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Forest Research Mount Gambier

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Adaptive management boundaries for the Lower Limestone Coast based on unconfined aquifer thickness, stratigraphy, structure and depth to water

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Summary

The *Water Allocation Plan for the Lower Limestone Coast Prescribed Wells Area* (Government of South Australia, 2019) (often termed the LLCWAP) is a water management framework in the Lower Limestone Coast (LLC) prescribed wells area (PWA) of South Australia which sets out the targets for managing groundwater. The plan details the available water resources across the region in 61 management zones and the conditions of their use. These management zones were originally derived based on Hundred boundaries which existed prior to current groundwater management requirements. For managing groundwater resources more appropriately, relevant resource management tools should consider aquifer thickness, structure, stratigraphy, depth to water, water table fluctuation and groundwater flow direction. Scientific investigations in the last 20 years have improved community understanding of the regional Tertiary aquifer stratigraphy. As such, the question may be posed - with the increased understanding of regional stratigraphy, structure and hydrostratigraphy, why is water in the Lower Limestone Coast being managed on administrative divisions?

The aim of this study was to review and apply current knowledge to identify what management boundaries could be with consideration of current groundwater science and what triggers could be applied to better manage groundwater resources. The objectives of this study were to:

- Consider available information on aquifer stratigraphy and structural control to evaluate suitable science-based boundaries for groundwater resource management in the LLCPWA
- Consider alternative groundwater trigger mechanisms that can be used to identify where extraction may cause risk to groundwater resources.

The project to identify alternative pilot management zones based on stratigraphy and structure of the unconfined aquifer was undertaken in four steps:

1. A review of current knowledge on stratigraphy of the aquifer in the LLC PWA.
2. A review of current knowledge on aquifer structure and faults in the aquifer in the LLC PWA.
3. A review of current knowledge on aquifer thickness in the LLC PWA
4. Delineation of alternative pilot zones based on the stratigraphy, structure and aquifer thickness.

Examination of data including the knowledge of stratigraphy enabled the delineation of proposed revised pilot management zones based on these aquifer parameters. The findings suggest that using aquifer properties, the current 61 management zones currently considered in the LLCWAP may be reduced to as few as six management zones. A map of these potential zones is presented in Figure 1. This data could be further refined by examining commonality between this set and the ten management zones presented by earlier investigations into adaptive management zones and considering the need to incorporate smaller zones for administrative purposes. This includes the 'Border Zones' subject to the Border Groundwater Agreement with Victoria which have been ignored to use the best available science, and other administrative, ecological and social impacts which could result in further delineation of the proposed zones.

It is also recommended that improved trigger responses be considered in each of the proposed management zones. Examples are provided below regarding the six management zones recommended from this study.

- MZ 1 - requires stronger triggers than currently used due to a thin and drying aquifer section
- MZ 2 – a combination of a percentage of aquifer thickness and two thirds of the aquifer licenced
- MZ 3 – licence the bottom two thirds of the aquifer for irrigation extraction
- MZ 4 – requires stronger triggers than current to be in place due to thin aquifer section

- MZ 5 – licence the bottom two thirds of the aquifer for irrigation extraction. This technique is important as coastal wetlands can be better protected with this technique.
- MZ6 – use current trigger mechanism due to no irrigation activity, but also the presence of important coastal wetlands that require protection

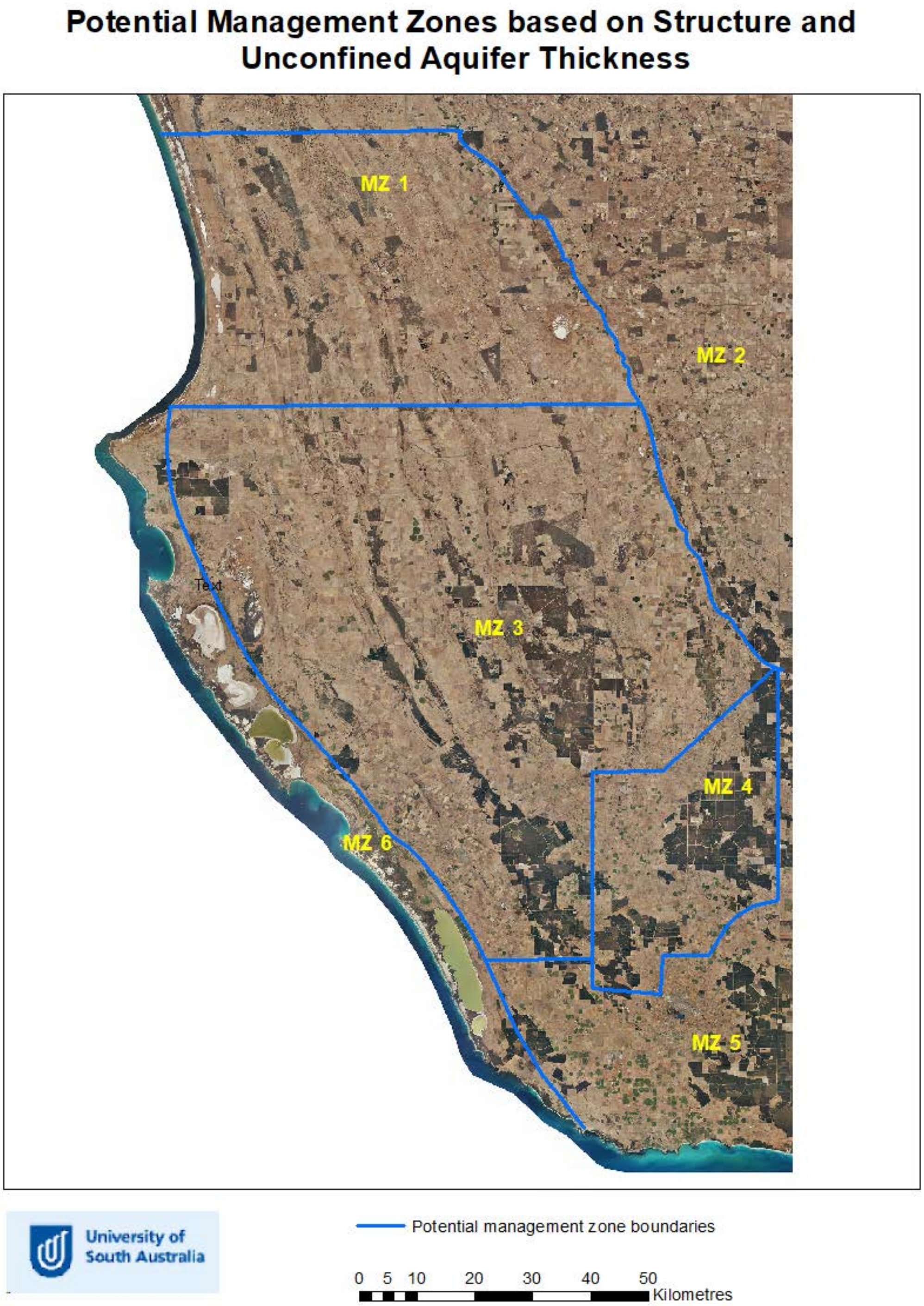

Figure 1: Potential Lower Limestone Coast Management Zones based on unconfined aquifer thickness and structural elements

1 Introduction

The *Water Allocation Plan for the Lower Limestone Coast Prescribed Wells Area* (Government of South Australia, 2019) (often termed the LLCWAP) is a water management framework in the Lower Limestone Coast (LLC) of South Australia which sets out the targets for managing groundwater. The plan details the available water resources across the region in 61 management zones and the conditions of their use. These management zones were originally derived based on Hundred boundaries which existed prior to current groundwater management requirements.

The management zones are based around a mapping dataset that reflects the official boundaries of 'Hundreds' (or administrative divisions) in South Australia as defined by the Crown Land Management Act 2009 or preceding Acts. Hundreds are used in conjunction with cadastral boundaries to assist in the definition of land parcels, and these Hundred boundaries have no scientific relationship to groundwater management (further details in Section 2.2). For managing groundwater resources more appropriately, relevant resource management tools should consider aquifer thickness, structure, stratigraphy, depth to water, water table fluctuation and groundwater flow direction. Scientific investigations in the last 20 years have improved community understanding of the regional Tertiary aquifer stratigraphy. As such, the question may be posed - with the increased understanding of regional stratigraphy, structure and hydrostratigraphy, why is water in the Lower Limestone Coast being managed on administrative divisions?

Previous studies have attempted to investigate more appropriate boundaries for groundwater management. When work commenced to revise a previous version of the LLCWAP in 2006, the then Department for Water, Land and Biodiversity Conservation (DWLBC) was requested by the then South East Catchment Water Management Board to consider recommending a reduction in the number of management zones in the LLCWAP region. Because the workload and timeline revolved around producing a 2006 water allocation plan (eventually adopted November 2013), the DWLBC informed the Board it was not possible to assess changes at that time but agreed the concept would be pursued further. Initial work regarding alteration of management zone boundaries occurred as part of a study within DWLBC in 2008, funded through a National Water Commission initiative that was based around 'Adaptive Management' for the region (Harrington et al., 2008). This work is summarised in Section 2.3 and considered the LLC, Tatiara and Tintinara water allocation planning regions. The result was recommendations for 11 management zones across the total area, with 10 of those in the LLC region (two partly in the LLC region). The report into adaptive groundwater management recommended that further investigations occur including the examination and merging of the hydrostratigraphic conditions and structural features (faults) which usually define aquifer boundary conditions.

The adoption of fewer management zones based on groundwater boundary conditions may present some advantages over the current administrative boundary approach. It could allow for increased water trading, which may alleviate some current 'hot spot' problems. For example, in the Hindmarsh management zone there is known to be high extraction due to the presence of an industrial site, but if the groundwater use calculations were combined with the adjacent Mayurra management zone (where allocation use is much less) and water use in the two areas treated as a single management zone, the over allocation problem is alleviated for the same hydrostratigraphic conditions. As such, the aim of this study was to use current knowledge to identify what management boundaries should be, with consideration of current groundwater science. A natural progression of this work is understanding water management boundaries in the LLC Region related to the current water allocation plan water level trigger conditions and whether they are fit for purpose.

An example of where current arrangements are sub-optimal includes many areas where irrigation water resources are accessed from deeper sections of the aquifer. Trigger levels for reducing available water in management zones include a 0.1 m drop in aquifer levels per year over a 5-year average (or 0.5 m over 5 years). In the MacDonnell management zone there are over 100 centre pivots used for dairy pasture production. Considering stratigraphy and structure, however, it is apparent that this groundwater is sourced from the Camelback Member within the Gambier Limestone at a depth of over 120 m and after a summer pumping period observation the upper section of the limestone indicates a 0.5 m drawdown, with deeper sections greater than 1 m of drawdown, indicating the current trigger assessment maybe inadequate.

1.1 Study aims and objectives

The aim of this study was to use current knowledge to identify what management boundaries could be with consideration of current groundwater science and what triggers could be applied to better manage groundwater resources.

The objectives of this study were to:

- Consider available information on aquifer stratigraphy and structural control to evaluate suitable science-based boundaries for groundwater resource management in the LLCPWA
- Consider alternative groundwater trigger mechanisms that can be used to identify where extraction may cause risk to groundwater resources.

1.2 Study Scope

This work is limited to the LLC Prescribed Wells Area (PWA). The work could potentially be extended further north than the LLC PWA (e.g. into the Tatiara, Tintinara and Padthaway PWAs) if required to cover a similar region as that considered by previous adaptive management investigations in the region (Harrington et al., 2008). Working to this larger region would require more resources and access to the Department for Environment and Water (DEW) SA Geodatabase including scanned images which are not easily available for public access through the Water Connect interface.

2 Background

2.1 Border groundwater agreement

A significant consideration in proposing any changes to the management of groundwater in the LLC region is what is generally termed the Border Groundwater Agreement. A legislated agreement between South Australia and Victoria exists via the Groundwater (Border Agreement) Act 1985 in both Victoria and South Australia. The Agreement between South Australia and Victoria covers an area that extends 20 kilometres either side of the border from the southern coast to the Murray River. This is known as the designated area and is divided into 22 management zones with 11 zones in each state, designated as A zones in South Australia and B zones in Victoria i.e., Zone 3A or 3B. The legislation behind the agreement overrides the LLCWAP arrangements in the LLC region. A border management group consisting of South Australian and Victorian representatives has met regularly to discuss groundwater issues. The Agreement provides that available groundwater shall be shared equitably between the two states and applies to all existing and future wells. Wells that extract groundwater for domestic and stock purposes are not covered by the Agreement. The Agreement sets out:

- the annual volume of groundwater allocation from each aquifer for each zone
- the distance from the border for each aquifer within a zone where an application for a water licence or a permit to drill a bore must be referred to Border Groundwaters Agreement Review Committee for approval
- the rate of groundwater level lowering.

2.2 Background to existing management zones

As noted in Section 1, the current groundwater management zones are based on Hundreds. The Hundreds layer is a data set that reflects the official boundaries of Hundreds in South Australia as defined by the Crown Land Management Act 2009 or preceding Acts. It is used in conjunction with cadastral boundaries to assist in the definition of land parcels. The current groundwater management zones were instigated using the regional Hundred boundaries. These zones were typically established as 10-mile by 10-mile squares, resulting in 100 square miles (hence 'Hundreds'). It is assumed they were adopted in earlier version of the LLCWAP because no other obvious mechanism was available to manage groundwater more effectively. However, Hundreds have no scientific relationship to groundwater management other than they were adopted when management zones were first utilised and are still currently in place. At the time of adoption there was probably no better way of managing the regions groundwater unless many Hundreds were combined into one and the science at the time could not support such an approach.

There has been some amendment of the Hundreds to produce the management zones in the LLCWAP. After the Groundwater (Border Agreement) Act 1985 was passed by the South Australian and Victorian governments the Hundred boundaries became irrelevant in the 20-kilometre zones either side of the border and most were generally 27 kilometres long (nearly twice as large as Hundreds). Minor adjustments have also occurred to some zones - one of which relates to geological structure, being the Kanawinka Fault to the east of Penola / Coonawarra which extends northwest past Naracoorte and splits the formerly named Zone 4A into 4 smaller zones (Joanna, Struan, Glenroy and Comaum). Another example is the former Zone 1A now split into Compton, Myora, Glenburnie and Donovans.

It should be noted also that the current groundwater management zones, while having varying groundwater recharge rates and unconfined aquifer thickness all use the same trigger values, but when depth to water and aquifer thickness based around structure and stratigraphy are considered, the result potentially makes little sense.

2.3 Previous adaptive groundwater management investigations in the LLC PWA

The LLC currently consists of 61 management zones. In 2006 the then South East Catchment Water Management Board (SECWMB) requested the then DWLBC to consider recommending larger management zones. It was not possible in 2006 due to time constraints due to the Water Allocation Plan expected to be released that year, however since that time the science around regional structure and stratigraphy is significantly improved due to ever-increasing studies.

An adaptive management boundary study commenced in 2008 through a project funded by the National Water Commission. On completion, this project derived suggested adaptive management boundaries which effectively reduced the number of management zones in the South East of South Australia including the LLC (Harrington et al., 2008). This review included a critical review of adaptive management approaches either previously trialled or currently adopted elsewhere in Australia. Public engagement in the process was very important. The project considered the following aspects to derive recommendations:

- Surface geology
- 5 year maximum and minimum standing water levels (SWL)
- 5-year water level trend from 1998 – 2002 using purpose constructed groundwater observation wells
- 5-year water level trend from 2003 – 2007 using purpose constructed groundwater observation wells
- Soil landscape
- Land use
- Minor data for an aquifer thickness map

Overall, the review recommended that the groundwater resources in South East SA are suited to an integrated approach to adaptive management that includes both an initial assessment of the sustainable yield of the resource and an ongoing program of Water Level Response Management (WLRM). The final recommendations made by Harrington et al. (2008) for adaptive management boundaries are shown in Figure 2. Note that for the LLCWAP region, the current 61 management zones were reduced to 10 (including 2 zones only partially in the LLC region, PZ2 and PZ3). The original boundaries used to derive the recommendations are shown in Appendix 1.

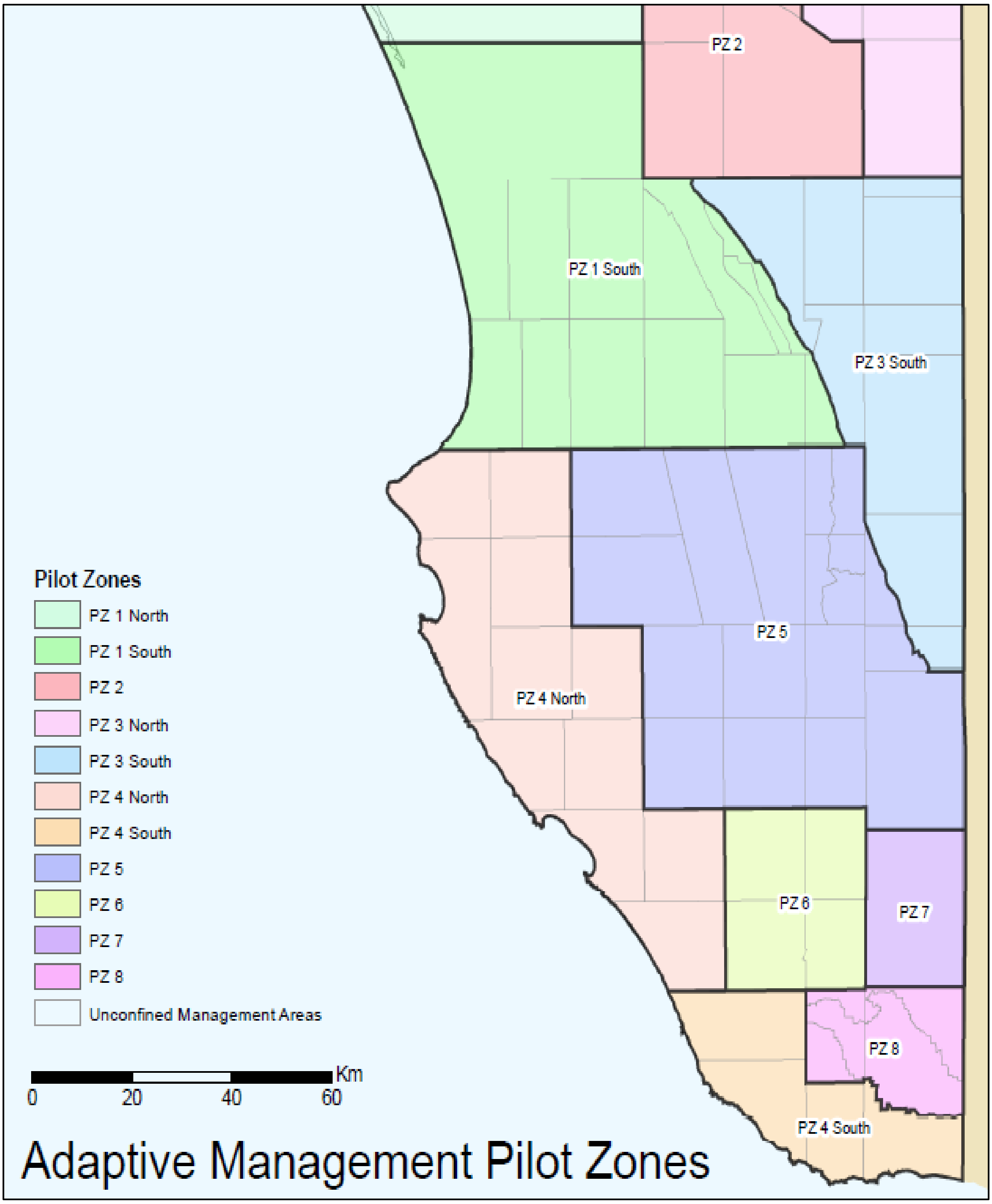

Figure 2: Adaptive management pilot zones covering the Lower Limestone Coast, Tatiara and Tintinara regions (Harrington et al., 2008)

3 Methodology

The project to identify alternative pilot management zones based on stratigraphy and structure of the unconfined aquifer was undertaken in four steps:

1. A review of current knowledge on stratigraphy of the aquifer in the LLC PWA.
2. A review of current knowledge on aquifer structure and faults in the aquifer in the LLC PWA.
3. A review of current knowledge on aquifer thickness in the LLC PWA
4. Delineation of alternative pilot zones based on the stratigraphy, structure and aquifer thickness.

3.1 Reviewing Aquifer Stratigraphy in the LLC PWA

A review of aquifer stratigraphy was undertaken based on previous studies of hydrostratigraphy. The review is based on earlier review activity (Lawson, 2013). The review of stratigraphy data is presented in Section 4.

3.2 Reviewing aquifer structure and faults in the LLC PWA

A review of current knowledge regarding aquifer structure and faults was undertaken primarily referring to a report by the then DWLBC and uploaded to the National Water Commission website (Lawson et al., 2009).

3.3 Aquifer thickness in the LLC PWA

There are currently 479 groundwater wells providing sediment intersections of the Dilwyn Formation available for public review. Additional data is available through a government database, the South Australian Resources Information Gateway (SARIG) but difficult to observe as the information is contained on scanned images. Based on these 479 wells, the assessed aquifer thickness for the LLC prescribed wells area (PWA) is shown in Section 6 (Figure 5).

The aquifer thickness (isopach) was obtained through the plotting of wells known to intersect either the top of the confining clay of the regional Dilwyn Formation or the top of the Mepunga Formation which overlays the Dilwyn but is so thin as to be not observable in some locations, but is treated as part of the confined aquifer. For each site a depth to the top of the unconfined aquifer was established and then taken from the top of the confining clay to establish an aquifer thickness. This data set was then overlain with the regional faults and the major structural or fault features that control the stratigraphy as detailed previously.

3.4 Delineation of alternative pilot adaptive management zones

The delineation of alternative management zones was undertaken with preference to the known stratigraphy, structure and aquifer thickness. Current structural knowledge in the form of major and or controlling faults was applied and boundaries drawn using a geographical information system (ArcMap Version 10). Boundaries were manually drawn with regard to thickness changes in the aquifer. Where the generated management boundaries were close to existing management area boundaries, they were clipped together however for others this was not easy and not undertaken. The reason for this was that this level of detail was not possible with available resources at this time. If the desire for boundary change occurred, then this greater level of detail can be conducted.

4 A review of current knowledge on stratigraphy of the aquifer in the LLC PWA

The stratigraphic and hydro stratigraphic understanding of the Tertiary aquifer systems have increased since 2006. This understanding is summarised by (Lawson, 2013) and includes research projects funded by the National Water Commission, an investigation into the confined aquifer on the South Australia / Victoria border (Lawson et. al, in prep) and research in the Mount Gambier area in conjunction with SA Water related to town water supply well drilling.

North of Mount Gambier and extending north throughout the LLC PWA, the initial hydrostratigraphic unit intersected is the sandstone of the Bridgewater Formation. This unit will generally extend from around 4 m below ground up to 16 to 20 m below ground (12 to 16 m isopach thickness). By both local and international definition this sandstone unit may be expected to have porosities of between 15 to 25% (Domenico and Schwartz, 1997) suggesting groundwater recharge rates may be higher than in the current LLCWAP which uses a figure of 10%.

Sandstone overlays the regional Gambier Limestone, now defined with three major divisions, being the Green Point Member, Camelback Member and the Greenways Member (Li et al., 2000). The Green Point Member has been further divided into four subdivisions being Green Point Member Units 1 to 4 (Lawson, 2013). The Narrawaturk Marl was defined by Li et al. (2000). as two units, but extensive logging of drill cuttings has shown that other than strong glauconitic staining, it is in every other way similar to the Greenways Member and as such considered a single unit. Each of these units exhibit slightly different aquifer parameters such as porosity, specific yield and permeability.

The significant unit is the Camelback Member which south of Mount Gambier is used extensively for irrigation supply (more than 120 centre pivots) and under Mount Gambier for stormwater drainage (the major stratigraphic unit recharging the Blue Lake) and to the north of Mount Gambier also as an irrigation supply.

South of the Tartwaup Complex of Faults and structural waupage the Camelback Member is observed in the dolomitic form and to the north of this location is often described by drillers as a green limestone. Because this unit is the primary source of irrigation water along with the sandstone unit in some areas, the current stratigraphic understanding needs to be considered as part of the unconfined aquifer water allocation and management process.

5 A review of current knowledge on structure and faults of the aquifer in the LLC PWA

As part of the earlier adaptive management investigation funded by the National Water Commission (Lawson et al., 2009), the Tertiary Faults for the Gambier Basin (the Tertiary section of the Otway Basin) were mapped with the results shown in Figure 3. Only faults interpreted as extending to ground surface were plotted. Many faults extended into the Dilwyn Formation and the Gambier Limestone but many finished (were pinched out) in the soft clays or marls.

The Gambier Basin is controlled by geological structure where upthrown and down thrown faults control the thickness of the unconfined aquifer. Major structural controls as shown in Figure 3 for the LLC area are:

- A thinning of the unconfined aquifer units as the Gambier Basin (Tertiary section of the Otway Basin) transitions (rolls) across into the Murray Basin to the north in the general Kingston / Lucindale area. This basin boundary transitions south east and moves into Victoria at the southern end of the Kanawinka Fault.
- In the immediate Kingston area, the underlying Dilwyn Formation does not exist until some kilometres inland due to uplift and likely erosion that occurred over millions of years.
- The Kanawinka Fault or at least the Tertiary expression of the fault, as it originates at significant depth i.e. 550 m on some seismic sections, controls both unconfined and confined aquifer thickness. The Naracoorte Ranges are affected by this uplift and it is recognised within the Border Zone boundaries.
- The Woakwine Dune overlays a major fault defined from seismic section. Where the limestone is divided into 3 major structural units to the east of this dune, the western or seaward side is controlled by major fault displacement of up to 80 m (Figure 4), downthrown on the seaward side. The consequent infill limestone while very thick, is strongly marly (calcareous clay) from top to bottom and results in practically no limestone production for irrigation use, observed when using aerial or satellite photography.
- A significant stratigraphic uplift in the Nangwarry area is defined by the Kalangadoo Fault (leakage also occurs to the confined aquifer through this fault) along with a fault Accommodation Zone defining the northern boundary which passes south of Penola. This uplifted area is assessed as potentially being a significant recharge zone to the confined aquifer.
- An stratigraphic uplift area extends from north west of Mount Gambier through to Glencoe where the structural high for the Dilwyn Formation occurs. This blends into the Nangwarry uplift area except for a zone in the Kalangadoo area where a graben fault occurs allowing both deep and shallow sediments.
- The Tartwaup Complex where multiple faults and a structural waupage occurs. The structural waupage controls an area where depth to the groundwater changes from shallow to deeper across a relatively short distance. The depth to the top of the Dilwyn Formation can be quite shallow through this zone especially north of Mount Gambier. North of the Tartwaup Complex the confined water levels are lower than water levels in the unconfined aquifer (negative head) and to the south this reverses to a positive head with the confined aquifer heads higher than the unconfined water levels. This line is not linear, but fault controlled. Additionally, the stratigraphy of the confined aquifer is much different.
- A major 80 m fault displacement was the weakness the Mount Gambier volcanics formed across and was defined from cored wells drilled on the north and south rims of the lake. A consequent further thickening of the unconfined aquifer occurs to the south.

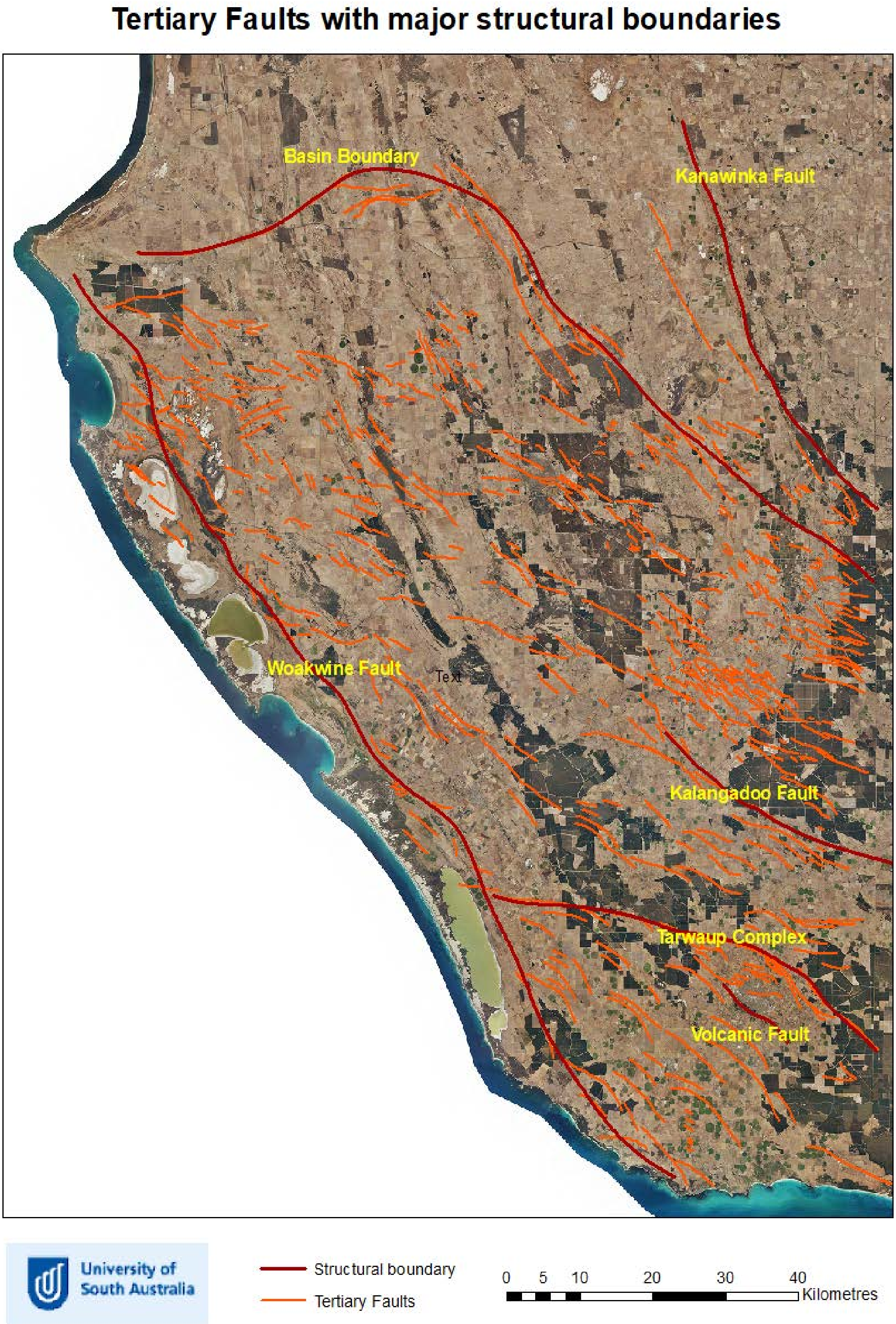

Figure 3: Tertiary surface faults and the major structural faults within the Gambier Basin

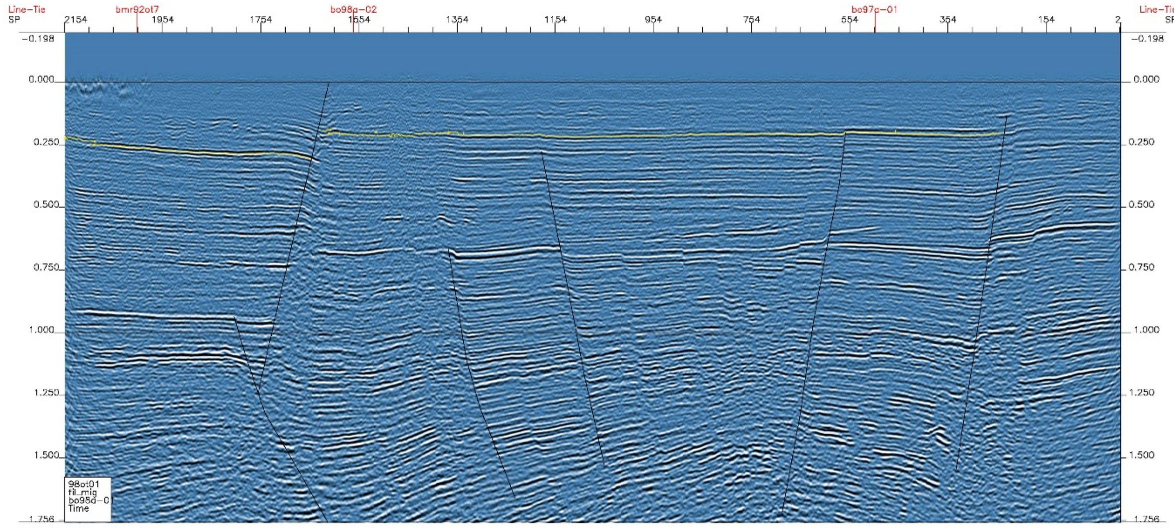

Figure 4: Seismic cross section indicating a fault displacement of about 80 m under the Woakwine dune

6 A review of current knowledge on aquifer thickness (isopach) in the LLC PWA

As noted previously, 479 drilled wells provided sediment intersections of the Dilwyn Formation available for public review. Based on these 479 wells, the assessed aquifer thickness for the LLC PWA is shown in Figure 5.

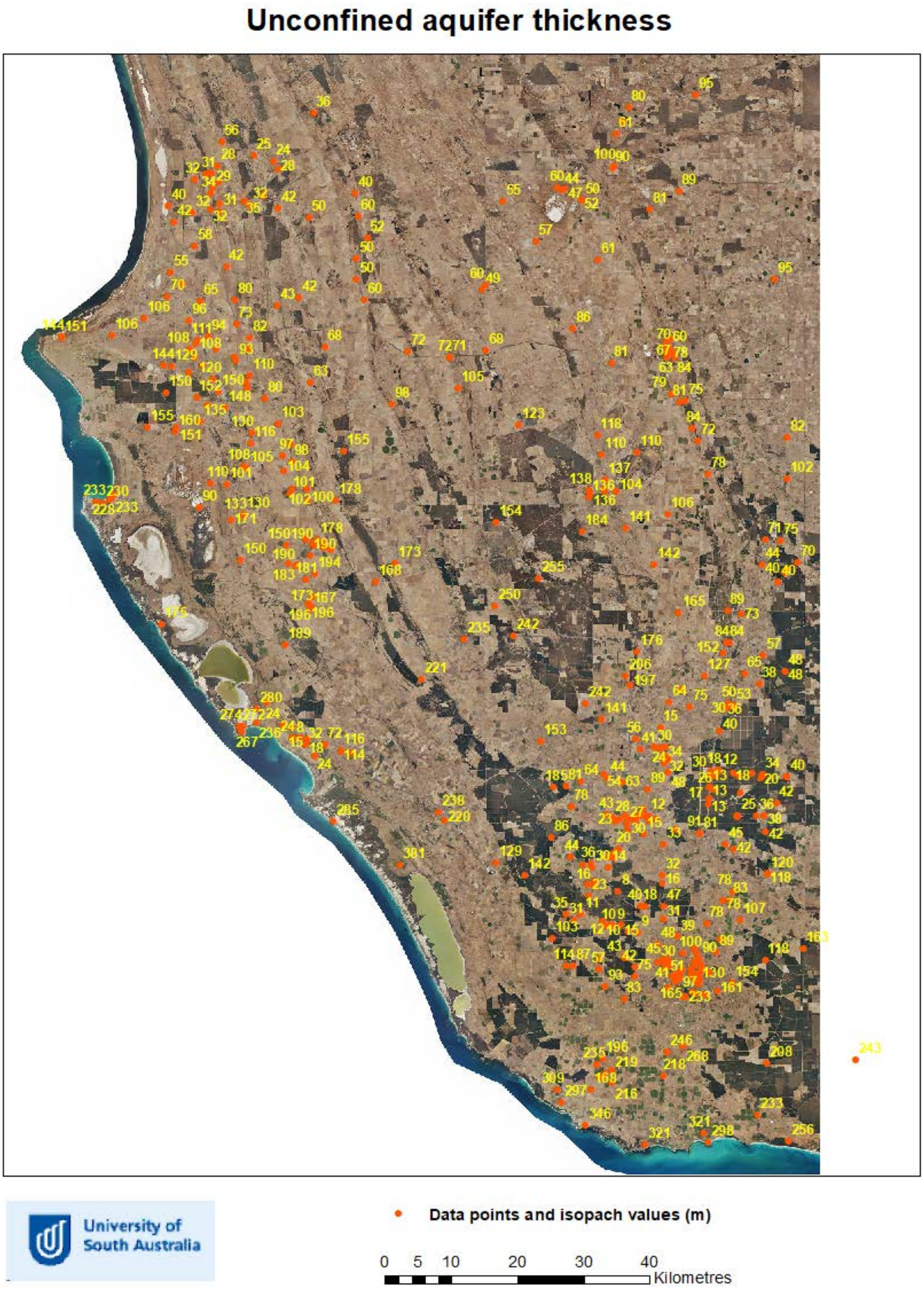

Figure 5: Aquifer thickness plotted from wells intersecting the top of the confined Dilwyn Formation

7 Production of new pilot management zone boundaries

Examination of data including the knowledge of stratigraphy (Section 4), structure (Section 0) and aquifer thickness (Section 6) enabled the delineation of revised pilot management zones based on these aquifer parameters. The findings suggest that using aquifer properties, the current 61 management zones currently considered in the LLCWAP may be reduced to as few as six management zones. A map of these potential zones is presented in Figure 6. This data could be further refined by examining commonality between this set and the ten management zones presented by earlier investigations into adaptive management zones (Harrington et al., 2008).

Note that in this study the 'Border Zones' subject to the Border Groundwater Agreement (see Section 2.1) have been ignored to use the best available science, and implementation of these zones in the LLCWAP would need to consider further delineation of the proposed pilot zones to include these administrative constraints (noting that some commonality exists regarding the Kanawinka Fault uplifted area). Other administrative, ecological and social impacts may also result in further delineation of the proposed zones.

A description of the stratigraphy and structure of the six management zones proposed in Figure 6 is provided below.

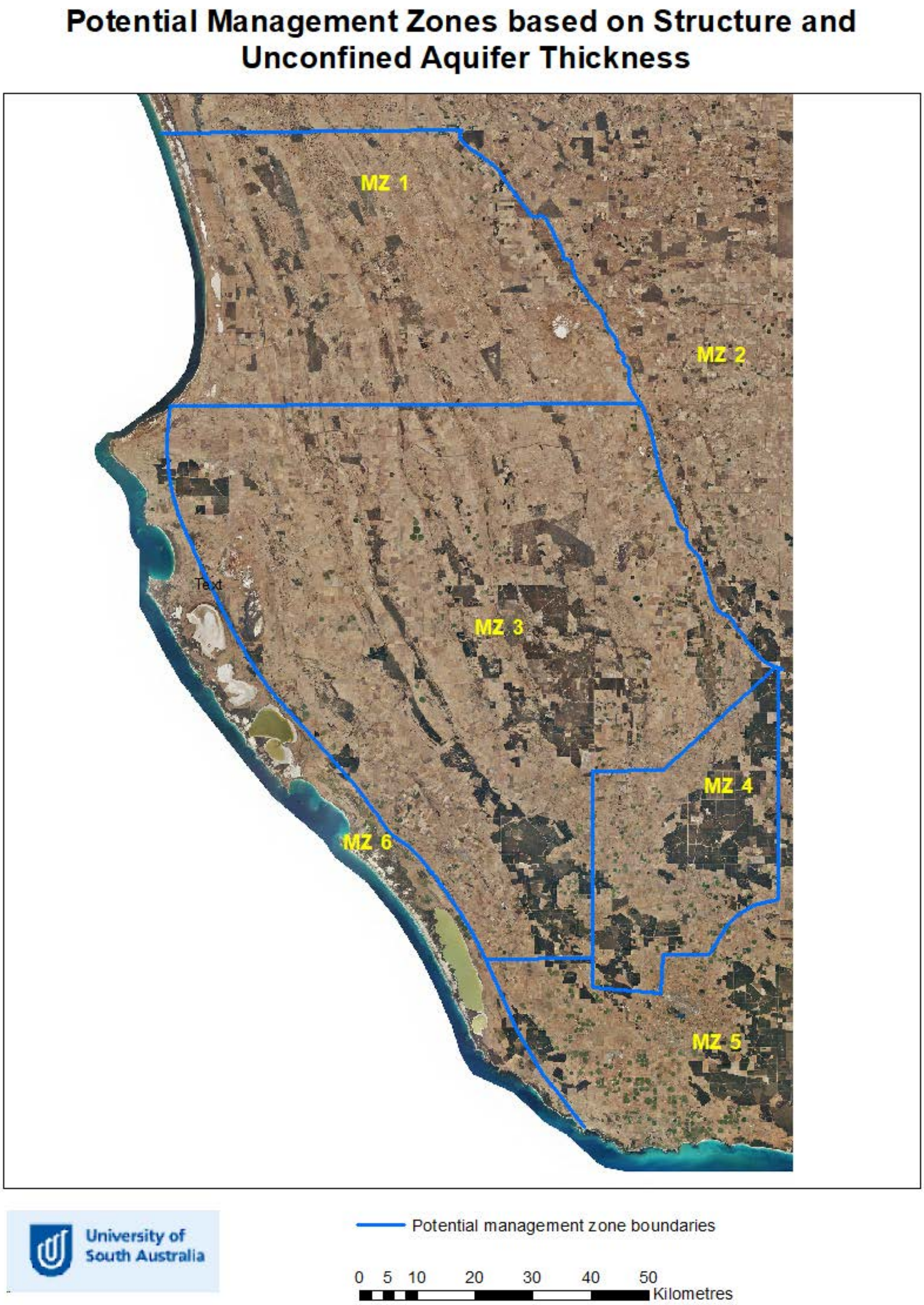

Figure 6: Potential Lower Limestone Coast Management Zones based on unconfined aquifer thickness and structural elements

7.1 Proposed management zone 1

Proposed management zone 1 highlights the section where the Gambier Basin (the Tertiary section of the Otway Basin) transitions across to the northern Murray Basin and the unconfined aquifer sediments thin markedly. Fault interpreted seismic sections indicate how the Gambier Basin boundary transitions to the south east and extends into Victoria as the Tertiary section of the Kanawinka Fault seems to end. The Kanawinka Fault sits at a depth of around 500 m but has Tertiary expression through uplift. Close to the coast near Kingston, total erosion of the Dilwyn Formation results in sediments going from the Tertiary limestone / Mepunga Formation to basement sediments.

7.2 Proposed management zone 2

In proposed management zone 2, the Naracoorte Range is controlled by uplifted sediments on the eastern or Victorian side of the Kanawinka Fault. The unconfined aquifer can be relatively thin in areas through this zone with Naracoorte town water supply well having an unconfined aquifer thickness of less than 70m, through to observation well CMM094 on the southern end near Coonawarra of less than 38 m. Through this zone the Dilwyn Formation can also be very thin with Naracoorte town water supply 13 intersecting basement sediments at 177 m.

7.3 Proposed management zone 3

Proposed management zone 3 represents an area in the middle of the south east with a deep unconfined aquifer. Sediment thicknesses vary in this zone from a little over 100 m to about 200 m.

7.4 Proposed management zone 4

Proposed management zone 4 represented the Nangwarry / Glencoe Dilwyn Formation uplift area. The area is very complex and has different structural events occurring which all result in a shallow unconfined aquifer. In the Nangwarry area the Kalangadoo Fault is a southern uplift boundary and south of Penola is a fault accommodation zone which defines the northern boundary of this confined aquifer recharge area.

To the north west of Mount Gambier the Dilwyn Formation is shallow and uplifting to Glencoe which is the regional structural high for the formation. Aquifer isopachs can be less than 15 m and in the Glencoe area the aquifer is almost dewatered in one location. The area between Glencoe and Nangwarry is also shallow although interrupted by the Kalangadoo fault (extending into Victoria) with a deeper aquifer corridor contained to the north and south by uplifted shallow sediments (Graben Fault). This area requires special management conditions instigated.

7.5 Proposed management zone 5

Proposed management zone 5 is an area containing the management zones of Myora, Glenburnie, Blanche central, Moorak, Donovans, MacDonnell, Kongorong, Benara and part of Zone 2A with aquifer thicknesses varying from about 100 m to greater than 300 m at the coast. This area has strong irrigation activity with greater than 120 centre pivots supporting the dairy industry. In terms of aquifer thickness it is similar to Zone 3 abutting it and there is no strong reason why they could not be combined into a single zone. For the point of this study they are left as two.

7.6 Proposed management zone 6

Proposed management zone 6 is the Western Coastal Zone with the defined topographic boundary the Woakwine Dune which overlays several major faults defined from seismic section. This zone is highlighted by strong fault displacement of about 80 m downthrown on the seaward side. The consequent newer infill limestone while very thick (>300 m), is strongly marl (calcareous clay) from top to bottom and results in practically no irrigation activity as can be observed from aerial or satellite photography. This limestone is not divided into the Green Point Member, Camelback Member and Greenways Member.

8 Options for trigger level management with fewer management boundaries

Climate change projections for the Lower Limestone Coast typically indicate the likelihood of a drying climate in the coming decades (Department for Environment and Water, 2022). There is a concern among some water users that climate change will result in less groundwater recharge and subsequent reductions in the available groundwater resource. The principal of Adaptive Groundwater Management is to ensure on-going sustainability of water resources by developing clear processes to adjust licensed water use (or groundwater extraction) to seasonal conditions.

One process involves setting agreed Resource Condition Limits as in the current LLCWAP (i.e. based on groundwater surface water levels and/or salinity) for key groundwater observation wells. This method can avoid undesirable outcomes for the resource and the ecosystems and people who depend on it. This method is illustrated in Figure 7. In the case of the Lower Limestone Coast, this diagram illustrates that near the end of winter, groundwater is typically at a high point in the annual water level cycle. If this fails to reach the defined management trigger, then intervention will be required resulting in the potential for reduced availability of water resources. Likewise, the regional unconfined aquifer reaches a lowest level in summer. The summer low level is the lowest groundwater elevation in a given year, but when this level reaches the designated summer drawdown limit, again, intervention is required. However, management zones based around aquifer thickness allows an increased number of management options to be discussed.

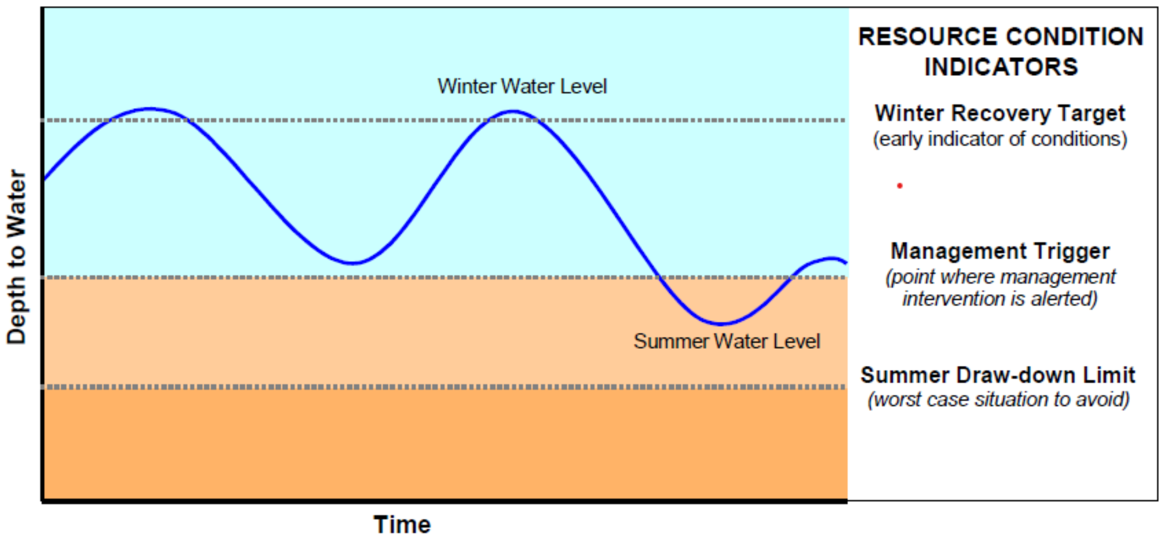

Figure 7: Example of a groundwater management technique (DWLBC, 2009)

8.1 Current trigger level rules

- The current trigger value of an average drop of 0.1 m averaged across 5 years for the management zones seems outdated, using a ‘one value fits all aquifer thicknesses’ assumption and geological conditions being too simplistic.
- Under changing climate conditions, if the trigger continues to be reached, is the economic outcome reduced primary production through license reductions?
- If an aquifer is over 200 m thick, what is the reconciliation between this type of management zone and one with a very shallow thickness?
- A one size fits all approach seems an outdated management option when better science allows other potential positive outcomes.

8.2 A community agreed level

- Community input into trigger levels has been encouraged and citizen science can be productive, however discussions need to be led by people who can explain the current science knowledge and what any implications mean.
- With climate rainfall decline which become the driver of water level declines, what are the economic implications once triggers are reached?
- If a wetland dries because of a lack of rainfall, that should not affect groundwater considerations.

8.3 Resource condition based on percentage of aquifer thickness

- With the current understanding of the regional stratigraphy and structure, a management consideration could be to assess aquifer decline as a percentage of aquifer thickness.
- Where an aquifer is thin as defined by zone MZ 4, then much stricter regulation needs to in place i.e., 0.1 m averaged across 5 years maybe much too broad and a smaller decline mechanism instigated.
- There are areas near Glencoe where the unconfined aquifer is close to being dewatered and irrespective of triggers, closer management required. The alternative for people in this situation will be to drill expensive wells into the confined aquifer and irrespective of management outcomes, this will likely occur in the future.

8.4 Licencing the unconfined aquifer Camelback Member section of the Gambier Limestone

- For the major areas of thicker aquifer such as MZ 3 and MZ 5 a management option is to licence sections of the aquifer for the taking of water.
- In regional terms there would be a licensed unconfined aquifer. Green Point Member sub units 1,2 and 4 available for all stock and domestic applications. Green Point sub unit 3 and the semi- confined section (Camelback Member) licensed for irrigation extraction. Then as now the confined aquifer sections (Mepunga Formation and Dilwyn Formation) are licensed separately.
- The Green point Unit 3 and the Camelback Member would require permit construction conditions such as pressure cementing casing to a depth based on applied science which then isolates this part of the aquifer from the upper shallow sections.
- This technique has worked successfully at Kimberly Clark where the production wells have been completed in this way and shown to have no drawdown effect in the upper limestone section. In fact, since the technique was implemented , the unconfined aquifer has indicated strong recovery.
- Management around this could be simplified further with the bottom two thirds of the unconfined formation licenced for irrigation extraction, with the top section reserved for stock and domestic use.
- Acceptable drawdown levels can be as simple as a decline percentage of aquifer thickness based on long-term water level trends
- The advantage of licensing the unconfined aquifer in this way is the protection of groundwater dependent ecosystems (GDEs), as pumping has been shown not to affect the upper aquifer sections.
- It will not protect wetlands and unfortunately if it does not rain the area will dry out. Groundwater management technique is irrelevant for a wetland.

9 Conclusions and recommendations

This report has examined the potential to use current knowledge of groundwater conditions on the Lower limestone Coast of South Australia to establish fewer groundwater management zones which may be more suitable to sustainable water resource management. Based on previous work on adaptive groundwater management and the results of this study, it is proposed that management zones could potentially be reduced from the current 61 to as few as six to 10 zones, noting the possibility that zones could be further delineated based on community consultation or specific needs. It is believed that fewer zones could lead to improved water trading and likely assist primary production through more flexible availability of water.

The results in this report are not considered final and should be compared with the earlier 2008 adaptive management zone project (Harrington et al., 2008) where 10 management zones were recommended for the LLC. It is also noted that other factors will need to be considered in the revision of management zone boundaries and any change may cause impacts on (for example) localised groundwater dependent ecosystems or the value of water assets.

This project has also found that the science behind current trigger level settings requires improved methodology. We have identified four different options available for setting trigger levels and further investigation is likely to reveal others.

It is recommended that consideration be given by the Landscapes Board to reducing the current 61 LLC management zones based on current knowledge of the groundwater conditions in the Lower Limestone Coast of South Australia.

It is also recommended that improved trigger responses be considered in each of the proposed management zones. Examples are provided below regarding the six management zones recommended from this study.

- MZ 1 - requires stronger triggers than currently used due to a thin and drying aquifer section
- MZ 2 – a combination of a percentage of aquifer thickness and also two third aquifer licenced
- MZ 3 – licence the bottom two thirds of the aquifer for irrigation extraction
- MZ 4 – requires strong triggers than current to be in place due to thin aquifer section
- MZ 5 – licence the bottom two thirds of the aquifer for irrigation extraction. This technique is important as coastal wetlands can be better protected with this technique.
- MZ6 – use current trigger mechanism due to no irrigation activity, but also the presence of important coastal wetlands that require protection

10 References

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Appendix A: Original 2006 Groundwater Management Boundaries prior to boundary clipping

The following images are reproduced from earlier investigations (Harrington et al., 2008) indicating the then understanding of the following properties:

- aquifer thickness (Figure A 1)
- quaternary aquifer unit boundaries (Figure A 2)
- seasonal variation in maximum and minimum water level (Figure A 3)
- trend in surface water levels (or depth to groundwater) in 2003 to 2007 (Figure A 4)
- trend in surface water levels (or depth to groundwater) in 2003 to 2007 (Figure A 5)
- land features (Figure A 6)
- land use (Figure A 7)

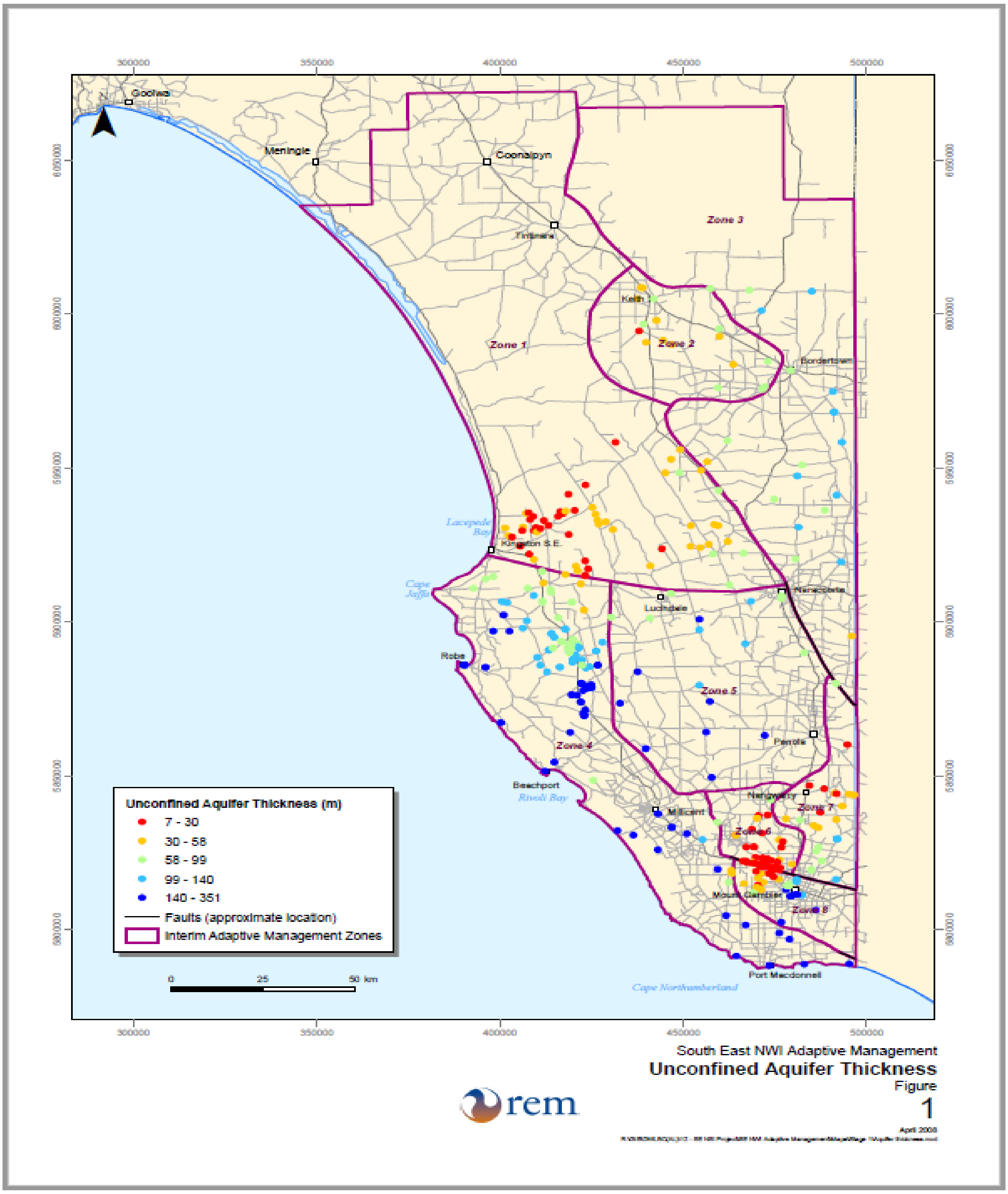

Figure A 1: Map indicating the estimated unconfined aquifer thickness across the South East of South Australia as considered by (Harrington et al., 2008) in the development of adaptive groundwater management pilot zone boundaries

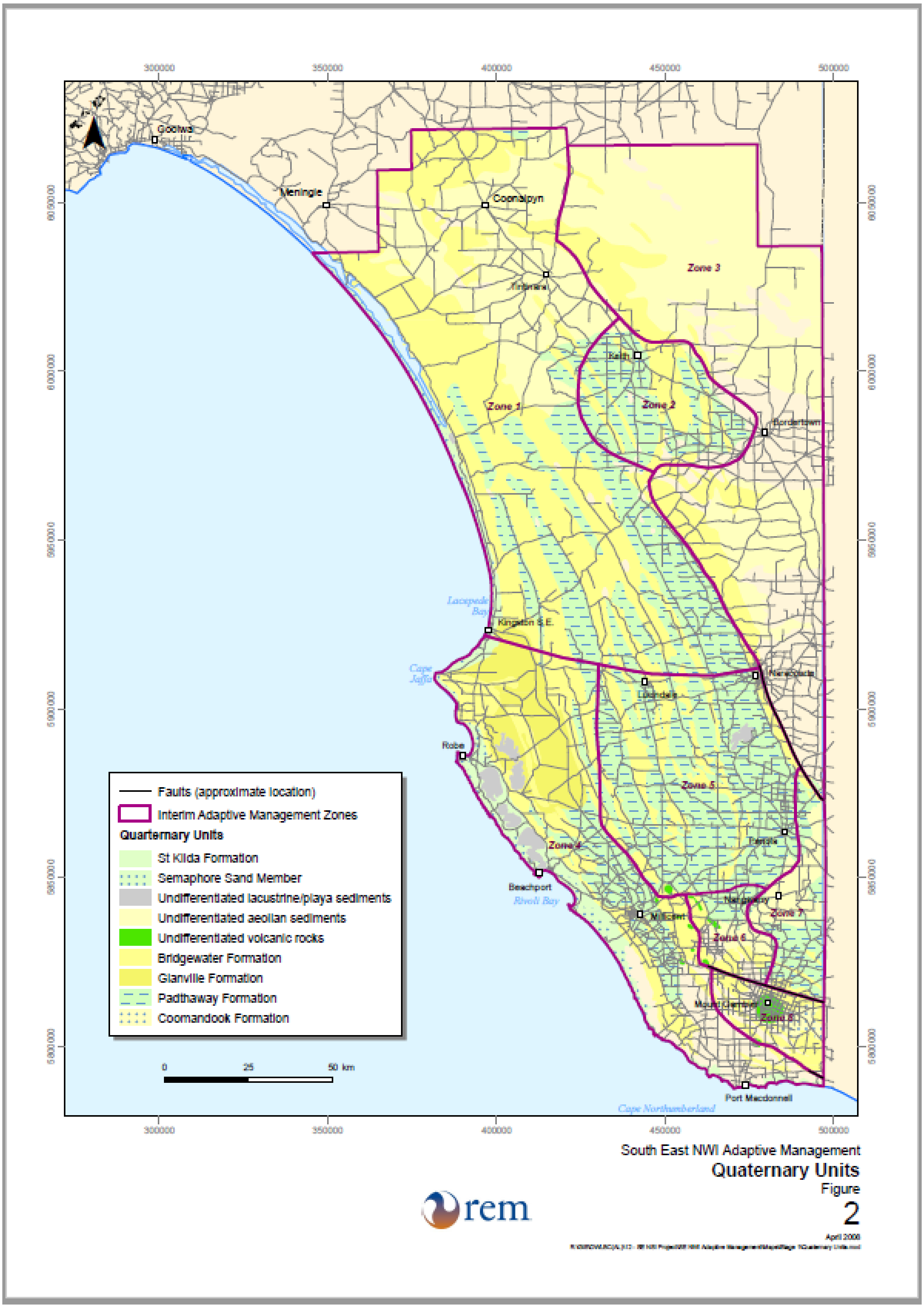

Figure A 2: Map of quaternary aquifer units in the South East of South Australia as considered by (Harrington et al., 2008) in the development of adaptive groundwater management pilot zone boundaries

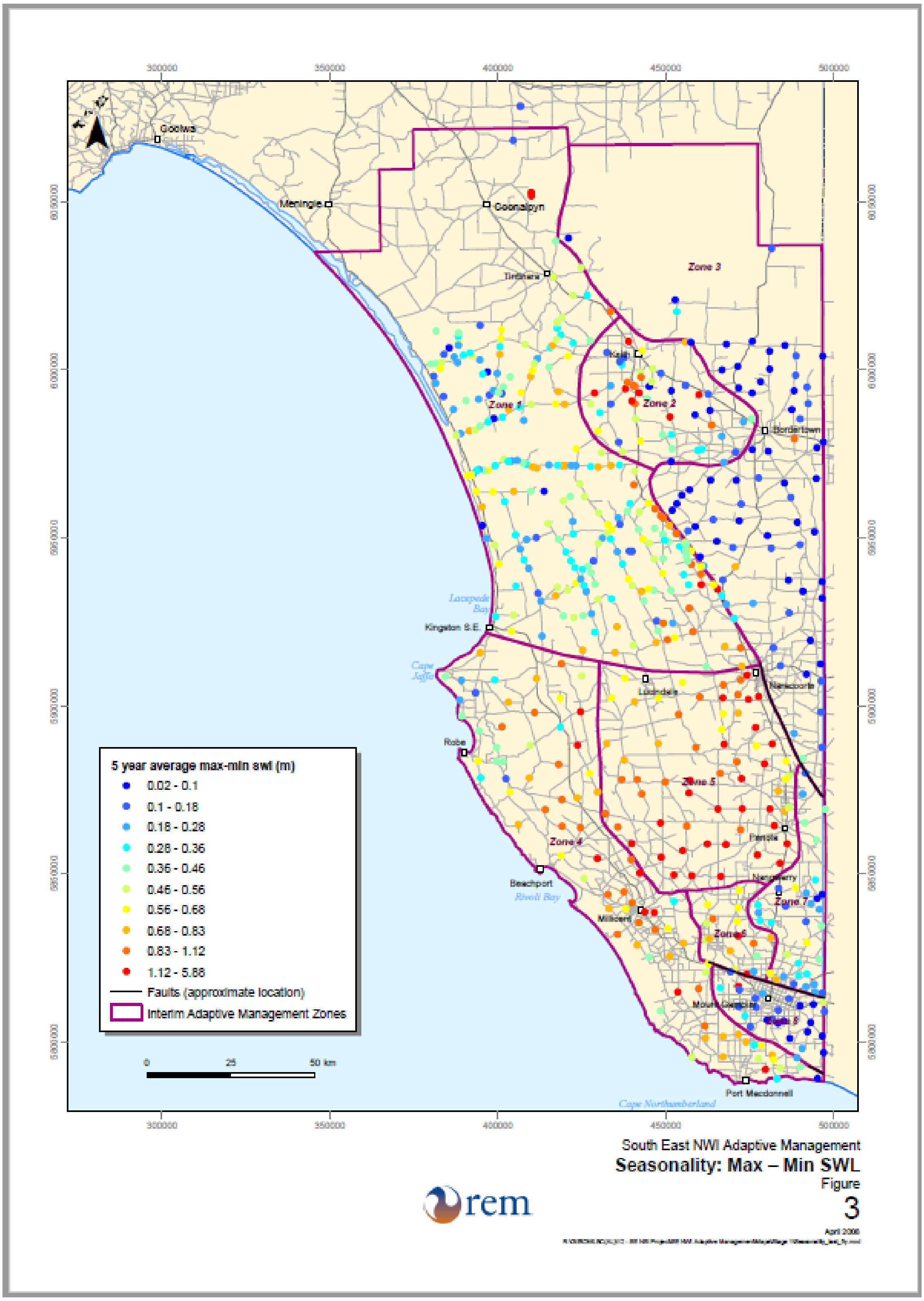

Figure A 3: Map indicating seasonal variation in surface water level (or depth to groundwater) in the South East of South Australia as considered by (Harrington et al., 2008) in the development of adaptive groundwater management pilot zone boundaries

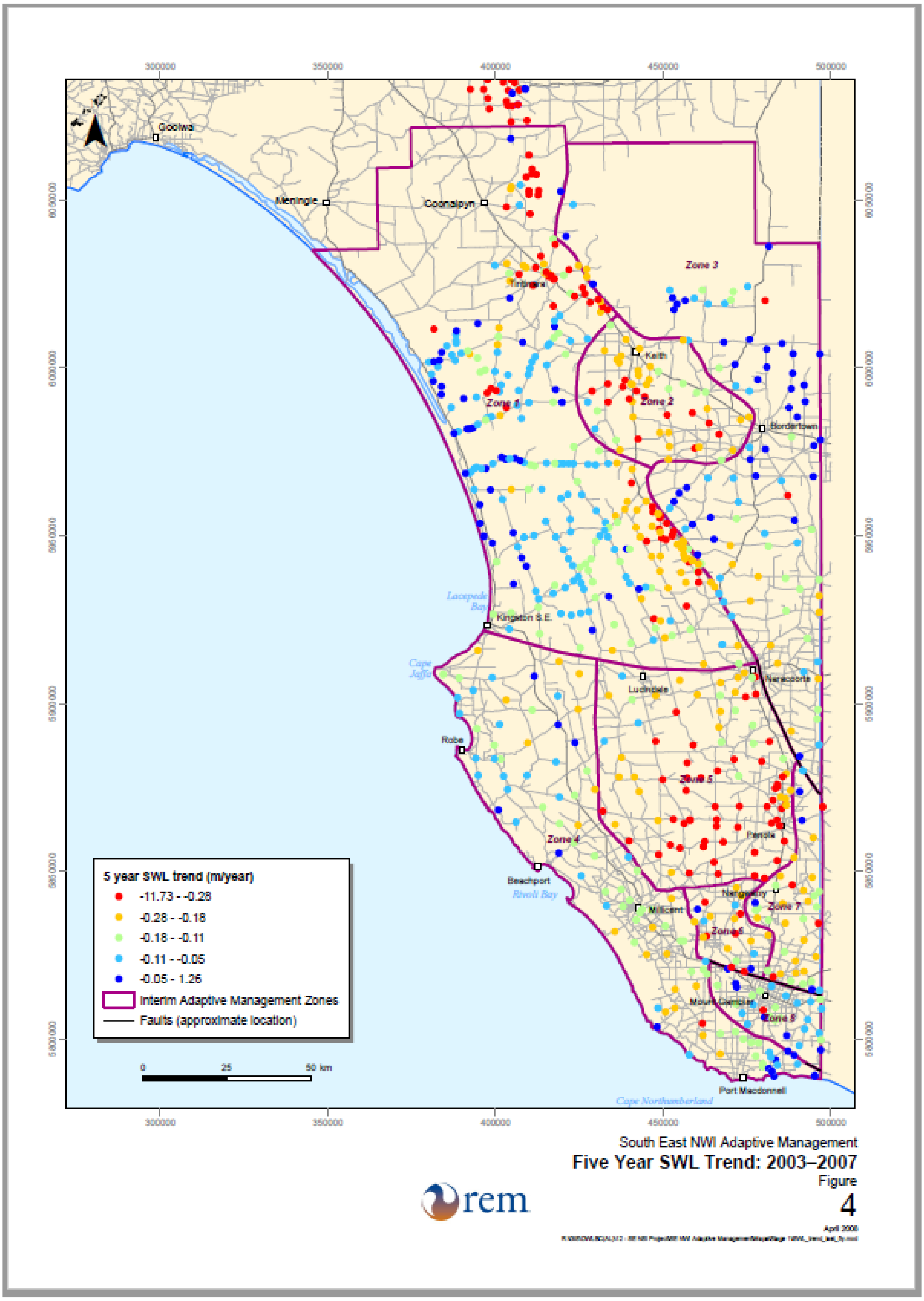

Figure A 4: Map indicating five year trend in surface water levels (or depth to groundwater) (2003 to 2007) in the South East of South Australia as considered by (Harrington et al., 2008) in the development of adaptive groundwater management pilot zone boundaries

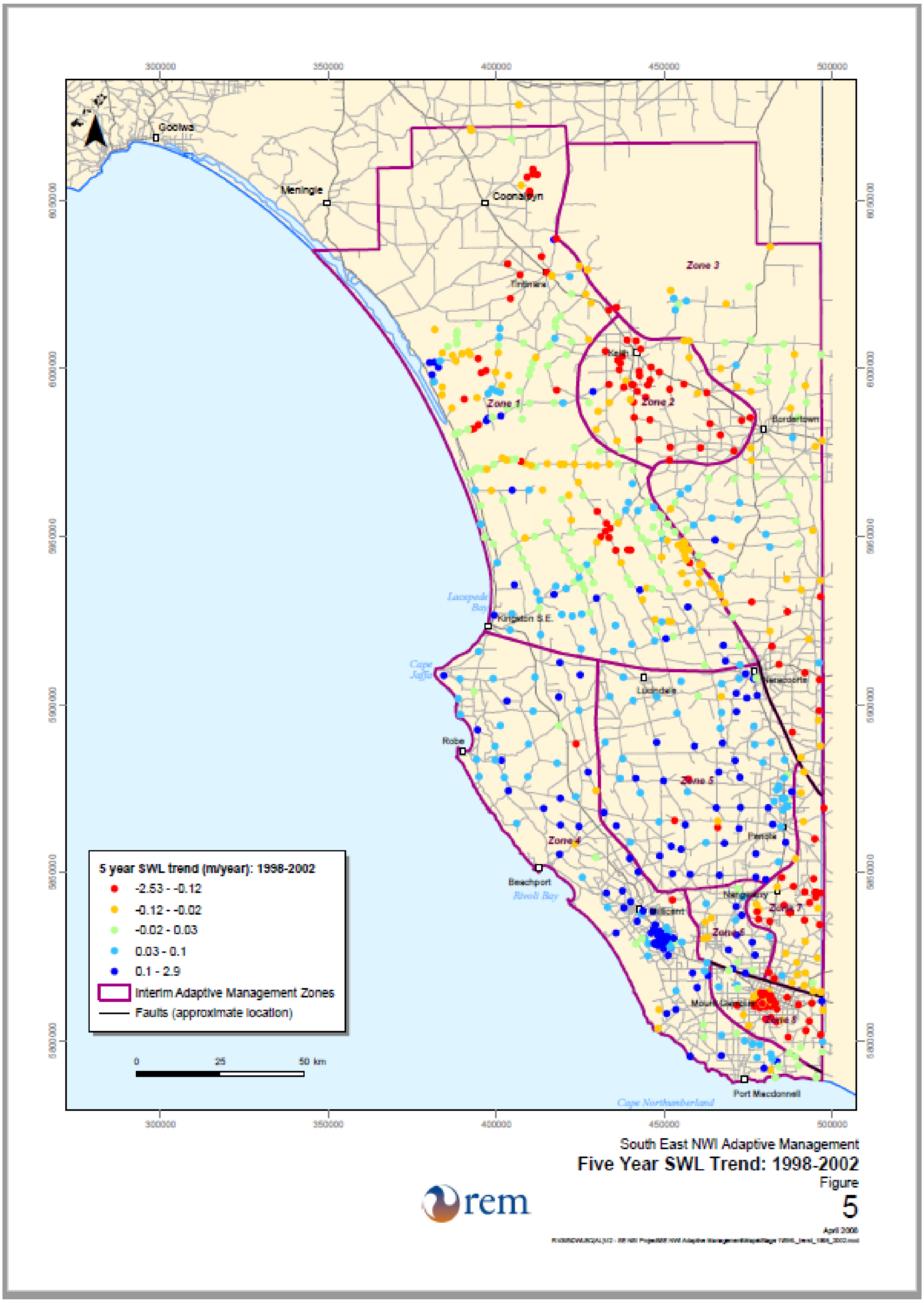

Figure A 5: Map indicating five year trend in surface water levels (or depth to groundwater) (1998 to 2002) in the South East of South Australia as considered by (Harrington et al., 2008) in the development of adaptive groundwater management pilot zone boundaries

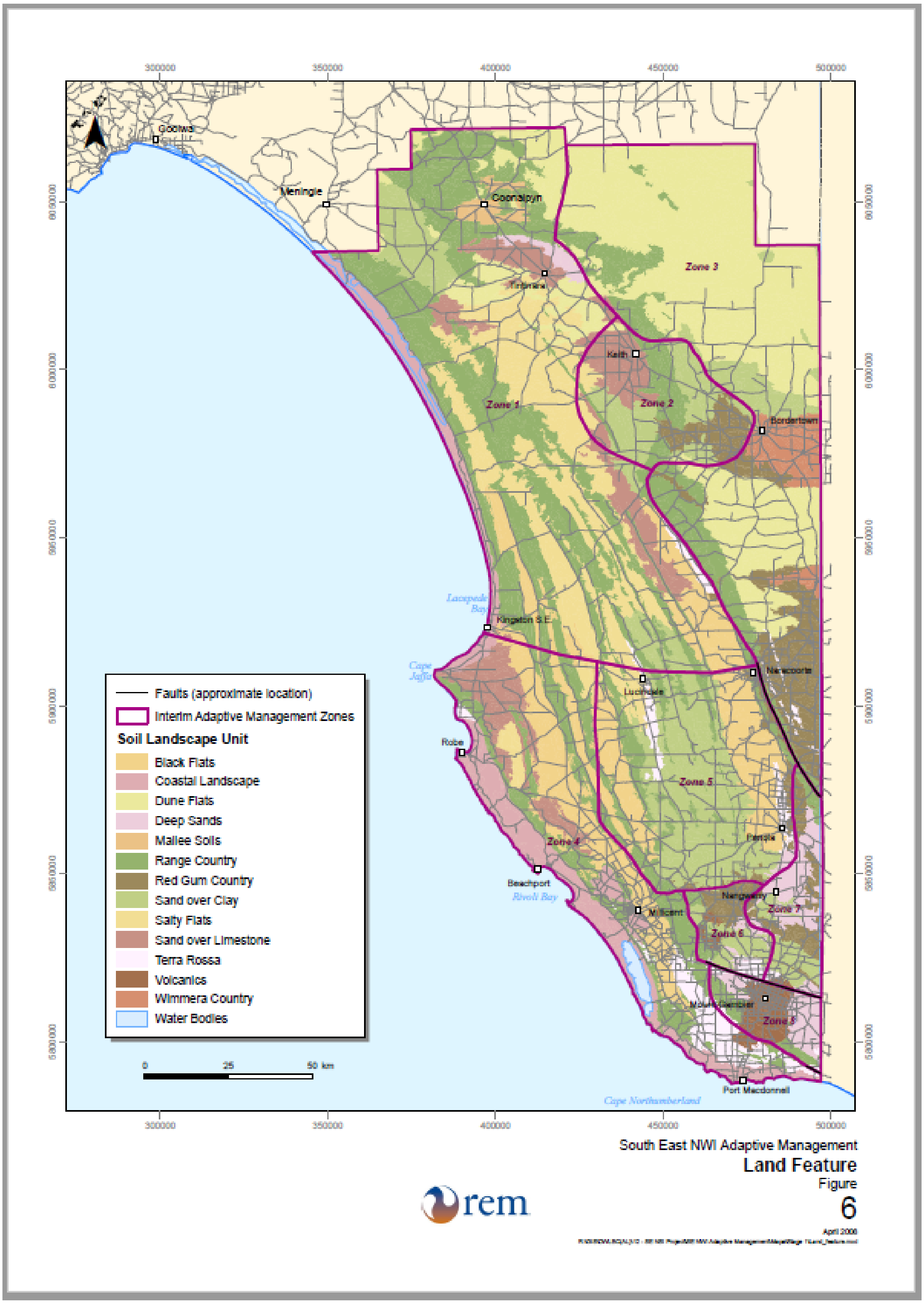

Figure A 6: Map of land features in the South East of South Australia as considered by (Harrington et al., 2008) in the development of adaptive groundwater management pilot zone boundaries

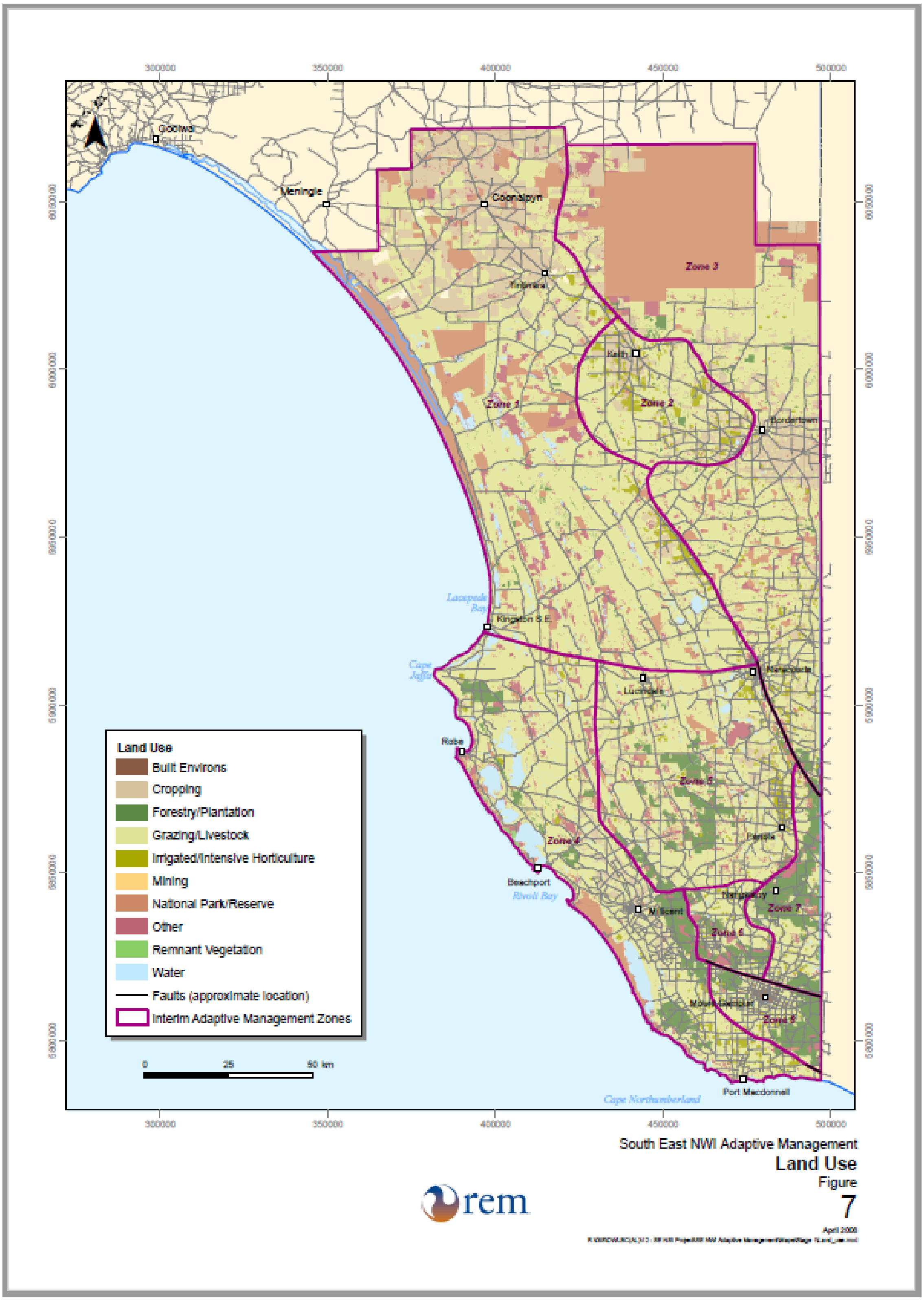

Figure A 7: Map of land use in the South East of South Australia as considered by (Harrington et al., 2008) in the development of adaptive groundwater management pilot zone boundaries