Tradable recharge rights in Coleambally Irrigation Area [#]

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Abstract

Irrigated agriculture in Australia often leads to recharge of shared groundwater systems causing saline shallow watertables and soil salinity. In turn, these biophysical impacts impose costs, including reduced agricultural productivity, damage to ecosystems and degradation of local and off-site infrastructure, on irrigators and other members of the community. To the extent these costs are external to landowners they are not fully included in their farm management decisions.

This paper will report on our progress in developing a pilot market-based instrument to test a trading mechanism to internalise externality costs associated with recharge to shared groundwater systems. The paper will discuss the issues faced by the community in developing such a scheme and consider a preliminary instrument framework. These issues include:

- how to define, measure and allocate spatially variable irrigator recharge responsibilities?
- what institutional and organisational infrastructure must be developed including property right instruments as well as monitoring and policing?
- what trading and compliance considerations must be incorporated (including the impact of flexibility measures such as banking and borrowing of property rights)? and,
- can an integrated cap and trade model with off-farm offsets be considered?

Keywords: Murrumbidgee Catchment, Coleambally Irrigation Area, cap and trade, offsets, net recharge, irrigation salinity management

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1. Introduction

Irrigation induced salinity is a well known problem in mature irrigation areas across Australia, and the Coleambally Irrigation Area (CIA) is no exception. Recharge occurs because the aggregate water supplied exceeds the evapotranspiration capabilities of irrigated crops and the absorptive capacity of shared aquifers. The salinity and water logging caused by such recharge imposes a range of agricultural production costs on individual landowners, their neighbours and the wider community. Wider ecosystem impacts include water logging of native vegetation, irrigation induced salinity and saline flow interception by natural and irrigation channels, drains and wetlands. The nature of the costs imposed by these ecosystem impacts are primarily reduced agricultural productivity, damage to flora and fauna communities and degradation of built infrastructure both locally and off-site. Because these costs are largely external to irrigators they are not fully included in their management decisions.

A number of instruments have been adopted to address the threat that irrigation induced salinity poses to Coleambally and other communities. These have included:

- regulatory approaches limiting crop areas or water use, for example through restrictions on the area of rice that can be grown by individual landholders;
- development of farm and regional measures of contributions to shared aquifers (for example the concept of net recharge management developed by Shahbaz Khan and colleagues at CSIRO Griffith[1]) and encouraging use of these tools in on-farm management; and,
- direct incentives for landholder management changes, for example through Land and Water Management Plan (LWMP) incentive programs.

Each of these actions has had some success in reducing the incidence of irrigation-induced salinity. However, no strategy to date has been wholly successful in achieving community management targets and protecting future livelihoods.

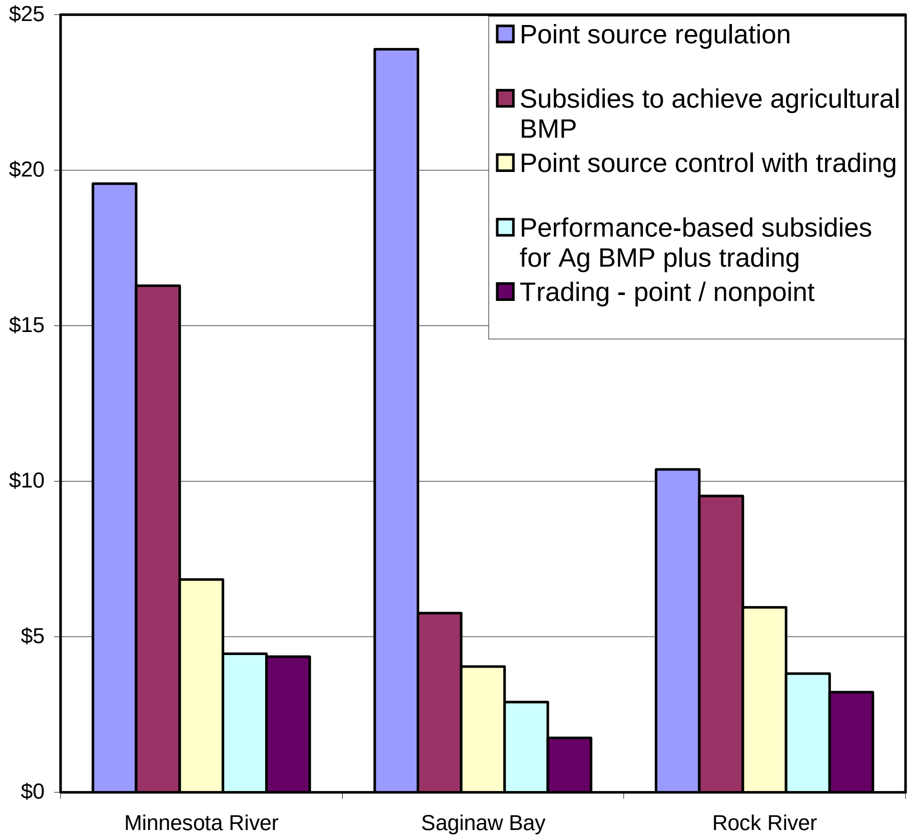
Within this context a tradable rights approach may offer efficiency, effectiveness and flexibility advantages over current and historical instruments. As an example, the potential cost savings associated with nutrient trading versus other policy approaches for three regions in the United States is shown in Figure 1.

An important pre-cursor to further consideration of a market-based net recharge management framework is definition and communication of why such a system may be preferred to alternative management options, how such a system would work and the key implementation issues. The key goal in this paper is identify these issues. In the next section the basic biophysical parameters of the research question are set out by taking an ecosystem services view of the problem and identifying who provides and who benefits from groundwater regulation ecosystem services. A particular focus is the necessary groundwater modelling and movement information as a basis for a market-based net-recharge management tool. Issues surrounding the level of service required are incorporated into the key market design issues that must be addressed in

[1] See for example the article by Shahbaz Khan and Tanya Ginns “Sustainable Irrigation Tools” in the Large Area Edition of the Farmers Newsletter (2003) No. 164, on pages 30 and 31 or CSIRO’s Research Project Sheet No. 11: Irrigation: Getting the balance right by Shahbaz Khan that can be downloaded from: http://www.clw.csiro.au/staff/khans/index.html.

designing a market-based recharge management tool. These design issues are the focus in section three. A summary of the key challenges and strategies for addressing these completes the paper.

Figure 1: Potential cost savings from trading versus alternative mechanisms



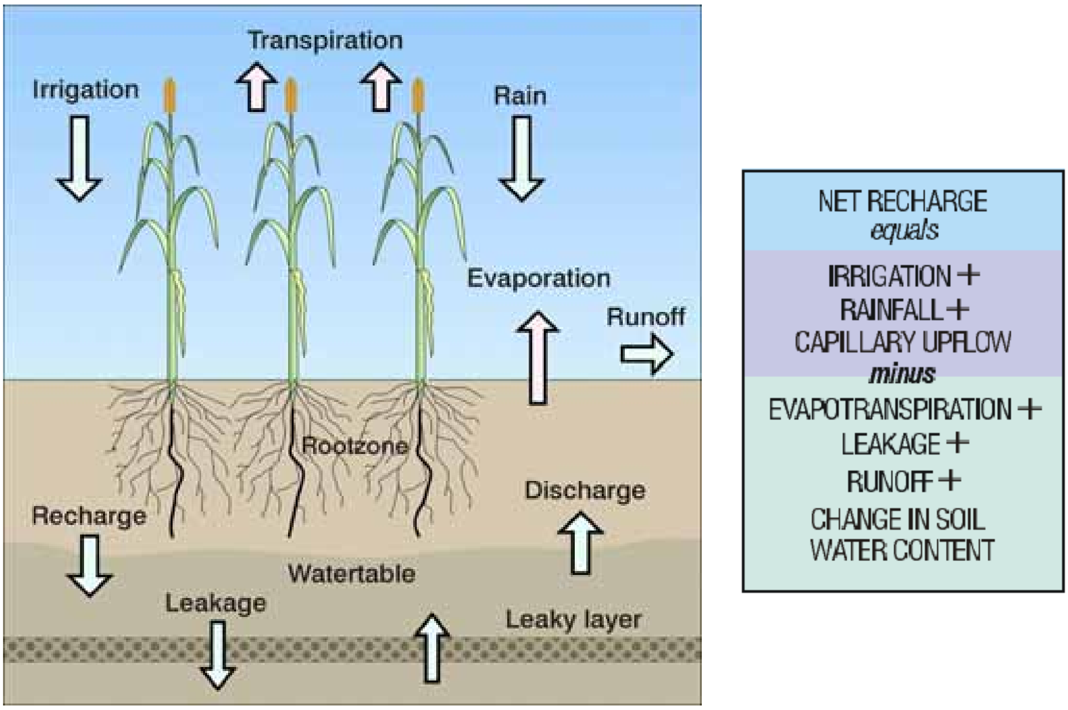
Notes: Costs saved are $US per pound of Phosphorus removed. BMP is 'best management practices'.
Source: Adapted from Faeth (2000) Table 8.

2. Who provides and who benefits from groundwater regulation ecosystem services

In developing a tradable rights approach to managing irrigation induced salinity, the very first question one must consider is which service you care about or, more to the point, which problem you care about and what actions are available to address it. In the case of irrigation-induced salinity, the problem is the damage to agricultural production, ecosystems and infrastructure that results when groundwater regulation ecosystem services begin to fail. Most irrigation communities have set a number of targets for managing the local and regional impacts of recharge reflecting their sustainability goals. The overall goal is to reduce the costs of irrigation induced salinity and waterlogging management to landowners. Catchment management frameworks such as the NSW Blueprints for catchment sustainability provide a wider catchment context for recharge targets.

Linking targets to actions and outcomes is the key to framing effective instruments. In many cases, the shared aquifers under irrigation areas are able to absorb some additional recharge for extremely long periods without waterlogging or salinity resulting. Furthermore, a combination of engineering and management solutions may help to manage and maintain groundwater regulation ecosystem services by reducing net recharge to shared aquifers. Identifying who can provide these services and who would benefit from them is critical to designing an effective tradable rights instrument. Hence, a pre-requisite to managing the beneficial groundwater ecosystem services and mitigation actions is information about the actions that generate or mitigate recharge. This information includes information about crop, soil and groundwater interactions under alternative irrigation management and climate conditions. Information is also required about the impact on the shared aquifer, including where and how long before negative impacts occur.

Figure 2: The net recharge concept



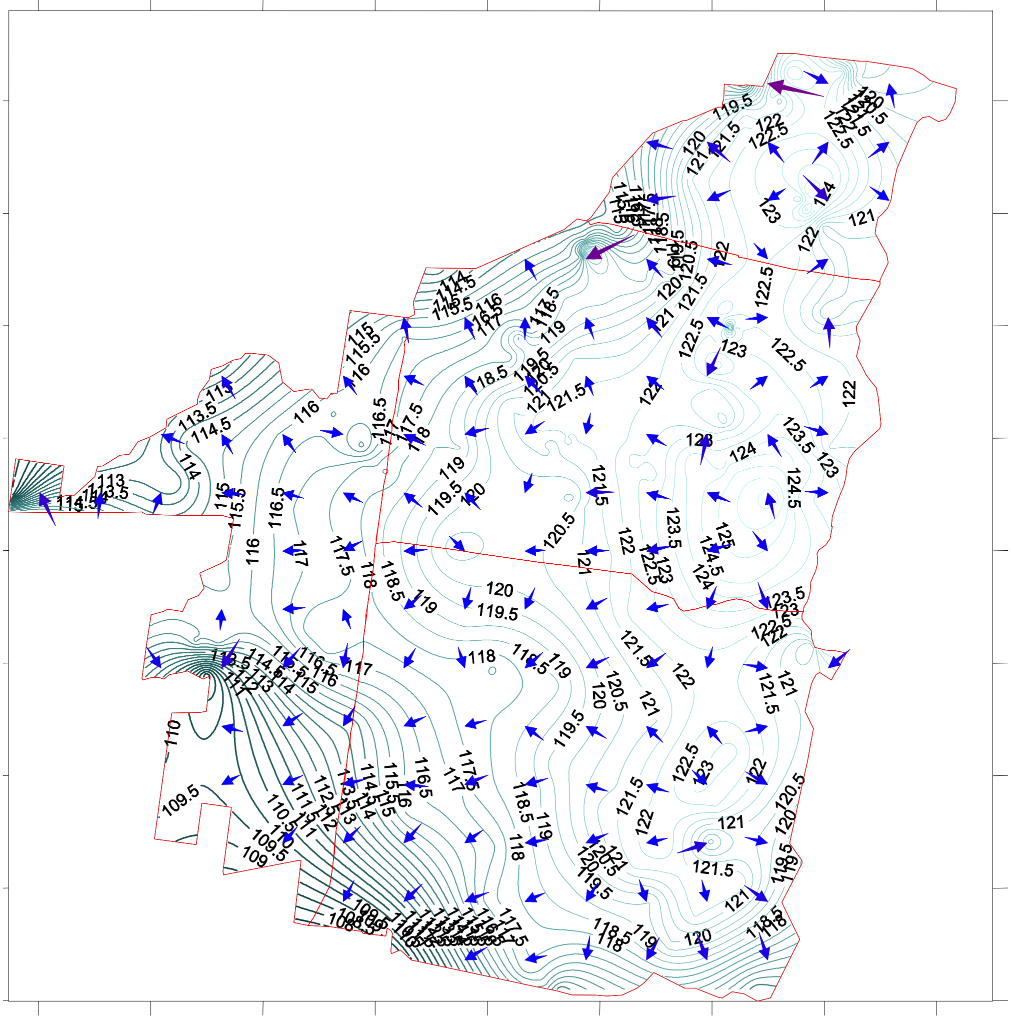
Source: *Khan (no date) CSIRO Research Project Sheet No. 11: Irrigation: Getting the balance right.*

Much of the basic data about soil type, climate conditions and crop-soil-water interactions has already been collected in the Coleambally Irrigation Area (CIA). For example, there are more than 800 shallow and deep piezometers in the CIA that can be used to accurately determine these impacts by measuring lateral groundwater flow and vertical leakage between aquifers. CSIRO Griffith has developed several modelling techniques in the region include a multi-layer groundwater flow and salt transport model and a customised series of models called 'SWAGMAN'®.[2] These tools provide very accurate estimates of regional groundwater recharge on a farm, sub-regional and regional basis as well as the potential impacts of mitigation actions. The SWAGMAN® series of models can be used to model the impacts of irrigation on salt and water movement in landscapes at the farm scale for any soil, crop, irrigation, watertable and climate combinations. Likely off-farm impacts on vegetation and infrastructure can also be identified through the regional groundwater flow and salt

[2] Shahbaz Khan and others at CSIRO Land and Water in Griffith have developed the SWAGMAN® series of models. More information about these models can be found at: http://www.clw.csiro.au/publications/projects/projects22.pdf.

transport models. For example, the basic principles of the net recharge concepts underlying the farm-scale SWAGMAN® model are shown in Figure 2. An example of the type of broad regional scale information needed for groundwater ecosystem services management is shown in Figure 3 using a shallow groundwater elevation map.

Figure 3: Coleambally Shallow Groundwater Elevation (upper Shepparton layer)



Note: Arrows show direction of flow and numbers the groundwater elevation.

The SWAGMAN® series of models allow measurement of the off-farm impacts of on-farm actions. These models facilitate identification of who provides mitigation services and who benefits from groundwater regulation ecosystem services. Therefore local community goals for managing local and regional impacts can be linked to target aggregate recharge rates. In turn, these aggregate recharge targets can be linked to individual irrigation management and impact mitigation decisions at the individual farm or enterprise scale – the key parameter for an effective tradable rights instrument for recharge management.

3. Designing a market-based recharge management tool

This section focuses on the steps involved in designing a market-based recharge management tool. These are not necessarily sequential and some aspects of each step may need to be completed before the design of the instrument as a whole can move forward. The overarching step is to identify what type of market-based mechanisms may suit the problem and why. Within this context the appropriate outcome or target the market parameters must be set. This involves reinterpreting local and catchment targets in the context of the market-based instrument (MBI). A means to assess performance against the target must also be established by identifying how the contribution of individual actions will be measured against the target. A number of other design issues must then be addressed including monitoring and penalties, how to incorporate flexibility (and thus minimise costs to participants), scheme administrative arrangements and market format. The final issue that should be considered is whether and how multiple forms of MBI can yield additional benefits – for example combining offsets with a cap and trade mechanism.

3.1 What might a ‘recharge’ based mechanism look like?

Irrigation recharge management to date has involved a combination of regulation (water and land use rules), information about impacts of net recharge, motivation via Land and Water Management Plans (LWMP) including cost sharing arrangements and in some cases active promotion of net recharge concepts. The rationale for these instruments is to reduce the current and future costs of irrigation induced salinity on irrigators and the community. These instruments have tended to lack sufficient incentive leverage or flexibility in implementation. For example, regulations often apply uniformly when the actual cause is much more site and action specific. The costs of complying with the regulation are also specific to the site and action undertaken. In addition, regulations rapidly become extremely complex when attempts are made to incorporate these differential impacts.

One alternative approach is to define a ‘recharge right’ for each individual contributor. These rights would be linked to aggregate recharge targets at the regional scale and to farm scale management decisions as shown in Figure 4. At the regional level, the total quantity of recharge rights would need to be less than or equal to the regional recharge target taking into account mitigation actions. At the individual irrigator level, the total impacts of actions would need to be less than or equal to the recharge rights held. That is, the total impacts of their paddock scale farm management decisions would need to be less than or equal to the recharge rights held.[3] Therefore, a net recharge property right must be able to be measured, allocated to individuals, and, monitored at the paddock scale. The options for linking regional targets to individual recharge rights are discussed in section 3.2. Issues that must be addressed to link the impacts of farm management decisions on net recharge to net recharge property rights are discussed in section 3.3.

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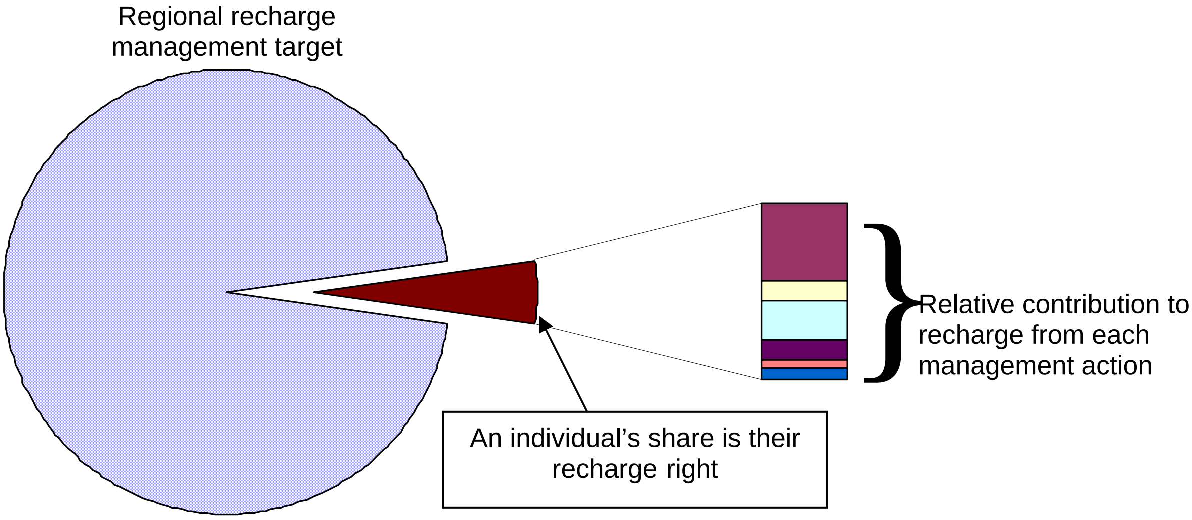
[3] Enhancing flexibility via trade and other measures is discussed in section 3.4 and 3.5.

Figure 4: Linkages between regional targets, recharge rights and farm management decisions



<u>What's in a name: what to call 'net recharge' rights?</u>

Rights to recharge from irrigation activities are generally termed *permits* because the rights specify permitted or allowable recharge under applicable regulations.[4] Property rights to reductions in net recharge through non-irrigation or other activities (such as groundwater pumping) are generally termed *credits* or *offsets* because they are voluntary and additional to any regulatory requirements and offset the impact of irrigation activities. Trading rules can be designed to allow permits and credits to be interchanged (see section 3.5).

Despite the generally adopted meaning of the terms *permits* and *credits*, use of the terms has varied in practice. For example, the Hunter River Salinity Trading scheme has allocated '*permits*' to a number of point sources of salinity in the catchment (mainly coal mines). In practice these '*permits*' are labelled '*credits*' in the Hunter scheme because stakeholders are more comfortable with the positive message incorporated in 'credit' based terminology. Some consideration should be given to the labelling of potential permits and credits in Coleambally because the perception of participants is important. Indeed, potential labelling should not be limited to permit-credit terminology and could use any label favoured by the community. For example, other acceptable terms may include *entitlements* and *allocations* that have accepted meanings in the context of irrigation water supplies.

3.2 Regional recharge targets

When linking regional recharge targets to the recharge rights held by individuals there are three questions that must be addressed:

1. who *should* own recharge rights?
2. what recharge target or targets should be set within the scheme? and,
3. how is the target allocated between individuals?

[4] There is significant confusion amongst the terms in this area but good references are Hockenstein, Stavins and Whitehead (1998), United States Environment Protection Agency (2003) or Organisation for Economic Cooperation and Development (2001).

Who should own recharge rights?

Who can create, trade and hold the new recharge rights will determine who may participate in any market-based management mechanism. Ideally, all significant positive or negative contributors to recharge should be included. Specifically, anyone who can change their management to reduce recharge within the target region *and* is large enough that the benefits of changing their management outweighs the costs should hold recharge rights.

In the context of irrigation, the primary actors are irrigators who are able to change their management to reduce recharge and in many cases are significant sources of recharge. While irrigators would be automatically included, two other categories of potentially recharge impacting right holders exist. The first of these is irrigation water supply companies who may be able to reduce recharge via remediation actions such as sealing of channels. The other comprises actors who can offset recharge via actions such as groundwater pumping. Consideration would need to be given as to whether these classes are restricted to a predetermined set of offset actions or whether possible actions are assessed on a case-by-case basis.

A final category of recharge right holders may be individuals or organisations that cannot directly manage recharge, but may wish to take ownership of credits for various reasons. This latter group could include, for example, investors, brokers, organisations representing downstream interests (who want a lower recharge target), or, the general public.

A registry of right ownership is needed in order to effectively identify who owns and can use recharge rights. Relevant details that should be included are:

- name and contact details of the owner;
- quantity of recharge rights;
- any third party interests (such as whether it forms collateral for a bank loan);
- any restrictions on the location within the irrigation area that the recharge can be contributed; and,
- any other restrictions on right use or trading.

Irrigation authorities or governments need not necessarily maintain registries as a number of private enterprises exist that specialise in this area.[5]

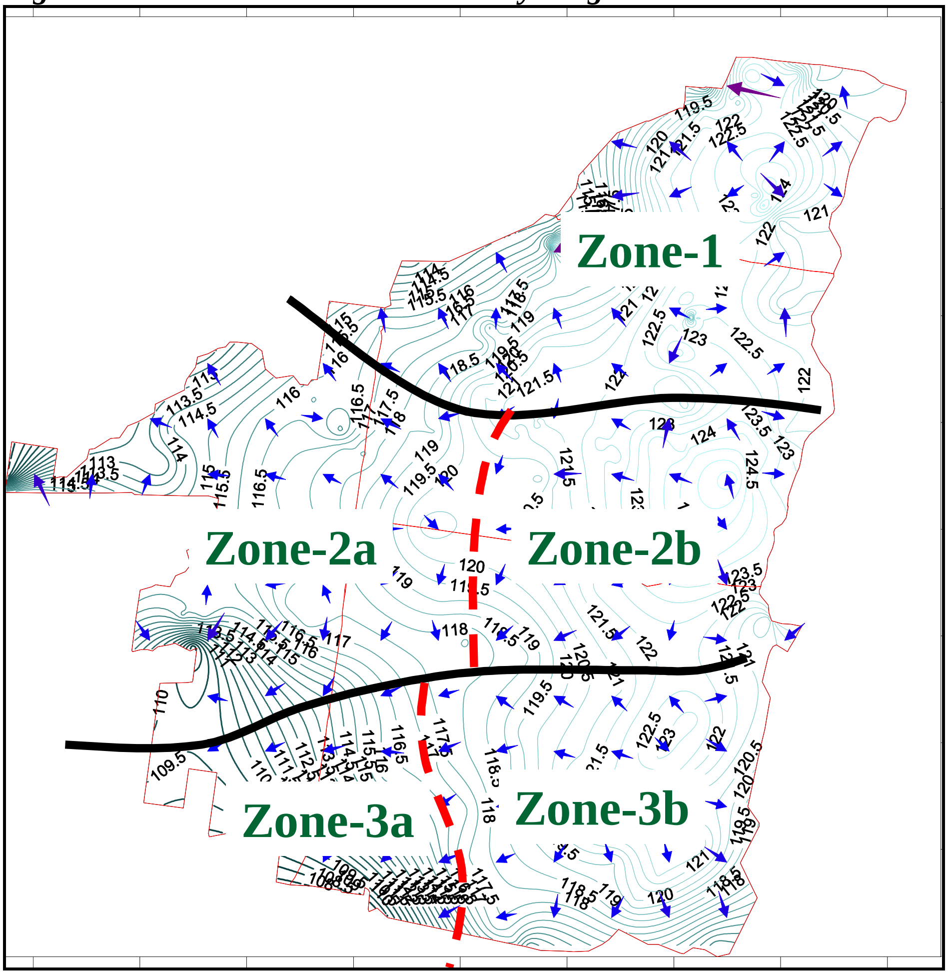
What recharge target should be incorporated into the scheme?

The goal of adopting a market-based mechanism is to improve irrigation induced salinity management and the resultant outcomes to the community. Fundamentally this means that recharge rights must be less than or equal to some total quantity of aggregate recharge across the entire irrigation area and potentially also at independent or interdependent sub-regional zones. That is, total recharge must be reduced (or capped) in order to achieve the recharge targets and reduce the costs of irrigation induced salinity and waterlogging. This target must be set in the context of who will own the recharge rights as discussed previously.

5 For example, The Market Place Company manages the central registry system for the Australian Office of the Renewable Energy Regulator (ORER). This authority issues Renewable Energy Certificates (RECs).

Within irrigation areas there are commonly a number of local and regional recharge and discharge zones. The area of influence for these zones are related to the soil types, irrigation activity and hydraulic properties of shared shallow groundwater aquifers (see Figure 3 for example). Therefore a region wide cap may reduce the total volume of recharge but fail to reduce the impacts in discharge zones. Worse, an inappropriate system wide cap may negatively impact on deeper aquifers and reduce potential future groundwater reserves. The risks of these undesirable outcomes will need to be considered before deciding on the number and location of sub-regional caps. For example, it is likely that three zones would be required to effectively manage shared aquifers in the CIA as shown in Figure 4. Partial zone subdivisions such as those shown in Figure 4 may also be necessary where significant differences in aquifer impacts occur across zones. However, there is a trade-off in the number and size of any sub-regional caps and the cost of defining these caps and managing the recharge rights in each. More sub-regions also create the potential for poor outcomes to arise from inadequate or inappropriate trading rules within and between regions or too few participants in markets.

Figure 4: Possible zones in Coleambally Irrigation Area



In order to integrate a cap within broader regional and local goals we need to know how much of the problem the MBI would address. Specifically we need to be able to measure and allocate responsibility for MBI contributions within a regional and local context. Potential measurement options include:

- targets based on groundwater outflow rates within and between shared aquifers; and,
- targets based on historic recharge and discharge rates from individual areas.

Using groundwater outflow rates or assimilative capacity as the basis to set MBI caps is the preferred option because it is more accurate than historic recharge and discharge rates that may change as thresholds are reached. Use of groundwater outflow approaches have been made possible through integrated research over the past five years to develop regional groundwater flow and salt transport models (see for example Khan, Xeiv and Meyer 2003). For example, in the CIA these models have been developed using historic piezometric data from over 800 piezometers in the region and aquifer composition information from thousands of bore logs. In turn this data has been calibrated with historic data sets and have been tested under a range of irrigation and climate scenarios. Using these regional groundwater models it is possible to zonal recharge and thus to specify quantitative regional and sub-regional targets as a specific volume.

A related question is the degree to which recharge varies from year to year in response to climate and irrigation activities. If variation is minimal then a fixed annual cap can be set and periodically reviewed against the target. However, substantial variation may require either a variable annual cap or 'special circumstances' allowances. These risks must be weighed up against the cost to irrigators of creating an irrigation drought or constraining actions in times of plentiful water supply.

Allocation of recharge rights

The recharge target, at either the irrigation area or sub-regional level, must be sub-divided between individuals. Leaving aside measurement of individual recharge contributions until the next section, there are a number of options for allocating rights. These include basing allocations on:

- existing or past activity and resultant recharge performance;
- existing or past performance adjusted for recent changes to management;
- recharge under best management practice; or,
- auction of rights to the highest bidder.

There are also combinations of the above methods as well as other less used options.

To date, most cap and trade type mechanisms involving tradable rights have based allocations on historical performance.[6] However, basing the allocation of recharge rights purely on past performance may be seen as inequitable because it fails to take into account biophysical management constraints or actions already undertaken by some irrigators to reduce their recharge. For example, basing allocation purely on historical crop areas may penalise farmers with more permeable soils over those with less permeable soils. Hence, allocation mechanisms that adjust historical crop areas for soil types or adoption of best management practices are often considered.

Many alternative allocation options could be devised. However, as is the case elsewhere, the more detailed the allocation procedure the higher the costs involved in defining and allocating individual rights. For example, each progressive adjustment

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[6] Auctions have been more prevalent where property rights to new or previously un-used resources, such as a new communication spectrum bandwidth such as for mobile phones, have been allocated.

to past behaviour will induce more computational complexity and impose additional costs in gathering and verifying information.

A second question that must be answered is whether the region-wide, and any sub-regional caps, are to be achieved immediately or at some point in the future. For example, in some schemes, caps have initially been set close to current levels and reduced over time, as experience with the scheme and alternative management options has increased. This issue is only important if there is a large gap between the current recharge performance and the target outcome. Again a number of alternative options have been used elsewhere including:

- no phase in period;
- a progressive reduction from current levels to the target level; or,
- allocating a modest quantity of recharge rights and purchasing and retiring sufficient from the market to achieve the target.

Whether targets are immediately met or there is an adjustment period will have important implications for the pace and cost of reducing recharge, as well as who bears the costs. For example, progressively declining allowable recharge under a defined schedule until the target is met would provide producers regulatory certainty and time to adjust irrigation practices. This could be particularly appealing to irrigators with large investments in crop specific enterprises (for example specialised equipment for water intensive crops such as rice) that would incur significant costs if recharge reductions were significant and imposed at short notice. Of course, such an approach will lengthen the time it will take to achieve recharge reduction goals. Alternatively, purchasing and retiring net recharge property rights would shift some compliance costs to those funding the purchases, such as the broader irrigation community via their supply company, or to taxpayers if government provided funding.

The selected allocation path may also impact on future targets because any delay in reducing recharge may require greater reductions in the future. In some circumstances the current drought may have reduced the need for greater future reductions if there have been falls in groundwater levels due to low rainfall and water allocations.

3.3 Measurement of individual recharge rights

There are a number of factors affecting recharge at the property level, including;

1. irrigation water use and application technology;
2. paddock soil type and underlying hydrogeology;
3. crop type; and,
4. climatic conditions and variability (including soil water conditions at the commencement of the irrigation season).

The SWAGMAN® series of models discussed in section 2 includes modules at the farm and regional scale. The farm scale model measures the paddock scale contribution to recharge by combining information on crop and soil type, groundwater outflow rate, irrigation technology and water use, and, initial soil and groundwater conditions. The SWAGMAN® Farm model is able to compute volumetric and area based measures of recharge.[7] Each potential recharge measure would give slightly different incentives to landholders. For example, units of recharge per Ml of water used will give maximum incentive to minimise total water use rather than recharge directly. Measures that deliver more direct incentives also require more complex information about farm management decisions. The costs imposed on landholders of inputting more complex information should not outweigh the benefits from improved incentives to manage their recharge contribution. Estimation of the impact of offset schemes such as agro-forestry or groundwater pumping will also be possible using modules of the SWAGMAN® series.

3.4 Other design issues

Incentives for participation,

To date the discussion has concentrated on the technical feasibility of designing and implementing a tradable recharge rights mechanism to manage irrigation induced salinity impacts on a common property resource. However, the practical decision to implement requires community acceptance and participation in the mechanism in order to access the potential gains from trade. This decision can be thought of in two parts – social acceptance and incentives to participate.

Social barriers to market-based systems include concerns about the social impacts of recharge credits (for example, equity considerations in property right allocation and trading), impacts of any additional costs on farm viability or cultural impediments to creation of new property rights that irrigators consider they already hold. A related concern relates to the risk of future government intervention (particularly given the potentially costly implementation process). Alternatively, the risk of increased regulation or other government driven actions may be viewed as being reduced by the adoption of a market-based property right structure that ensures compliance with water supply licence conditions.

It is important to deliver sufficient incentives to overcome a natural reluctance to participate in new schemes given the transaction costs and uncertainty involved. Potentially this could be overcome via a command and control regime based on the water supply contract irrigators hold with their bulk water supplier. Attracting participants via a method that is less punitive is likely to prove more politically sustainable. Potential options for attracting participants may include subsidising recharge reductions for early entrants (particularly in combination with a cut-off date when participation will be compulsory), offering concessional water prices, or other incentives to induce participation with a view to requiring participation once a particular threshold is reached.

Monitoring and penalties

The ability to cost effectively verify who holds and uses recharge property rights is necessary to ensure that farm and aggregate recharge targets are met. In part, this requirement is met via a register setting out recharge right ownership. However, verification also requires that use of the property right can be policed and appropriate penalties imposed for illegal use.

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[7] A working example of the SWAGMAN® Farm model developed by Shahbaz Khan can be viewed at: http://www.colyirr.com.au/swagmanfarm/allUser/SwagFarm.asp

Within many irrigation areas there are monitoring strategies for the area and location of key crops. For example, rice crop area and location is monitored in the CIA. These strategies are useful for policing a major proportion of recharge within the region. In some instances monitoring may involve remote sensing technology that can then be computer analysed against declarations to verify key crop compliance. An alternative monitoring option is a combination of random and targeted audits of crop area and water use. These options can be used separately or as a complementary strategy and can be effectively used to ensure compliance with property right ownership and use rules.

The issue of how to penalise net recharge property right holders who fail to observe the rules associated with exercising their property rights must also be considered. It is important that the penalties are largely non-punitive because of the cooperative nature of current management arrangements and in recognition of the management challenges that the new requirements may impose. Penalties should also be graduated to ensure that minor or technical breaches do not face as strong a penalty as more consistent or wilful violations. It is important that penalties are sufficiently strong to supply incentives to comply with the rules and that the community as a whole supports their imposition.

Incorporating flexibility measures to reduce irrigator costs

The adoption of tradable recharge rights is designed to maximise the net return to irrigation communities via a reduction in the costs of achieving recharge management targets (which in turn are set to maximise social benefits taking into account irrigation-induced waterlogging and salinity to irrigators and other members of the community). Tradable rights approaches will minimise compliance costs by firstly releasing the gains from trade between participants, and secondly by maximising compliance flexibility through trading between time periods – that is, via banking and borrowing provisions. Banking and borrowing provisions are particularly important in systems subject to substantial year on year variation, such as that driven by climate induced irrigation water availability, and where externality impacts are largely insensitive to the time of externality generation.

However, these provisions may also increase the potential for system abuse if rules are not carefully constructed. For this reason there are usually limits to both the quantity and duration for which property rights can be carried over or borrowed. Time limits should coincide at least partially with the expected duration of climatic cycles (for example the average length of an El Nino Southern Oscillation event). Special rules on banking and borrowing may also be considered during any transitional period to the target cap.

Who will fund market development and administration?

The design, implementation and ongoing management of MBIs is not cost free. Costs include defining and allocating property rights (including registry creation), ongoing monitoring of compliance, policing of any violations of rules, registry maintenance and administration. Options for funding ongoing costs include user-pays fees, incorporation within irrigation company costs (representing the irrigators), a levy on recharge right owners or a combination of these. User-pays fees are those directly attributable to costs imposed by a recharge property right owner's actions. These include costs to update the registry of property right owners for any changes to property right ownership and costs directly attributable to penalising any violation of property rights (for example, court costs). Any costs associated with property right carryover or borrowing from future years are also directly attributable to users. Often user-pays are applied where possible and remaining costs are socialised (for example through a levy or inclusion in water supply costs).

Reviewing outcomes and mechanisms

The design and implementation of MBI schemes is subject to a number of uncertainties about scientific and economic design parameters. A clear mechanism is required to correct errors and incorporate information advances. Review options include:

- limiting the duration of the right (for example, guaranteed for ten years);
- permanent rights with compensation for any future changes;
- proportional adjustment as required (for example a percentage reduction to all property rights); or,
- a combination of the above mechanisms (for example, up to ten percent adjustment at ten year intervals without compensation).

In making a decision about review provisions, the need to retain flexibility to cope with the scientific and market uncertainty inherent in any new market must be traded-off against the risk this introduces to the market and the implications of uncertainty on trade and recharge that result.

3.5 Creating a net recharge property right market

Tradable recharge rights reduce the cost of achieving sustainability goals by releasing the gains from trade as was shown in Figure 1. The effectiveness in releasing these gains will be determined in part by the transaction costs to market participants. A variety of potential trades can be envisaged including:

1. direct trades between individuals;
2. indirect trades using brokers such as stock and station agents; or,
3. a centralised electronic or physical market place.

Direct trades have been common in the water market, especially between neighbours and are likely to be prevalent in a recharge market. Marketplace trades using brokers (for example stock and station agents) and Internet based exchanges may also emerge, particularly in conjunction with existing water markets. Use of Internet trading facilities linked to the existing water market may lower transaction costs where individuals are comfortable with the technology. The monetary costs of setting such systems up are also likely to be low but they are reliant on irrigator acceptance and ability to manage the technology.

The administrative arrangements underpinning exchanges must also be considered. Specifically, an administrator must exist to approve trades (to ensure compliance with the registry and any trading rules) and maintain a trading log that feeds into the rights registry. Again, the role of market administrator could be filled by either the irrigation water supply company or by a specialist private sector firm.

Market power

If an individual player or small group of landholders can directly influence market outcomes then a market-based mechanism may be less effective than other options. Market power is generated in two main ways:

1. by controlling a large segment of the market and thus influencing market prices; or,
2. by being able to influence decisions to participate in a market in other ways.

In most irrigation areas it is unlikely that any single irrigator or group of irrigators will control a significant share of credits either within any sub-region or across the entire irrigation area. However, the risk of market power grows as the number of participant's falls, and consequent tradeoffs should be taken into account in conjunction with other design tradeoffs.

3.6 Including recharge offsets from non-irrigation activities

Some land management actions or engineering solutions can be foreseen that may 'offset' the net recharge from irrigation sources. For example, strategic tree planting or groundwater pumping to evaporation basins may reduce the total recharge to groundwater aquifers. A number of issues similar to those in Section 3.2 will need to be considered including:

- who is able to generate offsets?
- how would offset property rights be defined and measured?
- should the enforcement process differ? and,
- are specific trading rules required?

A new category of potential property right owners may be required if offsets can be undertaken by non-irrigator resource owners. These may include landowners outside irrigation areas or non-irrigating landowners within the irrigation area. The decision about who is able to generate additional property rights should take into account the costs of measuring and monitoring offset impacts. One means of minimising such costs is to use existing measurement, monitoring and enforcement structures where possible and only develop additional structures where required.

A key decision about offset property rights is translation of the recharge benefit through time to a tradable right. For example, a strategically placed woodlot could generate a stream of increasing benefits until maturity. However, there is a time lag between planting and the commencement of benefits. Moreover, the largest benefits do not commence until well into the future. Future benefits could be measured and included via:

- a constant benefit across the life of the project (for example total benefits divided by the life of the project); or,
- a modelled benefit for each year that may or may not include climatic variation.

Averaging benefits from future years effectively represents a forward borrowing of future benefits. At the extreme, the entire future benefits of the action could be sold at the start of the project but at the expense of increased risk if the project fails after commencement (for example because trees die after five years). The question then arises as to who bears the risk of failure.

4. Conclusions

Designing a market-based mechanism based on tradable recharge rights could potentially provide a more cost-effective and flexible way of managing groundwater regulation ecosystem services in irrigation areas. The potential benefits result from accessing the gains from trade through differential costs of adjustment between irrigators and the incorporation of flexibility provisions such as banking, borrowing and special circumstances allowances in applying recharge rights at the farm scale.

The key challenge in designing and implementing a recharge rights system and market lies in creating a market where none currently exists, that is in capturing the value of groundwater ecosystem services management by compensating its' providers. Through this approach and, notably *unlike* regulatory or tax instruments, one views groundwater management much as a business transaction between willing parties. Despite the business transaction nature of the mechanism it is reliant on actions at the irrigation area level on behalf of the impacted community – irrigators and non-irrigators alike.

A number of challenges emerge in applying this approach to designing a tradable rights based mechanism to manage irrigation-induced waterlogging and salinity in shared groundwater aquifers. Perhaps the greatest challenge, that of obtaining effective information, has been largely overcome via extensive biophysical modelling that has already taken place. These models describe the characteristics of groundwater management ecosystem services. This modelling facilitates the setting of targets at the individual farm level, sub-regional and regional scale. The main challenges emerge in designing a cost-effective tradable rights mechanism to act on this information. These primarily relate to the design of an effective rights allocation, measurement, monitoring and enforcement scheme that facilitates access to the gains from trade in a recharge rights market place. In this paper we have begun to address this design problem by setting out the design parameters for each issue.

The design and trial of a tradable recharge rights mechanism is one of several pilot markets being undertaken within the 'Markets for Ecosystem Services' Project at CSIRO. We are now moving to implement this and other pilots and to identify in more detail the practical obstacles to their implementation and further application.

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