The Department of
Water, Land and
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Conservation



Regional salt and water balances for the Lower Murray in SA

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Disclaimer

Foreword

South Australia's natural resources are fundamental to the economic and social well-being of the State. One of the State's most precious natural resources, water is a basic requirement of all living organisims and is one of the essential elements ensuring biological diversity of life at all levels. In pristine or undeveloped situations, the condition of water resources reflects the equilibrium between rainfall, vegetation and other physical parameters. Development of these resources changes the natural balance and may cause degradation. If degradation is small, and the resource retains its utility, the community may assess these changes as being acceptable. However, significant stress will impact on the ability of the resource to continue to meet the needs of users and the environment. Understanding the cause and effect relationship between the various stresses imposed on the natural resources is paramount to developing effective management strategies. Reports of investigations into the availability and quality of water supplies throughout the State aim to build upon the existing knowledge base enabling the community to make informed decisions concerning the future management of the natural resources thus ensuring conservation of biological diversity.

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Director, Knowledge and Information
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ABSTRACT

The Lower Murray irrigated swamps are discharge areas for regional groundwater systems (being at a lower elevation than the River Murray). Surface drains within the swamps collect not only irrigation drainage but also saline groundwater discharge, and pump both back into the river.

The project has more clearly defined the hydrogeology of three swamps (Mypolonga, Mobilong and Toora) by drilling transects across them. Actual salt loads being returned to the river were measured accurately by metering the volumes and salinity of drainage water pumped back to the river by four pumping stations. Of the total saltload of 11 920 tonnes/yr, regional groundwater was estimated to contribute 5575 tonnes.

The results show far less saltload contribution from these swamps than the 70 000 tonnes/yr indicated by an earlier study. Figures from the individual swamps give an indication of the overall irrigation efficiency, with those having a higher groundwater component exhibiting greater irrigation efficiencies resulting in lower volumes of irrigation drainage.

Groundwater modelling suggests a gradual ongoing rise in regional groundwater inflows to the swamps as the increased recharge following clearing percolates down and causes a rise in the regional watertable. If in the unlikely event that widespread revegetation could occur now, it would take about 25 years for the impacts to reach down to the watertable. Even then, revegetation would only stabilise the inflows at whatever rate it would be in 25 years time. No reduction in discharge is predicted.

Saltload contributions to the river from surface water are minimal because low runoff (due to the rain shadow effect) and significant losses ensure that only very rare events in Rocky Gully and Preamimma Creek would reach the River Murray floodplain. Salt is being concentrated in the hills landscape in areas of dryland salinisation, rather than being exported from the catchments.

The outcomes from this project will be considered in an options analysis of appropriate management strategies (eg drainage water reuse, land retirement) to mitigate the salinity impacts of land use change on the swamps. Monitoring of groundwater levels and drainage should continue in order to determine their responses to these imminent changes in land use.

1 INTRODUCTION

The Lower Murray irrigated swamps (Fig. 1) are discharge areas for regional groundwater systems (being at a lower elevation than the River Murray). Surface drains within the swamps collect not only irrigation drainage but also saline groundwater discharge, and pump both back into the river.

A preliminary hydrogeological assessment of the regional groundwater salinities and flow gradients by DWLBC suggested that about 70 000 tonnes of salt per year could be discharged to the river via the swamps. It also showed that three swamps (Mypolonga, Mobilong and Toora) could contribute about 75 % of the total load from all the 21 swamps.

One aim of the project is to define the hydrogeology more clearly for these three swamps and quantify the actual salt loads being returned to the river more accurately. Another is to determine whether salt loads into the area from surface water and regional groundwater are going to increase into the future.

Appropriate mitigation strategies (eg drainage water reuse, land retirement) could then be incorporated into the appropriate Land and Water Management Plan and contribute to fulfilling the goals of the SA River Murray Salinity Strategy.

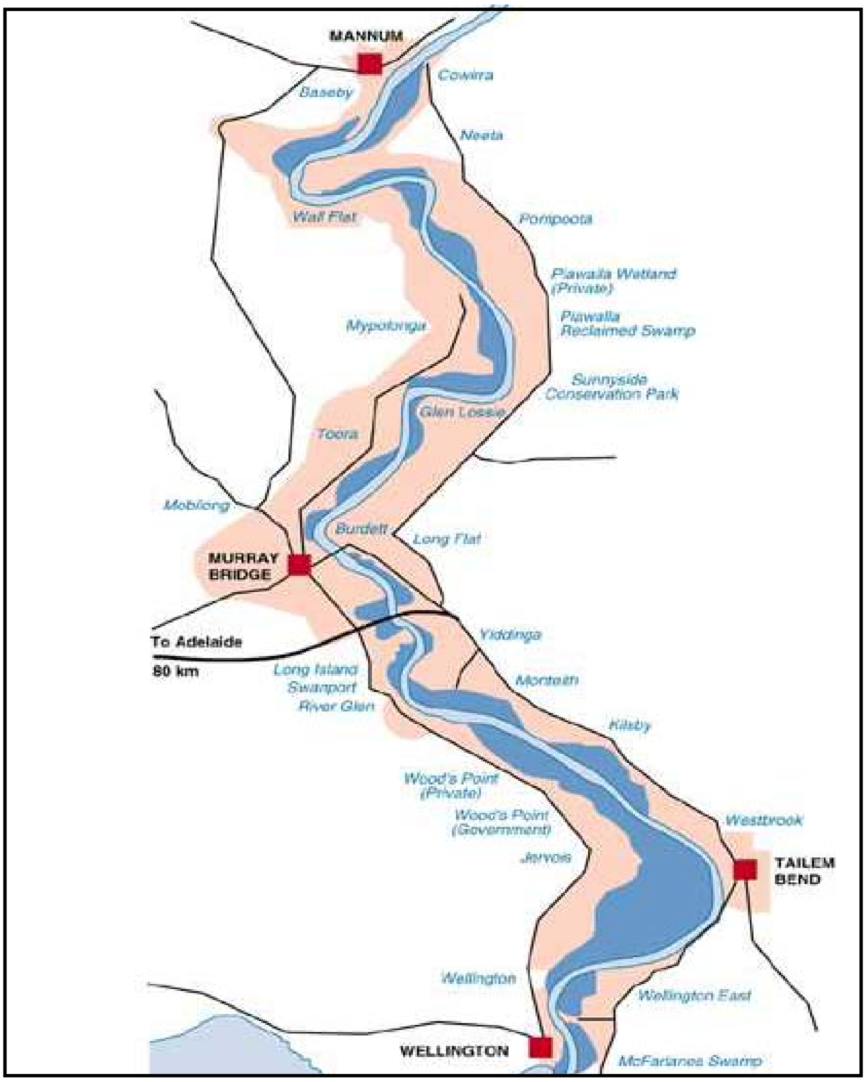


Figure 1. Location of irrigated swamps

2 HYDROGEOLOGY

The catchments under investigation can be divided into two distinct regions with different geology and consequently, different groundwater systems - the Hills Zone and Plains Zone which are separated by the Pallamana Fault scarp. Figure 1 shows a block diagram of these zones for a catchment immediately to the north of the area of interest.

The Hills Zone comprises the consolidated basement rocks of the Mt Lofty Ranges which consist of micaceous and feldspathic sandstones and siltstones of the Kanmantoo Group (of Cambrian age). These rocks have been metamorphosed by heat and pressure, and are generally tight and impermeable with few open systems of fractures and joints in which groundwater can be stored and transmitted. Borehole yields are consequently low. Salinites are generally high due to the low recharge and clayey weathering products from the metamorphosed rocks.

Unconsolidated sediments of the Murray Basin underlie the Plains Zone. They consist of layers of limestones, sands and clays up to 150m thick that overlie basement rocks which are exposed in the Hills Zone to the west. Groundwater flows through pore spaces in the sand and limestone beds towards the River Murray valley, where it eventually discharges.

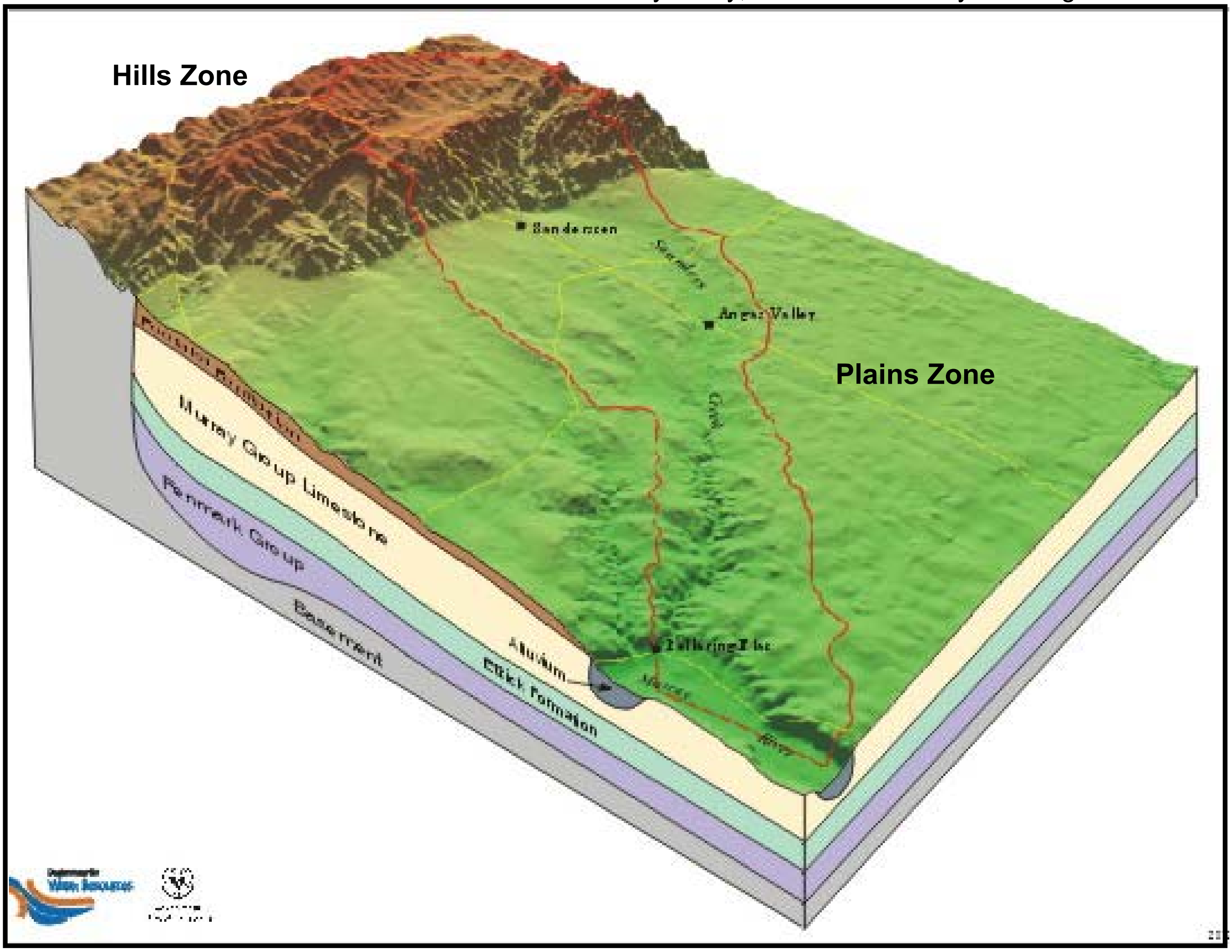


Figure 2. Block diagram of geology

The main aquifer of interest on the Plains Zone is the Murray Group Limestone which is yellow-brown to grey and highly fossiliferous. This limestone is the regional watertable aquifer that wholly encloses the river valley and is in hydraulic connection with it. The aquifer is about 25 – 30 m thick and contains groundwater with salinities increasing from 3500 mg/L near the Ranges where it is recharged by streams intermittently flowing out onto the plains, to 20 000 mg/L near the river.

These high salinities forced stock supplies just to the west of Mypolonga to be obtained from the underlying Renmark Group confined sand aquifer that lies at a depth of about 100 m with salinities in the range 7 – 10 000 mg/L.

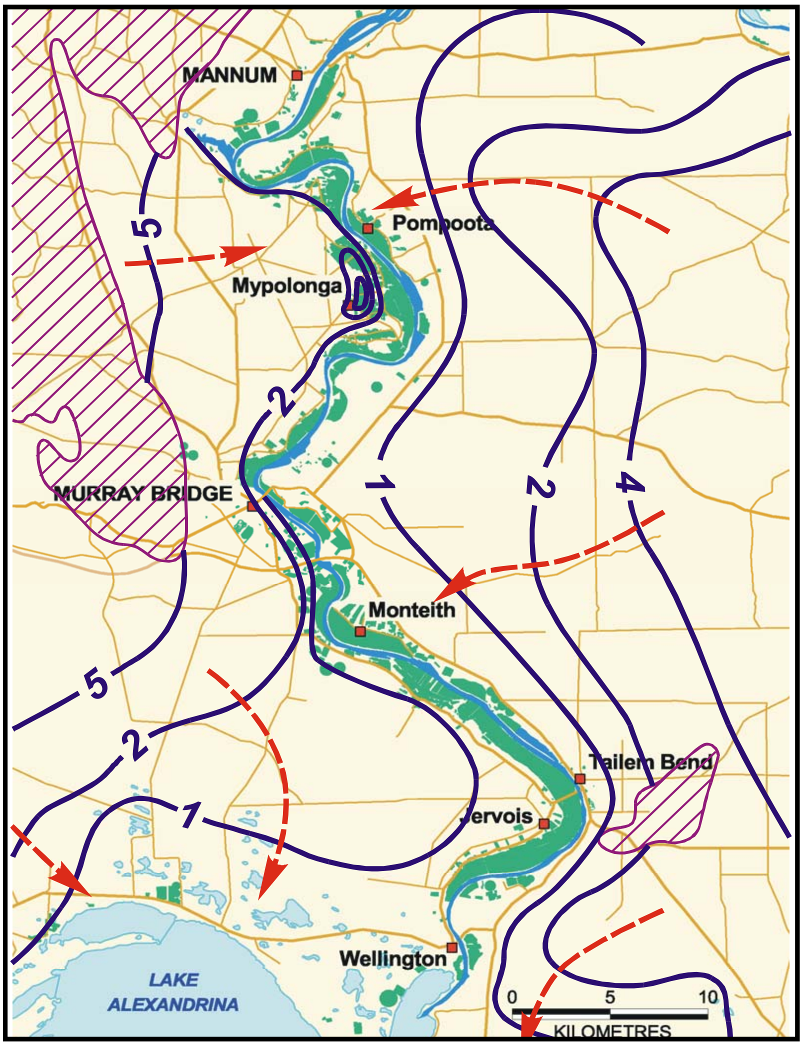


Figure 3. Regional groundwater flow directions

Figure 3 shows the watertable elevation contours and the regional flow directions which confirm the river valley as being the focus for regional groundwater discharge.

At the surface, the colluvial outwash of the Pooraka Formation form a wedge-shaped deposit of red-brown clays and minor gravels up to 50 m thick adjacent to the Pallamana Fault scarp, which decreases in thickness to about 15 m close to the river. These impermeable sediments have caused drainage problems in the Mypolonga highland area.

Deposition of the alluvial sediments within the river valley can be assigned to episodes related to post-glacial periods of rising sea levels. The river cut down through the underlying limestone sediments about 20 000 years ago during an ice age which caused the sea level to drop 120 m below its present level. At the end of this glacial period, a relatively rapid rise in sea level caused the Murray River to fill its valley with the medium to coarse grained quartz sands of the Monoman Formation. These sands form a permeable confined aquifer with artesian water levels of up to two metres above swamp level and a good connection to the regional limestone aquifer.

The younger valley deposits of the Coonambidgal Formation are generally finer grained than the underlying Monoman Formation and consist of alluvial clays, silts and sands. The Coonambidgal Formation extends to the present age and includes modern point bars, lagoonal deposits and heavy organic clays underlying the irrigated reclaimed swamps. These clays act as a confining layer for the underlying Monoman Formation sand aquifer. Because of the surface drainage and the influence of evapotranspiration, the watertable within the clays of the Coonambidgal Formation lies below ground level.

Table 1 presents a summary of the hydrogeology of the study area.

Table 1. Hydrogeological summary of the western Murray Basin

Stratigraphic unit	Lithology	Thickness (m)	Comments
Coonambidgal Formation	Alluvial grey-brown clays and silts	10 – 20	Floodplain watertable aquifer. Confines underlying sand aquifer
Monoman Sands	Medium to coarse pale brown quartz sands	5 - 20	Artesian aquifer beneath floodplain
Pooraka Formation	Silty clay, dark red to grey	0 - 15	Underlies sandy dunes, causes drainage problems beneath highland irrigation
Murray Group Limestone	Yellow-brown to off-white fossiliferous limestone	30 - 35	Regional watertable aquifer discharging to river valley
Ettrick Formation	Grey–green fossiliferous marl	20 – 50	Confining layer.
Renmark Group	Interbedded sands and lignitic clays	10 - 30	Confined aquifer
Basement	Micaceous and feldspathic sandstones and siltstones		Fractured rock aquifer in Hills Zone

3 DRILLING PROGRAM

The drilling program was planned to produce flow nets for the three swamps (Mypolonga South, Mobilong and Toora) that were thought to contribute most salt to the river. Figure 2 shows the locations of the sites and the depths of completions. The drilling program commenced on 14 April 2003 and concluded on 26 April 2003, with a total of 18 wells drilled at seven sites.

The wells were completed at various depths and cased with 80mm ID PVC casing with a two metre screened interval at the base with 1 mm slots. PVC end caps were used at the base of the casing. Three piezometers were completed at each of the six sites using the rotary method with samples taken at 1m intervals. At Toora, a well was drilled on the highland to determine the regional watertable gradient toward the swamps. Geological logs for the deepest piezometer at each site are presented in Appendix A.

The thickness of the Coonambidgal Formation was much greater than encountered at the first Mypolonga traverse, with total thicknesses of up to 20m recorded instead of the expected 11 – 12 m. As a result, the total depths of the piezometers varied considerably from the planned program. An additional problem was encountered with the deeper holes due to the fine-grained, unconsolidated nature of the Monoman Formation. These holes consistently collapsed prior to the casing being installed and as a result, required re-drilling to enable completion at the required depths.

After completion, an initial pump sampling revealed the holes to have significant quantities of polymer remaining from the drilling which was required to control the flowing Monoman Sands. The holes had to be dosed with chlorine to break the polymer down before resampling could occur to obtain representative groundwater salinities.

Flow nets were constructed using the potentiometric heads measured in the nested piezometers at each site after density corrections had been made.

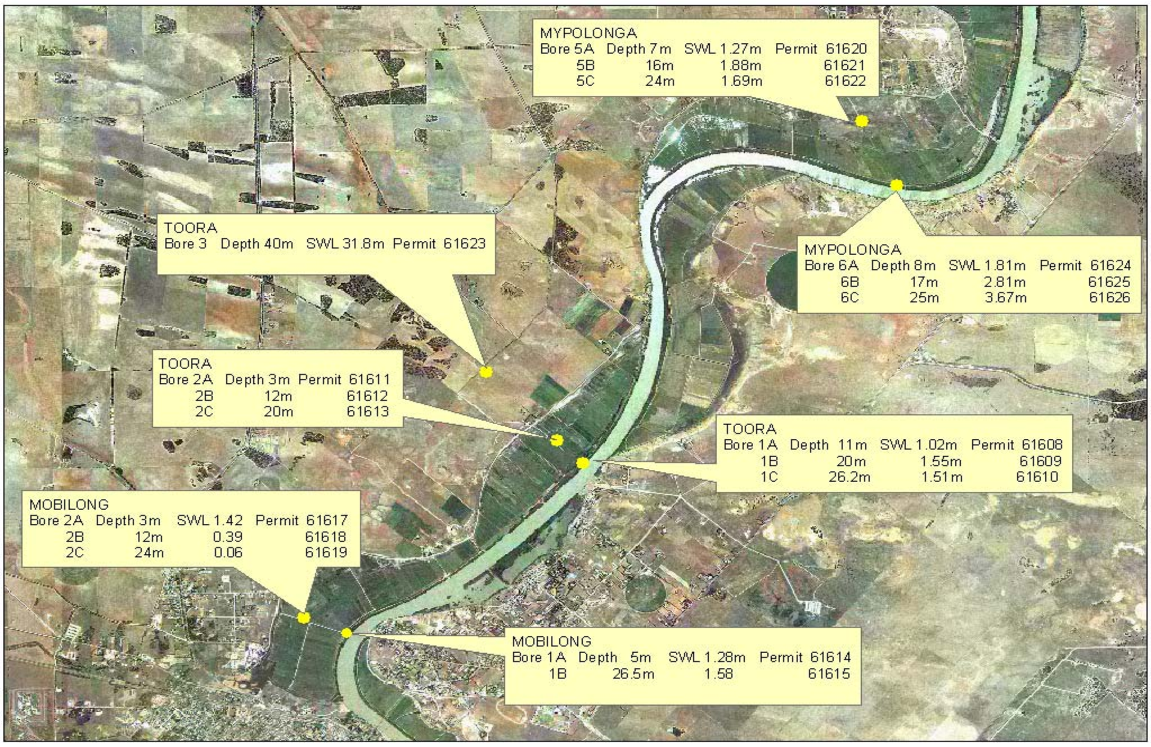


Figure 4. Location of drilling program

4 METERING OF DRAINAGE FLOWS

In order to refine the earlier estimates of salt contributions from the three swamps, a metering project was undertaken to measure the volumes and salinity of drainage water pumped back to the river by four pumping stations. Details of the installations are presented below.

4.1 Mobilong

At this site, a 460 mm Thompson axial flow pump producing up to 250 L/sec pumps through a 535mm diameter pipe that runs to the river bank some 40 m away. On inspection, it was found the only portion of pipework that was exposed showed turbulent flow characteristics and therefore could not be used for meter installation. A section of pipeline was then excavated between two goose necks, and laminar flow characteristics were observed. Because of the large diameter of the pipe, a Danfoss ultrasonic flowmeter was installed. The transducer mountings were welded directly onto the pipeline after it was drained. The transducers and mountings were wrapped with waterproof tape and the excavation backfilled with sand.

The intelligence behind the transducers is the Sono 3000 signal converter that is housed in the pump shed. The display of the Sono 3000 is configured to show flow in L/sec and cumulative flow in ML. The field conductivity unit is a Greenspan model EC250 (with a range of 0 to 20 000 EC) that was installed in the pump intake pit.

Both the Sono 3000 and the Greenspan EC probe are linked to a Greenspan SL300 data logger which is constantly monitoring site conditions. The data logger is programmed to log flow data only when the pump is running but log conductivity data on an hourly basis.

Figure 5. Sonokit transducer mountings at Mobilong

Figure 6. Insertion tube Sonokit at Toora

4.2 Toora

Here, a 305 mm Colville Revflow pump produces up to 220 L/sec through a 300 mm diameter black poly pipe that runs to the river bank some 50 m away. The only section of pipe that was not oval shaped was in the bank of the river. Consequently, a section of pipeline was excavated and laminar flow characteristics confirmed. Given the large diameter and the nature of the pipe, a Danfoss ultrasonic flowmeter with a D 300mm insertion tube was installed. To achieve this, the pipeline was drained, cut and two flanges welded on to the poly pipe and the meter then bolted between the flanges. The transducers and mountings were wrapped with waterproof tape and the excavation backfilled with sand. The electronics are similar to Mobilong.

4.3 Mypolonga South

At this site, a 300 mm Thompson axial flow pump producing up to 151 L/sec, pumps drainage water some 60 m to the river through a 380 mm diameter pipe. Procedures and equipment were similar to previous sites. Here, the transducer mountings were pre-welded to a stainless steel tapping band. The transducers were installed 'wet', which meant that the pipeline did not have to be drained (making installation much easier).

Figure 7. Tapping band and Sonokit transducer mountings at Mypolonga South

Figure 8. Transducers and mountings at Mypolonga

4.4 Mypolonga

Two Thompson axial flow pumps (610mm and 460mm) producing a combined flow output of 1044 L/sec, pump the drainage water some 80m to the river through a 660 and 460mm diameter pipelines. Both pipelines were equipped with procedures and equipment similar to previous sites.

5 DRILLING AND METERING RESULTS

5.1 Mobilong

The drilling found the Coonambidgal Formation to be much thicker than expected, up to 20 m. Limestone was encountered at 27 m near the river. Figure 9a shows the salinity recorded in each piezometer and the salinity contours in red. A typical salinity gradient was encountered, with salinities increasing from about 4400 mg/L near the surface, to over 10 000 mg/L at depth. Regional salinities in the limestone aquifer to the west are in the range 15 to 20 000 mg/L. Figure 9b records the watertable elevations recorded in each piezometer and the resultant flow net which shows as expected, groundwater flow (in blue) toward the centre of the swamp area where it discharges to drains. The river is losing water to the swamp.

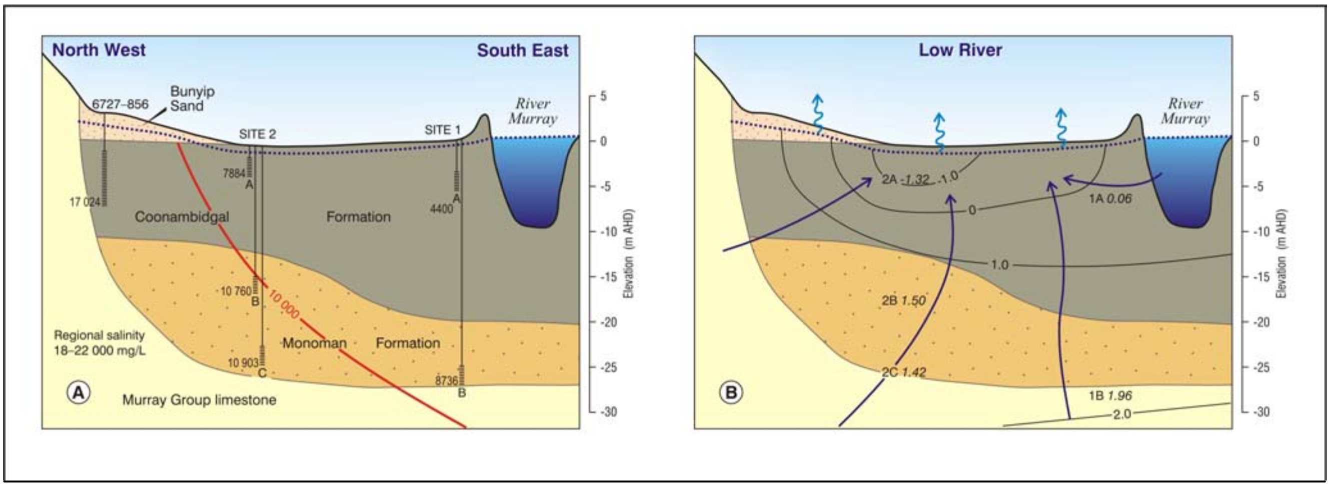


Figure 9. Mobilong hydrogeological section

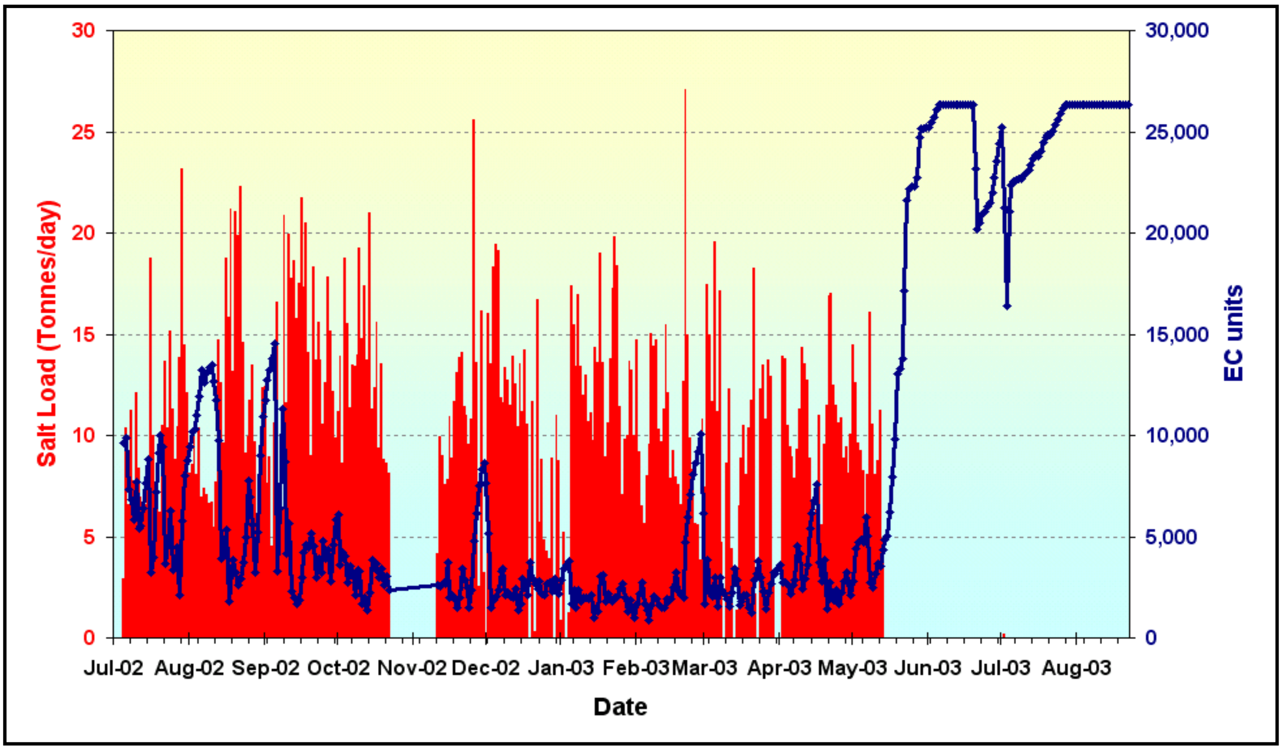


Figure 10. Mobilong drainage EC and salt load

The logger data revealed daily flows of up to 15 ML/day. Salinities of the pumped water varied between 1000 and 25 000 EC, with daily salt loads averaging 10 – 15 tonnes/day with peaks over 20 tonnes/day. Figure 10 shows the calculated saltloads (in red) and EC readings (in blue) from July 2002 to July 2003. When flood irrigation ceases, the water pumped from the drains is predominantly groundwater, as indicated by the higher salinity and lower volumes and the resultant low salt loads to the river. This is especially noticeable after May 2003 when irrigation and pumping through the metered pump ceased. For the remainder of the time when salinities increased (May to July), the unmetered No. 2 Pump was used (66 ML).

Unfortunately, because the volumes of irrigation drainage water aren't known, a simple salt balance can't be used to calculate the groundwater baseflow. From the volumes pumped during non-irrigation periods of high EC, an estimate of 5 tonnes/day may be assumed. Total discharge for 310 days monitored was 2104 ML containing 3250 tonnes of salt.

5.2 Toora

The hydrogeology encountered here is very similar to Mobilong, with sediment thicknesses and salinities much the same (Fig. 11a). Groundwater movement is also similar (Fig. 11b). Despite being of similar or slightly larger area, the daily flows are lower than Mobilong, being only up to 8 ML/day on average. During the irrigation season, Figure 12 shows that salinities (in blue) of the pumped water varied between 1000 and 7000 EC, with daily salt loads (in red) averaging 5 – 7 tonnes/day with peaks over 12 tonnes/day. When irrigation ceases, salinities quickly rise to about 15 000 EC indicating groundwater flow predominating with a base load of about 2 – 3 tonnes/day. Total discharge for 293 days monitored was 2331 ML containing 4200 tonnes of salt.

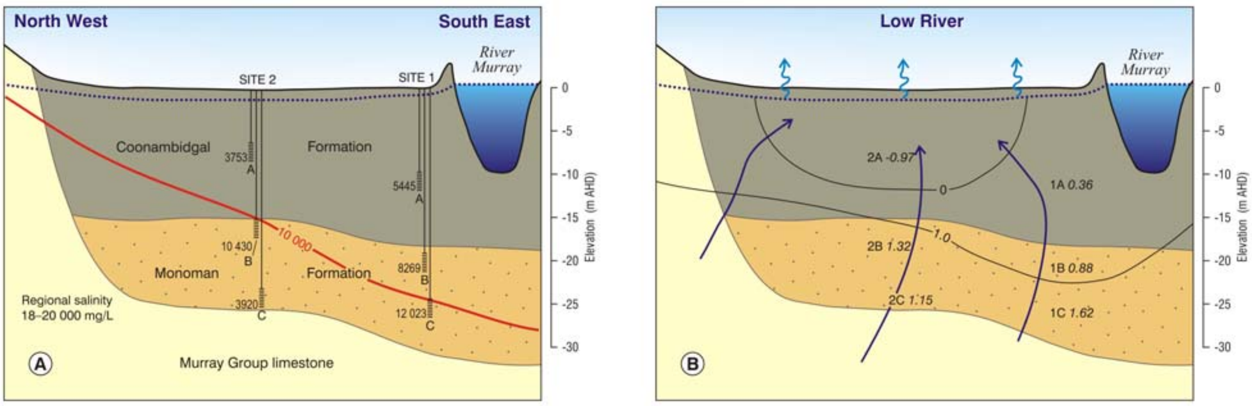


Figure 11. Toora hydrogeological section

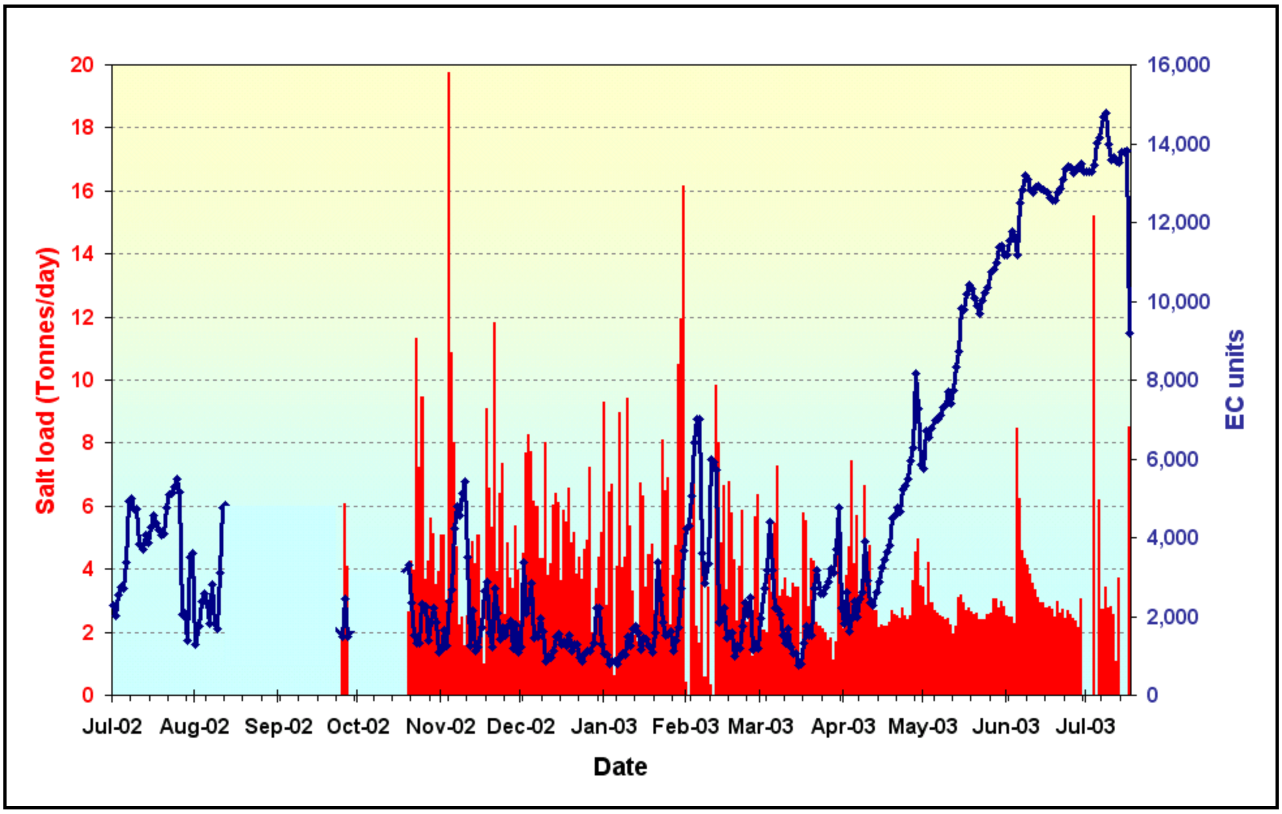


Figure 12. Toora drainage EC and salt load

5.3 Mypolonga South

Again, a similar hydrogeology to previous sites was encountered, with some interesting differences. The highland irrigation induced watertable mound has resulted in stronger lateral groundwater flow into the floodplain and higher than normal water levels as shown in the flow net and watertable elevations in Figure 13b. This has led to the salinisation of the floodplain south of the township with shallow watertable salinities over 70 000 mg/L, as depicted in Figure 13a. Salt is being concentrated in the floodplain and is not being removed by drainage. Salinities close to the river are quite low, indicating significant recharge from the river.

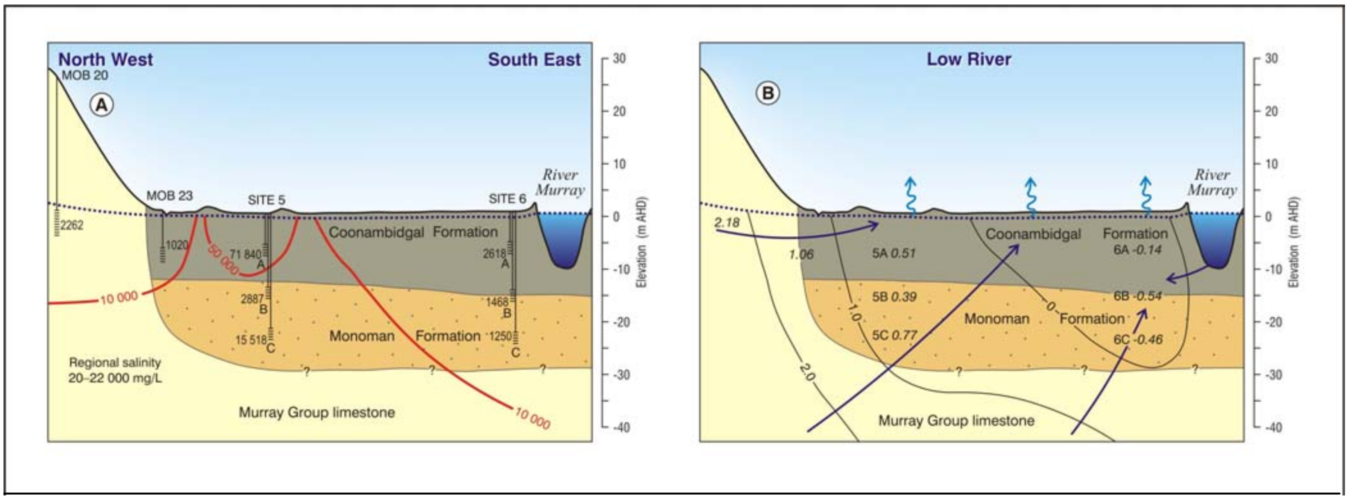


Figure 13. Mypolonga South hydrogeological section

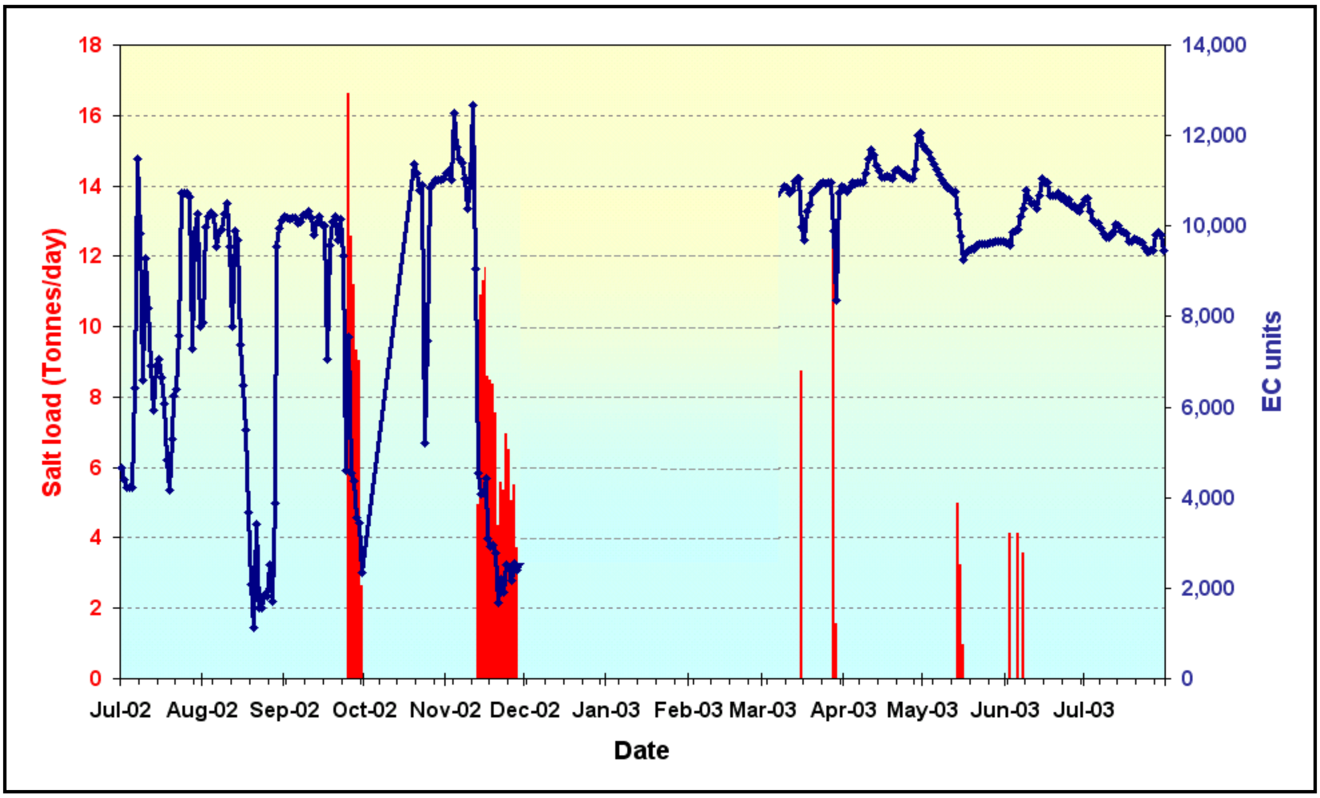


Figure 14. Mypolonga South drainage EC and salt load

Technical difficulties resulted in loss of data for certain periods (Fig. 14). Again, salinities (in blue) of 10 000 EC are associated with non-irrigation periods and groundwater predominating in the drainage channel. Fortunately, pumping to the river during these times is minimal. It is difficult to estimate groundwater inflows from this data, but they must be low due to the lack of pumping during the winter season. Total discharge for 178 days monitored was 104 ML containing 220 tonnes of salt.

5.4 Mypolonga

This transect was drilled earlier in 1982 which shows the ancient river channel almost fully penetrating the Murray Group limestone aquifer in the area known as "The Pound" (Fig. 15). At Site 2, sealed tube cores were taken at 8.0 and 10.0 m depth in the Coonambidgal Formation, and tested for vertical hydraulic conductivity by the E&WS Department Soils and Foundation Section. Low values of 4.0 x 10^{-5} and 5.3 x 10^{-3} m/day respectively, were obtained. The flow nets (Fig. 15b,c,d) show the strong upward vertical gradient through the confining clays and also the discharge from the river to the floodplain at entitlement flows and higher.

The impacts from the watertable mound at Site 4 are restricted by the underlying Coonambidgal Formation and the low elevation of the base of the Pound. Consequently, the shallow lateral flow component to the swamp is less than the Mypolonga South transect and there is no land salinisation. However the deeper pressures are slightly higher than elsewhere and probably indicate influence from the mound through the Monoman Sands. Again, salinities increase with depth. The low salinities of the irrigation drainage water are also seen.

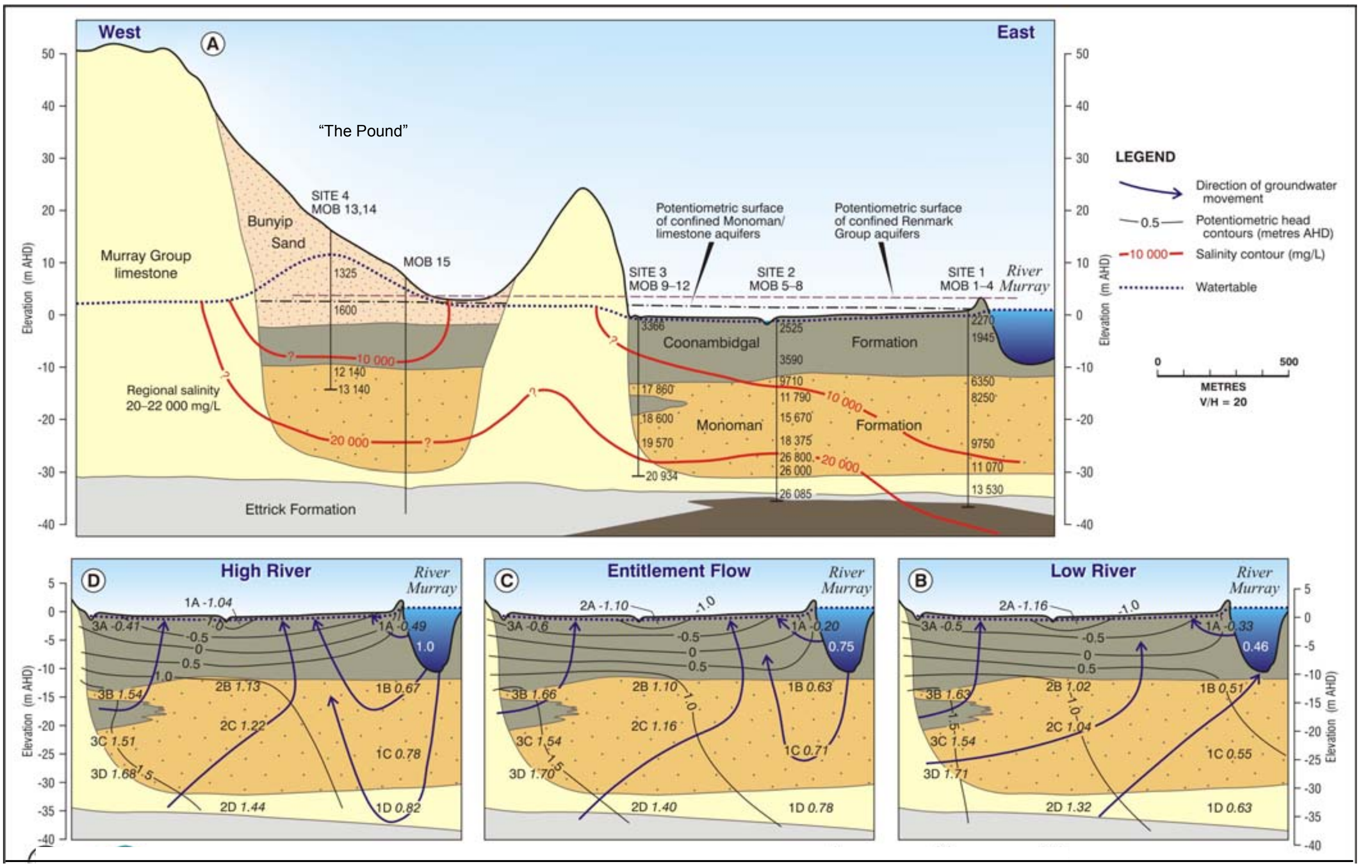


Figure 15. Mypolonga hydrogeological section

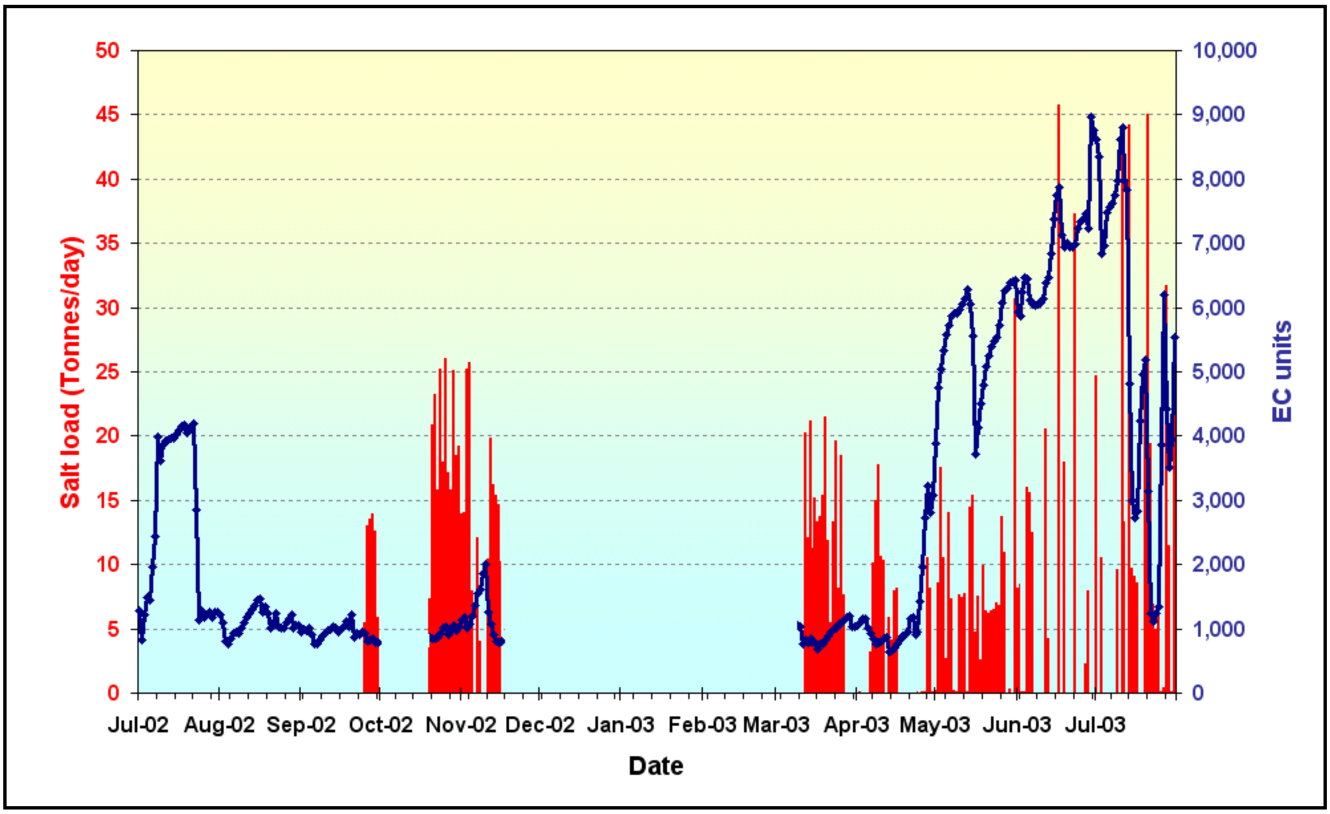


Figure 16. Mypolonga Central drainage EC and salt load

Again, technical difficulties, resulted in an incomplete data set. Saltloads during the winter non-irrigation period of high EC, indicate an average groundwater baseflow of 7.5 tonnes/day. Total discharge for 178 days monitored was 1907 ML containing 1608 tonnes of salt.

6 GROUNDWATER MODELLING

The model of the project area (the Murray Bridge model) was derived from an existing MODFLOW model covering an area from Morgan to Tailem Bend (Barnett et al, 2002). MODFLOW is a three dimensional finite difference groundwater flow model. It is widely used and was developed by the US Geological Survey (McDonald and Harbagh, 1988). In this modelling exercise, the finite difference groundwater flow equations were used to calculate the water level changes associated with the increase in vertical recharge.

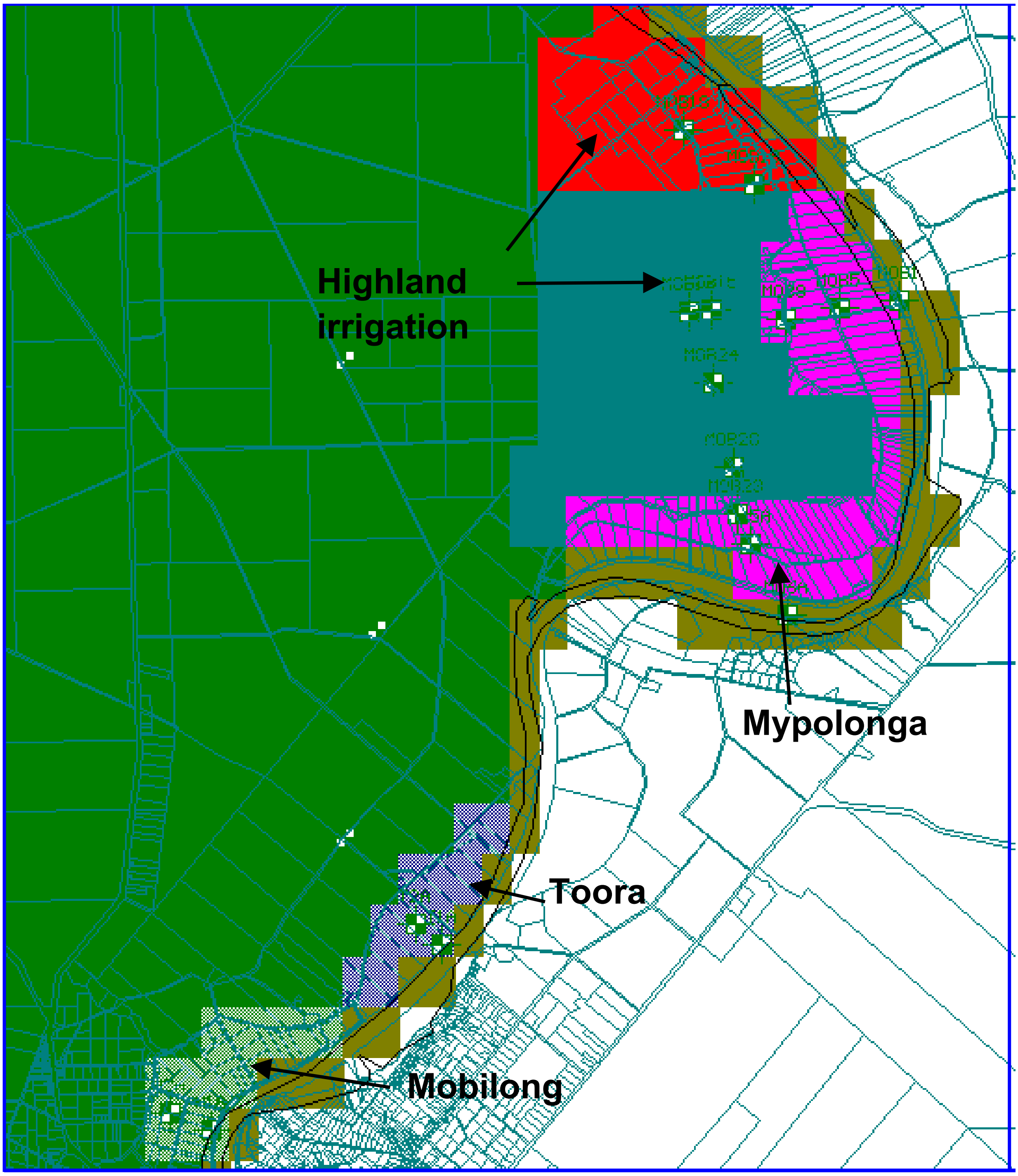


Figure 17. Model grid showing swamps and highland irrigation

The Murray Bridge model is a fairly simple model because of the uncomplicated geology, with land clearing and Mypolonga highland irrigation area the only major changes which have affected the groundwater levels (Fig. 17). The model has a uniform grid size of 323m (east-west direction) by 585m (north-south direction) and uses three layers that are described below with increasing depth.

Layer 1 – Unconfined aquifer

The unconfined aquifer comprises the regional Murray Group limestone aquifer and the floodplain sediments. The eastern model edge, the River Murray, was simulated as a constant head boundary corresponding with the river pool level of 0.75 m AHD. The western edge was represented as a general head boundary that allows flow into the model area. Drain cells were used on the reclaimed swamp area to simulate the real drainage system and evapotranspiration.

Layer 2 - Ettrick Formation confining layer

A low permeability layer, and as only very low volumes of water flow in and out from this layer, no flow boundaries surround the model edges.

Layer 3 - Renmark Group

A confined aquifer with transmissivity values calculated by multiplying the saturated thickness by the uniform hydraulic conductivity of 1 m/day. Fixed head cells were used to simulate the potentiometric head distribution observed in the aquifer.

6.1 Recharge Rates

The increase in recharge rates due to irrigation and following clearing are the key processes driving the increase in salt loads to the river. These rates vary with time since the establishment of irrigation and clearing, the depth to the water table, and soil type.

In dryland areas, recharge values were based on Cook (1989), namely 0.1 mm/year before clearance and then increasing to about 8 mm/year at year 2000, assuming an average depth to the watertable of 45 m, and a 25 year time lag between clearing and the commencement of watertable rise.

Irrigation drainage rates from the highland irrigation area were obtained from the Mypolonga Land and Water Management Plan (Australian Water Environments, 2001). A volume of 1140 ML/year was adopted which converted to an average recharge rate of 200 mm/year from 1920 to 2000. The regional groundwater discharge volumes to the edge of the floodplain at the swamps are shown below (solid line Figs 18 and 19).

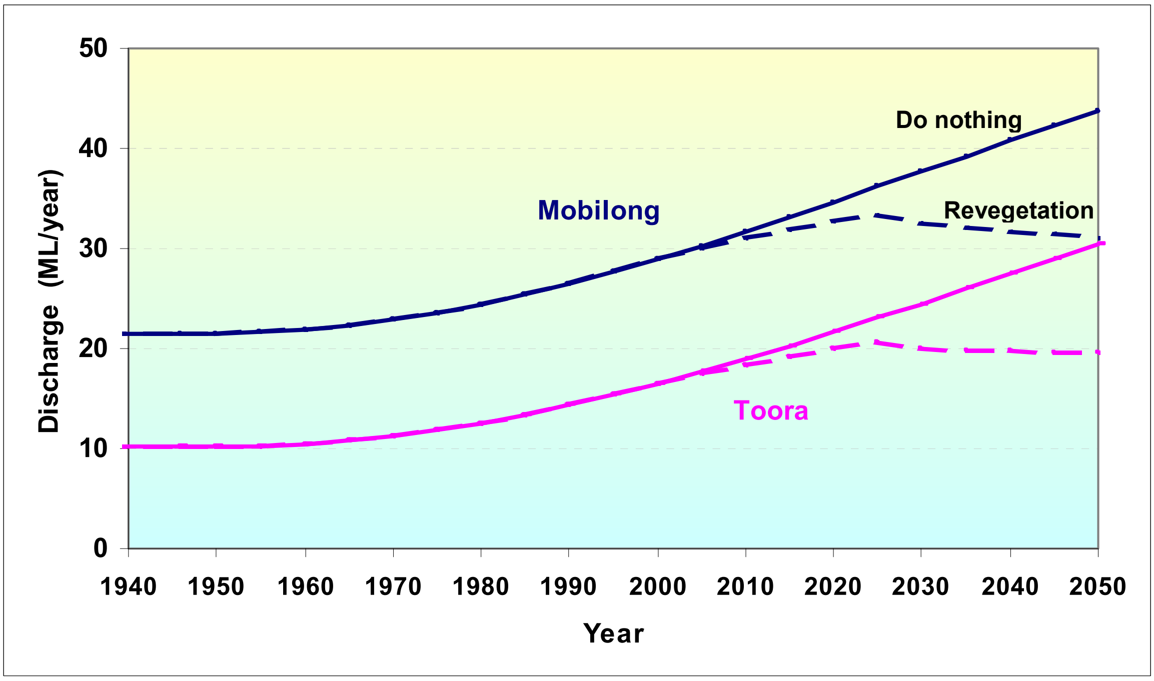


Figure 18. Regional groundwater discharge to floodplain at Toora and Mobilong

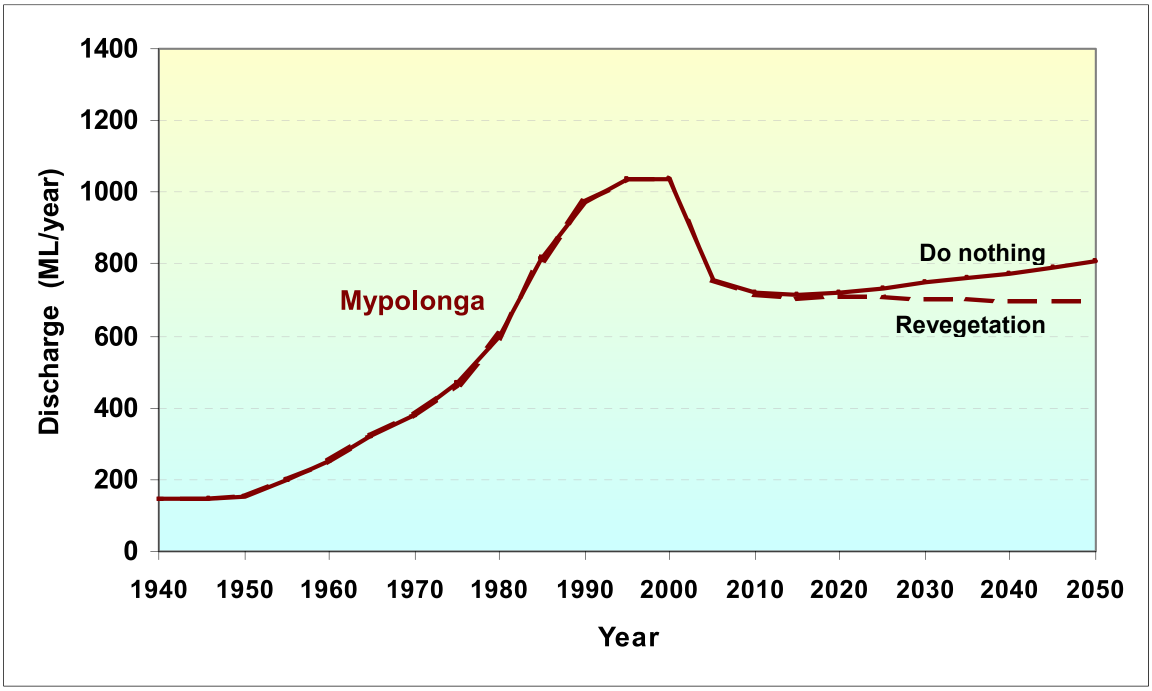


Figure 19. Regional groundwater discharge to floodplain at Mypolonga

A gradual rise in discharge can be seen as the watertable slowly rises. No evidence for such rises has been seen so far in areas away from the highland irrigation areas, suggesting that the time lag may be longer than first thought. Mypolonga shows the delayed impact of irrigation drainage that is being reduced by rehabilitation and irrigation efficiency gains. However the long term rising trend due to clearing continues into the future.

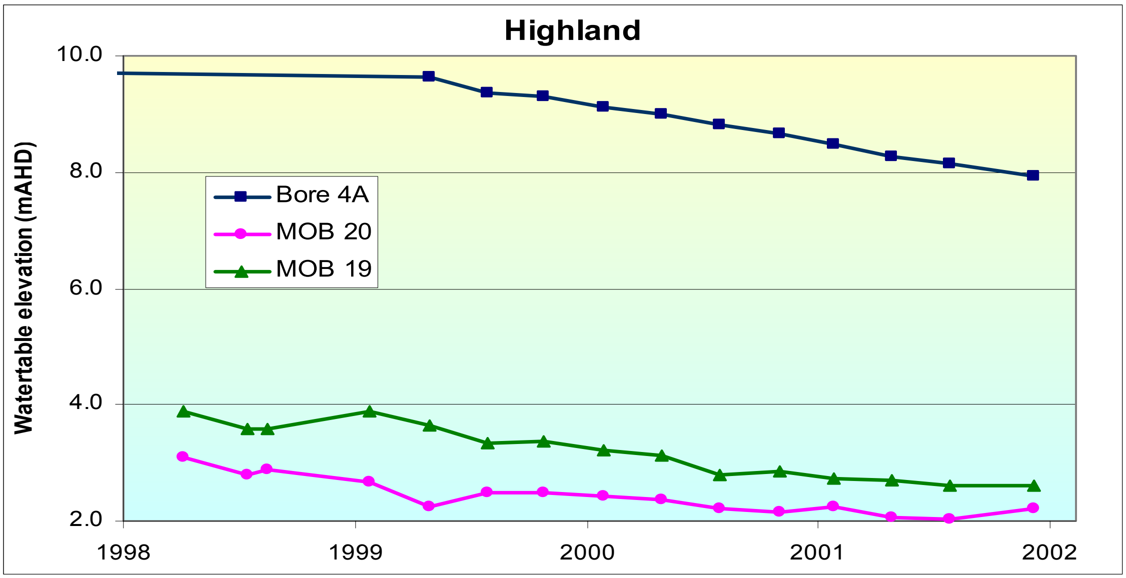
In order to simulate the impact of a revegetation exercise to reduce future dryland saltloads to the floodplain, recharge was reduced by 60 % from the current cleared rate over the whole highland area outside the irrigation areas (dark green area in Fig. 17). Assuming that revegetation occurred instantly now, a time lag of 25 years was allowed for the recharge reduction to impact on the watertable.

The dashed line in Figures 18 and 19 show that revegetation over the whole area now, would stabilise the discharge at whatever rate it would be in 25 years time (or however long it takes for the impacts to reach down to the watertable). No reduction in discharge to the floodplain is predicted. At Toora, the stabilised discharge after revegetation would be about double the preclearing discharge rate. At Mobilong, it would be 50 % greater. Obviously, the benefits from such a huge undertaking would take decades to become apparent and would not be of a magnitude to warrant the expenditure.

7 GROUNDWATER MONITORING

Monitoring of the observation wells in Figure 15 was carried out over 1983-84 to observe a high river flow, before ceasing due to being a low priority at the time. Monitoring recommenced in 1998 (together with drilling of new bores in the highland area) to monitor the impacts of rehabilitation of the highland water delivery infrastructure.

Comparison of trends for highland and floodplain observation wells at Mypolonga (Fig. 20) has reiterated the connection between the watertable mound beneath the highland at Site 4, and the adjacent floodplain at Site 3 (locations in Fig. 15). Rehabilitation has reduced leakage and drainage to the watertable beneath the irrigated areas, with a consequent decrease in mound elevation of 1 – 2 m at Site 4 where the watertable lies at a depth of 7 m in deep sand. The pressures at Site 3 have been reduced by 0.5 m. The watertable is unaffected as it is controlled by drainage and shows a slight seasonal pattern.



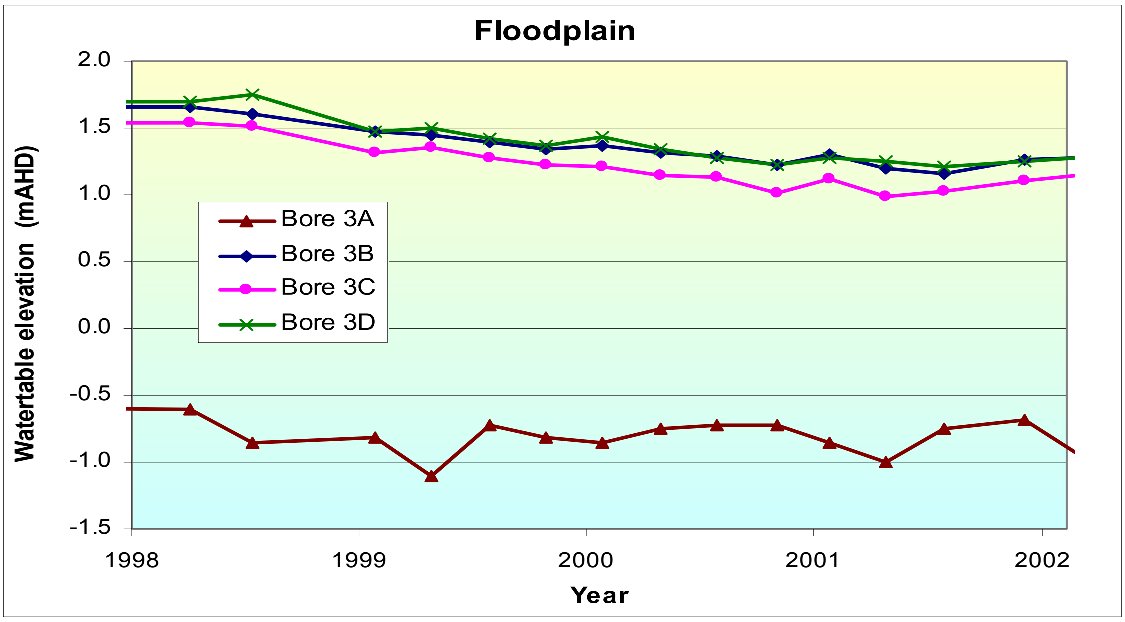


Figure 20. Hydrographs of Mypolonga observation wells

8 SURFACE WATER CONTRIBUTION

Initially, it was hoped to predict stream runoff volumes by using a modelling framework and comparing the model results with data from stream gauging sites. However the modelling exercise was severely hampered by lack of calibrated stream gauging information. Several rainfall/runoff models were applied with some success, but better results are anticipated by using a model that takes rainfall intensity into account.

The ability to estimate flows and salt contribution to the area is limited by the lack of adequate gauged flow information. Streamflow data is available at three stations on Rocky Gully and Preamimma Creeks for the period 1975 to 1991, but this is limited to water level only (Fig. 21). The stations were not rated and so no flow volume data is available. These stations were closed in 1992.

Data indicates that annual rainfall in the catchments is low, ranging from 300 to 500 mm and as a result, runoff is low. Higher in the catchment, winter runoff appears to occur in most years but the flow rapidly reduces downstream. Events of significant magnitude do occur, but are more likely linked to more intense storm events rather than winter rainfall. Over the 16 years of data, three significant events occurred with water levels of greater than 0.5 m recorded flowing over the weir structure. For the remainder of the record, typical peak flows in a season rarely exceeded depths of 200 mm.

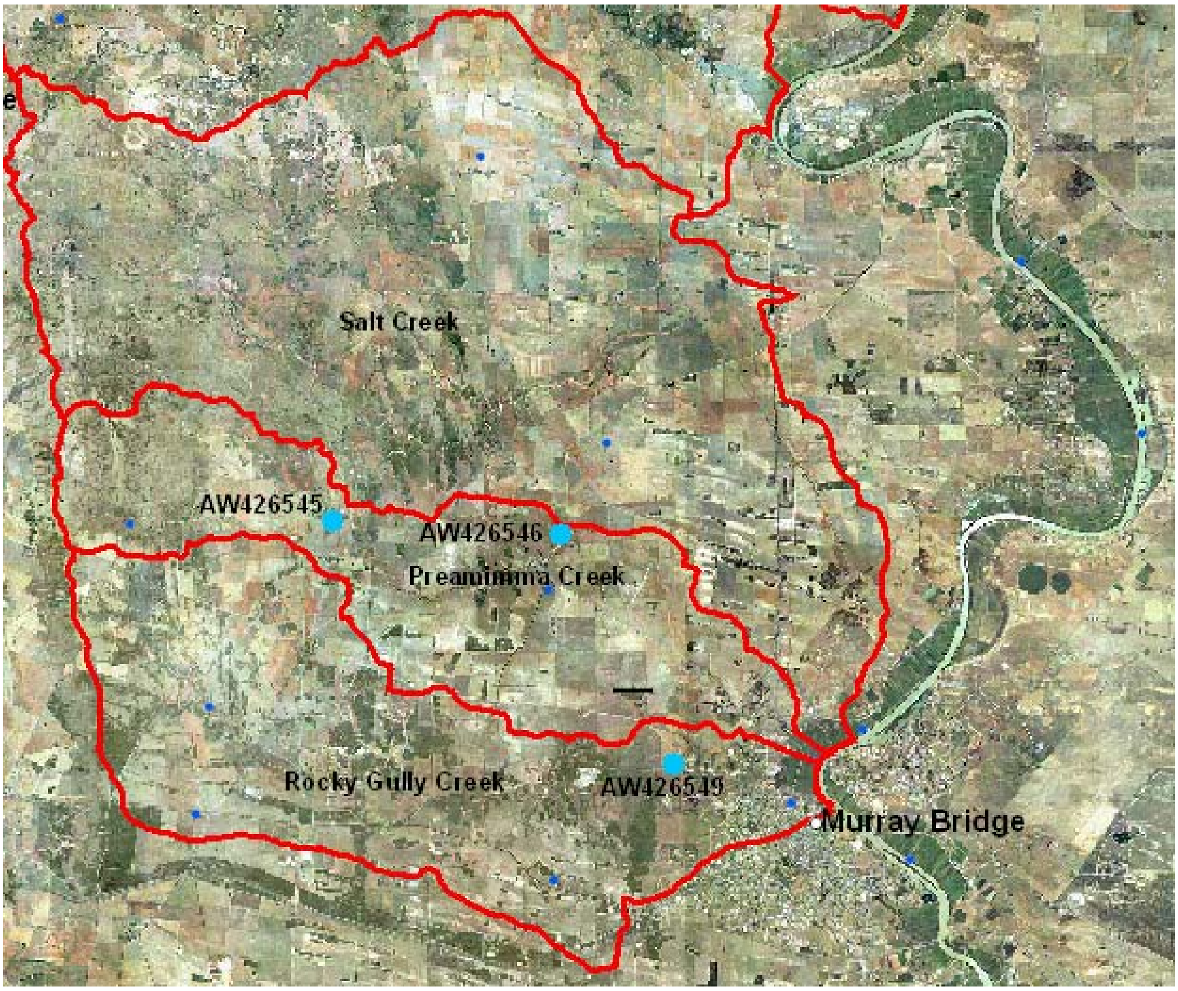


Figure 21. Location of gauging stations

Low runoff and significant losses ensure that only very rare events in Rocky Gully and Preamimma Creek would reach the River Murray floodplain. Losses in Salt Creek appear to be higher, as flows infiltrating through sandy soils have created a zone of lower than normal salinity (<5000 mg/l) in the limestone aquifer.

The CSIRO Milestone 4 report calculated theoretical salt outputs for the catchments in question based on comparisons with adjacent but wetter catchments. While significant areas of the Mt Barker and Bremer River catchments have similar rainfall to Salt and Preamimma Creeks, they also have far wetter headwaters located high in the Mt Lofty Ranges. As a consequence, the flow and salinity recorded leaving these catchments is more aligned with the wetter regions of the ranges and not ideally suited to estimate the flow and salinity influences of an arid catchment.

The consequence of using wetter catchments (ie. exaggerating the runoff) is a significant over estimation of the salt output to salt input ratios for the creeks in question. It is suggested that this ratio for Rocky Gully, Salt and Preamimma Creeks should be no worse and perhaps less than that of the wetter catchments. The salt is being concentrated in the landscape in areas of dryland salinisation, rather than being exported in streamflow which seldom reaches the Murray River.

9 CONCLUSIONS & RECOMMENDATIONS

The project has more clearly defined the hydrogeology of three swamps (Mypolonga, Mobilong and Toora) that were earlier thought to contribute about 70 000 tonnes of salt per year to the river from regional groundwater. Actual salt loads being returned to the river were measured accurately by metering the volumes and salinity of drainage water pumped back to the river by four pumping stations, with results projected for a whole water year presented in Table 2.

Table 2. Summary of salt inflows to river (tonnes/yr)

Swamp	Irrigation drainage	Groundwater	Ratio (ID : GW)
Mobilong	1145	1825	45 : 55
Toora	3350	900	80 : 20
Mypolonga South	400	100	80 : 20
Mypolonga Central	1450	2750	35 : 65
TOTAL	**6345**	**5575**	55 : 45

The results show far less saltload contribution from these swamps than indicated by the earlier study. Of interest is the low saltloads from the Mypolonga South drain which may be attributed to the salt being stored in the floodplain beneath the salinised area. Conversely, the higher groundwater saltloads at Mypolonga Central could be driven by the watertable mound beneath the highland irrigation.

The figures also give an indication of the overall irrigation efficiency of the swamps, with those having a higher groundwater component exhibiting greater irrigation efficiencies resulting in lower volumes of irrigation drainage.

Groundwater modelling suggests a gradual ongoing rise in regional groundwater inflows to the swamps as the increased recharge following clearing percolates down and causes a rise in the regional watertable. In the unlikely event that widespread revegetation could occur now, it would take about 25 years for the impacts to reach down to the watertable. Even then, revegetation would only stabilise the inflows at whatever rate it would be in 25 years time. No reduction in discharge to the floodplain is predicted.

Saltload contributions from surface water are minimal because low runoff (due to the rain shadow effect) and significant losses ensure that only very rare events in Rocky Gully and Preamimma Creek would reach the River Murray floodplain. The salt is being concentrated in the hills landscape in areas of dryland salinisation, rather than being exported from the catchments in streamflow.

The outcomes from this project will be considered in an options analysis of appropriate management strategies (eg drainage water reuse, land retirement) to mitigate the salinity impacts of land use change on the swamps. Monitoring of groundwater levels and drainage should continue in order to determine their responses to these imminent changes in land use.

10 REFERENCES

Australian Water Environments, 2001. Mypolonga/Woodlane Highland Irrigation District Land and Water Management Plan - Stage 1. For Mannum to Wellington Local Action Planning Committee.

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McDonald, M.G. and Harbaugh, A.W., 1988. A modular three-dimensional finite difference groundwater flow model. United States. Geological Survey. Open file report, 83-875.

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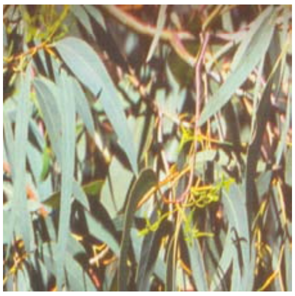
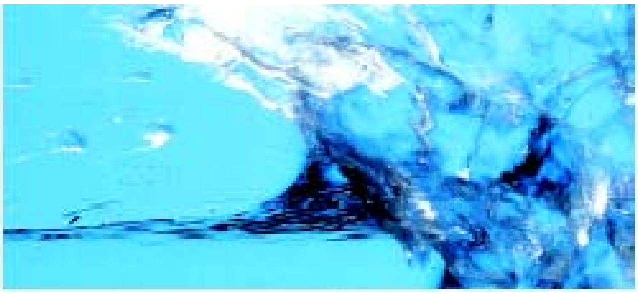
11 APPENDIX A





GEOLOGICAL LOGS

The Department of Water, Land and Biodiversity Conservation

GROUNDWATER PROGRAM

WATER WELL LOG

PROJECT: MOBILONG 1B

PERMIT No. 61615

UNIT No.

Hundred: Mobilong **Sec:** 1195

Coordinates: E 342803 N 6113892 El. Surface(m) El. Ref. Point(m) Datum:

AQUIFER SUMMARY	DEPTH TO WATER CUT (m)	DEPTH TO STANDING WATER (m)	INTERVAL (m) From	INTERVAL (m) To	SUPPLY L/sec	SUPPLY Test length	SUPPLY Method	TOTAL DISSOLVED SOLIDS mg/L	TOTAL DISSOLVED SOLIDS Analysis No.
	24.5	1.58 (TOC)						8736	

DEPTH (m) From	DEPTH (m) To	GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	Depth Core Sample	CASING Dia (mm.)	CASING From (m)	CASING To (m)
0.0	0.9		CLAY	Brown-black clay. Stiff, high density, low-moderate plasticity. 0.9 - 1.2m Green-grey clay as above.	COONAMBIDGAL FORMATION		80	0.0	24.5
1.2	4.0		CLAYEY SILT	Interbedded green-brown clayey silt, incompetent, slimy and brown-grey clay, stiff, low plasticity, moderate density.					
4.0	19.0		CLAY	Green-grey clay. Soft, low density, high plasticity, sticky, greasy. Visible muscovite Minor shell fragments (<10mm). Organic matter.					
19.0	20.0		CLAYEY SAND	Blue-grey clayey sand. Fine-grained silty quartz sand, well rounded-subangular, moderate-high sphericity, moderate-well sorted, mica flakes.	MONOMAN FORMATION				
20.0	26.5		SAND	Light brown quartz sand. Fine-grained, moderate-well sorted, subrounded-subangular, moderate sphericity. Minor mica and opaques. Becoming coarser with depth 23.0 - 24.0m medium grained 24.0 - 25.0m gravely medium to coarse-grained sands, poorly sorted					
26.5	29.0		LIMESTONE	Light yellow-brown sandy, fossiliferous, unconsolidated	MURRAY GROUP LST				

REMARKS: **MOBILONG 1B**

DRILL TYPE: Blade

COMPLETED: 23/4/2003

DRILL FLUID: Mud

LOGGED BY: T. Wilson

The Department of Water, Land and Biodiversity Conservation

GROUNDWATER PROGRAM

WATER WELL LOG

PROJECT: TOORA 2C	
PERMIT No. 61613	
UNIT No.	
Hundred: Mobilong	**Sec:** Pt 458

Coordinates: E 345159 N 6116243 | El. Surface (m) | El. Ref. Point (m) | Datum:

AQUIFER SUMMARY	DEPTH TO WATER CUT (m)	DEPTH TO STANDING WATER (m)	INTERVAL (m)		SUPPLY			TOTAL DISSOLVED SOLIDS	
			From	To	L/sec	Test length	Method	mg/L	Analysis No.
	23.0	1.21 (TOC)						3920 Not representative	

DEPTH (m)		GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	Depth Core Sample	CASING		
From	To						Dia (mm)	From (m)	To (m)
0.0	15.0		CLAY	Black-brown clay. Stiff, low plasticity, high density, sticky. Organic material. 2.0 – 9.0m Light blue-grey clay as above 8.0 – 9.0m Very minor shell fragments.	COONAMBIDGAL FORMATION		80	0	25
15.0	23.8		SAND	Light brown quartz sand. Fine-grained, poorly sorted, subrounded-subangular, moderate sphericity, shell fragments. Minor opaques and mica. Becoming coarser with depth. 20.0 – 22.5m Medium grained, occasional hard layers 22.5 – 23.8m Medium-coarse grained sands and fine gravels	MONOMAN FORMATION				
23.8	25.0		LIMESTONE	Light yellow-brown sandy, fossiliferous, unconsolidated	MURRAY GROUP LST				

REMARKS: **TOORA 2C**	DRILL TYPE: Blade	COMPLETED: 19/4/2003
	DRILL FLUID: Mud	LOGGED BY: T. Wilson

The Department of Water, Land and Biodiversity Conservation

GROUNDWATER PROGRAM

WATER WELL LOG

PROJECT: MYPOLONGA 6C

PERMIT No. 61626

UNIT No.

Hundred: Mobilong **Sec:** 624

Coordinates: E El. Surface(m) El. Ref. Point(m) Datum:

AQUIFER SUMMARY	DEPTH TO WATER CUT (m)	DEPTH TO STANDING WATER (m)	INTERVAL (m)		SUPPLY			TOTAL DISSOLVED SOLIDS	
			From	To	L/sec	Test length	Method	mg/L	Analysis No.
	23.0	3.67 (TOC)						1250	

DEPTH (m)		GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	Depth Core Sample	CASING		
From	To						Dia (mm)	From (m)	To (m)
0.0	15.0		CLAY	Black-brown clay. Stiff, low plasticity, high density, sticky. Organic material. 2.0 – 9.0m Light green-grey clay as above 11.0 – 14.0m Very minor shell fragments, abundant organic matter.	COONAMBIDGAL FORMATION		80	0	25
15.0	20.0		CLAYEY SAND	Brown-grey clayey quartz sand. Fine-grained, subangular-subrounded, moderate-high sphericity, well sorted. Minor opaques and mica. Shell fragments.	MONOMAN FORMATION				
20.0	25.0		SAND	Light brown quartz sand. Fine to medium grained, moderately sorted, subrounded-subangular, moderate sphericity, shell fragments. Minor opaques and mica. Becoming coarser with depth. 24.0 – 25.0m Grey-brown gravely sand, poorly sorted.					

REMARKS: : **MYPOLONGA 6C**

DRILL TYPE: Blade

COMPLETED: 24/4/2003

DRILL FLUID: Mud

LOGGED BY: Z. Marsden