Accounting for water flows: Are entitlements to water complete and defensible and does this matter?

Authors: Coggan*, A.J, Whitten, S.M and Abel, N.
Affiliation: CSIRO Sustainable Ecosystems, Australia

Water entitlements provide the institutional framework intended to facilitate secure and defensible use rights to a scarce resource and thus security for investment. In this paper we explore whether water entitlements are exclusive or defensible in Australia. Defensible entitlements to water prove to be problematic because of the impacts of time and space in hydrological systems. Allocation of the resource is framed within the physical constraints of a uni-directional, sequential hydrological system where upstream agents have, at the least, a time of access priority over downstream agents. Existing allocation institutions in Australia are dominated by a sequential allocation of water supply stocks, which for surface flows is most commonly specified as a share of the available resource that is converted to a supply volume each year. This allocation structure largely ignores the potential for agents in the system to systematically influence flows between these sequential stocks, for example by changing dryland management, water distribution management, or, irrigation management. As a result water entitlements are not fully defensible with impacts likely to be cumulative through systems because of priority environmental entitlements and residual user entitlements. The conclusions for the allocation institution are less clear because of the potential impacts of transaction costs, especially information requirements. We illustrate our arguments using examples from the Murray Darling Basin in Australia.

A previous version of this paper was presented at the IPA Symposium on Establishing Australian Water Markets in Melbourne, Australia, August 9th 2004. We are grateful for comments from Jeff Bennett (The Australian National University) and Russell Gorddard (CSIRO Sustainable Ecosystems). Naturally all errors remain the responsibility of the authors.
* Corresponding author: Anthea Coggan. Contact via CSIRO Sustainable Ecosystems, GPO Box 284, Canberra ACT 2601, Australia, email: anthea.coggan@csiro.au

1. Introduction

Institutions that structure resource access and use are intended to reduce uncertainty about the behaviour of others and make higher levels of coordination and social organisation possible. These institutions aim to facilitate the security of resource access that individuals and businesses need to invest and create income in the economy. Our goal, in this paper, is to explore the institution of water entitlements with a focus on the exclusivity of water use. Specifically, we ask whether existing water entitlements facilitate defensible exclusion of other potential and actual water users. We also comment on the transaction cost implications of alternative policy responses to incomplete exclusion.

Across Australia, entitlements to water are formally allocated through a licensing system. Although this system varies between States, in most cases, entitlements are defined in two parts. First, a specified share of the total water in a defined river or major storage that is available to the water user. Second, rules outlining responsibilities for this water use such as when, where and how this water can be used. Current entitlements include provisions to ensure water quality outcomes. These water quality criteria are not discussed in this paper despite their importance to water users.

Existing water entitlements are incomplete because they do not cover all aspects of the hydrological cycle of water, from its source as rainfall onto farms and other lands to its eventual exit from the system as evapotranspiration or runoff. Water is both a stock and a flow resource depending on where in the system it is considered and the time scales used. Entitlements are structured to specify access and use rights to stocks and flows of the water resource held in storages and in unregulated rivers and streams[1]. For example, entitlements as licences specify share and use conditions for regulated systems. However, these entitlements are incomplete because they do not cover all of the stocks and flows in the system. As a result there are opportunities for landholders to manage landscapes and operating regimes in order to capture additional water. In this respect, downstream agents are unable to defend their entitlements from upstream actions. However, the impact of transaction costs such as gathering information about the consequences of upstream agents' actions, as well as monitoring and policing those actions, means that incorporating these impacts into the market frameworks may not necessarily be the most efficient approach.

The paper is structured into five sections as follows. The hydrological processes yielding water resource generation and use are set out in the next section, this includes broad estimates of current water allocation and use. This section defines the physical space that complete rights need to extend across. In the third section the institutional framework defining the nature of entitlements to water and issues in their defensibility is set out along with the nature of the transaction costs in allocating water. Current water entitlements arrangements in Australia are then identified together with the implications of the existing entitlement structure for their defensibility in the fourth

[1] Water supply in Australia is either regulated or unregulated. Regulated water supply is that which is released from large storages operated by the State, unregulated supply is that water in rivers and streams not regulated by any storage.

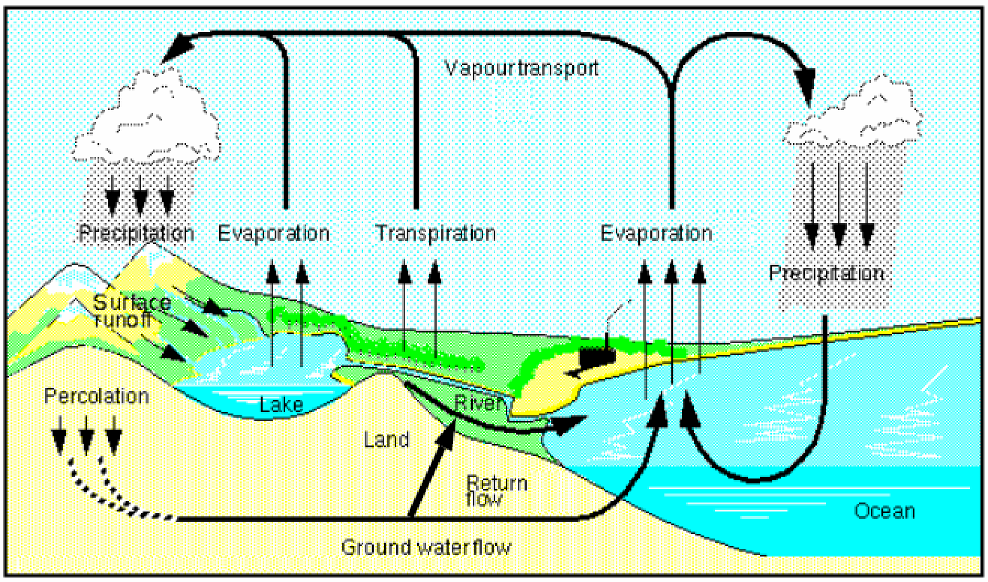
section. The focus is on the incompleteness of water entitlements and their potential implications given the impact of human activity on the availability of water resources. Emphasis is placed on the impact of harvesting surface flows, land use change (such as reafforestation) and irrigation efficiency. The paper is concluded with some discussion of policy options in light of the issues raised in the defensibility of water entitlements.

2. Water in Australia

2.1 The Hydrological Cycle

There are many pathways that water may take in its continuous cycle of falling as precipitation and returning to the atmosphere. On its journey, water may be intercepted by vegetation and evaporated directly back into the atmosphere (evapotranspiration) or absorbed into the soil and later be transpired by plants, or continue on to percolate into the groundwater. Alternatively, water may become surface runoff and reach rivers or be captured on land. Figure 1 demonstrates this "life cycle" of water.

Figure 1: The water life cycle

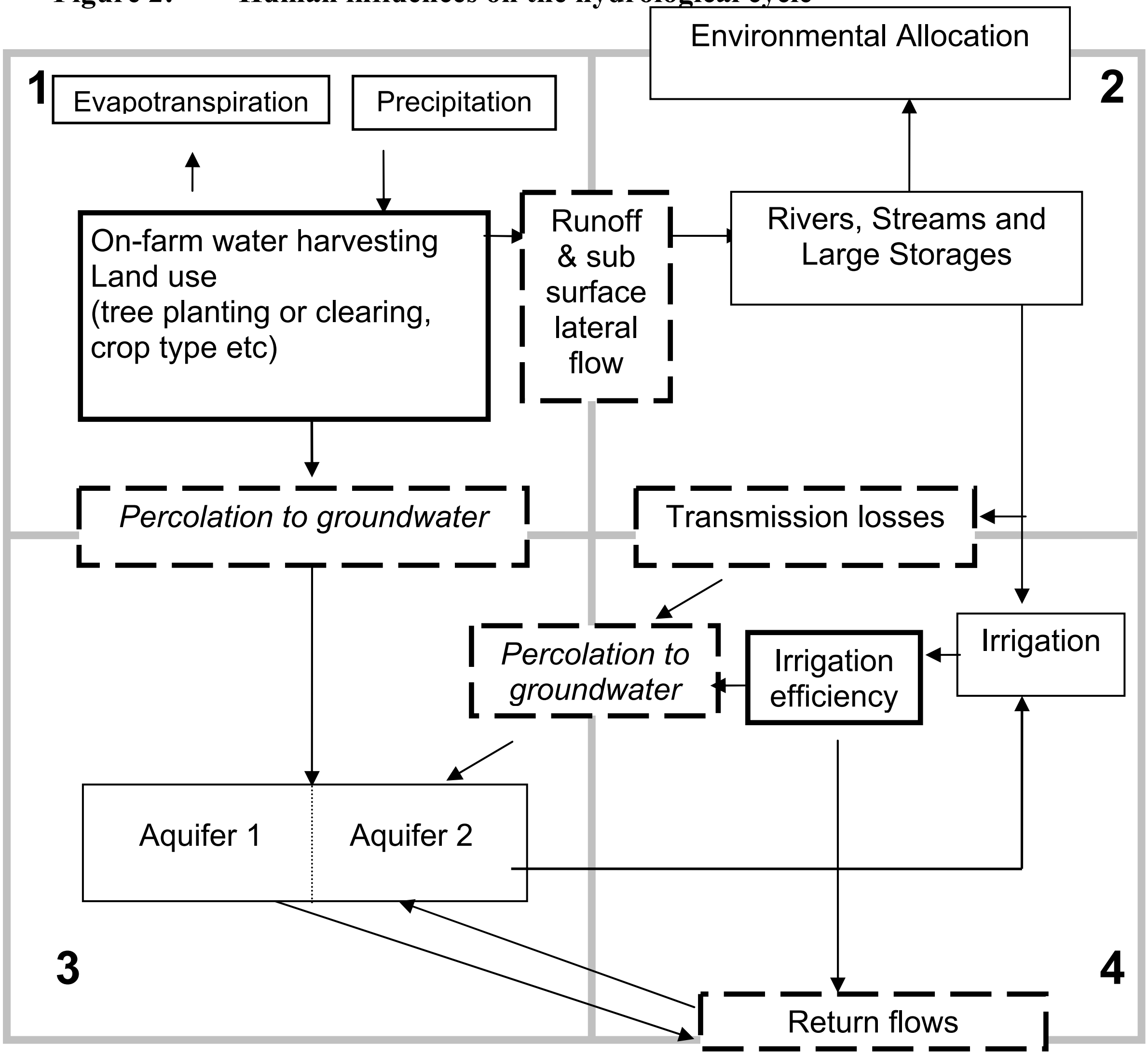


Source: Productivity Commission 2003 a

2.2 Human Influences on the Hydrological Cycle.

There are many places where human activity can influence the natural life cycle of water. Figure 2 simplifies the hydrological process into four interlinked quadrants. The heavy solid boxes demonstrate the places where human activity is identified as having a potentially significant impact on the rest of the water cycle. The dashed boxes represent one definition of the flows of water.

Figure 2: Human influences on the hydrological cycle



Notes: Return flows may return to rivers and stream from which they may then be reallocated. Environmental flows in one part of the system may be reallocated to consumptive uses further down the system. The link between return flows and the surface water system is not demonstrated in Figure 2.

The first quadrant of Figure 2 represents the point of contact with the ground. Once an initial stock of rain falls a number of things can happen:

- it may be absorbed into the soil and percolate through to underground water resources (aquifers), moving laterally to rivers, streams and storages as subsurface lateral flow;
- it may be absorbed from the ground by vegetation and then return to the atmosphere through transpiration; or,
- it could run off either naturally or through man made drainages joining surface flows such as rivers, streams and drainage channels.

From this very first water contact, landholders can immediately influence the life of that water through land use and on-farm water harvesting[2].

Water that is not captured where it falls or on-farm as overland flows will eventually reach rivers and streams either directly or through shallow groundwater flows. Some of these flows are captured in large storages to be released later as flows for extraction by licensed irrigators. Water is also allocated to the environment. For example in Victoria a share of water in rivers and aquifers is set aside for environmental uses through environmental water reserves (Victorian Government 2004). This environmental water is represented in quadrant 2 of Figure 2.

Whilst some water runs off the landscape, some water will infiltrate through the soil profile and, when not used by vegetation in transpiration, percolates through to the groundwater reserves. This flow of water is represented in quadrant 3 of Figure 2. Quadrant 3 also demonstrates the fact that many aquifers are connected with water flowing between aquifers and water flowing from aquifers back to rivers and streams as base flows. Aquifers are also used for irrigation and are impacted by land use and extraction in direct and related aquifers.

Human impacts once water leaves the farm or land management unit on which it falls are demonstrated in quadrant 4. In quadrant 4, water is extracted from rivers, streams and groundwater for use in irrigation and other consumptive and non-consumptive uses such as hydroelectricity generation. Figure 2 only refers to irrigation because it is the dominant consumptive use of water in much of Australia. Some of the water allocated to irrigators will be lost through transmission losses, or may return to the system following irrigation through percolation to groundwater or return flows to rivers and streams (all of these are in bold dashed boxes representing a flow of water). Of note is the fact that water that returns to the river or groundwater through return flows is often already allocated to downstream users. Therefore, activities by upstream water users that may reduce the amount of water recharging aquifers or returning to rivers may impact on the entitlements of downstream water users. Activities that can influence the flows of water to downstream users include transmission losses and irrigation efficiency.

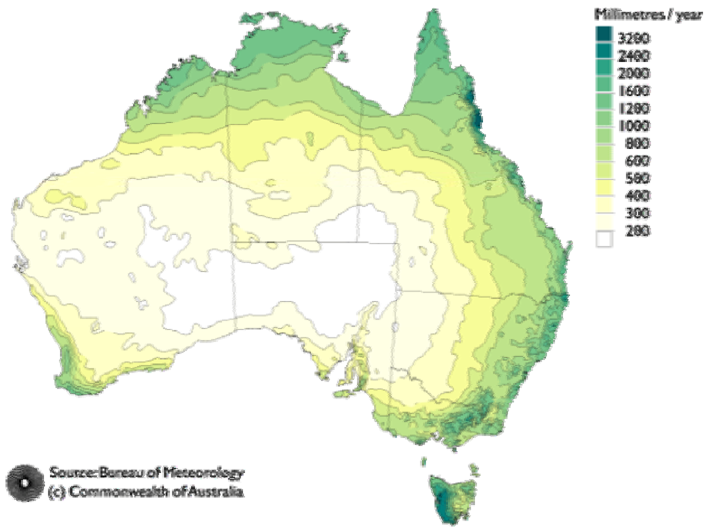
From Figure 2 it becomes apparent that there are key places in the life cycle of water where human impact can significantly influence the amount of water in the whole system. These actions, how they impact on water availability, and the property entitlements surrounding them are the focus of the paper.

2.3 Australian Water Availability

On average, Australia receives approximately 3.3 million GL of rainfall each year (Dunlop, 2001). But as demonstrated in Figure 3, Australia's rainfall is both spatially and temporally variable.

[2] Other agents may also influence the amount of water that reaches the ground through cloud seeding. This is not discussed in this paper.

Figure 3: Average annual rainfall based on 30-year climatology (1961-1990)

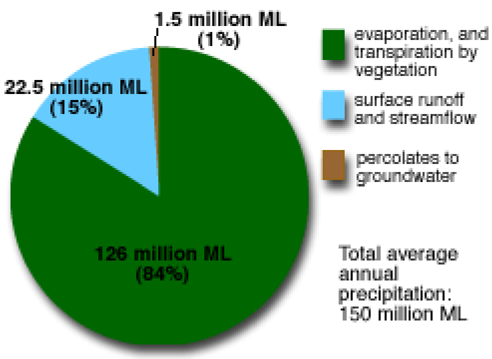


On average across Australia, only 12% of rainfall runs off to collect in rivers. Like rainfall, this runoff varies spatially across the continent.

For example, in Victoria, of the 150 million ML of rain or snow falling on Victoria each year (Victorian Government Department of Sustainability and Environment):

- 84% (126 million ML) evaporates, or is transpired by vegetation to the atmosphere (evapotranspiration);
- 15% (22.5 million ML) is discharged as surface runoff and stream flow; and,
- 1% (1.5 million ML) infiltrates the soil to groundwater aquifers.

Figure 4: Precipitation to water resources in Victoria.



Source: Victorian Government Department of Sustainability and Environment

Water users commonly access water from runoff (harvesting water before it reaches a waterway), surface flows (rivers and streams) and groundwater resources. The available resource of each of these is described in the following subsections.

2.3.1 Surface Water

Surface water resources are often represented by Mean Annual Run-off (MAR). This is the average annual stream flow passing a specified point or the maximum average annual flow observed in a river basin (ABS 2004). In 2000 the MAR for Australia was 385,923 GL (ABS 2004). Similar to rainfall, the MAR is spatially variable across Australia.

The physical capacity to extract water from a river is referred to as developed yield. Developed yield is the average annual volume of water that can be diverted for use with existing infrastructure. The developed yield demonstrates the extent to which surface water assets are, or can be used. In 2000 developed yield was approximately 14,859 GL, representing 4% of Australia's MAR (ABS 2004).

In 2001, according to the National Land and Water Resources Audit (NLWRA 2001) 84 of Australia's surface water basins were close to or over-used in terms of meeting sustainable flow regimes. Further, only 31 had a formal environmental allocation.

2.3.2 Groundwater

The volume of groundwater that exists in Australia is not known with certainty. Instead of an absolute measure of the groundwater stock the sustainable yield is used as a proxy. It is estimated that the sustainable yield of groundwater in Australia is 29,173 GL (ABS 2004). Sustainable yield is defined by the ABS (2004) to be the level of extraction measured over a specified planning time frame that should not be exceeded to protect the higher value social, environmental and economic uses associated with the aquifer. The NLWRA (2001) state that 2,489 GL of groundwater is currently used (NLWRA 2001).

In 2001, according to the NLWRA (2001), 168 of Australia's 538 groundwater management units are close to or over-allocated, and 161 are over-used. Only three of the groundwater management units across Australia have formal environmental allocations.

2.3.3 Stored Water

There are approximately 500 large dams in Australia with a storage capacity of 84,793 GL (ABS 2004). Australia also has several million farm-dams that contain an estimated nine percent of the total water stored (NLWRA, 2001). The total amount of water stored in farm dams is unknown. However, if nine percent of the known quantity of water in large storages is used as an estimate, water stored in farm dams could be as much as 7,631 GL.

2.4 Water Use in Australia

In 2000/01, 72,431 GL of water was extracted from the environment to be used within the Australian economy. Of this, 12,784 GL was extracted by water providers[3] and 59,647GL was self extracted[4]. Of the total water extractions, only 24,909 GL was

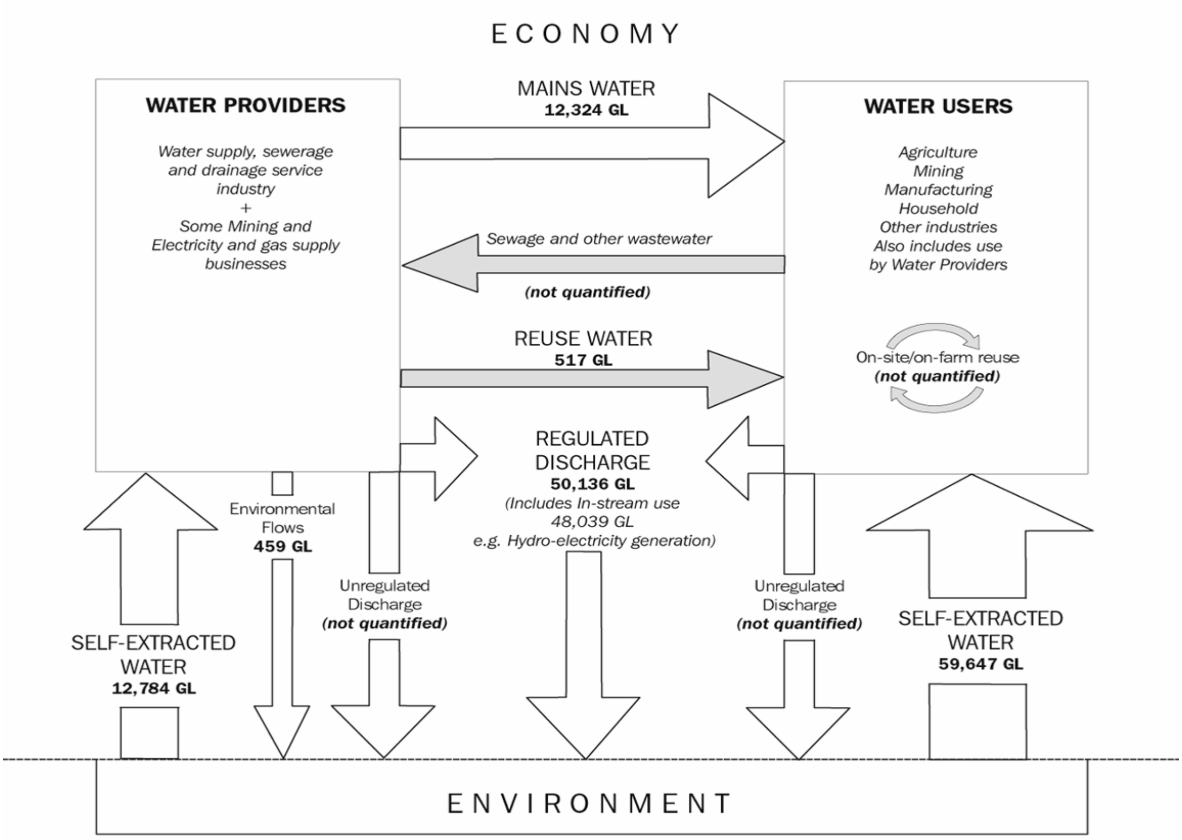
---

[3] As demonstrated in Figure 5, water providers are defined by the ABS as primarily the water supply, sewerage and drainage service industry. This water is extracted and provided to users through a network of infrastructure such as channels and pipes and is supplied to users for a fee.

[4] Defined by the ABS as water extracted from the environment and includes water from rivers, lakes, farm dams and other water bodies.

actually consumed by the economy (ABS 2004). The difference returns to the system as regulated and unregulated discharge[5] (see Figure 5).

Figure 5: Water Supply and Use in the Australian Economy 2000-01



Source: ABS, 2004.

In 2000/01 agriculture, the largest consumer of water in Australia, consumed 16,660 GL of water or 67 percent of Australia's total water consumption in this period (ABS 2004). Of the water used by the agriculture industry 9,132 GL was from self-extracted sources, 7,105 GL was from mains (supplied by irrigation authorities) and 423 GL was reuse water (ABS 2004).

3. The Security and Defensibility of Water Entitlements

Property rights are the fundamental institutional components that facilitate individual access to otherwise contestable resources. Water entitlements are the institutional framework used in Australia to assign rights to individuals intended to reduce

[5] Regulated discharge refers to water discharged after use where that discharge does not match the natural flow regime of the receiving water body. For example, wastewater discharged into a river, ocean or land outfall by a sewerage service provider is considered a regulated discharge. Many irrigation water providers were unable to quantify the volume of drainage water discharged and it is likely that this volume is larger than indicated in the flow tables. Unregulated discharges are currently not included in the ABS water account.

uncertainty about the behaviour of others and make higher levels of coordination and social organisation possible[6]. In short, the allocation of water entitlements is intended to facilitate the security of resource access that individuals and businesses need to invest and create income in the economy.

Entitlements can be defined as ‘a claim to a benefit (or income) stream that the State will agree to protect through the assignment of duty to others who may covet, or somehow interfere with, the benefit stream’ following Bromley (1991). Entitlements are a government allocated benefit to an individual to access or consume a resource.

The importance of rights such as water entitlements lies in the way in which they enable individuals to benefit from activities. For example, there are often different, graduated levels of rights such as Ostrom and Schlager (1996) describe which can be applied to water as follows (Whitten 2003):

- access: the right to access a defined physical area of water for non extractive benefits (for example swimming);
- withdrawal: the right to obtain water for a consumptive use (such as irrigation);
- management: the right to regulate internal water use patterns and transform the resource by making improvements (weirs and storages);
- exclusion: the right to determine who will have an access right and how that right may be transferred; and
- alienation: the right to sell or lease either or both of the access and withdrawal rights.

Entitlements to water usually comprise of withdrawal and alienation rights, often with some level of management rights attached. In this paper the focus is on the defensibility of water entitlements. Defensibility is broadly the completeness of the rights that are allocated combined with the legal ability to exclude others from use of the resource. However, many entitlements structures are a complicated bundle of explicit and implicit rights as discussed by Beare and Heaney (2003). Explicit rights have a sound and secure legal basis and those who do not hold these rights can be excluded from resource use. Implicit rights are less secure and may not even have an implied legal basis. Beare and Heaney (2003) describe two types of implicit rights:

1. Rights to resource use are implied by a history of resource usage. An example is where farmers modify tillage practices to more effectively capture and store water, and,
2. Implied rights may be bundled with explicit rights. Beare and Heaney use the example of implied rights to storage and delivery infrastructure in regulated systems that are bundled with water use licences in irrigation areas.

Implicit rights have no legal basis that facilitates their defence. Explicit rights are more secure but may still lack the legal basis for defence depending on how they are

---

[6] Water entitlements are not true “property rights” in the economic or legal sense as some attributes differ. For example, water entitlements are generally time limited rather than allocated in perpetuity.

structured. For example, explicit entitlement to a share of a variable stock of water may not be defensible against impacts on the source of the stock.

3.1 Some aspects of water entitlements that complicate defensibility

Water is often described as a common pool resource. The technical definition is a resource that is “rivalrous in use and from which it is difficult or costly to exclude users” (Grafton, Pendleton and Nelson 2001). In simple terms, common pool resources are “a valued natural or human made resource or facility that is available to more than one person and subject to degradation as a result of overuse. A common pool resource is one for which exclusion is costly and one persons use subtracts from what is available to others” (Connor and Dovers 2002). Hence, defence of entitlements incurs costs on the part of users.

The common pool nature of the water resource is further complicated by its physical properties as a fixed stock at any point in time and place that is linked by variable flow components. For example, at any particular point in time there is an extractable stock of water stored in the catchment in dams, streams and aquifers. The available stock varies from year to year according to flows, which in turn are influenced by seasonal conditions and water demands.

The stock / flow characteristics of water has been handled in many systems by specifying long-term entitlements as a share of the available resource, and short-term entitlements as a fixed maximum quantity available for harvest within a set time period. For example, irrigation water licences are commonly expressed as a share of the available resource (the variable flow). Each annual irrigation season the share of the resource is converted to an announced maximum volume of water that can be accessed. The harvestable volume is often calculated after allocating environmental or other priority entitlements that may or may not be related to the flow component.

The approach of allocating a share of the available resource that is then available as a specified quantity that varies according to time period is a standard approach to defining entitlements to most common pool resources such as fisheries. However, with respect to water, location specific and uni-directional flows complicate this process. Put simply, rain falls in a specific location and runs downhill. While some local pumping may reverse this flow it remains downhill for most practical purposes. This introduces two different but interrelated practical problems:

1. the degree of substitutability of water sources in catchments is location specific. Importantly, water sources become more substitutable at downstream locations as tributaries join together (but potentially at the cost of transmission losses); and,
2. upstream agents are independent of downstream agents but may be able to influence the quantity of resources available to downstream agents if water entitlements are incomplete or non-defensible.

Substitutability of water sources is often dealt with by considering separate aquifers or streams as separate common property resources. Special rules may then apply to the spatial alienability of entitlements to prevent trades from occurring that would compromise the entitlements of other holders. For example, there are a number of spatial rules governing trades in the Murray and Murrumbidgee systems.

The impact of uni-directional flows on entitlements is much more complex. The uni-directional nature of the system can be thought of as a set of sequential allocation decisions where the behaviour of upstream agents affects the resource availability of the downstream users. This problem is illustrated in Figure 2 with respect to irrigation and the hydrological cycle. At any stage in this cycle users are able to change their management to capture water resources. However, entitlements may not cover all steps in the cycle. For example, land managers in quadrant 1 may change their land management to reduce runoff or groundwater percolation. Similarly, delivery agents may be able to change their behaviour to be more or less efficient. If there are multiple irrigation areas then there will be sequential opportunities to capture additional water by reducing return surface or groundwater flows. If entitlements are not linked both upstream and downstream then they may not be defensible.

Two types of priorities in water systems may further complicate the sequential allocation problem that characterises water entitlements. First, the uni-directional system effectively grants prior entitlements to those upstream because their actions can be taken first. Furthermore, some residual entitlements, or abilities to influence the system, will always fall to on-ground users (Wills 1997) and upstream users can exercise residual entitlements first thus impacting on downstream users. Second, the entitlements of some users may be given priority over other users. For example, the environment or water used by urban areas and towns may be allocated before other allocations become available. Thus, in a sequential system, the impact on the downstream users may be cumulative. For example, Young and McColl (2002, 2003) identify these types of impacts at each stage in the hydrological cycle due to impacts such as farm dams, farm forestry, channel leakage and improved irrigation efficiencies.

From an entitlement defensibility perspective it is important to identify whether there is a legal entitlement to the source of water that can be enforced and who has the responsibility or ability to employ that entitlement. To some extent this depends on whether water users hold an implicit or explicit entitlement. An explicit entitlement would allow entitlement holders to enforce their entitlements using the courts. Water users with a history of use hold an implicit entitlement to continued usage (Beare and Heaney 2003), but have no legal mechanism to continue to benefit from that implied entitlement. However, implicit entitlements could be legally enforceable if they are held through other linkages in the supply chain such as water supply and transmission operators.

3.2 Transaction costs and entitlements

Entitlements define access to resources and facilitate the exchange of these resources by virtue of the agreed rules for measurement and access to water amongst other parameters that they represent. However, the design and implementation of the rules and any exchanges of entitlements are not cost free. Rather, significant investment is required to develop an effective system of property entitlements, and further costs are incurred in any changes to this system. Similarly, costs are involved in any exchange of entitlements. These costs are termed transaction costs and include:

1. codifying entitlements, and identifying and enforcing ownership over entitlements;
2. seeking out buyers or sellers of entitlements;
3. negotiating a sale;
4. measuring the quality and quantity of goods; and,
5. contracting specifications about the transfer of entitlements. Contracting issues include when delivery will occur and the uncertainty about any intervening period and incomplete aspects of the contract.

Transaction costs are important because they consume resources that could be used for other purposes (Wills 1997).[7] In the context of this paper transaction costs are important at two levels:

1. any change to existing water entitlements structures will involve transaction costs in changing policy. Information and monitoring costs may be especially important where yield parameters are poorly specified and large catchments feed into spatially separated or sequential storages; and,
2. any changes to policy are likely to influence transaction costs in markets. Who is allocated entitlements may be especially important in reducing transaction costs. For example, transaction costs are likely to be lower in well-established markets with easily identifiable buyers and sellers compared to new markets with uncertain and difficult to identify buyers or sellers.

The nature of the transaction costs will differ depending on the policy structure that is employed. For example, a command and control framework will incur a differing mix of costs to extending market frameworks. The influence of technology on transaction costs may also be important, particularly where tools and techniques such as remote sensing may significantly reduce the transaction costs.

In the remainder of this paper we focus on identifying where water entitlements may not be defendable with respect to the hydrological cycle in Australia and whether this is in fact a problem. We also note some of the transaction cost implications of potential policy options for dealing with incomplete entitlements.

4. Entitlements and water in Australia

4.1 Water entitlements in Australia

In Australia, formal entitlements to water are granted for stock and domestic use, regulated and unregulated surface water access, and, groundwater access. Although varying by State, entitlements to the water resource once it reaches defined streams and river stocks are generally well defined (see Table 1).

Figure 2 illustrates that there are also some significant flow components linking these stocks. In Figure 2 these flow components are represented by dashed boxes as the

[7] Transaction costs may be so high that no entitlements are allocated or alternatively no trades take place, even under the most efficient frameworks. In this case the optimal outcome will be to do nothing and allow the market or government failure to continue because no net benefit can be created by allocation or trading.

movement of water from one quadrant to another and separated out as water after it leaves the farm boundary to storages (quadrant 1 to 2), the transmission of water from the storage then back to land (quadrant 2 to 3), the flow of water from the land to and between groundwater systems (quadrant 1 to 3), and, the flow of the water to the irrigator and back to the stream or groundwater system (quadrant 4 back to 2 or 3).

In Table 1 the current structure of entitlements for water as a stock and a flow resource is summarised. Table 1 and the remainder of this section focuses on surface water interactions (quadrants 1, 2 and 4 of Figure 2 and the flows between them). Subsurface interactions (quadrant 2) are not included in the discussion of water entitlements. Although subsurface interactions are important, surface water use dominants water use issues and is therefore the focus of the remaining discussion.

Table 1: Water Entitlements in NSW, Victoria, South Australia and Queensland

	Quadrant 1 – before the farm boundary		Quadrant 2 - Transmission			Priority Entitlements [a]	Quadrant 4 – Surface water application		
	Land use[8]	Run off	Overland flows	Public distribution	Private distribution		Regulated	Unregulated	Return Flows
NSW	X	√, 10%	√, WAL	State	√	Yes	√, % stock, <Qm	√, % flow, <Qm	X
Vic	X	√, varies according to location	√, <Qm	State	X/?	Yes	√, % stock, <Qm	√, % flow, <Qm	X
SA	X	√, varies according to location	√, varies according to location	State	X/?	Yes	√, % stock, <Qm	√, % flow, <Qm	X
Qld	X	√, varies according to location	√, varies according to location	State	X/?	Yes	√, % stock, <Qm	√, % flow, <Qm	X

[a] Priority entitlements vary by State but usually include environmental flows, town water supplies and landholder entitlements have priority over licensed water use such as irrigation

Source: Productivity Commission (2003 a, b, c, d, and e); Whitten (2003); and, National Competition Council (2001 a, b, c and d).

Key

X	Entitlements not defined at all
√	Entitlements well defined
?	Entitlements to losses and savings in transmission are unclear. Entitlements are either not specified, or savings can not be isolated to either the public or private water distribution entity
WAL	Water Access Licence required
State	Before water enters a private irrigation district or area, transmission losses in its delivery are owned by the State
% stock	% of the stock of dam inflows available at any time
% flow	% of the volume of water that may be accessed at any given time
<Qm	Share of the available stock generally with a maximum quantity specified (it may be exceeded in certain circumstances)

[8] The National Water Initiative is currently considering a framework to address uncontrolled and significant interceptions of water from land use activities (Australian Government Department of Prime Minister and Cabinet)

4.2 What is missing in entitlements and landholder actions and implications for defensibility

There are some key hydrological characteristics that are not incorporated in water entitlements. These gaps in entitlement are circled in Table 1. The missing entitlements primarily relate to:

- flows of the water resource between allocated stock resources such as transmission losses (quadrant 1 to 2) particularly for private distribution systems;
- return flows from water application such as irrigation (quadrant 4 to 2 and 3); and
- to the initial stock of water falling as rainfall and subject to land use changes such as reafforestation before water leaves the farm boundary (quadrant 1).

Also included in Table 1 is an indication of whether there is some priority of entitlements. Different entitlement holders have different priorities to the water resource. The priority of entitlements is specified in the legislation for each State. For example, in NSW under the *Water Management Act 2000*, the fundamental health of a river or groundwater system must be protected and has priority. The Act then specifies that local water utility licences, along with major utilities (such as Sydney and Hunter Water Corporations and electricity corporations) and basic landholder entitlements have priority over other licensed water users. Basic landholder entitlements allow those landholders along a river, or who overlie an aquifer, to take water for their domestic and stock needs without an access licence (DIPNR 2003).

The lack of well-defined entitlements that are then compounded by the sequential allocation of water means that there are a number of actions that could have a potentially significant impact on the flow of the water resource and the resource available to other and downstream users. These actions include water source land use and interception, irrigation delivery efficiency and irrigation water use efficiency. The implications of these missing entitlements in terms of the biophysical outcomes and defensibility of entitlements are discussed in the remainder of this section.

4.2.1 Quadrant 1: Water within the farm boundary, land use and land use change

Currently, agricultural uses dominate land in Australia with 485 million hectares (63%) under agriculture (Keenan et al 2004). Annual crops and pastures common to Australia's agricultural lands use considerably less water through evapotranspiration than native or perennial vegetation. A number of Australian studies show that evapotranspiration from predominantly agricultural catchments ranges from 440mm/yr to 783mm/yr and never exceeds 700-800mm/yr, even in a wet year, due to other climatic limitations (Keenan et al 2004). The lower use of water by agriculture on some soils can result in a greater quantity of water percolating to groundwater or running off to streams and rivers. Groundwater percolation is estimated to have been between 1 and 5mm/yr before European settlement (under native vegetation across what are now mostly agricultural regions in Australia). On the same land, under agriculture, percolation can now range from 0 to 63mm/yr but can be as high as 150mm/yr in high rainfall regions (Keenan et al 2004).

Introducing grazing into the production mix can lead to soil compaction in some areas and result in increased runoff rather than increased percolation. Runoff associated with different land uses with and without grazing is presented in Table 2.

Table 2: Land use and runoff

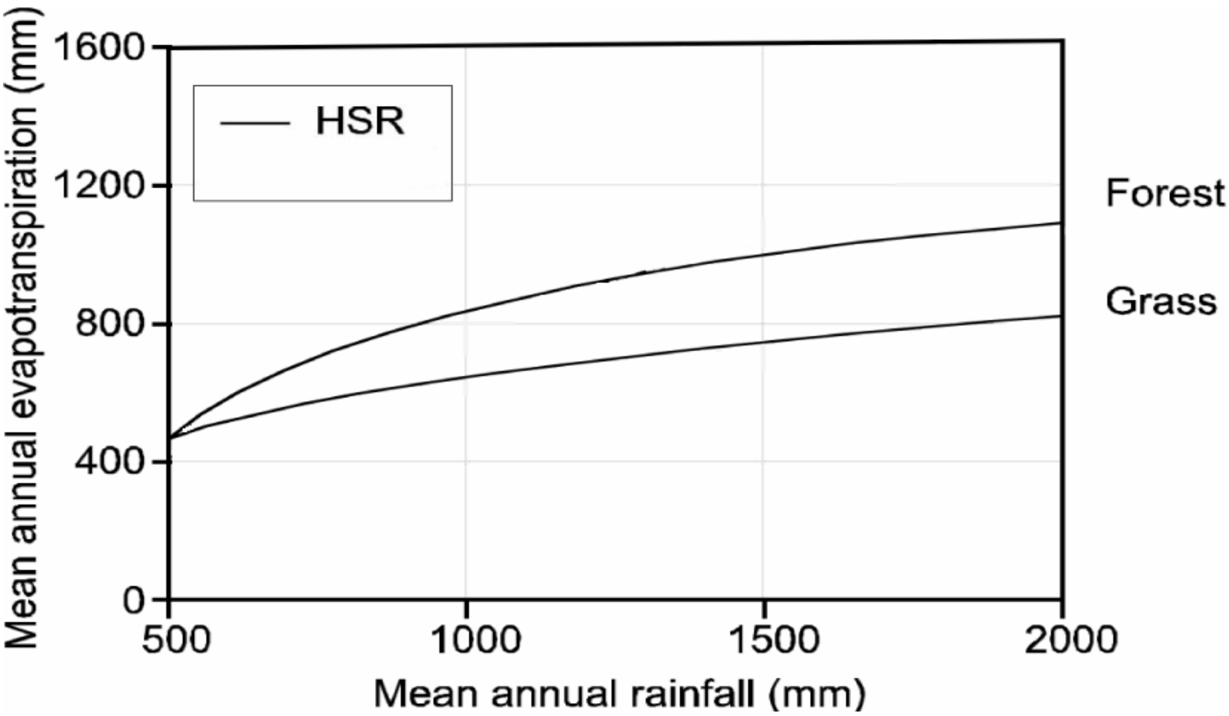
Site	**Treatment**	**Runoff as a proportion of total rainfall (%)**
Wheat Stubble	Heavy grazing	57-81%
	Ungrazed	4-42%
Pasture	Heavy grazing in summer	45-48%
	No grazing and pasture retained from previous 2 years	15%
	No grazing but pasture removed	30-60%

Source: Keenan et al 2004

In general, land use such as stable communities of vegetation (forests) capture and use a larger proportion of rainfall (through a higher evapotranspiration) compared to pasture or agricultural lands. Changes in land use of currently agriculture and pastoral lands such as reafforestation, if undertaken on a sufficiently broad scale, will have a profound affect on catchment hydrology (Keenen et al 2004). The most significant impact will be reduced water yields and reduced groundwater recharge. It is also likely that changes will be seen in the seasonal distribution of runoff, the timing and magnitude of peak flows and the length of low flow periods (Vertessy 2001). Current estimates of the likely impact of the government-endorsed vision of trebling plantation forestry across Australia by 2020 indicate that it is expected to reduce flows in the Murray-Darling Basin by around 1,300 GL (Young et al 2003).

The impact of changed land use (changing from agricultural land to native forest or vice versa) has been extensively researched by Holmes and Sinclair (in Keenan et al 2004). Here 19 catchments in Victoria were analysed to demonstrate that the difference in evapotranspiration between the two landuses (forest or agriculture) increases as rainfall increases above 500mm/yr (Keenan et al 2004). For example, when annual rainfall is 1500mm/yr, the evapotranspiration of forested land is 200mm greater than agricultural land (equivalent to 2ML/ha of forest/yr). When rainfall is 800mm/year the difference is smaller at 130mm/yr. The Holmes and Sinclair relationship is demonstrated in Figure 6.

Figure 6: Relationship between land cover, mean annual rainfall and mean annual evapotranspiration



Source: Holmes and Sinclair (1986) in Keenan et al 2004.

The implication is that landuse change in higher rainfall regions may significantly impact on downstream water yields, and a significant proportion of these areas are privately owned and may be subject to changing landuse. One potential solution to the impacts of land use on the stock and flow of water is to incorporate impacts on allocated stocks further down the system (Keenan et al 2004 and Productivity Commission 2003).

However, Keenan et al (2004) point out that if the impacts of upstream water users such as forestry are to be included in water entitlements a number of issues need to be well thought through first. Many of these issues are associated with the information transaction costs of a policy change and are as follows:

- although there is good science about the impact of reafforestation or clearing on stream flow, this knowledge is only site specific and results regarding relationships cannot be applied broadly across a catchment or catchments (for example, significant proportions of catchments can be hydrologically isolated from streams). Therefore for each small change the impact to the greater system is difficult to determine. This could make the defining of entitlements difficult.
- vegetation in forests provide a range of other benefits (biodiversity and water quality benefits for example). If water entitlements are established for water use by forests, then additional benefits of forests also should be considered and brought into the entitlements system. This is likely to have high information costs.

- where would entitlements start? Will owners of existing plantations be liable for water use? Will there be a water credit once the trees are harvested? Could this provide an incentive for land clearing? Should farmers who convert from annual to perennial pastures which also use more water be liable for this increase water use? Who is liable for the water use if the property and the trees are owned by different entities?

From the issues raised by Keenan et al (2004) it is clear that the transaction costs associated with defining and implementing any policy changes to better define entitlements related to land use change are likely to be high. Transaction costs would also influence the potential efficiency of the resultant market. For example, the cost of trades in any market is likely to vary depending on where the entitlements are assigned in the first place. Assigning water supply entitlements to downstream irrigators incurs a significant monitoring and enforcement cost to defend water supplies. Assigning entitlements to large numbers of upstream users with relatively small impacts would incur significant search and contract negotiation costs on the part of potential downstream purchasers. Indeed costs could blow out given the numbers involved and therefore the negotiation cost as well as the cost of information.

4.2.2 Quadrant 1: Water within the farm boundary – water harvesting

Currently landholders can, to an extent, capture water falling on a property as rain, or running over the surface of a property. Water harvesting includes capturing water on farm in dams to be used later in activities such as topping up irrigation allocation, or through on land works that slow down the runoff (to increase soil percolation). The impact of water harvesting on down stream water users has already been recognised by some governments. For example NSW, Victoria, Queensland and South Australia all have rules and entitlements regarding the harvesting of water. These entitlements and rules range from a blanket ten percent of flow restriction to a percentage take that varies according to the location of the property in the catchment.

In some catchments the sheer number of farm dams is having a significant impact on surface flows of streams. For example, Neal et al (2002) determined that in the Yass catchment in NSW, farm dams had increased from 491 dams in 1976 to 1402 dams in 1988, an increase of 911 dams in just over ten years. This increase in farm dams has seen an increase in storage capacity in the catchment from 1430ML to 5022ML. This is an increase in stored water in the catchment of approximately 300ML each year over the period of the analysis. In the same analysis Neal et al (2002) assessed the relationships between rainfall and runoff with farm dams. Over the period of the analysis there was a statistically significant (at the five percent level) reduction in stream flow of around 1,700ML each year. This reduction in stream flow corresponds to an approximate reduction in mean annual flow of eight percent.

Neal et al (2002) also found that farm dams in the Yass catchment have a greater than proportional impact on flows, with a 1 ML increase in on-farm storage corresponding to a 1.3 ML reduction in stream flows.

Despite the implementation of a cap on on-farm water harvesting in most areas, the impact of developments up to the cap together with any more than proportionate downstream impacts has yet to fully appreciated. For example, in NSW a ten percent blanket cap is applied to the harvesting of overland flows. Furthermore, in most cases the cap is not yet binding with resultant potential for future downstream impacts as development continues. This potential should be of particular concern given the recent decision of the NSW Farmers Federation to lobby for an increase in the NSW cap to 20 percent of on-farm run-off (Sydney Morning Herald July 21, 2004).

4.2.3 Quadrant 1 to 2 and 2 to 3: Transmission of water

Once water leaves the farm boundary, both in naturally occurring watercourses, streams and rivers and man made channels, there are significant quantity losses through evapotranspiration and percolation to groundwater systems (from which it may eventually return as return flows). These transmission losses can be significant with anecdotal reports of over 200 percent losses in some systems[9]. Entitlements surrounding the losses in transmission are complex as they are a combination of state-owned and private water entitlements depending where in the system they occur (See Table 1). Furthermore, some state-owned entitlements have been assigned to private or quasi-private interests.

Un-allocated transmission losses that occur between the water source and final water user are part of a common pool resource until water enters a distribution system for which a single responsible entity can be defined. It could be said that a system that clearly defines and allocates entitlements to losses to a single private entity would give a direct incentive to the entity to improve distribution efficiency. Even if this allocation occurs, this efficiency does not extend upstream to the state distribution agency. It appears that only NSW has a clearly specified entitlement to losses owned by supply management companies (Productivity Commission 2003 b).

Management actions that reduce transmission losses have often been called win-win outcomes as they have been seen to have the potential to provide additional water for the environment without reducing consumptive users entitlements. The potential for private investment to access efficiency gains in these systems is also of interest given the investment of the Pratt Water Group in the Murrumbidgee, in part to identify whether cost effective opportunities to reduce distribution losses via piping may exist. The current operating framework may have created some potential opportunities for private actions to receive entitlements from such actions. For example, the NSW Murray Wetlands Working Group (MWWG) and Wetland Care Australia (WCA) have undertaken works that reduce evapotranspiration in transmission by constructing weirs that facilitated wetland flooding and drying. In return they have been granted access to the evapotranspiration savings for use in flooding other wetland systems. This pragmatic mixed approach may be effective to achieve environmental outcomes but the administrative transaction costs will need to be carefully monitored. Already anecdotal evidence from both the MWWG and WCA indicates that much time and effort was required to secure water access but no formal entitlement to the water is held by either organisation.

4.2.4 Quadrant 4 to 2: Water Application - Irrigation efficiency

[9] The Yanco Creek anabranch south off the Murrumbidgee is reported to have losses of over 200 percent (Murrumbidgee Irrigation personal comment).

Irrigation efficiency is defined as the proportion of irrigation water extracted that is returned to the atmosphere through evapotranspiration. The remainder of the water that is applied returns to streams and rivers and groundwater aquifers. This relationship is demonstrated in quadrant 4 of Figure 2. In horticultural regions such as in Western Victoria and the South Australian Riverland, irrigation efficiency is around 75-80 percent for horticulture. In other areas where application is primarily through flood irrigation, efficiency is usually around 50 percent (Heany and Beare 2001). The range of evapotranspiration (Et) and groundwater recharge levels associated with different agricultural activities in different regions is displayed in Table 3.

Table 3: Irrigation water to evapotranspiration and groundwater percolation

Irrigation area	**Irrigated activities**	**Water allocation**		**Et fraction (a)**	**Recharge fraction (b)**
		Murray	**Tributary**		
		(GL)	**(GL)**	**(%)**	**(%)**
Goulburn Broken	Pasture, cropping, horticulture	320	853	65	50
Campaspe	Pasture, cropping	207	75	50	60
NSW Murray	Pasture, cropping	2,464	0	65	75
Loddon Barr Creek	Pasture, cropping	163	0	65	75
Loddon Cohuna	Pasture, cropping	455	0	55	75
Loddon Tragowel	Pasture, cropping	455	0	55	75
Murrumbidgee	Pasture, cropping, horticulture	0	2,045	65	80
Robinvale	Horticulture	31	0	80	100

Source: Heaney and Beare (2001)
Notes:
(a) Et is evapotranspiration, the percentage of irrigation subject to evaporation and transpiration
(b) The percentage of excess water, irrigation water and precipitation less evapotranspiration that enters the groundwater system (this is the same as "percolation to the groundwater" in Figure 2). The remainder exits as surface flows, some of which may be captured and recycled on- farm.

At present most irrigation licences are defined as an entitlement to access a quantity of water (share of the available volume) with no regard to the proportion that flows back to the river systems either through runoff or groundwater recharge (Young et al 2003). Irrigators pay for the volume that they divert, regardless of how much of that water they actually use. Improving water use efficiency means that less water is required to sustain current production therefore less water is applied to an area, less water percolates through or runs off and therefore less water re-enters the system. By allowing entitlement holders the ability to utilise gains from water use efficiency (for example, increase irrigation area) the current entitlement structure allows upstream users to “capture” an increasing share of the resource at no additional cost to themselves but at the potential expense of the downstream users.

Young et al (2003) highlight this impact. In the Riverland of South Australia it has been estimated that an increase in irrigation efficiency from 80 to 90 percent will reduce groundwater inflows to the Murray River in the region by approximately 22 percent (Young et al 2003).

Managing the impact of improved irrigation efficiency on return flows and downstream water entitlements could be relatively straightforward through the allocation of a net allocation. In other words an allocation that already takes into account the return flows. Young et al (2003) point out that this is already occurring in some states, particularly NSW and Victoria. Young et al (2003) also note that for some irrigation areas in these states “net” bulk entitlements are being allocated to irrigators which allow for a reduction in surface flow returns from improved irrigation efficiency. This means that as one irrigator improves irrigation efficiency, water is reallocated to this person, taking into account the reduction in return flows by reducing the allocation to other users in the system. In Victoria, this is achieved by reducing allocations of sales water and in NSW by decreasing allocations to general security irrigators.

The transaction costs associated with such a policy change will be influenced by the level of information on the current efficiencies and return flows and the numbers of irrigators involved in any potential negotiation.

5. Discussion and Conclusions

Water is both a stock and a flow resource depending on where in the system it is considered and what timescales it is considered under. Allocation of the resource via water entitlements tends to focus on a series of sequential stocks held in large storage dams and aquifers. Stocks (or flows) of water in streams and rivers are also allocated via water entitlements. These entitlements are held by a range of consumptive and extractive users including primarily irrigators but also including towns, households (stock and domestic) and other industrys and with prior allocation given to the environment. What is made clear in this paper is that the allocation framework for water entitlements does not fully capture the complete hydrological cycle of the resource. As a result water users higher up in the catchment are effectively granted a “first to access” priority over the water resource resulting in indefensible entitlements between downstream and upstream entitlement holders.

Incomplete entitlements to water resources imply that a number of land activities could potentially impact on the flow of the water resource and hence significantly compromise the defensibility of entitlements between entitlement holders at different points in the hydrological cycle. Land activities identified as having the greatest impact on water resource flows in the absence of complete entitlements include current and changed land use (for example moving from cropping to agroforestry), water harvesting and a change in irrigation efficiency. Although the scale of the impact of these activities is not known with certainty and perhaps does not appear large when viewed individually (for example a farm dam here and a 10 ha plot of agroforestry there), the cumulative impact on downstream users in an incomplete property entitlement framework is likely to be significant.

Finally, no discussion that has implications for policy should occur without reference to transaction costs. In the context of this paper, transaction costs were identified as significant at two levels. First, any change to existing entitlements may incur significant information and monitoring costs, especially where yield parameters are largely unknown and the catchments are large. Second, changes in policy such as introducing new entitlement holders could influence the transaction costs of already established markets. Further investigation should be undertaken into the nature and extent of transaction costs of better-defined entitlements before any recommendations for specific changes are made.

References

ABS, 2004. *Water Account Australia 2000-2001*, Cat no. 4610.0, Australian Bureau of Statistics, Canberra.

Barzel, Y., 1997. *Economic Analysis of Property Entitlements*, 2nd edn. Cambridge University Press, Cambridge.

Beare, S. and Heaney, A., 2003. *Water entitlements, transactions costs and water policy reform*. ABARE Conference Paper 03.17.

Bromley, D.W., 1991. *Environment and Economy*. Blackwell, Oxford.

Connor, R., Dovers, S., 2002. *Property Entitlements Instruments: Tranformative Policy Options*. Property Entitlements and Responsibilities: Current Australian Thinking, CSIRO Land and Water.

Department of Infrastructure, Planning and Natural Resources. 2001. *Water Access Information Sheet Number Seven. The Water Management Act 2000, What it Means for Town Water.*

Department of Sustainability and Environment (2004). *Securing Our Water Future Togethe*r; Victorian Government White Paper.

Dunlop, M., Hall, N., Watson, B., Gordon, L., Foran, B., 2001. *Water Use in Australia, Report 1 of 4 in a series on Australian Water Futures,* Working Paper Series 01/02, CSIRO.

Grafton, R.Q., Pendleton, L. H., Nelson, H.W., 2001. *A Dictionary of Environmental Economics, Science, and Policy*. Edward Elga, Cheltenham, UK.

Heany, A. Beare, S., 2001. Water Trade and Irrigation, defining property entitlements to return flows. *Australian Commodities, Vol 8, no 2, June quarter 2001*. Australian Bureau of Agriculture and Resource Economics, Canberra.

Keenan, R., Parsons, M., O'Loughlin, E., Gerrand, A., Beavis, S., Gunawardana, D., Gavran, M., Bugg, A., 2004. *Plantations and Water Use: A Review*. Forest and Wood Products Research and Development Corporation, Project Number PN04.4005. Australian Government.

National Land and Water Resources Audit (NLWRA) 2001. *Australian Water Resources Assessment 2000.* Natural Heritage Trust, Australian Commonwealth Government.

National Competition Council (2001)a. *Assessment of Governments Progress in Implementing the National Competition Policy and Relate Reforms: New South Wales reform*, June 2001, Canberra, Ausinfo.

National Competition Council (2001)b. *Assessment of Governments Progress in Implementing the National Competition Policy and Relate Reforms: Victoria reform*, June 2001, Canberra, Ausinfo.

National Competition Council (2001)c. *Assessment of Governments Progress in Implementing the National Competition Policy and Relate Reforms: Queensland reform*, June 2001, Canberra, Ausinfo.

National Competition Council (2001)d. *Assessment of Governments Progress in Implementing the National Competition Policy and Relate Reforms: South Australia reform*, June 2001, Canberra, Ausinfo.

Neal, B., Nathan, R., Schreider, S., Jakeman, A., 2002. Identifying the Separate Impact of Farm Dams and Land Use Changes on Catchment Yield. *Australian Journal of Water Resources,* Vol 5 No 2.

Ostrom, E. and Schlager, E., 1996. *The Formation of Property Rights*. Island Press, Washington D.C..

Perman, R., Ma, Y., McGilvray, J., 1996. *Natural Resource and Environmental Economics*, New York.

Productivity Commission 2003 a. *Water Entitlements Arrangements in Australia and Overseas*, Commission Research Paper, Productivity Commission, Melbourne.

Productivity Commission 2003 b. *Water Entitlements Arrangements in Australia and Overseas: Annex B*, *New South Wales*, Commission Research Paper, Productivity Commission, Melbourne.

Productivity Commission 2003 c. *Water Entitlements Arrangements in Australia and Overseas: Annex C*, *Victoria*, Commission Research Paper, Productivity Commission, Melbourne.

Productivity Commission 2003 d. *Water Entitlements Arrangements in Australia and Overseas: Annex D, Queensland,* Commission Research Paper, Productivity Commission, Melbourne.

Productivity Commission 2003 e. *Water Entitlements Arrangements in Australia and Overseas: Annex E, South Australia*, Commission Research Paper, Productivity Commission, Melbourne.

Sjasstad, E. and Bromley, D.W., 2000. The prejudices of Property Entitlements: On Individualism, Specificity, and Security Property Regimes. *Development Policy Review*, 18(4):365-389 pp.

Tan, P., 2002. *Legal issues relating to water use. Property Entitlements and Responsibilities: Current Australian Thinking*, CSIRO Land and Water.

Vertessey, R., 2001. Impacts of Plantation Forestry on Catchment Runoff Proceedings of a national workshop 20-21 July 2000, Melbourne. *Water and Salinity Issues in Agroforestry No 7* Rural Industries Research and Development Corporation. Publication No 01/20.

Whitten, S.M., 2003. *Water Property Entitlements and Water Management in the Fitzroy Basin*, report prepared for the Central Queensland University and the Central Highlands Regional Resource Planning Cooperative.

Wills, I., 1997. *Economics and the Environment, A signalling and incentives approach*. Allen and Unwin, St Leonards, Sydney.

Young, M.D. and McColl, J.C., 2002. *Robust Separation: A generic framework to simplify registration and trading of interests in natural resources*. CSIRO Land and Water.

Young, M.D. and McColl, J.C., 2003. *Robust Reform Implementing robust institutional arrangements to achieve efficient water use in Australia*, CSIRO Land and Water

Zhang, L., Dawes, W.R. and Walker, G.R. (1999a). *Predicting the effect of vegetation changes on catchment average water balance*. Cooperative Research Centre for Catchment Hydrology, Technical Report 99/12, 35 pp.

Internet references

Australian Government Department of Prime Minister and Cabinet: http://www.pmc.gov.au

NLWRA: http://www.nlwra.gov.au/

Victorian Government Department of Sustainability and Environment: http://www.dse.vic.gov.au

Sydney Morning Herald "Greens pour cold water on push for bigger dams" www.smh.com.au