DWLBC REPORT

Bookpurnong Land and Water Management Plan - Background Report

2009/12

Government of South Australia
Department of Water, Land and Biodiversity Conservation

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1. INTRODUCTION

The Bookpurnong Irrigation Area (IA) covers an area of approximately 1500 ha on the highland along the eastern bank of the River Murray in South Australia, between Lyrup to the north, and Loxton to the south. The Bookpurnong IA encompasses a diverse range of horticultural crops including citrus, nuts, stonefruit and vines. There are currently 81 water licenses allocated in the area of which 29 are for irrigation.

Prior to the installation of the salt interception scheme, Bookpurnong contributed approximately 60 tonnes of salt per day to the River Murray as a result of the geological and hydrogeological history of the area combined with the establishment of highland irrigation.

The community are now upgrading their Land and Water Management Plan (LWMP) to address issues that now affect their region in the ten years period since the previous LWMP was developed. This document provides background information for the production of the LWMP, with a primary focus on the technical and policy aspects of salinity management.

2. THE HYDROGEOLOGICAL PROCESSES

The hydrogeological processes that operate in any region, although mostly hidden below the ground surface, can have a major impact on the quality of the natural environment, particularly soil and water resources. These impacts often motivate investigations to obtain a greater understanding of these processes. This is certainly the case in the Bookpurnong region of South Australia.

2.1 THE REGIONAL GROUNDWATER SYSTEM

The Bookpurnong Land and Water Management Planning area falls within the Murray Geological Basin, which covers an area of 297 000 km^2 and underlies most of the southern and southwestern parts of the larger Murray-Darling Basin (Brown and Stephenson, 1991). Figure 1 illustrates the general movement of groundwater beneath the land surface within the Murray Basin.

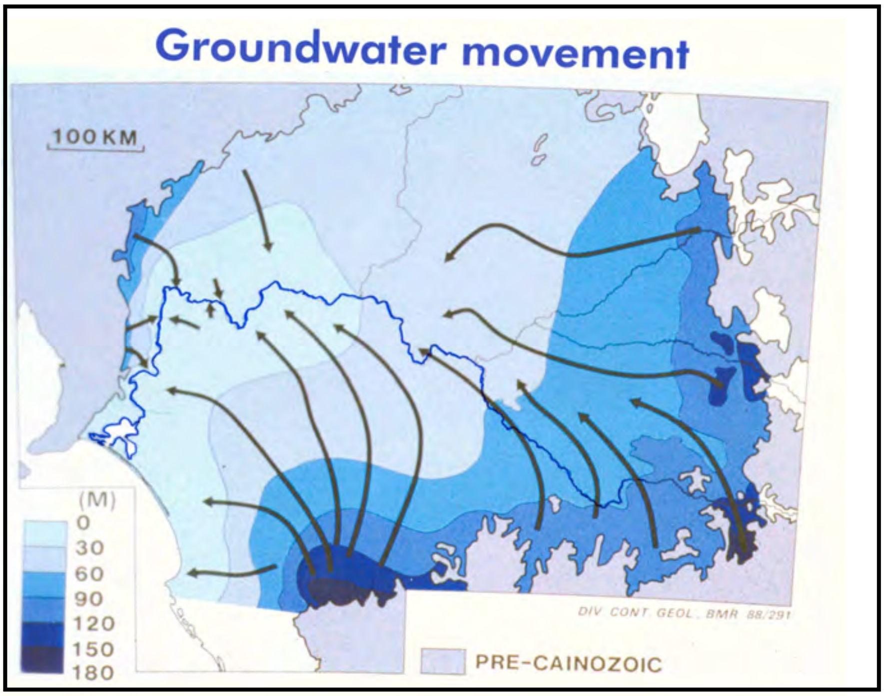

Figure 1: The direction of groundwater flow within the Murray Basin

It shows groundwater flowing from the highland recharge areas surrounding the Basin toward the River Murray which comprises the groundwater discharge area as it is the lowest point in the landscape. As a result of this regional flow system operating in an enclosed basin, the only way that salt which moves via groundwater can leave the Basin is by drainage into the River Murray, or relocation by wind action. The Murray Basin is essentially a salt trap with the River Murray acting as a natural drain for the groundwater system.

The Murray Basin contains a complex hydrogeological system comprising three major sedimentary aquifer systems. These are the Renmark Group, the Murray Group and the Pliocene Sands. Figure 2 displays a schematic east–west cross section across the Murray Basin that shows the three major aquifer systems and the broad direction of groundwater flow. The arrows emphasise that the discharge from all three regional aquifer systems is toward South Australia and the River Murray.

2.1.1 RENMARK GROUP

The Renmark Group is an accumulation of riverine sand, silt and clay, which was deposited around 30 to 50 million years ago (Brown and Stephenson, 1991). These sediments are the deepest and extend over most of the Murray Basin, forming a major confined aquifer. The groundwater salinity increases from recharge areas at the basin margins where it is fresh, to over 50 000 EC in the Riverland region of South Australia. As a result of the closed nature of the Basin, the only way groundwater can discharge from the confined Renmark Group aquifer is by upward leakage into the overlying sediments.

2.1.2 MURRAY GROUP

Unlike the underlying Renmark Group aquifer, the Murray Group is found only in the western parts of the Basin, underlying most of the South Australian portion of the Basin and the Mallee region of Victoria. It consists of a marine fossiliferous limestone laid down between 12 and 32 million years ago when the sea moved inland. This limestone aquifer is widely developed for stock and domestic, irrigation and town water supplies in the Mallee where salinities are low near the recharge areas.

However the salinity increases down–gradient, and where the aquifer discharges to the floodplain along the whole length of the River Murray downstream of Overland Corner, salinities often reach 30 000 EC. This discharge of saline groundwater has made significant contributions to the salinity of River Murray and has prompted the construction of salt interception schemes.

2.1.3 PLIOCENE SANDS

The final major aquifer is the Pliocene Sands Aquifer, which was deposited around two to six million years ago and occurs only upstream of Overland Corner in South Australia. The western part of the aquifer, which is of relevance in the Bookpurnong region, consists of marine sediments known as the Loxton Sands (Brown and Stephenson, 1991). The groundwater salinities in the region are high, ranging up to 130 000 EC. Groundwater movement is towards the River Murray along very low gradients, with a significant amount of the regional groundwater discharge occurring to the river floodplain.

2.2 THE LOCAL GROUNDWATER SYSTEM

The Bookpurnong region is underlain by a complex hydrogeological system comprising several distinct aquifers. An understanding of the local hydrogeology is critical for determining the location, magnitude and timing of impacts resulting from European settlement, and more importantly, how to manage and mitgate them. Numerous investigations have been carried out in the area and the local groundwater system is well understood in broad terms, however there may be small localised variations from one location to another.

Figure 2 is a cross section which shows the various sedimentary layers underlying the area of interest.

Table 1 summarises the layers in order of increasing depth. The two most important layers from a hydrogeological perspective are the Blanchetwon Clay and the Loxton Sands.

Table 1. Hydrological Layers

Sedimentary unit	Thickness (m)	Hydrogeology
Woorinen formation	5 –10	Perched aquifer
Blanchetwon Clay	5 –15	
Loxton Sands	25 – 35	Watertable aquifer
Lower Loxton Clays / Bookpurnong Beds	20	Confining layer
Pata / Winnambool / Glenforslan formations	40 – 50	Confined aquifer

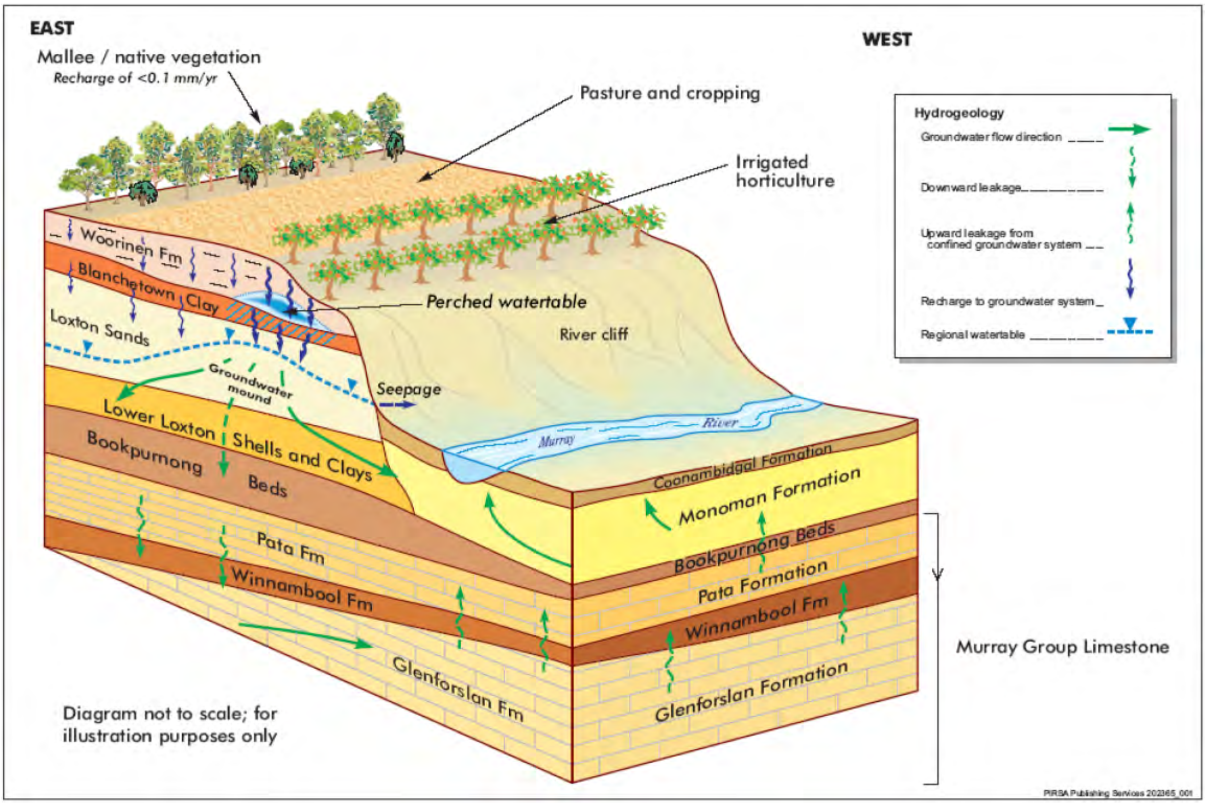

Figure 2: A cross section of sedimentary layers underlying a typical River Murray highland and floodplain area.

The Blanchetown Clay is a sedimentary unit which although often referred to as a clay, can vary locally from a silt to sandy clay. The thickness of this unit ranges up to 20m, but is most commonly only a few metres thick (Munday et al. 2004). The low permeability of the Blanchetown Clay results in drainage water from irrigation and rainfall perching in the overlying sandy sediments.

The Loxton Sands which underlie the Blanchetown Clay, contains the regional watertable aquifer which contains saline groundwater that drains toward the River Murray and floodplain (Munday et al. 2004).

Groundwater systems tend towards a natural balance over long periods of time, where natural inputs (for example, recharge from rainfall percolating down through the soil) roughly equal the outputs (discharge to the streams or lakes). Before European settlement, this equilibrium would have existed in the Bookpurnong area, with small discharges of saline groundwater to the river and floodplain. Regular high river flow events would have flushed the discharged salt from the riverine system.

3. THE IMPACTS RESULTING FROM EUROPEAN SETTLEMENT

Since the turn of the century, the natural hydrological balance at Bookpurnong (and other areas in the Riverland) has been destroyed by three main processes; the establishment of highland irrigation, river regulation and the clearance of native vegetation.

3.1 REGULATION OF THE RIVER MURRAY

River regulation was originally motivated by the difficulties in navigation incurred by paddle steamers, caused by the large natural variations in river flow. Steamships commenced operation in 1853, bringing prosperity and development to the Murray–Darling Basin. During normal years, the steamers could navigate the river for eight or nine months. However during dry periods, the paddle steamers would often be stranded by low river levels. While development of the railways caused a reduction in paddle steamer activity, a succession of dry years in the late 1900's culminated in a record drought of 1902. This drought motivated Governments to consider methods for drought protection.

The River Murray Waters Agreement was ratified in 1915 by the Commonwealth and State Governments. This agreement provided for water sharing arrangements and also the construction of water storages and locks and weirs on the river system.

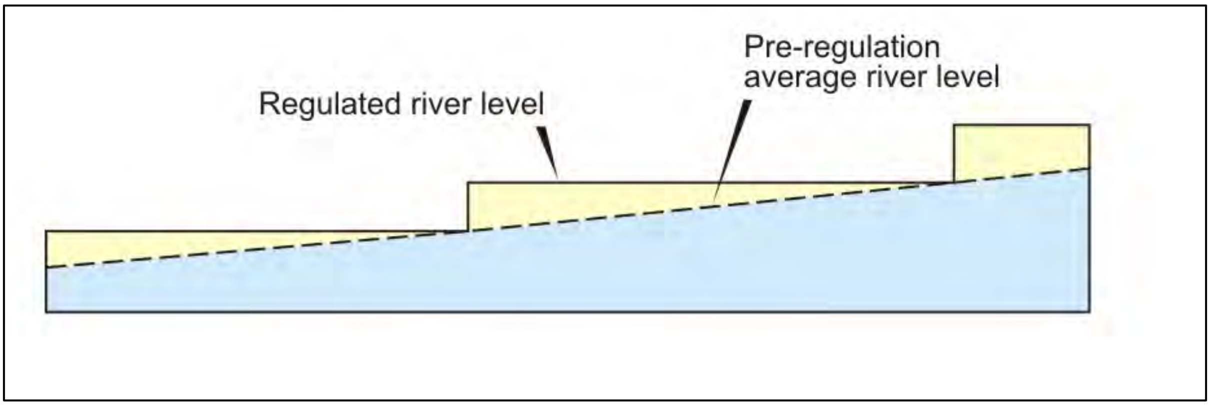

Figure 3: Regulation by locking has now imposed a permanent stepped increase in river levels upstream

River regulation through the construction of locks and weirs bought significant impacts to the river system. Before regulation, the river level rose and fell on a seasonal basis, and it also flowed under a very low but continuous gradient downstream. Regulation by locking has now imposed a permanent stepped increase in river levels upstream, as shown in Figure 3. It is estimated that at Morgan, where the only historical water level data exists, the minimum water level is now approximately three metres higher than it was prior to locking (AWE, 2003). The maintenance of a constant river level at these higher elevations has resulted in groundwater levels under the floodplain South Australian section of the River Murray to also stabilize at higher levels.

In many areas, groundwater has moved higher in the soil profile into the clays of the Coonambidgal Formation. This formation has a higher potential for capillary rise and evaporative discharge from the watertable than deeper sandy sediments. The plants on the floodplain extract the water from the soil, leaving behind the salt that concentrates in the profile and has negative impacts on floodplain health (Holland et al. 1995). Work undertaken in 2005 indicated that approximately 41% of the floodplain in South Australia was severely degraded by soil salinisation (Holland et al. 1995). Significant areas of the Bookpurnong floodplain show the impacts of high saline groundwater tables. The Living Murray project discussed later in this document has examined the effectiveness of strategies to mitigate this decline.

3.2 HIGHLAND IRRIGATION

The pumping of River Murray water up to the Bookpurnong Highland for irrigation has led to the formation of a watertable mound resulting from the infiltration of drainage water beneath irrigated crops. The quantity of drainage water depends on the efficiency or irrigation, and whether there are any impermeable layers present. Intensive irrigation is considered to have an average drainage rate of about 100 mm per year, which is approximately 1000 times the rate of drainage beneath the original mallee vegetation (AWE, 2003). Once the mound has formed, naturally occurring saline groundwater is displaced into the river or floodplain (Figure 4).

In some places, the Blanchetown Clay acts as an impermeable layer. This layer restricts the drainage of water down to the deeper aquifer and in the past, caused perched watertables to build up beneath the crop root zone. If these watertables rise up to within one or two metres of the soil surface, negative impacts on the health of the crops can occur due to waterlogging in the plant root zone and high salinity levels.

The problems of soil salinisation and waterlogging become evident soon after the establishment of the first irrigation schemes in the 1890’s when the main form of irrigation was by flooding, and drainage rates were much higher than today (Murray–Darling Basin Commission, 1999). These perched watertables have caused widespread damage throughout the Riverland and irrigators were encouraged to install drainage bores through the Blanchetown Clay to allow water to drain more freely down to the deeper saline aquifer. This process accelerated the formation of large watertable mounds which had noticeable impacts on the River Murray floodplain.

CSIRO carried out soil sampling of the unsaturated zone in the Bookpurnong area at a number of sites where perched groundwater was found between three metres and 16 m below the soil surface. Little information is available on the current impact of perched watertables on the root zones of the horticultural crops in the district.

Irrigation on the highland adversely affects the adjacent floodplain due to the displacement of saline groundwater to the floodplain (Figure 4). It is the major cause of modern tree death and health decline, both on the landward edge of the river flats and on the river edge. Systematic tree health decline on the adjacent floodplain usually follows 10 to 20 years of large-scale irrigation. The decline in floodplain vegetation health at Bookpurnong is part of a similar picture in most other areas of the Riverland.

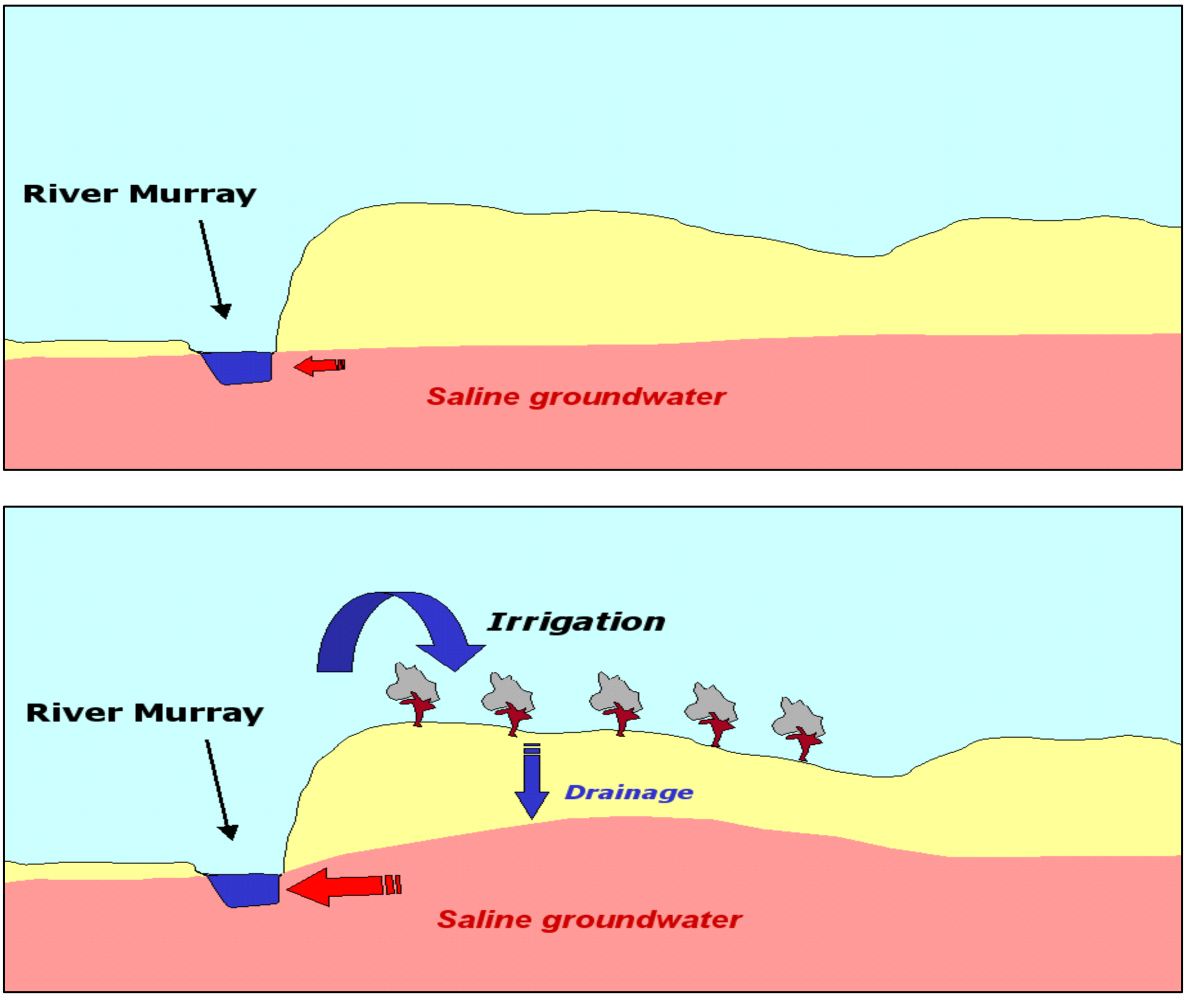

Figure 4: The process which occurs when irrigation is established on highland areas and drainage occurs beneath the root zone.

3.3 NATIVE MALLEE CLEARANCE

The deep-rooted Mallee vegetation is very efficient at using almost all the rainfall falling around it. Out of an annual rainfall of 250 mm in the Riverland, only about 0.1mm infiltrates past the root zone down to the watertable. However beneath areas cleared of mallee and sown with shallow rooted crops, water use is much lower and recharge rates are two orders of magnitude higher in the range up to 15mm/yr depending on the soil type. This is quite a significant increase (Figure 5).

Eventually, this increased recharge will infiltrate down to the watertable, which will rise in a similar fashion to the mounding beneath irrigation areas, and increase the discharge of saline groundwater to the river and floodplain. Because the increase in recharge is generally lower than drainage rates beneath irrigation, the impacts due to clearing will be lower and will take a longer period of time to take effect.

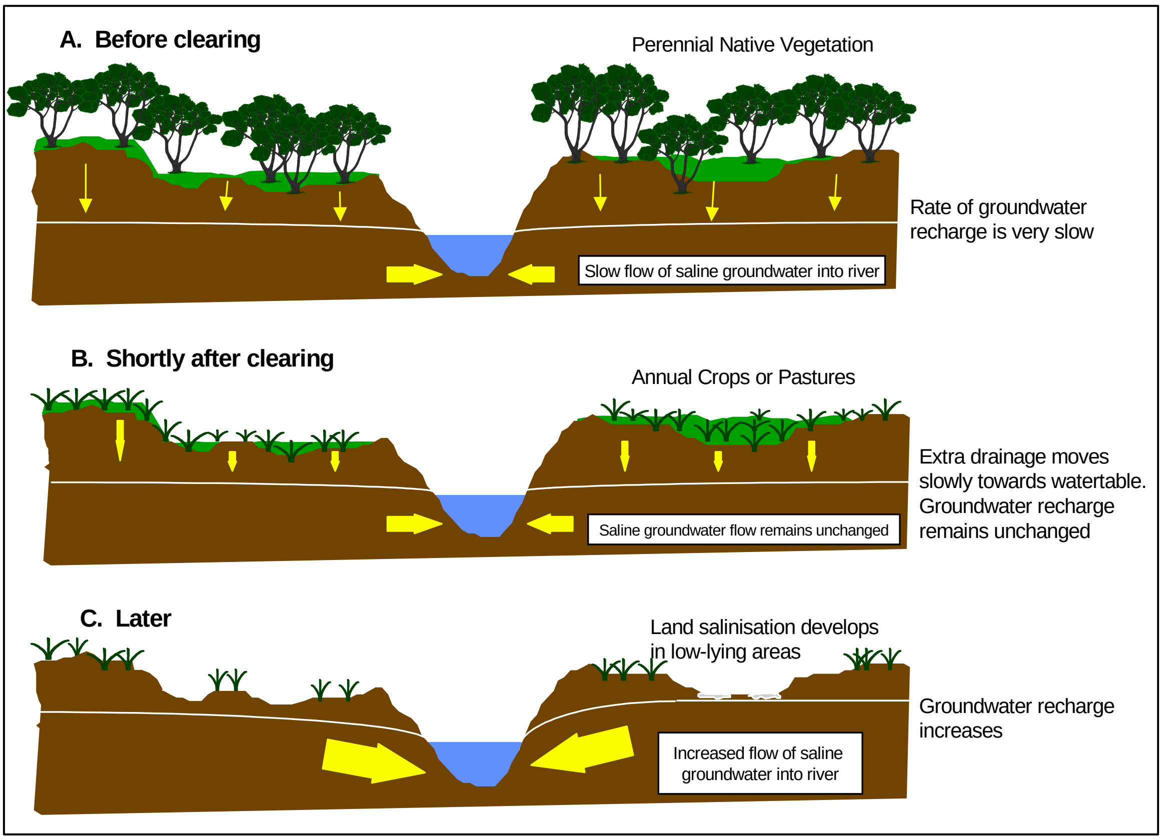

Figure 5: The process which occurs following clearance of native vegetation and the planting of annual crops and pastures.

3.4 RESULTANT CHANGES TO RIVER SALINITY

As the River Murray flows past Bookpurnong, some 100 tonnes of salt are added to the river each day due to the discharge of saline groundwater. Some of this inflow is natural with the remainder caused by the watertable mound beneath the irrigation area.

A groundwater model discussed in Section 4.3 Groundwater Modelling (Yan et al. 2005) has been used to predict the salt loads to the river under a number of scenarios.

These results show a significant difference in the outcomes from previous modelling, mainly brought about by model and data improvements. Perhaps the most significant is the reduced impact of vegetation clearance over the next 50 years (now estimated at 0.5 t/day, compared to 30 t/day previously). The impact of current irrigation is also less then previously modelled, as is the impact of future irrigation expansion. However, the effectiveness of the Salt Interception Scheme (SIS) in reducing salt loads is much greater than modelled previously.

4. HYDROGEOLOGICAL INVESTIGATIONS

Since the adoption of the original Bookpurnong Land and Water Management Plan, a number of hydrogeological investigations have been carried out in the Bookpurnong area. These can be grouped under three broad categories; regional investigations under the Salinity Mapping and Management Support Project (SMMSP) funded by the National Action Plan for Salinity and Water Quality, groundwater modelling and in-river electromagnetic (EM) conductivity surveys for river salinity investigations. Detailed investigations for the design and construction of the Bookpurnong SIS will be discussed in a later section.

4.1 SALINITY MAPPING AND MANAGEMENT SUPPORT PROJECT (SMMSP)

The primary objective of the SA SMMSP was to map the thickness of the Blanchetown Clay and then use the data in models to refine estimates of salt loads to the River Murray. In order to achieve this, a helicopter EM (electromagnetic) system was undertaken in a 10 to 15 km wide corridor following the southern bank of the River Murray, between the South Australian–Victorian border and Kingston-on-Murray. A total of 11 500 line km of data was collected. In addition, 14 soil cores were obtained beneath dryland agricultural land from within the survey area. Estimates of recharge since land clearance have been made from analyses of water content and chloride concentration on these cores.

Figure 6: The RESOLVE HEW system mounted on a 'bird' and towed beneath a helicopter.

The estimated mean recharge rates at these sites range between 0.1 and 14.8 mm/yr, with an average of 2.7 mm/yr. Empirical equations that relate recharge beneath dryland agriculture to soil texture and rainfall were developed, based on the point recharge estimates obtained in this and in previous studies. These equations were used to extrapolate these data across the northeast Mallee (and across the entire South Australian Mallee region) using Soil Landscape mapping data. The derived recharge map (Figure 7) has been combined with the map of Blanchetown Clay thickness to produce maps of aquifer recharge in the years 2003, 2023, 2053 and 2103 (Cook et al. 2004).

These revised estimates of aquifer recharge and lag times have been incorporated into MODFLOW groundwater models for the Riverland region. Previous modelling exercises to predict the impacts of vegetation clearance on river salinity were carried out with the best recharge information available at the time, but were ultimately hampered by the use of broad landscape units and recharge rates derived from measurements carried out in other wetter areas of the Murray Basin.

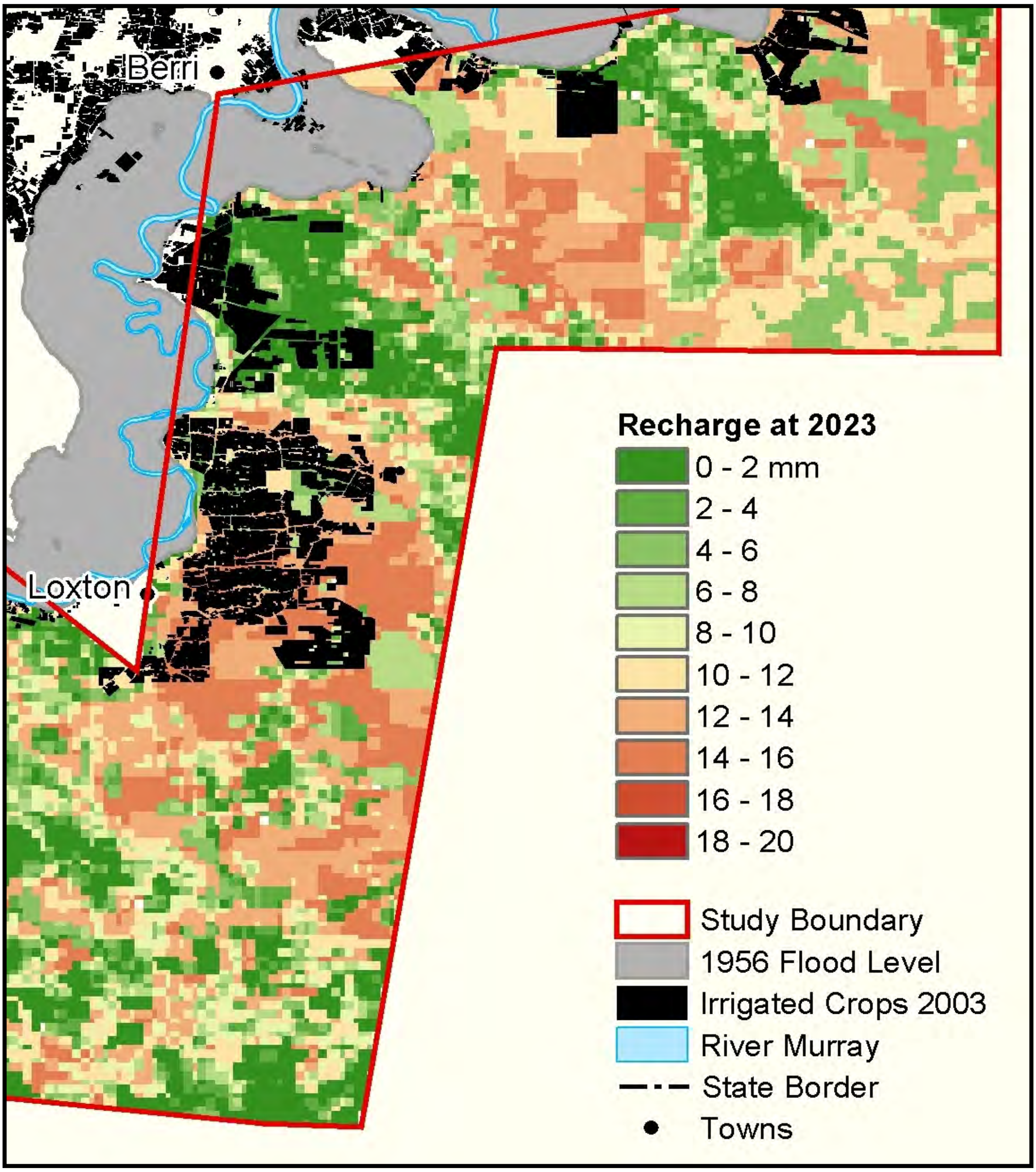

Figure 7: Dryland aquifer recharge for Loxton to Bookpurnong area in 2023

The complementary development of a revised MODFLOW groundwater model for the Riverland (including the Bookpurnong – Lock 4 LWMP area), which has a smaller grid size and better calibration than the models used previously in the study area, was also been completed (Barnett and Yan, 2006). This model has been used to predict the impacts of increased recharge following clearing on salt inflows to the river and floodplain.

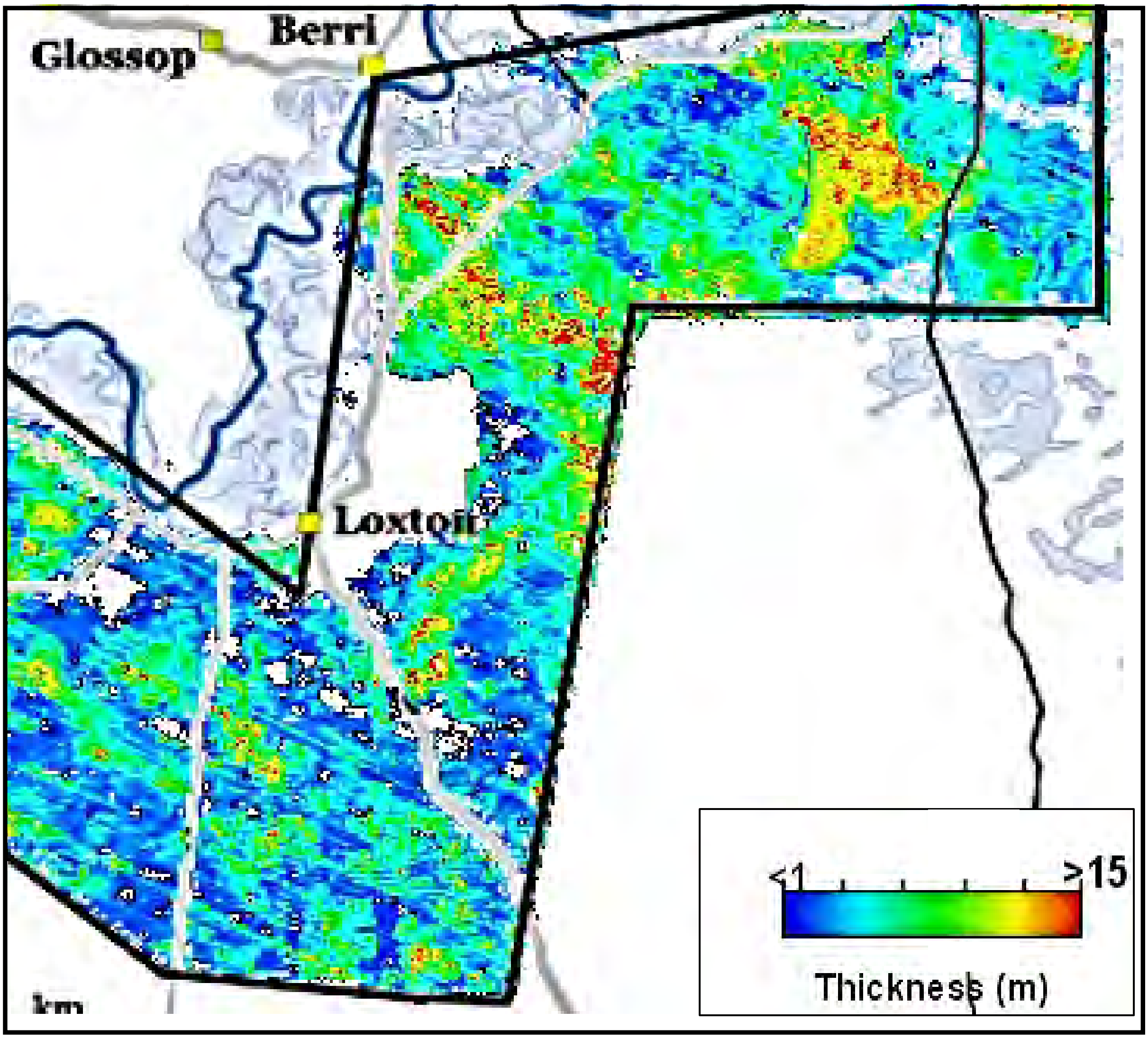

Figure 8: Thickness of Blanchetown Clay in the Loxton to Bookpurnong area

An unexpected result from the EM survey was an image of the ancient topography of the strandlines associated with the Loxton Sands (Figure 8) before the Blanchetown Clay was deposited in a large lake that once flooded the Riverland region (Lake Bungunnia). Manipulation of the EM data has helped to better define the geometry of this sedimentary system (Munday et al. 2004). Follow-up studies were carried out to contribute to a more informed approach to the design, development and potential performance of the Bookpurnong Salt Interception Scheme (Hill et al. 2004).

These multidisciplinary studies discussed below encompassed the fields of groundwater chemistry, hydrogeology, in-stream salinity surveys, basin analysis, sedimentology, geophysics, and groundwater hydraulics.

Borehole data and ground geophysics in the Bookpurnong area both indicate that the interpreted strandline locations from the aerial EM survey represent a maximum thickness of the Loxton Sands aquifer. A detailed In-Stream Salinity survey identified areas of salt accession throughout the Loxton – Bookpurnong reach, which exhibit a strong correlation with areas where surface seepage is evident and/or the river is immediately adjacent to cliff faces. An In-Stream EM survey (NanoTEM), which measures the sediments and soil water beneath and adjacent to the river, confirmed the presence of salt accession ‘hot spots’.

In September 2006, a more detailed aerial EM survey was flown over the Loxton – Bookpurnong floodplain areas and part of the highland in order to increase understanding of groundwater processes beneath the floodplain as shown in Figure 9.

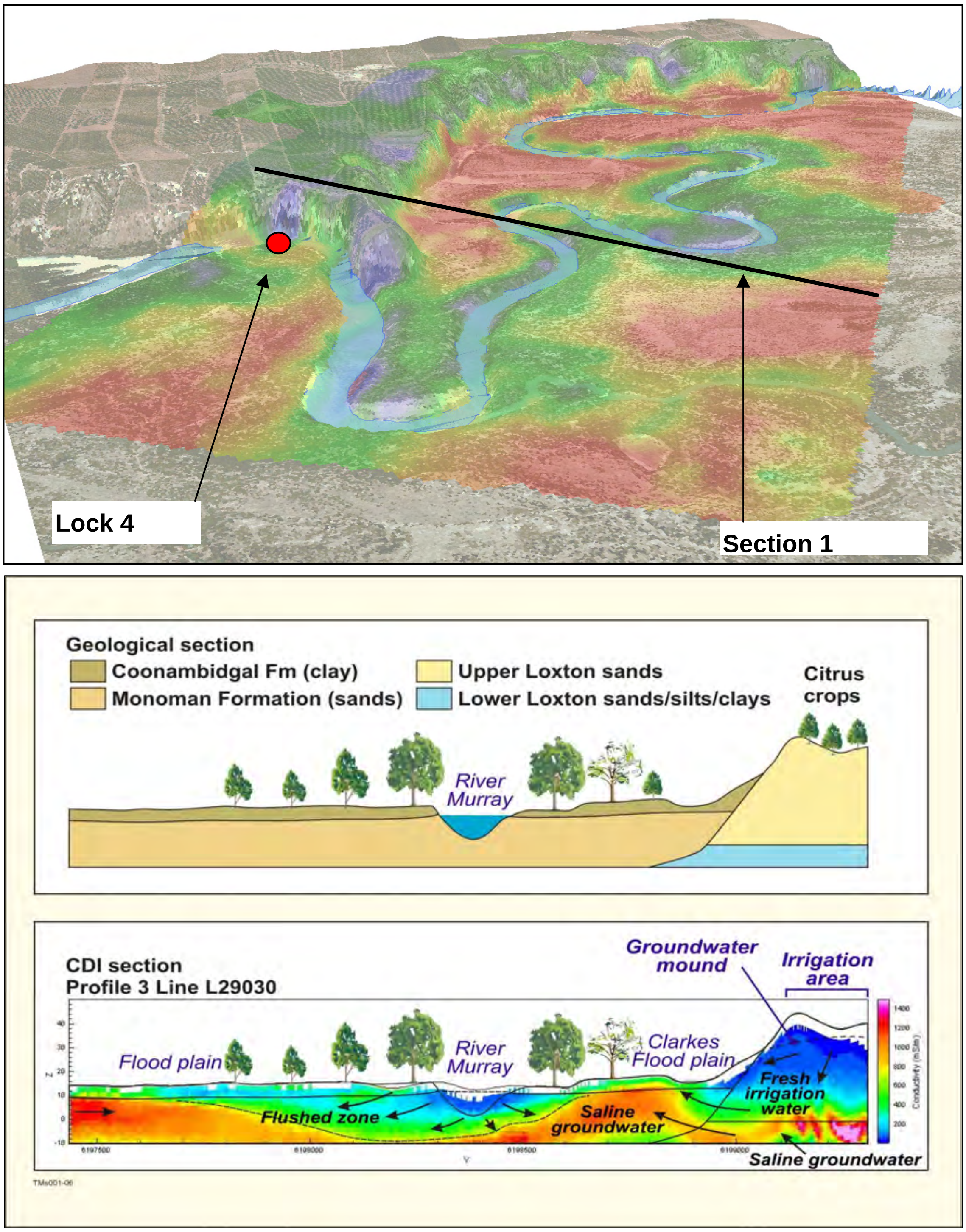

Figure 9: Bookpurnong Floodplain EM Survey and cross section

Another follow-up project under the SMMSP involves investigation of recharge mechanisms and drainage rates in the Bookpurnong area by CSIRO Land and Water. Three of the sites were in a vineyard where drainage estimates had been made previously using water balance methodology, and also a salt balance with solute samples collected via soil water suction devices. Estimates for the drainage rates below the root zone at the three vineyard sites were approximately 40, 140 and 20 mm/yr. Another site was in a citrus orchard where the drainage was estimated to be approximately 470 mm/yr, which is approximately 40% of irrigation applied. However, the Blanchetown Clay has caused a perched aquifer that is at least five metres thick.

Further investigations looked at how much the Blanchetown Clay impedes vertical movement of water. Soil cores were taken below the clay at several sites and at each one, a rapid increase in soil water salinity was observed, even though low salinity drainage water was perched on top of the clay (Figure 10). This suggests slow drainage rates and that the clay acts as a considerable barrier to drainage.

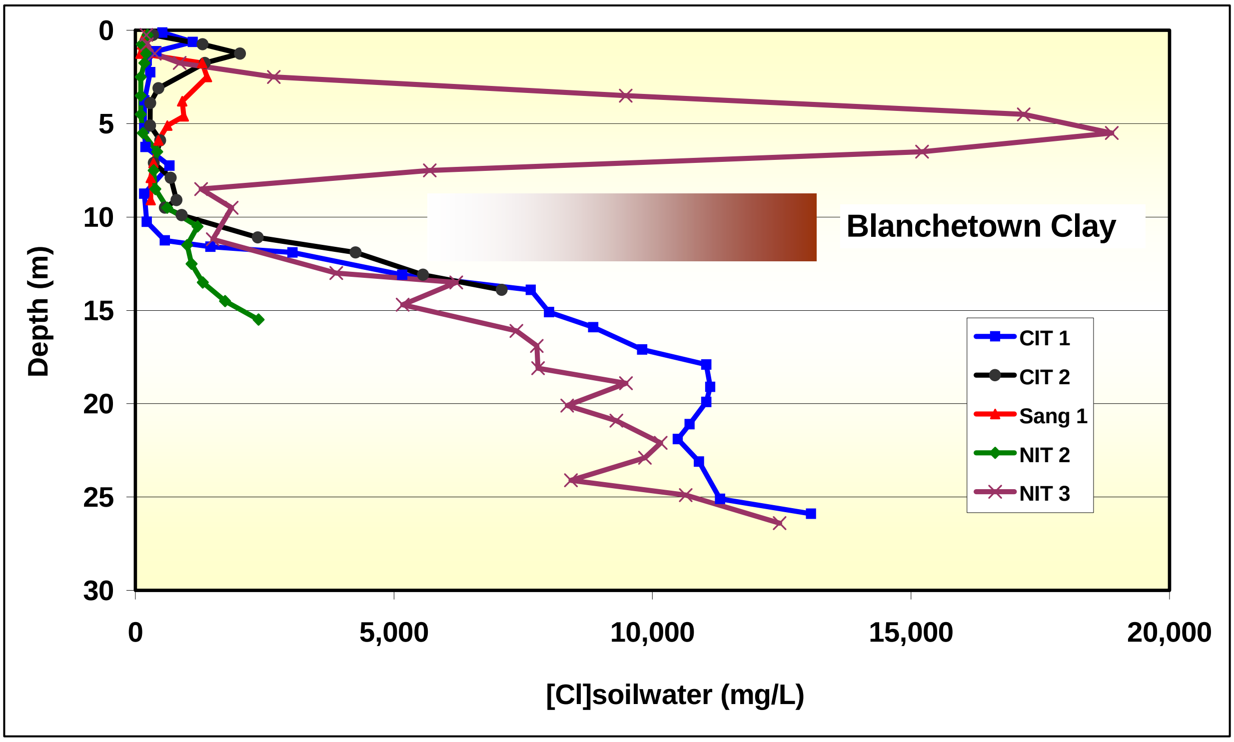

Figure 10: The results of samples soil salinity levels showing a saline bulge above the Blanchetown Clay.

4.2 THE LIVING MURRAY

In 2002, the Murray Darling Basin Commission (MDBC) established The Living Murray Initiative to protect and improve the health of the River Murray, in particular, six icon sites along the river including the severely stressed Chowilla Floodplain. Because of the remoteness of this site, Clark's Floodplain at Bookpurnong was chosen as a suitable study site for pilot investigations as it is conveniently located, and has existing power and SIS pumping and disposal infrastructure. The trials at Bookpurnong tested three different floodplain management initiatives at various sites as shown in Figure 11 (Berens et al. 2007):

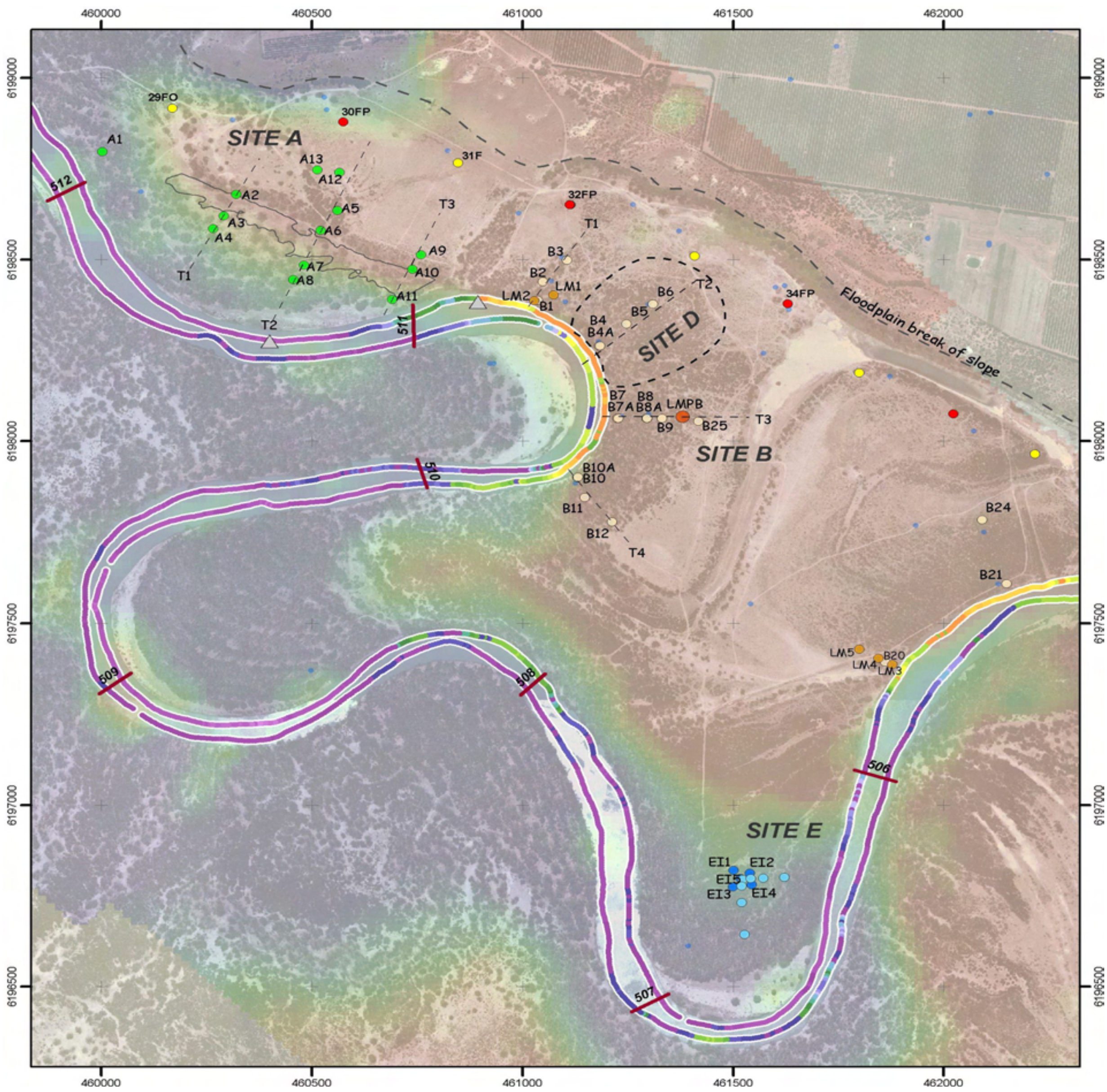

Figure 11: Location of Living Murray trials on the Bookpurnong Floodplain

Site A. - An artificial flooding of a 3.7 ha topographic depression with focus on the river red gum woodland. The aim is to leach salt from the soil profile and improve the salinity condition of the root zone and encourage tree rejuvenation and population replacement through providing suitable germination conditions.

Site B. – The construction of a purpose designed 'Living Murray' groundwater production bore (LMPB) to induce lateral movement of fresh river water through the adjacent floodplain aquifer creating a freshwater lens.

Site D – Artificial flooding of a dried creek system to compare the response on the Site B vegetation communities to surface flooding as opposed to groundwater freshening. Site D is a small subset within Site B study area.

Site E – Injection of fresh river water into the moderately saline groundwater aquifer via a 5 point injection array, and the monitoring of vegetation health response of a stress tree community.

These strategies were measured for their success in improving tree community health by using a variety of vegetation health assessments, and were supported by surface and groundwater investigations.

Artificial surface flooding – a section of floodplain was flooded for three months over winter/early spring and received four top-up waterings during this time. Watering dramatically improved tree health as a significant improvement was seen at sites inundated and immediately influenced by water as opposed to the control sites where there were no changes in tree health.

Enhanced bank storage – extraction of only 4 L/sec from production bore (LMPB) induced lateral movement of fresh river water 200 m through the adjacent floodplain aquifer creating a fresh water lens extending as far as well B9. This result far exceeded expectations.

Injection of fresh river water – injection into a moderately saline groundwater aquifer was attempted via a 5-point injection array. Although technically well implemented and serviced, the trial was not successful in injecting adequate volumes and only created very limited localised freshening. After 48 days of injection, a number of the wells had become clogged resulting in the breeching of the confining clays.

4.3 GROUNDWATER MODELLING

As part of the development of the LWMP, Australian Water Environments (AWE) constructed a four layer MODFLOW model (AWE, 1999) to predict future salt loads to the river under various growth scenarios, and determine the effectiveness of various management options.

In 2003, AWE developed a more detailed groundwater model of the Loxton – Bookpurnong area (AWE, 2003). The Department of Water Land and Biodiversity Conservation (DWLBC) simplified and calibrated it to the specifications in the MDBC Modelling Guidelines (Yan et al, 2005). The model has been used to estimate the salt loads entering the River Murray under different irrigation practices and development scenarios, and assisted with broad scale planning of conceptual SIS well field designs for the Loxton SIS.

The groundwater model (Yan et al. 2005) has been used to predict the salt loads to the river under a number of scenarios. Table 2 shows the predicted salt loads using the 2005 model, and a comparison with the 1999 values used in the previous LWMP.

Table 2: Predicted salinity impacts in EC

SCENARIO	**1999 model**		**2005 model**	
	Current	**2050**	**Current**	**2050**
Pre-European	34	-	16.5	
Current irrigation	62	132	100	117
Mallee clearance	20	50	17	17.5
Expansion of irrigation	62	216	100	132
Expansion + SIS	62	180	100	25

These results show a significant difference in the modelling outcomes, mainly brought about by model and data improvements. Perhaps the most significant is the reduced impact of vegetation clearance over the next 50 years (now estimated at 0.5 t/day, compared to 30 t/day previously). The impact of current irrigation is also less then previously modelled, as is the impact of future irrigation expansion. However, the effectiveness of the SIS in reducing salt loads is much greater in the current model.

4.3.1 MODELLING DATA GAPS

It is important to recognise that a groundwater model is only an approximation of the real world, and there is no such thing as a perfect model. All models should be regarded as works in progress, with continuous improvement as hydrogeological understanding and data availability improves. While the current model (Yan et al. 2005) is based on the best available information, the limitations are discussed below.

Although the hydrogeology of the highland and floodplain areas are considered to be well understood and well represented in the model, the detailed salt movement in the floodplain is less well known, and the model representation is a broad generalisation which serves well the estimation of fluxes passing from the highland irrigation areas to the River Murray.

The aquifer permeability and groundwater salinity values are critical in predicting salt loads to the river. The values applied in the model are considered to be reasonable, and represent the best current understanding.

There is high confidence in the historical drainage values used in the modelling, which are derived from irrigation surveys carried out by AWE, and calibration against observed groundwater level data. There is less confidence in the drainage values applied beneath new irrigation areas in the predictive modelling. It is highly likely that there will be changes in irrigation efficiency and therefore deviations from the predicted development sequence in the future. These factors will certainly affect the predicted salt load entering the River Murray.

4.4 INSTREAM NANOTEM

NanoTEM is a technique that provides a measure of the electrical conductivity of the river sediments and river water, and is a useful tool for indicating areas where there is potential for inflows of saline groundwater. In September 2003, a total of 80 km of data over a 37 km stretch of the River Murray was collected in the Loxton – Bookpurnong area between the Katarapko Island outlet and Lock-4. When the data has been processed, around 10 conductivity depth values between 0 m (river surface) and 30 m depth are determined at each measuring point. Of most interest is the shallowest river sediment resistivity value, which represents the salinity of the groundwater immediately below or adjacent to the river.

Zones of high conductivity (shown in Figure 12 as red and orange) can be interpreted as areas where saline groundwater could be discharging to the river as a result of steep watertable gradients along the cliffs, whereas low conductivity zones (green and blue) probably indicate lower salinity groundwater, which has been recharged from the river.

A comparison with the June 2003 run-of-river salinity survey yields broad correlations between high conductivity sediment zones and increasing run-of-river salt loads, and also between low conductivity sediment zones and decreasing run-of-river salt loads.

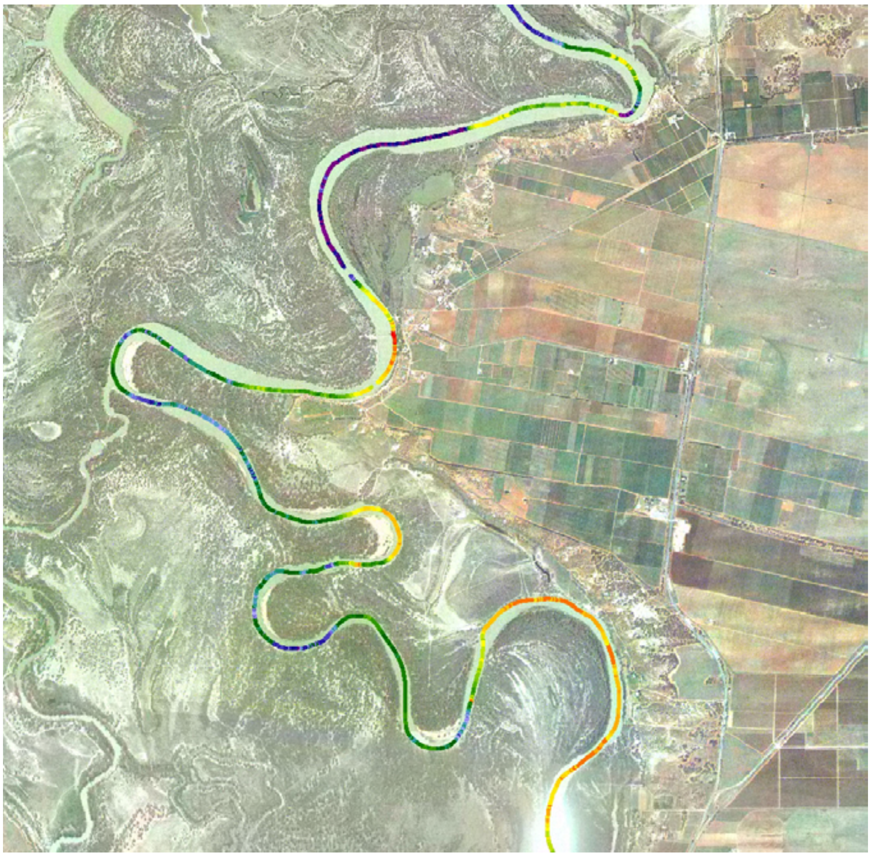

Figure 12: Results of the Instream NanoTEM.

4.5 GROUNDWATER MONITORING

The collection of groundwater level data began in 1987, when two observation wells were drilled by SA Water (GDN 51 and 52). This action was very timely as rises in the watertable beneath the irrigated area began soon after. A further five were drilled on the floodplain in 1992 to investigate causes of floodplain degradation. As part of investigations for the previous LWMP, another six observation wells were drilled on the Highland in 1998 (GDN 65 to 70).

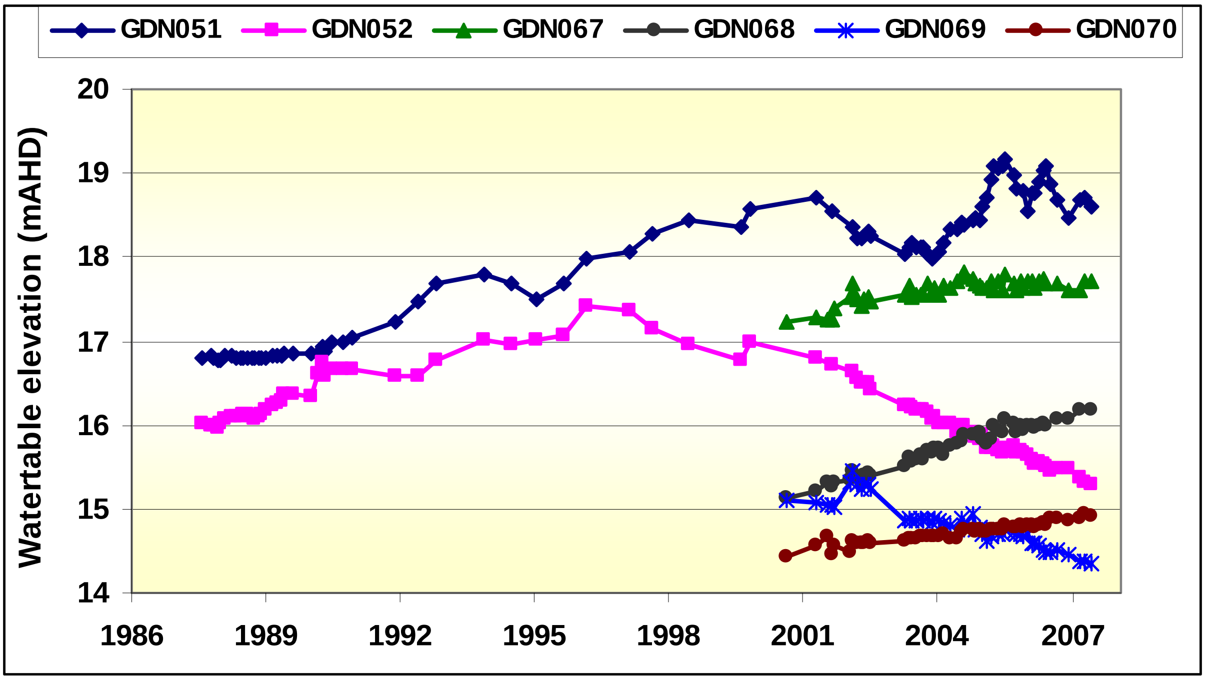

Figure 13: Hydrographs of bores in the Bookpurnong Region.

Figure 13 shows hydrographs from several of these observation wells that display various different trends—rising, falling and stable. Figure 14 shows the location of the observation network, selected hydrographs and the watertable elevation contours for 2005. On the northwestern margin of the irrigation area, wells are exhibiting a falling trend, most likely as a result of interception scheme pumping and possible improved irrigation practices. Those located in the centre of the mound are stable. Rising trends occur on the southern side of the irrigated area due to the coalescing of both the Bookpurnong and Loxton watertable mounds.

A time series of watertable elevation contours for the Bookpurnong area are presented in Figure 15, for 10 yearly intervals from before-irrigation (1940) to 2000. The growth of the watertable mound from 12 m to over 18 m AHD over this time frame can be clearly seen.

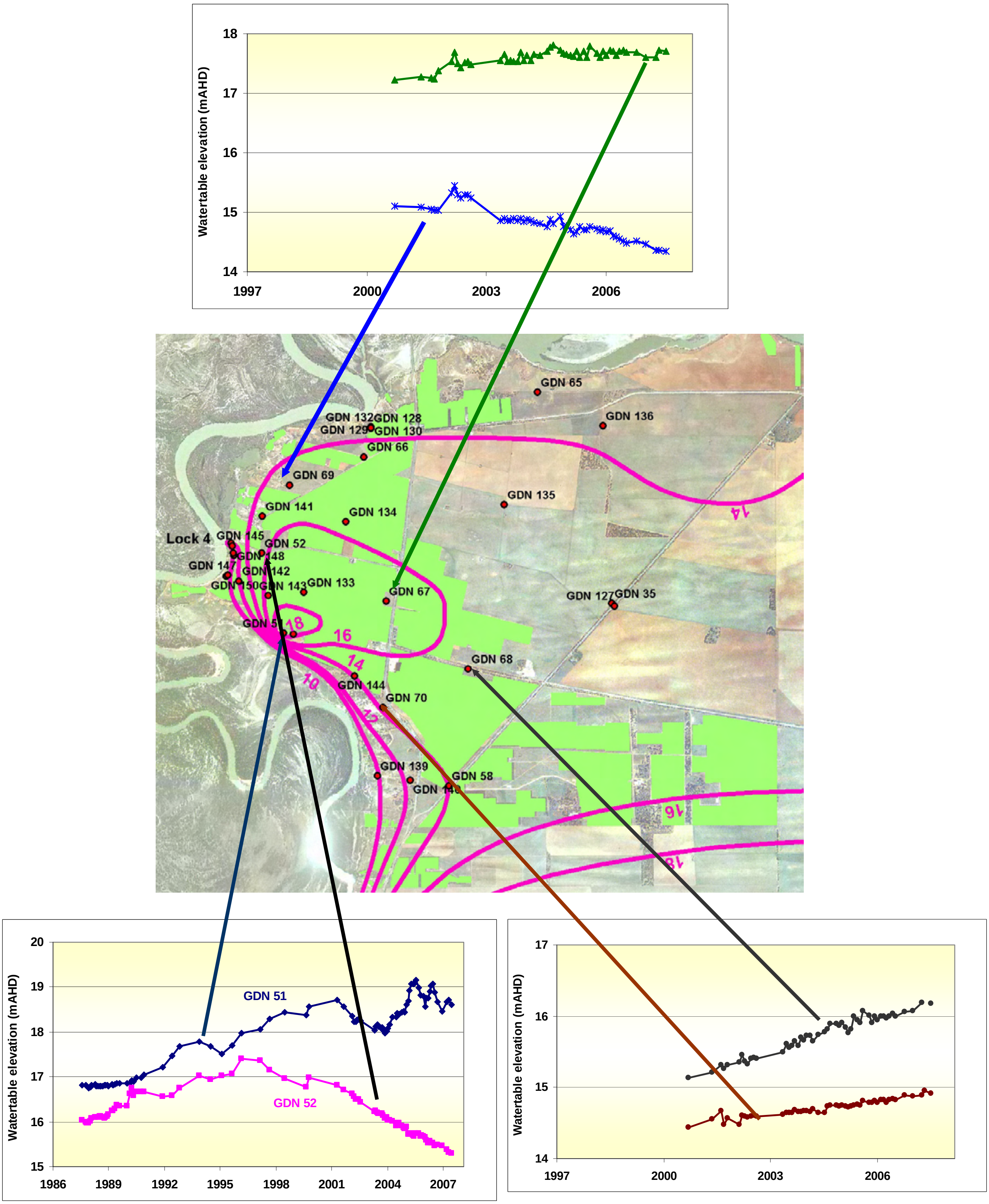

Figure 14: Separate hydrographs of areas around Bookpurnong, reflecting the location of the groundwater mound and the effects of the SIS

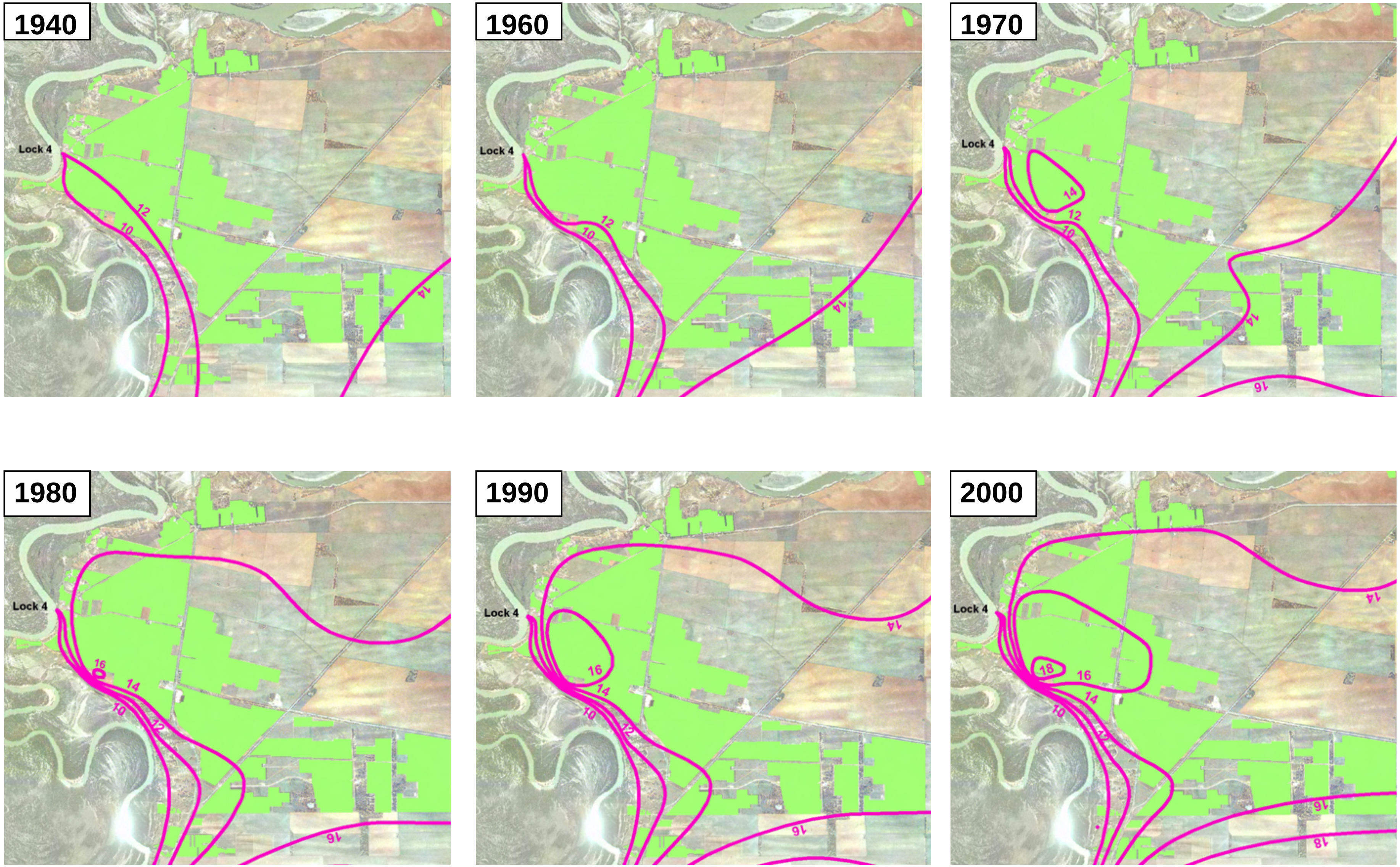

Figure 15: Time series of watertable elevation contours for the Bookpurnong area

5. BOOKPURNONG SALT INTERCEPTION SCHEME

5.1 INVESTIGATIONS

Australian Water Environments (AWE) was commissioned by SA Water to design and construct the bore field component of the Bookpurnong SIS, which is a central component of the Plan. Consequently, a number of investigations were initiated.

A series of drilling and aquifer tests were carried out in late 2002 and early 2003 as part of SIS investigations along the highland at Lock 4 (AWE, 2003a,b). This revealed rapid variability in the hydraulic properties in the Loxton Sands aquifer. During some of the aquifer tests a white gel-like material was formed which clogged pumps and reduced yields by up to 40%, an outcome with serious implications for the highland bore field design and performance. Investigations by DWLBC found that this substance was aluminium ox hydroxide (Harrington, 2004). This study, and trials carried out by AWE at four sites on Western's Highlands (AWE, 2004b) postulated that clogging will occur if;

- Pumping from the Loxton Sands aquifer leads to a dewatering of the aquifer,
- If the concentration of iron (Fe^{++}) exceeds 1.0 mg/L and oxidation produces acid,
- There are sources of aluminium in the formation, and/or
- Acid production lowers the pH to below 5.5.

A scout drilling of 49 holes was carried out in 2004 to identify potential SIS production well sites and also to provide data for ground truthing for geophysical surveys carried out under the SMMSP (AWE, 2004a). This program concluded that Western's Highland would not be included in the SIS design due to clogging problems, and that production bores would be located along Nitschke Road as an alternative. This would present a lower cost, but slightly less effective interception option compared to the edge-of-highland. Prospective sites at Brand's Highland and south of Lock 4 were also identified.

Bore field construction and aquifer testing of the floodplain component of the SIS was undertaken between December 2003 and July 2004, and involved the drilling of 15 production wells, seven test wells and performing 14 aquifer tests (AWE, 2004c). The work was carried out in stages on Graetz's, Stanitzki's and Clark's Floodplains. Eight-hour pumping tests on the production wells found theoretical maximum yields ranging up to 10 L/sec, and within the design yield.

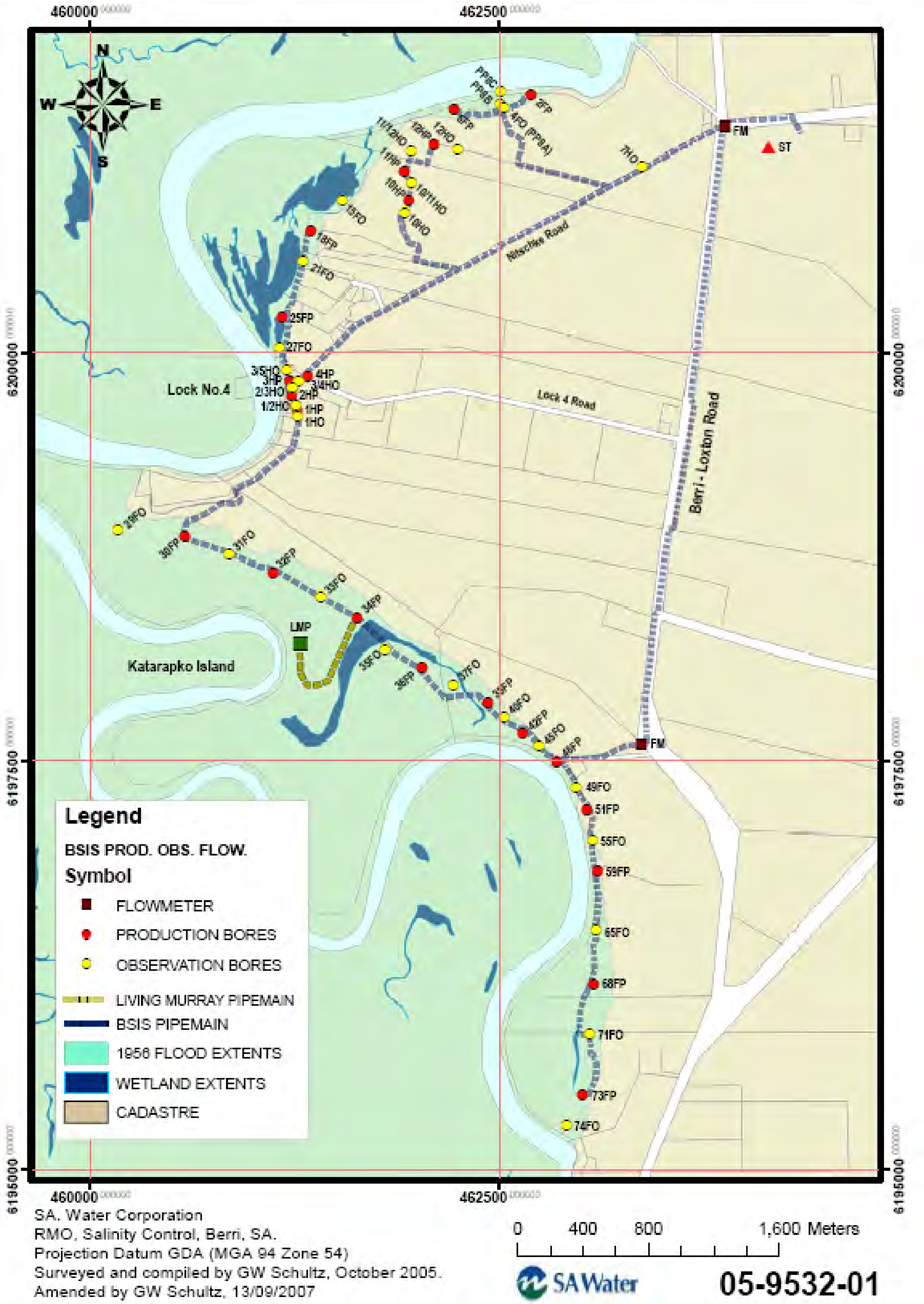

Figure 16: Bookpurnong SIS final design.

5.2 FINAL SCHEME DESIGN

The scheme consists of 22 production bores, 15 located on the floodplain and seven located on the highland as shown in Figure 16. To monitor the response of groundwater levels to the operation of the SIS, 28 observation bores have also been installed. The average pumping rate is 2.5 L/s, although rates vary between 1.5 and 3 L/s. The total scheme produces approximately 48 L/s and reduces salt inflow to the River Murray by 80 tonnes of salt per day. As the impacts of new irrigation development become apparent in the future, it is likely the scheme will increase the interception to 120 tonnes of salt per day. This equates to a reduction of approximately 21.8 EC at Morgan. The total construction cost of the Bookpurnong SIS was $11.1 million dollars, with the annual operating cost approximately $480,000.

The original design of the Bookpurnong SIS included a spur line on the northern side of the Bookpurnong region bordering the Gurra Gurra Lakes. The MDBC did not fund this spur line, as it would not provide substantial benefits to the in-river EC levels.

5.3 SALINE GROUNDWATER DISPOSAL AT NOORA

All saline groundwater water extracted by the Bookpurnong SIS is pumped to the Noora Disposal Basin, located about 20 km east of Loxton, where the water evaporates or percolates into the regional saline aquifer. The Noora Drainage Disposal Scheme was one of six measures proposed by the River Murray Salinity Control Programme (RMSCP) in 1978 and implemented to reduce saline inflows to the River Murray (Hayball 2004). The scheme was to pump saline irrigation drainage effluent from the Renmark Irrigation Area (Bulyong Island Disposal Basin and Disher Creek Disposal Basin) and Berri Irrigation Area (Berri Disposal Basin) to high points at Lyrup Heights and Bookpurnong respectively, and then to gravity feed the drainage water to the Noora Basin. The scheme had two principal aims:

1. To reduce the hydraulic seepage of saline water from the evaporation basins (Bulyong Island, Disher Creek and Berri Basin) to the River Murray.
2. Decrease the need to release the saline effluent into the River when the evaporation basins exceed storage capacity. (Hayball 2004).

From September 1982, saline irrigation drainage effluent was pumped to Noora Basin from Berri Basin and in February 1983, pumping commenced from Disher Creek.

The Noora Basin and associated small depressions are part of a naturally low-lying saline depression with groundwater levels at or near the level of the base of the basin (Hayball, 2004). The basin area is approximately 3500 ha, with a perimeter of 33 km (DWLBC 2006) with the adjacent land primarily used for cereal cropping and grazing, with some gypsum mining. Over the last 26 years, the amount of water being transferred to Noora Basin from floodplain disposal basins has drastically reduced due to improvements in irrigation efficiency and the upgrade of irrigation infrastructure. However the number of SIS has also increased. This has resulted in the Noora pipeline being utilised for transporting saline water from SIS while the floodplain pump stations remain idle at most times (DWLBC, 2006).

The Noora Basin has an allowable capacity estimate of 370 L/s (11 750 ML/yr), for the approximately 1800 ha of land that can be inundated. This is based on an operating level of 19 m AHD (DWLBC, 2006). There is sufficient capacity in the mains which deliver water to Noora and the basin itself to meet the forecasted disposal requirements for Bookpurnong, Loxton, Murtho, and Pike SIS and comprehensive drainage scheme (CDS) water until at least 2050 (DWLBC, 2006).

5.4 POTENTIAL USES FOR SIS WATER

The SIS along the River Murray dispose of saline water into specifically designed lakes or basins. Some of these basins are designed to leak a certain amount over time which results in ultimate disposal to underlying aquifers, while others are constructed to minimise leakage and rely solely on evaporation to dispose of water drawn from SIS works (Aral et al. 2004). For those designed for minimal leakage, it is anticipated that they will become ineffective over time due to increasing salinity levels.

Discussion on the potential use of SIS drainage water has emerged over the last ten years for a number of reasons. These include increasing the long-term capacity of some evaporation basins to reduce the overall impact on the River Murray, and obtaining some economic return from the SIS water even if the overall amount of water disposed does not change. The two main suggestions include processing the precipitated salts to produce industrial minerals with large volume applications and using the water for aquaculture.

Water quality should be an important consideration when accessing water from a disposal basin. Different basins may receive water from a number of SIS and other sources such as highly saline tile drain systems such as that at Ramco (in the case of Stockyard Plains). Any use of Noora Basin water would have to consider the impacts of chemical use to control aluminium clogging of interception scheme bores.

Legal considerations on how to access water from an SIS are not clear, but policies are being developed to provide clarity on this issue, which is complex due to the varying jurisdictions and legal constraints.

5.4.1 INDUSTRIAL MINERALS

It has been proposed that saline water in disposal basins be treated to produce industrial mineral salts such as gypsum, halite (common salt), sodium sulphate, magnesium sulphate and magnesium chloride bitterns (Aral et al. 2004). The halite (sodium chloride) fraction may be used to produce chemicals such as chlorine, hydrochloric acid and sodium hydroxide, while the bittern fraction may be converted to magnesium hydroxide and magnesium oxide. Further processing of these minerals may also be an option to create value added products (Aral et al. 2004).

As part of the investigation into this process, 10 disposal basins throughout the Murray Basin were sampled in June 2003 before any significant winter rainfall had occurred. These sites included Stockyard Plains Disposal Basin and Noora Disposal Basin, although only one sample was obtained at Noora (Aral et al. 2004). Relative to the test data for seawater, the magnesium samples in South Australia are lower, and magnesium levels relative to sodium and chloride levels decreases downstream from the Victorian sites into South Australia. Sulphate levels in the disposal basin samples are often higher than expected in comparison with seawater. However the study recommends that further work is required to provide a better understanding of the levels of trace elements in any salt products obtained from the Murray Basin waters.

While there are many methods which can be used to extract salts from disposal waters, solar techniques have been given the most emphasis in the study of disposal basins. Any solar salt operation should meet the following criteria (Aral et al. 2004).

- Sufficient supply of good quality water,
- Hot, windy and dry climate with high evaporation rates,
- A large area of flat-lying land having a base containing clay or some other impervious layer that would prevent leakage,
- A management program to control water movement and composition (both organic and inorganic),
- Low transportation costs and close to markets,
- Sufficient manpower and labour to operate the saltfield.

Solar evaporation can be expected to produce halite, probably gypsum, and magnesium salts (sulphate and chloride). The processing of these salts into other products is also possible. The value of salts and their products are determined by their quality, the quantity purchased, and the associated transport costs. It is expected that it would be possible to produce marketable quality halite (sodium chloride) and bitterns from each of the disposal basins. The thermodynamic modelling results indicate that the quality of the halite from most sites is expected to meet commercial pre-wash specifications. However, washing of the salt to achieve market grades would be necessary.

5.4.2 AQUACULTURE

The National Action Plan for Salinity and Water Quality (NAP) recently funded a pilot commercial scale, demonstration aquaculture facility near Waikerie, referred to as the Waikerie Inland Saline Aquaculture Centre (WISAC). The Centre utilises water from the pipeline delivering Waikerie, Woolpunda and Qualco SIS water to the Stockyard Plains Disposal Basin located 12 km southwest of Waikerie. The water from the pipeline is delivered at between 20 and 22°C at a salinity of 18-19 000 mg/L which is approximately half the salinity of sea water (SARDI, 2008).

The site was developed in 2006 and commercial scale production trials using mulloway are currently underway. The initial stocking of 3500 advanced mulloway (average weight 340 g), were transported from the South Australian Aquatic Science Centre (SAASC) to a 70 kl tank at the WISAC (stocking density 17 kg/m^3). A further 15 000 juvenile mulloway (average weight 2 g) were transported to the WISAC and split evenly between three fibreglass, 10 kl tanks. There has also been research into the production of snapper, however the conditions are not considered to be as suitable due to a lesser tolerance to low levels of potassium. Further research is currently underway to determine whether this can be overcome (SARDI, 2008).

The development of inland saline aquaculture has several benefits including:

- Use of high volume unexploited saline groundwater that is presently considered a waste stream,
- Potential for commercial production of a highly marketable product,
- Fast fish growth due to constant elevated water temperatures,
- Improved feed management and food conversion efficiencies, and
- Biosecure water supply and ability to manage environmental impacts such as water and nutrients.

The WISAC also provides opportunities for other research into alternative products such as edible crustacean, molluscs and finfish species, micro algae for pharmaceuticals and bio-fuel, and halophytes for food oil and fibre (SARDI, 2008).

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6. IRRIGATION EFFICIENCY PROJECTS

6.1 IRRIGATION ALLOCATION AND TRADE IN BOOKPURNONG

In the 2007/2008 water year, there were 29 Taking Irrigation Allocations in the Bookpurnong region representing approximately 23 GL. Water trade has been occurring within the district for some time and can be complex and misunderstood. Trade may not result in water moving permanently from the district, even if there are many trades taking place. Water trades can represent a number of processes including;

- Top up of water under the Notice of Restrictions for the River Murray from interstate and from within SA,
- Permanent transfer of water to both holding and taking licenses from interstate and from within SA, and
- A transfer of water within the district (for example neighbours buying and selling water in the same district will result in an intrastate trade being recorded).

As a result, water trade information must be interpreted with care to avoid misrepresenting the impact on a local district. For example, from July 2006 to March 2008, the following trades took place into the Bookpurnong area:

- 8% of trades occurred internally within Bookpurnong
- 16% of trades were temporary top up trades from within SA
- 69% of trades were temporary top up trades from interstate
- Less than 1% of trades were permanent taking trades from within SA
- 1.5% of trades were permanent taking trades from interstate
- Almost 6% of trades were permanent trades to holding allocations from within SA,
- Less than 1% of trades were temporary transfers to holding allocations from within SA,
- Approximately 2% of trades were temporary transfers to holding allocations from interstate, and
- Almost 3.5% of trades were permanent transfers to holding allocations from interstate.

Of all trades, less than 6% (approximately 1.5 GL) represented new water entering the district (of which some of this may be holding and therefore not available for use until converted to a taking allocation).

From July 2006 to March 2008, the following trades took place out of the Bookpurnong area:

- 54% were temporary trades of taking allocations to within SA,
- 4% were temporary trades of holding allocations to within SA,
- 8% were temporary trades of holding allocations to interstate, and
- 33% were permanent trades of holding allocations to within South Australia (some of these were within Bookpurnong).

Of all trades out of Bookpurnong, about 4% (approximately 50 ML) represented a permanent trade.

6.2 IRRIGATION MANAGEMENT PROJECTS

As an initiative to demonstrate accountability in irrigation management, the Bookpurnong Lock 4 Environmental Association (BL4EA) has supported the use of the Irrigation Recording and Evaluation Software (IRES). Growers who have participated in using IRES have provided their data to the Irrigated Crop Management Service (ICMS) for the production of an annual district irrigation report. This report will only truly be representative of the district if sufficient growers provide their data. The program has been operating since 2003. The report for the 2006/07 season with comparisons to previous season's results, are presented below. The following information should be taken into account when analysing the results from IRES.

- Field application efficiency figures were calculated using Loxton Bureau of Meteorology (BoM) data for ETo, rainfall for the 2006/07 season and a standard set of crop coefficients. It is hoped that future reports will be able to use NRM weather station data where a station may be located close to the property.
- All data sets have been calculated using water meter readings. Using hours of irrigation in calculations may result in different values.
- Ages of plantings were in not taken into account in calculations.

6.2.1 2006/07 IRRIGATION REPORT FOR THE BL4EA DISTRICT

The number of irrigators participating in the program is presented in Table 3.

Table 3: Participation rate

District *FAE	Season	No of properties participating	% of total properties	Area of irrigated land participating (ha)	% of total irrigated land
0.91	06/07	15	65	1420	79

*FAE (Field Application Efficiency – explanation on page 38)

Figure 17 displays the average application rate in megalitres per hectare for the past four seasons where district reporting has occurred. Less water was applied last season compared with previous seasons, probably due to water restrictions. Other influential factors may include making irrigation systems more efficient (e.g. converting to drip) and greater attention to irrigation scheduling.

Figure 18 represent the total volume applied only for the growers providing data, and not the whole district.

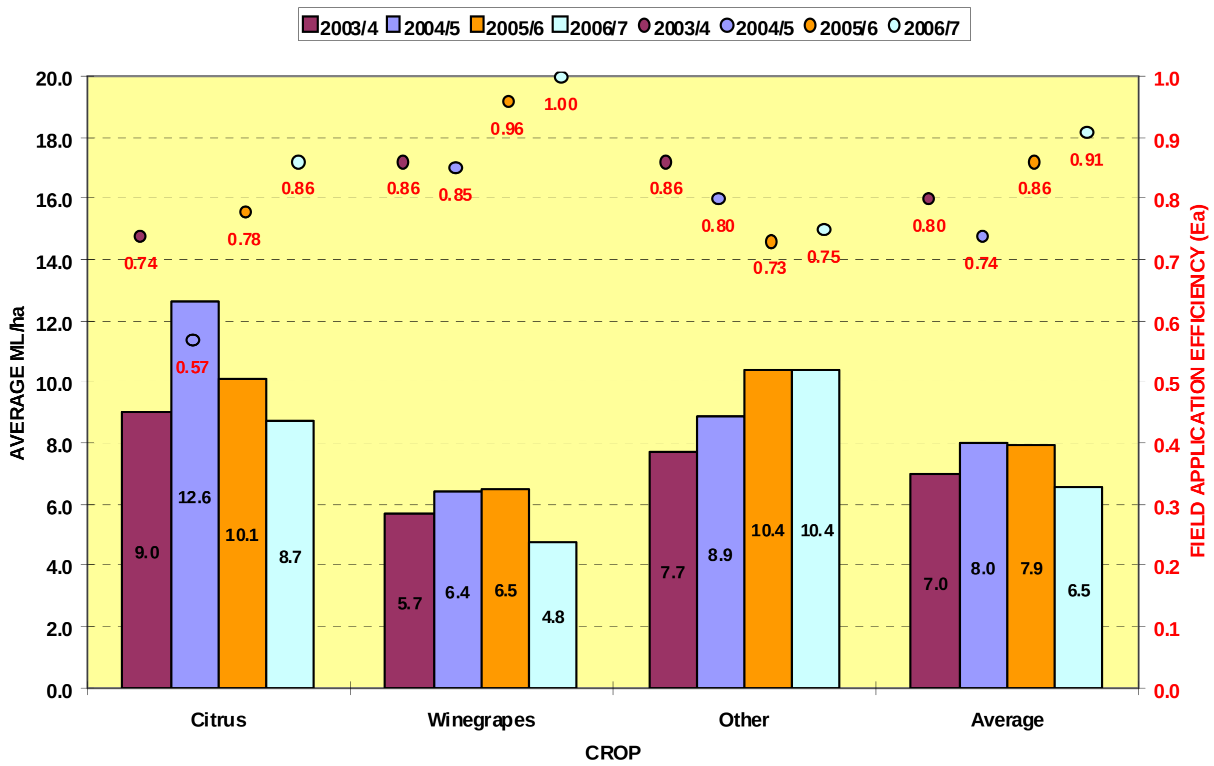

Figure 17: Average application rate for various crop categories.

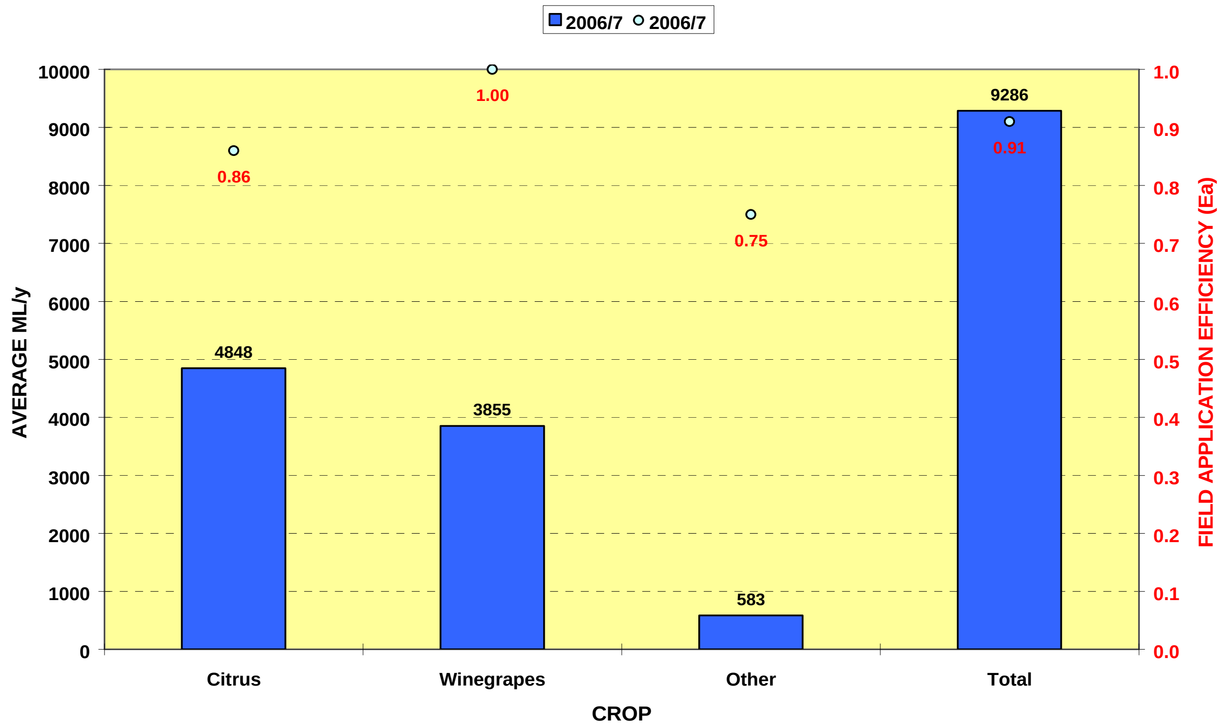

Figure 18: Total irrigation volume applied in the 2006/07 season for various crops.

6.2.2 FIELD APPLICATION EFFICIENCY IN INDIVIDUAL PROPERTY REPORTS

The Field Application Efficiency (FAE) index is calculated using the following formula:

$$\frac{\textbf{Total Water Available to the Crop}}{\textbf{Total Water Applied to the Crop}}$$

FAE considers the efficiency of each irrigation event and requires a soil water balance to be calculated daily. This calculation is very different to the method used in the Water Allocation Plan (WAP) whole of season calculation. Results are reported as an index between zero and one with values less than one estimating that drainage has occurred. FAE is comparable across different crops and properties if a consistent methodology is used. IRES automatically calculates FAE as irrigation records are entered.

An FAE of 0.91 (as shown in Table 3) means that 91% of irrigation water applied to crops is estimated to have been available to the crop. This conversely estimates that 9% of irrigation water applied to crops went to drainage which is required to leach salts in the crop root zone. Currently, salinity in the River Murray is relatively low and hence drainage requirements should also be low.

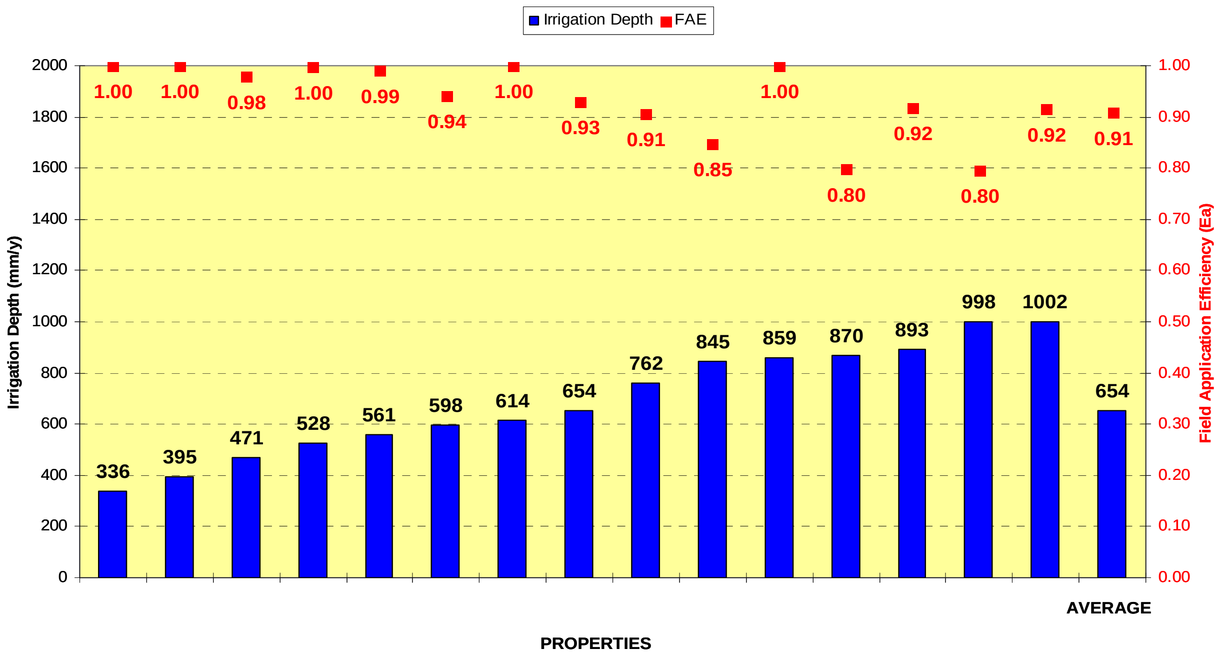

Figure 19: Average depth applied (mm) in the 2006/07 irrigation season.

Figure 19 displays the field application efficiency (FAE) and the average depth of water applied to individual properties in the district for the 2006/07 irrigation season.

The field application efficiency results displayed in Figures 20 and 21 are generally high, meaning that irrigations are scheduled well to meet crop needs. While this is highly commendable, soil salinity levels may be of concern in some cases because inadequate water may have been available to leach harmful salt accumulations out of the plant root zone. Informal discussions with irrigators suggest that few are measuring soil salinity, implying that salinity awareness and management are lacking on some properties. Salinity monitoring is highly recommended so that potential salinity problems can be managed and or avoided. The Irrigated Crop Management Service can provide methods for measuring soil salinity.

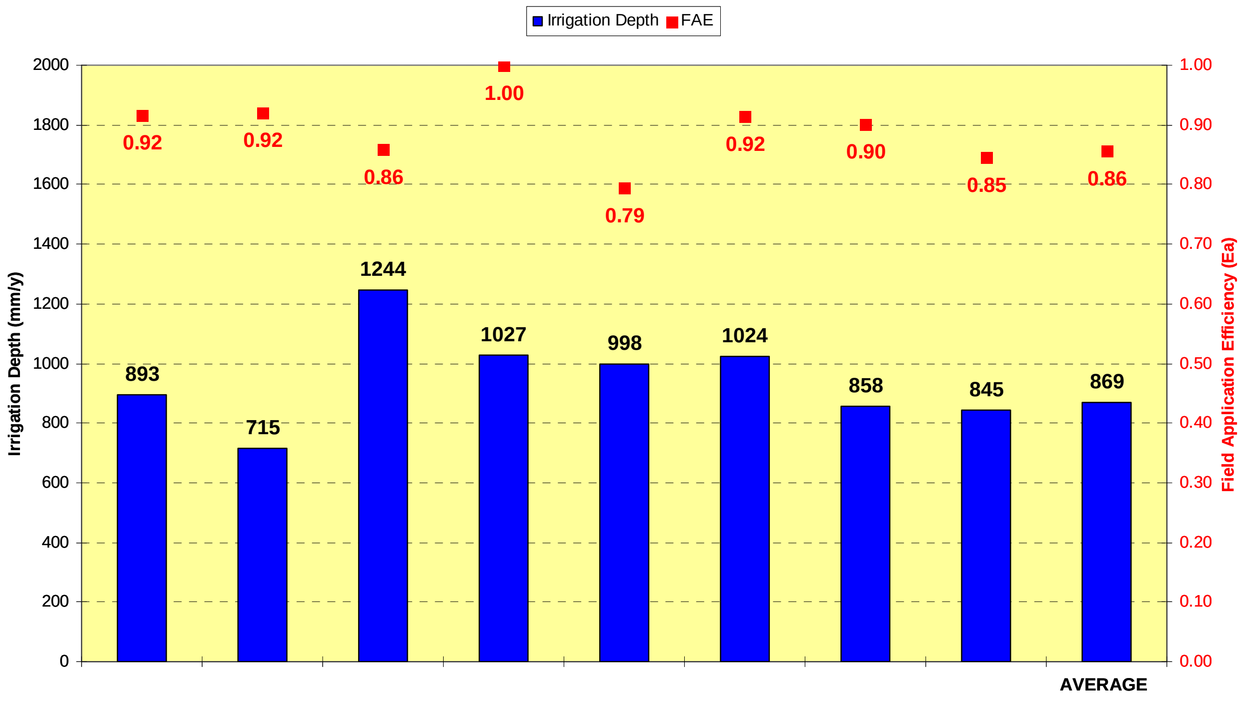

Figure 20: Comparison of average depth applied (mm) and FAE for various citrus properties for the 2006/07 irrigation season.

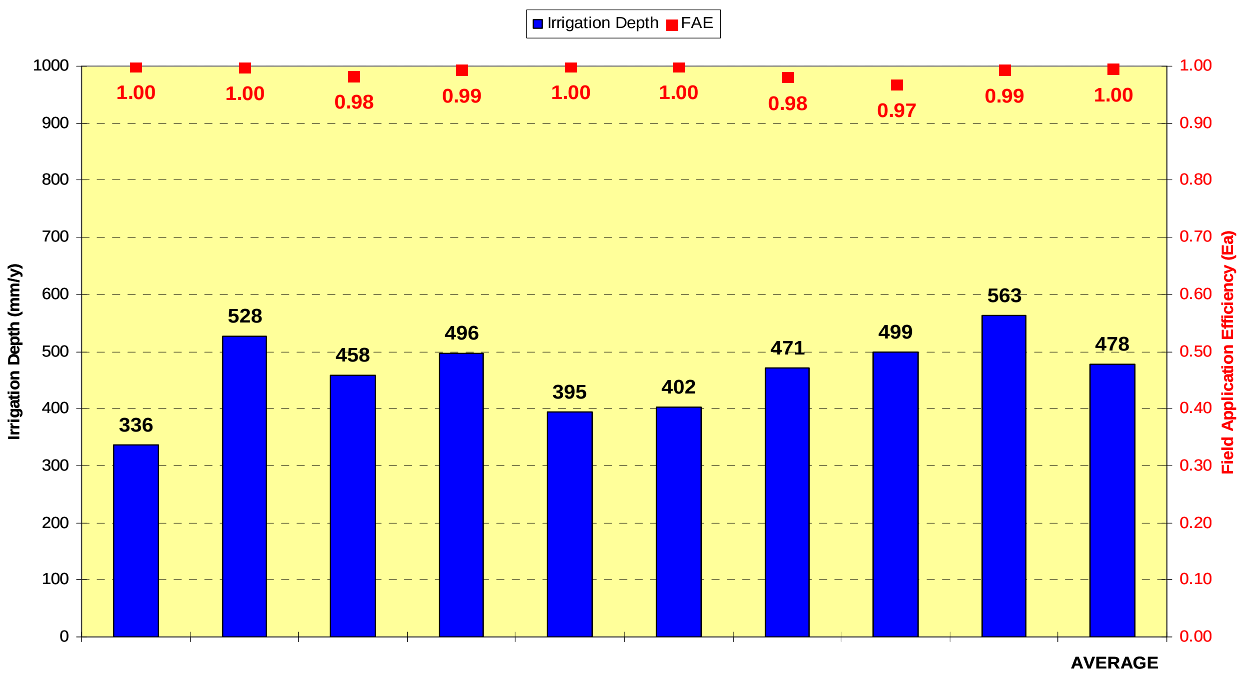

Figure 21: Comparison of average depth applied (mm) and FAE for various winegrape properties for the 2006/07-irrigation season.

6.2.3 DIFFERENCE BETWEEN IRRIGATION HOURS AND METER BASED CALCULATIONS

It is assumed that the volume applied measured by meter readings is the most reliable value, with the volume applied by hours expected to be within ±10% of meter readings. Figure 22 displays the average depth applied (mm) using irrigation meter readings compared to depth calculated using hours of irrigation entered.

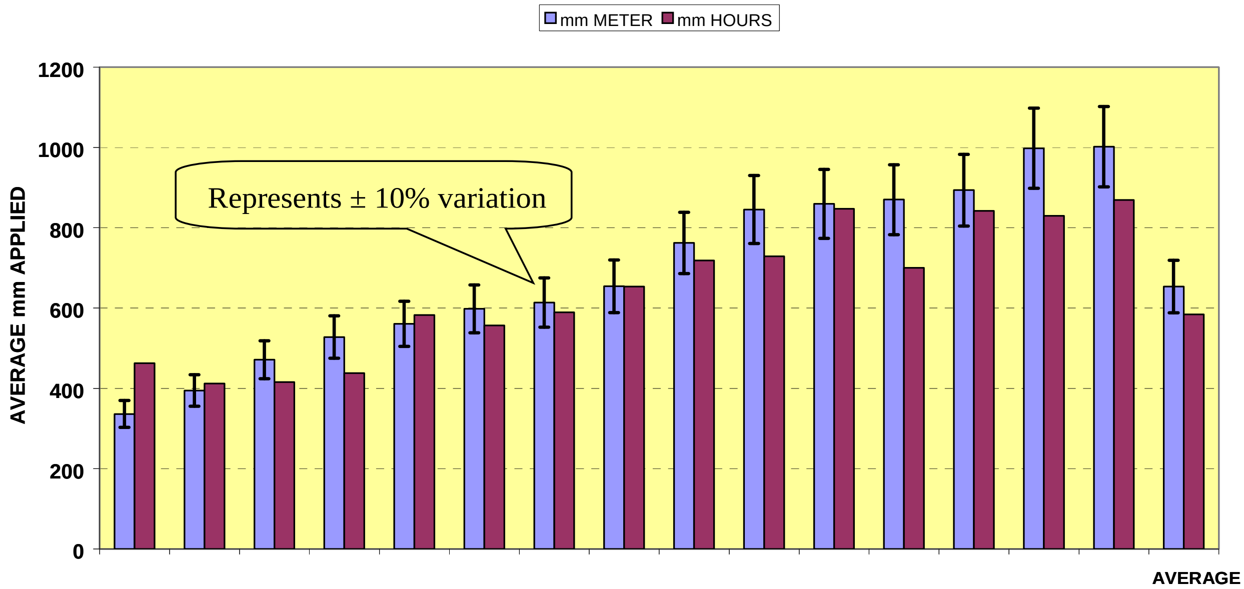

Figure 22: Comparison of depth applied (mm) by meter vs. hours for the 2006/07 irrigation season.

There are numerous reasons why the calculation may not match, which include:

- **Inaccurate emitter pressures recorded in IRES.** Ideally, the emitter pressures entered in IRES should be based on field assessment that is also compared to specifications in the irrigation system design.
- **Incorrect emitter specifications** such as nozzle size, spacing or flow rates. One mistake observed is forgetting that each row may have two lines of drip tube instead of one resulting in half the number of emitters being accounted for, or the % wetted area is not set correctly.
- **Emitter flow may be above or below design specifications.**

  This may happen if:

  - Valves operating together exceed pumping head capacity,
  - Valves operating together change (different shift arrangement),
  - Inadequate system flushing occurs,
  - Excessive pressure (greater than 300kPa) is applied to pressure compensated emitters
  - Flow regulators fitted to valves are removed or faulty.
- **Unaccounted water** not diverted for irrigation purposes such as filter flushing, spraying, domestic use, or for other purposes. In particular, filter flushing for drip irrigation can use significant water volumes.

- **Missing or incorrectly entered irrigation records.** This can be checked if a logging soil water monitoring device is located within the valve.
- If, after checking and being satisfied that all above points are correct, it may be likely that the difference can be explained by **inaccuracies in the water meter**.

6.3 IMPROVING IRRIGATION EFFICIENCY PROJECT

Growers from the Bookpurnong region have also participated in the Improving Irrigation Efficiency Project (IIEP) run through the South Australian Murray–Darling Basin Natural Resources Management Board (SAMDBNRMB). Based on the records of property participation (Table 4), there has been reasonable attendance to the two day Irrigation Management course and the one day Irrigation Scheduling course run as part of the IIEP, however the other courses have attracted few or no participants.

Table 4: Properties participating in the free IIEP courses

Course Name	**Number of properties with participants[1]**		
	Pre 2000	**Post 2000**	**Total number of properties**
Irrigation Management 2 days	9 (31%)	3 (10%)	12 (41.3%)
Soils	0	1	1 (3.4%)
System Management	0	0	0
Irrigation Management refresher	0	0	0
Drip Maintenance	0	0	0
Drip Management	0	4	4 (13.7%)
Irrigation scheduling	0	5	5 (17.2%)
Pump Efficiency	0	0	0

Conversely many properties have participated in the on-farm trial programs and subsidy programs offered by the IIEP, including soil moisture monitoring equipment and soil surveys (Table 5).

Table 5: Properties participating in the IIEP programs

Program	**Properties who have participated**	**% of properties who have participated**
Soil pits subsidy	3	10.3 %
System assessments	1	3.4 %
Diviner trial	10	34.4%
Flag test wells	7	24.1%

Uptake of the Diviner trial appears to be good, although no records have been provided to determine whether this trend is increasing or decreasing. Considering the participation in IRES it may be worthwhile encouraging further system assessments of Bookpurnong properties.

[1] Properties may have sent more than one person to a course.

7. GOVERNMENT POLICY TO MANAGE SALINITY IMPACTS

The 1999 Basin Salinity Audit illustrated that salt which was previously stored in the landscape was being mobilised on a massive scale by rising groundwater tables resulting from changes in land use across the Basin. To carry on with no change would mean exceeding the Australian Drinking Water Guidelines (NHMRC & ARMCANZ, 1996) for good-quality water within 50 to 100 years. In addition, average river salinities in key tributaries would rise and endanger their use for irrigation and urban purposes within 20 to 50 years. While the environmental impacts are not as well understood, clear and undeniable damage is occurring to floodplain environments along the Murray and particularly in South Australia.

7.1 BASIN SALINITY MANAGEMENT STRATEGY

With overwhelming evidence, the partner Governments to the MDBC established the Basin Salinity Management Strategy 2001–2015 (BSMS). This Strategy included the adoption of targets including the overall Basin target at Morgan, which is in effect a ‘cap’ on salinity. The target is

“*…to maintain the average daily salinity at Morgan at a simulated level of less than 800 E.C. for at least 95% of the time, during the Benchmark Period*.”

This target is underpinned by a currency of salinity debits and credits. Debits and credits generate a consistent currency through which trade-offs and basin accountability can be accommodated and the credits and debits are managed through two registers, which were established and are maintained by the MDBC. Register A is for tracking Salt Disposal Entitlement’s (debits and credits) and Register B tracks for actions to address the ‘legacy of history’, which is the predicted impacts of historical developments (prior to 1 January 1988). The registers keep track of actions undertaken in the Basin after the following agreed baseline dates:

1st of January 1988 for accountability for future actions by NSW, Victoria and South Australia,

1st of January 2000 for the responsibility to address the ‘legacy of history’ effects of partner governments.

The effects of actions are assessed with models using an agreed climatic/hydrologic sequence (otherwise known as the ‘benchmark period’). The benchmark period was from July 1975 to June 2000. An action will be considered as significant and included in the Commission Registers if it is assessed to cause a change in average EC at Morgan of 0.1 EC or higher within 100 years. For example, the Bookpurnong SIS is included on the registers because it will cause a significant change in average EC at Morgan.

A state contracting Government, such as South Australia, must take whatever action may be necessary to keep the total of salinity credits in excess of, or equal to, the cumulative total of all salinity debits attributed that State in both registers (i.e. that the registers remain in balance).

Every financial year South Australia, New South Wales and Victoria produce a report for submission to the MDBC outlining how they have achieved their obligations under the BSMS. This report is available at http://www.mdbc.gov.au/salinity.

In addition, a rolling five-year review and audit for each valley and Commission register entry is undertaken. This review and audit assesses the effect on river salinity (at end-of-valley or Morgan or both as appropriate) due to actions implemented to date, as well as an update of the expected change in the future flow, salt load and salinity regime due to the 'legacy of history' (and any other emerging effects such as climate change).

South Australia is committed to holding the line on River Murray salinity levels as recognised in the South Australia Strategic Plan (2004) in Target 3.11 (maintain SA's salinity registers in balance). South Australia has had extensive new irrigation development along the River Murray in the last 15 years, which will generate increased salt loads to the river, and therefore salinity debits on Register A. Until now, South Australia has managed to offset the salinity impacts of new irrigation development and to keep its salinity registers in surplus, by making strategic investments in rehabilitation of water supply infrastructure, salt interception and improved water use efficiency.

7.2 SALINITY ZONING POLICY

A salinity zoning policy has been adopted to implement the salinity management provisions in the Water Allocation Plan (WAP) for the River Murray Prescribed Watercourse. The policy affects water allocation transfers, conversions from water (holding) to water (taking) allocations and variations of licences to change the land on which water can be used.

Without a salinity zoning policy, future irrigation developments in high salinity impact locations close to the River Murray would require further significant and expensive efforts in salt interception or other actions to reduce river salinity. Further investment in salt interception is planned to deal with the future salt loads of existing irrigation, but there are limited opportunities to invest in salt interception beyond the planned schemes, due to a lack of suitable interception locations; sites for disposal of the saline water; and the increasing cost of designing, constructing and operating such schemes. The salinity zoning policy was applied from 1 July 2005, and builds on the interim policy that was in place since July 2003.

Under the salinity zoning policy, three zoning categories have been established:

1. **Low salinity impact zones** - licence transactions will be approved provided the salinity impacts of the proposed water use can be offset by salinity credits that are available to South Australia.

2. **High salinity impact zones** - licence transactions can only occur provided the salinity impacts of the proposed licence transaction can be fully offset by the proponent. An exemption applies to transactions for developments with significant commitment prior to 30 June 2003 at the specific location, but such licence transactions are also subject to the availability of salinity credits to South Australia.

3. **High salinity impact (Salt Interception) zones** - licence transactions will be approved provided the salinity impacts of the proposed water use can be managed within the available capacity of the salt interception scheme servicing that zone. If there is no capacity available in the scheme, this zone will be treated as the underlying zone. The area where the *Groundwater (Qualco-Sunlands) Control Act 2000* applies is essentially

a special case of a SIS, where the Act specifies its own system of risk management allocations to ensure irrigation development remains within the capacity of the groundwater control scheme.

All approvals, within all salinity zones are still subject to other River Murray WAP principles (including principles regarding water quality, floodplain impacts, water use efficiency and pumps on backwaters).

7.2.1 HOW WERE THE SALINITY ZONES IDENTIFIED?

The high salinity impact zone line was generated using the SIMPACT 2 model which is a spatially distributed analytical groundwater model that produces estimates of the timing and magnitude of salinity impacts on the River Murray that are driven by changes to deep drainage rates.

The model calculates increases in groundwater flow and hence salt delivered to the River Murray floodplain from land use changes within approximately 15 km of the River Murray. Essentially, salinity impacts are a function of:

- deep drainage (or Root Zone Drainage, RZD),
- depth to groundwater,
- distance from discharge,
- aquifer transmissivity,
- salinity of groundwater at discharge, and
- time

Driven by changes in deep drainage resulting from land use or management change, the model calculates increases in salt loads to the river by coupling two algorithms – describing unsaturated flow and saturated flow respectively as shown in Figure 23.

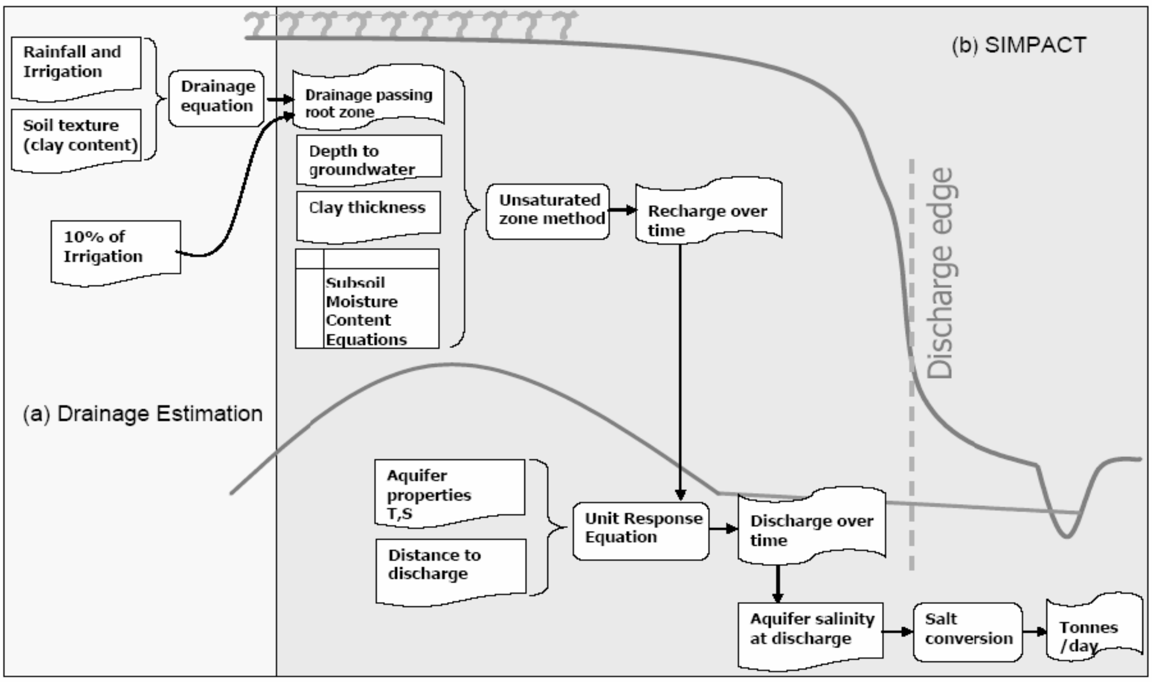

Figure 23: A representation of the SIMPACT Model

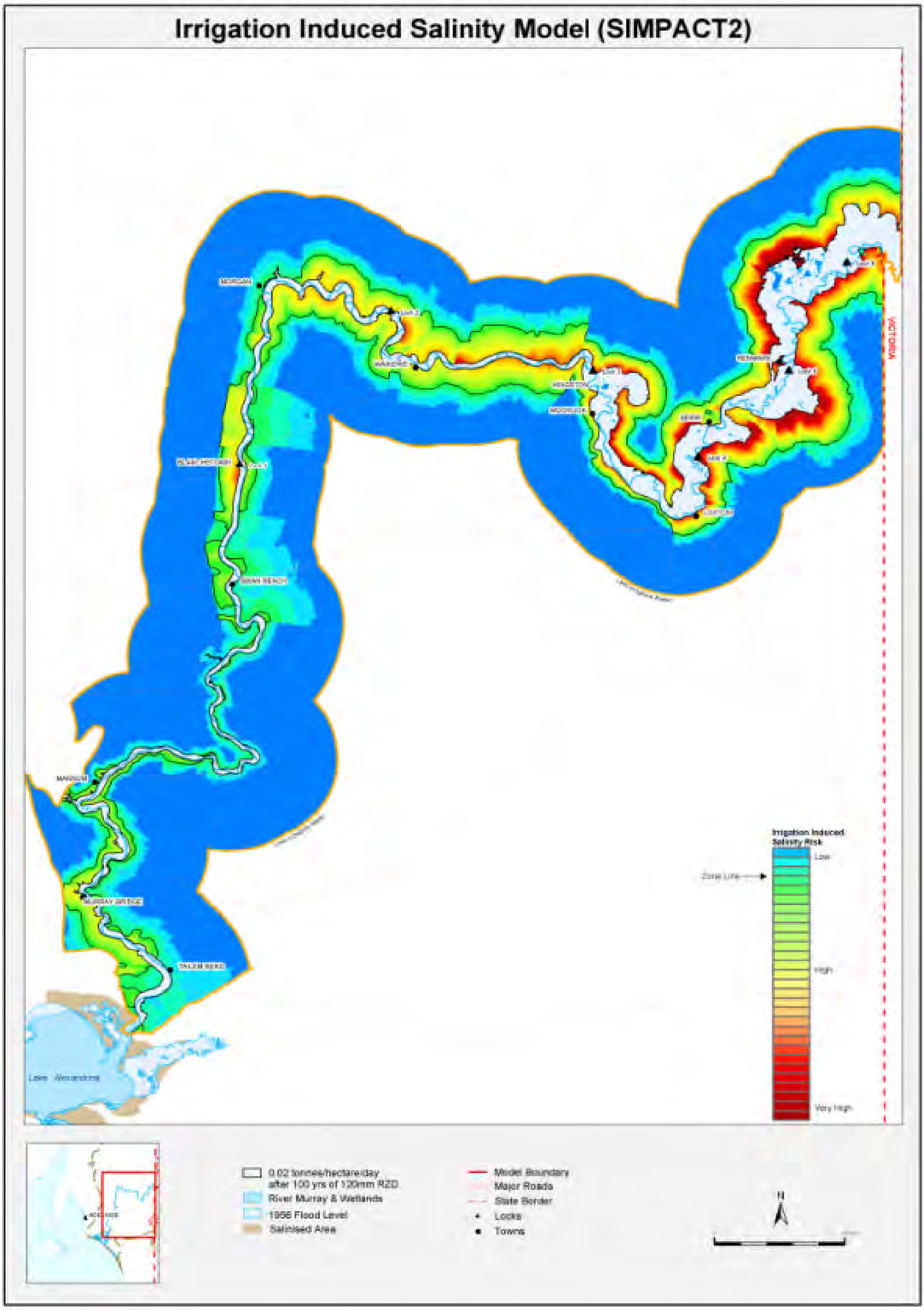

Figure 24: A representation of the impacts calculated by SIMPACT

Maps in the consultation workbook (Miles 2005) reproduced as Figure 24, illustrate how the combination of physical and hydrological factors varies gradually across the landscape.

These maps represent the impacts generated after 100 years of a constant 120 mm of deep drainage. The zone line is located at the 0.02 tonnes/hectare/day contour of that map. This roughly equates to 0.5 EC per gigalitre of water applied – a policy decision based on risk assessment and approximate conformity with Victorian zoning thresholds.

More information on Salinity Zoning can be obtained in the River Murray Salinity Zoning Fact Sheet 72, or at http://www.dwlbc.sa.gov.au/murray/salinity/zoning.html

7.2.2 HOW DOES SALINITY ZONING AFFECT THE BOOKPURNONG REGION?

The majority of the Bookpurnong Land and Water Management Plan region is classified as a high salinity impact (salt interception) zone, however there is a smaller corner to the southeast that is classified as a low salinity impact zone. A more detailed map of the zone boundaries is at http://www.dwlbc.sa.gov.au/assets/files/Loxton.pdf .

The Bookpurnong SIS was built with additional capacity to intercept induced groundwater inflows from future irrigation development up to a certain volume. This means that within the high salinity impact (salt interception) zone, water can be traded into the area until the capacity of the scheme is reached. The scheme will offset the salinity impacts of the irrigation development. Once the capacity of the scheme is reached, then the underlying high and low salinity impact zones come into effect.

Provisional access to scheme capacity can be applied for, but detailed information on the size of the development is required and provisional credits may only be held for twelve months.

The scheme currently has not constructed all the bores that were part in the original design. However once the scheme is no longer able to cope with the salt loads via the existing bores, the option to upgrade the scheme with construction of additional bores to enable further irrigation development is possible.

7.3 THE REVIEW OF THE WATER ALLOCATION PLAN

A Water Allocation Plan (WAP) is a legal document prepared under the *Natural Resource Management Act 2004* which outlines the rules for the allocation, transfer and use of available water from prescribed water resources, and also sets limits on the amount of water that can be taken and used for all purposes. The River Murray is a prescribed water resource. In setting these limits, a WAP must consider the needs of both the environment and consumptive users including irrigators. Therefore the WAP for the River Murray Prescribed Watercourse is one of the most important documents influencing water use in the South Australian Murray-Darling Basin. The guide entitled **Understanding the Water Allocation Plan for the River Murray** provides a simple explanation of the purpose and contents of the WAP.
http://www.samdbnrm.sa.gov.au/Portals/7/2002 wap exp guide.pdf

Overall, the WAP aims to ensure that the water resource is allocated and managed in a sustainable manner. This includes putting into operation the key salinity management policies in the South Australian River Murray Salinity Strategy 2002–2015. The previous WAP was adopted in July 2002. A review in 2007 resulted in the commencement of an amendment process, which is due to be completed in 2010.

7.4 SEPARATION OF WATER RIGHTS

The separation of water rights is designed to assist in the sustainable management of water in South Australia. The aim is to provide a flexible system that meets the management requirements of different water resources in the State, to protect property rights and the environment, and is easily administered. The separated scheme is detailed in the *Natural Resources Management (Water Resources and Other Matters) Amendment Act 2007* (the Amendment Act).

The objective of the system is to provide a separate instrument to manage each of the key aspects of water access, water taking and water use. This is a requirement under the National Water Initiative (2004) to separate the ownership of water access rights from regulatory approvals, enabling use at a particular site for a particular purpose, and to separate the ongoing water access right from the periodic or seasonal allocation of water.

Under the new scheme, the components of the scheme will be known as:

- A water access entitlement,
- A water allocation,
- A site use approval (including salinity impact assessments),
- A water resource works approval, and
- A delivery capacity entitlement

Under the Act, the Water Allocation Plan for the River Murray Prescribed Watercourse will determine the form and number of water access entitlements, define the consumptive pool(s), set out the method by which available water will be determined from time to time, and set out many of the principles that will underpin conditions on the approvals. These are currently being developed through the amendment process of the River Murray WAP. This will be undertaken with the upcoming review of the Water Allocation Plan in 2009 and 2010. The WAP will continue to set certain limitations around the taking and use of water connected with the trade in water and to ensure effective protection of water resources.

GLOSSARY

Aquifer — An underground layer of rock or sediment that holds water and allows water to percolate through

Aquifer, confined — Aquifer in which the upper surface is impervious (see 'confining layer') and the water is held at greater than atmospheric pressure; water in a penetrating well will rise above the surface of the aquifer

Aquifer, unconfined — Aquifer in which the upper surface has free connection to the ground surface and the water surface is at atmospheric pressure

Aquitard — A layer in the geological profile that separates two aquifers and restricts the flow between them

Baseflow — The water in a stream that results from groundwater discharge to the stream; often maintains flows during seasonal dry periods and has important ecological functions

Confining layer — A rock unit impervious to water, which forms the upper bound of a confined aquifer; a body of impermeable material adjacent to an aquifer; see also 'aquifer, confined'

CSIRO — Commonwealth Scientific and Industrial Research Organisation

DWLBC — Department of Water, Land and Biodiversity Conservation (Government of South Australia)

EC — Electrical conductivity; 1 EC unit = 1 micro-Siemen per centimetre (µS/cm) measured at 25°C; commonly used as a measure of water salinity as it is quicker and easier than measurement by TDS

Entitlement flows — Minimum monthly River Murray flows to South Australia agreed in to the Murray-Darling Basin Agreement 1992

Evapotranspiration — The total loss of water as a result of transpiration from plants and evaporation from land, and surface water bodies

GIS — Geographic Information System; computer software linking geographic data (for example land parcels) to textual data (soil type, land value, ownership). It allows for a range of features, from simple map production to complex data analysis

Groundwater — Water occurring naturally below ground level or water pumped, diverted and released into a well for storage underground; see also 'underground water'

Hydraulic conductivity (K) — A measure of the ease of flow through aquifer material: high K indicates low resistance, or high flow conditions; measured in metres per day

Hydrogeology — The study of groundwater, which includes its occurrence, recharge and discharge processes, and the properties of aquifers; see also 'hydrology'

Irrigation — Watering land by any means for the purpose of growing plants

Irrigation season — The period in which major irrigation diversions occur, usually starting in August–September and ending in April–May

Licence — A licence to take water in accordance with the Act; see also 'water licence'

Licensee — A person who holds a water licence

MDBC — Murray–Darling Basin Commission

Model — A conceptual or mathematical means of understanding elements of the real world that allows for predictions of outcomes given certain conditions. Examples include estimating storm run-off, assessing the impacts of dams or predicting ecological response to environmental change

Monitoring — (1) The repeated measurement of parameters to assess the current status and changes over time of the parameters measured (2) Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, animals, and other living things

Natural recharge — The infiltration of water into an aquifer from the surface (rainfall, streamflow, irrigation etc). See also recharge area, artificial recharge

NRM — Natural Resources Management; all activities that involve the use or development of natural resources and/or that impact on the state and condition of natural resources, whether positively or negatively

Piezometer — A narrow tube, pipe or well; used for measuring moisture in soil, water levels in an aquifer, or pressure head in a tank, pipeline, etc

PIRSA — Primary Industries and Resources South Australia (Government of South Australia)

Prescribed area, surface water — Part of the state declared to be a surface water prescribed area under the Act

Prescribed watercourse — A watercourse declared to be a prescribed watercourse under the Act

Prescribed water resource — A water resource declared by the Governor to be prescribed under the Act, and includes underground water to which access is obtained by prescribed wells. Prescription of a water resource requires that future management of the resource be regulated via a licensing system.

Property right — A right of ownership or some other right to property, whether real property or personal property

Recharge area — The area of land from which water from the surface (rainfall, streamflow, irrigation, etc.) infiltrates into an aquifer. See also artificial recharge, natural recharge

SA Water — South Australian Water Corporation (Government of South Australia)

Surface water — (a) water flowing over land (except in a watercourse), (i) after having fallen as rain or hail or having precipitated in any another manner, (ii) or after rising to the surface naturally from underground; (b) water of the kind referred to in paragraph (a) that has been collected in a dam or reservoir

Transmissivity (T) — A parameter indicating the ease of groundwater flow through a metre width of aquifer section

Underground water (groundwater) — Water occurring naturally below ground level or water pumped, diverted or released into a well for storage underground

Volumetric allocation — An allocation of water expressed on a water licence as a volume (eg. kilolitres) to be used over a specified period of time, usually per water use year (as distinct from any other sort of allocation)

Water affecting activities — Activities referred to in Part 4, Division 1, s. 9 of the Act

Water allocation — (1) In respect of a water licence means the quantity of water that the licensee is entitled to take and use pursuant to the licence. (2) In respect of water taken pursuant to an authorisation under s.11 means the maximum quantity of water that can be taken and used pursuant to the authorisation

WAP — Water Allocation Plan; a plan prepared by a Natural resources Management Board or water resources planning committee and adopted by the Minister in accordance with the Act

Water licence — A licence granted under the Act entitling the holder to take water from a prescribed watercourse, lake or well or to take surface water from a surface water prescribed area; this grants the licensee a right to take an allocation of water specified on the licence, which may also include conditions on the taking and use of that water; a water licence confers a property right on the holder of the licence and this right is separate from land title

Water-use year — The period between 1 July in any given calendar year and 30 June the following calendar year; also called a licensing year

Well — (1) An opening in the ground excavated for the purpose of obtaining access to underground water. (2) An opening in the ground excavated for some other purpose but that gives access to underground water. (3) A natural opening in the ground that gives access to underground water

Wetlands — Defined by the Act as a swamp or marsh and includes any land that is seasonally inundated with water. This definition encompasses a number of concepts that are more specifically described in the definition used in the Ramsar Convention on Wetlands of International Importance.

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