5% AEP.
Option 2	< 5% AEP	< 1% AEP	Road gradeline at just below the 5% AEP to the west of the junction of Warren St and the proposed bridge, and at approximately the 1% AEP (with no freeboard) to the east.
Option 3	>1% AEP	>1% AEP	Road gradeline approximately 2 m above the 1% AEP flood level.
Option 4	5% AEP	5% AEP	Road gradeline at a constant level of the 5% AEP plus 300 mm freeboard.
Option 5	2% AEP	2% AEP	Road gradeline at a constant level of the 2% AEP plus 300 mm freeboard.
Option 6	5% AEP	1% AEP	Road gradeline at the 5% AEP plus 300 mm freeboard to the west of the junction of Warren St and the proposed bridge, and at the 1% AEP plus 300 mm freeboard to the east.
Option 7	2% AEP	1% AEP	Road gradeline at 2% AEP plus 300 mm freeboard to the west of the junction of Warren St and the proposed bridge, and at the 1% AEP plus 300 mm freeboard to the east.

* The term 'protection' implies the road is not over topped by flood waters.

All options managed to achieve acceptable flood afflux while utilising a range of mitigation measures. A summary of the seven options and required mitigation measures is shown in the 2009 Study. Of the seven options, Options 2 and 6 were considered the most appropriate options as these options provided a higher level of protection at the eastern end of Warren Street and greater cost savings than other options.

As part of the Addendum, a revised option was explored denoted Mid West alignment Option 8 utilising a similar road gradeline to Option 2 and changing the Campaspe Bridge length to 300 m in total. Option 8 was assessed to determine the required culverts to mitigate the flood afflux with the changed bridge length over the Campaspe River. This was the preferred option for the bridge section over the Campaspe River. The details of the preferred option are summarised in Table 3-3.

The mitigation measures as summarised in Option C and Option 8 for the Mid West alignment were applied to the Mid West 2 preliminary assessment of the six proposed alignments.

Table 3-3 Selected Mid West alignment floodplain mitigation summary

Mitigation Culvert Set	Description	Selected Mid West Alignment
4796	Culvs. (No. x w x h in m)	12 x 3.6 x 1.2
	Total Mitigation Width (m)	43
	Waterway Area (m^2)	52
4797	Culvs. (No. x w x h in m)	18 x 3.6 x 1.8
	Total Mitigation Width (m)	65
	Waterway Area (m^2)	117
4798	Culvs. (No. x w x h in m)	40 x 2.7 x 0.9
	Total Mitigation Width (m)	108
	Waterway Area (m^2)	97
4799	Culvs. (No. x w x h in m)	40 x 2.7 x 0.9
	Total Mitigation Width (m)	108
	Waterway Area (m^2)	97
Campaspe River Bridge	Existing Design	240 m
	Additional Span	60 m
	Total Bridge Span Required	300 m
Total	Total Mitigation Width on Warren Street (m) (excluding bridge openings)	324
	Waterway Area on Warren Street (m^2) (excluding bridge openings)	363
	Hydraulic Performance (Acceptable Afflux)	Met
	Total Supply Cost* Mitigation Works (incl. 30% contingency)	$8.3 mill
	Trafficability** – to the west of the Link Rd junction (ARI)	20
	Trafficability** – to the east of the Link Rd junction (ARI)	20, 50, 100
	Additional Costs (not included in the Total Supply Cost above)	Campaspe bridge ext., fill for road gradeline.

* Supply costs based on Melbourne metropolitan area supply rates, and costs do not include installation costs.
** Road is trafficable if the flood depth is less than 0.40 m deep

4 Available Data

The following information was used in the study:

- Moama-Echuca Flood Study, prepared by SKM for the Department of Land and Water Conservation, NSW, and the Department of Conservation and Natural Resources, Vic, May 1997.
- Hydraulic river survey, feature survey and aerial photography provided by VicRoads December 2008.
- Drawings and plans showing details of existing bridges in the floodplain (provided by VicRoads and RTA February 2009).
- 1 m grid of ALS data provided by North Central CMA January 2009.
- An electronic copy of aerial photography showing proposed alignment (provided by VicRoads March 2009).
- DGN and PDF files of 3 vertical alignments (plan and long sections) (final version of file “042-pid-a-cps-06.dgn” provided via SKM 12/3/2009).
- Detailed Hydrology Study for the Echuca Moama Bridge Planning Study, prepared by Cardno for VicRoads, October 2009.
- DGN and PDF files supplied by SKM for the proposed design option 2A, 2B, 2C and 2D including:
    - X19567_SKM_CM2A1-120712.dgn
    - X19567_SKM_CM2B-120712.dgn
    - X19567_SKM_CM2C_120201.dgn
    - X19567_SKM_CM2D_120313.dgn

4.1 Review of Previous Studies

The following documents were reviewed as part of this investigation.

- Moama-Echuca Flood Study, prepared by SKM for the Department of Land and Water Conservation, NSW, and the Department of Conservation and Natural Resources, Vic, May 1997.
- Detailed Hydrology Study for the Echuca-Moama Bridge Planning Study – LJ5598 / RM2194 Final v1.1 (Cardno, 2009).
- Addendum: Detailed Hydrology Study for the Echuca-Moama Bridge Planning Study – LJ5598 / RM2277 Final v1.0 (Cardno, 2010).
- Detailed Hydrology Study for the Echuca-Moama Bridge Planning Study – Mid West 2 Alignment – LJ5748 / RM2336 Draft v0.3 (Cardno, 2012).

5 Hydrology

The basis of the hydrological analysis was taken from the Moama-Echuca Flood Study (SKM, 1997). The analysis in that report was based on a Flood Frequency Analysis (FFA) with over 100 years of data (1865-1996), and tested using a one-dimensional (1D) hydraulic model (MIKE11). The key hydrological findings of the Moama-Echuca Flood Study (SKM, 1997) are summarised as follows:

- The determination of flood flow in the area is complex due to the non-stationary nature of the interaction between the Campaspe and Murray Rivers. Consequently, various combinations of flows can cause the designated design flood-level at Echuca Wharf for each ARI.
- The design levels were translated to an estimated rating-curve giving the expected flow at each gauge height as shown in Table 5-1.
- A wide range of Murray flows can create similar levels at the Echuca gauge, depending on the flows of the Campaspe.
- Peak flood-flows in the Campaspe generally arrive at Echuca prior to peak flood-flows in the Murray (an average lag time of 6 days was assumed)
- The 1% AEP level of 95.45 m AHD gives an estimated flow at the Echuca gauge of 1,431 m3/s. However, other results in SKM's report indicate the flow in the Murray River for an equivalent gauge height ranges from 1,128 to 1,310 m^3/s.
- For double peaked inflows from the Murray River that seem to dominate the historical event, the effect of the Campaspe is diminished.

Table 5-1 Design Flows and Levels as per SKM's findings in the Moama-Echuca Flood Study

Design ARI (Years)	Estimated Murray Rating Curve Flow (m^3/s)	Design Peak Levels at Echuca Wharf (m AHD)
10	1,055	94.45
20	1,195	94.85
50	1,343	95.20
100	1,431	95.45
200	1,505	95.60

In order to address these issues when assessing the impact of the proposed works, consideration of an envelope of flood events is required. To ensure that peak flow and floodplain storage are appropriately taken into account various flood scenarios that can produce the peak flood-level at the Echuca gauge have been considered. This envelope of flood events modelled includes three scenarios:

- **Scenario 1**: Murray River inflows from the estimated rating-curve flows at the Echuca Wharf gauge, with a tailwater level set to achieve the design flood-level at the Echuca Wharf gauge. A low flow was added for the Campaspe River based on the design flow hydrographs in SKM's report.
- **Scenario 2**: A tailwater level set at the design flood-level at the downstream boundary of the model (taken from the SKM report, approximately 12 km downstream of the proposed works) with Murray River inflows set to achieve the design flood-level at the Echuca Gauge. A low flow was added for the Campaspe River based on the design flow hydrographs in SKM's report.
- **Scenario 3**: High (design) flow in the Campaspe with a low flow in the Murray, using a tailwater condition set at the design flood-level at the downstream boundary of the model (taken from the SKM report, approximately 12 km downstream of the proposed works). Scenario 3 was not undertaken for the 200 year event, as it was not required in the scope of the study.

The flow rates and tailwater conditions for the 20, 50, 100 and 200 year ARI's for each scenario are shown in Table 5-2. The modelled flood levels at the gauge are also shown for scenarios 1 and 2. For scenario 3, the level at the Echuca Wharf gauge is not critical as this event estimates the high flow in the Campaspe River.

Table 5-2 Design-Event Envelope - Assumed Hydrological Characteristics

	200 Year Scenario		100 year Scenario			50 year Scenario			20 year Scenario		
	1	2	1	2	3	1	2	3	1	2	3
Murray Flow (m^3/s)	1505	1100	1431	1000	50	1343	900	50	1195	780	50
Campaspe Flow (m^3/s)	40	40	40	40	1175	40	40	950	40	40	675
Tailwater Level (m AHD)	94.45	95.12	94.2	95.0	95.0	93.65	94.75	94.75	92.6	94.35	94.35
Flood Level at Echuca Wharf (m AHD)	95.60	95.61	95.46	95.44	N/A	95.22	95.20	N/A	94.87	94.84	N/A

Table 5-2 shows that the design flood levels at Echuca were replicated well (within +/- 0.02 m) in Scenarios 1 and 2. These scenarios provide an envelope that adequately caters for the high flows found in a large single storm-event (Scenario 1) and the effect of flood storage and high tailwater levels that occur during a longer term flood event (Scenario 2). This approach is consistent with the findings of the SKM report which showed that the joint occurrence of various flow combinations in the Murray and Campaspe (the Campaspe flows effectively contributing to a higher tailwater level) could cause the 1% AEP flood level at Echuca. The high flow in the Campaspe (Scenario 3) ensures that the critical events for the Campaspe Floodplain are modelled.

6 Model Setup

6.1 Existing Model Setup

The hydraulic model was built as a combined one and two-dimensional hydraulic model, using the SOBEK modelling package. The river cross-sections, culvert structures along Warren Street and the Campaspe Bridge at Warren Street are represented in 1D, whilst the overland terrain is represented in 2D.

The 1D channel sections have been defined from river survey data provided by VicRoads in December 2008. Existing bridges (at the Campaspe and Murray Rivers) and culverts (primarily along Warren Street) have been digitised from drawings and plans provided by VicRoads. The Shire of Campaspe indicated in February 2009 that two proposed pedestrian bridges over the Campaspe River at Anstruther St. and Eyre St. would both be above the 100 year flood level and were unlikely to have piers in the main river channel. As such these structures have not been included in the model as they are unlikely to have a significant impact on the flooding regime in the area. The Anstruther St. pedestrian bridge has replaced the existing pedestrian bridge.

The two-dimensional grid was generated from a DEM (Digital Elevation Model) developed using the spatial data analysis package, 12D, using the following data:

- Land survey provided by VicRoads in December 2008;
- 1m DEM grid provided by the North Central CMA in January 2009. This data originates from the Murray Darling Basin Authority, and was captured in 2001.

This project used a 10 x 10 m grid, and ensured that important hydraulic features such as roads and levee banks are adequately defined in the model. Figure 6-1 shows the grid extent and elevations, as well as the location of 1D elements and the model boundaries. The 10 metre grid spacing is appropriate for this investigation as the rivers and structures are represented with one-dimensional sections.

A 10 x 10 m roughness grid was generated for the same extent as the two-dimensional topography grid. The Manning's 'n' roughness values shown in Table 6-1 below were applied to this grid.

Table 6-1 Roughness Values by Land Use

Land Use	Roughness (Manning's 'n')
Road	0.018
Car Park	0.022
River	0.04
Park	0.05
Trees / Bush	0.06
Residential	0.08
Public Building	0.40
Commercial	0.50
Railway	0.05
Under Bridges	0.05
Crop / Pasture	0.03

The roughness values for Manning's 'n' were taken from Open Channel Hydraulics (Chow, 1973). Figure 6-2 shows the roughness map. The model was run with a constant discharge at the upstream boundaries on the Murray and Campaspe Rivers as discussed in Section 5. The downstream boundary was controlled by water level as discussed in Section 5.

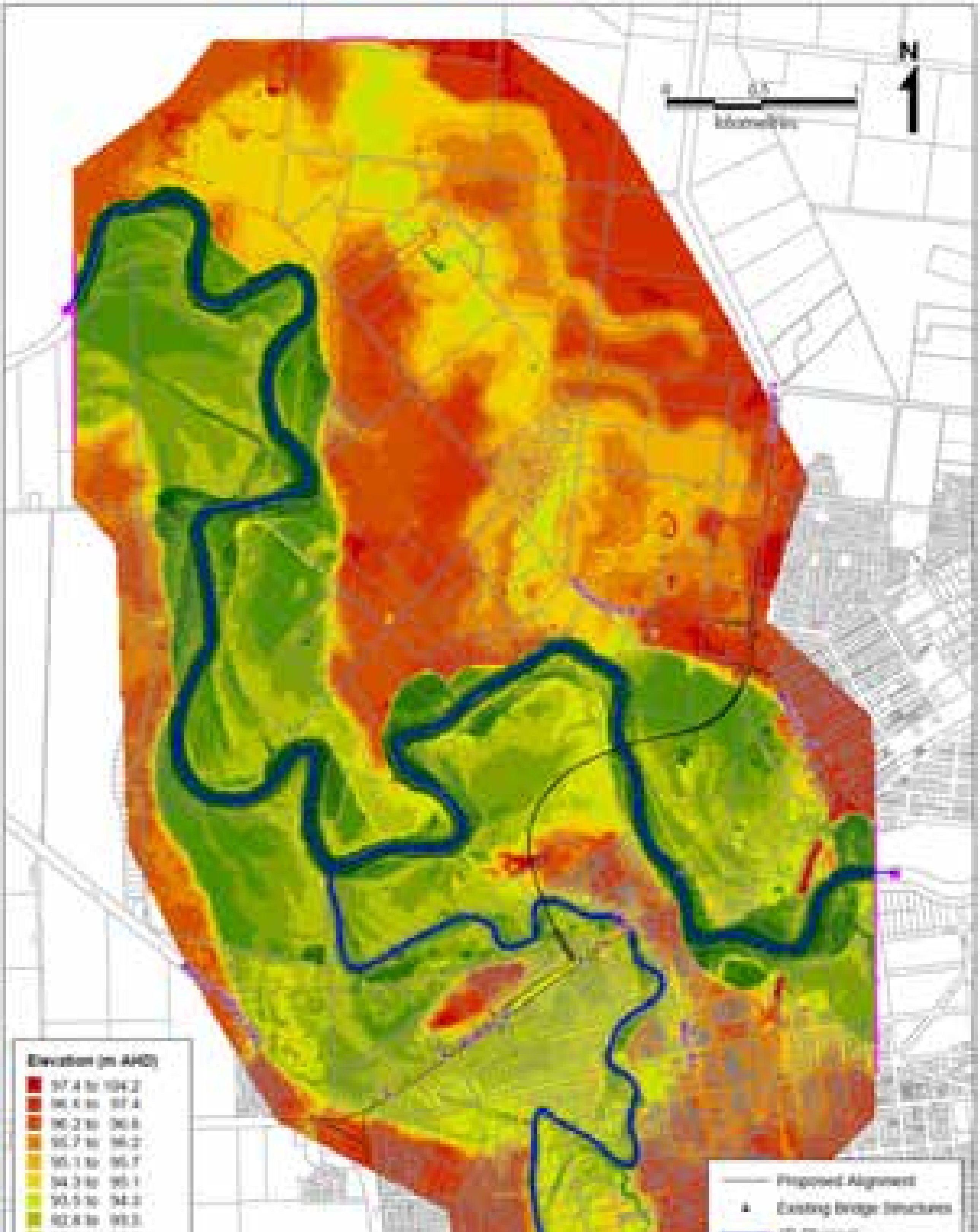

Figure 6-1 Topography for Echuca

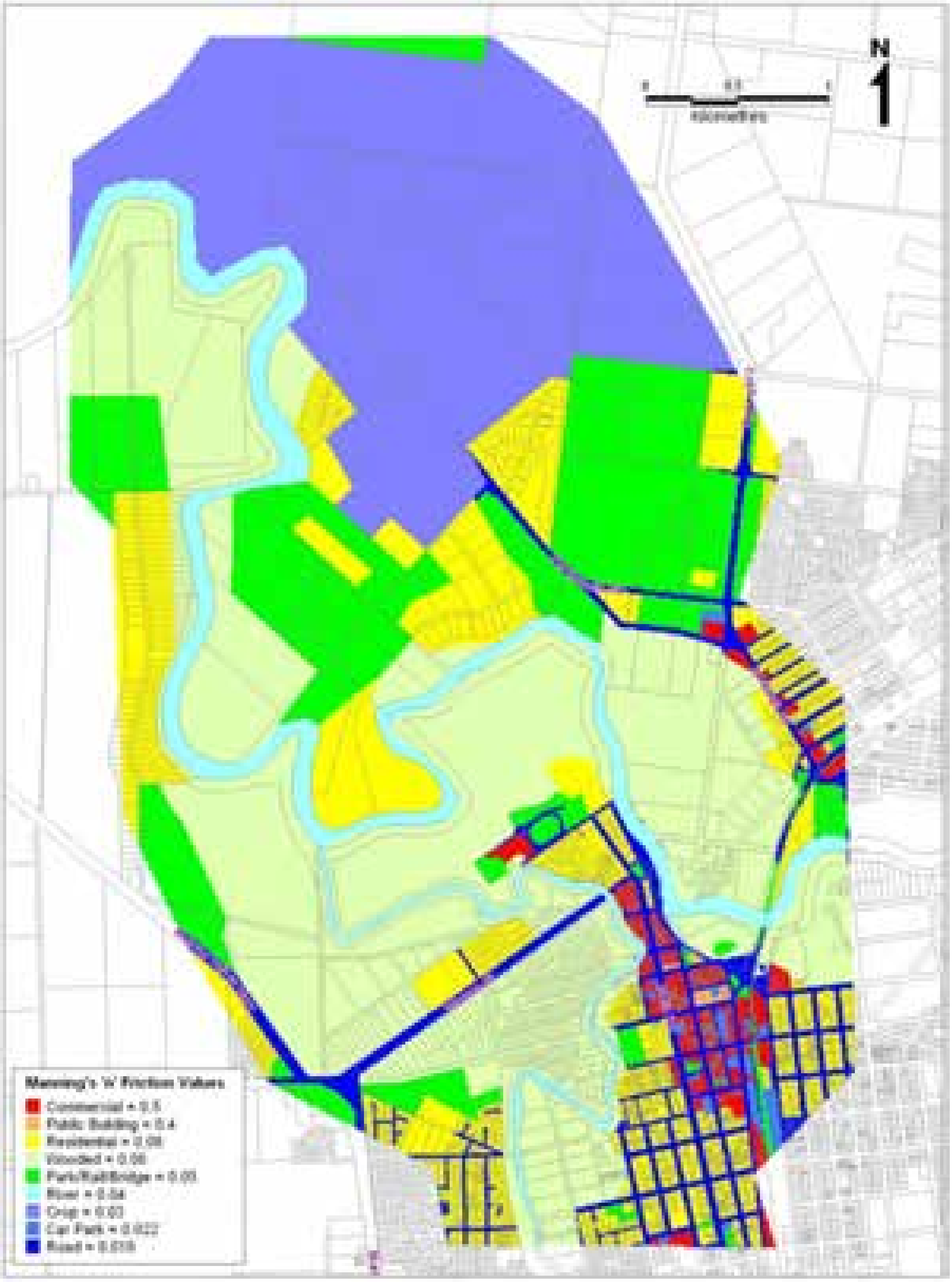

Figure 6-2   Roughness Grid for Echuca

6.2 Existing conditions

The existing conditions have been defined as per Section 5 Hydrology. The three events that have been modelled include the 5%, 2% and 1% AEP. For the three events depth plots have been developed that capture the peak flood depths reached during the events defined within the hydrology section.

The three events are presented in Figure 6-3, Figure 6-4 and Figure 6-5 respectively. The three plots show spot water surface elevations throughout the floodplain.

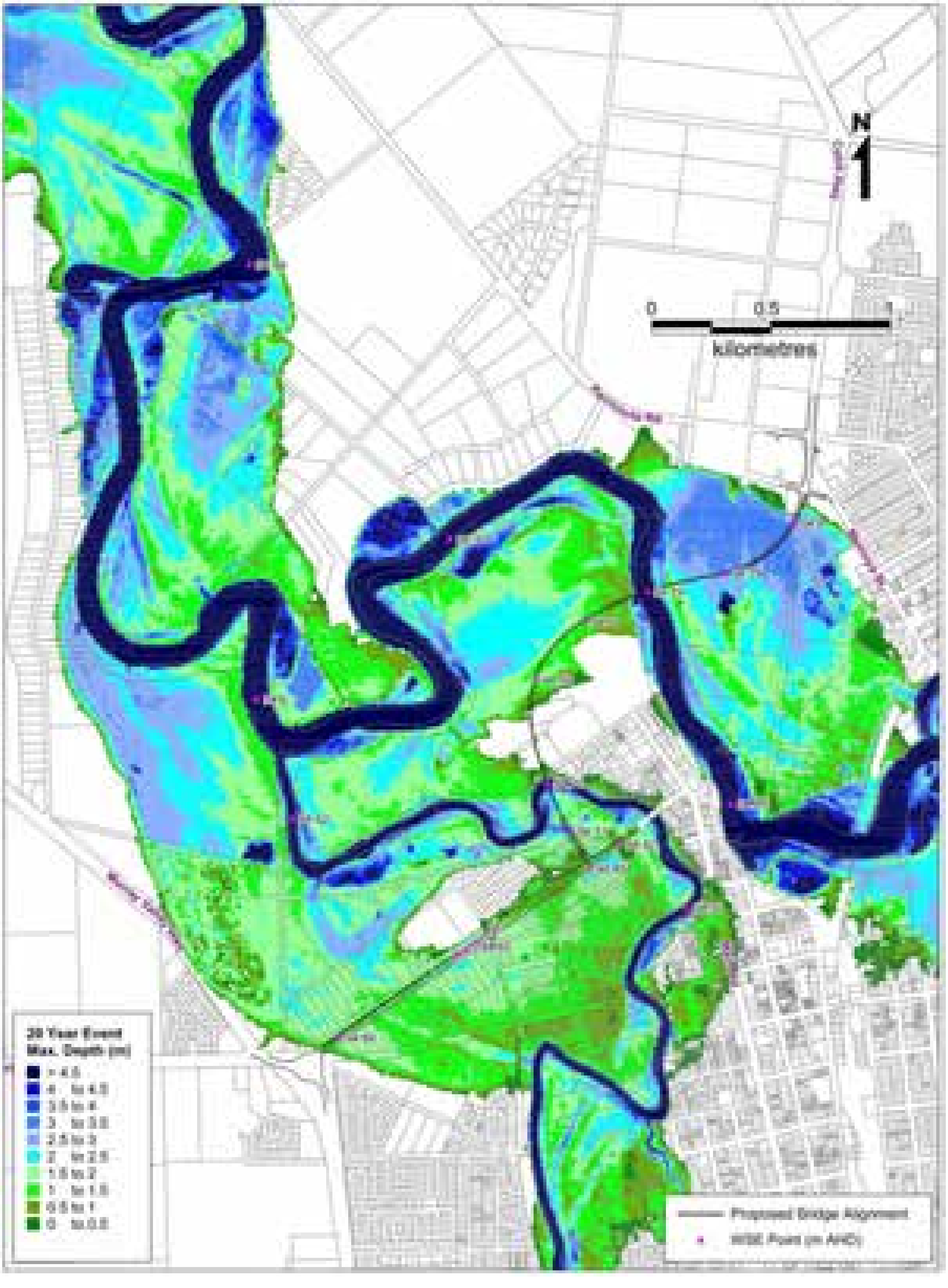

Figure 6-3 Existing 5% AEP (1 in 20 year ARI) maximum flood depths

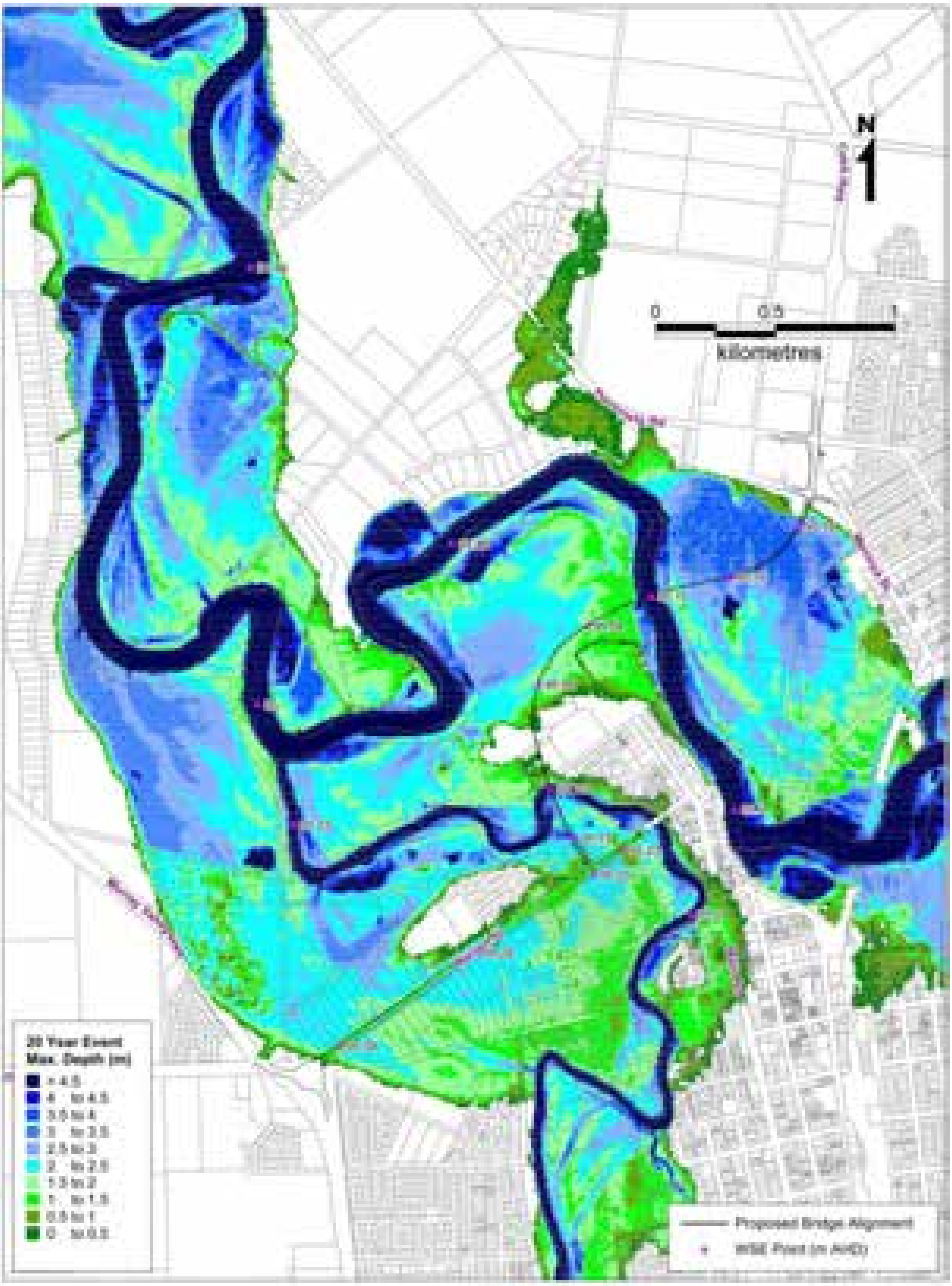

Figure 6-4 Existing 2% AEP (1 in 50 year ARI) maximum flood depths

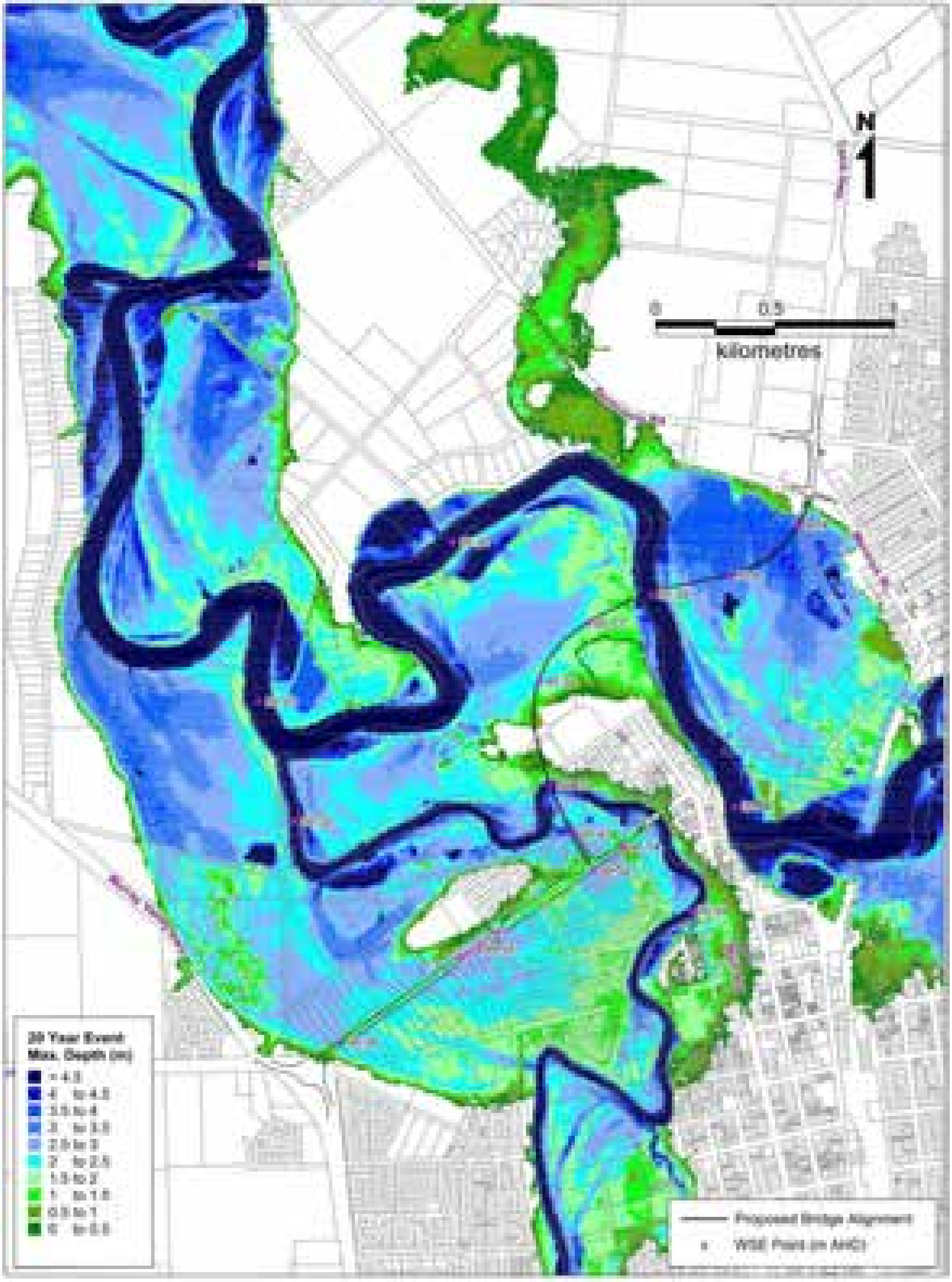

Figure 6-5 Existing 1% AEP (1 in 100 year ARI) maximum flood depths

7 Preliminary Assessment for Mid West 2

This section presents the preliminary assessment of the six (6) nominated Mid West 2 alignments. The nominated alignments are shown in Figure 7-1. Each of the alignments is flood free in the 1% AEP (1 in 100 year ARI) event as this was required as part of the design specifications.

Each alignment has been assessed using the same mitigation measures as applied in the previously selected Mid West Alignment. This method was applied in order to critically assess the performance of each alignment on a similar basis. The mitigation includes:

- 650 m clear span over the Murray River.
- Culverts Murray River – 12 x 3.6 m x 3 m (no. x w x h)
- 300 m clear span over the Campaspe River.
- Culverts 4799 – 40 x 2.7 m x 0.9 m (no. x w x h)
- Culverts 4798 – 40 x 2.7 m x 0.9 m (no. x w x h)
- Culverts 4797 – 18 x 3.6 m x 1.8 m (no. x w x h)
- Culverts 4796 – 12 x 3.6 m x 1.2 m (no. x w x h)

The Murray River bridge span and the Murray River culverts were identically placed within all six Mid West 2 alignments as the road alignment in this section was identical for all options and had not varied from the previous modelling. The remaining bridge span and culvert sets were placed appropriately for each scenario, however as each scenario's alignment changes, the culvert sets were required to be moved accordingly.

The results within this section are presented as difference plots that compare the Mid West 2 peak flood depths to the existing 5%, 2% and 1% AEP peak flood depths.

It should be noted that the objective of these preliminary runs was to establish which of the six options performed the best hydraulically using the mitigation as applied under the previously selected Mid West Alignment and would be taken to the next stage of detailed modelling. The next stage of modelling will appropriately size the mitigation structures in order to develop the most effective mitigation strategy that achieves the afflux criteria.

It should be noted that the alignments were only modelled as blockages to the main floodplain and the fully designed roadway was not modelled in the preliminary assessment. This implies that the full loss of floodplain storage was not accounted for in the preliminary modelling. These model runs were aimed at exploring the six (6) options relative to each other rather than to determine the final design specifications. Further detailed assessment is presented in Section 8.

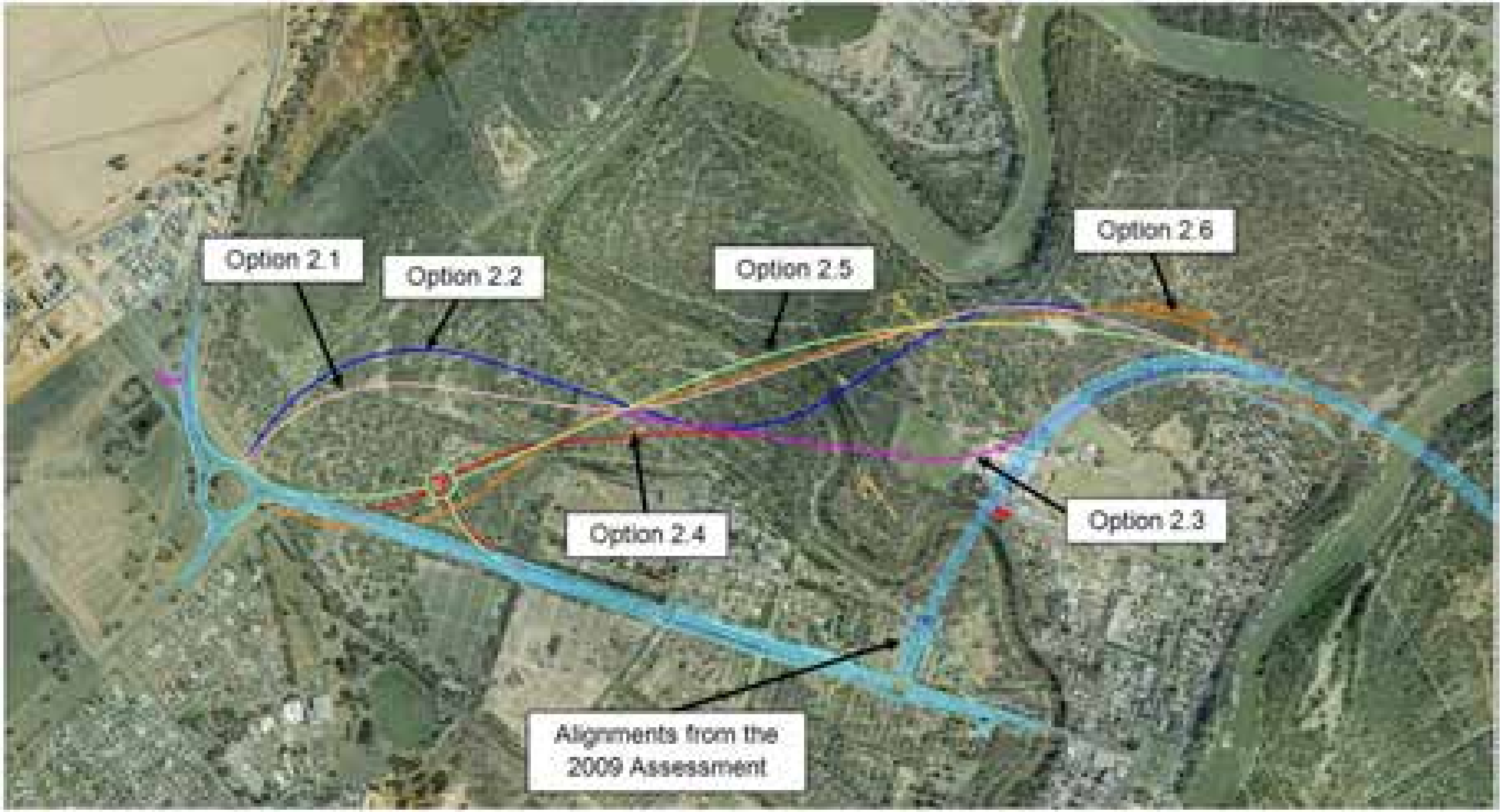

Figure 7-1 Proposed alignments for the Mid West 2 Echuca-Moama bridge crossing for the preliminary assessment

7.1 5% AEP

The results of the 5% AEP event are shown in Figure 7-2 to Figure 7-7 for Options 2.1 to 2.6 respectively. The primary observation from all of the alignments is that the initial set of mitigation is not sufficient to maintain the existing peak flood levels. The majority of the increase in peak flood depths is on the Campaspe River due to the blockage of the majority of this floodplain.

Options 2.1, 2.2 and 2.3 impact the peak flood depths mainly due to the insufficient mitigation on the western end of the nominated alignments. The peak increases in flood depths in these three alignments was +14 cm but flood depths through the Campaspe River floodplain were increased as shown in Figure 7-2, Figure 7-3 and Figure 7-4.

Options 2.4, 2.5 and 2.6 alignments merge with Warren Street at the western end of the alignment. This causes an additional constriction to the floodplain in this region and accordingly these three options show increased peak flood depths in this area and within the Campaspe River floodplain. The peak increase in depth was under Option 2.6 alignment with a 31 cm increase in flood depths observed. Options 2.4, 2.5 and 2.6 increased the flood depths on the Campaspe River floodplain as compared to Options 2.1, 2.2 and 2.3.

The peak flood depths were maintained between +/- 2 cm on the Murray River floodplain under all options aside from Option 2.6. Option 2.6 caused a small area within the Murray River floodplain to increase by between 2 to 5 cm.

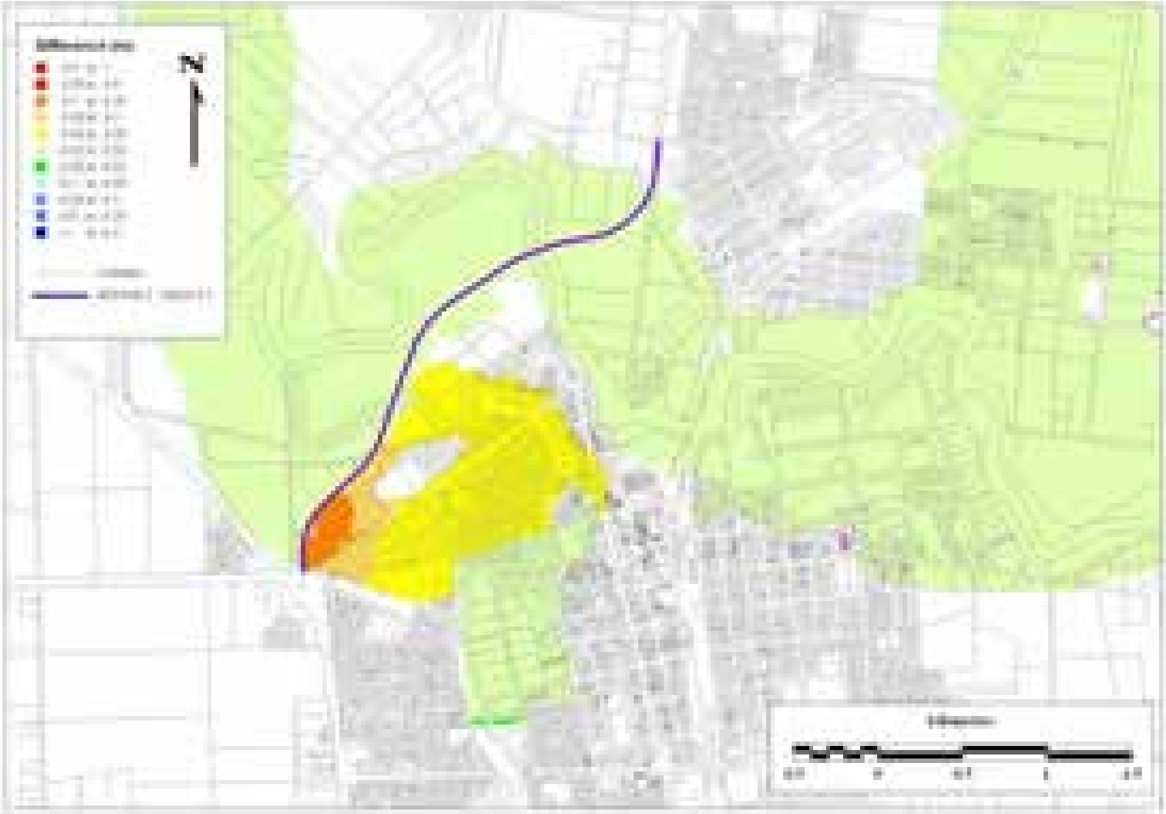

Figure 7-2 Flood difference for the preliminary Mid West 2 – Option 2.1 for the 5% AEP

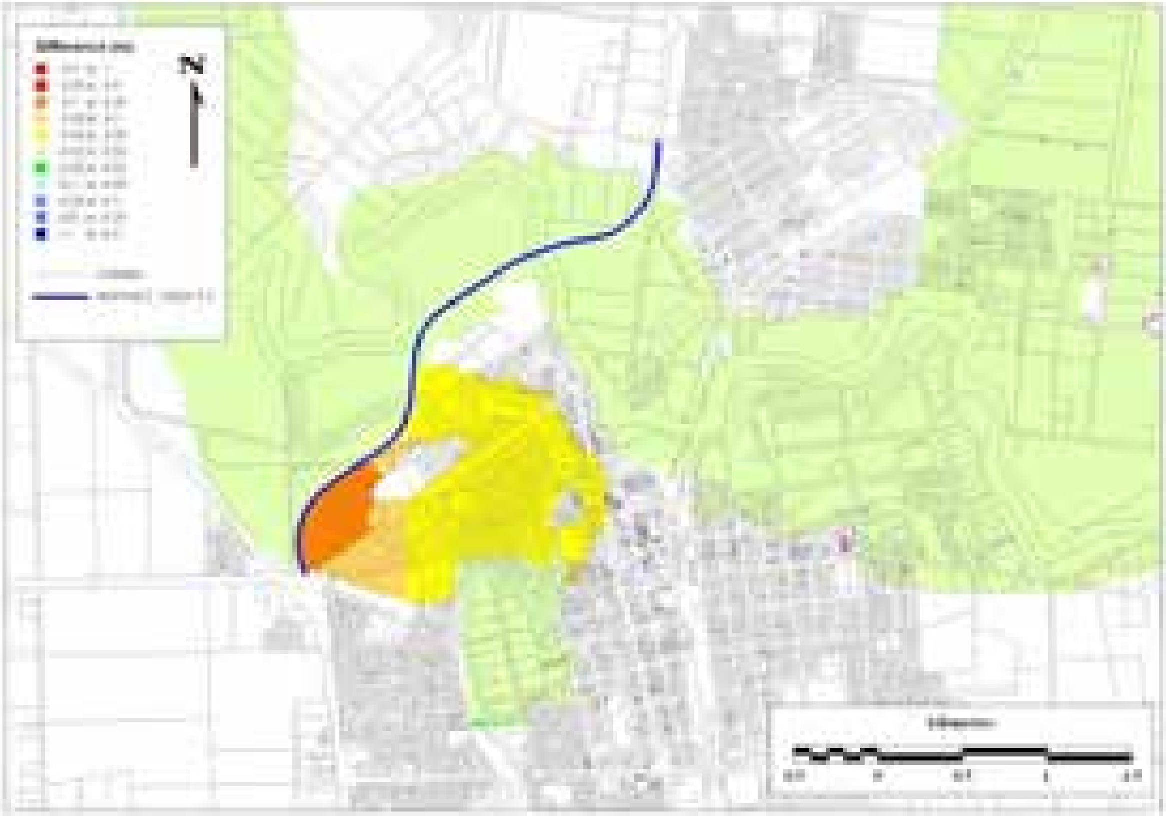

Figure 7-3 Flood difference for the preliminary Mid West 2 – Option 2.2 for the 5% AEP

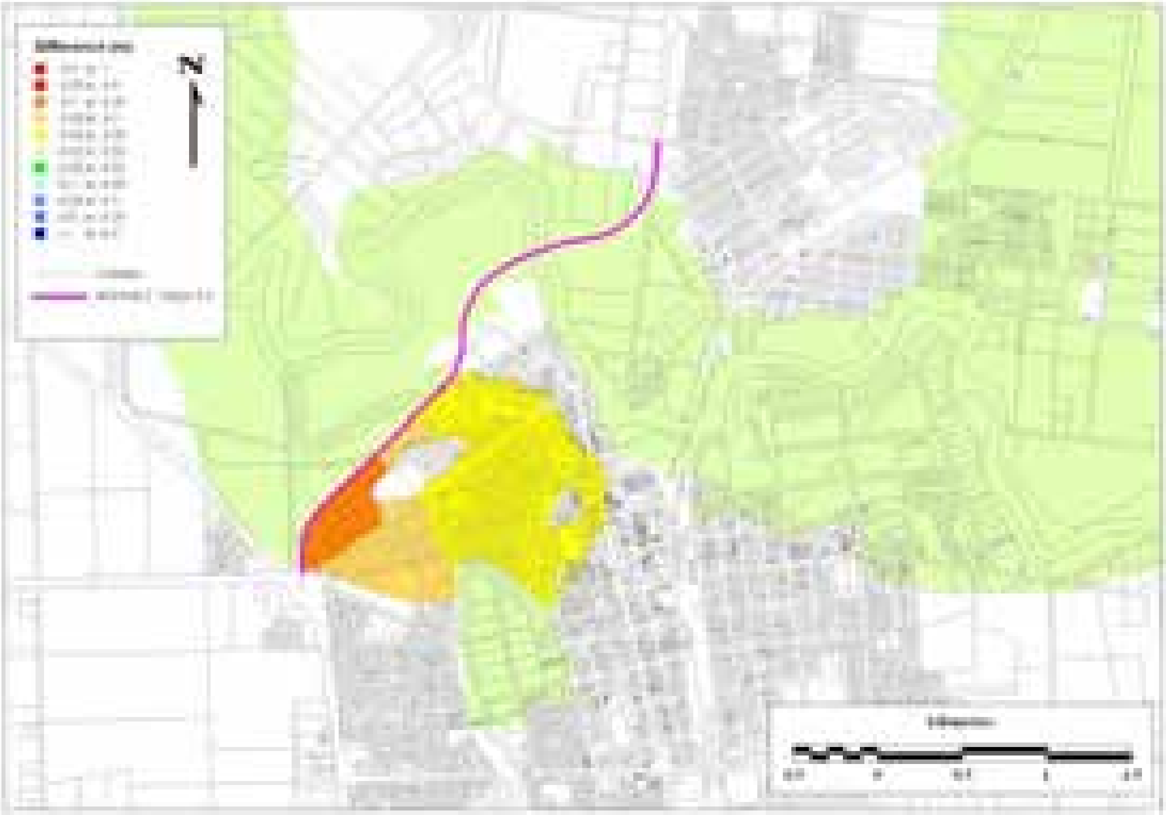

Figure 7-4 Flood difference for the preliminary Mid West 2 – Option 2.3 for the 5% AEP

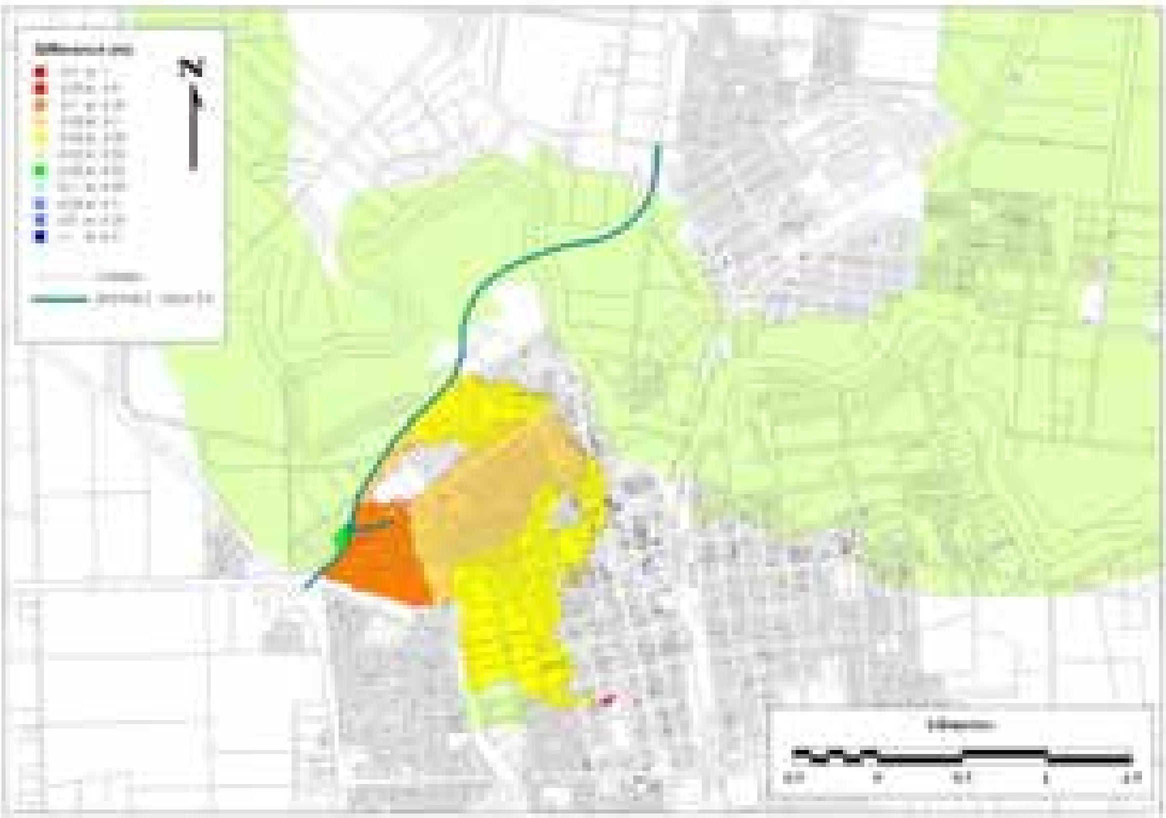

Figure 7-5 Flood difference for the preliminary Mid West 2 – Option 2.4 for the 5% AEP

Figure 7-6 Flood difference for the preliminary Mid West 2 – Option 2.5 for the 5% AEP

Figure 7-7 Flood difference for the preliminary Mid West 2 – Option 2.6 for the 5% AEP

7.2 2% AEP

The results of the 2% AEP event are shown in Figure 7-8 to Figure 7-13 for Option 2.1 to 2.6 respectively. The primary observation from all of the alignments is that the initial set of mitigation is not sufficient to maintain the existing peak flood levels. The majority of the increase in peak flood depths is on the Campaspe River due to the blockage of the majority of this floodplain, however for the 2% AEP event increased flood depths are observed on the Murray River floodplain.

As discussed as part of Section 7.1, Options 2.1, 2.2 and 2.3 impact the Campaspe River floodplain due to the insufficient mitigation applied at the western end of the alignments. In the 2% AEP this impact is exacerbated and the peak increase in flood depths increases to +22 cm. The increases in peak flood depths are extended further upstream in the Campaspe River floodplain.

Options 2.4, 2.5 and 2.6 alignments merge with Warren Street at the western end of the alignment and as previously discussed, this causes an additional constriction to the floodplain in this region and accordingly these three options show increased peak flood depths in this area and within the Campaspe River floodplain. The peak increase in depth was under Option 2.6 alignment with a 35 cm increase in flood depths observed. Options 2.4, 2.5 and 2.6 increased the flood depths on the Campaspe River floodplain as compared to Options 2.1, 2.2 and 2.3.

The peak flood depths were maintained between +/- 2 cm on the Murray River floodplain under Options 2.3 and 2.4. Options 2.1 and 2.5 showed a small area where flood depths increased between 2 and 5 cm. The largest increases in flood depths within the Murray River floodplain occurred under Options 2.2 and 2.6 as these alignments constricted the Murray River floodplain the most. The locations of the constriction to the Murray River floodplain are shown in Figure 7-8, Figure 7-9, Figure 7-12 and Figure 7-13 for Options 2.1, 2.2, 2.5 and 2.6 respectively.

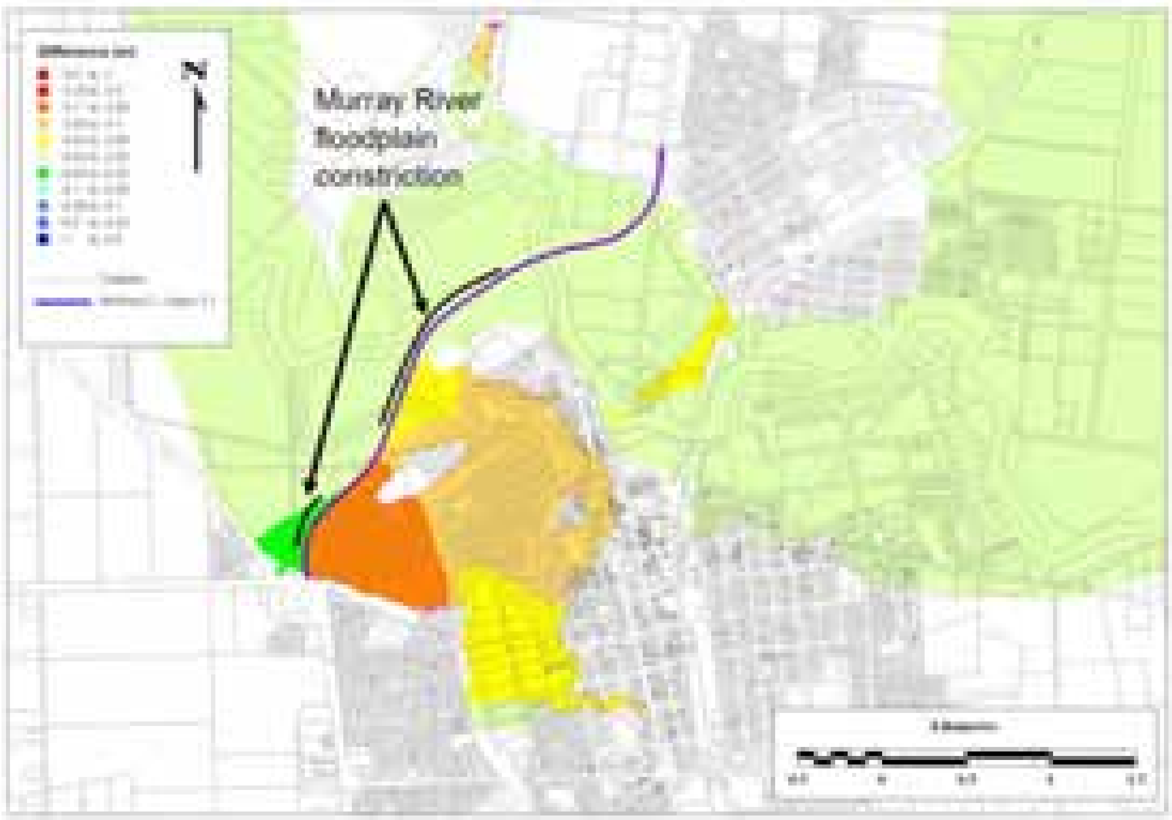

Figure 7-8 Flood difference for the preliminary Mid West 2 – Option 2.1 for the 2% AEP

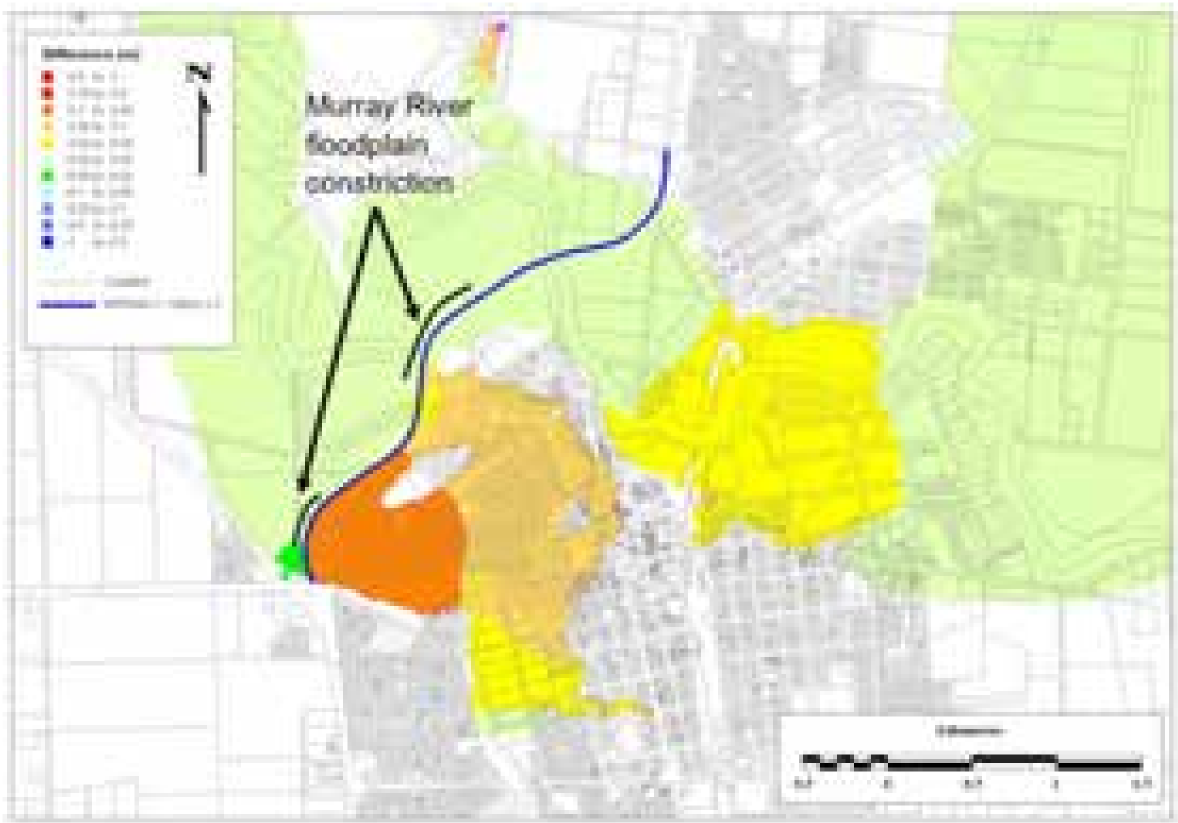

Figure 7-9 Flood difference for the preliminary Mid West 2 – Option 2.1 for the 2% AEP

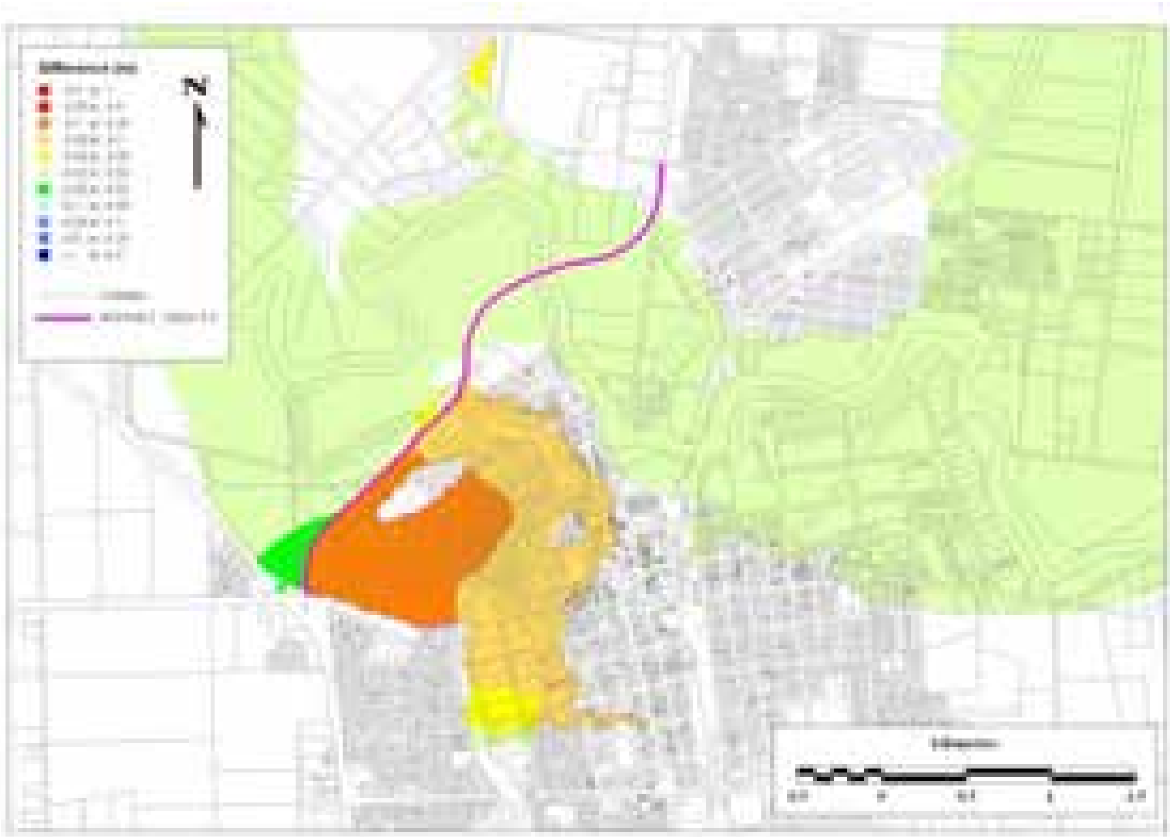

Figure 7-10 Flood difference for the preliminary Mid West 2 – Option 2.3 for the 2% AEP

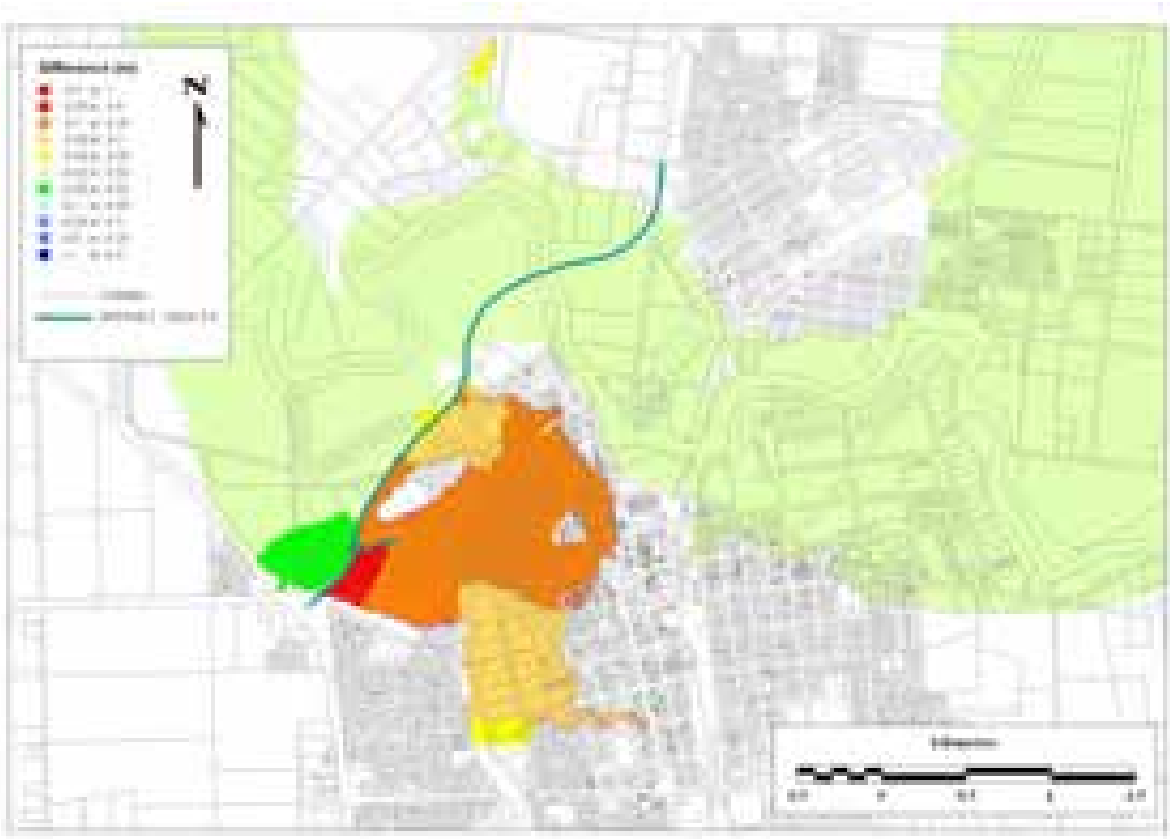

Figure 7-11 Flood difference for the preliminary Mid West 2 – Option 2.4 for the 2% AEP

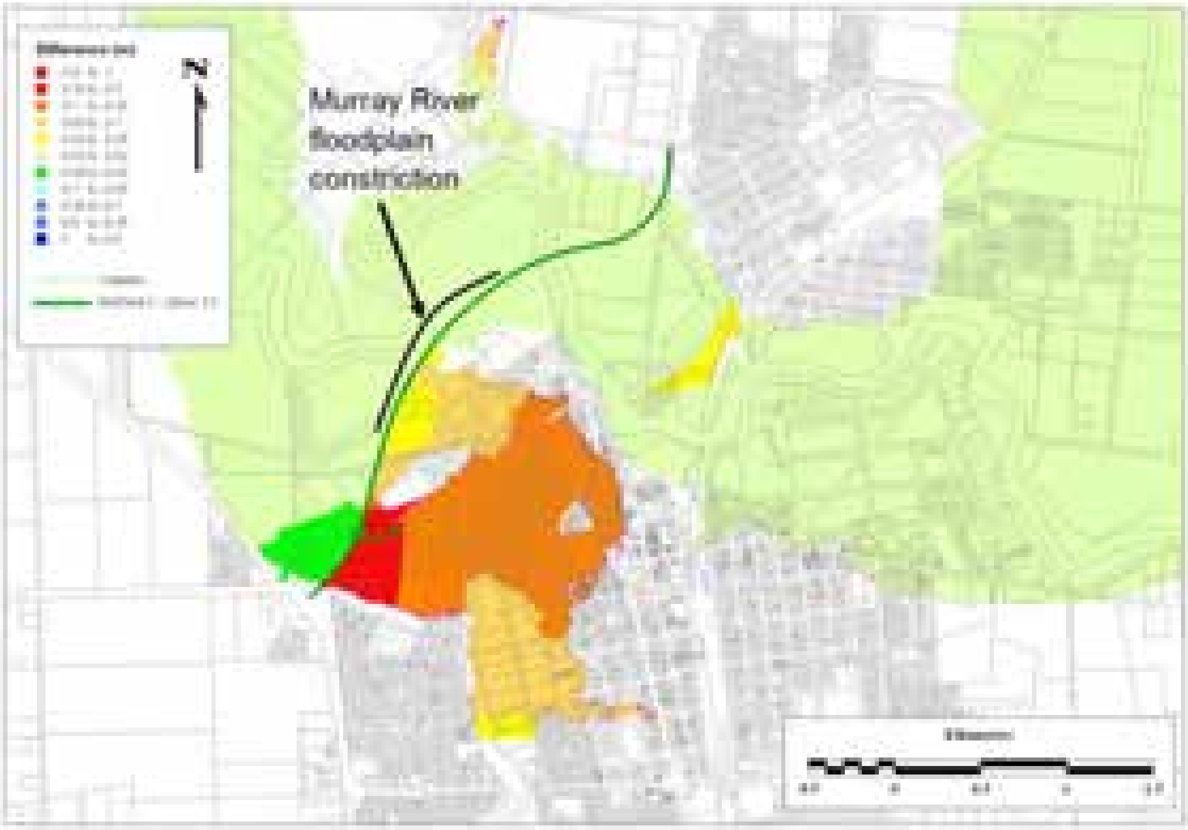

Figure 7-12 Flood difference for the preliminary Mid West 2 – Option 2.5 for the 2% AEP

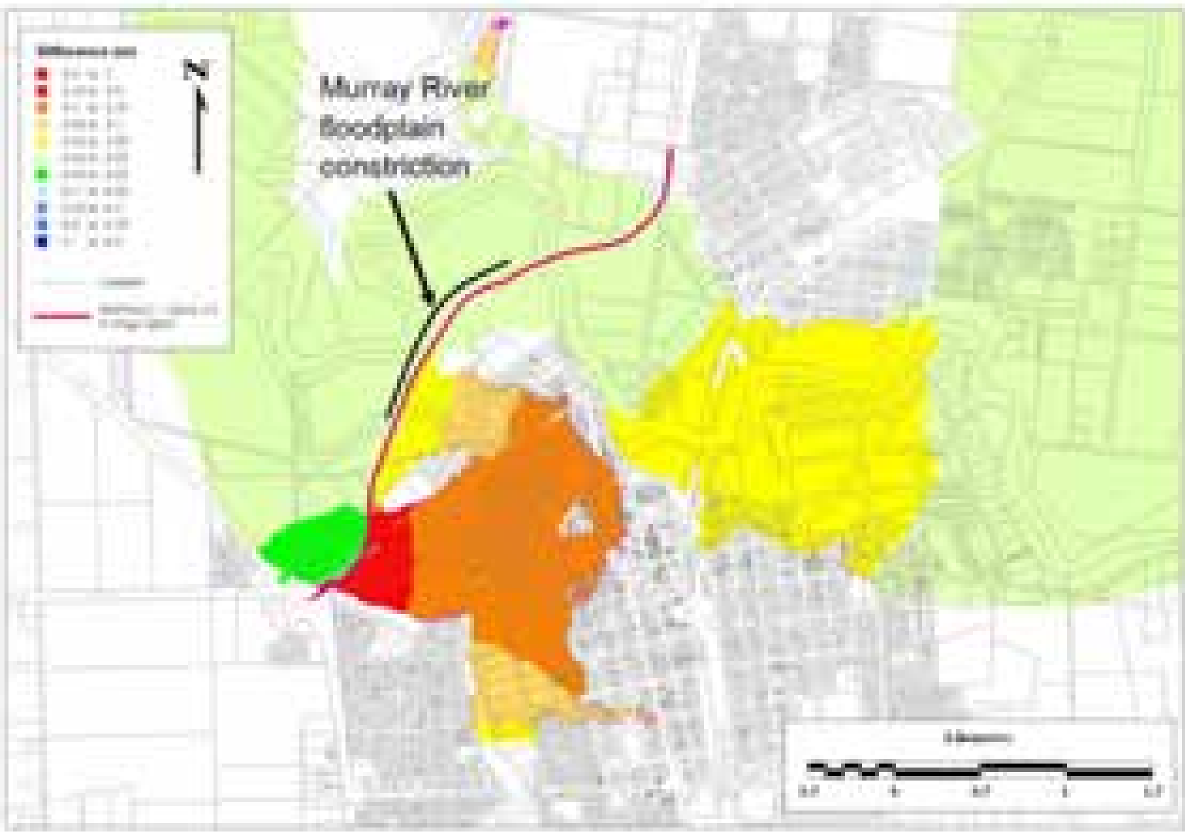

Figure 7-13 Flood difference for the preliminary Mid West 2 – Option 2.6 for the 2% AEP

7.3 1% AEP

The results of the 1% AEP event are shown in Figure 7-14 to Figure 7-19 for Options 2.1 to 2.6 respectively. As for the 20 and 2% AEP events, the primary observation from all of the alignments is that the initial set of mitigation is not sufficient to maintain the existing peak flood levels under the 1% AEP event. The majority of the increase in peak flood depths is on the Campaspe River due to the blockage of the majority of this floodplain, however the 1% AEP event increased flood depths are observed on the Murray River floodplain.

As discussed as part of Section 7.1 and 7.2, Options 2.1, 2.2 and 2.3 impact the Campaspe River floodplain due to the insufficient mitigation applied at the western end of the alignments. In the 1% AEP this impact is exacerbated and the peak increase in flood depths increases to +28 cm. The increases in peak flood depths are extended further upstream in the Campaspe River floodplain.

Options 2.4, 2.5 and 2.6 alignments merge with Warren Street at the western end of the alignment and as previously discussed, this causes an additional constriction to the floodplain in this region and accordingly these three options show increased peak flood depths in this area and within the Campaspe River floodplain. The peak increase in depth was under Option 2.6 alignment with a +41 cm increase in flood depths observed. Options 2.4, 2.5 and 2.6 increased the flood depths on the Campaspe River floodplain as compared to Options 2.1, 2.2 and 2.3.

The peak flood depths were maintained between +/- 2 cm on the Murray River floodplain under Options 2.3 and 2.4 under the 5%, 2% and 1% AEP events. Options 2.1 and 2.5 showed a small area where flood depths increased between 2 and 5 cm, however Option 2.1 produced less impact than Option 2.5. The largest increases in flood depths within the Murray River floodplain occurred under Options 2.2 and 2.6 as these alignments constricted the Murray River floodplain the most. The impacts on the Murray River floodplain were in similar locations to the 2% AEP results, however the area of the increased flood depths increased.

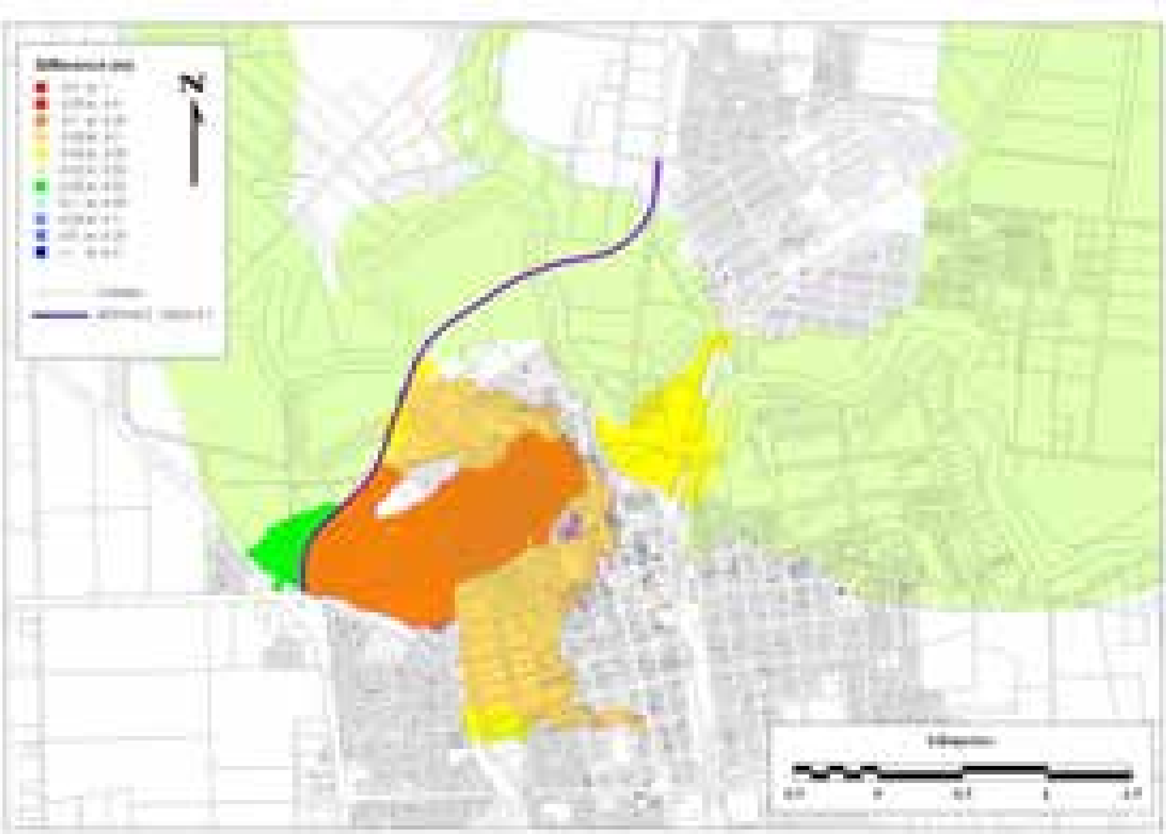

Figure 7-14 Flood difference for the preliminary Mid West 2 – Option 2.1 for the 1% AEP

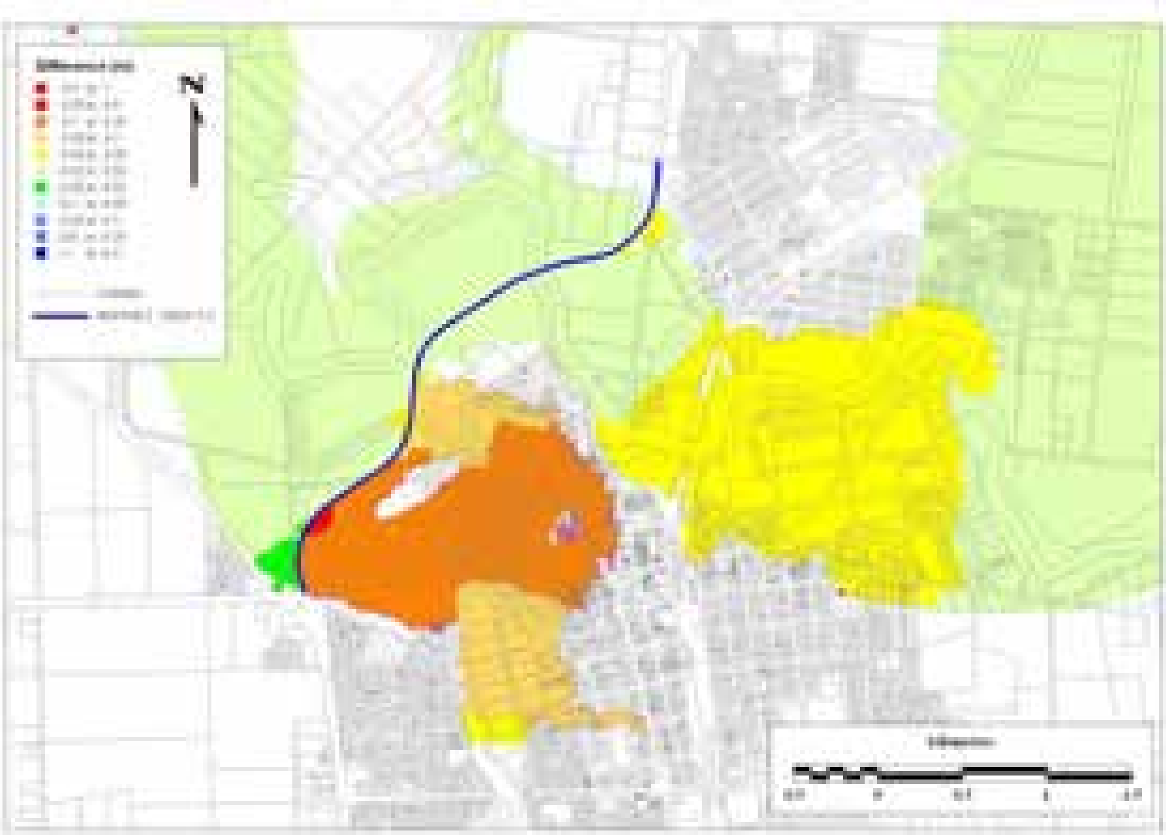

Figure 7-15 Flood difference for the preliminary Mid West 2 – Option 2.2 for the 1% AEP

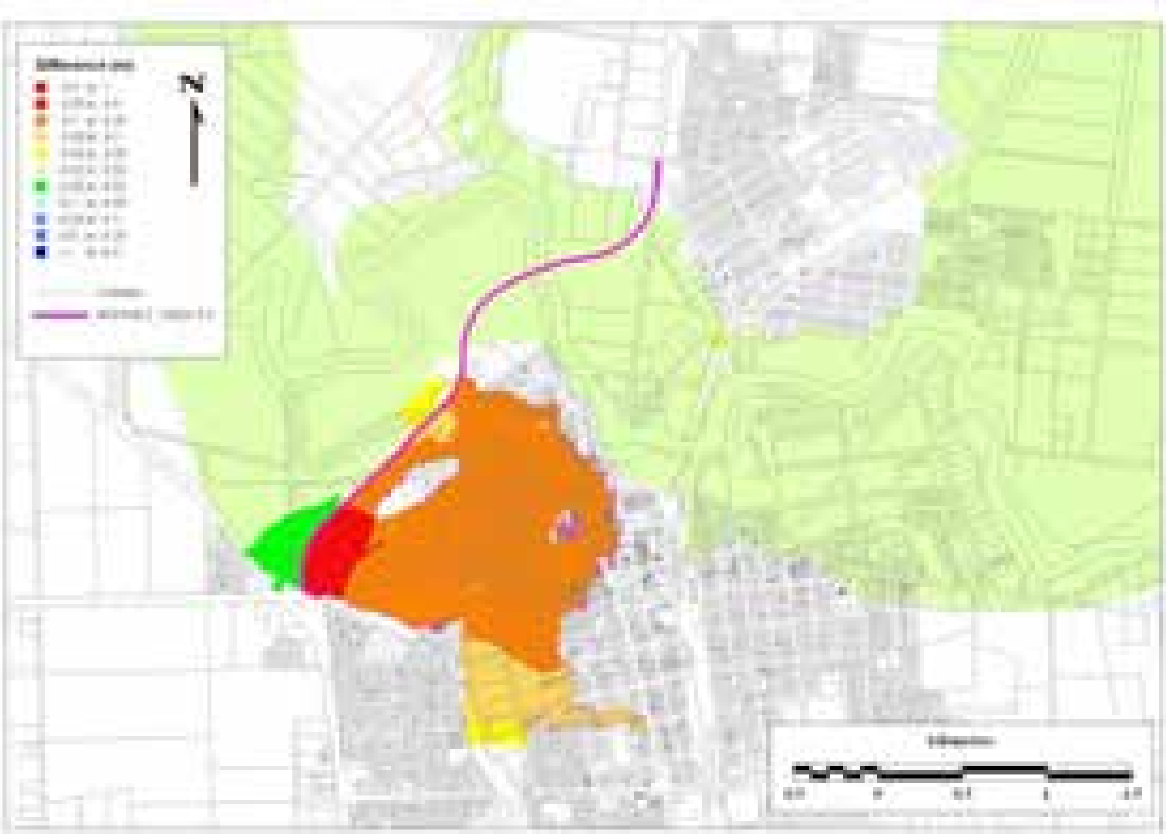

Figure 7-16 Flood difference for the preliminary Mid West 2 – Option 2.3 for the 1% AEP

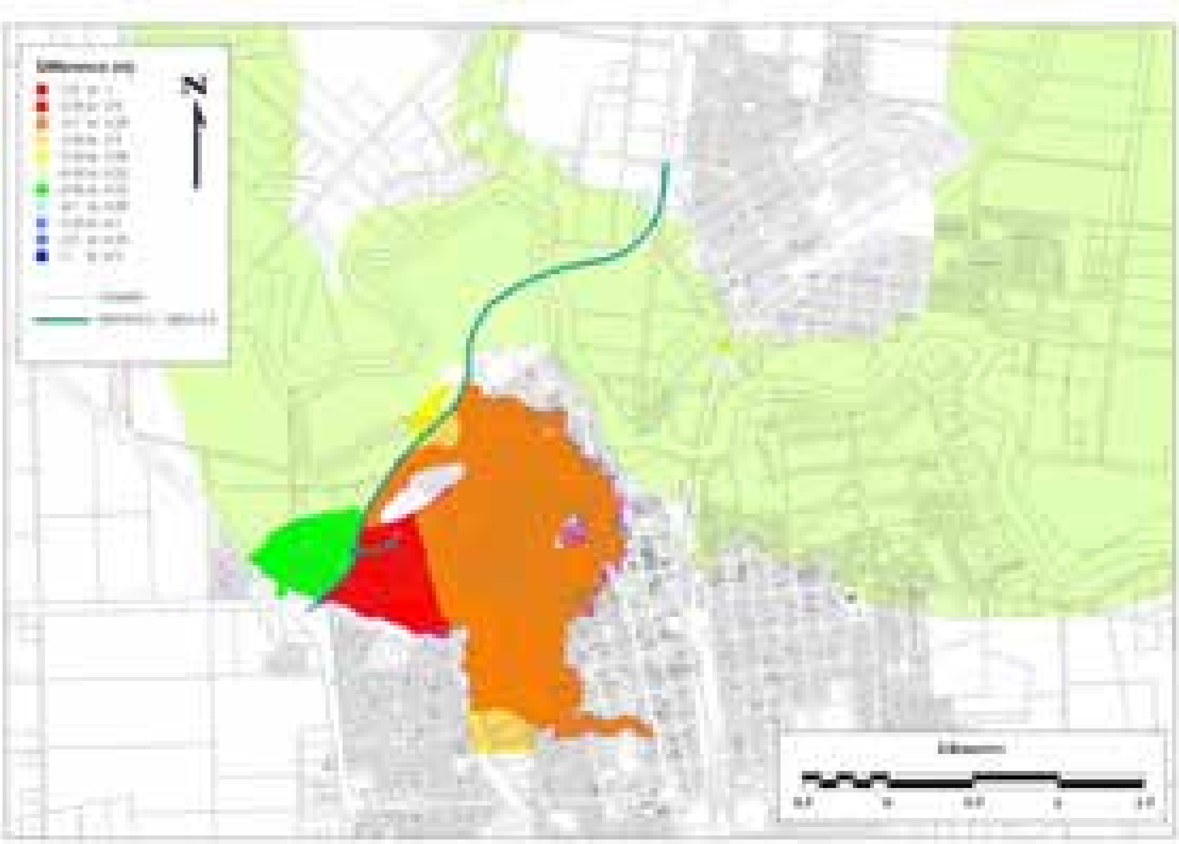

Figure 7-17 Flood difference for the preliminary Mid West 2 – Option 2.4 for the 1% AEP

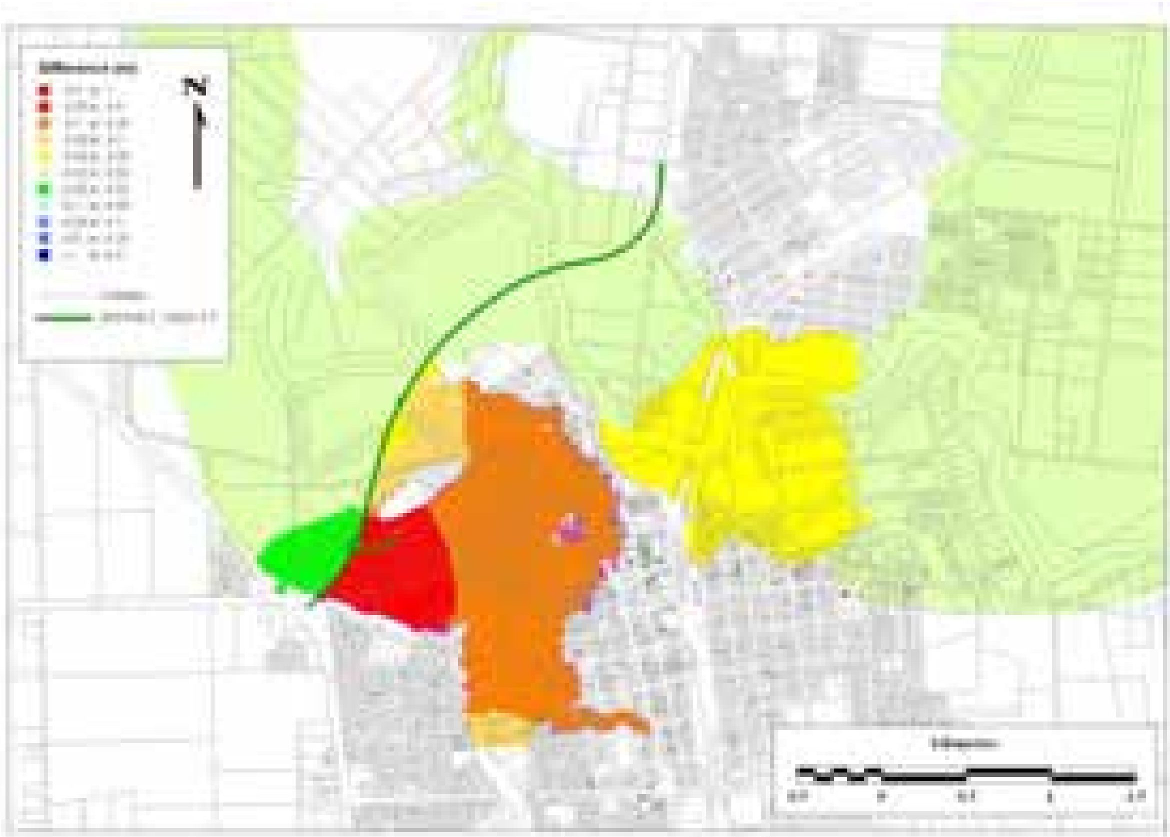

Figure 7-18 Flood difference for the preliminary Mid West 2 – Option 2.5 for the 1% AEP

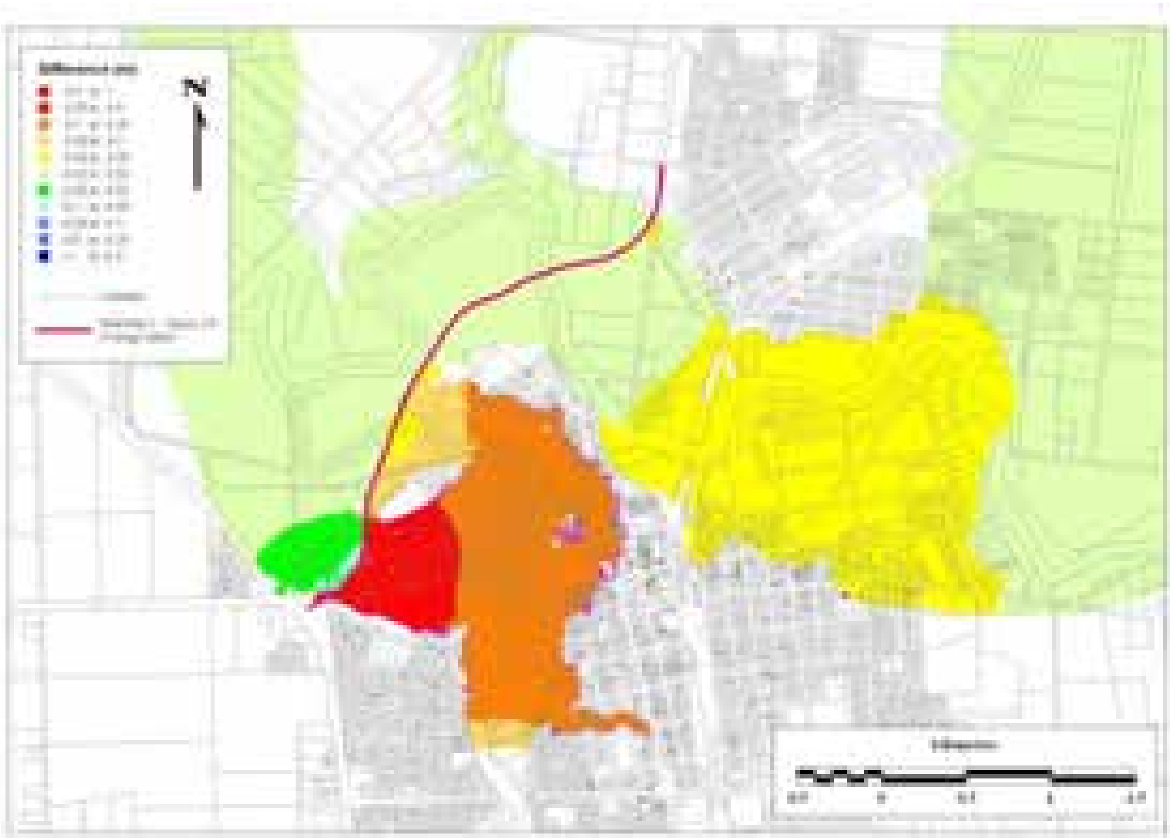

Figure 7-19 Flood difference for the preliminary Mid West 2 – Option 2.6 for the 1% AEP

7.4 Summary

The results from the assessment of Options 2.1 to 2.6 under the 5%, 2% and 1% AEP flood events showed some clear differences between the alignments. These comparisons can be made due to each alignment using the same mitigation measures (albeit clearly insufficient to mitigate increased flood depths). The main observations include:

- Campaspe River floodplain.
  - Options 2.1, 2.2 and 2.3 clearly produced a lesser impact on the Campaspe River floodplain as compared to Options 2.4, 2.5 and 2.6. However there were still significant increases observed in the floodplain.
  - Options 2.4, 2.5 and 2.6 constricted the floodwaters at the western end of Warren Street and significantly impacted the Campaspe River floodplain.
- Murray River floodplain.
  - Options 2.2 and 2.6 produce the largest area of increased flood depths in the Murray River floodplain. These depths are maintained between 2 and 5 cm but they cover a large area.
  - Options 2.1 and 2.5 produce some increased flood depths within the Murray River floodplain. The impacts are on a smaller scale than Options 2.2 and 2.6 but are still present.
  - Options 2.3 and 2.4 produce no significant increases in flood depths within the Murray River floodplain.

Overall, the six options considered were clearly under mitigated and would not constitute acceptable alignments in their present state. Of all of the options considered Option 2.3 produced the best compromise between reducing the impacts the Murray River floodplain and the Campaspe River floodplain.

Discussions of these results with VicRoads led to the selection of the following options to be modelled and designed in detail:

- Option 2.1 (denoted as ‘2A’ for the detailed assessment)
- Option 2.3 (denoted as ‘2B’ for the detailed assessment)
- Option 2.5 (denoted as ‘2C’ for the detailed assessment)
- Option 2.4 (denoted as ‘2D’ for the detailed assessment)

The detailed assessment and design is discussed in Section 8.

8 Detailed Assessment

The preliminary assessment was used to eliminate two options from the detailed design; of the preliminary runs the following were selected for detailed design:

- Option 2.1 (denoted as '2A' for the detailed assessment)
- Option 2.3 (denoted as '2B' for the detailed assessment)
- Option 2.5 (denoted as '2C' for the detailed assessment)
- Option 2.4 (denoted as '2D' for the detailed assessment)

It should be noted that the nomenclature for each of the alignments has been changed for the detailed design runs to ensure there is a clear difference between the alignments in the discussion. This section outlines the setup for each of the design runs and demonstrates the suitability of the mitigation (i.e. bridge openings and culverts) for each of the alignments.

The sizing of the mitigation was a result of numerous iterations of hydraulic modelling runs and constant redesign of the alignments. The final alignments are discussed in this section along with the final flood depth difference maps that illustrate the changes in flood depths due to the proposed alignment as compared to the existing conditions.

8.1 Detailed Alignment Setup

8.1.1 Alignment 2A

Modelling of the Detailed Option 2A alignment was undertaken using information provided by VicRoads on 12 July 2012. The following information was provided and was regarded to be best available;

- X19567_SKM_CM2A1-120712.dgn

This data contained information on roadway alignment, road levels and extents of embankments. It was input into 12d and overlaid onto a DTM of the natural surface level.

The objective of the above bridge spans was to ensure the alignment did not increase flood depths on the floodplain by more than 2.5 cm. Table 8-1 summarises the lengths and coordinates of each of the modelled bridge openings – note that these dimensions are approximate only.

Table 8-1 Alignment 2A bridge opening locations and spans

Crossing Location	Approximate Length (m)	Start Coordinates (m)	End Coordinates (m)
A	205	E 295475 N 5999426	E 295507 N 5999628
B	150	E 295557 N 5999715	E 295636 N 5999843
C	95	E 295713 N 5999966	E 295763 N 6000046
D (Campaspe)	450	E 295792 N 6000093	E 296028 N 6000471
E	460	E 296051 N 6000509	E 296310 N 6000889
F (Murray)	650	E 296677 N 6001134	E 297295 N 6001340
G	45	E 297439 N 6001416	E 297480 N 6001450
TOTAL	**2,055**		

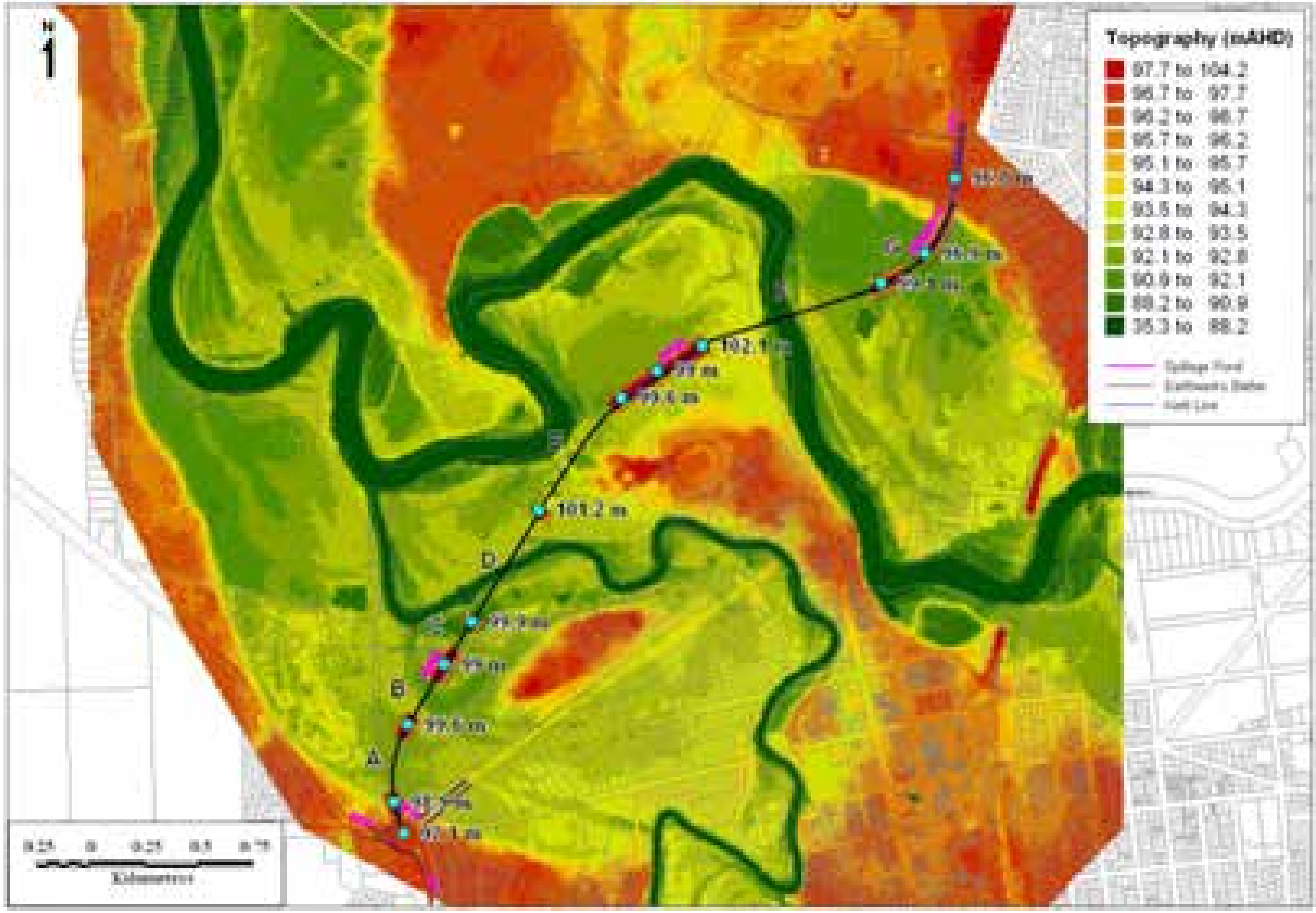

Figure 8-1 Alignment 2A detailed topography including spillage ponds

8.1.2 Alignment 2B

Modelling of the Detailed Option 2B alignment was undertaken using information provided by VicRoads on 12 July 2012. The following information was provided and was regarded to be best available;

- X19567_SKM_CM2B-120712.dgn

This data contained information on roadway alignment, road levels and extents of embankments. It was input into 12d and overlaid onto a DTM of the natural surface level.

The objective of the above bridge spans was to ensure the alignment did not increase flood depths on the floodplain by more than 2.5 cm. Table 8-2 summarises the lengths and coordinates of each of the modelled bridge openings – note that these dimensions are approximate only.

Table 8-2 Alignment 2B bridge opening locations and spans

Crossing Location	Approximate Length (m)	Start Coordinates (m)	End Coordinates (m)
A	200	E 295479 N 5999433	E 295522 N 5999628
B	220	E 295557 N 5999684	E 295712 N 5999840
C	85	E 295901 N 6000018	E 295963 N 6000077
D (Campaspe)	450	E 296065 N 6000173	E 296385 N 6000494
E	65	E 296480 N 6000898	E 296505 N 6000975
F (Murray)	650	E 296677 N 6001134	E 297295 N 6001340
G	45	E 297439 N 6001416	E 297480 N 6001450
TOTAL	**1,715**		

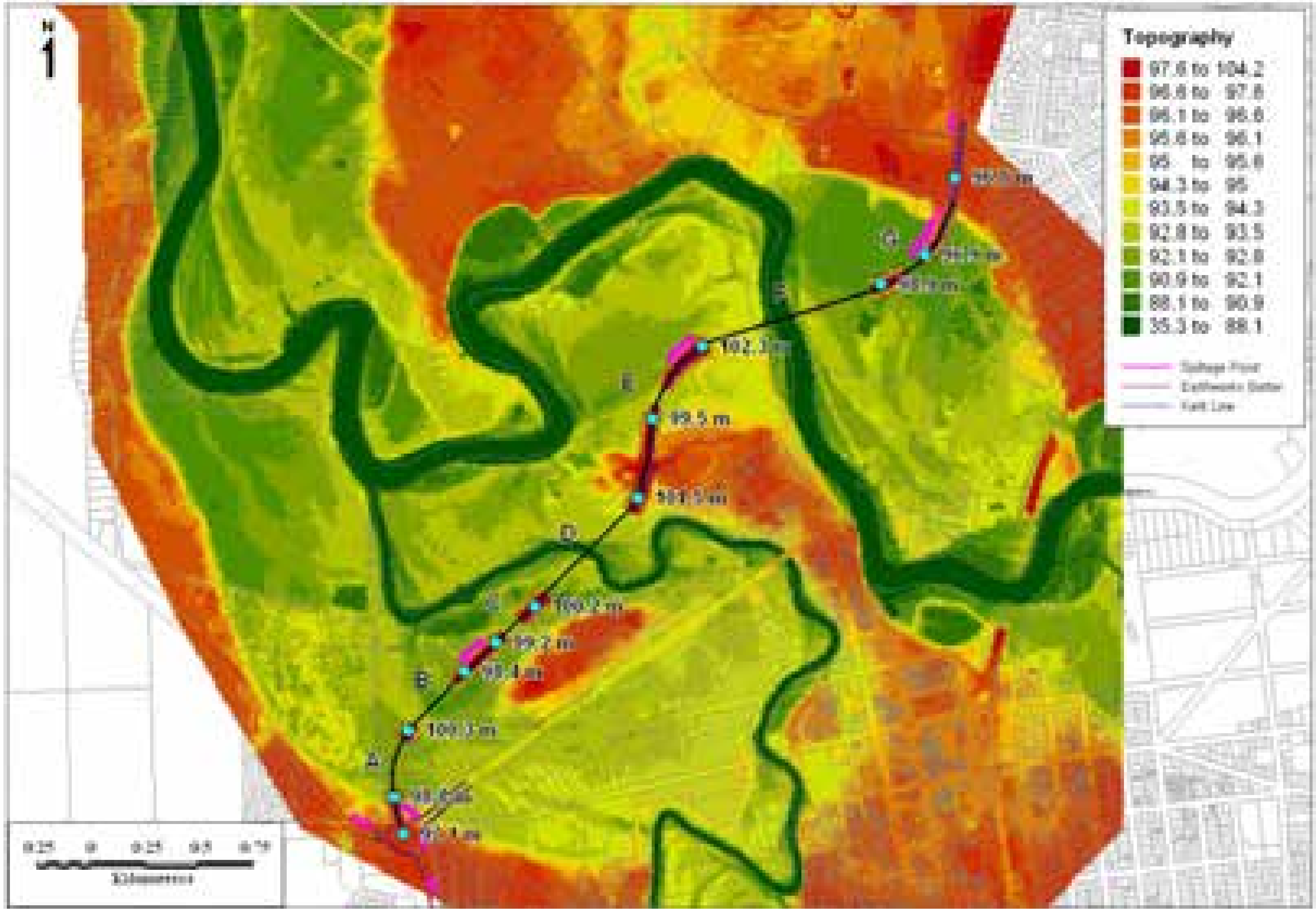

Figure 8-2 Alignment 2B detailed topography including spillage ponds

8.1.3 Alignment 2C

Modelling of the Detailed Option 2C alignment was undertaken using information provided by VicRoads on 12 February 2012. The following information was provided and was regarded to be best available;

- X19567_SKM_CM2C_120201.dgn

This data contained information on roadway alignment, road levels and extents of embankments.

Under the design conditions above, the Murray River floodplain experiences unacceptable impacts. This was due to an embankment encroaching upon the floodplain (refer tech note 7). In order to try to remove these impacts, the embankment has been removed from the model.

As per the previously modelled Alignment Option A, there is an embankment as part of this option which encroaches upon a sand bank. As per Alignment Option A, this stretch of embankment has been moved to the end of the Western side of the Murray River bridge embankment.

It has been assumed that the road opening to the east of the roundabout along Warren St is a culvert, as this area would benefit from head driven flow. During previous modelling of this option, unacceptable impacts within the Campaspe floodplain have been identified. In order to mitigate these impacts, the culvert set to the west of Warren St has been increased in size. The dimensions of the culvert are summarised in Table 8-3.

Table 8-3 Alignment 2C culvert requirements

Crossing Location	Description	Effective Area (m^2)	Upstream IL (mAHD)	Downstream IL (mAHD)
Warren Street	Culverts 80 x 3 x 2.4	576	92.95	92.94

Figure 8-3 outlines the Alignment Option C Bridge and Embankment arrangement. For the area where the existing Warren St floodplain Bridge is to be removed, the land surface was placed at the surrounding natural surface level.

The objective of the above bridge spans was to ensure the alignment did not increase flood depths on the floodplain by more than 2.5 cm. Table 8-4 summarises the lengths and coordinates of each of the modelled bridge openings – note that these dimensions are approximate only.

Table 8-4 Alignment 2C bridge opening locations and spans

Crossing Location	Length (m)	Start Coordinates (m)	End Coordinates (m)
A	275	E 295626 N 5999343	E 295844 N 5999514
B	220	E 295849 N 5999616	E 295830 N 5999833
C	60	E 295897 N 6000005	E 295919 N 6000061
D (Campaspe)	900	E 295945 N 6000127	E 296345 N 6000925
E (Murray)	650	E 296677 N 6001134	E 297295 N 6001340
F	45	E 297439 N 6001416	E 297480 N 6001450
TOTAL	**2,150**		

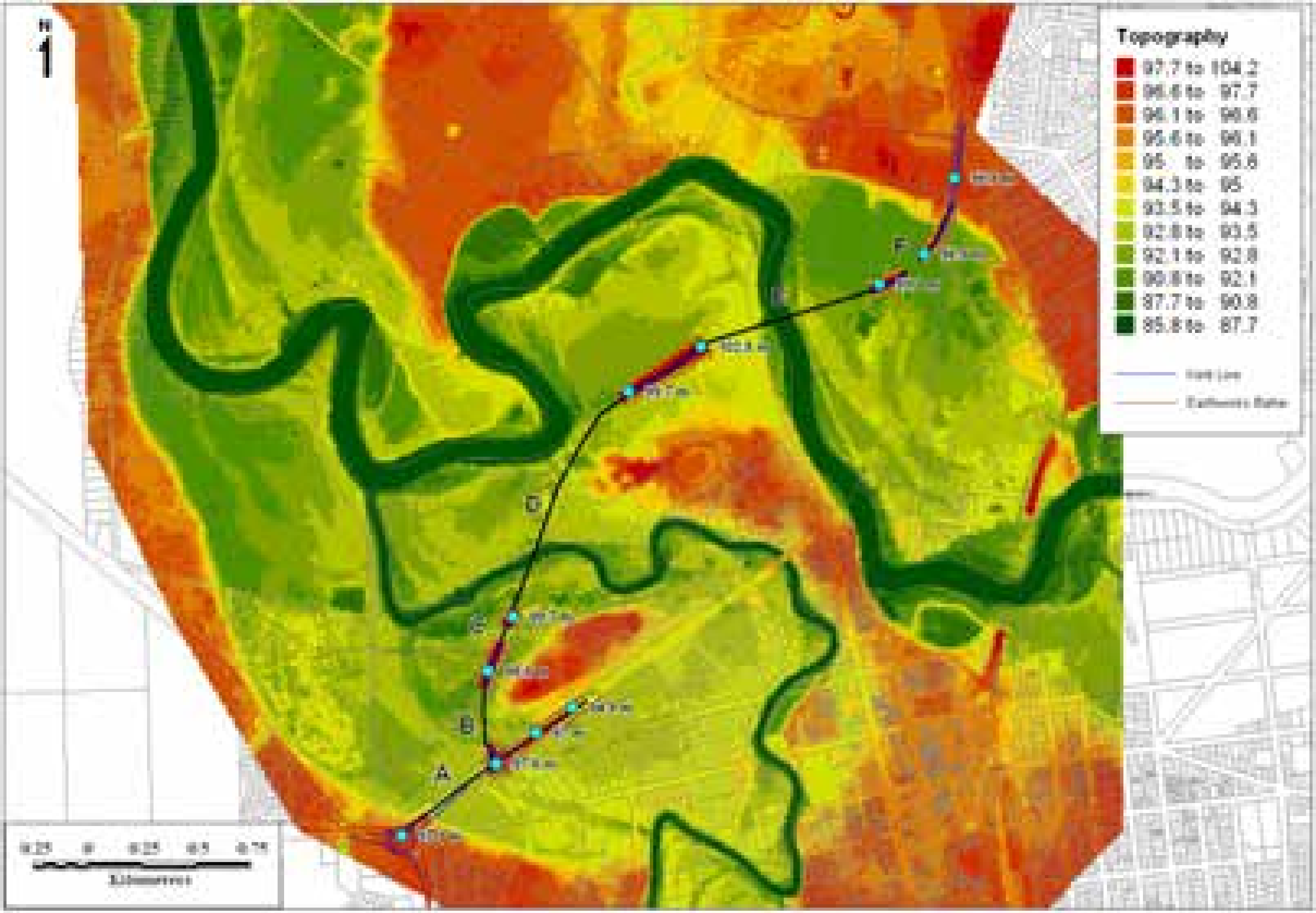

Figure 8-3 Alignment 2C detailed topography

8.1.4 Alignment 2D

Modelling of the Detailed Option 2D alignment was undertaken using information provided by VicRoads on 14 March 2012. The following information was provided and was regarded to be best available;

- X19567_SKM_CM2D_120313.dgn

This data contained information on roadway alignment, road levels and extents of embankments. It was input into 12d and overlaid onto a DTM of the natural surface level.

The original supplied design has been modified around the Warren Street area in order to achieve successful transfer of existing flood waters. A detailed design is required of this developed alignment for Option 2D. Culverts were included on Warren St to the east of the roundabout as a bridge was insufficient to pass the flows required to maintain existing flood levels. These were the same as for Option 2C and are shown in Table 8-5.

Table 8-5 Alignment 2D culvert requirements

Crossing Location	Description	Effective Area (m^2)	Upstream IL (mAHD)	Downstream IL (mAHD)
Warren Street	Culverts 80 x 3 x 2.4	576	92.95	92.94

The objective of the above bridge spans was to ensure the alignment did not increase flood depths on the floodplain by more than 2.5 cm.

The bridge spans for Option 2D are summarised in Table 8-6 with approximate eastings and northings supplied for the start and end of each bridge span.

Table 8-6 Alignment 2D bridge opening locations and spans

Crossing Location	Length (m)	Start Coordinates (m)	End Coordinates (m)
A	275	E 295605, N 5999345	E 295845, N 5999505
B	300	E 295845, N 5999615	E 295892, N 5999898
C	60	E 295959, N 6000031	E 295994, N 6000087
D (Campaspe)	450	E 296080, N 6000186	E 296395, N 6000505
E	65	E 296482, N 6000903	E 296505, N 6000956
F (Murray)	650	E 296677, N 6001134	E 297295, N 6001340
G	45	E 297439, N 6001416	E 297480, N 6001450
TOTAL	**1,840**		

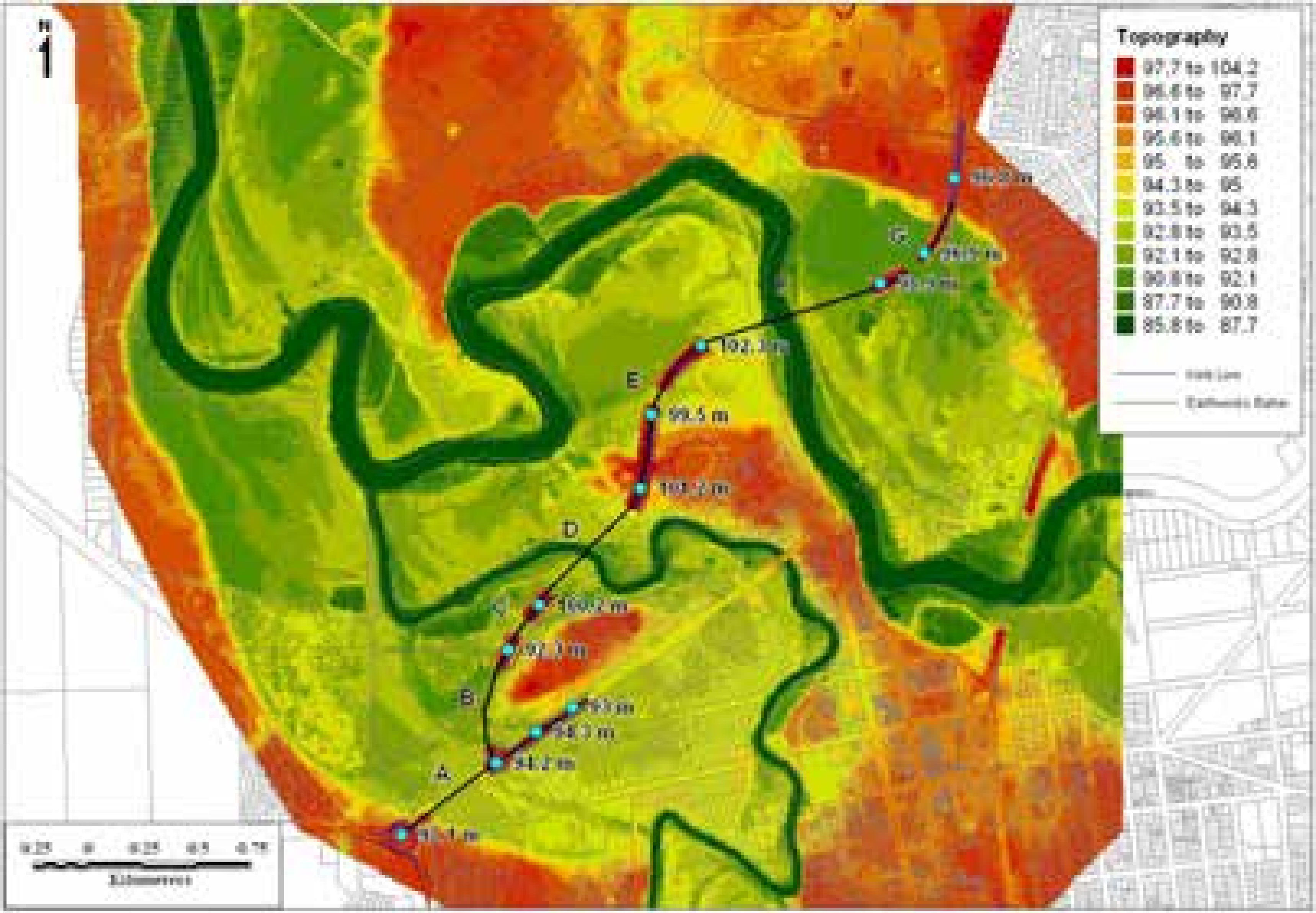

Figure 8-4 Alignment 2D detailed topography

8.2 Hydraulic Modelling Results

The process for determining the required mitigation involved developing the alignments within the hydraulic model and running these for the critical events (see Section 6 for details of the hydrology). The events that were modelled included the:

- 5% AEP (1 in 20 year ARI)
- 2% AEP (1 in 50 year ARI)
- 1% AEP (1 in 100 year ARI)

From the analysis it was evident that the 1% AEP event was the critical event with regards to the mitigation requirements. This was expected to be the case as the road embankments were elevated to above the 1% AEP flood levels. For the preliminary design runs the 5%, 2% and 1% AEP events were used initially to size the bridge openings and culverts, however the 1% AEP was the critical event.

The difference plots are shown in the following figures

- Figure 8-5 to Figure 8-7 shows the 5%, 2% and 1% difference plot for Alignment 2A
- Figure 8-8 to Figure 8-10 shows the 5%, 2% and 1% difference plot for Alignment 2B
- Figure 8-11 to Figure 8-13 shows the 5%, 2% and 1% difference plot for Alignment 2C
- Figure 8-14 to Figure 8-16 shows the 5%, 2% and 1% difference plot for Alignment 2D.

The difference plots are shown in Figure 8-5 to Figure 8-16 for alignments 2A, 2B, 2C and 2D respectively. Each of the difference plots shows that the floodplain peak flood depths are largely unchanged due to the proposed alignments. The plots demonstrate that the four proposed alignments meet the CMA's flood afflux requirements.

Alignments 2C and 2D show some increases near the onramp along Warren Street caused by the constriction to the peak flows through this area due to the multiple roundabouts. For these reasons 2C and 2D were not designed to the point where sedimentation basins were included. Alignments 2A and 2B include sedimentation and runoff basins and are the final design runs. The drainage requirements are discussed further in Section 8.3.

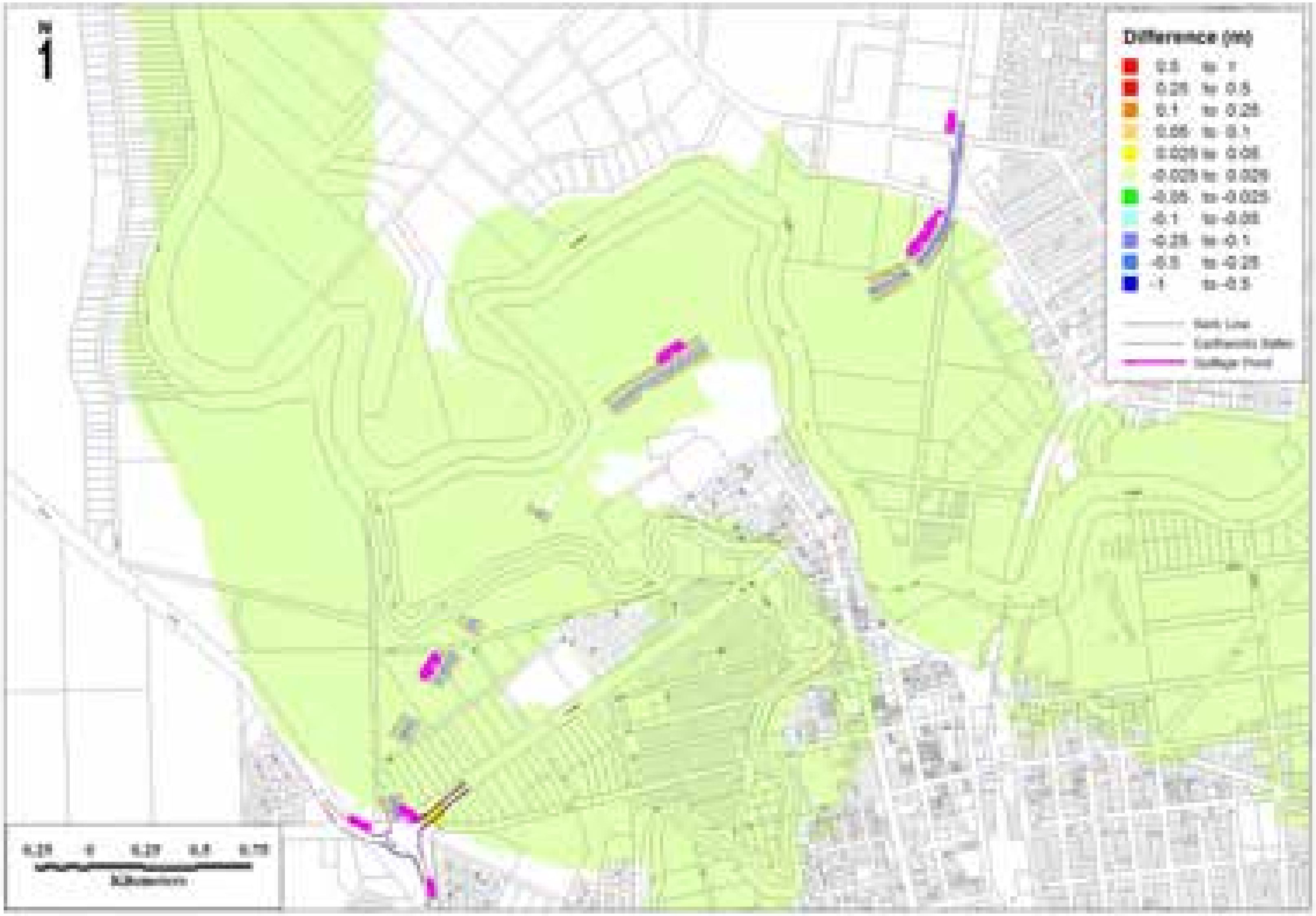

Figure 8-5 Alignment 2A peak flood height differences from existing for the 5% AEP

Figure 8-6 Alignment 2A peak flood height differences from existing for the 2% AEP

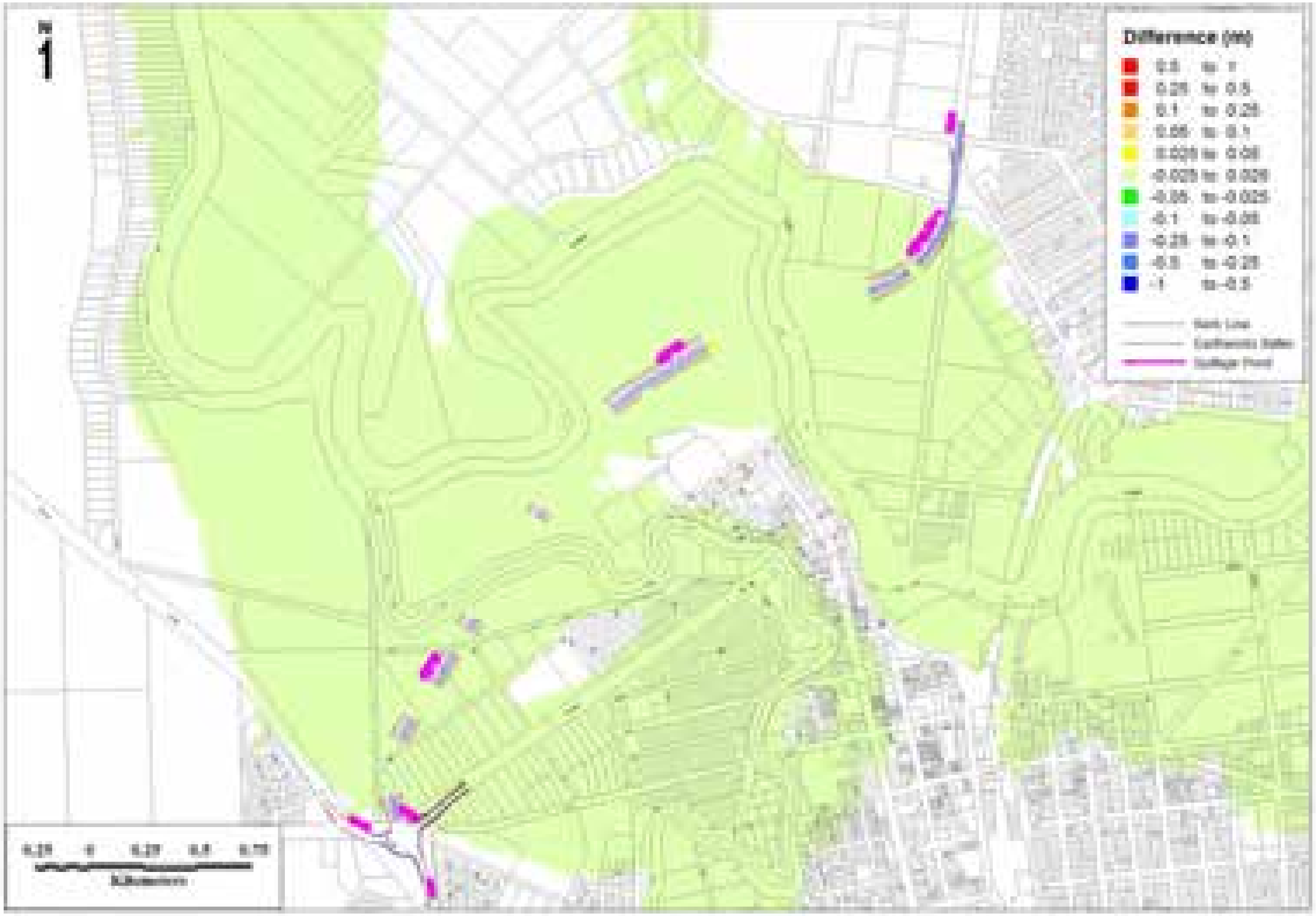

Figure 8-7 Alignment 2B peak flood height differences from existing for the 1% AEP

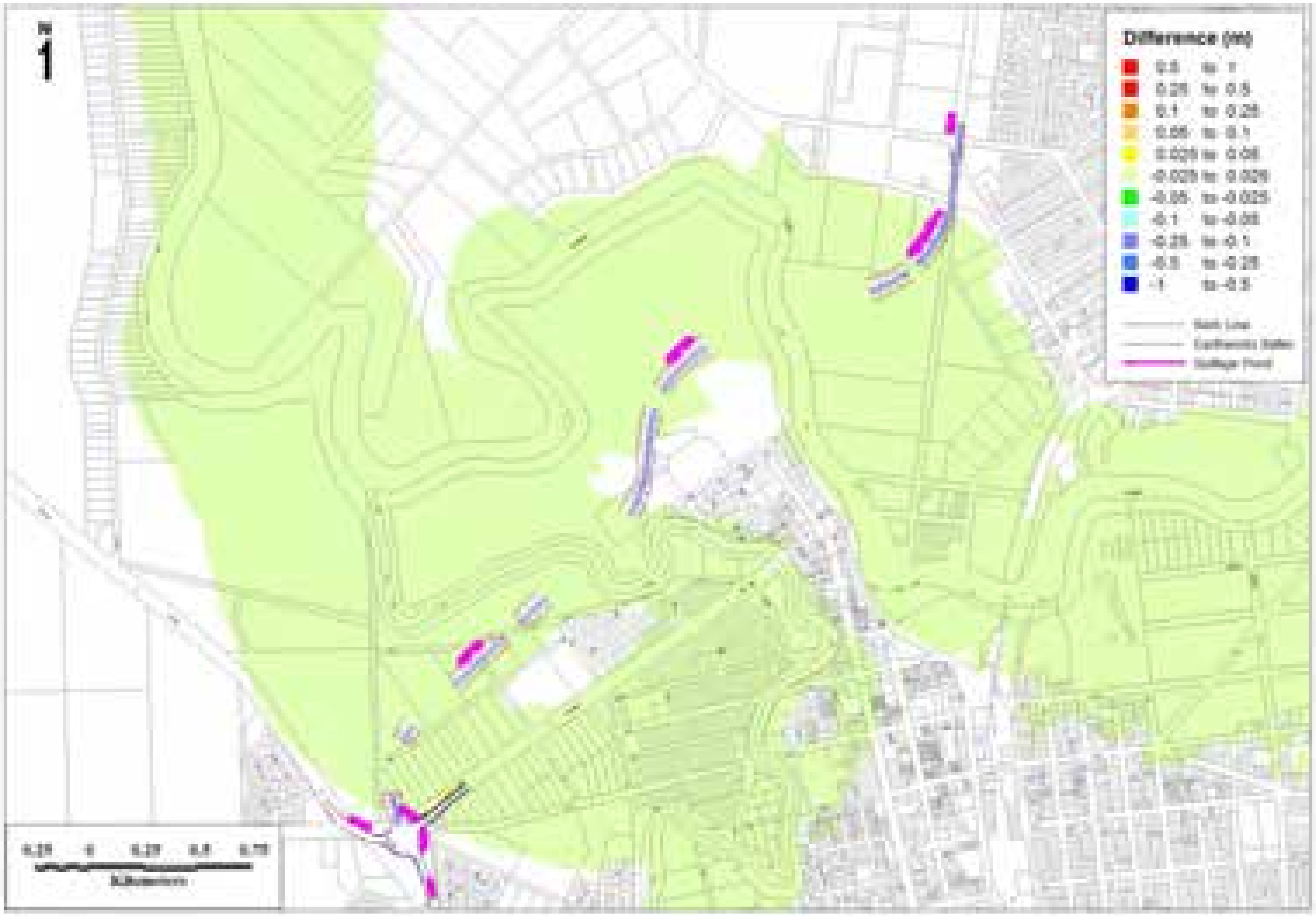

Figure 8-8 Alignment 2B peak flood height differences from existing for the 5% AEP

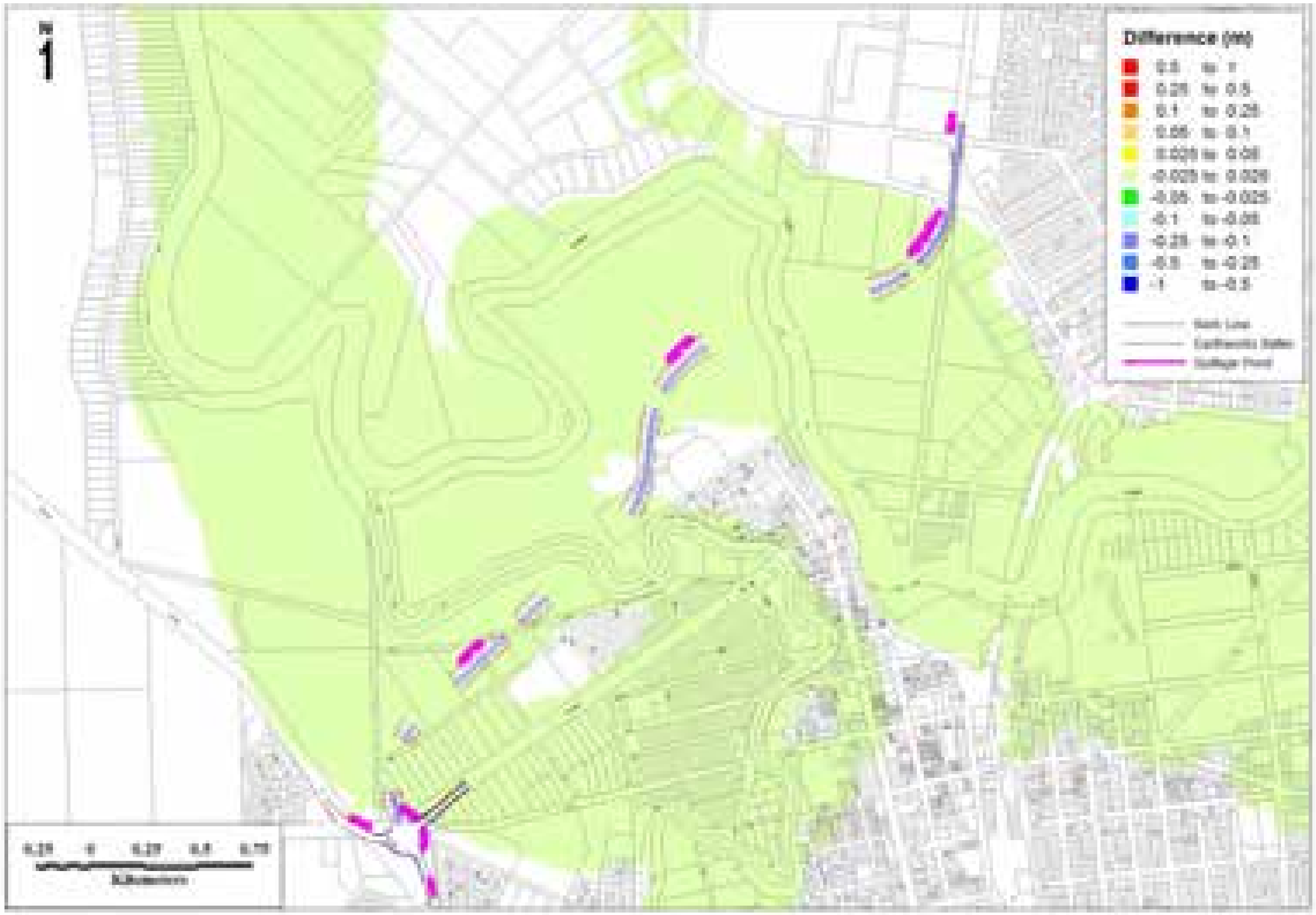

Figure 8-9 Alignment 2B peak flood height differences from existing for the 2% AEP

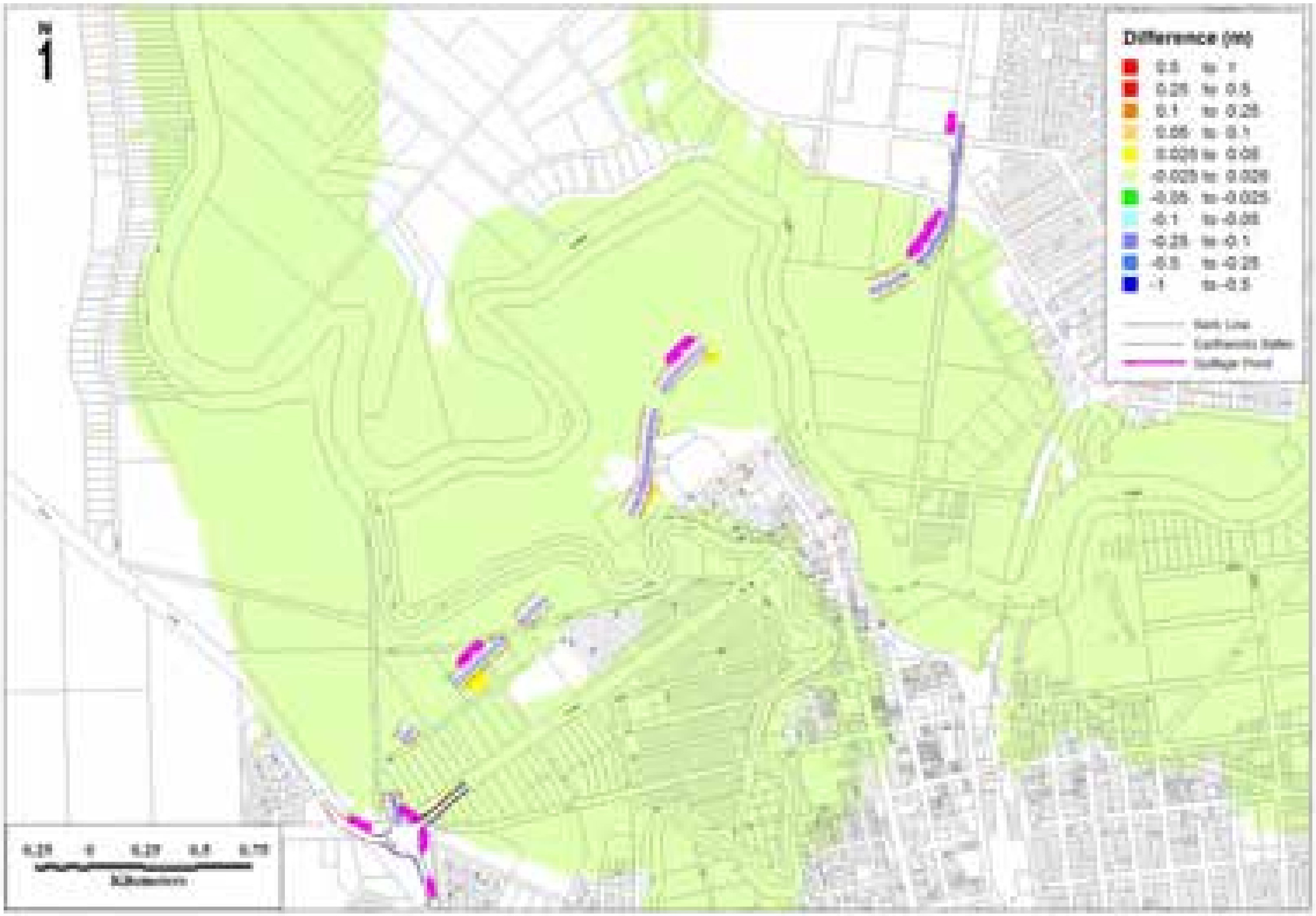

Figure 8-10 Alignment 2B peak flood height differences from existing for the 1% AEP

Figure 8-11 Alignment 2C peak flood height differences from existing for the 5% AEP

Figure 8-12 Alignment 2C peak flood height differences from existing for the 2% AEP

Figure 8-13 Alignment 2C peak flood height differences from existing for the 1% AEP

Figure 8-14 Alignment 2D peak flood height differences from existing for the 5% AEP

Figure 8-15 Alignment 2D peak flood height differences from existing for the 2% AEP

Figure 8-16 Alignment 2D peak flood height differences from existing for the 1% AEP

8.3 Discussion

8.3.1 Drainage System

The proposed alignments all meet the hydraulic constraints of maintaining the peak flood depth across the Murray and Campaspe Floodplains to within 2.5 cm of existing conditions. Of the four options, only options 2A and 2B had detailed drainage systems developed which is a requirement for the completed design. The design of the drainage systems was completed by SKM. These options were selected as the bridge lengths and culvert requirements are less than alignments 2C and 2D.

The main purpose of the drainage system is to manage the water quality exiting the structure. Rainfall runoff from the road surface may be loaded with suspended solids and have a lower water quality than the waters flowing down the Murray and Campaspe Rivers. The drainage system aims to capture this water and to improve the water quality prior to release into the river systems.

A secondary objective is to allow the drainage system to mitigate against the risk of spillage on the structure. The system can then be used to contain any spill that occurs on the site and allow for the cleanup to occur to prevent the contaminant entering the water system.

8.3.2 Groundwater Interaction

The proposed structure is expected to have little effect on the groundwater quality and conditions. The footprint of the proposed structure is likely to have minimal impact on the recharge to the water table particularly as the water table levels are set at approximately the surface water height of the Murray and Campaspe Rivers. The structure discharges all captured flows back to the river systems after the treatment chain.

Tree removal associated with the construction of the proposed roadway will also have a minimal impact on the groundwater table. Any increases in groundwater levels in the immediate area around the structure are limited by the discharge of the groundwater into the nearby rivers.

There is some risk that an emergency spill that is captured in a sedimentation pond or similar structure may enter the groundwater table and design of these structures should include a sufficient liner to stop infiltration in these locations.

8.3.3 Erosion Control

Ii is important for the design to incorporate appropriate erosion controls for both the proposed structure and the natural environment where flow rates are impacted i.e. around piers and abutments. The peak velocities throughout the floodplain are shown for alignments 2A, 2B, 2C and 2D in Figure 8-17 to Figure 8-20.

The peak velocities within the floodplain occur within the main river channels. The velocities are largely below 1.5 m/s. Within the broader floodplain the velocities are below 1.0 m/s. The velocities within the Campaspe and Murray River floodplains are not expected to cause significant scour or damage to the proposed structures.

The design of the piers and abutments should be based on the peak velocities defined within the hydraulic model. During the construction phase of the project care should be taken to ensure that adequate controls are maintained that are mindful of the peak velocities expected during large flood events.

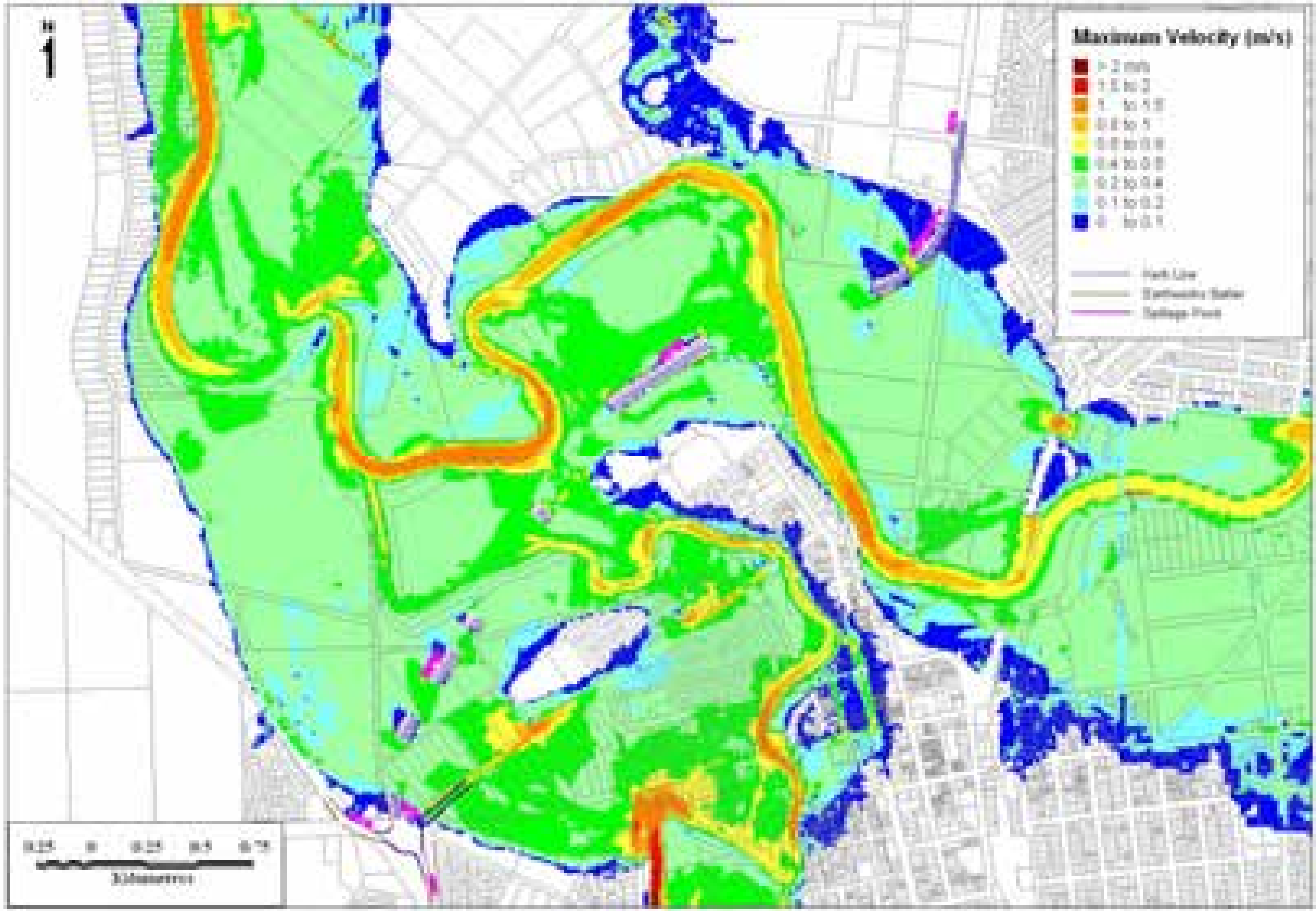

Figure 8-17 Maximum velocities for Alignment 2A with sediment basins (1% AEP event)

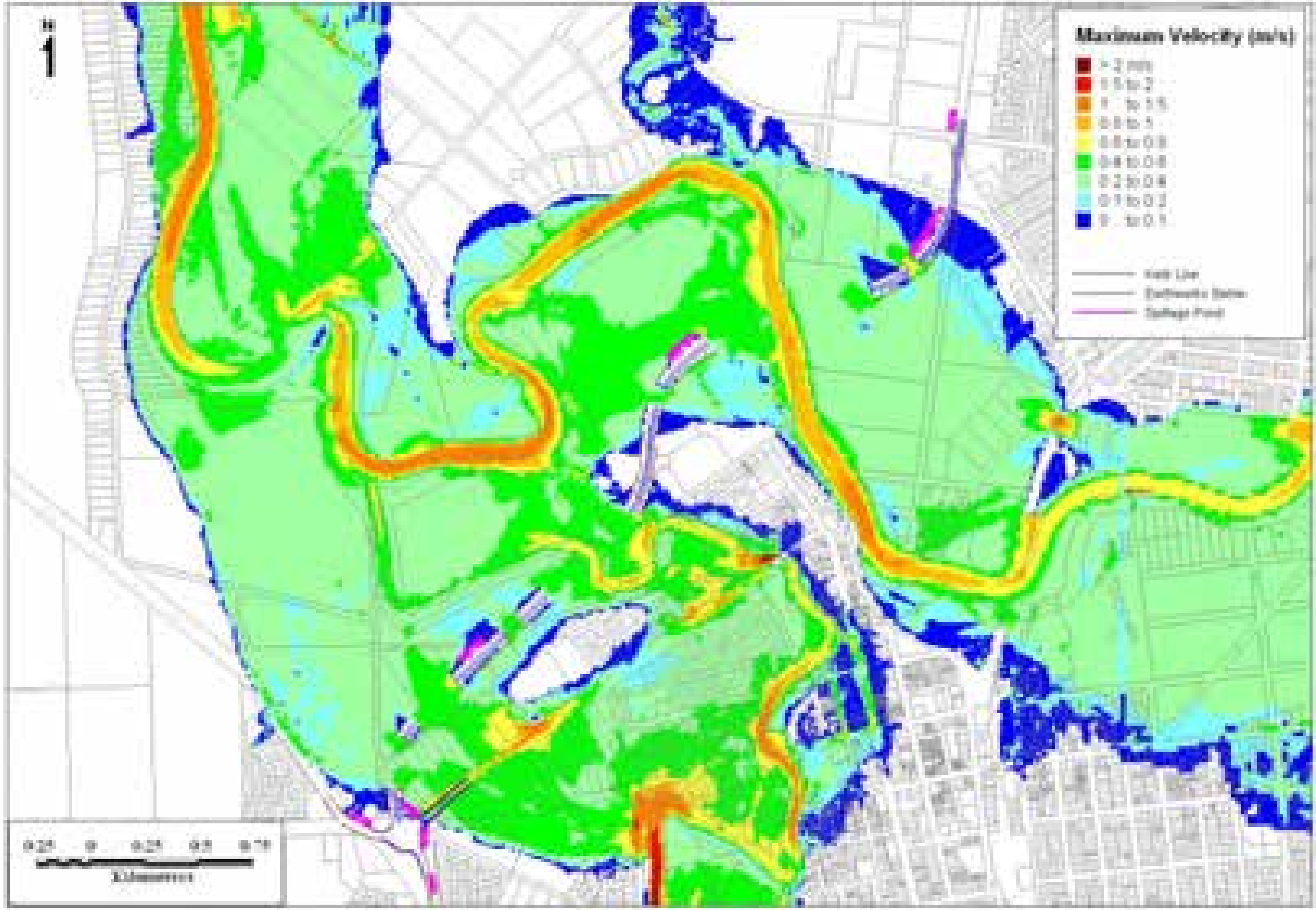

Figure 8-18 Maximum velocities for Alignment 2B with sediment basins (1% AEP event)

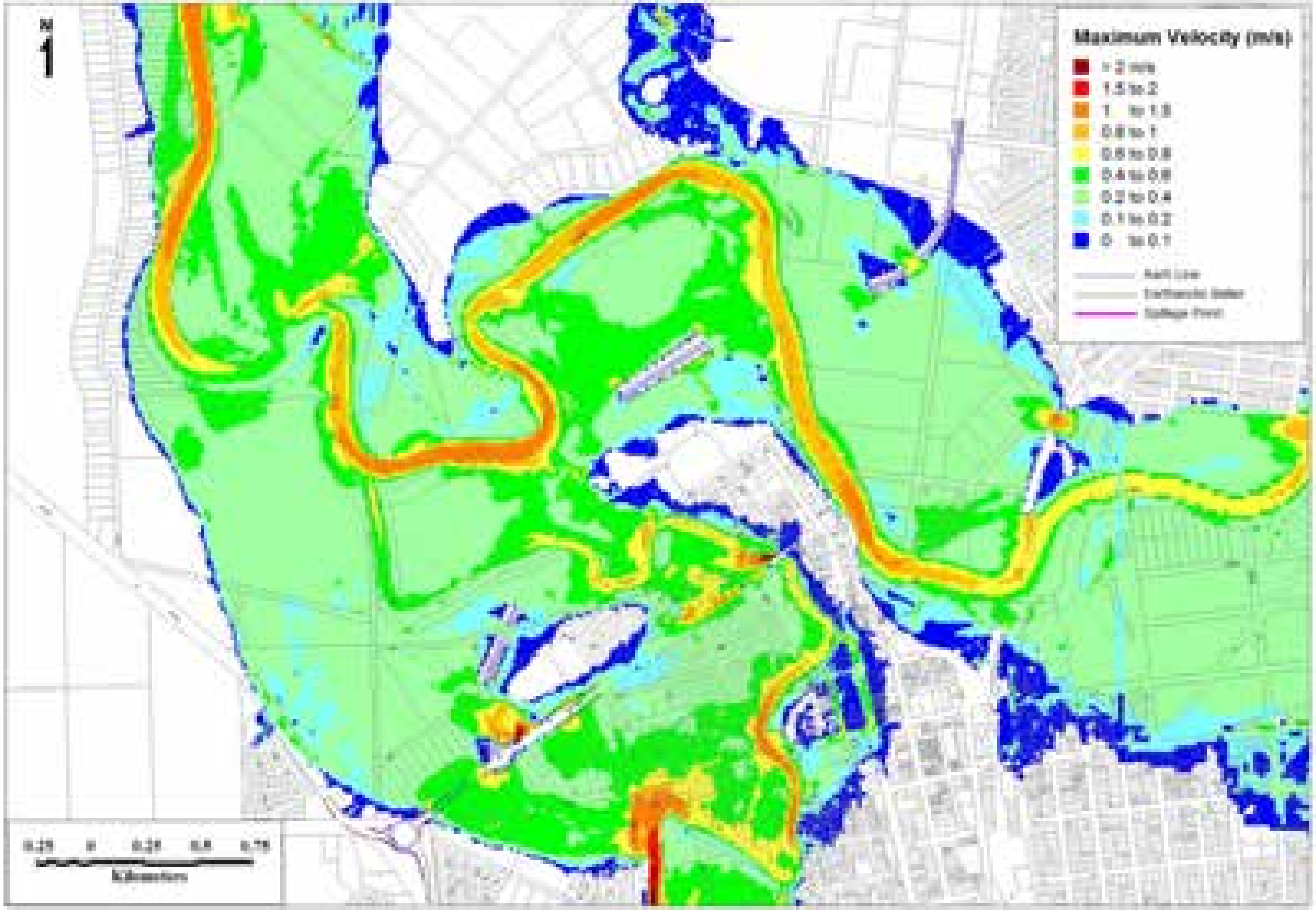

Figure 8-19 Maximum velocities for Alignment 2C (1% AEP event)

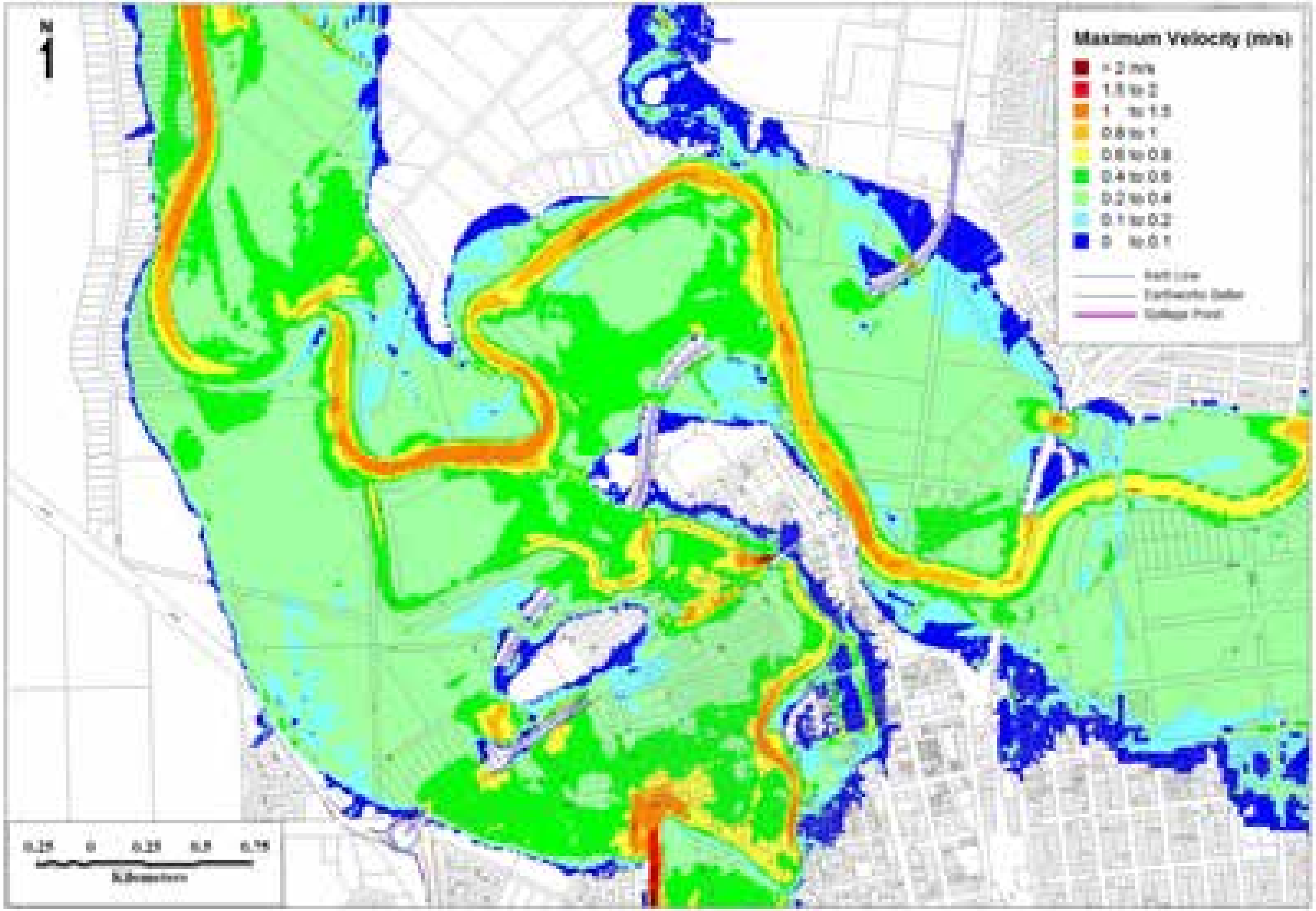

Figure 8-20 Maximum velocities for Alignment 2D (1% AEP event)

8.4 Summary

The detailed assessment examined four alignments, 2A, 2B, 2C and 2D, and all alignments were successfully developed to operate within the North Central CMA's requirements of not increasing the flood depths from existing conditions by 2.5 cm. The preferred option will be selected by examining a number of factors around the economic, environmental and social impacts of the structure. VicRoads plans to undertake a detailed costing of each option to help determine a preferred option however, at this stage the economic assessment is not complete.

Within this report the recommended option has been based on using the required bridge length openings and culvert width as a proxy for increased costs for the bridge construction. This is based on the knowledge that building the elevated structure and culverts is more expensive than constructing raised embankments. The total bridge opening lengths, culverts lengths and overall mitigation required is summarised in Table 8-7.

Table 8-7 Summary of the required mitigation for the detailed design alignments

Alignment	Bridge Length (m)	Culverts width (m)	Total Mitigation Width (m)
2A	2,055	-	**2,055**
2B	1,715	-	**1,715**
2C	2,150	240 (80 x 3m x 2.4m)	**2,390**
2D	1,840	240 (80 x 3m x 2.4m)	**2,080**

Alignment 2B requires the least mitigation length to meet the flood afflux criteria, followed by alignment 2A. This was the primary reason for alignments 2A and 2B having the detailed drainage design completed, whereas detailed drainage was not undertaken for alignments 2C and 2D. Alignments 2C and 2D also have the added complexity of multiple roundabouts for access to the proposed bridge structure. The location of these roundabouts is such that sets of culverts are required to be installed in the mitigation options. These culverts would be under the onramp from the existing Warren Street.

Alignment 2B provides the shortest length of mitigation to achieve the objectives for the proposed Echuca-Moama bridge and is therefore the recommended alignment from this study.

9 Conclusion and Recommendations

This assessment has developed four detailed design options from a set of six preliminary alignments for the Mid West 2 alignment. All details regarding the assumptions within the modelling and the hydrology have been outlined within the report.

The preliminary assessment extended upon the works completed by Cardno in 2009 on the Mid West alignment which is shown in Figure 9-1 as the 'Alignment from the 2009 Assessment'. The six preliminary alignments for Mid West 2 are shown in Figure 9-1.

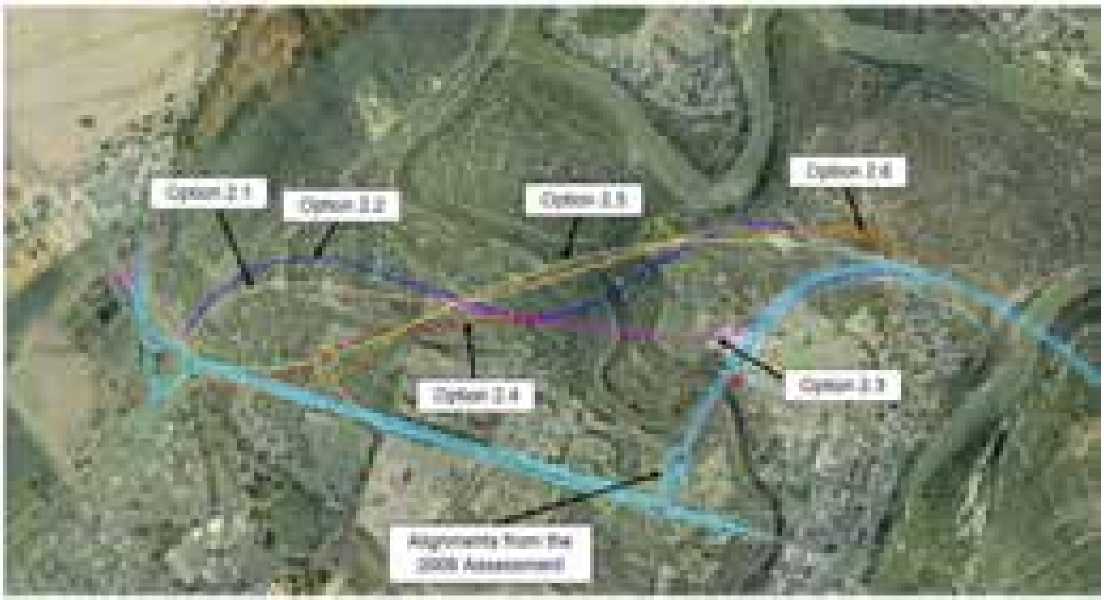

Figure 9-1 Proposed alignments for the Mid West 2 Echuca-Moama bridge crossing

From the six options four options were selected as a result of the preliminary analysis to undertake a detail design. The selected options included:

- Option 2.1 (denoted as '2A' for the detailed assessment)
- Option 2.3 (denoted as '2B' for the detailed assessment)
- Option 2.5 (denoted as '2C' for the detailed assessment)
- Option 2.4 (denoted as '2D' for the detailed assessment)

Within this report the recommended option has been based on using the required bridge length openings and culvert width as a proxy for increased costs for the bridge construction. This is based on the assumption that building the elevated structure and culverts is more expensive than constructing raised embankments. The total bridge opening lengths, culverts lengths and overall mitigation required is summarised in Table 9-1.

Table 9-1 Summary of the required mitigation for the detailed design alignments

Alignment	Bridge Length (m)	Culverts width (m)	Total Mitigation Width (m)
2A	2,055	-	**2,055**
2B	1,715	-	**1,715**
2C	2,150	240 (80 x 3m x 2.4m)	**2,390**
2D	1,840	240 (80 x 3m x 2.4m)	**2,080**

Alignment 2B provides the shortest length of mitigation to achieve the objectives for the proposed Echuca-Moama bridge and is therefore the recommended alignment from this study.

10 References

Bureau of Meteorology, (2003), The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method, Bureau of Meteorology, Melbourne, Australia.

Cardno, (2009), Detailed Hydrology Study for the Echuca-Moama Bridge Planning Study, LJ5598 / RM2194 Final v1.1, Australia.

Cardno, (2010), Addendum: Detailed Hydrology Study for the Echuca-Moama Bridge Planning Study, LJ5598 / RM2277 Final v1.0, Australia.

Cardno, (2012), Detailed Hydrology Study for the Echuca-Moama Bridge Planning Study – Mid West 2 Alignment, LJ5748 / RM2336 Draft v0.3, Australia.

Chow, (1973), Open Channel Hydraulics, McGraw-Hill.

Laurenson, Mein and Nathan, (2006), RORB Version 5.32, SKM and Monash University

Pilgrim, D. H. (ed). (1987), Australian Rainfall and Runoff, Volume 1 & 2, Institute of Engineers, Australia.

SKM (1997) Moama-Echuca Flood Study, prepared by SKM for the Department of Land and Water Conservation, NSW, and the Department of Conservation and Natural Resources, Vic.

Stelling, G.S. Kernkamp, H.W.J and Laguzzii M.M. (1999) Delft Flooding System - A Powerful Tool for Inundation Assessment Based Upon a Positive Flow Simulation, Hydroinformatics Conference, Sydney NSW.

WL|Delft Hydraulics Laboratory, (2005) Sobek Advanced Version 2.10.000.RC01, WL|Delft Hydraulics Laboratory.