GOULBURN-MURRAY WATER

Lower Campaspe Valley
Water Supply Protection Area

Technical Report

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Table of Contents

List of Figures

List of tables

1 Introduction

1.1 Purpose

The Minister for Water appointed a consultative committee to draft a groundwater management plan (GMP) for the Lower Campaspe Valley Water Supply Protection Area (WSPA) in October 2010. Goulburn-Murray Water (G-MW) was responsible for coordinating the development of the draft plan. The Minister provided the consultative committee with guidelines for the preparation of the draft plan.

G-MW appointed a Technical Working Group (TWG) to provide the consultative committee with the best available technical advice, with reference to current policy, to enable informed decision making to address the matters contained in the Ministerial guidelines. The TWG comprised Dr Phillip Macumber (Phillip Macumber Consulting), Rob Rendell (RMCG), Simon Baker (Department of Sustainability and Environment), Rohan Hogan (North Central Catchment Management Authority) and Brendan Cossens and Luke Richards (G-MW). The Technical Working Group benefited from discussions with the Consultative Committee who were able to provide local input and validate technical assumptions.

This report summarises the output from the Technical Working Group, which were communicated to the consultative committee through a series of discussion papers. The consultative committee was also provided with the more detailed reports that underpin the output from the Technical Working Group, including Macumber (2008a, 2008b), Aquade (2011), G-MW (2010, 2012).

1.2 Background

The Campaspe Deep Lead WSPA GMP was developed in 2003. In July 2007, Goulburn-Murray Water (G-MW) established the Campaspe Groundwater Reference Committee to undertake a review of the Plan.

The review considered the changes in policy and legislation and technical data gathered to better understand aquifer response to groundwater extractions and climate.

Issues identified with the Campaspe Deep Lead WSPA GMP included:

- the existing WSPA boundary did not fully cover the aquifer;
- the GMP involved complex restriction process that failed to accommodate for the dry conditions experienced since Plan implementation; and
- restricted trading opportunities.

The review also presented a number of management proposals for consideration in future management.

The Lower Campaspe Valley WSPA WSPA was declared in July 2010 based on the outcomes of the review of the Campaspe Deep Lead WSPA GMP (G-MW, 2010).

2 Strategic context

2.1 Policy considerations

The Minister for Water's guidelines for the Lower Campaspe Valley Water Supply Protection Area WSPA Consultative Committee (Appendix A) require the consultative committee to have regard to relevant water policy and planning while drafting the GMP. This includes the following relevant national, state and regional water policy and planning initiatives:

- National Water Initiative (NWI)
- Murray Darling Basin Plan
- *Water Act 1989*
- *Our Water Our Future*: the Victorian Government's long-term plan for water
- the *Northern Region Sustainable Water Strategy* (NRSWS) and other regional sustainability water strategies.

2.2 Discussion

National Water Initiative

The National Water Initiative (NWI) was established in 2004 to improve water management throughout Australia. The overall objective of the NWI is to achieve a nationally compatible market, regulatory and planning system for managing surface and groundwater resource (for rural and urban use) for Australia. This system will optimise economic, social and environmental outcomes. Under the NWI, state governments have committed to undertake a number of actions in water planning.

A commitment of NWI is to prepare water plans. A GMP for Lower Campaspe Valley WSPA fulfils this commitment for this area.

The NWI objectives that are most relevant to the development of the Lower Campaspe Valley WSPA GMP are:

- progressive removal of barriers to trade in water and clarify the assignment of risk arising from future changes in the availability of water
- recognise the connectivity between surface and groundwater resources and manage connected systems as a single resource
- water accounting to provide information for planning, monitoring, trading, environmental management and on-farm management
- addressing future adjustment issues that may impact on water users and communities.

The Murray-Darling Basin Plan

Legislation passed by the Commonwealth in 2007 (*Water Act 2007*) requires preparation of a Murray-Darling Basin Plan. The purpose of this plan is to provide an approach to managing water resources of the Murray-Darling Basin in a way that can be sustained through time and in the national interest.

The effects of the proposed Murray-Darling Basin Plan on the Lower Campaspe Valley GMP is not yet clear, but the *Proposed Basin Plan* released in November 2011 provides an indication of the Basin Plan's impact.

The *Water Act 2007* requires state water plans, such as the Lower Campaspe Valley WSPA GMP, to be accredited by the Commonwealth Minister for Water. The Basin Plan will set out the requirements with which state water plans will need to comply in order to be accredited. The requirements will include the mandatory requirements of the *Water Act 2007* (Commonwealth) which are:

- identification of the water resource plan area
- how the long-term annual diversion limit will be applied in the water resource plan area
- how the water resources of the area will be sustainably used and managed within the sustainable diversion limit
- how significant interception activities will be regulated or managed and possibly changed
- planning arrangements for environmental watering
- the water quality and salinity objectives for the plan area
- the water trade arrangements
- how risks to the water resources will be addressed
- metering and monitoring arrangements for the water resource
- reviews of the water resource plan and amendments arising from reviews
- the information and models upon which the water resource plan is based.

There may be other requirements set out by the Murray Darling Basin Authority for accreditation of management plans.

The Water Act 1989

The *Water Act 1989* (Victoria) is the central legislation for managing Victoria's water resources. Most relevant to development of the Lower Campaspe Valley WSPA GMP are:

- requirements for a WSPA and a management plan (Part 3, Division 3)
- permissible consumptive volumes (PCVs) (Part 3, Division 1)
- licensing of groundwater (Part 4, Division 2)
- licensing of bores and other works (Part 5, Division 2).

Figure 1 shows the water entitlement framework for Victoria, which describes the variety of rights to water that can be granted in Victoria. The circled boxes are most relevant to the Lower Campaspe Valley WSPA GMP. Other rights to water in the framework apply to regulated surface waters, the environment and urban water supplies.

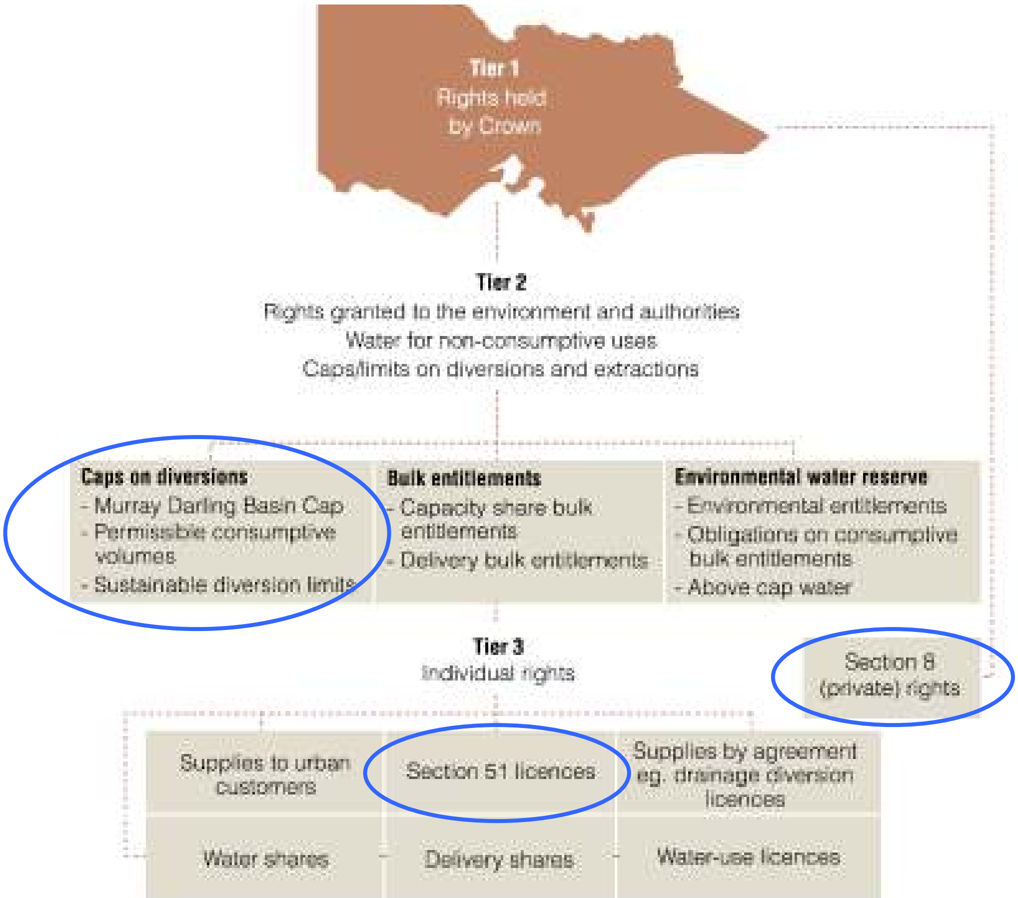


Figure 1 Victoria's water entitlement framework

An entitlement to take and use groundwater is granted through a section 51 licence. This licence allows a person to take a certain volume of groundwater and places some conditions on the taking and use of the water. The *Water Act 1989* (the Act) sets out the matters that must be taken into account when deciding whether or not to grant a licence (section 53, including section 40).

A PCV has been declared for the Lower Campaspe Valley WSPA. It acts as a cap on the taking of groundwater by not allowing the issue of new licence entitlement above the PCV.

Some taking of water does not require licensing. Section 8 of the *Water Act 1989* allows water to be taken under a private right for domestic and stock uses.

The construction, operation and removal of works, such as groundwater bores, require a licence under section 67 of the Act. The Act sets out the matters that must be taken into account when deciding whether or not to grant a licence for the works (section 68, including section 40).

Goulburn-Murray Water is the Minister's delegate for issuing licences for surface water, groundwater and works in the Lower Campaspe Valley WSPA.

Our Water Our Future

In 2004 the Victorian Government put in place a long-term plan for water, called *Our Water Our Future*. It set out 110 actions for sustainable water management across the state.

The policy included fundamental principles for water management in Victoria:

1. The management of water will be based on an understanding that a healthy economy and society is dependent on a healthy environment.
2. The Government will maintain overall stewardship of all water resources irrespective of source, on behalf of all Victorians.
3. Water authorities will be retained in public ownership.
4. Users of the services our water systems provide should, wherever practical, pay the full cost, including infrastructure, delivery and environmental costs associated with that service.
5. The water sector, charged with managing our water systems, will be capable, innovative and accountable to the Victorian community.

Regional Sustainable Water Strategies

Our Water Our Future committed to undertaking regional sustainable water strategies for long-term water planning across Victoria. There are four regional water strategies: Central region, Northern region, Western region and Gippsland region.

Each sustainable water strategy provides a stock-take of all the water resources available in the region, identifies potential challenges and risks to water resource management and outlines planning and actions needed to ensure water resources are secured into the future.

The Northern Region Sustainable Water Strategy (NRSWS) was completed in November 2009. It contains overarching principles and policies that should be taken into account in the development of the Lower Campaspe Valley WSPA GMP. Relevant actions of the NRSWS are:

- defining areas and limiting entitlement volumes in groundwater systems (Action 4.11)
- management of dairywash licences (Action 4.14)
- requirement for policies and standard conditions and improved records for section 51 take and use licences
- committed to the Lower Campaspe Valley WSPA GMP (Action 4.8)
- committed to the development of appropriate restriction policies in management plans and exploration of the merits of seasonal allocations rather than restrictions for appropriate groundwater systems (Action 4.12)
- continued recognition of unused section 51 licences (sleeper licences) (Policy 4.2)
- establishes carryover rules for groundwater (Action 5.5)
- improved trading rules (Action 5.6)
- groundwater/surface water interaction (Action 4.9).

The Victorian Government has also released regional sustainable water strategies for the Western region (WRSWS) and the Gippsland region (GRSWS). Although these regional strategies do not deal directly with northern Victoria, some of their actions and policies are relevant to groundwater planning in Lower Campaspe Valley WSPA, including:

- Proposal 4.4 (WRSWS) & Proposal 4.5 (GRSWS) The Department of Sustainability and Environment and rural water corporations will declare WSPAs and develop a management plan for highly stressed or utilised systems if:

- There is a need to amend licence volumes or conditions
- Permanent or ongoing restrictions on licensed extraction are required to protect consumptive licences, domestic and stock use or the environment
- The overall licensed volume needs to be reduced.

Local management plans and rules will be prepared for all other areas.

- Proposed policy 5.1 (WRSWS) Groundwater management in Victoria will:
  - align management units with groundwater systems to ensure management decisions are better informed by the major influences on those systems
  - adapt to climate change and variable groundwater availability by applying annual and longer-term processes to protect the resource base and meet the needs of water users and the environment
  - improve the way we identify groundwater dependent ecosystems and protect them in allocation and management decisions
  - recognise and account for all significant groundwater use
  - continuously improve, as we find out more about the resource
  - provide users with the means to manage the risk of future variability in groundwater supplies through water trading and, wherever possible, the ability to carryover unused water from year to year.
- Proposal 5.1 (WRSWS). The Department of Sustainability and Environment will work with water corporations to review and revise the boundaries of groundwater management units (GMUs). The revised boundaries will incorporate all areas of the region and better reflect the full extent of groundwater resources being managed (spatially and by depth).
- Proposal 5.4 (WRSWS): Clear management objectives for each GMU will be developed in consultation with water users, the catchment management authorities and the community for inclusion in local management rules or management plans, when these rules or plans are developed or amended. Management objectives will be based on the hydrogeological characteristics of the water resource and will aim to balance:
  - protection of the resource, including water quality, aquifer characteristics, resource interconnections and interference with other water users
  - environmental values including wetlands, streams and estuaries
  - economic values including regional investment and economic development
  - other social values such as critical needs and water available for future generations.
- Proposal 5.7 (WRSWS) and Proposal 5.5 (GRSWS). Groundwater dependent ecosystems (GDEs) will be managed through a risk-based approach. The following principles will guide how GDEs should be considered:
  - Where possible, the watering requirements for GDEs will be considered explicitly when setting or adjusting permissible consumptive volumes.

- GDEs with high value, at high risk and with a degree of connection between surface water and groundwater will be provided the highest level of protection.
- GDEs that rely on regional and intermediate scale groundwater systems will be included in GMP. This will consider the time lags between action and effects on GDEs. Groundwater planning outcomes to protect GDEs may include triggers, restriction rules and zones incorporated into a GMP.
- GDEs that rely on the surface expression of local scale groundwater systems will be assessed site by site at a local scale in the licensing regime, for example through conditions on licences. This will be included in the management planning process.
- GDEs at low risks will be managed indirectly through licensing decisions within existing requirements of Section 40 of the *Water Act 1989.*

- Proposed policy 5.3 (WRSWS) & proposed policy 5.7 (GRSWS). Climate change impacts on groundwater resources must be part of all resource appraisals using the most current available information. Management responses in management rules and plans should allow for adaptation to predicted climate change impacts on the groundwater resource.
- Proposed policy 5.4 (WRSWS) & Proposal 5.11 (GRSWS). Systems with high groundwater and surface water interaction will be identified and integrated management plans prepared where appropriate.
- Proposal 5.9: Groundwater trading will be further developed by:
  - Ensuring new groundwater management unit boundaries are set having regard to the need to enable trade to occur, as far as practical, between interconnected systems.
  - Finalising management plans (or local management rules) for all groundwater WSPAs in the region to resolve the water-sharing issues and trade rules required for sustainable management.
- Proposal 5.2 (GRSWS) & Proposal 5.3 (WRSWS). If required, annual processes will be used to reduce groundwater use to match water use to water availability and to minimise the risk of the resource being over-used. These arrangements may include annual restrictions and allocations from existing entitlements that can be extracted annually. The introduction of annual restrictions will be based on triggers set out in management plans and/or local management rules to ensure equitable and long-term sustainable use.

3 Lower Campaspe Valley

3.1 Location

The Lower Campaspe Valley WSPA extends from Lake Eppalock in the south to the Murray River in the north. It includes the towns of Axedale, Goornong, Elmore, Rochester, Lockington and Echuca covering an area of approximately 2100 km^2 (Figure 2). It includes the former Campaspe Deep Lead WSPA; part of the Southern Campaspe Plains Groundwater Management Area (GMA); and unincorporated area north to the Murray River and to the west of Lockington.

3.2 Background

The former Campaspe Deep Lead WSPA was formed from the amalgamation of the Diggora and Echuca South GMAs in 2003. The Diggora and Echuca South GMAs were established by the then Department of Natural Resources and Environment due to the high level of groundwater development in the area (DSE, 1998a, 1998b).

The Campaspe Deep Lead WSPA (CDLWSPACC, 2003) covered the most intensively developed aquifers in the Campaspe valley. This included the Calivil Formation and Renmark Group (comprising the Deep Lead) and Shepparton Formation from Runnymede in the south to Echuca in the north.

It should be noted that shallow bores (<25 m) are managed under the Shepparton Irrigation Region (SIR) WSPA GMP (SIRWSPACC, 1997) and the Campaspe West Salinity Management Plan where the areas overlapped with the Campaspe Deep Lead WSPA (CWSIG, 1992).

The former Southern Campaspe Plains GMA was established in 2007 in response to increased demand for groundwater and observed aquifer stress in the Campaspe Deep Lead WSPA. The Southern Campaspe Plains GMA, which includes the former Ellesmere GMA, extended south of the Campaspe Deep Lead WSPA, from Runnymede to Lake Eppalock, and included the Huntly Deep Lead.

3.3 Boundary

Key considerations for setting the boundary of the Lower Campaspe Valley WSPA included:

1. spatial extent of groundwater system
2. groundwater availability and sustainable yield
3. vertical connection between the Shepparton Formation, Calivil Formation and the Renmark Group
4. groundwater salinity
5. ease of communication

The spatial extent of the aquifer system has been mapped by SKM (2011), which illustrate that aquifers are constrained in the south by outcropping bedrock and broaden with distance to the north (Figure 3).

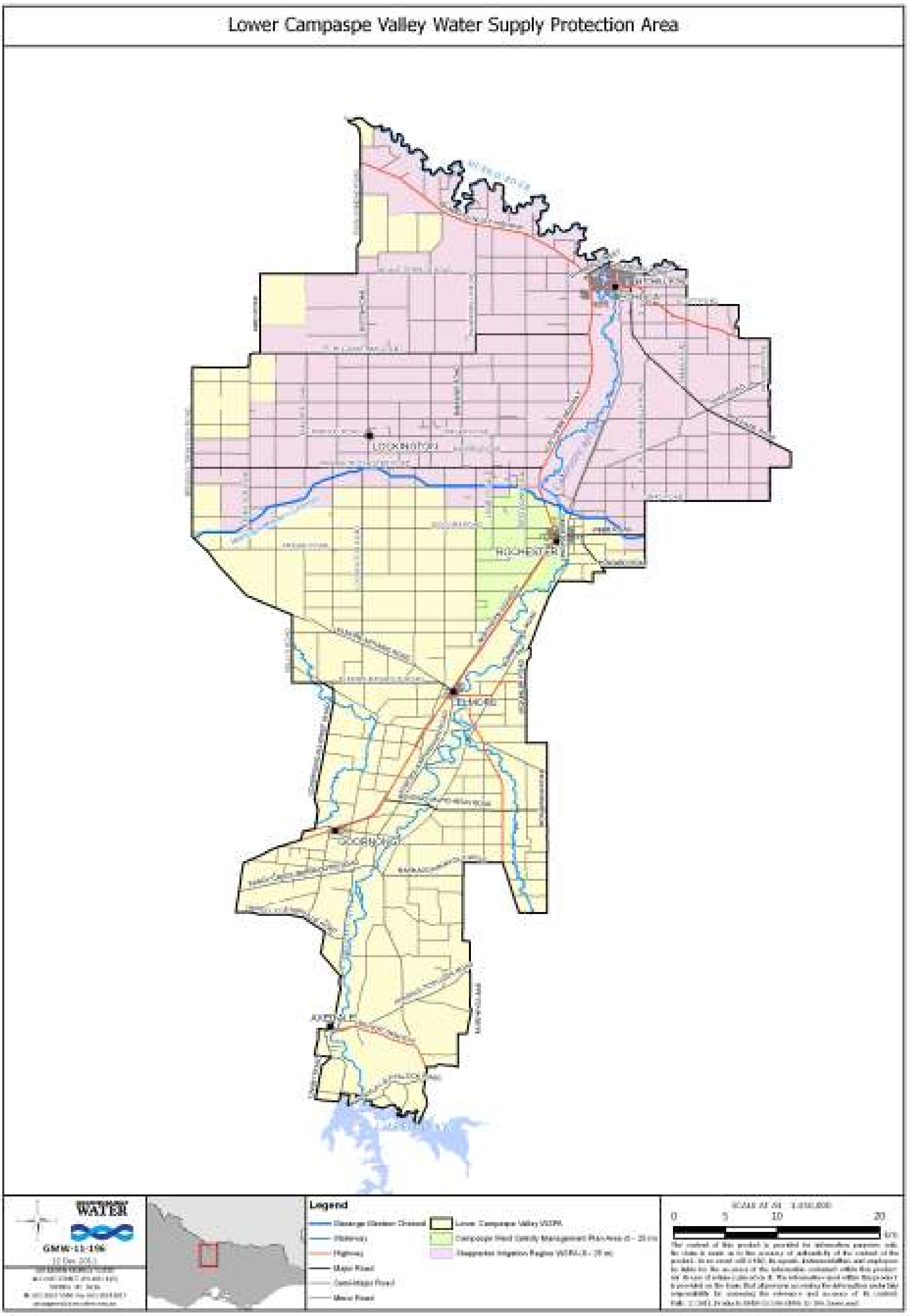


Figure 2 Lower Campaspe Valley WSPA

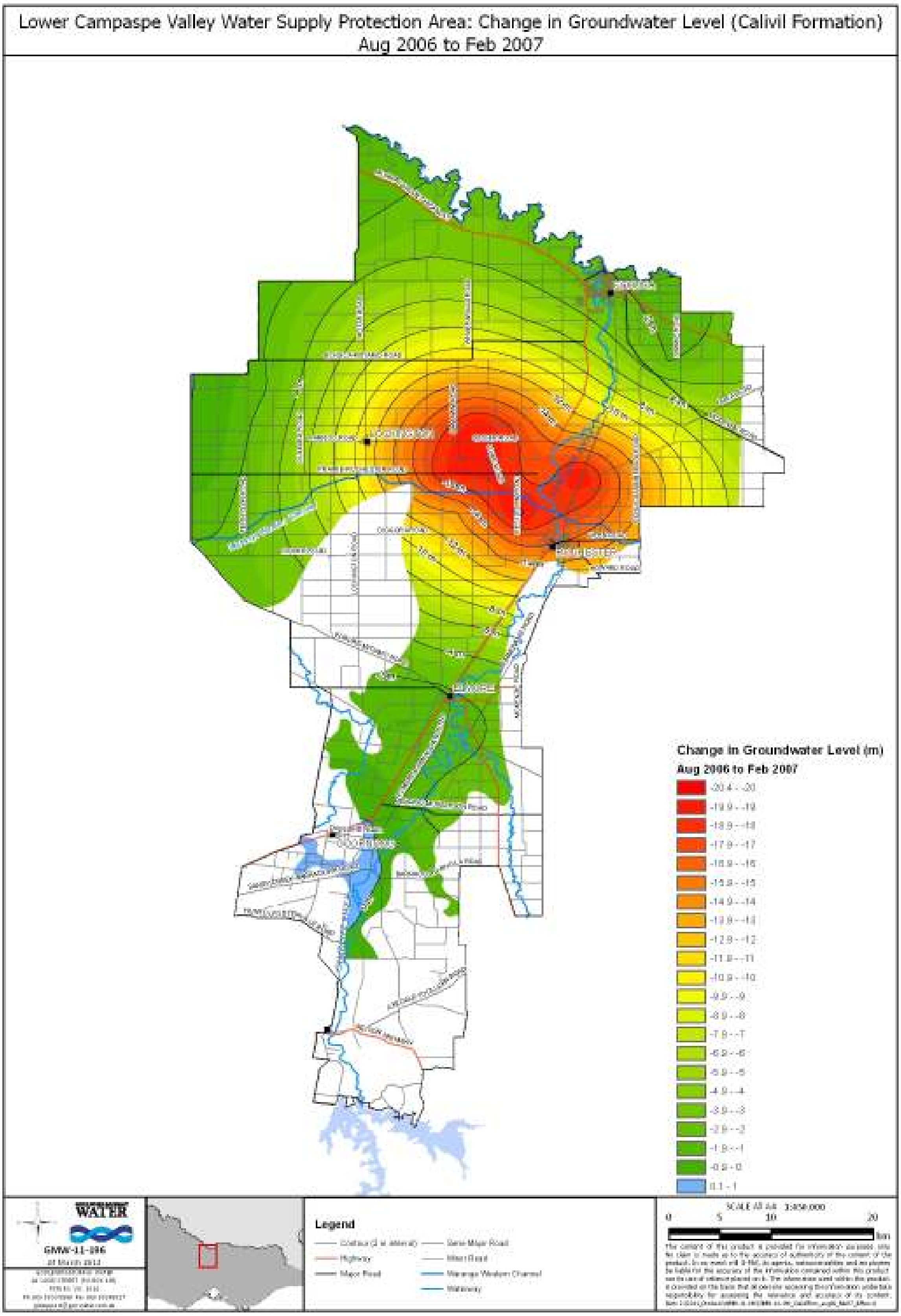


Figure 3 Extent of Calivil Formation in the Lower Campaspe Valley WSPA and seasonal drawdown between August 2006 and February 2007

Macumber (2008a) provided a conceptual understanding of the groundwater system in the Lower Campaspe Valley noting the occurrence of recharge, the significance of throughflow in managing the resource; and the strong interaction between the Shepparton Formation and the Deep Lead in parts of the area. Figure 4 describes groundwater flow and the aquifer response to pumping in the Lower Campaspe Valley.

Webb (2011) suggested that the Calivil Formation and Renmark Group are separate aquifers further west, but merge towards the east and become hydraulically connected. Macumber (2011) completed a review of nested bores screened in the Calivil Formation and Renmark Group across the Riverine Plain incorporating the Mid-Loddon, Katunga and Lower Campaspe Valley WSPAs. He found that these bores show a near identical groundwater response indicating a strong connection between the two aquifers.

Macumber (2008b) describes the boundaries of the Lower Campaspe Valley with respect to the hydrogeology and groundwater salinity, concluding that the inclusion of the region between Hunter and Lockington, and the exclusion Bendigo Creek Valley upstream of Goornong is appropriate. Consideration was also given to the extent of the Shepparton Irrigation Area and the potential to shandy groundwater for irrigation. Figure 5 illustrates have groundwater salinity in the Deep Lead varies across the Lower Campaspe Valley.

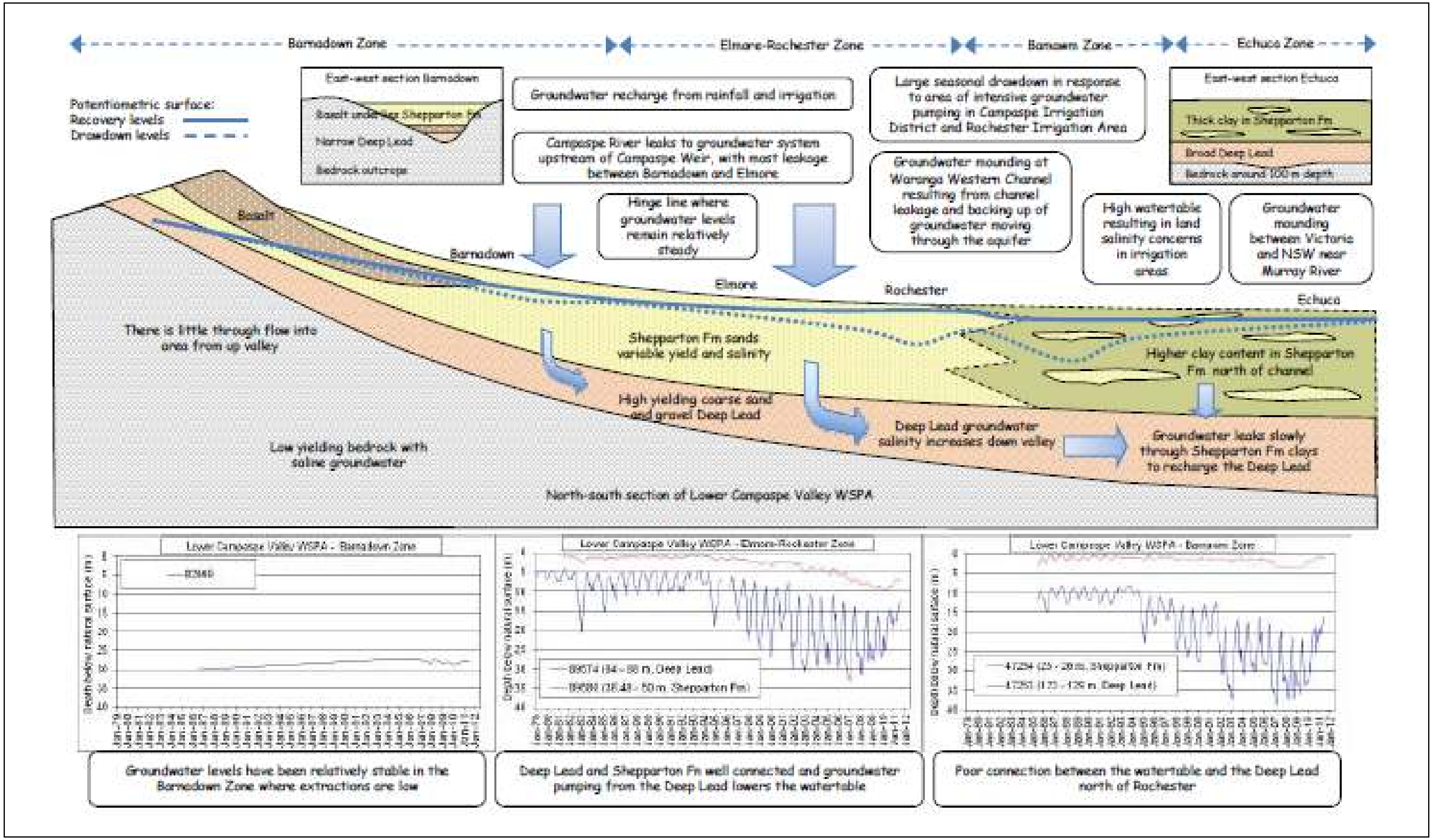


Figure 4 Groundwater flow

Lower Campaspe Valley Water Supply Protection Area: Salinity (Calivil Formation)

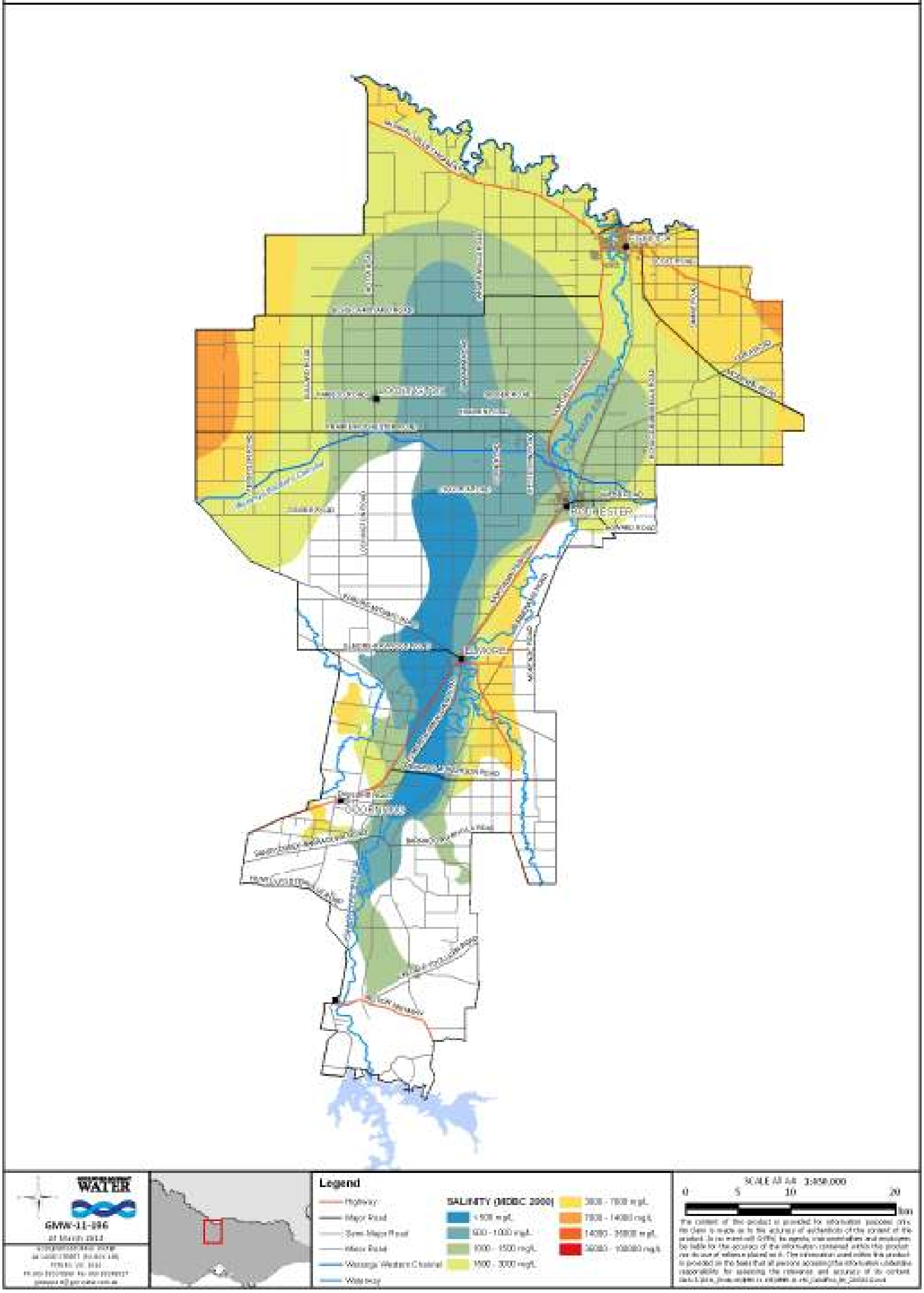


Figure 5 Groundwater salinity in the Lower Campaspe Valley

The boundary has been set to incorporate the key aquifers in the Lower Campaspe Valley while following easily identifiable surface features (i.e. roads and rivers) for simplicity of communication and management. As aquifers do not follow such boundaries, the WSPA incorporates an area greater than the aquifer extent in the south to ensure it and its major recharge areas are included. In some cases this results in areas being incorporated where the key aquifers do not exist (e.g. bedrock outcrop), however in these areas it is considered unlikely that significant yields could be obtained.

North

The northern boundary is the Murray River between Roslynmead Road and Simmie Road. The main Deep Lead aquifer extends into New South Wales where the resource is managed by the NSW Office of Water.

The boundary has been extended north of the former Campaspe Deep Lead WSPA to the Murray River to include a previously unincorporated area where there is potential for development, although it is noted that the groundwater becomes more saline to the north.

East

In the south, the eastern boundary is generally marked by outcropping bedrock where yields are low and groundwater quality is poor. In the north, the eastern boundary extends to the influence of the drawdown cone where the groundwater quality deteriorates within the Campaspe catchment (Figure 3).

The eastern boundary extends from Simmie Road to Scott Road, Fraser Road, Graham Road, Gray Road, Quarry Road, Howard Road, Bonn Road, McKenzie Road, and McNamara Road, Hayes Bridge Road, Northern Highway, Myola Road, Muskery East School Road, Murphys Lane, School House Lane and Moorabee Road to Lake Eppalock.

South

The southern boundary of the Lower Campaspe Valley WSPA is Lake Eppalock. In this area the Deep Lead and alluvial deposits narrow, confined within a basement rock valley. The narrowing of the alluvial and Deep Lead aquifer extent limits development in the region. Further south the surface geology is dominated by bedrock outcrop and basalt where yields are typically lower.

West

In the south, the western boundary is generally represented by outcropping bedrock where yields are low and groundwater is more saline. Only part of the Huntly Deep Lead has been included because of the poor water quality and limited demand. Groundwater salinity in the Huntly Deep Lead ranges from 4,000 to 16,500 µS/cm EC.

In the north, the western boundary has been extended from former management areas to include the extent of the influence of the drawdown cone, areas of potential development because of better groundwater quality (e.g. around Diggora possibly due to upward movement of groundwater from the Deep Lead and/or infiltration following flooding of the Bendigo Creek) and potential to shandy with surface water (e.g. aligned with the Shepparton Irrigation Region).

The western boundary extends along Cannys Road, Crows Road, Axedale-Goornong Road, Huntly-Fosterville Road, Old Stock Route Road, Midland Highway, Old Murray Road, Goornong-Mayreef Road, Elmore-Raywood Road, Kellys Road, Elmore-Mitiamo Road, Bendigo-Tennyson Road, Echuca-Mitiamo Road, Aird Road, Mount Terrick Road, Roslynmead Road and Bail Road to join the Murray River.

Depth

The Lower Campaspe Valley WSPA applies to the management of groundwater resources to all depths except where it is overlain by the Shepparton Irrigation Region WSPA and the Campaspe West Salinity Management Plan area. In these areas the Lower Campaspe Valley WSPA applies to the management of groundwater resources from 25 m to all depths. This is to ensure that all alluvial aquifers are incorporated as basement depth varies.

The shallow aquifers in the upper 25 m of the Shepparton Irrigation Region WSPA and the Campaspe West Salinity Management Plan area are managed to provide watertable relief and salinity benefits to improve agricultural productivity (SIRGSPACC, 1997).

4 Groundwater system

4.1 Aquifers

The key aquifers in the Lower Campaspe Valley WSPA are the Shepparton Formation sands and the underlying Deep Lead coarse sands and gravels.

The Shepparton Formation is found at the surface over much of the Lower Campaspe Valley WSPA. It increases in thickness and clay content to the north. Newer Volcanic basalt and the Coonambidgal Formation are found within the Shepparton Formation. Basalt is found in the south of the WSPA, upstream of Barnadown. The Coonambidgal Formation is the more recent shallow alluvial deposits found on the flood plains, which have cut into the Shepparton Formation forming terraces along the Campaspe River.

The Deep Lead, which comprises the Calivil Formation and Renmark Group sediments, is the primary aquifer system developed in the Lower Campaspe Valley WSPA because it is high yielding and the groundwater is generally of good quality. It underlies the Shepparton Formation. The Deep Lead broadens and increases in thickness to the north (SKM, 2011a).

The Lower Campaspe Valley WSPA may be divided into four management zones based on:

- recharge characteristics
- aquifer response to pumping
- differences in groundwater salinity
- throughflow
- current distribution of licence entitlements and extraction
- availability and source of surface irrigation supplies

From south to north the zones are Barnadown, Elmore-Rochester, Bamawm and Echuca (Figure 6). Groundwater flows northward through the aquifer, draining to the Murray Basin. The groundwater salinity in the Deep Lead generally increases along its flow path.

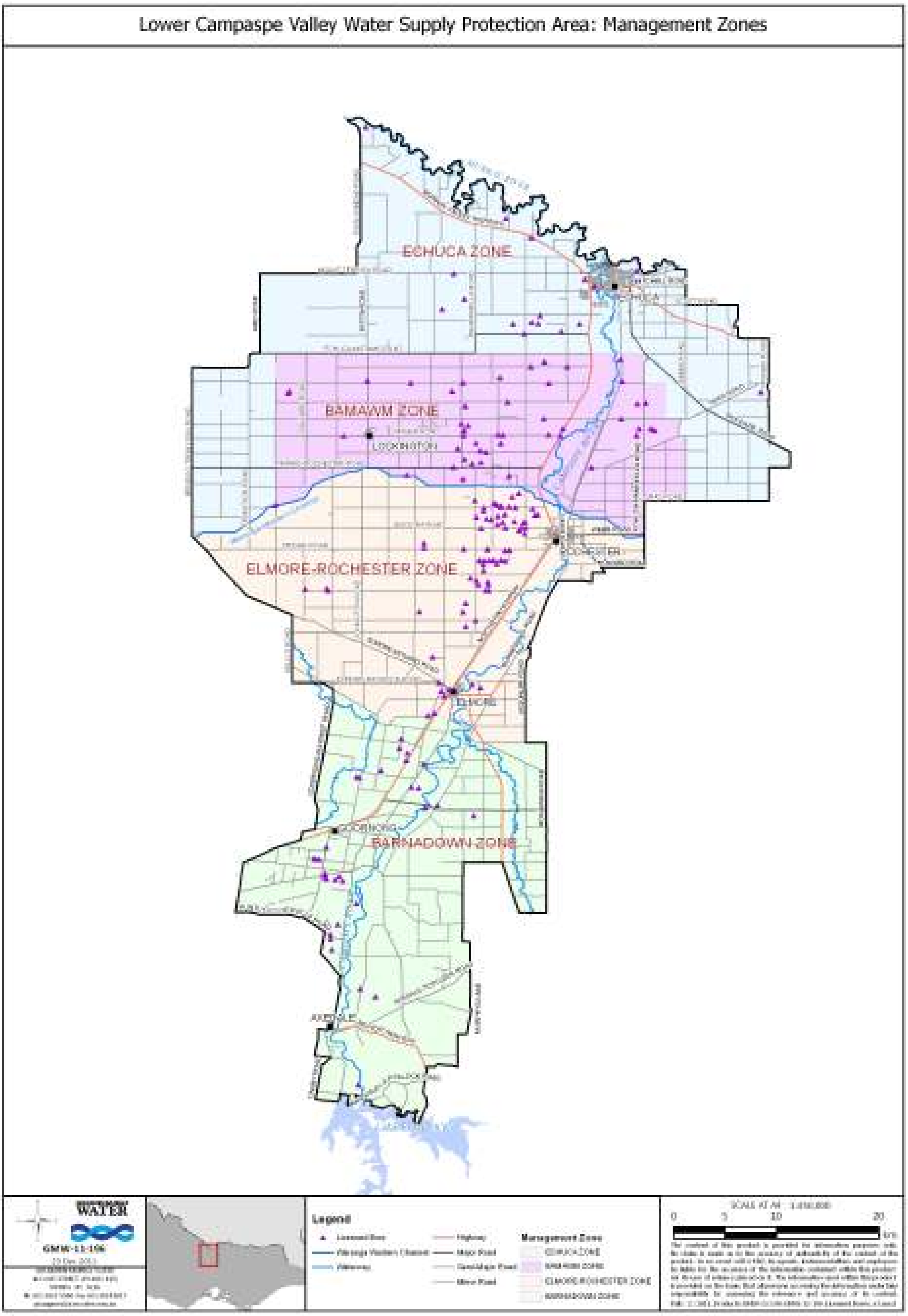


Figure 6 Management Zones

4.2 Management zones

Barnadown Zone

In the Barnadown Zone the Deep Lead is narrow and the valley defined by outcropping bedrock. Basalt is also found underlying the Shepparton Formation in the Barnadown Zone which may confine the Deep Lead in parts.

In the Barnadown zone there is significant recharge from rainfall as well as leakage from the Campaspe River (G-MW, 2013; Aquade, 2011).

Groundwater levels have remained relatively constant in the Barnadown Zone despite the severe dry conditions experienced over the last decade.

Monitoring records suggest that groundwater levels in the Barnadown Zone are largely unaffected by pumping in zones further to the north. That is, groundwater pumping in the Elmore-Rochester Zone does not affect levels in the Barnadown Zone and conversely pumping in the Barnadown Zone does not appear to have a discernible impact on groundwater levels in the Elmore-Rochester Zone.

A hinge line, where groundwater levels have remained relatively steady, is interpreted to occur around the boundary between the Barnadown Zone and Elmore-Rochester Zone (Macumber & Macumber, 2011). At this point it is suggested that the aquifer is unconfined and groundwater removed is from gravity drainage. The hinge line could also be a manifestation of groundwater pumping up gradient and down gradient having little impact at this point.

Groundwater is generally of a good quality.

Elmore-Rochester Zone

In the Elmore-Rochester Zone the Deep Lead begins to broaden into an alluvial fan. There is a good hydraulic connection between the Shepparton Formation and the Deep Lead in the Elmore-Rochester Zone such that groundwater pumping from the Deep Lead results in watertable decline.

There is significant recharge from rainfall and irrigation accessions as well as leakage from the Campaspe River where it overlies the Deep Lead (G-MW, 2013; Aquade, 2011).

Groundwater levels in the Deep Lead were relatively steady in the Elmore-Rochester Zone between the early 1980s and the mid 1990s. From the mid 1990s to 2010 groundwater recovery levels (the level to which groundwater rises during winter/spring each year) fell by up to 10 m in response to dry conditions and groundwater pumping. Increased rainfall recharge and reduced groundwater pumping resulted in rising groundwater levels in 2010/11 (Figure 4).

Seasonal drawdown (the difference in groundwater levels between pumping and non-pumping conditions) of up to 20 m has been observed in areas of intensive groundwater pumping in the Campaspe Irrigation District.

Lowering the watertable in the Elmore-Rochester Zone can impact on surface water features, ecosystems that depend on groundwater and supply for shallow domestic and stock bores. However, lowering the watertable has provided land salinity benefits in the region and could reduce discharge of saline groundwater to the Campaspe River between the Campaspe Weir and Rochester (SKM, 2008).

Groundwater is generally of a good quality.

Bamawm Zone

The Deep Lead is more confined in the Bamawm Zone, north of the Waranga Western Channel. In this region the Campaspe valley opens up to the riverine plain and is no longer bordered by outcropping bedrock.

In the Bamawm Zone the Deep Lead is recharged slowly from water leaking downward through thick clay units within the Shepparton Formation.

Groundwater mounding at the Waranga Western Channel may be caused by leakage from the channel and a backing up of groundwater created by more confined aquifer conditions further north. It should be noted that there may be some places where the Shepparton Formation is better connected to the Deep Lead in close proximity to the Waranga Western Channel.

Groundwater through flow from the Elmore-Rochester Zone to the Bamawm Zone is significant as it is driven by a steep hydraulic gradient. This indicates that groundwater pumping in the Bamawm Zone has an impact on the resource in the Elmore-Rochester Zone.

Groundwater level trends in the Bamawm Zone are similar to those in the Elmore-Rochester Zone. Groundwater levels were relatively steady between the early 1980s and the mid 1990s; there was a fall in recovery levels of up to 10 m from the mid 1990s to 2010 in response to dry conditions and groundwater pumping; and good recovery in 2010/11.

Seasonal drawdown of up to 20 m has been observed in areas of intensive groundwater pumping in the Rochester Irrigation Area.

In contrast to the Elmore-Rochester Zone, groundwater pumping in the Bamawm Zone has negligible impact on the watertable because of the poor hydraulic connection between the Deep Lead and the shallow Shepparton Formation sands.

Groundwater salinity in this zone is generally good to brackish.

Echuca Zone

The characteristics of the groundwater system in the Echuca Zone are similar to the Bamawm Zone.

The Echuca Zone has been delineated in recognition of higher groundwater salinity. It includes the more saline areas of the Deep Lead aquifer to the north, east and west of the WSPA. Groundwater salinity may limit the use of the water in this zone, although there is potential to shandy groundwater with surface water.

4.3 Groundwater use

Licensed use

The total licence entitlement in the Lower Campaspe Valley WSPA is 56.2 GL/year. Almost half of this entitlement is in the Bamawm Zone (Table 1). There is also significant entitlement in the Elmore-Rochester Zone.

Table 1 Number of licence holders and licence volume in June 2011

Management Zone	Number of licences	Total licence volume (GL/yr)
Barnadown	20	8.3
Elmore-Rochester	55	15.3
Bamawm	46	26.0
Echuca	17	6.6
TOTAL	138	56.2

Good metered usage data exists across the entire Lower Campaspe Valley WSPA from 2007/08 (Figure 7). Groundwater use is greater in dry periods which correlate with reduced surface water availability.

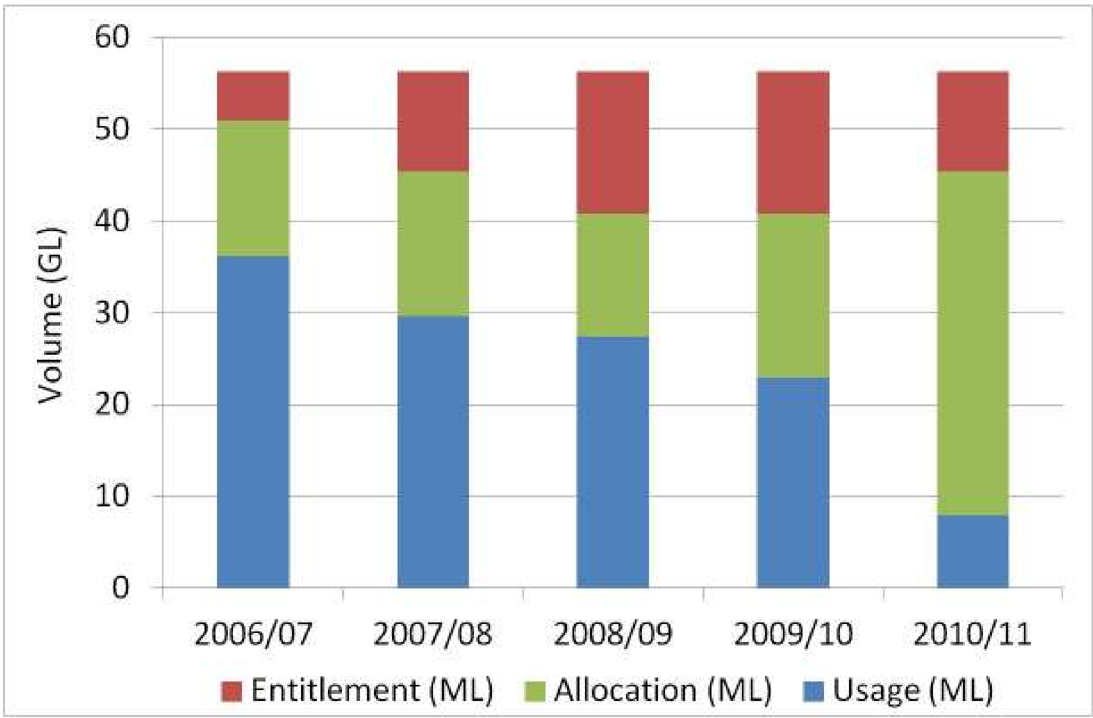


Figure 7 Metered use in the Lower Campaspe Valley WSPA

Restrictions on extractions under the former Campaspe Deep Lead WSPA GMP between 2006/07 and 2009/10 resulted in lower usage. High rainfall and flooding in 2010/11 resulted in little groundwater usage.

A water balance has been prepared which suggests that groundwater levels would remain relatively steady under average climatic conditions for recent usage (G-MW, 2012b)

Domestic and stock use

There are around 100 registered domestic and stock bores in the Lower Campaspe Valley WSPA. There are also a number of older unregistered domestic and stock bores.

Domestic and stock access to groundwater is a statutory right under section 8 of the Act. Landholders can apply to G-MW for a works licence to install a bore for domestic and stock purposes.

The operating status of domestic and stock bores is not monitored. Stock and domestic usage is considered to be relatively small (around 2 ML/yr per bore on average).

Some domestic and stock bores were installed in wetter conditions to tap the watertable. These bores do not penetrate the aquifer. As such these bores may be at risk, particularly south of the Waranga Western Channel where the Shepparton Formation can fall in response groundwater pumping from the Deep Lead.

Generally landholders will be able to deepen their bores to maintain supply if groundwater levels fall. G-MW needs to consider impacts on domestic and stock users when making licensing decisions. For this reason, domestic and stock users are encouraged to ensure that their bore is registered.

5 Groundwater salinity

5.1 Background

Poor groundwater quality can have significant economic impacts by reducing agricultural and horticultural productivity.

In aquifers unaffected by human activity, the quality of groundwater results from geochemical reactions between the water and rock matrix as the water moves along flow paths from areas of recharge to areas of discharge. In general, the longer groundwater remains in contact with soluble materials, the greater the concentrations of dissolved materials in the water.

Groundwater quality may also be adversely impacted by human activities. Groundwater can be contaminated by point sources such as landfills or localised chemical spills, or diffuse sources such as widespread fertiliser use or urban runoff. Pollutants can include microbiological contaminants from sewage and effluent; heavy metals; petroleum fuels; industrial solvents; excessive nutrients (e.g. phosphates and nitrogen); detergents; and pesticides. Groundwater close to the surface is generally the most at risk of pollution.

Irrigation, inappropriate disposal of wastewaters and land clearing can all increase groundwater salinity. Increasing groundwater salinity levels can be a problem in areas where excessive groundwater pumping results in more saline water being drawn into the aquifer from surrounding areas. The quality of groundwater also can change as the result of the mixing of waters from different aquifers.

The State Environment Protection Policy (Groundwaters of Victoria) was developed to maintain and, where necessary, improve groundwater quality to a standard that protects existing and potential uses and values of groundwater (EPA, 1997). The protection of beneficial uses, defined by ranges in groundwater total dissolved solids (TDS), is to be achieved through maintenance of the current level of environmental quality or through realistically achievable improvements (Table 2).

In the Lower Campaspe Valley WSPA there have been groundwater quality investigations to establish baseline conditions (Anrad and Evans, 1987; Callinan, 2003; Bartley Consulting, 2005) and under the Campaspe Deep Lead WSPA GMP licence holders were required to provide a groundwater sample for salinity analysis. Some licence holders have established groundwater quality monitoring programs such as Coliban Water and Fosterville Gold Mine.

Table 2 Protected beneficial uses for groundwater salinity

Beneficial uses		Segments (mg/L TDS)				
		A1 (0-500)	A2 (501-1000)	B (1001-3500)	C (3501-13000)	D (> 13000)
1. Maintenance of ecosystems		✓	✓	✓	✓	✓
2. Potable water supply	- Desirable	✓				
	- Acceptable		✓			
3. Potable mineral water supply		✓	✓	✓		
4. Agriculture, parks and gardens		✓	✓	✓		
5. Stock watering		✓	✓	✓	✓	
6. Industrial water use		✓	✓	✓	✓	✓
7. Primary contact recreation (e.g. bath, swim)		✓	✓	✓	✓	
8. Building and structures		✓	✓	✓	✓	✓

5.2 Groundwater salinity in the Lower Campaspe Valley WSPA

Groundwater in the Lower Campaspe Valley WSPA is generally of good quality. The main trunk of the Deep Lead aquifer runs south-north, approximately parallel to the Campaspe River, from Lake Eppalock to Echuca. In the south it is confined within a palaeo-valley but widens as the river leaves the highland tract south of Elmore.

While there are some anomalies, groundwater salinity in the Deep Lead generally increases to the north. Water quality in the main trunk of the aquifer is generally between 350 to 1,000 mg/L (550 to 1,550 EC) south of the Waranga Western Channel, to between 1,000 to 1,600 mg/L (1,550 to 2,500 EC) to the north. The water quality deteriorates to brackish toward the north eastern and north western margins of the WSPA.

Groundwater salinity is low in the Elmore area and to the west of the Campaspe Irrigation District (CID) (Macumber, 2008). Deep Lead groundwater salinity is higher in the CID and to the north of the Waranga Western Channel where it ranges from 650 mg/L (1,000 EC) to over 1,600 mg/L (2,500 EC). The higher groundwater salinity is interpreted to be due to recharge from the high salinity groundwater (2,550 to 5,100 mg/L or 4,000 to 8,000 EC) in the Shepparton Formation.

Water quality in the overlying Shepparton Formation aquifer is fresh in the south but also deteriorates to be generally more brackish further north in the WSPA. Groundwater salinity in the Deep Lead is lower than the groundwater salinity in the Shepparton Formation over much of the region.

The salinity of the Renmark Group and the Calivil Formation is similar for much of the central part of the WSPA where there is strong interconnection between the two geological units. However, away from the main trunk there are a number of bores in the Renmark Group which have a higher salinity. The higher salinity in the Renmark Group may be due to throughflow from the saline Corop trough, while lower salinities in the Calivil Formation represent mixing with fresher water passing down the main trunk of the Campaspe Deep Lead.

Macumber (2008) undertook a preliminary analysis of groundwater salinity and found that salinity increases are concentrated, although not restricted to, areas having higher permeability soils. Further, he found that areas where salinity has risen coincide mostly to where deepest seasonal drawdowns occur.

Macumber (2008) identified a number of sites with increasing groundwater salinity over a 25 year period, the most extreme being a rise from near 650 mg/L (1,000 EC) to over 1,950 mg/L (3,000 EC) in bore 89669. He also found a number of sites with increasing groundwater salinity in the south, however the rate of rise is low (bores 62628 and 60259). Macumber (2008b) identified groundwater salinity increasing at rates up to 250 mg/L/yr (381 EC/yr), but were typically around 20 mg/L (30 EC) in the CID.

Callinan (2003) had found the groundwater salinity had been increasing slightly in the Campaspe Deep Lead WSPA between 1981 and 2003 and the greatest increases were concentrated together in the high drawdown area.

Groundwater salinity in the Lower Campaspe WSPA may also be influenced by the more saline Huntly Deep Lead, which is interpreted to join the Campaspe Deep Lead south-west of Goornong, and Deep Lead from the Corop Lakes which joins the Campaspe Deep Lead south of Echuca.

5.3 Groundwater salinity risk

The potential threats of increasing groundwater salinity from development of groundwater resources in the Lower Campaspe Valley include:

(i) increased leakage to the Deep Lead from the overlying Shepparton Formation;

(ii) lateral movement groundwater into the WSPA at the northern margins; and

(iii) upward movement of groundwater from the Renmark Group to the Calivil Formation.

Leakage from the Shepparton Formation

In the north of the Lower Campaspe Valley WSPA the Shepparton Formation is brackish. Lower groundwater levels in the Deep Lead could draw more saline groundwater into the Deep Lead from the Shepparton Formation.

South of the Waranga Western Channel the Shepparton Formation is well connected to the Deep Lead. Land use in the CID has resulted in higher groundwater salinity over this region. Changes in land use due to the closure of the CID and lower watertables may result in lower groundwater salinity similar to that reported to the west of the CID.

Groundwater salinity should be monitored in the CID and north of the Waranga Western Channel in areas of most intense development to identify any changes in groundwater salinity that may result from leakage from the Shepparton Formation. Sampling should be undertaken at a nested monitoring bore sites where bores are screened in the Shepparton Formation and the Calivil Formation.

Lateral movement

Lateral movement of groundwater from the margins of the area may occur in response to drawdown induced by intense pumping. Groundwater salinity in the Deep Lead is higher to the north. Intensive groundwater pumping in the Campaspe Deep Lead can draw in more saline groundwater from these northern regions. While some of this groundwater might be drawdown from the eastern and western margins of the WSPA, the greatest risk is interpreted to from NSW along the main trench of the Deep Lead.

It should be noted that while there is potential to draw saline groundwater into the WSPA from the margins during the irrigation season, groundwater levels recover quickly. In this case there is interpreted to be a shifting transition zone.

Groundwater salinity should be monitored on the northern margins of the WSPA (including the eastern and western margins) to monitor any changes in groundwater salinity that may result from lateral movement. Sampling should be undertaken from the Calivil Formation; however monitoring should target nested bore sites to assist with data interpretation.

Upward movement from Renmark Group

Outside of the main trench the groundwater salinity in the Renmark Group can be higher than in the Calivil Formation. Together these two geological units form the Deep Lead; however in some cases there may be clay deposits that locally reduce their connectedness.

In such cases, development of groundwater resources from the Calivil Formation could induce saline groundwater from the Renmark Group into the Calivil Formation.

It should be noted that any rise in groundwater salinity is likely to be tempered by the buffering capacity of the large volume of relatively fresh groundwater in storage and throughflow.

Groundwater salinity should be monitored on the northern margins of the WSPA (including the eastern and western margins) to monitor any changes in groundwater salinity that may result from upward movement of groundwater from the Renmark Group. Sampling should be undertaken from nested bores screened in the Calivil Formation and Renmark Group.

Managing risk of increasing groundwater salinity

The risk of rising groundwater salinity due to saline groundwater being drawn into the areas in response to groundwater pumping may be managed by limiting drawdown through restrictions on extractions. A groundwater monitoring program should be established to more accurately assess any trends in groundwater salinity over time.

5.4 Salinity sampling options

Groundwater salinity sampling options include:

(i) salinity mail out;

(ii) targeted groundwater salinity monitoring of licensed bores; and

(iii) sampling selected SOBN bores.

Salinity mail-out

Each year G-MW sends out a sample bottle to groundwater licence holders. Under the Campaspe Deep Lead WSPA GMP licence holders were required to take a sample from their bore and return it to G-MW for salinity testing.

Unfortunately, the return rate was usually low; between a low of 2% in 2003 and a high of 46% in 2006, but generally around 24%. Moreover, it was uncommon for G-MW to receive a salinity sample from the same bore more than two successive years. This makes any analysis of groundwater salinity very difficult as trends cannot be analysed with confidence. Further, there are uncertainties around the quality of samples as there is no control over sampling procedures.

A statistical analysis of salinity sampling in the Campaspe Deep Lead was completed in 2005 by Bartley Consulting. It concluded that due to the discontinuous nature of data of the salinity mail-out it is not possible to distinguish a trend in a change in salinity from a natural variability in salinity over time. It also determined that it was more likely for licence holders in stressed or higher salinity areas to return samples, which would skew the water quality results.

While the salinity mail-out can provide a relatively inexpensive method of obtaining groundwater salinity measurements over a wide area and provide licence holders with important information about the groundwater salinity in their bore, the usefulness of the data for groundwater resource management is poor when the return rate is low and haphazard.

If there was a good return rate from consistent bores this approach could provide good spatial information of groundwater salinity that may be used to evaluate the risk of lateral movement of more saline groundwater from the margins of the WSPA. Further, a consistent return from bores in the areas of intensive groundwater pumping could assist with analysis of leakage from the Shepparton Formation.

Targeted salinity monitoring of licensed bores

Licensed bores in strategic locations could be sampled by G-MW on an annual basis. This option would require effective communications between G-MW and the licence holder about when they were operating their bore so that a sample could be taken.

This option would be more expensive and there would be fewer samples; however it would provide an improved data set for analysis by:

- providing greater confidence in the quality of the samples obtained; and
- ensure that a sample was taken from a bore each year.

While this option would improve the quality of the data for analysis, it would not provide samples from nested bores to assess the risks of saline groundwater being drawn into the Calivil Formation from the Shepparton Formation or Renmark Group.

Sampling selected State observation bores

Sampling from selected State observation bores would provide the best information on groundwater salinity as nested bores sites could be sampled. Nested sites could be targeted for sampling so that the interaction between aquifers could be assessed. This approach is more expensive as a pump would need to be hired to obtain a groundwater sample.

Analysis of samples

Previously, G-MW has undertaken analysis of salinity mail out samples. Samples have been tested for EC only. The level of confidence in the results is only moderate as there is a lack of quality assurance.

To improve the understanding of groundwater changes over time, selected samples could be sent to a NATA accredited laboratory for analyses of a range of parameters. This could also provide an opportunity to test for any contaminants.

Sampling from State observation bores and analysis of the samples at a NATA accredited laboratory would provide the greatest level of confidence in water quality results, but it is more expensive.

6 Groundwater interaction with surface water

6.1 Surface water management

The Campaspe River is the primary surface water drainage feature in the Lower Campaspe Valley WSPA. It flows north from Lake Eppalock to the Murray River, which forms the northern boundary of the WSPA.

Flows in the Campaspe River are regulated by releases from the Lake Eppalock, which has a storage capacity of 312 GL. River regulation has effectively turned the Campaspe River into a perennial system from a system that previously had periods of no flow during dry conditions. The mean annual flow in the Campaspe River at Barnadown is 480 ML/month (Figure 8).

Mount Pleasant Creek, Axe Creek and Forest Creek are tributaries of the Campaspe River. The Bendigo Creek passes through the western parts of the Barnadown and Elmore-Rochester Zones and turns to the northwest away from the Campaspe River. These creeks are unregulated systems.

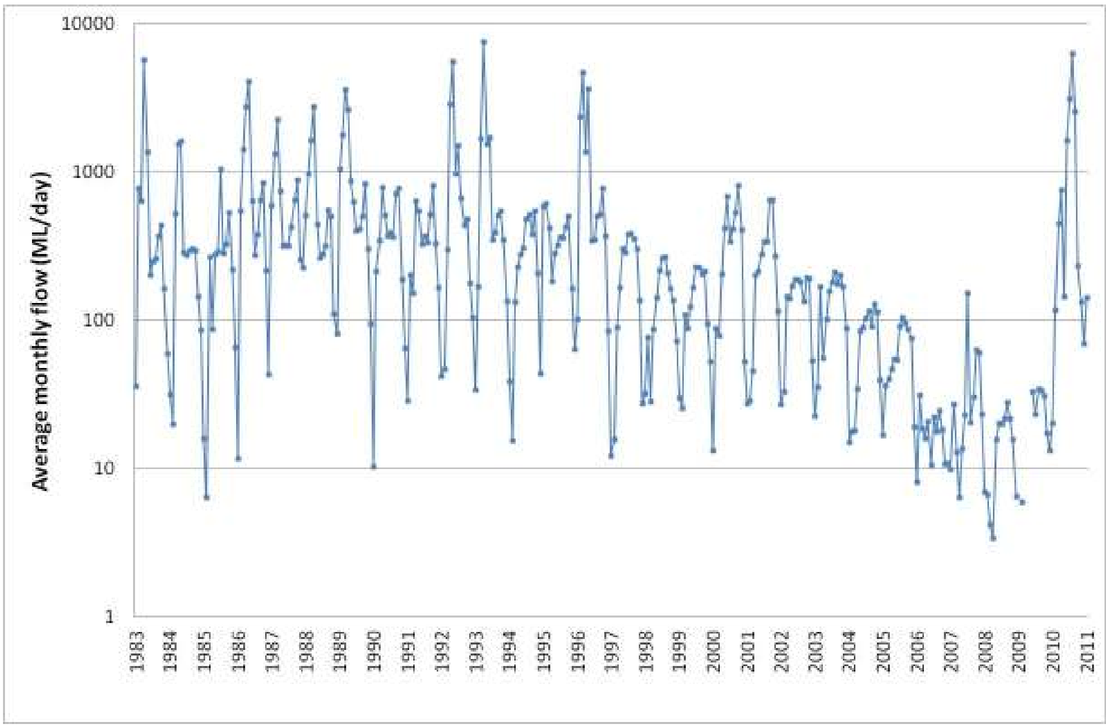


Figure 8 Campaspe River average monthly flow at Barnadown station 406201

Water is diverted from the Campaspe River for consumptive use. The Campaspe Weir and the weir at the Siphon, where the Waranga Western Channel is piped under the Campaspe River north of Rochester, are structures that support the irrigation channel network.

The Campaspe Irrigation District is located between the Campaspe Weir and Rochester. The infrastructure for the Campaspe Irrigation District is to be decommissioned. The Rochester Irrigation Area is located north of the Waranga Western Channel.

The Wananga Western Channel carries water from the Goulburn River to the irrigation districts. The Waranga Western Channel flows east to west across the Lower Campaspe Valley WSPA and forms the boundary between the Elmore-Rochester Zone and the Bamawm Zone.

The resource manager makes allowances for losses for evapotranspiration and leakage to the groundwater system from the Campaspe River. Losses range between approximately 5 GL/yr during low allocation years and 14 GL/yr during high allocation years (Aquade, 2011).

An environmental flows study of the Campaspe River recommended flow regimes to maintain the environment, fish stocks and manage potential salinity impacts. The flows study recommended that from Lake Eppalock to Campaspe Weir there should be:

- A summer cease to flow event lasting fourteen days, a summer low flow of 10 ML/day (or natural) and summer freshes of 100 ML/day, up to three times per year for five days, for fish movement.
- A winter low flow of 100 ML/day (or natural), a winter high flow of 1,000 ML/day, up to four per year for four days, a winter bankfull of 10,000 ML/day lasting two days and a winter overbank flow of 12,000 ML/day.

The flow study recommended that from Campaspe Weir to the siphon there should be:

- A summer flow of between 10 and 20 ML/day to maintain flow through the reach. Average flows above 20 ML/day were not recommended but up to three summer freshes per year of 100 ML/day, for six days duration were.
- A winter low flow of 200 ML/day and a winter high flow of 1,500 ML/day, a winter bankfull flow of 8,000 ML/day, up to two times per year for two days, and a winter overbank of 12,000 ML/day.

The flow study recommended that from the siphon to the River Murray there should be:

- A summer low flow of between 10 and 20 ML/day to maintain flow and aquatic habitat. Flows should not exceed 20 ML/day. Summer freshes of 100 ML/day, up to three times per year for six days to wet very long low lying benches in the bottom of the channel.
- A winter flow of 200 ML/day (or natural), a winter high flow of 1,500 ML/day, ap to two per year for four days, and a winter bankfull flow of 9,000 ML/day, up to two times per year for two days.

6.2 Investigations

A comprehensive investigation has been undertaken to investigate the relationship between the Campaspe River and the groundwater system (Aquade, 2011). The investigation has identified reaches of the river that are leaking to the groundwater system, and reaches of the river where the groundwater discharges to the river.

Key findings from the investigation were:

- The Campaspe River is well connected to the Coonambidgal Formation.
- River regulation has enhanced groundwater recharge as groundwater levels in the Coonambidgal Formation are maintained by the river level.
- Upstream of the Campaspe Weir the river leaks to the groundwater system and always has.
- The rate of leakage from the Coonambidgal Formation to the Deep Lead is controlled by the width of the Coonambidgal Formation, the thickness of clays in the underlying Shepparton Formation and the head difference between the

river or Coonambidgal Formation and the Shepparton Formation or Deep Lead.

- Leakage to the groundwater system upstream of Barnadown is negligible.
- The greatest leakage occurs between Barnadown and approximately 4 km downstream of Elmore.
- There is a reduction in groundwater salinity in the Deep Lead between Barnadown and Elmore which raises some questions about river leakage over this reach.
- Declining groundwater levels in the Elmore-Rochester Zone, associated with the closure of the Campaspe Irrigation District, could result in water leaking from the river rather than discharging to it.
- Groundwater discharges to the Campaspe River downstream of the Campaspe Weir. Groundwater levels in this area are elevated as a result of land use change.
- Discharge to the river downstream of the Campaspe Weir is small in comparison to leakage upstream.

The river length was divided into seven reaches to reflect varying conditions such presence of Deep Lead beneath the river, thickness of clay units in the Shepparton Formation and reaches where the river leakes to the groundwater system or groundwater discharges to the river (Aquade, 2011). The calculated average, maximum and minimum annual flux for each reach is given below:

Table 3 Leakage from the Campaspe River

Flux	Axedale	Barnadown	Ferguson	Elmore South	Elmore North	Rochester	Murray	Net flux
Average annual	0.0	0.2	1.0	1.8	0.2	-0.1	-0.4	2.6
Min. annual (1997)	0.0	0.2	0.7	1.2	-0.1	-0.2	-0.4	1.4
Max. annual (2010)	0.0	0.3	1.6	2.6	0.7	0.0	-0.1	5.0
Previous study av.	0.0	0.3	0.4	0.7	0.0	-0.1	-0.4	0.9

The findings indicate that there is not a strong seasonal impact on river flow due to groundwater pumping as leakage is restricted by clays in the Shepparton Formation. Lower groundwater levels could increase leakage / reduce discharge annually from the Campaspe River. If the proposed Barnadown trigger was reached (a groundwater level fall of around 2 m from 2010 levels) leakage from the river could increase from by around 2 GL/yr. This impact would be within the existing operational range of losses as groundwater levels have been rising since the construction of Lake Eppalock in 1964.

6.3 Conclusions

It was concluded that:

- There is not a strong connection between the Campaspe River and the regional groundwater system and therefore groundwater and surface water should not be managed conjunctively i.e. no trading between surface water and groundwater and each system should have its own restriction methodology.

- Groundwater extraction should not be licensed within the Coonambidgal Formation which is well connected with the river.
- Falling groundwater levels can induce leakage from the river or reduce groundwater discharge to the river. Impact on flow in the Campaspe River is within the existing operational range of losses for proposed groundwater level triggers.
- Falling groundwater levels in the Elmore-Rochester Zone can provide environmental benefits to the Campaspe River by reducing saline groundwater discharge.

7 Groundwater dependent ecosystems

7.1 Context

Sections 32A(3)(i) and (ia) of the *Water Act 1989* enable a plan to specify any conditions necessary to protect the environment.

In relation to groundwater, protection of the environment means protecting GDEs. GDEs include surface ecosystems that depend on groundwater discharge to the surface (river base flows; wetlands and estuaries); those that tap directly into groundwater (such as terrestrial vegetation) and those within aquifers.

7.2 Background

The Department of Primary Industries undertook a project to map where GDEs may exist using remote sensing products (DPI, 2011). The mapping identifies large areas where GDEs may occur, but there has not been any reported field verification of the mapping.

The Ministerial guidelines for the preparation of a draft GMP specify that field investigations are needed to verify potential GDEs identified by the Department of Primary Industries (DPI), assess their level of dependency on groundwater and identify high-value ecosystems to be protected in the area. Further, the guidelines state the if the investigations of GDEs or groundwater interaction with surface water are not complete before the plan is drafted, the plan should specify how the provisions of the plan will be adjusted to protect relevant GDEs, including interaction with waterways.

7.3 Considerations

Very little is known about GDEs in the Lower Campaspe Valley WSPA. There has been little field mapping to identify GDEs, and where they have been identified no work has been undertaken to determine their water requirements or value.

The DPI (2010) GDE mapping has been undertaken at a broad scale with many large areas requiring investigation. There is insufficient time and funding to undertake comprehensive mapping to inform the GMP. Further, it could take many years of monitoring to determine the GDE water requirements.

The DPI (2011) undertook a project to evaluate the potential locations and sensitivity of GDEs in the Lower Campaspe Valley. This project built upon prior mapping and assessed GDE sensitivity on a combination of species tolerance modelling and hydrogeologic evaluation. The report concluded that potential GDEs in the Lower Campaspe Valley WSPA occur mainly along watercourses, particularly the Campaspe and Murray Rivers. It was concluded that the Coonambidgal Formation is well connected to the Campaspe River, so the groundwater dependency is strongly affected by river regulation and likely much less so by groundwater usage. Non-regulated streams, such as Bendigo Creek, may also have some groundwater dependency but the sensitivity analysis indicates a lower sensitivity then the Campaspe River.

Due to the time constraints in developing a GMP that gives appropriate consideration to the protection of GDEs, and the lack of knowledge of GDEs and their groundwater dependency, Goulburn-Murray Water (G-MW) undertook a project to:

1. develop tools to assist with identifying GDEs in the field;

2. use remote sensing to assess riparian vegetation water use trends of likely GDEs to establish management triggers; and
3. undertake mapping of GDEs where there was evidence of high likelihood of GDE at risk.

G-MW has worked collaboratively with the North Central Catchment Management Authority (CMA) and the Department of Sustainability and Environment to deliver this project.

Tools developed

A field evaluation sheet has been developed to assist with identifying GDEs in the field. There are three sections of the field evaluation sheet that recognise the multidisciplinary approach required to locate GDEs and assess their water requirements.

The first section enables field officers, who may not be familiar with GDEs, to capture site information. The second section is a desktop assessment whereby additional data can be considered, such as groundwater levels and trends, along with field information captured to develop a conceptual understanding of the site. At this stage an assessment can be made of the likelihood of groundwater dependence. The third section, if necessary, requires a detailed field inspection to capture additional information, such as species type that can assist with GDE valuation.

Once all the necessary information has been compiled an assessment may be undertaken to value the GDE by the North Central CMA through their Regional Catchment Strategy. The information should then be incorporated in into the National GDE Atlas so that it can be used to assist with future groundwater planning and licensing decisions.

Riparian Vegetation

Due to the lack of time series data upon which to consider management triggers for GDEs, G-MW undertook a project to use remote sensed evapotranspiration (ET) data over time to assess trends in apparent water stress and examine relationships with changed groundwater levels and surface water availability (SKM, 2011).

Remotely-sensed ET data was used to evaluate the groundwater dependence of riparian vegetation throughout the Loddon and Campaspe catchments. A remote-sensing approach was taken as it provided a rapid catchment-wide assessment tool. The period from 2001 to 2009 was chosen for the acquisition of data as it enabled the study of ET of riparian vegetation under a period of declining groundwater levels and reduced water availability.

Regional statistics confirmed a correlation between groundwater levels and ET for all years of data, suggesting that a high summer ET is indicative of greater access to groundwater, and that a decline in groundwater levels may lead to a reduction in ET, which could have adverse impacts on the riparian vegetation.

The project proposed priority riparian zones for site investigations that may be considered for the development of triggers.

Field mapping

Unfortunately, due to the very wet summer experienced in 2010/11 conditions for mapping GDEs were not ideal. In this case much of proposed mapping was postponed until the summer of 2011/12.

However, to verify outcomes from the enhanced remote sensed mapping, and guided by local knowledge and anecdotal evidence, G-MW and the North Central CMA have undertaken some initial field investigations to confirm the presence of GDEs (G-MW, 2012).

More field mapping needs to be undertaken to confirm GDEs. This should be done through specific project work. Additionally G-MW will continue to collect information on GDEs through their groundwater licensing process. Field investigations should be targeted to areas of greatest likelihood of GDE presence where the risk is greatest e.g. areas of intensive groundwater development.

The information should be collated and incorporated into the National GDE Atlas so that it can then be used to assist with future planning and licensing decisions.

7.4 Knowledge of GDEs

North of the Waranga Western Channel the Deep Lead is not well connected to the shallow aquifers. Given this understanding then groundwater pumping from the Deep Lead is unlikely to impact on base flow or any GDEs in this region.

South of the Waranga Western Channel groundwater levels are generally greater than 10 m depth, which suggests that it is only deep rooted trees that may be dependent upon groundwater. Clusters of River Redgum trees (*Eucalyptus camaldulensis*) have been identified on the Bendigo Creek flood plain as potential GDEs. It is thought that these trees are supported by perched aquifers, but further investigations are required to confirm this interpretation.

It has been suggested that GDEs in the Lower Campaspe Valley WSPA mainly occur along watercourses. Aquade (2011) found that the Campaspe River is well connected to the Coonambidgal Formation which leaks slowly to the regional aquifer system. Lowering of groundwater levels could induce further leakage from the river which could threaten GDEs during low flow periods.

7.5 Conclusions

More work is required to confirm the presence of GDEs; their dependence on groundwater and their value. This can only be achieved through field mapping and monitoring. It is proposed that any high value GDEs be protected though groundwater licensing decisions, and establishing trigger levels and restrictions.

Section 40 of the *Water Act 1989* requires that in considering an application for a groundwater licence, G-MW must have regard for the need to protect the environment. G-MW has a well developed procedure for assessing groundwater licence applications. This ensures that high value GDEs will be protected from direct impacts of a nearby groundwater bore.

Groundwater level declines can occur over large areas in response the cumulative impacts of groundwater pumping in areas of intensive groundwater development or usage beyond the sustainable yield. In these areas groundwater trigger levels and restrictions should be established to arrest the rate of groundwater level fall.

It is recommended that:

- GDE mapping be undertaken focusing on areas where there is a high likelihood that they are present and there is a high risk from groundwater pumping.
- The North Central CMA identifies high value GDEs that need to be protected.
- Groundwater trigger levels are established to protect GDEs, particularly the potential for increased leakage from the Coonambidgal Formation. The trigger should give consideration to the recorded historical shift in groundwater levels and losses from the river operation.

- GDEs are appropriately considered when assessing new groundwater licensing applications.
- Monitoring is undertaken of any high value GDE likely to be impacted by falling groundwater levels in areas of intensive groundwater development to refine management actions.

8 Water balance

8.1 Approach

A water balance has been developed using Microsoft Excel spreadsheet approach (G-MW, 2012). A transient simulation using simple mass balance equations has been applied using annual time steps to simulate and quantify components of the groundwater balance. Components of the water balance are shown in Figure 9.

The water balance is based on the period 1983/84 to 2010/11 as there is good quality groundwater monitoring data over this period to assist with calibration. The sustainable level of extraction has been determined for the following conditions:

- very wet conditions based on rainfall in 2010/11
- wet conditions based on the period of higher rainfall from 1983/84 to 1993/94
- long-term average conditions from 1983/84 to 2010/11
- dry conditions based on the period of reduced rainfall and declining groundwater levels from 1994/95 to 2009/10
- very dry conditions based on the period of low rainfall and drought from 2001/02 to 2006/07

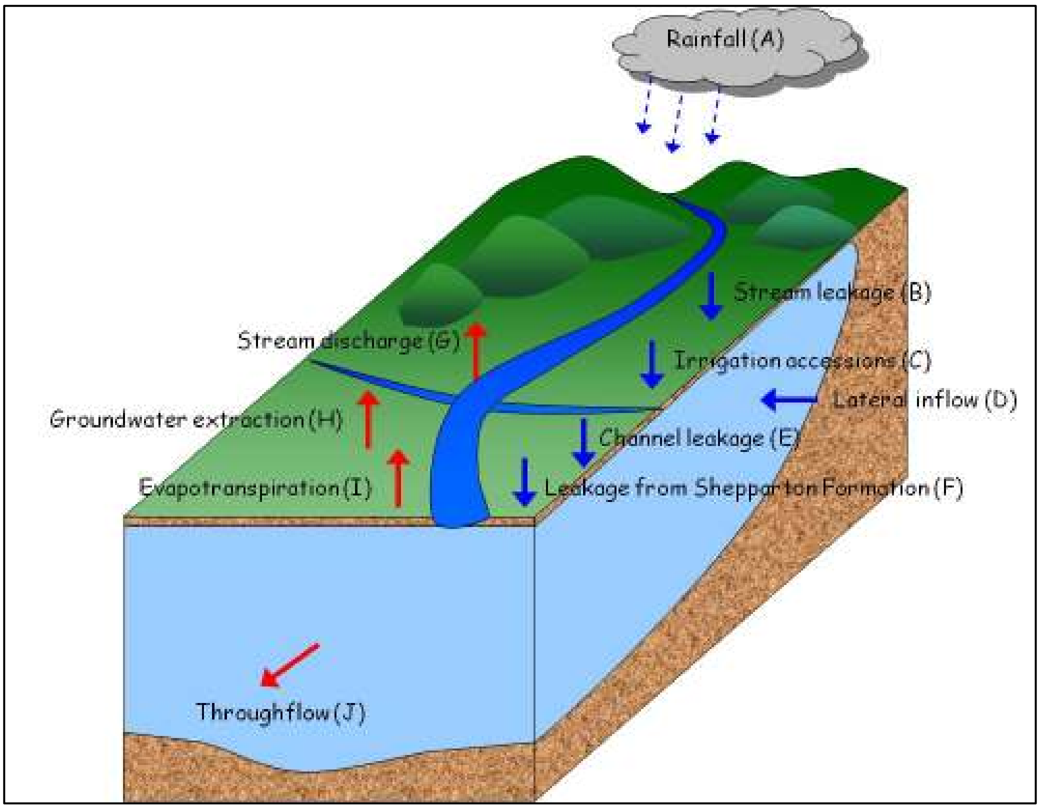


Figure 9 Water balance inputs and outputs

The change in storage has been determined using the following equation:

Equation 1 Storage change = (A + B + C + D + E + F) – (G + H + I+J)

Based on the conceptual understanding of the groundwater system, individual water balances have been developed for:

1. Barnadown Zone
2. Elmore Rochester Zone
3. Bamawm and Echuca Zone

The individual water balances have been linked to determine the sustainable level of extraction for the Lower Campaspe Valley WSPA.

8.2 Results

The water balance indicates that the greatest input to the system is rainfall recharge, which can be highly variable ranging from around 9 GL/yr in very dry seasons to 26 GL/yr in very wet seasons (Figure 10). Irrigation accessions and leakage from the Shepparton Formation are also important sources of recharge, particularly during dry seasons. Channel leakage, losses from the Campaspe River and lateral inflow are relatively minor components of the water balance.

Groundwater pumping is the greatest output from the system, with extractions increasing for drier conditions. Throughflow has been relatively constant, but falling groundwater levels in recent years have reduced the volume moving north out of the Lower Campaspe Valley WSPA. Discharge to land has reduced with falling groundwater levels and is a minor component of the water balance.

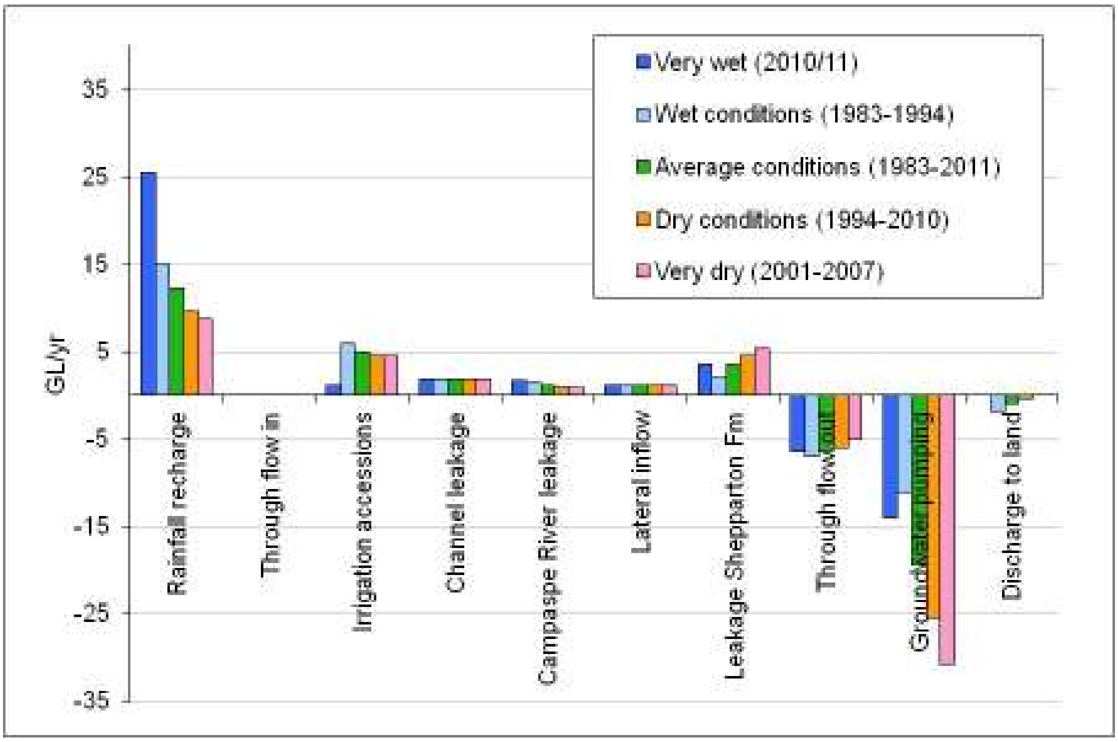
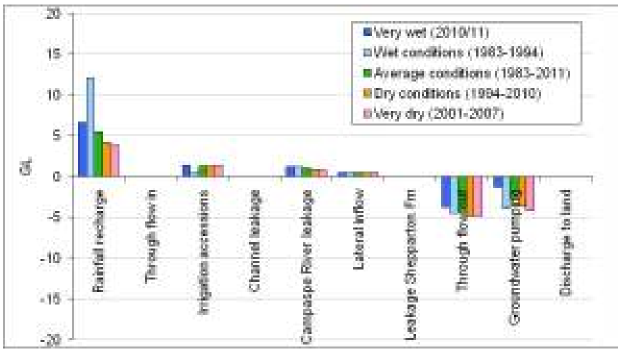


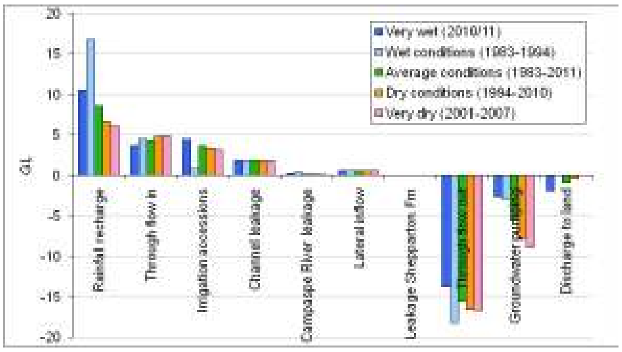
Figure 10 Lower Campaspe Valley WSPA water balance results

The greatest contribution from rainfall recharge and irrigation accessions is in the Elmore-Rochester Zone (Figure 11). While leakage from the Shepparton Formation is an important source of recharge in the Bamawm and Echuca Zone, much of the water entering the zone comes from throughflow from the Elmore-Rochester Zone.

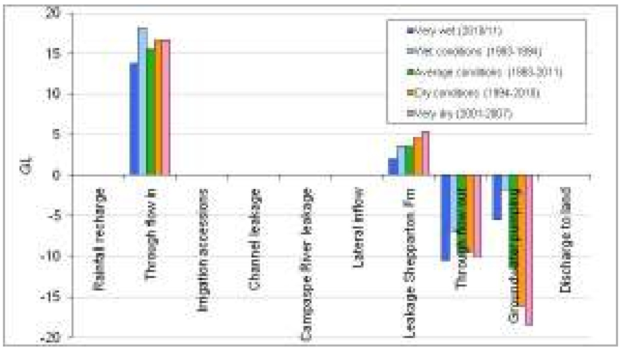
Groundwater extractions are greatest in the Bamawm and Echuca Zones and the Elmore-Rochester Zone.



(a) Barnadown Zone



(b) Elmore-Rochester Zone



(c) Bamawm and Echuca Zones

Figure 11 water balance results for zones

8.3 Discussion

Over the period 1983/84 to 2010/11 there was a reduction in groundwater storage of around 2 GL/yr (Figure 12).

Total inputs were around 25 GL/yr. Total outputs were 27 GL/yr, including 6 GL/yr throughflow out of the WSPA.

The results are an approximate indication of the volumes of the various components of the water balance parameters and can be used to provide guidance on the relative importance of each parameter.

If the throughflow was minimised, then there would be around 25 GL/yr available for extraction while maintaining equilibrium in storage.

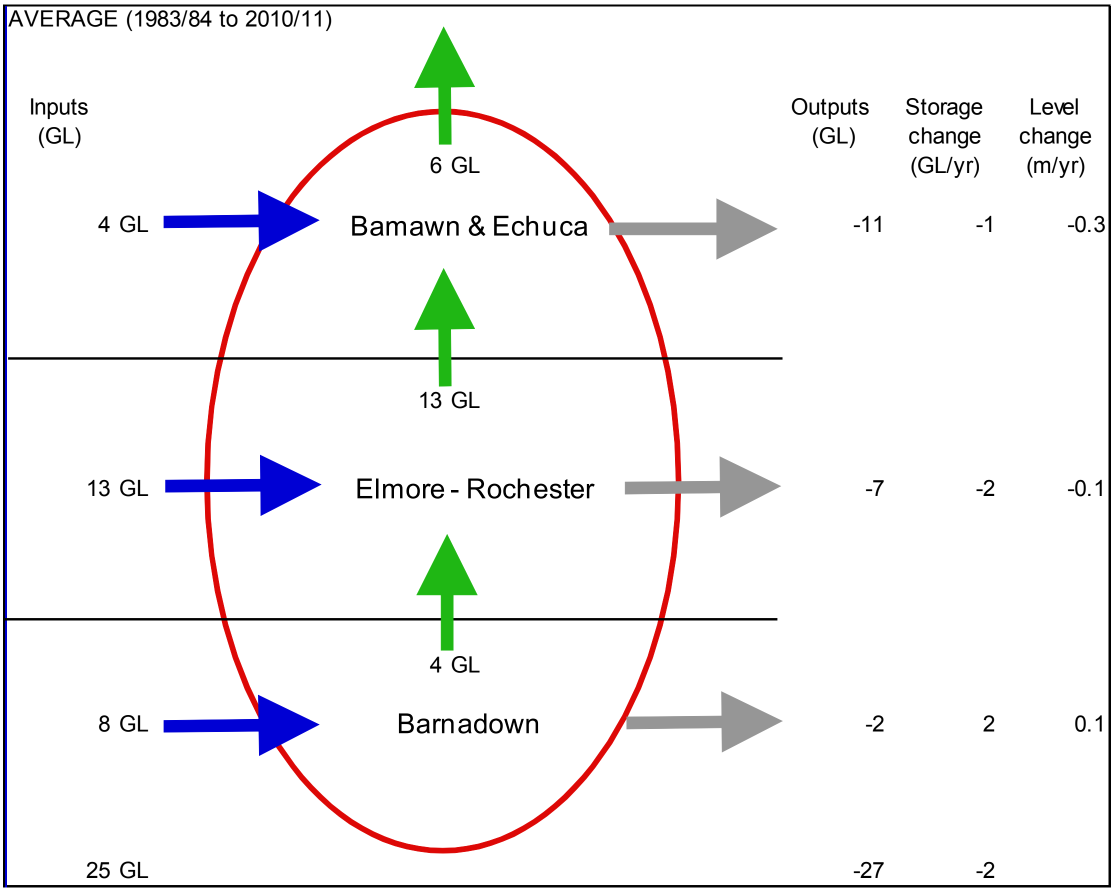


Figure 12 Modelled output for period 1983/84 to 2010/11

The sustainable level of extraction has been determined for various climatic scenarios (Table 4). The results suggest that for average conditions experienced between 1983/84 and 2010/11 the sustainable level of extraction was around 45% of licence entitlement.

If groundwater levels were to fall to the proposed trigger levels then this would induce more groundwater into the system (i.e. increase lateral inflow, leakage from the river and leakage from the Shepparton Formation) and more water may be available for extraction.

Table 4 Sustainable level of extraction for various climatic scenarios

Climatic conditions	Sustainable level of extraction (GL/yr)	% Licence entitlement
Very wet (2010/11)	35	63
Wet (1983/84 to 1993/94)	27	48
Average (1983/84 to 2010/11)	25	45
Dry (1996/97 to 2010/11)	23	41
Very dry (2001/02 to 2006/07)	22	39

Closure of the Campaspe Irrigation District may reduce groundwater recharge in the area by around 4 GL/yr comprising reduction in channel leakage and irrigation accessions in the Elmore-Rochester Zone.

The sustainable level of extraction for various climatic conditions may be used to inform restrictions.

Based on the storage coefficient used in calibration, a change in storage of 5 GL/yr would result in a modelled seasonal groundwater level shift of around 0.2 m in the Barnadown Zone, 0.4 m in the Elmore-Rochester Zone and 0.9 in the Bamawm and Echuca Zone. These values can be considered when deliberating the spacing between trigger levels and the impact of restrictions and management rules for carryover and trading.

9 Trigger levels

9.1 Context

Triggers are required to activate restrictions for the sustainable management of groundwater resources.

Typically, groundwater levels have been used to trigger restrictions. Restrictions could also be triggered by rainfall received, evapotranspiration, or the volume of groundwater extracted in a previous seasons (e.g. Katunga WSPA).

There is a poor understanding of recharge and evapotranspiration rates in the Lower Campaspe Valley WSPA. Further, metering problems and unlicensed usage make it difficult to accurately determine the volume of groundwater extracted. In this case, a trigger level based on the groundwater level appears the most acceptable. Trigger levels based on groundwater levels are generally easy to communicate and have been well accepted in other areas.

9.2 Considerations

To determine groundwater trigger levels consideration has been given to:

1. available drawdown for existing users;
2. watertable relief and land salinity benefits;
3. groundwater quality;
4. groundwater dependant ecosystems (GDEs);
5. groundwater interaction with surface water; and
6. conceptual understanding of the aquifer system.

Available drawdown

In the north of the Lower Campaspe WSPA (Echuca and Bamawm Zones) the boundary depth is 25 m below the natural surface. The watertable is close to the surface in this area and the Deep Lead is not well connected to the watertable aquifer. Therefore there is little risk for loss of access for groundwater users in this region.

In the Elmore-Rochester Zone the Shepparton Formation is well connected to the Deep Lead and extraction from the Deep Lead will impact on the watertable level. There may be some shallow domestic and stock bores that were installed during wetter climatic periods when groundwater levels were high that may be at risk of reduced supply if groundwater levels fall. These bores do not penetrate the aquifer. In this case the owners have the option of deepening their bore if required as the Shepparton Formation sands are well connected to the Deep Lead and there is a significant depth of aquifer material.

Similarly in the Barnadown Zone the Shepparton Formation aquifers are well connected to the Deep Lead and shallow bores installed in wetter climatic periods may be deepened.

On the margins of the WSPA, bedrock is closer to the surface which could limit the drilling depth into the Shepparton Formation; however the sand lenses in the Shepparton Formation are not as likely to be well connected to the Deep Lead in these areas.

Watertable relief and land salinity benefits

When groundwater levels were high, land salinity was an issue in the region, particularly in the Echuca, Bamawm and Elmore-Rochester Zones.

The Shepparton Irrigation Region WSPA GMP seeks to provide watertable relief in the Echuca and Bamawm areas. Groundwater extraction from the Deep Lead can increase the potential for drainage from the upper Shepparton Formation to the Deep Lead. In this case a downward hydraulic gradient should be maintained and groundwater pumping encouraged in this region. Consideration should be given to the potential to increase the groundwater salinity of the deeper aquifers.

In the Elmore-Rochester Zone pumping from the Deep Lead lowers the watertable level. Groundwater levels have fallen in this region from the late 1990s to early 2000s in response to reduced rainfall and irrigation recharge and groundwater pumping. Presently there appears to be little risk of land salinity resulting from a high watertables. Groundwater levels in this region should be managed so as to reduce the risk of land salinity by maintaining groundwater levels at depth.

Groundwater quality

Groundwater salinity increases to the north. Lowering the potentiometric surface in the Deep Lead may induce more saline groundwater into the WSPA, particularly from New South Wales.

In this case groundwater levels should be managed to maintain a net throughflow from Lake Eppalock to New South Wales to reduce the potential for saline groundwater intrusion.

Bore 79324 is one of the northern most State observation bores in the Lower Campaspe Valley WSPA with a long monitoring history. The nearest bore to the north in New South Wales is bore GW036765/3. These bores have been used to investigate the hydraulic gradient to New South Wales (Figure 13 and Figure 14).

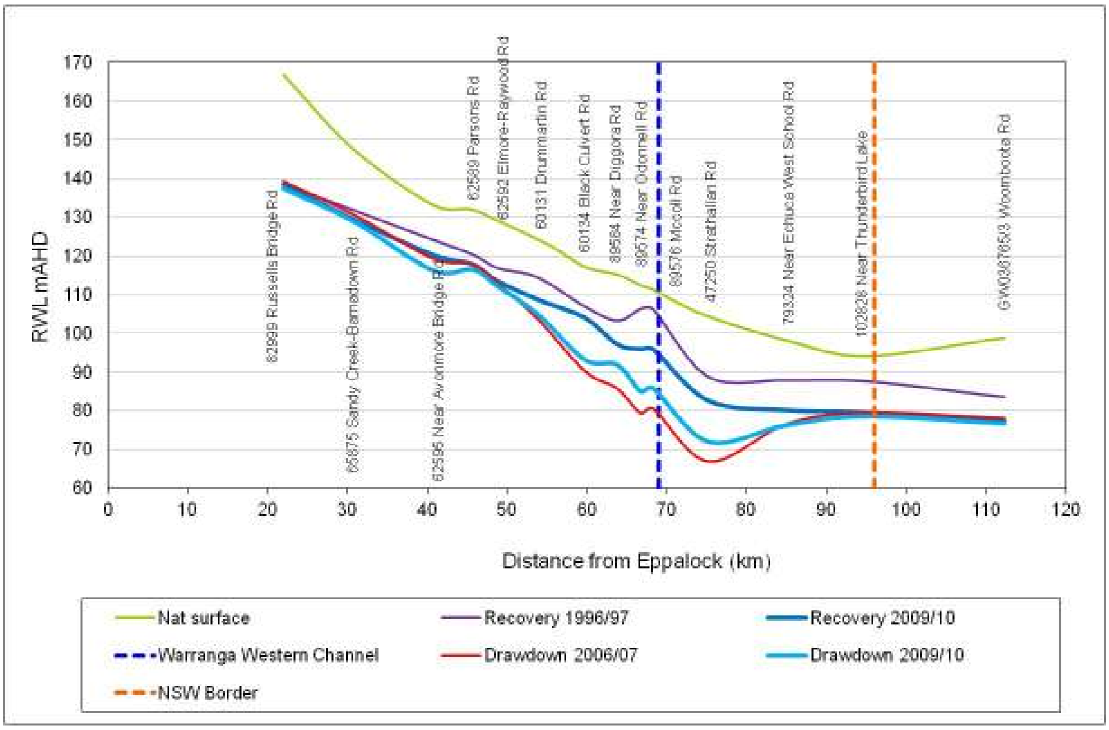


Figure 13 South to north section in

A groundwater recovery level of 22 m below the natural surface (76.1 m AHD) at State observation bore 79324, which is located in the area of most intensive groundwater pumping, will ensure that there is a net throughflow to New South Wales. Higher trigger levels at 19 m and 16 m could be adopted to slow the rate of groundwater level fall in the Lower Campaspe Valley WSPA.

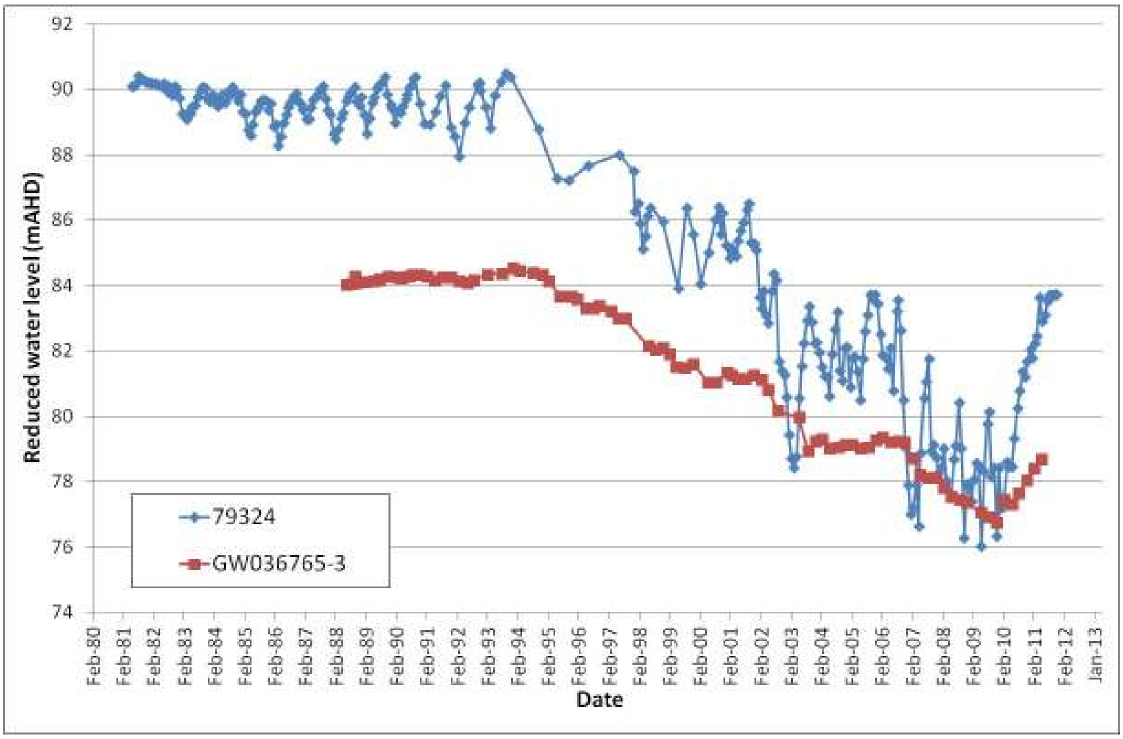


Figure 14 Hydraulic gradient to New South Wales over time

Groundwater dependent ecosystems

Presently there are no confirmed GDEs in the Lower Campaspe Valley. Mapping to date suggests that there may be GDEs to consider along the Campaspe River (e.g. River Redgums accessing water from Coonambidgal Formation), but this requires further investigations to determine their dependency on groundwater.

North of the Waranga Western Channel the Deep Lead is not well connected to the shallow Shepparton Formation sands. Therefore, groundwater pumping from the Deep Lead in this region is unlikely to adversely impact upon base flow or GDEs.

South of the Waranga Western Channel the Deep Lead is generally well connected to the shallow Shepparton Formation aquifers. In this case groundwater pumping from the Deep Lead can impact on the watertable depth.

Between the Waranga Western Channel and Campaspe Weir groundwater discharges to the Campaspe River. In the past high watertable levels have resulted in land salinity issues in this area (CWSIG, 1992). Further, discharge of saline groundwater over this reach of the Campaspe River has been identified as a concern (SKM, 2008). Therefore, lower groundwater levels in this area can provide environmental benefits.

South of the Campaspe Weir groundwater levels are generally well below the surface and unlikely to support GDEs.

Regulation of the Campaspe River maintains groundwater levels in the Coonambidgal Formation. Leakage from the Coonambidgal Formation is controlled by underlying clays in the Shepparton Formation. Lowering regional groundwater levels could induce further leakage from the river and may reduce water availability to GDEs during low flow periods, but this requires further investigation.

Groundwater trigger levels should be established to limit leakage from the river within existing operational losses south of the Campaspe Weir.

Interaction with surface water

Flows in the Campaspe River are regulated by releases from Lake Eppalock. Regulation has effectively turned the Campaspe River into a perennial system whereas before regulation there were periods of no flow. Falling groundwater levels can reduce groundwater discharge to the river, or induce further leakage from the river.

Downstream of the Campaspe Weir, where groundwater levels are elevated as a result of land use (i.e. irrigation), groundwater discharges to the Campaspe River.

North of the Waranga Western Channel there is not a strong hydraulic connection between the Deep Lead and the shallow Shepparton Formation aquifers. In this case pumping from the Deep Lead has negligible impact on the watertable.

Falling groundwater levels between the Campaspe Weir and the Waranga Western Channel could provide environmental benefits by reducing saline groundwater discharge. Falling groundwater levels would have little impact on flow over this reach as the Campaspe River does not overly the Deep Lead (Aquade, 2011).

Upstream of the Campaspe Weir the Campaspe River leaks to the groundwater system and always has (pre and post regulation). The greatest leakage is expected to occur between Barnadown and around 4 km downstream of Elmore where the Deep Lead underlies the Campaspe River. Falling groundwater levels could induce further leakage from the river, although more investigations are required to confirm this interpretation as it could be that the maximum leakage rate has already been reached.

Based on groundwater levels in 2010, Aquade (2011) suggest that leakage was between 2.1 and 5.2 GL/yr upstream of the Campaspe Weir. For every 1 m of groundwater level fall it is interpreted that leakage could increased by up to 300 ML/yr, if the maximum leakage rate has not already been reached.

It is proposed that a trigger be established between Barnadown and 4 km downstream of Elmore. Over this reach it is noted that:

- In the Barnadown Zone groundwater levels continued to rise to around 2000 despite drier conditions in the late 1990s.
- Groundwater levels were reported to be rising by 0.2 to 0.26 m/yr south of Elmore between 1900 and the mid 1970s (Macumber, 2008).
- Groundwater levels were rising in the Barnadown Zone had a rising trend of around 0.17 m/yr over the 1980s and early 1990s (Aquade, 2011)
- A hinge line has been interpreted to occur around Parson's Road.

It is proposed that bore 62589 located near Parson Road be adopted as a trigger bore. If the groundwater levels fall below 16 m (around 2 m below the 2009/10 levels) below the natural surface then restrictions should be considered. A 2 m fall in groundwater levels at this site is a relatively large shift and similar to the fall observed between 2005/06 and 2009/10.

A further fall in groundwater levels would suggest that conceptual understanding should be reviewed as groundwater pumping may be impacting on the interpreted hinge line. It is proposed that a second trigger 18 m below the natural surface at bore 62589, which is considered significant in comparison to historical levels at this bore, be adopted to trigger a review of the Plan.

Conceptual understanding of the aquifer system

Groundwater flows from south to north through the aquifer system. Throughflow is an important component of the water balance.

Groundwater levels are observed to have been declining at greater rates in both the Elmore-Rochester and Bamawn Zones. Licence volume and extraction is greatest in these zones.

Groundwater levels in the Barnadown Zone indicate that the aquifer is not under stress, with levels remaining relatively steady despite the severe dry conditions experienced between the mid 1990s and 2010.

It has been identified that groundwater level responses in the Barnadown Zone are largely independent of aquifer response in zones further north. This is due to a hinge line that has been interpreted at Parsons Road where groundwater extraction from the north of the WSPA does not impact upon groundwater levels in the south.

In this case trigger levels should be considered for:

1. Barnadown Zone; and
2. Elmore-Rochester, Bamawm and Echuca Zones

9.3 Proposal

It is proposed that a single bore is used as a trigger and that the levels in that bore are validated b surrounding bores. This acknowledges the strong seasonal recovery observed in groundwater levels across the region. This provides a transparent trigger and restriction methodology.

Based on the above considerations, the greatest risk is the potential for saline intrusion to from adjacent areas and potential for increased leakage from the Campaspe River between Barnadown and around 4 km downstream of Elmore. In this case it is proposed that:

- A groundwater level trigger of 22 m below the natural surface is adopted at bore 79324 located on Echuca West School Road for the Echuca, Bamawm and Elmore-Rochester Zones to ensure that there is a net through flow to New South Wales. Higher trigger levels at 19 m and 16 m should be adopted to slow the rate of groundwater level fall in the Lower Campaspe Valley WSPA.
- A groundwater level trigger of 16 m below the natural surface is adopted at bore 62589 located near Parsons Road for the assessment of restrictions in the Barnadown Zone. If groundwater levels were to fall to 18 m below the natural surface (114 m AHD) then further restrictions should apply and the conceptual understanding of the groundwater system should be reviewed.

10 Restrictions

10.1 Context

The development of the Lower Campaspe Valley WSPA GMP requires restrictions on the taking of groundwater to:

1. prevent the level of groundwater declining below a specified level or specified average level to ensure long term sustainability of the resource;
2. prevent the relevant permissible consumptive volume being exceeded;
3. ensure the environmental water reserve (EWR) is maintained in accordance with the EWR objective.

The Ministerial Guidelines for the development of the Lower Campaspe Valley WSPA GMP specifies that the plan must clearly explain the method of calculating the water levels in specified bores that will be used for setting restrictions, the trigger levels at which restrictions would be introduced and the means by which such restrictions will be introduced and relaxed or lifted.

10.2 Background

Previously, under the Campaspe Deep Lead WSPA GMP, allocations were imposed to ensure that groundwater levels didn't fall below minimum average annual levels (AALs) specified in the plan. The AAL took into account the groundwater recovery levels in that season and the expected drawdown levels resulting from any specified seasonal allocation. A mathematical model based on empirical relationships was used to undertake the necessary calculations.

In the management plan, a seasonal allocation was announced on 15 August each year. If restrictions were imposed, a review was conducted mid-season to determine whether an increase in allocation could be announced based on an improvement in groundwater recovery.

The review of the Campaspe Deep Lead WSPA GMP identified that the method used for setting the levels were not risk-based and the complexity of the allocation process proved difficult to communicate to customers (G-MW, 2010).

In the former Southern Campaspe Plains Groundwater Management Area and unincorporated areas licence holders have never been on restrictions.

10.3 Discussion

For the development of a GMP in the Lower Campaspe Valley groundwater trigger levels have been determined based on the greatest risk due to development of groundwater resources.

To manage groundwater levels a restriction rationale is proposed that is:

- simple to calculate;
- transparent; and
- easy to communicate and interpret.

The restriction rationale proposed is based a rolling average that is compared to trigger levels. Staged restrictions, that allow movement of groundwater levels within established ranges, would apply on the use of licence entitlement when trigger levels are reached.

Restrictions would be introduced through the use of allocations. Allocations are a percentage of licence entitlement that may be extracted in a given season. For example, if a licence volume was 100 ML, and a 50% allocation was announced, then up to 50 ML may be extracted under that licence.

10.4 Restriction rationale

Rolling average

If allocations were based on the groundwater recovery levels in that season, then the final allocation announcement may not be made until possibly November, which doesn't provide licence holders with certainty upon which to plan their operations. To overcome this, it is proposed that the allocations for a particular season be based on a rolling average.

A rolling average is calculated by summing the seasonal maximum groundwater recovery levels (generally seen between August and November) for a specified time period and dividing by the length of this time period.

A three year rolling average period was determined to be the most appropriate in the Lower Campaspe Valley. Shorter periods resulted in an overly reactive response to a dry spring or drought season. Longer periods resulted in greater time to increase allocations if groundwater levels were to rise.

An example of the rolling average approach is provided below. The rolling average for season 4 is the average maximum seasonal groundwater recovery levels for the proceeding three seasons. In this example, it is calculated by summing the levels in seasons 1, 2 and 3 (100 +102 + 104 = 306) and dividing by the time period (3) to get a value of 102, which would be assessed against the trigger level to determine allocations in season 4.

Example

Season	1	2	3	4
Maximum groundwater recovery levels	100	102	104	
Rolling Average				102

Allocation ranges

It is proposed that allocations of 100%, 75% and 50% of entitlement be established to manage groundwater levels. These allocation ranges will facilitate decision making and planning by licence holders and is less confusing than a system with incremental changes.

A 25% change in allocations has the potential to provide a measurable shift in groundwater levels. Smaller changes in allocation may not achieve the desired groundwater level response.

Movement of groundwater levels will be allowed within ranges. A separation of 3 m between trigger levels was determined to be most appropriate based on groundwater level response to a change in storage in the northern zones. This separation allows licence holders to plan ahead with some certainty as they can see what the likely allocations will be. A separation of 2 m is proposed for the Barnadown Zone trigger bore where levels are relatively steady.

Allocation announcement

It is proposed that the allocations be based on the maximum groundwater recovery level from the previous three seasons. In this case allocations may be announced by 1 July each year. This approach provides licence holders with certainty on allocations so that they can plan for the season ahead.

As it is proposed that allocations are to be determined from the maximum recovery level from the previous seasons, allocations will not be reviewed during the season. In this case, allocations remain in place until the 30 June of the following year.

Benefits and limitations

The benefits of the proposed allocation rationale include:

- The allocation for the following season is known in advance enabling licence holders to make early business decisions.
- The allocation is fixed for the whole season.
- The allocation percentages can provide a measurable difference in groundwater levels and movement within a trigger range.
- The method allows licence holders to predict whether restrictions would apply in the following season and plan accordingly.

The limitations of the allocation rationale include:

- The actual seasonal groundwater level could be below the trigger level, but allocations would not have reduced because the rolling average level remains above the trigger. To account for this it is proposed that there be a staging of restrictions.
- The actual seasonal groundwater level is above the trigger level, but the rolling average remains below the trigger. In this case licence holders would be on reduced allocations despite higher groundwater levels. While this method may limit licence holders as groundwater levels are rising, the increase in groundwater storage will provide them with greater certainty for future seasons. It is also likely that when groundwater levels are rising in wetter seasons there will be less demand for groundwater.

Elmore-Rochester, Bamawm and Echuca Zones

It is proposed that the minimum trigger level be set at 22 m below the natural surface at State observation bore 79324 situated on Echuca West School Road to trigger a 40% allocation in the Elmore-Rochester, Bamawm and Echuca Zones and review of the Plan (Figure 15). It is proposed that a 75% allocation apply between 16.1 and 19.0 m and that a 50% allocation apply between 19.1 and 22.0 m.

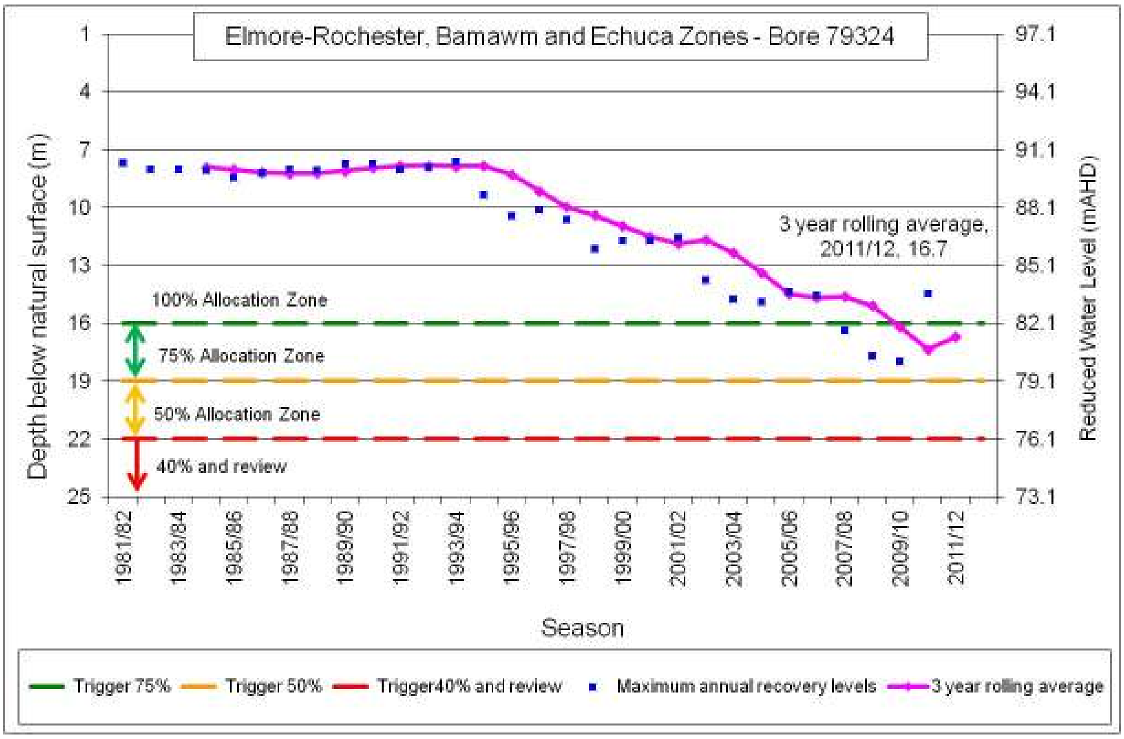


Figure 15 Trigger level and allocations for Elmore-Rochester, Bamawm and Echuca Zones

Barnadown Zone

It is proposed that a 16 m trigger level at bore 62589 result in a 75% allocation in the Barnadown Zone and that an 18 m trigger level result in the same allocation as applied to the Elmore-Rochester, Bamawm and Echuca Zones at that time (Figure 16).

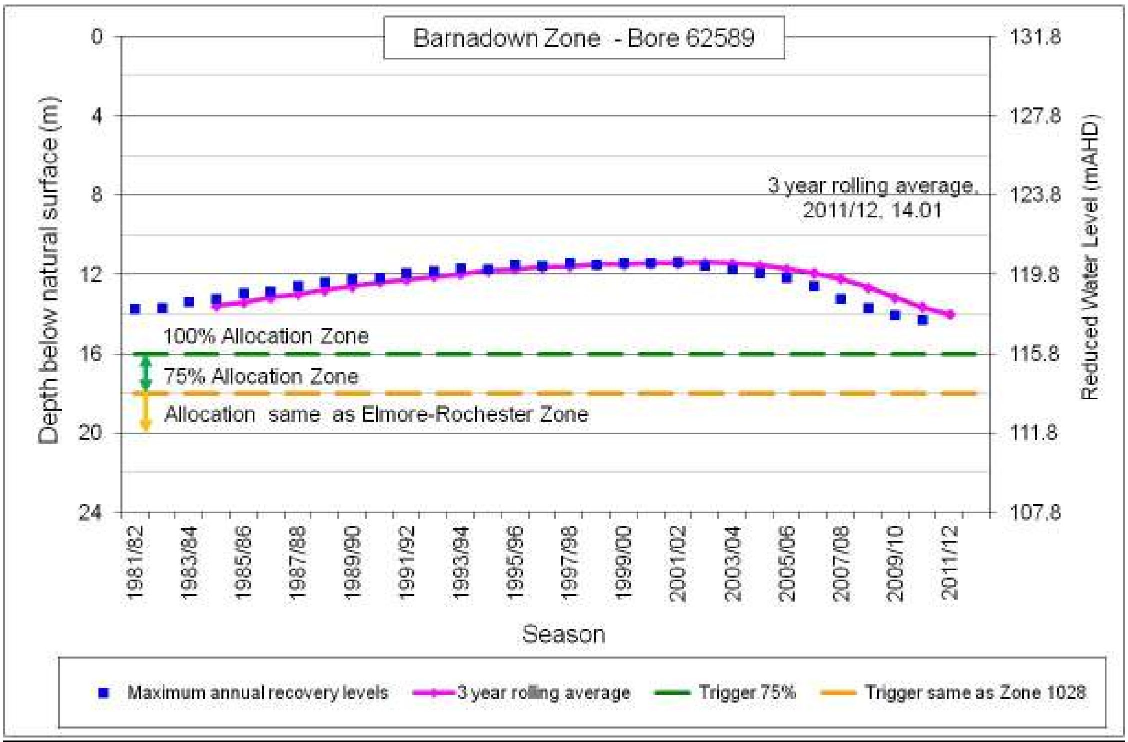


Figure 16 Trigger level and allocations for the Barnadown Zone

11 Intensive groundwater pumping

11.1 Background

Groundwater pumping results in a decline in groundwater levels surrounding the bore being pumped. The decline in groundwater level is referred to as the ‘drawdown cone’ or ‘cone of depression’. The distance the drawdown cone extends, and the shape of the cone depends primarily on the nature of the aquifer, the pumping rate and pumping duration. Drawdown decreases with distance from the bore, and the cone expands in size whilst pumping continues until steady-state conditions are reached.

When bores located in close proximity are extracting from the same aquifer it can result in intersecting drawdown cones as illustrated below (Figure 17). Unacceptable drawdown levels could be a consequence of the cumulative impacts of a number of pumps operating in a local area (intensive groundwater pumping).

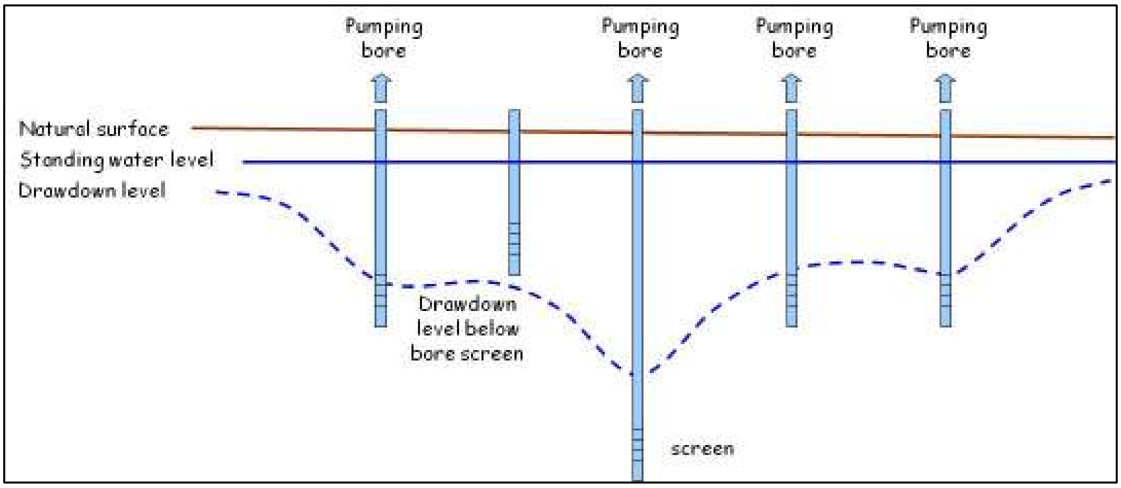


Figure 17 Interference caused by intensive groundwater pumping

11.2 Discussion

There is a need to set limits to prevent intensive groundwater pumping having unacceptable impacts on surrounding groundwater users including the environment. Managing groundwater pumping intensity allows more site specific assessment and seeks to reduce unnecessary administrative zone boundaries.

Ideally, each individual application would be assessed to determine the cumulative impacts when all licensed bores are operating and assess if the drawdown would result in unacceptable impacts. However, this approach is limited by the availability of accurate information to undertake the assessment (i.e. aquifer hydraulic characteristics, pumping rates and duration of all neighbouring bores, available drawdown) and investigations would be an added expense to the applicant. Further, such an approach may hinder groundwater development as there would be a reluctance to invest in the installation of a new bore without some assurance that the licence application may be approved.

It is therefore proposed that an intensity rule be established for the annual volume of groundwater pumped in a given area. This approach has been adopted in the Mid-Loddon Groundwater Management Area and provides some certainty with respect to siting new bores and development potential in a given area.

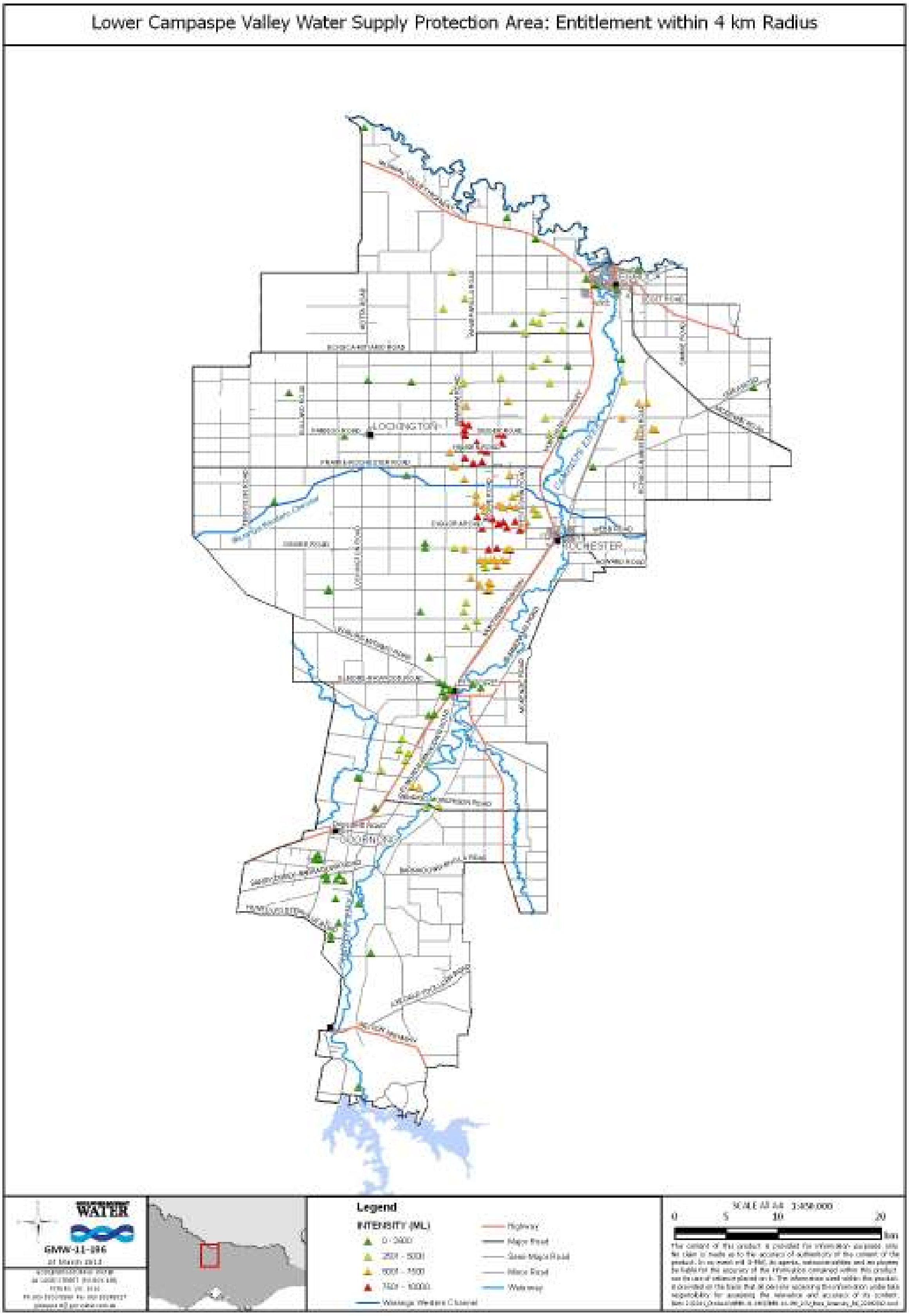


Figure 18 Intensity of groundwater pumping

The area to apply must be large enough to permit reasonable development, but still provide some limit to protect access to existing users. An assessment was undertaken to determine the current intensity of pumping in the WSPA. Based on metered use and observed drawdown, it is proposed that extractions from an applicant's bore be limited to 7.5 GL/yr within a 4 km radial area.

It is recognised that some areas the licence volume currently exceeds the proposed intensity limits. In these areas a licence holder's usage is to be limited to 125% of licence volume (from either a temporary transfer or carryover) in any season, unless they trade from another licence holder with the 4 km radius.

The proposal recognises current entitlement and use, provides scope for future development, and caps intensity of pumping in any developing areas.

Example

The three shapes in the Figure 19 represent bores each licensed to extract 3,000 ML/year.

The sum of the licensed entitlement within a 4 km radius of both the red triangle and the grey square is 6,000 ML/yr. That is, the red triangle and the blue diamond are within 4 km of each other. Similarly, the grey square and the blue diamond are both within a 4 km of each other.

The owners of the red triangle and the grey square may apply to extract up to an additional 1,500 ML/year through a groundwater transfer as this is the difference between licensed entitlement and the 7,500 ML threshold within a 4 km radius of an applicant's bore.

The licensed entitlement within a 4 km radius of the blue diamond is 9,000 ML/yr. That is, the red triangle and the grey square are both within 4 km of the blue diamond. As entitlement within a 4 km radius of the blue diamond exceeds the threshold of 7,500 ML, the owner of the blue diamond is limited to usage of 125% of entitlement (3,750 ML/yr) in one year unless trading from others within the 4 km radius (red triangle or grey square).

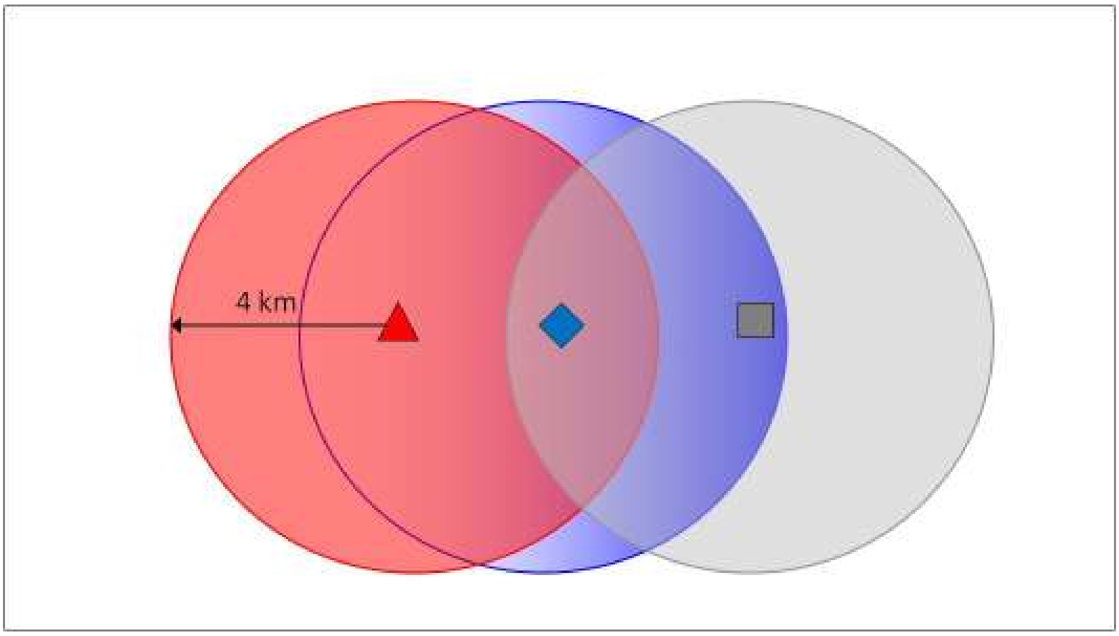


Figure 19 Intensity rule example

12 Groundwater trading

12.1 Background

A review of the Campaspe Deep Lead WSPA found that the previous trading rules were restrictive and recommended the provision for both temporary and permanent transfer as well as fewer barriers to trade (G-MW, 2008).

The removal of barriers to trade water is one of the objectives of the National Water Initiative.

12.2 Advantages and limitations of trading

The transfer of licence entitlement allows individuals to adjust their enterprises depending on their circumstances.

Some of the advantages of temporary trading include:

- greater flexibility for licensed groundwater users to increase production
- market opportunities for sleeper licences
- drought management option

Some of the advantages of permanent trading include:

- opportunity to improve groundwater resource management through redistribution of entitlement
- establishment of new groundwater developments or growth of existing business with increased security of supply

Some of the possible limitations of the transfer of licence entitlement include:

- activation of sleeper licenses, which could impact on allocations
- concern for groundwater interference resulting from a transfer

12.3 Discussion

Four management zones have been proposed for the Lower Campaspe Valley WSPA based on the conceptual understanding of the groundwater system:

1. Barnadown
2. Elmore-Rochester
3. Bamawm
4. Echuca

Management zones are a useful management tool to assist with managing stressed parts of the aquifer through groundwater trading rules or restrictions. Effective management of groundwater resources through zoning can also provide salinity benefits by delineating areas of risk.

Barnadown

Groundwater levels in this region indicate that the aquifer is not under stress, with groundwater levels remaining relatively constant despite the severe dry conditions experienced over the last decade.

It appears that groundwater level responses in the Barnadown Zone are independent of aquifer response in zones further north. That is, groundwater pumping in the Barnadown Zone doesn't impact on the levels in the Elmore-Rochester Zone and groundwater pumping in the Elmore-Rochester Zone doesn't impact on the levels in the Barnadown Zone. A hinge point is interpreted to occur around Parsons Road where groundwater levels have remained relatively steady, despite falling groundwater levels to the north.

The licence volume in the Barnadown Zone is approximately 8 GL/yr with usage being around 50%. The water balance suggests that licence volume approximates the average sustainable level of extraction (determined for the period 1983 to 2011) in this zone.

It is proposed that:

- Groundwater entitlement may be transferred either temporarily or permanently within the Barnadown Zone.
- No transfer of entitlement into the Barnadown Zone unless triggered by groundwater levels falling below 18 m in bore 62589
- No transfer of entitlement out of the Barnadown Zone unless triggered by groundwater levels falling below 18 m in bore 62589

Elmore-Rochester Zone

Groundwater levels in the Echuca-Rochester Zone fell by around 10 m in response to dry conditions and groundwater pumping between the mid 1990s and 2010. There has been a sharp increase in groundwater levels in response to rainfall in 2010/11.

Throughflow to the Bamawm Zone is significant and is driven by the steep hydraulic gradient to the Bamawm Zone. This indicates that groundwater pumping in the Bamawm Zone has an impact on the resource in the Elmore-Rochester Zone.

The licence volume in the Elmore-Rochester Zone is around 15 GL/yr. Usage is around 50% of licence volume, increasing to around 60% in dry years.

Increased groundwater pumping in the Elmore-Rochester Zone will lower the watertable. This could reduce supply to groundwater users with shallow bores and induce leakage from the Campaspe River.

On the other hand, lowering the watertable has provided land salinity benefits in the region and could reduce discharge of saline groundwater to the Campaspe River between the Campaspe Weir and Rochester.

It is proposed that:

- Groundwater entitlement can be transferred either temporarily or permanently within the Elmore-Rochester Zone.
- Groundwater entitlement may be transferred either temporarily or permanently to the Bamawm Zone and the Echuca Zone.
- Groundwater entitlement may be temporarily or permanently transferred into the Elmore-Rochester Zone so long as the total licence volume does not exceed 18 GL/yr. This provides some scope for the transfer of entitlement (potential to increase licence entitlement in the zone by 20%, which is 3 GL/yr and less than 0.5 m change in groundwater levels) without unacceptable risk to existing groundwater users and the environment.

Bamawm Zone

Groundwater levels in the Bamawm Zone fell by around 10 m in response to dry conditions and groundwater pumping between the mid 1990s and 2010.

Licence volume in the Bamawm Zone is around 26 GL/yr. Usage is around 50% increasing to around 60% in dry years. Groundwater extraction in this zone results in a large drawdown cone during the irrigation season.

Groundwater extractions in either the Elmore-Rochester Zone or Echuca Zone can impact on storage in the Bamawm Zone.

Increased groundwater pumping in the Bamawm Zone will have little impact on the watertable because of the poor hydraulic connection between the Deep Lead and the upper Shepparton Formation, but it does have the potential to improve drainage from the shallow aquifers.

Increase groundwater pumping will lower groundwater levels and has the potential to draw in more saline groundwater from adjacent areas. The proposed trigger level and allocations will reduce the likelihood of saline groundwater intrusion.

It is proposed that:

- Groundwater entitlement can be transferred either temporarily or permanently within the Bamawm Zone.
- Groundwater entitlement may be transferred either temporarily or permanently to the Elmore-Rochester Zone or the Echuca Zone.
- Groundwater entitlement may be temporarily transferred or permanently into the Bamawm Zone so long as the total licence volume does not exceed 28.5 GL/yr. This provides some scope for the transfer of entitlement (potential to increase licence entitlement in the zone by 10%, which is 3 GL/yr and less than 1.0 m change in groundwater level) without unacceptable risk to existing groundwater users and the environment.

Echuca Zone

Groundwater levels in the Echuca Zone fell by around 10 m in response to dry conditions and groundwater pumping between the mid 1990s and 2010.

Licence volume in the Echuca Zone is around 6.6 GL/yr. Usage is around 30%. Impacts of groundwater pumping in the Echuca Zone are similar to those in the Bamawm Zone.

There is a marked increase in groundwater salinity in the Echuca Zone, which is the defining reason for this zone.

It is proposed that:

- Groundwater entitlement can be transferred either temporarily or permanently within the Echuca Zone.
- Groundwater entitlement may be transferred either temporarily or permanently to the Bamawm Zone or Elmore Rochester Zone.
- Groundwater entitlement may be temporarily or permanently transferred into the Echuca Zone so long as the total licence volume does not exceed 9.6 GL/yr. This provides some scope for the transfer of entitlement (potential to increase licence entitlement in the zone by 3 GL/yr which is less than 1.0 m change in groundwater level) without unacceptable risk to existing groundwater users and the environment.

13 Groundwater carryover

13.1 Context

Carryover is unused allocation that may be used in subsequent years. It allows groundwater users to manage their own risk as it gives them greater flexibility to use water when it is of greatest benefit to them.

Some of the advantages of carryover are that it:

- provides security of supply when surface water or groundwater allocations are low;
- provides licence holders with greater flexibility with management of their entitlement (i.e. it may be used this season or be retained and used next season);
- avoids potential for overuse issues;
- reduces reliance upon finding someone to transfer entitlement from;
- increases opportunities for transfer of groundwater as license holders will want to benefit from available water; and
- provides investment opportunities where licence holders might choose to carryover and transfer in dry seasons.

13.2 Assessment

Carryover has not previously been available in any part of the Lower Campaspe valley WSPA. The Northern Region Sustainable Water Strategy (NRSWS) states that carryover may be introduced where:

- there is adequate data about the aquifer and likely responses to extraction
- the licensed bores in the areas are metered
- there is enough volume in the aquifer to buffer levels against variable pumping rates from year to year
- third parties, including the environment, are not adversely impacted
- relevant management arrangements are in place, such as PCV and triggers levels.

The NRSWS states where carryover is introduced that groundwater users may be able to carrying over a maximum of 50% of their entitlement. However, 5% of the carry over volume will be deducted each year to account for losses from the system, such as throughflow and discharge.

There is an extensive bore monitoring network in the Lower Campaspe Valley WSPA with a good history of aquifer response to groundwater pumping and climate impacts.

All licensed bores in the Lower Campaspe Valley WSPA are metered.

The aquifer system in the Lower Campaspe Valley is very large, with the depth of the saturated formation increasing from around 40 m to 80 m down the valley. Groundwater recovery levels declined by up to 10 m between the mid 1990s and 2010 in response to reduced recharge and groundwater pumping indicating that there is sufficient volume in the aquifer to buffer levels against variable pumping rates from year to year. This is supported by a water balance that has been prepared for the region that suggests that a change in storage of 5 GL/yr would result in groundwater levels falling by less than 1 m.

Existing licence conditions should be sufficient to effectively manage the impacts of drawdown to existing groundwater users and the environment with the introduction of carryover. Licence conditions limit daily extraction rates and volumes to manage interference. A licence holder may apply to increase their pumping rate as a result of having access to carryover, but a decision to vary the pumping rate would need to take into account bore interference and environmental considerations.

A PCV has been set for the Lower Campaspe Valley WSPA and it is proposed that carryover be introduced under GMP for the area which shall have triggers levels to manage groundwater levels.

The 5% deduction from carryover is not warranted as usage below entitlement provides for throughflow. Further, it is unlikely that usage would equal entitlement as most users frequently have unused allocation, additional to the maximum carryover volume, that would move through the aquifer.

13.3 Discussion

Carryover is likely to be accumulated in wetter seasons when demands for water are less, or when there is plenty of surface water available as irrigators will generally use surface water rather than groundwater if available. In this case carryover will result in more efficient use as there will be less of a ‘use it or lose it’ philosophy.

It is likely that most people will retain carryover for use when reduced allocations have been announced, or in dry years due to increased water demands and reduced surface water availability.

Carryover, combined with trading, can result in increased groundwater usage. Licence holders that do not use their annual allocation will accumulate carryover to the maximum percent of their entitlement and use it in a subsequent year.

When the carryover is used there will be a fall in groundwater levels relative to the volume used. An upper limit is required for the volume of groundwater that can be carried over in a given system. The relevant rules should aim to increase flexibility for licence holders without causing unacceptable third party impacts.

A higher carryover volume provides greater flexibility for individual licence holders and would make more water available to them when reduced allocations are applied. However, it will cause a greater fall in groundwater levels the season that it is used. This fall could be exacerbated by reduced recharge, or increased groundwater pumping.

A lower carryover volume would mean that any unused entitlement that is not carried over would remain in storage. While this may not provide as much flexibility for the individual it could possibly provide for higher allocations. Further, a lower volume of carryover will likely reduce the period of time that restrictions are required as groundwater level will not fall as far when carryover is used.

The acceptable limit of carryover might be that volume that will not result in groundwater levels falling to an even lower trigger under dry conditions. The buffer between triggers in the Lower Campaspe Valley WSPA is 3 m in the northern Elmore-Rochester, Bamawm and Echuca Zones.

13.4 Proposal

It is proposed that a maximum of 25% of licence entitlement may be carried over in the Lower Campaspe Valley WSPA.

With a maximum of 25% the most water that could be carried over would be 14 GL, comprised of approximately 2 GL/yr in Bamawm Zone, 4.5 GL/yr in Elmore-Rochester Zone and 7.5 GL/yr in the Bamawm and Echuca Zones.

Proposed trigger levels in the Lower Campaspe Valley are 2 m and 3 m apart in the Barnadown Zone and northern zones respectively. In a dry season, with high entitlement and carryover use, there could be a sharp fall in groundwater levels which could result in harsher restrictions the following year, or take longer for groundwater levels to recover and restrictions to be eased. A greater percentage of entitlement for carryover would only exacerbate the problem. Limiting carryover to 25% will reduce the likelihood of sharp groundwater level declines.

A maximum carryover of 25% enables licence holders to maintain production at the same rate if lower allocations are announced for at least another season as the proposed restrictions are a 25% reduction in allocation.

Licence holders with carryover would have the potential to use 125% of their licence entitlement in any season, provided they could extract the water under their licence conditions. Where the licence conditions limit extractions, licence holders may apply to amend their licence to increase the extraction rate. The Corporation would then undertake a risk assessment to determine the impacts of additional extraction from a bore on surrounding groundwater users and the environment and either approve, approve with conditions or refuse the application.

Alternatively, carryover could be a maximum of 50% of licence entitlement, with usage of carryover limited to 25% each year. This option would allow an individual to carryover more water and provide greater flexibility to manage their entitlement. On the other hand, if licence holders were to use their carryover in subsequent dry seasons it could result in lower groundwater levels and harsher restrictions sooner, or take longer for allocations to increase.

Example

An example of carryover use is provided in Table 5. In this example the licence holder has an entitlement of 100 ML/yr and potential to carryover 25 ML (25% of licence entitlement).

Table 5 Carryover example

Season	1	2	3	4	5
Entitlement (ML)	100	100	100	100	100
Allocation	100%	100%	100%	75%	75%
Subtotal (ML)	100	100	100	75	75
Carryover (ML)	0	25	20	10	5
Trade in (ML)	0	0	0	10	0
Trade out (ML)	0	25	0	0	0
Balance (ML)	100	100	120	95	80
Usage (ML)	70	80	110	90	75
Remaining water (ML)	30	20	10	5	5
Available for carryover (ML)	25	20	10	5	5

In season 1 the allocation is 100%. The licence holder users 70 ML and has 30 ML remaining. A maximum of 25% may be carried over (25 ML) for throughflow and groundwater discharge. In this case the licence holder can carryover 25 ML to season 2.

In season 2 the allocation is 100%, so the licence holder has 125 ML available. The licence holder trades out 25 ML and uses 80 ML, leaving 20 ML available for carryover.

In season 3 allocation is 100% and the licence holder has carried over 20 ML, providing 120 ML for the season. The licence holder uses 110 ML and has 10 ML available for carryover.

In season 4 allocations are 75%. The licence holder has 10 ML carryover and trades in 10 ML, so the licence holder has a total of 95 ML available. The licence holder uses 90 ML and can carryover 5 ML.

In season 5 allocations are 75% and the licence holder has 5 ML carryover, providing a total of 80 ML. The licence holder uses 75 ML and can carryover 5 ML.

14 Monitoring

14.1 Context

Section 4 of the Ministerial guidelines requires that the GMP consider groundwater monitoring.

Monitoring, evaluating and reporting of groundwater levels and quality from a network of strategically located monitoring bores over time are critical to inform effective groundwater resource management.

The guidelines state that the plan must specify key performance indicators to be monitored for the purpose of assessing whether the plan's objectives are being achieved. It must identify the location of monitoring points and measurement frequency.

Monitoring may include such things as:

- Water levels in particular bores as a trigger for reducing seasonal allocations
- Water levels and/or quality to observe the impacts of extractions and transfers and therefore improve the understanding of how the system responds.
- Water chemistry sampling to determine quality trends and groundwater movement within and between aquifers

The plan should identify any requirement for additional monitoring locations to improve the spatial location of monitoring points and integrity of monitoring data and include a timeframe for the installations of the monitoring points within the term of the plan.

14.2 Background

The Lower Campaspe Valley has an extensive network of State observation bores, with over 100 bores monitored by the Department of Sustainability and Environment on a quarterly basis in February, May, August and November (Figure 20). Many of the bores have a reasonably long groundwater level monitoring record, stretching back to the late 1970's. G-MW monitors 38 of these State observation bores on a monthly basis to further to inform resource management decisions.

There is no ongoing program to monitor groundwater quality in the Lower Campaspe WSPA. G-MW send sample bottles to licence holders on an annual basis to record any changes in groundwater salinity. Unfortunately the sample return rate is low, quality assurance procedures are poor and samples are not always received from the same bores making it difficult to determine any trends with confidence.

14.3 Considerations

To establish an effective groundwater monitoring network for effective resource management consideration has been given to:

1. groundwater quality;
2. land salinity;
3. groundwater interaction with surface water;
4. groundwater dependent ecosystems;
5. long-term sustainability;

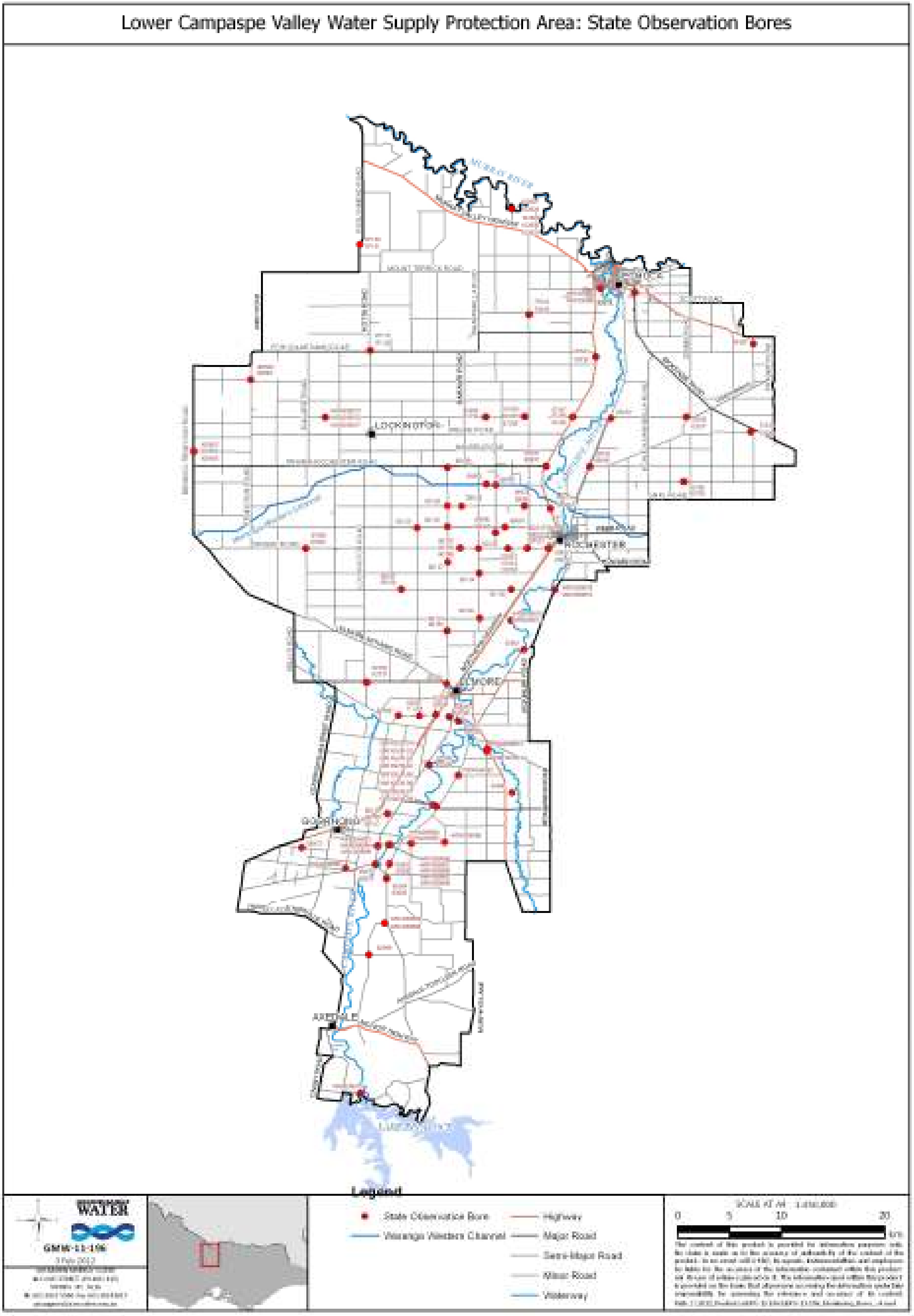


Figure 20 Monitoring bores

6. confirm understanding of groundwater system and aquifer response to pumping; and
7. spatial distribution

The bores proposed to be monitored to support a GMP are listed in

Table 6. Groundwater levels should be monitored monthly and groundwater salinity annually.

Groundwater quality

Potential threats for saline intrusion into the Deep Lead aquifer in the Lower Campaspe Valley WSPA are:

1. leakage from the overlying Shepparton Formation;
2. lateral movement groundwater from the margins of the area due to drawdown induced by intense pumping; and
3. upward movement of groundwater from the Renmark Group to the Calivil Formation.

To monitor these threats groundwater quality will be monitored at nested bores in areas of intensive groundwater pumping and northern margins of the WSPA. If there is a consistent decreasing water quality trend over the period of implementation of the Plan then investigations should be undertaken to determine the cause and identify mitigating options as part of the review of the plan.

Land Salinity

The Shepparton Irrigation Region WSPA GMP seeks to provide watertable relief in the Echuca and Bamawm areas overlying the Lower Campaspe Valley WSPA. Groundwater extraction from the Deep Lead can increase the potential for drainage from the upper Shepparton Formation to the Deep Lead.

While there is no specific need to monitor for land salinity in the Lower Campaspe Valley WSPA, monitoring of groundwater levels in nested bores in the north of the WSPA will inform of any drainage benefits. In this case a good spatial distribution of nested monitoring bores should be maintained.

Groundwater interaction with surface water

An investigation of the groundwater interaction with surface water in the Lower Campaspe Valley WSPA found that the river leaks to the groundwater system upstream of Campaspe Weir, with the greatest losses between Barnadown and the Campaspe Weir. Groundwater level falls in this reach could increase the rate of leakage from the Campaspe River. If the groundwater levels were to fall this would increase the rate of leakage from the river.

It is estimated that a 1 metre fall in groundwater levels equates to an increase in leakage of around 300 ML/yr from the Campaspe River over this reach. A trigger level of 18 m has been proposed at bore 62589. This would allow groundwater levels to decline by around 1.6 m from the lowest level recorded in 2010 before restrictions were imposed.

It is proposed that groundwater level monitoring be undertaken at nested bore sites near Fergusons Bridge in the Barnadown Zone; Gregory's Lane south of Elmore on the boundary between the Barnadown and Elmore-Rochester Zone; and at Campaspe Weir bores.

Further, the investigations found that groundwater discharges to the river downstream of the Campaspe Weir. North of Rochester extraction from the Deep Lead is unlikely to have a significant impact on the river because of the poor hydraulic connection with the upper Shepparton Formation sand aquifers. However, south of Rochester where the Shepparton Formation and the Deep Lead are well connected, falling groundwater levels could reduce discharge to the river.

It is proposed that groundwater level monitoring be undertaken at nested sites along Bunnewang Road and Settlement Road in the Elmore-Rochester Zone downstream of the Campaspe Weir.

The purpose of monitoring these bores is to observe any changes in groundwater levels that do not agree with the understanding of the groundwater system and enabled a more detailed analysis of the groundwater interaction with surface water at a later date if required. If there are ay observed changes in groundwater levels that do not agree with the understanding of the groundwater system and suggest that there would be increased leakage from the river, such as continued declining groundwater levels that cannot managed through restrictions under the Plan then it should trigger a review of the Plan.

Long-term sustainability

Trigger bores have been proposed to activate restrictions on extractions in the Echuca Zone (bore 79324) and at the boundary between the Barnadown Zone and the Elmore-Rochester Zone (bore 62589).

Bores 79324 and 62589 should be monitored monthly; however consideration could be given to installing a data logger with telemetry at this site and to provide readings more frequently (i.e. every 8 hours), particularly at bore 79324.

To validate the monitoring data from the trigger bores it is proposed that State observation bores in an east-west transect across the WSPA also be monitored.

Aquifer response to pumping

It is proposed that a north-south transect of observation bores be monitored to confirm the understanding of groundwater systems response to pumping and the gradient to New South Wales.

Pumping intensity

The Rochester Irrigation Area and the Campaspe Irrigation District are where there is high entitlement and use in the Lower Campaspe Valley WSPA. It is proposed that more intense monitoring be undertaken in these area to assist with trading decisions.

Spatial distribution

The network of groundwater State observation bores in the Lower Campaspe Valley WSPA is considered sufficient at present. There is a good spatial distribution that enables the aquifer response to groundwater development to be observed.

There are no recommendations for any new bores. It is also important that the current monitoring network is maintained. Many of the older bores are constructed with steel and are susceptible to corrosion and failure. A program of State observation bore replacement should be developed and implemented over the life of the plan.

Proposed monitoring network

The proposed groundwater monitoring network to support the implementation of the Lower Campaspe Valley WSPA GMP is provided in

Table 6.

Table 6 Proposed monitoring network

Groundwater levels are to be measured monthly and groundwater quality annually

Bore ID	Zone	Monitoring purpose							
		Groundwater quality	Interaction with surface water	Groundwater dependent ecosystems	Trigger levels	Support trigger levels (east-west section)	Pumping intensity	Aquifer response to pumping (north-south section)	Land salinity / deep drainage
62595	Barnadown		✓					✓	
62597	Barnadown					✓			
62599	Barnadown		✓	✓					
65875	Barnadown							✓	
65876	Barnadown								
82999	Barnadown							✓	
111204	Barnadown					✓			
G8010638-01	Barnadown		✓						
G8010638-02	Barnadown		✓						
G8010638-03	Barnadown		✓						
G8010638-04	Barnadown		✓	✓					
G8010638-05	Barnadown		✓						
G8010638-06	Barnadown		✓						
G8010638-07	Barnadown		✓						
G8010638-08	Barnadown		✓						
53661	Elmore-Rochester		✓						
60130	Elmore-Rochester		✓						
60131	Elmore-Rochester							✓	
60134	Elmore-Rochester							✓	
60181	Elmore-Rochester								
62589	Elmore-Rochester				✓			✓	
62592	Elmore-Rochester							✓	
62600	Elmore-Rochester					✓			
62601	Elmore-Rochester		✓			✓			
62602	Elmore-Rochester		✓	✓		✓			
62605	Elmore-Rochester		✓			✓			
62606	Elmore-Rochester		✓			✓			
89574	Elmore-Rochester						✓	✓	
89580	Elmore-Rochester						✓		✓
89584	Elmore-Rochester	✓					✓	✓	
89596	Elmore-Rochester	✓					✓		✓
109521	Elmore-Rochester		✓						
109522	Elmore-Rochester		✓						
WRK059870	Elmore-Rochester		✓						
WRK059871	Elmore-Rochester		✓						
73425	Echuca	✓							
79324	Echuca				✓			✓	
97119	Echuca					✓			
97120	Echuca					✓			✓
102827	Echuca	✓							
102828	Echuca	✓						✓	
102829	Echuca	✓							
102831	Echuca								
73426	Echuca (SIR)	✓							✓
79329	Echuca (SIR)					✓			✓
102830	Echuca (SIR)								✓
47247	Bamawm		✓				✓		
47248	Bamawm		✓				✓		
47250	Bamawm	✓					✓	✓	
47251	Bamawm	✓					✓		✓
47253	Bamawm						✓		
47254	Bamawm						✓		✓
47255	Bamawm						✓		
79327	Bamawm					✓			
79328	Bamawm					✓			✓
89576	Bamawm							✓	
WRK059873	Bamawm	✓							
WRK059876	Bamawm	✓							
WRK059877	Bamawm	✓							
47249	Bamawm (SIR)		✓				✓		✓

15 Recommendations for future work

Future technical investigations that would enhance the understanding of groundwater resource management and inform Plan review are provided in Table 7.

Table 7 Proposed technical investigations to enhance groundwater resource management

Project	Description
GDE mapping	Build on recent field mapping of GDEs undertaken by the North Central Catchment Management Authority and Goulburn-Murray Water and identify high value sites. Establish on-going monitoring of high value GDEs to inform the review of the GMP.
Groundwater chemistry	Undertake investigations to better understand the risks to groundwater salinity in the lower Campaspe catchment.

To increase the reliability of supply for groundwater users in the Lower Campaspe Valley it is recommended that a feasibility study be undertaken to evaluate the potential for managed aquifer recharge.

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Appendix A

WATER ACT 1989

CONSULTATIVE COMMITTEE AND MANAGEMENT PLAN GUIDELINES

LOWER CAMPASPE VALLEY WATER SUPPLY PROTECTION AREA

Ministerial Authorisation

I, Tim Holding, Minister for Water, in accordance with Section 30 of the *Water Act 1989*, provide these guidelines for the Lower Campaspe Valley Water Supply Protection Area Consultative Committee to prepare a draft groundwater management plan for my consideration. Section 31(1)(a) of the Act requires that the draft management plan is prepared in accordance with these guidelines.

TIM HOLDING MP
Minister for Water

Date:

Table of contents

1 Objective

Section 32A(1) of the *Water Act 1989* (the Act) provides that:

"The object of a management plan is to make sure that the water resources of the relevant water supply protection area are managed in an equitable manner and to ensure the long-term sustainability of those resources."

Consistent with these high level statutory objectives, the draft management plan (the plan) must include more specific groundwater resource management objectives that balance economic, environmental and social management values relevant to the Lower Campaspe Valley Water Supply Protection Area (LCV WSPA). The success of the plan will be determined by the extent to which the plan achieves these management objectives.

2 Strategic context

In deciding the groundwater resource management objectives for the plan the committee must be cognisant of the principles of the Intergovernmental Agreement on a National Water Initiative (NWI) to which Victoria is a signatory.

The NWI is Australia's blueprint for national water reform. Its overall objective is a nationally compatible market, regulatory and planning based system of managing surface and groundwater resources for rural and urban use that optimises economic, social and environmental outcomes.

Victoria is preparing strategic regional water plans, called Regional Sustainable Water Strategies. The Northern Region Sustainable Water Strategy was released in November 2009. The strategy includes a range of policies and proposals aimed at securing the region's water resources and giving individuals tool such as groundwater carryover to manage their water risks. The plan must give effect to these policies or explain why any particular policy is considered to be unsuitable at this time.

The committee should also consider further groundwater management policy reforms arising from the release of the Western and Gippsland Region Sustainable Water Strategies as drafting of the plan progresses.

The committee includes representatives of organisations and agencies expected to contribute their knowledge of other relevant state, regional and local policies or strategies that may have a bearing on the objectives and prescriptions of the plan. For instance, the Minister for Planning has highlighted DIIRD's *Regional Blueprint*, DPI's *Future Farming Strategy* and *Victoria in Future* population projections as being relevant to future decision making about water resources. The committee should consider how this broader contextual information is relevant to the plan.

3 Risk management

The committee's role is to determine how best to manage the risks to the groundwater resource, summarised in appendix 9.3, using the management tools available under s33(A)3 of the Act and detailed in section 3 of these guidelines.

The key risks were identified in a range of technical reports available to the committee. The suitability of these reports to underpin the plan will be assessed in a report by the Technical Audit Panel (TAP). The TAP includes independent technical experts in ecology, hydrology and hydrogeology. The TAP assessment will also be available to the committee.

Goulburn-Murray Water (G-MW) completed a five-year review of the previous management plan for the Campaspe Deep Lead Groundwater Supply Protection Area, which is now part of the LCV WSPA, in April 2010.

In addition to proposing a larger management area which led to the declaration of the LCV WSPA, the 'Report on the Campaspe Deep Lead GSPA Management Plan' (the Report) included a range of other proposals for managing the risks associated with the use of groundwater in the area.

The committee should revisit the risk assessment having decided upon its preferred management approach. The committee's assessment should be submitted to the TAP with the draft plan for review prior to community consultation.

4 Management tools

Section 32(A)3 of the Act details the management prescriptions that can be included in a plan to achieve the objectives of the plan. Drawing upon the proposals in the Report the committee must ensure the plan addresses the following matters.

4.1 Metering, monitoring and accounting for groundwater

Section 32(A)(3)(a) enables a plan to contain requirements for metering, reading and reporting groundwater use.

4.1.1 Metering

Data gathered through metering is critical to understand how the groundwater system responds to use and to ensure that users comply with their entitlement. State policy requires that any new groundwater licences and all existing licences for 20 ML or greater are metered. If necessary a plan can impose more stringent requirements.

Metering is a pre-requisite for the introduction of carryover (see below). Therefore, the plan must include a requirement that all operational licensed bores in the area are metered and, as proposed by the Report, that meters are read a minimum of three times each season.

4.1.2 Monitoring

The plan must specify key performance indicators to be monitored for the purpose of assessing whether the plan's objectives are being achieved. It must identify the location of monitoring points and measurement frequency.

The Report proposes water levels in particular bores that may be used as a trigger for introducing seasonal allocations. The Report also proposes regional water level monitoring for the purpose of observing the impacts of pumping and transfers on groundwater levels and salinity. The plan should also identify the location of the trigger bores and the bores to be used for monitoring salinity.

4.1.3 Reporting

The plan may require users to notify the corporation responsible for enforcing the plan of the taking of groundwater from any specified bore or group of bores as a private right under s8 of the Act.

4.2 Restrictions on the issue of licences

Section 32(A)(3)(d) enables a plan to impose restrictions or prohibitions on the issue of licences under s51 or 67.

A permissible consumptive volume (PCV) of 56,381ML has been declared for the LCV WSPA. This prevents the issue of new s51 licences that would result in the PCV being exceeded except in some clearly defined circumstances. One of those circumstances is the issue of new licences or increase in licence volumes for applications received under the Dairy Shed Water Licence Transition Program (DSWLTP). The plan should not prevent implementation of the DSWLTP.

The plan should allow new s51 licences to be issued as the result of the transfer of a licence or a change in land ownership, provided there is no increase in the total licence volume.

A plan can also include restrictions on the issue of s67 works licences to construct or alter bores.

4.3 Restrictions on taking of groundwater

Section 32A(3)(f) enables the plan to impose restrictions on the taking of groundwater from any specified bore, group of bores or the aquifer to:

i) prevent the level of groundwater declining below a specified level or specified average level;
ii) prevent a relevant PCV being exceeded;
iii) ensure the environmental water reserve (EWR) is maintained in accordance with the EWR objective.

The Act describes the EWR as water set aside for environmental benefits through environmental entitlements, conditions on licences and other entitlements, or limits on extractions. When the EWR is unable to be quantified as a volume, which will be the case for many groundwater systems, it can be achieved through:

a) setting a PCV as per 4.2;
b) the operation of conditions on any licence;
c) the prescriptions in a management plan.

The plan must clearly explain the method of calculating the water levels in specified bores that will be used for setting restrictions, the trigger level/s at which restrictions would be introduced, and the means by which such restrictions will be introduced, relaxed or lifted. Unless there is good reason to do otherwise these should be consistent with the proposals in the Report.

4.4 Conditions relating to the protection of the environment

Sections 32A(3)(i) and (ia) enable a plan to specify any conditions necessary to protect the environment.

In relation to groundwater, protection of the environment means protecting groundwater dependent ecosystems (GDEs). GDEs include surface ecosystems that depend on groundwater discharging to the surface (river base flows, some wetlands and estuaries), those that tap directly into groundwater (such as terrestrial vegetation) and those within aquifers. A range of management prescriptions may be relevant to protection of GDEs in the area, including any developed to meet requirements of sections 32A(3)(a), (d), (f), (k) and (m).

Field investigations are needed to ground truth the potential GDEs identified by the Department of Primary Industries' recent mapping work and assess their level of dependency on groundwater. The plan should identify the high-value ecosystems to be protected in the area.

Groundwater salinity varies across the LCV WSPA and needs to be monitored to manage the risks:

- to groundwater quality from saline water leaking downward from the Campaspe Irrigation District, intruding from the northern boundary, and moving upward from the underlying Renmark Formation.
- to water quality where groundwater discharges to the Campaspe River.

Recent actions to provide environmental flows to Reach 3 of the Campaspe River identified saline groundwater discharging to the Campaspe River as a management issue and indicated regional groundwater discharges to surface water. While it may adversely affect water quality, the discharge may serve to maintain flows to provide sufficient mixing and reduce impacts associated with low flow events. Further investigation is planned by G-MW.

If the investigations of GDEs or groundwater interaction with the Campaspe River are not complete before the plan is drafted, the plan should specify how the provisions of the plan will be adjusted to protect relevant GDEs, including interaction with the Campaspe River.

In addition, management prescriptions under sections 32A(3)(d), (f), (i) and (m) are also relevant for managing the salinity risk.

4.5 Licence conditions

Section 32A(3)(k) enables a plan to specify the conditions on which a s51 licence is issued. Any new conditions or variation from the standard conditions set out in the *Policies for Take and Use Licences* should be detailed in the plan.

4.6 Carryover

Carryover is the unused portion of any allocation associated with a licensed entitlement that may be used in subsequent seasons. Carryover can have the following benefits:

- it allows individuals to manage their own risk
- It provides more reliable supply when access to groundwater is restricted and surface water allocations are low
- it reduces potential for overuse
- it creates investment opportunities
- it reduces the need to find someone to transfer entitlement from when a seasonal allocation is not sufficient for the groundwater user.

For carryover to be considered as a management option:

- there must be good information about the aquifer and how it responds to groundwater extraction;
- all licensed extractions must be metered in accordance with existing policies;
- there must be enough storage volume to buffer levels against variable pumping rates from year to year; and
- water level triggers must be in place that ensure other users and the environment are not adversely affected.

The Northern Region Sustainable Water Strategy says that licence holders should not be permitted to carry over more than 50 percent of their allocation in any one year and that carryover must not have any detrimental impacts on third parties and the environment.

Carryover can only be authorised by Ministerial declaration under section 62A of the *Water Act 1989.* The declaration would include carryover rules and be made when the plan is approved.

The Report includes recommendations for the introduction of carryover. These should be included as recommendations in the plan unless the committee can show good reason to deviate from the recommended arrangements.

4.7 Conditions for the transfer of licences

Section 32A(3)(m) enables a plan to impose conditions on s51 licences and transfers under s62, including a condition relating to the maximum volume of water which may be taken and used under the transferred licence.

Conditions proposed by the review include:

a) the use of zones;
b) limits on intensity of groundwater extraction in a zone;
c) restrictions and associated trigger levels for the commencement and easing of restrictions.

Proposals in the Report should be adopted unless there is good reason to vary or add to the conditions.

5 Completing the plan

The consultative committee has up to 18 months from the date of appointment to complete the LCV WSPA plan. However, every effort should be made to complete the plan earlier.

The Murray Darling Basin Authority (MDBA) has commenced the process for the preparation of a Basin Plan. Being in the Murray-Darling Basin (MDB), the LCV WSPA will be affected by the Basin Plan.

The Basin Plan will set limits, know as Sustainable Diversion Limits (SDL) on the amount of groundwater that can be extracted for consumptive use. SDLs will be set for Water Resource Plan (WRP) areas. Victoria has been divided into two WRP areas: the first reflecting the region managed by Grampians Wimmera Mallee Water (GWMWater) and the second reflecting Goulburn-Murray Water's (G-MW) region. The Basin Plan will include an environmental watering plan and trading rules for basin water resources.

Under the *Commonwealth Water Act 2007*, existing plans can be recognised as either transitional plans if made prior to 3 March 2008 or interim plans if they were made on or after 25 January 2007 and before the Basin Plan takes effect. Current advice is that the Basin Plan would not be completed until December 2011. Interim plans continue until 2014 or five years after the plan was created, whichever is the longer.

In the event that the LCV WSPA management plan is not approved before the Basin Plan takes effect then the LCV management plan must comply with the requirements for Water Resource Plans (WRP) in the basin and would need to be accredited by the MDBA. The accreditation requirements and process are unclear at this time. DSE will coordinate communication with the MDBA during the preparation of the draft management plan and ensure that the committee is kept abreast of Basin Plan developments and requirements for accreditation.

6 Documenting the plan

The plan must be written in plain English and able to be understood by licensees and people unfamiliar with the groundwater resource in the area and the use or management of groundwater. In particular, the rationale and plan prescriptions must be unambiguous.

The plan should be set out in accordance with the format in Appendix 10.1.

7 Annual reporting and review

The plan must require the rural water corporations to submit an annual report, in accordance with section 32C of the Act, by 30 September each year. The Annual Report will cover the period 1 July to 30 June.

The plan must include a requirement that it be reviewed at intervals of no more than five years.

8 Community consultation

8.1 Purpose

Under s31 of the Act, the Committee must make the plan available for comment by interested persons within the 18 month timeframe to prepare the plan.

Community consultation is necessary to ensure community involvement in developing the plan. Community consultation helps raise public awareness of environmental and water management issues and gives people the opportunity to express and debate their concerns and be satisfied that the plan is capable of meeting its objectives.

8.2 Timing

The plan should be reviewed by the TAP prior to the plan being released for community comment.

At least *twenty eight days* should be allowed for the community to comment on the plan.

The committee should consider the comments it receives on the plan. If the committee subsequently make significant amendments to the plan then a further *twenty eight days* should be allowed for community comment on the amendments.

A copy of the draft plan should be submitted to the DSE, Executive Director, Water Entitlements and Strategies on each occasion it is released for community consultation.

9 Committee Governance

The previous sections of these guidelines set out *what* the committee is expected to do. This section relates to *how* the committee must fulfil its role, that is, the essential values and principles to be upheld.

The committee should conduct itself in accordance with the policies and procedures set out in the “DSE Guide to Good Governance”.

Chapters of particular relevance for the Committee are:

- Chapter 5 – Essential Values and Principles
- Chapter 6 – Board (Committee) meetings
- Chapter 7 – Board (Committee) decisions
- Chapter 8 – Conflict of interest or duty

A copy of the guide will be provided on compact disc. A hard copy will also be provided to the Rural Water Corporation for the committee to reference.

For meetings, a quorum will comprise two-thirds of members (the Chair is counted as a member), with at least 50% of the quorum consisting of owners or occupiers of land in the WSPA.

10 Appendices

10.1 Management plan format

Approval page
The plan should include an approval page for the Minister's signature.

Glossary
Describe the terms used in the plan.

Introduction
Describe why the plan is being prepared making reference to the relevant sections of the Act. Give a brief summary of the main elements of the plan.

The Protection Area
Describe the physical characteristics of the area and include a map. Provide information on groundwater level trends. Include hydrographs, figures and tables where appropriate.

Provide information on technical studies and a summary of any review completed by the TAP.

Water Entitlements and Use
Provide details of water entitlements including the various types of licences and their conditions.

Describe past water usage making comment on the range and extent of irrigated agriculture and other industries in the area.

Include a map showing the location of licences and any other relevant information.

Object of the Plan
State the object of the plan consistent with section 32A(1) of the Act including more specific water management objectives that balance the economic, environmental and social values for the area.

Administration and Enforcement of the Plan
Name the Corporation who will be responsible for administering and enforcing the plan if it is approved.

Prescriptions
When the plan requires a prescription describe the rationale followed by the prescription as per the following example:

Prescription

1. **All meters will comply with the national standards adopted in State Government and Corporation metering policy.**
2. **The Corporation must:**
    a. Ensure all meters with the area are read twice per year, in or around January and June;
    b. Determine the volume of water extracted from the bore since the

meter was last read; and

   c. Within 30 days after the meter in read, record the amount of water used on a database.

3. **The Corporation may request the licensee to read a meter and to provide the Corporation with the reading:**
   a. The licensee must comply with the request; and
   b. For the purposes of this clause the Corporation must provide a phone number, email address, pre-paid mail or similar method for the licensee to lodge the meter reading.

Restrictions on Taking Water
Describe the restrictions on taking water under the plan and the rationale for the restrictions including the need to protect the environment and the need to maintain the environmental water reserve.

Licence Transfers
Describe the types of transfers and the conditions of transferred licences.

Identify any restrictions on transfers and use a map if certain parts (management zones) of the area have different arrangements.

Distinguish between licence transfers as a result of the sale or conveyance of land where the licence remains with the property and off-property transfers.

Restrictions and Prohibitions on the Issue of Licences
Describe the licences, both works licences and take and use licences to which restrictions or prohibitions are proposed under the plan.

Metering and accounting for water
Detail the metering program including the installation and maintenance of meters and responsibilities for meter readings.

Detail the water accounting program where meters are not installed e.g. domestic and stock or where the corporation determines that it is impracticable to install a meter in accordance with the *Policies for Managing Take and Use Licences*.

Monitoring Program
Identify the monitoring regime and include a map of bores to be monitored.

Licence conditions
Specify the conditions on licences that will be imposed under the plan including any conditions proposed in relation to works licences.

Other matters
Include, if appropriate, prescriptions relevant to the objectives of the management plan and the rationale.

Annual Report and review
Detail the annual reporting requirements and future reviews of the management plan.

Implementation costs

Include an estimate of the cost to implement the plan, how this is likely to affect user charges and how implementation costs, taking into account changes that may be required to the Water Register, will be recovered.

References
List references to studies relied up for the preparation of the plan.

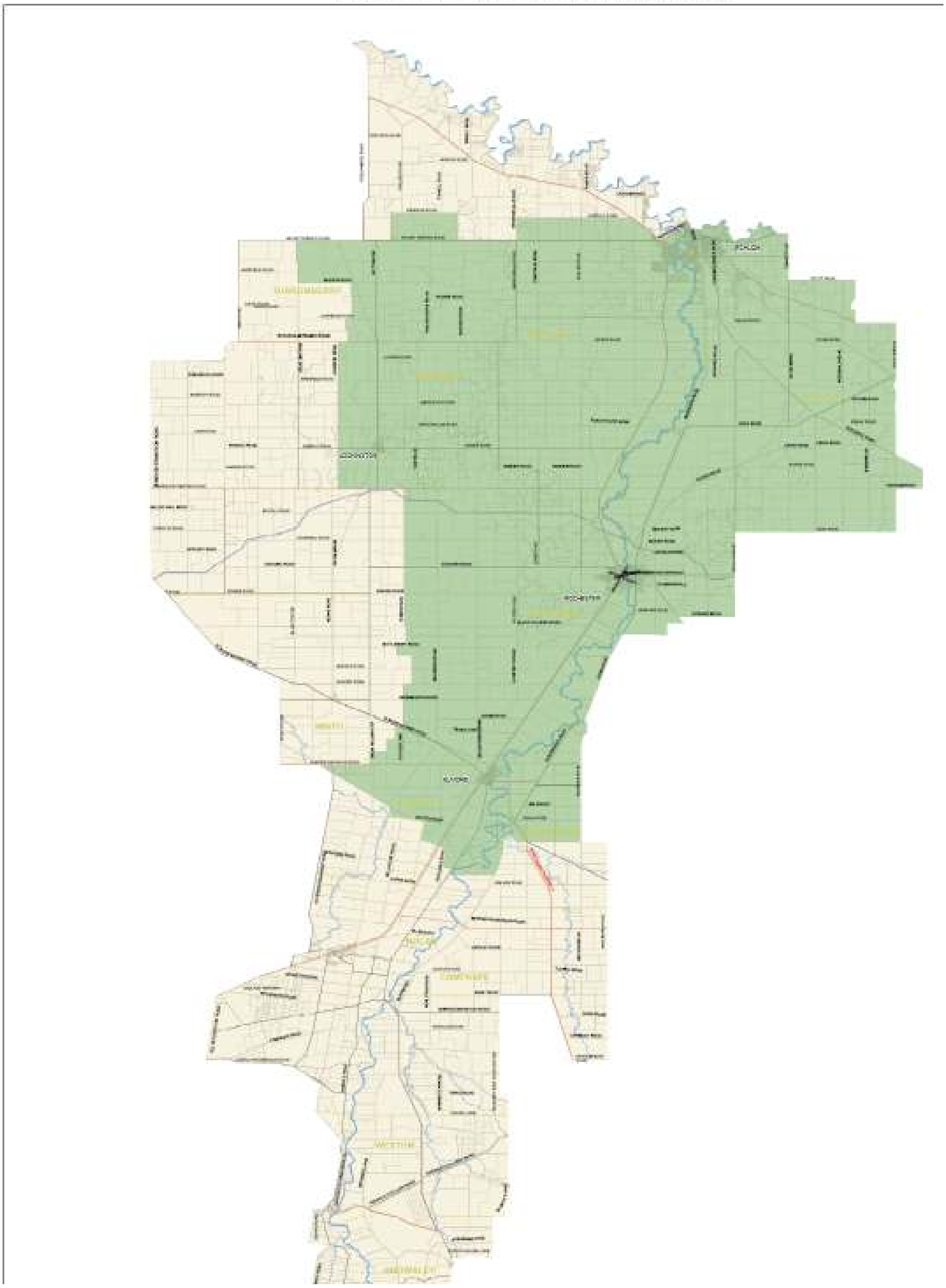
Future technical investigations
Identify future technical investigations, if any, to inform plan review.

Comments by the Committee
If the committee wishes to make comments about the development of the plan, or make recommendations that are outside the formal requirements of the plan, it may consider including such comments or recommendations in an accompanying letter when it submits the plan to the Minister for approval.

10.2 Map of LCV WSPA

The Campaspe Deep Lead GSPA was declared in 1999. It covers all aquifers at depths greater than 25 metres within an area from south of Elmore and north to Echuca. The Campaspe Deep Lead GSPA is illustrated in the following figure in green and additional areas incorporated in 2010 to create the Lower Campaspe Valley WSPA appear light brown.

Lower Campaspe Valley Water Supply Protection Area
PLAN NO. LEGL./09-255 Sheet 3 of 3



10.3 Risk assessment

The risk assessment aims to identify and quantify the risks to the resource. The assessment is based upon technical information from reports available to the committee. The assessment involves considering the source of risk (i.e. what can happen?) and the potential result (the impact?). The likelihood and the consequence of the event occurring is assessed.

The assessment involves considering measures that can be implemented to mitigate the risk and then reassessing the likelihood and consequence of a risk with the measures in place. The table indicates of the management tools detailed in section 3 of these guidelines might be suitable to mitigate each risk.

LOWER CAMPASPE VALLEY RESOURCE RISK ASSESSMENT

				Unmitigated Risk Assessment						
Objective	The risk (the event)	What can happen? (the source)	What can result? (the impact)	Likelihood	Consequence	Risk Score	Risk Rating	Tools in the Act that can be used to address risk	Act ref	Other risk management activities
Ensure long-term sustainability of the water resources	Lowering groundwater levels	Groundwater users outside of the WSPA but hydrologically connected to the LCV aquifers may be affecting groundwater levels.	Loss of water security for groundwater users (current and future)	4	4	8	High	N/A	N/A	Monitoring: a) The proposed boundary excludes the Shepparton Irrigation Region (SIR) WSPA and the Campaspe West Salinity Management Plan area and future work undertaken for the "SIR Salt and Water Balance Project" which is being funded by the GBCMA and the DSE Sustainable Irrigation Program will need to be reviewed and considered
Ensure long-term sustainability of the water resources	Lowering groundwater levels	Overextraction of groundwater causing groundwater levels to be lowered.	Loss of water security for licensed and D&S groundwater users (current and future)	4	4	8	High	restrictions in new s 51 licences, restrictions on taking groundwater including the appropriateness of the current PCV	32A(3)(d), (f); 32A(4)	Management Proposal 1 "Boundary and entitlement" in Review of the Campaspe Deep Lead Water Supply Protection area Groundwater Management Plan Final Report. Monitoring: a) Assess Groundwater licence applications outside boundary to make sure they don't impact on the deep lead aquifer and if necessary decare Groundwater management units for areas adjoining the proposed WSPA or revise the declared boundary.
Equitable management of water resources	Localised lower groundwater levels	High intensity of groundwater users causing interference and lowering of water available to other existing users.	Loss of water availability and inequitable use of groundwater.	3	3	6	Moderate	restrictions in new s 51 licences, restrictions on taking groundwater including the appropriateness of the current PCV	32A(3)(d), (f); 32A(4)	Management Proposal 3 "Interference" in Review of the Campaspe Deep Lead Water Supply Protection area Groundwater Management Plan Final Report
Equitable management of water resources	Localised lower groundwater levels	The drawdown in current intensive groundwater pumping "hotspots" in Barnawm and CID will increase and future "hotspots" will develop if intensive groundwater usage is not addressed	Loss of water availability and inequitable use of groundwater	3	3	6	Moderate	restrictions in new s 51 licences, restrictions on taking groundwater including the appropriateness of the current PCV	32A(3)(d), (f); 32A(4)	Management Proposal 4 "Managing intensity of groundwater extraction" in Review of the Campaspe Deep Lead Water Supply Protection area Groundwater Management Plan Final Report
Protect significant environmental values	Lowering groundwater levels	Declining groundwater levels impacting on third parties, the environment, the aquifer.	Loss of water availability and inequitable use of groundwater	4	4	8	High	restrictions in new s 51 licences, restrictions on taking groundwater including the appropriateness of the current PCV	32A(3)(d), (f); 32A(4)	Management Proposal Management Proposals 2 "Zones" and 5 "Maintain groundwater levels" in Review of the Campaspe Deep Lead Water Supply Protection area Groundwater Management Plan Final Report
Equitable management of water resources	Localised lower groundwater levels	Carryover or transfers cause unacceptable local drawdown and interference with other users.	Loss of water security for groundwater users (current and future)	5	3	8	High	restrictions in new s 51 licences, restrictions on taking groundwater including the appropriateness of the current PCV	32A(3)(d), (f); 32A(4)	Management proposals #2 & #9 in Review of the Campaspe Deep Lead Water Supply Protection Area Groundwater Management Plan final report
Ensure long-term sustainability of the water resources	Reduced groundwater quality	Groundwater water quality deteriorates if groundwater levels drop significantly and there is saline intrusion.	Loss of water security for groundwater users (current and future)	3	3	6	Moderate	Conditions to which s51 licences are to be subject	32A(3)(k)	Management Proposal 11 "Groundwater Salinity" in Review of the Campaspe Deep Lead Water Supply Protection area Groundwater Management Plan Final Report
Ensure long-term sustainability of the water resources	Lowering groundwater levels	Monitoring of groundwater does not provide sufficient information on the resource resulting in inappropriate management decisions	Loss of water security for groundwater users (current and future)	3	3	6	Moderate	Requirements for metering, monitoring and accounting for groundwater and surface water or both	32A(3)(a)	Management Proposal 12 "Record meter reading" in Review of the Campaspe Deep Lead Water Supply Protection area Groundwater Management Plan Final Report