Regulation in Environmental Markets: What can we learn from Experiments to Reduce Salinity?

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Abstract

Market based mechanisms are growing in importance in environmental policy making. In theory market based mechanisms equate marginal abatement costs between polluting sources, thereby allocating emissions control responsibility at least cost. The step from theory to field implementation is, however, difficult, as many aspects of policy must be made operational at the same time. Policy mistakes can be very costly to society and are extremely difficult to correct ex-post. Experimental Economics is an innovative method beginning to be used to design, test and illustrate public policy prior to field implementation. In this paper we discuss two types of market incentives, taxes and tradable emissions permits. We then illustrate an experiment being implemented to test these market mechanisms for the management of salinity in the Murray Darling Basin.

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Section 1: Introduction

Point -source pollution is an important environmental issue in Australia.[1] Point sources account for approximately 42% of nitrogen emissions to Port Phillip Bay, Victoria (Parslow et. al. 1996). In the Murray River, point sources contribute a significant portion to the estimated forty six million dollar per annum cost of salinity (MDBC, 1999). Naturally occurring markets do not fully account for these external impacts as water quality is non-rivalrous and non-excludable. It is therefore important for regulators to intervene in the economy to mitigate this market failure.

Policy interventions available to regulators include command and control regulation and market based or economic incentives. This paper will discuss two forms of economic incentives, taxes and tradable emission permits. Economic incentives differ from command and control regulation in two main ways: 1) differences in firms' marginal pollution control costs determine the allocation of pollution control responsibility, and firms can shift their marginal cost curves through innovation. 2) The marginal costs of pollution control are equalised in equilibrium.

1.1 Tradable emissions permits

Emissions trading systems induce rational firms to reduce pollution at the least possible cost. The least cost property of emissions trading, in the presence of asymmetric information and heterogenous abatement costs arises, as tradable permits create incentives for firms to reveal their private marginal valuation for an additional permit. The revealed marginal utility reflects the firm's private marginal abatement costs. The market acts as an arena for the transfer of this private information. Trading

[1]Pollution can be generated from point sources or non-point sources. Point-source emissions can be verified (directly monitored or indirectly modelled) within reasonable margins of scientific error and at reasonable cost. For non-point sources or diffuse sources, on the other hand, it is often not possible to attribute emissions to a specific source and therefore it is very difficult and expensive to verify changes in emissions.

between firms will continue until marginal abatement costs are equalised across permitted firms. When marginal costs are equalised economic surplus is maximised and a given environmental standard is reached at lowest cost (Dales 1968, Montgomery 1972, Tietenberg 1985 and Baumol and Oates 1988). Figure 1 in the Appendix illustrates this least cost property. Tradable emissions permit systems also allow private abatement or innovation as excess emissions permits, generated due to the use of innovative methods and machines, can be sold in the market.

1.2 Taxes

Economic theory suggests that a tradable permit system and an emissions tax system should work equally well in controlling pollution. However, in the presence of uncertainty about the marginal costs of pollution control, emissions permits are preferred if marginal benefits of emissions reduction are more steeply sloped than marginal costs. Emissions taxes are preferred if marginal costs are more steeply sloped than marginal benefits, because the deadweight loss due to the asymmetric information is smaller with taxes in this case (Weitzman, 1974; Adar and Griffin, 1976; Stavins 1996). Further, in situations where marginal damages from emissions exhibit a threshold effect (for example if emissions threaten a species with extinction), a quantity regulation like the permit system, that caps aggregate damage, is often preferred as it yields a sure quantity of pollution (Kolstad, 2000).

While markets for pollution have been extensively studied in theory (Tietenberg, 2001), operating market mechanisms remain few and there is limited empirical data about their performance. Economic theory can answer many questions about the expected behaviour of firms engaged in different pollution control policies. The step from economic theory to field implementation is, however, a difficult one.

Many important issues such as the market institution used[2], the possibility of banking permits[3], the transactions costs involved in trading[4] and the market power of some of the participants[5] must be considered in designing a practical emissions trading program. Similarly, efficiency impacts of targeting[6], the degree of cost uncertainty and the correlation between cost uncertainty and benefit uncertainty[7] are important issues when designing a tax system.

Experimental economics can provide important insights into the design of policy. In the rest of the paper we discuss the role of experimental economics in policy design, illustration and testing, and illustrate how experiments can be used to understand some of the policies associated with salinity in the Murray River in Australia.

Section 2: Experimental Economics

Through the decisions they make, individuals shape the ultimate outcomes that can be observed across the economy. Individual behaviour occurs and interacts in a complex manner across a range of groups including consumers, producers, regulators, policy-makers and community organisations more broadly. Behaviour depends on the initial conditions that the relevant group faces, the incentives they have for pursuing particular objectives, and also the unpredictability of human nature.

An innovative new branch of economics – commonly labelled 'experimental economics' – provides a richer means of predicting behaviour compared to traditional approaches. Experimental economics more explicitly factors in the range of

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[2] For example, Cason, 1993, and Cason and Plott, 1996, investigate the auction allocation mechanism used in the United States Environmental Protection Agency's Sulphur Dioxide Emissions Trading Program. Foster and Hahn, 1995, and Cason and Gangadharan, 2001, investigate the market institution employed in the Regional Clean Air Incentives Market in Southern California.

[3] For example, Franciosis et. al. 1999, Cronshaw and Brown-Kruse,1999, and Mestelman, Moir and Muller 1999, investigate if banking improves market performance for different market institutions.

[4] For example, Stavins 1995, and Cason and Gangadharan, 2001, investigate the effect of transaction costs on firms' decisions to trade.

[5] For example, Hahn, 1984, explores market power and the impact of initial permit allocation, Newberry, 1990, and Vickers and Yarrow 1991, provide empirical studies of market power.

[6] For example, Kahn, 1998; Freebairn, 2000; Kopczuck, 2003, discuss the issue of targeting inputs that generate the pollution externality or targeting the pollution externality directly.

competing interests that parties have, and the sometimes unpredictable nature of human behaviour. It couples intense theoretical research with actual testing (or 'experiments') that seeks to replicate the incentives of real-world situations and as a result provide meaningful insight into policy design. Participants in the experiments receive actual financial payments to mimic the payoffs that parties would face under different policy scenarios.

The experiments take place under controlled 'laboratory' conditions, which has benefits in terms of being able to vary some conditions while holding others constant, in order to isolate the specific influence of particular factors. The laboratory set up also facilitates tests for robustness of results by repeating experiments and checking their replicability. This is of particular importance because traditionally, as economics is a social science, it has not been possible to conduct tests of outcomes ahead of time. And it is clearly infeasible given the cost to undertake policy actions across the economy simply to better understand the outcomes. Experiments also provide data for analysis and decision-making more akin to the rigorous approaches used in physical science disciplines.

A significant number of experiments related to emissions trading have been reported over the past decade (Muller and Mestelman, 1998 provide a very good survey of this area). The following two sections discuss the salinity problem and an experiment currently being implemented to test policy mechanisms for managing salinity in the Murray River, Australia.

Section 3: Salinity in the Murray River

The Sunraysia region in the Mallee is a collection of irrigation districts and private irrigators located along the Murray River from Nyah to the South Australian boarder. The region includes the city of Mildura, and production is predominantly horticulture and growing wine grapes.

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[7] For example, Stavins, 1996, discusses cost and benefit uncertainty.

Salinity externalities from irrigation are non-standard[8], and five separate salinity impact zones have been created within the region (DNRE, 2001). Figure 2 in the Appendix shows the region, main irrigation areas and the five salinity impact zones. There is a thirty fold increase in the magnitude of the externality as water use moves from Low Impact Zone One, where groundwater moves slowly towards the river, to the High Impact Zone, where salt addition to the river per unit of water used is the greatest (SRWA, 2002). Knowledge of these marginal external impacts allows irrigation externalities to be managed as a point-source.

3.2 Salinity levy on water trades

In April 2002 the Victorian Government introduced a new system of salt impact levies (taxes) in the region. The levies create constraints on the trade of water between irrigators in different impact zones. Irrigators located in the 'High Impact Zone' (HIZ) can only buy water from sellers also located in the HIZ. Irrigators located in the Low Impact Zones 1 to 4 can purchase water from sellers in any impact zone but must pay a salt levy per unit of water traded. The magnitude of this differential levy depends on the impact zones the water is traded between (SRWA, 2002). The objective of this policy is to create disincentives for water trade into higher salinity impact zones and thereby encourage new development in zones with a low impact on river salinity. [9]

The salt levy is an innovative policy mechanism. It has community support and has successfully sent signals to the regional economy that the external impacts of irrigation must be paid for. The policy, however, misses a few attributes that are desirable in long term salinity management. First, the levy precludes any sources of

[8] Excess irrigation water (water not used by the plant for growth or not evaporated from soil and plant surface) can enter the groundwater system via vertical drainage; depending on soil type, gradient and distance from watercourse, salt contained in the soils and groundwater is moved towards the river.
[9] This tax policy differs from standard externality taxes that are discussed in theory. Firstly, the tax is on the input (water) and not on the externality (salt). Secondly, the policy does not allow for free trade of water across zones. For example, no water can be traded into the High Impact Zone. Standard

salt abatement outside of government. The prevention of any private salt abatement removes any incentive for irrigators to seek out innovative methods of controlling salt on their property before it reaches the river. Second, the levy targets water inputs not the salinity externality. Taxing water encourages irrigators to adopt innovative water use methods. Water savings can have both a positive and negative impact on river salt concentrations (ABARE 2002). While water savings will lead to less groundwater re-charge, it may also reduce water run-off as excess water is decreased. Reduced run-off may decrease return flows to downstream users and may reduce dilution flows thereby increasing salt concentrations downstream. Third, water trade from a higher to a lower salt impact zone would reduce salt externalities. The salt levy, however, does not create incentives for irrigators to trade water into lower impact zones. The salt levy is a one-sided system. It places a levy on water trades that increase salt concentrations but does not provide a benefit to irrigators if a water trade reduces salt concentrations. The policy may therefore miss opportunities to improve water quality through water trade.

3.3 Tradable Property Rights for Salinity

Tradable property rights for salt are a potential alternative to salt taxes on water trade. A tradable right would confer the ability to contribute a defined concentration of salt to the river. An irrigator would have to hold a salt property right if he wants to use his water allocation. For each unit of water used he will have to hold corresponding salt property rights. Irrigators located in higher salt impact zones would need to hold more permits per unit of water than irrigators in lower salt impact zones. The total number of salt permits in the region would be limited. This limit would be set such that the total concentration contributions from the region do not cause the aggregate contributions from the basin to exceed the salinity cap at Morgan

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externality taxes would allow trade into the High Impact Zone and impose an exorbitant tax on the trade, hence reducing the number of trades into this zone.

in South Australia. This is different to the salt levy, which does not limit the aggregate contributions from the region: as more water is traded into the region the total salt contributions increase. The government will need to iterate the levy over time to manage the rate of water transfers. In a tradable permit scheme, new water transfers will need to find salt permits from within the region. This means total salt contributions remain capped overtime and it removes the need for government to adjust salt levies upward in regions with positive net water transfers. Further tradable permits would allow for free trade between impact zones and the environmental impact of these trades would be reflected in the price of salt.

Property rights for salt can more effectively inform irrigators, government and society about the cost of salt in rivers. This is because the salt property right unbundles the salt right from the water. The water price will reflect the scarcity of water quantity; the salt property right will reflect the scarcity of water quality.

Tradable permits can focus management effort on both water and salt. The water input is an essential factor in production. The user pays for the resource in the water market. Salt is an unavoidable output of the production process. The beneficiary – the user – can pay for using the resource – the river water – in the salt market. Both become essential factors of production and will be considered in all production decisions.

Water and salt concentrations could be traded separately. Irrigators would be able to choose how they pay for their salt impacts on the river. For example, irrigators could, purchase salt property rights to cover their salt impacts; purchase water to dilute their salt impacts; undertake (approved) abatement on their property to mitigate salt additions to the groundwater.

Government could also be a player in the market by supplying additional salt permits. For example, the state, regional water authorities and Catchment

Management Authorities could supply salt permits by undertaking infrastructure works which mitigate salt impacts in their region.

Firms could benefit as the ones that can mitigate salt could also supply additional salt property rights. For example, salt producers in the region currently extract salt from the Murray River, and sell it both domestically and internationally as table and bath salts (often extracting a significant profit from consumers by labelling it as Murray River Salt and advertising the environmental benefits of their product). The firm receives a private benefit — profit from selling the salt, however they also generate an external benefit by removing salt from the river. Currently policy is missing the opportunity to capture this external benefit. Salt property rights could engage these activities.

Section 4: The Economic Experiment

To examine the impact of different regulatory policies on salinity problems in the Sunraysia region we conduct the following economic experiment. In the first instance a water trade only baseline case — called 'the control'— is implemented in the economic laboratory. Subjects — often university students, but can also be farmers or government policy development officers — play the role of irrigators.[10]

Subjects using their private production information interact in a water market through their computers.[11] Buyers make bids to buy water by comparing the private return they receive from using water in production and the price (the cost) of water in the water market. A buyer will buy water if he expects his return to be greater than the cost he incurs. Sellers make offers to sell by comparing the private cost they incur

[10] Subjects are allocated across seven industry sub-sectors, and the sub-sectors are allocated across the salt impact zones to represent the distribution of land-use in the region. Production characteristics are taken from the field such that subjects have information that reflects irrigation technologies, skill differences, water requirements, costs of production and productivity from the region. Salt impacts are taken from the salinity impact review (SKM 2001) and the salinity zoning system (DNRE 2001).

[11] The water market is modelled as a double auction market, where buyers of water can make bids to buy and sellers of water can make offers to sell at anytime the water market is open. Similarly, buyers can accept sellers' offers to sell and sellers can accept buyers' bids to buy at anytime. A double auction

from using less water in production and the price (the return) they receive from selling water. A seller will sell water if the price is greater than her expected costs Participants receive real financial payments dependant on the decisions they make in the market. Figure 3 in the Appendix shows the main components of the economic experiment.

Next the salt levy currently operating in the region is implemented in the economic laboratory as Treatment One. The water market is calibrated to the region in the same way as the control. This time, however, participants must take account of the salt levy. It is important to note that only buyers pay the salt levy and the magnitude of the levy payable depends on where the buyer and seller to the transaction are located along the river. In Treatment One, buyers make bids to buy water by comparing the private return they receive from using water in production and the price of water plus any levy they may need to pay. A buyer will buy water if he expects his return to be greater than the price of water plus the tax he incurs. Sellers make offers to sell by comparing the private cost they incur from using less water in production and the price (the return) they receive from selling water. A seller will sell water if the price is greater than her expected costs.

The results from Treatment One would inform government about, the expected price for water in the region when salt externalities are managed through the salt levy; the direction of water trade when participants incur a levy, salt concentration impacts with the levy as compared to the control, and the quantity of levy collected which can then be used for abatement works by government.

This information is useful to government, as the salinity levy has only been operating since 2002. It is not therefore possible to conduct robust evaluation of the

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market is used in the experiment because the Victorian Mallee water market is most like a double auction market.

policy using field data.[12] Observations from experiments can provide insight into expected response to the policy. This could help with future improvements to salinity management in the region and inform other regions about the operation of salinity levies.

The salt market is implemented in the economic laboratory as Treatment Two. The water market is calibrated to the region in the same way as in the control and treatment one. In treatment two, however, participants must hold salt permits if they want to irrigate.[13] Buyers make bids to buy water by first comparing the private return they receive from using water in production and the price of water. A buyer will buy water if the return from buying water is greater than the cost of water. Buyers must also compare the price they must pay for a salt permit in the salt market. A buyer will therefore choose to buy water if the price of water plus the cost of the salt permit is less than the return to water. Buyers could also invest in salt abatement. Salt abatement is a source of additional salt permits. A buyer will choose to invest in salt abatement if the cost of private abatement is less than the price of a salt permit

Sellers make offers to sell water by comparing the private cost they incur from using less water in production and the price (the return) they receive from selling water. A seller of water can elect to also sell their salt permit to a buyer of water, or they could retain their salt permit. By retaining salt permits irrigators create additional water flows in the river. This is because the supply of salt permits in the market is decreased and this limits the quantity of water that can be used in production. Instead the water remains in the river as environmental flows.

The results from Treatment Two can inform government about the expected price for water in the region, the expected price for salt, the expected price for salt

[12] The data for the water market with the salt levy are not available for the Sunraysia region.
[13]The water and salt markets are modelled as simultaneous double auction markets, where buyers and sellers make bids and offers in two double auction institutions. The first is the input – water market and the second is the output – salt market.

abatement — both private and government abatement, and the direction of water trade as compared to the control and treatment one.

Section 5: Conclusion

Emissions trading is slowly but firmly becoming established as the principal mechanism for regulating environmental problems in a cost effective way. To be able to obtain the maximum gains from these programs policy makers need to think about the design of permit markets carefully. In this paper we discussed some policy options available to manage irrigation-induced salinity in the Murray River. Creating a market for salt seems to be an option that would improve efficiency in this region. The step from theory to field implementation is however large and entails significant monetary and political costs. In the paper, we summarised the design of experiments that are being conducted to examine the impact of salinity. Experimental economics allows policy designers to observe agent behaviour under the policy incentives in a controlled setting. In particular, experimentation provides a controlled way to investigate the stability and efficiency of an economic institution. The implementation of a proposed trading institution or policy in a laboratory setting, could also serve as a demonstration that communicates the nature of emissions trading to policy makers. Experimental testbeds help us in uncovering problems with the design early on and hence reduces the possibility of policy failures, which could be very expensive for society. This is a methodology that has a very important role to play in environmental regulatory policy making.

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Appendix

Figure 1: Marginal Costs of Control (Abatement)

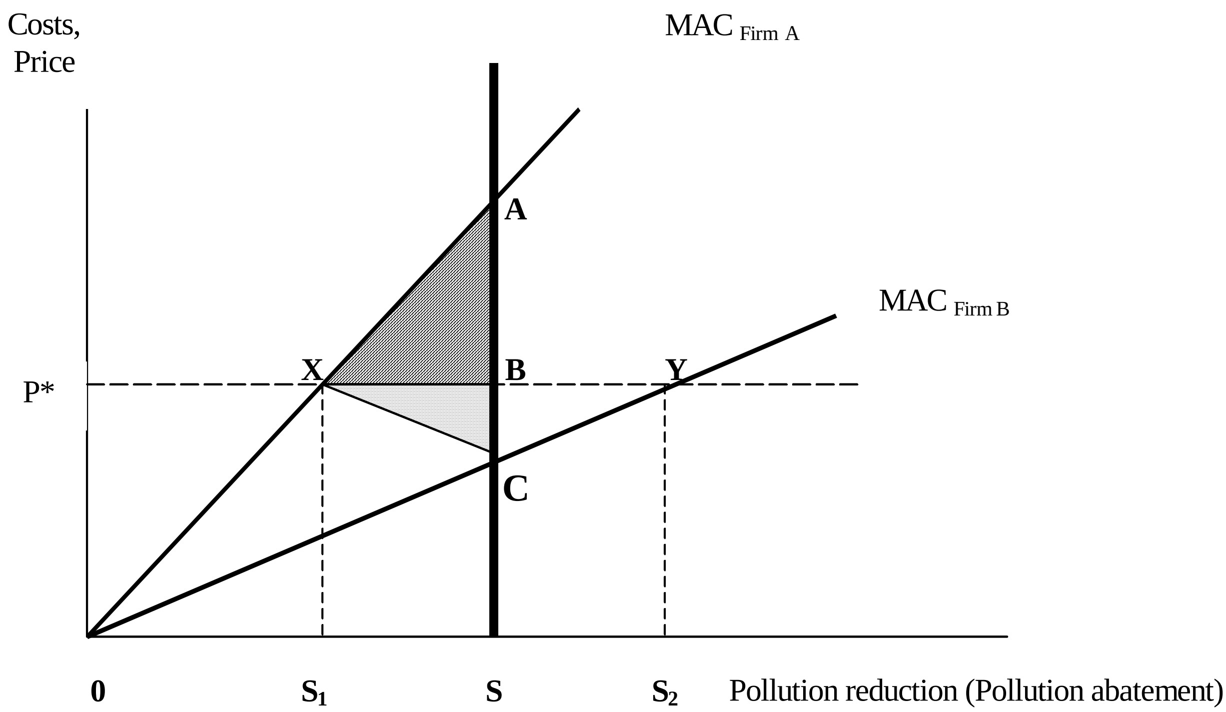

Figure 1 illustrates a simple economy, where the emissions are generated by two firms, *Firm* A and *Firm* B. For any given level of abatement, *Firm* A has the higher marginal costs of controlling pollution. Consider two policy setups: the first being command and control that regulates emission reductions from each firm to **S** such that total emissions abated in the economy are 2**S**. *Firm* A, faced with command and control regulation, will undertake pollution abatement up to the required level of abatement, **S**. *Firm* B will (also) undertake abatement up to the required level, **S**. The total abatement cost of controlling emissions to 2**S**, under command and control regulation, in this economy would be: $\mathbf{TAC_{CC}}$ = **OAS** + +**OCS**.

In another setup, firms can use economic incentives to trade emission permits with each other to comply with the overall environmental standard of 2**S**. *Firm* A and *Firm* B are each allocated (free) permits, such that total emissions in the economy are (again) 2**S**. Market price for permits is p*. Under perfectly competitive conditions, individual firms accept the price of permits from the market. From 0 to S_1 it is cheaper for *Firm* A to abate pollution than to buy permits from the market as P* lies above $MAC_{Firm\ A}$ for all pollution units abated from 0 to S_1. From 0 to S_2, it is cheaper for *firm* B to abate pollution than purchase permits from the market. Note that the overall standard 2**S** is achieved, but that *firm* A with the higher abatement costs, has abated pollution less than **S** while *firm* B with the lower abatement costs has abated more than **S**. The tradable permit scheme allows the higher cost firm to buy permits and expand production and the lower cost firm to undertake more pollution control and release permits for sale. The total abatement costs with tradable permits comes out to be: $\mathbf{TAC_{permits}} = \mathbf{OXS_1} + \mathbf{OYS_2}$.

If we compare the total costs in the two setups;

Total abatement cost under command and control regulation ($\mathbf{TAC_{cc}}$) minus total abatement cost under a tradable permit scheme ($\mathbf{TAC_{permits}}$) is equal to $\mathbf{S_1XAS}$ (the cost saving *Firm* A realises as it is undertaking less abatement) minus $\mathbf{SCYS_2}$ (the additional costs *Firm* B incurs as it is undertaking more abatement). $\mathbf{S_1XAS}$ is clearly greater than $\mathbf{SCYS_2}$, and the difference is shown by the two shaded areas in Figure 1.[14] Area **XAB** is a real resource saving as fewer scarce resources need be allocated to pollution reduction under permits as compared to command and control. And, **XBC** is a transfer from *Firm* A to *Firm* B.

[14] To make the analysis simple, we assume that $(S_1 - S) = (S - S_2)$ and $S_1 + S_2 = S$.

Figure 2: Salinity Impact Zones in Sunraysia: Nyah to the South Australian Border

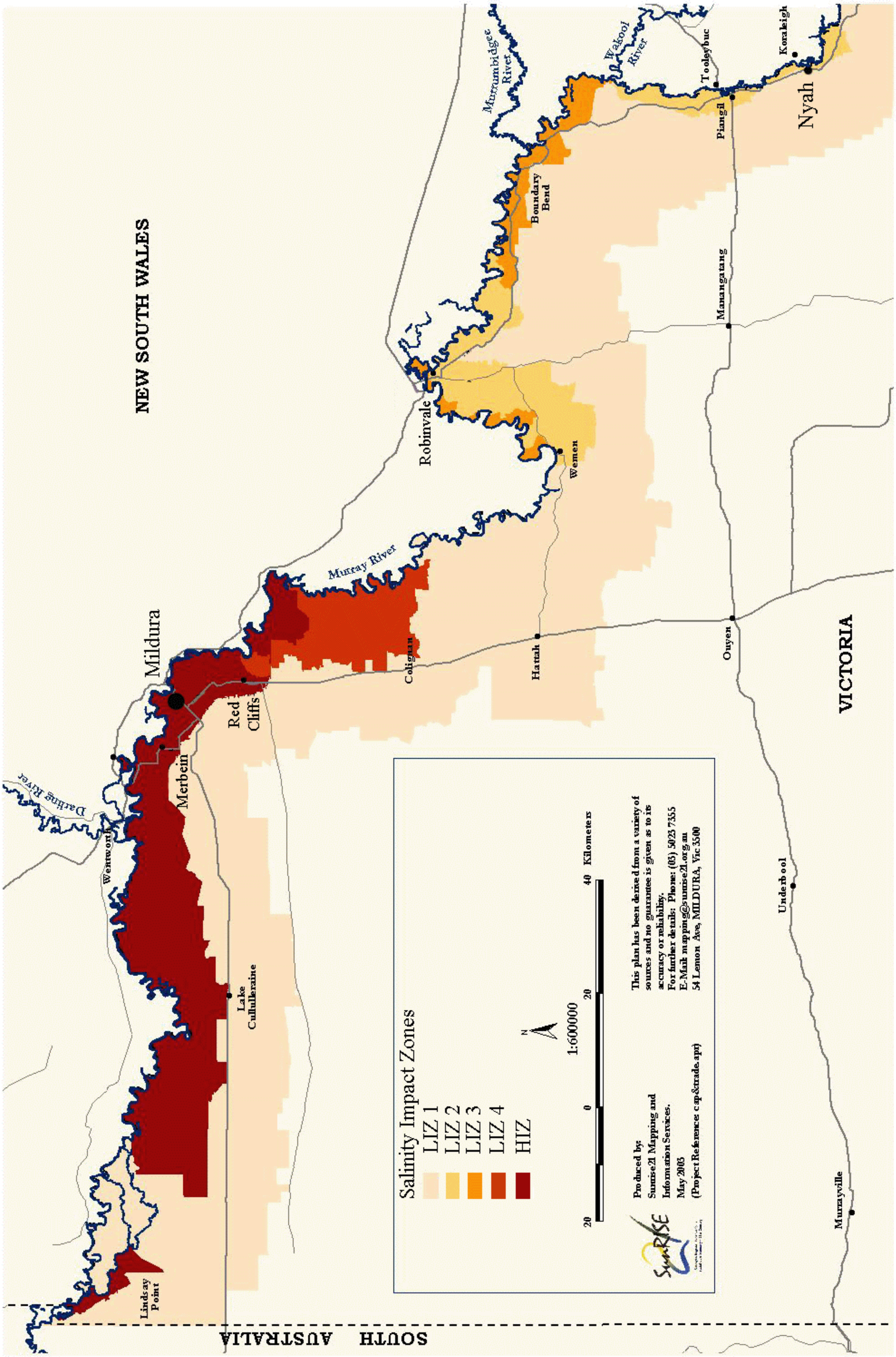

Figure 3: Control and Treatments: Experimental Design and Procedure