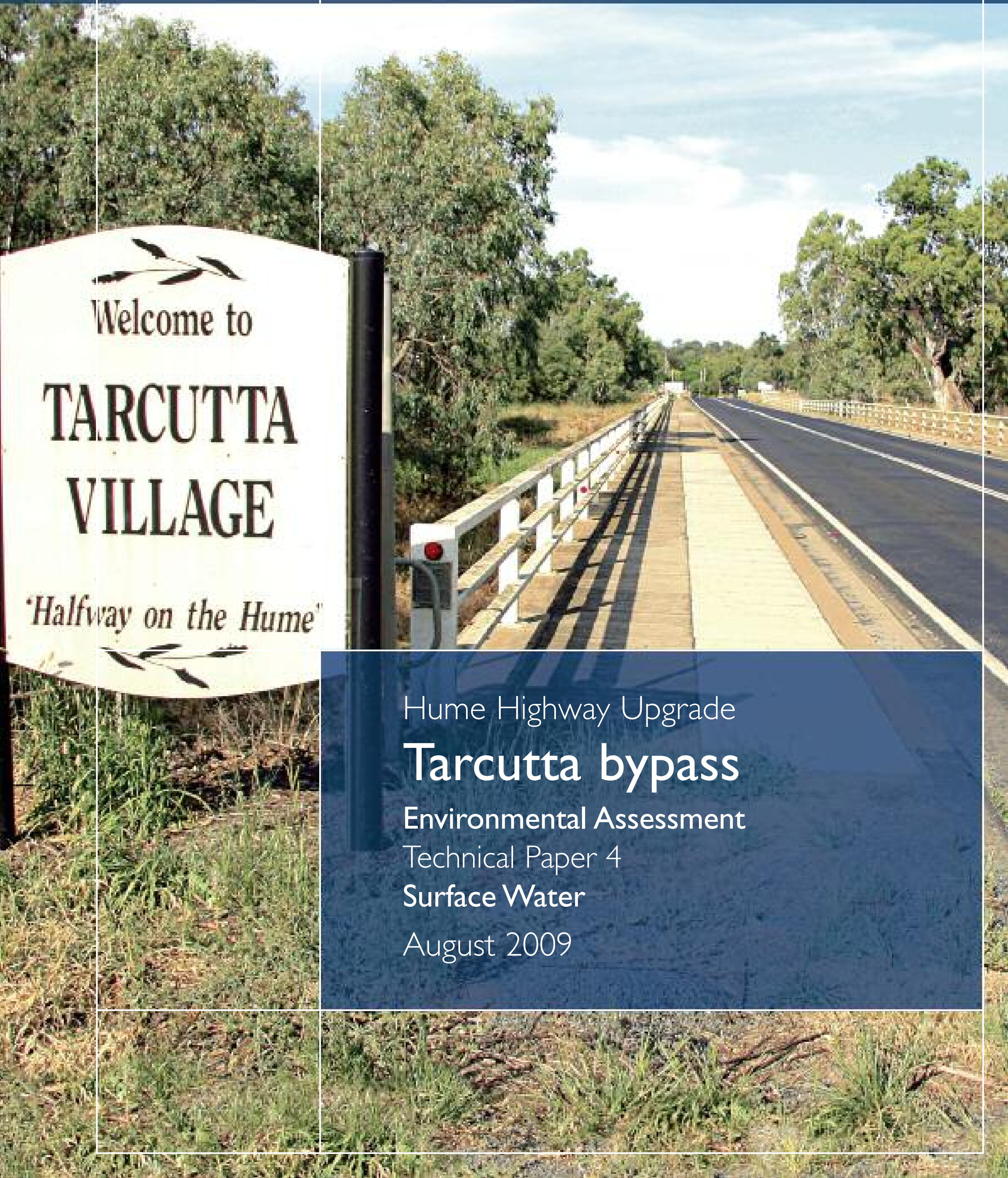
New South Wales Government

RTA



Hume Highway Upgrade

Tarcutta bypass

Environmental Assessment

Technical Paper 4

Surface Water

August 2009

Hume Highway Upgrade
Tarcutta Bypass

Surface Water Report

July, 2009

Roads and Traffic Authority

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Glossary

Airborne laser scanning (ALS) or Lidar	ALS or Lidar (light detection and ranging) are laser scanning methods of undertaking land survey. ALS involves laser scanning of both ground and non-ground features and produces raw data in the form of spot levels across the survey area. The survey method works by measuring distance to the ground from the instrument (located on an aircraft) using a laser light. The time taken for the laser beam to hit the ground surface and return to the instrument is measured and the distance calculated based on the speed of light.
Afflux	The rise in water level (above normal) on the upstream side of a bridge or obstruction caused when the effective flow area at the obstruction is less than the natural width of the stream immediately upstream of the obstruction.
Annual exceedance probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of five per cent, it means that there is a five per cent chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see average recurrence interval).
Australian height datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average recurrence interval (ARI)	The long-term average number of years between the occurrence of a flood as big as or larger than the selected event. For example, floods with a discharge as great as or greater than the 20 year ARI flood event will occur, on average, once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
Catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
Digital elevation model (DEM)	A digital representation of ground surface topography or terrain. It is also widely know as a digital terrain model (DTM).
Discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving, for example metres per second (m/s).
Flood	Relatively high stream flow that overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences, excluding tsunami.
Floodplain	Area of land that is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
Hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
Hydrograph	A graph that shows how the discharge or flood level at any particular location varies with time during a flood.
Hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
m/s	Metres per second. Unit used to describe the velocity of floodwaters.
m^3/s	Cubic metres per second. A unit of measurement for flows or discharges. It is the rate of flow of water measured in terms of volume per unit time.
Model	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
Peak discharge	The maximum discharge occurring during a flood event.
Probable maximum flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature

	and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probable maximum precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
Runoff	The amount of rainfall that actually ends up as stream flow, also known as rainfall excess.
Velocity	The term used to describe the speed of floodwaters, usually in m/s (metres per second).
Water surface profile	A graph showing the flood level at any given location along a watercourse at a particular time.
BTEX	BTEX is an acronym for benzene, toluene, ethylbenzene and xylenes. These compounds are found in petroleum products.
Environmental value	A quality, characteristic or attribute that is considered to have community value and requires protection from the effects of pollution, waste discharges and deposits. Values may include human uses (drinking water or recreation) or natural resource values, such as the protection of aquatic ecosystems.
Water quality objective	A numerical concentration limit or narrative statement that has been established to support and protect the designated environmental value of a receiving water body.
First flush	Pollutants deposited onto exposed areas can be dislodged and entrained by the rainfall-runoff process. Usually the stormwater that initially runs off an area will be more polluted than the stormwater that runs off later, after the rainfall has 'cleansed' the catchment. The stormwater containing this high initial pollutant load is called the 'first flush'.

Note: Glossary definitions based on the NSW Government, Floodplain Development Manual, 2005.

1. Introduction

The Roads and Traffic Authority of NSW (RTA) proposes to construct a highway bypass of the village of Tarcutta on the Hume Highway, located in south-west NSW. Figure 1-1 shows the proposed bypass alignment.

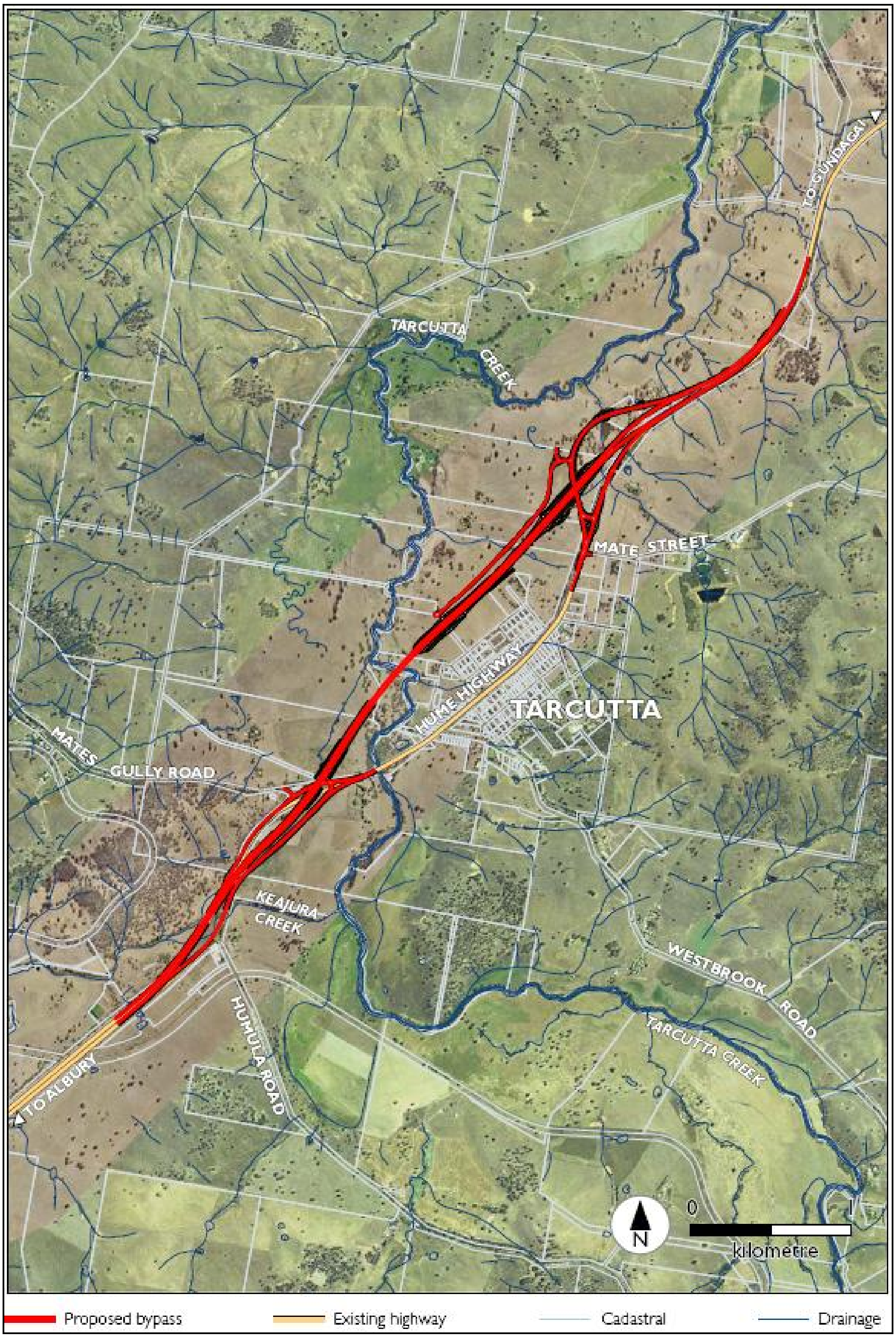

Figure 1-1 Proposed Tarcutta bypass location map

The proposed highway bypass would improve safety, amenity and convenience for local residents, and travel efficiency for freight vehicles, through traffic, and local traffic.

This report has been prepared to identify and address the surface water impacts associated with the proposed bypass. The existing surface water environment of the Tarcutta area has been examined through desktop assessment, and field reconnaissance undertaken by Parsons Brinckerhoff (PB) in October 2008. This assessment is aimed at determining the likely impacts of construction and operation of the proposed bypass on the surface water environment and identifying potential mitigation measures. The risks to surface water resources and relevant legislation requirements under the *Water Act 1912* (WA) and the *Water Management Act 2000* (WMA) are also considered.

1.1 Scope of works

The Director General's environmental assessment requirements for the Tarcutta Bypass are listed under Hydrology, including but not limited to;

- Site water demands on water sources and users
- Impacts to watercourses, and riparian corridors
- Changes to existing flood regimes and characteristics, taking into account the NSW Floodplain Development Manual (2005)

The scope for the surface water was based on the following tasks to address the these requirements:

- Tarcutta Creek flooding: evaluate the effects of the proposed bypass on the existing Tarcutta Creek flood regime, considering the 20 year, 100 year, 2000 year average recurrence interval (ARI) and probable maximum flood (PMF) events. The assessment includes:
  - The distribution and impact of low and high flows across the floodplain.
  - The impact both upstream and downstream on waterways in close proximity to or across the proposed upgrade.
  - The impact on existing property and infrastructure, and the future development potential of affected land.
- Local catchment assessment:
  - Assess the potential impact on water quality in the receiving waters in the vicinity of the proposed bypass during construction and operation.
  - Identify a suite of mitigation measures to mitigate potential impacts on surface water quality during construction and operation.
  - Identify water monitoring and analysis requirements to be carried out during construction.
  - Identify construction sites and activities and estimate the water consumption.
  - Identify and assess the potential impact on potable water sources of neighbouring communities.
  - Identify techniques to minimise water usage, and to use recycling options to reduce the reliance on potable water.

1.2 Overview

1.2.1 Catchment description

The village of Tarcutta and the proposed bypass are located in the catchment of Tarcutta Creek. The Tarcutta Creek catchment area is part of the Murrumbidgee River catchment area of NSW, with flows discharging into the Murrumbidgee River near Oura, north-west of Tarcutta. The study area catchment is approximately 1,660 km^2 and extends from Courabyra and Carabost in the south, through Tarcutta in the north to the Old Borambola streamflow gauge, north-west of Tarcutta.

The catchment has been highly modified by agricultural land use practices in the catchment since the mid 1800s. Currently the catchment is comprised primarily of pastoral farming land, and contains a number of forested areas (including Murraguldrie, Carabost and Bago state forests).

Tarcutta Creek has two main tributaries: Keajura Creek and Umbango Creek. Carabost and Murraguldrie Creeks form tributaries to Umbango Creek in addition there are a number of smaller tributaries to Tarcutta Creek.

The *Murrumbidgee Stressed Rivers Report* (Department of Land and Water Conservation (DLWC), 1999) described Tarcutta Creek as being under a high level of environmental stress and a medium level of hydrological stress from surface water extraction. Tarcutta Creek is currently under high levels of hydrological stress owing to recent drought conditions and extraction for the purposes of stock watering, domestic uses and irrigation.

Salinity is a major issue within the Murrumbidgee catchment and dryland salinity is known to occur in the Tarcutta area. Salt mapping around Tarcutta village identified an area on the southern outskirts as a salinity hazard and the urban salinity study for Tarcutta (Murrumbidgee CMA, 2007) also indicated that the area to the west of the village is at the greatest risk to salinity due to very shallow groundwater levels. Further investigation and discussion of salinity around Tarcutta is provided in the Technical Paper 4 — Groundwater for this project.

1.2.2 Soils

Soil mapping has been partially completed for the Tarcutta 1:100, 000 soil landscape map sheet under the Soil Landscape Mapping Program; however, it has not yet been published, and is unavailable for this assessment.

The proposed Tarcutta bypass traverses the alluvial soils of Tarcutta Creek and its floodplain, and the colluvial soils of the lower gradient foot slopes. The alluvium surface soils are predominantly silts and clays, with some sand, where soil profiles are likely to be relatively deep and may be prone to flooding, waterlogging and shrink-swell behavior. The colluvial soils are generally stony clays that have moved downslope by soil creep, but may include a proportion of windblown red clay and higher terrace alluvium. Due to their topographic situation, these soils have a tendency to become waterlogged and salinised in places (RTA, 2007).

1.2.3 Stream flow

Flows in Tarcutta Creek are characterised by a seasonal pattern with lower flows over summer and autumn, and flood events throughout winter and spring. Based on available recorded data from the Department of Water and Energy (DWE), the median annual discharge is 119,365 ML/year, with a maximum recorded discharge of 530,021 ML in 1974, and a minimum recorded annual discharge of 14,078 ML in 2006 (Old Borambola gauge 410047 – located close to the confluence with the Murrumbidgee River and downstream of Tarcutta village). There are no stream flow records available for Keajura Creek or other tributaries of Tarcutta Creek.

A stream flow duration curve, shown in Figure 1-2, for Tarcutta Creek has been developed based on 70 years of flow data collected at the DWE Old Borambola gauge (410047) between 1939 and 2009 (DWE water information website, accessed 22/4/09). The curve shows that while the highest recorded mean daily flow is 25,510 ML/day, which occurred in August 1983, for 50 per cent of the time during this period of record, flows in Tarcutta Creek were less then 145 ML/day and for 5 per cent of the time, stream flow within Tarcutta Creek was less than 7 ML/day.

During site investigations undertaken by PB on 30 October 2008, Tarcutta Creek was noted to consist largely of stagnant pools within the creek bed and low flow. DWE records of stream flow at the Old Borambola gauge on this day indicate that the mean daily flow was 19.5 ML/day.

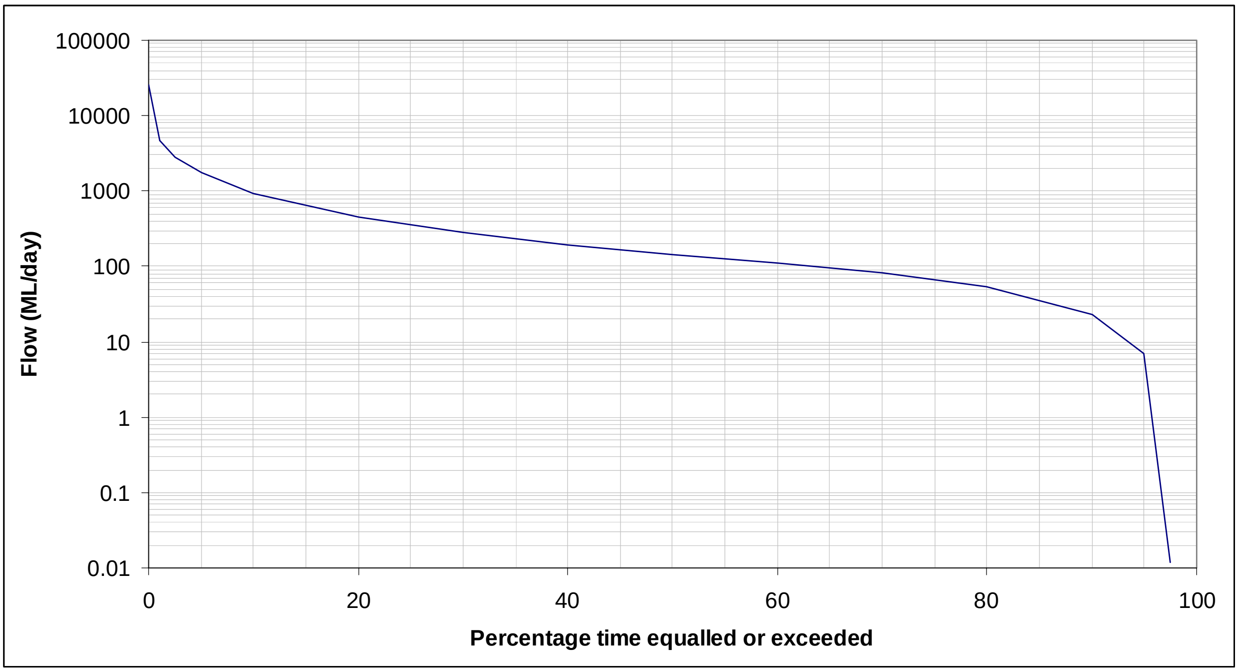

Figure 1-2 Tarcutta Creek flow duration curve

Data Source: DWE water information website, accessed 22 April 2009.

1.3 Proposed bypass description

The Hume Highway bypass of the village of Tarcutta would be approximately seven kilometres in length presenting as a gently graded and straight alignment (see Figure 1-1). At its northern extent, the project would adjoin the Hume Highway duplication works, which are under construction to the north of Tarcutta. The route then heads south, maximising opportunities to retain the existing Hume Highway carriageway as the southbound carriageway, where appropriate. An interchange would be constructed on farmland to the west of the existing highway in the vicinity of Bardwell Street. The interchange would have a northbound on-load ramp and a southbound off-load ramp.

The route would deviate to the west of the existing highway, skirting the boundary of Tarcutta General Cemetery, parallel to the existing highway south to Tarcutta Creek. Twin bridges would be required over Tarcutta Creek and would be situated downstream (north) of the existing highway bridge. South of these bridges, the route would turn east toward the existing highway at the southern end of the village of Tarcutta and would cross over the existing highway to the east, just north of the Mates Gully Road intersection. An interchange is proposed at this location to provide an on-load ramp for southbound traffic.

The route would continue in a south-westerly direction on the eastern side of the highway for approximately one kilometre, where it would again cross the existing highway from east to west, just north of the Humula Road intersection. An interchange is proposed at this location, providing an off-load ramp for northbound traffic heading into Tarcutta. South of the interchange, the route would cross over Keajura Creek on twin bridges. The alignment would adjoin the Hume Highway duplication works and the existing highway south of Humula Road.

1.4 Previous Studies

1.4.1 Preliminary Environmental Assessment

The *Hume Highway Town Bypasses - Tarcutta, Holbrook and Woomargama Groundwater and Surface Water Preliminary Assessments Preliminary Environmental Assessment* (PEA) was completed by PB in May 2008. The PEA identified several potential surface water impacts associated with the proposed bypass (referred to as the Western Option). These potential impacts included:

- Changes to Tarcutta and Keajura Creek's flooding behaviour including changes in water levels (afflux), duration of inundation and time to peak water level.
- Redistribution of local overland runoff, ponding of water upstream of the bypass embankment, and changes to potential ground water recharge.
- Blockage of farm dam and wetland water sources and basic landholder water access rights.
- Changes to water quality related to construction and operational management of stormwater.

1.4.2 Preliminary Flood Investigation

The RTA undertook a Preliminary Flood Investigation in July 2008 to assess existing flooding conditions and estimate a bridge opening size over Tarcutta Creek for the proposed bypass. The investigation consisted of a HEC-RAS hydraulic model to estimate the flood extents using flows derived from a Watershed Bounded Network Model (WBNM) hydrologic model of Tarcutta Creek developed by Webb, McKeown and Associates for the RTA. The investigation report, with results from the modelling, hydrographs for the Tarcutta Creek catchment, and surveyed cross-section data, was available to PB for review. However the HEC-RAS and WBMN models were not made available.

The preliminary investigation recommended a 200 metre bridge opening for the selected bypass option.

1.5 Local and State Government policies

Development of the proposed bypass will be governed by both local government and state government policies as described below.

Water Sharing Plan for the Tarcutta Creek Water Source

The *Water Sharing Plan for the Tarcutta Creek Water Source* (DNR 2004) was gazetted on 7 February 2003 with amendments gazetted on 1 July 2004. The Plan commenced on 1 July 2004 and applies to 30 June 2014. It is a legal document made under the WMA. The Plan is implemented by DWE.

The water sharing rules allocate water for the environmental needs of Tarcutta Creek as well as directing how water is to be shared among different water uses.

Wagga Wagga Rural Local Environmental Plan 1991

The *Wagga Wagga Local Environmental Plan 1991* (LEP) applies across the whole of the Wagga Wagga local government area, including the village of Tarcutta. The general aim of the plan is to encourage the proper management, development and conservation of natural and man-made resources within the local government area. The LEP includes restrictions on the construction of buildings or infrastructure within the floodplain or floodways. However, planning approval from Wagga Wagga City Council is not required as the project is subject to assessment under Part 3A of the *Environmental Planning and Assessment Act 1979*, which prevails over the local planning instrument.

Floodplain Development Manual

The *Floodplain Development Manual* (DIPNR 2005) is the NSW Government's Manual relating to the management of flood liable land in accordance with Section 733 of the *Local Government Act 1993*. The manual supports the NSW Government's *Flood Prone Land Policy* in providing for the development of sustainable strategies for managing human occupation and use of the floodplain. The manual applies to floodplains across NSW, in both urban and rural areas. It is also used to manage major drainage issues in local overland flooding areas.

2. Tarcutta Creek flooding

A flood assessment of Tarcutta Creek was undertaken to evaluate the impacts of the proposed bypass on the existing flow regime and on the properties in the vicinity of the village of Tarcutta. The assessment consisted of a review of available information and data, and hydrologic and hydraulic modelling of Tarcutta Creek.

2.1 Tarcutta Creek characteristics

The proposed bypass would cross Tarcutta Creek approximately one kilometre north and downstream of the existing Hume Highway. The field investigation, undertaken on the 30 October 2008, in the vicinity of the proposed creek crossing identified Tarcutta Creek to consist largely of stagnant ponds within the creek bed, as shown in Photograph 2-1.

Photograph 2-1 Tarcutta Creek during field visit, 28/10/2008

The ponds appear to be disconnected at the surface; however, the presence of a shallow water table may indicate sub-surface flow through the alluvium (Technical Paper 4 — Groundwater), or that a small rainfall event had run through the creek in the days prior to the field investigation.

The creek banks were found to be densely vegetated, with long grass covering the creek bed where dry. Terracing of the banks was apparent in some places.

2.2 Historic flooding

Tarcutta Creek has experienced a number of historic flooding events, with significant events occurring in July 1939, October 1955, August 1970, October 1974, September 1978, August 1983, October 1992, October 1993, and September 2005.

In 1969, the RTA constructed two levees on the upstream side of the existing Hume Highway as part of the Tarcutta Creek bridge upgrade and floodway bridge construction. The left bank levee and the right bank levee (referred to as the Tarcutta Town levee) were constructed to guide floodwaters under the Hume Highway bridges and to provide some level of flood protection for structures within the floodplain. A large storm event occurred in the 1980s during which both levees were overtopped. Subsequently, both levees were raised by RTA in the 1990s to increase the level of flood protection for the adjacent properties, while minimising flooding over the existing Hume Highway.

In September 2005, an approximate five year ARI storm event occurred and flood levels were recorded at the back of Tarcutta Hotel and near a small bridge upstream of the Hume Highway as 227.35 metres Australian height datum (AHD) and 231.69 metres AHD, respectively (*Preliminary Flood Investigation*, RTA 2008). More details regarding the observed water levels are presented in Appendix A.

2.3 Existing flooding conditions

Hydrologic and hydraulic modelling was undertaken to establish the base line existing flooding conditions for Tarcutta Creek in more detail than the *Preliminary Flood Investigation* (RTA 2008) and to improve the understanding of the flooding behaviour to inform the impact assessment. The modelling approach is described below.

2.3.1 Hydrologic modelling

A hydrologic model of the Tarcutta Creek catchment was developed using the WBNM software program. WBNM has been used extensively across Sydney and NSW for both urban and rural flood investigations and was considered suitable for this application.

WBNM is an event-based hydrologic model that calculates flood hydrographs from either recorded storm rainfall hyetographs or design storm rainfall parameters. The catchment is represented in the model as a series of sub-catchments for which factors affecting runoff, such as land use (proportion of pervious and impervious land surfaces), rainfall losses, and routing of runoff both through the catchment and through channels, are defined.

The model of the Tarcutta Creek developed for this study was used to estimate design flows generated from the catchment during the 20 year, 100 year and 2000 year ARI design storm events and the probable maximum precipitation (PMP) design event. The flows were input into the hydraulic model. Details of the WBNM model developed for the Tarcutta Creek catchment are presented in Appendix A.

2.3.2 Hydraulic modelling

A hydraulic model of the Tarcutta Creek floodplain was developed using the two dimensional (2D) hydraulic modelling software, TUFLOW. TUFLOW is an implicit finite difference model that is specifically orientated towards establishing flow patterns in coastal waters, estuaries, rivers, floodplains and urban areas. The software has the ability to dynamically link to the one dimensional (1D) network hydrodynamic program ESTRY, meaning that both the 2D and 1D domains are combined to form one model. This has the advantage of increased resolution and accuracy for in-channel flows, which are essentially 1D in nature, while still accurately modelling the complex floodplain flows and their interaction with channel flows.

The model of the Tarcutta Creek developed for this study was used to establish the existing flooding behaviour and design levels of Tarcutta Creek during the 20 year, 100 year and 2,000 year ARI design storm events and the probable maximum flood (PMF) design event. Details of the TUFLOW model developed for Tarcutta Creek are presented in Appendix A.

2.3.3 Model calibration and sensitivity

Model calibration involves adjusting one or more of the model parameters in order to match observed or measured data. Streamflow data was available from Tarcutta Creek at the Old Borambola gauge (Station number 410047). Six minute pluviograph rainfall intensity data was available from four rainfall gauges close to the catchment: Hume Reservoir (72023), Wagga Wagga Amo (72150), Adelong (Etham Park) (72159) and Tooma (Eudlo) (72163).

The WBNM hydrologic model was calibrated against four historical events (October 1992, October 1993, September 2000 and September 2005). The modelled total event volumes and peak discharges were compared to the recorded hydrographs.

The hydrographs obtained from the calibrated WBNM model for the September 2005 event were used as input into the TUFLOW hydraulic model. This enabled comparison of the modelled peak water levels to observed high water marks for the 2005 event. Details of the calibration methodology are presented in Appendix A.

2.3.4 Design flows

Design flow hydrographs for Tarcutta Creek and Keajura Creek, upstream of their junction, and for the catchment area downstream of the confluence of Tarcutta Creek and Keajura Creek within the TUFLOW model boundary (see Appendix A) were required for input into the TUFLOW model. The design peak flows derived from the WBNM model are listed in Table 2-1. These flows represent the critical duration storm event, determined to be 18 hours.

Table 2-1 Design peak flows

Location	Peak design flows, m^3/s			
	20 year ARI	100 year ARI	2,000 year ARI	PMF
Tarcutta Creek	449	779	1,956	7,471
Keajura Creek	91	166	446	1,697
Downstream catchment area	43	61	167	572

2.3.5 Design flood levels

Peak design flood levels for Tarcutta Creek at key locations within the floodplain extents are listed in Table 2-2 for the 20 year and 100 year ARI storm events. Levels in bold font in Table 2-2 indicate that the finished floor level for a building on the property is below the design flood level under existing conditions. The key locations indicating critical structures, such as buildings and bridges that are currently at risk of inundation during larger flooding events are presented in Figures 2-1 and 2-2. Figures 2-3 and 2-4 show the finished floor levels (RTA, 2008) for some of the buildings.

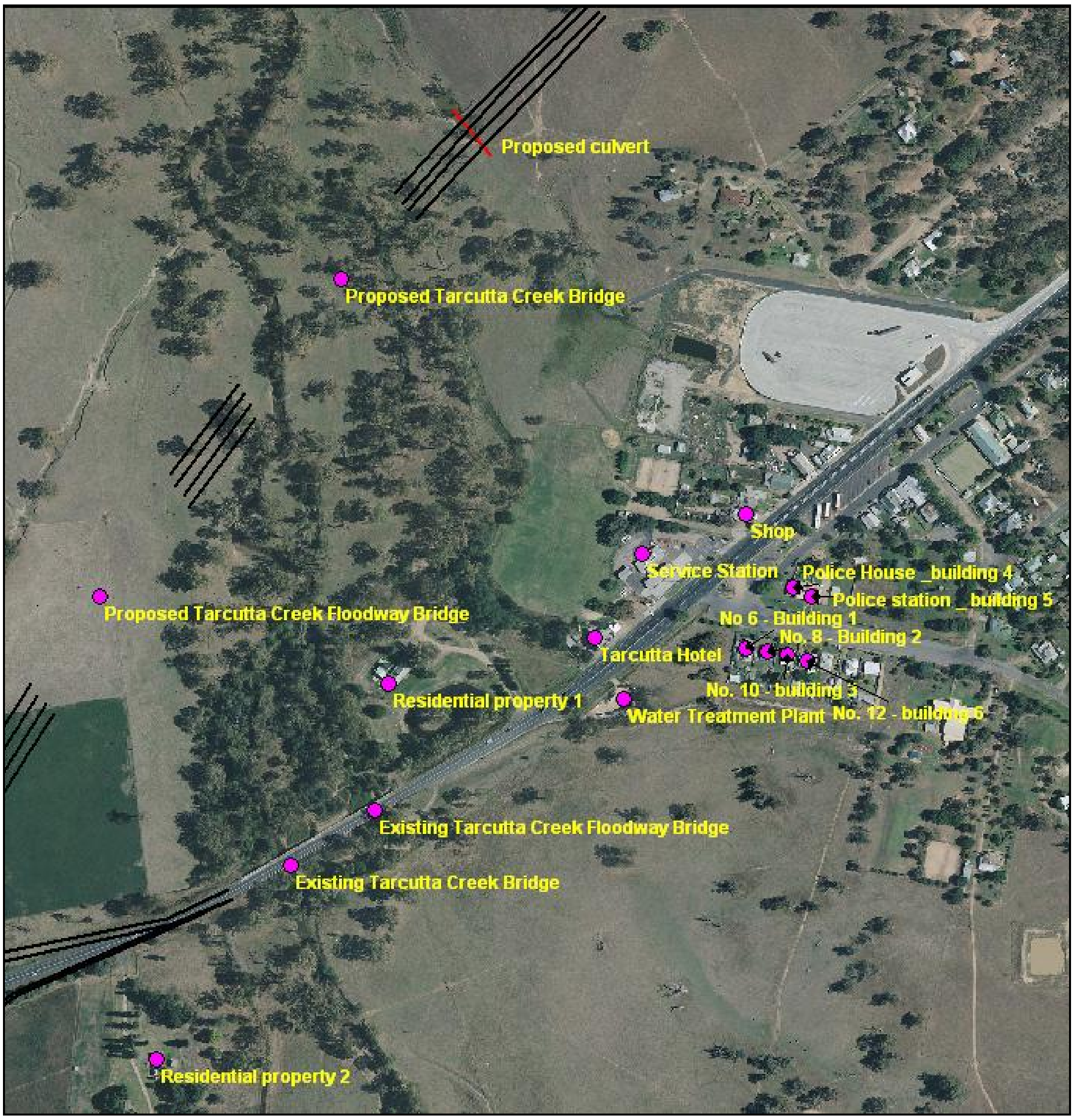

Figure 2-1 Critical structures in the village of Tarcutta

Figure 2-2 Critical structures at Keajura Creek

Figure 2-3 Finished floor levels (mAHD)

Figure 2-4 Finished floor levels inset (mAHD)

Table 2-2 Peak design flood levels, (mAHD*)

Location	20 year ARI	100 year ARI
Properties		
Residential Property 1	227.69	**228.02**
Residential Property 2	Protected by levee	**229.61**
Water treatment plant	Protected by levee	**227.72**
Tarcutta Hotel	227.33	**227.61**
No 6 - Building 1	Protected by levee	227.71
No. 8 - Building 2	Protected by levee	227.72
No. 10 - Building 3	Protected by levee	227.87
No. 12 - Building 6	Protected by levee	Not flood affected
Police House (Building 4)	Protected by levee	Not flood affected
Police station (Building 5)	Protected by levee	Not flood affected
Service Station	Protected by levee	Not flood affected
Shop	Protected by levee	Not flood affected
Bridges		
Existing Hume Highway bridge over Tarcutta Creek	228.61	229.38
Existing Hume Highway bridge over Tarcutta Creek floodway	228.54	229.20
Existing Hume Highway bridge over Keajura Creek	230.53	231.44
Proposed Hume Highway bridge over Tarcutta Creek	226.75	226.99
Proposed Hume Highway bridge over Tarcutta Creek floodway	227.45	227.71
Proposed Hume Highway bridge over Keajura Creek	230.66	231.54

*Note that while values are listed to the nearest 0.01m for the purpose of this assessment, the accuracy of model is within the order of (+/- 0.1m). Levels in bold font indicate finished floor level below the exiting 100 year ARI flood level. Riverina Water County Council has advised that the water treatment plant infrastructure (ie pump, electrical controls) is above 228 metres AHD.

2.3.6 Existing conditions flow characteristics

As detailed in the Director General's requirements (section 1.1), an understanding of the behaviours of flooding is critical for predicting potential changes. The 100 year ARI design flood event, with a critical rainfall event duration equal to 18 hours, results in approximately

45-50 hours of out of bank flooding. The following points document the existing 100 year ARI design flood behaviour in and around Tarcutta, as predicted from the hydraulic model.

- Flood waters generally remain within the Tarcutta and Keajura Creek main channels for the first 2 hours of the event.
- The existing Hume Highway Floodway Bridge in the Tarcutta Creek floodplain begins to operate once flood waters reach approximately 226.1mAHD.
- Left overbank flooding downstream of the existing Hume Highway and upstream of the Tarcutta and Keajura Creek confluence, which causes ponding upstream of the Railway embankment, occurs at approximately 2.5 hours after the beginning of the event.
- Overtopping of the Tarcutta Town levee and subsequently the existing Hume Highway, begins at approximately 8.5 hours after the beginning of the event.
- The left bank levee overtops at approximately 9.5 hours after the beginning of the event.
- The peak flow and resulting peak water level occurs at approximately 13 hours after the beginning of the event.
- Floodwaters subside over the next 1 to 2 day period.

During the 20 year ARI event, neither the Tarcutta Town nor the left bank levee are overtopped, nor is the existing Hume Highway. The property downstream of the existing Hume Highway (Residential Property 1) experiences some flooding.

2.4 Impact assessment

This assessment is based on the concept design described below which is just one option for minimising flooding impacts and is subject to change with the optimisation of the final design.

The proposed bypass was modelled with TUFLOW to represent one possible concept design option consisting of a proposed main Tarcutta Creek bridge (Proposed Tarcutta Creek Bridge) of approximately 233 metres length and a floodway bridge (Proposed Tarcutta Creek Floodway Bridge) of approximately 233 metres in length within the left overbank area, and a five cell 3.6 x 2.7metre box culvert (Proposed Culvert) within the right overbank as shown in Figure 2-1. Additionally, the concept design includes a 66metre bridge across Keajura Creek (Proposed Keajura Creek Bridge) shown in Figure 2-2. The existing bridge over Keajura Creek would remain and would be used for the bypass on-ramp. Impacts to flow distribution, peak flood levels (afflux), duration of inundation and velocities due to the construction and operation of the proposed bypass based on this concept design option are presented below.

2.4.1 Construction

Construction of the proposed bypass would involve site establishment and preparation works, earthworks, drainage works (culverts, bridges, water quality basins), pavement construction, and some ancillary works. These works will occur across the Tarcutta Creek and Keajura Creek floodplain and have the potential to affect flood behaviour should a flood event occur during the construction period. There is also potential for construction works to be affected by flooding. The proposed construction works and facilities are not known in detail for this assessment and is therefore discussed in general terms.

Construction works would include ancillary facilities required for construction (i.e. haul roads) and placement of construction equipment, stockpiles, and construction materials within the floodplain. These works have the potential to change flood flow distribution as a result of blockage of usual flow paths (resulting from construction equipment, stockpiles, and construction materials). Depending on the location of flow blockages in relation to properties within the floodplain there is potential that flood flow distribution changes may have temporary impact to properties.

The occurrence of a flood during construction would also affect water quality as a result of sediment and construction materials being transported with flood flows. Water quality impacts of the project are further assessed in Section 4.

2.4.2 Operation

Flow distribution and floodplain storage

The proposed bypass embankment would change the distribution of flow within the Tarcutta Creek floodplain both upstream and downstream of the proposed Hume Highway crossing. The bypass would reduce the floodplain storage in the vicinity of the bypass footprint where it encroaches into the existing floodplain. The embankment will also prevent floodwaters from accessing storage areas, specifically areas south of the existing Hume Highway within Residential Property 2 and areas in the left over bank immediately downstream of the proposed bypass. The embankment would block the conveyance of flows, except where bridges or openings are constructed. Changes in flow distribution can lead to increased flood levels (afflux), changes in flood inundation times and changes in velocity; these are discussed in detail below.

Afflux

The proposed concept design on which the surface water assessment has been based is subject to refinement during detailed design. The final design will seek to minimise change in afflux, however the concept design has been assessed against the following afflux design objective for the 100 year ARI event:

- Land without buildings or sensitive structures — minimise impacts.
- Land where buildings or sensitive structures are already below the 100 year ARI flood level — minimise and manage impacts.
- Land where buildings or sensitive structures previously not inundated in the 100 year ARI event would be at increased risk of inundation — no additional impacts.

The proposed concept design causes some afflux in the adjacent floodplain areas for the 100 year ARI event. Additionally, afflux for the 20 year ARI was also assed to provide further understanding of the existing flooding conditions for more recurrent events.

Table 2-3 summarises the afflux for the 20 year and 100 year ARI events at the key locations shown in Figures 2-1 and 2-2. Figure 2-5 shows the 100 year ARI flood extents under the existing scenario and with the proposed bypass.

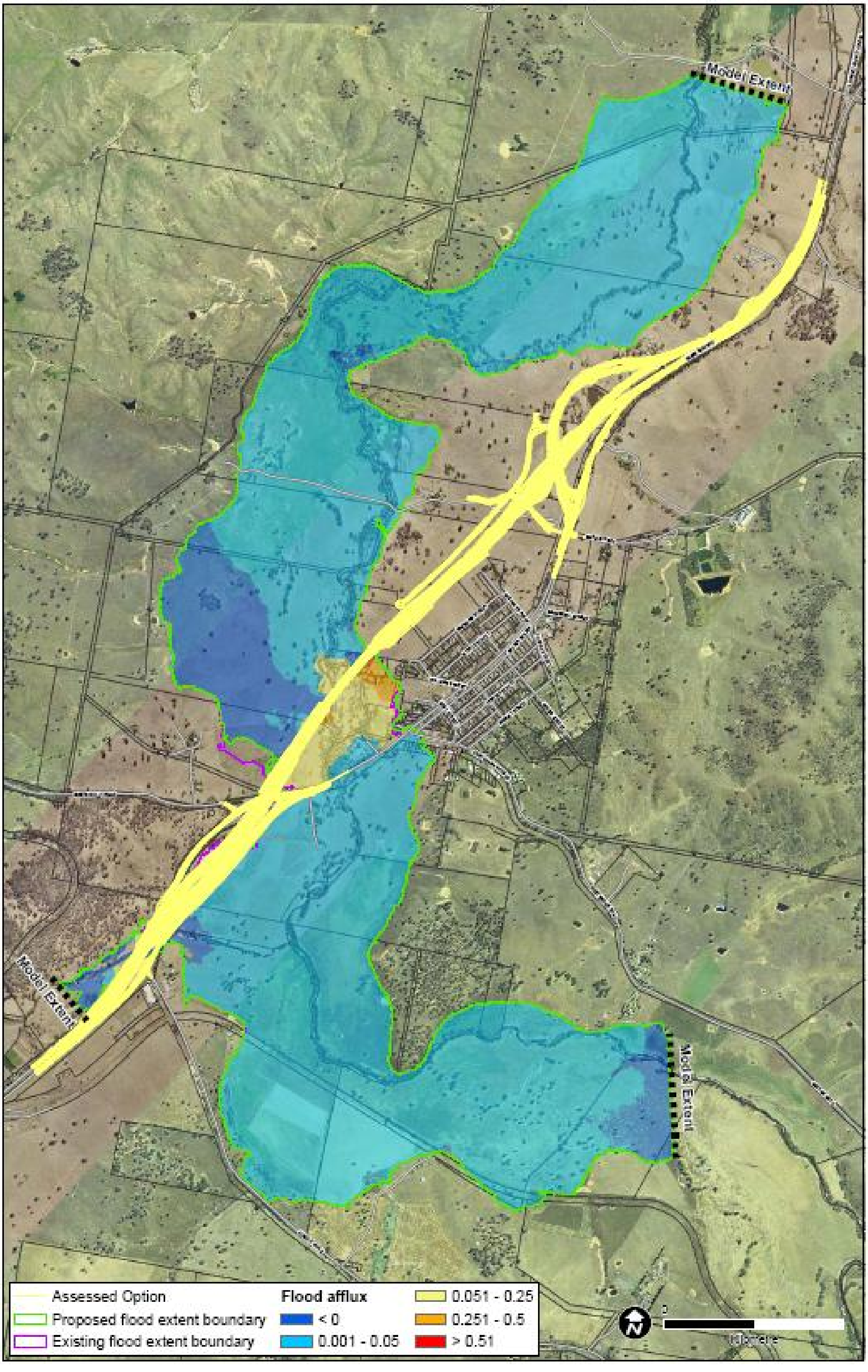

Figure 2-5 Existing and proposed 100 year ARI flood extents and afflux

Table 2-3 20 year and 100 year ARI afflux (mAHD)*

Location	Existing *20 year ARI	Proposed *20 year ARI	Afflux 20 year ARI	Existing *100 year ARI	Proposed *100 year ARI	Afflux 100 year ARI
Property						
Residential Property 1	227.69	227.70	0.01	228.02	228.06	0.04
Residential Property 2	Protected by levee	Protected by levee	-	229.61	229.62	0.01
Water treatment plant*	Protected by levee	Protected by levee	-	227.72	227.75	0.03
Tarcutta Hotel	227.33	227.34	0.01	227.61	227.71	0.10
No 6 - Building 1	Protected by levee	Protected by levee	-	227.71	227.75	0.03
No. 8 - Building 2	Protected by levee	Protected by levee	-	227.72	227.75	0.03
No. 10 - Building 3	Protected by levee	Protected by levee	-	227.87	227.87	0.00
No. 12 - Building 6	Protected by levee	Protected by levee	-	Not flood affected	Not flood affected	-
Police House (Building 4)	Protected by levee	Protected by levee	-	Not flood affected	Not flood affected	-
Police station (Building 5)	Protected by levee	Protected by levee	-	Not flood affected	Not flood affected	-
Service Station	Protected by levee	Protected by levee	-	Not flood affected	Not flood affected	-
Shop	Protected by levee	Protected by levee	-	Not flood affected	Not flood affected	-
Bridges						
Existing Hume Highway bridge over Tarcutta Creek	228.61	228.62	0.01	229.38	229.40	0.02
Existing Hume Highway bridge over Tarcutta Creek floodway	228.54	228.55	0.01	229.20	229.21	0.01
Existing Hume Highway bridge over Keajura Creek	230.53	230.53	0.00	231.44	231.42	-0.03

*Note that while values are listed to the nearest 0.01m for the purpose this assessment, the accuracy of model is within the order of (+/- 0.1m). Riverina Water County Council has advised that the water treatment plant infrastructure (ie pump, electrical controls) is above 228 metres AHD.

Duration of inundation and frequency of flooding

The duration of inundation is the amount of time that a property experiences flooding during a particular storm event. Table 2-4 summarises the approximate duration of inundation during the 100 year ARI event for some of buildings shown in Figures 2-1 and 2-2.

Table 2-4 Estimated duration of inundation (hours) 100 year ARI event

Location	Time*	Existing	Time*	Proposed	Impact
Residential Property 1	8.5	15	8.5	15	0
Residential Property 2	10.5	8.5	10.5	8.5	0
Water treatment plant	10.5	9.5	9	11	1.5
Tarcutta Hotel	8.5	11.5	7	13	1.5
No 6 - Building 1	Floor level not innundated		Floor level not innundated		-
No. 8 - Building 2	Floor level not innundated		Floor level not innundated		-
No. 10 - Building 3	Floor level not innundated		Floor level not innundated		-
No. 12 - Building 6	Property not flood affected		Property not flood affected		-
Police House (Building 4)	Property not flood affected		Property not flood affected		-
Police station (Building 5)	Property not flood affected		Property not flood affected		-
Service Station	Property not flood affected		Property not flood affected		-
Shop	Property not flood affected		Property not flood affected		-

*Time indicates when a property becomes inundated by floodwaters in hours after the start of the storm event, i.e. start time is 0.00 hours.

The results indicate that the water treatment plant and the Tarcutta Hotel may experience an additional 1.5 hours of flooding during the 100 year ARI storm event and may experience flooding up to 1.5 hours earlier than under existing conditions.

Changes in flood behaviour due to the proposed bypass have the potential to change the frequency of flooding in some locations, i.e. some location may flood more regularly than under existing conditions. The current concept design option does not change the frequency of flooding for the properties in the vicinity of Tarcutta.

Velocity

Changes in velocity can lead to changes in scour and/or sediment movement within the waterways and around structures, such as bridge piers and abutments and levees. Scouring at structures can lead to undermining and failure. High velocities have the potential to move structures in a downstream direction if not properly accounted for in the structure design.

Sedimentation can lead to a reduction in flow conveyance area within a waterway or through bridge structures by filling of the channel, raising inverts and vegetation growth. Reduction in conveyance area can potentially lead to increases in water levels during storm events.

Table 2-5 summarises the velocity impacts at the existing and proposed bridge locations shown in Figures 2-1 and 2-2.

Table 2-5 Peak velocities at bridge structures (m/s*)

Location	Event	Existing	Proposed	Impact
Existing Hume Highway bridge over Tarcutta Creek	20 year ARI	3.73	3.69	-0.04
	100 year ARI	4.85	4.78	-0.07
	2,000 year ARI	4.65	4.31	-0.34
Existing Hume Highway bridge over Tarcutta Creek floodway	20 year ARI	1.71	1.70	-0.01
	100 year ARI	2.40	2.39	-0.01
	2,000 year ARI	2.80	2.74	-0.06
Existing Hume Highway bridge over Keajura Creek	20 year ARI	1.20	1.16	-0.05
	100 year ARI	1.92	1.69	-0.24
	2,000 year ARI	3.75	3.58	-0.18
Proposed Hume Highway bridge over Tarcutta Creek	20 year ARI	0.81	0.97	0.17
	100 year ARI	0.92	1.26	0.35
	2,000 year ARI	1.47	2.27	0.80
Proposed Hume Highway bridge over Tarcutta Creek floodway	20 year ARI	1.63	1.77	0.14
	100 year ARI	2.19	2.47	0.29
	2,000 year ARI	2.85	3.48	0.63
Proposed Hume Highway bridge over Keajura Creek	20 year ARI	0.98	1.52	0.54
	100 year ARI	1.41	2.23	0.82
	2,000 year ARI	1.82	3.59	1.77

* Note that while values are listed to the nearest 0.01m/s for the purpose of this assessment, the accuracy of model is within the order of (+/- 0.1m/s)

Flood hazard within a floodplain is defined within the NSW Floodplain Development Manual (NSW Government 2005) and is based on hydraulic principles of flood depth and flood velocity that affect the safety of individuals or properties. These other factors include flood warning, flood awareness, flood readiness and evacuation methods. From a hydraulic perspective if flood depths are greater than 1m and/or flood velocities are greater than 2m/s then the degree of flood hazard is considered to be high. Table 2-6 summarises the velocity impacts at key residential properties shown in Figures 2-1 and 2-2.

Table 2-6 Peak velocities at key properties (m/s*)

Property	Event	Existing	Proposed	Impact
Residential Property 1	20 year ARI	0.14	0.19	0.05
	100 year ARI	0.65	0.79	0.14
	2,000 year ARI	0.48	0.36	-0.12
Residential Property 2	20 year ARI	Protected by levee	Protected by levee	-
	100 year ARI	0.04	0.03	-0.01
	2,000 year ARI	0.56	0.61	0.06
Water treatment plant	20 year ARI	Protected by levee	Protected by levee	-
	100 year ARI	0.02	0.03	0.01
	2,000 year ARI	0.96	1.01	0.04
Tarcutta Hotel	20 year ARI	0.09	0.08	-0.01
	100 year ARI	0.44	0.35	-0.10
	2,000 year ARI	2.38	2.14	-0.24
No 6 - Building 1	20 year ARI	Protected by levee	Protected by levee	-
	100 year ARI	0.02	0.02	0.01
	2,000 year ARI	0.70	0.72	0.02
No. 8 - Building 2	20 year ARI	Protected by levee	Protected by levee	-
	100 year ARI	0.03	0.05	0.02
	2,000 year ARI	0.75	0.77	0.01
No. 10 - Building 3	20 year ARI	Protected by levee	Protected by levee	-
	100 year ARI	0.00	0.01	0.01
	2,000 year ARI	0.91	0.94	0.03
No. 12 - Building 6	20 year ARI	Protected by levee	Protected by levee	-
	100 year ARI	Not flood affected	Not flood affected	-
	2,000 year ARI	1.18	1.23	0.05
Police House (Building 4)	20 year ARI	Protected by levee	Protected by levee	-
	100 year ARI	Not flood affected	Not flood affected	-
	2,000 year ARI	0.58	0.64	0.07
Police station (Building 5)	20 year ARI	Protected by levee	Protected by levee	-
	100 year ARI	Not flood affected	Not flood affected	-
	2,000 year ARI	0.56	0.63	0.07
Service Station	20 year ARI	Protected by levee	Protected by levee	-
	100 year ARI	Not flood affected	Not flood affected	-
	2,000 year ARI	0.03	0.08	0.05
Shop	20 year ARI	Protected by levee	Protected by levee	-
	100 year ARI	Not flood affected	Not flood affected	-
	2,000 year ARI	0.31	0.39	0.08

* Note that while values are listed to the nearest 0.01m/s for the purpose of this assessment, the accuracy of model is within the order of (+/- 0.1m/s)

2.5 Management of impacts

2.5.1 Construction

Mitigation measures to minimise potential flood impacts during construction would need to ensure that major flow paths are maintained and that adequate planning of construction activities takes place. Proposed measures to be implemented include:

- Maintain major flood flow paths during construction activities (Keajura Creek, Tarcutta Creek and main Tarcutta Creek floodplain).
- Ensure material stockpiles and storage areas are not located within the 20 year ARI floodplain.
- Design ancillary facilities (i.e. haul road) to overtop in a flood event.
- Use diversion bunds to divert flows around construction works.
- Water quality impacts would be dealt with through usual erosion sediment control practices. See Section 4.3 for further details regarding water quality impacts and mitigations measures.

2.5.2 Operation

Floodplain Storage

The modelled concept design option would decrease floodplain storage within the proposed bypass footprint due to the embankment and would prevent floodwaters from accessing some of the storage areas south of the existing Hume Highway within Residential Property 2 and areas in the left overbank immediately downstream of the bypass. Additionally, the proposed on-ramp to the existing Hume Highway within Residential Property 2 would also prevent floodwaters from reaching floodplain storage areas. A possible mitigation measure to allow floodwaters to reach these areas is the installation of culverts under the proposed bypass embankment and under the on-ramp. Allowing floodwaters to access these storage areas would likely decrease afflux.

Afflux and duration of inundation

The modelled conceptual design option causes afflux for the 100 year ARI design event, as detailed in Section 2.4.2. The greatest afflux is within the right overbank area near Residential Property 1 (located directly downstream of the existing Hume Highway bridge), the Tarcutta Hotel, water treatment plant and Residential Property 2. These buildings have a finished floor level below the existing 100 year ARI flood level. The increase in duration of inundation for the properties shown in Table 2-4 is related to the afflux.

The final alignment for the proposed bypass will ensure that these impacts are minimal.

Residential Property 1 and Tarcutta Hotel

Flood waters would begin to inundate Residential Property 1 when an existing berm located around the west and north side of the property is overtopped. The Tarcutta Hotel begins to experience flooding soon after. During the 100 year ARI, additional floodwaters overtopping the existing Hume Highway would also impact the properties. The afflux is due to floodwaters in the left overbank area between the existing Hume Highway and the proposed bypass being displaced by the proposed bypass embankment and diverted back towards the main channel of Tarcutta Creek and into the right overbank area. Under the current concept design, a 233 metre floodway bridge would be located in the left overbank area.

Possible mitigation measures to address the afflux and increased duration of inundation would include:

- Increase the length of the floodway bridge or add additional culverts to convey more flow under the bypass in the left overbank.
- Raise the existing berm around the property and extend it around the property on the south side.
- Flood-proof the building on the properties.

Water treatment plant

Floodwaters would begin to inundate the water treatment plant when the Tarcutta Town levee is overtopped and from backwater overtopping the existing Hume Highway from the north. The afflux would be caused by additional backwater effects and overtopping of the Hume Highway from the north with the backwater extending upstream of the existing Hume Highway causing further overtopping of the Tarcutta Town levee. These backwater effects would result from the change in flow distribution in the left overbank area between the existing Hume Highway and the bypass as described for Residential Property 1. Riverina Water County Council has advised that the water treatment plant infrastructure (ie pump, electrical controls) is above 228 metres AHD, which is above the proposed water level.

Possible mitigation measures to address the afflux and increased durations of inundation at the water treatment plant grounds may include:

- Increase the length of the floodway bridge or add additional culverts to convey more flow under the proposed bypass in the left overbank.
- Raise the Tarcutta Town levee.
- Flood-proof the buildings on the property.

Residential Property 2

Floodwaters would begin to inundate Residential Property 2 when the levee around the property is overtopped. The afflux would be caused by increased backwater extending upstream of the existing Hume Highway to cause additional overtopping of this levee. Possible mitigation measures to address the afflux and increased durations of inundation would include:

- Increase the length of the floodway bridge or add additional culverts to convey more flow under the proposed bypass in the left overbank.
- Raise left bank levee.
- Flood-proof the buildings on the property.

Note: agreement between key stakeholders and the Tarcutta Hume Alliance is required to select the preferred mitigation measures to deal with the various impacts.

Velocity

The velocity changes as summarised in Table 2-5 would not pose a major risk to the operation of the proposed bypass or to the main channels of Tarcutta and Keajura Creeks. The changes in velocities can be mitigated with appropriate scour protection measures around the proposed bridge piers and abutments and additional scour protection measures at the existing bridges as needed.

Velocities noted within Table 2-6 indicate that flood hazard at these locations within the Tarcutta Creek floodplain is considered to be low. This is the case under both existing and proposed conditions. The flood impact assessment has indicated that the proposed bypass would not significantly increase flood depths or flood velocities and therefore the project is not likely to change the existing flood hazard in the vicinity of Tarcutta.