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Reducing the cost to South Australia of achieving agreed salinity targets in the River Murray

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The views expressed in this report are those of the author and do not necessarily reflect the official position of the project sponsors. The author claims sole responsibility for any errors or omissions.

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Executive Summary

Past irrigation development has lead to rising salt loads in the River Murray and it floodplains, and reduced river flows. Even in the absence of any further development, river and floodplain salt loading as the result of this irrigation is anticipated to grow over the decades. Any new development will bring additional salinity loads and further reduce River flows.

South Australia is obligated under the Murray Darling Basin Commission (MDBC) *Basin Salinity Management Strategy* (MDBC, 2001) to address salinity by not contributing to a rise in River salinity above 2002 levels. Considerable investment in salt interception will be required to meet this obligation.

In addition, South Australia has committed to protect ecologically significant floodplains and wetlands in the River corridor. This commitment is described in policies including the *Water Allocation Plan for the River Murray Prescribed Watercourse* that require any adverse impacts of irrigation on floodplains and wetlands of conservation significance be offset (Government of South Australia, 2001a).

The Department of Water, Land and Biodiversity Conservation (DWLBC) is the South Australian Government agency responsible for implementing salinity policy in South Australia. To support policy option evaluation and development DWLBC has entered into a partnership with the Policy and Economics Research Unit (PERU) of CSIRO Land and Water.

This report summarises three studies undertaken by PERU to support policy deliberation including:

1. An evaluation of the cost and capacity of technical options to reduce the salinity impacts of irrigation;

2. Estimation of expected future salt interception investment requirement necessary for South Australia to meet its MDBC salinity targets; and

3. Estimation of salinity charge options and evaluation of trade offs between efficiency and equity for each option.

Cost and capacity of technical options

The first set of studies undertaken for the CSIRO-DWLBC project evaluated cost and capacity of technical options. Some options are widely applicable and hence have the capacity to offset a large amount of salinity while others have limited capacity. Some options act by preventing salinity at its source while others, like salinity interception, treat the symptom where it occurs.

Under plausible development scenarios and depending upon how much salinity is prevented from occurring, estimates produced for this study suggest that the State can be expected to have to find between 50 to 110 EC worth of salt interception capacity.

Technical options evaluated include increased salt interception, influencing the location of irrigation; increasing water use efficiency, the revegetation of cleared Mallee areas within 10 km of the River floodplain, and the provision of irrigation water for dilution flow.

Salinity interception is the only mechanism that can address salt loads that are already in train. Thus, some increase in salinity interception must be expected. At present, eight potential sites for further salinity interception have been identified in South Australia.

Not all capacity at these sites is available exclusively to South Australia. Under Schedule E of the Murray Darling Basin Agreement, States have agreed to allow joint access to the salinity credits made available as a result of the introduction of salinity interception and other salinity reduction activities. This means that the benefits of some but not necessarily all the salinity reduction activities will be available to South Australia. In fact there is considerable risk that other States will make prior claim to many of the more cost effective salt interception sites identified in this report.

If this occurs, the costs of meeting the State's obligations could be higher than those estimated for this report. Another key implication is that under some scenarios all of the impacts of increased irrigation in South Australia could not be managed via the installation of salinity interception schemes.

There are, however, ways to ensure that continued irrigation development in the South Australian River Murray is compatible with meeting State MDBC salinity obligations. Technical options that influence the location of irrigation and increase irrigation efficiency have the capacity to significantly reduce the salinity impacts of future irrigation. Both options are potentially cost-effective alternatives to investment in salt interception that would otherwise be required over the next 10 to 30 years.

The return of water to the River as a dilution flows could also significantly reduce River water salinity concentration. However, the cost per unit of salinity reduction is estimated to be 10 to 100 times more costly than salt interception.

Revegetation of most, but not all, locations that have been cleared within 10 km of the River offers limited capacity of reduce salinity impacts. In most locations, GIS modelling has revealed that this revegetation option will have no measurable impact on river salinity within 50 years. There are, however, a few areas where revegetation can be expected to reduce river salinity within 50 years. The total capacity of this revegetation option is estimated at less than 6 EC.

Salinity interception investment requirements

The second set of analyses undertaken estimated the expected future investment in salinity interception or offset arrangements that would be necessary for South Australia to meet its MDBC salinity targets. The level of investment that will be required depends upon how much development is allowed to occur, where it occurs and the efficiency of the irrigation installed.

The results suggest that if irrigation in the South Australian Riverland continues to expand and locate in high salinity impact areas as it has in the past, salt interception investment requirements will be very large. Under a policy scenario representing maintenance of the *status quo*, it is reasonable to expect a 72 GL expansion of irrigation into high salinity impact areas over the next decade. This would result in an estimated increase in river salinity of 110 EC. Installation of salinity interception schemes to prevent this salinity impact would require expenditure over the next 50 years with an estimated net present value of $162 million.

It is possible to reduce this cost significantly by preventing the problem from emerging. One way would be to prevent any new irrigation from locating in high salinity impact areas. If the anticipated 72 GL expansion is confined to medium and low salinity impact areas then the quantity of salinity interception required is estimated to be less than half. Under this option, the net present value of the required investment is $70 million versus the $162 million if expansion is allowed to occur in all areas. That is, introduction of location controls could save $92 million.

The above calculations assume that on average irrigation across all irrigation areas achieves 85% irrigation efficiency. However, the results are very sensitive to changes in irrigation efficiency. If one half of all (new and existing) irrigation achieves 90% rather than 85% irrigation efficiency, then the overall efficiency of all irrigation would be 87.5%. Modelling suggests the required salt interception investment could be reduced to $40 million. Put differently, a program that results in a further 2.5% increase in water use efficiency could save an additional $30 million.

In summary, the quantity of salinity interception required depends upon the policies adopted and the way that future and existing salinity interception is implemented to meet agreed commitments to the MDBC. Over the next 50 years the estimated net present value of the investment in salinity interception required is

- $162 million if present development arrangements continue;
- $70 million if no development is allowed in high salinity impact areas; and
- $40 million if average irrigation efficiency can be increased from 85% to 87.5% and no development is allowed in high salinity impact areas.

It needs to be stressed, however, that when the needs of other States are considered, it may not be technically feasible to build sufficient salinity interception to offset the entire salinity impact required to meet MDBC responsibility for all scenarios. Thus, even if the State wanted to allow irrigation development to continue without policy change, it may not be able to do this and comply with MDBC requirements. A mix of options to control salinity will be required. Astute use of a wider array of control mechanisms would enable the State to meet it obligations and reduce the cost of doing so.

Another caveat is necessary. All of the above estimates assume, as is currently the practice, that any water evaporated via a salinity interception scheme can be sourced outside cap requirements. Salt interception reduces environmental flow. If the State via other processes also has to pay to offset the cost of salt interception on flows by purchasing irrigation entitlements from irrigators then cost may be higher.

Salinity charge options

The third set of studies evaluated four salinity charge options with regard to efficiency and equity:

1. **Uniform charges** – This option involves simply charging all irrigators the same amount per ML of irrigation applied.

2. **Impact zone-based charges** – This option involves reflecting spatial differences in salinity impact of irrigation in salinity charge rates. Those located in higher impact areas pay at higher rates to reflect greater salinity impact.

3. **Efficiency incentive charges** – This option involves differentiating charge levels based on differences in irrigation efficiency. Those who irrigate more efficiently are charged less because the result of their efficiency is less need to invest in salt interception.

4. **Development charges** – This option involves assigning different salinity charge rates to existing and new irrigators. The option represents a potential implementation of the *Water Allocation Plan for the River Murray Prescribed Watercourse* (Plan) that describes new and existing irrigation salinity responsibilities differently (South Australian Government, 2001b). Consistent with the Plan new irrigation developers would be required to pay charges based on the investment required to offset all salinity impacts of new irrigation. In contrast, existing irrigators pay charges required to finance only increases in salinity above July 2002 levels resulting from actions of existing irrigators.

For each charge approach considered both partial and full cost recovery options are evaluated as well as a range of assumptions about irrigation expansion. Under the partial cost recovery option irrigators pay operation and maintenance but not capital cost.

Uniform charges

The estimates of charge rates that irrigators would face under the uniform charge option ranged between \$3/ML and \$10/ML for partial cost recovery, and between \$9/ML and \$38/ML for full cost recovery. The lower bound estimates represent charges that could be expected with either little irrigation expansion or significant improvements in irrigation efficiency. The upper bound estimates represent charges that could be expected with significant uncontrolled irrigation development.

An attractive feature of a uniform salinity charge is that it is administratively straightforward. The weakness of this approach, however, is that it does not vary with location or irrigation efficiency. Thus the incentive to avoid causing salinity is weak. If this mechanism is used on its own the full cost of salinity interception would likely remain close to $162 million.

Zone-based charges

Zone-based charges could be implemented by using existing GIS groundwater models to delineate zones where the impact of irrigation on the River is similar. Charge rates in proportion to the expected impact of irrigation could then be introduced in each zone. This approach of using zone-based charges is somewhat similar to the zoning approach used in the Victorian Sunraysia Irrigation Trust and in the Qualco-Sunlands scheme.

This analysis estimated rates for a three impact zone charge scheme. The estimated rates varied from $1/ML to $4/ML in the lowest impact zone and from $5/ML to $32/ML for the highest impact zone. Variations in estimated charge rates within zone result from different assumption about cost recovery and irrigation expansion.

On first reflection, one would expect that such an approach would reduce salinity impacts. The results from the evaluation of the introduction of a zone-differentiated salinity charge are, however, surprising and counter-intuitive. The reason for the surprising results has to do with the location of high salinity impact areas and the costs to irrigators of pumping water. Pumping costs are directly related to distance from the River and the height that water has to be lifted for irrigation. Unfortunately, low salinity impact areas are located away from the River where pumping costs are high. This means that the water pumping costs and the cost of any zone-differentiated salinity charge are inversely related. Pumping costs tend to be high in places where salinity charges are low and vice versa. From a private irrigation perspective, it is actually less expensive to locate irrigation in high impact zones than in low impact zones. That is, when the cost of a zone-based salinity charge is added to the cost of pumping water for irrigation, the most profitable option is often to locate most irrigation in high salinity impact areas.

As a standalone policy option, a zone-differentiated charge does not provide certainty about the level of development that will occur in any given area. This result holds, even if the State decides to implement a full salinity interception cost recovery policy and require all irrigators to meet the full cost of new salinity interception schemes introduced to offset the impacts of their actions on the River.

Efficiency incentive charges

This approach involves charging less to irrigators who achieve greater irrigation efficiency. For the scenario evaluated, irrigators achieving 90% irrigation efficiency were assumed to pay charges that would represent their share of the total cost of salt interception investment that would be required if all irrigators achieved 90% efficiency.

An important finding is that large discounts on charge rates for irrigators who irrigate very efficiently can be justified because large reductions in the salt interception investment requirement could be expected as a result. This option was modelled as a complement to zone-based charges approach. The estimated charge rate for 90% efficient irrigators in high impact areas was less than $2/ML on a full cost recovery basis while the charge for irrigators achieving only 85% efficiency was $32/ML. The estimated charge is so much smaller for more efficient irrigators because at 90% efficiency for all irrigation, estimated salinity obligations are nearly zero, even though the modelled scenario involved a significant (72 GL) expansion in irrigation.

These findings suggest that when combined with zone-based charges, efficiency incentive charges have the potential to offer particularly significant incentives to irrigators located in highest impact areas where irrigation creates greatest salinity impact. An advantage of this approach is that it can motivate new as well as existing irrigators to adopt more efficient practices. In addition, the approach is attractive from an equity perspective because it gives irrigators who located in high impact areas without knowledge that they would face a high salinity charge an opportunity to reduce the rate they face.

Development charges

The final charge option evaluated involves introduction of charges that reflect the cost of mitigating all salinity impacts for new irrigation allocations. For existing irrigators charges would reflect the cost of offsetting any increase in River from 2002 that can be attributed to existing irrigation. The results suggest that the salinity charge for new irrigation development would be close to three times higher than the rates that existing irrigators would face with this charge option. For example, the estimated marginal cost charge in the medium impact zone for this option is $44/ML assuming a 72 GL expansion that is restricted to medium and low impact areas. Under the same circumstances, the medium impact zone charge for existing irrigators is estimated at $14/ML.

Charges are much lower for existing irrigation with this approach because they receive what is in essence an entitlement to continue discharging salinity into the River at 2002 levels. Thus existing irrigator charges only reflect the cost of dealing with discharges above that level. New irrigators, in contrast, would pay charges that reflect the cost of any salinity that results from their irrigation.

In the absence of any complementary policies this approach could be problematic. The relatively low charge faced by existing irrigators would create little incentive for such irrigators to take action to reduce their impact. In effect the approach penalises irrigators for retiring existing irrigation from high impact areas and redeveloping at lower impact sites by charging them higher salinity charges as a result of such actions.

Summary of salinity charge estimates

The salinity charge rates estimated for this study are summarised in the Table below.

	Partial cost recovery	**Full cost recovery**		
Uniform charge[1]	$3/ML-$10/ML	$9/ML-$38/ML		
Zone-based charge[2]				
High impact zone	$9/ML	$32/ML		
Low impact zone	$1/ML	$4/ML		
			For irrigators @ 85% efficiency	**For irrigators @ 90% efficiency**
Efficiency incentive charge[3]				
High impact zone			$32/ML	$1.1/ML
Low impact zone			$3.5/ML	$0.1/ML
			New development	**Existing irrigation**
Development charge				
Uniform[4]			$12-$41/ML	$4-$11/ML
Zone-based[5]				
Medium impact zone			$44/ML	$14/ML
Low impact zone			$11/ML	$4/ML

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[1] Lower bound estimates apply to scenario with no irrigation expansion and to a scenario with 72GL expansion but assuming 87.5% rather than 85% irrigation water use efficiency.

[2] All charges in for this option in the Table are estimated for a 72GL irrigation expansion scenario with all development restricted to medium and low salinity impact areas.

[3] All charges in for this option in the Table are estimated on a full cost recovery basis for a 72GL irrigation expansion scenario with all development restricted to medium and low salinity impact areas.

[4] Upper bound estimate for scenario with 72 GL of uncontrolled development; Lower bound estimate for this option in the Table are estimated for a 72GL irrigation expansion scenario with all development restricted to medium and low salinity impact areas.

[5] All charges in for this option in the Table are estimated for a 72GL irrigation expansion scenario with all development restricted to medium and low salinity impact areas

Part 1 - The River Murray salinity issue and emerging policy approaches

The River Murray salinity issue

Groundwater in the vicinity of the River Murray in South Australia is very saline. In many areas of the Riverland groundwater salinity is more than half the concentration of salt in ocean water. Even before river regulation and development, this groundwater flow was a natural source of salt entering the lower reaches of the River in South Australia. The rate of natural salt inflow to the River has been greatly increased by mallee land clearing and irrigation developments.

Figure 1 illustrates how irrigation causes increased saline groundwater inflow to the river and floodplains. Irrigation increases recharge to the groundwater and results in localised groundwater mounds beneath irrigated areas. The rising groundwater levels result in greater inflows of saline groundwater to the river and its floodplains.

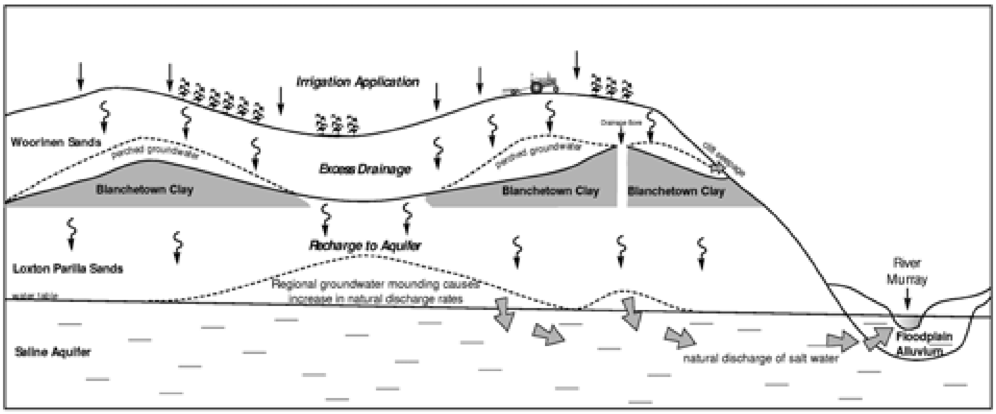


Figure 1: The relationship between irrigation and River salinity (source: Miles et al, 2001)

The salinity impacts of irrigation and mallee clearance typically occur with long time delays (10 to 100+ years). Thus, when early irrigation development and clearance occurred, salinity consequences were not understood. By the 1970s impacts of past irrigation and clearance began to become evident as a rising River salinity trend. As shown in Figure 2, by the 1980s, salinity at the lower end of the River where it provides water for Adelaide was on trend to exceed the recommended salinity concentration for drinking water.

More recently it has become clear that holding of saline groundwater to the River at a level that meets MDBC River salinity target alone will not restore ecological health to the River. More water is needed for the environment and the River will need to be managed differently.

One additional issue is the impact that increased groundwater recharge from irrigation and clearing is having on floodplain and wetland health. Inflows of groundwater from irrigation drainage are raising water tables below floodplains. When groundwater tables rise above a critical threshold level, ecologically significant River Red Gum and Blackbox trees experience poor health because there is not sufficient rooting depth above saline groundwater. Recent assessment shows that significant areas of the floodplain in the South Australian Riverland are at risk from current inflows and the area at risk will increase if inflows increase (Overton *et al.*, 2003). The level of threat varies spatially depending on characteristics such as width and topography of the floodplain.

Saline groundwater discharge is not the only source of elevated groundwater tables that are threatening the health of River floodplain, wetland ecosystems (MDBC, 2003a). Weir levels maintained at higher than natural levels for prolonged periods also contribute to high watertable. This was clearly evident in the Overton analysis, where high level of salinity threat could be seen just behind locks 3 and 4 in the South Australian River Murray.

More fundamentally, addressing River Murray ecological health will require re-organisation of the River flow regime including:

- Increasing the frequency of large water volume flood events to flush salts from wetlands and floodplain;

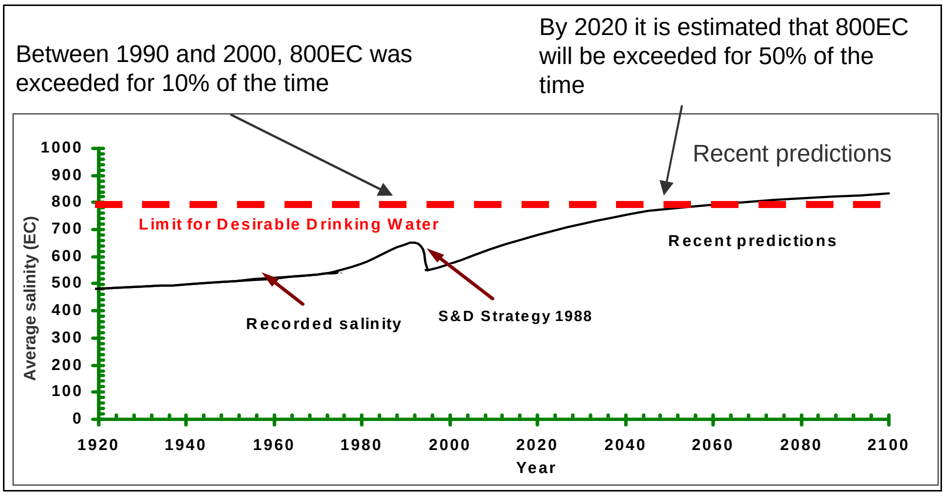
- Manipulating river level maintenance to periodically drain floodplains currently subject to longer than natural sustained high water tables;

- Moderate but sustained increases in flow to flush the accumulated sediment load that currently blocks the outlet of the River into the sea; and

- Installation or modification of drains, weirs and other infrastructure to allow more natural wetting and drying regimes in sensitive riverine ecosystems.

Existing and emerging salinity policy frameworks

The first major policy initiative to address salinity in the River Murray at the Basin scale was the *Salinity and Drainage Strategy*, agreed to by the Murray-Darling Basin Ministerial Council in 1989. It was an agreement for a program of investments to address rising River salinity with financing shared between the States and the Commonwealth. Major investments included salt interception schemes such as Woolpunda and Waikerie along the River Murray in South Australia (SA). Together, these schemes have reversed the salinity trend in the River Murray over the period 1990-2000. However, as shown in Figure 2, it is clear that new threats to the River Murray can be anticipated if no further action is taken.



Between 1990 and 2000, 800EC was exceeded for 10% of the time

By 2020 it is estimated that 800EC will be exceeded for 50% of the time

Recent predictions

Figure 2: River Murray Salinity Impact Trends (Source: MDBC, 1999)

To address the need for further action, in 2001, the Murray-Darling Basin Ministerial Council adopted the *Basin Salinity Management Strategy* (BSMS). The BSMS is an agreement between all the basin states that each will do its part to maintain River Murray salinity below 800 EC at Morgan for 95 % of the time, as well as manage salinity in the Basin's sub-catchments. In essence the BSMS requires States to ensure salinity loading along their stretch of the River and its tributaries does not exceed agreed "baseline" levels.

Under the BSMS, a new program of joint works will be undertaken, aimed at offsetting the "legacy of history" salinity increases expected to result from past mallee land clearing and irrigation developments. A program of works is planned that will produce 61 EC of salinity credits through new salt interception schemes and disposal capacity. 31 EC will be financed by the Commonwealth and be used for general River health. The States of NSW, SA and Victoria will each receive 10 EC credits that they can use to offset rises expected debits from irrigation.

As a partner to the Murray Darling Basin Agreement, SA is accountable to mitigate the salinity impacts of any new irrigation development in the State. Available estimates of growth in River salinity from SA (MDBC, 1997) suggest that to meet these obligations SA will have to make additional salt interception capacity investments over and above investment planned under the joint works program (MDBC, 1999; Australian Water Environments, 2003).

SA has already or is in the process of implementing policy that defines irrigator salinity obligations. The *South Australian River Murray Salinity Strategy 2002-2015* outlines broad principles of irrigation salinity obligations development in SA (Government of South Australia, 2001a). One key principle outlined in the Strategy is that new irrigation development should be responsible to offset salinity impacts of irrigation. Responsibility for salinity impacts of existing irrigation should be joint responsibility of irrigators and the government. Another principle is that irrigator responsibility includes an obligation to protect ecologically significant floodplains and wetlands from adverse impacts of irrigation drainage.

More detailed definitions of irrigator salinity responsibilities in SA are contained the *Water Allocation Plan for the River Murray Prescribed*

Watercourse – the WAP (Government of South Australia, 2001b). This Plan describes rules for allocation, transfer and use of water in the River Murray. For the purposes of the WAP, the River in SA is treated as three management zones. Most of the provisions focus on the River Murray Irrigation Management Zone, RMIMZ (the area along the River from the Victorian border to Mannum). Within the RMIMZ the WAP describes irrigator responsibilities to avoid or offset for salinity impacts of irrigation including:

- Increases in river salinity loading;
- Adverse impacts on ecological health of floodplains and wetlands of ecological significance.

In addition, SA has established a system that includes Land and Water Management Plans, and Local Action Plans as mechanisms for local planning of actions to address salinity impacts of irrigation (among other issues). Exactly how these local planning processes will be coordinated with State level salinity policy has not been fully clarified at this point. There is potential to use these mechanisms as a basis for collective action agreements between irrigators and the government.

Much of the implementation of irrigation salinity policy is likely to be under provisions of the *River Murray Act*, 2003 assented to by both Houses of Parliament on July 31, 2003 but not yet commenced. The Act provides the Minister powers to place conditions on water licences and irrigation development including: requirements for irrigators to participate in schemes to "*protect, restore or otherwise benefit the River Murray specified by the minister*" (SA Parliament, 2003).

Key provisions allow for: zoning of irrigation development, collection of levies with the condition that all revenues be spent on River environmental improvements. Additional provisions would allow the Government (if it wished) to: require irrigators to post bonds, treat irrigators differently based on differences in expected environmental impact of irrigation or differences in when water was allocated; and development of collective obligations for groups of irrigators.

From policy principles to implementation

While the policy frameworks and legislation outlined above describe irrigation salinity policy principles and bound the realm of allowable options in broad terms, they do not describe many of the important details of implementation. In particular, no detailed description of exactly how irrigators are to meet salinity obligations is outlined. The Minister for the Environment is ultimately responsible through the Department for Water, Land, and Biodiversity Conservation for development of an implementation plan.

Conceivably actual policy implementation could include any of the range of policy instruments outlined in

Table 1 and allow for any of a range of technical options to offset or reduce salinity impacts of irrigation potentially including:

- Salt interception and drainage disposal schemes;
- Revegetation of cleared Mallee areas[6];
- Increasing irrigation efficiency[7];
- Location of new irrigation away from high impact areas and closing down of existing irrigation; and
- Provision of dilution flows.

Until recently, government has largely provided for reductions in salinity through investment in salt interception. Given that there are a limited number of sites where future salt interception can be built, it will be increasingly important to reduce salt loads using the other technical measures outlined above. Many of these options will require decentralised action by individuals rather than the government acting alone. While there will be a need for continued Government effort to provide salt interception. Past experience with environmental policy suggests that salinity policy objectives will best be accomplished with a suite of instruments including instruments that create incentives for individuals to reduce the source of impact by reducing groundwater recharge.

There is an opportunity to ensure that SA can fulfil its salinity responsibilities by including market-based instruments in the mix. Market based instruments in the policy could include the salinity charge, tendering, offset and tradeable salinity permit options described in Table 1. The real advantage of such approaches are that they provide incentives for irrigators working in a decentralised way to provide greatest effort to reduce salinity where it can be done at least cost.

The challenges in implementing irrigator salinity policy will involve balancing tradeoffs between efficiency, equity and administrative/monitoring effort. The key will be to find innovative approaches that create effective incentives to reduce impact yet do not involve overly complex administrative and monitoring systems. It will be crucial to ensure that salinity policy is designed to ensure adaptability. Both the increasing volatility of natural physical conditions influencing salinity such as climate change and the quickly evolving State, Commonwealth and MDBC River Murray policy environment make it imperative that salinity policy be easily updateable.

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[6] Revegetation can in principle: a) reduce the amount of future groundwater recharge by replacing annual plant cover with perennial cover that takes up more rainfall on the area that is revegetated; b) extract groundwater. The second option is largely limited to areas where there are shallow perched groundwater tables above impeding clay layer.

[7] For the purposes of this study the irrigation efficiency option includes drainage capture and re-use though this is sometimes treated as a distinct option.

Table 1: Policy options to reduce or offset salinity impacts of irrigation

Government investment in salt interception - Government has in the past and is continuing to invest in salt interception schemes. SA will receive 10 EC of salinity credit to offset impacts of irrigation development in the State through the agreed MDBC joint works investment that will involve building 61 EC of salt interception capacity in total. In addition the State is likely to make additional investment in capacity to meet State MDBC salinity targets.

Salinity charges – The idea is that irrigators are charged a levy on irrigation water use to compensate part or all of the cost of mitigating salinity impacts of water use. Variants of the charges approach could involve:

- Setting higher charge rates in areas where the salinity impact of irrigation is greater, and lower charge rates where irrigation impact is less as is done in Victoria (Sunraysia Rural Water Authority, 2002).
- Offering rebates on charges for actions that reduce recharge in proportion to the level of recharge reduction. For example, increasing irrigation efficiency, revegetating cleared dryland areas close to the River, or providing dilution of River salinity with environmental flows.

Zoning - This would involve precluding irrigation in areas where salinity impacts on the River or floodplain were deemed too damaging or too expensive to mitigate. In addition a zoning approach could involve differentially charging by “impact zones” where average salinities differ. This is the approach taken by the Sunraysia Rural Water Authority in Victoria (see Box 3).

Irrigation efficiency requirements - This approach involves making a certain standard of efficiency mandatory. This approach is already a part of the Water Allocation Plan for the River Murray in the form of a condition on water use that irrigation efficiency exceed 85% (Government of South Australia, 2001).

While details of implementation have not yet been worked out. One implementation would involve requiring some form of best management practice. Irrigators who implemented certain practices (for example irrigation system design and irrigation scheduling to a specified standard) would be certified as meeting the 85% efficiency requirement.

An alternative implementation would involve requiring performance to a standard (achievement of >85% efficiency) measured with a combination of flow metering and crop water use modelling.

Tradeable salinity credits - A tradeable salinity credit approach would involve setting individual limits (quotas) on salinity loading. Irrigators would then only be allowed to exceed their quota if they purchased additional quota from someone who is under quota. Those who can achieve large reductions at low cost would then have an incentive to sell part of their quota at a profit to those who would only be able to achieve similar levels of reduction at higher cost.

Offsets – Environmental offsets are actions taken to reduce some environmental impact at a site away from where the impact occurs. The offset action can be taken by the person whose action results in the impact or the person can pay others to take offsetting action on their behalf. A prerequisite to implementing an offset policy is some kind of limit on actions with adverse environmental impact. For example, the concept has been applied to wetlands in the U.S. where any new development that involves draining a wetland is prohibit unless offset action is taken by restoring a greater area of wetland than is drained at another site (Van Buren, 2001).

One variant of the offset approach that could be used to deal with irrigation salinity would involve first limiting irrigation water allocations in high impact areas (for example to the current level). Additional development in such areas could then be allowed, if the developer provided an offset in the form of a reduction in greater water allocation or groundwater recharge reduction at another site in the high salinity impact area.

Grants - The basic idea is that the Government offsets part of the cost for irrigators to adopt practices that have some public environmental benefit. The approach is also often referred to as cost sharing.

Tenders - Tenders are a variant of grants. The basic idea is that those interested in taking some action to improve an environmental outcome compete for cost-sharing funds by bidding. Bids describe actions that would be taken and the level of cost sharing that would be required. The government ranks bids based on the level of environmental improvement per cost sharing dollar offered based on a pre-set protocol and funds bids that offer best value.

Tendering approaches have allowed attainment of higher levels of environmental improvement for a given expenditure would have been achievable had a single cost-sharing rate been offered to all. For example, evaluation of the biodiversity on-ground works tendering program piloted in Victoria in 2001 and 2002 suggest that significantly more environmental services per cost share dollar were attained using this approach than could have been attained using a single cost share rate approach (e.g. Stoneham *et. al.*, 2002).

The Colorado River Basin Salinity Control Program run in seven states in the USA is a good example of how tendering could be applied to irrigation salinity. Each year that this program ran, the government advertised requests for proposals for projects to reduce salinity and was required to assess offers based on cost per tonne removed and level of risk. Risks of cost overruns or sub-optimal performance are borne by project proponents through contractual limits on the Governments payment obligations (US Bureau of Reclamation, 2001).

Source: Connor, 2003

Part 2 - Screening analysis of cost and capacity of technical options to reduce salinity impacts

The MDBC Basin Salinity Management Strategy assigns responsibility to the States of NSW, Victoria, and SA to mitigate impacts of post January 1988 actions that increase salinity. The exact extent of responsibility that SA faces under these arrangements has not yet been finalised. However, results presented in Part 3 of this report suggest that under plausible scenarios SA could be required to find between 50 and 110 EC of salinity credits to meet its obligations.

Part 2 of this report is a screening of technical options to meet MDBC salinity targets for SA. This involves assessment of:

- Capacity - the amount and timing of salinity impact that can be controlled with each option and
- Cost – the cost of controlling salinity with each option.

The intent of this analysis is not a detailed accurate assessment but rather a course scale screening with readily available data. Estimation procedures used to assess the strategies considered vary from integrated hydrogeology-economics modelling to simple “back of the envelope” calculations.

The technical options addressed include:

- Salt interception and drainage disposal schemes;
- Revegetation of cleared mallee areas;
- Increasing irrigation efficiency;
- Location of new irrigation away from high impact areas and closing down of existing irrigation; and
- Provision of dilution flows.

Salt interception and drainage disposal

Recharge to groundwater from irrigation and clearing is the cause of elevated groundwater mounds near the river. These mounds create a hydraulic gradient that pushes saline discharge into the River and its floodplains. The basic idea of salt interception is to reduce the hydraulic gradient pushing salt into the River by drawing down the elevated saline groundwater table at the edge of the floodplain with pumps. The saline water accumulated from interception is piped to evaporation basins, areas several kilometres away from the River where saline discharge is deposited.

Salt interception is currently the primary strategy used to reduce river salinity impacts. The top frame in Figure 3 is a schematic drawing of the two Salt interception schemes that already exist in SA: the Woolpunda scheme (built in 1990) and the Waikerie scheme (built in 1992). As can be seen in the top frame, drainage from both schemes is sent to the Stockyard Plains evaporation basin about 8 km from the River via large pipelines.

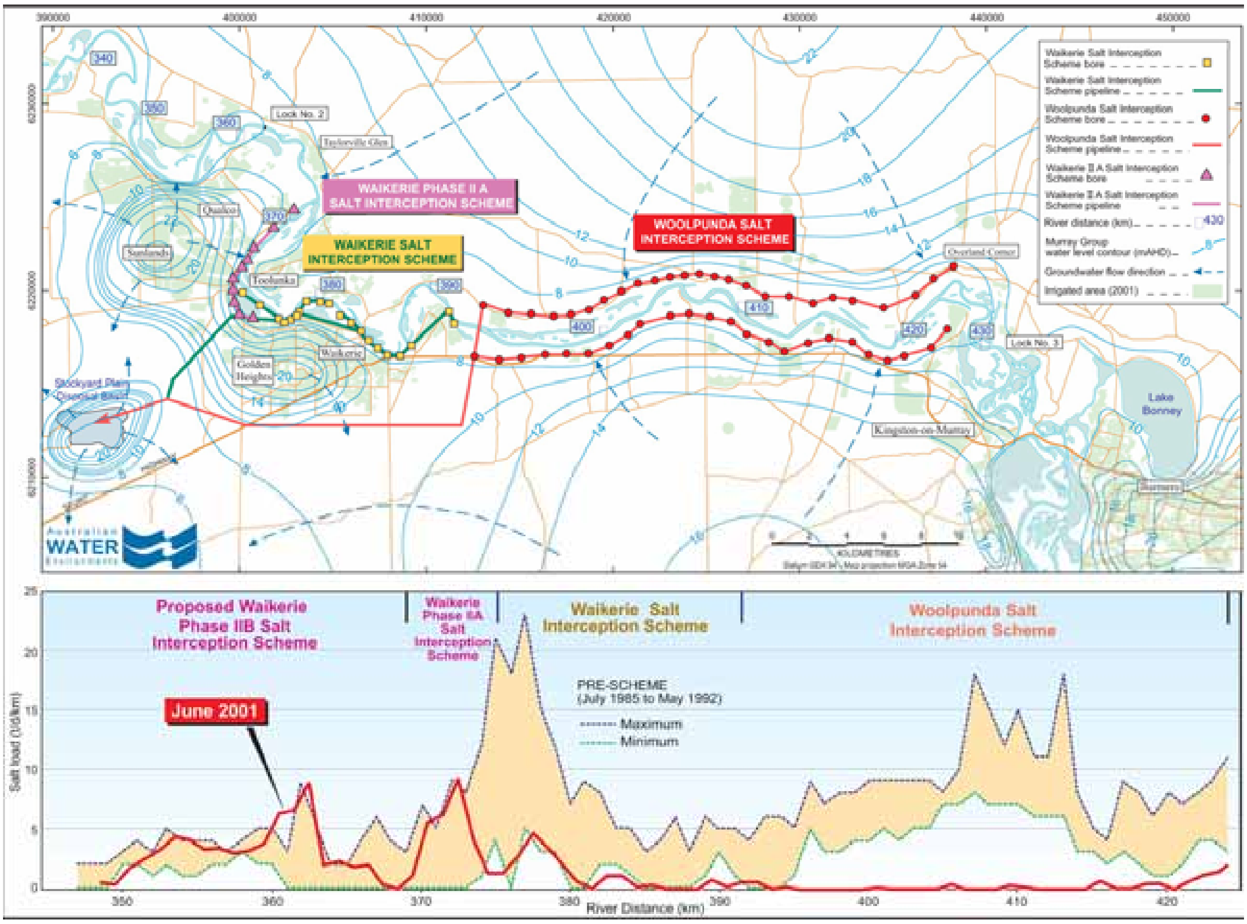

Figure 3: Schematic Representation of Waikerie and Woolpunda Salt Interception Schemes (source: AWE, 2001)

The bottom frame in Figure 3 shows the salt load reductions that resulted from the schemes relative to the 1985-1992 baseline level. It is believed that the schemes are removing 90% of all groundwater discharge to the River. In total an average 300 to 350 tonnes/day salt load reduction is being achieved (Forward, 2003). The reductions in salinity load from the two schemes have gone onto the MDBC salinity register as a 50.6 EC unit credit (MDBC, 2003).

Capacity

Figure 4 shows that there are eight potential salt interception schemes in addition to Waikerie and Woolpunda that are under consideration or already being planned along the SA River Murray. The collective capacity of these schemes to provide salinity mitigation has not yet been assessed with detailed engineering studies and will depend on the level and location of new irrigation adding to salt loads. The success of the Woolpunda and Waikerie schemes suggests that salt interception could remove a large portion of saline inflows into the River and floodplain.

Under a scenario of very moderate (24GL) growth in irrigation (above the 2001 level) for the River Murray in SA, Australian Water Environments (2003) predicts salt loads at the potential salt interception sites will exceed 1000 t/day. This implies a total capacity to remove salt in the order of three times the capacity of Waikerie/Woolpunda, or somewhere in the order of 150 EC units might be expected, assuming:

- Salt interception schemes at these sites are 90% effective (as effective as the Waikerie/Woolpunda schemes are);
- On average tonnes removed convert to EC unit reductions in River salinity at the same rate for new schemes as they do at the existing Waikerie/Woolpunda schemes.

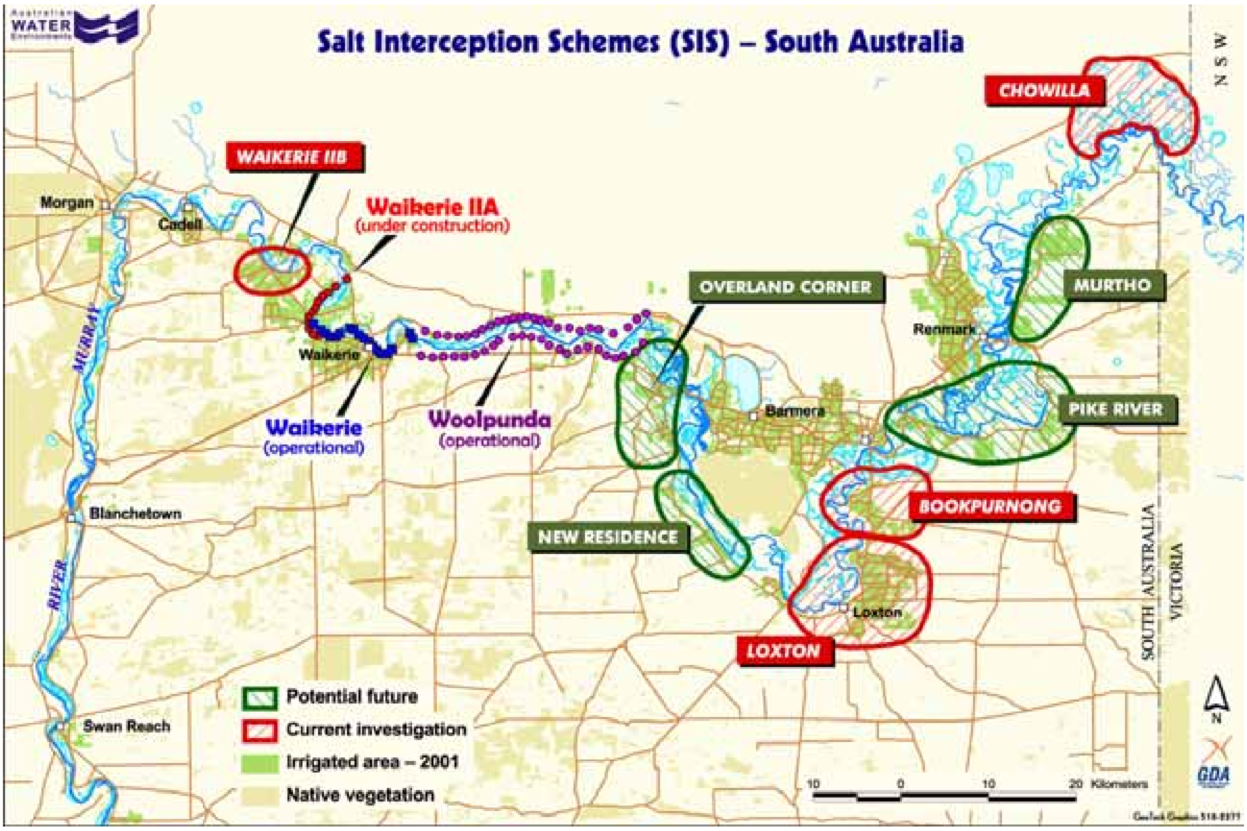

Figure 4: Existing and Potential Salt Interception Schemes in South Australia (source: Australian Water Environments, 2001)

The ‘back of the envelope’ calculations presented above suggest that the salt interception option alone may have sufficient capacity (150 EC units) to offset SA salinity obligations over the next 50 years. While this capacity exceeds irrigation salinity impact growth estimates of between 50 and 110 EC is predicted in Part 3 of this report, there at least four reasons to believe that it will be important to find additional strategies as well:

- If irrigation expands where salt interception is feasible, the scale of salt interception can generally be expanded to pump away the resultant additional discharge to the River. However, there are a number of locations where irrigation and consequent salinity impacts could grow but salt interception projects have not yet been considered and may not be feasible;

- Not all of the salt interception capacity in SA will necessarily be available to the offset SA MDBC salt responsibilities. Under Schedule C to the Basin Salinity Management Strategy, The Commonwealth, Victoria and NSW can all assist in financing salt interception built in SA and claim part of the resultant salinity credits (MDBC, 2003);

- As currently operated, salt interception schemes pump water to unlined evaporation basins several kilometres from the River. While some of the water placed into basins evaporates, a significant amount leaks into the groundwater table where it can cause elevated groundwater mounds. As can be seen in the bottom frame of Figure 3 a groundwater mound is building below the Stockyard Plains evaporation basin where the Woolpunda and Waikerie salt interception scheme water is pumped. Eventually, the mounds below unlined evaporation basin may cause additional salinity impacts on the River;

- Meeting goals of improved River ecological health could involve the need for additional salt interception capacity. One reason additional capacity may be necessary is to protect certain ecologically sensitive floodplain from the adverse consequences of a rising watertable. The other reason is that protection of floodplains may require large flooding events to flush salts.

Cost

Experience to date suggests that the cost of reducing salinity impacts of irrigation will vary significantly across salt interception sites. As explained in more detail in Box 1, the cost of salt interception capacity is likely to be influenced by four key factors that vary across potential and existing salt interception sites:

- Groundwater salinity,
- Floodplain attenuation of salt,
- Salinity damage per tonne of salt loading, and
- The distance and lift required to pump water from salt interception schemes to evaporation basins.

Box 1: Key determinants of the cost of salt interception capacity

Groundwater salinity – Where groundwater is more saline, less needs to be pumped to remove a given mass of salt. Thus cost per unit salinity impact reduction at sites is less where groundwater salinity concentration is higher, all other things equal.

Floodplain attenuation of salt – Not all discharge resulting from elevated groundwater mounds reaches the River's edge at all locations; a fraction is attenuated by the floodplain in some instances. The percentage of salt discharge attenuated varies across sites depending on the width and shape of the floodplain, the volume of discharge and other factors (Overton, *et al*, 2003). Salt interception schemes are typically located at the edge of the floodplain. Much of the salt pumped to evaporation basins would not reach the River even in the absence of salt interception at sites where a large percentage of salt loading from discharge is attenuated by the floodplain. Thus, sites where the rate of floodplain salt attenuation is low are more cost-effective sites for reducing River salinity concentration, all other things equal.[8]

Salinity damage per tonne of salt loading to the River – Salinity credits and debits entered on the MDBC salinity register are denominated in what are referred to as 'Equivalent EC' units (MDBC, 2003) or just EC units. These units are in essence tonnes of salt weighed by the amount of damage to crops and urban infrastructure that results per tonne. The number of EC units credited per tonne of salt varies by River reach as shown in Figure 5. As can be seen in the graph, EC units per tonne are lower further down stream for the South Australian portion of the River reflecting declining salinity cost per tonne of salt removed further downstream where less crops are potentially exposed and especially below the Adelaide urban water extraction point at Murray Bridge. This means that at sites further upstream where more EC units of credit result per tonne of salt, the cost per unit salinity impact reduction will be lower, all other things equal.

Distance and lift required to pump water from salt interception schemes to evaporation basins – The distance and lift required to move intercepted salt water to an appropriate drainage disposal basin varies across sites. Cost per salinity credit will obviously be higher at sights where required pumping lift or distance are greater, all other things equal.

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[8] The measure of cost effectiveness considered here $/EC unit salt load reduction is exclusively focussed on salt concentration in the River. Building salt interception where floodplains attenuate large amounts of salt tend to be relatively unattractive by this criteria. However, salt interception schemes at such sites may in some instances be effective at protecting ecologically significant floodplain flora and fauna from rising watertable. If floodplain ecological benefits as well as River salinity benefits were accounted for, some investment in salt interception at that rate poorly on River salt load reduction alone might in fact be attractive.

Figure 5:Conversion of Salt Tonnes to EC Credits (Modelled results assuming 100 tonnes/day over 1975-1985 benchmark)

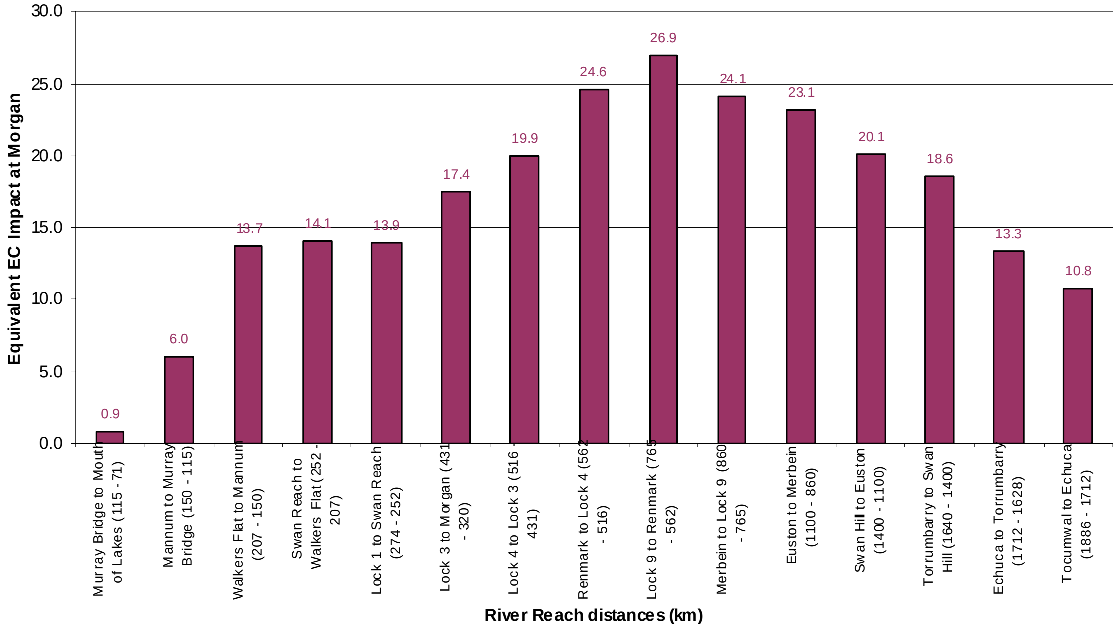

Figure 19. Salinity Cost Effect (Equivalent EC) of Salt Entering Various Reaches of the River Murray (Modelled results assuming constant inflow of 100 tonnes/day over 1975-1985 benchmark)

The cost of salt interception has only been estimated with detailed engineering economics studies for the existing Woolpunda/Waikerie sites and the potential Bookpurnong and Loxton salt interception sites. This information along with data describing levels of salt interception cost determinants described in Box 1 at other potential salt interceptions sites was used to estimate cost of salt interception at all sites. The estimation procedures are documented in more detail in the appendix to this report.

The resulting estimates of salt interception capacity cost are shown in Figure 6. It is clearly evident from the figure that as capacities at least-cost salt interception sites are exhausted the marginal cost of additional capacity will increase quite sharply.

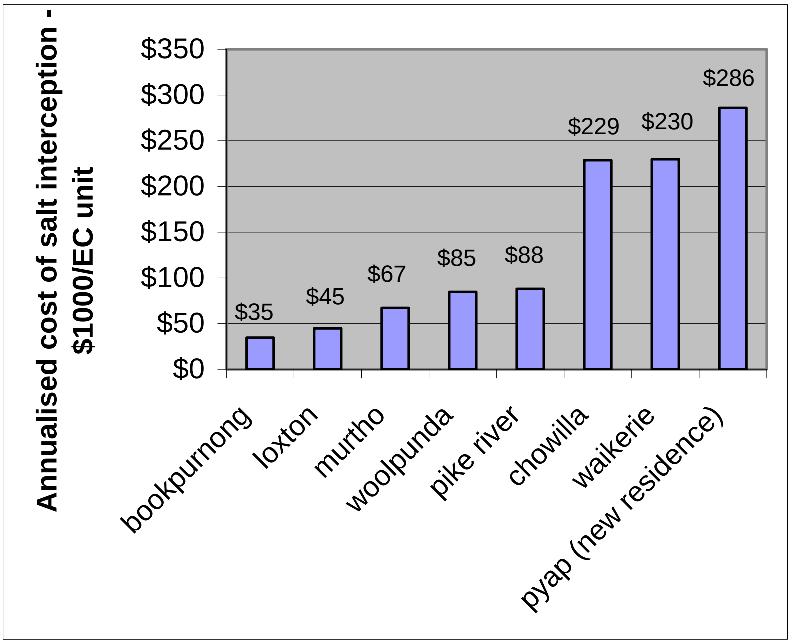

Figure 6: Estimated cost of salt interception capacity

Revegetation of cleared mallee areas

The native mallee vegetation that grows along the River Murray in SA is extremely water-efficient with roots often extending to depths of more than 20 m. Studies measuring rates of groundwater recharge below such vegetation find that it is often less than 0.1 mm/yr (Allision, 1990). In many areas, native mallee along the River has been cleared to establish shallow rooted crops and pasture. These plantings are less water efficient than native mallee and have thus lead to an increase in water draining below the root zone. This increased drainage is one of the sources of the hydraulic gradient causing increased flows of salt water into the River Murray. Revegetation of cleared areas with deep-rooted perennial cover is one option to reduce salinity impacts.

Capacity

A salinity model building on previous work by Cook and Connor, 2002 was used to predict the capacity of revegetation to reduce salinity. The salinity model integrates unit response equations developed by CSIRO hydrologists with a GIS framework developed by the State Department of Environment and Heritage (Connor & Cook, 2003).

The analysis to date is somewhat limited as only 9% of potential revegetation area was evaluated at the screening stage. This is because of hydrogeology modelling limitations at the time of analysis. Algorithms to account for time delays to impact in the areas underlain by Blanchetown clays had not yet been developed.

Analysis showed that in general, revegetation is a challenging strategy because there are long time delays between replanting and a measurable salinity load reduction in the River. In most of the areas analysed, the estimated time lag until River salinity load reduction as the result of revegetation is visible exceeds 50 years. This was true even though analysis was narrowly focussed on the part of the River corridor where revegetation is likely to reduce salt load most quickly because there are no impeding clay layers to slow drainage.

There are, however, some exceptions to the general findings of long time delays until revegetation can reduce River salinity. It was estimated that targeted investment in revegetation on the 6000 best-suited hectares in the River corridor could achieve a 6 EC salinity benefit in 50 years.

In the longer term (100 to 200 years) revegetation is likely to offer considerably greater salinity benefits. This is because in these longer timeframes revegetation will decrease salinity in many areas where it has no effect within 50 years (Cook and Connor, 2002).

Cost

The cost effectiveness of revegetation was assessed by comparing the present value of future investments in salt interception that could be avoided through revegetation to the cost of revegetation. The key finding was that investment in revegetation is unlikely to be justified by future salt interception cost savings in most areas of the River corridor. For 94% of the area considered (which was already very targeted), the estimated cost of establishing and maintaining native vegetation exceeded the estimated net present value of providing salt interception that achieves the same River salinity reduction.

Increasing irrigation efficiency

Increasing irrigation efficiency increases the fraction of water applied that is taken up by crops. This decreases the amount of water applied in excess of crop requirements that drains below the root zone. Less drainage results in less groundwater mounding which in turn results in less hydraulic pressure forcing saline discharge into the River.

Capacity

Because there have been no systematic surveys of current irrigation efficiency across the region it is difficult to estimate the capacity to reduce salinity impacts through irrigation impacts with any real precision. Still, the available evidence suggests that the capacity of this option is likely to be large.

A recent assessment by Australian Water Environments (2003) found that reducing drainage everywhere in the Riverland from 85% to 90% would reduce expected total ground inflows to the River by approximately 22%. Multiplying this 22% by the MDBC Salinity Audit estimates of average River Salinity contributions from SA sources (190 EC units in 1998, to 320 EC units in 2050) suggest that the capacity of irrigation efficiency to reduce salinity impacts of irrigation that was on the ground in 1998 would be approximately 42 EC units by 2020 and approximately 70 EC units by 2050. Obviously, as irrigation area expands there will be more salinity loading and greater scope to reduce salinity loading by increasing irrigation efficiency.

A significant feature of the irrigation efficiency option is that it can reduce the salinity impact of existing irrigation. This is important because much of existing irrigation is located in very high salinity impact areas. A simple calculation based on salt loads per hectare in highest impact areas of 3.5 tonnes/ML from Miles (2002) suggests that increasing irrigation efficiency from 85% to 90% on 100 hectares in such areas could reduce the need to invest in additional salt interception capacity by 0.5 EC at a cost savings of $500/ha/year[9].

Cost

The cost of this option is not assessed. This is because accurately evaluating the potential cost or returns to increasing irrigation efficiency would require detailed understanding of the irrigated crop production and

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[9] 3.5 t/ML/yr is the estimated average salinity impact of irrigation in high impact areas of the Riverland (Miles, 2002) 3.5 t/ML/yr * 8ML/ha = 28 t/ha/yr

28t/ha/yr * 100 ha * 1 yr / 365 days = 7.67 t/day salt load

a one third reduction would thus equal a 2.55 t/day reduction, given the conversion 5t/d = 1EC at Morgan for the reach between lock 3 and 4, a .5 EC reduction is estimated.

This results in a $50,000/year savings from increasing irrigation efficiency on100 ha assuming an average cost of salt interception of $100,000/EC/year irrigation efficiency investment opportunities faced by irrigators. These opportunities and costs are likely to vary considerably across irrigators. At a minimum assessment of the cost of reducing salinity impacts of irrigation by increasing irrigation efficiency would require detailed information for a representative sample of Riverland irrigators. No such information is available.

Still, limited anecdotal evidence suggests that irrigation efficiency improvement could be one of the most cost effective salinity control investments available. Benchmarking studies from the Riverland show that the most efficient irrigators are achieving in excess of 90% irrigation efficiency and achieving higher returns per unit water applied than other irrigators (Skewes and Miesner, 1997a and1997b). In addition, irrigators can attain benefits by becoming more efficient because they can sell water saving or use them to expand irrigation.

Location of new irrigation away from high impact areas and closing down of existing irrigation

Evaluations by the South Australian Department of Environment and Heritage found that there are large differences across the Riverland in the amount of salt load to the River resulting from the same level of irrigation application. This can be seen in Figure 7 where blue to green shaded areas are least impact (.004 to .04 tonnes of salt/ha/day), yellow areas are moderate impact (.04 to .12 tonnes/ha/day), and orange areas are highest impact (> .16 tonnes/ha/day).

Given these differences in expected impact there is obviously scope for reducing salinity impact with strategies that influence location of irrigation. In principle, this could involve either the location of new irrigation to lower rather than higher impact locations, or the closing down of existing irrigation in high impact locations.

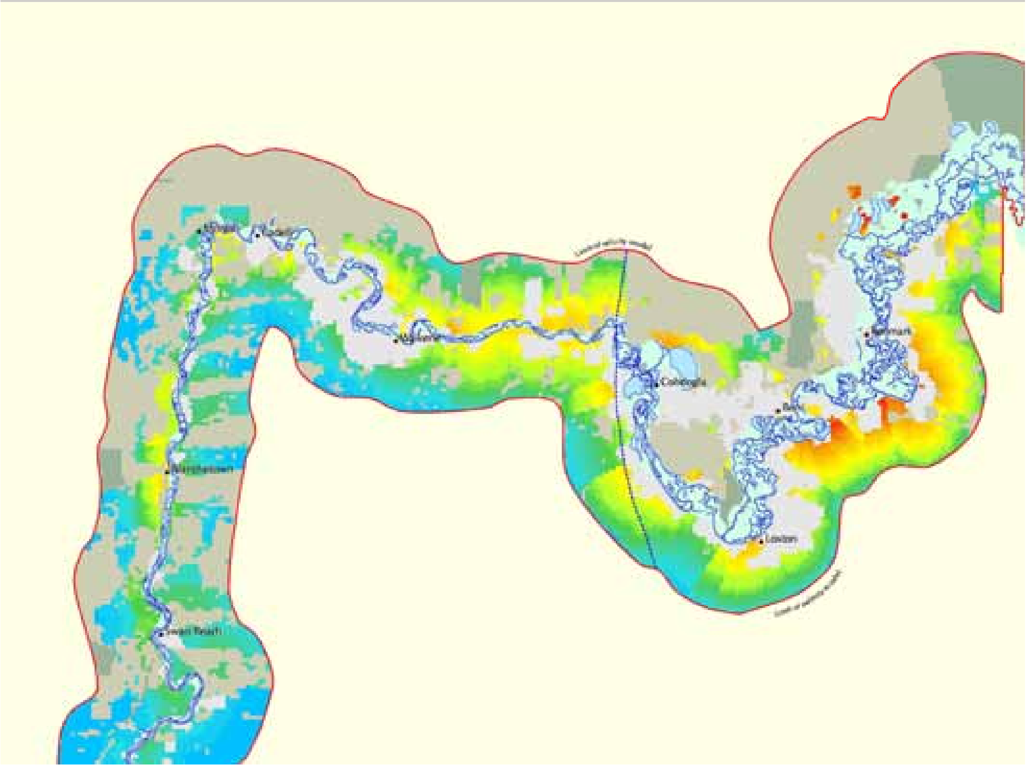

Figure 7: Expected salinity load/ha from 8ML/ha of irrigation at 85% efficiency

Capacity

Figure 8 shows the location of existing irrigation superimposed on estimated salinity loads from application of 8ML of irrigation at 85% irrigation efficiency. In the figure, salinity impact of irrigation is averaged over three areas, a low, medium and high salinity impact zone.

Figure 8: Location of high, medium and low irrigation salinity impact zones

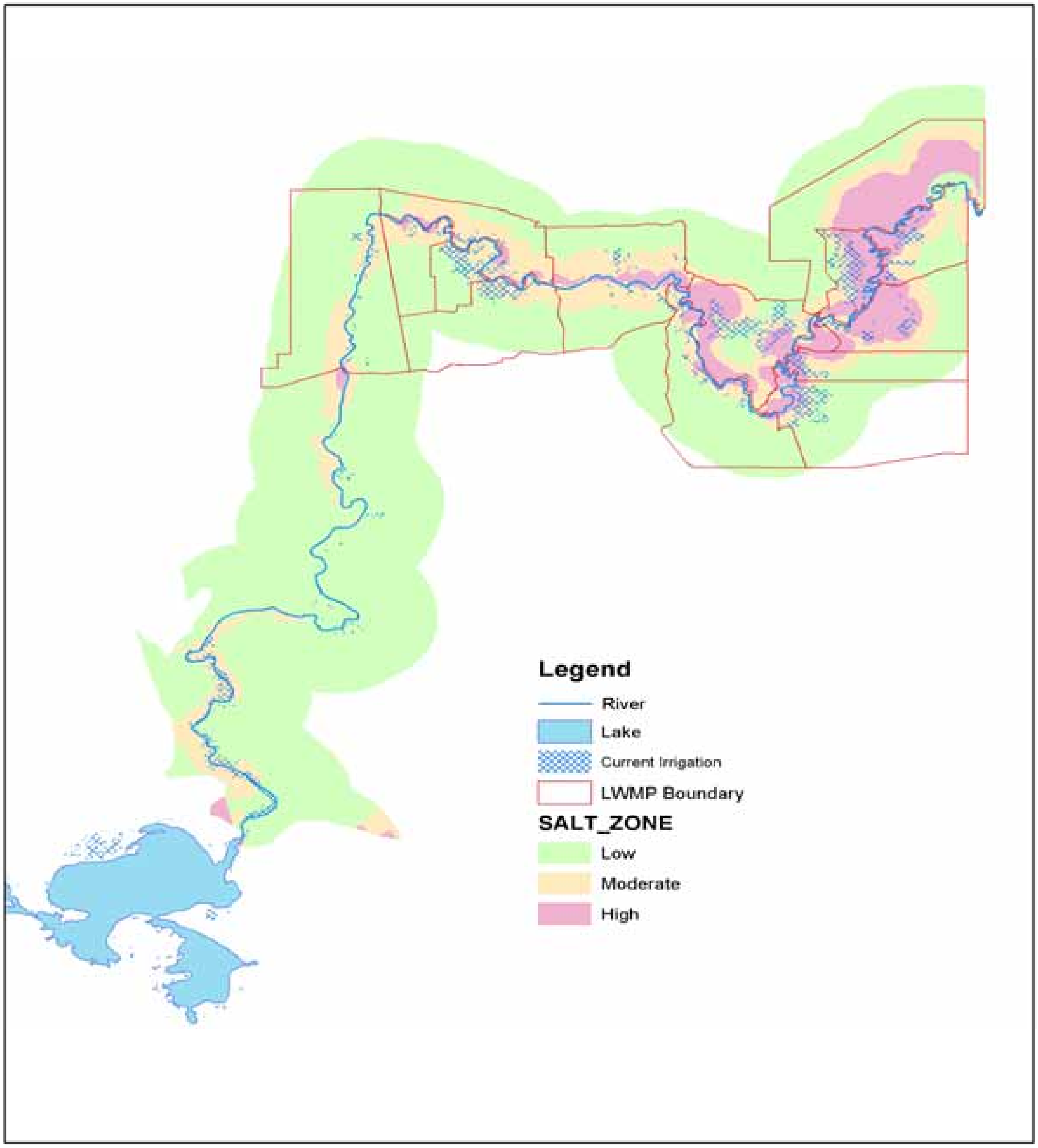

Table 2 shows the areas that are currently irrigated or potentially irrigable by salinity impact zone. In addition, the table summarises the predicted average salinity impact of irrigation by zone, in both tonnes of salt and EC units.

This information can be used for rough estimation of capacity to reduce salinity impact with irrigation location options. For example, the table allows the inference that closing all of the approximately 10,000 hectares of irrigation currently in high salinity impact areas would reduce salinity impact of irrigation by 100 EC units[10]. Similarly, it can be inferred that 5,000 hectares of new irrigation development in low rather than high impact areas would reduce growth in salinity by 44.5 EC[11].

Table 2: Estimated average salinity impact by zone of 120 mm of irrigation drainage

Salinity impact zone	Existing irrigated hectares in 2001*	Potentially irrigable hectares*, **	Average salinity impact (tonnes/ml/year)	Indicative EC unit impact of 100 ha***
High impact zone	10,103	14,038	3.5	1.0
Medium impact zone	23,800	168,572	1.6	0.45
Low impact zone	10,452	64,924	0.4	0.11

*The areas of both existing and potential irrigation are estimates for the area above the lower lakes. While they are underestimates of total area, the area covered does include most of the high salinity impact areas, as can be seen in Figure 8

** Potentially irrigable land is land within 10 km of the river classified as well suited to irrigated almond production using the PIRSA soil suitability classification assessment, not currently irrigated, not currently in native vegetation and not zoned for Municipal land use.

*** Based on a conversion factor of 20 EC units into 100 tonnes per day, which understates salinity impacts above lock 3 and overstates impacts below lock 4 (see Figure 5 for more precise EC unit to tonne conversion factors by River reach).

Cost

The cost of closing existing irrigation would likely be substantial. Over 90% of irrigated hectares in the study area is in perennial crops, including grapes, citrus, stone fruit and nut crops (PIRSA, 2003). Establishing such crops involves considerable investment, typically made with the intent of earning returns over moderately long time frames (typically 20 years or more).

The cost of removing these crops is the profit that would be forgone as a consequence. This amount will vary across sites depending on enterprise factors such as cost of capital and site factors including age, condition, and type of the perennial stock and irrigation equipment, crop yield and quality, and cost of water supply.

Still, crop development budgets for the region can give some sense of the magnitude of costs associated with closing down irrigation. Consider the wine grapes, a crop that accounted for more than half of the value of

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[10] 10,000 ha at 1 EC unit/100 ha

[11] 5,000 ha at .11 EC units/100ha rather than 1 EC unit/100 ha

irrigated crop production in the Riverland in 2001/2 (PRISA, 2003). A recent development budget suggests that the net present value of profits a representative shiraz planting that would be forgone if a 5 year old planting were removed, would be $9600/ha/year (PRISA, 2003). In the high salinity impact zone removing 100 hectares is estimated to reduce salinity impact by 1 EC unit. At $9,600/ha the annual cost would be $960,000 or three to twenty times the estimated cost of an equivalent salinity impact reduction with salt interception (see Figure 6 for the comparative cost of salt interception).

This does not mean that retiring currently irrigated land will not be cost effective in some instances. Profits forgone as the result of removing irrigated crops could be relatively small in some instances for a number reasons. For example, some irrigated perennial crops currently in the ground in the region are not profitable either because of the variety grown or the age and condition of the plantings[12]. In such cases the profit forgone as a result of removing the crops would be much less than the indicative cost of reducing salinity by removing a five year-old shiraz grape planting.

The cost of locating new irrigation development at low rather than high salinity impact sites will depend on the attributes of potential irrigation development sites that influence profitability. Site attributes that influence profit include: potential crop yield, production costs, transport distances, and cost of water delivery. Figure 8 shows that the result of past decisions has been irrigation development primarily in high to medium salinity impact areas. This is an indication that it may, in many cases, be more expensive to locate in lower salinity locations. Table 3, showing the average annualised cost of building and operating water supply by zone, confirms that water supply cost is one factor that contributes to higher cost of locating in lower salinity impact zones in most cases[13]. As explained in the modelling methods appendix to this report, it is relatively more costly to locate in lower impacts zones on average than in high impact zones. This is because lower impact areas are generally further from and higher above the River so that more pipe, pump and power expenditure is required per ML of water delivered to these areas.

Table 3: Estimated average annual cost of water supply capital plus operations and maintenance cost

Salinity impact zone	$/ML/year
High impact zone	$49
Medium impact zone	$64
Low impact zone	$87

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[12] For example, PIRSA (2003) crop enterprise budgets suggest that navel oranges (2500 hectares) are not profitable in many cases.

[13] The basis for the way these costs were calculated is explained in the appendix to this report.

The estimated average differences in water supply cost in Table 3 can be used to provide a rough estimate of the cost of reducing salinity impacts by locating new development where salinity impact is less. Assuming an 8 ML/ha application rate locating in a low rather than a high impact zone would require an additional $304/year expenditure on water supply. The estimated reduction in salinity impact from locating 100 ha in a low rather than a high salinity impact zone would be .9 EC[14]. Thus a rough estimate of the cost per EC unit of reducing salinity impact by locating new irrigation in low rather than high salinity impact zones is approximately $34,000/EC. This is just slightly less than the cost of salt interception at the least cost site and significantly less than the cost of salt interception at the more expensive sites (see Figure 6).

Furthermore, there are likely to be some locations where the cost of supplying water to low impact areas is less than estimated average value used in this analysis. This means that there may be significant low cost opportunities to reduce salinity impacts through judicious choice of site for new irrigation development.

Dilution flow

In principle, salinity mitigation is possible through dilution by leaving water in stream. The basic idea of a dilution flow strategy is that irrigators could offset salinity impacts of irrigation by providing to have water left in stream for salinity dilution.

Capacity

Estimates of the reduction in EC unit impact possible through dilution are summarised in Table 4. They were provided by the MDBC using their Big Mod River simulation modelling capacity (MDBC, 2002). The estimates are based on a simulation of the impact of retiring 10 GL of South Australian entitlement water currently used for irrigation and maintaining it in stream.

To give a sense of dilution capacity to reduce salinity, dilution rates in Table 4 for Lock 5 to Berri were multiplied by the MDBC Living Murray initiative upper bound reference flow of 1500 GL (MDBC, 2003). The resulting rough estimator[15] is that there could be capacity of up to 87 EC units of salinity reduction provided by releasing dilution flows from Lake Victoria. This assumes that the sole purpose of the water is to reduce salt concentration in the River.

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[14] 100 ha at .11 EC units/100ha rather than 1 EC unit/100 ha

[15] One reason that the estimator is very approximate is that if 1500 GL were made available for an environmental flow it would likely be in a different temporal pattern and spatial pattern than the dilution modelled for this study. Another is that dilution is a function of volume and the transformation from 10GL to 150GL is not actually linear as assumed here.

Table 4: Estimated dilution impacts of leaving 10 GL of irrigation entitlement in stream

River reach where water is sourced	EC unit reduction at Morgan
Lock 5 to Berri	0.59
Lock 3 to Lock 4	0.33
Lock 2 to Morgan	0.345
Murray Bridge to Mouth	0.06

Cost

The cost of a dilution flow strategy was estimated by assuming a price of $1000/ML of permanent water entitlement ($10 million for 10GL). Thus reductions in salinity through dilution would cost between $16.7 million/EC unit salinity reduction (Lock 5 to Berri) and $167 million/EC (Murray Bridge to Mouth). These costs are approximately 10 to 100 times more than the cost of achieving equivalent reductions in salinity with salt interception.

Conclusion

The intent of this analysis is to provide rough estimates of capacity (the amount and timing of salinity impact that can be controlled); and the cost of controlling salinity with five technical approaches:

- Salt interception and drainage disposal schemes;
- Revegetation of cleared Mallee;
- Location of new irrigation away from high impact areas (or relocation of existing irrigation to lower impact areas);
- Increasing irrigation efficiency; and
- Provision of dilution flows.

The rough estimates of cost and capacity developed are summarised in Table 5.

Table 5: Estimated cost and capacity of technical options to reduce River Murray salinity impacts in South Australia

Option	Capacity	Cost
Salt interception	150 EC units?	$35,000 - $286,000/ EC unit
Revegetation	6 EC units within 50 years	The cost of revegetation with native vegetation estimated to exceed the cost of salt interception for 94% of areas evaluated.
Irrigation efficiency	70 EC units within 50 year from an increase from 85% to 87.5%	Cost is not well understood. Anecdotal evidences suggest it could be less costly than salt interception in many instances.
Closing existing irrigation in high salinity impact areas	100 EC units from closing down 10,000 ha	3 to 20 times the cost of providing same reduction with salt interception at most costly sites. Less elsewhere.
Locating new irrigation development in low rather than high salinity impact sites	44 EC from locating 5,000 ha in low rather than high salinity impact zones.	$34,000 /EC unit / year. Less at some locations.
Dilution flows	87 EC units from 1500 GL of flow dedicated exclusively to reducing River salt concentration	10 to 100 times more costly than providing same salinity reduction with salt interception.

One conclusion is that development of some additional salt interception capacity will be essential. Salt interception is necessary because it is the only approach that can address salt loads that are already in train. However, it is unlikely that salt interception alone can provide all of the salinity reduction that will be required for SA to meet its MDBC salinity responsibilities. Demand for salinity credits from salt interception could outstrip supply available for SA if additional measures are not taken.

Irrigation location and efficiency have capacity to significantly reduce the amount of future salinity impacts from irrigation and represent potentially cost-effective alternatives to investment in salt interception that would otherwise be required over the next 10 to 30 years.

Dilution flows has a considerable capacity to offset the salinity impacts of irrigation. However, buying water at market prices for salinity dilution is estimated to be 10 to 100 more costly than reducing salinity impacts with salt interception. Nevertheless, if irrigation entitlements are secured to enhance environmental flows the potential of this mechanism to reduce salinity needs to be considered. In particular, consideration needs to be given to how these benefits would be shared among the States.

Revegetation of cleared mallee within 10 km of the River was found to have is limited capacity to address irrigation salinity. Detailed GIS based modelling for this project and summarised in Connor and Cook (2003) and Cook and Connor (2002) found that revegetation at most locations where cleared mallee exists within 10 km of the River will primarily have impact on salinity loading in more than 50 years. In some targeted areas revegetation has the potential to reduce salinity within 50 years but capacity of this option is small less than 6 EC.

A final qualification is that estimates of cost provided here average costs and based on preliminary data. Actual costs will vary significantly across individuals and locations.

Part 3 - Future salt interception investment requirement necessary for South Australia to meet its MDBC salinity targets

SA is obligated under the 2001 *Basin Salinity Management Strategy* to offset any increases in contributions to River salinity from sources in the state resulting in concentration above 2000 levels (MDBC, 2001). How much effort and expense this will require will depend on the level of future irrigation growth as well as the location and efficiency of continuing and new irrigation.

The objectives of the analysis reported on here is to predict:

- The increase in River salinity that could be expected over a range of irrigation expansion, location and efficiency assumptions, and
- The amount and cost of salt interception expected to be necessary to meet South Australian MDBC salinity responsibilities over a range of irrigation expansion, location and efficiency assumptions.

Sets of alternative assumptions are modelled as the four scenarios summarised in Box 1.

Methodology

The analysis is an application of the salinity policy analysis (SPA) model represented conceptually in Figure 9 and mathematically in Figure 10 and described in more detail in the appendix to this report. The SPA framework is an integrated hydrogeology-economics framework for modelling salinity policy in the South Australian River Murray that involves three interrelated process models:

- A water allocation model (WAM) simulating quantity and location of irrigation water application;

- A water and salt process model (WSPM) simulating the location, magnitude and timing of salt loading to the River and the floodplain, given irrigation water drainage, as well as dryland and naturally occurring salinity; and

- A salt interception investment model (SIIM) for estimating the level of salt interception investment required for SA to meet its MDBC salinity targets, given salt load predictions.

The modelled area includes currently irrigated and potentially irrigable land in most of the River Murray Irrigation Management Zone (RMIMZ)[16].

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[16] The RMIMZ actually also includes the area below Swan Reach but above the lower lakes, with the exception of the Lower Murray Swamps (Government of South Australia, 2001). The entire area was not modelled because of the lack of underlying modelling of salinity impacts of existing irrigation below Blanchetown.

The RMIMZ is the area along the River where SA will require irrigators to offset salinity impacts of irrigation (Government of South Australia, 2001). The SPA framework produces estimates that are disaggregated by Land and Water Management Plan areas. These areas are planning units of several hundred or thousand irrigated hectares designated by the South Australian Government as shown in Figure 12.

Box 2: Salinity futures modelling scenarios

Scenario 1: Existing development – In this scenario, no additional water is brought into the study area. All existing irrigation is assumed to remain where it is presently located and apply 8ML/ha/year at 85% irrigation efficiency, producing 120 mm/ha/year of drainage[17].

Scenario 2: Uncontrolled expansion – This scenario models:

- Irrigation in the study area grew by 72 GL over the next ten years (an annual expansion rate similar to that experienced in the last ten years)[18], and
- No zoning of new irrigation development location (irrigators chose to locate where it was least costly to provide water supply).

As in scenario 1, all existing irrigation is assumed to remain where it is presently located and apply 8ML/ha/year at 85% irrigation efficiency, producing 120 mm/ha/year of drainage. New irrigation development is assumed to expand to LWMP areas in proportion to the level of existing irrigation in each area. Within each LWMP area, irrigation is assumed to locate where the cost of supplying water net of salinity charges is least.

Scenario 3: Expansion and zoning - This scenario models:

- Irrigation in the study area increasing by 72 GL over the next ten years, and
- The location of expansion zoned to low and medium impact zones.

As in scenario 1, all existing irrigation is assumed to remain where it is presently located and apply 8ML/ha/year at 85% irrigation efficiency producing 120 mm/ha/year of drainage. New irrigation development is assumed to expand to LWMP areas in proportion to the level of existing irrigation in area. Within the medium and low impact zones in each LWMP area, irrigation is assumed to locate where the cost of supplying water net of salinity charges is least.

Scenario 4: Expansion, zoning and efficiency - This scenario models:

- Irrigation in the study area growing by 72 GL over the next ten years (an annual expansion rate similar to that experienced in the last ten years);
- The location of expansion zoned to low and medium impact zones; and
- One half of all existing and new irrigation achieving 90% efficiency (80 mm of drainage) while the other half is at 85% (120 mm).

As in scenario 2, new irrigation development is assumed to expand to LWMP areas in proportion to the level of existing irrigation in each area. Within the medium and low impact zones in each LWMP area, irrigation is assumed to locate where the cost of supplying water net of salinity charges is least. Water efficiency savings are assumed to be "spread," or reused to expand the area under irrigation. Specifically, it is assumed that half of all reduction in drainage is re-applied at 90% efficiency and half at 85% efficiency.

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[17] The assumption of a uniform drainage is used because it is the basis for salt loading estimates on which the model is built. Results reported in the sensitivity analysis section assess impacts of assuming that drainage in some areas is greater.

[18] This number was chosen because it represents continuation of the current growth trend. Between 1988 and 2001 irrigation in the region has expanded by more than 8000 hectares (Miles, 2002). Approximately 70 Gigalitre have been traded into and within the area in the same period (Franssen, 2003).

Figure 9: Conceptual representation of hydrologic economic policy (SPA) framework

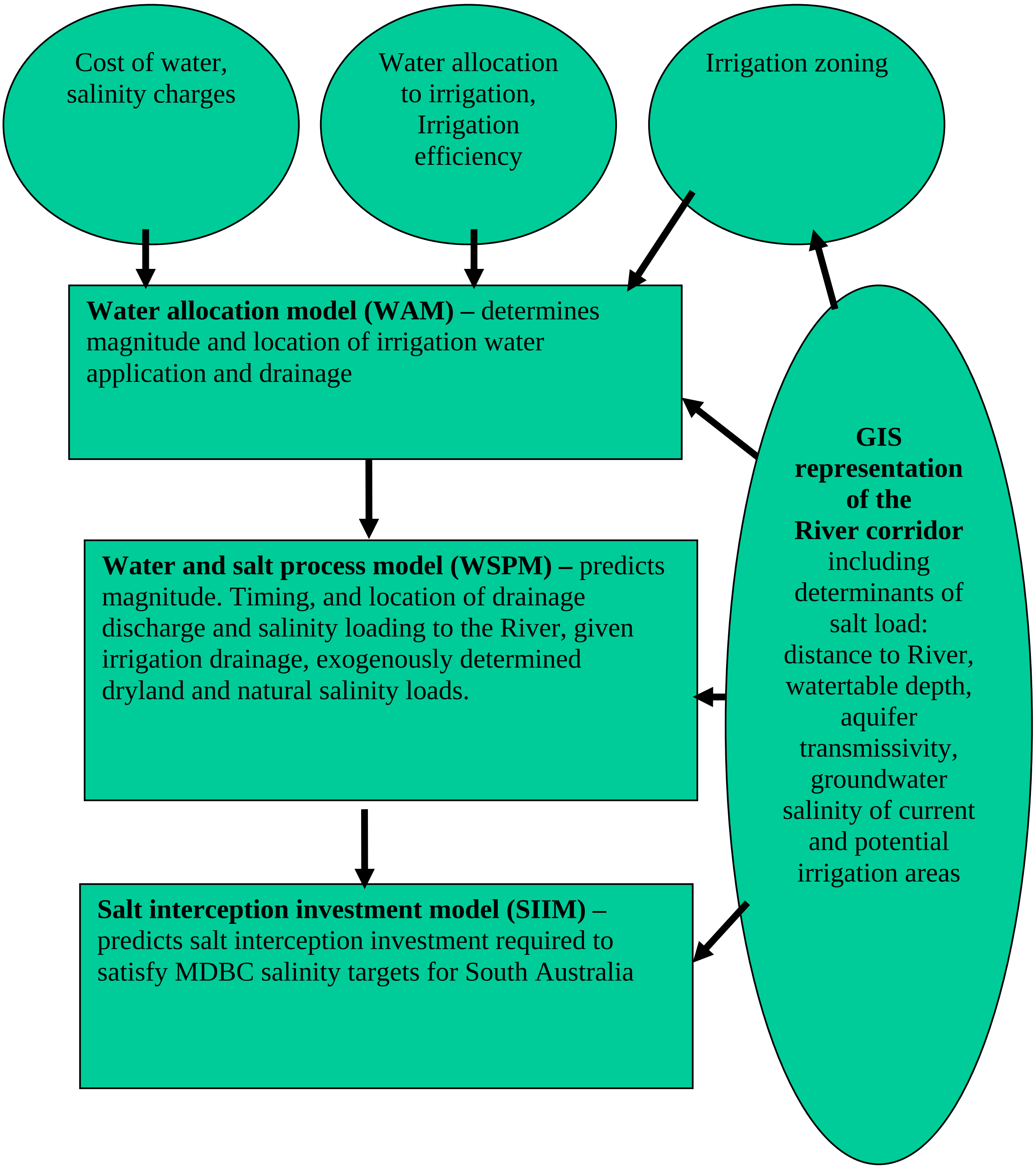
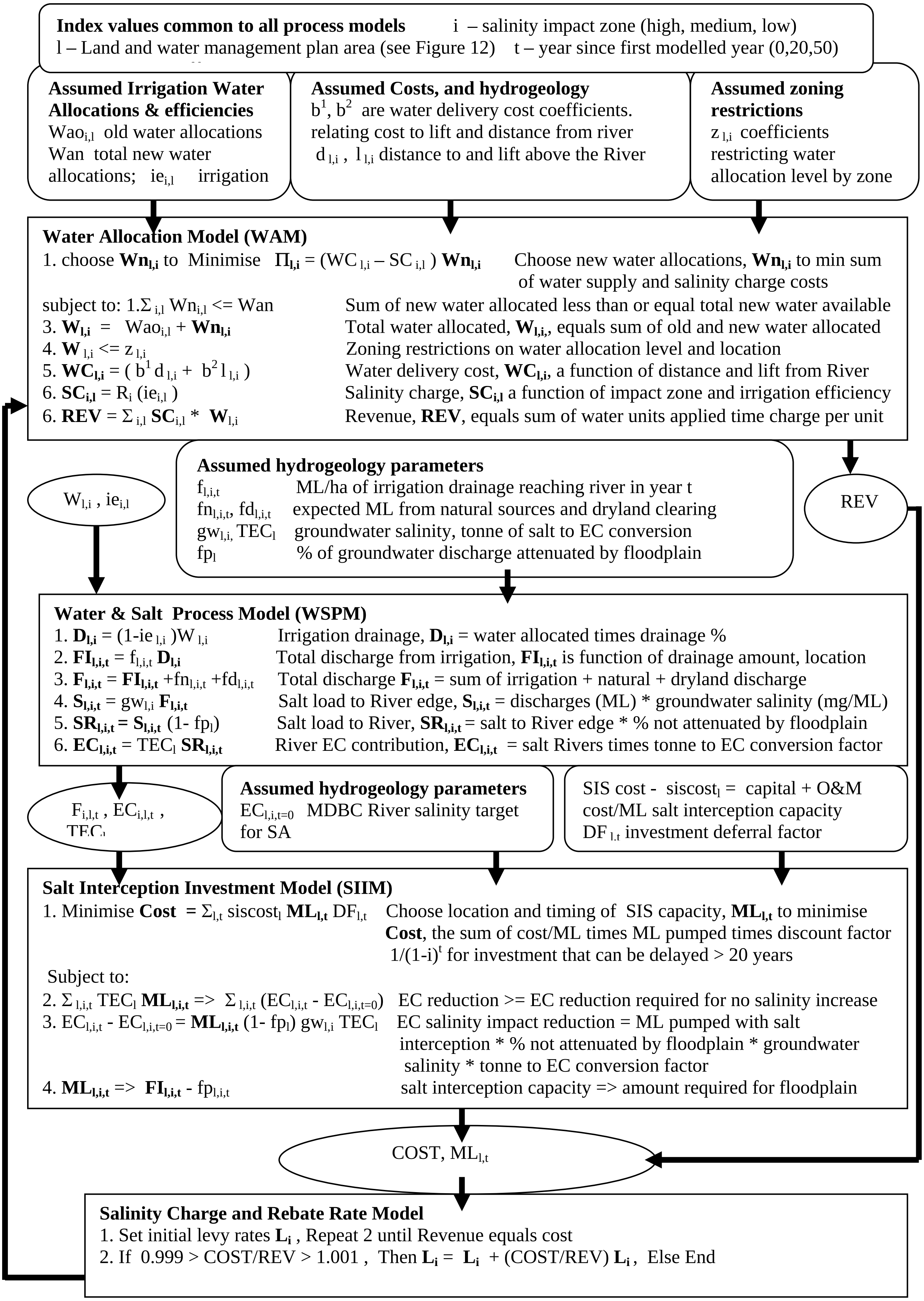


Figure 10: Functional Relationships Governing the Salinity Policy (SPA) Framework



Index values common to all process models i – salinity impact zone (high, medium, low)
l – Land and water management plan area (see Figure 12) t – year since first modelled year (0,20,50)

Assumed Irrigation Water Allocations & efficiencies
$Wao_{i,l}$ old water allocations
Wan total new water allocations; $ie_{i,l}$ irrigation

Assumed Costs, and hydrogeology
b^1, b^2 are water delivery cost coefficients.
relating cost to lift and distance from river
$d_{l,i}$, $l_{l,i}$ distance to and lift above the River

Assumed zoning restrictions
$z_{l,i}$ coefficients restricting water allocation level by zone

Water Allocation Model (WAM)

1. choose $\mathbf{Wn_{l,i}}$ to Minimise $\Pi_{l,i} = (WC_{l,i} - SC_{i,l})\ \mathbf{Wn_{l,i}}$	Choose new water allocations, $\mathbf{Wn_{l,i}}$ to min sum of water supply and salinity charge costs
subject to: 1.$\Sigma_{i,l} Wn_{i,l} <= Wan$	Sum of new water allocated less than or equal total new water available
3. $\mathbf{W_{l,i}} = Wao_{i,l} + \mathbf{Wn_{l,i}}$	Total water allocated, $\mathbf{W_{l,i,}}$, equals sum of old and new water allocated
4. $W_{l,i} <= z_{l,i}$	Zoning restrictions on water allocation level and location
5. $\mathbf{WC_{l,i}} = (b^1 d_{l,i} + b^2 l_{l,i})$	Water delivery cost, $\mathbf{WC_{l,i}}$, a function of distance and lift from River
6. $\mathbf{SC_{i,l}} = R_i\,(ie_{i,l})$	Salinity charge, $\mathbf{SC_{i,l}}$ a function of impact zone and irrigation efficiency
6. $\mathbf{REV} = \Sigma_{i,l}\ \mathbf{SC}_{i,l} * \mathbf{W}_{l,i}$	Revenue, **REV**, equals sum of water units applied time charge per unit

$W_{l,i}$, $ie_{i,l}$

REV

Assumed hydrogeology parameters
$f_{l,i,t}$ ML/ha of irrigation drainage reaching river in year t
$fn_{l,i,t}$, $fd_{l,i,t}$ expected ML from natural sources and dryland clearing
$gw_{l,i,}$ TEC_l groundwater salinity, tonne of salt to EC conversion
fp_l % of groundwater discharge attenuated by floodplain

Water & Salt Process Model (WSPM)

1. $\mathbf{D_{l,i}} = (1-ie_{l,i})W_{l,i}$	Irrigation drainage, $\mathbf{D_{l,i}}$ = water allocated times drainage %
2. $\mathbf{FI_{l,i,t}} = f_{l,i,t}\ \mathbf{D_{l,i}}$	Total discharge from irrigation, $\mathbf{FI_{l,i,t}}$ is function of drainage amount, location
3. $\mathbf{F_{l,i,t}} = \mathbf{FI_{l,i,t}} + fn_{l,i,t} + fd_{l,i,t}$	Total discharge $\mathbf{F_{l,i,t}}$ = sum of irrigation + natural + dryland discharge
4. $\mathbf{S_{l,i,t}} = gw_{l,i}\ \mathbf{F_{l,i,t}}$	Salt load to River edge, $\mathbf{S_{l,i,t}}$ = discharges (ML) * groundwater salinity (mg/ML)
5. $\mathbf{SR_{l,i,t}} = \mathbf{S_{l,i,t}}\ (1-fp_l)$	Salt load to River, $\mathbf{SR_{l,i,t}}$ = salt to River edge * % not attenuated by floodplain
6. $\mathbf{EC_{l,i,t}} = TEC_l\ \mathbf{SR_{l,i,t}}$	River EC contribution, $\mathbf{EC_{l,i,t}}$ = salt Rivers times tonne to EC conversion factor

$F_{i,l,t}$, $EC_{i,l,t}$, TEC_l

Assumed hydrogeology parameters
$EC_{l,i,t=0}$ MDBC River salinity target for SA

SIS cost - $siscost_l$ = capital + O&M cost/ML salt interception capacity
$DF_{l,t}$ investment deferral factor

Salt Interception Investment Model (SIIM)

1. Minimise $\mathbf{Cost} = \Sigma_{l,t}\ siscost_l\ \mathbf{ML_{l,t}}\ DF_{l,t}$	Choose location and timing of SIS capacity, $\mathbf{ML_{l,t}}$ to minimise **Cost**, the sum of cost/ML times ML pumped times discount factor $1/(1-i)^t$ for investment that can be delayed > 20 years
Subject to:	
2. $\Sigma_{l,i,t}\ TEC_l\ \mathbf{ML_{l,i,t}} => \Sigma_{l,i,t}\ (EC_{l,i,t} - EC_{l,i,t=0})$	EC reduction >= EC reduction required for no salinity increase
3. $EC_{l,i,t} - EC_{l,i,t=0} = \mathbf{ML_{l,i,t}}\ (1-fp_l)\ gw_{l,i}\ TEC_l$	EC salinity impact reduction = ML pumped with salt interception * % not attenuated by floodplain * groundwater salinity * tonne to EC conversion factor
4. $\mathbf{ML_{l,i,t}} => \mathbf{FI_{l,i,t}} - fp_{l,i,t}$	salt interception capacity => amount required for floodplain

COST, $ML_{l,t}$

Salinity Charge and Rebate Rate Model
1. Set initial levy rates $\mathbf{L_i}$, Repeat 2 until Revenue equals cost
2. If $0.999 > COST/REV > 1.001$, Then $\mathbf{L_i} = \mathbf{L_i} + (COST/REV)\ \mathbf{L_i}$, Else End

Figure 11: Study area

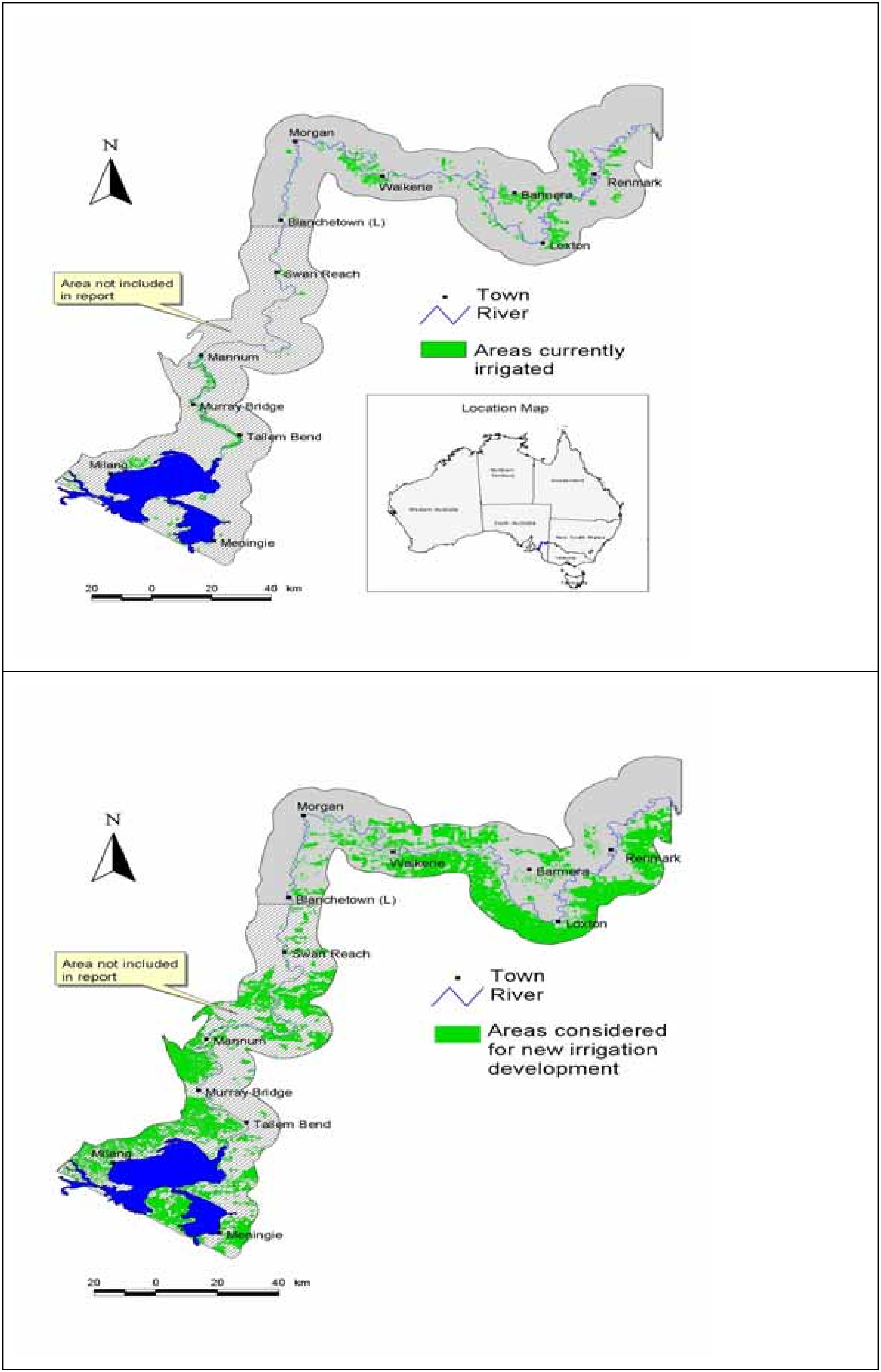
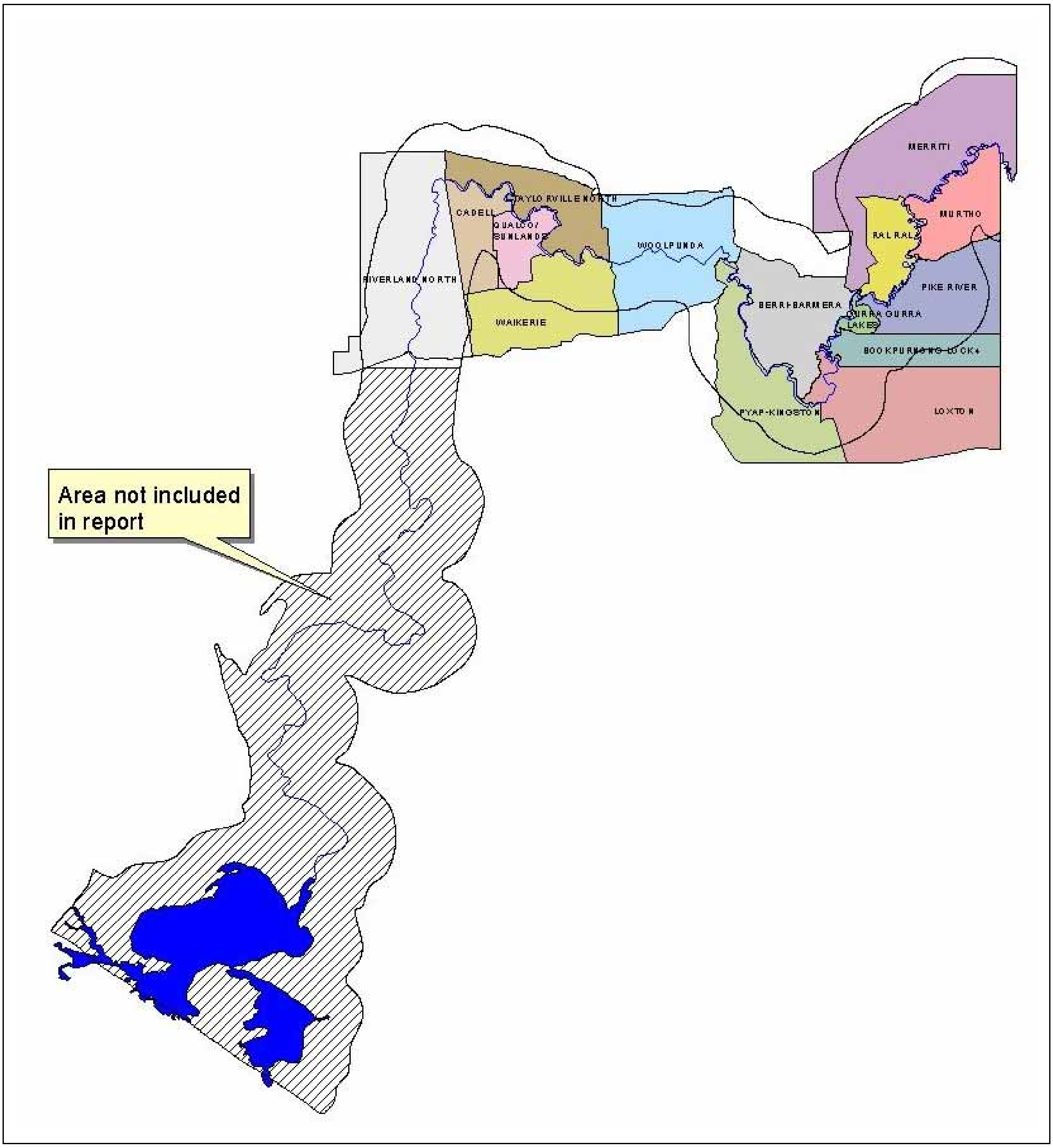


Figure 12: Land and Water Management Plan Areas within study area



Results

Figure 13 shows the estimated cost of meeting MDBC salinity goals for SA for the modelled scenarios.

Figure 13: Estimated cost of meeting MDBC salinity goals for South Australia

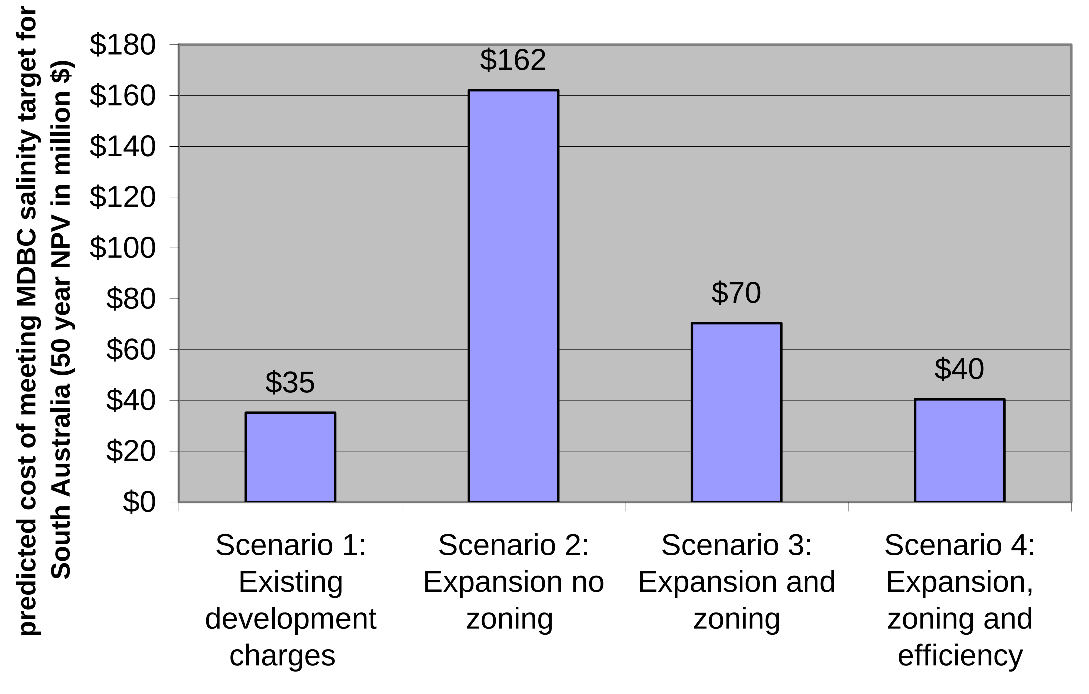


Table 6 summarises results in more detail including a breakout of capital versus operation and maintenance cost, estimates of annual payment equivalent costs and the River salinity increase that would be expected for each scenario if salt interception to mitigate were not built.

Table 6: Salinity mitigation cost analysis results

Scenario 1: Existing development charges	Scenario 1: Existing development charges	Scenario 2: Expansion no zoning	Scenario 3: Expansion and zoning	Scenario 4: Expansion, zoning and efficiency
Predicted River salinity increase with no additional action	49.2	109.9	77.8	46.3
Additional SIS capacity required (ML)	5472	12820	7496	5550
Total cost of additional SIS ($million)	$35.2	$162.1	$70.4	$40.5
SIS capital cost	$24.4	$112.4	$48.8	$28.1
Present value of operation and maintenance cost	$10.8	$49.7	$21.6	$12.4
Annual payment capital ($ million)	$2.0	$9.0	$3.9	$2.2
Annual payment O&M ($ million)	$0.9	$4.0	$1.7	$1.0
Annual payment total ($ million)	$2.8	$13.0	$5.6	$3.2

Scenario 1 assesses expected salt interception investment requirement from current irrigation in the absence of any additional irrigation development. Results show that given the projected future impact of existing irrigation, an estimated $35 million in salt interception investment will be required to meet MDBC salinity targets in SA even if no additional water enters the region.

Scenario 2 simulated essentially uncontrolled development of irrigation. This was modelled as irrigation continuing to expand at current rates (expansion by 72 GL) at 85 % irrigation efficiency in high and medium impact areas. The prediction for the scenario is that SA would be required to make very large investments in salt interception ($162 million) to meet MDBC salinity responsibilities.

Comparison of scenario 1 and 2 results shows that as a result of uncontrolled development, the level of salt interception investment required would grow more quickly than the level of River salinity impact. While EC impact that SA is responsible to mitigate in scenario 2 is around twice the scenario 1 level (110 EC compared to 49.7 EC), salt interception investment requirement is more than four times greater ($162 million compared to $35 million). This is a result of increasing marginal cost of salt interception as capacity at least cost sites is exhausted. This was discussed in part 2 of the report and shown is in Figure 6 (in part 2). In scenario 1, all required capacity can be supplied for the relatively low cost at the Bookpurnong, Loxton, Woolpunda, Murtho, and Pike River sites. In contrast, meeting the salt interception investment requirement for scenario 2 is predicted to require 45 % of total salt interception capacity (in volume pumped terms) at the much more expensive Pyap, Waikerie and Chowilla sites.

Scenario 3 results show that the expected future cost of salt interception required to meet salinity targets in SA can be reduced significantly by judicious choice of new irrigation location. Scenario 3 simulated a 72 GL expansion with new development restricted to low and medium salinity impact areas. The estimated result is a reduction in salt interception investment requirement by more than one half to $70 million (in comparison to scenario 1 where the same expansion was modelled but without zoning of new development).

Scenario 4 simulated continuing irrigation expansion with all new development in medium and low impact zones, and one half of all (new and existing) irrigation achieving 90% rather than 85% efficiency. Results show that if high irrigation efficiencies are achieved and most new development is restricted to medium and low salinity impact areas, a reduction of salt interception investment requirement to $40 million is possible (even with a 72 GL growth in irrigation water allocations in the area).

Part 3 Summary and Conclusions

This analysis estimated the cost of salt interception that SA can expect to face, in order to meet salinity targets under the MDBC agreement on salinity. Estimates are presented for four scenarios representing alternative assumptions about key determinants of irrigation salinity loading.

One finding is that SA could be required to make very large investments in salt interception if irrigation continues to expand as it has in the past and additional measures are not taken. For a scenario involve a 72 GL of essentially uncontrolled expansion it was estimated that SA would be required to provide 110 EC of salt interception to meet its MDBC salinity target. The estimated cost of providing this capacity is $162 million (in 50 year net present value terms). The conclusions to Part 2 of this study, raises serious questions about whether it is even technically possible to put sufficient salt interception capacity in place to satisfy South Australian salinity responsibilities in an uncontrolled expansion scenario.

Several of the scenarios analysed estimated potential scale of salt interception investment required to meet MDBC salinity goals with zoning of irrigation location and irrigation efficiency improvements. A key conclusion is that the expected future demand for salt interception and cost of meeting salinity targets in SA can be reduced significantly. If new development were kept out of the highest salinity impact areas, estimated salt interception investment requirement could be cut by more than one half. Less than 80 EC of capacity would be required at an estimated cost of $70 million. If in addition one half of all (new and existing) irrigation achieved 90% rather than 85% irrigation efficiency average irrigation efficiency would increase to 87.5%. The result would be that expected salt interception investment could be reduced less than 50 EC at a cost of $40 million.

A key implication is that to ensure that it can meet its MDBC salinity obligations SA will need to develop policies that can effectively influence irrigation location and efficiency. In developing such policies there is the potential to reduce the cost of mitigating salinity impacts of irrigation considerably.

Part 4 - Salinity charge option analysis

Part 3 of this report estimated the investment that would be required in salt interception for SA to meet MDBC salinity targets for the State. It was concluded that the required investment would be between $35 million and $162 million (50 and 110 EC) worth of salt interception scheme capacity. There is a range of possible arrangements for sharing these costs between irrigators and government. If irrigators are to pay part or all of the cost, a salinity charge will be required.

The purposes of the analysis reported on here are:

- To estimate cost to the Government and irrigators that would result from a range of salinity charge arrangements and assumptions about irrigation expansion, location and efficiency; and
- To outline the trade-offs between cost to irrigators, and cost to Government (taxpayers).

Charge options evaluated

Consistent with the terms of reference set by DWLBC four salinity charge options for two levels of cost recovery and several irrigation development scenarios were evaluated. The four options are:

1. **Uniform charges** – This option involves simply charging all irrigators the same amount per ML of irrigation applied.

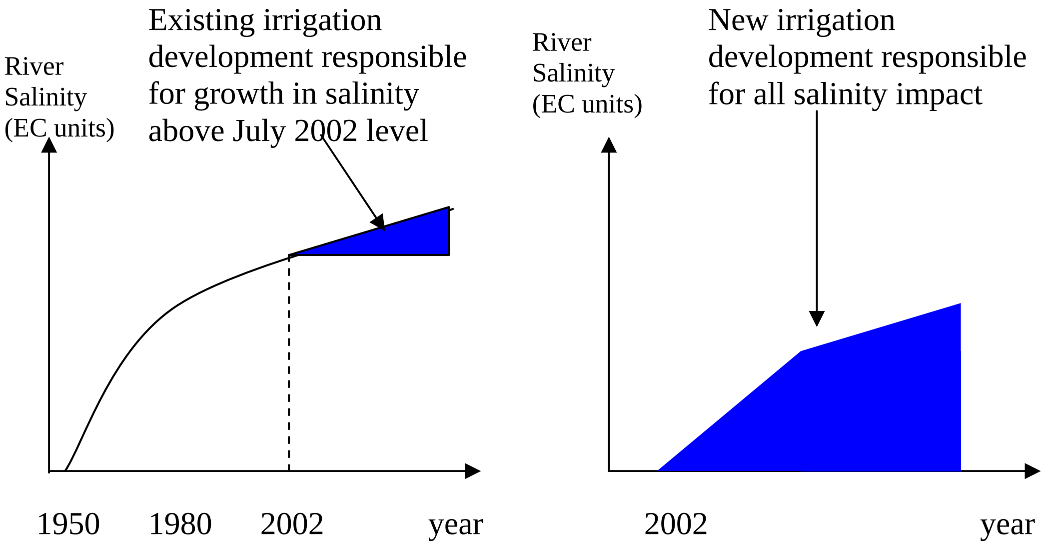
2. **Impact zone-based charges** – This option involves reflecting spatial differences in salinity impact of irrigation in salinity charge rates. This approach has already been implemented in the Sunraysia Irrigation Trust in Victoria as explained in more detail in Box 3. The basic idea is to zone potentially irrigable land into areas where irrigation would be expected to have roughly similar levels of impact. Charge rates are then differed to reflect expected average impact from the same level of irrigation in each zone.

3. **Efficiency incentive charges** – This option involves differentiating charge levels based on differences in irrigation efficiency. Those who irrigate more efficiently are charged less because the result of their efficiency is less need to invest in salt interception.

4. **Development charges** – This option involves assigning different salinity charge rates to existing and new irrigators. The option represents a potential implementation of the *Water Allocation Plan for the River Murray Prescribed Watercourse* (Plan) that describes new and existing irrigation salinity responsibilities differently (South

Australian Government, 2001b). Consistent with the Plan new irrigation developers would be required to pay charges based on the investment required to offset all salinity impacts of new irrigation. In contrast, existing irrigators would be required to pay charges necessary to finance only increases in salinity above July 2002 levels resulting from actions of existing irrigators. The definitions of new and existing irrigation responsibility in the Plan are shown conceptually in Figure 14.

Figure 14: Conceptual representation of different salinity responsibilities for new and existing irrigation development described in the *Water Allocation Plan for the River Murray Prescribed Watercourse*



Modelling Methods

The modelling involves partitioning Part 3 estimates of salt interception investment required to meet salinity targets among irrigators and the Government. Each charge option involves sharing the costs of required investment differently.

For the uniform charges option, a salinity charge per ML of irrigation applied is computed as the total cost of required salt interception investment divided by the total volume of water applied.

For the impact zone-based charge option, charges are modelled for three impact zones (high, low, and medium) as shown in Figure 8. The charge rate in each zone is modelled as the cost of mitigating River salinity impacts from irrigation in that zone divided by volume of water applied in the zone. The rates of salinity impact per ML applied by zone assumed in this assessment come from Miles (2002) and are shown in Table 2 in Part 2 of this report.

For the efficiency incentive charge option, two charge rates are assumed: a "standard" efficiency rate for achieving 85% irrigation efficiency and a "high" efficiency rate for achieving 90%. The "standard efficiency" charge is modelled as the cost of required salt interception investment divided by water applied assuming all irrigation is at 85%. The "high efficiency" charge is modelled as the cost of required salt interception investment divided by water applied assuming all irrigation is at 90%.

For the development charge option, irrigators who purchase an additional allocation or start to use a previously unused allocation are charged a higher rate for any expanded allocation. Note, however, that under this option, irrigators who increase irrigation efficiency can expand irrigated area without paying the higher charge. Salinity charges for new irrigation are computed as the cost of salt interception required as the result of new irrigation development divided by the volume of water applied by new irrigation development.

The charge for the salinity impact of existing irrigation below the 2002 levels in the River is zero. Under this option, existing irrigators are deemed to be responsible for any increase in River salinity above the 2002 level as a result of their activities. The cost of this development charge for existing irrigator is based on the cost of salt interception required to meet existing irrigator responsibilities divided by the volume of water applied by existing irrigators.

Modelling Assumptions

Each of the four salinity charge options outlined above is evaluated over a range of assumptions. For each option, one or more of the irrigation development scenarios from Part 3 (and summarised in Box 3 in Part 3) is modelled.

In addition, two alternative cost recovery approaches are modelled: partial cost recovery and full cost recovery. Under partial cost recovery, operating and maintenance costs but not capital costs are recovered. This approach is conceptually similar to the cost sharing approach that the SA Government has often taken in the past. An example of this approach is the Qualco-Sunlands where the Government finances the capital cost of a salt interception scheme and irrigators cover operations and maintenance costs through a charge per ML of irrigation water (Riverland West Local Action Planning, 2003). Following this precedent the partial cost recovery charges are modelled as the rate required to cover operations and maintenance cost of required salt interception investment.

The other approach modelled is charging on a full cost recovery basis. Under full cost recovery irrigators pay the full cost of mitigating adverse impacts of irrigation salinity including capital costs. Full cost recovery charges are estimated as the amortised annual cost of:

- The full cost foreseeable over the next 50 years of capital, operations and maintenance of salt interception capacity necessary to meet MDBC salinity responsibility that arises from irrigation,
- A renewal charge to offset the amortised costs of salt interception that will be required to offset continuing salinity impacts of irrigation beyond 50 years even if irrigation ceases operation,
- The cost of replacing flow to the River that is removed by salt interception (it is assumed that the required flow can be purchased in the water market for $1,300/ha).

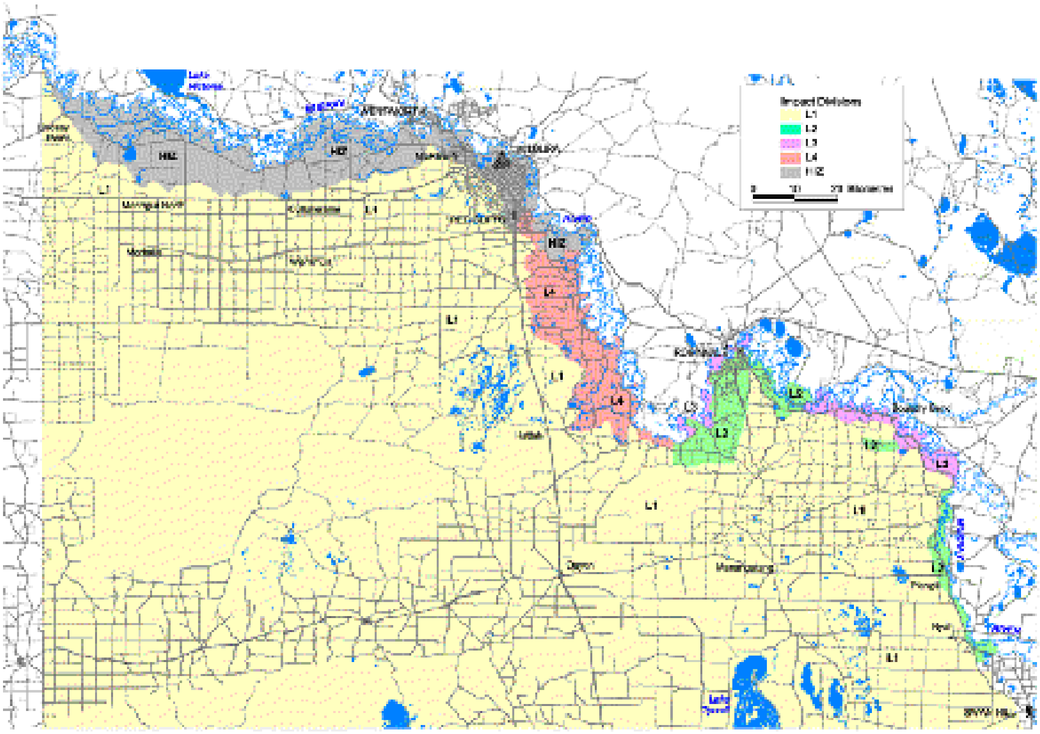
The options and assumptions modelled for each option are outlined in Table 7.

Table 7: Salinity charge options modelled

Salinity charge option	Cost recovery basis	Impact zone-based charges	Marginal cost charge for new development	Efficiency incentive charge	Irrigation expansion, zoning and efficiency scenarios modelled
Uniform salinity charge	Full & Partial				Scenarios 1-4
Impact zone-based charges	Full & Partial	√			Scenarios 1,3&4
Efficiency incentive pricing	Full	√		√	Scenario 4
Marginal cost charges for new development					
i.Uniform charge	Partial & Full		√		Scenario 2&3
ii.Impact zone-based charge	Full	√	√		Scenario 3

Box 3: A Victorian Salinity Zoning and Charges Policy

The Nyah to the South Australian Border Salinity Management Plan has been in place in the Victorian Sunraysia Irrigation Trust since 1993. The policy involves a levy for irrigation development proportional to the salinity impact that the irrigation causes. Proceeds finance salt interception. The area under the plan has been classified into five zones, as shown in Figure 6 based on hydrogeology modelling of salinity impacts of irrigation.



The grey shaded area denoted HIZ in the figure above is designated high impact zone. No new irrigation development is allowed in this area because, in the judgement of plan administrators, salinity impacts of irrigation in this area are so high that they would result in very rapid depletion of the limited supply of salinity mitigation capacity in the region.

In the four low impact zones (L1-L4), irrigation development is allowed. However, in addition to other conditions, salinity charges are levied. The charges are proportional to modelled average salinity impact of irrigation in each zone as shown below. The levy can be paid on a once off basis or as ten annual payments.

Zone	Estimated Salinity (EC/1000 ML)	Charge per ML (Paid Once Off)	Annual Charges per ML if paid over 10 years
L1 – low impact zone 1	0.02	$26	$3.21
L2 – low impact zone 2	0.05	$65	$8.01
L3 – low impact zone 3	0.1	$130	$16.03
L4 – low impact zone 4	0.2	$260	$32.06

* There is an additional $3.20/ML/year charge for operations and maintenance in all zones.

Source: Sunraysia Rural Water Authority, 2002

Results

Uniform charges

Uniform salinity charges involve charging all irrigators the same salinity charge per ML of irrigation applied.

Table 8: Estimated salinity charges - option 1: uniform charge

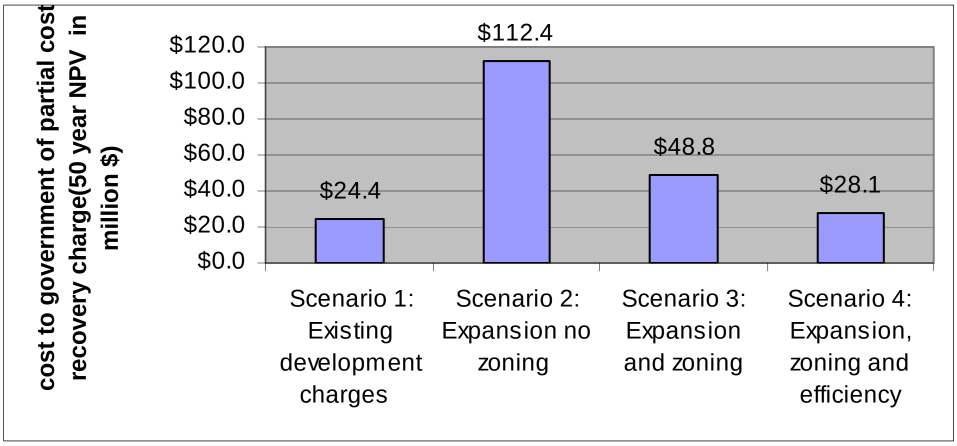
Cost recovery basis	Scenario 1: Existing development	Scenario 2: Expansion no zoning	Scenario 3: Expansion and zoning	Scenario 4: Expansion, zoning and efficiency
Partial cost recovery ($/ML/year)*	$3.0	$11.0	$4.8	$2.7
Full cost recovery ($/ML/year)*	$10.4	$37.8	$16.4	$9.3

Results summarised in Table 8 show estimated salinity charges for the uniform charge option. Under scenario 1 assumptions (no irrigation expansion), the estimated partial cost recovery charge is $3/ML while the estimated full cost recovery charge is $10/ML. Both of these charge levels are quite modest in comparison to both current Victorian charges (see Box 3) and irrigated crop gross margins in the region (PIRSA, 2003).

Scenario 2-4 results in Table 8 show the partial and full cost recovery salinity charges estimated to be required with a 72 GL expansion in irrigation. Scenario 2 results show that with no zoning or improvement in efficiency (above the assumed 85%) a full cost recovery charge of $38/ML could be expected. In contrast, the partial cost recovery charge under these circumstances is estimated to be $11/ML. Scenario 3 results show that with zoning of new irrigation out of highest impact zones and a 72 GL expansion, the expected charge rate would be less than half the estimated rates in the absence of zoning ($16/ML rather than $38/ML for a full cost recovery charge and $5/ML rather than $11/ML for a partial cost recovery charge).

Figure 15 shows the cost to taxpayers that would result if a uniform partial cost recovery charge were implemented and irrigators simply absorbed the cost without reducing water use. The results show that the potential cost of this type of charging approach to taxpayers could be high especially if effective policy to influence new irrigation location and new and existing irrigation efficiency are not put in place.

Figure 15: Estimated cost to government of a partial cost recovery salinity charge



Scenario 4 results in Table 8 are estimated charge rates on both a full and partial cost recovery basis for a scenario where irrigation expands by 72 GL but average irrigation efficiency also increases from 85% to 87.5%. It is instructive to compare charge rates estimated in this scenario and in scenario 1 where no irrigation expansion is assumed but no irrigation efficiency increase is assumed either. The comparison shows that even with a significant irrigation expansion it is possible to reduce salinity charge rates by increasing irrigation efficiency.

Impact zone-based charges

Table 9: Estimated salinity charges - option 2: impact zone-based charge

Cost recovery basis	Scenario 1: Existing development	Scenario 2: Expansion no zoning	Scenario 3: Expansion and zoning	Scenario 4: Expansion, zoning and efficiency
Partial cost recovery ($/ML/year)*				
Low impact zone	$0.6		$1.0	$0.6
Medium impact zone	$2.6		$4.1	$2.3
High impact zone	$5.7		$9.1	$5.2
Full cost recovery ($/ML/year)*				
Low impact zone	$2.2		$3.5	$1.9
Medium impact zone	$9.0		$14.3	$8.1
High impact zone	$19.9		$31.6	$17.8

The impact zone-based charge rates estimated on both a partial and full cost recovery basis are shown in Table 9. For all of the scenarios modelled charge rates are nearly ten times as large in the high impact zone as they are in the low impact zone and estimated charges are twice as large in high impact zones as they are in medium impact zones. Despite the differences in charge rates across zones, very little change in the location chosen for new irrigation is expected to occur.

This surprising and counter-intuitive observation is due to the location of high salinity impact areas and the costs to irrigators of pumping water. Pumping costs are directly related to distance from the River and the height that water has to be lifted for irrigation. Unfortunately, low salinity impact areas are located away from the River. This means that the irrigation water pumping costs and the cost of any zone-differentiated levy are inversely related. Pumping costs tend to be high in places where levy costs are low and vice versa. From a private irrigation perspective, it is actually less expensive in most cases to locate irrigation in high impact zones than in low impact zones. That is, when the cost of a zone-based salinity levy is added to the cost of pumping water for irrigation, the most profitable option is to locate most irrigation in high salinity impact areas.

Though the modelling predicts very little location response to zone-based charges, this does not necessarily mean that in actual experience such little response would be observed if charges were implemented. Modelled response is based on the conservative assumption that there is no existing excess water supply capacity. If in fact some excess capacity exists in low and medium impact zones, it may indeed be less expensive to locate in these areas than is assumed in this analysis. The modelled response is based on averages while in some particular cases, the motivation that lower charges provide may in fact be sufficient to motivate location in lower impact areas.

The results do suggest that as a standalone policy, zone-based charges may not suffice to ensure that there is not a large expansion of irrigation into high impact areas. Zoning where new irrigation can and cannot occur is a more certain way of limiting development in high impact areas. A key implication is that zoning location of new development may be a preferred policy option, at least at locations where limiting groundwater recharge from new irrigation development is important because of limited or expensive salt interception capacity or floodplain risks.

Efficiency incentive charges

Table 10: Estimated salinity charges - option 3: efficiency incentive charge (on a full cost recovery basis)

	Scenario 4: Expansion, zoning and efficiency	
	85% Efficiency	90% Efficiency
Low impact zone	$3.5	$0.1
Medium impact zone	$14.3	$0.5
High impact zone	$31.6	$1.1

Efficiency incentive salinity charges involve lower rates for irrigators who achieve higher levels of irrigation efficiency. The logic behind this approach is that more efficient irrigation reduces groundwater recharge and consequent need for investment in salt interception to meet MDBC salinity targets. The option was modelled as a different salinity charge rate for different irrigator types. "Standard efficiency" irrigators (achieving 85% efficiency) are charge one rate and "high efficiency" irrigators (achieving 90%) are charged a lower rate. The rates charged to each type of irrigator represent a share of the total cost of salt interception cost that would be required to meet salinity targets if all irrigators were of that type.

The estimated efficiency incentive charge rates for high and standard efficiency irrigators are shown in Table 10. Notably, the estimated rate is significantly lower for those who achieve very high irrigation efficiency. The charges estimated are for an efficiency incentive charging scheme superimposed on an impact zone-based charge. This approach is estimated to save irrigators in the high impact zone $30 per ML for irrigators achieving 90% rather than 85% irrigation efficiency. The large charge reduction reflects the potential to substantially reduce investment in salt interception if there are significant improvements in irrigation efficiency.

Development charges

Table 11: Estimated salinity charges - option 4: Development charges

Cost recovery basis / spatial differentiation	Scenario 1: Existing development	Scenario 2: Expansion no zoning	Scenario 3: Expansion and zoning	Scenario 4: Expansion, zoning and efficiency
uniform charge / partial cost recovery		$41.7	$12.1	
uniform charge / full cost recovery		$152.3	$40.6	
impact zone-based charge / full cost recovery				
Low impact zone			$10.7	
Medium impact zone			$44.3	
High impact zone			NA	

Development charges involve assigning different salinity charge rates to existing and new irrigators. The option represents a potential implementation of the *Water Allocation Plan for the River Murray Prescribed Watercourse* (Plan) that describes new and existing irrigation salinity responsibilities differently (South Australian Government, 2001b). Consistent with the Plan new irrigation developers would be required to pay charges based on the investment required to offset all salinity impacts of new or previously un-activated water allocations. In contrast, existing irrigators pay charges required to finance only increases in salinity above July 2002 levels resulting from existing irrigation.

The results presented in Table 11 show that new irrigators would pay higher charges if this option were implemented. For example, the charge for an irrigator wishing to locate new irrigation in the medium impact zone is

$44/ml under Scenario 3 conditions (72 GL of irrigation growth, zoning of development to medium and low impact zones, and zone-based charges). The cost for an existing irrigator with zone-based charges set on a full-cost recovery basis in contrast would be just $14/ML under the same scenario (see Table 9).

Part 4 Summary and conclusions

This part of the report estimates the cost of a range of salinity charge options over alternative cost sharing and irrigation expansion assumptions. One of the options considered was a uniform charge per ML for all new and existing irrigation development. An attractive feature of this approach is that it is an administratively straightforward way to recover a share of the cost of salt interception investment from irrigators.

However, such charges represent only a small share of production cost and don't relate charge rates to location or drainage level. As a consequence they create little incentive to locate where impacts are low or to reduce drainage. A key implication is charge approach as a stand-alone policy could well result in salt interception investment requirement close to the estimated $162 million. This is the investment expected if irrigation continues to expand at rates experienced over the last decade with no effective policy addressing irrigation location and efficiency.

Another charge approach evaluated involved setting charge rates to reflect location impact differences. The approach could be implemented using GIS to delineate salinity impact zones. Similar approaches are already in place in the Victorian Sunraysia Irrigation Trust and in the Qualco-Sunlands scheme.

Results of this zoning analysis also indicate that the incentive effect of zoned based charges may be quite limited even if set on a full cost recovery basis. This is because charge rates reflecting spatial differences in salinity impact are directly related to distance from and lift above the River. The cost of providing water supply (pumps, pipes and power) for new irrigation is inversely related to the same factors. The results of this analysis show that for the zone-based charge rates modelled, it was actually less expensive for irrigators to locate in high impact zones than in low impact zones when the sum of salinity charges (higher in low impact zones) and water supply cost (lower in high impact zones) are considered.

A key implication is that zone-based charges alone are unlikely to reduce salinity interception scheme investment required to meet MDBC salinity targets. This is because zone-based charges are not predicted to motivate new irrigation to locate away from highest impact areas. This is problematic because results from part 2 of this study suggests that significant growth of irrigation in high salinity impact areas could lead to salinity impact exceeding capacity to offset with salt interception. An alternative or complementary policy to zone-based charges that can ensure

South can meet its salinity targets worth considering is zoning the location of new irrigation development away from high impact areas.

A distinct advantage of charging less to more efficient irrigators is that it can motivate existing irrigators to reduce salinity impact. In addition, the approach is attractive from an equity perspective because it gives irrigators who located in high impact areas without knowledge that they would face a high salinity charge an opportunity to reduce the rate they face.

One option modelled involved charging existing irrigators less than those who expand irrigation application in the area. In the absence of any complementary policies this approach could be problematic. The relatively low charge faced by existing irrigators would create little incentive for such irrigators to take action to reduce their impact. In effect the approach penalises irrigators for retiring existing irrigation from high impact areas and redeveloping at lower impact sites by charging them higher salinity charges.

One way to create an incentive for existing irrigators to reduce the salinity impact of their irrigation is the efficiency incentive charge option considered in this analysis. The option involves lower charge rates for those who irrigate more efficiently. This could provide significant motivation for existing irrigation located in high impact areas to take action to reduce salinity impact. For example, given irrigation efficiency incentive charge rates estimated here an irrigator in the high impact zone applying 8ML could save nearly $250/ha on salinity charges by applying irrigation at 90% rather than 85% efficiency.

Furthermore, the approach potentially offers an attractive way to balance equity and efficiency trade-offs inherent in salinity policy choice. It may be considered inequitable to impose high charges on those who made investments in production without knowledge that they would face a high charge (or high costs of meeting standards) as the result of how or where they produce. However, efficiency incentive charging may be considered fair because, while it involves creating a potential significant cost for existing irrigators, it also gives these irrigators an incentive to reduce this cost by becoming more efficient.

A particularly significant challenge arises in implementing this kind of approach because irrigation efficiency is difficult to measure with precision. One way that this challenge could be addressed would involve requiring meeting some form of irrigation best management practice standard to qualify for the reduced salinity charge rate. Irrigators who implemented certain practices (for example irrigation system design and irrigation scheduling to a specified standard) would be certified as efficient and qualify for the lower rate.

An alternative strategy would involve requiring performance to a set efficiency standard (e.g. >85% efficiency) measured with a combination of flow metering and crop water use modelling. A key question that arises is whether cost effective and reliable approaches to monitoring, auditing, and administering charge rate reductions for more efficient irrigation can be worked out.

References

Allison, G.B., Cook, P.G., Banett, S.R., Jolly, I.D. and Hughes, M.W. (1990) Land clearance and River Salinisation in the Western Murray Basin, Australia. *Journal of Hydrology*, 119:1-20.

Australian Water Environments (1999) *Assessment of the Trends in Salt Loads and Salinity Along the River Murray in South Australia.* Consulting report prepared for the South Australian Department of Environment and Heritage. Adelaide, May 1999.

Australian Water Environments (2003). *Regional Saline Water Disposal Strategy- Stage 1.* Final Draft Report for DWLBC.

Cole, Phil (2003) personal communication.

Connor, J. and Peter G. Cook. 2003. *Maximum Justified Investment in Revegetation as an Alternative to Salt Interception for the South Australian River Murray.* Proceedings of the 47th Annual Australian Agricultural and Resource Economics Meetings.

Connor, J., P. Cook and D. Miles (2003) Maximum Justified Investment on Alternatives to Salt Interception for the South Australian River Murray. Interim Report prepared for the South Australian Department for Water, Land and Biodiversity Conservation, March, 2003.

Cook, P.G, and J. Connor (2002) REVEG: A Model for Predicting Costs and Benefits of Recharge Reductions Strategies in the Mallee Region of South Australia. CSIRO Technical Report 26/02, July 2002.

EconSearch Pty Ltd (2003) *Economic Analysis of the Proposed Bookpurnong-Loxton Salt Interception Scheme*. Consulting report, January, 2003. Adelaide.

Forward, Peter, SA Water Manger of Salinity Control (2002) Personal correspondence and unpublished working documents.

Franssen, Ingrid (2003) “Holding the line for salinity in the River Murray in SA: illusion or reality?” Proceedings of *Salinity – Causes, effects, manifestations, remedies and revolutions*. Hydrological Society of South Australia, July, 2003, Adelaide.

Government of South Australia (2001a) *Water Allocation Plan for the River Murray Prescribed Watercourse.* River Murray Catchment Management Board, Berri.

Government of South Australia (2001b) *River Murray Salinity Strategy, 2001-2015.* Department for Water Resources, Adelaide.

Hajkowicz, S.A. and M.D. Young (Eds) (2002) *Value of returns to land and water and costs of degradation*, A consultancy report to the National Land and Water Resources Audit, CSIRO Land and Water, Canberra.

Knight J.H., Gilfeder, M. and Walker, G. (2002) Impacts of irrigation and dryland development on groundwater discharge to rivers – a unit response approach to cumulative impacts analysis, CSIRO Land and Water, Technical Report 03/02.

MDBC (2002) Msm_Bigmod Suite Version 2.0.27. MDBC Canberra, October, 2002.

MDBC (2003) The health of the River Murray. Living Murray Fact Sheet fslm002.101
http://www/mdbc.gov.au/publications/factsheets/fslm002_101.html

MDBMC (1999) *The salinity audit of the Murray-Darling Basin: a 100-year perspective.* MDBC Canberra, 1999.

Miles, M.W., Kirk, J.A. and D.D. Meldrum (2001) Irrigation SIMPACT, a salt load assessment model for new highland irrigation along the River Murray in SA. Environmental and Socio-Economic Databases, Government of South Australia.

Miles, Mathew (2003) personal communication.

Murray-Darling Basin Ministerial Council (2001) *Murray-Darling Basin Salinity Management Strategy.* MDBMC, Canberra.

Overton, Ian; Ian Jolly; Kate Holland; and Glen Walker (2003) *The Floodplain Impact Model (FIP): A Tool for Assisting the Assessment of Impacts of Groundwater Inflows to Floodplains of the Lower River Murray.* Progress Report for the River Murray Water Management Board, May, 2003.

PIRSA. (2003) *The socio-economic impacts of introducing a salinity levy in the South Australian Murray Darling Basin*. Primary Industry and Resources South Australia, Adelaide, 2003.

Riverland West Local Action Planning (2003) *The Qualco-Sunlands Groundwater Control Scheme*. http://www.riverland.net.au/~rwlap/qsdd.html

Skewes, Mark and Tony Miessner (1997a) *Irrigation benchmarks and best management practices for citrus*. Primary Industries and Resources SA Technical report No. 259. November, 1997. Loxton.

Skewes, Mark and Tony Miessner (1997b) *Irrigation benchmarks and best management practices for winegrapes*. Primary Industries and Resources SA Technical report No. 259. November, 1997. Loxton.

South Australian Parliament (2003) *River Murray Act, 2003.*

Stoneham, Gary, Vivek Chaudhri, Arthur Ha, and Loris Strappazzon (2002). *Auctions for conservation contracts: an empirical examination of Victoria's BushTender Trail.*

Sunraysia Rural Water Authority. (2002) *Refinement of the River salinity impact zoning system.* The Irrigator, volume 1, no 16, July 2002, pp 6-17.

U.S. Bureau of Reclamation (2001) *Progress Report No 20 on the Quality of Water in the Colorado River Basin*.

Van Buren, Martin (2001) *Emerging markets for environmental services: Implications and opportunities for resource management in Australia.* A report for RIRDC/Land and Water Australia/FWPRDC. November 2001. RIRDC publication No. 01/162.

Appendix: the salinity policy model (SPA) methods and data

The brief for this project included an objective of developing a salinity policy simulation capacity. The goal was to design a framework that would allow understanding of how spatial and temporal characteristics of irrigation and salinity loading interact to determine the cost and effectiveness of technical and policy options to reduce salinity impacts of irrigation. The model developed - the Salinity Policy Analysis (SPA) model is described briefly in Part 3 of this report. Additional explanation of modelling methods and data is provided here.

SPA is programmed in the General Algebraic Modelling System (GAMS) programming language (Brooks, Kendrick, Meeraus, and Raman, 1998). The language has been used in hundreds of large integrated biophysical-economics modelling studies. It is often applied to such problems because it is well suited to compact representation of large and complex models and can be modified simply and safely.

The model builds on GIS coverage of the River corridor mapped by the South Australian Department of Environment and Heritage – DEH (Mile, Kirk and Meldrum, 2001). The GIS coverage is used to account for spatial differences in hydrogeology and past patterns of irrigation development that influence salinity outcomes.

Using the GIS coverage, the River corridor area is divided into polygons based on:

- Land and Water Management Plan (LWMP) areas divisions of River corridor of several hundred or thousand irrigated hectares for planning purposes. The locations of the fifteen LWMP areas modelled in this study are shown in Figure 12 in part 3.
- Salinity impact zones, divisions of the study area based on expected average salinity impact. These zones are modelling by DEH based on fine scale (25 hectare polygon) modelling of estimated salinity load per hectare expected from a constant 120 mm of irrigation drainage/year for 100 years. As can be seen in Figure 8 in Part 2, three zones are considered:

    - A low impact zone (LIZ) where average impact is less than six times the minimum estimated impact,

    - A medium impact zone (MIZ) where average impact is between six and fifteen times the minimum; and

    - A high impact zone (HIZ) where average impact exceeds fifteen time the minimum level.

The SPA model is illustrated conceptually in Figure 9 and mathematically in Figure 10 (both figures can be found in part 3). It consists of three sub-models:

- The water allocation model (WAM) simulates irrigator water allocation decision-making that results in choice of location, area, and depth of irrigation drainage given policy settings. Both existing and new irrigation development are modelled.

- The water and salt process model (WSPM) simulates location, volume and timing of groundwater recharge and salt loading to the River and floodplain that result from water allocations.

- The salt interception investment model (SIIM) simulates government salt interception investment in response to anticipated salt loads. The model also estimates salinity charge rates as a function of charge policy and the required level of salt interception investment.

The remainder of this appendix describes the methods, data and assumptions underpinning the three sub-models in more detail.

Water Allocation Model (WAM)

This model simulates the total area irrigated, water application location, and depth of irrigation drainage for existing and new irrigation development.

Existing irrigation is assumed to remain where it is presently located. This is modelled as the assumption that existing irrigated hectares by LWMP area and impact zone remain constant at levels and locations observed in 2001 as in the DEH River corridor GIS (Miles, Kirk and Meldrum, 2001).

In expansion scenarios, new irrigation development is assumed to expand to LWMP areas in proportion to the level of existing irrigation in each LWMP area. Within each LWMP area, irrigation location is determined with a linear programming algorithm. The algorithm chooses location for new irrigation to minimise the cost of supplying water net of salinity charges. The underlying assumption is that irrigation expansion will require new water delivery infrastructure because all existing capacity is fully utilised.

In scenarios simulating zoning of irrigation location the cost minimisation is subject to the constraint that new allocation be located in medium or low impact zones. In all modelling zone locations are those shown in Figure 8.

Cost of building and operating water supply infrastructure is computed as a function of distance to River and lift above the River. Costs are computed as an average value for each LWMP area and impact zone using engineering formulas and costing provided by SA Water (Peter Forward, 2002). Capital cost of capacity to deliver 8 ML per hectare to 1000 hectares are assumed to be: $2,000,000 (pumps) + $580,000 * km (pipes) or on a per hectare basis this is = $2,000 + $580/km * km piped. This cost is converted to an annual payment basis assuming financing over 30 years at 7%.

Per ML energy cost are assumed based on a 1000 ha pump station which requires 850 l/s delivered 2800 hours/year to deliver 8000 ML in an irrigation season. The power requirement per hour is calculated with the engineering formula

power(kw) = {head(friction factor(1.5)*distance(km)+lift(m))

*flow(l/s)*0.0098}/effic.(0.63)}

cost to deliver 8000 ML = power(kw)*hours*dollars/kwh

= power(kw)*2800*$0.1

where 0.14 is a weighted average of the local utility - AGL (01/03) industrial rate $.18/kwh and offpeak rate of $.075/kwh. This rate is multiplied by 1.16 to account for the 16% rate increase expected later this year. The estimated annual costs of water supply by impact zone averaged across all LWMP areas considered in the study are shown in Table 12.

Table 12: Estimated average annual cost of water supply capital plus operations and maintenance cost

Salinity impact zone	$/ML/year
High impact zone	$49
Medium impact zone	$64
Low impact zone	$87

In all but the **Scenario 4: expansion zoning and efficiency** (refer to Box 2 in part 3) both new and existing irrigation are assumed to apply 8ML/ha/year at 85% irrigation efficiency. This means that a uniform groundwater recharge rate of 120 mm/ha/year is assumed for all irrigation.

In the expansion zoning and efficiency scenario one half of all new irrigation is assumed to achieve 90% efficiency (80 mm of drainage) while the other half is assumed to be at 85% (120 mm). In efficiency scenarios it is assumed irrigation efficiency savings is “spread” - reused to expand the area under irrigation. Specifically, it is assumed that one half of the savings from drainage reduction is re-applied at 90% efficiency and the other half at 85% efficiency.

Water and Salt Process Model (WSPM)

The Water and Salt Process Model accounts for how River salinity is influenced by irrigation water allocation. Salinity impacts are estimated separately for existing development and irrigation expansion.

The assumed rates of River loading with salt and water from existing irrigation was based on two sources of hydrogeology modelling:

1. The *Regional Saline Water Disposal Strategy – Stage 1* Australian Water Environments (AWE), 2003 (hereafter referred to as the RDS study). This source provided predictions of salt loads and groundwater flux growth trends by LWMP area from:

    1. Naturally occurring groundwater accessions,

    2. Groundwater accessions resulting from recharge below cleared dryland, and

    3. Growth in irrigation recharge predicted to result from irrigation development in existence in 2001.

    The RDS study provided estimates of groundwater discharge and salt loads at 2001, 2008, 2020, 2030, and 2050. These estimates are split into a portion that is attenuated by the river floodplain and a portion that reaches the River's edge. The natural and dryland salt load predictions provided by AWE were based on updates of an earlier investigation (AWE, 1999). Irrigation salinity loads are based on a series of available LWMP level investigation reports.

2. Estimates of total salt flows to the River's edge and fraction of salt attenuated by the floodplain were sourced from the Floodplain Impacts Model (Overton, *et al,* 2003). This data was used to calibrate estimated baseline (2001) salinity loads by LWMP from the RDS study. Specifically, this involved assuming that the total load in 2001 was that estimated by Overton *et al,* 2003. The percentages of total load by LWMP area and growth rates in salt load over time from natural, irrigation and dryland sources are those assumed in the RDS study.

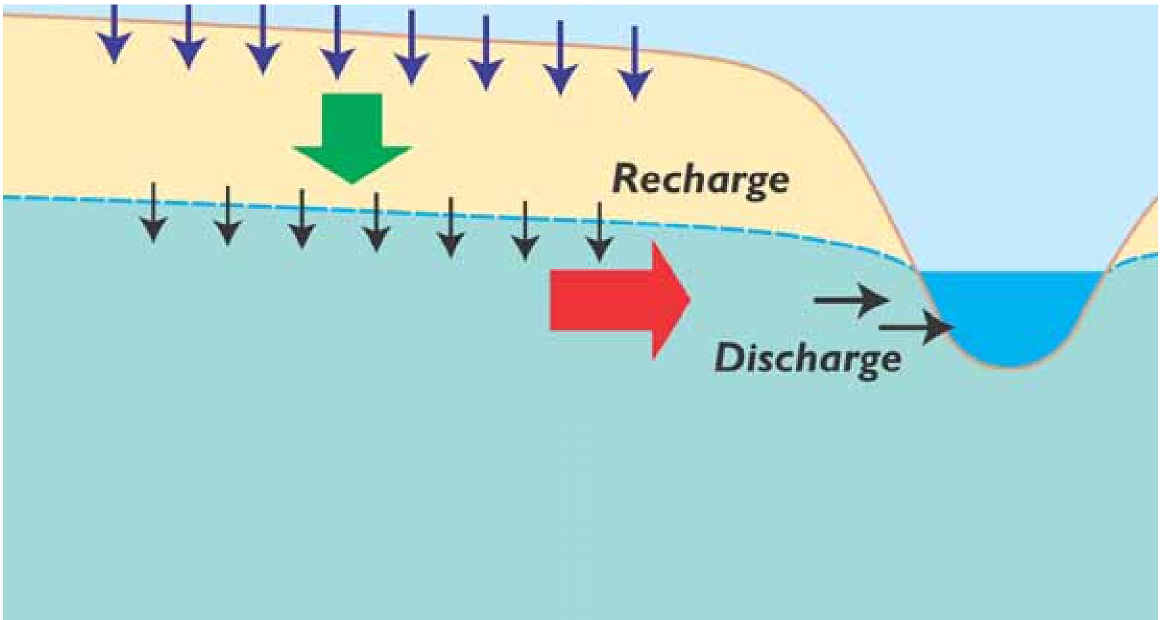
New irrigation groundwater flux and salinity loading rates per ML of irrigation applied (in 20 and 50 years after irrigation) were estimated with an updated version of the Department of Environment and Heritage (DEH) Simpact model (Mile, Kirk and Meldrum, 2001). The DEH model is built on the assumption that the ultimate salinity impact, **S** of irrigation is the simple mass balance

$$\mathbf{S = \Delta R * A * G}$$

where the assumed drainage depth change is denoted Δ**R**, **A** is the area to which the drainage depth change is applied and the salinity of the groundwater displaced into the River is **G**.

Delay until the salinity impact of a drainage change is modelled as a function of two processes. As shown schematically in Figure 16, the first delay modelled is the delay resulting from the change in the moisture level in the unsaturated zone above the water table. An example of this is the time that it takes for moisture already in the unsaturated zone to drain after an area of cleared mallee has been revegetated. This delay is modelled as a function of rate of deep drainage initially and after the modelled land management change and the distance through the unsaturated zone to the water table. The second delay is the result of the time that it takes for an elevated groundwater mound to change the rate of discharge to the River. This delay is determined by distance to the River, aquifer transmissivity and aquifer specific yield. The modelling approach used is a refinement of the unit response equations developed by CSIRO (Gilfeder, Knight, and Walker, 2001).

Figure 16: Schematic Delays in Salinity Impact of Infiltration changes



DEH used the model to predict salt loads that result from uniform irrigation applications of 8 ML/ha/year on potentially irrigable land at 85% irrigation efficiency resulting in a uniform 120 mm (15%) deep drainage. The entire area modelled is divided into 25 ha polygons and a separate prediction for 2020 and 2050 salinity loading was made for each polygon. These estimates were aggregated to produce curves representing the salinity load per hectare for high, medium and low salinity impact zones[19] within each LWMP.

Salt Interception Investment Model (SIIM)

The SIIM is a linear programming model that simulates salt interception investment. The objective of the model is to choose the locations and sizes of salt interception capacity investment that meets MDBC salinity targets for South Australia in 2050 at least cost.

The choice is subject to constraints requiring salt interception at certain locations to meet floodplain protection requirements. In particular restrictions require salt interception to protect certain healthy floodplains be built first. Floodplain protection restrictions are modelled in this study as requirements that:

- A salt interception schemes be built at the Murtho LWMP,
- Capacity be expanded at Woolpunda to pick up any future loading in excess of current salinity[20].

The cost per unit salinity reduction across potential salt interception sites is modelled beginning with the recent assessment of the cost of salt interception at the Bookpurnong site (Econsearch, 2003)[21]. Cost at other sites is estimated by adjusting the Bookpurnong cost to reflect the impact of site characteristics (groundwater salinity, percentage of salt attenuated by

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[19] The low, medium and high impact areas used in SIMPACT modelling are means of differentiating among potentially irrigable land based on the level of salinity impact that can be expected to result. Low impact areas are defined as areas where the 100 years predicted delivery of salt to the floodplain edge is less than six times greater than the minimum level predicted for any polygon. In the medium impact areas impact is six to 15 times the minimum and in the high impact areas salt load per hectare is > 15 times the minimum.

[20] It should be noted that neither the generic rules for floodplain protection in Box 3, nor the specific operational interpretation of the rules modelled in this scenario represent actual South Australian policy. The actual rules will be set when assessment of actions required to insure floodplain health that are currently underway are completed and the implications of assessment finding reviewed. The policy is simulated as requirements to protect floodplains at Murtho and Woolpunda because floodplains at these locations are in relatively good ecological health and further salinity loading would like impact them adversely. Currently there is no SIS at Murtho. The existing Woolpunda SIS is operating at about 80% of full capacity in typical years. In order to provide adequate capacity in flood years and because some pumps are already at full capacity intercepting salinity form any increase in groundwater accessions will require expanded capacity.

[21] The estimated the total cost of capital and investigations associated with a salt interception scheme at Bookpurnong and Loxton with a design capacity of 400 l/s to be $35 million. Assuming that over the life of the scheme it operates at 60% of design capacity on average, the annualised cost per ML would be $348. If the portion of the Noora evaporation basin that this project will use and the piping to reach the basin had to be paid for this would add another $75/ML/year to this cost. While at the Bookpurnong site no cost of disposal to an evaporation basin is assumed (excess capacity already exists), at other sites no capacity generally exists so the $75/ML/year is assumed. The assumed cost of operating and maintaining the scheme is based on the Econsearch (2003) estimate of $1.5 million / year which equates to $187/ML/year.

floodplain and distance to appropriate evaporation basin sites) that will make salt interception more expensive elsewhere[22].

The data values used in the cost calculations is summarised in Table 13. The results are shown in Figure 6 in part 2.

Table 13: Determinants of cost per MDBC salinity credit at potential salt interception scheme sites

Site	Groundwater salinity* (mg/l)	% of discharge attenuated by floodplain	MDBC EC credits per 100 tonnes/day removed	EC reduction in River salinity per ML pumped	assumed cost per ML pumped per year
Bookpurnong	34300	0.13	24.6	0.0201	610
Loxton	28900	0.1	24.6	0.0175	610
Woolpunda	24100	0.03	17.4	0.0111	610
Murtho	25300	0.17	26.9	0.0154	915
Pike River	38800	0.48	24.6	0.0136	915
Chowilla	35400	0.65	26.9	0.0091	915
Waikerie	21100	0.67	17.4	0.0033	610
Pyap (new residence)	24300	0.63	19.9	0.0049	915

Salt interception schemes are long-term investments. Many components such as pipes have expected lives of up to 80 years. Over time the loads that these schemes will have to handle are anticipated to grow. As a consequence, such schemes are typically designed to handle anticipated future rather than just current capacity requirements.

For this study the estimated capacity requirements and consequent cost are modelled assuming that all salt interception schemes are built based on estimated capacity required fifty years from the building date. This is a conservative assumption that may lead to some overstatement of cost. In fact, there maybe some opportunity to stage development by building parts of the scheme initially, and then adding on extra capacity as it is needed.

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[22] The estimated cost per EC of River of other salt interception schemes is estimated as a transformation of the cost per ML at the Bookpurnong site computed by:

Multiplying the $/ML cost at Bookpurnong by ML/tonne at each site (groundwater salinity or tonnes of salt dissolved in each ML of water pumped) to attain $/tonne at River's edge avoided for each site;

Dividing the $/tonne at River's edge by the fraction of salinity loading that is not attenuated by the floodplain at each site to attain $/tonne of River salinity mitigation at each site;

Multiplying $/tonne of River salinity mitigation by the MDBC tonne/EC conversion factor at each site (based on Figure 5 values – see Part 2 of this report). The MDBC tonne/EC conversion factor weighs tonnes of salt more along stretches of the River where more damage to infrastructure and crops result.

Multiplying cost by a factor of 1.5 for the Pyap, Murtho, Pike River and Chowilla sites to account for the significantly greater distances that will have to pumped to appropriate evaporation basins at these sites.

If capacity development can be staged, total cost of capacity will be less than estimated here because there will be an opportunity to delay investment. Investment delay reduces total cost because funds that are not needed immediately can earn be invested to interest that they could not have if they were used to build salt interception capacity immediately.

An investment renewal cost was included in all estimates of salt interception investment requirement for this study. This is required because salinity impacts of irrigation continue long after irrigation ceases. Over the fifty-year time horizon considered in this analysis, irrigation recharge will build considerable groundwater mounds. The hydraulic gradient that these mounds exert would then continue to force saline discharge into the River for a considerable amount of time, even if irrigation ceased.

The cost of continuing salt interception operation that will be required to deal with this delayed irrigation salinity is accounted for by including a renewal component in estimated total cost of salt interception. The renewal cost is the present value of the cost of rebuilding the salt interception capacity in 50 year and operating it for an additional 50 years. Present value in this calculation is discounted using a 3% real interest rate to represent expected returns from setting aside charge revenue to finance salt interception capacity renewal net of inflation.

Sensitivity Analysis

The estimates of salt interception investment required for SA to meet MDBC salinity targets and salinity charges presented in this study build on many parameters that are not understood with absolute certainty. Sensitivity analysis is used to gain a sense of how significantly cost and charge predictions are likely to be influenced by plausible variations in three key parameters that are understood with less than perfect certainty:

- The interest rate used in discounting;
- The potential to delay investment in salt interception; and
- Irrigation water use efficiency.

Interest rate - All investments in salt interception are assumed to be financed over 30 years and 7% interest. The 7% rate was chosen because it is consistent with NSW and Victoria Treasury recommendation for cost benefit analysis, and is close to the average interest rate over the period 1990-2002[23]. There have been periods of both considerably higher, and somewhat lower interest rates. To estimate the impact of interest rates

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[23] The average call rate on overnight funds over the period based on Reserve bank of Australia data is 6.78%.

cost based on both 5% and 9% interest rates are calculated. The finding is that a 5% interest rate would result in costs and charges being 21% less than those estimated in the main body of this report. A 9% interest rate would result in estimated costs and charges 19% higher.

Deferred investment - The costs and charges presented in the main body of this report were estimated assuming that immediate investment in salt interception capacity would be made at the capacity level required to mitigate salt load anticipated up to 50 years in the future. This is a conservative assumption because in fact investment in some capacity can probably be delayed. Deferring investment saves money because if money is not invested immediately, it can be deposited in an account that bears interest.

To evaluate how investment deferral could reduce cost, investment and charge requirements were recalculated assuming that capacity to address any salt interception required in more than 20 year would be delayed 20 years. The fraction of total investment that can be delayed because salinity first “hits the River” in more than 20 years, varied across scenarios considered from 24% to 60% of total salt interception capacity requirement. It is assumed in this analysis that deferred investment earns a real (inflation adjusted) return of 3%[24]. The finding is that investment deferral could reduce estimated costs and charges by between 11% and 27%.

Irrigation water use efficiency - Most of the cost and charge estimates in this study are based on the assumption that all irrigation is on average 85% efficient. The exception is irrigation efficiency scenarios where an average 87.5% efficiency is assumed. It is, however, conceivable, that the 85% efficiency aspiration is not realised. The sensitivity of results to the assumed average 85% efficiency is tested by evaluating cost of only reaching an average 82.5% efficiency for scenario 3, a scenario assuming a 72 GL expansion restricted to low and medium salinity impact areas. The results of the sensitivity analysis is that costs and charges are estimated to be 27% higher as the result of water use efficiency 2.5% less than the assumed 85%.

Sensitivity Analysis Conclusion

The results of the sensitivity analysis is that under a variety of plausible assumptions, cost and charge rates could be 20% to 30% more or less than the estimated levels presented in the main body of this report.

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[24] This real discount rate is chosen because it is the nearest whole percent rate to the actual inflation adjusted rate over the 1992 to 2002 period based on ABS and Reserve Bank of Australia data.