Future Water Strategy Groundwater Options - position paper

September 2011

Rous Water

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Contents

List of tables

List of figures

Appendices

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.

Aquifer, confined — An aquifer that is overlain by a confining, low permeability strata. The hydraulic conductivity of the confining bed is significantly lower than that of the aquifer.

Aquifer, unconfined — Also known as a water table or phreatic aquifer. An aquifer in which there are no confining beds between the zone of saturation and the surface. The water table is the upper boundary of unconfined aquifers.

Australian Height Datum (AHD) — The reference point (very close to mean sea level) for all elevation measurements, and used for correlating depths of aquifers and water levels in bores.

Baseflow — The part of stream discharge that originates from groundwater seeping into the stream.

Beneficial use — Groundwater use that depends upon water quality present and the potential values of the water in the long term.

Bore — A structure drilled below the surface to obtain water from an aquifer system.

Discharge — The volume of water flowing in a stream or through an aquifer past a specific point in a given period of time.

Discharge area — An area in which there are upward or lateral components of flow in an aquifer.

Drawdown — A lowering of the water table in an unconfined aquifer or the potentiometric surface of a confined aquifer caused by pumping of groundwater from wells.

Fracture — Breakage in a rock or mineral along a direction or directions which are not cleavage or fissility directions.

Fractured rock aquifer — Occur in sedimentary, igneous and metamorphosed rocks which have been subjected to disturbance, deformation, or weathering, and which allow water to move through joints, bedding plains and faults. Although fractured rock aquifers are found over a wide area, they generally contain much less groundwater than alluvial and porous sedimentary aquifers.

Groundwater — The water contained in interconnected pores located below the water table in an unconfined aquifer or located in a confined aquifer.

Groundwater Dependent Ecosystems (GDEs) — Groundwater dependent ecosystems are communities of plants, animals and other organisms whose extent and life processes are dependent on groundwater.

Groundwater flow — The movement of water through openings in sediment and rock; occurs in the zone of saturation.

Groundwater flow system	A regional aquifer or aquifers within the same geological unit that are likely to have similar recharge, flow, yield and water quality attributes.
Hydrogeology	The study of the interrelationships of geologic materials and processes with water, especially groundwater.
Hydrology	The study of the occurrence, distribution, and chemistry of all waters of the earth.
Infiltration	The flow of water downward from the land surface into and through the upper soil layers.
Perched water	Unconfined groundwater separated from an underlying body of groundwater by an unsaturated zone and supported by an aquitard or aquiclude.
Permeability	The property or capacity of a porous rock, sediment, clay or soil to transmit a fluid. It is a measure of the relative ease of fluid flow under unequal pressure. The hydraulic conductivity is the permeability of a material for water at the prevailing temperature.
Permeable material	Material that permits water to move through it at perceptible rates under the hydraulic gradients normally present.
Piezometer (monitoring bore)	A non-pumping monitoring well, generally of small diameter, that is used to measure the elevation of the water table and/or water quality. A piezometer generally has a short well screen through which water can enter.
Porosity	The proportion of interconnected open space within an aquifer, comprised of intergranular space, pores vesicles and fractures.
Precipitation	(1) in meteorology and hydrology, rain, snow and other forms of water falling from the sky (2) the formation of a suspension of an insoluble compound by mixing two solutions. Positive values of saturation index (SI) indicate supersaturation and the tendency of the water to precipitate that mineral.
Pumping test	A test made by pumping a bore for a period of time and observing the change in hydraulic head in the aquifer. A pumping test may be used to determine the capacity of the bore and the hydraulic characteristics of the aquifer.
Recharge	The process which replenishes groundwater, usually by rainfall infiltrating from the ground surface to the water table and by river water entering the water table or exposed aquifers. The addition of water to an aquifer
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.
Recovery	The difference between the observed water level during the recovery period after cessation of pumping and the water level measured immediately before pumping stopped.
Saturated zone	The zone in which the voids in the rock or soil are filled with water at a pressure greater than atmospheric. The water table is

	the top of the saturated zone in an unconfined aquifer.
Sedimentary aquifers	These occur in consolidated sediments such as porous sandstones and conglomerates, in which water is stored in the intergranular pores, and limestone, in which water is stored in solution cavities and joints. These aquifers are generally located in sedimentary basins that are continuous over large areas and may be tens or hundreds of metres thick. In terms of quantity, they contain the largest groundwater resources
Specific yield	The ratio of the volume of water a rock or soil will yield by gravity drainage to the volume of the rock or soil. Gravity drainage may take many months to occur.
Surface water-groundwater interaction	This occurs in two ways: (1) streams gain water from groundwater through the streambed when the elevation of the water table adjacent to the streambed is greater than the water level in the stream; and (2) streams lose water to groundwater by outflow through streambeds when the elevation of the water table is lower than the water level in the stream.
Unconfined aquifer	Where the groundwater surface (water table) is at atmospheric pressure and the aquifer is recharged by direct rainfall infiltration from the ground surface.
Water table	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
DLWC	Department of Land and Water Conservation
DNR	Department of Natural Resources
DPWS	Department of Public Works and Services
EC	Electrical conductivity
GDE	Groundwater dependant ecosystem
LTAAEL	Long Term Average Annual Extraction Limit
mAHD	metres Australian Height Datum
mbgl	metres below ground level
NHMRC	National Health and Medical Research Council
NOW	NSW Office of Water
PB	Parsons Brinckerhoff Australia
REF	Review of Environmental Factors
SWL	Standing water level
WA	Water Act
WBZ	Water bearing zone
WMA	Water Management Act
WSP	Water sharing plan

List of units

km^2	square kilometres
L/s	litres per second
ML	megalitres
m/d	metres per day
mg/L	milligram per litre
µS/cm	micro Siemens per centimetre

Executive summary

Parsons Brinckerhoff (PB) was commissioned by Rous Water to produce a “position paper” to assess the technical feasibility of increased groundwater use to augment Rous Water’s existing potable water sources. This paper considers the groundwater systems, licensing and planning requirements and subsequent distribution requirements for the Rous Water supply area. The study area is experiencing population growth and increased demands on existing water resources. As part of the Future Water Strategy, a range of groundwater supply augmentation options will be assessed.

The study identified the fractured basalts and coastal sand aquifers as the most prospective based on their reliable and/or high yields and good water quality, with the Kangaroo Creek Sandstone also showing potential for water supply.

NSW groundwater legislation states that new groundwater licences (or the transfer of an existing licence) in the Alstonville Basalt Water Sharing Plan (WSP) area are managed under the *Water Management Act 2000* (WMA 2000). New groundwater licence applications for the coastal sands, Kangaroo Creek Sandstone and fractured basalt areas outside the Alstonville Basalt WSP area are currently not covered by a WSP and are therefore currently managed under the *Water Act 1912* (WA 1912).

Rous Water’s existing groundwater supply bores are located in the coastal sand and Alstonville Basalt aquifers. The bores are not used to their full potential, a combination of spare capacity of the existing infrastructure and available licensed volumetric entitlement. It is recommended that the Lumley Park bore and the Woodburn Bores may be used on a more regular basis. However, appropriate groundwater monitoring of levels and quality is advised. It is also recommended to not use the Convery’s Lane bore as groundwater levels in the surrounding area are very sensitive to pumping of this water supply bore or only use it for emergency water supply. Instead it is recommended to potentially transfer this bore’s license within Zone 3 of the Alstonville Basalt WSP area.

The augmentation of Rous Water’s current groundwater licence entitlement was also considered. It is recommended additional bore(s) could be sited within Zone 3 of the Alstonville Basalt WSP, fractured basalt areas outside the Alstonville Basalt WSP area, the coastal sands aquifer or the Kangaroo Creek Sandstone. Exploration drilling and aquifer testing would be required at selected highly prospective target areas with a view to installing a water supply bore or borefield that feeds directly into the bulk water main or provides groundwater to local growth areas.

1. Introduction

1.1 Background

Parsons Brinckerhoff (PB) was commissioned by Rous Water to produce a "position paper" that assesses the technical feasibility of increased groundwater use to augment existing potable water sources. The paper focuses on the groundwater systems in the area but also considers licensing and planning requirements, and subsequent distribution requirements for the Rous Water supply area (the study area) as shown on Figure 1-1. The study area is located on the far North Coast of NSW, approximately 700 km north of Sydney and 200 km south of Brisbane.

The main purpose of this position paper is to provide preliminary information on potential groundwater supply options to stakeholders as part of Rous Water's Future Water Strategy. The paper presents a clear and concise summary of available information relating to the existing abstraction capacity, current allocation use and the potential for increasing groundwater abstraction as an integral component of the strategic water security plan.

At this early stage in the strategic planning process, a high level assessment is provided with indicative cost estimates. Further studies would be required to investigate the potential viability of any groundwater augmentation.

1.2 Scope of works

The project scope of works was as follows:

- Identification of existing groundwater use and constraints within the Rous Water supply area.
- Analysis of Rous Water's existing groundwater share component vs. yield and recommendations to maximise this relationship.
- Consider resource impacts and threats associated with increased groundwater use.
- Recommend ongoing resource monitoring requirements and protocols.
- Identify practical options for augmentation including locations, infrastructure requirements and likely production volumes.
- Provide an indicative estimate of construction and ongoing operating costs, including resource monitoring activities.
- Consider technical, environmental and social issues and potential risks as identified in the Future Water Strategy feasibility assessment measures.

1.3 Methodology

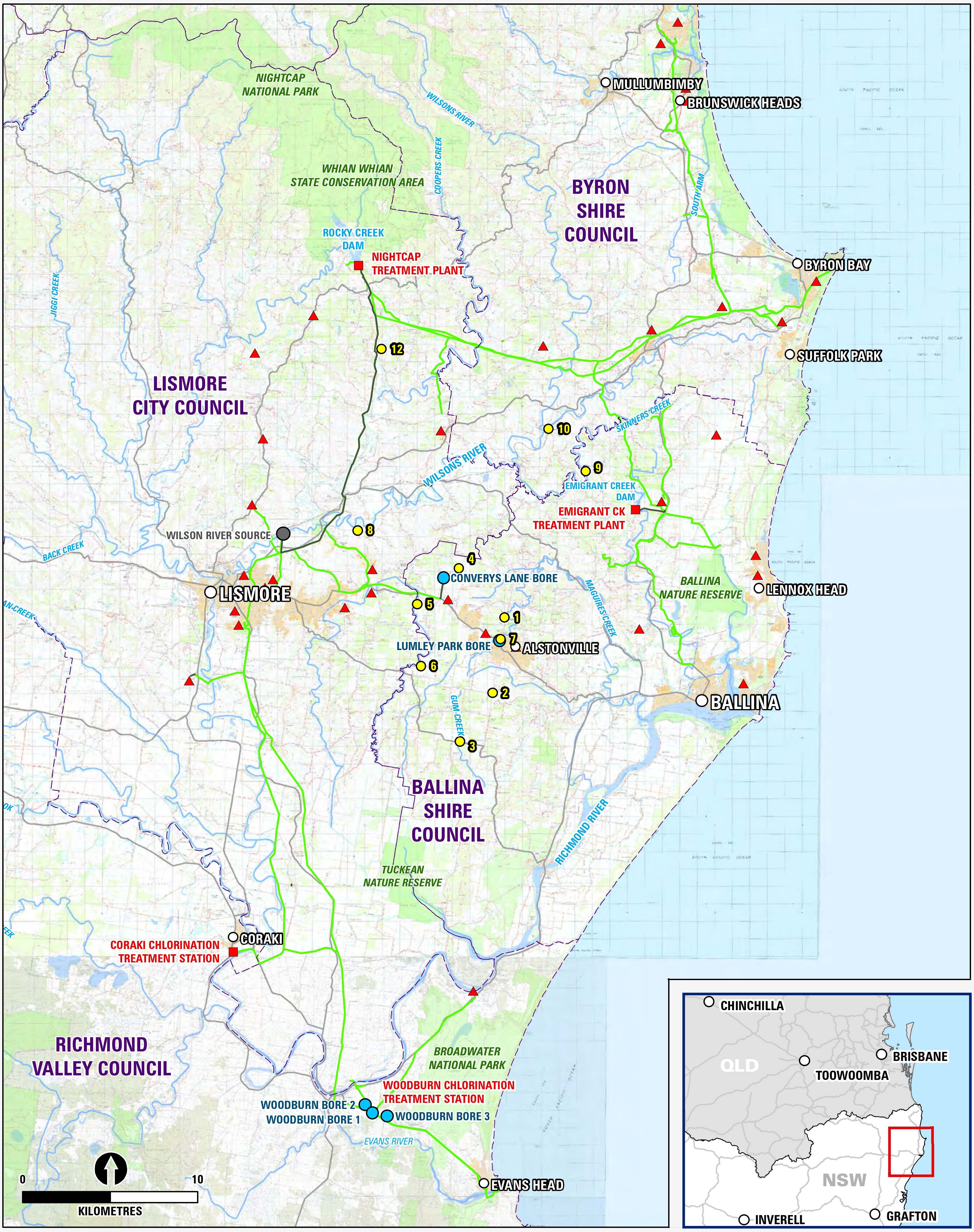
PB reviewed existing data and reports supplied by Rous Water and the NSW Office of Water (NOW), including:

- Geological maps for Tweed Heads (Brunker et al, 1972) and Maclean (Rose, 1970)
- NOW groundwater bore database (NOW, 2011)
- Relevant NSW groundwater policies, including WSPs in the study area
- Woodburn Bores - Condition Assessment (NSW Department of Public Works and Services (DPWS), 2002)
- Groundwater Drilling Details of Bores GW040868 and GW040869 (Department of land and Conservation (DLWC, 2002a)
- Alstonville Groundwater Investigations, Status Report 2006 (Draft) (Department of Natural Resources (DNR), 2006a)
- Groundwater Drilling Details of Monitoring bores Drilled for Alstonville Basalt Aquifers North Coast NSW (Draft) (DNR, 2006b)
- Upper North Coast Groundwater Resource Study (McKibbin, 1995)
- State of the Rivers and Estuaries Report: Upper North Coast (DLWC, 2000)
- Richmond River Valley Groundwater Investigation (Drury, Water Resources Commission (WRC), 1982)
- A Hydrogeological Assessment of the Fractured Basalt Aquifers on the Alstonville Plateau, NSW (Brodie and Green, 2002).

Relevant details relating to the existing environment are described in Chapter 2 and Chapter 3 discusses the groundwater resource assessment. NSW groundwater legislation in the study area is detailed in Chapter 4.

An analysis of Rous Water's existing groundwater share component is presented in Chapter 5 and recommendations on how to maximise this relationship are provided. The potential impacts to the groundwater resource associated with increased groundwater use have been considered and an appropriate monitoring program to monitor the groundwater resource and ensure groundwater extraction is sustainable is proposed.

Practical options for increasing groundwater supply including potential locations, infrastructure and likely production volumes are presented in Chapter 6. For selected practical groundwater options, an indicative cost estimate is provided for construction and ongoing operating costs. This includes resource monitoring activities.



Main road
Minor roads
Drainage
Shire boundaries
Wilson River source rising main
Rous Water pipelines
Water treatment plant
Reservoir
Rous Water bore
NOW monitoring bore site

Figure 1-1 Site location showing the Rous Water distribution network & NOW monitoring sites

2. Existing environment

2.1 Climate

The study area has relatively mild temperatures and high rainfall. The area is one of the wettest in NSW, with the average annual rainfall ranging between 1,360 mm near the coast at Woodburn (BOM station 58061, 1886-2011) and exceeding 1,800 mm at Alstonville on the Plateau (BOM station 58141, 1966-2011).

The average rainfall over the past 45 year period for Alstonville (1966–2010) was 1808 mm/yr. Cumulative deviation from the mean long-term rainfall represents discrete rainfall events as a continual trend over time, showing periods of below average rainfall (declining trend) and above average rainfall (increasing trend). The rainfall data when plotted as a cumulative deviation using the long-term average of 1808 mm/yr, indicates above average rainfall (a rising trend) for the period 1980-1989 and 2007 onwards, and below average rainfall (a decreasing trend) for the period 1990 – 2007 (Figure 2-1).

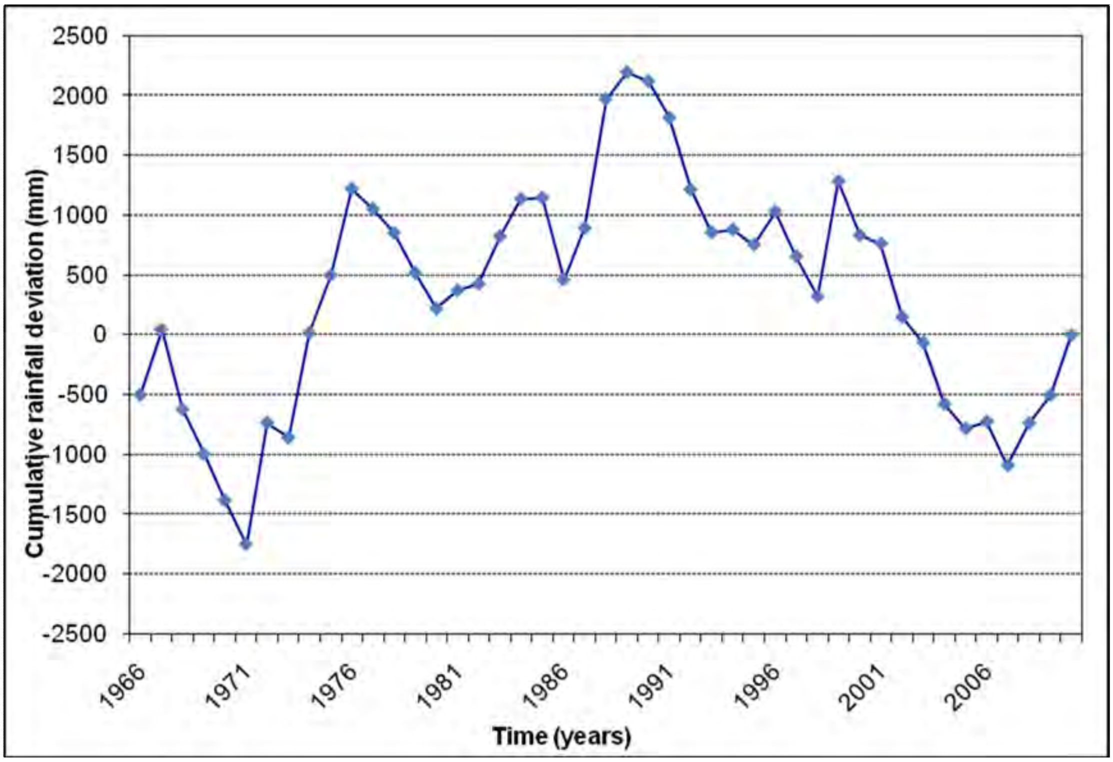


Figure 2-1 Cumulative rainfall deviation (Alstonville, BOM station 058141)

2.2 Topography

The landscape in the study area is varied with a narrow and low plain of sand dunes, swamps and lagoons along the coastline, and rolling hills with typical elevations of 100-150 metres above Australian Height Datum (mAHD) on the Alstonville Plateau. Landscape features on the plateau reflect the underlying basalt, such as structural benching caused by hard basalt plateau. Platforms can create small waterfalls and cascades on the plateau edge when cross cut by drainage lines (Brodie and Green, 2002). The Richmond River estuary is a broad alluvial flat that runs through the study area (McKibbin, 1995).

2.3 Land use

Prior to European settlement the study area was part of the largest tract of lowland sub-tropical rainforest in Australia. Today only 0.4% of the original rainforest exists, occurring as isolated patches. The study area is now dominated by agricultural use such as horticulture, dairying, grazing as well as rural residential and urban areas.

Original clearing of the local forest for timber was followed by subsequent clearing to obtain agricultural land for agricultural activities such as dairying and sugar cane (around 1950). Today, many crops are grown on the plateau, including stone fruit, citrus, pecan nuts, coffee, potatoes, kiwi fruit, blueberries and cut flowers. The North Coast region, including Alstonville, is currently experiencing increasing urban development (Brodie and Green, 2002).

2.4 Geology

The study area is underlain by various rock types, but predominantly hard fractured rocks occur on the higher tablelands, plateau and valley slopes and less fractured and softer rocks exist in the undulating areas. Unconsolidated sediments occur along the valley floors and coastal strip. A geology map of the study area is shown on Figure 2-2.

The predominant geology in the study area is the fractured basalt, which was formed from a Tertiary sequence of basaltic flows collectively known as the Lismore Basalt. The Lismore Basalt extends over some 3000 km^2 from Kyogle to the coast and from Coraki to Mullumbimby. The basalt flows form the southern extent of the Lamington Volcanics that are associated with the Tweed Shield Volcano. The volcanic complex is centred at Mount Warning (Brodie and Green, 2002).

Periods of hiatus between volcanic activity has allowed episodes of weathering. This is reflected in the development of fossil soils (red krasnozem) and alluvial and lake deposits before further extrusion of basalt lava. There are at least eight of these palaeosol marker horizons within the Lismore Basalt (Budd et al, 2000; Brodie and Green, 2002). A conceptual geological cross-section is shown in Appendix A.

The Lismore Basalt is underlain by the Carboniferous age Neranleigh-Fernvale Beds which are comprised of metamorphosed sedimentary units and associated with the development of the New England Fold Belt. These ancient rocks have been deformed over hundreds of millions of years and mainly consist of slates, greywacke and granites.

Clarence-Moreton Basin sediments outcrop in the Richmond River Valleys (Figure 1-1) and consist of sedimentary units including shales, sandstones and coal measures. These can be differentiated from the New England Fold Belt metasediments by their structures which are less fractured and have not been significantly metamorphosed (McKibbin, 1995).

Quaternary alluvial deposits, comprising clay, silt, sand and gravel, can be found along the valley floors of short coastal rivers that have carved valleys into older rocks. These deposits generally do not exceed 50 metres in depth and are most developed along lower non-tidal areas. Clays, silts and muds dominate in estuarine areas (McKibbin, 1995).

Holocene aeolian and beach deposits, consisting of fine to coarse sand and minor fine gravel, occur along the coastal strip between fractured rock headlands (McKibbin, 1995). A conceptual geological cross-section is shown in Appendix A.

2.5 Groundwater Dependent Ecosystems

Groundwater dependent ecosystems (GDE's) are communities of plants animals and other organisms that depend on groundwater for survival (DLWC, 2002b). A GDE may be either entirely dependent on groundwater for survival, or may use groundwater opportunistically or for a supplementary source of water (Hatton and Evans, 1998). GDEs are most likely to occur in areas with shallow groundwater levels close to the surface, such as near springs or discharge zones.

The potential impacts on groundwater dependent ecosystems need to be considered with respect to each proposed town water supply bore. With respect to the basalt aquifers from the Alstonville Plateau three fundamental types of groundwater dependent ecosystems (GDE's) were recognised as existing on the plateau as follows (Brodie and Green, 2002):

- groundwater-fed wetlands such as seepages and springs
- riparian and aquatic ecosystems (including the hyporheic zone) within or adjacent to streams fed by groundwater baseflow
- terrestrial vegetation communities that have seasonal groundwater dependency, such as rainforest remnants that access the shallow groundwater.

There are significant sand beds along the coast of the study area which are highly permeable and easily recharged through rainfall. The groundwater in these aquifers supports various groundwater dependent ecosystems, such as wetlands (DLWC, 2002b).

Lumley Park is a significant rainforest remnant located in Alstonville, which contains at least one spring that provides base flow to Maguires Creek. In the headwaters of Maguires Creek is a small melaleuca swamp community which is maintained by groundwater discharge. The Duck Creek rainforest remnant is a good example of a riparian corridor that acts as a retreat for native fauna during drought periods. Another small rainforest remnant with platypus occurs in the headwaters of a Maguires Creek tributary (Brodie and Green, 2002). A map showing GDE's near Alstonville is shown in Appendix B.

There are significant sand beds along the coast of the study area which are highly permeable and easily recharged through rainfall. The groundwater in these aquifers supports various groundwater dependent ecosystems, such as wetlands. It is important that these systems are protected against contamination, as well as over-extraction, which can result in saline water being drawn into the aquifer from the ocean and nearby estuaries, degrading the groundwater quality (DLWC, 2002b).

Groundwater extraction can lower groundwater levels and therefore has the potential to impact on GDE's if groundwater levels fall below the root zones of these ecosystems. Mitigation measures to protect GDE's include imposing minimum distance requirements from GDE's and to construct bores so that shallow aquifers are sealed off and not directly impacted from extraction from deeper aquifers.

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FUTURE WATER STRATEGY GROUNDWATER OPTIONS

ROUS WATER

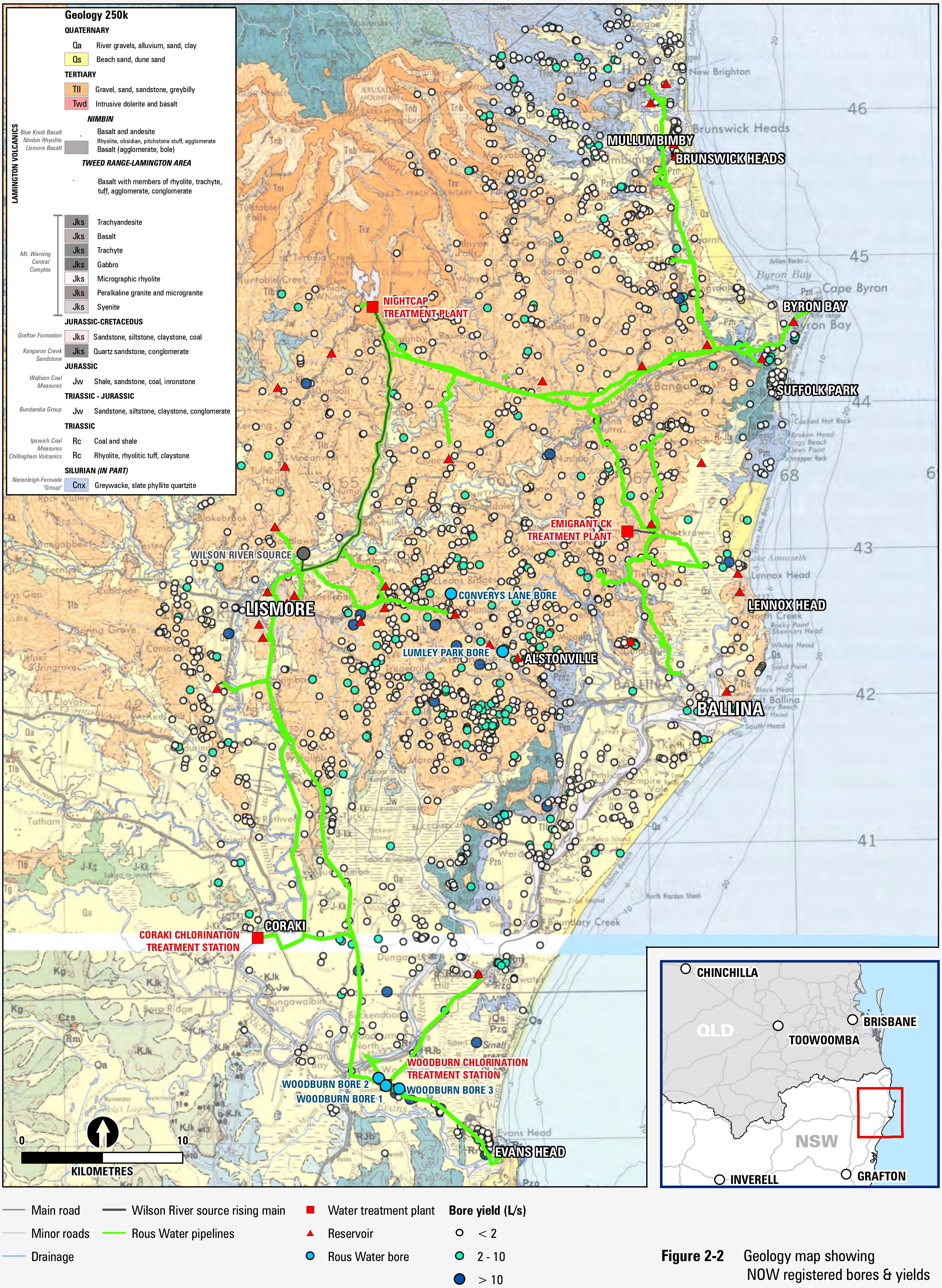

Figure 2-2 Geology map showing NOW registered bores & yields

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3. NSW groundwater legislation

3.1 *Water Act 1912* and *Water Management Act 2000*

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 in NSW via the commencement of WSPs. Once a WSP has commenced, the WA 1912 is repealed for that water source and existing licences are converted to new consents under the WMA 2000. 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 basic landholder rights (Basic landholder rights cover the taking of water for domestic and stock usage, constructing small farm dams (harvestable rights) and native title rights to water).

The minimal harm provisions of Sections 63 and 97 of the WMA 2000 inform this assessment. The WMA 2000 outlines water access licence, water supply works and water use approval requirements within the WSP water source boundary.

3.2 Water sharing plans

The WSPs describe the annual groundwater recharge volumes for each identified groundwater source and also the volumes of water that are available for sharing (the Long Term Average Annual Extraction Limit (LTAAEL)). Provisions are made for environmental water allocations, basic landholder rights, domestic and stock rights and native title rights.

Two WSPs are currently operating within the study area (shown on Figure 3-1):

- Alstonville Plateau Groundwater – Water Sharing Plan for the Alstonville Plateau Groundwater Sources – commenced 1 July 2004.
- Richmond River Area Unregulated, Regulated and Alluvial - Water Sharing Plan for the Richmond River Area Unregulated, Regulated and Alluvial Water Sources – commenced 17 December 2010.

Macro Plans are proposed for the remaining water sources in this area. Macro Plans are being prepared for alluvial, coastal sand, fractured rock and porous rock aquifers and are currently being drafted by NOW. The Macro Plan for the Coastal sands will likely come into effect in December 2012 (pers. comm. John Paul Williams, NOW, May 2011).

3.2.1 Water Sharing Plan for the Alstonville Plateau Groundwater Sources

The Alstonville Plateau Basalt Groundwater Sources are located between Lismore and Ballina and comprise shallow (2 to 50 m) and deep (50 to 150 m) aquifers. The upland basalt rock covers an area of approximately 391 km^2. In some parts (Zones 1 and 2), the groundwater sources have been classified as being at high risk of possible over-extraction and contamination.

The Alstonville Plateau WSP establishes a LTAAEL for each groundwater source that is the allowable limit of extraction for that water source, the LTAAEL is equal to the average annual recharge less the volume set aside for the environment. Each year a provision is made for basic rights to ensure the total extraction from the water source is within the LTAAEL. Applications can be made for local water utilities under an exemption (NSW Department of Infrastructure, Planning and Natural Resources, 2005).

There are six zones within the Alstonville Plateau WSP (as shown on Figure 3-1):

- Zone 1: Alstonville, LTAAEL: 2,315 ML/yr
- Zone 2: Tuckean, LTAAEL: 2,481 ML/yr
- Zone 3: Bangalow, LTAAEL: 2,333 ML/yr
- Zone 4: Coopers, LTAAEL: 707 ML/yr
- Zone 5: Wyrallah, LTAAEL: 715 ML/yr
- Zone 6: Lennox, LTAAEL: 344 ML/yr

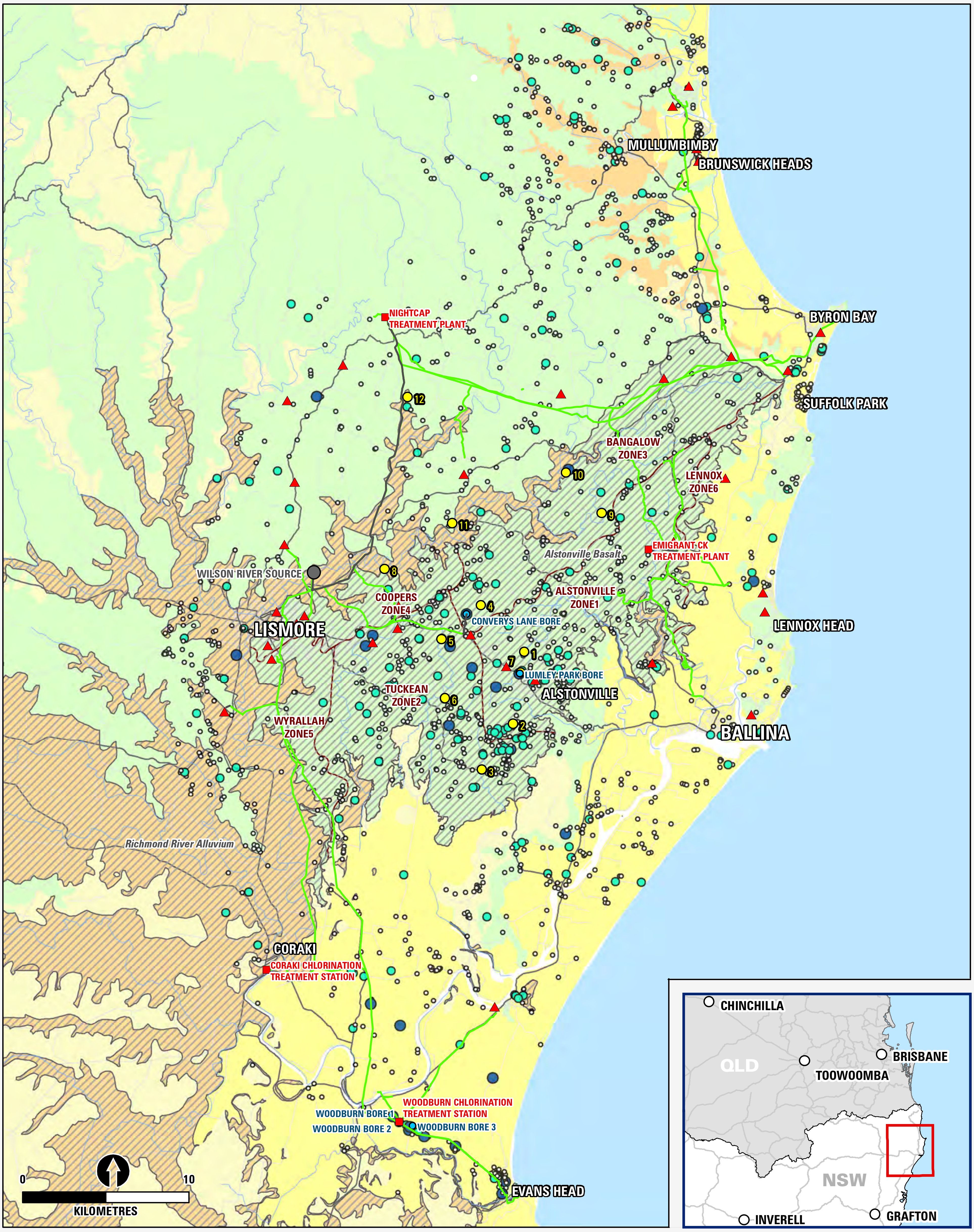
For Zones 1 and 2, licences can be transferred within the zone or out of it, but no licence can be transferred into it. For the other zones (Zones 3 to 6), water can be transferred within, into and out of all zones (pers. comm. John Findlay, NOW, Feb 2011).

3.2.2 Water Sharing Plan for the Richmond River Area Unregulated, Regulated and Alluvial Water Sources

The plan area for the River Richmond catchment and the smaller coastal catchment of Evans Creek covers 21 unregulated water sources and one regulated water source. All alluvial aquifers that occur within the plan area are included in this plan. Coastal sands are not included in this plan and they will be managed under a separate Macro WSP that will not come into effect until December 2012 (pers. comm. John Paul Williams, NOW, May 2011).

The WSP provides for the sharing of water between the environment, town water supplies, basic landholder rights and commercial uses of water. The volume of water that is available to meet all competing environmental and extractive needs varies on a yearly and daily basis, depending on the climatic conditions (primarily rainfall and river flows).

Except for basic landholder rights, all other water extraction either requires an authorisation under a water access licence or some form of exemption. Applications can be made for local water utilities under an exemption (NOW, 2010). Existing licences can also be transferred or traded.



Geology: © Copyright (2005) New South Wales Department of Primary Industries (Mineral Resources) / Monitoring sites (DNR, 2006) / Registered bore database search (NOW, 2011)

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Main road	Wilson River source rising main	Water treatment plant	**Bore yields (L/s)**	**Groundwater sources**
Minor roads	Rous Water pipelines	Reservoir	< 2	Alluvial
Drainage		NOW monitoring bore site	2 - 10	Coastal Sands
		Rous Water bore	> 10	Fractured Rock
				Porous Rock

Water sharing plan area

Alstonville Basalt WSP subzones

Figure 3-1 Groundwater sources & water sharing plan areas

3.3 Groundwater licensing

In order to drill, construct and extract groundwater from a bore in NSW a licence and or approval is required. The NSW Office of Water administers water legislation in NSW, and the primary legal instruments for this are the Water Act 1912, and the Water Management Act 2000. The Water Act 1912 is gradually being repealed as water sharing plans for water sources under the Water Management Act 2000 are made and commence. Town water supply bores under the Water Act 1912 require a licence, and under the Water Management Act 2000 require an Aquifer Access Licence, and a Work and Use Approval. Written landholder consent is required if the land is not owned by the proponent under both Acts.

3.3.1 *Water Act 1912*

In areas where WSPs do not exist, the WA 1912 still applies. The *Water Act 1912* requires landholders to hold a groundwater licence to extract groundwater using any type of bore, well, spearpoint or groundwater interception scheme.

For the study area this means that bores in the coastal sands, porous rocks and fractured rocks outside the Alstonville WSP area are managed under the WA 1912.

A ‘Groundwater Licence Application’ form, which can be downloaded from the NOW website, will have to be completed and submitted to the nearest NOW office (Grafton). This is the case for test bores, monitoring bores and production bores. The application charge for test and monitoring bores is free of charge and for production bores it is $151.

It is recommended to lodge both test bore and production bore applications concurrently. However it is common practice to install test bores prior to installing a production bore. The production bore licence will have an assigned volume. NOW may request that a pumping test is undertaken on the test bore before granting the licence and/or Review of Environmental Factors (REF) documentation to be provided. A document detailing ‘Test pumping groundwater assessment guidelines for bore licence application’ for Coastal Groundwater has been prepared by NOW (September 2010). This document is attached in Appendix C.

3.3.2 *Water Management Act 2000*

The WMA 2000 governs the issue of new water licences, the trade of water access licences and entitlements for groundwater in NSW where WSPs have commenced. For the study area this means that bores located in the Richmond River Alluvium and Alstonville Basalt WSP areas (as indicated on Figure 3-1) are managed under the WMA 2000. Water access licences under the WMA 2000 differ from licences under the WA 1912, in that they:

- provide a clearly defined share of the available water in a particular water source that can be sustainably extracted
- provide a clearly defined entitlement that is separate from land ownership
- separates the entitlement to access water from the approvals associated with supply works and the use of water
- in the case of 'continuing' water access licences (licences granted in perpetuity), allow for the licence and water allocation available under that licence to be bought and sold

fully or in parts and for the licences to be subdivided, consolidated and changed (e.g. for category, zone, water source).

- are listed on a public Water Access Licence Register.

The *Water Management Act 2000* requires landholders to hold:

- a water access licence to take the water - unless the water is to be taken to use under a basic landholder right
- a water supply work approval to construct a bore, well or spear point
- a water use approval to use the water – unless the water is for use under a basic landholder right (or you have obtained a development consent from the local council).

NB: In some cases, the works and use approvals are combined as a joint approval.

To construct a test or monitoring bore a 'Water Supply Work Approval' form, which can be downloaded from the NOW website, will have to be completed and submitted to the nearest NOW office (Grafton). To construct a production bore the same form will have to be filled out together with a 'Water Use Approval' form. NOW may request that a pumping test is undertaken on the test bore before granting a licence for a production and/or REF documentation is to be provided. If successful, a water access licence will be granted.

Details regarding the mandatory conditions for the approval of a water supply work (bore) can be found on the NOW website (www.water.nsw.gov.au).

4. Groundwater resource assessment

4.1 Aquifer systems

Table 4-1 summarizes the main aquifers in the study area. It shows typical aquifer thickness, salinity and bore yields, as well as the relevant groundwater management legislation. Groundwater sources can be divided into four broad categories: alluvial (A), coastal sands (CS), fractured rocks (FR) (including basalt and granite aquifers) and porous rock (PR) (including Clarence-Moreton Basin aquifers). Figure 3-1 shows these groundwater sources as well the areas where water sharing plans have commenced.

Table 4-1 Summary of main aquifers in the study area (McKibbin, 1995; DLWC, 2000)

Aquifer	Geology	Typical saturated thickness	Typical salinity (mg/L)	Bore yields	WSP
Coastal Sands (CS)	Beach and dune sands	15 m	< 500	Typical: 0.5 - 6.0 L/s Maximum: 34 L/s	No
Estuarine and Fluvial River Alluvium (A)	Unconsolidated cobbles, gravels, sand, silts, muds and clays	25 m	200-3,500	Typical: 0.5 - 2.0 L/s Maximum: 15 L/s	Yes
Alstonville Basalt /North Coast Fractured Rock Basalt (FR)	Fractured basalt with vesicular zones and interlayered sediments	60 m	< 500	Typical: 1 - 15 L/s Maximum: 38 L/s	Yes/ No
Clarence-Moreton Basin – Kangaroo Creek Sandstone (PR)	Quartz sandstone, conglomerate	200 m	500	Typical: < 1 L/s Potential: 10 L/s	No
NEFB Basement Rocks – Fractured rock (FR)	Fractured, altered metamorphosed sediments and basalts	50 m	< 500	Typical: 0.1 – 0.5 L/s	No
NEFB Basement Rocks – Granites (FR)	Fractured and weathered granite	15 m	< 500	Typical: 0.1 – 1.0 L/s Maximum: 19 L/s	No

*NEFB = New England Fold Belt

4.1.1 Coastal sand aquifers

The coastal sand aquifers are located on the eastern coastline of the study area and are not within a WSP area and are currently managed under the Water Act 1912 (WA 1912) (shown on Figure 3-1). Groundwater within the coastal sands is generally of fresh water quality (< 500 mg/L) and bore yields range from 0.5 - 6 L/s. Groundwater is suitable for irrigation and town water supply purposes.

One of the main coastal sand aquifers is the Woodburn Sand, occurring near Woodburn in the south of the study area. The groundwater has a low pH and high dissolved carbon dioxide content which could make the water slightly corrosive. Water needs to be treated to remove the high iron concentration and aeration is required to remove hydrogen sulphide

and carbon dioxide gases. In Drury (1982) it is implied that the Woodburn Sand is recharged from local creeks and Tuckean Swamp draining the basalt.

The estimated potential yield from the Woodburn Sand ranges from 4.5 to 6 L/s. The aquifer is very transmissive, but has a lower potential yield due to limited available drawdown. Using a battery of spearpoints, large groundwater supplies (>25 L/s) could potentially be obtained (Drury, 1982).

Groundwater levels in the Woodburn Sand aquifer are shallow and the water table tends to be a subdued reflection of topography. Groundwater recharge occurs via rainfall that infiltrates through the floodplain deposits to the surface, the Tuckean Swamp, and associated water courses draining the basalt plateau. Groundwater is discharged into the Richmond River and its tributaries and in drought conditions Tuckean Swamp may also act as a point of discharge (Drury, 1982).

4.1.2 Alluvial aquifers

Alluvial aquifers make up the large coastal floodplain of the Richmond River and also the smaller floodplains deposited along most major and minor streams. Alluvial aquifers in the study area are closely connected to rivers. The alluvial aquifers in the study area have been managed under the ‘Richmond River Area Unregulated, Regulated and Alluvial’ WSP since December 2010.

Groundwater is mainly suitable for stock and domestic purposes with water quality varying from fresh (< 200 mg/L) to brackish (3,500 mg/L). Bores yields generally range from 0.5 - 2 L/s, although some bores in the alluvial aquifers can yield in excess of 15 L/s.

The Richmond River catchment contains by far the most alluvium of north coast valleys. However there has been relatively little development of this groundwater system due to bores often not producing high yields and brackish water quality.

4.1.3 Basalt aquifers - Alstonville Basalt and North Coast Fractured Rock Basalt

The basalt aquifers are an important resource of fresh groundwater and the majority of groundwater use in the study area is from these aquifers. The Alstonville Basalt aquifer is managed under the ‘Alstonville Groundwater Sources’ WSP, which commenced on 1 July 2004. The North Coast Fractured Rock Basalt aquifer includes all basalt aquifers outside the boundary of the Alstonville Basalt WSP area and is not managed by a WSP (Figure 3-1).

Groundwater is used for town water supply, irrigation and stock and domestic purposes. Groundwater flow is via joints, fractures, vesicular units and interlayered palaeosols and sediments (Brodie and Green, 2002). High yields are dependent on intersecting one or more of these water bearing fracture zones. Bore yields are variable, ranging from less than 0.5 L/s to greater than 30 L/s.

Basalt aquifers of the plateau generally contain low salinity groundwater and have low nitrate concentrations. The pH values range from 4.6 to 9.8, and generally increase (becoming more alkaline) with depth. Shallow groundwater is slightly acidic, possibly due to the acidic krasnozem soils, and this causes a natural increase in dissolved metal concentrations, particularly aluminium, zinc, manganese, copper, iron and lead. Contamination is a major issue in the aquifers and sources of contamination are likely faecal and are due to a combination of natural fauna, livestock and human waste (Brodie and Green, 2002).

The basalt groundwater system can be divided into two main components:

- A shallow, unconfined groundwater flow system in the weathered and shallow highly fractured basalt. This system tends to be localised with groundwater flow direction following topography.
- A deep, semi-confined to confined groundwater flow system in fractured horizons within the basaltic sequence. Groundwater flow is controlled by geology with flow direction following the dip of the geological sequence.

Historical water level data indicate that shallow bores (less than 15 m deep) constructed in the unconfined aquifer, respond dynamically to rainfall, i.e. an immediate and rapid rise in groundwater level following rainfall events. Bores constructed at intermediate depths (15-40 m) generally show a similar hydraulic response, which implies a high degree of vertical connection between these shallower aquifers. Bores constructed in the deeper aquifers (greater than 50 m) show little short-term response to rainfall (Brodie and Green, 2002) and therefore this represents a poorer hydraulic connection with surface water inputs. Jointing and/or fracturing can provide localised hydraulic connection between the shallow and deep basalt aquifers (Brodie and Green, 2002).

4.1.4 Clarence Moreton Basin - Kangaroo Creek Sandstone aquifer

Groundwater associated with the porous rocks of the Clarence-Moreton Geological Basin, extending from the border of Queensland to 50 km south of Grafton, has variable potential for development. Bores within this basin indicated a variation in yield and water quality. This aquifer is not managed under a WSP.

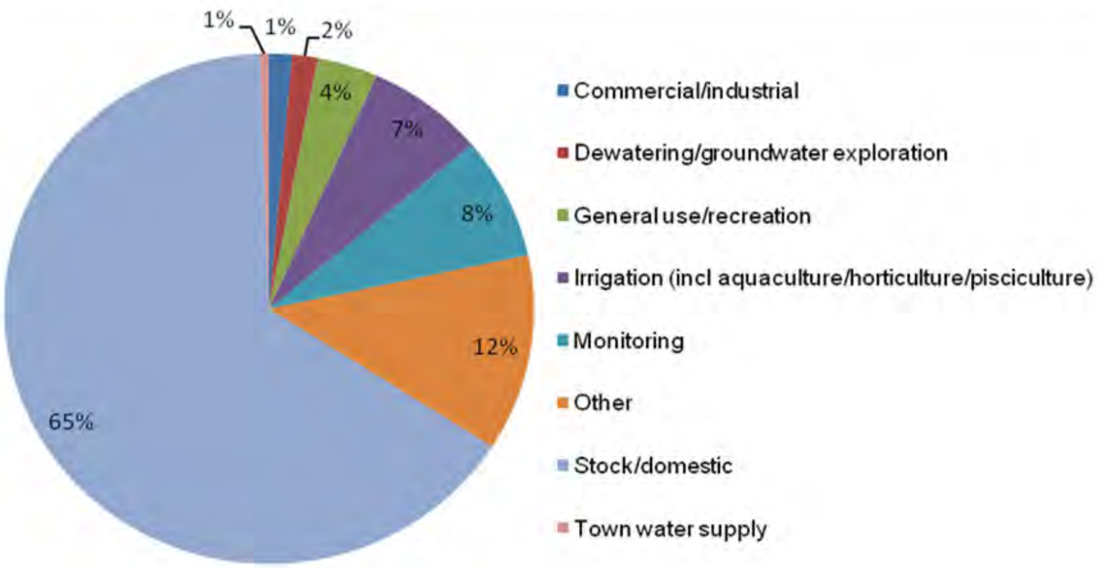
The Kangaroo Creek Sandstone is the most favourable formation for groundwater development potential due to higher yields and lower groundwater salinity. Geology consists of medium grained sandstone and groundwater salinity is generally low at depths between 30 and 50 metres below ground level (bgl). Yields are mostly less than 1 L/s, but there is potential for high yields, up to 10 L/s, when fractures are intercepted. Resource potential is not well known, but fractured zones could possibly be significant sources of water supply (McKibbin, 1995).

4.1.5 Basement fractured rocks – Metasediments and granite aquifers

The basement rocks do not outcrop at the surface in the study area except for a small band along the southern and eastern fringes of the Alstonville Plateau. These aquifers are not managed under a WSP. The metasediments are highly fractured and structurally deformed and groundwater is mainly stored in fractures and weathered zones. Groundwater quality is generally good, but bore yields are generally low (<1 L/s) (McKibbin, 1995; DLWC, 2002a).

4.2 Groundwater use

A search of the NOW registered groundwater bore database found approximately 3000 bores in the study area, most of which are located on the Alstonville Plateau water source. The main bore purposes were stock/domestic (65%), monitoring (8%) and irrigation (7%) as shown on Figure 4-1. The actual extraction from bores in the study area is not clear, due to the majority of bores in the area being for stock and domestic purposes, which do not have a volumetric entitlement volume, and are not metered.



NB: This figure shows the number of registered bores for each purpose and is not total volume extracted

Figure 4-1 Purpose of registered groundwater bores (NOW, 2011)

Bore yields are shown on Figure 2-2. Bores were classed as being low (<2 L/s), medium (2-10 L/s) or high (>10 L/s) yielding. Most high yielding bores are located on the Alstonville Plateau,other fractured basalt areas, and coastal sands. The final yield of a bore depends on a combination of the aquifer parameters (hydraulic conductivity) of the aquifer intersected and the bore construction (depth, diameter, length of screen).

4.3 NOW monitoring bores

Groundwater levels have been monitored by NOW (formerly DNR) in the shallow and medium (2-50 m), medium and deep (50-150 m) basalt aquifers of the Alstonville Plateau since the late 1980s. There are currently 13 monitoring sites, shown on Figure 1-1. Pumping tests were carried out in 2005 and 2006 at each site and the results are shown in Table 4-2. Yields range from 0.01 to over 12 L/s. Salinity was below 1,000 mg/L for all monitoring bores. Data loggers were installed by NOW in several of these bores (DNR, 2006).

Table 4-2 Summary of pump test results for monitoring bores (DNR, 2006)

Site	Monitoring bore ID	WBZ/screens (m)	Screened aquifer	SWL (m)	Bore yields (L/s)
1	GW081005	60-71	Basalt (fractured)	44.1	2.6-9.3
	GW081006	7.5-12	Basalt clay	7.5	1.8
2	GW041005	4.2-11.2	Basalt	4.2	0.01
	GW081002	52-55, 63-65	Basalt and shale	28	1, 5
	GW081003	32-36	Basalt (fresh)	8.8	1
	GW081004	2.5-3.5	Basalt (weathered)	2.4	<0.01
3	GW081000	87.107	Basalt (weathered)	85.9	4
	GW081001	4-9	Basalt (fresh)	3.7	5.3
4	GW036702_1-4	60	Basalt (fractured)	10.7	4.5
5	GW041006	13-23.5	Basalt (weathered)	na	0.01
	GW036701_1-4	90	Basalt (fractured)	47.7	5
6	GW040999_1	16-27	Clay and gravel	11.6	0.5
	GW040999_2	61-83	Basalt	na	3.3
7	GW041001_1	36-36.5, 66-66.5	Basalt (fractured)	na	0.1, 3.7
	GW041001_2	na	na	na	na
8	GW041002_2	50-51, 54.8-55.7	Basalt (fractured)	na	0.4, 10
9	GW041003_1	3-9.3	Basalt (weathered)	2.3	0.05
	GW041003_2	na	Basalt and chert	na	0.25
10	GW041004_1	11-21	Basalt	7.4	1
	GW041004_2	11-56	Basalt (fresh, fractured)	7.1	>12
11	GW041007_2	27-40	Basalt (weathered)	7.9	1
12	GW041008	71-77	Basalt (fractured)	na	>12
13	GW041000	88-94	Basalt	27.4	>8

Notes: *WBZ = water bearing zone, SWL = standing water level, na = not available

Groundwater level analysis by NOW confirmed that shallow basalt aquifers (<50 m) are rapidly recharged by rainfall (Figure 4-2) and are impacted by drought. During drought conditions from late 2000 to early 2001 groundwater levels in the shallow aquifers dropped by up to 3 m. However, rainfall and river floods in February and March 2001 resulted in rapid recovery of the aquifer's groundwater levels. On an annual basis groundwater levels in this aquifer generally vary between 1 and 9 m below ground level (DNR, 2006).

Shallow groundwater level fluctuations generally correlate to stage height in local creeks. Creeks on the Alstonville Plateau are generally gaining rivers (i.e. receiving groundwater discharge) and, when there is no rainfall, flows increase as they move downstream. Shallow groundwater level rises were found to correspond with rises in river levels (DNR, 2006).

Analysis of deep basalt groundwater levels by NOW (Figure 4-3) found that deep aquifers (>50 m) are not directly responsive to rainfall. There has however been a steady increase of groundwater levels since 2003. Between 1987 (the start of monitoring) and 1997, groundwater level trends showed an overall decrease varying from 8 to 19 m and levels remained at these levels until early 2003, the peak of the drought. Groundwater levels started to increase in early 2003, which correlates to the end of the drought. It is also noted that extraction rates decreased from 2003 onwards.

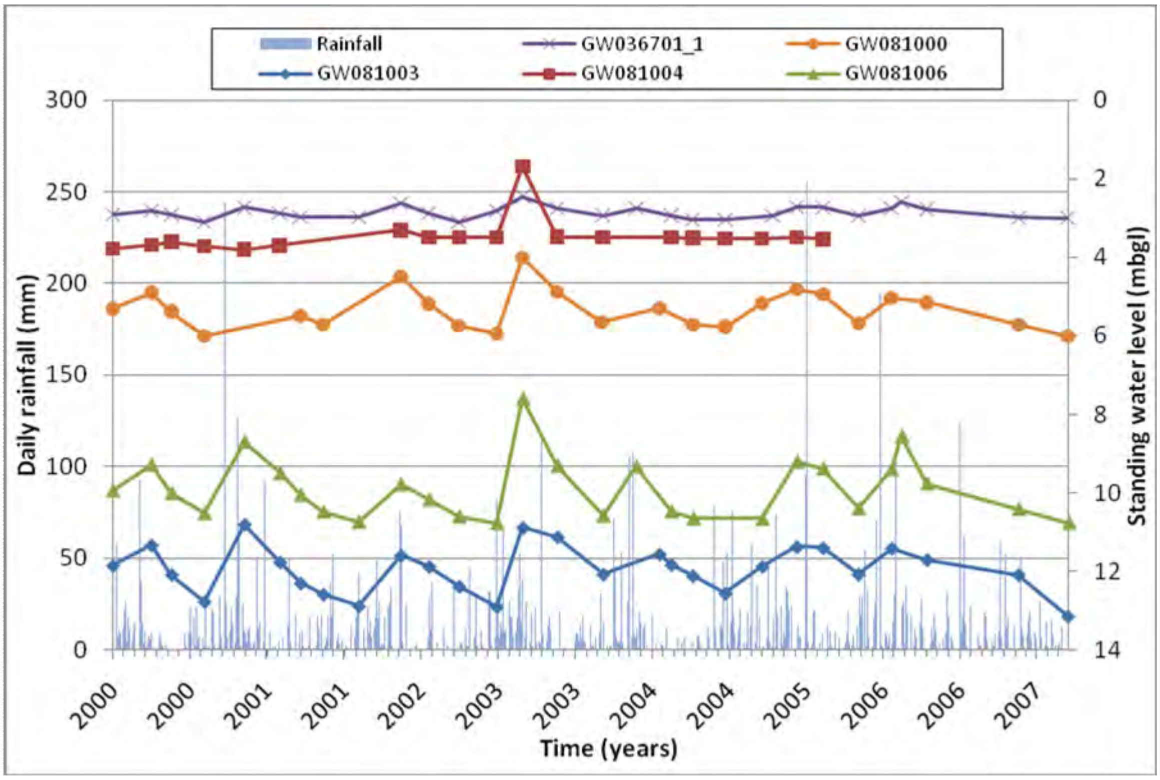


Figure 4-2 Groundwater levels in the shallow basalt aquifer and rainfall

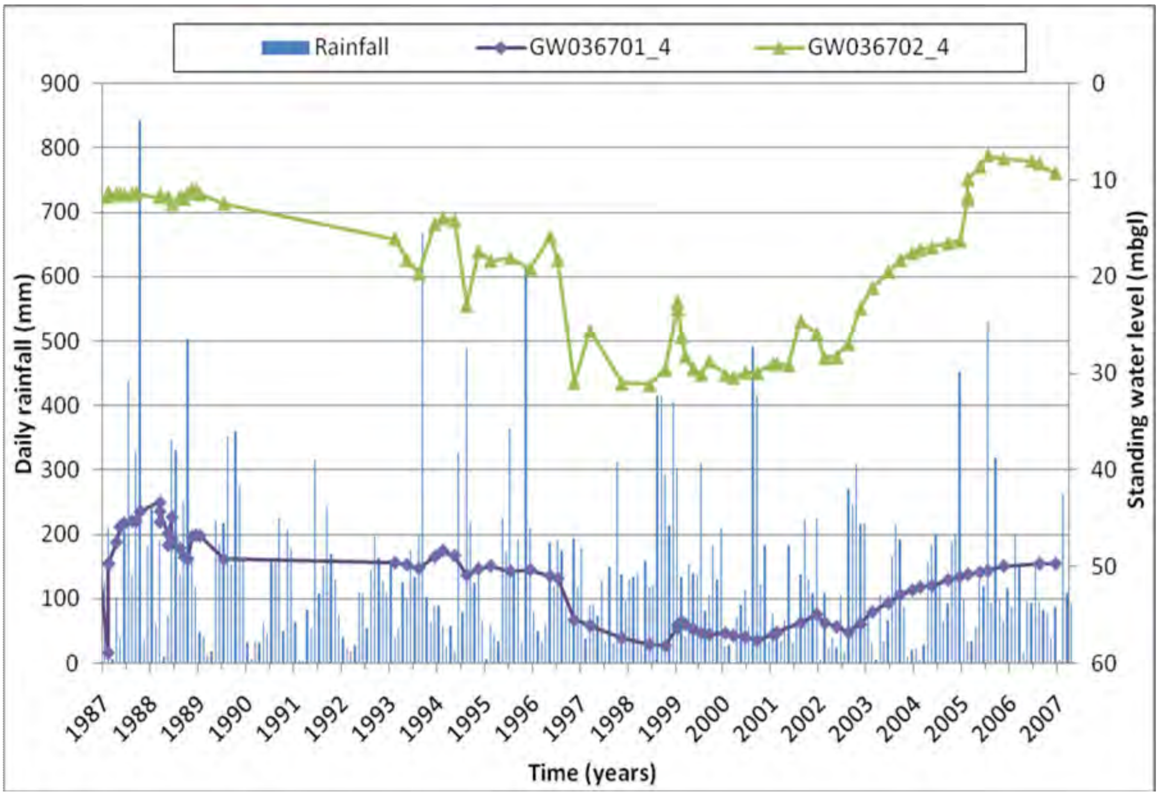


Figure 4-3 Groundwater levels in the deep basalt aquifer and rainfall

5. Current groundwater supply infrastructure

5.1 Existing Rous Water bores

5.1.1 Existing infrastructure and licences

Rous Water currently operates five groundwater bores within the study area. Two bores on the Alstonville Plateau at Lumley Park and Convery's Lane and three bores in the coastal sand aquifer at Woodburn (Figure 1-1). The licence details of the existing Rous Water bores are summarised in Table 5-1. The bores are currently used to supplement water supplies during periods of water shortage and have a combined licensed volume of approximately 922 ML per year.

Table 5-1 Summary of Rous Water bore details

Bore site	Bore no	Licence numbers	Licensed volume (ML/year)	SWL (mbgl)	Estimated potential yield (L/s)	Depth (m)	Screened formation	WSP
Woodburn	GW040869	30BL180631	242 (combined)	1.99	6	16.5	Coastal sands	no
	GW040868	30BL180632		2.03	12	22		
	GW053237	30BL119125		0.8	19	17.3		
Convery's Lane	GW065981 WA1912 GW300353 WMA2000 (NB This is 1 bore)	30BL143389 30WA300013 30AL300012	150	21.62	16	111	Bangalow Basalt	Alstonville Basalt (Zone 3)
Lumley Park	GW039387	30BL137383 30WA301677 30AL301676	530	60.3	14.2	82	Alstonville Basalt	Alstonville Basalt (Zone 1)

Note: SWL = standing water level, mbgl = metres below ground level, WSP = Water Sharing Plan

The Woodburn bores are located in the coastal sands and are not currently included in a WSP plan, therefore they are managed under the WA 1912. The bores have a combined licensed volume of 242 ML/year. Woodburn Bores 1 and 2 were originally installed in 1971, but replaced in 2002, when extended drought conditions severely restricted water supplies. Woodburn Bore 3 was installed in 1982 and reconditioned in 2002. Bore depths for the Woodburn Sand bores range between 16.5 and 22 m. Bore yields range between 6 and 19 L/s for the coastal Woodburn Sand aquifer. Pumping tests were conducted on Woodburn Bores 1 and 2 (GW040869 and GW040868) by DLWC in November 2002 and pumping rates of 7 and 14 L/s respectively were recommended for sustainable groundwater supply.

The Convery's Lane bore and the Lumley Park bore are located in the Alstonville Basalt WSP area. Convery's Lane bore has a licensed volume of 150 ML/year in Zone 3 and the Lumley Park bore is licensed for 530 ML/year in Zone 1. The Convery's Lane bore was installed in 1991 and the Lumley Park bore was installed in 1987. Bore yields range between 7 and 16 L/s for the bores installed in the Alstonville Basalt aquifer. The Convery's Lane bore is 111 m deep and the Lumley Park bore is 82 m deep.

Ballina Shire Council also holds groundwater licences for 350 ML/year in Zone 1 and 200 ML/year in Zone 2. This groundwater supply offsets the demand for potable water from Rous Water.

5.1.2 Usage versus potential

The Rous Water bores contributed less than 1% of the total water supply between 2000 and 2010. Figure 5-1 shows the yearly usage in ML/year as well as the licensed volume. The Woodburn Bores maximum usage was 61% of their licensed volume in the year 2003. The maximum usage for the Convery's Lane bore was 42% of its licensed volume in 2000 and for the Lumley Park bore it was 37% of its licensed volume in 2003. The bores have not been used for groundwater supply since 2007.

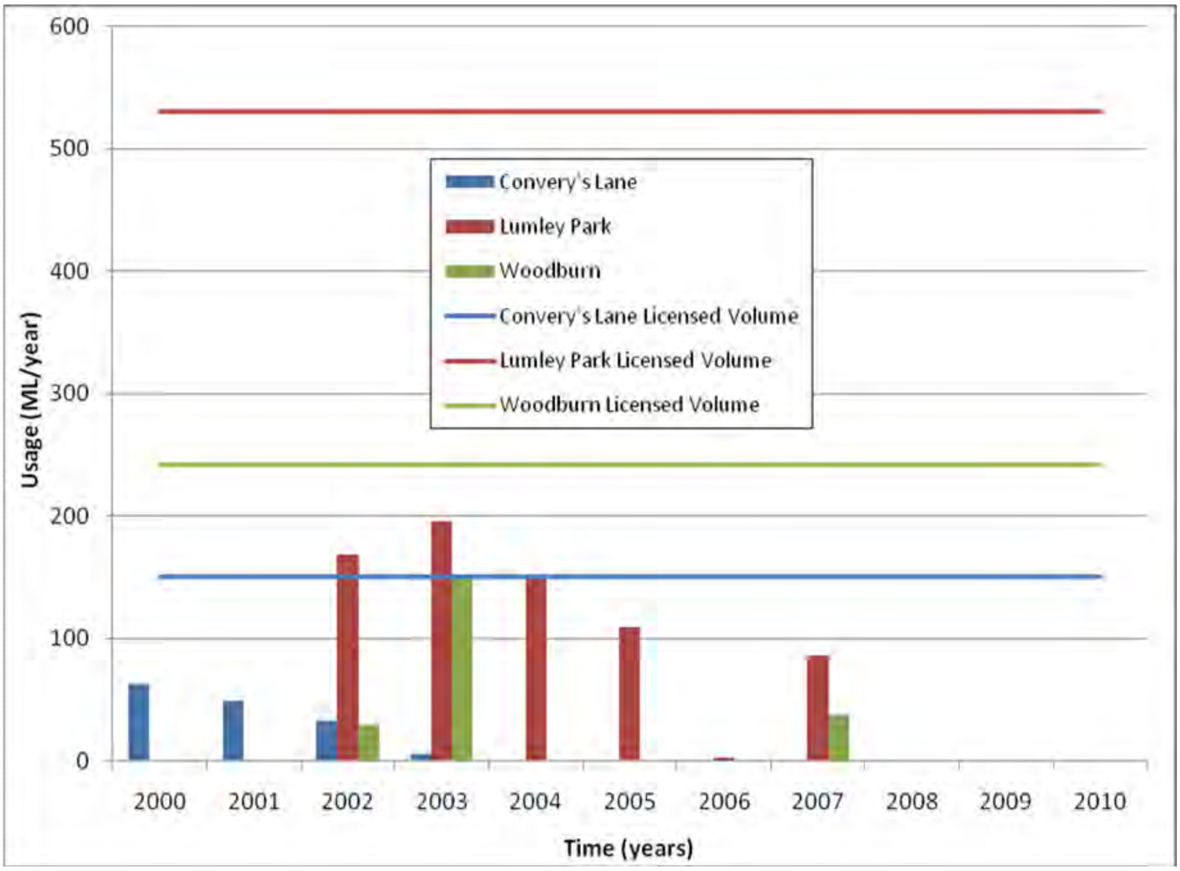


Figure 5-1 Convery's Lane, Lumley Park and Woodburn bores usage in ML/year from 2000 to 2010 (Rous Water, 2011)

Table 5-2 tabulates the licensed volume, maximum pumping capacity and maximum historical usage for each of the Rous Water bores. The maximum pumping capacity is considered to be the volume pumped at the bore yield, assuming 50% pumping duty throughout the year. This is considered to be the maximum feasible bore usage.

Currently however, none of the Rous Water bores are used to either their licensed volume or their maximum pumping capacity. For the Woodburn Bores and the Convery's Lane's bore the licensed volume is lower than the maximum pumping capacity, therefore to pump at maximum capacity additional entitlement volume must be approved by NOW. For the Lumley Park bore the current bore infrastructure does not allow it to be pumped to its full licensed volume.

Table 5-2 Usage versus potential of Rous Water bores in ML/year

Bore site	Licensed volume	Maximum pumping capacity *	Maximum historical usage	Theoretical max	Limiting factor
Woodburn	242^	584	148^	584	License
Convery's Lane	150	253	63	253	License
Lumley Park	530	224	196	224	Infrastructure

Notes: * Based on estimated potential yields (L/s) in Table 5-1, assuming 50% pumping duty
^ Combined volume for all three Woodburn Bores

5.1.3 Groundwater quality

Groundwater quality data was available for the Lumley Park bore between July 2004 and September 2007, with the range of values shown in Table 5-2. Groundwater samples from the Woodburn Bores 1 and 2, installed in 2002, were analysed and the results are shown in Table 5-2. The Australian Drinking Water Guidelines are shown for comparison.

The electrical conductivity (EC) of the groundwater in both Woodburn Bores and the Lumley Park bore is low and indicates fresh water quality (< 500 µS/cm).

Historically there have been problems with high iron levels in water from the old Woodburn Bores 1 and 2 (pers. comm. Robert Cawley, Rous Water, Feb 2011).

Table 5-3 Available groundwater quality data and guidelines

	Unit	NHMRC / NRMMC (2004) ADWG[1]	Lumley park – GW039387 (Jul 2004 – Sep 2007)	Woodburn – GW040868 (Nov 2002)	Woodburn – GW040869 (Nov 2002)
Field Parameters					
pH	pH units	6.5-8.5	6-8.49	6.5	6.2
EC	µS/cm	-	170-352	411	256
Major ions					
Chloride	mg/L	250[3]		97	49
Calcium	mg/L	-		3.8	1.1
Magnesium	mg/L	-		4.8	3.7
Potassium	mg/L	-		2.6	1.9
Sodium	mg/L	180[3]		61	42
Sulphate	mg/L	500[2]/250[3]		14	18
Bicarbonate as HCO3	mg/L	-		34	35
Carbonate as CO3	mg/L	-		<1	<1
Nutrients					
Nitrate as N	mg/L	11.3	0-0.65	<0.2	
Nitrite as N	mg/L	0.9	0-0.37		
Ammonia as N	mg/L	-	0.01-0.74		
Metals					
Iron	mg/L	0.3[3]		4.6	3.9
Manganese	mg/L	0.5[2]/0.1[3]		<0.02	0.02

Notes: 1 ADWG - Australian Drinking Water Guideline Criteria.
2 Criteria are based on health considerations. 3 Criteria are based on aesthetic considerations.

5.2 Potential impacts

All groundwater extraction results in some impact to groundwater levels in the short term. The long term impacts to groundwater levels need to be assessed in detail before any conclusion as to the level or duration of impacts can be made. Changes in groundwater levels can potentially impact on other users, including the environment. Increased usage of the Rous Water bores to their maximum licensed volumes will have an impact on groundwater levels and in some locations these impacts may be significant and at other locations they may be negligible. Significant impacts to groundwater levels could impact other groundwater users, including groundwater dependant ecosystems.

When comparing groundwater usage with groundwater levels, Figure 5-2 indicates that when the Convery's Lane bore was turned on, water levels in the deep basalt aquifer decreased immediately. Once the bore was turned off in 2003 groundwater levels increased by almost 20 m as shown in the water level graph for monitoring bore GW036702_4 (at NOW monitoring site 5), located close to the Convery's Lane bore. This indicates that the Convery's Lane bore is likely to have significant effects on other groundwater users, including GDE's and the environment.

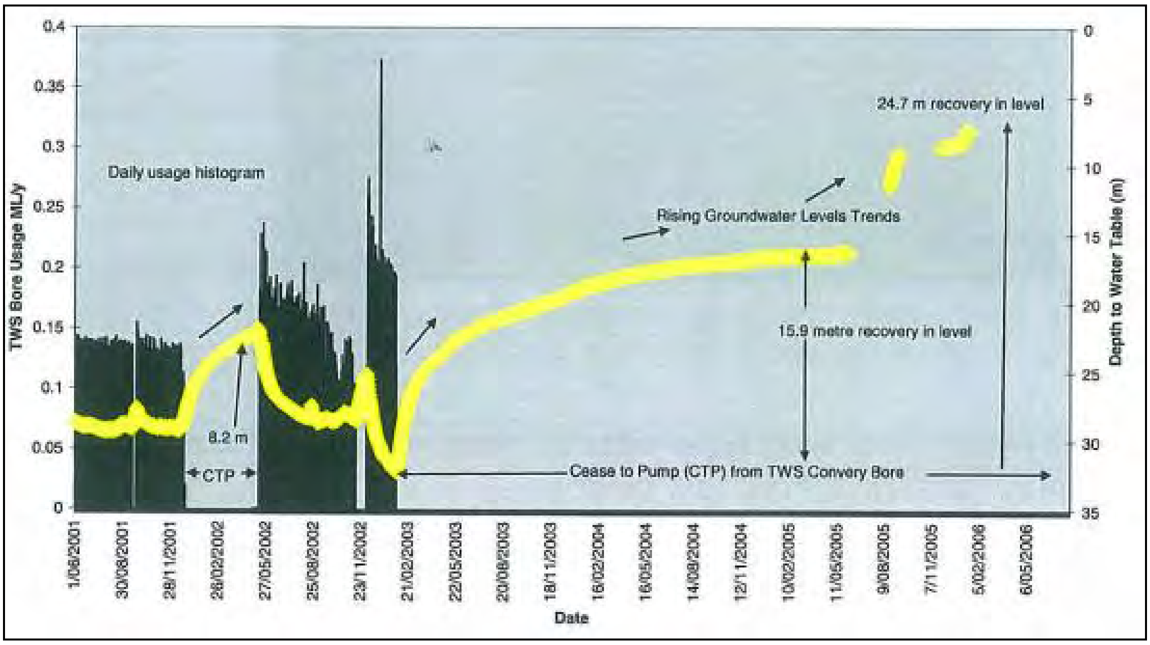


Figure 5-2 Convery's Lane bore usage and water levels for GW036702_4 (DNR, 2006)

Comparing groundwater usage with water levels, Figure 5-3 indicates that when the Lumley Park production bore was turned on, groundwater levels in the deep basalt aquifer monitoring bore were largely unaffected. They remained at 45 mbgl as shown in the water level graph for deep basalt monitoring bore GW081005 (at NOW monitoring site 1), which is located close to the Lumley Park bore. Furthermore, no impacts were observed in groundwater levels for the shallow basalt aquifer in monitoring bore GW081006 (also located at NOW monitoring site 1). Groundwater within the actual pumping bore, or in very close proximity to it, is likely to have been temporarily lowered during pumping.

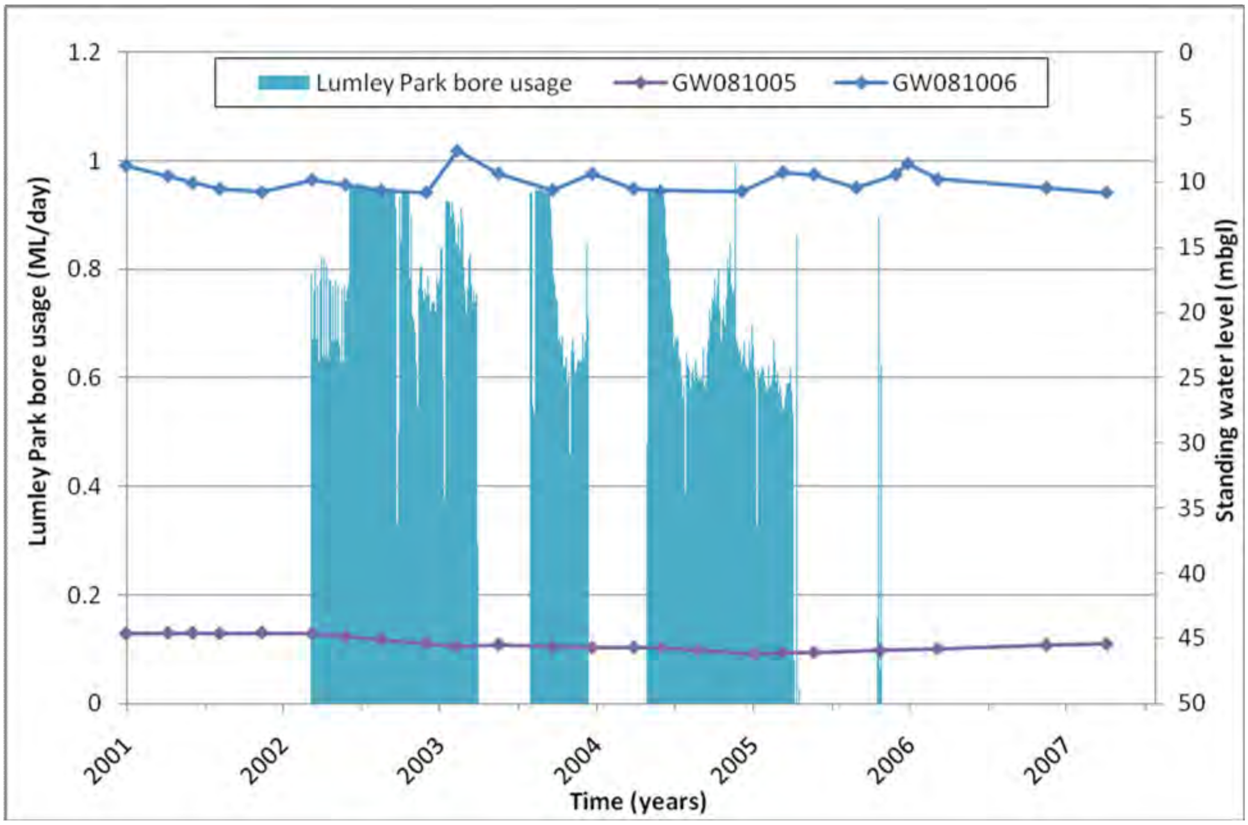


Figure 5-3 Lumley Park bore usage and water levels for GW081005 and GW081006

Pumping test results for Woodburn Bores 1 and 2 (GW040869 and GW040868) show a maximum drawdown of approximately 7.5 mbgl for a 24 hour test (DLWC, 2002a). It was recommended that standing water levels be monitored and accurate pumping records be kept to assess the aquifer performance over a longer period of time.

5.3 Recommendations

5.3.1 Testing and redevelopment to increase potential

Groundwater levels recorded for the Convery's Lane bore indicate a strong correlation to groundwater trends in the area. It is known that pumping at this location does impact local water levels and therefore there is potential to impact upon local users (both extractive users and the environment). It is therefore recommended that the Convery's Lane bore is used for emergency supply. NOW has advised that the license for this bore can be transferred within Zone 3 or to Zone 4, 5 or 6 within the Alstonville Basalt WSP area (pers. comm. John Findlay, NOW, Feb 2011). A full or partial transfer of the licence volume (either permanently or temporarily) would be another option for this bore licence. During pumping the Lumley Park bore did not appear to trigger a response in surrounding groundwater levels (see section 4.3) and therefore the impact to surrounding users is likely to be minimal. It is not recommended to transfer this bore licence as it is currently located within Zone 1 of the Alstonville WSP and water cannot be traded into Zone 1. It is recommended to investigate the existing infrastructure using a down-hole camera, as the bore has not been used for over 4 years. It is also recommended to conduct a pumping test on the bore to re-assess its safe yield and test the well efficiency with a step test. Because the bore has not been used consistently, the bore efficiency may have decreased if clogging of the screen has occurred.

the bore has not been used consistently, the bore efficiency may have decreased if clogging of the screen has occurred. If the screen is found to be clogged, the bore can be redeveloped to attempt to clean it out and improve efficiency. Cost estimates are shown in Table 5-4.

From a hydrogeological point of view, the Lumley Park bore and the Woodburn Bores could be used on a more regular basis and not only for drought relief water supply. The Lumley Park bore site supplies water to an area of expected population growth. However, Rous Water has advised that the Woodburn bores supply a small service area and population, so demand is limited. Also, adding water at the lower end of the mains may not be an efficient management option (pers. comm. Rob Cawley, Rous Water, Aug 2011).

Table 5-4 Cost estimates for bore assessment, pumping tests and monitoring program

Option	Bore assessment	Pumping test	Monitoring program
Lumley Park bore	$ 20k	$ 10k	$ 5k/year

Notes: Cost estimates are for contractors only and do not include supervision or management of contractors, analysis of pumping tests or reporting. The monitoring program is an indicative cost estimate, should Rous Water undertake this work internally.

5.3.2 Groundwater monitoring program

Groundwater level monitoring is undertaken by NOW for the Convery's Lane and the Lumley Park bores. It is however recommended that Rous Water undertake additional monitoring of groundwater levels (using data loggers) and quality for both the shallow and deep basalt aquifers at the Lumley Park bore if this bore will be used in future, since it is close to groundwater dependant ecosystems and other groundwater users. Monitoring bores GW081005, GW081006 and GW039384 (Rous Water monitoring bore) could be used for monitoring.

To improve knowledge of the baseline groundwater conditions in the area, Rous Water could undertake regular monitoring of bores (groundwater levels and quality) at the Woodburn site. This is particularly relevant if these bores are likely to be used in future. If no suitable monitoring bores are located in the area, these could be installed.

It is recommended that groundwater monitoring occurs on a monthly basis for groundwater levels and field parameters, including EC, pH, temperature and redox potential. Annual monitoring for a more comprehensive suite of analytes, including major ions, metals and nutrients is recommended to gain a better understanding of the groundwater quality and detect changes.

6. Potential groundwater bore sites

6.1 Opportunities and constraints

The opportunities and constraints for increasing the groundwater supply for Rous Water have been considered. Constraints and opportunities were assessed to identify prospective target areas for additional groundwater development using geospatial analysis. Prospective target areas (indicated with light purple) are shown on Figure 6-1.

Hydrogeology

The final yield from bores constructed within fractured or porous rock is largely dependent on the degree of fracturing and the interception of these fractures during drilling. Yields generally vary between 1 and 15 L/s depending on fractures intercepted and the bore construction. These fracture rock systems are considered to be viable aquifers, and can potentially produce volumes up to 235 ML/year from a single bore.

The final yield from bores constructed in the coastal sands is more uniform and bore yields could be expected to range between 5-15 L/s.

When installing bores in the fractured basalt and sandstone aquifers overlain by shallow alluvial deposits it is recommended to seal off these shallow aquifers during bore construction. The objective being, to prevent pumping bores from directly impacting creeks and GDE's.

Upon consideration of the likely yield of bores, licensing requirements and the groundwater quality of the various aquifers in the study area, the focus for increasing groundwater supply is;

- Fractured basalt
- Coastal sands
- Kangaroo Creek Sandstone.

Infrastructure

Consideration of practical options for increasing groundwater supply includes the actual on ground location for a bore, and the associated infrastructure requirements. The main highly prospective target areas considered the following criteria:

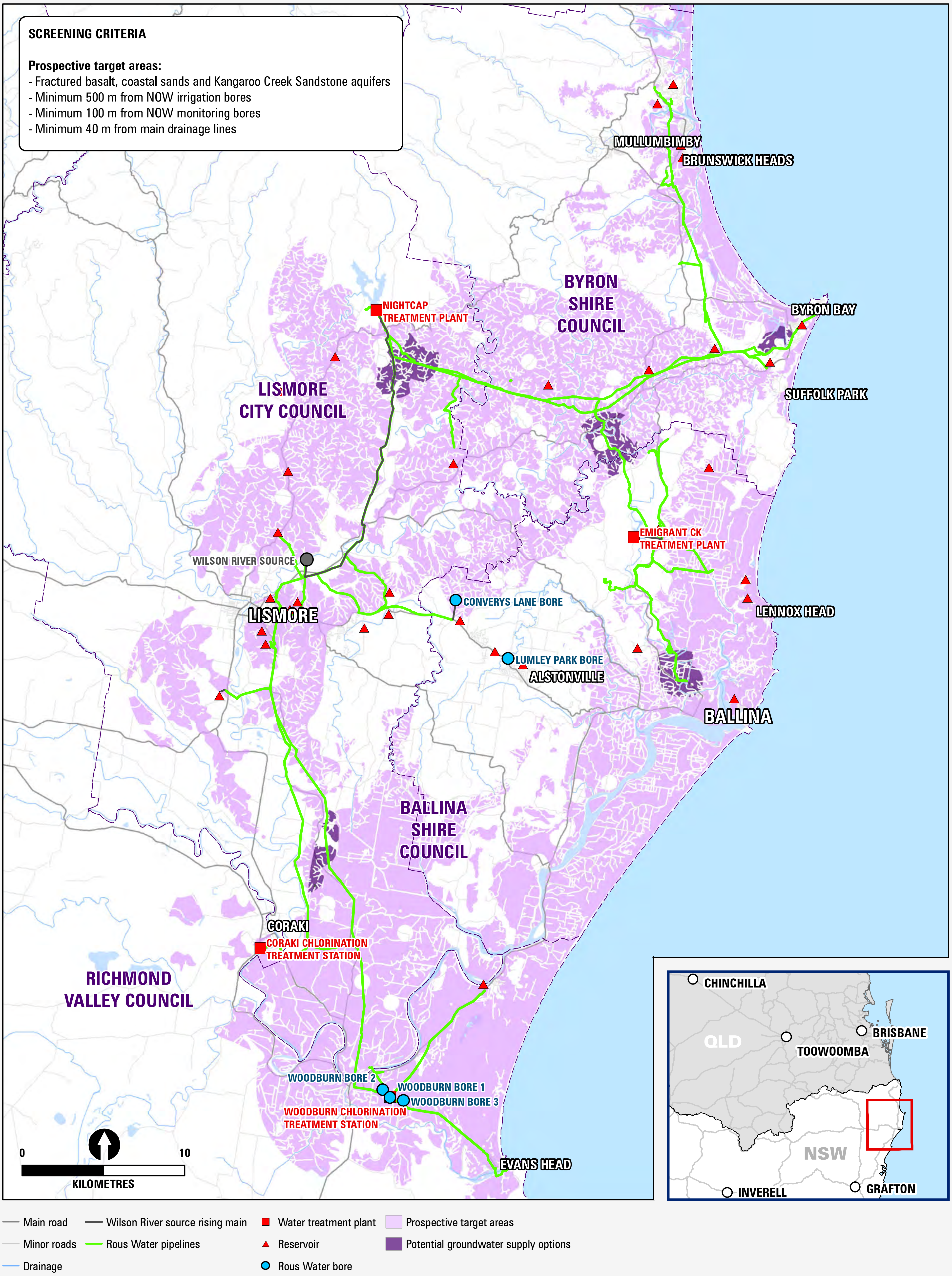
- Distance from existing groundwater bores. Minimum distance criteria of 500 meters from an existing irrigation bore and 100 metres from an existing NOW monitoring bores were used. These distance constraints are in accordance with current NSW licensing requirements for this study area.
- Distance from rivers and identified groundwater dependant ecosystems. A minimum distance of 40 m from the nearest stream or recognised GDE is assumed and this correlates to the recommendations from NOW.
- General and high level consideration of the known areas of demand and infrastructure constraints, although this was not the major focus of the study.

Embargoed areas (Zones 1 & 2 of the Alstonville WSP) and unsuitable aquifers were excluded.

Technical, environmental and social issues and potential risks as identified in the Future Water Strategy's feasibility assessment measures are included in provisions for the WMA 2000 and the WA 1912.

PARSONS BRINCKERHOFF

FUTURE WATER STRATEGY GROUNDWATER OPTIONS
ROUS WATER



Geology: © Copyright (2005) New South Wales Department of Primary Industries (Mineral Resources) / Monitoring sites (DNR, 2006) / Registered bore database search (NOW, 2011)

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Figure 6-1 Groundwater target areas

6.2 Groundwater target areas

Table 6-1 below shows specific target areas that are considered highly prospective and have the potential to be future groundwater supply options (also shown in dark purple on Figure 6-1).

Table 6-1 Potential groundwater supply options

Option (target area)	Production volumes^	Advantages	Disadvantages
Coastal sand aquifer near Ballina or Byron Bay	▪ Likely: 10 ML - 95 ML ▪ Max potential: 535 ML	▪ Growth areas ▪ Close to main pipe network ▪ Good water quality ▪ Reliable yield, typically 0.5-5 L/s, potential for 34 L/s	▪ Drawdown could potentially affect GDEs ▪ Potential high iron ▪ Potential saline intrusion
Alstonville Basalt North of Emigrant Dam in Zone 3 of the WSP	▪ Likely: 15 ML - 235 ML ▪ Max potential: 600 ML	▪ Close to main pipe network ▪ Good water quality ▪ Potential high yield (15 L/s, up to 38 L/s) ▪ Convery's Lane bore licence can be transferred to this site (in Zone 3)	▪ Within Alstonville Basalt WSP area, but can transfer licence from Convery's Lane ▪ Drilling costs will be higher ▪ Top aquifers will need to be sealed off to prevent negative impacts of shallow groundwater
North Coast Fractured Rock Basalt South of Rocky Creek Dam	▪ Likely: 15 ML - 235 ML ▪ Max potential: 600 ML	▪ Close to main pipe network ▪ No WSP ▪ Potential high yield (15 L/s, up to 38 L/s)	▪ Drilling costs will be higher ▪ Top aquifers will need to be sealed off to prevent negative impacts of shallow groundwater
Kangaroo Creek Sandstone between Lismore and Coraki	▪ Likely: < 16 ML ▪ Max potential: 160 ML	▪ Close to main pipe network ▪ Potential for good yields (10 L/s) ▪ No WSP	▪ Yields are variable ▪ Potential brackish water quality

Note: ^ = Based on estimated potential yields (L/s) in Table 3-1. Volumes are per bore, per year, assuming 50% pumping duty

The potential production volumes shown in the above table are based on 12 hr/day pumping duty, which is considered to be the maximum feasible operation duration. It is recommended that several groundwater supply bores could be installed in each target area to increase production volumes. Final volumes will depend on the safe yield, the number of bores, the hours each bore will be in operation, and licensing and legislative constraints.

Exploration drilling and aquifer testing would be required at these selected highly prospective target areas with a view to installing a water supply bore or borefield that feeds directly into the bulk water main or provides groundwater to local growth areas.

6.3 Cost estimate

For selected practical groundwater options shown in Table 6-1, an indicative cost estimate is provided for construction and ongoing operating costs (Table 6-2). This includes resource monitoring activities, but does not include costs for fully equipping the trial bore (i.e. pumps, electric controls and transfer infrastructure not included). Further work is required to provide more detailed cost estimates.

The monitoring program cost estimate allows for monthly monitoring of groundwater levels and field parameters, including EC, pH, temperature and redox potential. Annual monitoring for a more comprehensive suite of analytes, including major ions, metals and nutrients is also recommended to gain a better understanding of the groundwater quality.

Table 6-2 Cost estimates for test bore installation and pumping tests (per bore)

Option	Test bore	Pumping test	Monitoring program
Coastal sand aquifer	$ 33k	$ 8k	$ 5k/year
Alstonville Basalt or North Coast Fractured Rock Basalt	$ 35 k	$ 10k	$ 5k/year
Kangaroo Creek Sandstone	$ 35k	$ 10k	$ 5k/year

Notes: Cost estimates are for contractors only and do not include supervision or management of contractors, analysis of pumping tests or reporting. The monitoring program is an indicative cost estimate, should Rous Water undertake this work internally.

7. Conclusions and recommendations

Groundwater is capable of securing a significant water supply and is a viable addition to other water supply sources. The current groundwater supply infrastructure could be optimised to use allocated licenced volumes to their full potential and a new borefield could be installed to supply additional groundwater.

The groundwater resource assessment identified the fractured basalts and coastal sand aquifers as the most prospective based on their reliable and/or high yields and good water quality, with the Kangaroo Creek Sandstone also showing potential for water supply.

Rous Water's existing groundwater supply bores are not used to their full potential and the Lumley Park bore and the Woodburn Bores could be used on a more regular basis. However, Rous Water has indicated that Woodburn Bores do not service a demand area and are therefore not considered as optimal locations for increased use. It is recommended to use the Convery's Lane bore as an emergency supply due to the sensitivity that groundwater pumping has on local groundwater levels. One option may be to transfer all or part of this bore's licensed volume (permanently or temporarily) within Zone 3 of the Alstonville Basalt WSP area to an area which is less sensitive to groundwater extraction.

Highly prospective target areas for the augmentation of Rous Water's current groundwater licence entitlement were identified. Additional bore(s) could be sited within:

- Zone 3 of the Alstonville Basalt WSP,
- fractured basalt areas outside the Alstonville Basalt WSP area, and
- coastal sands aquifer or the Kangaroo Creek Sandstone in close proximity to the bulk water main or local growth areas.

A new borefield, in Zone 3 of the Alstonville Groundwater Source north of Emigrant Creek Dam, is considered to be a viable option for secure future groundwater supply. It is located close to the Treatment Plant at Emigrant Creek Dam and can be easily integrated in the current supply infrastructure. It has the potential to yield a maximum of 600 ML per year per bore.

It is recommended to liaise with NOW before new WSPs or Macro Plans are gazetted to ensure allocated licensed volumes for Town Water Supply can be incorporated in the new plans.

It is recommended to liaise with Ballina Shire Council regarding their groundwater licences and usage to investigate the potential for optimising this water supply.

It is noted that Permian Coal Measures that are explored for coal seam gas potential are present in the study area and these developments need to be considered when planning the development of any borefield.

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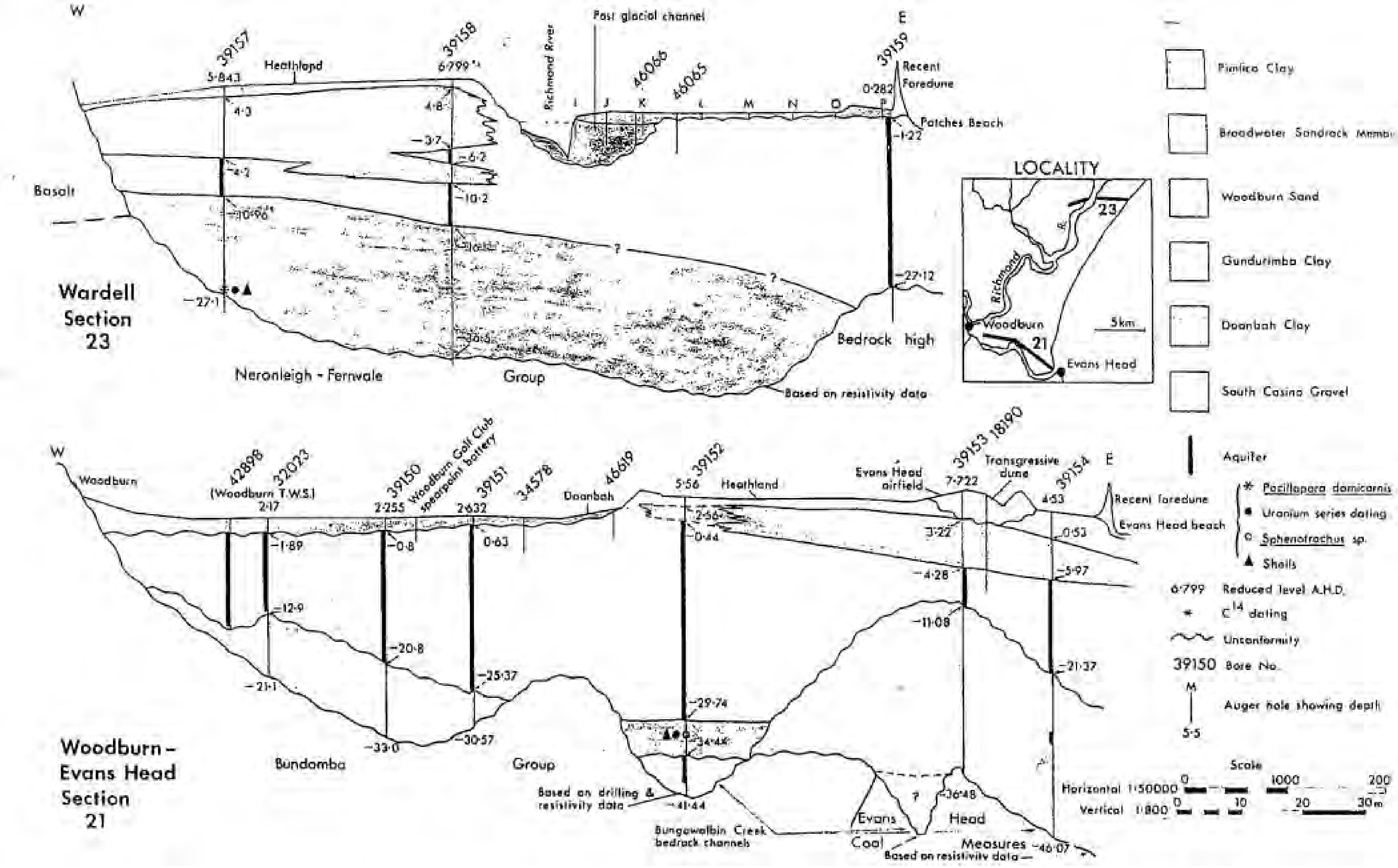
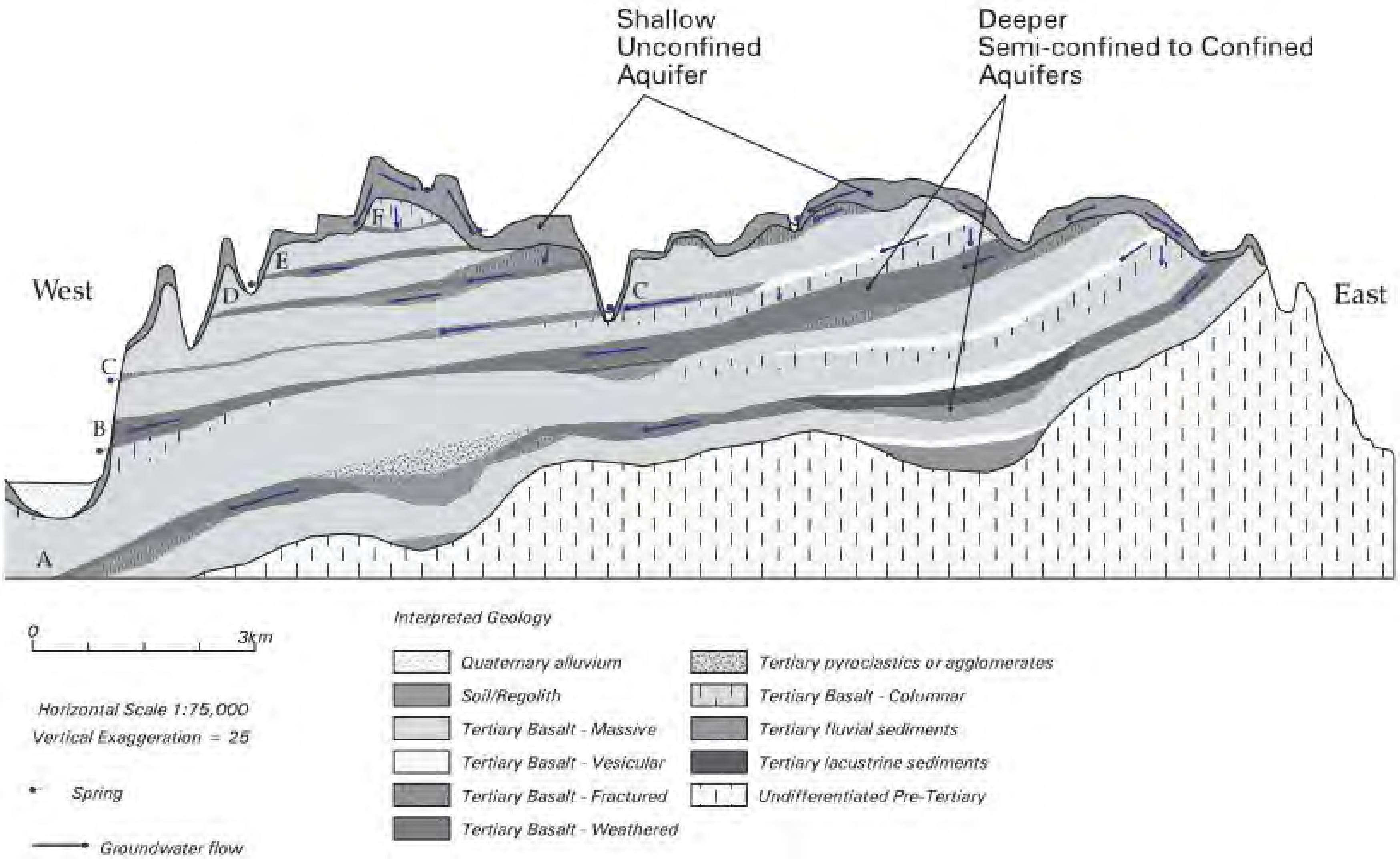
Appendix A

Geological cross-sections

Geological cross-section of the unconsolidated sediments at Wardell and Woodburn-Evans-Head (Drury, 1982)



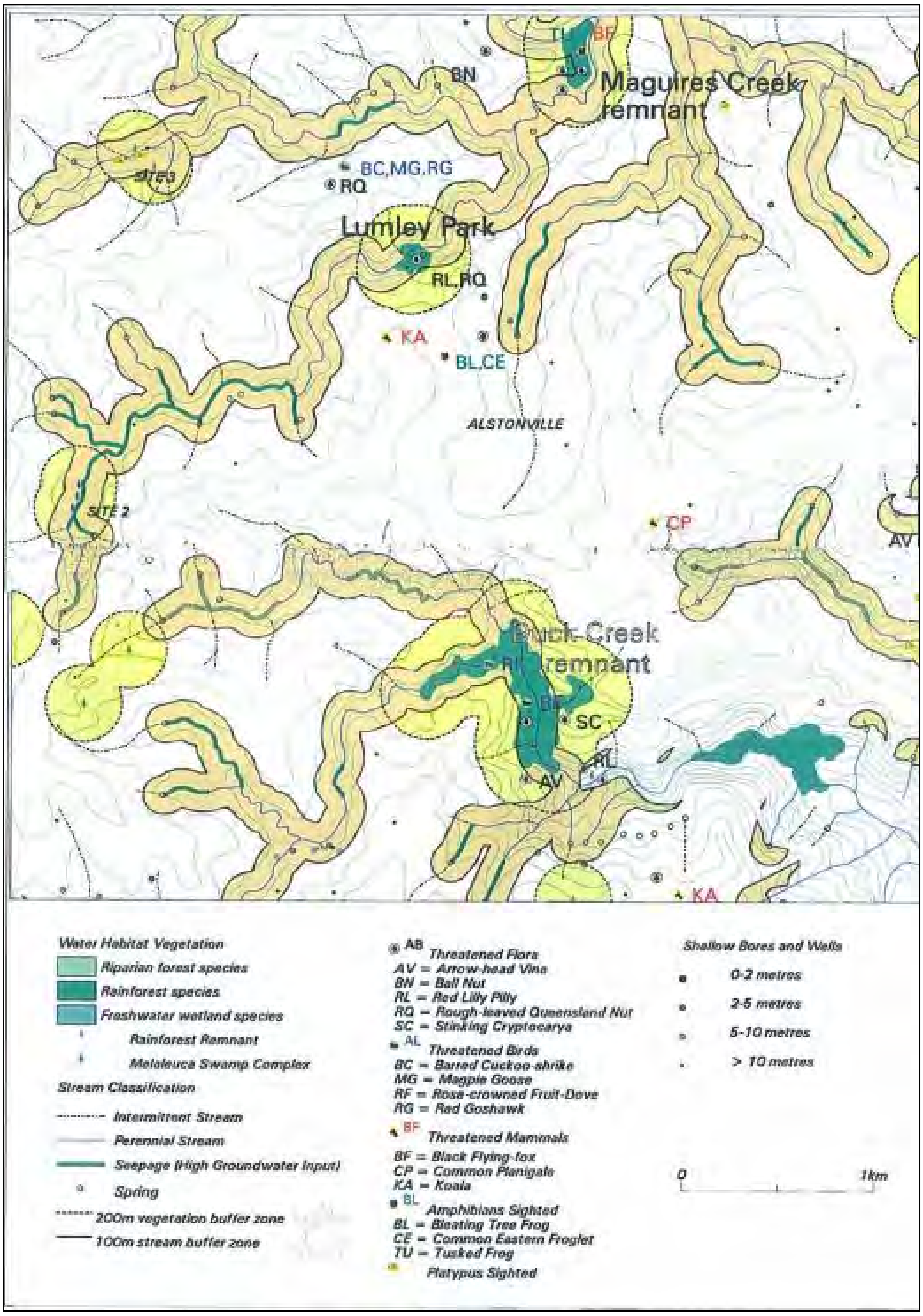
Conceptual model for groundwater flow in the Lismore Basalt (Brodie and Green, 2002)



Appendix B

Groundwater dependent ecosystems

Groundwater dependant ecosystem mapping near Alstonville (Brodie et al. 2002)



Appendix C

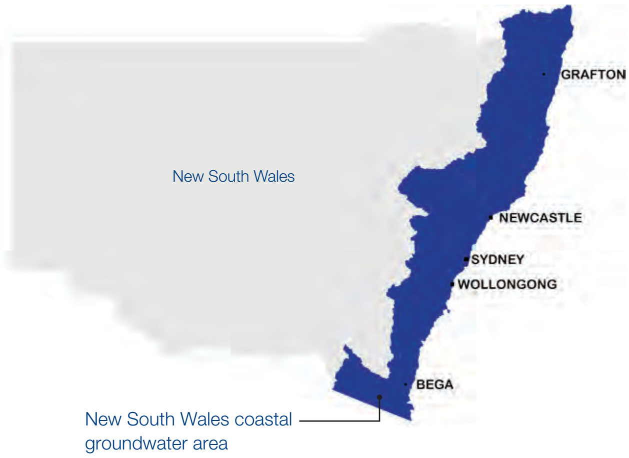
Test pumping groundwater assessment guidelines

NSW GOVERNMENT | Office of Water

Coastal groundwater

Test pumping groundwater assessment guidelines for bore licence applications

A pumping test to determine the possible yield of the subject bore and of the potential drawdown impacts is required to assess bore licence applications for the purpose of irrigation, industrial, recreation or commercial extraction from a groundwater source in the coastal groundwater area of NSW. All proponents of groundwater licence applications greater than 20 ML/year are requested to engage a *groundwater consultant* to manage a pumping test and report the results in accordance with the following guidelines. For all low yield bore licence applications seeking a volumetric entitlement of less than 20 ML/year (i.e. low volume uses) an assessment of the application details will be undertaken by the NSW Office of Water without the need for a pumping test.



APPLICATIONS FOR A LICENCE WITH A VOLUMETRIC ENTITLEMENT OVER 20 ML/YEAR

These guidelines apply if you are seeking a groundwater licence with a volumetric entitlement in excess of 20 ML/year (i.e. medium, high or very high volume uses) in coastal areas, where test pumping of the proposed water supply bore is mandatory. A test bore licence (currently under the *Water Act 1912*) is required from the NSW Office of Water in order to investigate the safe yield of the bore as part of the entitlement assessment. All pump tests are to be conducted in strict accordance with Australian Standard AS 2368 – 1990 Test Pumping of Water Wells. Pumping tests of durations between one day and 70 days are to be conducted depending on the volume of groundwater sought (see table 1).

A site specific *hydrogeological investigation report* is required in support of the application for medium, high or very high volume licences that includes:

- technical analysis of the pumping test information
- identification of the potential drawdown impacts of the proposed operation on neighbouring users and surrounding sensitive environmental assets.

The pump test program and reporting should be prepared and managed by a suitably qualified groundwater consultant experienced in irrigation or commercial water supply assessments.

The hydrogeological investigation report is to follow the standardised table of contents (see table 2), and is to include, but not be limited to, all of the aspects specified to allow a reasonable assessment of the proposed water supply operation to be undertaken. Failure to supply a detailed hydrogeological assessment of suitable quality will be taken into consideration in determining the entitlement to be authorised by the licence and will be capped at a maximum of 20ML/year.

For all pumping tests conducted, the annual volumetric entitlement will be calculated based on the rate at which the bore was tested.

All aspects of the bore installation and testing must comply with distance and operating rules as set by the test bore licence conditions. In some instances observation bore measurements will be required by the NSW Office of Water as part of the pumping test analysis. All raw data and the specialist report interpreting the results are to be provided to the NSW Office of Water in support of the licence application. The entitlement volume requested may not be granted if it can not be demonstrated that the bore is capable of yielding the required volume or if the amount sought will have significant impact on nearby users, including groundwater dependent ecosystems.

PUMPING TESTS

Table 1: NSW coastal pumping test assessment for application entitlement categories

Entitlement category	Assessment of application
LOW 0 - 20ML/year	■ Production bore licence obtained from the NSW Office of Water before drilling. ■ Entitlement allocated on basis of average bore yields in the area and demonstrated need (i.e. required water usage). ■ Drawdown impacts of pumping on neighbouring areas considered. ■ Requested entitlement subject to reduction if insufficient information provided. ■ Entitlement review allowed with provision of additional information ■ Driller - conducted airlift of minimum 1 hour duration clearly reported on Form 'A' – Particulars of Completed Bore ■ Entitlement validated on receipt of Form 'A' completed to reasonable standard.
MEDIUM 21 - 50ML/year	■ Test bore licence to be obtained prior to drilling. ■ Constant rate test (greater than or equal to operating rate) or constant rate and step test to be completed to a reasonable standard. ■ 1 day pumping duration (minimum) ■ 1 day recovery (unless full recovery achieved earlier) ■ Drawdown and recovery measurements from observation bores may be required. ■ Specialist hydrogeological consultants report required completed in accordance with standardised table of contents. ■ Entitlement allocated on basis of demonstrated need. ■ Requested entitlement subject to reduction if insufficient information provided. ■ Entitlement review allowed with provision of additional information
HIGH 51 - 100ML/year	As above with the following modifications: ■ 7 day pumping duration (minimum) ■ 7 day recovery (unless full recovery achieved earlier).
VERY HIGH >100ML/year	As above with the following modifications: ■ 70 day pumping duration (minimum) ■ 70 day recovery (unless full recovery achieved earlier) ■ Drawdown and recovery measurements from observation bores are mandatory.

In preparing for and conducting the pumping tests, attention is to be paid to the following:

- Additional permits or authorisations may be required to allow ancillary activities associated with the test pumping to be undertaken (section 3.1 of the Australian Standard AS 2368–1990 Test Pumping of Water Wells).
- The duration of the test is to be of sufficient length to identify the presence of recharge or barrier boundaries that may influence the long-term yield of the bore (section 3.3 of the Australian Standard AS 2368–1990 Test Pumping of Water Wells).

- Multiple aquifer tests may be required to demonstrate that the identified yield of the bore can be sustained without adverse impacts on individual water bearing zones or groundwater sources (section 5.5 of the Australian Standard AS 2368–1990 Test Pumping of Water Wells). Seek advice from the NSW Office of Water if in doubt.
- Discharge of pumped water is to be controlled so that it does not generate a hazard or damage the environment (section 3.2 of the Australian Standard AS 2368–1990 Test Pumping of Water Wells).
- Specific information is to be presented to enable an assessment of the data collected (section 8.2 of the Australian Standard AS 2368–1990 Test Pumping of Water Wells).

GROUNDWATER CONSULTANCY REQUIREMENTS

Table 2: Information required for the assessment of a water licence application (Hydrogeological investigation report standardised table of contents)

Chapter	Section	Specifics
Certification		Groundwater consultant (qualified)
Introduction		Details of the property location, including the relevant cadastral information. Identification of the proposed development and the purpose for which the licence is being sought.
Geology		Geological description of the property and surrounding region, including the identification of any stratigraphic boundaries or structural features that may influence groundwater availability.
Hydrogeology	Setting	Description of the type of aquifer and a summary of typical water bearing zones encountered in test bores in the vicinity of the property.
	Licensed works	Details of licensed water supply bores within one kilometre of the property including purpose and likelihood of being impacted should the proposed development proceed.
	Environment	Identification of ecosystems likely to be groundwater dependent, surface water systems that could be affected by reductions in discharge with prolonged pumping, with particular identification of sensitive ecosystems of special conservation value.
Field work	Test bore establishment	Details of the drilling and construction of the subject bore, identifying the test bore licence under which it was authorised. A statement of compliance with the Minimum Construction Requirements for Water Bores in Australia – Second Edition 2003 or subsequent equivalent guideline.
	Test pumping and recovery	Measurements and graphical analysis documentation of drawdown and recovery data for pumping and observation bores. Calculated aquifer transmissivity and storativity values, together with bore efficiency estimates. Details of the water quality tests undertaken to demonstrate the groundwater is suitable for the intended purpose. A statement indicating that the test was conducted in compliance with Australian Standard AS 2368–1990 Test Pumping of Water Wells.
Impact assessment	Sustainability	Predictions of the impacts of pumping of the subject bore on neighbouring licensed users and potential groundwater dependent ecosystems based on the required controlled test pumping, together with the predicted effects on groundwater levels for the region surrounding the subject property and the potential to affect discharge to surface water systems.
	Trigger levels	Identification of the threshold drawdown levels adopted to prevent impacts on neighbouring bores or ecosystems, and estimations of the maximum drawdown impact on neighbouring bores, monitoring bores and ecosystems with and without trigger levels being active.
	Management responses	Actions to be taken if threshold levels are reached or exceeded, including reporting to regulatory authority, cease-to-pump conditions, and provision of water to affected users.

Table 2 continued: Information required for the assessment of a water licence application

Chapter	Section	Specifics
Operation	Schedule	Identification of the proposed operating regime including discharge rate and hours of pumping.
	Monitoring	Descriptions of the location of monitoring bores, the frequency at which monitoring is to be undertaken and the type of data to be collected.
	Reporting	Details of the timing of reports, the type of information to be reported to the regulatory authority, the number and nature of exceedances and response times between an occurrence and management actions being implemented, and methodologies to be adopted to mitigate impacts should they be ongoing.
Constraints		Identification of any consent conditions imposed by council or other regulatory authority that would prevent the requested entitlement being realised in full for the purpose for which the licence is being sought. In particular, conditions limiting the supply of water to other parties are to be identified.
References		Citations of all documentation referred to within the report.
Figures		All diagrams referred to within the report, including a locality map, a plan of the property identifying separation distances between the subject bore and site boundaries or other features (especially suspected groundwater dependent ecosystems, licensed works and surface water bodies), geological map and sections, together with a plan illustrating the extent of predicted drawdown during the proposed pumping operation. Specific inclusions as laid out in Australian Standard AS 2368–1990 Test Pumping of Water Wells.
Appendices		Raw data (spreadsheet data may be requested) and additional diagrams or text required to provide background or support to the findings of the investigation.

All water bores are to be installed by an appropriately licensed water bore drilling contractor and in accordance with the Minimum Construction Requirements for Water Bores in Australia – Second Edition 2003.

WHERE DO I GO FOR ADDITIONAL INFORMATION?

Find out more about groundwater and bore licence applications at www.water.nsw.gov.au

CONTACT US

Contact a water licensing officer at a local office listed on our website, free call the licensing information on 1800 353 104 or email information@water.nsw.gov.au

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