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Double trouble: the importance of accounting for and defining water entitlements consistent with hydrological realities*

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When entitlements to access water in fully allocated river and aquifers are specified in a manner that is inconsistent with the ways that water arrives, flows across and flows through land, inefficient investment and water use is the result. Using Australia's Murray Darling Basin as an example, this paper attempts to reveal the adverse economic and water management consequences of entitlement and water sharing regime misspecification in regimes that allow water trading. Markets trade water products as specified. When entitlements and the water sharing system are not designed in a way that has hydrological integrity, the market trades the water management regime into trouble. Options for specification of entitlement and allocation regimes in ways that have hydrological integrity are presented. It is reasoned, that if entitlement and allocation regime are set up in ways that have hydrological integrity, the result should be a regime that can autonomously adjust to climatic shifts, changes in prices and changes in technology without compromising environmental objectives.

Key words: hydrological integrity, interception, water accounting, water markets, water rights, water trading.

1. Introduction

Most water allocation regimes were set up and developed in times when water was not scarce. As a direct result, they often end up being specified in a manner that is inconsistent with the hydrological realities that constrain choice in fully allocated river and aquifer systems. In the early stages of the development of these systems there is excess capacity and, hence, the resultant misspecification is not considered to be a serious problem. In fully or over allocated systems, however, entitlement misspecification can cause serious problems. The most common form of entitlement misspecification is the omission of processes that intercept water from the accounting regime.

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Unlike the seniority entitlement systems used in much of the United States of America, most Australian water entitlement systems define pools of water that are shared in proportion to each person's volumetric entitlement. Every season and depending upon availability, allocations are then made in proportion to the number of entitlements held. Under this pooled arrangement and as all entitlement holders have the same status or are of equal seniority, the costs of entitlement trading are much lower than under a seniority entitlement system as there is no need to check to see if a trade would disadvantage other entitlement holders. As a result, Australia has developed relatively low-cost water markets where willing irrigators can buy and sell entitlements and, also, buy and sell annual allocations with one another.

Another significant difference between the Australian approach to water management and those used elsewhere is the way decisions are made about how much water to set aside for system maintenance and for the environment. In Australia, the most common approach is to rely on water sharing plans, developed in consultation with stakeholders, to determine when and how water is allocated to users and how much should be put aside for system maintenance and the environment. A typical water sharing plan, once approved by a Minister, lasts for 10–15 years and is very difficult to change. The stated reason for this temporal fixity is that it is necessary to provide all consumptive water users with the investment security necessary to ensure efficient investment.

As a result of the above processes and the legislation that underpins them and in contrast with the approach taken in much of the United States of America, the role of lawyers in formulating and changing allocation rules and in vetting entitlement trades is minimal. Investment security is offered by putting in place a regime that is supposed to stop the nature of the entitlement from being eroded. As a result, when entitlement misspecification occurs the main loser tends to be the environment.

In this paper, we focus on the economic consequences of misspecifying entitlements and, as a result, either misleading investors or causing over-allocation. Over-allocation occurs when the amount of water being set aside for system maintenance and for the environment is insufficient to satisfy these needs.

2. Forms of entitlement and plan misspecification

As noted in Australia's National Water Initiative (NWI) (CoAG 2004), one of the most common forms of entitlement misspecification is the description of entitlements and associated water allocation rules in a manner that does not account for the 'interception'. Section 55 of the Agreement underpinning this Initiative states that

> 'The Parties recognise that a number of land use change activities have potential to intercept significant volumes of surface and/or ground water now and in the future. Examples of such activities that are of concern,

many of which are currently undertaken without a water access entitlement, include:
• farm dams and bores;
• intercepting and storing of overland flows; and
• large-scale plantation forestry.'

While the potential of these interception processes to cause harm to existing interests is recognised, most of the entitlement systems and water sharing processes used in Australia have yet to be changed to ensure that decisions made by current water entitlement holders are efficient.

If the quantity of interception remains constant, then interception does not cause a problem. When interception increases, however, the integrity of the entitlement system starts to fall apart. The hydrological reality is that whenever one water use is increased another must decrease. The preparation of sharing plans, the specification of entitlements and, also, the allocation of water to entitlement holders in ways that deny this reality misleads investors and investment mistakes are made. The outcome is worst when water sharing plans in the interest of maintaining investment security don't acknowledge the reality of what is happening and, hence, put in place rules that reduce the amount of water available for environmental and system maintenance purposes.

The other main form of entitlement misspecification is to issue entitlements and describe them in ways that imply natural shifts in the average amount of water available to users will not occur.

The Murray Darling Basin Commission is aware of the adverse consequences of defining allocation and use of rules that are inconsistent with hydrological principles, and has begun commissioning research on what it calls 'risks to the shared water resources.' So far the Commission has formally recognised six 'risks' to water allocation regimes in the Basin:

1. climate change;
2. bushfires;
3. afforestation;
4. increased farm dam construction;
5. reduced return flows from irrigation; and
6. increased groundwater use.

Of these six 'risks', only the first two – climate change and bushfires – can be described correctly as 'risks'. The remaining 'risks' are more appropriately described as processes that are already reducing inflows into the River Murray system. As the current drought in the Southern Connected River Murray system is demonstrating (see Figure 1), when the average amount of water entering the system is reduced, either allocations to the environment and/or entitlement reliability must be reduced.

In addition to the above six risks, the Commission also continues to install salinity interception schemes without requiring them to hold a water entitlement. Salinity interception schemes operate by pumping groundwater, which

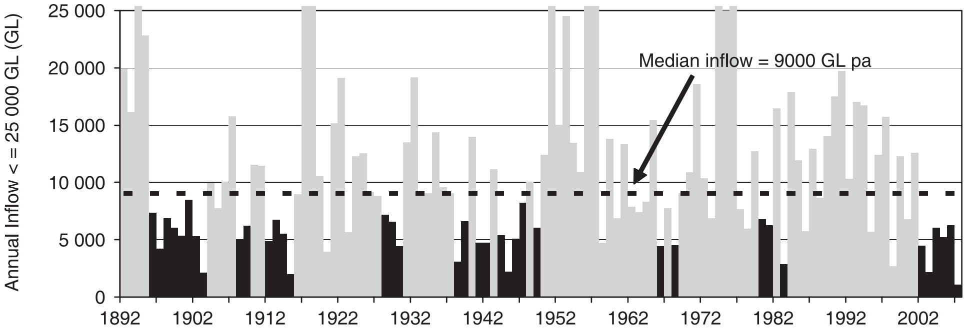

Figure 1 Total River Murray System Inflows including Darling River (Modelled current conditions – extended droughts shown in black).
Source: MDBC, pers. comm., 2007.

previously would have flowed into the river, into evaporation basins. The result, in every case, is a reduction in the amount of water that reaches the river.

Drawing attention to the consequences for rivers of increased groundwater use, Evans (2007) describes the interception problem as 'double counting'. In Australia, a number of groundwater systems are managed as if they are not connected to the surface water system, when the available science suggests that they are. As Evans points out, whenever there is an increase in the rate of water extraction from an aquifer that is connected to a surface water system, the amount of water that ultimately enters the surface water system will be less. Under such a regime, if hydrological integrity is to be maintained, whenever groundwater extraction is increased surface water allocations must be reduced.

Estimates of the extent of double counting, or as many prefer to call them, interception problems, water-supply affecting activities, or over-allocation problems in the Murray Darling Basin remain controversial, but all those that have been published suggest that this is a very serious problem. Putting climate change and bushfires to one side,[1] estimates suggest that the failure to define allocation arrangements in a manner that has hydrological integrity can be expected to erode the irrigation potential of the Murray Darling Basin by between 20 and 30 per cent of water entitlements currently allocated to consumptive users (van Dijk *et al*. 2006; Earth Tech Engineering Pty Ltd 2003; Young and McColl 2003).

In the remainder of this paper, we search for guidelines and opportunities to specify entitlements and associated allocation rules which are specified in a manner that are consistent with basic hydrological principles and accounting rules, and therefore can be expected to encourage efficient investment in water allocation regimes where water entitlements and allocations are tradeable.

[1] A recent CSIRO study has observed that the worst-case scenario for the impact of the 2003 bushfires in Victoria's alpine region would be a reduction in annual water yield of 80 000 ML in 2020 (Benyon 2008).

3. Entitlement and water sharing regimes

To make it easier to present options for the resolution of this class of problem, we assume a fully allocated river system with a tradeable water entitlement and water sharing regime similar to that which Australia's NWI requires States and Territories to implement.[2] In essence, this NWI requires:

- Water entitlements to be defined as tradeable shares of all the water allocated for use in defined pools of water;
- Water sharing plans to set out the rules for determining how much water to allocate periodically to each defined pool of water and how much to leave in the system to cover system losses and provide for environmental needs;
- All water users to hold a licence that defines the conditions under which water may be applied to the land they irrigate;[3]
- The use of water markets to facilitate the transfer of water entitlements, water allocations and delivery entitlements from one entity to another at minimal cost and without any administrative impediments to trade.

In addition to these arrangements required under Australia's NWI we also assume:

- Unused allocations, less an adjustment for evaporation losses, can be carried forward for use in a subsequent time period.[4]

4. Information and investment

Conceptually, there are two economically efficient ways to manage entitlement misspecification.

The *first* option is to live with the problem and keep all entitlement holders informed of the extent to which entitlement reliability is likely to be eroded and draft the water sharing plan rules in a way that specify how this will be done. Under this option, interception is treated as a prior right; no attempt is made to guarantee investment security. It is made perfectly clear that allocations will be reduced as interception increases. At the time of writing, no Australian water sharing plan includes such a mechanism. Moreover, no State regularly estimates and annually informs entitlement holders about the rate of increase in interception.

[2] In another report, we argue that the water sharing approach used in Australia, is inferior to one that is based upon first defining the amount of water needed to cover evaporative and other losses, then issuing shares to all consumptive users and environmental trusts in a way that gives both sides of the debate the same property right. See Young and McColl (2008).

[3] In some regimes, delivery entitlements are defined using a separate instrument and made tradeable on either a permanent or temporary basis.

[4] One of the more serious mistakes that Australia has made in the development of water markets has been its failure to allow water users to optimise water use between years. As a result, the costs of trade in some areas has been greater than the gains (Brennan 2007).

The *second* approach is to bring all interception processes into the water allocation and accounting regime. When this approach is taken, there is no need to adjust water sharing plans. Where the interception process is meterable, inclusion in the regime is relatively simple. In the case of salinity interception schemes, for example, the obvious solution is to require those responsible for managing each scheme to hold sufficient allocations to allow them to operate.

In cases, where the interception process is un-meterable, the only feasible option is to develop a way to estimate the amount of water that is used by the process, deem this to be the amount used, and then make an arrangement to ensure that increases in these forms of interception neither reduce the reliability of existing entitlements nor reduce the reliability of volumes of water left in the system.

In effect, this latter approach extends the boundary of the water management regime to include all significant anthropocentric processes that affect the amount of water that flows through the system.

5. Specification issues and options

We can now turn to consideration of options to manage water supply affecting activities that can undermine the reliability of allocations made to tradeable water entitlements.

5.1 Long dry periods, bushfires and adverse climate change

When the affects of all water sharing plans under the Murray Darling Basin Agreement that determine how much water is used by consumptive users and how much is allocated to the environment is modelled, the results suggest that all plans have been written on the assumption that there will be no adverse shift in the supply regime. In dry periods, allocations to consumptive users are reduced by 17 per cent whilst allocations to the environment are reduced by 83 per cent (Close, pers. comm., 2008). Those responsible for preparing the water sharing plans explain that this regime can be justified because the environment receives a much larger proportion of allocations during very wet periods. This approach works if there are no long dry periods and if there is no increase in interception. But long dry periods do occur and were common during the first half of last century (see Figure 1).

One of the main unappreciated consequences of a shift to a drier regime is that for every reduction in total inflow into the system, much less water is available for use as the system still evaporates as much water (possibly more), and some flow to the sea is still required. An important relationship to keep in mind is that between rainfall in a catchment and inflow into storages. In the Murray Darling Basin, for example, a 10 per cent decrease in rainfall results in an average reduction in system inflow of around 30 per cent (see DSE 2008).

But, as it gets drier in systems like the Southern Connected River Murray System, evaporation remains the same and hence, the reduction in the

Table 1 An illustrative overview of the consequences of a shift to a drier regime for a 10 000 GL system similar to the River Murray's. (Readers are encouraged to enter their own assessment of how best to configure such a system, if there is a 20% decline in mean rainfall)

Mean rainfall shift		10% reduction in mean rainfall	20% reduction in mean rainfall
Mean inflow*	10 000	7000	4000
Mean evaporation	2 000	2000	2000
Mean flow to the sea	2 000	2000	.....
Net volume available for discretionary use	6 000	3000	.....
Environmental entitlement	1 500	1500	.....
Consumptive user entitlement	4 500	1500	.....
Unallocated water	0	0	0
Reduction in mean volume available to consumptive users	–	67%	....%

* Murray–Darling Basin historical records indicate that mean annual inflows into the southern River Murray system including the Lower Darling is 11 229 GL per annum and the median inflow is 9033 GL per annum.

amount of water available for use declines even more rapidly. As shown in Table 1, for a river like the River Murray, a small reduction in mean rainfall can cause a massive reduction in the average amount of water that can be supplied to water users.

The most efficient entitlement system is one that has hydrological integrity, including a capacity to adapt autonomously to long dry periods (climate shifts) and climate change. Amongst other things, this requires an amount first to be set aside to account for system evaporative losses and provide for a minimum flow to the sea. The remaining water can be defined either as shared water or floodwater. Under this regime, the environment and all consumptive users can be treated equally and issued secure entitlements to a share of any allocations made (Young and McColl 2008). Provided any shareholder is allowed to use, sell, or with an adjustment for evaporative losses, carry-forward allocations, the result is a regime that allows the efficient management of water during long dry periods. It also puts in place a regime that allows the efficient management of a permanent shift to a drier regime as a result of adverse climate change or increased interception.

5.2 Plantation forestry

If water is to be allocated using a planning rather than an entitlement sharing approach, and if plans cannot be changed as interception increases, then in order to ensure that water markets produce efficient investment decisions, it is important to bring all significant forms of interception into the allocation regime. Given the fact that Australia is now proposing to introduce a greenhouse gas emissions trading program, plantation forestry is arguably one of the most important forms of interception to bring into all water allocation regimes. If this is not done, massive amounts of water currently allocated to irrigators and to the environment can be expected to be permanently removed from the system as landholders plant trees in order to gain carbon credits.

When land is converted from annual to perennial vegetation or some other significant water supply affecting activity, the amount of water per hectare that either evaporates or is transpired increases and less water runs off into surface water systems or seeps through the soil into groundwater.

Research on these processes suggests that the difference between the amount of water intercepted by perennial plants and annual plants increases with rainfall (Vertessy *et al.* 2000, 2003; Hairsine and van Dijk 2008). For water managers, this empirical observation is important as the majority of water supplied to river systems, like the River Murray system comes from upper catchment high rainfall areas that are well suited to both plantation forestry and grazing, re-establish a forestry plantation and the amount of water that runs off reduces significantly. High up in the Eastern Divide where annual rainfall exceeds 1120 mm per annum and the majority of water in the River Murray is derived from, plantation establishment reduces water yield by around 2.5 ML/ha. Assuming that around 80 per cent of this water yield reduction reduces river flow, at 2007/8 entitlement prices, the cost of buying the equivalent water used at $2400/ML of High Security entitlement is around $4800/ha (Young and McColl 2006).

To put the above estimates in perspective, the Murray Darling Basin Ministerial Council's 'first step' in restoring River Murray flows aims to secure 500 GL from consumption. CSIRO estimates suggest that plantation forestry can be expected to reduce mean water supply in the Southern Connected River Murray system by between 550 and 1400 GL by 2026 (van Dijk *et al.* 2006). If this happens, then all the claimed benefits of the proposed first step 500 GL will be dissipated.

In addition to all the above considerations, as trees tend to establish deeper root systems, in places where groundwater is relatively close to the surface, these plants can access groundwater directly. For example, in the groundwater system in the lower south-east of South Australia, research suggests that plantation forest trees can access groundwater down to a depth of six metres below ground level. In areas where the groundwater is closer than six metres to the surface, these trees have an un-metered opportunity to extract as much water as they need from the groundwater system. The estimated rate of extraction is in the vicinity of 1.66–2.55 ML/ha (see Table 2).

The question that we can now turn to is that of whether it would be more efficient to assign a prior right to forest plantation developers to access as much water as they need or, alternatively, to put in place rules that bring water market disciplines into any decision to establish a plantation.

As set out in Young (2005), plantation forestry can be brought into the water sharing planning system via any one of three approaches. Each approach does, however, require governments to require an aspiring forester to obtain

Table 2 Estimated impacts of plantation forestry on water supplies in the South-east of South Australia

Industrial plantation forest type	Groundwater management area recharge reduced by:	Extraction by plantations where underlying water table median depth is < 6 m:
Short rotation (hardwood)	78%	1.82 ML/ha/year
Long rotation (softwood)	83%	1.66 ML/ha/year
Hardwood coppiced for a second harvest cycle	–	2.55 ML/ha/year

Source: South-east Natural Resource Management Board Consultation Document (2007).

permission to plant a forest in any area where the water supply system is fully allocated.

1. The simplest approach is to require foresters to *offset* the impact of their forest on water supplies by surrendering water entitlements equivalent to the estimated impact of the proposed forest on the volume of allocations that can be made to all other water users. Once the entitlements are surrendered, the forester drops out of the entitlement and allocation regime. In recognition of the protection from adverse climate change that this offset arrangement gives a forester, determination of the number of entitlements to surrender should include a climate change insurance premium.
2. A more complex approach is a long run or *partial accounting approach* that includes a mechanism designed to slowly adjust for the effects of adverse climate change should it occur. Foresters are required to put aside and not use a deemed number of entitlements per hectare. Every year, the local water manager estimates the amount of water used and debits this in the water accounting system. When the forest is clear felled all use debits and allocations credits are added up and if the allocation account is in deficit the forester is required to leave the area clear until the until the resultant increase in recharge over the clear felled area brings the account back into positive balance. As soon as the water account returns to positive balance, another forest can then be planted.
3. A *full accounting approach* that treats every forester in the same way as every irrigator. Every year, the local water manager estimates how much water the forest has used and deducts this amount of water from the forester's water account. If there is insufficient water in the account, the forester is fined and required to make good the account.

Each of the above approaches has different risk implications for the forest industry, other water users, the environment and the body responsible for issuing and managing water entitlements. As summarised more detail in Table 3, each approach has to be evaluated from the viewpoint of incentives given to existing plantation owners, and to those considering whether or not to establish a new plantation.

Whilst a full accounting approach can be made to work, in un-meterable systems administrative costs associated with this third approach tend to be expensive, and as water use can only be estimated using modelling approaches, it is likely to result in many arguments between forestry and other water users.

Similarly, whilst politically attractive, use of a partial accounting system is problematic particularly if market conditions change and it no-longer pays to clear fell a plantation. If, for example, it became more economically attractive to use a forest as a perpetual carbon sink and the forest is never cleared, then the system could remain in deficit for ever. If one is interested in maintaining system integrity, the partial accounting system can be rejected on the simple grounds that it does not provide a solution in circumstances where it becomes more profitable to retain rather than clear the forest.

One of the key features of the offset approach is that it has much lower administrative and transaction costs as it does not require annual estimation of the amount of water that has been extracted by each plantation area. Instead, it relies upon an estimate of the average amount of water that a typical forested area would be expected to use and the surrender of entitlements equivalent to the estimated impact of the forest. The result is a system that enables each entitlement to be defined in terms of the amount of water held in storage or extractable from an aquifer.

Another key feature of the offset approach is that, once an appropriate number of water shares are surrendered, the forester is protected from the need to provide additional water allocations should the system get drier. In effect, the forester is protected from the risk of adverse climate change and, as a consequence, all other entitlement holders are exposed to a greater risk. In recognition of this protection from climate change risk, when determining the most appropriate number of water shares to be surrendered per hectare of forest established consideration can be given to adding an insurance premium to the estimated mean effect that the forest is expected to have on water supplies. The result is an arrangement that makes more water available to all other entitlement holders until such time as an adverse climate shift occurs. In practice, this can be achieved either by transferring some 'insurance premium' shares to all other entitlement holders or by increasing allocations to them. In the former case, whilst the number of entitlement shares transferred is likely to be small, the merit of this approach is that it fully informs all remaining entitlement holders that they are exposed to increased allocation risk and that if an adverse climate shift occurs, allocations per share will be reduced in an appropriate manner.

A variant of the above options included in Table 3 is the proposition that in each region an attempt could be made to define a threshold area of land that for aesthetic, conservation, environmental service and other reasons, should be under some form of permanent vegetation. It would then only be necessary to bring forestry into the entitlement and allocation regime when the area under plantation exceeds the threshold above which the adverse

Table 3 Key features and summary of implications for existing and new plantations by each system option

	Full accounting approach	Partial accounting approach	Offset approach
Entitlement issued to land owners where there is an existing forest plantation	Share entitlements are issued in proportion to the estimated amount of current recharge interception and direct groundwater extraction currently deemed to be occurring	As for full accounting	Land owner, issued with a legally binding commitment to receive share entitlements equivalent to the deemed increase in recharge and reduced direct groundwater extraction when a forest permit is surrendered or permanently removed
Action required to establish a forest plantation in an area where the forest area threshold has been exceeded	Source sufficient allocations to enable forest allocation account to be kept in positive balance by buying entitlements, leasing entitlements or buying allocations. No requirement to source a water entitlement before applying for a forest licence as the land holder is allowed to secure allocations on an annual basis	Must secure access to an entitlement sufficient to offset the deemed impact of recharge interception and direct groundwater extraction	Must secure and surrender access to an entitlement sufficient to offset the deemed impact of recharge interception and direct groundwater extraction PLUS any adverse climate change insurance premium. This premium is reallocated to existing entitlement shareholders
Nature of responsibility for adjustment if deemed values or allocations per share decline	**Annual.** In every year, the shareholder's closing allocation account must be non-negative. As with any other irrigator, if the closing account is negative administrative action is taken. As the water market in many regions could remain thin the forestry industry can be expected to hold some water entitlement shares in 'reserve.' Plantation investment risk is more dynamic if allocation announcements are made on an annual rather than, say, every 5 years	**At clear felling.** When a forest is clear felled, it may not be replanted until as a result of either increased recharge, decreased direct groundwater extraction or the purchase of announced allocations the account in returned to a positive state. If there is, say, a 20% decline in allocations per share, then this would result in a 100% debt every five years and require either the entire area under forest to be fallowed for a year or the licensed area reduced by an equivalent percentage so that the debt is gradually cleared	**None until the announced allocation per share held by all other water users drops to zero.** At this point in time, foresters would be required either to clear fell a proportion of their forest and/or purchase sufficient allocations or surrender sufficient shares to enable aquifer height to be maintained

Table 3 *Continued*

	Full accounting approach	Partial accounting approach	Offset approach
Implications for other entitlement share holders	All water users are treated equally. The forestry industry can be expected to hold more entitlement than it needs. Costs of estimating and accounting for water use by forestry are likely to be significant. The forest industry can be expected to argue that the deemed use estimate should be adjusted for annual rainfall, forest age, etc. Without care, the system could become so detailed that it becomes extremely difficult to manage	For irrigators, the downside risk is substantial and management of this could prove difficult There is a significant opportunity for the forest industry to game the system and accumulate debits that are never cleared	Other entitlement holders receive an increased entitlement and if there is no adverse climate shift, a greater allocation

effects of increased permanent vegetation – whether by forestry or for conservation purposes – should be offset.

5.3 Farm dams

The effect of each additional farm dam on water supply is similar to that of a plantation forest. As with a forest, inflows into dams and evaporation losses are significant and are both un-metered and un-meterable. Nevertheless, it is possible to estimate the amount of water which, as a result of interception, is not available elsewhere in the system. The dam builder could then be required to offset the impact of building a dam by surrendering an entitlement whose value is deemed to be equivalent to the impact that the dam will have on downstream entitlement reliability.

In the Murray Darling Basin, CSIRO has estimated that water supply reductions as a result of farm dam development over the next 20 years is likely to be somewhere between 250 and 3000 GL. Every mega litre of farm dam storage is estimated to reduce flow by 0.84 ML. Once again, the amounts are significant and likely to be greater than the Murray Darling Basin Ministerial Council's 'first step' decision in November 2003 to secure 500 GL of water entitlements for the environment. Moreover, as with plantation forestry, this water is equivalent to a high security allocation in the sense that farm dams tend to capture every drop of water that reaches them until the dam is full. At a price of $2300/ML, the entitlement cost of offsetting a dam that 'uses' 5 ML/year would be around $9660.

Most States now include policies that require permission to build dams in excess of a specified storage volume. In Victoria, for example, permission is required to build dams with a capacity which, depending upon wall height is greater than 20–50 ML (DSE 2007). In New South Wales, farmers are allowed to build dams that capture up to 10 per cent of run-off. As yet, however, no State has implemented the obvious solution of requiring all aspiring dam builder to purchase and surrender a water entitlement equivalent to their expected impact of future water supplies. An alternative approach, which could also be used for forestry, is to introduce an array of dam trading rules that would in essence cap the development of small farm dams and then allow trading of dam capacity within a subcatchment.

While much small farm dam construction is for stock and domestic purposes, many small dams can add up to a lot of interception. In areas where there is considerable subdivision occurring, it may be more administratively efficient to assign responsibility for offsetting the impacts of increased farm dam development to local governments rather than to individual farms. Local governments could use satellite imagery to assess retrospectively the extent of impact, and surrender the quantity of entitlements estimated as necessary to offset the impact of increased small farm dam development in their region. Once again, and as with forestry, the offset rules put in place could require the surrender of an adverse climate change insurance premium that is transferred to all other entitlement holders.

5.4 Groundwater–surface water connectivity

The effects of groundwater development on opportunities to use surface water and vice versa are different to those associated with forestry and farm dam development. The problem here is one of managing interaction and exchange between two metred use systems that sit side by side with one another (Resource and Environmental Management 2004, 2006). Very close to a river, extraction from groundwater systems has almost the same effect as extraction from the river itself. Further away, however, the effect is delayed and the exact location and extent of the effect on river flow difficult to determine. At the zone of interaction between a river and an aquifer, rivers can be defined as either 'gaining' because the aquifer water is flowing into the river or 'losing' because the river is recharging the aquifer. In severe droughts and when groundwater development is excessive, a 'gaining' river can change into a 'losing' river.

In such situations, one of the necessary conditions for efficient water use is that the two systems be managed as one. That is, an arrangement must be put in place that ensures increased allocations (or takings) from one system lead to transparent reductions in allocations to the other system. At the very least, this requires the extent of groundwater development to be reported to the holders of surface water entitlements and statements made as to the likely affects of these approved developments on their future water allocations.

In Australia's recent drought and as allocations to high security entitlements were reduced, a number of irrigators purchased groundwater entitlements that were some distance from the Murray River and then transferred these groundwater entitlements to a location very near the River. As allocations per groundwater share were not reduced during the drought in the same way that allocations per surface water shares were reduced, this enabled these new groundwater users to access much more water than otherwise would have been the case. As well as being inefficient, such arrangements are also inequitable, as those located elsewhere in the system cannot take legal action to prevent these new groundwater users from accessing water that was previously available to them.

5.5 Increased irrigation efficiency

As a general rule, increases in the efficiency of water use are achieved partially by reducing evapo-transpiration and partially by reducing return flows to the river through reduced accessions through the root zone to groundwater and/or reduced surface drainage back to the river. Surface drainage back to the river can also be reduced by installing an on-farm drainage recycling system. In addition, reducing channel seepage to groundwater, either on-farm or in water supply systems can also reduce return flow. Unfortunately, less return flow ultimately means that less water is available either elsewhere in the system from which it was taken and/or from the groundwater system it is connected to. In short, reductions in evaporation and transpiration are real savings, but most other so-called savings as a result of increased water supply or irrigation efficiency come at a cost of the capacity to allocate water to other users and/or to the environment.

Unlike many water entitlement allocation systems in the United States of America (where water entitlements are defined as 'nett' entitlements) most water entitlements in Australia are defined as 'gross' entitlements. This authorises the entitlement holder to take water but does not require any of that water to be returned back to the system.

The problem is that, as a general rule, irrigation developments tend to begin with the use of relatively inefficient technology which leaks or returns lots of water back to the system. As the irrigation industry further develops and markets drive investments in technology to improve irrigation efficiency, the result is a reduction in the amount of water that is available to others. Recent estimates undertaken for the Murray Darling Basin Commission suggest that the future impact of increases in irrigation efficiency are likely to be less than those associated with farm dams and forestry. Pursuit of increased irrigation efficiency was one of the very first consequences of the introduction of water trading. During the period from 1995 to 2001, Bryan and Marvanek (2004) estimated that the area under irrigation in the Southern Connected River Murray System increased by 20 per cent without any significant breach of the maximum amount of surface water that was diverted. Under such conditions, this increase in irrigated area must have been achieved primarily by a reduction in return flows, partly as a result of increases in the technical efficiency of irrigation.

5.6 Salinity interception schemes

Salinity interception is a special form of groundwater use whose impact on the quantity of water available to irrigators has still not been officially acknowledged by the Murray Darling Basin Commission. Along the River Murray, the process involves construction of a curtain of groundwater wells to pump saline groundwater otherwise returning to the river to off-river evaporation basins. The problem is that whilst salinity interception provides gains in terms of decreased river salinity, it does so at the cost of increased water use and a decrease in the volume of water that flows down the river. Moreover, those responsible for operating these schemes are neither required to hold an entitlement nor an allocation.

In a dry year, like 2006/07, the salinity interception schemes located along the River Murray pumped approximately 22 GL, in an 'average' rainfall year around 32 GL is pumped, whilst in a wet year it has been necessary to pump as much as 50 GL of water from the system (Pfieffer, pers. comm., 2008). All of this water is taken from saline groundwater aquifers next to the river and contains considerable amounts of salt, nevertheless, it still remains a volume of water that ultimately would have entered the river. Once again, there is a flaw in the accounting system that could be resolved by requiring the operators of these schemes to hold an entitlement and secure allocations commensurate with the amount of water they extract allocate.

Interestingly, whilst all these schemes have been required to pass a cost-benefit assessment, none of these assessments have included an assessment of the cost of buying the necessary water entitlement. In a year like 2007/08, when allocations to high security entitlements are currently at 32 per cent, in order to operate the scheme without entering the market to acquire the necessary allocations it would be necessary for the system manager to have held 69 GL of high security entitlement.

6. Ways forward

The purpose of this paper has been to reveal the consequences of defining water entitlements and allocation rules in a manner that lacks hydrological integrity in the sense that entitlements are not defined in a manner that is consistent with the ways that water arrives, flows across and flows through land and can be intercepted.

As a general rule, the result is the emergence of a suite of misentitlement and over-allocation problems, and environmental problems that emerge with increasing severity as entitlement reliability is eroded and less water is made available to the environment. The overall impression that emerges from the available information is that the impact of these processes is much greater than most people appreciate. Existing water sharing plans do not deal adequately with these problems. As a result, in Australia and elsewhere, a wide array of inefficient investment decisions have been made. Moreover, current water trading arrangements aggravate the extent of this inefficiency.

Approaches to dealing with these problems and establishing a system that has hydrological integrity, including a capacity to adapt to climate shift and climate change have been described. In addition to the development of low cost entitlement and allocation markets, elements of the pathway forward include specification of the water entitlements as shares, definition of share pools in a way that recognises the reality of system evaporative losses irrespective of inflows and the need to allow some water to reach the sea. The other main element is the introduction of practices that require the offset of the adverse impact of un-metered and un-meterable forms of water use, and the management of connected ground and surface water systems as one.

As outlined in this paper, proposing solutions to these problems is relatively simple. In practice, however, overcoming the political and institutional difficulties associated with transforming a misspecified water entitlement and allocation system into one that has hydrological integrity remains a significant challenge.

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