Right opportunity— Using right markets to manage diffuse groundwater pollution

Final report to LWRRDC by

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"The irreversibility of groundwater processes demands serious consideration of the needs for management to ensure sustainability of the resource."[1]

ARMCANZ, 1996

1. Anon (1996), *Groundwater allocation and use: a national framework for improved groundwater management in Australia.* A report to ARMCANZ.

Contents

List of figures, tables and boxes

Tables

Figures

Boxes

Preface

This report has been commissioned by the Land and Water Resources Research and Development Corporation (LWRRDC) as part of its new initiative to encourage research into groundwater problems facing Australia. Finding workable options to control diffuse groundwater pollution represents a major unresolved issue facing groundwater management agencies throughout Australia. LWRRDC have specifically required that this project address one of Australia's most 'intractable' water management problems—the management of diffuse groundwater pollution. In many areas, groundwater quality is declining. Regulatory attempts to prevent this from occurring are failing. Consequently, LWRRDC asked us to examine the potential of right-market mechanisms to help prevent further declines in groundwater quality.

This project has been supported by a Steering Committee comprising Graham Allison (Chairperson), Peter Hoey, Terry A'Hearn, Volker Aeuckens and Stuart Critchell. Their enthusiasm, support and incisive comments are gratefully acknowledged.

The four case studies described in the appendices of the report (in Western Australia, South Australia, Victoria and New South Wales) were only possible because of the active support by all those involved. In addition to funding from LWRRDC, we also received, and would like to acknowledge, financial assistance from the South Australian Department of Environment and Natural Resources and the Victorian Department of Natural Resources and Environment.

All reports benefit from review. In addition to those on our steering committee and those who participated in our case studies, we would like to acknowledge the many useful comments received from Hendrik Bosman, Noel Dawson, Cris Liban, Ric Morgan, Les Russell, Sarah Ryan and Jim Skipper.

Notwithstanding the obvious difficulties in obtaining community support for the new concepts presented in this report, we encourage all groundwater managers and those with a passion to protect Australia's groundwater resources, to give serious consideration to the ideas presented herein. We believe that, in spite of some difficulties setting them up, right markets offer one of the most cost-effective and politically feasible means to get on top of groundwater pollution. In a number of cases, we know of no other effective option.

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Executive summary

Diffuse groundwater pollution is an intractable problem as yet unsolved by Australia's water managers. The aim of this report is to identify the potential of right-market mechanisms to contribute to this process. We define a right-market mechanism as any legal arrangement granting somebody a right to do something or to transfer that right to someone else. Any conditions constraining transfer of that right are prescribed in advance of a person beginning to arrange a transaction.

Whilst we do not see right markets as a panacea for the control of pollution from diffuse sources, we do see them as a mechanism worthy of serious consideration by water resource managers. In particular, we recommend that, as the Council of Australian Governments (COAG) water reforms are implemented, **no groundwater user be given a secure groundwater use-right in a manner that precludes the attachment of land and wateruse conditions to that right. When conditions are attached to use rights, groundwater pollution can be controlled efficiently at its source.**

Diffuse pollution

The diffuse groundwater pollution problems considered in this report include:

- nitrate and phosphate pollution;
- pesticide pollution from agricultural practice;
- groundwater salinisation due to agricultural practice;
- bacteria and nitrate pollution from septic tanks; and
- seawater intrusion.

Application of right-market mechanisms to diffuse groundwater pollution is challenging because groundwater is hidden from sight, slow moving, broad scale and often naturally contaminated. Groundwater is also a medium where pollutants accumulate and where mis-management can have irreversible consequences.

Right-market options

As summarised in the tables on pages 9–11, we identify five types of right-market mechanisms that can be useful in managing groundwater pollution:

1. *Tradeable Emission-Right Systems* where the total annual load entering an aquifer is capped. Polluters are issued right to a share of this load. Trading is encouraged. Maximum concentrations are set. Surrogate indicators can be used to reduce monitoring costs.

2. *Emission-Offset Systems* where development approval is conditional upon pollution reduction elsewhere. No development is allowed to cause a net increase in the pollution rate.

3. *Treater-Pays Systems* where water treatment plants and ecosystem managers pay for pollution reduction activities because this is more cost-effective than water treatment.

4. *Polluter-Pays Systems* where polluters are forced to share the costs of groundwater treatment and protection in proportion to their contribution to the problem.

5. *Conditional Groundwater-Use Right Systems* where conditions are attached to surface and/or ground water rights so that the polluting activities are either encouraged to move to less vulnerable areas, discouraged, prohibited or phased-out.

International and national experience

Review of international and national experience and our case studies, suggests that, while right-market mechanisms have been used to control surface water pollution, they have rarely been used to control groundwater pollution. Because of this lack of experience both in Australia and overseas, we conducted four case studies to help us evaluate the potential of right-market mechanisms to reduce diffuse groundwater pollution.

While there is little experience with the use of market mechanisms to control groundwater pollution, we draw attention to the growing experience with the use of right-market mechanisms to control surface water pollution. Progress in the Hunter River in NSW, the Murray–Darling Basin Salinity Strategy and Victoria's Nyah to Border Salinity reduction scheme are all beginning to demonstrate the greater efficiencies, greater equity and greater capacity of right-market mechanisms to help alleviate intractable diffuse pollution problems. Right-market mechanisms are being used and are being found to be effective in resource management.

Experience indicates that right-market mechanisms always need to be underpinned by regulations. Introduction of right-market mechanisms makes it easier to enforce these regulations and obtain local ownership of them.

An important characteristic of any successful right-market mechanism is that the entitlements, conditions and obligations that attach to these rights can be changed periodically in an equitable manner. To do this it is necessary to recognise the difference between rights, entitlements and obligations. A right, such as a proportional share of the quantity of water that can be sustainably used for consumptive purposes, can be defined in perpetuity. Sometimes, however, as new information becomes available it is necessary to respecify what that right entitles a person to do. There is a need to recognise that new technologies emerge and knowledge about the characteristics and limitations of an aquifer can change. Similarly, it can be necessary from time to time to change reporting requirements. In a well designed system, rights are secure and careful attention is given to the processes used to ensure that periodic adjustments to entitlements and obligations are equitable.

Potential identified

At the most general level, the case studies in this report show that right-market mechanisms have a place in the control and reduction of groundwater pollution from diffuse sources and, also, multiple point-sources. The three systems that offer the greatest potential are conditional use-right systems, emission-offset systems and treater-pays systems. Generally:

- *conditional use-right systems* have application anywhere where there is licensed groundwater use, primarily, irrigation;
- *emission-offset systems* have application wherever development controls are in place; and
- *treater-pays systems* have application wherever a water authority has to treat water prior to distributing it for human use or has to treat sewage before disposing of it into a waterbody.

Tradeable-emission right systems are also identified as a mechanism which has potential. In most cases, however, these systems require new databases to be established and are unlikely to obtain political acceptance.

Conditional groundwater use-right systems

Conditional groundwater use-right systems have the greatest potential as they can be linked to existing licensing systems which can and, in some cases, are being made transferable. It is possible to use a conventional volumetric or area allocation systems to define each person's share of a groundwater resource. Definition of the right as a formal share makes the true intent of any allocation much more transparent. Any allocation granted as a result of that share may need to be changed for one of many reasons including climate change and, also, improvements in knowledge about the sustainable yield of an aquifer.

By calling the right—*a share*—water users are clearly informed that changes in the actual quantity allocated may need to be varied from time to time as climate, information and the number of forms of wateruse included in the system varies.[2]

When the right issued is a proportional share of the water that can be used for consumptive purposes, it is administratively easier to deal with over-allocation problems. Share systems guarantee that any change in water allocations will be on a *pro rata* basis. Well designed share systems facilitate periodic review of the entitlements and conditions that attach to that share. This makes it possible to use this right-market mechanism to reduce the total amount of pollution permitted in an area.

Emission-offset systems

Emission-offset systems work primarily by requiring any person who wishes to undertake a potentially polluting activity or expand one that is already in place to first offset the likely impact on a groundwater body of that activity. Thus, for example, in an area where a person wishes to establish a septic tank, they may first have to arrange for one or more existing septic tanks to be removed. Experience in the United States of America, indicates that such mechanisms can be used to gradually reduce groundwater pollution by requiring people to offset more pollution than they can be expected to contribute to the problem. When offset arrangements are applied to point-sources of pollution, polluters may find that it is cheaper for them to pay for the clean-up of diffuse sources of pollution elsewhere rather than reduce their own emissions.

Treater-pays systems

Treater-pays systems are usually linked to emission-offset mechanism similar to that described above. In this report, we treat treater-pays systems separately from offset systems because waste water treatment works are required to meet very high standards. In many cases, the cost of removing the last trace of nitrate or phosphate from sewage every day can be prohibitively expensive. Sometimes, it will be cheaper for a waste water treatment works to pay someone else to remove pollutants rather than improve their own performance.

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2. If, for example, the quantity of groundwater available for irrigation is determined by groundwater recharge and there is an increase in the area planted to trees then in order to keep groundwater use within sustainable limits either.
   a) each shareholder's annual allocation has to be reduced; or
   b) new plantation owners will have to acquire shares from existing users.
   If the second option is taken then either all existing plantation growers need to be included in the system or plantation development needs to be brought under development control and approval only given to landholders who acquire groundwater shares from an existing wateruser. If all existing plantation owners are added to the system then the total number of shares has to be increased.

In Geographe Bay, for example, the Busselton Waste Water Treatment Plant is facing the choice of spending $4.5 million followed by an annual maintenance cost of $0.5 million per annum or, simply, paying $0.5 million per annum towards the cost of a program designed to reduce diffuse sources of nitrate and phosphate from agricultural land. This latter option would save the people of Busselton a capital cost of $4.5 million and remove more nitrates and phosphates from Geographe Bay than any investment in improving treatment of their sewage. By contributing to a diffuse source reduction program, diffuse source pollution reduction is expected to be in the vicinity of 10–20% while if a plant upgrade goes ahead water quality in Geographe Bay would improve only by between 1% and 3%. Even though it may seem ethically wrong to pay others not to pollute, pragmatically all people in the region will be better off if money is spent on reducing diffuse rather than point-source pollution.

Tradeable-emission right systems

One attraction of tradeable emission-right systems is their outcome focus on pollution reduction and the fact that these systems make polluters pay for the costs of implementing a groundwater pollution control program. Control is achieved by setting an ecological limit and leaving market forces to decide how emissions are kept within this limit. Each emitter has the choice of either reducing their own emissions or paying someone else to reduce them. Under an tradeable emission-right system those who reduce emissions are reimbursed for at least part of the cost of doing so by those who do not.

In one case we identify, Venus Bay, there is opportunity to implement a tradeable emission-right system which effectively makes polluters pay for the costs of reducing groundwater pollution from septic tanks. Some people are permitted to use septic tanks but most are encouraged to move either to a pump-out or communal septic tank system. Those who 'upgrade' would receive a payment of between $1,500 and $2,500 from a pool established via a levy on those who choose to retain their current septic tank.

Tradeable-emission rights also have application to the control of dryland salinity. Under such a regime all people would be levied and those who agree to plant trees and are prepared to enter into a management agreement would be entitled to be reimbursed from the pool of money created by the levy. Such mechanisms would be best applied at the catchment or sub-catchment level. They can also be used to control groundwater pollution from animal waste. It needs to be stressed, however, that in most cases it is necessary to first set up a database and monitoring system to establish control. Such arrangements can be prohibitively expensive and, in some cases, politically unacceptable.

Extent of specific problems and assessment of potential

The geographic extent and economic importance of diffuse groundwater pollution across Australia has not been defined. This means that the documented and reported examples of diffuse groundwater pollution are often sporadic and based, largely, on statements by individuals. Moreover, the extent of reporting and monitoring of diffuse groundwater pollution in the Australia's States and Territories ranges from almost nil up to only a modest level of reporting. The scale of the problem is not well understood. Consequently, any assessment of the ability of rights markets to deal with non-point-sources of pollution must be highly subjective. Nonetheless, and assuming State government willingness to use right markets to control diffuse groundwater pollution, the table below shows our subjective assessment of the potential of right markets to make a significant contribution to the extent and intensity of diffuse groundwater pollution in Australia.

It is our assessment that right-markets mechanisms have only a very small scope to control diffuse groundwater pollution due to pesticides; a moderate ability in the case of nitrates, and a high ability in the case of groundwater salinisation and seawater intrusion.

We were unable to find any examples of serious diffuse pesticide groundwater pollution and, hence, our assessment of the applicability of rights markets could be very much in error in this case. Pragmatically, however, we do point to the fact that right-market mechanisms have much wider public acceptance in the control of pollutants which occur naturally in groundwater. Licensing people to place 'approved' quantities of pesticides in groundwater would, in our judgement, be likely to be politically unacceptable. We see little potential for the use of right-market mechanisms to control pollutants that are not naturally present in an aquifer.

Across Australia the highest priority diffuse groundwater pollution problem is probably nitrate pollution. Hence, even with only an assessed moderate applicability, the use of right markets to control nitrate pollution is worthy of serious consideration. They are easily used to reduce nitrate pollution in irrigation areas, are powerful in areas where animal manure spreading is common and, also, in areas where people have to pay to remove nitrates from groundwater. We, however, can not see them making a significant contribution to the control of nitrate pollution from non-irrigated pastures or livestock grazing. As salinity problems are often associated with groundwater use, however, we see the mechanism as a powerful means of controlling this problem.

Subjective assessment of the applicability of right-market mechanisms to reduce non-point-source groundwater pollution in Australia

Diffuse pollution problem	Ability of right-market mechanisms to significantly reduce diffuse pollution problem (% of problem area amenable)
Nitrates	
Excess fertiliser applications	30%
Animal excreta	20%
Legume pasture	10%
Pesticides	1%
Groundwater Salinisation	
Land Clearing	40%
Recycling	75%
Lateral migration	75%
Irrigation	50%
Bacteria, nitrates from septic tanks	50%
Seawater intrusion	90%

As a final observation, while we set out to find a means to use right markets to control nitrate pollution from unirrigated legume pastures and pesticide pollution of groundwater, we found no case where these problems are sufficiently severe to justify use of right markets to achieve this end. This does not mean that they are not going to become a problem, only that they are not yet a problem.

Technical issues

Finally, we draw attention to a number of technical issues which, if resolved, will make use of right-market mechanisms easier. There is a need for improved hydro-geological knowledge about the natural variation of contaminants in groundwater systems; better information on the level of pollution loads that can be sustained; coupled with more technical data on the limit of acceptable pollution; and also, more work on the development of cost-effective monitoring systems.

Implementation

Throughout the course of this study, we were asked continually for more information on the steps necessary to implement each of the options identified in this report.

To set up a *conditional groundwater-use right* system to control groundwater pollution it is necessary to:

1. announce that the new system is going to be introduced and define the basis on which licences will be issued so that people do not undertake activities that increase use solely for the purpose of obtaining a greater share;
2. validate all existing groundwater irrigation licences so that they can be converted into a formal right system;[3]
3. decide whether or not to include other groundwater users, like town water supplies and stock and domestic users, in the share system. If they are not included then it is necessary to decide whether or not expansion of these uses is to be capped or if they have a prior right. If a prior right is recognised then every time one of these uses is expanded every right holders share is diminished;
4. prepare a management plan which defines the entitlement embodied in each share. One hundred shares, for example, may entitle a person to use up to 1 ML per annum for the next five years. If meters are not in place then the management plan may translate this entitlement into a right to plant either *x* ha of pasture or 2.7 times *x* ha of grapes under drip irrigation. The plan would also set out the land and wateruse conditions that each shareholder would be required to comply with;
5. convert all existing licences into formal conditional groundwater use shares (or equivalent) and make any legislative changes necessary to make it possible to give waterusers security of tenure;[4]
6. put the necessary monitoring system in place to a) ensure compliance; and b) ensure that information necessary for the first management plan review is collected; and
7. appoint the body to conduct periodic management plan reviews and decide on the means by which they will be chosen and the powers that they have.

One key to the success (or failure) of a conditional groundwater-use right is the presence of a mechanism that enables the periodic review of the conditions that attach to a right.

3. Often departmental records are not kept in a manner that makes it possible to quickly determine who has a groundwater licence. This is particularly likely to be the case where there is no requirement to provide an annual report on consumption.
4. The incentive for resource stewardship is greater if security is conditional upon compliance with the land and wateruse conditions set out in the management plan; if the rights are mortgageable; and if the breach of any conditions results in loss of a pre-specified number of shares.

To set up a *treater-pays system* it is necessary only to promote the idea and then leave those most affected by the more stringent standards generally applied to point-sources of pollution to develop an innovative proposition that is consistent with groundwater quality objectives. Reduction of diffuse source pollution is notoriously more difficult than it is for point-sources. Experience in the United States of America with treater-pays systems suggests that plants should be required to reduce around two times as much diffuse source pollution as is required from a point-source. A diffuse-point-source ratio of, at least, 2:1 provides a buffer to reflect the fact that diffuse source reduction mechanisms are less reliable than used to reduce point-source pollution.

To set up an *emission-offset system* to control groundwater pollution it is necessary to:

1. obtain administrative agreement and commitment to the proposed mechanism;
2. announce the new offset policy and convince the community of its wisdom;
3. decide on the rules for offsetting. In particular, it is necessary to decide if it is only necessary to offset expected emissions on a 1:1 basis or if a more progressive ratio of, say, 2:1 is required. The first simply stops the situation from getting worse. The latter enables a gradual reduction in total emissions. Where response rates are uncertain, 2:1 ratios can also be used to account for that uncertainty; and
4. establish the arrangements necessary to ensure that the offset are enforced. In particular, it is important to ensure that none of the authorities involved grant special exemptions.

To set up a *tradeable emission-right system* to control groundwater pollution it is necessary to:

1. establish an emission history or some other means of defining the quantity of emissions made by each landuser;
2. define the expected relationship between each person's rights and entitlements;
3. where appropriate, define the means by which each person's entitlement will be reduced and what incentive arrangements will be used to reduce emissions;
4. prepare an appropriate management plan setting out the relationship between rights, entitlements and obligations;
5. issue or define each person's emission-rights;
6. put the necessary monitoring system in place to a) ensure compliance; and b) ensure that information necessary for the first management plan review is collected; and
7. appoint the body to conduct periodic management plan reviews and decide on the means by which they will be chosen and the powers that they have.

To set up a *polluter-pays system* to control groundwater pollution it is necessary to:

1. identify the surrogate indicator of pollution load to be levied. Examples include presence of a non-complying septic tank, area of crop planted, or area of land owned;
2. work out how those who reduce pollution loads will have their levy reduced in an equitable manner;
3. identify the appropriate size of the levy;
4. identify where the money raised is to be spent and who should decide how that money is spent;
5. work out how to collect the levy; and
6. work out how the money will be spent in an equitable and efficient manner.

Recommendations

As a result of the range of case studies and experience analysed in this report, we conclude that, *right-market mechanisms are best suited to the management of contaminants naturally present in aquifers.* Nitrates, phosphates, and salt clearly fall into this category. Where a community aspires to near-zero contamination levels, a strong regulatory approach is likely to be more effective. In conclusion, we recommend that:

1. no groundwater user be given a secure groundwater-use right that:
   - precludes the attachment of land and wateruse conditions to that right; and
   - does not facilitate the periodic review of the entitlements, conditions and obligations that attach to that right.

With regard to the effects of land-use change on the amount of groundwater recharge and, hence, the amount available to irrigation, we recommend that:

2. all groundwater allocation systems be designed so that, at a later stage, it is possible to vary annual allocations as rainfall, recharge rates and environmental considerations change;
3. in areas where there is over-allocation or over-use of an aquifer, consideration be given to the merits of including forms of landuse like timber plantations and deep-rooted perennial pastures within the allocation system;
4. consideration be given to the introduction of share-based allocation systems which give each licensed groundwater user a formal share of the amount of water available in an aquifer for consumptive use. Such an arrangement gives each user a guaranteed right to use groundwater sustainably but, at the same time, provides periodic opportunity to review and improve definition of the entitlements, conditions and obligations that attach to that right; and
5. offset mechanisms be used as an interim measure to control reduction of recharge from areas placed under plantations.

With regard to the reduction of diffuse pollution from multiple-point-sources, like septic tank installations which are linked to development approvals, we recommend that:

6. offset mechanisms be used as a means to prevent increases in the flow of nutrients to groundwater and, where appropriate, reduce the flow of these nutrients to groundwater.

With regard to the high cost of removing nutrients from groundwater sources in some locations and the relatively low cost of achieving much greater rates of improvement from diffuse sources, we recommend that:

7. State and Commonwealth agencies encourage water treatment authorities to become involved in programs that reduce the flow of nutrients to groundwater in the most cost-effective manner possible.

Recommendations from a report of this nature require careful consideration by many people. We recommend that this report be:

8. referred to the COAG Task Force on Water Reform for consideration of the advantages of designing water allocation systems so that they encourage waterusers to reduce groundwater pollution; and
9. Commonwealth, State and Territory groundwater and surface water managers give careful consideration to the merits of using the current water reform process as a means to improve water quality.

Table 1
Summary of applicability of different right-market mechanisms to assist in controlling groundwater pollution by nitrates

Pollution Problem or Source	Right-Market Mechanism (Options with most potential are in bold)				
	Tradeable-Emission Right Total annual load entering an aquifer is capped. Polluters are issued a right to a share of this load. Trading is encouraged. Maximum concentrations are set. Surrogate indicators can be used to reduce monitoring costs.	**Emission-Offset** Development approval is conditional upon pollution reduction elsewhere. No development is allowed to cause a net increase in the pollution rate.	**Treater-Pays** Water treatment plants and ecosystem managers pay for pollution reduction activities because this is more cost-effective than water treatment.	**Polluter-Pays** Polluters are forced to share the costs of groundwater treatment and protection in proportion to their contribution to the problem.	**Conditional Use-Right** Conditions are attached to surface and/or groundwater rights so that the polluting activities are either encouraged to move to less vulnerable areas, discouraged, prohibited or phased out.
Excess Fertiliser Application	**Tradeable crop-area rights that cap total crop-area and establishes an opportunity to trade in crop area equivalents.** ✓✓	✘ (Appropriate for point sources subject to development approval. Can link to non-point source).	Treatment works pays for the cost of assisting farmers to prepare nutrient management plans and/or for extension officers. ✓	Levy based on quantity of surplus nutrients assessed from annual nutrient account. Politically difficult to implement. ✓	**Wateruse rights conditional upon preparation of nutrient management plans that meet prescribed standards.** ✓✓
Animal Excreta (From diffuse sources and manure spreading from intensive feedlots etc.)	Quota on animal numbers. ✓ (Difficult to enforce).	**A maximum ratio of livestock to land area is set. Livestock owners prepare accounts summarising manure distribution. Spreading manure on other people's land is encouraged.** ✓✓	As above ✓	As above ✓	Plausible but limited potential as few feedlots use large amounts of irrigated water. (Manure spreading and offset controls more equitable and cost effective) ✘
Nitrogen Produced by Legume Pasture	Tradeable crop-area rights for a recharge area. Only possible on irrigated land. ✓	Legume planting unlikely to ever be subject to development approval. ✘	As above ✓	As above ✓	**Wateruse rights conditional upon preparation of a nutrient management plan meeting specified standards** ✓✓

✓✓ = Very Applicable (Cost-effective, technically feasible, & equitable); ✓= Applicable (If technical challenges can be resolved, cost effective & equitable); ✘ = Not Applicable

Table 2

Summary of applicability of different right-market mechanisms to assist in controlling groundwater pollution by pesticides, from septic tanks and from seawater intrusion

Pollution Problem or Source	Right-Market Mechanism (Options with most potential are in bold)				
	Tradeable Emission-Right Total annual load entering an aquifer is capped. Polluters are issued a right to a share of this load. Trading is encouraged. Maximum concentrations are set. Surrogate indicators can be used to reduce monitoring costs.	**Emission-Offset** Development approval is conditional upon pollution reduction elsewhere. No development is allowed to cause a net increase in the pollution rate.	**Treater-Pays** Water treatment plants and ecosystem managers pay for pollution reduction activities because this is more cost-effective than water treatment.	**Polluter-Pays** Polluters are forced to share the costs of groundwater treatment and protection in proportion to their contribution to the problem.	**Conditional Use-Right** Conditions are attached to surface and/or groundwater rights so that the polluting activities are encouraged to move to less vulnerable areas, discouraged, prohibited or phased out.
Pesticides	(More cost effective to regulate and only allow use of biodegradable chemicals). ✘	(More cost effective to regulate and only allow use of biodegradable chemicals). ✘	Treaters pay for preparation of pesticide management plans. Theoretically possible but requires acceptance of contamination. ✘	Could make pesticide users pay for the cost of monitoring. ✓	Wateruse right conditional upon preparation of pesticide management plans meeting specified standards ✓
Bacteria from Septic Tanks	Shares in allowed discharge issued with entitlements that require more shares to be held by people who cause the most problems. ✓	**Person installing a septic tank must organise for another tank to be removed. Two for one exchange is possible.** ✓✓	**Sewage works pays for or subsidises sewage connection.** ✓✓	**A large charge is introduced; connection and/or other options are made cheaper. Payments to those who upgrade.** ✓✓	✘
Seawater Intrusion	✘	✘	✘	**Issue groundwater recharge credits so that people have an incentive to recharge from surface water systems.** ✓✓	**Introduce tradeable groundwater shares and cap extractions to a sustainable level.** ✓✓

✓✓ = Very Applicable (Cost-effective, technically feasible, & equitable); ✓= Applicable (If technical challenges can be resolved, cost effective & equitable); ✘ = Not Applicable

Table 3

Summary of applicability of different right-market mechanisms to assist in controlling groundwater salinisation due to agricultural practice

Pollution Problem or Source	Right-Market Mechanism (Options with most potential are in bold)				
	Tradeable Emission-Right Total annual load entering an aquifer is capped. Polluters are issued a right to a share of this load. Trading is encouraged. Maximum concentrations are set. Surrogate indicators can be used to reduce monitoring costs.	**Emission-Offset** Development approval is conditional upon pollution reduction elsewhere. No development is allowed to cause a net increase in the pollution rate. (1)	**Treater-Pays** Water treatment plants and ecosystem managers pay for pollution reduction activities because this is more cost-effective than water treatment.	**Polluter-Pays** Polluters are forced to share the costs of groundwater treatment and protection in proportion to their contribution to the problem.	**Conditional Use-Right** Conditions are attached to surface and/or groundwater rights so that the polluting activities are encouraged to move to less vulnerable areas, discouraged, prohibited or phased out.
Land Clearing	Theoretically possible but cheaper and more politically feasible to mimic the features of such a system. ✘	**Mandatory obligation to offset (plant trees) so that there is no change in groundwater recharge.** ✓✓	**Treatment plants could pay for purchase of dryland salinity control covenants.** ✓✓	**Establish a fund to acquire dryland salinity control covenants.** ✓✓	✘
Groundwater Recycling	✘	✘	✘	✘	**Trading arrangements organised so that the highest price is likely to be paid by people in low salinity hazard areas.** ✓✓
Lateral Migration	✘	✘	✘	✘	**Trades encourage movement away from problem areas.** (As above) ✓✓
Irrigation	**Tradeable salinity rights.** ✓✓	**All irrigation works subject to salinity offset requirement.** ✓✓	✘	✘	**As above** ✓✓

✓✓ = *Very Applicable (Cost-effective, technically feasible, & equitable)*; ✓= *Applicable (If technical challenges can be resolved, cost effective & equitable)*; ✘ = *Not Applicable*

Groundwater pollution and management

Introduction

Interest in the use of right-market mechanisms as a means to improve resource use is growing. In the water sector, this interest is being driven by the Council of Australian Government's (COAG) (1994) commitment to "*implementation of the strategic framework for the efficient and sustainable reform of the Australian water industry.*" Through COAG, States have agreed to try to "*implement comprehensive systems of water allocations or entitlements backed by separation of water property rights from land title and clear specification of entitlements in terms of ownership, volume, reliability, transferability and, if appropriate, quality.*" Financial assistance to states is conditional on satisfactory progress being made. To date, the COAG water reform agenda has focused on allocation issues but if the first outcome is to be one that incorporates a transition to sustainable forms of wateruse, then pollution issues must also be addressed. Some pollution comes from joint venues and good progress is being made in its reduction. Pollution from diffuse varies, however, is much more difficult to control.

This report deals with the most difficult of these issues—the potential of right markets to reduce diffuse groundwater pollution problems. We perceive resolution of diffuse groundwater pollution problems to be one of the most challenging environmental issues likely to emerge next century. We stress, however, that both point and diffuse sources of water pollution need to be managed. Moreover, at the outset we wish to dispel any belief that right-market mechanisms—on their own—can solve any diffuse pollution problem.

We define a right market as any legal arrangement granting somebody a right to do something or to transfer that right to someone else. Any conditions constraining transfer of that right are prescribed in advance. By doing this, market rather than political processes can be used to redistribute opportunities to use natural resources in ways that are equitable and consistent with community values. Examples of right markets include tradeable irrigation licences, a tradeable emission permit or a system where sewage treatment works contribute to the cost of reducing nitrate pollution from a dairy.

Many people believe fundamentally that all natural resources should be owned collectively by society and, hence, it is wrong to assign rights to them. This report is not about allocation of absolute rights. Rather it is about allocation and distribution of opportunities to use natural resources and the environment in a manner consistent with social objectives. Our focus is on diffuse sources of groundwater pollution.

Diffuse pollution is pollution spread over space and time which is not caused by local and specific discharges or events. Pragmatically, we define diffuse sources of pollution to include small multiple point-sources of pollution. Diffuse pollution is caused by the spread of pollutants or by the accumulation of many individual, and often small, and frequently ill-defined events (NRA, 1992). Diffuse pollution is hard to detect and characterised by the fact that it is difficult to precisely identify the specific action that caused the problem to emerge. Described in more detail later in this report, a number of fundamental characteristics of groundwater make groundwater pollution much harder to manage than diffuse surface water pollution problems. In particular, we examine the issues of:

- nitrate and phosphate pollution;
- pesticide pollution from agricultural practice;

- groundwater salinisation due to agricultural practice;
- bacteria and nitrate pollution from septic tanks; and
- seawater intrusion.

Many lay people perceive that those who advocate the use of market mechanisms do so in a way that compromises standards attainable through regulation. In the United States, this is known as 'backsliding.' The US EPA's (EPA) Clean Water Act (s402(o)) expressly prohibits the issuance of any licence or permit less stringent than the existing technology-based limit (US EPA 1996). In this report, we limit consideration to factors that facilitate improvement beyond levels attainable through regulation on its own. In no case do we envisage a system that will allow groundwater quality standards to be lowered. Similarly, in no case do we envisage systems that legitimise any polluting activity already prohibited by legislation. We recognise that many actions that pollute groundwater either are illegal or should be made illegal.

The global and national importance of diffuse groundwater pollution

The magnitude of diffuse (or non-point) groundwater pollution across the world is immense. The fact that it is so hard to identify and characterise, let alone control, is testament to the huge size of the issue. Dudda (1993) describes the world-wide importance of diffuse pollution; "hundreds of millions of people suffer from disease, billions of dollars of economic development investment is lost, and trillions of dollars of environmental remediation needs are being accumulated for future generations to address". Dudda emphasises that a fundamental change in thinking and attitude is required throughout the world in order to even begin to address this immense problem.

In recognition of the serious and increasing level of nitrates in groundwater used for potable supplies in many European countries, early in the 1990s, the European Community introduced a 'Nitrate Directive' which, for the first time, directed introduction of legislative controls in an attempt to reduce nitrate pollution of groundwater from agricultural sources.

The extent of both point-source and diffuse groundwater pollution in Australia is not as great as in many more populated parts of the world. Australia is almost in a unique position where we have the opportunity to learn from problems elsewhere and not make the same mistakes. Consequently, as part of the National Water Quality Management Strategy, the Agricultural and Resource Management Council of Australia and New Zealand produced the *Guidelines for Groundwater Protection in Australia* (ARMCANZ September, 1995). The guidelines are underpinned by the premise of prevention being far more effective than a cure. The guidelines are also based upon a planning framework within a legislative and Government controlled environment. This fundamental framework has been shown to be moderately effective in dealing with point-source groundwater pollution, but quite ineffective in dealing with diffuse groundwater pollution. The genesis of this project derives from a recognition of the fact that—if the problem is to be solved—alternative approaches are necessary.

The spatial extent and magnitude of diffuse groundwater pollution across Australia is poorly understood and very little data exists. In relation to organic chemical contamination, for example, Knight (1993) observes that there have been very few systematic attempts to detect and monitor pesticide/herbicide compounds from diffuse agricultural sources. The lack of positive published findings is believed by Knight to possibly be due to inadequate experimental design.

Several major projects funded by the Land and Water Resources Research and Development Corporation and by the Australian Geological Survey Organisation, are currently underway to investigate pesticide contamination beneath irrigated agriculture. Preliminary results (Hoxley, pers. comm. and Bauld, pers. comm.) indicate substantial groundwater contamination by pesticides. As identified in this report, several one-off surveys have recently been undertaken by State Governments. Contamination by atrazine has been reported beneath pine plantations in the lower south-east of South Australia (Staedter, pers. comm.).

Dillon (1993) has reported on the effects of rural activities on groundwater quality. He discusses the effects of grazing, clearing of native vegetation, use of fertilisers and the use of herbicides and pesticides on groundwater pollution. He focuses on the build up of nitrates in groundwater due to both grazing activities and the application of nitrogenous fertilisers and expresses concern that, in spite of hundreds of fertiliser trials undertaken across Australia, very few have considered the consequences for groundwater quality. Nonetheless, high nitrate levels in groundwater have been reported by many studies (eg. Lawrence, 1983; Dillon et *al.*, 1989). Moreover, the use of nitrogenous fertilisers is steadily increasing in Australia (Australian Fertiliser Manufacturers Committee, 1990). In addition, irrigation for dairying is increasing. These concerns and, also, leguminous pastures are now being perceived as a significant source of groundwater pollutants (Dillon, 1993).

The role and value of groundwater in Australia

The management of groundwater in Australia has traditionally focused on allocation of good quality water for domestic, stock, urban, irrigation and industry needs. The major use of groundwater is clearly for irrigation, although the value of groundwater for supporting rural domestic and stock use is immense, with in the order of 70% of Australia being largely or fully dependent on groundwater. Sinclair Knight Merz (1995) has estimated that out of approximately 26,000,000 ML per annum available, about 15% is used in an average year. There are in the order of 540,000 wells available for use. Significantly, 466 cities and towns are totally dependent on a reticulated groundwater supply and a further 107 cities and towns are partially dependent on groundwater. The value of groundwater infrastructure assets is in the order of $6 billion.

It can be argued, however, that the major role of groundwater across Australia is not so much as a direct water resource but in two other ways:

1. as a **maintainer of surface water flows.** A typical 'rule of thumb' for rivers and streams is that approximately 50% of the flow is groundwater derived. This is especially important during low rainfall months; and

2. **as a process which maintains ecosystems.** The significance of groundwater in maintaining the ecological health of vegetation, wetlands and many other ecosystems is only just beginning to be recognised.

The cost of pollution of groundwater from both point and diffuse sources and, hence, threatening or even destroying the above three major roles of groundwater across Australia has not been estimated. Patchy evidence and knowledge available to us suggests that Australia spends in the order of $50 million per annum cleaning up polluted groundwater. But this represents only a very small proportion of the real cost of point-source contamination; much of the costs of cleaning up or living with diffuse groundwater contamination are being deferred to future generations to deal with.

Characteristics of groundwater

Some fundamental characteristics of groundwater are important in the consideration of the feasibility and design of possible right markets for managing groundwater pollution. These are:

1. it is **hidden**—groundwater is a hidden resource and a hidden process. Consequently its behaviour, quality, flow rate and location will always be imprecise and poorly understood. Any rights mechanism must reflect this grossly imperfect technical knowledge and uncertainty;

2. **it is slow moving**—groundwater under most natural hydraulic gradients in Australia is very slow moving with typical rates of movement of 0.1 to 1 m per year. Hence, typically, pollution plumes move off site and/or discharge to the surface after decades. This slow rate of movement has many implications. For example, the original polluter has frequently moved and/or sold the original property; records and memories of possible polluting activities are lost (eg. cattle dip locations);

3. **it is broad scale**—groundwater recharge and discharge occurs at a broad range of scales, ranging from local processes (metres up to a few kilometres), up to regional processes (tens of kms up to 1,000 km). In addition, these processes occur in three dimensions, frequently at great depth. The broad range of scales which occur may mean that issues and problems are frequently site (ie. plan area) specific and cannot be readily translated from one area to another;

4. **natural contamination is common**—the natural (or base) level of many chemicals in groundwater may be at or above international and national standards for water pollution. For example, high natural fluoride and nitrate levels are common in many groundwaters throughout Australia. In the basalts of south-eastern Australia, the level of nickel is clearly above the Dutch B pollution criteria. Hence, the definition of what level of contamination is considered to be unacceptable is frequently difficult to define. Nonetheless, a conservative approach to considering the problem is considered to be warranted and hence, even though accurate data may not be available to indicate unacceptable pollution, the use of instruments (including right markets) to address the issue is justified;

5. **pollutants cumulate**—some so called 'point-source' pollution sources (eg. septic tank pollution) frequently coalesce to form diffuse groundwater pollution. Aquifers can fall victim of the 'tyranny of small decisions'. Each individual action may be inoffensive and trivial in scale but if such actions are frequent and dispersed over large areas the result can be a major pollution problem. Thus, right markets need to be designed which acknowledge that, although an individual activity may be acceptable, the same activity frequently occurring over an area may not be acceptable and, hence, market instruments may be applicable; and

6. **much pollution is irreversible**—in most groundwater systems the very high cost, impracticality and virtual impossibility of cleaning up polluted groundwater means that for most practical timeframes and purposes, groundwater pollution is essentially irreversible. This especially applies to diffuse groundwater pollution. This irreversibility calls for a conservative approach to be adopted.

Diffuse groundwater pollution issues covered by this report

Even though a broad variety of diffuse groundwater pollution problems may exist in both urban and rural environments, and as outlined in the introduction, this report focuses on the more 'intractable' problems. In brief, the issues are as follows.

Nutrient pollution (nitrates)

Nitrate pollution caused by fertiliser use

The application of nitrogenous fertilisers, as discussed in the introduction, is a very widespread rural activity which can pollute groundwater.

In addition to the use of nitrogenous fertilisers, nitrogen is returned to pasture due to stock excreta. When the extremely high nitrogen concentrations of the myriad of 'point' sources of excreta (effectively diffuse pollution) exceed the uptake and attenuation capacity of the soil and plants, then nitrate pollution of the groundwater can occur. Phosphate pollution of groundwater as a result of fertiliser use is not as great a problem as phosphates often bind tightly to soil and, hence, are rarely a problem. It is possible, however, that phosphate contaminated groundwater may contribute to the incidence of algal blooms when it discharges into a surface waterbody.

Nitrate pollution caused by widespread use of leguminous pastures

Leguminous pastures are widespread in southern Australia. Nitrogen 'fixing' occurs with these pastures where atmospheric nitrogen (N_2) is converted to ammonia (NH_3). In an aerobic environment, the ammonia is converted to nitrate. Nitrate accumulates in the soil profile over summer when annual pasture is inactive. With the onset of autumn and winter rains, the nitrate may be leached down to the groundwater. Hence, the increasing use of leguminous pastures has the potential to cause increased groundwater pollution.

Groundwater pollution caused by disposal of animal manure

The spreading of high volumes of animal manure from often intensive animal industries (eg. cattle feedlots) is gradually becoming a common practice throughout the world. Increases in this form of production throughout Australia means that we can expect many of the problems already widespread across Europe and North America. Very high nutrient loading rates can be expected in localised areas and, where this occurs, serious nitrate contamination of groundwater can be expected.

Contamination from agricultural pesticides, herbicides, fungicides

Groundwater contamination from pesticides, herbicides and fungicides is often blamed on specific industries and application methods. In practice, however, application rate and soil type are likely to be equally important considerations. Even though widespread groundwater contamination by pesticides etc has not been reported in Australia (see Aylmore and Kookana, 1993), nevertheless research in the United States of America suggests a close association between pesticide use and groundwater diffuse.

With a six-fold increase in pesticide use over the last decade, significant groundwater pollution may be occurring, but as yet, contamination at levels above those deemed safe for domestic consumption is not common. Recognition of the precautionary principle and public preferences for zero levels of contamination from this source, however, suggest a need for control in this area. During the course of this project, we have identified no area where regulatory instruments are in place to prevent or control groundwater contamination from this source.

Increased groundwater salinity and nitrates caused by agricultural practices

There are a variety of mechanisms which can cause an increase in groundwater salinity (and nitrates, in one case) due to agricultural practices, as follows:

Land clearing

The clearing of native vegetation in many parts of Australia's wheat sheep-belt causes a major increase in recharge rate (due to a lack of evapotranspiration) and, hence, salinity and nitrate concentration of recharging water. Cook (1992), for example, has determined that nitrate content in soil water in the South Australian Mallee was sufficiently high to produce a nitrate concentration of recharging water of 10 to 20 mg/L. The Australian standard for drinking water is not more than 10 mg/L of nitrate. Significant research is underway to determine the salt content of the unsaturated zone in the Mallee and, hence, the potential impact of increased recharge following clearing on groundwater salinity (see Leaney and Herczeg, 1997).

Recycling

The use of groundwater for irrigation and the resulting increase in salinity of the recharging water (ie. the plants use the water, leaving the salt to build up in the soil, which is then flushed down to the watertable) and, hence, the increase in salinity of the groundwater has been described in many cases around Australia (eg. Prendergast and Heuperman, 1988). Over time, typically decades, the salinity of the groundwater gradually increases and this may reach salinity levels whereby the resource is degraded sufficiently such that it is unusable for the original purpose, primarily irrigation. Salinity increases in the order of 10 mg/L per year have been recorded in some areas.

From a right-market perspective this process is directly linked with the use of groundwater and, hence, can be dealt with as part of the licensing/approval/management process.

Lateral and vertical migration

This process is caused by lateral and/or vertical movement of groundwater induced by pumping. Pumping reduces the pressure within the aquifer (the potentiometric surface in a confined aquifer) which, in turn creates a pressure gradient that encourages lateral and/or vertical migration of poorer quality water in adjacent aquifers or aquitards. Over time (sometimes years), this can cause the salinity of the aquifer to increase in a similar manner to that observed when recycling occurs.

Irrigation

Surface water based irrigation causes salt to be imported into a region. Some of this water flows through to the groundwater system with the consequence that groundwater salinity can become a serious problem in surface water irrigation areas.

Groundwater pollution from septic tanks

As septic tank distribution is very widespread and in an urban or semi-urban environment the density of septic tanks can be high, it is considered that septic tanks result in diffuse groundwater pollution. Although many overseas references have documented significant groundwater pollution results from septic tanks, there is very little published Australian data on the extent of groundwater pollution from septic tanks (Hoxley and Dudding, 1994).

The major pollutants from septic tanks are microbiological (bacteria, principally), nitrates and, possibly, phosphates. It is well known that the potential for groundwater pollution from septic tanks varies greatly depending upon the design of the system and how it is constructed and maintained. Suffice to say that well maintained systems of recent design should have only a very small potential for pollution. Also, new design methods have been developed and are undergoing testing in North America (eg. Groundwater Monitor, 1996) which are specifically aimed at reducing groundwater pollution. Nonetheless, it is quite common for an Australian domestic water supply bore to be located very close to a septic tank disposal system. Contamination is surprisingly common.

Seawater intrusion to groundwater

Seawater intrusion has been documented at many places around the world as being a major groundwater management problem. Seawater intrusion occurs where groundwater extraction occurs close to the sea (or other saline surface water bodies). Generally, the reduction in the head of good quality groundwater caused by pumping creates a pressure gradient that encourages adjacent seawater to move inland and, hence, pollute good quality and useable groundwater. The geographic extent of the intrusion depends on a range of hydrogeological factors and especially the location and magnitude of the groundwater extraction.

Seawater intrusion occurs at many places around the Australian coastline, but is especially common in Queensland where large scale groundwater usage close to the coast has caused large scale intrusions (see, for example, Hillier, 1993).

The clear link with groundwater usage exceeding the sustainable yield of an aquifer points to specific right-market measures to deal with the problem.

Groundwater vulnerability mapping

The susceptibility to pollution of groundwater is a function of many hydrogeological factors, principally soil type, unsaturated zone lithology, depth to watertable, hydraulic conductivity, presence or absence of aquitards, recharge rates, contaminant application rate, contaminant attenuation behaviour, decay rate and chemical stability. All of these factors can vary significantly and consequently any assessment of the vulnerability of a groundwater resource to being polluted indicates a very high spatial variability with respect to vulnerability. It will also vary according to properties of any specific contaminant or landuse being investigated.

Active research is underway throughout the world to attempt to find a technically rigorous approach to define vulnerability (eg. Barber *et al.*, 1993). Most approaches result in groundwater vulnerability maps which show great variability from low to high, at a scale of hundreds of metres to kilometres. The differing properties of different potential contaminants add further complications. The aquifer in a zone, may be very vulnerable to one polluting substance but not very vulnerable to a different polluting substance. Furthermore, some substances (eg. nitrates and chlorides) are very conservative. It may be argued that an area may show low vulnerability in the short-term, but high vulnerability in the long-term. Essentially, the application of conservative contaminants is likely to cause aquifer contamination in the long-term (in all cases other than where the aquifer is strictly confined).

The large spatial variation in vulnerability may be viewed as rendering the application of right-market concepts invalid. The argument that could be proposed is that even though a particular polluting activity may be highly undesirable on, for example, one particular area of land on one farm, the same activity on the adjacent farm may cause no undesirable consequences. The counter argument is that it depends on the type of polluting substance and on the timeframe under consideration. Many conservative substances, principally nitrate and chloride, given sufficient time and even low recharge rates, will pollute all the aquifer, even though a vulnerability map may show a large spatial variation in vulnerability. Hence, in spite of whatever is shown on a vulnerability map, a conservative approach is required for many polluting substances and the broad principles inherent in the application of a right market can apply. However, this assumes that loading and place are not significant factors influencing pollution by conservative contaminants.

Since conservative contaminants are going to get 'there' anyway (once their applied loading exceeds levels of take-up by vegetation), the question of where 'there' is becomes important, and must be considered in any planning decision. High nitrate or chloride loading near to rivers, for example, may result in groundwater fed streams being contaminated. In other areas, away from rivers, in an area where the underlying aquifer is largely confined (and may even be of poor quality), the application of potential contaminants is less significant.

SECTION FOUR

Beneficial use

The beneficial use of an aquifer is defined as the most valuable use for which the water can be used. Beneficial use is commonly defined with respect to the groundwater quality, as frequently measured by total dissolved solids content. The development of beneficial use objectives for each aquifer provides the fundamental 'cornerstone' against which groundwater pollution is measured and hence provides the trigger for when action needs to occur to protect a certain specified beneficial use. Hence, the application of right-based mechanisms, or any other physical or policy measures, is frequently contingent upon a beneficial use assessment being carried out for all major aquifers in Australia. This especially applies to diffuse groundwater pollution. The question which this report seeks to address is: "What is the role of right-market mechanisms in maintaining beneficial use?".

The National Water Quality Management Strategy (NWQMS, 1995) has recommended that by the year 2000, all major aquifers in Australia should have their beneficial use assessed. The key benefit of this task is to prompt the community to recognise the need to protect groundwater resources. To a certain measure, the use of right-based mechanisms may not be broadly adopted until the public recognition of the need to protect groundwater resources from diffuse pollution is significantly increased.

The potential of right markets

Properly arranged, and in concert with contestable markets and astute institutional arrangements, right markets can make investment consistent with community values. Generally, they provide an economic incentive for people and firms to find the most cost-effective way to minimise pollution impacts across space and through time. Well-designed right systems permit resource users to take advantage of new technology and pursue new market opportunities without having to negotiate a change in government policy. They encourage diversity and encourage resource users to continue to search for efficient solutions within constraints set by society. An added characteristic, which makes resource-right systems superior to many other allocation mechanisms, is their capacity to compensate those who give up their rights. This leads many economists (who tend to put effects on third-party interests to one side) to argue that right-market solutions tend to be more equitable than pricing and regulatory systems. Well-designed right systems encourage structural change and continually reward environmental improvement (Young 1992). A key feature, not appreciated by many people, is the fact that they can also be used to periodically reduce the amount of pollutant allowed to flow into the environment.

What is a right-market?

Unfortunately, the use of right-market or property right-systems as a means to manage natural resources raises many emotions. A significant number of people, for example, believe that renewable resources like groundwater should always remain the property of the community at large and no-one should be allocated a fee-simple title to them. Nevertheless, most are prepared to allow some use of these resources. The question that really needs to be asked is one of "What is the best mechanism to allocate opportunities to use natural resources?". So that we can address this question with a minimum of preconception we use, throughout this report, the term right-market to discuss a broad concept: the notion that some legally assigned rights to use a resource may be sold to another person without selective interference from an administrator. This does not mean that administrators cannot place restrictions on such transfers. Instead, it means that any restrictions must be transparent and specified in advance.

Many of the advantages from right markets come from this requirement to fully specify opportunities and restrictions in advance. It means that governance of natural resource use is limited to proactive and preactive action. Selective or re-active interference is not possible. Managers are forced to focus on strategy and are forced to think through all the actions necessary to deliver the outcomes necessary to realise that strategy. Markets are then left to deliver those outcomes without external interference. A key characteristic of markets is that those who sell a resource are paid for the value of the opportunity they create by giving up that right.

In the case of pollution, many people object to any proposition that a person be given a right to pollute. If a farmer, for example, has been causing groundwater pollution by applying nitrate at twice the rate necessary for optimal production, why should they be given a legal right to do this? To answer this question it is necessary to make a clear distinction between:

1. rights;
2. entitlements; and
3. obligations.

In the conceptual framework we prefer to use, rights are the means by which opportunities are distributed among people. They define a proportional share of opportunities. Thus if an aquifer has a sustainable yield of 10,000 ML per annum and a person has a license to use 100 ML of water, then they implicitly have a right to a 1% share of the opportunity to use that aquifer in a way that does not damage it. Rights allocate opportunities among people. In a well-defined system, definition of the 'right' is kept very separate from definition of entitlements and obligations.

By separating definition of rights from *entitlements*, it is possible to periodically redefine the entitlement without affecting a person's right. Thus, in one five-year period, the person who owns 1% of the sustainable opportunity may be entitled to use 100 ML for flood irrigation. In a subsequent period, however, drip irrigation may be required. The entitlement may change but the right remains the same. Separation of rights from entitlements, means that right-market mechanisms can be used to bring about a transition to land-use arrangements that promote, rather than discourage, sustainable resource use.

Similarly, the *obligations* or conditions placed on a right to use a resource may change. As technology alters, for example, resource users may be required to use very different meters to record the volume of water used.

What well-designed right markets do is recognise that existing licence systems foreclose many management options because they combine rights, entitlements and obligations into one instrument. Separation of a license into its various entities makes it possible for administrators to use markets to make politically difficult and problematic allocation decisions while they focus on implementing the strategy necessary to achieve efficient and sustainable forms of resource use.

Application to diffuse pollution

Within the context of diffuse sources of pollution and groundwater management and recognising that any classification system is arbitrary, essentially there are five types of right markets that, with many caveats, offer opportunity to reduce groundwater pollution. The five types are as follows.

1. *Tradeable emission-right markets* where firms (and individuals) sell emission-rights that are surplus to their requirement to others. Often these rights are called credits because the firm is credited with the fact that it has reduced emissions. An example is a limit on the area of land that may be cropped within an area vulnerable to groundwater pollution

   If used to control diffuse groundwater pollution, the total annual load allowed to enter an aquifer would need to be capped. Polluters would then be issued shares in this permitted load and encouraged to trade them. Maximum concentrations are set. Where monitoring costs are high, surrogate indicators, like the area that may be sown to irrigated pasture, may be used.

2. *Emission-offset systems* where total emissions are capped and those who wish to increase emissions pay someone else to reduce their emissions so that they can increase their own emissions.

   If used to control diffuse groundwater pollution, any development approval or change in an emission permit would be made conditional upon pollution reduction elsewhere within the same aquifer. No development is allowed to cause a net increase in the pollution rate. Permission to build a golf course, for example, might be conditional upon reductions elsewhere so that this development causes no decline in groundwater quality.

3. *Treater-pays systems* where a person who incurs the cost of cleaning up pollution pays someone else to stop polluting. A drinking water-treatment plant, for example, may find it cheaper to remove nutrients at the source by paying for the cost of preparing farm nutrient management plans than to upgrade expensive treatment equipment.

When used to control diffuse groundwater pollution, wastewater treatment plants and/or ecosystem managers are encouraged to pay for diffuse pollution reduction activities because it is more cost-effective for them to do this than to upgrade their water treatment plants.

4. *Polluter-pays systems* where those who cause the problem are forced to pay part, or all, of the cost of controlling the pollution problem they cause.

   If used to control diffuse groundwater pollution, polluters would be forced to share the costs of groundwater treatment and protection in proportion to their contribution to the problem. Those who adopt practices that reduce their contribution would pay less.

5. *Conditional water-right markets* where rights to use valued inputs like water for irrigation are constrained so that those exercising that right do so in a manner that reduces pollution. Introduction of the option to trade these rights creates a strong incentive for people to use water more efficiently and, as a result, reduce diffuse groundwater pollution. Within the context of this report, the most obvious opportunity lies with rights to use groundwater for irrigation. Such arrangements are quite easily modified to encourage people to transfer groundwater use to areas and/or practices that cause less groundwater pollution.

   If used to control diffuse groundwater pollution, conditions would be attached to surface and/or groundwater irrigation rights so that the polluting practices are either encouraged to move to less vulnerable areas, discouraged, prohibited or phased-out.

In practice, the boundary between each of the above categories is blurred. As indicated in the case studies in the appendices to this report, tradeable emission-right systems can change into conditional water-right systems and it is not uncommon for several systems to operate in tandem with each other.

Tradeable emission-right markets

Tradeable rights are being used for many natural resources like water and, in a few places, for pollution control. They work primarily by capping the flow of pollutants to a waterbody so that a water quality standard is maintained and then setting up a mechanism enabling industry to trade rights to emit that pollution. Excellent reviews of the potential of tradeable-right systems have been produced by the Bureau of Resource Economics (1992), the Victorian Environmental Protection Authority (1995) and in a series of publications by the NSW Environmental Protection Authority.[5] Environment Australia is about to release a report summarising recent Australian experience in the use of incentive instruments in Australia (James 1997). The report includes considerable detail on a number of right-based options.

As noted by the Victorian EPA,

> *"The key theoretical advantage of a tradeable permit system is that it should enable the burden of emission control to be shared more cost efficiently among emitters. Therefore, if a tradeable permit market functions effectively, it should provide the same level of environment protection but at a lower cost to society than will the theoretical fixed emissions limit system with which it is contrasted.*
>
> *"The questions of which pollutants are most appropriately dealt with by a tradeable permit system and whether the cost efficiency benefits of such a system can be captured appear to be far more complicated than in simple theory" (EPA 1995).*

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5. See, for example, EPA (1996), South Creek Bubble Licence: reducing nutrients in the Hawkesbury-Nepean. Environmental Protection Authority, Chatswood.

Using a model developed by the United States Environmental Protection Agency, Box 1 (page 25) shows how tradeable emission-right markets reduce the cost of point-source pollution controls. In this hypothetical example, the sewage treatment plant that can treat its waste at least cost takes all the action necessary to do this and the other plant pays them to do this. Extended to diffuse sources of emissions, such as nitrate leaching associated with excess fertiliser use, similar opportunities arise. Introduction of such schemes can develop interest in their extension to diffuse sources. Extension to diffuse sources is most likely when farmers can reduce pollutant flows to a waterbody at less cost than point-sources like a sewage treatment plant. To do this, however, farmers need to be included in the tradeable emission-right system.

Set-up of a tradeable emission-right system is easier when, at least, all point-sources of pollution have moved to a load-based licensing system which limits the total volume of emissions permitted per annum coupled with limits on the maximum allowable concentration at any point in time. Once this has been done, all licensees are easily grandfathered into the system. Grandfathering occurs when each person is given a 'share' of the total permitted load on the basis of the load they are already permitted to put into the aquifer. Where load-based licensing is not in place, an emission history needs to be constructed using surrogate data. Considerable pragmatism is necessary as the exact relationship between the polluting activity and aquifer pollution often is poorly understood.

Despite many papers advocating the widespread use of tradeable-right systems for diffuse source pollution control, administrators and politicians have been reluctant to use them for this purpose (Hahn 1989). Experience is limited and administrators seem to have a much stronger interest in the pursuit of regulatory solutions to environmental problems. Regulatory solutions, at least for point-sources of pollution, are seen as being more dependable and, hence, preferable even though it comes at greater cost to industry.

It is often argued by economists that resource-right systems are superior to conventional regulatory or 'command and control' systems because they enable the same environmental objective to be achieved at significantly less private cost.[6] Reviewing empirical estimates of the benefits, Tietenberg (1985) has estimated that the control costs can be expected to be reduced by 50% and in one case, 90% (Krupnick 1986). Some systems also offer the opportunity to reallocate production opportunities so that greater profit can be made without increasing any adverse effect on the environment (see Box 1). More recently, however, Atkinson and Tietenberg have reduced the size of most of these estimates and are pointing out that the necessary conditions to realise these theoretical benefits rarely eventuate.[7] One of the reasons for these reductions, is that in the process of implementing a tradeable-rights system, political compromise can cause considerable departure from the theoretically best set of administrative arrangements. Box 3 (page 28) summarises some of the necessary administrative arrangements.

6. The classic study is that by Baumol and Oates (1995).

7. For all the theoretical benefits to be realised, the market must be fully informed, there must be many buyers and sellers of the right, trades must occur simultaneously and backsliding must be permitted. In the real world, the number of firms involved is quite small, trades occur sequentially and most pollution control authorities do not permit backsliding. Backsliding is the process by one firm decreases its emissions so that another can increase its emissions.

Box 1
Pollution reduction costs without and with trading— a hypothetical example[8]

Lake Aqua has exhibited a steady decline in water quality over the past several years. Algal blooms are becoming a problem and the water is no longer safe for human consumption. Studies indicate high nutrient levels, especially nitrogen (N). Nearly 100% of nitrogen loadings into the lake are discharged from two sources: Mammoth and the Spruce Wastewater Treatment Plants (WWTP). In response to this problem, the local water quality district has determined that nitrogen discharges into Lake Aqua must be reduced by 200 kg per day. The local catchment management authority decides to introduce regulations that require each plant to reduce its emissions by installing new equipment.

Mammoth and Spruce WWTPs have different equipment and different loads and, hence, face different costs. Spruce is able to remove nitrogen more cheaply because it processes much more effluent than Mammoth, resulting in an economy of scale. Unit load reduction costs for nitrogen are as follows:

Mammoth	Spruce
$30/kg	$10/kg

The chart below shows per day compliance costs for this scenario.

	Mammoth	Spruce
Nitrogen Reduction Responsibility	100 kg/day	100 kg/day
Amount of N Removed In-House	100 kg/day	100 kg/day
Unit Load Reduction Cost	$30/kg	$10/kg
Cost Regulatory Compliance without Trade	$3,000/day	$1,000/day

Using a tradeable emission-right system that caps the total amount of nitrogen that can enter the lake per day and per annum, Mammoth and Spruce WWTPs can meet Lake Aqua's standards more efficiently. In the trade, Mammoth WWTP buys 100 kg of nitrogen reduction from Spruce WWTP for $20/kg. Thus, Mammoth WWTP does not reduce its nitrogen discharge, and pays Spruce $2,000 to reduce its discharge by an additional 100 kg. This transaction is summarised in the table below.

Nitrogen Reduction Responsibility	100 kg/day	100 kg/day
Amount of N Reduced In-House	0 kg/day	200 kg/day
Unit Load Reduction Cost (N)	$30/kg	$10/kg
In-House Control Costs	$0/day	$2,000/day
Payment from Buyer to Seller	$2,000/day	$–2,000/day
Compliance Costs with Trade	$2,000/day	$0/day
In-House Savings from Trading	$1,000/day	$1,000/day

Saving from giving the plants the option to use trading = $2,000/day

Emission-offset systems

A variant of a full tradeable-right system is a series of pollution and environmental degradation offset systems used in the United States. These systems usually begin by allowing firms to trade within a 'net'. Each firm has its emissions capped but they are allowed to reduce emissions from one part of their activities and increase them somewhere else. The main advantage of an emission-offset system over a tradeable emission-right system is the former's much lower transaction costs. Costs tend to be much lower because there is no attempt to monitor total emissions. Instead, all current emission entitlements, usually in the form of a licence, are frozen and each firm told that they will not be allowed to increase emissions without decreasing emissions elsewhere.

8. Adapted from Exhibit 3.3 in US EPA (1996), *Draft framework for water-based trading.* Office of Water Quality, US Environmental Protection Agency, Washington DC.

The simplest form of an emission-offset system is to introduce a bubble licence policy. Under a bubble licence policy, an emission licence is given to an entire production plant. Under a bubble licence, a firm is allowed to expand total production by installing a plant that produces less pollutants per unit of production. They are then allowed to expand production up to the limit defined by their previous emissions. From this the progression is to allow trade in emission-rights between adjoining landholders and those in the immediate vicinity of the pollution source. One firm is only allowed to increase emissions if it arranges for another to decrease emissions. The main advantages of these offsetting approaches is that there is no need for a central register and formal trading scheme. All initiative is left with those firms that wish to increase emissions. The regulating authority simply makes it clear that any approval to increase emissions will be conditional upon prior arrangement to decrease emissions elsewhere.

Offsetting is quite common for wetland drainage in the United States. In this situation a firm that wishes to drain a small wetland must rehabilitate or restore another. The idea is that there should at least be no net loss in the area under wetlands—even though some biodiversity may be lost. Where it is impossible for a firm to offset the damage it proposes to do or when they only wish to develop a small area, some authorities allow payments into a wetland rehabilitation and restoration trust fund. This approach has the added advantage that there are often considerable economies of scale and ecological benefits in pooling lots of small offsets so a large one can be made.

Offsetting arrangements are less common for diffuse pollution sources as these are usually not subject to development approval. Conceptually, however, they would be very easy to apply to any practice that is subject to development approval. As there is more uncertainty about trades in diffuse pollutants, it is possible to require a reduction in the total volume of pollutant that can be emitted.

Treater-pays systems

In most OECD countries, it is common to argue that polluters should be made to pay for the costs of pollution control or prevention. Indeed, all OECD countries have committed themselves to adopt practices consistent with the Polluter-pays Principle (see Box 2 on page 27). In the case of diffuse sources, however, it is not always possible to identify the polluter. One pragmatic solution to this problem is to finance programs and activities likely to reduce pollution. Opportunities to do this are common in areas where groundwater is used for drinking water and must be treated. The upgrade of a treatment plant can be expensive, and in these circumstances, it can be more cost-effective to remove pollutants at the source. Arrangements that do this include the development of extension programs that encourage farmers to use less fertiliser and financing the development of nutrient management plans.

Polluter-pays systems

As far as we are aware a polluter-pays system has never been used to control diffuse groundwater pollution. Polluter-pays systems are, however, being used with increasing frequency to reduce water pollution from surface water. In South Australia, for example, fees are now being used to encourage adoption of the 'Best Available Technology that is Economically Achievable (BATEA)'.[9] Fees are set for any discharge to any tidal waters in South Australia on the basis of a formula which takes account of estimated flow, quantity of dissolved salts, type of pollutant and impact area (James 1997).

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9. In other parts of the world this is known as BATNEC (best available technology not excessive cost).

Box 2
The OECD Polluter-Pays Principle

In 1973, all governments of OECD member countries agreed to adopt the Polluter-Pays Principle.[10] The agreement states that:

"The Principle to be used for allocating the cost of pollution prevention and control measures to encourage rational use of scarce environmental resources and to avoid distortions in international trade and investment is the so called 'Polluter-Pays Principle.'

The Principle means that the polluter bears the expense for carrying out the above mentioned measures decided by public authorities to ensure that the environment is in an acceptable state. In other words, the cost of these measures should be reflected in the cost of goods and services which cause pollution in production and/or consumption. Such measures should not be accompanied by subsidies that would create significant distortions in international trade and investment."

The agreement provides that an exception can be made during a transition period when new pollution control and prevention measures are introduced. Occasionally a short-term subsidy is necessary to obtain political acceptance of a proposed change and achieve a speedy transition to the new policy framework. Such transitional subsidies, however, should not cause significant distortions in investment and international trade.

In short, subsidised pollution control and prevention programs should only be maintained for short periods of time. The transfer of money from tax-payers, through government programs, to polluters should not be a continual process.

Conceptually, a similar system could be introduced to control diffuse groundwater pollution. The formula would need to take account of flow which would be a function of land area, type of pollutants and impact on the aquifer. The money so raised could be hypothecated and used solely to pay for the treatment of water. If organised in this way, each polluter would have a direct incentive to find ways to avoid causing the need for water treatment and, hence, the need to pay. As with a tradeable emission-right system, implementation of a system is simpler where a load-based licensing system is already in place.

Conditional-right markets

Conditional-right markets work by piggy-backing emission control requirements onto tradeable rights for inputs into the production system. The most obvious example of this opportunity is a right to use water for irrigation. In the case of groundwater, for example, tradeable rights to extract groundwater could be conditioned so that they favour the adoption of less polluting activities. As summarised in Box 3, Victoria's Nyah to SA Border salinity trading framework, which encourages trade in irrigation rights away from areas where irrigation causes salinity problems, provides an excellent example of this type of right system (Hoxley and Dowe no date). Opportunities to trade are conditioned so that the greatest rewards go to people who trade from high to low salinity impact areas.

At a more general level, the current water reform agenda being pursued through the COAG process provides significant opportunity to pursue improvements in water quality throughout Australia. Introduction of tradeability for surface and groundwater is likely to result in improvements in wateruse efficiency. If this structural adjustment improves management at all levels then it is possible that the process may result in reduction of the flow of pollutants. Theoretically, flow-on benefits of this kind will be most likely to occur when there is a close linkage between action taken by a farmer and the value of the farmer's and his immediate neighbour's property. Thus, introduction of tradeable rights may bring significant gains in salinity management. Suggestions such as this, however, require many qualifications. Trade to new areas, for example, may only start the entire degradation process again.

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10. OECD (1974), *The Polluter-Pays Principle: definition, analysis and implementation.* OECD, Paris.

Box 3
An Australian example of the use of conditional-right markets to reduce the salinity impact of irrigation on the Murray River

The Nyah to the South Australian Border Salinity Management Plan represents a unique example in Australia of a conditional wateruse right-based mechanism to reduce salinity impacts of irrigation development. Incorporating almost all private diverters along the River Murray from Nyah to the SA Border, the plan includes programs that address drainage to the river, disposal bores and irrigation management, the environment and water trading. A key element of the plan is an arrangement whereby trade in irrigation rights is encouraged from high salinity impact zones (HIZ) to low salinity impact zones (LIZ). A LIZ is defined as any area where one ML of irrigation water causes less than 1 tonne of salt to enter the Murray River. HIZs contribute more than one tonne of salt per ML.

Water transfer is controlled by whether it is in the HIZ or LIZ, used or unused water. In brief, water trades within LIZ areas result in no salinity impact whereas when the transfer is from the HIZ to the LIZ there is a net salinity benefit. Water is not permitted to trade from the LIZ to the HIZ. Trading within the HIZ on 'used' water (ie. water that is currently used) is permitted. New development in the LIZ using water from outside the region must pay for the full River Murray salinity impact.

Trading under the above rules commenced in 1993 and to-date 23,164 ML has been traded and auctioned (ie. Dartmouth water) as per the following table:

Transfers	ML
HIZ to HIZ	1,907.6
LIZ to LIZ	8,111.2
HIZ to LIZ	5,135.1
Dartmouth to LIZ	7,920.0
Other to LIZ	90.0
Total	23,163.9

These trades have resulted in an overall net dis-benefit of only approximately 0.8 EC. This right-based trading plan has allowed for a major increase in irrigation activity but under conditions which have resulted in minimal adverse environmental impact with the introduction of a further 5,000 ha of high value irrigation development which, otherwise, would not have been possible. The adverse impact which has occurred (ie. the very slight increase in salt discharged to the Murray River) has been countered by a reduction in salt inflow elsewhere through salt interception schemes. Hence, overall, there is a net environmental gain.

Illustrative of the conditional nature of many effective right-market mechanisms, irrigators in this region are required to have irrigation layouts approved, keep drainage on the property and generally maintain environment quality.

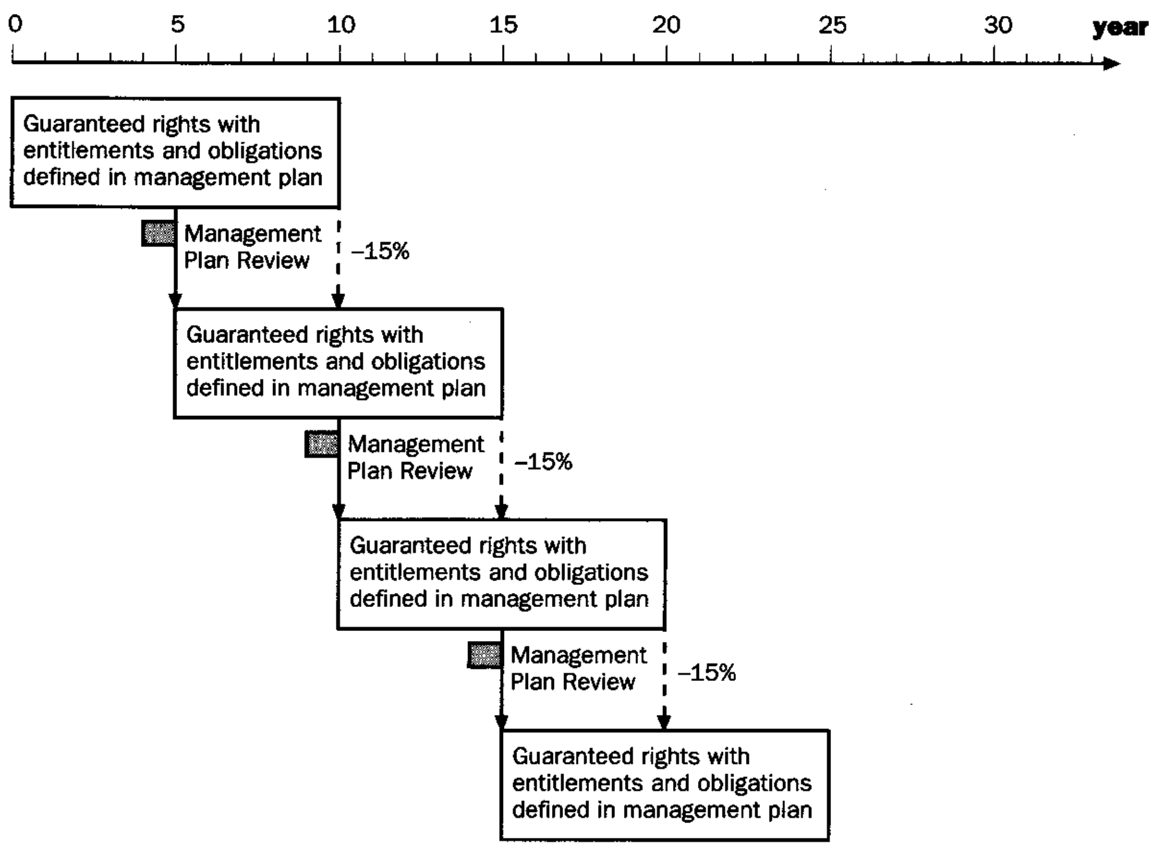
Source: Nyah to SA Border Salinity Management Plan Annual Reports

More significantly, the COAG water reform agenda opens the way to couple wateruse rights with management plans. Developing these ideas further, Young and McCay (1996) and Young (1996), have begun to develop guidelines for the introduction of tradeable property-right systems that include mechanisms that reward stewardship, maintain equity and are resilient to changes in information and understanding about the nature of water resources. Consistent with COAG's (1994), ARMCANZ's (1994) and ARMCANZ's and ANZECC's (1996) recommendations, the introduction of tradeable shares is recommended. Entry to, trade within and exit from the system is facilitated by issuing each user with a formal share of the resource and making these shares mortgageable. The precise definition of the entitlements and obligations that attach to each share are defined in a periodically revised management plan. All shareholders who comply with the entitlements and conditions set out in the management plan are guaranteed the opportunity to do this in perpetuity. That right can only be removed via the payment of compensation.

As summarised in Figure 1 (below), shareholders are protected from rapid changes in management plan conditions by making it possible for them to choose between immediate acceptance of revised conditions or delaying for up to five years and loosing 15% of their shares when accepting the conditions that attach to the new management plan.

Conceptually, any form of a conditional-right market, also makes it possible to control seawater intrusion and the lateral migration of saline water into less saline water bodies. To do this, however, a prior commitment must be made to cap rights to extract groundwater in an area. Having made this initial decision, rights can be converted into proportional rights (shares) and then each person's entitlement progressively reduced until the seawater or lateral migration problem is solved. Tradeability of shares during this transition period creates an incentive for those who can reduce groundwater extraction most efficiently to do so.

Figure 1
An adaptive share-based tradeable-right system that uses periodic reviews to facilitate incorporation of new information while maintaining resource security (after Young 1996)



Diffuse groundwater pollution

International experience

While point-source trading is becoming more common as a means to control water and air control pollution, diffuse source trading is still in its infancy. Summarised in Table 4 (pages 31–32), most progress with the use of right markets has been made in the United States. One of the most studied and debated schemes is the Lake Dillon Scheme that was originally known as the Dillon Reservoir Scheme. This scheme mixes concepts characteristic of a tradeable emission-right system with an incentive for emission-offsets. Total emissions of phosphorous to Lake Dillon are capped and any sewage treatment plant wishing to increase emissions to the lake must either:

1. buy phosphorus emission-rights from another plant; or
2. reduce diffuse sources of phosphorous emission.

Assessments are made on the basis of models that predict the flow of phosphorous given different types of land-use practice. For trades from diffuse to point-sources, a precautionary trading ratio is used in recognition that the nature of nutrient flows from diffuse sources to Lake Dillon is uncertain. Two kilograms of diffuse source pollutants must be reduced to gain the rights to emit one kilogram from a point-source.

Arising from one trade, the Town of Frisco plans to use phosphorous loading reductions achieved through storm-water controls to offset additional phosphorous loadings expected to flow from a golf course. In another trade, Keystone Resort paid for sewering of individual septic tanks so that it could offset phosphorous run-off from a resort development that it wanted to build in the area.[11] Hahn and Hester estimate that the potential cost savings from this scheme are in the vicinity of US$773,000 per annum.[12]

Another well known tradeable emission-right system, although in this case it is a point-source system, is the Wisconsin Fox River Scheme. Introduced in 1981 to reduce biological oxygen demand from pulp and paper mills, initial estimates suggested that trading could save $7 million per annum.[13] Illustrating the importance of design detail, however, only one trade has occurred between 1981 and 1995. Hahn[14] argues that the reasons for this failure were the existence of oligopoly markets that made trade unnecessary and, also, the insecurity caused by the fact that rights where only issued for five years without a renewal guarantee.

In the Netherlands, and driven by the fact that a significant number of groundwater resources now contain nitrate concentrations well above that judged to be safe for human consumption, a tradeable emission-right framework is used to control the pollution of groundwater and surface water resources from livestock production. The approach taken in the Netherlands is to cap the amount of manure that can be spread per hectare and then require all farmers to prepare an annual account showing how they have kept within these requirements.

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11. US EPA (1996), *Draft framework for water-based trading.* Office of Water Quality, US Environmental Protection Agency, Washington DC.
12. Hahn, R.W and Hester, G.L. (1989), "Marketable permits: lessons for theory and practice", *Ecology Law Quarterly* 16, pp 361-406.
13. O'Neil, W. (1983), "The regulation of water pollution permits under conditions of varying streamflow and temperature", in Joeres, E. and David, M. (eds.), *Buying a better environment: cost-effective regulation through permit trading.* University of Wisconsin Press, Madison. Quoted in Hahn (1989).
14. Hahn, R.W. (1989), "Economic prescriptions for environmental problems: how the patient followed the doctor's orders", *Journal of Economic Perspectives* 3(2), pp 95-114.

Animal keepers have the option to: spread manure over land that they own; make private arrangements with other Dutch landholders with unused manure spreading capacity; or deliver excess manure for a fee to a manure bank. As a result of these requirements and the existence of a manure bank, a significant quantity of manure is exported to other countries.[16] A key feature of this system, which makes it of particular interest to Australian administrators, is the capacity of this type of mechanism to spread a potential pollutant across space so that land-use remains within assimilative capacity.

Table 4
Examples of right-based, diffuse source emission-control programs in the United States of America

Location of right market and type of scheme	Type of pollutant or environmental problem	Type of trade	Effectiveness [15]
Lake Dillon, Colorado (Formerly known as Dillon Reservoir) *Tradeable emission-rights*	Phosphorus	Diffuse/point (with 2:1 trading ratio); Diffuse/diffuse.	Improvements in treatment efficiencies and slower than expected economic growth has resulted in few diffuse/point source trades.
Boulder Creek, Colorado *Treater-pays system*	Ammonia	Diffuse/diffuse nutrient trades. City of Boulder is paying for riparian enhancement to alleviate an un-ionised ammonia problem and defer expensive sewage treatment upgrades which even if made may not solve the problem.	Short-term results look promising. Monitoring is in place to assess long-term effects.
Tar-Pamlico, New Caledonia *Tradeable emission-rights*	Nitrogen	Diffuse/diffuse phosphorus (with 3:1 trading ratio). Sewage plants have formed an association that gives credits by paying $56 per kilogram to an Agricultural Cost Share Fund that supports adoption of best management practice. When they hit capacity, technical upgrade of plants will cost US$250 to US$500 per kilogram.	Began in 1992. Sewage treatment plants have responded by improving the efficiency of their operations. Few trades until recently but plants are funding demonstration programs in anticipation of the need to make the system work.
Arkansas Nature Conservancy *Emission-offset system*	Wetlands protection	Diffuse/diffuse. Mitigation (replacement) cost pricing. Licence fees contribute to wetland acquisition and enhancement at various mitigation ratios.	Six trades since March 1993.

15. As described in US EPA (1996), *Draft framework for water-based trading*. Office of Water Quality, US Environmental Protection Agency, Washington DC. Appendix C.
16. Grontmij NV (1991), "Dutch approaches to the management of pollution from intensive livestock production", in Young, M.D. (ed.), *Towards sustainable agricultural development*. Belhaven Press, London.

Table 4 (continued)
Examples of right-based, diffuse source emission-control programs in the United States of America

Location of right market and type of scheme	Type of pollutant or environmental problem	Type of trade	Effectiveness
Maryland Non-tidal Wetlands Conservation Fund *Emission-offset system*	Wetlands protection	Diffuse/diffuse. Department accepts payment to trust fund in lieu of wetland mitigation. Fund used for large restoration project.	As of 3/93 15 fee-funded projects have been completed. Fee deposits had reached $200,000.
Chehalis River Basin, WA *Tradeable emission-rights*	To be determined. (Problem is Biological Oxygen Demand)	Point/diffuse.	Scheme still being set up. Will be based on a cap on emissions to a segment of the river.
Wicomico River, Maryland *Tradeable emission-rights*	Phosphorus	Point/diffuse.	EPA sponsored a simulation study that shows significant cost savings but no progress.
Cherry Creek, Colorado *Tradeable emission-rights*	Phosphorus	Point/diffuse. Point-sources can earn credits by installing, operating, maintaining and monitoring diffuse source phosphorous controls. But the scheme may not start until urban diffuse source loads have been reduced by half.	Urban diffuse loads not yet halved.

Source: Adapted from US EPA (1996), *Draft framework for water-based trading.* Office of Water Quality, US Environmental Protection Agency, Washington DC.

In a number of US jurisdictions and in Germany,[17] emission-offset arrangements are combined with a polluter-pays system. Under this arrangement, polluters have the choice between paying for government to offset the pollution they produce or finding a cheaper way to offset that pollution themselves. The advantage of this approach is that it encourages people to find innovative and more cost-effective ways to achieve the outcome sought by government. Given this opportunity, firms have the choice of paying the regulatory authority to find a solution to their problem or making arrangements themselves. Usually the latter is more cost-effective.

This approach has been particularly successful in encouraging people to change practice so that the total quantity of emissions from all their activities remains the same.[18] Box 4 (page 33) summarises the impact of such arrangements in setting up arrangements that seek to achieve no net loss of wetlands in Maryland and Louisiana. Conceptually, the same principles could be established to control some forms of diffuse source emissions to groundwater.

17. Young, M.D. (1992a), "Putting the environment into the market: Micro-economic policy opportunities", Chapter 6 in Sustainable investment and resource use: equity, environmental integrity and economic efficiency. Parthenon Press, Carnforth and UNESCO, Paris.
18. The operation of this mechanism is similar to a bubble licence system that enables a firm to choose where it reduces its emissions.

Illustrating the willingness of some US agencies to improve water quality in the most cost-effective manner, the State of North Carolina has established a Tar–Pamlico Basin Association that involves industry and municipalities. Every five years, this Association plans to significantly reduce the quantity of nutrients that flow into the Tar–Pamlico River. Recognising that 80% of water pollution in the Tar–Pamlico River comes from diffuse sources, they have agreed to cap each point-source, allow trading of credits among point-sources and, via a levy of US$56 per kilogram of nutrients, fund programs to reduce diffuse sources. Formation of this Association gave members an incentive to improve practice and 80% of each group's pollution reduction target has been achieved via operational changes alone. From 1989 to 1993, average nitrate concentrations dropped from 14.4 mg/L to 8.9 mg/L even though point-source emissions increased by 18%. Recognising the importance of making point/diffuse trades work, the Association has funded a range of diffuse control demonstration projects, construction of the models and geographic information systems needed to implement trading.[19] They recognise that attainment of the increasingly stringent targets can be achieved via diffuse sources at around $56 per kilogram rather than US$250–500 per kilogram from point-sources.

Box 4
Fee-funded wetland mitigation programs in Maryland and Louisiana

The Maryland Department of Natural Resources (DNR) may accept fee-funded compensation for mitigation requirements if it determines that creation, restoration, or enhancement of non-tidal wetlands is not feasible. In most cases, monetary compensation is acceptable if the size of the non-tidal wetland loss is less than one acre and mitigation is not feasible on-site. DNR determines the mitigation acreage requirements as a function of the size of the permitted impact and an established mitigation ratio—3:1, 2:1, or 1:1. Per acre mitigation fees are determined based on the cost to buy land in the affected county, plus design, construction, and monitoring costs. (In 1993, they ranged from $11,000 to $52,000 per acre.) The fee option enables DNR to collect and pool compensatory mitigation fees from small development impacts to fund larger non-tidal wetland restoration, creation, and enhancement projects. DNR presented the fee option as a mechanism not only to reduce the administrative burden on the regulatory process, but also to serve as a means of fulfilling its responsibility to mitigate for impacts of less than 5,000 square feet, for which it does not require individual mitigation projects.

The Nature Conservancy's Louisiana field office (LNC) administers a program in which it accepts fees in compensation for unavoidable losses of wetlands stemming from development activities located in south-eastern Louisiana. LNC uses compensation fees for off-site preservation and long-term management activities of degraded pine flatwood wetlands. In all cases, the US Army Corps of Engineers (Corps) determines whether fee-funded compensatory mitigation is acceptable after potential impacts have been avoided, unavoidable impacts have been minimised and feasible on-site mitigation measures have been determined to be impracticable. The Corps also determines the amount of acreage that must be mitigated through a standardised process that quantifies the overall natural quality of the wetlands in the area. Compensatory fees payable to the trust fund take into account the appraised ecological value of the developed property and the estimated loss of ecological value as a result of the development. Valuation calculations are primarily the Corps's responsibility.

Source: US EPA (1996.

National experience

In Australia and as far as we are aware, the only formal right-market systems used to reduce water pollution are:

- the Hunter River Salinity Trading Scheme;
- the Murray–Darling Basin Salinity and Drainage Strategy;
- the Nyah to Border Salinity Management Plan; and
- the irrigation licence system used in the lower south-east of South Australia.

19. Hall, J. and Howett, C. (1994), "Albermarle-Pamlico: case study in pollutant trading", *EPA Journal* Summer Issue, pp 27-29.

The Hunter River Salinity Trading Scheme[20] operates among 11 mines that discharge saline water into the Hunter River during periods of high flow. In 1995 the NSW Environmental Protection Authority (EPA) approved one mine transferring its 26 credits to allow another mine to discharge in its place. In May 1995, a third mine was advertising its credits for sale. Characteristic of many such schemes, the flow of emissions is regulated. Discharges may only be released during high flows and a total allowable discharge is set for each day.[21] Although the EPA considers the scheme to be a success it is still too early for it to be fully evaluated. As yet there has been no attempt to introduce an offset policy that would allow mines to increase emissions in return for actions that decrease diffuse flows of salt to the Hunter River.

The Murray–Darling Basin Salinity and Drainage Strategy enables states to trade in salt disposal entitlements with each other and earn them by investing in capital works that reduce EC levels in the Murray River. Credits are tradeable between states and, officially, between individuals. Victoria has earned River Murray Salt Disposal Entitlements (SDEs) through its financial contributions to the Murray Darling Salinity and Drainage strategy. New developers are required to purchase a SDE to offset the impact of their development on the River Murray from the Victorian Government's pool of SDEs. The Victorian Government is also allocating SDEs to fix up existing salinity problems. NSW is considering introducing a salinity trading scheme for all people who contribute salinity drainage to the Murray Darling System. It is proposed that all existing users will be 'grandfathered' into the system on the basis of recent emission history.

The third operational system in Australia is the Nyah to South Australian Border Scheme described earlier in Box 3. Differing from the systems set out above, this system is a conditional use-right system that places constraints on trade in irrigation rights so that wateruse shifts to areas where the impacts of salinity are less. Although not as well documented as the schemes listed above, this is the only one that has had a significant number of trades and, hence, can be forcefully used as an example of a system where market mechanisms have been used to drive an improvement in water quality.

The last Australian right-market mechanism for water quality management that we are aware of, is the irrigation right system used in the south-east of South Australia. As it is the subject of a case study in Appendix 2 to this report, here we point out that, like the Nyah to South Australia Border Scheme, officially it is a conditional irrigation-right system. In some parts of the south-east, however, and as rights are given to grow a crop area rather than use a volume of water, in many ways it resembles a tradeable emission-right system.

Another option that we wish to draw attention to is summarised in Box 5 (page 35). Recognising the huge inefficiencies that flow from forcing point-sources to meet very stringent conditions while placing almost no restriction on non-point-sources, the WA Water Corporation is proposing that the Busselton Waste Water Treatment Plant pay for the cost of reducing non-point-sources of pollution rather than spending much more money on a plant upgrade that would produce no noticeable benefit.

Finally, as summarised in Box 6, the water resource managers in Victoria are proposing to reduce salinity problems in the Shepparton Irrigation Region by manipulating groundwater licence conditions, in a manner that penalises those who do not comply with proposed conditions. The example is included because it demonstrates the characteristics of a regulatory approach rather than a market approach.

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20. For more information on this scheme see James, D. (1997) Environmental incentives: Australian experience with the economic instruments for environmental management. Environmental Economics Paper No. 5.
21. Anon (1995), "Rain water brings Hunter salinity and discharge success", Environmental Economics Update. NSW EPA, Sydney. May.

Box 5

Would a Treater-pays system reduce water pollution in Geographe Bay, WA?

Geographe Bay is located approximately 100 km south of Perth. Nitrate and phosphate concentrations in the Bay have reached unacceptable levels and there is pressure on the Busselton WWTP to reduce emissions. A plant upgrade would bring the Busselton WWTP within the Department of Environmental Protection and the WA Water Corporation's 'zero discharge goal' for outflows from WWTPs. The most cost-effective option available is to introduce a woodlot irrigation system that would use effluent to produce timber. The cost would be an up-front capital expenditure of $4.5 million over five years followed by ongoing running costs of $0.5 million per year. But there is a catch. Having spent all this money, there would be no noticeable change in the quality of Geographe Bay.

At present, around 3% of the phosphate and 1% of nitrate emissions to Geographe Bay come from the Busselton WWTP. The remaining 97% and 99% of emissions come from diffuse rural sources. A *noticeable* improvement in the quality of water in Geographe Bay can be achieved only if emissions from non-point-sources are reduced. This observation has led the WA Water Corporation to ask the question: "Would it be wiser to spend the money more cost-effectively?" In return for Department of Environmental Protection permission to continue to emit relatively small amounts of nitrate and phosphate into the Bay, the Corporation is offering to spend $0.5 million per year on a program that would target non-point-source pollution reduction from rural sources. Within three to five years, the Water Corporation estimates that this approach is likely to reduce nitrate and phosphate loads by between 10% and 20% and, possibly, as much as 40–50%.

At the community level, the choice is one of absolute adherence to the 'zero emissions principle' versus a $4.5 million saving and between a 20 and 45 fold improvement in water quality. The choice is made more stark by the simple observation that the main beneficiaries of a non-point-source load reduction program will be the local residents of the Busselton area whose rates will have to be increased to pay for the woodlot irrigation scheme but who will see no noticeable improvement in the quality of the Bay at their doorstep. From their limited perspective and without the capacity to charge rural landholders, this treater-pays system, despite its breach of the polluter-pays principle, appears to be the most cost-effective solution.

Source: Bob Humphries, WA Water Corporation, pers. comm.

Box 6
Using groundwater licences to reduce salinity in the Shepparton Area.

In the Shepparton Irrigation Region the shallow groundwater is both a valuable resource as a low cost source of irrigation and also a nuisance because when groundwater rises within two metres of the surface it can cause salinity problems. A shallow groundwater table can also destroy remnant vegetation and pollute valued wetlands.

Currently about 100,000 ha of the Shepparton Irrigation Region is underlain by a watertable within one metre of the surface which has been estimated to be reducing the value of agricultural production by approximately $30 million per annum. If nothing is done to abate this trend, these losses are expected to increase to over $90 million per annum by the year 2020. Salt loads into the River Murray are expected to increase from 50,000 tonnes per annum to 129,600 tonnes by the year 2020.

In response to this problem, a Salinity Management Plan has been adopted to address the region's salinity problem. Essentially, the primary aim of the Salinity Management Plan is to improve irrigation management practices and surface drainage in order to reduce groundwater recharge and is complemented by shallow groundwater pumping to reduce the watertable level.

A draft Groundwater Management Plan has been developed with the primary aim to encourage and support regular and responsible pumping of groundwater from the region's 1,100 bores. This plan aims to reduce groundwater levels and thereby reduce salinity by encouraging people to use groundwater in preference to surface water for irrigation. Checks and balances are included to ensure that there is an equitable access to the resource, that the land resource and the general environment is protected from the adverse impacts of groundwater re-use. Financial assistance is available to those bore owners who consistently use at least 65% of their licence's allocation, and who consistently discharge groundwater off-site in accordance with their Salt Disposal allocation.

This example violates the right-market principles set out in this report in that those who choose not to operate within the Salinity Plan guidelines have been told that their licensed allocations may be reduced if Salinity Plan bores are needed nearby and that preference will be given to renewal of licences for bores which comply with the Salinity Plan.

Irrigation with groundwater will not be allowed unless 85% productivity can be achieved or some salinity net benefits can be demonstrated. The period of licence tenure will be set initially at five years to reflect the need for regular review of resource availability and quality. In short, a regulatory command and control rather than a market mechanism is being proposed as the means to reduce land salinisation.

Source: S. Critchell, Victorian Department of Natural Resources and Environment, Melbourne.

Case study summaries

The desk top case studies summarised in this section are presented more fully in Appendices 1 to 4 (pages 59–89) of this report. Table 5 (below) shows how these studies cover the diffuse groundwater pollution issues explored in this report. We stress that each case study has been conducted as a brief desk top study without the time to make final recommendations. Each case study should be regarded only as a backdrop against which ideas and propositions can be evaluated and the generic feasibility of right-market options demonstrated.

Table 5
Diffuse groundwater pollution issues covered by case studies

Pollution Issue	Wanneroo, WA (Appendix 1)	South-east, SA (Appendix 2)	Venus Bay, VIC (Appendix 3)	Namoi, NSW (Appendix 4)
Nitrate Pollution caused by				
Fertiliser use	xxx	xxx		
Leguminous pasture		xxx		
Animal manure spreading	xxx			
Pesticide contamination				x
Groundwater salinity and nitrate pollution caused by				
Land clearing				
Recycling		xxx		x
Lateral and vertical migration				xxx
Groundwater pollution caused by septic tanks		xxx		
Seawater intrusion	x			

x = partially covered, xx = covered, xxx = well covered

Case Study 1
The Wanneroo Groundwater Area, Western Australia

By 2010, groundwater will contribute nearly 50% of all water supplied to Perth. The Wanneroo Groundwater Area (WGWA) is located on the northern outskirts of the Perth metropolitan area.

The principal diffuse groundwater pollution problem is raised nitrate and phosphate concentrations in the shallow groundwater due primarily to high fertiliser applications and, to a lesser extent, animal waste from intensive animal industries, especially poultry. This affects drinking water quality and the health of the relatively few wetlands that are left (80% have been destroyed.) Nitrate levels are often low, but sometimes exceed 5 mg/L beneath urban areas and greater than 10 mg/L beneath horticultural areas. The Australian drinking water standard is 10 mg/L of nitrate. Indicating significant potential for improvement, nutrient applications, mostly of poultry manure, exceed crop uptake by about five times for nitrogen and at least ten times for phosphorous.

The main mechanism used to control groundwater pollution is zoning so that polluting activities are excluded from areas used to extract water for domestic consumption. Most diffuse water pollution is associated with groundwater irrigation.

The right-market options identified as suitable to improve groundwater quality are:

1. an *emission-offset system* requiring any person wishing to increase emissions to first make arrangements that ensure that their emissions are offset by a reduction elsewhere. By linking an emission-offset requirement to development it is simpler to implement this mechanism by making compliance a pre-condition for development approval. The main weakness of most emission-offset systems is that they place most pressure for groundwater quality improvement on new development. Existing landholders may regard this as equitable but usually new developers perceive that they should not have to pay to clean up existing problems;

2. a *tradeable emission-right system* targeted directly at sources of nitrate pollution from animal waste and fertiliser use. Under this system, each landholder would be required to prepare a nitrate budget showing how their fertiliser and manure spreading practices have been kept within environmental capacity. Shares would be issued and across-the-board emission reductions forced via a zero-revenue tender system. A periodically reviewed management plan would show how to calculate each shareholder's entitlement to spread manure and apply fertiliser to different crops. The system is complex and, at this stage, probably unwarranted; and

3. a *conditional groundwater-use right system* that uses a periodically reviewed management plan to constrain irrigation so that nitrate emissions from all landuse practices associated with it are kept within acceptable limits.

The most attractive mix of the three options is the use of the last option—introduction of conditional groundwater-use right system—as much as possible coupled with an emission-offset requirement for new sources of pollution that do not use groundwater for irrigation. Proposed administrative amendments make policy adjustment to incorporate these options relatively simple.

Case study 2
Lower South-East of South Australia

In the lower south-east of South Australia, groundwater is used principally for irrigation of pastures, vineyards and a range of horticultural crops. These same aquifers are an important source of drinking water for some people.

The two main diffuse groundwater pollution problems are nitrate pollution and groundwater salinity. 18% of bores have nitrate concentrations above the safe potable level for infants and 3% above the potable limit for all people. In some areas, groundwater recycling is causing salinity levels to increase at a rate of 50 mg/L per year. As a result, some wine from Padthaway no longer satisfies European Community standards for free sodium and Australian Food Standards for sodium chloride in wine.

Officially, groundwater allocation is on a volumetric basis but, as wells are not metered, the irrigation right is defined in terms of 'irrigation equivalents.' An irrigation equivalent is an entitlement to irrigate an area of crop whose water needs for optimum production are equivalent to that used to irrigate one hectare of pasture. In some areas, this mechanism is used as a means to control groundwater salinity. Trading in these allocations is not allowed within highly saline areas but is allowed out of these areas. No trades are taking place as the most profitable way to use water is to grow grapes in the highly saline areas.

The case study focused on a key viticultural area—Padthaway, where groundwater recycling is the main problem—and an area further south where nitrate pollution is the current problem. However, if changes in the pattern of landuse continue, increases in the area under pine plantation may produce absolute shortages in groundwater. The right-market options identified as suitable to improve groundwater quality are:

1. conversion of existing crop-area allocations into *crop-area shares* allocated in proportion to the number of irrigation equivalents held and made subject to conditions designed to reduce groundwater recycling. Periodically-reviewed management plans would define the relationship between shares and crop area entitlements in a way that rewards those who improve wateruse efficiency;
2. an annual *zero-revenue tender system* requiring each shareholder to place, say, 5% of their shares up for sale and set a reserve price for them. This would force people to recognise that irrigation rights are transferable and enable adjustment within zones to keep pace with reductions in the available water;
3. use tradeable crop-area rights to formally define *nitrate-emission rights*. These would give people a right to grow an area of a crop based upon the quantity of nitrate expected for flow from that crop to groundwater. Under this system, a tradeable emission-right system is easily converted back to a conditional irrigation right system. If landuse change makes groundwater rather than nitrate the limiting resource, then this can be very important; and
4. *inclusion of pine plantations in the water allocation system* either via a requirement that all new pine plantations acquire irrigation rights equivalent to the amount of recharge reduced by the plantation or, alternatively, a framework that grandfathers all existing plantation owners into the water allocation system.

In practice, a mix of the options presented is likely to be most effective in improving groundwater quality in the south-east of South Australia. The existing irrigation system is relatively easy to convert into a fully operational conditional groundwater use-right system. Zero-revenue tenders in the Padthaway region would help resolve the acute groundwater recycling problem. In other areas, consideration needs to be given to the merits of linking plantation development with groundwater management.

Case study 3
Venus Bay, Victoria

Venus Bay is a coastal holiday town on the South Gippsland Coast of Victoria with a permanent population of 120 and a summer population of about 3,000 people. Most of the town's 512 houses have septic tanks relatively near groundwater bores used to obtain domestic water. Movement of bacteria and nitrate from septic tanks to the local groundwater aquifer is rapid. High levels of bacteria contamination are routinely recorded and nitrate concentrations of up to four times World Health Organisation levels have been recorded. The Local Council warns that groundwater should not be used for in-house consumption. Bacteria may be possibly controlled by locating bores at least 15 m and, preferably, 30 m from a septic tank.

If beneficial use standards are to be maintained, then either septic tanks need to be made more efficient and more spatially separated from groundwater bores or a sewage system needs to be installed. Sewering the town has been estimated to cost $8–16 million. Installation of a communal pump out scheme is possible, as is installation of communal septic tanks at a cost of around $640,000. The right-market options identified as suitable to improve groundwater quality are:

1. *an emission-offset scheme* that would cap the number of septic tanks in Venus Bay and require all new houses to either not use tanks or remove at least two tanks for each one they install. All new tanks would have to be, at least, 30 m from a bore. Bores could be decommissioned. Even if the town's housing stock grows at 2.5% per annum, it would take nearly ten years to reduce the number of septic tanks by 20%. Groundwater quality would not reach acceptable levels before 2020. Moreover, at the end of this period, localised problems would still remain;

2. *a tradeable sewage emission-right system* with shares initially issued in inverse proportion to the distance of each tank from a bore. A periodically-revised management plan would then be used to define the minimum number of shares required to use a septic tank at various distances from a bore. Revisions would increase the number of shares required to locate a tank close to a bore. A zero-revenue tender would be used to speed adjustment. Those without enough shares would be required to either not occupy their house or pay a levy 20% above share value. The cost of this system is estimated, roughly, to be around $523,000; and

3. *a quasi tradeable emission-right system* where all non-complying houses pay a levy sufficient to pay $3,500 to each person who upgrades to 30 m separation within two years and $2,500 to each person who upgrades at a later date. The total cost of this scheme would be in the vicinity of $680,000.

A fourth option, whilst not a right-market option, is to force the entire town to convert to a pump out scheme. This option, however, is more expensive than the quasi-tradeable-right system described above.

Each of the three right-market options is significantly cheaper than installation of a fully-fledged sewage system or pump-out option and, hence, for a holiday town provides a set of very attractive alternatives. The easiest to implement is the last, a quasi-tradeable emission-right system. This system, however, is likely to be less efficient than a formal tradeable emission-right system but, after administrative costs are accounted for, may provide the most cost-effective solution.

Case study 4
The Namoi Region, New South Wales

In the Upper Namoi Valley of New South Wales both groundwater and surface water resources are used extensively for agricultural enterprises. Since 1985, volumetric licences have been used in an attempt to control extraction rates that are excessive. Most of the ten zones show a clear decline in groundwater level. A new Management Plan aims to achieve long-term sustainability and protect groundwater quality. Permanent transfers of groundwater allocation were introduced in the Namoi Valley in 1995/96 as an interim measure. They have now ceased for 1996/97.

From a total of 62 samples collected from the shallow aquifers during 1992/93, five sites recorded detectable levels of the herbicide atrazine. Sampling in other areas of the Namoi Valley produced similar results. The highest level recorded was 5 μg/L. The other diffuse pollution issue is lateral migration of saline water. In some bores, a two or three-fold increase in levels of Total Dissolved Solids from approximately 400 ML to 800 ML has been recorded. In some locations, the increase has been up to 1,200ML.

In the case of pesticides, the technical solutions in relation to pesticides are to ban use, improve management and restrict use in vulnerable zones. In the case of lateral migration of saline water, the main solution is to reduce allocations in problem areas. We conclude that there is virtually no opportunity to use right-market mechanisms to reduce pesticide contamination of groundwater.

The main right-market option identified is to introduce secure groundwater shares with entitlements and associated obligations set out in a periodically reviewed management plan. The emphasis is on a planning process that encourages shareholders to use this right system to avoid causing declines in groundwater quality. No opportunity to use right markets to control pesticide pollution is identified.

Addressing a different issue, dryland salinity, the possibility of using a system similar to that proposed for Venus Bay is suggested. Under this arrangement, a local catchment committee would be empowered to levy all land owners and establish a fund that would be used to reimburse people for the costs of planting trees and taking other measures to stop increases in groundwater salinity.

Technical challenges

The previous section develops a range of right-market options for dealing with different diffuse groundwater pollution issues. The application to practical problems of some of these approaches can proceed with little additional technical data, while to other approaches there is a fundamental requirement for more technically rigorous data and understanding before the approaches can be realistically applied as noted by Russell and McKinnon (1977) and Stevens *et al* (1995), there are many risks and knowledge deficiencies associated with the management of both groundwater and diffuse pollution of it. The following general areas are identified.

Uncertainty in the variability of delivery mechanisms

What is the role of the soil zone in providing attenuation of pollutants? For example, is there a difference in the risk of pollution if the pollutant is applied more directly to the aquifer, rather than being filtered through the soil? How does this differ across the great soil groups in Australia? How do different pollutants bond with different soil types?

What is the relative effectiveness of different sewage treatment systems? For example, if disposal to land of secondary treated effluent is being considered, how would this affect the aquifer when compared to the use of a number of broadly spread septic tanks? Also, what impact on effluent quality results from different septic tank designs? Can more effective treatment be achieved using composting toilets with grey waste disposal separately?

Hydrogeological knowledge

Groundwater quality has significant natural variation. The extent to which this variation may impact on the effect of the pollutant should be considered. How does natural variability in an aquifer represent the different flow conditions and the extent to which pollution may be allowable? How much needs to be known before a right market can be implemented?

Uncertainty in the limits to which a system can be affected

Whilst concentration limits are generally set for a variety of compounds, the total load which any natural system can sustain is not. Is there a total load limit, irrespective of concentration limits which is desirable for natural systems, such as aquifers? Is 1 kg of pollution the same in space and time? Should pollution rights be 'discounted' over time?

In many instances, indicators are used in place of actual harmful pollutants. For example, in septic tank effluent, there is a question over the life of bacteria and viruses which are tested for by indicator compounds, such as *E. coli.* Do these adequately represent the risk of pollution?

Specific compounds, such as pesticides have a natural 'market life.' New compounds are being introduced into the market all the time. To what extent should limits on compounds take into account the period of sale of similar compounds?

Concentration and/or loading rate definition

At a general level, significant additional technical data and understanding is required to define what is the limit of acceptable pollution for the complete range of diffuse polluting agents (eg. pesticides). It is not technically sensible or meaningful to say that no concentration of a potential pollutant is acceptable. Diffuse pollution is currently occurring and defining what are acceptable concentrations and/or loads of various agents is necessary to enable the 'cap' (as required, for example, with tradeable pollution rights) to be defined. For example, defining acceptable fertiliser application rates for a variety of hydrogeological environments remains a significant technical challenge.

Is pollution up to a limit or cap acceptable? If a limit is set, should pollution up to this limit be allowed, or should a restricted rate of change be used instead? Should the limit be defined in terms of annual emission rate or maximum ambient concentration in the aquifer?

Degradation/transformation rate

It is well recognised that due to a broad range of processes, many pollutants degrade and/or transform with time and in various hydrogeological environments. For example, the presence of carbon in the soil will significantly alter the decay rate of many chemicals and microbiological processes. Also, many pesticides have 'half lives' which can vary depending upon the environment. To enable all these factors to be considered as part of a management plan, the timeframe over which various processes operate needs to be better defined, albeit not to a high degree of accuracy.

Monitoring

The effectiveness of any rights-based mechanisms and other approaches needs to be measured so that credibility in the community is maintained. Monitoring can, for some agents, be technically difficult and costly. In some cases, surrogate indicators can be monitored but when this approach is used the surrogate needs to be periodically calibrated against a direct measure. How often is it necessary to calibrate surrogates against direct measures?

The key technical challenge is to identify, amongst a broad range of agents which could be monitored, which agents (eg. which particular pesticide or which particular key monitoring bore) represent key indicator parameters and, hence, reduce the need for a large and expensive monitoring program.

Opportunities to use right markets to control diffuse groundwater pollution in Australia

Overview

So far, this report has identified the types and forms of right markets that have potential to reduce diffuse groundwater pollution in Australia. Although the focus of this report is on diffuse sources of pollution it is necessary to point out that groundwater bodies will usually be managed with consideration of opportunities to reduce point, multiple point and diffuse sources of pollution.

Review of international and national experience and our case studies suggests that, while right-market mechanisms have been used to control surface water pollution, they have rarely been used to control groundwater pollution. Because of this lack of experience both in Australia and overseas, we conducted four case studies to help us evaluate the potential of right-market mechanisms to reduce diffuse groundwater pollution. We also draw attention to the growing experience with the use of right-market mechanisms to control surface water pollution. Progress in the Hunter River in NSW, the Murray–Darling Basin Salinity Strategy and Victoria's Nyah to Border Salinity Reduction Scheme are all beginning to demonstrate the greater efficiencies, greater equity and capacity of right-market mechanisms to help to overcome intractable diffuse pollution problems.

General opportunities

At the most general level, the case studies show that right-market mechanisms have a place in the control and reduction of groundwater pollution from diffuse sources and, also, multiple point-sources. At the same time, however, right-market mechanisms are by no means a panacea. As observed in the Namoi case study, which focuses on groundwater contamination from pesticides, in some cases, regulation is preferable to the use of right-market mechanisms. As a general observation, we suggest that right-market mechanisms are best suited to the management of contaminants that are naturally present in aquifers. Nitrates, phosphates, and salt clearly fall into this category. Where the goal is zero contamination, regulation is the preferred strategy. As illustrated by the Venus Bay case study, however, sometimes there is an opportunity to use right-market mechanisms to assist with a transition from a highly polluted to situation to one that meets community standards. In this latter case, the mechanism is used to share the cost of reducing emissions in an efficient and equitable manner. Right-market instruments can be used only in situations where an ongoing level of emissions is acceptable.

In many cases, the most appropriate approach will be a mixed one involving the provision of information, regulation and use of right-market mechanisms. As new information becomes available and, also, as economic and technology changes, any system will have to be reviewed so that the outcomes sought continue to be realised.

To a large extent, opportunities to use right-market mechanisms to control groundwater pollution are dependent upon the answers to four questions.

1. Does the polluter have an interest in using groundwater for irrigation or other production purposes?

2. Is there a person or organisation who has to treat the polluted water so that they can use it for a beneficial purpose, like the supply of drinking water to an urban population?

3. Are the standards required of point-source emitters much higher than they are for non-point-source emitters and are point-sources located so that it might be more cost effective for them to reduce non-point-source emissions than to reduce their own emissions?

4. Is the rate of development in the area such that people or industries have an interest in expanding an activity that is a significant source of groundwater pollution?

The answer to each of these questions highlights an opportunity to use a different right-market mechanism whose applicability is summarised in Table 7 (page 47). We stress, however, that the classification used is somewhat arbitrary. In practice, well-designed systems often combine elements of each of the mechanisms we put forward.

Conditional groundwater use-rights

Earlier sections to this report have demonstrated that many of the groundwater pollution problems found in Australia are caused by people using groundwater for irrigation and by practices closely associated with irrigation. Where groundwater use is associated with pollution, there is opportunity to make groundwater use-rights conditional upon compliance with conditions necessary to keep that pollution within acceptable limits. The main pollution problems caused by irrigation are groundwater salinity and nitrate pollution. In the south-east of South Australia, for example, groundwater salinity is causing salinity levels to increase to a level where export markets for wine are threatened. In such circumstances, groundwater irrigation licences have, with few exceptions, already been issued. Consequently, the transition to a formal conditional *groundwater use-right system* is not a major step. Moreover, it is consistent with the COAG reform agenda for water reform throughout Australia. Indeed, we would like to go so far as to recommend that **no groundwater user be given a secure groundwater use-right in a manner that precludes the attachment of land and wateruse conditions to that right so that groundwater pollution can be efficiently controlled at its source.**

A conditional groundwater use-right is a formal right to use water, with conditions attached to it, that are designed to encourage either the avoidance of polluting activities and/or their transfer to less vulnerable areas. Within the context of this report, we assume that any conditional groundwater use right is tradeable and secure in the sense that:

1. the right cannot be cancelled without payment of compensation (usually the right would be to a proportional share of the groundwater available for extractive use);

2. any changes in the land or wateruse entitlement would only be made in a way that applies equally to all right holders; and

3. the right could be mortgaged and traded in a manner similar to a title to land.

In many places throughout this report, and also as a result of the meetings necessary to complete the case studies summarised in this report, we have recommended that a clear difference be made between rights, entitlements and obligations. Moreover, wherever possible we recommend that the right issued be a proportional share of the opportunity defined by the right. Many people regard this recommendation as threatening because it is different to the current practice of allocating a fixed quantity of water for a period of time. Share systems increase security but do so in a manner that still facilitates change in entitlement. The way a share system works is summarised in Box 7 (page 48).

Table 6
Indicative scenario of the way a conditional groundwater use rights system might develop through time

Year	1998	2002	2007	2012	2017	2022	2027
No shares	10,000,000	10,000,000	11,000,000	15,000,000	15,000,000	15,000,000	15,000,000
Water available of use (ML)	10,000	10,000	9,900	12,000	10,500	12,000	12,000
Annual groundwater allocation (ML per share)	0.0010	0.0010	0.0009	0.0008	0.00070	0.00080	0.00080
Hectares of turf that may be grown per 1,000 shares	0.30	0.28	0.27	0.26	na	na	na
Hectares of vegetables that may be grown per 1,000 shares	0.66	0.62	0.64	0.64	na	na	na
Hectares of flowers that may be grown per 1,000 shares	0.55	0.50	0.50	0.50	na	na	na
Nature of change		Monitoring reveals that turf is a major source of nitrate pollution	Vegetables make greater use of drip irrigation technology. Some pine plantations are cleared and all are rolled into the system.	Urban water users become part of the system so they can buy up water	In response to long-term drought all users roll over to meters. Restrictions on use per hectare are introduced for each crop type to reduce nitrate flow to groundwater.	Drought ends but shareholders decide to keep allocations less so that seawater intrusion problem can be overcome and two wetlands rehabilitated	

Experience with other renewable natural resources, like fisheries, has demonstrated that when a person receives a right to a fixed quantity of a resource the only way to vary that right is to pay compensation. In contrast, a share-based system encourages waterusers to recognise and plan for changes in the amount of water available to them. The major reasons for change include improvements in knowledge about the aquifer, climatic variability and land-use change. In the south-east case study, for example, we point to the fact that increases in the area under pine plantations reduces the amount of groundwater available for irrigation and, also, the quality of that water.

The alternative approach, used in many water allocation systems, is to give people a base allocation but treat this as an entitlement to a proportional share. This latter approach, however, is less transparent than a direct specification of right in terms of shares. The added advantage of specifying rights in terms of shares is that, once issued, no more shares can be issued unless this is done in the same way that a company makes a share issue. With a base allocation, it is possible for a Minister to diminish the value of every existing right by issuing more base allocations.

Another important concept is the difference between rights and the entitlements and obligations that attach to those rights. Effectively, a right constrains the way an entitlement can change. If, for example, there is a need to reduce wateruse by 10%, then all users must receive a 10% cut in their entitlement to use water.[22] Similarly, any restriction or obligation on a right holder must apply equally to all users and all potential users. Political decisions that would enable one person to be favoured over another would be precluded.

Definition of the entitlements and obligations attached to each share are most appropriately placed in a periodically-reviewed management plan which, amongst other considerations, requires catchment and aquifer managers to assess the risks they are taking with the resource they are responsible for. Using the structure set out more fully in the case study for the south-east of South Australia, we recommend periodic review somewhere between five and seven years and an administrative framework that forces that review.[23] It is possible for the periodic management plan review to be conducted by a committee or board involving a majority of groundwater use-right shareholders.

To set up a conditional groundwater use-right system to control groundwater pollution it is necessary to:

1. announce that the new system is going to be introduced and define the basis on which licences will be issued so that people do not undertake activities that increase use solely for the purpose of obtaining a greater share;
2. validate all existing groundwater irrigation licences so that they can be converted into a formal right system;[24]
3. decide whether or not to include other groundwater users, like town water supplies and stock and domestic users, in the share system. If they are not included then it is necessary to decide whether or not expansion of these uses is to be capped or if they have a prior right. If a prior right is recognised then every time one of these uses is expanded every right holder's allocation is diminished. There is no change in the number of shares but the allocation per share will need to be reduced with the consequence that the market value of each share will change and, probably, increase to reflect the fact that water has become more scarce;

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22. It is possible to have preference shares so that some people have greater security than others in a drought but we leave the explanation of that option to another report.
23. For more information see Young (1992), Young (1997) and Young and Good (1997) and Young and McKay (1996).
24. Often departmental records are not kept in a manner that makes it possible to quickly determine who has a groundwater licence. This is particularly likely to be the case where there is no requirement to provide an annual report on consumption.

Table 7

Overview of identified groundwater pollution issues amenable to the use of right mechanisms for evaluation via case studies.

Pollution Problem	Pollution Source	Right-based Mechanism				
		Tradeable Emission-Right The total annual load entering an aquifer is capped. Polluters are issued shares in this permitted load and encouraged to trade them. Maximum concentrations are set. Where monitoring costs are high, surrogate indicators are used.	**Emission-Offset** Development approval is conditional upon pollution reduction elsewhere. No development is allowed to cause a net increase in the pollution rate. (1)	**Treater-Pays** Water treatment plants and ecosystem managers pay for pollution reduction activities because this is more cost-effective than water treatment.	**Polluter-Pays** Polluters are forced to share the costs of groundwater treatment and protection in proportion to their contribution to the problem.	**Conditional Use-Right** Conditions are attached to surface and/or groundwater rights so that the polluting activities are either encouraged to move to less vulnerable areas, discouraged, prohibited or phased out.
Nutrient Pollution (Nitrate and Phosphate)						
	Excess Fertiliser Application	✘	✘	✓	✓	✓
	Animal Excreta (includes diffuse animal excreta and manure spreading from intensive feedlots etc.)	✓	✓✓	✓	✓	✘
	Nitrogen Produced by Legume Pasture	✓✓	✘	✓	✓	✓✓
Pesticides		✘	✘	?	✓	✓✓
Salinity due to agricultural practice						
	Land clearing	✘	✓✓	✓✓	✓	✘
	Groundwater Recycling	✘	✘	✘	✘	✓✓
	Lateral Migration	✘	✘	✘	✘	✓✓
	Irrigation	✓✓	✓✓	✘	✘	✓✓
Bacteria from Septic Tanks		✘	✓✓	✓✓	✓✓	✘
Seawater Intrusion		✘	✘	✘	✓✓	✓✓

✓✓ = Very Applicable (Cost-effective, technically feasible, & equitable); ✓= Applicable (If technical challenges can be resolved, cost effective & equitable); ✘ = Not Applicable

Box 7
Elements of a share system

The concept of a proportional share of the available resource, rather than a fixed quantity, is an important concept but, while it is common and well understood in the corporate market place, is one that is foreign to water managers. The basic idea is that, in any situation where there is uncertainty, the best property right to allocate is one that commits any change in the amount of water available for consumptive use to be made on a proportional basis. This means that once shares have been issued all changes in water allocations are made on a pro-rata basis. Waterusers are then free to trade water with each other at prices that they determine. As demonstrated by corporate arrangements throughout the world, shares give people a secure right to a series of opportunities that can be varied through time but only in an equitable manner. In the case of water, the share is a formal or proportional share of the quantity of water in an aquifer available for consumptive use. Each person's share is fixed but tradeable. Any person who wants a larger permanent share of the water available for consumptive use, must buy shares from someone else. Annual allocations, like company dividends, are distributed in proportion to the number of shares held and made on the basis of information available to water managers. Waterusers, like shareholders, have to estimate what the future yield will be and, hence, what shares are worth.

Usually the number of shares issued in a catchment or aquifer are greater than the smallest volume of water traded. If, for example, 1,000,000 ML are expected to be available then around 2,000,000 million shares would be issued. A person who held 100,000 shares would have an inviolate right to 5% of any water allocated. No minister, irrespective of their wishes, would be allowed to allocate water to any-one without buying shares from an existing shareholder.

The amount of water allocated, however, may need to vary as climate or knowledge about the aquifer or other factors change. Consequently, we recommend a formal review every five years. To keep transaction costs low, we recommend that a dual right system be set up. Under this arrangement, shares are recorded on a central register in a manner that enables them to be mortgaged. Annual allocations are recorded separately on another register that works like a bank account. Credits and debits to this account are made on a periodic basis and any temporary transfer is organised by simply writing a cheque to the person you transfer water to. The result is a very low cost and administratively simple system.

An issue that always emerges with the definition of such systems is the question of which uses of water should be left out of the right system. Stock and domestic waterusers, for example, are often left out of the system and are, in effect, given a prior right to use groundwater. Similarly, a prior right is usually given to timber plantation development even though this reduces groundwater recharge and, hence, the amount of water that can be used by other people for irrigation etc. Water needed for environmental flows and that needed for urban and industrial purposes can also be given a prior right. The only situation when more shares can be issued is when one or more of these prior rights are bought within the right system. In effect, more water is bought into the system by removing the prior right. Operationally, and following a period of consultation, an estimate is made of the amount of shares people who had a prior right are equitably entitled to. The administering agency then issues each of these people an appropriate number of shares and amends the legislation so that they no longer have a prior right to use water. One example of a situation where this could be done is in the case of stock and domestic wateruses. If all existing stock and domestic waterusers where bought into the system then a cap would be placed on all allocations.

For more information see Young (1992, 1996, 1997), Young and Good (1997), and Young and McCay (1995).

4. prepare a management plan which defines the entitlement embodied in each share. One hundred shares, for example, may entitle a person to use up to 1 ML per annum for the next five years. If meters are not in place then the management plan may translate this entitlement into a right to plant either *x* ha of pasture or 2.7 times *x* ha of grapes under drip irrigation. The plan would also set out the land and wateruse conditions that each shareholder would be required to comply with;
5. convert all existing licences into formal conditional groundwater use shares (or equivalent) and make any legislative changes necessary to make it possible to give waterusers security of tenure;[25]

25. The incentive for resource stewardship is greater if security is conditional upon compliance with the land and wateruse conditions set out in the management plan; if the rights are mortgageable; and if the breach of any conditions results in loss of a pre-specified number of shares.

6. put the necessary monitoring system in place to a) ensure compliance; and b) ensure that information necessary for the first management plan review is collected; and
7. appoint the body to conduct periodic management plan reviews and decide on the means by which they will be chosen and the powers that they have.

One key to the success (or failure) of a conditional groundwater-use right is the importance of designing the system so that it can adapt as circumstances change. Table 6 indicates how this might occur over a period of 20 years. The table is based on that in the West Australian case study (see Appendix 1). In the scenario, existing licences are converted into shares and each share given an allocation for a five year period. At the end of that five year period each shareholder is given the choice between accepting the entitlements per share and conditions in the new management plan or staying with the old system for another five years with the knowledge that if they take this alternative path they will lose 15% of their shares at the end of that period.

The next few years turn out to be dry ones and allocations are reduced. At the same time, plantation owners request to enter the system so that they can clear fell their forests and sell the resultant increase in groundwater recharge and, hence, water availability to turf farmers. Water scarcity increases and becomes more valuable so that the urban water supply authority enters the system so that it can buy up some water. Meters are introduced with controls on the maximum quantity of water that can be used per hectare under each crop type so that nitrate pollution can be reduced. By this stage, management plans are developed primarily by shareholders in consultation with water administrators. Collectively, all shareholders decide to fix a seawater intrusion problem and rehabilitate two wetlands.

Treater-pays systems

When, or wherever, a person or water treatment body has to treat water so that it can be used for domestic purposes, it is sometimes cheaper to prevent the problem at its source rather than remove it just prior to delivery to a consumer. In certain situations, different standards apply for point, multiple point and non-point-sources of pollution. When this occurs, those who have the higher standards imposed on them can sometimes reduce groundwater pollution at less cost by contributing to the cost of reducing pollution elsewhere. A classic example of this can be found in Geographe Bay in Western Australia where it has been estimated that the Busselton Waste Water Treatment Plant could reduce nitrate and phosphate pollution by well over 10% by helping to reduce nutrient flows from agricultural land but only 1% by upgrading its own plant. Moreover, by working on diffuse sources, principally dairies, they can save $4.5 million and a subsequent annual maintenance cost of $0.5 million per annum. In short, the attraction of treater-pays systems is that they deliver the environmental cost sought by society at less cost than is achievable through regulation. The main objection to them is that they violate the polluter-pays principle and are considered to be inequitable. Many people perceive "people should have to clean-up there own mess" and that is morally wrong for any member of society to have to pay to have access to a clean environment. Nevertheless, when it is politically infeasible to make polluters pay for the cost of achieving groundwater quality objectives, treater-pay systems provide a pragmatic way to improve water quality at least cost to society.

To set up a treater-pays system it is only necessary to promote the idea and then leave those most affected by the inconsistent standards to develop an innovative proposition that is consistent with groundwater quality objectives. Experience in the United States of America with such arrangements suggests that a treatment plant should be required to achieve an expected saving of, at least, 2:1 from non-point-sources as the mechanisms used to achieve non-point-source reduction are less reliable than those specified for point-sources.

Emission-offset systems

There is a high degree of similarity between treater-pays systems and emission-offset systems. Emission-offset systems, however, require a demand for an increase in emission load. This is usually driven by population increases or by changes in market circumstances that make expansion of a polluting activity profitable. Examples identified in this report include the demand for softwood in the south-east of South Australia that will reduce groundwater recharge, population increase in Venus Bay and urban development near Perth.

The basic concept under an emission-offset system is that a decision is made to prevent any form of development that will result in a net increase in pollution. The main control instrument is the requirement to obtain local government approval to start a proposed development. The outcome is similar to that required for a tradeable emission system but it is administratively much simpler to implement. The main problem with such systems is that they require a high degree of coordination across different jurisdictions. Often the body responsible for approving development does not perceive that it is responsible for managing groundwater pollution. Moreover, they may be unwilling to place such restrictions on development when pollution from non-point-sources is not under their control continues to increase.

One weakness of most emission-offset systems is that they only provide a few people with an incentive to reduce emissions. Pressure is put on aspiring developers and a few people willing to adjust, but most others are given little incentive to adjust. As illustrated by the Venus Bay case study, this means that progress can be quite slow even under quite rapid rates of economic growth. They can, however, provide a very effective means to bring consistency between the requirements for a conditional groundwater use-right system and related forms of water or landuse. Sometimes they are a very useful interim measure. In the south-east of South Australia, for example, offset mechanisms provide a means to make people aware of the impact of plantations on groundwater recharge and, through this, the size of the dairy industry and the concentration of nitrates in local groundwater. If a conditional groundwater use-right system is in place, then irrigators can argue that approval to establish a plantation should be limited to those people who acquire an irrigation right-equivalent sufficient to offset the decline in water recharge caused by the plantation. Once the nexus between pine plantations and the area under irrigation is understood, pine plantation owners may demand to be included in the system so that they have the opportunity to profit from a decision to clear their plantation and sell the resultant increase in groundwater recharge to another person or, alternatively, use it themselves.

To set up an emission-offset system to control groundwater pollution it is necessary to:

1. obtain administrative agreement and commitment to the proposed mechanism;
2. announce the new offset policy and convince the community of its wisdom;
3. decide on the rules for offsetting. In particular, it is necessary to decide if it is only necessary to offset expected emissions on a 1:1 basis or if a more progressive ratio of, say, 2:1 is required. The first simply stops the situation from getting worse. The latter enables a gradual reduction in total emissions. Where response rates are uncertain, 2:1 ratios can also be used to account for that uncertainty; and

4. establish the arrangements necessary to ensure that the offset are enforced. In particular, it is important to ensure that none of the authorities involved grant special exemptions.

Tradeable emission-right systems

As a general rule, it is very difficult to set up a tradeable emission-right system if there is no administrative system on which to base it. Tradeable emission-right systems are, however, much easier to introduce when an existing irrigation-right or crop licensing system can be converted into an emission-right system. It would, for example, be possible to create a groundwater emission-right system from the crop-registration system used by cane growers in Queensland and northern New South Wales. Similarly, and as demonstrated in the south-east of South Australia case study and the WA case study, because some groundwater irrigation-right systems issue a licence to grow a crop area, no changes are needed to convert them into an emission-right system. All that the administrator needs to do is recognise that the factor limiting use has changed.

Where no existing licence system or registration system is in place, surrogate indicators are used to create an emission history and define entitlements. The most common measure is crop area but other indicators like livestock numbers or fertiliser use are possible. To set-up a tradeable emission-right system, equity arguments mean that it is necessary to begin by 'grandfathering' in all existing polluters. Grandfathering is the process by which all existing sources of emission are given a licence or interim right to continue to do so. In the Venus Bay case study, for example, it is suggested that each household be given septic tank shares in proportion to the contribution they make to the overall problem.

An alternative approach, developed by the Dutch, is to require each emitter to prepare an annual statement showing how they have kept emissions within acceptable limits. In this case, developed further in the Western Australian case study, each person is required to prepare a nutrient balance sheet for their land and any other person's land they have used. Applying this widely may be difficult but it is possible to introduce it as a special requirement for the disposal of manure from intensive animal production units. In this case, they would have to prepare a nutrient balance sheet for all land where they dispose of manure.

To set up a tradeable em*ission-right system* to control groundwater pollution it is necessary to:

1. establish an emission history or some other means of defining the quantity of emissions made by each landuser;
2. define the expected relationship between each person's rights and entitlements;
3. where appropriate, define the means by which each person's entitlement will be reduced and what incentive arrangements will be used to reduce emissions;
4. prepare an appropriate management plan setting out the relationship between rights, entitlements and obligations;
5. issue or define each person's emission-rights;
6. put the necessary monitoring system in place to a) ensure compliance; and b) ensure that information necessary for the first management plan review is collected; and
7. appoint the body to conduct periodic management plan reviews and decide on the means by which they will be chosen and the powers that they have.

Polluter-pays systems

A polluter-pays system is a system where those who create the need for an emission-control system and/or water treatment pay for the full costs of doing this. Even with point-sources of pollution, fully fledged polluter-pays systems are rarely used. Nevertheless, pollution charges are being gradually introduced throughout Australia. Moreover, it is possible to imagine a system where polluters are required to meet, for example, the full costs of treating groundwater. Before going further, it is also useful to point out that most tradeable emission-right systems produce very similar outcomes to a polluter-pays systems and, because they leave room for individual initiative, they can be more efficient. Under an emission-right system, such as that proposed for Venus Bay, all the costs of cleaning up the town's water supply are born by those people who pollute. This case study also explores the possibility of using what we call a quasi emission-rights system to try and remove bacteria from the domestic water supplies in Venus Bay.

To set up a polluter-pays system to control groundwater pollution it is necessary to:

1. identify the surrogate indicator of pollution load to be levied. Examples include presence of a non-complying septic tank, area of crop planted and area of land owned;
2. work out how those who reduce pollution loads will have their levy reduced in an equitable manner;
3. identify the appropriate size of the levy;
4. identify where the money raised is to be spent and who should decide how that money is spent;
5. work out how to collect the levy; and
6. work out how the money will be spent in an equitable and efficient manner.

Speed of adjustment

At the start of this report, we identified a number of characteristics of groundwater aquifers that make management of groundwater quality problems more difficult than they are for many other bodies. In particular, we observed that groundwater tends to move at very slow rates and is hidden. This means that it is often very hard for people to appreciate the need to control groundwater quality and even harder for them to see whether or not a new system is resulting in an improvement in groundwater quality. Given this, there can be benefits in using market mechanisms to speed up the rate of acceptance of a new right-based mechanism and bring about a more rapid rate of improvement in groundwater quality. A conditional property-right system or tradeable emission-right system adjustment can be speeded by introducing a 'zero revenue' tender process.

When a zero revenue tender mechanism is used, each share or right holder is required to place, say, 5% of their shares up for sale and set a reserve price for them. The mechanism is called a zero revenue tender because all the money received is returned to the shareholders and 'zero revenue' (ie. 5%) goes to the government or administering body. Each shareholder is free to set their reserve price as high as they like but the mechanism forces each user to decide how much their existing groundwater shares are worth and how much they would sell them for. First developed for air pollution rights in the United States, zero revenue tenders[26] force people to recognise that their new rights are transferable and have value. By forcing the market for shares to mature more quickly than otherwise would be the case, they can bring about a much faster improvement in groundwater quality.

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26. In the United States this mechanism is known as a zero-revenue auction and no reserve price is set. In Australia, if a reserve price is set no capital gains tax is payable. If a person buys back their own right, however, capital gains tax may be payable on any increase in the value of the shares they buy back.

Zero revenue tenders are particularly effective in stopping monopolistic and oligopolistic behaviour in a region where only a small number of firms are involved. This is achieved because the reserve prices set are anonymous and no-one knows in advance who is interested in buying. Speculators are allowed to enter the market at their own risk. As all are forced to set a reserve price, any person who wants to buy groundwater irrigation-rights is free to do so. Moreover, because all exchanges take place at the same time, transaction costs are low.

Another advantage of the zero revenue auction is that it can be used to facilitate an equitable reduction in each person's entitlement. If as suggested above, the number of shares required to irrigate one irrigation equivalent is increased from 100 shares to 110 shares, those able to improve irrigation efficiency at least cost would do so. Those less able would turn to the market to acquire additional shares. A person who converted 10 ha of grapes to drip irrigation, for example, would be able to make the change and sell 56 shares to a person who was less able to do so.[27] The outcome would be an across the board 10% increase in wateruse efficiency and a transfer in irrigation-rights in a manner that equitably rewards those who facilitated the improvement. The cost of increasing wateruse efficiency is shared by all but made in those areas where this transition can be achieved at lowest cost.

Optimising the mix of right and other instruments

The final issue that we would like to draw attention to, is the importance of recognising that most pollution problems arise from a multitude of sources and that these sources can change through time. Often, for example, nitrates come from several different sources. In Western Australia, urban growth is changing landuse around Perth and, hence, diffuse sources of nitrate pollution. In this area, turf farms are a recent but now very significant source of nitrate pollution. Similarly, in the Namoi region, cotton production is a relatively new form of crop production. Likewise in the south-east of South Australia, increases in pine plantations might have a significant impact on groundwater production. All this suggests that, in many cases, groundwater quality management will be most effective if several right-market and other mechanisms are used in combination. Thus, for example, we recommend that in Western Australia, an emission-offset system be used to control nitrate pollution from intensive animal units in combination with a conditional groundwater use right to control nitrate pollution from irrigated areas.

27. Prior to the review, 370 shares would be required to grow 10 ha of grapes under flood irrigation {(10/2.7)*100=370}. After the review, to drip irrigate 10 ha 314 shares would be required {(10/3.7)*110=314}. The remaining 56 shares could be sold to a third party in a manner that might help offset some of the costs of installing the drip irrigation system.

SECTION TEN

The applicability of rights markets to control diffuse groundwater pollution across Australia

The geographic extent and economic importance of diffuse groundwater pollution across Australia has not been defined. This means that the documented and reported examples of diffuse groundwater pollution are often sporadic and based, largely, on statements by individuals. The extent of reporting in states ranges from almost nil up to only a modest level of reporting. The scale of the problem is not well understood. Consequently, any assessment of the ability of rights markets to deal with non-point-sources of pollution must be highly subjective. Nonetheless, assuming state government willingness to use right markets to control diffuse groundwater pollution, Table 8 (page 55) provides our subjective assessment of the potential of right markets to make a significant contribution to the extent and intensity of diffuse groundwater pollution in Australia.

As indicated in Table 8, it is our assessment that right-markets mechanisms have only a very small scope to control diffuse groundwater pollution due to pesticides; a moderate ability in the case of nitrates, and a high ability in the case of groundwater salinisation and seawater intrusion. We were unable to find any examples of serious diffuse pesticide groundwater pollution and, hence, our assessment of the applicability of rights markets could be very much in error in this case. Pragmatically, however, we do point to the fact that right-market mechanisms have much wider public acceptance in the control of pollutants which occur naturally in groundwater. Licensing people to place 'approved' quantities of pesticides in groundwater would, in our judgement, be likely to be politically unacceptable.

Across Australia the highest priority diffuse groundwater pollution problem is probably nitrate pollution. Hence, even with only an assessed moderate applicability, the use of right markets to control nitrate pollution is worthy of serious consideration. They are easily used to reduce nitrate pollution in irrigation areas, are powerful in areas where animal manure spreading is common and in areas where people have to pay to remove nitrates from groundwater. We, however, can not see them making a significant contribution to the control of nitrate pollution from non-irrigated pasture or livestock grazing. As salinity problems are often associated with groundwater use, however, we see the mechanism as a powerful means of controlling this problem.

In summary, the use of rights markets is considered to be a partial solution to the nitrate problem, whereas it is believed that it is likely to be a highly applicable solution in the case of most types of groundwater salinisation. All of the above assessment is predicated upon the assumption that government and the community are seriously desirous to solve the problem.

Table 8
Subjective assessment of the applicability of right-market mechanisms to reduce diffuse groundwater pollution in Australia

Diffuse pollution problem	Ability of right-market mechanisms to significantly reduce diffuse pollution problem (% of problem area amenable)
Nitrates	
Excess fertiliser applications	30%
Animal excreta	20%
Legume pasture	10%
Pesticides	1%
Groundwater Salinisation	
Land Clearing	40%
Recycling	75%
Lateral migration	75%
Irrigation	50%
Bacteria, nitrates from septic tanks	50%
Seawater intrusion	90%

Recommendations

As a result of the range of case studies and experience analysed in this report, we conclude that *right-market mechanisms are best suited to the management of contaminants naturally present in aquifers.* Nitrates, phosphates, and salt clearly fall into this category. Where a community aspires to near-zero contamination levels, a strong regulatory approach is likely to be more effective. In conclusion, we recommend that:

1. no groundwater user be given a secure groundwater use-right that:
   - precludes the attachment of land and wateruse conditions to that right; and
   - does not facilitate the periodic review of the entitlements, conditions and obligations that attach to that right.

With regard to the effects of land-use change on the amount of groundwater recharge and, hence, the amount available to irrigation, we recommend that:

2. all groundwater allocation systems be designed so that, at a later stage, it is possible to vary annual allocations as rainfall, recharge rates and environmental considerations change;
3. in areas where there is over-allocation or over-use of an aquifer consideration be given to the merits of including forms of landuse like timber plantations and deep rooted perennial pastures within the allocation system;
4. consideration be given to the introduction of share-based allocation systems which give each licensed groundwater users a formal share of the amount of water available in an aquifer for consumptive use. Such an arrangement gives each user a guaranteed right to use groundwater sustainably but, at the same time, provides periodic opportunity to review and improve definition of the entitlements, conditions and obligations that attach to that right; and
5. off-set mechanisms be used as an interim measure to control reduction of recharge from areas placed under plantations.

With regard to the reduction of diffuse pollution from multiple point-sources that are linked to development approvals, we recommend that:

6. offset mechanisms be used as a means to prevent increases in the flow of nutrients to groundwater and, where appropriate, reduce the flow of these nutrients to groundwater.

With regard to the high cost of removing nutrients from groundwater sources in some locations and the relatively low cost of achieving much greater rates of improvement from diffuse sources, we recommend that:

7. State and Commonwealth agencies encourage water treatment authorities to become involved in programs that reduce the flow of nutrients to groundwater in the most cost-effective manner possible.

Recommendations from a report of this nature require careful consideration by many people. We recommend that the report be:

8. referred to the COAG Task Force on Water Reform for consideration of the advantages of designing water allocation systems so that they encourage waterusers to reduce groundwater pollution; and
9. Commonwealth, State and Territory groundwater and surface water managers give careful consideration to the merits of using the current water reform process as a means to improve water quality.

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Groundwater and pollution in the Wanneroo groundwater area, Western Australia

Introduction

The Wanneroo Groundwater Area (WGWA) is located on the northern outskirts of the Perth metropolitan area and overlies the Gnangara Mound. The Gnangara Mound is a large shallow groundwater aquifer which extends from the Swan River in the south to Gingin Brook in the north; and from the Darling Range Scarp in the east to the Indian Ocean in the west. The mound covers an area of 2,200 km^2 and is the most important groundwater resource of Perth (Moore *et al.*, 1996). The Wanneroo Groundwater Area is a specific area approximately 27 km long x 5–20 km wide. This area has been chosen for this case study because:

- a range of diffuse groundwater pollution issues exists;
- a variety of diverse agricultural enterprises is present;
- the area is of significant importance to Perth's water supply;
- the area is experiencing landuse changes and development pressures; and
- the area might well be suitable for the application of right-based market instruments to control, or at least limit, diffuse groundwater pollution.

The Wanneroo Area has a variety of landuses ranging from native banksia woodlands and forests, irrigated agriculture, intensive animal industries, wetlands and 'hobby farm' housing development. Rural landuses include market gardening, turf production, poultry farming, viticulture, orchards, fodder cropping, nurseries, sheep, cattle and pig husbandry, flower, mushroom and strawberry growing and pheasant production. Most of the area, however, is state forest comprising large pine plantations and natural bushland (Gomboso, 1997).

The principal diffuse groundwater pollution problem in the Wanneroo Groundwater Area is raised nitrate and phosphate concentrations in the shallow groundwater due primarily to high fertiliser applications and, to a lesser extent, animal waste from intensive animal industries, especially poultry. This concern about diffuse pollution is set within a context of important urban and domestic and stock groundwater supply bores and possible interference with groundwater discharge to maintain wetland water levels. Most of the wetlands are an intimate part of the groundwater system. Since European settlement, however, many (about 80%) of the wetlands have been destroyed due to landfills, stormwater disposal, road construction and urban development. The protection of the remaining wetlands is seen as of vital importance not only from the above activities, but also from groundwater pollution. The wetlands are a major environmental issue because they play a key role in aquatic, plant and animal habitat and, also, as a drought refuge.

Hydrogeological environment

The Gnangara Mound is situated on the Swan Coastal Plain and comprises groundwater contained within the superficial sediments. These sediments occur to a depth of about 30 m and comprise predominantly sands with varying amounts of organic carbon. The superficial aquifers form extensive unconfined or locally semi-confined aquifer recharged directly from rainfall (Hirschberg and Appleyard, 1996). The depth to the watertable is usually less than 30 m and may be only five metres in low elevation areas. The crest of the mound has an elevation of 75 m above sea level. Groundwater flow is predominantly westerly (towards the coast) from the top of the mound, at a rate varying from 0.01 to 100 m per year. Around the mound crest, radial flow occurs.

Groundwater quality on the Gnangara Mound is generally excellent. Salinity averages about 500 mg/L on the mound, but varies from 130 to 12,000 mg/L TDS. Low salinity groundwater occurs close to the crest with higher salinity groundwater occurring near the discharge areas and in areas underlain by clayey sediments. pH ranges from 4.5 to 6.5 near the centre of the mound to 6.5 to 8.0 near the coastal limestone areas. The acid groundwaters are due to organic acids leached from wetland areas and reactions involving dissolved iron. Iron content varies greatly from <1 to 10 mg/L, as does hardness.

Nitrate levels are often low, but may exceed 5 mg/L beneath urban areas and greater than 10 mg/L beneath horticultural areas. The Australian drinking water standard is 10 mg/L N. Similarly, total phosphorus is generally less than 0.1 mg/L but may be higher in specific locations.

Groundwater pollution

By 2010 groundwater will contribute nearly 50% of all water supplied to Perth (Stokes et al., 1996). Consequently, the protection of the groundwater resource from pollution is seen as a vital short and long-term priority. As of 1994 (Legislative Assembly, WA, 1994) there were 700 known and inferred point-sources of groundwater contamination in the Perth metropolitan area. These cover a broad range of categories, for example, landfills, industrial sites, leaking underground storage tanks and so on. In addition diffuse sources—including fertilisers, herbicides and pesticides, septic tanks—are known to be a major concern.

Cadee (1996) has identified a range of high risk pollution sources for the Gnangara Mound:

1. microbiological contamination, due to on site wastewater disposal systems;
2. petroleum hydrocarbon, from underground storage tank failure, particularly in older, poorly installed tanks;
3. pesticides, with the greatest threat arising from their manufacture and formulation, and their broad-scale use for agriculture and silviculture;
4. industrial chemicals, ranging from organic solvents, petroleum-based products to inorganic toxins, such as heavy metals; and
5. to a lesser extent, agriculture, due to the broad-scale use of pesticides and nitrogen-based fertilisers.

Dealing with the last aspect, this is the key diffuse concern. Work by Pionke *et al.* (date unknown) on fertiliser applications for irrigated horticulture indicates the potential for nitrogen and phosphorous losses to groundwater to be very high, indicating the extent of the potential for improvement. Nutrient applications, mostly of poultry manure, exceed crop uptake by about five times for nitrogen and at least ten times for phosphorous. Most groundwater quality data indicates nitrate levels < 1.0 mg/L–N, however some isolated values of > 20 mg/L–N have been recorded in the Wanneroo Underground Water Pollution Control Area (WUWPCA).

Based on the above considerations, it is generally believed that the widespread use of fertilisers and pesticides in agriculture is potentially the major source of groundwater contamination on the Swan Coastal Plain (Hirschberg and Appleyard, 1996).

Current controls

Three categories of protection (so called, 'Priority Source Protection Areas') have been proposed with the aim of protecting the quality of groundwater. These three categories are within the declared WUWPCA. The three categories (Cadee, 1996) are:

Priority Source Protection Area 1 (P1)

P1 source protection areas are designated with the objective of keeping the groundwater free from contamination through avoiding risk. This level of protection is appropriate for strategically important water resources which are in an uncontaminated state and which can be protected from significant development. In practice, most P1 land is in government ownership.

Priority Source Protection Area 2 (P2)

P2 source protection areas are designated for land which is primarily in private ownership, and for which it is in the interest of the community to allow some development. The water resource is of strategic importance and as a result risks need to be kept very low and minimised through restricted landuses. Landuse is restricted to low intensity rural residential, non-intensive agriculture and low-risk mining activities. Urban development is not a preferred landuse and there is a preference for parks and passive recreation as the predominant landuse.

Priority Source Protection Area 3 (P3)

P3 source protection areas are predominantly urban areas where other landuses are valued more highly than water production. Some risks of contamination exist, but these are managed by prohibiting high-risk activities and regulating others. Explicit in this level of protection is an acceptance by the government that some water resource may be lost to contamination or that higher levels of treatment to remove man made contaminants may be required.

This differential protection policy provides a high degree of protection while providing some flexibility to allow for the needs of landowners.

In addition to the above proclaimed catchment areas a broad range of landuse planning and environmental strategies have been adopted to protect groundwater quality and protect wetlands and natural vegetation. These are explained in Cadee (1996) and Moore et *al.* (1996). Acceptable and unacceptable landuses and practices are defined by the Gnangara Statement of Planning Policy (SPP) and the Environmental Protection (Gnangara Mound Crown Land) Policy (EPP).

In the WUWPCA, even though most of the land is crown land, there is some freehold land present. All the WAWPCA is located in a priority one (P1) area. Serendipidously the key recharge areas are also the location of the main natural banksia forests.

Land-use change scenarios

Being at the edge of the expanding Perth metropolitan area there is considerable pressure from developers to expand urban housing areas in the WUWPCA. Currently there are many 'hobby' farms and some specialised animal production and agricultural landuses. Several landuse options exist for the future:

1. *no change*—hold the 'status quo', maintain tight controls on acceptable activities in freehold land and do not permit any landuse change on crown land, ie. maintain pine forests and native vegetation;
2. *sell the forests*—gradually move to expand the urban zone into the currently forested areas and probably also expand the 'hobby' farm enterprises into the previously forested areas; and
3. *urban encroachment*—the forest areas would be maintained, however, urban expansion into the previous agricultural areas would be permitted.

These options and many variations thereof are under consideration. The Gnangara Land-Use and Water-Management Strategy is proposed and it is understood that it will be considering options for those freehold landowners whose land lies within existing or future P1 areas. According to Moore *et al.* (1996) some of the options available for landholders within the P1 areas may include:

- maintain freehold land status and prohibit further development through current restrictions;
- government purchase of properties with lease-back entitlement for existing residents; and
- pay landholders to accept attachment of a covenant to the title to their land which prevents land-use change in any way that might cause groundwater pollution.

While these options make sense for P1 areas, they are less attractive for P2 and P3 areas. As summarised above, the significant nitrate and phosphate concentrations found in areas P2 and P3 are, at least in part, due to high fertiliser applications in both urban and agricultural environments. The remainder of this case study examines opportunity to reduce nutrient flows to groundwater via the use of rights-based markets. The fundamental goal is to at least maintain the current level of groundwater quality, if not improve it.

Right-based options

Essentially, there are three right-based options that could be used to control threats to groundwater pollution in the Wanneroo Region. We describe these as threats rather than actual sources because of the diffuse nature of the problem. Not all threats lead to pollution but as actual sources can not be identified precisely, it is necessary to control each category of threat on the assumption that there is a direct linkage between land-use practice and pollution. The options available are:

- an *emission-offset system* where any person wishing to change land-use must first enter into a private arrangement that will reduce groundwater pollution by the amount that the proposed landuse is expected to create;
- introduction of a *tradeable emission-right system* targeted directly at sources of nitrate pollution from animal waste; and
- development of a *conditional-irrigation right system.*

Right-market option 1—An emission-offset system

An emission-offset system requires each potentially polluting activity to be offset by one that means that there is no increase in the total amount of pollutants likely to flow to a groundwater body. Emission increase at one location is offset by prior decrease elsewhere. Implementation is low cost and achieved by introducing a policy requiring each aspiring developer to offset their proposed activity. In the Wanneroo region this could be achieved by introducing much more stringent land-use control or by linking this requirement to any groundwater irrigation licence.

While low cost this option is a second best solution. Amongst other things, offset systems place all the costs of adjustment on the proponents of new development. It is these proponents who have to make all the necessary arrangements and incur all the costs of offsetting what they wish to do. In the simplest case, a group of aspiring horse owners might make arrangements to either dispose the manure from an intensive animal production unit outside the Wanneroo Groundwater area or, alternatively, persuade the intensive animal production unit to shut down so that they can keep horses without increasing nutrient flows to groundwater. The main weaknesses of this mechanism is that it does not provide a mechanism to reduce total pollution load to an aquifer.[28] Moreover, because polluters can profit from their 'dirty' habits, no existing polluters have any incentive to move to best management practice unless paid to do so by an aspiring developer. In some cases, well-targeted regulations can be more cost-effective. Where such arrangements are politically unacceptable, however, emission-offsets provide an effective alternative. Often they are only implemented partially and limited to larger developments, like a new intensive animal production unit. Existing landholders may regard this as equitable.

Right-market option 2—Tradeable emission-right systems

Tradeable emission-right systems have higher administrative costs but, because they work across all polluting sources, they overcome many of the environmental and equity-based criticisms of an offset system. There is pressure on all people to adjust, not just those who wish to expand production.

One of the best known tradeable pollution right systems for diffuse pollution is the Dutch system used to control flow of animal wastes to ground and surface water. The system works by requiring each person to prepare an annual statement or account showing how they have kept animal-waste disposal within 'environmental' capacity. All land is rated in terms of its capacity to have manure spread upon it. Any landholder who has 'spare' capacity can accept manure from another person and spread it accordingly. Sometimes, people who own land with spare assimilative capacity charge people for the right to spread manure on their land, others accept it as a free source of nitrate and phosphate. Surplus manure can, for a fee, be delivered to a manure bank.

Application of such a system to the Wanneroo Region is possible as a means to control and even reduce diffuse nutrient pollution to groundwater. To implement it, however, it would be necessary to establish a set of manure and fertiliser spreading standards that apply to each land-use type. Each landowner would then be required to show how they have spread manure and fertiliser. Choosing which land-users would be exempt from the system would be difficult but might include all properties which only contain unirrigated pasture and/or no stables. All market gardens, intensive animal-production units, stables and turf farms would be included in the systems on a nitrate-equivalent system.[29] Total emission entitlements would be capped by zone and trade between zones allowed only within the cap applying to each zone.

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28. This weakness can be overcome to some extent by introducing two for one type rules. Under this arrangement the proponent has to remove twice as much load as that expected from the new development.
29. This assumes that nitrate, not phosphate, is the factor limiting groundwater quality and that these two pollutants are linked together.

In the interests of attaining acceptance of the system, in the first instance, all existing land-users would be grandfathered into the system and given an entitlement to emit as much nitrate as they are deemed to currently be emitting. Subsequent emissions in excess of that entitlement would be levied at a penalty rate sufficient to virtually force all people to trade un-utilised capacity and stop all people from considering adopting practices that exceed their entitlements. In practice, the levy would be set at a rate that is, say, 20% above the cost of offsetting that extra flow of nitrate to the groundwater system. In effect, this is a recommendation for a replacement or offset pricing strategy. Replacement cost would be identified by monitoring trades and, if no trades are occurring, increasing the levy until landholders find begin to trade rather than pay the levy.

The main merit of such a tradeable emission-right system is that, once in place, the total cap on allowable emissions can be reduced proportionally. In effect, each person is given a proportionate share of the total amount of emissions allowed in a zone and then forced to remain within that limit. In an area where there is only a small number of people involved and/or there is reluctance to trade, trade in emission-rights can be forced by introducing a 'zero revenue' tender.[30] This is presented below.

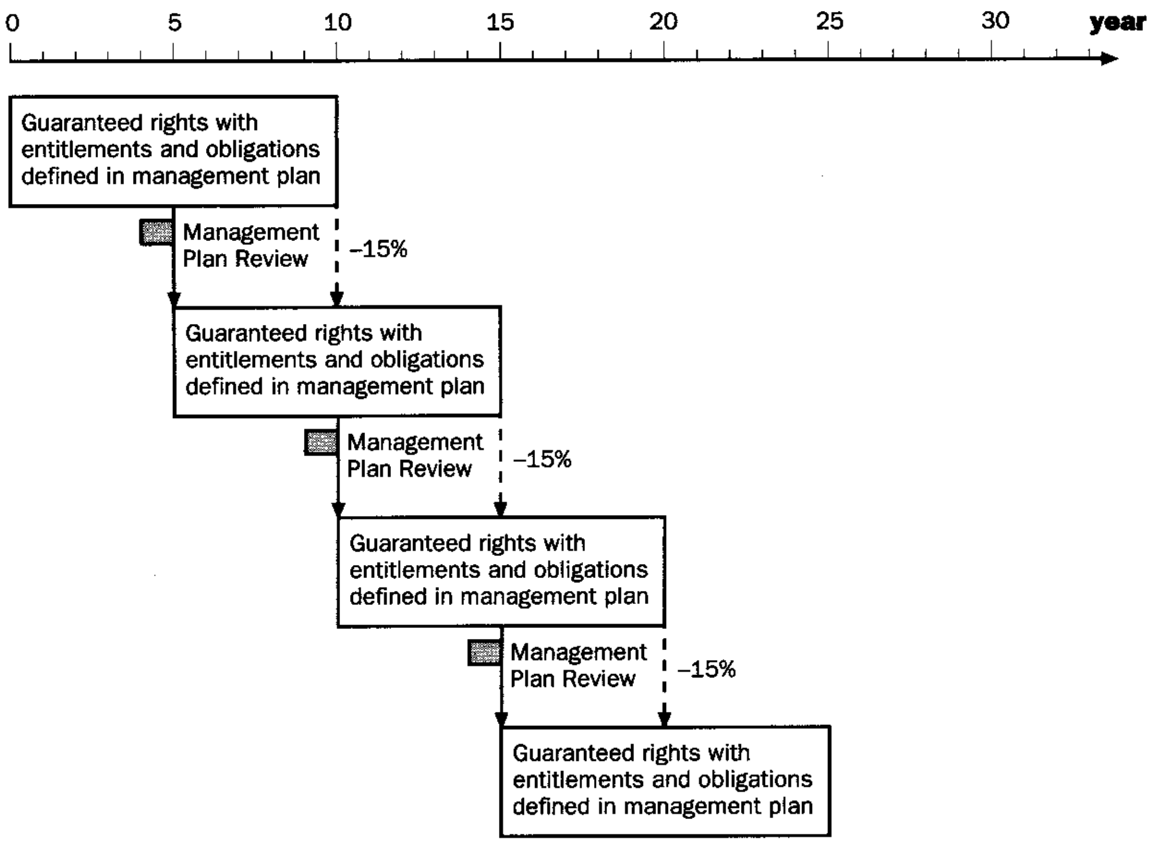
When a zero revenue tender is in operation, each permit or shareholder is forced to set a reserve price for, say, 5% of their holding and make that proportion available for sale by tender. The result is a process by which 5% of the total amount of allowable emissions is offered periodically for sale. If someone offers a price higher than the reserve then the tradeable emission-right changes hands and the person who set the reserve receives a cheque for the full amount offered. The mechanism is called a 'zero revenue' tender because the administering authority receives no commission or share of the revenue received.

Obviously, the greater the value of the emission-right, the more people will aspire to adopt practices that reduce nitrate and phosphate emissions. Pragmatically, right value can be maximised by issuing shares for, say, ten years with a guaranteed right to receive an offer of an equivalent share of total nitrate emission capacity every five years. That offer would be made immediately after a formal review of the management plan used to define the entitlement associated with each share. Those who accept the entitlements and conditions in each management plan would retain their full share of total allowable emissions for the region. As a means to prevent rapid change of entitlements, which might discourage investment, those who find that the specification of entitlements and obligations in the new plan are unacceptable, would be entitled to remain under the previous entitlements and obligations for up to another five years. If they follow this latter pathway, however, they would have to surrender, say, 15% of their shares when they 'drop-through' to the new plan (see Figure 2).

The two reasons for this drop-through framework first to make it administratively difficult to avoid regularly reviewing progress and second to encourage all adverse reductions in entitlement to be phased in slowly. When reductions are phased in slowly all people have a chance to adjust in an efficient and equitable manner. A key component of any such arrangement are the institutional arrangements used to redefine the new plan. There is considerable capacity to devolve much of the process associated with a periodic review to the community of people affected by any change.

30. In air pollution markets in the United States of America, this mechanism is known as a zero-revenue auction.

Figure 2
A generalised framework for a right system involving reviews to periodically adapt the linkages between shares, entitlements and obligations[31]



Right-market option 3—Conditional irrigation-rights

As most groundwater pollution problems in the Wanneroo Region are closely associated with irrigation, an alternative option is to translate existing irrigation licences into conditional wateruse rights. In practice, there is little difference between the tradeable emission-right option outlined above and a conditional wateruse right. In either case, the entitlement is most likely to be specified in terms of the area of activity that can be carried out. An example, might be a licence to irrigate five hectares of turf.[32] In this case of a conditional wateruse right, however, rather than using nitrate emissions to work out each person's entitlement, rights are linked back to the amount of water that may be used. Rights are allocated to use groundwater subject to conditions designed to keep diffuse groundwater pollution within sustainable limits. Operationally, and is already the case, each right would translate into a land-use equivalent based on:

- the expected quantity of water used with each crop; and
- the amount of diffuse nitrate pollution likely to be associated with the proposed land-use practice.

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31. It is possible to modify the drop through arrangement so that right holders can delay dropping through at increasing cost. One option would be 15% for a five year delay, 50% for a 10 year delay and 100% for a 13 year delay.
32. For regional accounting purposes, this entitlement will also define a maximum annual volume of water that can be used but, at present, there is no requirement to install a meter to record use.

Under this arrangement, conversion factors from, say, turf farming to vegetable growing would be developed. For example, six hectares of turf may be deemed equivalent to six hectares of vegetables or five hectares of flowers. Table 9 provides an indicative overview of the type of look-up table that would be placed in a management plan used to show how a right to grow one crop area would be converted into another. Over time these conversion ratios could change as differences in groundwater quality emerge.

Table 9
Scenario showing changes in entitlements to irrigate different crops as information on groundwater quality effects accumulate and technology changes

Management Plan	Crop Area Equivalents		
Period	Turf	Vegetables	Flowers
1st five years	3 ha	6 ha	5 ha
2nd five years	2.8 ha	6.2 ha	5 ha
3rd five years	2.7 ha	6.4 ha (Drip-irrigated strawberries 8 ha)	5 ha

Finally, under a conditional wateruse-right system, it would be possible to introduce meters and do away with the need to define equivalence. Once again, rather than mandating the introduction of meters by a certain time, entitlement conversion factors could be revised so that conversion to a meter is attractive. With meters in place, nitrate flows to groundwater on some soil types may be reduced by setting maximum application rates per hectare.

Evaluation

An attractive dimension of this case study is that none of the options presented are mutually exclusive. Moreover, with appropriate political and administrative will all could be used to achieve significant reductions in nutrient flows to groundwater. Of the three options, perhaps the most attractive is the last option as the Department is already in the process of introducing more formal groundwater irrigation-rights. The proposed framework simply proposes that groundwater extraction management plans be used as the principal means to control groundwater quality and that this be achieved by bringing all existing licences into a consistent framework with an emphasis on transparency and equity. Market processes would be used to drive improvement in water quality via entitlements to trade groundwater irrigation-rights only in ways that improve groundwater quality.

The other issue is the marginal cost of implementing such a system. Given that it is already planned to introduce more formal irrigation-rights in the Wanneroo area, the administrative cost of achieving these reforms would be minimal. The main problems would come in the estimation of conversion factors that, in some instances, would require estimation of poorly understood relationships. Hence, it would be necessary to build in an adaptive management process similar to that set out in Figure 2. Nevertheless, implementation of such an arrangement would require only a re-orientation of existing policy processes to give the local community strong incentives to improve groundwater policy. A major benefit of the proposed approach would be strong community recognition of the fact that wateruses causes groundwater pollution.

In parallel with this latter option, changes to the management plan could introduce offset arrangements for units that do not use large amounts of water per hectare but are a significant source of nitrate pollution. For example, a management plan might, for example, require any expansion in the number of animals kept in an intensive animal husbandry units to be offset by the reduction in the irrigated within some other part of the zone where that unit is located. Once again, if linked to a periodically revised management plan, the administrative cost of implementing such an arrangement could be low.

The middle option which requires introduction of a formal emission-right system, however, would require significant start-up costs. As such its implementation could be justified only if the previous two measures—a conditional wateruse right system coupled with an offset system—failed to produce significant improvements in water quality.

Acknowledgment

While all the statements and brave assumptions made in the interests of preparing this quick desk case study remain the responsibility of the authors, we would like to acknowledge the contribution of Harry Ventriss, Jeanette Gombosso and Rueben Taylor who helped us develop many of the ideas summarised in this case study.

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APPENDIX 2

Groundwater and pollution in the south-east of South Australia

Introduction

In the lower south-east of South Australia, groundwater is used principally for irrigation of pastures, vineyards and a range of horticultural crops. In addition, the aquifers are used to supply drinking water to towns like Mount Gambier, Naracoorte and Kalangadoo. Groundwater also plays an important role in the maintenance of a number of important wetland ecosystems. Most use is from unconfined aquifers whose depth to watertable is less than five metres (Schmidt *et al.* 1996). Lateral flow rates are in the order of 10 to 200 m per 100 year. Around 90% of recharge is local. The remaining 10% of recharge is thought to flow into the region from Victoria.

In this case study, we aim to examine the opportunity to use 'Tradeable Pollution Rights' and 'Conditional Wateruse Rights' as a means to reduce groundwater pollution in the area. For simplicity, we focus on two areas:

- the Proclaimed Area of Padthaway; and
- the Hundred of Grey.

Padthaway is well known for the quality of its red wine. The Hundred of Grey is just north of Mount Gambier and contains the town of Kalangadoo. Grey is an important area for dairy production, pine plantations and potato production.

Pollution problems

The two main diffuse groundwater pollution problems in the south-east are nitrate pollution and groundwater salinity. These problems, however, are not uniformly distributed across the region. A recent survey of 129 bores, not likely to be contaminated by point-sources, found that 18% had nitrate concentrations above the safe potable level for infants of 10 mg/L and 3% had nitrate concentrations above the potable limit of 20 mg/L (DENR 1996). In some areas, salinity levels are increasing at a rate of 50 mg/L per year. Table 10 contains an estimate of the amount of nitrate that flows to groundwater in the south-east as a result of the main land-use practices adopted in the area. These quantities are high and, in slow moving bodies, can make groundwater unfit for human consumption. Some towns like Mount Gambier and Bordertown use highly vulnerable, unconfined aquifers to obtain domestic drinking water while others like Kalangadoo obtain domestic drinking water from a confined aquifer. Major towns, like Mount Gambier and Kalangadoo, routinely use a confined aquifer to obtain groundwater for domestic purposes but the unconfined aquifer is used by a significant number of people for domestic purposes. Rain water is often used by rural communities for drinking purposes.

The other main groundwater quality problem in the south-east is groundwater salinity. In isolated but important areas groundwater salinity has now reached unacceptably high levels. As a result of groundwater recycling, the sodium content of some Padthaway wines is approaching the maximum allowable concentration for wine within the European Community. But the problem is not this simple, vegetation clearance, loss of deep rooted lucerne to aphids in the late 1970s and greater use of shallow rooted pastures have also contributed to the problem.

Table 10
Mean annual flow of nitrate to groundwater from different land-use practices

Landuse	Mean annual flow of nitrogen to groundwater as a result of landuse
Irrigated pasture [a]	20–30 kg N/ha/yr
Potato cropping in a pasture–potato–pasture rotation in a six year cycle [b]	40 kg N/ha/yr
Non-irrigated pasture [a]	9–12 kg N/ha/yr
Pine plantation [c]	3–4 kg N/ha/yr

Sources: Estimated by L. Schmidt from information in a) Pakrou, N. "Impact of pastoral land-use of groundwater quality", LWRRDC Project CWW9; b) Dillon, P.J. and Pakrou, N., PRDC Project CRC1P and LWRRDC Project CWS5. Centre for Groundwater Studies, CSIRO Division of Water Resources; and c) Smethurst, P.J. and Nambiar, E.K.S (1989), "Dynamics of organic matter and nitrogen between crop cycles of Radiata pine: a progress report." CSIRO Division of Forestry and Forest Products.

Another diffuse groundwater pollution issue is the emergence of persistent pesticides and herbicides in groundwater. Concentrations, however, are not yet regarded as critical. The groundwater quality survey, mentioned above, found pesticide traces in 15% of bores at concentrations, at least, one order of magnitude below the maximum safe drinking water limits. Three of the four pesticides detected in this survey are no longer registered for agricultural use in Australia.[33] A separate study has detected atrazine and simazine in groundwater under irrigation areas and pine forests (Stadter et al. 1992). Atrazine and simazine are persistent pesticides whose use for agricultural purposes is still permitted.

Allocation of use rights

Allocation of rights to pump groundwater for stock and domestic purposes in the south-east is unrestricted. The majority of water resources in the south-east are now proclaimed under the Water Resources Act. A license is required to sink a bore and, if water is required for more than stock and domestic purposes, an extraction licence is required. Water for irrigation is still available over approximately half the area. For the other half, however, irrigation water is available only on transfer from an existing licencee in a manner consistent with management plan requirements and departmental policy. In many areas, use of groundwater for irrigation is capped to prevent depletion and, although not a clearly stated goal, the emergence of unacceptable salinity problems. Generally, licences are issued for between one and four years. It has been the custom of the Department of Environment and Natural Resources and its predecessors to renew these licences on application but, while there is a reasonable expectation, there is no guarantee that these licences will be renewed. Under the 1997 Water Resources Act, licences will be in perpetuity but entitlements to use water can be varied.

Officially, allocation is on a volumetric basis but, as wells are not metered, the right is defined in terms of 'irrigation equivalents.' An irrigation equivalent is an entitlement to irrigate an area of crop whose water needs for optimum production is equivalent to that used to irrigate one hectare of pasture. In practice, however, the licensing system establishes a *defacto* tradeable pollution right system. In a number of areas where landuse intensity is high, the factor limiting development is diffuse groundwater pollution caused by irrigation, not the total amount of water available. The main diffuse pollution problems are groundwater salinity, caused by recycling, and nitrate pollution. Indeed, it is not difficult to present the system used to allocate groundwater in the south-east of Australia as one of Australia's first ventures into the use of tradeable pollution-rights to improve groundwater quality.

33. All were organochlorides.

Under the irrigation equivalent system, any combination of crops may be irrigated provided that the sum of each irrigated crop area divided by the appropriate crop-area ratio for each crop, does not exceed the irrigation equivalent endorsed on the licence. For example, a licence might authorise a person to use three hectares of irrigation equivalents of water. Subject to restrictions designed to avoid further deterioration of water quality, temporary and permanent trades are permitted. In Padthaway, 2.7 ha of vines is equivalent to 1 hectare of pasture with the consequence that the typical licencee described above would have a right to plant up to 2.7 x 3.0 = 8.1 ha of vines.

Underscoring the point that the groundwater allocation system is driven by groundwater pollution issues, irrigation licence transfer policy aims to "achieve maximum benefit to the community from the use of groundwater consistent with the requirement to utilise the resource within sustainable limits" (DENR 1997). In practice, this means that transfers are *not* permitted into areas where significant salinity problems exist. As yet, there has been no attempt to use groundwater irrigation licences to reduce nitrate pollution.

Although not part of this case study, it is useful to point out that the introduction of a formal rights-market mechanism for groundwater use in the upper south-east of South Australia has been received very positively. In the Hundred of Stirling, for example, after an extensive consultation process, irrigators agreed to a 30% reduction in all allocations.

Padthaway

The Padthaway Proclaimed Wells area contains 93 licences which collectively entitle their holders to take-up to 34,952 ML or irrigate a total of 925 ha. The area is divided into four sub-areas so that water budgets and salinity management strategies can be formulated separately. In some areas, groundwater salinity is increasing while in other areas it is deceasing.

The main groundwater management problem is groundwater salinity. Salinity problems in the area are primarily caused by *groundwater recycling* and are being observed to increase at rates of up to 45 mg/L per year. At this rate and without change, the future scenario for the main wine growing area would be bleak: A relatively large area south of Padthaway will be expected to have groundwater salt concentrations in excess of 1,500 mg/L by 2004 and most of the area where the soils are suitable for vineyards will have reached this concentration by 2014. Once salinity levels exceed 1,500 mg/L, it is difficult to produce red wine that will satisfy European Community standards for free sodium and Australian Food Standards for sodium chloride in wine. The industry, however, is responding to this challenge. Changes to irrigation practice and related strategies is expected to keep salt concentrations within acceptable limits.

Given the above, the challenge is to extend the life of the vineyards in sub-areas 2 and 3 which are the two areas where groundwater salinity problems are worst. Six options have been identified:

1. reduce groundwater use;
2. increase irrigation efficiency;
3. pump in better quality groundwater from the Naracoorte Range;
4. pump from deeper parts of the aquifer sequence;
5. artificially recharge from Morambro Creek; and
6. introduce a groundwater drainage or interception scheme.

Groundwater-right markets provide an opportunity to assist the first two of these options: increasing irrigation efficiency and reducing groundwater use. They do this by making reduction of use via increased wateruse efficiency the most profitable or, alternatively, the least-cost option. The remainder of this case study identifies options to do this.

In an attempt to slow increases in groundwater salinity by reducing use, irrigators are allowed to transfer irrigation entitlements out of the highly saline areas: sub-area 2A and sub-area 3. As yet, however, there have been no transfers of any irrigation licences from the areas where salinity is a problem.[34] This is primarily because soils within sub-areas 2A and 3 are much more valuable than elsewhere. Thus, as a means to reduce groundwater salinity, this transfer policy has no effect.

Right-market option 1—Introduce secure rights by converting existing crop-area allocations into crop-area shares

Consistent with new water resource legislation in South Australia, each groundwater user could be given a formal share in opportunities to use groundwater in the Padthaway Proclaimed Wells area. Shares would be allocated in proportion to the number of irrigation equivalents held and then conditions attached to shares used as the means to manage groundwater pollution.[35] In passing, it is worth noting that defining sub-area 2A and sub-area 3 licences as pollution rights would significantly increase public perceptions of the extent of salinity problems in the area.

A formal share system would guarantee that any changes to the system would be equitable in the sense that any changes in the conditions that apply to each zone would occur only on a pro-rata basis. In practice, one irrigation equivalent could be converted into, say, 100 Padthaway Wells district groundwater shares.

When such Conditional Wateruse Rights are introduced, users have a greater incentive to help drive the reforms necessary to prevent groundwater pollution. Formal share systems maximise this benefit by allocating all groundwater rights and requiring any person wishing to use groundwater to buy groundwater shares from an existing shareholder. Reduction in groundwater pollution would be contingent upon the conditions attached to each share. This is normally achieved by defining the entitlements and obligations associated with a share in a management plan for the region. A typical plan would specify rights to carry forward unused water and to borrow from a future year.

Right-market option 2—Attach management plans to shares and organise periodic reviews of entitlements and obligations that attach to groundwater shares

A share system would enable development of formal management plans that would define the entitlements and obligations associated with each share. Periodically, say, every five years, the relationship between shares, irrigation equivalents and crop-area ratios could be revised so as to provide incentive for waterusers to adopt more efficient irrigation practices and reduce diffuse pollution.

Introduction of periodic management plan reviews would force irrigators to discuss the long-term implications of current practice and give them an incentive to discuss alternative options that increase wateruse efficiency. An example, best illustrates the way this process might increase wateruse efficiency and thereby reduce increases in salinity caused by groundwater recycling.

At present, no distinction is made between flood and drip irrigation. An irrigation equivalent converts into an entitlement to grow 2.7 ha of vines irrespective of the effect of associated wateruse on groundwater quality or consumption. Introduction of a secure water right system and development of a sense of ownership of that right might drive significant reform. Irrigator participation in management plan reviews and recognition of the impact of salinity on the long-term value of their asset might result in a decision to change the crop-area ratio tables used to translate Padthaway groundwater shares into crop-area entitlements.

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34. The only trade that has occurred has been from one land title to another owned by the same person (DENR, pers. com 1997).
35. Experience suggests that it is easier to allocate rights that mimic existing entitlements. This ensures that all changes are equitable and encourages stewardship (Young and McCay 1995).

Following a review it might be proposed, for example, that one hectare of flood irrigated pasture be equivalent to 2.7 ha of flood irrigated vines or 3.5 ha of drip-irrigated vines. This would give irrigators a direct incentive to convert from flood to drip irrigation and either sell off surplus shares or increase the area under vines. In parallel with such a change and in order to increase wateruse efficiency, the number of shares required to irrigate an irrigation equivalent might be increased from 100 shares per hectare to 110 shares per hectare so that irrigators are forced to either upgrade or acquire rights from those who have upgraded. The restriction on transfer into the area would still apply but might be converted to a provision that there be no 'net' transfer of Padthaway groundwater shares into sub-area 2A or sub-area 3 so that adjustment within these zones is encouraged.

Right-market option 3—Zero-revenue tenders

As already indicated, despite the existence of a formal licence system and a transfer policy, as yet there have been no licence transfers out of Padthaway's prime vine production area. The main reasons for this lack of use of the appears to be the simple fact that viticulture is still the most profitable land-use for sub-areas 2A and 3 and, also, the fact that the system gives little incentive for irrigators to reduce use.

Given implementation of the above two options, it would be possible to further speed adjustment to a less polluting regime by conducting what is known as a 'zero-revenue tender.' Under this mechanism, each shareholder is required to place, say, 5% of their shares up for sale and set a reserve price for them. The mechanism is called a zero-revenue tender because all the money received is returned to the shareholders and 'zero-revenue' goes to the government. Each shareholder is free to set their reserve price as high as they like but the mechanism forces each user to decide how much their existing groundwater shares are worth and how much they would sell them for. First developed for air pollution rights in the United States, zero-revenue tenders[36] force people to recognise that irrigation rights are transferable and have value. Once all the resource has been allocated, zero-revenue tenders are particularly effective in stopping monopolistic and oligopolistic behaviour in a region where only a small number of firms are involved. This is achieved because each person does not know the price set by each other person and does not know who their shares will sell too. As all are forced to set a reserve price, any person who wants to buy groundwater irrigation rights is free to do so. Moreover, because all exchanges take place at the same time, transaction costs are low.

Another advantage of the zero-revenue tender is that it can be used to facilitate an equitable reduction in each person's entitlement. If, as suggested above, the number of shares required to irrigate a one irrigation equivalent is increased from 100 shares to 110 shares, those able to improve irrigation efficiency at least cost would do so. Those less able would turn to the market to acquire additional shares. A person who converted 10 ha of grapes to drip irrigation, for example, would be able to make the change and sell 56 shares to a person who was less able to do so.[37] The outcome would be an across the board 10% increase in wateruse efficiency and a transfer in irrigation rights in a manner that equitably rewards those who facilitated the improvement. The cost of increasing wateruse efficiency is shared by all but takes place in those areas where the transition can be achieved at lowest cost.

36. In the United States this mechanism is known as a zero-revenue auction and no reserve price is set. In Australia, if a reserve price is set no capital gains tax is payable. If a person buys back their own right, however, capital gains tax may be payable on any increase in the value of the shares they buy back.

37. Prior to the review, 370 shares would be required to grow 10 ha of grapes under flood irrigation {(10/2.7)*100=370}. After the review, to drip irrigate 10 ha 314 shares would be required {(10/3.7)*110=314}. The remaining 56 shares could be sold to a third party in a manner that might help off set some of the costs of installing the drip irrigation system.

If introduced in sub-areas 2A and 3, a zero-revenue tender would give all the licence holders an incentive to give up some of their rights and move water to another area where it is less likely to cause salinity problems. In order to retain equity, however, modification of the existing guidelines to allow some 'within sub-area' transfer would be necessary. In practice, the system would operate by requiring each shareholder to set a reserve price for their shares and then calling for people to tender to buy shares. Money collected from successful tenderers would be paid to those who gave up their rights. The result would be a much more rapid transition to a less polluting regime than would be the case if the small number of viticulturists involved waited until they could find someone to sell some of their shares too.

Finally, we observe that at present crop-area equivalents rather than irrigation meters are used to control groundwater use. Once shares are issued, it would be possible to introduce meters and use this as a means to encourage the adoption of more efficient groundwater-use practices.

The Hundred of Grey

The Hundred of Grey is to the south of and wetter than Padthaway. In recent years, landuse has moved in two directions. There has been a significant expansion of:

- potato production and, also, irrigated pasture production for dairying in ways that have increased nitrate flows to groundwater; and
- pine plantations which reduce the amount of water available for irrigation.

This draws attention to the fact that the primary factor limiting land-use in an area can change through time. Transition from unirrigated pasture to a pine plantation reduces groundwater recharge to about 10% (McEwan and Leaney no date) of that which flows to the groundwater table when the land is under pasture. This means that, while nitrate pollution is presently limiting groundwater use, at a later stage in the development of Grey, an absolute shortage of groundwater may become the critical issue.[38] Indeed, a recent land-use survey has indicated that there is already an over-allocation of groundwater in the Hundred of Grey.

Recognition of the fact that the limiting factor might change has major implications for the design of a property right-based instrument which relies upon scarcity to achieve its objective. In such circumstances, a simple share-based system is problematic because at the point of transition from one limiting factor to another, entitlements change. Conceptually, it is possible to run independent systems whose role in regional resource management changes through time. For the purpose of this case study, we identify options to solve each issue separately and then put them together.

Right-market option 4—Introduce secure system of tradeable area rights entitling, holders to plant an area of crop that varies in proportion to the quantity of excess nitrate produced

Essentially, this is a formalisation of the current system. We would, however, recommend that licence security be increased and that periodically-reviewed management plans be used as the prime means to change crop-area entitlements and associated land-use conditions. The result would be increased willingness on the behalf of irrigators to use the resultant land-use incentive options to reduce diffuse nitrate pollution as they would be guaranteed the right to share in the benefits of doing this.

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38. During the first three years after a pine plantation is clear felled, 106-135 kg/N flows to the groundwater table. After five years the Nitrate flow to groundwater remains near zero until the next clear felling operation which occurs around every 35 years.

Periodic management plan reviews would be used to define the maximum permitted annual flow of nitrates to the groundwater and crop-area ratios adjusted accordingly. Ultimately, a reference crop would be defined in terms of nitrate emissions per hectare. This would mean that rather than being equivalent to an entitlement to place 446 mm of water over a hectare, the entitlement would be redefined to be equivalent to the emission of not more than, say, 20 kg of N per annum.

Right-market option 5—Inclusion of pine plantations in the water allocation system

This option might be considered by many to be radical. Past some point, further expansion of pine plantations in the Hundred of Grey is possible if and only if any new plantations are associated with a reduction in the area under irrigation. This change would occur at the point when availability of water rather than nitrate pollution becomes the factor that limits wateruse. Ultimately, however, if the area under pine plantation continues to expand, then water rather than nitrate absorption will become the factor limiting irrigation development. If this action is not taken, then ultimately the groundwater table would begin to drop.

Right-market option 5a—Require new pine plantations to offset their impact on groundwater recharge

The simplest option is to wait until recharge rates start to reduce irrigation opportunities and then introduce an offset scheme. This would operate by requiring any person wishing to establish a pine plantation to first acquire an irrigation right equivalent to the decline in recharge likely to be caused by the plantation. If the annual recharge rate for native pasture is 100 mm per year but only 10 mm per year for a pine plantation, then a 100 hectare pine plantation would need to be associated with acquisition of 10 ha of pasture or its irrigation equivalent. Under this arrangement, the implicit signal is that landholders do not have a prior right to reduce groundwater recharge. Conversely, and under this option, any person who removes a pine plantation would have a right to sell the increased water to an irrigator.

Right-market option 5b—Bring pine plantation owners into the system well before groundwater becomes the limiting factor

The weakness of option 5a is that it operates by placing additional financial pressure on new plantations. The alternative approach is to bring them into the existing system well before inclusion is imperative. This would have the effect of building an integrated groundwater management system enabling incentive structures to be used to simultaneously manage groundwater recharge, extraction and pollution. If this option is adopted then all the opportunities associated with introduction of groundwater shares identified for Padthaway, become available. Depending on the factor limiting landuse, sometimes the system would resemble a tradeable pollution right system while at other times it would resemble a conditional wateruse or irrigation-right system.

Finally, we need to point out that other crops like dryland lucerne also affect groundwater recharge. In a fully developed system all crops would be considered. The cost of doing this, however, needs careful evaluation. Sometimes the cost of the last theoretical improvement in a right-market mechanism is greater than its benefits.

Evaluation of potential of options

This case study has highlighted a range of opportunities to use right-based markets to reduce groundwater pollution in the lower south-east of South Australia. Significantly, the study begins by observing that a right-based market structure is already in place. Whilst this has probably slowed the emergence of groundwater salinity problems, it has not stopped them. Moreover, the existing system has not been used to control nitrate pollution. Whilst considerable analysis would be required to estimate the rate at which the options put forward would improve groundwater use, it is clear that mechanisms exist to do this.

A key consideration is the cost of introducing a system of the sort outlined above. As part of its new Water Management Act, however, the South Australian Government has already committed itself to the introduction of conditional water-right systems to this area. Consequently, the marginal cost of adding the above features onto the existing framework are not great. We estimate that an additional two to four people would need to be employed in the area during the transition period when the new system is evaluated, negotiated with landholders and introduced. Even if implemented immediately, however, the gains from a conditional groundwater-use right system would be relatively slow to materialise as it will take a long time before significant quantities of salt and nitrate to move through the system. Nevertheless, the opportunities identified offer a powerful means to bring landuse and wateruse throughout much of the south-east of South Australia within sustainable limits. The problem would stop getting worse.

Acknowledgment

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Groundwater and pollution in Venus Bay, Victoria

Overview of the extent of the problem

Physical situation

Venus Bay is a coastal holiday town on the South Gippsland Coast of Victoria. The town has 512 houses located on standard quarter acre block sizes (with a typical width of 16 m. There is a permanent population of 120 and a summer population of about 3,000 people.

Venus Bay does not have a reticulated water supply or a reticulated sewage system. This has led to dependence on rainwater and groundwater for domestic water supply and septic tanks for sewage disposal. There are 800 registered stock and domestic (S & D) bores, and it is estimated that there are, at least, 200 unregistered bores.[39] These bores tap a shallow sand aquifer, principally of aeolian origin.

Causes of the problem

The sandy nature of the sediments underlying the Venus Bay area result in little scope for attenuation of the seepage from septic tanks, before leaching to the groundwater occurs. Amongst other things, this means that movement of bacteria and other pollutants like nitrate and phosphate from a septic tank to a local groundwater source can be quite rapid. In many cases, an attempt to maintain water quality is made by separating the bore and septic tank. Often, the bore is in the front yard, while the septic tank is in the back yard. By doing this, it is hoped that any bacteria leaving the septic tank will die before they reach the bore. Bacterial contamination is aggravated by groundwater pumping which leaves a 'cone' which is quickly filled in by surrounding groundwater. High levels of bacteria contamination[40] are routinely recorded and nitrate concentrations of up to four times World Health Organisation levels have been recorded in many of the 22 observation bores. In recognition of the extent of ground water contamination, the local council has issued warnings to all landholders not to use the groundwater for in-house purposes.

Future growth scenarios

There are no accurate estimates for population growth in Venus Bay. Typically, planners assume growth rates for eastern rural Victoria of 1.5% per annum. It is postulated, however, that seaside holiday towns within a moderate distance from Melbourne, like Venus Bay, could be expected to grow more rapidly. In addition, in terms of number of persons per household per year (and hence sewage loading) it can be expected that a significant number of current owners of holiday homes established through the 1960s to 1980s will retire to Venus Bay. Hence, a growth rate of people in Venus Bay of 2.5% per annum is assumed for the purposes of this case study. At this rate, the town's permanent resident population will double to 240 by the year 2020. Similarly, the summer resident population will increase from 3,000 to 6,000 but this would only be possible if the housing stock doubled. If this occurs, however, demand on groundwater both as a domestic water source and as a way to dispose of nutrients can be expected to double too. The latter—doubling of nutrient loads with associated bacterial loadings—is not likely to be acceptable to people living in the area.

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39. Sinclair, Knight Merz (1997), Venus Bay and Sandy Point Groundwater Investigations: draft management options report. Sinclair Knight Merz, Armadale.
40. *E. coli*, Total coliforms, faecal streptococci, plate count.

Technical solutions

Essentially the technical challenge is to find a way to separate groundwater extraction from sewage effluent so that conjunctive use of the aquifer is not necessary. Apart from systems that keep sewage out of groundwater, the other approach is to locate septic tanks at least 15 m from domestic groundwater supply bores and make them as effective as possible. This requirement has frequently been ignored in the past. Maximising the spacing between tanks and bores is the essential objective. But 15 m is seen as an absolute minimum[41] and is generally assumed to be inadequate. A spacing of, at least, 30 m is really a desirable goal and should be seen as minimum acceptable practice. Experience, principally from the United States (Hydro Technology, 1993), indicates that when septic tank densities exceed 15 tanks per km^2, groundwater pollution problems are possible. This density equates to approximately 0.1 tanks per quarter acre block. However, the 'trigger' density is highly dependent on soil type and many other variables.

Essentially, and assuming that the goal is to reduce groundwater pollution, there are four technical solutions to the problem. An alternative option that is outside our terms of reference is to sacrifice groundwater quality and, either, decommission a large number of bores or build a town water supply system using water pumped in from an area where the groundwater water supply is protected.

Technical solution 1—Reticulated sewage system

The simplest approach to the resolution of Venus Bay's groundwater pollution problem is to install a reticulated sewage system so that no more effluent reaches the aquifer. Once that has occurred, presumably, it would not be long until the groundwater bacteria contamination problem is resolved. Significant reductions in nitrate and phosphate pollutants would take longer but, within a relative short period of time, fresh conditions would be re-established.

There is a catch, however. Installation of a reticulated sewage system has been estimated to cost in the vicinity of $8–16 million which would have to be funded by a significant increase in property rates. Moreover, the nature of effluent flows in Venus Bay would pose additional problems. The transient nature of the population would result in substantial variations in the volume of effluent generated which means that the treatment plant would have high management costs.

In addition, pursuit of the reticulated sewage option is likely to be resisted by landholders due to both the increased charges that will inevitably follow and the small short-term benefit to most of the residents who spend very little time in the town. Most summer residents would prefer to rely on rain or bottled water for drinking purposes. A public health issue, especially for young children playing with hoses and taking baths, would remain.

Technical solution 2—Run a pump-out scheme

The replacement of existing septic tanks with fully contained storage tanks which are regularly pumped out. Selection of the tanks to be replaced with a pump-out system would be based primarily on spacing rules. It is estimated that a typical 'once off' pump-out cost is $160 per time. As part of a well planned systematic program involving a large number of tanks, the cost would be significantly reduced. Estimates as low as $20 per tank per time have been provided. The cost of installing a pump-out tank is estimated to be in the vicinity of $500 to $1,000. To be effective, at least every second septic tank would need to be replaced with a pump-out facility. Equity requirements suggest that the costs of doing this should be shared between *all* adjoining households. One option, developed later in this case study, is to use right-based mechanisms as a means to force costs to be shared.

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41. Sinclair, Knight Merz (1997), Venus Bay and Sandy Point Groundwater Investigations: draft management options report. Sinclair Knight Merz, Armadale.

Technical solution 3—Improve the efficiency of existing septic systems

This option is based on the assumption that many septic tanks within Venus Bay operate below optimum levels. Septic tanks require regular maintenance to remove scum build-up which reduces their efficiency. The objective of this approach is to upgrade the efficiency of the septic systems to a point where the septic systems provide effective treatment of waste and very few bacteria enter the groundwater. This will result in minimisation of the impacts of septic tank seepage on the aquifers. Operationalising this strategy and enforcing it could prove difficult. Moreover, it would require replacement of a significant number of substandard tanks which where installed when standards where much lower. Whilst some improvement is possible, we do not see a program designed to increase the effectiveness of each tank as a dependable long-term solution. Nevertheless, as part of a wider strategy, the option has merit.

Technical solution 4—Establish communal septic tanks

An alternative means of reducing the concentration of septic tanks is to install communal tanks which connect several houses together. Tank capacity would need to be increased, but the cost of installation is likely to be less than installation of a number of separate systems. We estimate that three houses could be connected to a single tank for less than $6,000. While total effluent volume will be similar, the localisation of the source will allow for greater separation between the tank and extraction bores. Installation of modern tanks would also simplify the maintenance requirements set out in Technical Solution 3. Once again, the cost of doing this would need to be spread between all households.

These options are most applicable to new developments rather than existing ones. The block size of new developments could also be controlled by the introduction of maximum septic tank densities. If proposed block size cannot meet the requirements, blocks would need to be enlarged or alternative waste disposal methods employed. Large septic tank systems can be installed for under $5,000 per tank which means that all 512 houses in Venus Bay could be connected for less than 512/3*$5,000= $853,000. This is significantly cheaper than the reticulated sewage option outlined above.

Right-based options

The challenge for this case study is to examine the opportunity to use right-based market instruments as a means to assist in implementing one or more of the technical solutions set out above.

Essentially, there are three market-based options for the resolution of groundwater pollution problems found in Venus Bay. The first option is to use an offset program so that growth in the housing stock pays for clean-up and stops the situation from getting worse. The second is the introduction of a tradeable emission-right system while the third is a quasi-tradeable emission-right system that mimics the main features of this latter option without incurring its full set-up costs. We call it a quasi-emission-right scheme because, in this case, it is possible to achieve an outcome similar to that achievable for Venus Bay at less cost than that achievable under a fully fledged scheme.

Right-market option 1—An emission-offset scheme

Under an offset scheme, the number of septic tanks in Venus Bay would be capped and builders informed that housing approvals would be limited to those proposals that either:

1. do not use septic tanks at all; or
2. are linked with arrangements that result in a net reduction of at least one septic tank per new house.

In practice, this latter option would mean that developers would have to organise themselves so that in the course of building a new house they must remove two other septic tanks and only locate any new septic tanks in places more than 30 m from all existing bores. In practice, the cheapest way to do this would be to locate a new house between two existing houses and connect all houses to a communal tank. Some bores may have to be decommissioned. Where this is not possible, a developer could pay for the cost of connecting other houses together or connecting them to a pump-out service. Either way, the council need not be involved in financing the solution. But, by requiring all people wishing to increase aquifer load to first reduce that load, the Council would gradually solve the problem.

While such schemes have been used to reduce fishing quotas and other similar systems, under an offset scheme, the rate of improvement in groundwater quality at Venus Bay could be quite slow and financed by growth. Even if the town's housing stock grows at 2.5% per annum, it would take nearly ten years to reduce the number of septic tanks by 20%. For resolution of the problem, it may be necessary to reduce the number of septic tanks in Venus Bay by as much as 50% which, under the most optimistic growth scenarios, could not be achieved before 2020. Moreover, at the end of this period, localised problems would still remain. The system would still leave some blocks with bores too close to a septic tank.

Under the offset option, progress would be faster if all building approvals, including renovations, were made conditional upon a 30 m separation of any septic tank on the block from all surrounding bores. In such circumstances, neighbours would be forced to privately negotiate solutions to their public health problem. Considerable backlash from the building industry could be expected as this action would be seen as a tax on and a barrier to economic development.

Right-market option 2—A tradeable emission-right system

An alternative approach is to introduce a tradeable emission-right system. Under such a system, the total number of septic tanks in Venus Bay would be capped and each house given a proportional share of that capacity. A periodically-revised management plan would then be used to define the minimum number of shares required to use a septic tank at various distances from a bore.

Spatial separation rules would be introduced and the closer the tank to a bore, the greater the number of shares required. One septic tank share might be required for a tank that is 30 m from all bores; two shares for a distance of 20 m; four shares for a distance of 15 m and ten shares for a distance of less than 10 m.[42] Initially, shares would be allocated to mimic existing arrangements but once allocated, the number of shares required to use 'sub-standard' tanks would be increased. Those who have the worst separation problem have the greatest incentive to remove a tank or a bore.

To speed up the rate of adoption of the new regime, to educate all people of its importance and lower the cost of administering the system a 'zero revenue tender process'[43] could be introduced. A zero revenue tender is a system whereby every year 5% of each person's share is put up for tender. Each person then sets a reserve price and if someone offers more than this price then the shares transfer to that person and the original person receives a cheque equivalent to the price paid for the shares. Those people who do not own sufficient shares for their septic tank would be required to pay a levy equivalent to, say, two times the number of shares necessary to regularise their share holding. People would be free to decommission bores in order to reduce the number of shares they would need to have.

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42. The actual conversion rates would need to be modelled carefully.
43. In air pollution markets in the United States of America, this mechanism is known as a zero-revenue auction. They are called zero-revenue auctions because the administering authority receives "zero" revenue from the transaction.

Those who decommission their septic tank and convert to a pump-out facility or a communal septic tank could sell their shares to those who need more shares to enable them to continue to use their septic tanks. New bores would only be allowed at locations that are more than 30 m from an existing tank.

The result is the rapid emergence of a mature market for septic tank rights and an environment where each person has an incentive to reduce the impact of their emission on the environment. Those who hold insufficient shares for a septic tank would be required to either:

- organise to buy shares from someone else;
- pay the non-compliance levy; or
- sign a statutory declaration indicating that their house will not be occupied until they hold sufficient shares to live in it.

Theoretically, and before administrative costs, such a scheme would bring about the rapid separation of septic tanks from groundwater bores. A dramatic and rapid improvement in groundwater quality would occur across the entire town. Each householder would be given a strong economic incentive to reduce their and their neighbour's impact on groundwater quality. Neighbours would be encouraged to negotiate fair and equitable solutions to a common problem. The catch, however, is that it could be quite difficult to do so. Conceptually, the cost to the community should be in the vicinity of the most favourable technical solution of about $5,000 per three house system which would translate into a total cost of 314*$5,000/3=$523,000 plus administrative costs.

The question that we would now like to ask is: "Is there a cheaper or administratively simpler solution?".

Right-market option 3—A quasi-tradeable emission-right scheme

The main characteristics of right-market systems that differentiate them from standard levy and charge systems are that:

1. Right-market systems guarantee that direct payments are made to those people who act to reduce the problem. The concept is one of reward for action. Thus, in the tradeable emission-right system set out above, if one person wants to keep their septic tank and three other people are prepared to install a communal pump-out scheme, then the person who retains a septic tank connection has to buy shares from the people who convert to a communal pump-out facility. Those who put in the communal pump-out facility receive a direct payment in return for the shares they sell and this money substantially reduces the expense of installing the facility and may even make it profitable.

2. Right systems force attainment of the water quality goal sought at least cost and in a manner that encourages individual people and industry to find efficient solutions. In the above case, it is not difficult to imagine a host of private sewage treatment firms advertising and brokering cost-effective solutions.

Conceptually, it is possible to design a levy system that mimics the main feature of a tradeable emission-right system and, because it is simpler, is administered at lower cost. Strictly, a levy system is not a right-based system but if designed so that all the money collected passes to those people who make the change, then it could be described as a quasi-tradeable emission-right system. The system would begin by establishing the number of septic tanks to be removed from Venus Bay (we assume 314) and then levying all people who have septic tanks within 30 m of a domestic bore. The money raised would then be used to subsidise those who pay for the cost of separating domestic bores from septic tanks. People would have the choice of paying the levy or upgrading to a system that achieves, say, a 30 m or greater separation.

To speed the transition, those who upgrade in the first year might receive a higher payment than those who move more slowly. Pragmatically, those who remove a septic tank in either of the first two years might receive a cheque for $2,500, while those who make the change in year three or four might only receive a cheque for $1,500.

Both the levy and upgrade payments would continue until all septic tanks have achieved spatial separation of at least 30 m from all domestic groundwater bores. If 314 septic tanks are to be removed, under this system the total cost of the payments made would be in the vicinity of 314*($(2,500+1,500)/2)=$680,000 plus administrative costs. While this system would not create as strong an incentive for the emergence of innovative solutions, it would be much simpler to administer and hence may, when total costs are considered, be cheaper.

Evaluation

Of the three market-based options considered, clearly the tradeable emission-right option is the one that, in association with a well-controlled system to control the introduction of new bores, has the most potential to continually improve groundwater quality in the Venus Bay area. It does this by placing the greatest pressure on those people whose tanks are closest to bores and gives them a strong incentive to either decommission a bore or septic tank. The main attraction of the system is its relatively low cost and its capacity to encourage each person to find the most cost-effective solution to their local problem. The main problem with the system is the difficulty in explaining such an innovative system to a group of landholders who own but rarely occupy their house in Venus Bay. This problem, however, could be handled by giving people the choice between all three right-based options backgrounded against the extremely expensive alternative of a fully fledged sewage treatment system.

The main advantage of the fully tradeable emission-right system is that it encourages continuous adjustment and gives people an incentive to develop innovative solutions. Close evaluation, however, may reveal that a quasi-tradeable-right system may be easier to administer and to gain political acceptance for. Moreover, it may be more effective if all people receive a similar payment and, hence, neighbours do not have to negotiate a 'fair' solution in the absence of some basic principles. Both mechanisms could achieve similar outcomes but the quasi-right option is easier to understand.

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Groundwater and pollution in the Upper Namoi region of NSW

Introduction

The Upper Namoi Valley is a large alluvial filled valley in north central New South Wales. Both groundwater and surface water resources are used extensively for a broad range of agricultural enterprises. A volumetric allocation scheme was introduced in 1985 to control groundwater use in the Valley. Since then, groundwater levels have continued to decline over most of the valley and a significantly changed management plan is currently under discussion. This new plan is aimed at reducing usage to a sustainable rate. Running in parallel to this quantity focused plan are concerns about groundwater quality deterioration, due principally to pesticide use, but also possibly due to lateral migration of poor quality groundwater into adjacent fresher groundwater resources. This case study is concerned with the right-based options to address these groundwater quality issues. It differs from the other case studies in two important ways. First, existing groundwater irrigation-rights are allocated on a volumetric basis without restriction as to which crop can be grown. Second, groundwater use is often on a conjunctive basis with a significant proportion of irrigators using both surface water and groundwater for irrigation.

Hydrogeological setting

The following description is based on the DLWC (1977) Interim Groundwater Management Plan.

The climate of the area can be characterised as semi-arid with moderately low rainfall. Summers are hot to very hot while winters are cool. The driest period is during April and May with the wettest period from December to February and a secondary wet period in June/July. Annual rainfall average on the valley plains is 609 mm. Several major periods of droughts and floods have been recorded in the last few decades.

The unconsolidated sediments associated with the Namoi and Mooki Rivers and Coxs Creek form the aquifer system of the Upper Namoi Valley. The alluvial sediments consist predominantly of sand, gravel and clay and their thickness is largely controlled by the bedrock topography and by a major fault system which runs along the eastern side of the Mooki Valley. To the west of the fault, in the Mooki and Namoi Valleys, alluvial thickness is in excess of 170 m. The total area of alluvium is in the order of 2,945 km2. The main palaeo-channel is generally limited to the central portions of the valley and in most cases does not follow the present drainage lines.

Groundwater is located in two main alluvial formations that occur throughout the Upper Namoi Valley.

The Narrabri Formation consists predominantly of clay, sand and gravel and conformably overlies the Gunnedah Formation. It represents the shallow aquifer in the valley and ranges in thickness from 10 to 40 m, although it can reach 90 m in its greatest thickness. Water from the formation has a variable salinity from 200 mg/L TDS up to 22,400 mg/L. Bore yields range from 0.5 to 40 L/s.

The Gunnedah Formation underlies the Narrabri Formation and consists of moderately well-sorted sand and gravel interbedded with clay. It rests on solid bedrock and forms the deep aquifer in the valley. Basement is located usually between 60 and 140 m below the surface although depths in excess of 170 m have been recorded. It consists of well-sorted sand and gravel with bore yields up to 200 L/s. Salinity is generally low being less than 1,000 mg/L TDS over most of the area.

The main aquifer zone currently being pumped by the high-yield irrigation bores is the deeper Gunnedah Formation. Most stock and domestic bores within the valley are abstracting water from the shallower Narrabri Formation at maximum depths of about 25 m.

Approximately 875 high-yield irrigation bore licences have been issued to 450 properties which are widely distributed throughout the valley, although there are areas where bores are concentrated.

Natural recharge of the alluvial system is predominantly from stream and river flow and flooding associated with the Namoi River and its tributaries, with less amounts from rainfall and upward leakage of groundwater from the underlying rocks. Recharge from irrigation water or surface storages is minimal compared to the other sources primarily due to efficient irrigation practices and low infiltration soil types.

Groundwater level and usage trends

Currently in the whole of the Upper Namoi Valley, 253,000 ML per year of groundwater is allocated in a year of full surface water allocations and 269,000 ML per year in a year of zero surface water allocation. Annual usage during normal rainfall years between 1985/86 and 1992/93 has averaged 63,000 ML per year for the whole valley although in 1993/94 this rose to 109,368 ML and was 163,441 ML in 1994/95.

Overall, the groundwater levels in both the Narrabri and Gunnedah Formations show relatively small declines on an annual basis. However, the long-term declining trend and lack of significant recovery during the winter off-irrigation period is of concern indicating that the resource is over-allocated. The decline is the result of intensive irrigation, particularly during the summer months, followed by only partial recovery during the winter months.

Monitoring of water levels indicate quite clearly that, whilst there is sufficient groundwater available in the deeper aquifer systems, the main problem of concern is the progressively reduced access to the water by the shallow bores and wells as the levels continue to decline. The entire Upper Namoi Valley is divided into ten zones. Most zones show a clear decline in groundwater level, although some show an increase in water level. In some areas, new irrigation development, combined with the drought conditions, has caused large drawdowns to occur to the extent that yields from some shallower stock and domestic bores and wells is declining. Some town water supplies are also being effected.

The problem of access has been addressed through the Stock and Domestic Bore Deepening Program which provided a 2/3 subsidy to landholders to deepen their existing shallow bores and wells or to construct new, deeper bores so that access can be maintained, even with the larger drawdowns.

Groundwater quantity management

The prime goal of the new Management Plan is to achieve long-term sustainability of the resource whilst recognising the need to maintain and improve equity of access to shallow stock and domestic bores and wells, and town water supplies. To date, however, there has not been any close linkage between groundwater quantity and quality issues. In the Interim Groundwater Management Plan it is proposed to proceed in two stages:

1. the first stage is to reduce the groundwater component of surface water/groundwater conjunctive allocations by a change to the conjunctive scale; and
2. the second stage will involve an annually announced groundwater allocation for each property as a percentage of their base allocation.

Permanent transfers of groundwater allocation were introduced in the Namoi Valley in 1995/96 as an interim measure. They have now ceased for 1996/97.

Groundwater quality trends

Associated with the expansion of irrigated agriculture, especially cotton, since the 1960s, there has been a large increase in pesticide applications. In response to concerns of groundwater and surface water pollution, in 1991 the Department of Land and Water Conservation initiated a study of possible pesticide pollution of groundwater in the Namoi Valley. In the Upper Namoi Valley, from a total of 62 samples collected from the shallow aquifers during 1992/93, five sites recorded detectable levels of the herbicide atrazine. Sampling in other areas of the Namoi Valley produced similar results. The highest level recorded was 5 µg/L which is still well below the Australian drinking water guideline of 20 µg/L. (The USA guideline, however, is 3 µg/L.) The monitoring bores were sampled annually. No monitoring of the deeper aquifers occurs.

Atrazine is used to kill broad leaf weeds associated with many crops. It is also used to kill grasses along irrigation channels (often associated with cotton production). Atrazine is highly soluble. The presence of any level of pesticides in drinking water is undesirable. The groundwater resources of the Upper Namoi Valley are extensively used as a water supply for many towns and farms. The presence of any pesticides indicates the need for the development of a strategy to control their use and hence eliminate groundwater pollution.

Note that the cotton industry is paying a water quality monitoring levy of 20 cents per ML of entitlement.

Lateral migration of saline water

It is well known that there is poor quality groundwater (ie. high salinity levels) along the fringes of the alluvial sequence and also at intermediate depths (about 30 m deep). Recent monitoring (G. Gates, pers. comm.) has indicated in some bores a two or three-fold increase to TDS levels from approximately 400 mg/L to 800 mg/L and at some locations up to 1,200 mg/L. It appears that lateral migration of this poor quality adjacent groundwater into the better quality useable resources is occurring.

As good quality groundwater is pumped, the pressure or water level decline in the vicinity of the pumping bore causes a flow of laterally or vertically adjacent groundwater into the influence of the pumping bore. If this adjacent water is of poorer quality, this is obviously reflected in the quality of the water pumped. This process is well understood and has been observed in many places around Australia.

Technical solutions in relation to pesticides

A range of options are available to control groundwater pollution due to pesticides in the Upper Namoi Valley.

Technical solution 1—Ban use of pesticides found in groundwater

The main pesticide found in groundwater is atrazine which is used as a herbicide. It is understood that there are not readily available and effective alternatives to atrazine. Hence, a ban on atrazine (and other pesticides) could have a significant economic impact on users.

Technical solution 2—Improve management practices

Defining an acceptable application rate for various pesticides, such that groundwater pollution does not occur, is technically difficult as it is a function of a large number of variables. In addition, ensuring that good management practices are adhered to is also difficult. Nonetheless, community education and good technical understanding are required, regardless of whatever other strategies are adopted. The principal goal with this approach is to reduce use of atrazine. Defining what level of use is acceptable, however, is difficult.

Technical solution 3—Move pesticide use to low impact areas

Atrazine use is essentially linked with irrigation activities. Relatively little atrazine (less than 10%) is used in dryland farming practices. Hence, to identify which irrigation farming areas are less susceptible to groundwater pollution from atrazine is an initial requirement. Vulnerability mapping could be undertaken to define these areas. However, it is unknown at this time whether there are, in practice, significant 'low impact areas'. Also, this option would involve significant social and economic disruption if atrazine use was banned or reduced in high impact areas (assuming they can be defined). Another assumption, which may not be valid, is that groundwater and surface water availability is inversely related to aquifer vulnerability, ie. where water resources are available there are significant low impact areas. Significant technical work would be required to assess the above factors and hence identify low impact areas.

Technical solutions in relation to lateral migration

Groundwater salinity increase due to lateral migration is intimately linked to groundwater allocations and usage. The 'sustainable yield' of an aquifer has historically been defined in quantity terms. In recent years, it has begun to be appreciated that, in certain circumstances, quality may be the controlling factor. In these cases, the sustainable yield may well be significantly lower to stop, or at least reduce, salinity increase. Hence, to reduce groundwater use several technical options may be considered.

Technical solution 4—Reduce allocations in certain areas

The proposed Interim Groundwater Management Plan is aimed at reducing allocations to sustainable levels in certain areas. To allow for salinity changes, two fundamental changes to the plan would be required:

- new zones would need to be defined and declared which would be based on where salinity increases have been observed and where they might be observed in the future; and
- reduced allocations would need to be calculated based upon a rigorous technical understanding of 'quality controlled sustainable yields'.

An important part of the reduced allocations approach would be to reduce the 'density' of high usage in certain key areas.

Technical solution 5—Counter pumping options

It is technically feasible to install 'scavenger' pumps to reduce groundwater pressures near existing production bores and hence stop lateral migration. This, however, is rarely economic and practical. This option is not considered viable.

The first action, ie. reducing allocations in certain areas, is the only feasible technical option. How it might be introduced is, however, complicated. It is far more feasible to consider introducing this option in a right-market context than in a conventional allocation context.

Right-market options

The main right-market options in the Namoi Region are ones that seek to facilitate the technical solutions identified above.

Right-market option 1—Introduce secure groundwater shares

Under present arrangements, all users of groundwater and all users of water from regulated streams in the Upper Namoi have volumetric allocations which can be varied from year to year. The main opportunity for improvement lies in steps to improve the effectiveness of this system. The first option is to increase stewardship incentives by making the rights more secure, making them tradeable and giving a significant role to shareholders in the development of groundwater management plans for the Upper Namoi Valley.

This would be achieved by giving each existing licensee a set of groundwater shares that would formally define their entitlement to a proportion of the groundwater in the region available for consumptive use. Initially, 100 shares might entitle a person to extract 1 ML of groundwater per annum but that entitlement could vary in response to changes in climate. If a run of droughts or wet years occurred, each person's share would stay the same but their entitlement to take water in any one year would vary. Unlike existing rights, these shares would be fully tradeable and mortgageable. Restrictions on the maximum volume of water that could be pumped per area of land owned would be used to prevent salinity problems induced by lateral migration, but wherever that occurred, any person who had too many shares would be free to sell them to another area.

The framework could be improved further by establishing similar rights for surface water entitlements so that the entire water resource in the Upper Namoi is managed as a single integrated resource. People who could make profitable use of groundwater would then be able to sell surface water shares and rely entirely on groundwater and vice versa. Conceptually, it would even be possible for people to pump groundwater into a stream and sell this groundwater to a person who normally only has access to surface water.

Right-market option 2—Make the final management plan for the Upper Namoi a periodically reviewed document that defines the relationship between shares and entitlements in each zone and, also, defines the obligations that attach to these entitlements

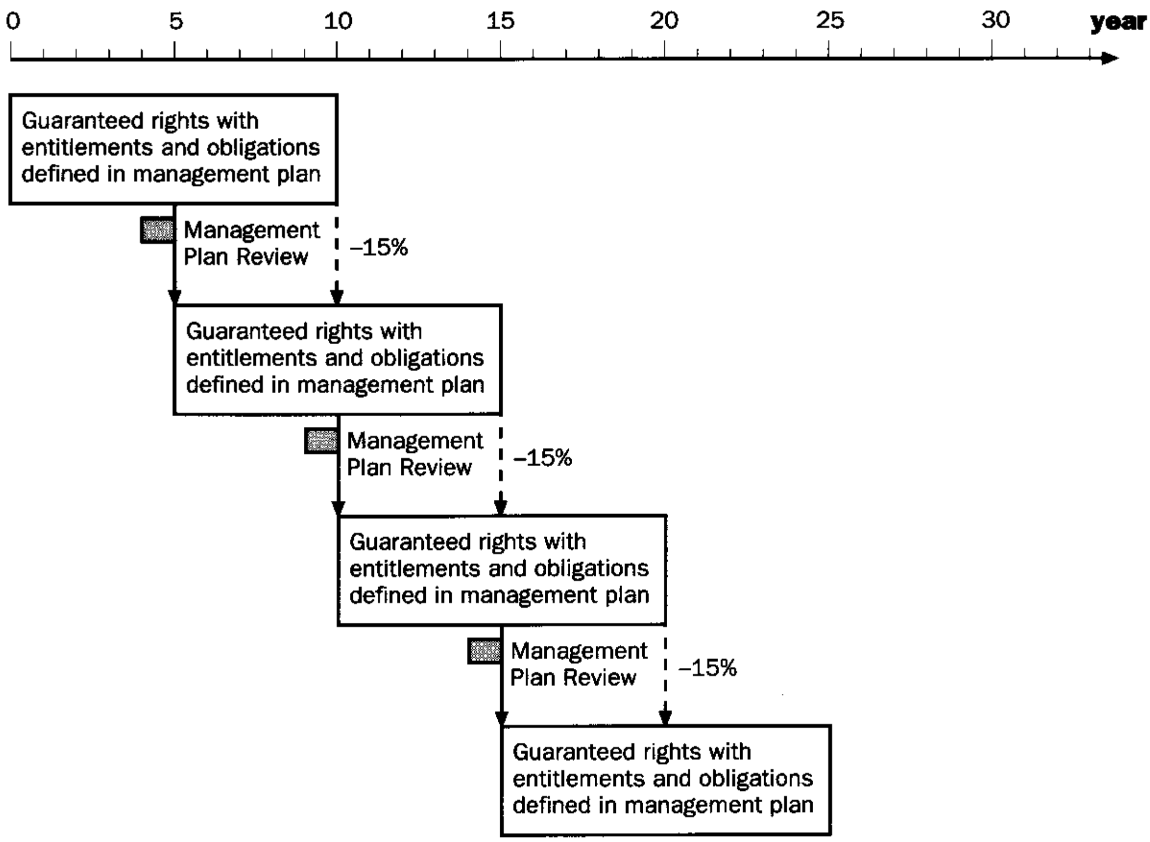
This option builds on the first and proposes the use of a periodically reviewed management plan as the means to define the entitlements and opportunities that attach to a groundwater shareholding in a manner that encourages adaptive management. Building on the five year timeframe proposed in the Interim Management Plan for the Upper Namoi, the review period would be every five years. But shares would be issued on a ten years basis. After five years and following completion of the Management Plan review, each shareholder would be guaranteed the opportunity to convert their existing shares into a new set of shares that would require that person to comply with all the arrangements and conditions set out in the new Management Plan. Those who find the new set of conditions unacceptable would be free to choose to remain under the old management plant until they expire. As illustrated in Figure 3, on expiry, 15% of these shares would be surrendered and 85% of them converted into shares subject to the conditions of the next management plan. The reason for this arrangement is counter intuitive. Because it would be politically unacceptable for the majority of shareholders not to accept the conditions set out in the new plan, this arrangement forces any adverse arrangements to be phased in. The arrangement also forces the periodic review to be conducted regularly rather than being delayed until "it is needed and fits in with the political agenda of the current Minister for Water Resources". Experience with perpetual-right mechanisms has revealed that the resultant delays eventually result in the collapse of the entire system. Finally, such an arrangement forces administrators to think strategically about water management in the Upper Namoi and to do so in a transparent manner.

At each review, the main issues to be explored would be the effects of current irrigation practices on groundwater quality. If lateral migration of saline water, for example, is a problem, then water extraction per hectare in that area (zone) might be capped, and people encouraged to sell shares to those in other zones where the groundwater could be used. As a result, people disadvantaged by the decision to phase in this requirement would be compensated.

Right-market option 3—Build in biases in the range of entitlements and obligations with a view to reducing pesticide use and lateral migration

At the outset, we would like to observe that, as far as we can tell, and given the extent of pesticide contamination of groundwater in the Upper Namoi Valley, there is little point in using right-market instruments to control pesticide use. If the aim is to stop contamination from atrazine then the most cost-effective strategy is to ban its use. Nevertheless, should such a problem emerge at some stage in the future, the adaptive framework set out above would enable use of a pesticide, or even planting of a certain crop type, to be prohibited. This highlights the flexibility of the recommended management system.

Figure 3
A tradeable groundwater share system incorporating periodic reviews with an arrangement to protect shareholders from sudden adverse variations in the entitlements that attach to each share.



Right-market option 4—Establish a fund to reimburse people for the cost of planting trees and taking other measures to stop increases in groundwater salinity

One of the biggest issues in the Upper Namoi is the need to find a cost-effective means to control dryland salinity. One of the main means to do this is to plant trees and generally revegetate large areas. One option would be to establish a tradeable emission-right system that would require people to obtain a permit to allow water to flow through to an aquifer. Operationally, the surrogate measure for this would be a permit to have cleared land. Shares in rights to cleared land would be issued and the total area that could be held would be reduced over time until dryland salinity is brought under control. Those who did not hold sufficient shares for the area of land they had cleared would be required to pay a levy that would be used to offset the problems that they cause. Although conceptually it is possible to design such a system, it is our judgement that such a system would prove to be politically unacceptable.

One more pragmatic alternative, however, is to give local catchment committees the power to levy landholders in the area in proportion to the area of cleared land that they own and then use this money to pay people to enter into 'dryland salinity control agreements'. These agreements would be in perpetuity and require any such area to remain covered with trees in perpetuity. All further clearing in the area would be prohibited unless that clearance is offset by someone entering into a dryland salinity control agreement elsewhere. Subject to controls on spatial distribution, it could also be possible to trade dryland salinity control agreements.

Evaluation

This case study has briefly summarised the essential elements of a tradeable groundwater right system that uses a management plan as a means to define entitlements to use water in any locations and the conditions or obligations associated with these entitlements. Given that management plans are already required and that there is a government commitment to introduce secure rights for water, the marginal costs of implementing the above framework are minimal. Consequently, the only issue is one of feasibility. For maximum value, the framework proposed would need to be mimicked by a similar set of arrangements for surface water. It is clear, however, that the mechanism proposed provides an equitable means to reduce wateruse in areas where it is causing diffuse groundwater salinity problems and, also, to control other problems as they emerge in an equitable and efficient manner.

The option of establishing a local fund to help alleviate dryland salinity problems is a very attractive alternative worthy of serious consideration. A key element in the design of such a fund is that it should mimic, as closely as possible, the features of a tradeable emission right system. These are that people should pay in proportion to the extent of their contribution to the problem and that those who reduce emissions should receive payments from those who continue to make them.

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