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Identifying groundwater discharge in the Coorong (South Australia)

Multi-disciplinary study maps major indicators

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The Coorong, and the Lower Lakes (Lake Alexandrina and Lake Albert) in South Australia are major interconnected coastal water bodies between the Murray River and the Southern Ocean (figure 1). During the 1940s, five barrages were constructed between Lake Alexandrina and the opening to the ocean to establish a reservoir of potable water in the Lower Lakes. As a consequence, freshwater inflow from the Murray River to the Coorong became restricted. In addition, freshwater delivery through the Murray River has declined over decades but more markedly during recent years, leading to an increase in salinity levels in the Coorong.

Degradation of habitats and the ecological character of the region have been associated with these changes in the flow regime and water quality. This has become a major concern given the ecological value of the region, particularly in providing highly diverse habitats for migratory birds, rare plant and fish species.

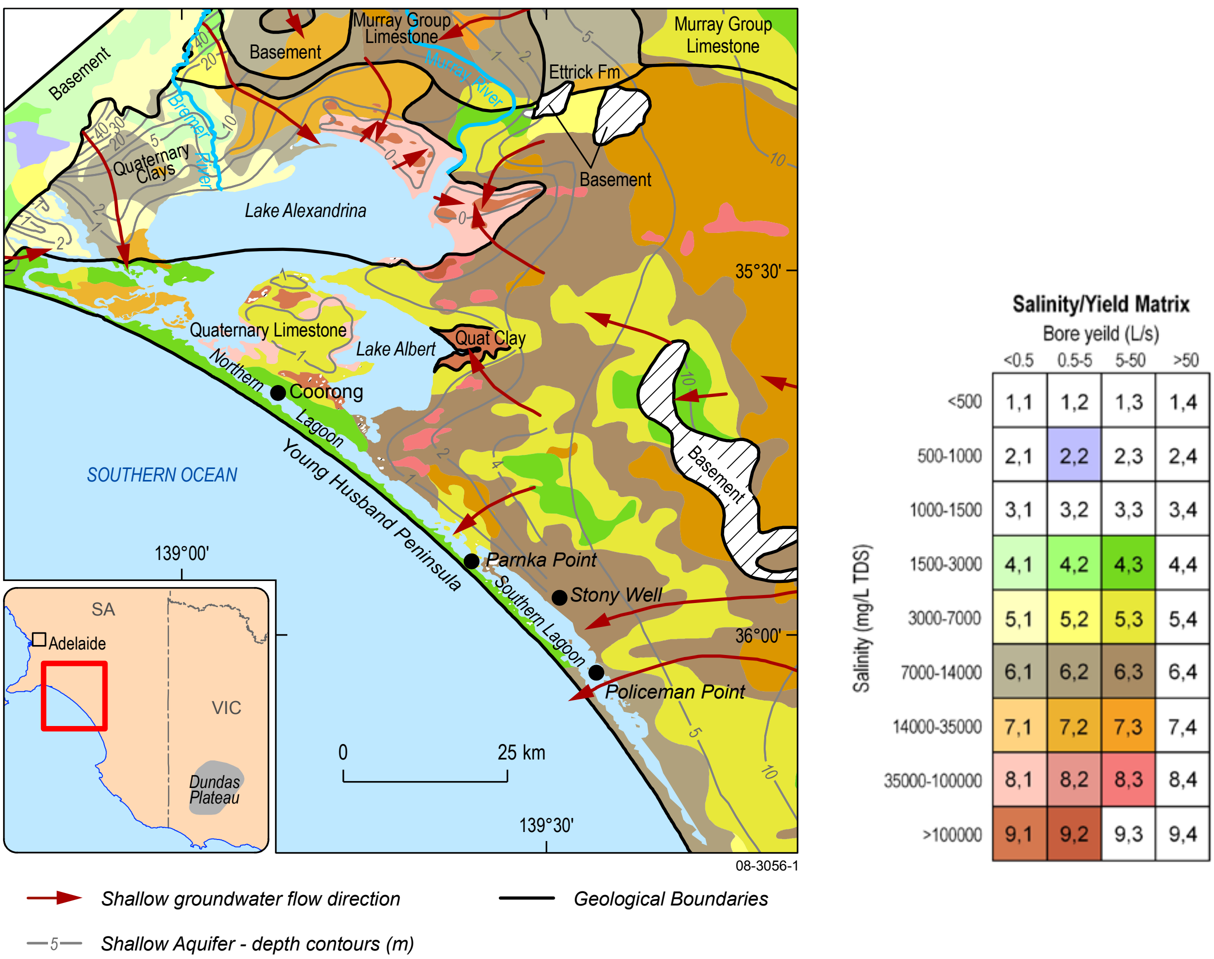

Figure 1. Hydrogeological map of the Coorong Lagoon and Lower Lakes Region (based on Barnett 1991, Barnett 1994, Cobb & Barnett 1994).

The need to protect the Coorong and Lower Lakes region was formally acknowledged in 1985, with designation onto the Ramsar List of Wetlands of International Importance.

Research into the physical and chemical conditions, and the ecological character of the Coorong and the Lower Lakes is currently being undertaken as part of CSIRO's Flagship for a Healthy Country involving CSIRO, the University of Adelaide, Flinders University, the South Australian Research and Development Institute and Geoscience Australia. Geoscience Australia undertook an initial field survey to the Coorong in August 2007 to identify nutrient sources and sinks. Preliminary field observations suggested the potential importance of groundwater discharge for water quality in the Coorong. In order to evaluate the possible occurrence of groundwater discharge along the Coorong more systematically, three approaches were taken and the results are presented below:

- A literature and data review on the regional groundwater system
- Interpretation of remote sensing data (Landsat 5 TM)
- Field observations and measurements of groundwater seepage.

Hydrogeology of the Coorong and Lower Lakes region

The Coorong and Lower Lakes are located in the south-western edge of the Murray Geological Basin. The significant aquifers (or geological formations which hold water) in this region are the Quaternary and Murray Group Limestone sequences, and the deeper confined Renmark Group sands. The limestone sequences are in good hydraulic connection (Barnett 1994) and form the shallow watertable aquifer. The Renmark and Murray Groups are separated by a series of confining clay aquitards (Brown et al 2001).

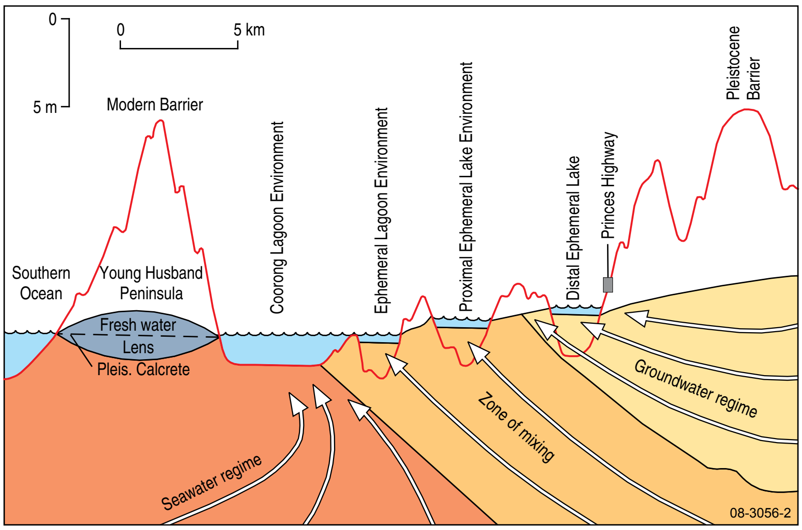

Figure 2. Generalised cross section of the Coorong Lagoon and the coastal plain indicating the groundwater/seawater interface (from Van der Borch et al 1975). Note the perched freshwater lens.

A hydrogeological map of the Lower Lakes and Coorong region (figure 1) and the associated description have been derived from three previously compiled map sheets (Barnett 1991, Barnett 1994, Cobb and Barnett 1994). Major processes such as groundwater recharge and discharge, dryland salinisation, irrigation and groundwater/ surface water interaction were identified within this region. The map uses a matrix approach to display salinity and yield characteristics for the shallow aquifer. Dryland salinity in the region is a major land degradation problem on the low-lying coastal plain, where clearing of native vegetation has led to a rising watertable. The risk of salinisation is most prevalent where depth to the watertable is less than two metres.

As was originally concluded by O'Driscoll (1961), groundwater flows radially from the zone of recharge at Dundas Plateau in the east, northward to the Murray River (Tyler et al 1983) or westward, discharging to the Coorong, the Lower Lakes or low-lying salinised areas (Barnett, 1994), demonstrated by the potentiometric contours (figure 1). A groundwater-seawater conceptual model has also been developed for the Coorong (Von Der Borch et al 1975). The model (figure 2) shows the following sequence of water bodies:

- a typical saltwater wedge intruding from the ocean
- fresher, lower density, terrestrial groundwater located above seawater
- a large mixing zone at the groundwater-seawater interface, with discharge at the surface.

The model also explains the occurrence of ephemeral lakes and freshwater-dependent vegetation communities ('soaks').

On the western side of Lake Alexandrina, the watertable is within a Quaternary clay which overlies and semi-confines the limestone aquifer. Elsewhere in low-lying areas around the Lower Lakes, the watertable occurs in organic-rich clays which were deposited when the Lower Lakes expanded in response to a higher sea level about 6000 years ago. These areas contain highly saline groundwater (>100 000 milligrams per litre) due to strong evaporative discharge which has lowered the watertable below sea level. The watertable contours show that these areas are the focus for regional groundwater discharge in preference to the Lower Lakes which are at a higher level of 0.75 metres Australian Height Datum (AHD). Lower Lake levels have subsequently declined in the 14 years since the publication of these map sheets.

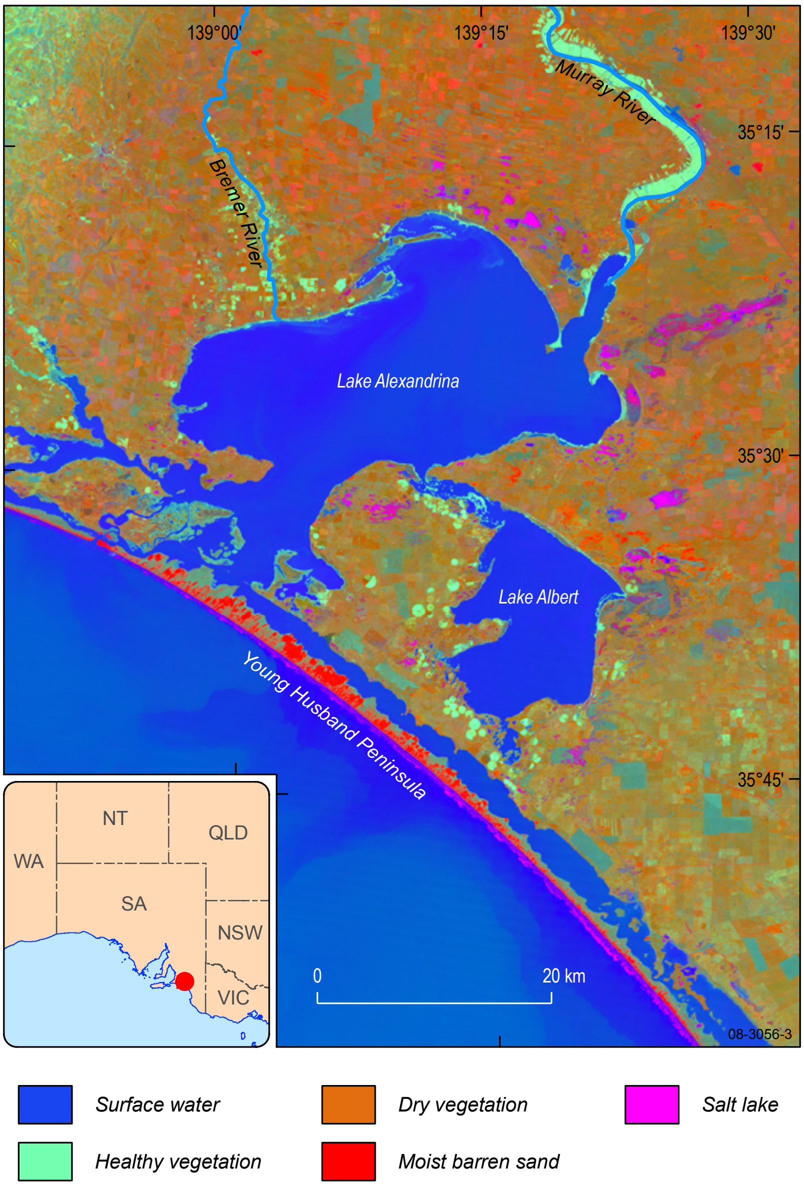

Figure 3. Tasselled Cap Transform of Landsat 5 TM imagery for December 1993.

Groundwater processes identified by remote sensing

Groundwater processes have the potential to influence wetland hydrology and ecosystems. In this study, remote sensing was used to map indicators of groundwater discharging at the surface, the presence of a shallow watertable or sustained soil moisture. For example, persistent vegetation health, particularly through prolonged dry periods, can be an indicator of groundwater influence. To this end, Landsat 5 Thermal Mapper (TM) imagery was used to detect seasonal and annual changes in vegetation health within the region, using a combination of well-established algorithms (Normalised Difference Vegetation Index, Normalised Difference Water Index and Tasselled Cap Transforms).

The Tasselled Cap Transform of Landsat 5 TM imagery for December 1993 is shown in figure 3. Orange represents dry vegetation, blue is surface water and green indicates healthy vegetation. The latter effectively maps irrigated agriculture, particularly bordering the Murray and Bremer Rivers. Relatively healthy riparian vegetation in these areas also has a similar signal but does not conform to the regular dimensions observed of agricultural regions. These riparian regions may represent a localised shallow watertable. Salt lakes, distributed around the edges of the Lower Lakes are indicated as pink. Other image processing suggests that it is not the availability of saline groundwater that is supporting vegetation in these areas, but seasonal fresh surface water. Along the Younghusband Peninsula, red areas are exposed moist sand dunes and green areas are relatively healthy native vegetation. In this case, dune vegetation is accessing a perched freshwater lens (figure 2), rather than the regional watertable.

Figure 4. Thermal based classification of the Coorong and Lower Lakes region. Red areas are groundwater discharge zones.

Thermal imagery was also used to identify groundwater discharge areas, soil moisture and surface water extent. This is possible, because the summer daytime surface temperature of water is cooler than soil and rock, damp soil is cooler than dry soil, and discharging groundwater is cooler than surface water. A series of classifications were thus produced for the region based on thermal signatures (figure 4). Areas that become clearly evident include irrigated crops (rectangular or circular dark brown areas) and the salt lakes (irregularly shaped dark brown and light blue areas bordering the Lower Lakes). Importantly, relatively cool zones of surface water, indicated in red, are prevalent in the southwest of Lake Alexandrina and south of Parnka Point in the Coorong. These are interpreted as potential sites of significant discharge of cooler groundwater into the surrounding water bodies. Direct groundwater discharge may be

Figure 5. Observed features in the field (February 2008) giving evidence for past and current groundwater discharge in the South Lagoon. (a) Carbonate tube 'tufa' at Policeman Point; (b) stranded pools at Stony Well; (c) active seep showing agitated sediment south of Parnka Point (see figure 1).

occurring elsewhere, however it is difficult to detect temperature contrasts in the deeper waters of Lake Alexandrina. The thermal Landsat band used is also of low resolution (30 metres) and more detailed interpretation could be produced from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) imagery, particularly with the comparison of daytime and night-time scenes.

Field observations and measurements of groundwater discharge

Several indications of groundwater discharge are often visible in the field including the precipitation of minerals (typically carbonates and iron oxides) at the groundwater–surface water interface, the presence of water bodies without surface water inputs, and the occurrence of visible seeps. After initial indications of groundwater discharge were observed during a survey of the Coorong in August 2007, a second survey in February 2008 targeted field groundwater discharge features. The low water levels of the Coorong at the time of the survey sub-aerially exposed many of the normally inundated features.

Carbonate deposits were found to be pervasive along the eastern shore of the Coorong's South Lagoon (figure 5a). These deposits often take the form of cylindrical tubes (5 to 100 centimetres diameter) commonly known as 'tufa' which are indicative of groundwater discharge. The tufa in the Coorong are composed of concentric carbonate laminations millimetres thick, suggesting cyclic accretion. Tufa were found adjacent to the majority of bays and headlands, generally within 100 metres of the shoreline, forming either elongated reefs that parallel the coastline or shelfs that extend from the shore into the lagoon. The size and extent of the tufa indicate groundwater has occurred throughout the history of the Coorong and may have been much greater in the past.

Stranded pools were also common along the eastern shore of the South Lagoon, and often associated with tufa (figure 5b). As a result of low water levels prevalent during the survey, the main water body of the Coorong was typically tens to hundreds of metres from the shoreline. Stranded pools of water disconnected from the main water body persisted. The pools were typically several metres wide running parallel to the coast line with strings of pools stretching for kilometres. The presence and extent of stranded pools indicate the presence of groundwater discharge even under drought conditions.

Visible seeps were observed at several sites within the Coorong's South Lagoon (figure 5c). Like the tufa and stranded pools, the seeps were located at the edge of the Coorong within 100 metres of the shoreline. The seeps were identified by the agitation of sediments as groundwater flowed rapidly upwards, and by the difference in density between surface water and the inflowing groundwater. Individual seeps were several centimetres in diameter and spaced several centimetres to metres apart. Direct measurement of groundwater discharge showed high flow rates of 38 to 246 $lm^{-2}\ h^{-1}$ from visible seeps but also high flow rates of 11 to 38 $lm^{-2}\ h^{-1}$ where visible seeps were not present. This, in conjunction with tufa and stranded pools, indicate that visible seeps are only the surface expression of a much larger groundwater discharge zone that extends along the eastern shoreline of the Coorong's South Lagoon.

Conclusions

Near the southwest margin of the Murray Basin, shallow, unconfined limestone aquifers and a deeper confined sand aquifer are found. The upper aquifer is recharged at the Dundas Plateau from where groundwater flows westward into the Coorong and the ocean. In the vicinity of the Coorong, a mixing zone between groundwater and underlying seawater is formed and has surface exposure at distinct locations forming ephemeral lakes and distinct vegetation communities ('soaks'), particularly at the southern end of the Coorong. These soaks can be identified by remote sensing techniques, using vegetation health and soil moisture as indicators.

Groundwater discharge is widespread in the south lagoon of the Coorong judging by the distribution and abundance of features such as tufa, stranded pools, and active seeps. Significant active seepage was measured at three sites along the south lagoon even where sediments were not agitated. Active seeps can also be identified using thermal imagery. A major groundwater discharge site was identified on this basis just south of Parnka Point, where active seeps have been observed in the field.

It remains unknown how much groundwater is currently discharged into the Coorong, therefore the impact of groundwater on water quality in the Coorong remains speculative. Given the size and abundance of tufa and the extended drought period over recent years, groundwater discharge was likely an important factor affecting flow and water quality in the Coorong in the past.

For more information

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References

Barnett SR. 1991. Pinnaroo Hydrogeological Map (1:250 000 scale). Australian Geological Survey Organisation.

Barnett SR. 1994. Adelaide-Barker Hydrogeological Map (1:250 000 scale). Australian Geological Survey Organisation.

Brown KG, Love A & Harrington G. 2001. Vertical groundwater recharge to the Tertiary confined sand aquifer, South East, South Australia. Report DWR 2001/002. Department for Water Resources.

Cobb MA & Barnett SR. 1994. Naracoote Hydrogeological Map (1:250 000 scale) Australian Geological Survey Organisation.

O'Driscoll EPD. 1961. The hydrology of the Murray Basin Province of South Australia. Department of Mines South Australia. Geological Survey Bulletin 35 Volumes 1 & 2.

Tyler M J, Twidale CR, Ling JK & Holmes JW. 1983. Natural history of the South East. Royal Society of South Australia Inc.

Von der Borch CC, Lock D & Schwebel D. 1975. Ground-water formation of dolomite in the Coorong region of South Australia. Geology (May): 283-285.

Related websites

Nutrient sources and sinks in the Coorong (Geoscience Australia)

www.csiro.au/partnerships/CLAMMGApartnership.html