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The Impact of Irrigation on Floodplain Vegetation Health adjacent to the River Murray

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SUMMARY: Irrigation occurs adjacent to approximately 50% of the River Murray floodplain. This paper summarises the results of the first surveys to be undertaken to assess and isolate the impact of highland irrigation on floodplain vegetation adjacent Loxton and Bookpurnong/Lock 4 Irrigation Districts in South Australia's Riverland region. The surveys indicate that irrigation 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 occurs following ten to twenty years of large-scale irrigation. Vegetation communities have changed on the floodplain, and regeneration does occur. The regeneration is thought to coincide with floods in 1956 and 1972. However, the longevity of the regeneration is not assured, with some regeneration wiped out quite recently. The major cause of tree health decline appears to be increased groundwater levels under the floodplains due to the discharge of irrigation drainage water from the irrigation areas. However, the role of reduced flooding cannot be dismissed as a complementary causal factor. The prognosis for tree health in the river valley in South Australia is grim, particularly in the Riverland region. This prognosis is further worsened by the potential impacts of the current rapid expansion in the viticulture industry adjacent the river throughout the region, and particularly in areas where irrigation has hitherto been essentially absent. A systematic review of tree health along the river's length, and continued examination of the relative influences of degradative processes, are essential elements in determining both causes and ameliorative strategies. The use of groundwater interception schemes to simultaneously reduce salt loads to the river and provide for improvements in vegetation health appear feasible at some locations. Regulatory land use controls are recommended to protect the floodplains from the adverse impacts of irrigation.

THE MAIN POINTS OF THIS PAPER

- Irrigation occurs adjacent to approximately 50% of the River Murray floodplain.
- This paper summarises the results of the first surveys to be undertaken to assess and isolate the impact of irrigation on floodplain vegetation.
- The major cause of tree health decline appears to be increased groundwater levels under the floodplains due to the discharge of irrigation drainage water from the irrigation areas.
- The prognosis for tree health in the river valley in South Australia is grim, particularly in the Riverland region.
- A systematic review of tree health along the river's length, and continued examination of the relative influences of degradative processes, are essential elements in determining causes and ameliorative strategies.

1. INTRODUCTION AND BACKGROUND

This paper draws on detailed site inspections adjacent the Loxton and Bookpurnong/Lock 4 irrigation areas. The results from the Bookpurnong/Lock 4 area are used to illustrate the methodology and results.

The Bookpurnong/Lock 4 Irrigation District is part of the Riverland region in South Australia (Figure 1). The dominant industry within the region is irrigated horticulture with approximately 1,100 ha of land currently under irrigation.

Irrigation development throughout much of the Murray Darling Basin has resulted in a decline in the health of natural ecosystems. Those areas exhibiting the most extensive signs of degradation correlate to the regions with the longest, most extensive history of irrigation (Bone and Davies, 1992). Throughout the South Australian sector of the Riverland approximately 43% of the river banks are estimated to be negatively influenced by irrigated horticulture, and large regions of adjacent floodplains are at risk of further degradation (Bone and Davies, 1992). The irrigated areas have increased significantly over the last seven years.

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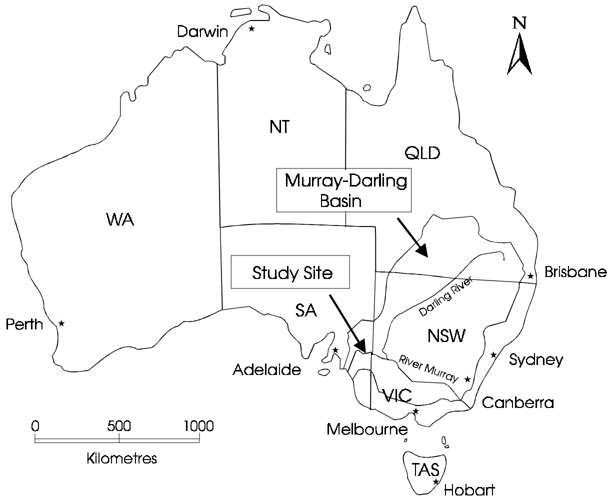

Figure 1 Location map

The introduction of river regulation in the 1920's resulted in subsequent degradative impacts on the local environment including a decline in the frequency of floodplain inundation and a rise in the saline water tables. Irrigation development adjacent to the floodplain has resulted in the development of a groundwater mound, which inturn has lead to an increase in river salinity due to the increased saline groundwater discharges from the mound. The compounding effect of river regulation and increased irrigation increases the rate of evaporation and salt accumulation in floodplain soil profiles (Bone and Davies, 1992; Jolly, 1995). These changes have led to a decline in the health of native vegetation communities as a direct result of osmotic and soil moisture stress.

In 1997 and 1998, two studies were undertaken for the Loxton to Bookpurnong Local Action Planning Association Inc. The results discussed in this paper relate to assessment of the floodplain vegetation communities adjacent the Bookpurnong irrigation districts, and particularly intends to identify the areas of floodplain that have been degraded as a direct result of irrigation in the region.

2. STUDY OBJECTIVES, APPROACH AND METHODOLOGY

The primary **objectives** of the studies were to:

- Document the current status and the historical trends in vegetation health and community structure.
- Identify the processes affecting vegetation health on the floodplain, including dominant processes where evident.
- Estimate future trends in vegetation health resulting from current and alternative future irrigation management options.
- Provide a preliminary assessment of options for reducing future degradation.

The **approach** adopted in the studies was to develop an understanding of the processes leading to degradation, and isolate the impacts attributable to irrigation. The ability to predict changes in vegetation health depends on this understanding.

To summarise the **methodology**, floodplain condition was mapped and then compared to historical information and groundwater and flooding information. The patterns of degradation were compared to hydrologic and hydrogeologic patterns, and conclusions as to the causes of degradation were then deduced. The methodology is presented in detail in PPK (1998).

The mapping process produced three vegetation maps of the Bookpurnong riparian vegetation at a scale of 1:10,000, one for each year of the historical record. The vegetation was mapped for communities that exhibit the major overstorey species and their associations. There was no restriction on the type of groundcover in the area, but where multiple potential classes occurred, classes were based on the dominant vegetation community and the overall impression of the area. For example, where trees had died but regeneration had occurred, the regenerating community was recorded. Similarly, the type of vegetation community present, rather than observation of an actual water body often indicated the presence of water. Vegetation communities that indicate the presence of water include dead Redgums or reeds.

Correlations were developed between the patterns of degradation and:

- various environmental parameters;
- the timing and pattern of vegetation degradation; and
- the timing and patterns of land management practices such as irrigation, changes to flood frequency, grazing history, floodplain irrigation and logging.

If correlations were identified between irrigation activity and vegetation degradation, then modelled changes in groundwater discharges (for future options) are used to estimate the potential environmental improvement.

3. THE SITE

Bookpurnong Irrigation District comprises primarily private irrigators, with more than 1,100 ha of irrigated land planted to vegetables and nut crops, pome/stone fruit, vines and citrus.

The site and vegetation health are shown in Figure 2

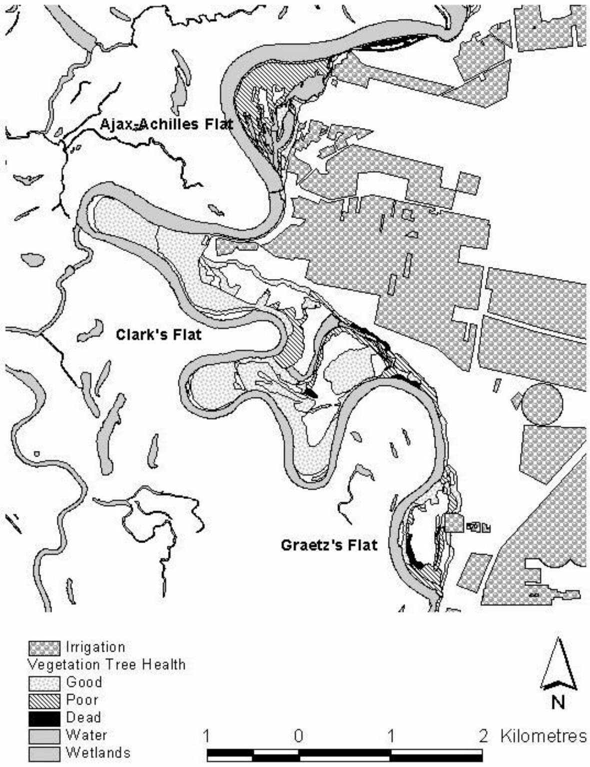

Figure 2 Bookpurnong Floodplain Tree Health 1998

The introduction of irrigation within the Bookpurnong/Lock 4 area has resulted in an elevated rate of recharge of water into the subsoil that is much greater than the recharge rate that existed under natural conditions. As a result, a shallow perched watertable on a low permeability soil base has formed, which has instigated drainage problems within the area (Woodward-Clyde 1998).

A major impact of the perched drainage water is waterlogging within the root zone and increased soil salinisation. Both factors result in a decline in agricultural productivity and long term degradation of the soil profile. The drainage water has also caused the development of a groundwater mound in the Loxton Sands aquifer, which in turn promotes discharge of water from the cliff-face and increased water levels within the Monoman Formation aquifer on the floodplain.

The above impacts all lead ultimately to substantial financial, ecological and aesthetic losses. In addition, cliff seepage causes cliff erosion and floodplain waterlogging. Cliff seepage has negatively impacted on the health of Clark's Flat in recent times.

A brief chronological history of events related to irrigation and drainage developments in the Bookpurnong Irrigation Area is presented in Table 1.

Table 1: Chronology of Irrigation and Drainage

Year	Event
1921-23	Small scale irrigation implemented at Graetz's Flat.
1950	Major irrigation area development commences.
1965	Waterlogging emerges and first two drainage bores constructed.
1970	Cliff seepage becomes evident at Clark's Flat – volume unknown.
1976	Salt load to River Murray and flood plain increases markedly.
1976-85	Eight more drainage bores installed.
1990	Rate of irrigation development increases.
1993	Diversion volume reached 8 GL.

4. HYDROGEOLOGY

The region is underlain by the Upper Pliocene Sands (regional unconfined aquifer), Lower Pliocene Sands, Bookpurnong Beds (regional aquitard), Monoman Sands, (alluvial aquifer), Murray Group Limestone (regional confined aquifer) (Woodward-Clyde 1998, Watkins, 1992). The major geological units are the Blanchetown Clay, Loxton Sands, Bookpurnong Beds, Winnambool Formation, Morgan Limestone, Coonambidgal Formation and Monoman Formation (Watkins, 1992).

The geological composition below the Bookpurnong/Lock 4 area is consistent with that found throughout the eastern Riverland region and comprises the geological units as described in Table 2.

Prior to settlement, the Pliocene Sands water table aquifer discharged saline groundwater to the floodplain (Woodward-Clyde 1998). The salinity of the groundwater in the regional watertable aquifer is in excess of 22,000 mg/L. A proportion of the discharge infiltrates the River Murray since the river is incised into the alluvial Monoman Sands aquifer.

Increased salinity in the River is also affected by the displacement of saline native groundwater within the Monoman Sands aquifer downstream of the Lock, because of the hydraulic gradient that exists between the upper and lower pool level.

A groundwater mound has formed below the irrigated areas due to the recharge of excess drainage water. The mound forms a pressure head and as a result, naturally occurring saline groundwater is discharged to the river and floodplain along the area of increased hydraulic gradient. Increased waterlogging and salinisation of the floodplain and increased salinity of the river has therefore occurred adjacent the mound. Bone and Davies, (1992) suggested that as the groundwater mound developed, the increased pressure raised the watertable beneath the floodplain resulting in salinisation of the rootzone of the riparian vegetation and hence a decrease in health. This hypothesis is supported by PPK (1997) and PPK (1998) in the assessment of the factors influencing vegetation health adjacent the Loxton Irrigation Area and Bookpurnong/Lock 4 Irrigation Area. The estimated historical trends in major components of the salt and water balance for the Bookpurnong area (Woodward-Clyde, 1998) indicates that the volume of irrigation diversion was around 1 GL/a in 1972, increasing to 4 GL/a in 1985 and 8 GL/a in 1996. Cliff seepage is likely to have increased in parallel with the diversion volumes, although probably lagging by a few years. Irrigation diversions are continuing to increase rapidly, and it is therefore expected that discharge to the floodplain and cliff seepage will also continue to increase over the next decade.

Table 2: Hydrogeology

Unit	Lithology	Hydrogeology
Monoman Formation	Alluvial sand deposits within the river valley	High permeability aquifer
Woorinen Sands	Surficial red-brown dune sands of wind blown origin	Permeable
Carbonate Soils	Fine lime in a clayey soil and medium to highly impermeable compact mixtures of fine and rubbly lime and loamy soil	Low permeability soil layer
Blanchetown Clay	Clays and sandy clays with gypsum and occasional thin limestones. Red-brown lower member, grey-green upper member	Low permeability clay. Responsible for development of perched waterlogging
Pliocene Sands	Fine to coarse grained upper sand unit and a lower fine grained silty sand unit. Kaolinitic? layers observed	Unconfined water table aquifer
Bookpurnong Beds	Micaceous glauconitic marls and fine silty sands	Vertical aquitard with poor horizontal sub-aquifers
Murray Group Limestone	Marly limestone and bryozoal, limestone, fossiliferous	Regional confined limestone aquifer

The groundwater mound has also led to increases in discharge of water (and salt loads) to the river. River salt loads adjacent the irrigation area (between river distances 502 km and 521 km) have been measured at 51 t/day. A flow net analysis of the groundwater levels and salinities (Woodward-Clyde, 1998) indicated that 56 t/day (20,600 t/annum) is discharging into the same reach. The salt loads are significant, and a salt interception scheme has been proposed for Clark's Flat.

The hydrogeological degradation issues for the Bookpurnong/Lock 4 Irrigation District can be summarised as follows:

- Groundwater recharge has increased as a result of inefficient irrigation infrastructure and management practices, causing a groundwater mound in the Loxton Sands aquifer.
- The groundwater mound is displacing saline groundwater, causing waterlogging and vegetation degradation on the floodplain.
- The groundwater mound is also causing increases in salt loads to the River Murray.

5. HYDROLOGY

The River Murray catchment upstream from the study site covers an area of approximately one million square kilometres. In South Australia the River Murray is managed primarily as a domestic, stock and industrial water supply and to supply water for irrigation purposes. The River Murray supplies the primary water source for irrigation and domestic water use in the Loxton area. River regulation commenced in 1922 (Suter et al. 1993) and resulted in a system whereby there was a continuous supply of river water for these purposes.

The alteration in hydrological regime through river regulation has resulted in the decline of riparian vegetation health along the River Murray. Some of the impacts of river regulation have been summarised in the SA River Murray Wetlands Ten Year Plan (SARMWMC, 1996) as follows:

- reduction in the height and frequency of medium and large floods;**{** TC "Figure 2.6" \f F \l "4" **}{** TC "Figure 2.7" \f F \l "4" **}**
- reduction in the frequency and average duration of floodplain inundation;
- alteration of seasonality of flooding from winter to autumn;
- increase in rate of fall of river levels following flooding;
- permanent inundation upstream of Locks of previously temporary wetlands;
- elevation in saline water tables, and mobilisation of groundwater flows into the river caused by the hydraulic pressure of differential water levels either side of the weirs;
- maintaining the river level at or above a minimum pool level at each weir and therefore eliminating the effect of droughts in the main stream.

In addition, the percentage of water diverted from the river has increased substantially over the last decades, compounding the impacts of river regulation by significantly reducing flows.

The increase in river salinity has important economic implications for a number of sectors of the community and so it is of interest to reduce the salt loads. The greatest salt load occurs downstream of the south end of Clark's Flat. This is consistent with a major discharge of groundwater to a deep hole in the river at the southern end of Clark's Flat, and subsequent mixing with river water over the succeeding kilometres.

6. RIPARIAN VEGETATION

The floodplains of the South Australian Murray Valley provide a variety of habitats which support diverse populations of aquatic, littoral and riparian plants and animals and are considered to be a conservation resource of high value (Thompson, 1986).

Vegetation communities are distributed on the floodplain according to the soil type and frequency of inundation. The vegetation of the River Murray floodplains in South Australia is dominated by Eucalyptus camaldulensis (River Redgum) on the river banks and lower lying floodplain and Eucalyptus largiflorens (Blackbox) on the higher parts of the floodplain. Acacia stenophylla (Coobah) and Muehlenbeckia cunninghamii (Lignum) are common understorey and shrub species. The higher ground areas adjacent the floodplains are mainly dominated by mallee species including Eucalyptus porosa, E. oleosa, E. gracilis and E. socialis, and also Calitrus rhomboidea (Cypress Pine).

In its natural state the hydrological processes influencing the floodplain were the main factors influencing riparian vegetation health. Regular floodplain inundation ensured that accumulated salt was leached and soil moisture and nutrient levels maintained in the floodplain soils. The effects of river regulation and irrigation (Jolly and Walker, 1995; Bone and Davies, 1992; PPK 1997), combined with other impacts such as grazing and invasion by pest plants and animals, have caused widespread floodplain degradation. Until recently (PPK 1997) the systematic assessment of floodplain health and contributing factors had not been undertaken.

7. RESULTS

The **earliest** vegetation dieback is apparent in a Blackbox community at the southern end of Graetz's Flat and the southern end of Clark's Flat. It appears most likely that the cause of this dieback is the expansion of the groundwater mound that is located within the Loxton Irrigation Area. Other Blackbox communities that are growing in similar **locations** are not affected. On both Clark's and Gurra Gurra floodplains a substantial amount of **Lignum** death is also evident.

The most **severe** vegetation degradation is noted to occur at the base of the cliff on Clark's Flat. In this region irrigation is causing seepage to discharge onto the floodplain at salinities ranging from 12,000 EC to 50,000 EC units. Degradation is also occurring in the middle region and near the river edge of Clark's Flat in proximity to the seepage zone, however in these regions the degradation is **progressive**. In contrast, the vegetation on the peninsulas of Clark's Flat is the **healthiest** and most **diverse** of the Loxton and Bookpurnong flats.

As indicated, the patterns of degradation upstream of the lock are substantially different. The large Redgum trees fringing the backwater on Ajax-Achilles Flat are dying or have already died and anecdotal evidence suggests this decline is restricted to the **last decade**.

The Redgum trees growing immediately **adjacent the river** upstream of the Lock are all showing signs of stress, whereas downstream of the lock, trees growing within a comparable ecosystem are not affected. It appears that the construction of the **causeway** across Gurra Gurra Flat has compromised vegetation health upstream of the structure.

Irrigation practices in the Bookpurnong/Lock 4 Irrigation District are having a significant effect on the vegetation on the floodplains. In addition, it appears that irrigation at Loxton is affecting the Southern end of Ajax-Achilles Flat. The **distance** to irrigation affects vegetation health at the inland edge of the floodplain, with small setbacks creating significant impacts and large distances to irrigation producing much smaller impacts. This study suggests that irrigation is having a greater affect on river edge vegetation health than was evident in the Loxton study.

There is **regeneration** evident on the floodplains for Redgum trees. Regeneration however, appears to be related to flood cycles, de-stocking and also the decline in rabbit populations on the floodplain. The longevity of revegetation where it occurs within areas of tree death is uncertain.

8. DISCUSSION AND CONCLUSIONS

The causes of vegetation degradation and vegetation change at any one location are not always attributable to a single process. If river locking were the sole or primary cause of vegetation degradation at the edge of the floodplain, then the reduction in vegetation health would be expected to occur simultaneously everywhere along the river. This study however shows that this is not the case, and instead the pattern of degradation appears to correlate closely with the pattern of growth of groundwater mounds beneath irrigation districts. The degradation processes attributed to a range of typical landforms are summarised in Table 3.

Table 3: Processes Causing Floodplain Degradation

Location	Process Causing Degradation
Landward edge of flat with irrigation proximal	Irrigation
Landward edge of flat with irrigation distal	Irrigation/river regulation/locking
Flat with Anabranch	Irrigation/river regulation
Flat without Anabranch	Irrigation/drainage
River Edge Upstream of Lock	River regulation/locking/irrigation
River Edge Downstream of Lock	Irrigation

Where multiple processes are implicated, the most significant is listed first.

It is clear that the principal causes of floodplain degradation are:

- irrigation induced groundwater discharge onto the floodplain; and
- reduced flood frequency.

Both the Loxton (initially) and Bookpurnong (later) Irrigation Districts are causing vegetation degradation across the floodplains.

Irrigation management to reduce the rate and volume of irrigation drainage accessions is an essential prerequisite for maintaining and improving floodplain health. The predicted future vegetation impacts are that the floodplain vegetation will continue to degrade under most proposed irrigation development scenarios.

Groundwater interception may be an economic option for reducing salt loads in the River Murray, and from our current understanding it is clear that a salt interception scheme implemented at the base of the cliffs on Clark's Flat would also have significant environmental benefits. The environmental and economic benefits of a salt interception scheme will soon be quantified.

Quantifying the environmental benefits of salt interception and improved irrigation management requires quantification of the relative contributions of the degradation processes. On the floodplain, the relative contributions have been deduced from examination of the vegetation health, however, these deductions need to be tested and quantified through examination of the relationships between:

- tree health;
- depth to and salinity of groundwater;
- soil salinity; and
- tree elevation (and hence flooding frequency).

It is recommended that transects through Clark's and Ajax-Achilles Flats be undertaken to quantify the relative contribution of the principal degradation processes.

Further work on quantifying and modelling vegetation health on Clark's Flat is to be undertaken as part of a Land and Water Resources Research and Development project which has been funded and will be undertaken in 1999.

The severe degradation and waterlogging occurring at the base of the cliff at Clark's Flat would be avoided if irrigation had not occurred immediately adjacent the cliff top. With over 43% of the riverbank affected by irrigation in 1992, and probably a much higher percentage now, it is clear that continued unregulated development of the cliff line is likely to cause severe degradation to a similar percentage of the floodplain vegetation at the foot of the cliff. It is therefore recommended that development controls be formulated and implemented, using the Development Act, to restrict new irrigation development from occurring within one kilometre of the line defining the maximum extent of the 1956 flood.

It is clear that locking is affecting vegetation health, but the exact processes are not yet clear. Some additional survey work is planned to document trends in vegetation health between Locks. This work is important as broader patterns or trends may become evident that point to large scale degradation processes which will not be apparent from the current site assessment.

Installation of piezometers to monitor groundwater levels, salinity and nutrient levels, both on the floodplain and the highlands, is also recommended. This data will provide an insight into any changes in groundwater height and quality that may occur over time. From these patterns, correlations with changes in floodplain vegetation health may be derived. Piezometer transects to measure groundwater levels and salinities, soil chlorinity and matric suction have been installed on Clark's and Ajax-Achilles Flats.

Implementing and developing improved environment flow regimes will also improve floodplain vegetation, particularly if more efficient and more regular flooding could be reinstated to increase the rate of removal of salt from the floodplain soils. It should be noted though that this process may have adverse impacts on river salinity, and therefore optimal flooding regimes will need to be developed.

These recommendations are aimed at reducing the rate and area of floodplain degradation. Vegetation regeneration on the floodplain may, over time, mask the current vegetation decline. The rate and longevity of regeneration has not been documented to date, although in major dieback in regeneration has been observed on other floodplains of the river Murray adjacent irrigation areas. The preservation of the existing natural resources has to be a priority for the environmental, recreational and economic sustainability of the Riverland and the River.

In summary, the prognosis for tree health in the river valley in South Australia is grim, particularly in the Riverland region. This prognosis is further worsened by the potential impacts of the current rapid expansion in the viticulture industry adjacent the river throughout the region, and particularly in areas where irrigation has hitherto been essentially absent. A systematic review of tree health along the river's length, and continued examination of the relative influences of degradative processes, are essential elements in determining both causes and ameliorative strategies. The use of groundwater interception schemes to simultaneously reduce salt loads to the river and provide for improvements in vegetation health appear feasible at some locations. Regulatory strategies are also required to protect the remaining unaffected floodplain from the adverse impacts of irrigation.

9. REFERENCES

Bone, B, and Davies, (1992). Effects of Irrigation on Riparian Vegetation in the South Australian Riverland of Agriculture.

Jolly, I, and Walker, G, (1995). A Sketch of salt and Water Movement in the Chowilla Floodplain. CSIRO Division of Water Resources : Adelaide.

PPK (1997). Assessment of the Loxton Irrigation District on Floodplain Health and Implications for Future Options. Prepared by PPK Environment and Infrastructure for the Loxton Irrigation Advisory Board and the Loxton to Bookpurnong Local Action Planning Committee. PPK Report No 97/542

PPK (1998). Assessment of the Impact of the Bookpurnong/Lock 4 Irrigation District on Floodplain Health and Implications for Future Options Prepared by PPK Environment and Infrastructure for the Loxton Irrigation Advisory Board and the Loxton to Bookpurnong Local Action Planning Committee. PPK Report No 98/422

SARMWMC (1996). South Australian River Murray Wetlands Ten Year Plan. South Australian Department of Environment and Natural Resources : Adelaide.

Suter, P, et al. (1993). A Biological and Physio-chemical Monitoring Study of Wetlands from the River Murray Floodplain in South Australia - Australian Centre for Water Quality Research : Adelaide.

Thompson, (1986). River Murray Wetlands: Their Characteristics, Significance and Management. University of Adelaide for the DENR and NCS : Adelaide.

Watkins, N, (1992). Loxton Salinity Drainage Investigation: Status Report on Hydrogeology, Engineering and Water Supply Department, Adelaide 92/20 EWS&Watkins.

Woodward-Clyde (1998). Bookpurnong/Lock 4 Area Drainage Reconnaissance Study Stage 3. Loxton to Bookpurnong LAP Committee. February 1998.

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