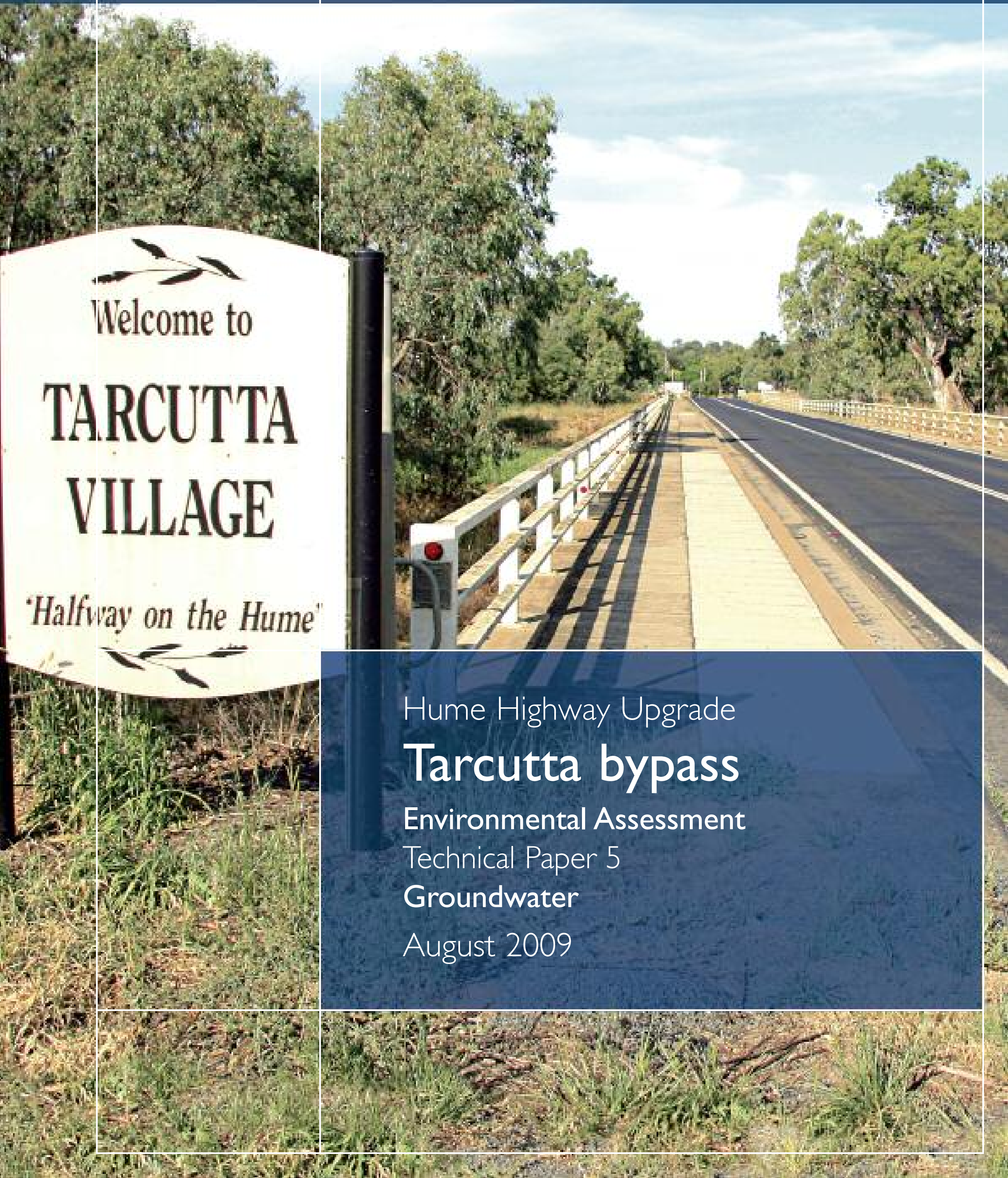
New South Wales Government

RTA



Hume Highway Upgrade

Tarcutta bypass

Environmental Assessment

Technical Paper 5

Groundwater

August 2009

Hume Highway Upgrade Tarcutta bypass

Groundwater environmental assessment

July, 2009

NSW Roads and Traffic Authority

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Glossary

Aquifer	Rock or sediment in a formation, group of formations, or part of a formation that is saturated and sufficiently permeable to transmit economic quantities of water to wells and springs.
Confined aquifer	Where water-bearing rocks are overlain by a confining layer of low permeability strata.
Groundwater	The water contained in interconnected pores located below the watertable in an unconfined aquifer in a confined aquifer.
Groundwater flow	The movement of water through openings in sediment and rock; occurs in the zone of saturation.
Hydrogeology	The study of the interrelationships of geologic materials and processes with water, especially groundwater.
Infiltration	The flow of water downward from the land surface into and through the upper soil layers.
Permeability	The capacity of porous medium for transmitting water.
Recharge area	An area in which there are downward components of hydraulic head in the aquifer. Infiltration moves downward into the deeper parts of an aquifer in a recharge area.
Unconfined aquifer	Where the groundwater surface (watertable) is at atmospheric pressure and the aquifer is recharged by direct rainfall infiltration from the ground surface.
Watertable	The surface in an unconfined aquifer or confining bed at which the pore water pressure is atmospheric. It can be measured by installing shallow wells extending a few feet into the zone of saturation and then measuring the water level in those wells.

List of abbreviations

ADWG	Australian Drinking Water Guidelines
ANZECC	Australian and New Zealand Environment and Conservation Council
bgl	Below ground level
CoC	Chain of Custody
DECC	Department of Environment and Climate Change
DWE	Department of Water and Energy
EC	Electrical conductivity
GDE	Groundwater dependant ecosystem
NATA	National Association of Testing Authorities
NHA	Northern Hume Alliance
NHMRC	National Health and Medical Research Council
GIS	Geographical Information System
GPS	Global Positioning System
PB	Parsons Brinckerhoff Australia
TDS	Total dissolved solids
WA	Water Act
WMA	Water Management Act

List of units

g/L	gram per litre
L/s	litres per second
m AHD	metres Australian height datum
m bgl	metres below ground level
ML	Megalitres
µm	micrometre
mV	milli Volt
m/d	metres per day
mg/L	milligram per litre
µS/cm	micro Siemens per centimetre
ppm	parts per million

Executive summary

Tarcutta is located in south-west NSW and is situated within the NSW South-western Slopes Bioregion, which is characterised by foothills and ranges along the western fall of the Great Dividing Range (PB 2008). The exposed geology consists of Ordovician metasediments and Quaternary alluvial deposits associated with Tarcutta Creek and its tributaries. The metasediments make up the higher relief areas of the landscape with the unconsolidated alluvial sediments overlying the fractured rock in lower lying areas, specifically, alluvium is found along Tarcutta and Keajura Creeks, and their tributaries (Adamson and Loudon 1960).

There are two main groundwater flow systems present in the Tarcutta area, the unconsolidated alluvium and the consolidated fractured Ordovician metasediments. The previous desktop study (PB 2008) suggests that the sand and gravel beds of the alluvium are the main water-bearing aquifers in Tarcutta. Water levels in the alluvium and the surrounding fractured metasediments are generally shallow. Groundwater flow in both the unconfined alluvium and the confined fractured rock is generally to the north-west and follows the catchment topography. The Tarcutta town obtains its water supply from groundwater bores within the alluvial aquifer sediments.

A hydrogeological investigation was conducted in the field at Tarcutta for four days in October 2008 along the proposed RTA Hume Highway Tarcutta bypass route. The investigation aimed to provide insight into groundwater levels and groundwater quality; the results from this study form the basis of this report. Water level measurements and groundwater samples were taken from boreholes that were identified in the preliminary investigation (PB 2008), Department of Water and Energy (DWE) bore searches and community consultation.

Groundwater salinity (EC) conditions in the Tarcutta region ranges from fresh to brackish. Groundwater pH conditions ranged from slightly acidic to slightly alkaline. Groundwater from the Tarcutta region generally displayed the following ionic characteristics: (Na>Mg>Ca)-(HCO_3>Cl>SO_4). Dissolved iron and manganese concentrations were above the Australian Drinking Water Guidelines in some bores.

A limited supply of groundwater would be available from the alluvial aquifer and the fractured rock aquifer. The ability to supply water sufficient for construction purposes will depend on the actual volume and rates required.

The final detailed design of the raised road needs to be considered in terms of the groundwater system and its users. The potential impacts of compaction of the aquifer should be considered during the design stage. This will assist in preventing or alleviating any potential impacts to the groundwater system and its users that may arise from the highway construction.

1. Introduction

The NSW Roads and Traffic Authority (RTA) proposes to construct a highway bypass of the township of Tarcutta located on the Hume Highway in south-west NSW (see Figure 1-1). The Hume Highway Tarcutta bypass ('the project' or 'the proposed bypass') will improve safety, amenity and convenience for local residents and travel efficiency for through and local traffic.

Parsons Brinckerhoff (PB) was commissioned by the RTA to undertake a desktop assessment of possible options for the bypass route. The study, completed in early 2008, identified a preferred route for the proposed bypass. For the Tarcutta area the western option was selected. The proposed route will cross an area of the Tarcutta Creek floodplain that has several overland flow paths in addition to the main Tarcutta Creek channel. The floodplain in this area is relatively flat and uninterrupted on both sides of the river channel and is estimated to be 1.5 kilometres wide.

This report details a hydrogeological investigation to assess groundwater conditions at Tarcutta and potential impacts of the proposed bypass on those conditions. The assessment has been prepared to meet the Director General's requirements for the Environmental Assessment of the project in relation to groundwater, which include but are not limited to:

- Site water demands and water supply.
- Existing and proposed water licensing requirements under the *Water Act 1912* (WA 1912) and *Water Management Act 2000* (WMA 2000).
- Impacts to groundwater dependent ecosystems.

The findings will provide baseline measurements (the pre-development conditions), to which future results can be compared. The detailed assessment of groundwater also aims to reaffirm the findings of the previous desktop study (PB 2008).

The report also addresses the likely impacts on groundwater quality and groundwater flow from construction and operation of the project, and proposes possible mitigation/management options for such impacts.

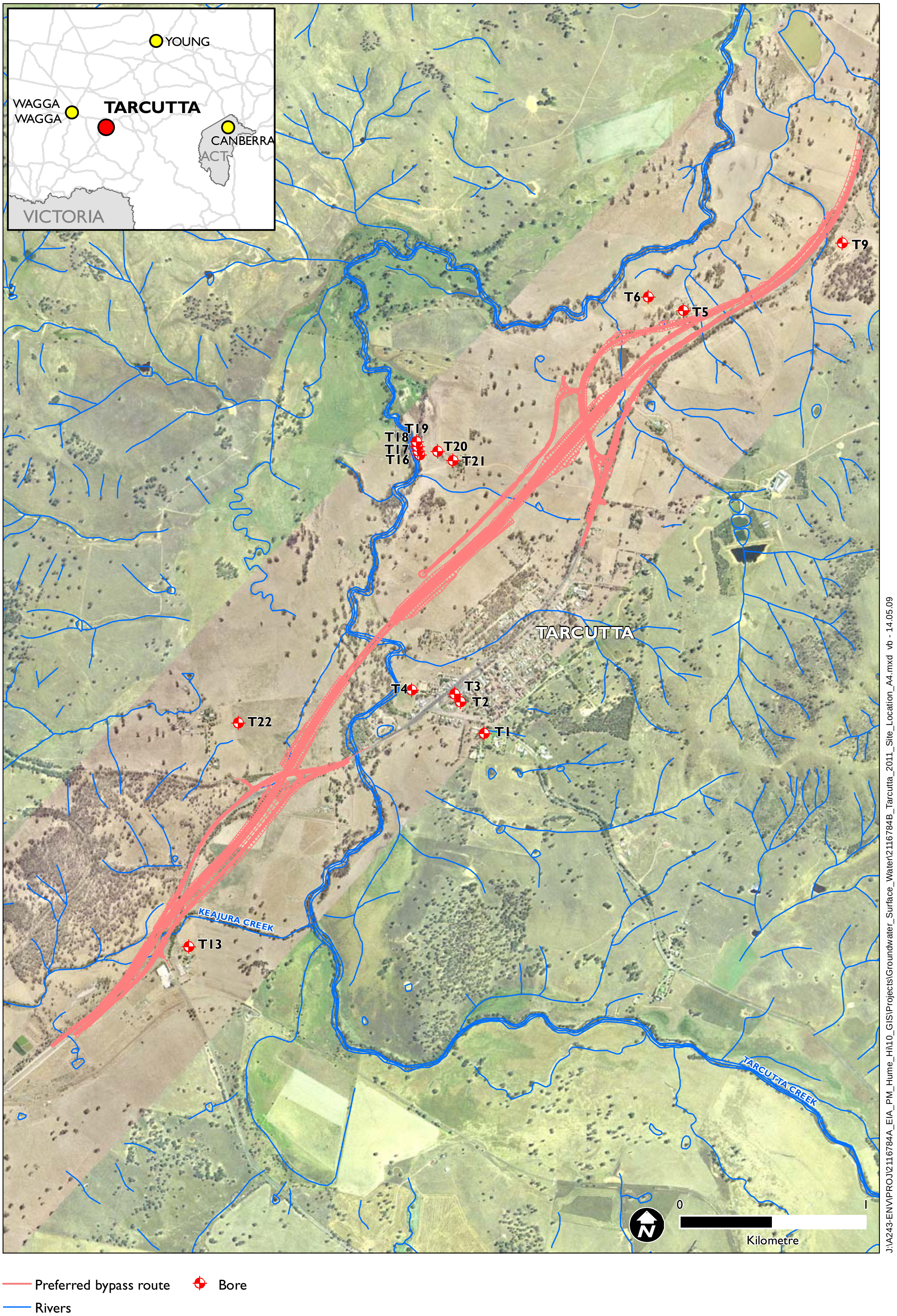


Figure 1-1 Site & bore locations

2. Legislation, Water sharing plans and policy

2.1 Water legislation

Water in NSW is managed under two primary legal instruments – the *Water Act 1912* (WA 1912) and *Water Management Act 2000* (WMA 2000). The WMA 2000 is gradually being introduced across NSW and as it becomes active for given areas the old WA 1912 is repealed.

Basic landholder rights are managed under the WMA 2000 and for groundwater it generally refers to the taking of water for domestic and stock usage. Under the WMA 2000 any development taking or using water must:

- Include assessment of whether there is an adverse impact from the development to the river or aquifer and its dependent ecosystems
- Protect access for basic landholder rights.

This assessment is achieved by the minimal harm provisions of sections 63 and 97 of the WMA 2000.

Access licence holders (irrigation, industrial or town water supply licences) within a water source are managed under the WMA 2000 where a water sharing plan has commenced. Once a water sharing plan has commenced the WA 1912 is repealed for that water source and existing licences are automatically converted to new consents under WMA 2000. In water sources where a water sharing plan has not yet commenced the WA 1912 applies.

For groundwater sources surrounding Tarcutta there are no water sharing plans that have commenced. Therefore groundwater in the Tarcutta area is administered under the WA 1912.

Groundwater for irrigation, town water supplies and other purposes (with the exception of Basic Landholder Rights) are managed under the old WA 1912 until such time as a water sharing plan for the respective groundwater source commences. The basic landholder rights provisions within the WMA 2000 have commenced for all of NSW.

2.2 Groundwater sharing plans

There is no water sharing plan for groundwater sources within the Tarcutta area. The macro water sharing plan for groundwater sources in NSW are being prepared at a NSW state scale and are not likely to commence within the next 12 months.

A water sharing plan is currently in place and has commenced for the unregulated Tarcutta Creek, however this only covers surface water within the Tarcutta Creek itself and does not include groundwater in the alluvium.

Macro water sharing plans are currently being developed within NSW and these will provide a high level generic plan for water sources to be transitioned to the WMA 2000. It is likely that the Tarcutta alluvium would be included in the macro water sharing plan currently being developed for inland alluvial systems. The Ordovician metasediments are likely to be included in the macro water sharing plan currently being developed for fractured rock systems within NSW.

The alluvial sediments of the Mid Murrumbidgee are within the Groundwater Management Area 013 (GWMA 013). The management area is broken into 5 zones for management purposes. Zones 1, 2 and 3 comprise the alluvial sediments adjacent to the Murrumbidgee River between Gundagai and Narrandera, Zone 4 comprises the alluvial sediments of Tarcutta Creek, and Zone 5 the Kyeamba Creek Alluvium (DLWC 2000).

2.3 Local and state government policies

Development of the proposed Tarcutta bypass will be governed by the *NSW Groundwater Policy Framework* (Department of Land and Water Conservation (DLWC) 1997). The NSW state groundwater policy is a set of three policy documents comprising:

- *NSW Groundwater Quality Protection Policy* (DLWC 1998)
- *NSW Groundwater Quantity Management Policy (draft)* (DLWC n.d.)
- *NSW Groundwater Dependent Ecosystem Policy* (DLWC 2002)

The aim of the NSW groundwater policy is to slow, halt or reverse degradation in groundwater resources, ensure long term sustainability of the biophysical characteristics of the groundwater system, maintain the full range of beneficial uses of these resources and maximise the economic benefit to the region and state.

3. Assessment approach

3.1 Scope

The groundwater field investigation of the land along the proposed Tarcutta bypass alignment comprised the following:

- Identification and recording (photograph and GPS location) of groundwater bores and springs.
- Gauging and sampling of groundwater bores that could be accessed.
- Laboratory analysis of water quality samples and measurement of physical water parameters, and comparison to the relevant guideline values.
- Overall assessment of pre-construction groundwater quality and levels.
- Characterisation of local and regional groundwater flow systems.
- Consideration of potential groundwater supply options.
- Consideration of the likely impacts on groundwater levels and quality during construction and ongoing operation.
- Proposal of management and mitigation solutions for potential groundwater impacts.

3.2 Field investigations

Previous work on the Hume Highway town bypasses for Tarcutta, Holbrook and Woomargama (PB 2008) recommended that a detailed groundwater investigation be undertaken. The investigation was conducted in the field at Tarcutta over four days during October 2008. Existing groundwater bores were identified in the preliminary investigation (PB 2008), from Department of Water and Energy (DWE) bore searches and community consultation. These used for the groundwater assessment.

To assess groundwater conditions the following activities were completed:

- Boreholes that could be accessed for water level measurements at Tarcutta were gauged. Boreholes and springs were photographed.
- Boreholes that were able to be sampled were purged where possible and the following physical parameters were recorded: electrical conductivity (EC), temperature, pH, dissolved oxygen (DO), total dissolved solids (TDS) and redox potential (redox Eh).
- Groundwater samples from selected bores were submitted to a National Association of Testing Authorities (NATA) accredited laboratory for detailed chemical analysis. Groundwater samples were analysed for major cations and anions, and dissolved metals (manganese and iron). Samples were flown to Sydney and then submitted to a NATA registered laboratory (ALS Environmental) under the appropriate chain-of-custody documentation and storage/transport protocols.

3.3 Data and study limitations

The following limitations apply to the fieldwork and subsequent data assessment for this report:

- The conclusions of this report are based on available data at the time of preparing the report and are indicative of the environmental conditions at that time.

- The Tarcutta area is currently experiencing prolonged drought conditions, and therefore, the measured groundwater levels and occurrence of dryland salinity is likely to be influenced by the dry climatic conditions.
- There was a limited number of bores accessible for measurement of water levels and for water quality sampling.
- Bore head works often prevented access to undertake water level measurements. The bore may have recently been pumped and therefore, the water level was deemed to be unrepresentative of the local groundwater conditions. Water quality samples were taken as grab samples, and many bores were not able to be purged correctly prior to the taking of samples. In addition, some bores could not be accessed or pumps activated to enable the taking of water quality samples.

4. Climate, topography and geology

4.1 Climate

The climate of Tarcutta is characterised by warm to hot summers and cool to cold winters. Seasonal rainfall variation is not great, but rainfall is winter dominant. Tarcutta has an average rainfall of approximately 630 millimetres per year (mm/yr); this figure is based on records maintained by the Bureau of Meteorology for the last 135 years (Station No 072042, Bureau of Meteorology 2008).

Yearly rainfall for the last 30 years (1978–2008) was analysed and graphed using the cumulative deviation from the mean. Cumulative deviation from the mean rainfall represents discrete rainfall events as a continual trend over time; ultimately periods of below and above average rainfall are highlighted. When below average rainfall is experienced a downward trending slope is seen, while an upward trending slope represents above average rainfall.

The average rainfall for this 30 year period was 613 mm/yr. The rainfall data, when plotted as a cumulative deviation, indicates above average rainfall (a rising trend) for the period 1983 to mid 2000 and below average rainfall (a decreasing trend) over the last seven years since 2001 (refer Figure 4-1).

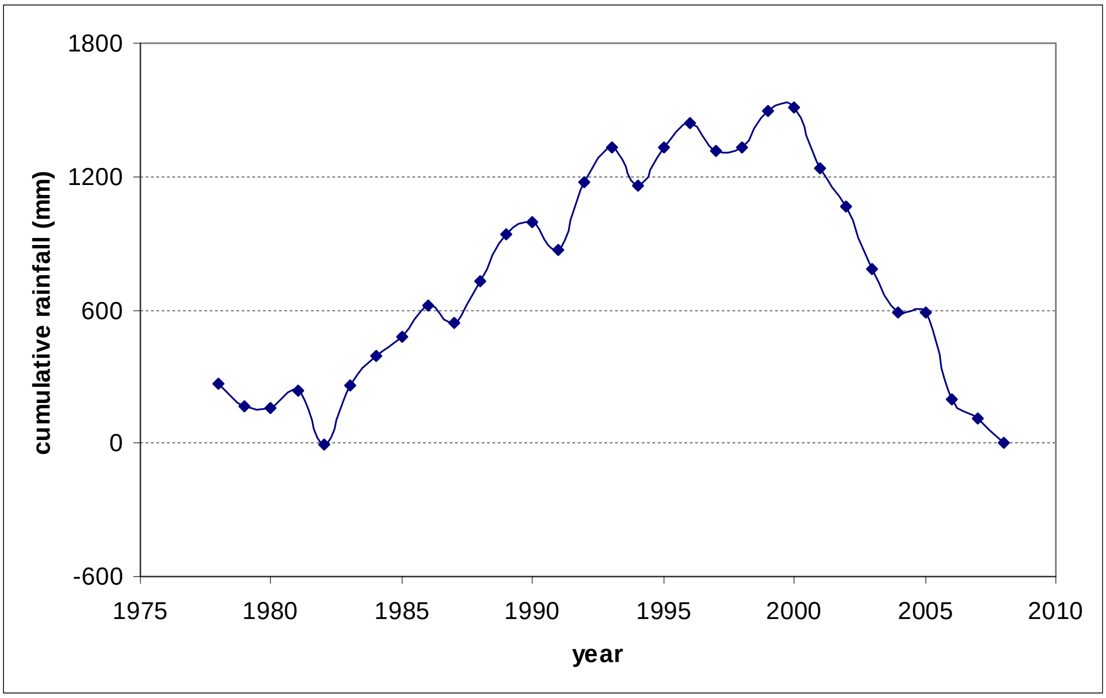


Figure 4-1 Cumulative deviation rainfall

4.2 Topography

Tarcutta is located within the NSW South-western Slopes Bioregion, which is characterised by foothills and ranges along the western fall of the Great Dividing Range. The town is at an elevation of approximately 250 metres (m) above Australian height datum (mAHD). The nature of the topography in this area is distinguished by north–south trending valleys and ridges (PB 2008).

4.3 Geology

The study area is located within the Wagga-Omeo Zone of the Lachlan Fold Belt, which is mapped on the *Wagga Wagga 1:250,000 Geology map, sheet no SI 5515* (Adamson and Loudon 1960). The Lachlan Fold Belt in the Tarcutta area is characterised by Ordovician metasediments, which make up the higher relief areas of the landscape. Quaternary alluvium has accumulated in lower lying, major drainage lines and forms flats and floodplains on the valley floors. The geology map (see Figure 4-2) does not show any major structural features or faults in the vicinity of the study area; however, the trend of lineaments is generally north-westerly, and this may reflect major joints, local faults, structural discontinuities or dykes.

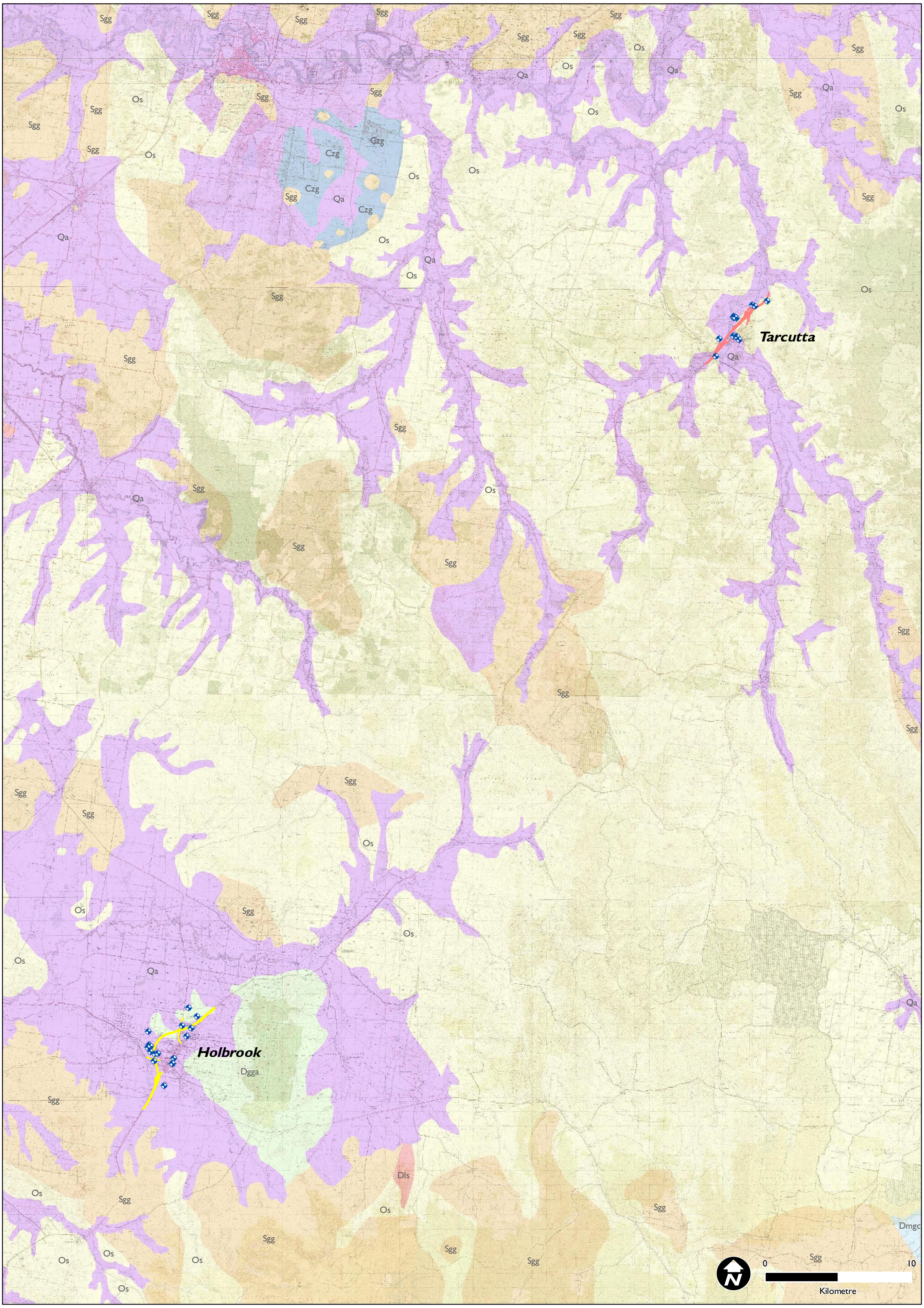
The Ordovician metasediments in the Tarcutta area comprise low metamorphosed slate, greywacke, quartzites, phyllite, hornfels and schists in the lower reaches. Weathering and fracturing of the Ordovician metasediments has resulted in secondary porosity (fracturing) within the unit.

The unconsolidated alluvial deposits in the Tarcutta area are all of Quaternary age and overly the fractured rocks in the valleys and lower lying areas. The greatest thickness of alluvium is associated with Tarcutta and Keajura Creeks, and their tributaries. The alluvial deposits comprise sand, silt, gravel and clay, with the thickness of the alluvium typically ranging between 10 and 30 metres; thickness is governed by bedrock topography.

4.4 Groundwater dependent ecosystems

Groundwater dependent ecosystems (GDEs) are communities of plants animals and other organisms that depend on groundwater for survival (Department of Land and Water Conservation 2002). A GDE may either be entirely dependent on groundwater for survival, or may use groundwater opportunistically or for a supplementary source of water (Hatton and Evans 1998).

The groundwater systems within the study area comprise the unconsolidated alluvial sediments associated with Tarcutta Creek and the fractured rock. Riparian vegetation associated with the Tarcutta Creek may depend on groundwater to some degree, and this has been discussed further in the biodiversity assessment undertaken for the project (PB 2009).



Tarcutta preferred bypass route
Holbrook preferred bypass route
Bore

Geology

Quaternary Alluvium (Qa)
Terrace Alluvium (Czg)
Holbrook Granite (Dgga)
Munderoo Granodiorite (Dmgc)
Devonian Conglomerates (Dls)
Silurian Granite (Sgg)
Ordovician Metasediments (Os)

Figure 4-2 Geology

5. Methodology

5.1 Field investigations

The groundwater field investigation was undertaken at Tarcutta over a four day period from October 27 through to October 30, 2008. Landholders identified as directly affected by the proposed bypass option were contacted and arrangements were made to visit each property and to inspect bores and springs if present.

Bores on the DWE database that were identified in the previous report (PB 2008) were not all accessed during the field trip. Those not accessed either:

- Were not on a property directly affected by the proposed bypass and therefore, there was no agreement with the relevant landholder for an on-site inspection.
- Could not be located on the ground due to incorrect coordinates in the DWE database.
- Were old and have since been decommissioned.

During the field inspection the majority of bores sampled and gauged were not registered with the DWE.

Bores were inspected and standing water levels were measured using a water level meter where access could be obtained. The bore depths were also measured using the water level meter, when possible. The nature of the bore head works and pumping equipment within the bore sometimes prevented the taking of a water level. Some bores had pumps that were active at the time of inspection. In these cases water levels were not measured due to the risk associated with damaging equipment or the pump. In addition the water level from an actively pumping bore would not be representative of local groundwater conditions. Where bores could not be measured an estimate of the total bore depth and an estimated water level was provided by the landholders, if known.

Bores sampled for groundwater chemistry were selected based on access and the feasibility of taking water samples. Preference was given to active bores equipped with pumps, as these bores were deemed to have groundwater representative of the aquifer (due to recent pumping/purging of the water in the bore column). Bores located along the entire length of the proposed bypass route were sampled, including bores in both aquifer systems. Table 5-1 lists bores and springs inspected during the field investigations. It indicates the bores that were gauged and sampled for water quality field parameters and/or for laboratory analysis.

Table 5-1 Gauged and sampled bores

Site number	Groundwater level measurement	Field parameters measured	Sample taken for laboratory analysis
T1	X	X	X
T2			
T3	X	X	
T4	X	X	
T5	X	X	X
T6	X	X	
T9	Dry		
T13	X	X	X
T16	X	X	X
T17	X		

Site number	Groundwater level measurement	Field parameters measured	Sample taken for laboratory analysis
T18	X		
T19	X		
T20	X		
T21	X	X	X
T22	X		

Many of private bores visited had pumps installed and samples were collected from well heads, taps or available pipe outlets. At locations where bores were not used regularly, pumps were generally turned on and water allowed to flow prior to sampling. Where bores were not equipped with pumps, or where the pump could not be activated, grab samples were collected using a 45 millimetre (mm) disposable bailer.

Groundwater bores were sampled for water quality field parameters to establish baseline values of water quality in the Tarcutta region. Field parameters which included temperature (^{o}C), electrical conductivity (micro Siemens per centimetre (μS/cm)), pH (pH units), dissolved oxygen (milligrams per litre (mg/L) and per cent saturation), total dissolved solids (mg/L) and redox potential (milli Volts (mV)) were measured using a Quanta Hydrolab water quality meter. Electrodes were calibrated daily according to the manufacturer's specifications.

Land along the proposed bypass route was inspected to identify the presence of springs and salt scalds. No scalds were identified during the field investigations. Many dams in the area are known to be partially spring fed. However, the spring fed dams were not specifically defined during the field investigation.

The locations of sites visited were recorded using a GPS and the sites were also marked on large scale aerial photos map (Figure 1-1*)*. Photographs of bores T13 and T16-T21 are shown in Photos 1 and 2*.*

5.2 Analytical assessment and criteria

Selected samples were submitted for analytical laboratory analysis of major dissolved cations and anions, and dissolved iron and manganese in sample bottles as specified by the laboratory and listed in Table 5-2*.*

Table 5-2 Sample bottles and preservation types

Parameter	Preservation
Major cations and anions – Ca, K, Na, Mg, Cl, HCO_3, SO_4	1 x 250 mL plastic, unpreserved
Dissolved metals – iron and manganese	1 x 125 mL plastic, preserved with HNO_3 (field filtered)

Samples for dissolved metals were filtered in the field using 0.45 micrometre (μm) cellulose acetate membrane filters and preserved in the field by acidification using concentrated analytical grade nitric acid (HNO_3) to pH<2. All samples were stored on ice and couriered to the laboratory within the laboratory holding periods. Analysis of the samples was performed by ALS Laboratory Group (a NATA registered Laboratory) in Smithfield. Chain of Custody (CoC) procedures were followed and copies of the CoC documents and analysis results are provided in Appendix A.

Assessment criteria from the *Australian Drinking Water Guidelines* (ADWG) (National Health and Medical Research Council (NHMRC) 2004) and the *Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters* (ANZECC) (2000) were used to assess the groundwater quality against the guideline values for the identified beneficial uses. Groundwater from sampled bores is mainly used for stock and domestic water supply and some minor recreational supply (watering of sportsgrounds). Groundwater may also provide base flow discharge to local streams.

Table 5-3 shows the guideline values for the water quality parameters.

Table 5-3 Assessment criteria

Parameter	**ADWG**		**ANZECC Guidelines**
	Health (mg/L)	Aesthetic (mg/L)	Trigger values (mg/L)
Temperature (^oC)	c	N/A	
EC (μS/cm)			125-2200[b]
pH	d	6.5-8.5	6.5-8.0[b]
TDS (mg/L)	d	500	
DO (% saturation)	c	>85	85-110[b]
Redox potential (mV)			
Sulphate as SO_4	500	250	
Chloride	c	250	
Calcium			
Magnesium			
Sodium	c	180	
Potassium			
Manganese (dissolved)	0.5	0.1	1.9[a]
Iron (dissolved)	d	0.3	ID

Notes:

a- ANZECC (2000) - 95% protection levels (trigger values) for the protection of freshwater aquatic ecosystems

b- ANZECC (2000) - trigger values for lowland rivers in south-east Australia

c- ADWG (2004) - no health based guideline value is considered necessary

d- ADWG (2004) - insufficient data to set guideline value based upon health considerations

ID- ANZECC (2000) - insufficient data to derive a reliable trigger level

6. Groundwater flow systems

6.1 Background

6.1.1 Aquifer characteristics

There are two main aquifer systems present in the Tarcutta area:

- Unconsolidated and unconfined alluvial aquifers.
- Semi-confined fractured rock aquifers (Ordovician metasediments).

The previous desktop study (PB 2008) suggested that the alluvial aquifer is the major aquifer accessed for groundwater resources in the area, and that groundwater levels in the alluvium were likely to be relatively shallow (approximately less than 10 m). The groundwater levels in the fractured metasediments are likely to be deeper, with lower bore yields and higher groundwater salinity than in the alluvium.

The watertable in the Tarcutta area is generally a muted reflection of the topography for both the alluvial and the fractured rock aquifers, and there is hydraulic connectivity between the two aquifer systems. Recharge into the groundwater systems occurs via direct rainfall and run-off and also via hydraulic connectivity to overlying creeks. Groundwater discharge is likely to be in the lower lying areas of the landscape (springs), at the break of slope and as base flow to surface water bodies (creeks/dams).

Groundwater movement in the alluvium is via intergranular flow. Sand lenses or bands are interconnected and provide preferential pathways of higher permeability and induce groundwater flow. Groundwater flow in the fractured rock aquifer is predominantly via secondary porosity (fractures). Groundwater movement within both systems is from the south-east to the north–west, which is consistent with the local topography.

Unconsolidated alluvial aquifers

The majority of boreholes in the Tarcutta area are shallow and obtain their supply from the groundwater within the alluvial systems. The alluvium within the Tarcutta area, specifically of Tarcutta Creek and Keajura Creek, has a higher permeability than the surrounding fractured rock aquifers. Yields from bores constructed within the alluvial aquifer at Tarcutta range from 0.3 to 1.5 litres per second (L/s).

From the data contained in the DWE database the bore depths in the alluvium range from 4 to 23 mbgl.

Fractured rock aquifers

The fractured rock aquifers generally produce low and unpredictable groundwater yields and the groundwater quality is often variable and may be brackish or saline. Yields from bores constructed in the fractured rock range from 1 to 2 L/s where dense jointing occurs (Baker et al 2001) and are, therefore, typically connected via secondary porosity.

Only a small number of bores are installed within the fractured rock and from the data contained in the DWE database bore depths extend to between 23 and 126 mbgl.

6.2 Groundwater levels

Groundwater level information was collated for the two separate flow systems — fractured rock and the alluvial aquifers. The levels were then converted into metres Australian height datum (mAHD) so that the groundwater flow direction could be determined. A water level contour map could not be prepared for either the alluvial areas or the fractured rock aquifers due to insufficient data.

The overall groundwater flow direction in the alluvium is towards the north-west, flowing in the same direction as Tarcutta Creek. It is assumed that groundwater in the fractured rock aquifer follows the surface and general catchment topography, and therefore, the flows are likely to also be generally towards the north-west.

Bore depths and water level measurements collected at the visited sites in Tarcutta are shown in Table 6-1.

Table 6-1 Bore depths and water level measurements

Site name	Date measured	Bore depth (mBGL)	Water level (mBGL)	Water level (mAHD)	Aquifer
T1	29/10/2008		11.93	226.73	Alluvium
T3	29/10/2008		9.26	222.01	Alluvium
T4	29/10/2008	4.15	3.8	221.47	Alluvium
T5	29/10/2008	+/- 40	14.25	218.33	Ordovician metasediments
T6	29/10/2008		3.08	224.60	Alluvium
T9	29/10/2008	+/- 20	Dry		Alluvium
T13	29/10/2008	+/- 12.2	8.63	221.51	Alluvium
T16	30/10/2008		3	224.49	Alluvium
T17	30/10/2008	> 25	3.01	224.20	Alluvium
T18	30/10/2008	9.12	1.67	225.39	Alluvium
T19	30/10/2008		2.9	224.01	Alluvium
T20	30/10/2008	16.76	2.71	225.74	Alluvium
T21	30/10/2008	10	7.65	222.37	Alluvium
T22	30/10/2008		3.25	224.86	Alluvium

Groundwater levels in the alluvium are generally shallow, ranging from 1.67 to 11.93 mbgl. However, it should be noted that the deepest water level at T1 is unlikely to be representative as it was likely to have been influenced by nearby groundwater pumping. The groundwater table in the alluvium is very flat, with a total fall of 5.26 m between the maximum and minimum groundwater level for alluvial bores.

The groundwater levels within the fractured rock aquifer were slightly deeper below ground than the alluvial aquifer. Bore T5 in the fractured rock was being pumped for domestic water supply when the water level measurement was taken and is, therefore, not considered to be representative of water levels within in the fractured rock aquifer. Once converted into to mAHD there was minimal difference between the relative groundwater levels in the alluvium and fractured rock aquifers. The groundwater table was relatively flat with a total fall of 8.4 m between the maximum and minimum groundwater level across all of the bores gauged.

Wagga Wagga City Council constructed six monitoring bores in the township of Tarcutta for the purpose of monitoring urban salinity. The bores were constructed in January 2007 and

Council has been monitoring the groundwater level and salinity level in the bores on a monthly basis.

The measured water levels have been graphed in mbgl (see Figure 6-1). Two of the monitoring bores have been dry since construction and another has been dry for much of this time. The three monitoring bores with measured levels are presented. The groundwater levels are relatively stable over the period of record and range from approximately 16 mbgl, Bore 3, to 3 mbgl, Bore 6 (Wagga Wagga City Council 2008).

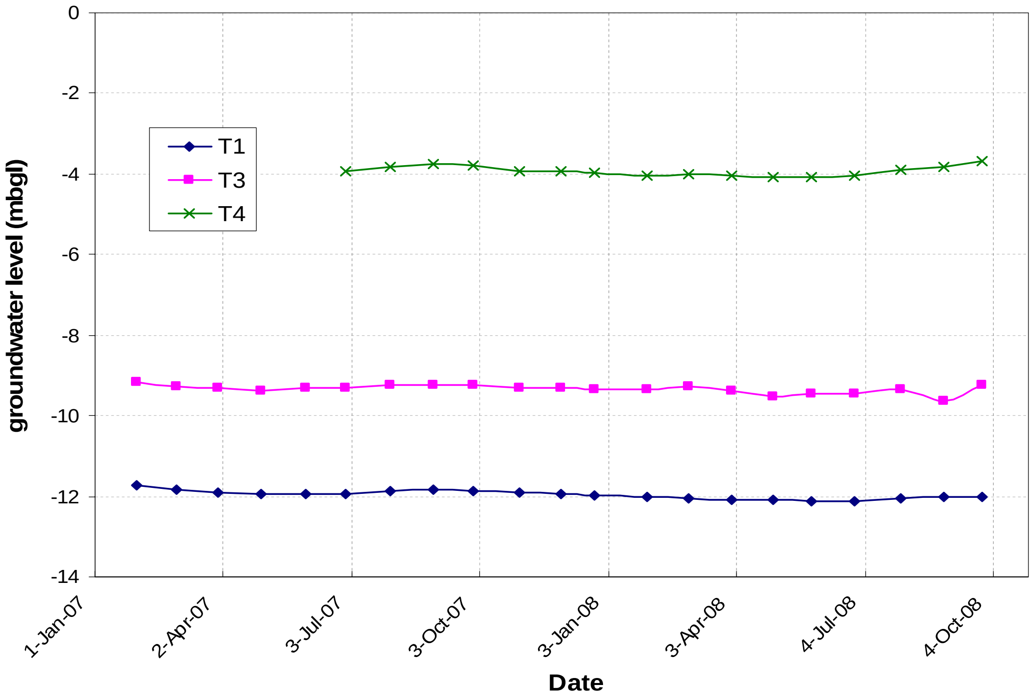


Figure 6-1 Water level measurements for Wagga Wagga City Council bores

6.3 Groundwater use

As listed on the DWE groundwater database, the majority of bores in the Tarcutta area are licensed to supply domestic and stock requirements. Three boreholes are registered and licensed for town water supplies for Tarcutta and two boreholes are licensed for commercial/industrial purposes (DWE 2008). There were no bores within the immediate vicinity of the Tarcutta town that were licensed for irrigation. However, there are known groundwater irrigators within the greater Tarcutta Creek Catchment.

The town water supply bores are located between the Tarcutta township and the Tarcutta Creek and are south-west of Tarcutta. The bores are therefore located on the up-gradient side of the proposed bypass.

There were no bores registered with the DWE and there were no bores during the field investigations that were located directly within the current proposed bypass corridor. However, bore T5 is located within close proximity to the proposed bypass.

During the field visit one of the registered bores (industrial monitoring bore GW400617 at field site T4) could be correlated to a borehole on the ground. There were many bores measured and sampled at Tarcutta that were not registered on the DWE database and most of these bores were being used for stock and domestic supplies.

The majority of high yielding bores within the Tarcutta Catchment obtain their groundwater supplies within the alluvial sediments. Within the GWMA 013 Zone 4 Tarcutta alluvium the total volume of groundwater entitlements is 2,453 megalitres and this volume is distributed between 18 renewable licences (Pers. Comm. DWE 2009). During the 2007-2008 water year only 235 megalitres (ML) of the total allowable 2,453 was actually extracted.

There are some limited high yielding bores within the Tarcutta Catchment that are located within the fractured rock sediments, but the total volume from these fracture rock aquifers is 397 megalitres and this volume is distributed between 12 licences which are all licensed for irrigation (Pers. Comm. DWE 2009, DLWC 2000).

Table 6-2 Renewable ('high yield') licences in the Tarcutta Catchment

Water Source	Total entitlements (ML)	Usage 2007-2008	Total number of bores
Tarcutta Alluvium GWMA 013 Mid Murrumbidgee Alluvium – Zone 4	2,453 15 irrigation licences (2,349ML) 2 town water supply (100ML) 1 recreation (4ML)	235	18
Fractured Rocks of the Lachlan Fold Belt Sub catchment within GWMA 802	397 12 irrigation licences (397 ML)	NA	12

6.4 Potential for groundwater supplies

There is some limited availability for a groundwater supply to be obtained for road construction from either the alluvial sediments associated with Tarcutta Creek or the fractured rock. The availability of water is largely dependent on the volume required. Small volumes would be available (such as less than 100ML per year). However, larger volumes of groundwater for continuous supply are unlikely to be available from either aquifer.

The Northern Hume Alliance (NHA) undertook a drilling investigation program in the alluvium and fractured rock in the northern section of the bypass area, to assess the water supply potential for the NHA. A new groundwater extraction bore was drilled in July 2007 at Dellateroy Creek, intersecting the fractured rock (Ordovician shale) to a depth of 64 mbgl. The yield for this bore was estimated at 6.5 L/s (NHA 2008). This bore is registered with DWE as GW403803 and licensed for groundwater extraction of 150ML per year.

Two groundwater extraction bores were also installed in the alluvial sediments in June 2007 on Ingold's property. These bores were installed at depths of 22 and 24 mbgl and had low yields and were unlikely to have intercepted the deeper more productive areas of alluvium (NHA 2008).

The fractured rock aquifers are generally considered to be less productive than the alluvial aquifers. However, bores drilled in the fractured rock for the NHA obtained greater yields than the bores drilled in the alluvium.

Groundwater extraction from within both alluvial sediments and fractured rock would require a licence under the Water Act 1912. Currently both the alluvium and the fractured rock aquifers are embargoed under the Water Act 1912, and therefore additional entitled volumes are not being granted.

The RTA has an existing licence for 150ML/yr in the fractured rock aquifer, which allows for extraction from the fractured rock only and not the alluvium. The trading of groundwater entitlement (or trading of temporary allocation) within the Zone 4 alluvial groundwater source is currently available but the water trading market is limited (mainly due to the small number of total licences). In order to obtain a groundwater supply within the alluvium a licence would need to be granted, and this is not currently allowable under the embargo.

The extraction of groundwater extraction may have a small localized impact on groundwater levels and new bores should therefore be located at a maximum distance from existing groundwater bores. Licence conditions from DWE would state a minimum distance condition from neighbouring bores. Impacts to existing bores would have been considered by DWE upon granting of the licence.

7. Groundwater quality

7.1 Background

The two main aquifer systems present in the Tarcutta area are slightly different in terms of groundwater chemistry. The alluvial aquifers are expected to be lower in salinity, while the fractured rock is generally characterised by higher levels of salinity. However salinity levels can be quite variable within each aquifer. The salinity level of sampled groundwater is dependent on the surrounding geology, the flow path and residence times (the time water has been in the aquifer).

Wagga Wagga City Council has been monitoring the EC (salinity) in six bores on a monthly basis since January 2007. The average EC of the groundwater ranges between 860 and 2,100 μS/cm (Wagga Wagga City Council 2008).

Dryland salinity is known to occur in the Tarcutta area and is generally associated with the Ordovician metasediments. The following was identified with regard to salinity within the study area:

- An area to the south of Tarcutta has been recognised as a salinity hazard. This area is in proximity to the intersection of north-east and north-west trending faults where changes in ground conditions have created a discharge zone.
- Shallow groundwater levels to the west of Tarcutta make this area vulnerable to salinity.
- Areas of contact between the metasediments and alluvium sediments are prone to dryland salinity (PB 2008).

No salinity scalds were identified within the highway bypass area during the field investigations. The lack of obvious signs of salinity may be due to extended drought conditions in the area and the likely reduction in groundwater levels across the fractured rock aquifers.

7.2 Results

7.2.1 Field Parameters

Eight bores were sampled during the four day groundwater field investigation at Tarcutta. The bores were sampled for field parameters of water temperature (^{o}C), EC (µS/cm), pH (pH units), DO (mg/L and per cent saturation), TDS and redox (mV). Field parameters are summarised in Table 7-1.

Table 7-1 Field parameters

Site No	Aquifer type	Temperature (°C)	EC (µS/cm)	DO (mg/L)	pH	TDS (mg/L)	DO (% saturation)	Redox potential (mV)
T1	Alluvium	18.32	1640	3.26	6.85	1000	34.4	-11
T3	Alluvium	19.53	1590	2.02	6.79	1000	18.2	-88
T4	Alluvium	18.42	1133	6.23	7.02	750	65.7	5
T5	Ordovician Metasediments	20.13	1312	3.38	6.87	800	35.5	115
T6	Alluvium	16.78	755	4.25	7.52	500	34.7	-35
T13	Alluvium	24.51	804	3.57	6.75	500	45.3	130
T16	Alluvium	18.17	312	1.20	6.83	200	11.5	-69
T21	Alluvium	19.51	120	2.43	6.59	100	24	-18

Groundwater temperature in the Tarcutta region ranged from 16.78 to 24.51 °C.

EC ranged from 120 to 1,640 µS/cm. The highest salinity was measured in bores T1 (1,640 µS/cm) and T3 (1,590 µS/cm), which penetrate the alluvial aquifer in the vicinity of the Tarcutta township. The salinity of the groundwater in the fractured rock bore (T5) was 1,312 µS/cm and was considered relatively low for a bore intercepting the fractured rock aquifer. The location of T5 is immediately adjacent to the alluvial aquifer and the bore was being pumped at the time the groundwater sample was taken. There were no bores with EC values above the ANZECC (2000) guidelines. The EC values indicate that the bore water ranges from fresh to slightly brackish.

TDS values ranged from 100 to 1,000 mg/L. As expected, the highest TDS of 1,000 mg/L occurred in bores T1 and T3, which also recorded the highest EC measurements.

The pH levels in the Tarcutta region ranged from slightly acidic to slightly alkaline (6.59 to 7.52). All bores were within the ADWG (2004) pH range (6.5 – 8.5). The pH of bore T9 was above the ANZECC (2000) guideline range (6.5 – 8.0).

DO (per cent saturation) concentrations in the groundwater were generally low, ranging from 11.5 to 65.7 % saturation and were below the ANZECC (2000) guideline range (85–110 % saturation) and ADWG (2004) guideline concentration (greater than 85 % saturation).

Redox potential ranged from slightly reducing (-88 mV) to oxidising (+130 mV).

7.2.2 Major ions and water type

Groundwater samples from selected bores were submitted to the laboratory for the analysis of major dissolved cations (calcium, magnesium, sodium and potassium), anions (chloride and sulphate) and alkalinity (bicarbonate alkalinity as $CaCO_3$). Results are summarised in Table B-1 in Appendix B.

Change in water type highlights the change in the relative proportion of major ions due to water-rock interaction and hydrogeochemical reactions in an aquifer. Water type was calculated from the cation and anion concentrations in the groundwater using Aquachem version 5.1, using a classification scheme based on the occurrence of major species that comprise more than 20 % of total cations and anions, calculated in mill equivalents per litre (meq/L).

Cation concentrations ranged from 7 to 42 mg/L for calcium, 7 to 52 mg/L for magnesium, 15 to 234 mg/L for sodium and 1 to 3 mg/L for potassium. Bore T1 had a sodium concentration (234 mg/L) above the ADWG (2004) concentration of 180 mg/L (NHMRC 2004).

Anion concentrations ranged from less than 1 to 92 mg/L for sulphate and 7 to 258 mg/L for chloride. Bore T1 had a chloride concentration (258 mg/L) above the ADWG (NHMRC 2004) value of 250 mg/L.

Bicarbonate alkalinity (as $CaCO_3$) ranged from 70 to 410 mg/L.

The water type calculated for the Tarcutta region is shown in Table 7-2.

Table 7-2 Groundwater type

Site	Water type
T1	Na-Mg-Cl-HCO3
T5	Na-Mg-HCO3-Cl
T13	Na-Mg-Ca-HCO3-Cl
T16	Mg-Na-Ca-HCO3
T21	Na-Mg-Ca-HCO3

Bores T1 and T5 had a sodium, magnesium and chloride water type, and bore T13 was classified as mixed cation-bicarbonate-chloride type water. Bores T16 to T21 had mixed cation-bicarbonate water types. The majority of bores sampled were shallow and located in alluvial sediments. Bore T5 is a deep bore (greater than 40 mbgl), and screened in the fractured rock Ordovician metasediments.

A dominance of chloride in the chemical composition indicates that there is possible recharge from freshwater sources including rainfall recharge and possibly surface water. The bicarbonate component of the water type indicates that the chemistry of the water is being affected by the surrounding geology.

The cation/anion contribution to the water type is also shown in the Piper plot in Figure 7-1.

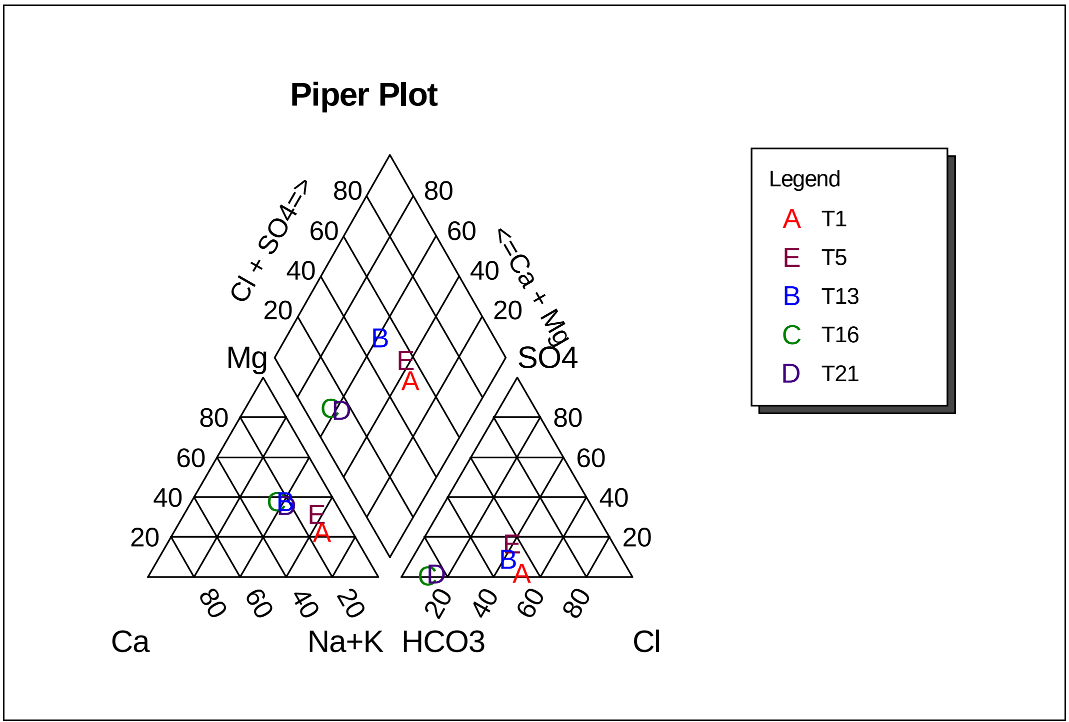


Figure 7-1 Piper plot of groundwater in the area

7.2.3 Metals

Groundwater samples were collected for the analyses of the dissolved metals — manganese and iron. A summary of the dissolved metal results is provided in Table B-1 in Appendix B.

Dissolved manganese concentrations ranged from 0.002 to 0.582 mg/L. Bore T21 (0.331 mg/L) and bore T1 (0.26 mg/L) exceeded the ADWG concentration (aesthetic) of

0.1 mg/L. Bore T16 (0.582 mg/L) exceeded the ADWG concentration (health) of 0.5 mg/L (NHMRC 2004).

Dissolved iron concentrations ranged from less than 0.05 to 26.4 mg/L with Bore T21 (15.1 mg/L) and Bore T16 (26.4 mg/L) exceeding the ADWG (2004) aesthetic value of 0.3 mg/L.

8. Potential groundwater impacts

Aquifers beneath the bypass alignment may be impacted both by the bypass construction and in the longer term. Whilst some of these impacts seem the same it is important to acknowledge that impacts will become apparent as construction commences and that impacts will remain for the long term.

8.1 Construction impacts

Construction of the proposed bypass will have short-term impacts on ground conditions, and therefore, potentially groundwater flows. Considering the results and findings of the groundwater assessment, potential impacts during construction may include:

- Potential short-term impacts on unconfined alluvial aquifers as a result of aquifer compaction caused by construction of controlled fills, structures and other compaction activities. The effects of ground compaction include:
  - Aquifer compaction may result in impediment or prevention of the natural groundwater flow to the north-west. This may cause water logging and ponding to the immediate east of the construction site, and may also result in the lowering of the watertable to the west and north-west.
  - The disruption to shallow groundwater flow from compaction of the shallow sediments may contribute to water logging and ponding on the up-gradient (eastern) side of the bypass. Dryland salinity may then be introduced into previously unaffected areas, or the impact of areas affected by dryland salinity may increase.
- Bore T5 is located within close proximity to the proposed bypass, and depending on the final corridor location the bore may be destroyed or impacted during the construction process. This bore may need to be replaced at a distance from the highway. The new location would need to be assessed as suitable for the landholder who may have infrastructure associated with the bore in its present location, including power and pipes.
- There is potential for excavations into the alluvium that are deeper than approximately two metres to receive groundwater inflow. The groundwater levels within the alluvium are shallow (three to four metres), therefore, excavations for road construction, footings, overburden removal, service trench excavation and other purposes may result in groundwater ingress.
- Accidental spills or leakage from equipment has the potential to contaminate groundwater aquifers. The alluvial aquifer is vulnerable to groundwater contamination and the Tarcutta town water supply bores obtain drinking water supplies from within this alluvial aquifer. Groundwater could potentially become contaminated with road construction materials, such as fuels, lubricants and hydraulic oils. Contamination of groundwater could be problematic for groundwater users and the environment.
- Groundwater extraction for construction will result in some local groundwater level drawdown from the aquifer. The impacts are likely to be localized due to the small volumes being extracted. It is likely that only those users within very close proximity would be affected and it is unlikely that either the aquifer integrity or water quality will be affected from groundwater extraction due to the low extraction volumes.

8.2 Operational impacts

Following construction of the bypass, the ground conditions in the vicinity of the highway may potentially change permanently, these long-term impacts may include:

- Potential long term impact to unconfined alluvial aquifers as a result of aquifer compaction under the bypass. This compaction was also identified as a short term impact during the construction phase. The construction of the highway bypass has the potential to change ground conditions permanently and has therefore been included as a long term operational impact. The potential consequences of aquifer compaction include:
  - Aquifer compaction may result in impediment or prevention of the natural groundwater flow to the north-west. This may cause water logging and ponding to the immediate east of the construction site, and may also result in the lowering of the watertable to the west and north-west.
  - Potential risk in the development of dryland salinity may be associated with the changes to flow regime induced by construction works. The disruption to shallow groundwater flow from compaction of the shallow sediments may contribute to water logging and ponding on the up-gradient (eastern) side of the bypass. Dryland salinity may then be introduced into previously unaffected areas, or the impact of areas affected by dryland salinity may increase.
  - Water logging on the eastern side of the bypass may impact the township of Tarcutta.

9. Management and mitigation of impacts

Final design of the raised road is a key issue for the management and mitigation of the groundwater system. Taking ground condition and groundwater flow into consideration during the design stage will assist in preventing or alleviating potential impacts that may arise from the highway construction and operation. Potential impacts and mitigation or management strategies are discussed below and have been summarised in Table 9-1.

9.1 Management of groundwater impacts

- The road design should take into consideration the impacts to the alluvial aquifer from ground compaction. Road construction is anticipated to cause some shallow compaction of the alluvial sediments and this in turn may induce changes to groundwater flows. The degree of compaction will be assessed in the geotechnical investigations, and the groundwater impacts (if substantial) may be managed or prevented by:
  - Design of the road being mainly as a bridge structure over the deepest sections of the alluvium immediately north-west of Tarcutta.
  - Adequate drainage measures in the road design if/where the alignment is being constructed on a fill platform. This may include culverts and diversion drains.
- Bore T5 is located within close proximity to the proposed bypass, and depending on the final corridor location the bore may be destroyed or impacted during the construction process. It is likely that this bore (and associated infrastructure such as tanks, pipes and power supplies) will need to be decommissioned and relocated. The hydrogeology of the landholder's property for the location of a new bore needs to be considered to maintain security and quality of water supply.
- Although no other bores were identified directly within the bypass corridor during the field investigations small alterations to the bypass corridor and or the proximity of the bypass corridor to bores or bore infrastructure may mean that some bores are impacted. It may be necessary to decommission and relocate certain boreholes where the bypass corridor is within very close proximity to an existing borehole or infrastructure associated with the borehole (such as tanks, pipes and power supplies). The hydrogeology of the landholder's property for the location of a new bore needs to be considered to maintain security and quality of water supply.
- Implement a hazardous materials plan (and spill emergency procedure) as part of the construction environmental management plan (CEMP). Fuels or hazardous materials should be stored in accordance with relevant standards and legislation depending on the volumes and nature of the materials. Spill kits should be kept with plant or vehicles to clean up any accidental spills that may occur during construction.
- The location of additional extraction bores should consider the proximity to existing groundwater users. The new bore should ideally be placed at the maximum distance away from any neighbouring bores.

Table 9-1 Potential groundwater impacts and mitigation measures

Potential impact	Timeline	Mitigation/management measure
Ground compaction inducing changes to shallow aquifer conditions. Increased incidence of salinity	Construction and operation	Road design should consider the impacts of ground compaction on the aquifer conditions. Incorporating bridges, culverts, diversion drains and pondages into final road design in areas over alluvium may alleviate or prevent impacts to shallow aquifer conditions. Ongoing groundwater level and water chemistry monitoring during construction and operation.
Water extraction boreholes may be near proposed road alignment	Construction and operation	Boreholes may need to be decommissioned and relocated to maintain a reliable water supply for landowners.
Releases of hazardous materials (fuels, chemicals etc) to groundwater	Construction	Implementation of hazardous materials plan and spill management procedure during construction. Use of spill kits and bunded areas for refuelling and maintenance.
Groundwater extraction for construction may result in some local groundwater level drawdown from the aquifer	Construction	Location of potential new extraction bores should be at the maximum distance away from existing groundwater users to minimize potential impacts.

10. Groundwater Management Plan

A groundwater management plan may be required for the construction of the Hume Highway Tarcutta town bypass. The plan would need to be developed in accordance with the relevant government legislation and policies. Suggested content for the Groundwater Management Plan would include but not be limited to;

- DWE and Department of Climate Change (DECC) specific requirements and procedures to ensure that construction works are undertaken in accordance with relevant legislation and government policy.
- The potential for groundwater to supply the water requirements of the bypass option should be considered. Negotiation with DWE and Riverina Water on issues such as obtaining a licence to construct water supply bores and options for temporary trading of groundwater allocation for use in an existing bore (such as the town water supply bores) should be considered and incorporated into the management plan.
- Specific mitigation measures to prevent identified potential impacts to the aquifer from occurring.
- Establishment of a groundwater monitoring network (combination of drilling monitoring boreholes and or monitoring existing stock bores). Monitoring locations should consist of both down-gradient and up-gradient bores. The number and location of bores is not critical, but should consider both groundwater systems (alluvial and fractured rock), and also consider up-gradient and down-gradient locations. Provision for changes to the monitoring network and program may be required if changes to groundwater conditions are observed during construction.
- The monitoring network should be monitored for both water level and water chemistry. The plan should determine the frequency of monitoring and the parameters to be monitored (at a minimum quarterly monitoring, or dataloggers should be installed, and field parameters and major ions should be monitored).
- Emergency response procedures for any critical incident which may potentially impact the aquifer system (such as spills overlying the aquifer). The aquifer supplies town water to Tarcutta and therefore contamination should be considered in relation to the beneficial use of the aquifer.
- Communication procedures for educating the project team on groundwater issues.

11. Conclusions

Based on the findings of the groundwater investigation the following conclusions can be made:

- There are two main flow systems present in the Tarcutta area — the unconsolidated alluvium and consolidated Ordovician metasediments.
- The sand and gravel beds of the alluvial flow system are the main aquifer for water resources in Tarcutta.
- Tarcutta obtains town water supply from the groundwater within the local alluvial aquifer.
- Water levels in the alluvium are generally shallow (less than 12 mbgl). The water level in the Ordovician fractured rock aquifer was measured at 14.3 mbgl.
- The overall groundwater flow direction in the alluvium is towards the north-west, following Tarcutta Creek. It is assumed that groundwater in the deeper fractured rock aquifers follows the catchment topography and flows towards Tarcutta Creek and generally towards the north-west.
- EC ranged from 120 to 1,640 µS/cm. The highest salinity was measured in bores T1 (1,640 µS/cm) and T3 (1,590 µS/cm) which penetrate the alluvial aquifer. The salinity of the groundwater in the fractured rock bore (T5) was 1,312 µS/cm and was considered relatively low for a bore intercepting the fractured rock aquifer.
- Groundwater pH conditions in the Tarcutta region ranged from slightly acidic to slightly alkaline (6.59 to 7.52). Redox and dissolved oxygen values were variable. Groundwater from the Tarcutta region generally displayed the following ionic characteristics: (Na>Mg>Ca)-(HCO3>Cl>SO4). Dissolved iron and manganese concentrations were above the ADWG in some bores.
- There is some potential for a groundwater supply to be obtained for use in road construction from the alluvial sediments associated with Tarcutta Creek and the fractured rock, but it will depend largely on the actual volume required. The RTA has an existing licence for 150ML/yr in the fractured rock aquifer, which allows for extraction from the fractured rock only and not the alluvium.
- During highway construction and operation the potential impacts to groundwater may include:
  - Compaction of soils during highway construction may impact groundwater flow.
  - The up-gradient (eastern) side of the highway may experience raised groundwater levels, water logging and/or dryland salinity.
  - The down-gradient (western) side of the highway may experience lowered groundwater levels.
  - The location of borehole T5 is within close proximity to the highway corridor and it is likely that this bore (and associated infrastructure) may need to be decommissioned and relocated to another suitable area on the property.
  - Other boreholes or bore infrastructure located close to the alignment may require relocation depending on the final highway alignment.
  - Releases of hazardous materials during construction have potential to impact groundwater quality. Contaminated run-off from the roadway whilst the highway is operational may also potentially impact the aquifer. In particular interest is the protection of the Tarcutta town water supply boreholes.

- Potential mitigation measures include:
  - Considering the impacts of aquifer compaction during the design of the highway and incorporating bridges, culverts and drainage infrastructure into the road design to prevent or alleviate potential water logging impacts.
  - Incorporating a hazardous materials management plan and spill management procedures into the CEMP.
  - Relocating boreholes that are close to the bypass alignment and may be affected by the road construction so that water supply to landowners is maintained.

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