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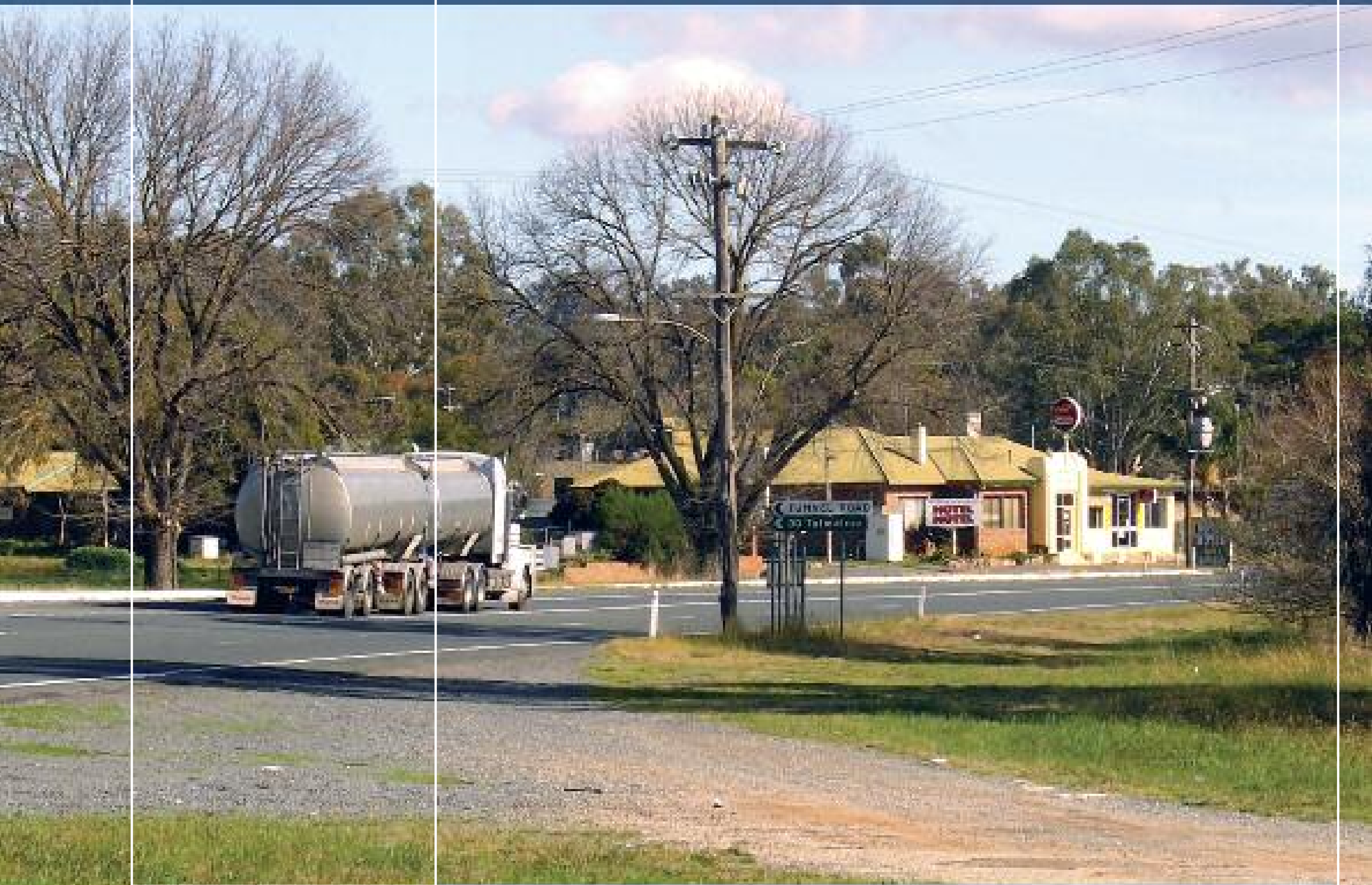

Hume Highway Upgrade

Woomargama bypass

Environmental Assessment
Technical Paper 3 – Surface Water

September 2009

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Hume Highway Upgrade
Woomargama bypass

Surface Water Report

September, 2009

NSW Roads and Traffic Authority

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Glossary

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

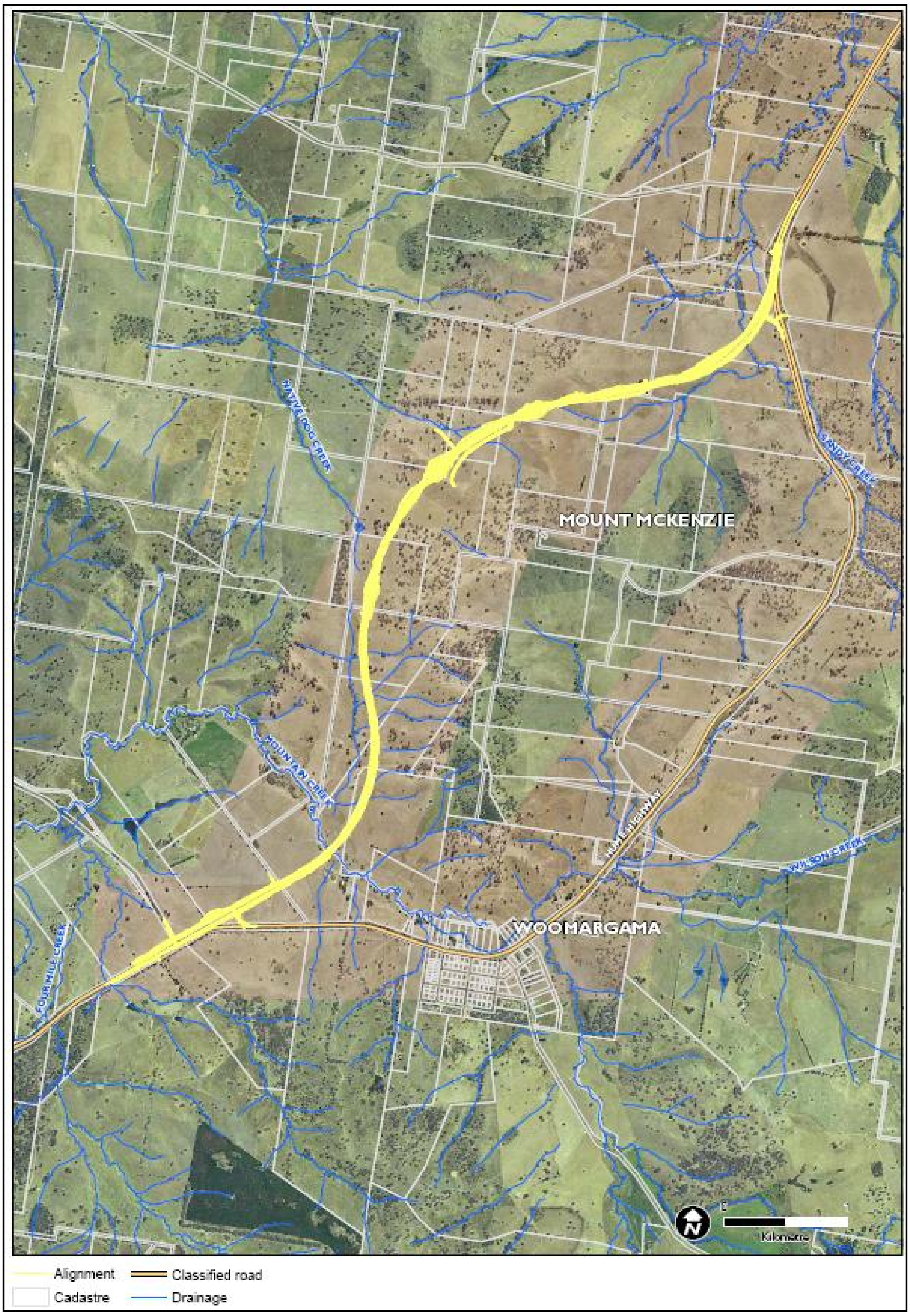

Figure 1-1 Proposed Woomargama bypass location map

The proposed 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 address the surface water impacts associated with the proposed bypass. The existing surface water environment of the Woomargama bypass area has been examined through desktop assessment, and field reconnaissance undertaken by Parsons Brinckerhoff (PB) in February 2008 and May 2009. The assessment aimed to determine the likely impacts of construction and operation on the surface water environment and provide 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) were also considered.

1.1 Scope of works

The relevant Director-General's environmental assessment requirements for the proposed Woomargama bypass are listed under surface and groundwater, including but not limited to:

- Site water demands on water sources and users.
- Existing and proposed water licensing requirements under the WA and the WMA.
- Impacts to watercourses and riparian corridors.
- Changes to existing flood regimes and characteristics, taking into account the NSW *Floodplain Development Manual* (2005).
- Impacts to water supply for identified local agribusiness.

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

- Mountain Creek flooding: evaluated the effects of the proposed bypass on the existing Mountain Creek flood regime, considering the 20 year, 100 year, 2000 year average recurrence interval (ARI) and probable maximum flood (PMF) events. The assessment included:
  - The distribution and impact of low and high flows across the floodplain.
  - The impact both upstream and downstream of waterways in proximity to or across the proposed bypass.
  - The impact on existing property and infrastructure, and the future development potential of affected land.
- Local catchment assessment:
  - Assessed the potential impact on water quality in the receiving waters in the vicinity of the proposed bypass during construction and operation.
  - Identified a suite of mitigation measures for potential impacts on surface water quality during construction and operation.
  - Identified water monitoring and analysis requirements to be carried out during the construction stage.
  - Identified construction sites and activities and estimate the water consumption.

- Identified potential sources of water supply for construction.
- Identified and assessed the potential impact on potable water sources used by neighbouring communities and agribusinesses.
- Identified techniques to minimise water usage and recycling options, to reduce reliance on potable water.

1.2 Overview

1.2.1 Catchment description

The proposed bypass works fall within the Mountain Creek catchment and would cross Mountain Creek approximately two kilometres downstream of the existing Hume Highway crossing. The existing Hume Highway crosses Mountain Creek at Woomargama to the east of the village.

Additionally, the project would cross a number of small drainage lines, most of which are unnamed; however, two drainage lines form the headwaters of Native Dog Creek and Sandy Creek. Native Dog Creek is a tributary of Mountain Creek. Sandy Creek flows in a generally northerly direction and is a tributary of Ten Mile Creek (joining the creek downstream of Holbrook).

Mountain Creek is a tributary of Billabong Creek, which itself is a tributary of the Murray River. Mountain Creek joins Billabong Creek approximately 17 kilometres north-west of Woomargama. In the vicinity of Woomargama, Mountain Creek is also known as Woomargama Creek.

Major tributaries of Mountain Creek within the study area include Spring Creek, Tunnel Creek, Wilson Creek and Four Mile Creek. Spring Creek and Tunnel Creek both join Mountain Creek upstream of Woomargama. Wilson Creek joins Mountain Creek at Woomargama, just downstream from the existing Hume Highway bridge, and Four Mile Creek joins Mountain Creek just downstream of the Fairbairn Road bridge.

Upstream of the junction of Mountain Creek and Four Mile Creek, Mountain Creek has a catchment area of 130 square kilometres (km^2). The upper reaches of the catchment have steeper topography and are densely forested, containing areas of the Woomargama State Forest.

There is little catchment-specific information available for Mountain Creek. From a review of available data, the features of the upper Billabong Creek catchment apply similarly to Mountain Creek. The catchment is predominantly cleared, with the hilltops and uplands to the east containing scattered patches of native vegetation. The top end of the catchment is mainly grazed, but cropping is important in the lower catchment. Similar dominant crops occur in the catchment, including wheat, triticale and oats, followed by lupins, barley and canola.

1.2.2 Soils

According to the 1:100 000 Holbrook and Tallangatta soil landscape map, the soil landscape in the Woomargama area is characterised by red and yellow earths/light alluvial soils that cover the flats and lower slopes, while the hills are covered by sandy yellow earths.

The proposed bypass traverses the undulating plains and rolling hills, with soils of moderate to high erosion hazard. The proposed bypass would traverse the Buckargingah erosional (bu) soil landscape. This landscape consists of undulating low hills with moderately deep soils. Localised poor drainage and waterlogging occur, with moderate erosion hazard.

For further investigation of the area's geology see Technical Paper 4 – Groundwater.

1.2.3 Climate

The average annual rainfall for Woomargama is about 740 millimetres per year (mm/yr), which is based on 126 years of rainfall data recorded at the Bureau of Meteorology Station No 072049, located approximately 4.5 kilometres south of Woomargama at Woomargama Estate. The climate is characterised by warm to hot summers and cool to cold winters, and rainfall is winter dominant. The average annual class 'A' pan evaporation for Holbrook (located about 15 kilometres north of Woomargama) is 1161 mm/yr (Water Conservation and Irrigation Commission, 1975) (PB, 2008).

1.2.4 Stream flow

Flows in Mountain Creek are characterised by a seasonal pattern with lower flows generally occurring over summer and autumn. Based on available recorded data from the former Department of Water and Energy (DWE), the mean daily discharge is 216 megalitres per day (ML/day) with a maximum recorded daily discharge of 10967 megalitres per day (ML/day) on 26 August 1983, and a minimum recorded daily discharge below the recordable level at several times in the catchment record (e.g. December 1977, March 1980, and January and March 1981). The data were recorded at flow gauge 410096 (Thomond North, decommissioned in 1994), located on Mountain Creek approximately 10 kilometres downstream of Woomargama. There are no stream flow records available for the tributaries of Mountain Creek.

A stream flow duration curve for Mountain Creek (presented in Figure 1-2) has been developed based on 18 full years, plus a few additional months, of daily maximum flow data collected at the DWE Thomond North gauge (410096) between 1974 and 1994 (DWE gauge operator supplied, July 2009). Although daily maximum flow data is available throughout the vast majority of the record (minus a few days of unrecorded flow), the gauge data is coded predominantly 'poor' quality (DWE water quality codes 68, 80, 130, 201 and 255). Further discussion with the hydrographer at DWE confirmed that the quality of the gauged data is considered poor and that the majority of data appears to be unprocessed, or based on poor extrapolations.

The stream flow curve shows that while the highest recorded maximum monthly flow is 10967 ML/day on 26 August 1983, for 50 per cent of the time during this period of record, monthly maximum flows in Mountain Creek are less then 43 ML/day and for one per cent of the time, stream flow within Mountain Creek is not detectable.

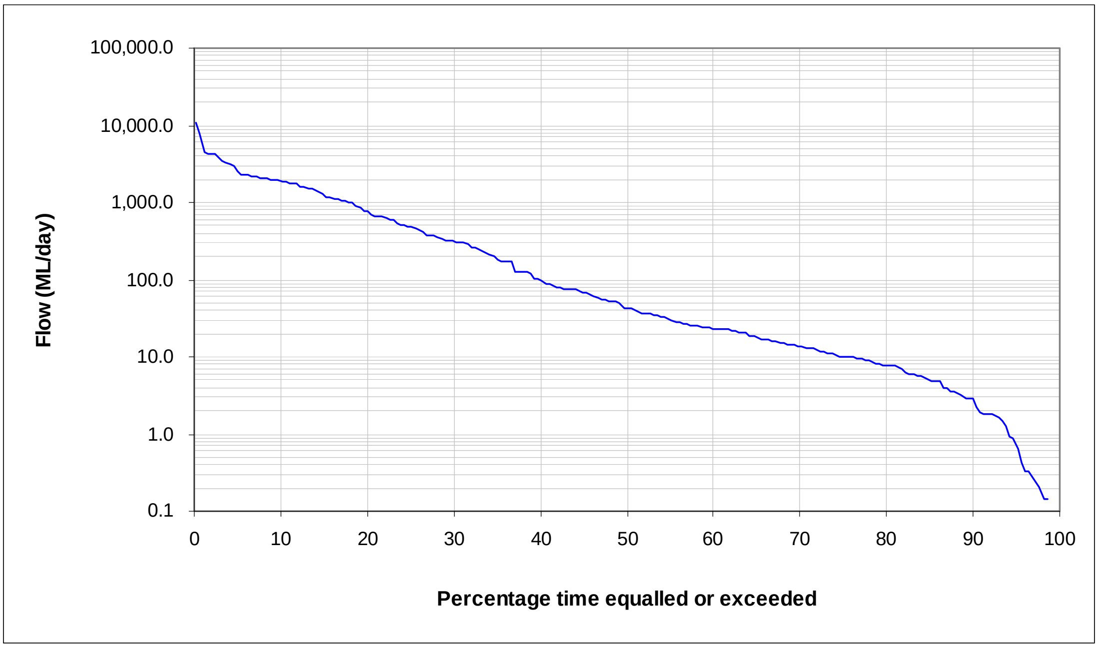

Figure 1-2 Mountain Creek flow duration curve

Data Source: DWE gauge operator, supplied July 2009.

1.3 Proposed bypass description

The project would include the following key components:

- Approximately nine kilometres of dual carriageway.
- An at-grade intersection with the existing Hume Highway approximately 6.5 kilometres north of Woomargama village.
- Bridges over Sandy Creek.
- Six deep cuttings.
- Twin bridges over Mountain Creek.
- An at-grade intersection with the existing Hume Highway approximately two kilometres south of Woomargama village.
- An upgrade to the at-grade intersection at Fairbairn Road.

The project would be undulating and form an elongated curved alignment. It would lie to the west of Woomargama village at a maximum distance of approximately three kilometres from the existing Hume Highway.

At its northern extent, the project would tie-in to the existing Hume Highway. The project would continue south and gradually veer away, in a slight westerly direction, from the existing highway. At approximately 500 metres from the start of the project a new at-grade intersection would be constructed. This intersection would tie-in the project with the existing highway about 6.5 kilometres north of Woomargama village and would provide access to Woomargama village from the north.

The project would include bridges over Sandy Creek. The project would continue in a westerly direction gradually ascending and traversing through the saddles of Mount McKenzie and would require three deep cuts on the ascent.

The project would then gradually descend in a southerly direction and pass through two further cuts. Still descending the project would travel adjacent to a drainage line.

Twin bridges would be constructed to enable the crossing of Mountain Creek and its floodplain. The project would continue travelling in a south-westerly direction.

A new at-grade intersection would be constructed approximately 900 metres south of Mountain Creek. This intersection would tie-in with the existing Hume Highway approximately two kilometres south of Woomargama village. This would provide access to the village from the south.

A final deep cut would then be required for the project. The project would include an upgrade of the intersection at Fairbairn Road. It would then tie-in to the new section of Hume Highway dual carriageway scheduled to be completed in December 2009.

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 of the proposed bypass. These potential impacts included:

- Changes to Mountain Creek 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 groundwater recharge.
- Blockage of farm dam and wetland water sources and basic landholder water access rights.
- Stormwater quality related to construction and operation.

1.4.2 Previous flood investigations

PB completed the *Hume Highway – Woomargama Bypass Mountain Creek Flood Study* (Appendix A) for the RTA in March 2008 to supplement the PEA. This study included hydrologic and hydraulic modelling, using XP-RAFTS and MIKE11 respectively, to analyse Mountain Creek in the vicinity of Woomargama and to establish the existing flooding conditions. PB undertook subsequent hydraulic analysis for the RTA using TUFLOW, building on the original study to improve the understanding of the flooding environment in the vicinity of Woomargama (Appendix A).

The preliminary investigation recommended a minimum 185 metre bridge opening across Mountain Creek 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. These include:

1.5.1 Greater Hume Shire Local Environmental Plan (not available)

Due to the amalgamation of the former Hume and Holbrook shires to form the Greater Hume Shire in 2004, Council has commenced the preparation of a new local environmental plan (LEP), to apply across the whole of the new Shire of Greater Hume, including Woomargama and Holbrook, and replace the existing planning instruments. The draft LEP was adopted by Council for negotiation with Department of Planning in March 2009 with expected final adoption within 18 months. Planning approval from the Greater Hume Shire 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.

1.5.2 Floodplain Development Manual (DIPNR 2005)

The *Floodplain Development Manual* 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.

1.6 Objectives and guidelines

1.6.1 RTA water policy

The RTA has developed a water policy that identifies a set of objectives for the management of water issues related to planning, design, construction, operation and maintenance of RTA roads. The policy summarises key design practices used to contain and treat road runoff and to minimise potential impacts to receiving aquatic and riparian environments. This is achieved through treatment of road runoff through 'non-point' source, or 'dispersed' techniques and maintaining existing stream/system hydrology.

1.6.2 ANZECC Guidelines

The Australian and New Zealand Environment and Conservation Council (ANZECC) published the revised Australian and New Zealand guidelines for fresh and marine water quality in 2000. The guidelines form the central technical reference of the National Water Quality Management Strategy, which the federal and all state and territory governments have adopted for managing water quality.

1.6.3 Department of Environment and Climate Change and Water (DECCW) catchment objectives

For each catchment in NSW, the NSW government has endorsed the community's environmental values for water, known as 'water quality objectives'. These were adopted following extensive consultation with the community in 1998.

Additionally, the NSW government has adopted ‘River Flow Objectives’ (RFOs) from the DECCW. The RFOs have been developed to help maintain natural low flow and river health. The objectives have been used to assess the impacts of the road construction and operation.

2. Mountain Creek flooding

The *Hume Highway – Woomargama Bypass Mountain Creek Flood Study* (PB, March 2008) and subsequent studies have been undertaken to evaluate the impacts of the proposed bypass on the existing flow regime, mainly in relation to Mountain Creek and properties in the vicinity of the village of Woomargama. The following sections summarise the methodology (in accordance with NSW *Floodplain Development Manual* (2005)) and the outcomes of these studies.

2.1 Mountain Creek characteristics

The proposed bypass would cross Mountain Creek approximately two kilometres north-west and downstream of the existing Hume Highway. Mountain Creek is an ephemeral system. The DWE (now part of DECCW) has advised that stream flow generally occurs only after catchment rainfall or when base flow from groundwater is sufficient. At other times, the creek is reduced to a series of disconnected pools. Advice from DWE suggests that there is generally no flow during the summer months.

A field inspection of the study area was conducted on the 19th February 2008. During this inspection, it was noted that Mountain Creek had an incised channel with primarily sandy banks and floor. The creek exhibited a high level of sinuosity, which was attributed to the low gradient of the creek and the soils present. The creek had ponded water in locations at the time of the inspection, which was slowly flowing in some locations.

The floodplain narrows near Woomargama and the Hume Highway bridge, being confined by a large hill on the right hand side of the creek and the Hume Highway on the left hand side (looking downstream). Further downstream near the proposed bypass crossing, the floodplain widens, principally spreading out from the right hand side of the creek through the valley.

Vegetation in the main channel was sparse, but large eucalypts and willows lined the banks. There were also occasional large logs and snags across the channel. Floodplain vegetation consisted primarily of long grass with scattered native trees.

Photograph 2-1 shows a typical section of the Mountain Creek channel. Photograph 2-2 shows typical Mountain Creek over bank areas.

Photograph 2-1 Typical Mountain Creek channel

Photograph 2-2 Typical Mountain Creek over bank area

2.2 Historic flooding

Mountain Creek has experienced a number of historic flooding events, with significant events occurring in September 1974, November 1975, August 1981, September 1983, August 1986, August 1990 and February 1991. Flooding events after 1994 have not been recorded at station 410096 since it was decommissioned.

It was noted from discussions with local property owners during the field investigation that Mountain Creek experienced a large flood in 2003. Local property owners indicated that during flooding events, floodwaters are contained within the floodplain (below the top of the embankment on the left hand side of the creek) and spread across the wide floodplain. The assessment of the existing flooding conditions reflects these observations.

2.3 Existing flooding conditions

The *Mountain Creek Flood Study* (PB, March 2008), Appendix A, included a hydrologic and hydraulic assessment that established the existing flooding conditions for Mountain Creek. Subsequent studies have built upon this original study with revisions to the XP-RAFTS hydrologic model and flood modelling using TUFLOW two dimensional hydraulic model (Appendix B).

Design flows generated from the catchment were estimated for the 20 year, 100 year and 2000 year ARI design storm events and the PMF design event, in line with the *NSW Floodplain Development Manual* (2005). Design flood levels were also established for these events.

2.3.1 Hydrologic modelling

A hydrologic model of the Mountain Creek catchment was developed for the previous flood study (PB 2008) using the XP-RAFTS software program. XP-RAFTS has been used extensively across NSW for both urban and rural flood investigations and was considered suitable for this application.

XP-RAFTS 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 XP-RAFTS model for Mountain Creek was revised for this study and 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 XP-RAFTS model developed for the Mountain Creek catchment are presented in Appendix A with revisions to the model presented in Appendix B.

2.3.2 Model calibration and sensitivity

Hydrologic modelling

Model calibration involves adjusting one or more of the model parameters in order to match observed or measured data. Streamflow data was available for Mountain Creek at the now decommissioned 410096 flow gauge located approximately 10 kilometres downstream of Woomargama. Six minute Pluviograph rainfall intensity data was available from the rainfall gauge located closest to the catchment, Hume Reservoir (72023) located approximately 37 kilometres to the southwest of the 410187 flow gauge and outside to the Mountain Creek catchment. Rain gauge data was also available from three other rain gauges located further away from the catchment: Wagga Wagga Amo (72150), Adelong (Etham Park) (72159) and Tooma (Eudlo) (72163).

Flow data for Mountain Creek gauge (410096) consisted of peak flow values recorded predominantly in one to six hourly intervals. The gauged data is considered by DWE to be poor in quality while the majority of values appear to be unprocessed or based on extrapolations. The three largest flow events on record were chosen for calibration including the 26 August 1983, 06 July 1990 and 25 January 1991 flow events.

Calibration involved the adjustment of the initial loss model parameter to match modelled and recorded peak flows and hydrograph volumes. A reasonable calibration was achieved for the 26 August 1983 event, but not for either of the 1990 or 1991 events. This is most likely due to the poor quality of the gauge data and poor correlation of the rainfall data to the flow gauge. Therefore, adopted loss values for the design events are based on the 26 August 1983 calibration event.

Sensitivity analyses were also undertaken in order to establish the levels of confidence for the adopted model parameters since the model could not be verified with a recorded event. Sensitivity analyses involve varying parameters relating to catchment characteristics for the 100 year ARI event within the XP-RAFTS model. The results of the sensitivity analyses suggested that the XP-RAFTS model was relatively robust and not greatly sensitive to changes in adopted catchment parameters (initial and continuing losses). Details of the sensitivity analyses are presented in Appendix B.

2.3.3 Design flows

Design flow hydrographs for the Mountain Creek TUFLOW hydraulic modelling included inputs for Mountain Creek and Wilson Creek upstream of the existing Hume Highway. A lateral inflow to Wilson Creek downstream of the existing Hume Highway and a lateral inflow to Mountain Creek downstream of the proposed bypass crossing were also included. The design peak flows for the 20 year, 100 year, 2000 year ARI and PMF events are listed in Table 2-1.

Table 2-1 Design peak flows

Location	Design peak flows (m^3/s)			
	20 year ARI	100 year ARI	2000 year ARI	PMF
Mountain Creek (upstream of existing Hume Highway)	76	134	493	1675
Wilson Creek (upstream of existing Hume Highway)	35	57	175	543
Lateral inflow to Wilson Creek	11	18	47	142
Lateral inflow to Mountain Creek	9	16	58	210

2.3.4 Flood depth and flooding extents

Flood depths and approximate flooding extents were established using the TUFLOW model for the 20, 100 and 2000 year ARI and PMF design events. The existing 100 year ARI design peak flood depths and extents are shown in Figure 2-1. All other design events are detailed in Appendix B.

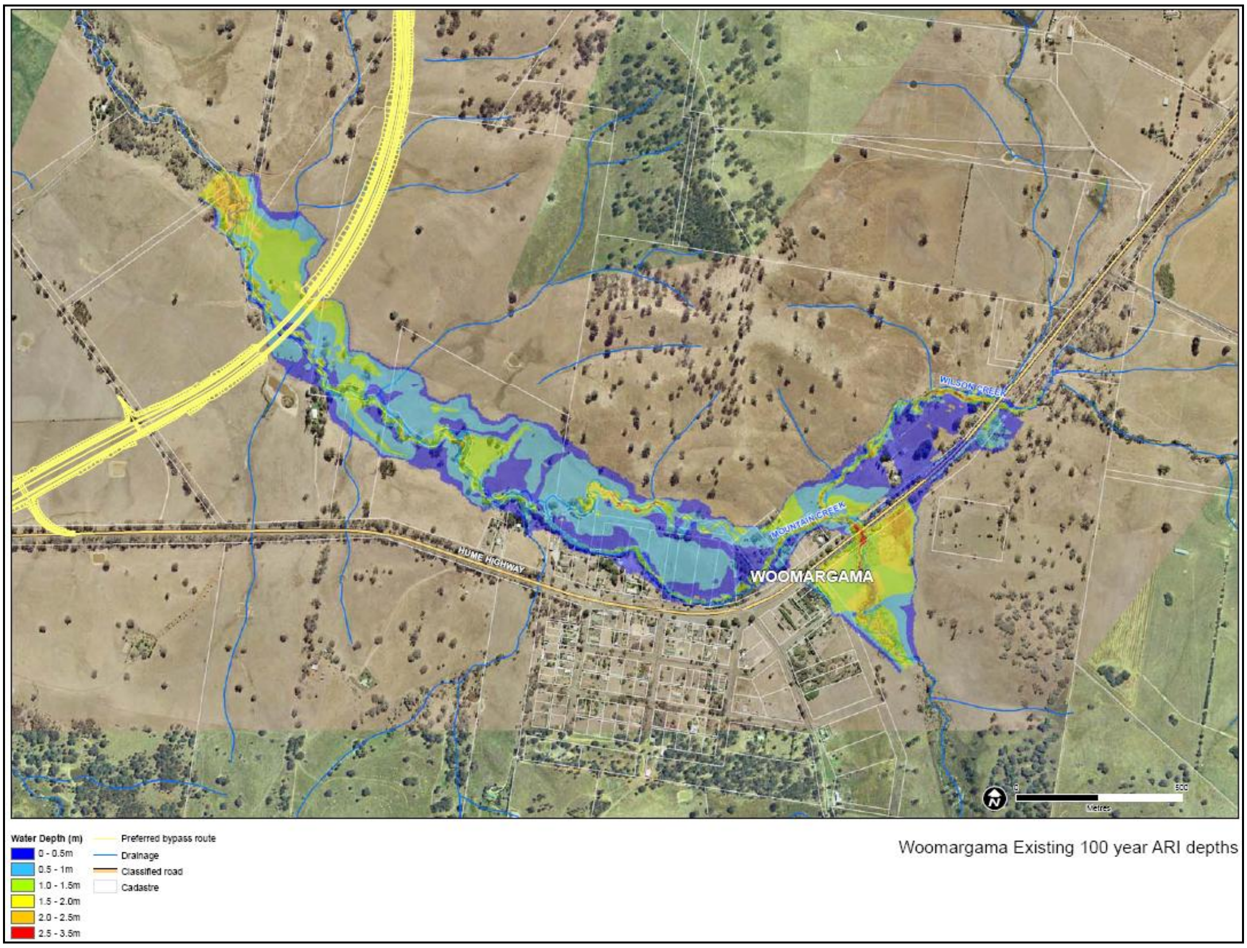

Figure 2-1 Design Peak 100 year ARI flood depths and approximate flood extents

*Note that flood extents are approximate due to the level the accuracy of the input data

2.4 Impact assessment

Construction and operation impacts were assessed in accordance with the RTA's Water Policy and DECCW RFOs. This assessment was based on the concept design, one potential option for the road alignment and is subject to change with the final design. The final design of the bypass will need to meet the assessment criteria described in the following sections.

The proposed bypass was modelled with TUFLOW to represent one possible concept design option, comprising 180 metre twin bridges opening over Mountain Creek as shown in Figure 2-1. 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 in the following sections.

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 would occur across the Mountain 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 yet known in detail for this assessment and are, 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. Flooding also has the potential to damage construction equipment.

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

2.4.2 Operation

Flow distribution

The proposed bypass embankment has the potential to affect the distribution of flow from local drainage lines (further discussed in Section 3.0) and within the Mountain Creek floodplain both upstream and downstream of the proposed bypass by contracting flow through proposed bridges and culverts. Twin bridges of 180 metres in length at the Mountain Creek crossing would almost span the entire existing 100 year ARI floodplain extent and the impacts to the flow distribution Mountain Creek flood waters would be minimal. Changes in flow distribution may lead to increased flood levels, changes in flood inundation times and changes in velocity; these are discussed in detail below.

Afflux

The detailed design would 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:

- Rural land without buildings or sensitive structures — minimise impacts.
- Rural land where buildings or sensitive structures are already below the 100 year ARI flood level — minimise and manage impacts.
- Any 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 considered concept design would cause some afflux in the floodplain areas adjacent to the 180 metre twin bridges and embankment for the 100 year ARI event, though this would be minimal within the village of Woomargama. Figure 2-2 shows the 100 year ARI design event afflux with the proposed bypass.

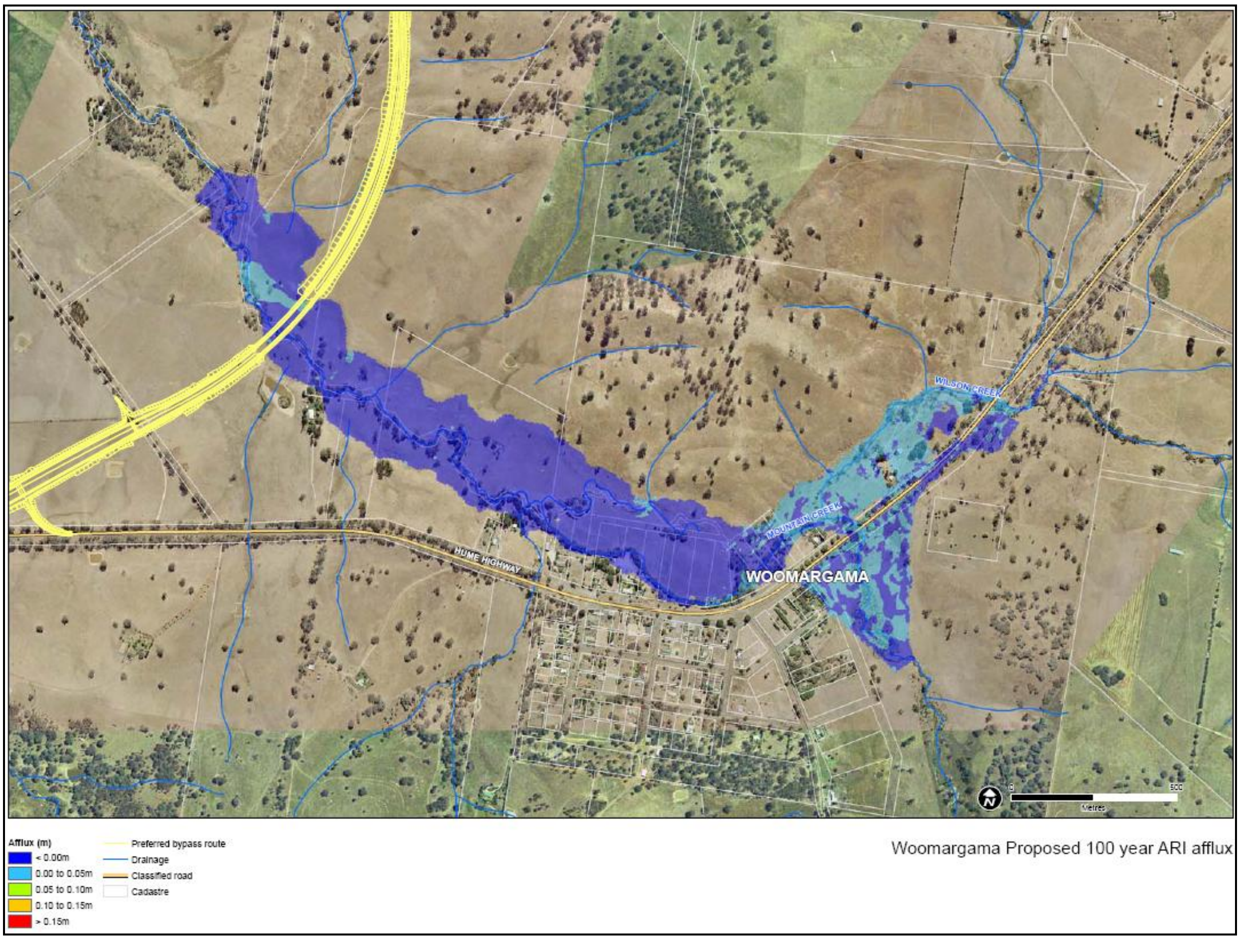

Figure 2-2 100 year ARI design event afflux with the proposed bypass

Duration of inundation and frequency of flooding

The duration of inundation is the amount of time that floodwaters are out of the main channel and on the floodplain land and/or that a property experiences flooding during a storm event. There would be minimal to no change in the duration of inundation of flood affected lands expected due to the proposed bypass.

Changes in flood behaviour due to the proposed bypass have the potential to change the frequency of flooding in some locations (i.e. some locations may flood more regularly than under existing conditions). The assessed concept design would not change the frequency of flooding for the properties in the vicinity of Woomargama.

Velocity and flood hazard

Changes in velocity can lead to scour and/or sedimentation within the waterways and around structures, such as bridge piers and abutments. 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 flood events. Additionally, sedimentation can smother plants and crops downstream.

There would be little to no changes in velocity expected due to the proposed bypass except locally at the proposed bridge, where there are slight increases as expected due to the constriction of flow. Table 2-2 shows the velocity impact at the proposed bridge.

Table 2-2 Peak velocity (m/s)

Location	Event	Existing	Proposed	Impact
Existing Hume Highway Bridge over Mountain Creek	20 year ARI	1.6	1.6	0.0
	100 year ARI	2.0	2.0	+0.0
	2000 year ARI	3.8	3.9	+0.1
180 metre twin Hume Highway bridges over Mountain Creek	20 year ARI	1.4	1.6	+0.2
	100 year ARI	1.7	1.8	+0.1
	2000 year ARI	1.8	2.0	+0.2

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 and other relevant factors that affect the safety of individuals or structures. These other factors include flood warning, flood awareness, flood readiness and evacuation methods. From a hydraulic perspective, if flood depths are greater than one metre and/or flood velocities are greater than two metres per second (m/s) then the degree of flood hazard is considered to be high. 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 Woomargama.

2.5 Management of impacts

2.5.1 Construction phase

Construction and operation impacts should be managed in accordance with the RTA's Water Policy and DECCW RFOs. 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 should include:

- Maintain major flood flow paths during construction activities (Mountain Creek).
- Ensure material stockpiles and storage areas are not located within the 10 year ARI floodplain.
- Design ancillary facilities (i.e. haul roads) to overtop in a flood event.
- Use diversion bunds to divert flows around construction works.
- Use erosion sediment control practices to manage erosion potential and water quality impacts. See Section 4.3 for further details regarding water quality impacts and mitigation measures.

2.5.2 Operational phase

Afflux and duration of inundation

The assessed concept design would cause minimal afflux for the 100 year ARI deign event as detailed in Section 2.4.2. The greatest afflux would be just upstream in the immediate vicinity of the proposed bypass. Minimal afflux would occur within the village of Woomargama. Additionally, no change in duration of inundation would be experienced. No flood mitigation measures would be required with a bridge length opening of 180 metres.

The final design for the proposed bypass would ensure that these impacts are minimal.

Velocity and flood hazard

The changes in velocities summarised in Table 2-2 could 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. Additionally, 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 Woomargama.

3. Local catchment assessment

The local catchment assessment considered drainage lines with small contributing catchments. The assessment is relevant because these local drainage lines potentially contribute to local water storages or become active drainage lines during large flood events. Understanding their relevance to the local area is, therefore, important to ensure the proposed bypass has minimal to no impact.

3.1 Assessment methods

The local catchment assessment was undertaken through a desktop study and field investigation. The desktop study consisted of:

- Review of the Hume Highway – *Woomargama Bypass, Preliminary Environmental Assessment Report undertaken by PB (November 2008).*
- Review of aerial photographs and topographic data to identify creek crossings, floodways, irrigation channels and any other surface water flow paths that cross the proposed bypass.
- Identification of water storages, and other infrastructure both upstream and downstream of the proposed bypass.
- Consideration of the distribution and impact of low and high flows for each waterway, both during construction and operation.
- Evaluation of surface water supply options for the construction of the bypass in line with legislative and licensing arrangements.
- Review of objectives pertaining to the study catchment: RTA Water Policy Objectives and DECCW RFOs.

The field investigation was undertaken on 26 and 27 May 2009. Each watercourse that was identified in the desktop study as potentially affected by the proposed bypass was assessed (where local access permitted) for the following:

- Quantity of water present.
- Evidence of a shallow water table.
- Evidence of erosion.
- Any connection to existing infrastructure, such as local dams.
- Groundcover and surrounding land use type.

Water samples were taken for laboratory analyses (where water was present in the waterway) and in potentially affected farm dams in the vicinity of the proposed bypass to determine pre-construction water quality. More details regarding the water quality assessment are presented in Section 4. Some drainage lines and dams could not be assessed due to restricted site access.

3.2 Drainage lines and surface water bodies

Aside from Mountain Creek, the proposed bypass of Woomargama would cross 17 local drainage lines. Several dams exist along or near some of these drainage lines. The drainage lines and dams are numbered for reference on Figure 3-1 and are described below.

Drainage line 1 joins Sandy Creek (Drainage line 2) just downstream of the proposed bypass crossing at the northern end of the alignment. Drainage line 1 is classified as order 1 by the Strahler system, whereas Sandy Creek is classified as order 3. No fish species were identified to inhabit Sandy Creek (Technical Paper – 1, Flora and Fauna) though some flow was observed at the sampling site during the field investigation (Figure 3-1, Photograph 3-1). However, Sandy Creek was not flowing further north of the proposed bypass near Spring Valley Road (Photograph 3-2).

Photograph 3-1 Sandy Creek (drainage line 2) at sampling site

Photograph 3-2 Sandy Creek downstream of Spring Valley Road

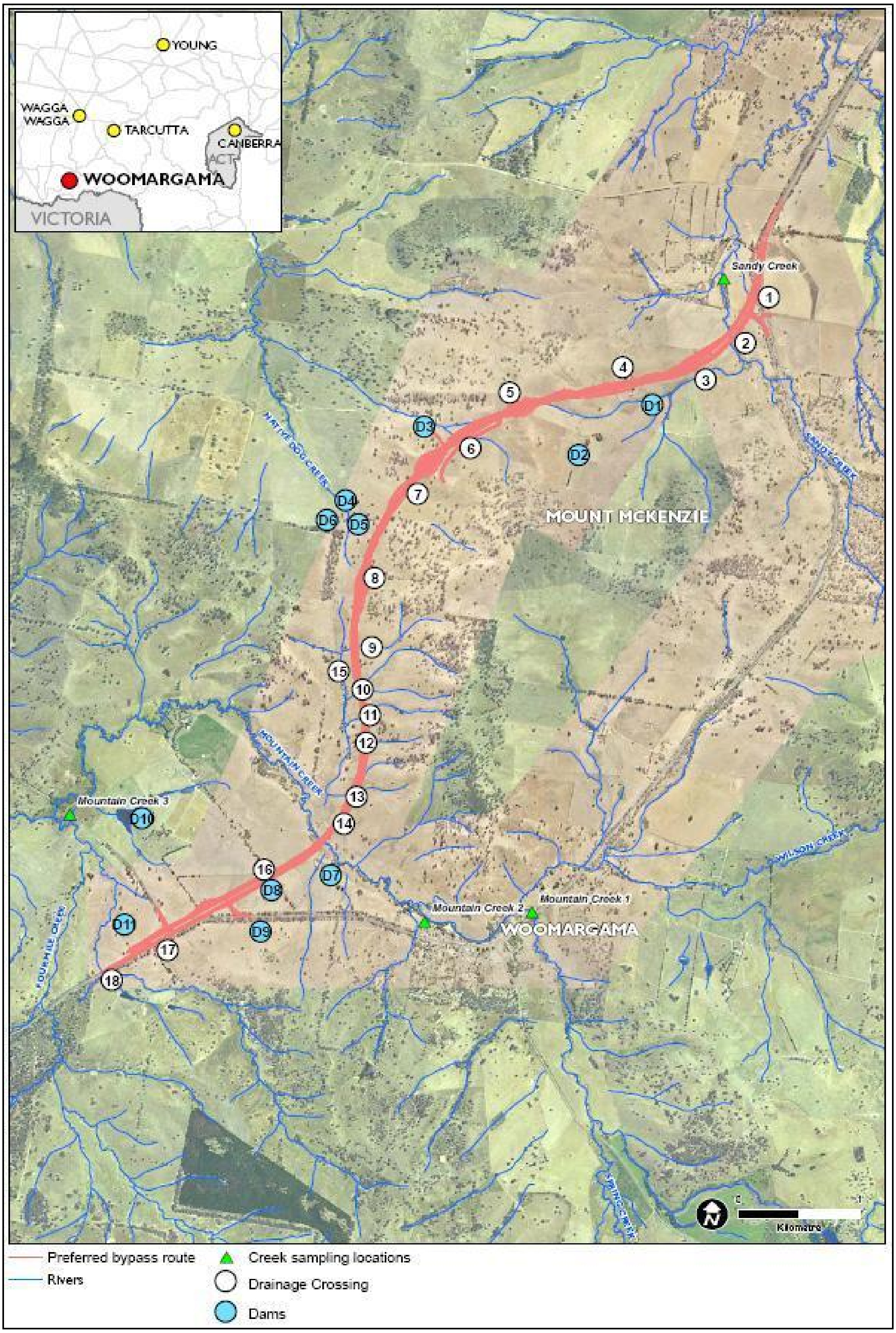

Figure 3-1 Local catchment assessment sites

The proposed bypass would run almost parallel to a tributary of Sandy Creek at the northern end of the alignment, shown as Drainage line 3. This tributary is classified as Strahler order 2. Photographs 3-3 and 3-4 show the eastern tributary to Drainage line 3. Photograph 3-7 shows this drainage line downstream of Dam D1, with heavy vegetation present in part of the channel (willow trees in mid-ground of photograph).The tributary has a wide and shallow channel definition compared to other more narrow and incised channels in the area.

Photograph 3-3 Tributary to Drainage line 3, facing downstream (north)

Photograph 3-4 Tributary to Drainage line 3, facing upstream (south)

Drainage line 4 is a minor drainage path that flows to Drainage line 5, a tributary of Sandy Creek. Due to the lack of channel definition, the drainage line could not be accurately located in the field. The drainage line at location 5 is classified as order 3. This drainage line is at the headwaters of the Sandy Creek sub-catchment, and therefore, channel definition was not apparent.

Dam D1 is located in this sub-catchment, along Drainage line 5, just upstream of the confluence with Drainage line 3. Water was present in this partially spring-fed dam, shown in Photograph 3-5. Photographs 3-6 and 3-7 show the landscape upstream and downstream of Dam D1 respectively. Dam D1 was surrounded by low ground cover. According to anecdotal evidence the study area had experienced a significant rainfall event several weeks prior to the field investigation. This may have caused nutrient-rich sediment to flow into the Dam D1, sighted as a yellowish brown colouring of the water. This is also the case for dams D2, D3 and D5.

Photograph 3-5 Dam D1

Photograph 3-6 Dam D1 - upstream

Photograph 3-7 Dam D1 – downstream

Dam D2 is located south of the proposed bypass, upstream of Dam D1. This dam had some water present at the time of field investigation.

Drainage line 6, a tributary of Native Dog Creek, is crossed by the proposed bypass and is classified as Strahler order 2. A small dam, D3, is present along Drainage line 6 downstream of the proposed bypass crossing. This dam is locally known to be partially spring-fed in years of average rainfall. Photographs 3-8 and 3-9 show Drainage line 6, upstream and downstream of Dam 3, respectively. Minimal ground cover was observed within this drainage line, along with minimal channel definition.

Photograph 3-8 Dam D3 – upstream

Photograph 3-9 Dam D3 – downstream

Drainage line 7 is a minor drainage path within the Native Dog Creek catchment and is classified as order 3. Due to the lack of channel definition, the drainage line could not be exactly located in the field.

Native Dog Creek is labelled as Drainage line 8 on Figure 3-1 and is classified as an order 1 flow path. Channel definition was not apparent in the field at the location of the proposed bypass, since it is at the headwaters of the catchment. Water was present in Native Dog Creek downstream of the proposed bypass. Native Dog Creek in the vicinity of the proposed bypass is anecdotally known to have been constantly running until 2001, and since that time has been mainly pooling. This may be attributed to the low rainfall levels over the past eight years. Springs are common in this area, so the creek is believed to be spring-fed downstream of the proposed bypass.

Two online dams (D4 and D5) exist downstream of the proposed crossing. Dam D4 was dry during the field investigation, whereas dam D5 had water present, as shown in Photograph 3-10. This dam is anecdotally known to not be spring-fed. Photograph 3-11 shows the landscape upstream of Dam D5, highlighting the lack of channel definition in the vicinity of the proposed bypass crossing.

Photograph 3-10 Dam D5 – downstream

Photograph 3-11 Dam D5 – upstream

Dam D6 is located just west of Native Dog Creek and was dry during the field investigations.

Drainage lines 9 through 14 are crossed by the proposed bypass and are classified as Strahler order 2. These drainage lines were not observed during the field investigation due to restricted site access. However, they are likely to have similar characteristics to the drainage lines studied in the northern portion of the proposed bypass. The drainage lines join to form Drainage line 15, a tributary of Mountain Creek. Drainage line 15 runs nearly parallel to the proposed bypass and confluences with Mountain Creek downstream of the proposed Mountain Creek crossing. Drainage line 15 is classified as order 3.

Drainage line 16 is a minor drainage path that is classified as order 3. The drainage line flows to Mountain Creek. This drainage line was also not observed in the field due to site access restrictions, but is likely to have similar characteristics to other drainage lines sited in the area.

Dams D7 to D11 were not inspected due to restricted site access. Dams D7, D8 and D9 are small dams upstream of the proposed bypass and are unlikely to be impacted. Dam D10 is a significantly sized dam downstream of the proposed bypass. The dam captures its water from a sub-catchment of Mountain Creek, with dam overflows running into Mountain Creek.

Drainage lines 17 and 18 represent minor drainage lines of order 3 and are small tributaries to Four Mile Creek, which itself is a tributary of Mountain Creek. A small dam, D11, is located downstream of the proposed crossing of the minor drainage line.

3.3 Impact assessment

Construction and operation impacts were assessed in accordance with the RTA's Water Policy and DECCW RFOs. All drainage lines and dams that occur along the preferred bypass route were assessed in order to protect the quality of water resources and preserve ecosystems.

3.3.1 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. As indicated in the previous sections, the proposed bypass would cross several local drainage lines. These drainage lines may potentially be blocked or diverted during the construction of the proposed bypass. Blockage of a drainage line has the potential to create areas of flooding or ponding on the upstream side of the proposed bypass and could prevent flows from reaching downstream in-line farm dams and receiving waters. Diversion of a drainage line also has the potential to prevent flows from reaching downstream in-line farm dams and receiving waters and may result in new areas experiencing flood inundation both upstream and downstream of the proposed bypass.

Management of runoff from the construction site has the potential to concentrate flows and erode the landscape. Removal of soil within fields through erosion processes may reduce the production potential of the fields. This also has potential water quality impacts, which are detailed in Section 4. Additionally, interception of flows during construction may impact existing local and regional water users, including agribusinesses. Water supply is discussed in detail in Section 5.

3.3.2 Operation

As with the construction phase, the drainage lines that are crossed by the proposed bypass embankment have the potential to be impacted by blockage or diversions. Blockage or diversion of flows has potential to cause localised flooding both upstream and downstream of the proposed bypass and impact water supplies to downstream on-line dams and receiving waters.

Table 3-1 Potential operational impacts

Location	Potential impacts
Drainage lines 1-15	Upstream ponding or flooding, increased in-flows, scour.
Drainage lines 16-17	Upstream afflux, ponding, increased in-flows, scour.
D1	Blockage of receiving water from drainage line 5, increased in-flows, water quality and supply.
D2	No perceived impacts.
D3	Blockage of receiving water from drainage line 6, increased in-flows, water quality and supply.
D4, D5, D6	Blockage of receiving water from drainage line 8, increased in-flows, water quality and supply.
D7, D8, D9	No perceived impacts.
D10	Blockage of receiving water from drainage line 15, increased in-flows, water quality and supply.
D11	Blockage of receiving water from drainage line 17, increased in-flows, water quality and supply.

During the site visit it was confirmed with land owners that the main use of the dams is stock watering.

The proposed bypass would potentially create additional impervious areas that would generate additional runoff. Additionally, the runoff collected through the proposed bypass' longitudinal drainage system has the potential to concentrate and/or redirect flows. Runoff from the proposed bypass also has the potential to affect water quality and water use as detailed in Sections 4 and 5.

3.4 Management of impacts

Construction and operation impacts should be managed in accordance with the RTA's Water Policy and DECCW RFOs. Management guidelines are needed to protect the quality of water resources and preserve ecosystems. These are discussed for all drainage lines and dams that occur along the proposed bypass.

3.4.1 Construction

It is recommended that the mitigation measures required for the operation of the proposed bypass, as detailed in Section 3.4.2, be implemented at the beginning of the construction phase to maintain the current flow paths of the drainage lines and minimise the construction impacts. These measures are likely to include installation of crossings or modification of existing culvert crossings and associated scour protection works.

A soil and water management plan in accordance with *Soils and Construction: Managing Urban Stormwater* (Landcom, 2004) would be developed for the construction phase that would include Best Management Practice measures (such as silt fencing, temporary diversions, berms, temporary sediment basins), to minimise the disturbance to the drainage paths. Runoff from the construction site would be considered dirty water and would be treated before releasing into the downstream environment. Further details regarding water quality impacts and management measures are provided in Section 4.

3.4.2 Operational

Drainage lines

Mitigation measures would be required to maintain flow paths, to maintain inflow to some dams, and to prevent scour and sediment impacts. Proposed measures would include:

- Extension or replacement of the existing culverts to convey flow under the proposed bypass and designed to prevent unacceptable increases in velocity or water levels.
- Installation of new culverts.
- Appropriate scour protection measures implemented at the downstream end of proposed outlets.

The concept design does not indicate a requirement for diversion and/or realignment of Mountain or Sandy creeks. If it is determined, following more extensive investigation and detailed design development, that realignment or diversion of Mountain or Sandy creeks is required, the need for, and design of diversion or realignment would be determined in consultation with the DECCW, Department of Industry and Investment and other relevant stakeholders.

Waterway crossings would be installed in accordance with the Department of Industry and Investment guidelines for fish friendly crossings, where required. In accordance with the guidelines, a bridge would be required at Mountain Creek only.

The longitudinal drainage system for the proposed bypass should ensure that flow distribution is maintained to match the existing flow distribution as closely as possible. Runoff from the proposed bypass should be managed and treated before being discharged;

flow should be discharged into the existing drainage lines where possible. Discharge points would be designed with appropriate scour protection where required. Further details regarding water quality impacts and management measures are provided in Section 4.

Dams

All flow paths to existing dams would be maintained to the extent that is practical. Water quality measures would be implemented to prevent sediment inflow (see Section 4 for further details).

There is potential, though unlikely, for increased flow to some dams due to increased impervious surfaces from the road. Excess flows would be mitigated by:

- Increasing the capacity of the dam (subject to basic landholder rights compliance).
- Capturing flows in retention or detentions facilities.

Further assessment of required changes to dams would be conducted during detailed design. Any proposed modifications would require a more detail assessment of the dam structure and potential approval from DWE depending on works proposed.

4. Water quality

Storm water runoff from the proposed bypass has the potential to impact the water quality of downstream receiving waters, which include Mountain Creek, Native Dog Creek, Sandy Creek and Four Mile Creek. An assessment of water quality for these creeks has been conducted to assess potential impacts of construction and operation of the proposed bypass on the existing environment. The assessment was based on a review of background information and a 'snap shot' sampling event within the catchment. Mitigation measures aimed at protecting the existing water quality within these creek catchments have been identified.

4.1 Objectives and guidelines

Construction and operation impacts should be assessed in accordance with the RTA's Water Policy, ANZECC guidelines and DECCW water quality objectives.

Mountain Creek, Sandy Creek, Native Dog Creek and Four Mile Creek and tributaries within the project area are classified within the DECCW (NSW) objectives as 'uncontrolled streams' within the Murray River Catchment. Environmental values endorsed for these waters, relevant to this assessment, are listed in Table 4-1, along with key indicators used to assess water quality for each of these values.

Table 4-1 DECCW water quality objectives

Environmental value	Key indicators
Protection of water for aquatic ecosystems	Total phosphorous, total nitrogen, chlorophyll-a, turbidity, electrical conductivity, dissolved oxygen, pH and temperature
Protection of water for primary and secondary contact recreation	Turbidity, faecal coliforms, enterococci, pH and temperature
Protection of water for visual amenity	Clarity, surface films and litter, nuisance organisms
Protection of water for livestock, irrigation and homestead water supply	Electrical conductivity, faecal coliforms, pH, turbidity
Protection of water for consumption of aquatic foods (cooked)	Faecal coliforms, temperature

The DECCW catchment objectives, along with ANZECC guidelines, provide numerical water quality criteria for the protection of the above values. A summary of the numerical water quality criteria is provided in Appendix E.

4.2 Existing conditions – water quality

4.2.1 Background information

There is limited published water quality data for the Mountain Creek catchment. However, the *Threatened Species Monitoring Program - Hume Highway Duplication, Assessment of Fish Populations* was prepared for the RTA by Bio-Analysis Pty Ltd in May 2008 and provides some insight into the water quality of Mountain Creek.

In the fish species monitoring process, Bio-Analysis identified the general quality of the water at all sample sites, including Mountain Creek at Woomargama, to be within ANZECC (2000) water quality guidelines for freshwater. In November of 2008, the Department of Primary Industries (now Department of Industry and Investment) conducted a survey of fish populations during the duplication of the Hume Highway for the RTA. Water was sampled at two locations in Mountain Creek; sample location ‘S1’ in the Woomargama village and sample location ‘S2’ approximately five kilometres downstream of Woomargama. Table 4-2 lists the (November, 2008) results for Mountain Creek.

Table 4-2 Mountain Creek water quality parameters (NSW DPI, November 2008)

Indicator	S1	S2
Temperature (^{o}C)	13.7	13.4
pH	6.9	6.81
Conductivity (µS/cm)	498	682
Turbidity (NTU)	14	15
Dissolved oxygen (mg/L)	No data	2.90
Dissolved oxygen (per cent saturated)	No data	28

All parameters were within the ANZECC (2000) guidelines, except for dissolved oxygen. The saturated dissolved oxygen level was read at 28 per cent dissolved oxygen, below the ANZECC (2000) guideline of 85 per cent.

4.2.2 Surface water sampling

To provide further information regarding existing water quality within the waterways and water storages within the area of the proposed bypass, sampling was undertaken by PB during a site visit on 26 and 27 May 2009. This sampling was a one-off event providing a ‘snap shot’ view of the water quality at this time. Samples were collected from Sandy Creek, three locations on Mountain Creek (Mountain Creek 1, Mountain Creek 2 and Mountain Creek 3) and four small dams (D1, D2, D3 and D5) located in the vicinity of the proposed bypass (see Figure 3-1 for site locations). During the sampling event, Sandy Creek was noted to have high flows due a rainfall event in the catchment approximately one month previously and water was being extracted for stock and domestic use. Mountain Creek was noted to consist of a series of pools (Mountain Creek 3) and minimal surface flow (Mountain Creek 1 and 2). According to anecdotal evidence Mountain Creek always has water present. A description of the field methodology adopted and detailed sampling results is provided in Appendix C.

The sampling results have been compared to guideline values for the three key water uses in the area (aquatic ecosystems, irrigation and livestock water supply) provided in both the DECCW catchment water quality objectives and the ANZECC guidelines. In summary, the results of the sampling indicated:

- Physical parameters:
  - Surface water was found to range in temperature from 11.66 to 14.34˚C.
  - Surface water ranged from slightly acidic to slightly alkaline (pH 5.64 to 7.95). Two of the Mountain Creek sites (Mountain Creek 1 and Mountain Creek 2) recorded levels below the guidelines for protection of aquatic ecosystems, but within the guidelines for irrigation and livestock water supply.
  - Electrical conductivity (a measure of salinity) was above the aquatic systems guideline range (0.35 mS/cm) in all dams and creek sites with an electrical conductivity range of 0.445 to 2.23 mS/cm.
  - Dissolved oxygen levels ranged from 31 per cent to 234.1 per cent with only Mountain Creek (Mountain Creek 1 and Mountain Creek 2) and D5 having dissolved oxygen levels below guideline levels. The low levels of dissolved oxygen can be attributed to the low levels of water within each of the pools of the creek and dam.
  - Turbidity was above the guideline values for the protection of aquatic systems in all of the dams, with a range of 46 to 112 NTU. The creek locations all had low turbidity with a range of 4 to 7.7 NTU.
- Nutrients:
  - Total nitrogen had a concentration range of 0.3 to 16.5 mg/L. All of the sites recorded total nitrogen concentrations above the guideline value for protection of aquatic ecosystems and irrigation water supply.
  - Total phosphorus had a concentration range of less than 0.01 to 2.22 mg/L. All of the sites recorded total phosphorous concentrations above the guideline value for protection of aquatic ecosystems and above guideline values for irrigation water supply, except for Mountain Creek 1 and Mountain Creek 3. Mountain Creek 2 only exceeded aquatic system guidelines.

  Increased nutrient levels in the Woomargama region could be attributed to the land use in the area. The surrounding area around the village of Woomargama is used for grazing and cropping. Fertilisers are commonly used to improve pastures and increase the fertility of land for crops, with runoff during higher rainfall into local dams and creeks contributing to the increased nutrient levels.

- Metals: Cobalt, lead and zinc concentrations were analysed at each of the sampling locations. The results indicated that cobalt and lead levels were within guideline values, except for D1 and D5 for lead. Zinc concentrations exceeded the guideline value for ecosystem protection, but were within guideline levels for irrigation and livestock water supply at all locations.
- Total petroleum hydrocarbons were below the laboratory level of recording at all sampling locations except for D3 and D5, which had C15-36 fractions detected. These fractions had low levels, with a range of 100 to 800 μg/L.
- Concentrations of BTEX compounds (benzene, toluene, ethyl benzene, meta- and para-xylene and ortho-xylene) were below the laboratory level of recording at all sampling sites.
- Oil and grease concentrations at all sampling locations were less then the laboratory limit of reporting (5 mg/L).

No data was obtained to assess faecal coliform or enterococci levels to allow comparison of existing water quality to environmental values where these parameters are key indicators of the suitability of the water for human recreational activities and stock use (see Table 4-1).

In summary, the results of this sampling event indicate that surface water within the Mountain Creek, Native Dog Creek and Sandy Creek catchments has elevated nutrient levels and elevated zinc levels. Elevated nutrients are typical of catchments where grazing and cropping land uses are dominant as at Woomargama. Elevated EC values were noted in Sandy and Mountain creeks and dams. This indicates a salinity issue in this area. Further discussion regarding salinity risk within the area is provided in the Technical Report 4 - Groundwater.

4.3 Impact assessment

The potential impacts to water quality relate to the construction of the proposed bypass and the management of stormwater for both the construction and operation of the bypass. The water quality in the existing waterways could be affected by sediment, pollutants from roads (hydrocarbons and particles from vehicle wear and tear etc.) and additional nutrients following rehabilitation of exposed surfaces. Water quality can also be affected by the change in the hydrologic cycle resulting from the impervious surface of the road potentially altering groundwater recharge regimes.

Any impacts to water quality would affect aquatic ecosystems and water users within the catchment. It is noted that Mountain Creek forms part of the Aquatic Ecological Community in the Natural Drainage Systems of the Lower Murray River Catchment, which is listed as an endangered ecological community. Further assessment and discussion regarding impacts to this community is provided in Technical Report 1 – Flora and Fauna.

4.3.1 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 activities have the potential to generate pollutants that could affect surface water quality if appropriate controls are not put in place.

The primary impact to water quality during construction would result from increased sediment loads as a result of land disturbance. Exposed soils would be readily transported with surface flows to nearby dams and waterways. It is noted that soils in the area predominately comprise silts and clays. These finer particle type soils tend to remain in suspension for longer periods of time, and hence there is a greater risk of sediment loads spreading further downstream from the construction area than if the sediments were larger. Increased sedimentation of waterways can smother benthic habitats and organisms, and can increase levels of nutrients, metals and other potential toxicants that attach to the sediment particles.

During the construction phase there would be a need to undertake work within the main flow paths, such as during construction of the proposed bridges across Mountain Creek. The impacts of increased turbidity and sediment loads in locations such as this would be short-term, but may have longer term ramifications depending on the flow behaviour within these waterways and the measures implemented during construction.

Other potential pollutants that could affect water quality during the construction period include:

- Hydrocarbons and chemicals as a result of spills and leakages from construction vehicles or fuel/chemical stores on construction sites.
- Oils and greases from construction equipment.
- Localised erosion of creek beds due to temporary works being placed within flow paths.
- Nutrients attached to sediment particles and from fertilisers used in landscaping works.
- Wastewater generation from construction sites.
- Gross pollutants/general litter from construction sites.

4.3.2 Operation

There is potential for pollutant export from the proposed bypass to adversely affect Mountain Creek, Sandy Creek, Native Dog Creek and tributaries of these waterways and small storages within the catchment. Road runoff typically contains a range of pollutants including:

- Gross pollutants and litter.
- Sediment (pavement wear, vehicles, maintenance activities).
- Nutrients (roadside fertiliser application).
- Heavy metals (vehicle wear and tear).
- Petroleum hydrocarbons (vehicle spills and leaks).

Pollutants such as these would have greatest impact during small rainfall events following prolonged dry periods. Such situations allow pollutants to accumulate on the road surface during dry weather with the small rainfall event washing a concentrated ‘first flush’ of pollutants to receiving waters while stream flow is low.

Another key risk for water quality during operation of the proposed bypass is that of large spills from trucks/vehicles transporting a broad range of materials. Depending on the nature of the spilt material, such an occurrence could have catastrophic impacts on local waterways.

There is potential for sedimentation and/or scour impacts during operation of the proposed bypass at bridges and at culvert crossings. Piers on proposed bridges could provide localised sedimentation and scour locations. Similarly, the entrance and exit of culvert structures are key areas where sedimentation and scour could occur. Soils in the area are predominately silts and clays, which tend to remain in suspension for longer periods of time. The impacts of localised sedimentation or scour, therefore, have the potential to spread further downstream as sediments are transported with flow.

4.4 Mitigation measures

4.4.1 Construction

Mitigation measures would be required to prevent impacts that may result during construction of the proposed bypass. Measures required would include both management measures aimed at minimising the production of pollutants requiring treatment and physical measures aimed at settling sediment and preventing polluted water from entering the local creeks. The measures would be documented within a soil and water management plan to be prepared as part of the construction environmental management plan in accordance with *Soils and Construction: Managing Urban Stormwater* (Landcom, 2004). The soil and water management plan would aim to achieve best practice soil and water management and would include measures such as:

- Implementation of erosion and sediment controls, such as sediment basins, staked straw bales, silt traps, sediment fences, bunds and other containment devices.
- Diversion of clean surface water runoff around construction works/disturbed areas to minimise the volume of water requiring treatment. These diversion works would be installed as soon as practical to ensure that drainage is in place during the early stages of construction activities.
- Planning construction activities to minimise length of time that soils are exposed.
- Waterway structures and works:
  - Permanent drainage structures (e.g. culverts) should be installed as early as possible to ensure cross drainage is in place during early stages of construction.
  - Installation of scour protection in creek bank areas where erosion risk is high.
  - Scheduling of construction activities within waterways to coincide with dry periods or low flow periods where possible (generally summer to autumn period).
- Restricting construction traffic to defined internal roads, and where required, operating wheel cleaning areas at locations where vehicles leave the construction site.
- Ensuring that chemicals and fuels are appropriately stored and bunded.
- Revegetating and stabilising finished construction areas progressively.
- Regular maintenance and inspection of all erosion, sediment and pollution control devices to ensure efficient operation. This may also include regular water quality monitoring to ensure that the plan is effectively preventing impacts.
- Regular maintenance of construction vehicles and equipment to minimise risk of leaks and spills.

- Training of construction employees to implement spill response procedures and implement, maintain and be aware of sediment and erosion control measures and requirements.
- Training of construction employees on appropriate water management to minimise generation of gross pollutants.

Sediment basins would be a key pollution control measure and would be designed during the detailed design phase in accordance with procedures in the *Managing Urban Stormwater: Soils and Construction Volume 1* (Landcom 2006) and *Managing Urban Stormwater: Soils and Construction, Volume 2D, Main Road Construction* (DECC 2008). The sediment basins would be designed to cater for any fine sediment that may runoff from the proposed bypass, and for the fine particle soils (silts and clays) that are present around Woomargama. Monitoring during construction would also assess requirements for flocculating agents to be used to assist settling of sediment particles.

Site facilities would provide toilet and staff washing facilities, from which wastewater would be collected. This would ensure that no wastewater generated from site enters local waterways.

4.4.2 Operation

Pollutants generated with road runoff would require treatment prior to surface waters entering local waterways. Treatment measures (such as basins, buffer zones, and vegetated swales) would be designed to treat runoff that occurs during small, frequent events. As discussed in Section 4.3, these are the events that have the most potential to affect water quality in local creeks and dams within the project area. During larger storm events, pollutants are likely to have been washed off the road surface relatively early in the storm event (and hence would have some treatment by various measures implemented), and during the peak of the event, local creeks and waterways would have much higher flows and hence a much higher assimilative capacity.

Sediment basins used during construction may be retained to provide an ongoing water quality improvement function during the operation of the proposed bypass at key sensitive areas (Mountain Creek). Design of water quality basins would be assessed during detailed design and would ensure that basins and/or any other treatment necessary would be installed at strategic locations to ensure that impacts of pollutants on local environmentally sensitive waterways are minimised.

Scour protection works would be implemented at proposed bridge abutments and piers and waterway crossings. Requirements for scour protection would be assessed during detailed design of bridge and culvert structures. Such protection measures would be included in the design of these structures. These works would ensure that sedimentation resulting from scour within Mountain Creek, Sandy Creek and other local waterways is minimised.

5. Water supply

The assessment of potential changes to water supply as a result of the proposed bypass is relevant because of the need to identify water supplies for the project without impacting the local and regional environment and users. The construction of the proposed bypass would require the use of water and may impact existing local and regional water users. The specifics of the impact(s) on existing water users, including agribusinesses, would be examined once the construction phase has been planned for and water requirements have been determined.

5.1 Existing conditions – water supply

5.1.1 Legislation

The access, taking and use of water is managed under two primary legal instruments in NSW — the WA and WMA. Both Acts may apply to the proposed bypass. Relevant issues administered under these Acts include:

- Taking water from a river, dam or aquifer for road construction and dust suppression.
- Changing the course of a river.
- Constructing works on a designated floodplain.
- Protecting aquatic environments and domestic and stock water users including managing small farm dams.

In relation to water licensing and approvals, the WMA only applies where a water sharing plan has commenced. The Mountain Creek system is yet to have its own Water Sharing Plan.

Therefore, the WA continues to be the main water licensing legislation. There is an embargo in place on the granting of new licences for commercial purposes within the Murray-Darling Basin.

Basic landholder rights cover the taking of water for domestic and stock use, constructing small farm dams (harvestable rights) and native title rights to water. Under the WMA any development taking or using water must assess whether there is an adverse impact from the development to the river or aquifer and its dependent ecosystems, and must protect basic landholder rights. This assessment is achieved by the minimal harm provisions of sections 63 and 97 of the WMA.

Any structure constructed on a designated floodplain that potentially alters the passage of floodwater may need to be assessed in accordance with the WA regulations and may require a floodplain work approval.

Part of the Billabong Creek catchment is listed as a designated floodplain under Part 8 of the WA. However, the area covered by the designated floodplain does not include Mountain Creek. A Part 8 approval would not be required for any construction on the Mountain Creek floodplain (note — this may not exclude separate approvals for development on the floodplain under the *Environmental Planning and Assessment Act 1979*).

Any activity or earth works (e.g. embankments, road culverts, causeways, concrete footings for buildings on water front land) can now potentially require a controlled activity approval under section 91 (2) of the WMA. Clause 39A of the *Water Management (General) Regulation 2004* outlines exemptions for a controlled activity approval. The RTA, as a public authority is exempt from requiring a controlled activity approval.

If water for construction is chosen to be sourced from Mountain Creek, this water may need to be obtained through the water trading market to overcome the embargo currently in place on the granting of new licences for all surface water within the Murray-Darling Basin.

5.1.2 Water access

Mountain Creek is outside any water sharing plan areas and as a result, surface water licences are administered under the WA. The Mountain Creek catchment has a small number of active water users, with three WA water licences granted within the catchment; two of these licences are for catchment dams and do not take water directly from the creek. Most water use is for domestic and stock purposes. As Mountain Creek is currently experiencing hydrologic stress caused by drought conditions, DECCW has advised that in order to share water between in stream and riparian environments and domestic and stock water users, it is unlikely to approve an application for a permit to access water for road construction. Additionally, due to the ephemeral nature of Mountain Creek, it is not recommended as a source of water for road construction.

However, the Mountain Creek catchment supports large numbers of unlicensed domestic and stock users. These users access water under the domestic and stock right. As these users are not required to hold a water licence, DECCW does not maintain records of where users are located or the volumes of water they require. DECCW has indicated that domestic and stock rights water use is common within Woomargama village.

5.2 Impact assessment

5.2.1 Construction

Water would be used during construction of the project for dust suppression, washing of plant and equipment, drinking water, hand washing, toilets, watering of landscaped areas, compaction and pavement stabilisation during earthworks, and concrete batching. The activities with the highest water consumption include concrete production and general construction water (dust suppression and compaction activities).

Concrete production requires relatively high quality (potable) water to produce concrete. Water required for the general construction purposes, such as dust suppression, moisture control of general fill and wetting of road base material for compaction is not required to be potable, but must be of a high enough standard that it can be handled and used near watercourses without causing any detrimental effects.

Estimated water requirements

Indicative quantities of water required during construction are outlined in Table 5-1.

Table 5-1 Estimated volumes of water for construction

Water type	Activities	Quantities (approximate)[1,2]
Potable or reclaimed water	Earthworks construction (compaction and pavement stabilisation of soft soils, if encountered) and concrete and asphalt batching.	336 ML over the construction period (based on 180 L per cubic metre of earthworks material and 150 L per cubic metre of concrete produced)
Potable or reclaimed water	Dust suppression.	Included in the earthworks allowance above.
Potable or reclaimed water	Vegetation watering (from vehicle only).	54 ML (estimated 250,000 plants, each receiving 25 L watering over nine applications to allow for establishment)
Potable water only	.Construction site offices.	5 ML

Notes: 1. ML = megalitres; L/day = litres per day
2. These quantities would be subject to refinement during detailed design.

Water sources

Water could be supplied from a number of sources. It is expected that they would be from a combination of the options described below.

- Groundwater from the Woomargama township supply — There is potential for the project to access water from the town water supply. This would be undertaken in agreement with Riverina Water County Council (the authority responsible for supplying water to Woomargama). As part of the agreement, the project may upgrade the existing town bore infrastructure. The transfer of water from the town bore to the project would likely be via pipeline placed on the ground surface.

- Extraction of water from the Hume Weir: The RTA currently extracts water from the Hume Weir via a licensed extraction point for the Hume Highway Duplication to the south of the project. The water is currently pumped to two sites via a surface pipeline. This pipeline currently extends to Mullengandra (approximately nine kilometres south of the project). Should this water be required for the project the pipeline would be extended from Mullengandra to the project. The pipeline would be placed on the ground surface along the project and the existing highway. The pipeline would be temporary and would not require earthworks or vegetation clearing. Figure 6-2 shows the location of the existing pipeline under the Hume Highway Duplication project and the proposed extension of the pipeline for the project.

- Recycled effluent water from industrial facilities in the surrounding region: Should a suitable source be identified, water would either trucked or piped to the site. If a pipe is required it would be as per the pipeline described above.

- Construction of offline water storages to store water from sediment basins: Potentially three large water storage dams would be constructed, one at either end of the project and one in the middle of the project (up to 50 megalitres in total volume). Water from temporary sediment basins and/or the industrial sources would be diverted to these dams and used during construction. This would provide added flexibility in the management of stormwater runoff after rainfall. These dams may be left in place at the completion of the project subject to the provision of harvestable rights.

- Use of existing on-site and off-site farm dams: There are some existing farm dams on surrounding land that may be used for the project as a localised supply of construction water. Water would be sourced in consultation with landowners.

Water access

Once a water source for construction is confirmed, the method of conveyance and storage can be determined. If water is to be sourced from existing local dams, further storage is likely to be unnecessary and tanker trucks may only be required for transport to the work site. If water is to be sourced from local groundwater bores, water may be pumped and transported as needed. If water is to be sourced from a more distant location, storage tanks or reservoirs may be necessary to store water closer to the work site.

5.2.2 Operation

No water source would be required for the operation of the proposed bypass. The potential operational impact to water supply due to the proposed bypass is dependent on the water source. New offline water storages that potentially would remain in place after construction have the potential to reduce flows to the downstream environment or receiving waters. This could reduce the amount of water available to local landholder users and agribusinesses, though this would be minimal.

5.3 Mitigation measures

5.3.1 Construction

Arrangements would be investigated to construct the offline water storages to be mutually beneficial to the local landholders for use during and after construction of the proposed bypass. Constructed storages would be designed so as not to prevent environmental or operational flows from reaching downstream environmentally sensitive areas or receiving waters.

Sourcing water from local dams would require arrangements with local landholders, including agribusinesses, for access and agreement on the amount of water to be extracted.

During the next phase of the proposed bypass design, a more detailed analysis of anticipated water requirements during construction would be conducted. Understanding water requirements would enable a more informed decision as to the most appropriate combination of sources of water.

5.3.2 Operation

Again, arrangements would be investigated to construct the offline water storages to be mutually beneficial to the local landholders for use during and after construction of the proposed bypass. Constructed storages would be designed so as not to prevent environmental or operational flows from reaching downstream environmentally sensitive areas or receiving waters.

6. Conclusions

This report has identified and addressed the surface water impacts associated with construction of the proposed Hume Highway bypass of Woomargama. The assessment has looked at impacts to flooding, local catchments, water quality and water supply. Conclusions follow below.

6.1 Flooding

Potential flooding impacts identified during construction can be mitigated through adequate construction planning and implementation of mitigation measures identified in Section 2.5.1. Based on the current concept bypass alignment design option, this assessment has identified a potential increase in flood levels immediately upstream of the proposed bypass. Changes to flood velocities were found not to be significant, however, would require further assessment during detailed design. Measures to mitigate potential impacts would be incorporated into the proposed bypass design.

Incorporation of identified measures during both construction and operation of the project would ensure flood impacts are managed appropriately.

6.2 Local catchments

Potential impacts to local watercourses during construction can be mitigated through measures outlined in Section 3.4.1. These measures focus on ensuring that current flow paths are maintained and best management practices are implemented to protect the watercourses.

Measures to protect local watercourses during operation of the proposed bypass would be incorporated into the bypass design. The longitudinal drainage system would be designed to ensure that distribution of flow is maintained to match the existing flow distribution as closely as possible. Existing culverts would be extended or replaced and new culverts installed, where required, to maintain flow paths. Scour protection measures would be incorporated to each of these crossings as required. Runoff from the proposed bypass would be managed and treated before being discharged into the existing drainage lines where possible. Waterway crossings would be installed in accordance with Department of Industry and Investment guidelines for fish friendly crossings where required. In accordance with the guidelines, a bridge would be required at Mountain Creek only.

6.3 Water quality

Mitigation measures would be required to prevent water quality impacts during construction of the proposed bypass. Measures required would include both management measures aimed at minimising the production of pollutants requiring treatment, and physical measures aimed at settling sediment and preventing polluted water from entering the local creeks. These measures would be documented within a soil and water management plan to be prepared as part of the construction environmental management plan in accordance with *Soils and Construction: Managing Urban Stormwater* (Landcom, 2004).

There is also potential for impact to water quality during operation of the proposed bypass.

Treatment measures (such as basins, buffer zones and vegetative swales) would be designed to treat runoff from small, frequent events and would be designed to capture the 'first flush' of pollutants at sensitive environments. Design of water quality basins would occur during detailed design and would ensure that basins and any other treatment necessary would be installed at strategic locations to ensure that the impacts of pollutants on local environmentally sensitive waterways are minimised.

Scour protection works would be implemented at proposed bridge abutments and piers and waterway crossings as required. These works would ensure that sedimentation resulting from scour within Mountain Creek and other local waterways are minimised.

6.4 Water supply

The availability of surface water sources to supply water for the project is discussed in Section 5. During the next phase of the proposed bypass design, a more detailed analysis of anticipated water requirements during construction shall be conducted. Understanding water requirements would enable a more informed decision as to the most appropriate source of water.

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