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Institutional Impediments to Groundwater Trading: the case of the Gnangara groundwater system of Western Australia

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14th November 2011 (Revised June 2012)
Working Paper 1113, School of Agricultural & Resource Economics
www.are.uwa.edu.au



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Citation: Skurray, J.H., Pandit, R. and Pannell, D.J., 2012. *Institutional impediments to groundwater trading: the case of the Gnangara groundwater system of Western Australia*. Working Paper 1113, School of Agricultural and Resource Economics, University of Western Australia. Available at <http://purl.umn.edu/117825>.

*Author's Accepted Manuscript of an article published in JEPM, Sept. 2013, copyright Taylor & Francis, available online at: <http://www.tandfonline.com/>. Article citation: J.H. Skurray, R. Pandit & D.J. Pannell (2013) Institutional impediments to groundwater trading: the case of the Gnangara groundwater system of Western Australia, *Journal of Environmental Planning and Management*, 56:7, 1046-1072, DOI: 10.1080/09640568.2012.716368 .*

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Abstract

The development of a market in groundwater usage rights can be inhibited by constraints arising from the institutional context. Such impediments may reduce the potential gains from trade and may generate high transaction costs for prospective traders. We analyse the regulations and policies influencing groundwater transfers in a case-study area – the Gnangara groundwater system around Perth, Western Australia – and identify significant impediments to a groundwater market. Property rights are found to be conditional, temporary, and vulnerable to amendment. Regulatory approval is required for all transfers. Facilitating infrastructure is lacking, and price information is unavailable. Management area boundaries reflect land ownership and use rather than hydrogeological realities; the limitation of transfers to within these boundaries eliminates much of the potential for gains from trade. Over-allocation and weak monitoring also impede the development of a market. The current management system is likely to obscure unmet demand for water-rights transfers between users and usage-types.

Keywords

Water markets; institutions; transaction costs; externalities; environmental impacts.

Introduction

Water trading has become a popular concept in Australia and elsewhere, although effective groundwater trading schemes are rare worldwide. The idea is not new; by 1965 the exchange of water between uses and locations was considered essential "for the public interest in economic efficiency" (Hartman & Seastone 1965, p. 165). In 1984, Vaux and Howitt demonstrated dramatic potential benefits from inter-regional water transfers in California. The literature on the topic – particularly with regard to surface water – is now substantial, and examines actual or potential water markets in a wide range of locations including, among others, Spain (Gomez-Limon & Martinez 2006), Australia (Sturgess 1997; Bjornlund 2003; Crase et al. 2004; National Water Commission 2010), Chile (Bauer 2004), Bangladesh (Akteruzzaman et al. 1998), Oman (Zekri et al. 2006), and a range of U.S. states (National Research Council 1992; Haddad 1996, 2000a; Howe 1997; Vaughan & Emerson 1997; Brewer et al. 2007). Australia's 2004 National Water Initiative gives a central role to water markets, and its signatories (by 2006 all Australian states and mainland territories) agreed to specific actions intended to facilitate trading (PWC 2006). The National

Water Commission now annually publishes the Australian Water Markets Report, and the Australian Government coordinates the National Water Market System project whose objectives include improving the accessibility of market information, and increasing transparency.¹ In this paper, we refer to water trading and water markets interchangeably, and use the word transfers to denote individual transactions (whether or not they occur within the context of an established market or trading scheme).

One reason for the popularity of the concept is that water markets are often seen as an equitable, efficient, and politically neutral means of managing water under conditions of scarcity – conditions which are increasingly prevalent worldwide, as population growth drives increases in demand and as supplies are curtailed by decreases in rainfall, for example. The expected benefits of trading in water, or in water entitlements, include the promotion of both physical and economic efficiency in water use, the former through price signals, and the latter through improved flexibility in the allocation of the resource among uses and locations. These benefits are particularly desirable in contexts of full- or over-subscription of available water resources. The potential for beneficial reallocation of scarce water away from historical consumptive uses is a common feature of many water resource systems. Indeed, Haddad notes that the term 'available water' is currently understood to imply "that new demand can be met only with *reallocations*" (2000b, p. 15, emphasis in original). In some cases, such reallocation may be seen as urgent (e.g., see Glennon 2009). Increases in streamflow and/or groundwater levels to prevent or reverse environmental damage, and increases in urban water supplies are often proposed as appropriate recipients of water reallocated from lower-value uses (often the highly water-intensive production of low-value crops, for example).

The potential means of bringing about such reallocations are limited, and in some cases may be controversial. A purely regulatory (or 'command and control') approach would require certain reallocations by fiat. To be effective this would require a governance apparatus unencumbered by the political factors and influences that have produced and perpetuate current water allocations in many cases.² Market-based approaches to water reallocation, by contrast, allow the voluntary redistribution of rights, informed by price signals and market forces. Market systems operate within their regulatory context, which can either facilitate or inhibit transactions, depending on regulatory intent. Markets, therefore, are not the 'opposite' of command and control regulation; regulations provide vital institutional support and context to markets. As Bell and Quiggin argue, "markets as a mode of

governance require substantial 'meta-governance' " (2008, p. 713). We do not propose markets in isolation or without the appropriate institutional underpinnings.³

The theoretical basis of water trading is a central principle of economics: gains from trade. Potential gains are derived from the disparity between two valuations of the same good: the opportunity cost of supply, and the willingness to pay of a prospective purchaser. For the two parties to trade voluntarily, opportunity cost must be lower than willingness to pay; that is, the potential for value creation must exist. The terms of the actual exchange (the price) apportion this value between the parties. Potential gains from water trades arise in many situations. For example, municipal water users (commonly through an entity acting on their behalf) often place a higher value on a unit volume of water than do agricultural users (or irrigation districts or co-operatives). Disparities between these urban and agricultural valuations of water can be substantial (e.g., see Brewer *et al.* 2007, who provide a range of examples). Disparities are generally smaller within user groups (e.g., agriculture) than between them. Transaction costs reduce the value captured by the transacting parties, or may outweigh the potential gains from trade altogether, such that the transaction does not occur.

Transaction costs have various sources and are often regulatory, or 'policy-induced' in nature. They impede or increase the costs of undertaking transactions and are frequently identified in the context of water transfers.⁴ Haddad (1996) describes three large-scale, long-term, agriculture-to-urban water transfers in California.⁵ The highest-profile of the three – that between the Imperial Irrigation District and the Metropolitan Water District of Southern California – is also described in National Research Council (1992). Each of these transfers relied on exceptional motivating circumstances to overcome extensive transaction costs. These were water transfers with high value-creation potential. Transfers with lower value-creation potential, such as those between agricultural users, for example, are even more susceptible to non-consummation as a result of transaction costs. Similarly, Haddad notes that "[t]he potential profit margin for water transfers of relatively small quantities, or for a physically-unreliable source of water [...] may not be large enough to cover policy-induced transaction costs" (Haddad 1996, p. 181). Transaction costs are of particular relevance to the establishment of new markets, especially where they involve a dramatic change from an entrenched historical system. McCann *et al.* distinguish between the transaction costs arising from market transactions, and those arising from either the necessary enabling institutional activities (implementation, monitoring, maintenance, enforcement) or the need to

make changes to the “broader institutional environment, such as the legal system” (2005, p. 530).

As the transfers analysed by Haddad demonstrate, exchanges of water or water entitlements can occur in the absence of policies or regulations expressly intended to encourage them. Indeed, *ad hoc* exchanges have occurred in the case-study examined in this paper, following legislative amendments made in 2001 which allow trading but do not facilitate it. Rather than focusing on these few exchanges, however, we examine the transaction costs arising from legal and policy sources, and their role in impeding expanded groundwater trading. We distinguish between ownership rights and the rights to the use of water. In the case-study described, ownership of water rests with the Crown.

The study area is the extensive Gnangara aquifer system, supplying groundwater for irrigation as well as for a majority of the public water supply of the growing metropolitan area of the city of Perth (population 1.7 million) in Western Australia. The transaction cost analysis provides insights that apply to nascent markets for non-water goods; the physical setting provides a case-study pertinent to other low-rainfall, groundwater-dependent urban and agricultural regions, especially those in which urban expansion and population growth fuel heightened competition for water resources.

The paper is organised as follows. First we address a number of the management challenges that are particular to groundwater, and which relate directly to the design of a successful groundwater trading scheme. We then introduce the study area in more detail, before moving on to the legal and policy contexts, and their analysis from a transaction costs perspective. Discussion and concluding remarks follow.

Groundwater Management Challenges

Groundwater management has developed since the 1861 Ohio court finding that groundwater and its movements are generally “so secret, occult and concealed” that attempts to regulate it would be “practically impossible” (in Supreme Court of Ohio 2005, p. 4). It still presents, however, a number of distinctive issues that responsible groundwater managers must take into account. We discuss issues relating to property rights, which are central to some institutional challenges in groundwater management and which have

particular relevance to the design of an effective groundwater trading scheme. We also address two other management challenges: the wide variations between conditions from case to case, and the matter of administrative versus hydrological management area boundaries.

Groundwater is naturally a common-pool resource and, in the “absence of enforced property rights”, has the potential to suffer from the open-access problem (Ostrom *et al.* 1999, p. 279; see also Howe 2002, Libecap 2006). Property rights in this context are of prime importance. Rights to emit CO₂, for example, may be regulated by a government with the intention of limiting emissions. In many cases, rights to groundwater extraction, by contrast, may be virtually unlimited (e.g., Texas, Ohio, pre-1980 Arizona). Even where groundwater rights are quantitatively defined and enforced, these limits may pre-date modern recognitions of supply limitations and issues of sustainability. Clarity and transferability of rights are prerequisites to effective trading. In addition, the inherent variability of groundwater resources has implications for property rights definition. Entitlements to constant annual withdrawals of groundwater are inconsistent with the hydrological reality that the resource is often highly variable. As aquifer replenishment is a function of rainfall, year-to-year safe withdrawal amounts from a given aquifer will vary. (Non-renewing groundwater sources are not subject to this variability.) Vaughan and Emerson caution against the use of fixed quantitative rights in resources that are by nature “inherently variable” (1997, p. 179). Libecap adds that assigning rights as shares of total allowable use (rather than as specified volumes) would reduce “the potential for third-party harm from trades” (2011, p. 71).

Table 1 summarises a range of other factors which may need to be considered in the definition of tradeable property rights to groundwater use. The prospect of trading in groundwater rights focuses attention on their definition, yet there is a tradeoff between comprehensiveness in the specification of rights, and their ready transferability. The more finely specified the rights, the ‘thinner’ the market for them will be, potentially reducing the overall benefits of market establishment. In terms of trading scheme design, the converse of highly specified property rights is the implementation of other measures to protect against environmental and other third party damages. An extensive per-trade regulatory review process is one approach in cases where property rights do not incorporate all the matters discussed here and described in Table 1. We highlight some areas in which administrative review in the Gnangara case may be unnecessarily onerous on all parties.

Management Issue	Considerations
External costs that are difficult to quantify	<ul style="list-style-type: none"> Financial costs: <ul style="list-style-type: none"> pumping cost externality; stock externality (depletion of future groundwater stocks); storage externality (irreversible reductions in future aquifer storage capacities, due to over-extraction and aquifer compaction). Non-monetary impacts: the drying of wetlands, springs, creeks, caves, and lakes, with the attendant habitat impacts; depletion of baseflow to streams and rivers; subsidence, fissures; seawater intrusion; water quality effects. Complexity and uncertainty of effects.
Spatial heterogeneity of effects	<ul style="list-style-type: none"> Even where hydrogeological conditions exhibit little spatial variation, impacts are distributed according to distance from the cause. Spatial variation in hydrogeological conditions compounds and adds complexity to this spatial heterogeneity of effects. Adds to difficulty in prediction and quantification of external costs.
Delayed effects of pumping	<ul style="list-style-type: none"> Inter-temporal nature of many external costs of groundwater over-use: heterogeneity in distribution of impacts over time compounds difficulties in prediction and quantification. Time lags between cause and effect depend on transmissivity and other hydrogeological factors; further complexity.
Interaction with surface water	<ul style="list-style-type: none"> “Physical interconnections” with surface water (Howe 2002, p. 627). Historically managed as separate resources. Groundwater pumping can reduce surface streamflows; diversions from rivers can reduce groundwater recharge. Problem of “double accounting” (Evans 2007, p. 56) or “entitlement misspecification” (Young and McColl 2009, p. 19), where separate surface water and groundwater entitlements represent claims to the same water.
Interception of recharge	<ul style="list-style-type: none"> Although modelling could provide quantitative estimates of interception, it is not a traditionally-measurable use of groundwater, yet can have substantial effects on resource availability for other uses. The year-by-year impacts of interception vary with factors such as rainfall, tree age, and depth to groundwater, adding to the inherently variable nature of the available resource. Gnangara case-study area: plantations of maritime pine (<i>Pinus pinaster</i>) intercept rainfall that would otherwise contribute to recharge (DoW 2009b). Not amenable to conventional measurement, interception could be a source of controversy in adjudication of groundwater resources. Recharge rates depend on the permeability of infiltration areas. ‘Armouring’ of natural surfaces due to urbanisation causes the loss of permeable area and of evapotranspiring vegetation, increasing runoff. This generally results in reduced recharge (depending on case-specific stormwater management regimes).

Table 1: Some additional factors relevant to the definition of property rights to groundwater use and their transferability.

Aquifer hydrogeology varies greatly from case to case. Hydrogeological systems cannot be examined with the ease of surface water systems, for example. This has consequences given the variations in the many factors influencing the behaviour of groundwater systems (such as transmissivity, locations of hydraulic boundaries, gradients, groundwater divides, and the interconnections between aquifers within a given system). As suggested by the 1861 court's finding, quoted above, some aspects of groundwater management are particularly dependent on expert knowledge of local conditions. It may be difficult or ineffective to transpose management regimes from case to case, because heterogeneity of conditions means that optimal management practices may vary widely between locations. This can be contrasted with the management of emissions of CO₂ – a 'well-mixed' pollutant – in which spatial heterogeneity of conditions between emission locations is of lower importance. A flexible groundwater trading scheme can be tailored to local conditions, and may, for some purposes, be less dependent than other management tools on detailed information about the local hydrology and hydrogeology.

Management regimes often apply within jurisdictional boundaries that bear little or no relation to the natural boundaries of the systems being addressed. Hydrological systems, and especially groundwater, are particularly susceptible to this "geographic fragmentation of decision-making responsibility" (Howe 2002, p. 626). To overcome this, decision-making for planning and management needs to incorporate and reflect the interconnectedness of natural systems. In the section *Restrictions on trading*, we examine the number, size, and basis of the management sub-areas in the Gnangara case – delineated by boundaries that are largely jurisdictional and administrative rather than hydrogeological – in terms of the impediment these present to effective groundwater trading.

It is clear that an essential aspect of groundwater management in general is the flexibility to accommodate not only differing hydrological and hydrogeological conditions from case to case, but also the variation in conditions from time to time within a particular management context. An additional reason for the importance of management flexibility in the groundwater context is that the impacts from over-extraction may be both delayed and uncertain. Responsiveness to changing conditions and to evolving knowledge is thus to be valued over rigid regulations which may be based on incomplete or out of date information, or on assumptions failing to incorporate hydrogeological considerations.^{6, 7} The groundwater licences now used in the Gnangara system are a case in point; normally of 10 years' duration, they specify fixed volumetric annual water entitlements. The entitlements relate to management sub-area allocation limits which were established under higher rainfall conditions. We propose that groundwater trading, implemented with proper consideration for

hydrological and hydrogeological conditions, and able to adapt to developing knowledge of those conditions and improvements in modelling and monitoring them, can be a useful tool in addressing management issues such as those described above.

The Gnangara Groundwater System

The Gnangara groundwater system (GGS) extends for approximately 90 kilometres north of the Swan River, and borders the Western Australian coast north of Perth, the state's capital and the fourth-largest city in the country (ABS 2012). Its eastward extent is roughly 40 kilometres inland, and the total area is around 2,200 square kilometres (see Figure 1). Consisting of several layers, it is referred to as an aquifer system. In order of increasing depth, it consists of the superficial aquifer (or Gnangara Mound – uppermost and unconfined), the Mirrabooka aquifer (semi-confined and underlying only part of the area in Figure 1) and the confined Leederville and Yarragadee aquifers (each extending much further than the superficial aquifer, to the south and north respectively) (DoW 2009a, GSST 2009). Total extractions from the GGS in 2009 were an estimated 321 gigalitres (GL) (DoW 2009a).

Perth depends heavily on the GGS, which is the source of around 60% of the city's public water supply (GSST 2009). Self-supplied irrigated horticulture in the region is extensive, primarily of vegetables and orchards, but also including vineyards, turf farms, and plant nurseries. Other uses of groundwater include those by industry, and the self-supplied irrigation of municipal parks and private gardens. There are numerous wetlands and lakes in the region, whose ecosystems are dependent on Gnangara groundwater. Other native flora and fauna also rely on GGS water, as do the unique groundwater-dependent stygofauna of the Yanchep Caves. The Gnangara system is a vital resource for the biodiversity of the region.

Private bores generally draw from the superficial aquifer, while the majority of extraction for public supply is from the confined aquifers. In an audit of environmental management of groundwater withdrawals, Malcolm was primarily concerned with the superficial aquifer, it "being most closely linked to the health of wetlands and vegetation on the mound, and having significant competing uses for the water" (2004, p. 1). In certain locations, however, some hydrogeological connection exists between the superficial and deeper aquifer levels (DoW 2008a).⁸ As a result, although around two thirds of the Water Corporation's extensive

extractions are from the confined aquifers, ecosystems at the surface and users of the superficial aquifer are not protected from the resulting impacts, although these may be delayed and diffused (relative to impacts from superficial aquifer extractions). Water Corporation extractions for public supply were 136 GL/year in 2009, or 42% of the total volume used from the system (DoW 2009a, p. 28). Water Corporation bores number around 180 and draw from all aquifers. As of April 2012, the Department of Water recorded just under 2,500 licences (for all uses and across all applicable aquifer levels) on its register for the GGS management areas depicted in Figure 1. Over 75% of these are held in the management areas of Swan (vineyards) and Wanneroo (horticulture); in Wanneroo there are 887 licences to take water from the superficial aquifer (DoW 2012). This distribution of licence numbers does not correspond with the distribution of extraction volumes, however. Some licences are for multiple extraction points. In one sub-area, two licences held by the Water Corporation account for a total allocation of 11.1 GL and for over 30 extraction points.

The Gnangara system is under increasing pressure from a number of factors, including:

- reduced recharge, due to decreasing rainfall;
- increased pumping by horticultural growers and municipal suppliers;
- population growth, which is forecast to increase demand for potable water by 50 GL/year by 2020 (GSST 2009). Perth's population increased by around 24% between 2001 and 2011 (ABS 2002, 2012).

Between 1979 and 2008 there was a decrease of approximately 700 GL in the stored water reserves of the superficial aquifer (DoW 2009a). Over a roughly similar period the Water Corporation's groundwater extractions increased from approximately 18 GL (1976) to around 142 GL (2008) (GCC 2009). The water-table has fallen by more than 4 metres in parts of the superficial aquifer (GSST 2009). In the 2004 audit of environmental management of groundwater extraction in the area, Malcolm reported persistent failure to meet targets set for the management of wetlands (2004). Froend (2004) finds that forecast water-table declines for at least ten sensitive wetlands were far greater than would be consistent with low risk of ecosystem damage. Skurray and Pannell provide further examples and discussion of "management failure to enforce sustainable extraction levels to reduce environmental damage" (2012). Concerns over environmental impacts have led to the closure of around 40 Water Corporation bores since 1998 (GSST 2009).



Figure 1: Groundwater areas in the Gnangara system, Western Australia. Adapted from DoW 2009a, p. 5. Reproduced with permission.

There has been an increase in the proportion of extraction for public supply that is drawn from the confined aquifers and a proportional reduction from the superficial aquifer with the goal of reducing environmental impacts at the surface level (GCC 2009). Extraction from the confined aquifers, as a proportion of extractions for public supply, increased from 46% of total in 1984 to 63% of total in 2008 (GCC 2009, p. 23). Given the interconnections between the aquifers, however, this cannot be seen as a permanent solution to the underlying problem, which is that of overuse. Indeed the draft Gnangara Sustainability Strategy noted that “[r]ecent investigations by the Department of Water have shown that the use of groundwater from the confined aquifers has increased leakage to them from the Superficial aquifer” (GCC 2009, p. 23).

The Department of Water (the Department) manages water licensing and allocation in Western Australia. A metering program was begun in 2005. The majority of horticultural water use is from the superficial aquifer, with the exception of the Swan Valley (the Swan groundwater area in Figure 1) where the superficial aquifer is largely absent and the Leederville aquifer is used (GSST 2009). Horticultural water use represents approximately 18–22% of the total extractions from the system (GSST 2009, DoW 2009a). Individual licences for horticultural use can be for significant volumes, and much such consumption is yet to be subject to metering.⁹ In the Wanneroo groundwater area (see Figure 1) only 40% of licences were reported as being metered (DoW 2010a). This is despite a 2001 policy statement that “[i]n accordance with the Commission’s policy on measurement of use this will usually be in the form of calibrated flow meter” (WRC 2001, p. 3). Another substantial water use which remains unmetered is that of bores in private gardens, commonly used for watering. These do not require a license. Rough estimates have been made that there are between 72,500 and 80,000 garden bores, each using around 800 kilolitres per year from the superficial aquifer, totalling 58 GL per year, or a similar proportion (18%) of total use from the GGS as that of horticulture (DoW 2009a; GCC 2009).

A limited number of transactions have occurred between groundwater users in the Gnangara area. The Australian Water Markets Report for 2010-11 shows a total of 45 transfers within the Gnangara system’s management areas, plus two short-term leases, for a combined transacted volume of 14,768 megalitres (ML) (NWC 2011). (Similar numbers of transactions are reported for the preceding two water years, although the total volumes were much lower: 2,242 ML for 2009-10 and 2,144 for 2008-09.) The transfers include those taking place on the sale of the associated land. Further transactions have been foregone; in many cases we

suggest this is a function of impediments such as those presented here. A high profile instance was featured in the state's major newspaper (Taylor 2010). After purchasing land in 2009, the new owner wished to augment the 163 ML entitlement which had been transferred with the property sale. A neighbour was denied permission to sell 60 ML to the willing buyer, on the basis that the neighbour's entitlement had gone unused for three years. The newspaper reported that the 163 ML had also gone partly unused by the previous owner, but that it had not been recouped by the Department. The would-be seller intended to put the 60 ML to use in order to qualify to sell it at a later date. One user was reported as describing the system as incomprehensible. Another example of a foregone transaction was suggested by a staff-member of the Water Corporation as having potential environmental benefits. Lake Mariginiup is a wetland of high conservation value in the Mariginiup sub-area of the Wanneroo management area shown in Figure 1. This sub-area is more than 776 ML per annum over-allocated (DoW 2009a; see also Skurray and Pannell 2012). A purchase of extraction rights to superficial aquifer water by the Water Corporation from this sub-area, for example, for subsequent use in the adjacent Gnangara management area, would reduce over-extraction and its associated environmental impacts in the Mariginiup sub-area. This would be desirable, and the staff-member suggested that this could be considered a beneficial trade. As we discuss in a subsequent section, such an inter-area transfer would not be possible under the current management rules; transactions are limited to within sub-area boundaries, constraining the potential for beneficial reallocation through trading. The only Gnangara area price information specified in the NWC report is a mean price of \$742 per ML for the Wanneroo management area; this is based on only 5 transactions. We also discuss the issue of price information availability below.

Current environmental conditions and trends within the Gnangara system, as well as aspects of the management regime, clearly present a strong case for the reform of policy and of the legal framework within which it operates. The remainder of this paper analyses this institutional context with respect to its suitability for the implementation of a trading scheme for groundwater.

Legal Context

The applicable Western Australian legislation is the 1914 Rights in Water and Irrigation Act (the Act) amended in 2001. Under section 5C of the Act, self-supplied use of GGS water is conditional upon the user obtaining a licence. A small number of uses are exempt, including the watering of non-intensively raised cattle or other stock and of gardens not exceeding 0.2

hectares, and “other ordinary domestic uses” (DoW 2009a, p. 48). Under the Act, the Department grants licences only on application, and has significant discretion in the granting and administration of water licences (detailed in Schedule 1, Division 2 of the Act). The following sections consider the provisions of the Act in terms of their influence on the environment for groundwater trading.

Property rights

Vaughan and Emerson observed that “[n]o matter what the specifics of the contracts, it is absolutely crucial that property rights be secure and contracts enforceable so that water markets can develop and water users can be confident of access to water in times of scarcity” (1997, p. 183). The Act vests ownership of Western Australian water in the Crown. Groundwater rights in Western Australia (either of ownership or use) are thus not legally inherent in the ownership of the overlying land, as they are, for example, in Texas.¹⁰ Land rights, however, are an important component of the licensing process which governs groundwater use in the GGS; there is no water usage right that is separable from the rights of access to and use of the land to which the licence application applies.

There is an important distinction between ownership rights and rights to the use of water (usufructuary rights). By “water users” in the quote above, Vaughan and Emerson are referring to “farmers and the rural community”, which appears to encompass both owners and users of the water.¹¹ Use rights are a subset of complete ownership; Haddad presents 11 elements of Honoré’s “concept of full or liberal ownership”, of which the right to use is only one; the “right to the income” derived by permitting the asset’s use by others is a prerequisite component of ownership for trading (1996, p. 194).

Licensed groundwater use in the GGS is conditional in terms of both purpose and duration. Licences are granted for a particular use, specified by the applicant, and each licence granted specifies the 'authorised activities' that may be undertaken. The licence itself does not represent an unconditionally-owned asset. In addition, licences are issued with a fixed duration, normally 10 years (Gov. WA 2011, p. 106). They are thus a temporary, as well as a conditional, right to water use.

Under the Act, licences are issued with an associated annual volumetric entitlement, specifying a quantitative limit on extraction. Entitlements do not constitute a right in themselves, but exist only in association with the respective licence. In effect, they quantify

the temporary and conditional right represented by the user's licence. Historically, entitlements have been calculated with reference to average water consumption figures for an applicant's proposed crop and land area. Annual entitlements are not periodically revised, but are constant throughout the duration of a licence unless down-rated for some reason (such as consistent under-use, discussed below). Licences do not constitute ownership of the associated water entitlement.

Such conditional rights as are embodied in the licences and entitlements are vulnerable to amendment, suspension, or cancellation under clauses 24 and 25 of Schedule 1 of the Act. Licences are vulnerable to 'amendment' where, "in the opinion of the Minister, the quantity of water that may be taken under the licence has consistently not been taken" (Gov. WA 2011, p. 114). Unused portions of licensed entitlements may thus be 'recouped' by the Department; that is, withdrawn from the licensee's entitlement. According to one staff-member, the Department had recouped around 2.3 GL by late 2009. The same power of licence amendment may be used more generally: where Ministerial opinion is that amendment is "necessary or desirable" to protect either a third party, the water resource, and/or the environment (Gov. WA 2011, p. 114). This power to limit third-party impacts has not been exercised to the same degree as the power to recoup unused entitlements. The Act also allows amendments under additional conditions, such as where considered necessary "otherwise to more effectively regulate the use" of the water resource (Gov. WA 2011, p. 114). Further, licences may be cancelled or suspended indefinitely, for similar reasons to those which allow licence amendments. While these powers have historically been implemented to only limited degrees, these provisions of the Act nonetheless collectively represent significant legal attenuation of the property rights represented by licences to use groundwater in the Gnangara system.

Further conditions are stipulated on a per-licence basis. The Act provides for the "inclusion of terms, conditions and restrictions" in licences (Gov. WA 2011, p. 108). Licences carry at least one of a total set of more than 80 conditions; these relate to monitoring, well depth, infrastructure, reporting, and time-of-use requirements, among other things (DoW 2010c). One of the most common of these states that the Department may impose reductions on permitted extraction volumes in cases where "the licensee's draw adversely affect[s] the aquifer or other users in the area" (DoW 2010c). It is not clear how a reduction under this condition would differ from the exercise of the power of ministerial amendment specified in

the Act. Conditions apply for the duration of the licence; licences are renewed on reapplication by licensees who have adhered to their licence conditions.

Where a licensee “suffers damage, including loss of profit” as a result of suspension, cancellation, or amendment (except for the recouping of unused entitlements) the Act stipulates that the licence holder be compensated (Gov. WA 2011, p. 125).¹² A duty to compensate connotes the existence of a property right to the volume of water allocated under the original entitlement. In late 2009, however, a Department staff-member noted that no case of such compensation had thus far arisen. Indications are that this remains the case (Gardner 2012). A further provision of the Act applies where the Minister considers that a new or newly-amended licence will result in another person being unable to extract their full licensed entitlement: “if the Minister considers that equity so requires” a licence condition may be imposed that the new “benefiting licensee” pay financial compensation to the affected person (Gov. WA 2011, p. 109).

When contemplating reductions to licensed entitlements, the Department appears to prefer an across-the-board approach that would reduce all entitlements, in which case the duty of compensation does not apply. The 2009 Gnangara Sustainability Strategy proposed such a down-rating of entitlements, recommending a 20% “reduction on all licensed private abstraction” (GCC 2009, p. 30).¹³ Although it has not yet been invoked, and despite the duty of compensation in some cases, this power to reduce entitlements by amendment represents an additional attenuation of the property right embodied in the licence.

The property rights represented by a licence in Gnangara groundwater are limited in a number of ways. Even once granted, they remain administratively restricted, purpose-limited, temporary, and conditional rights, vulnerable to amendment or cancellation. These licences, then, represent only a rather tenuous right to use a limited volume of water, whose ownership ultimately rests elsewhere. These are a long way from the secure property rights that Vaughan and Emerson describe as crucial (1997). The converse of the attenuation of private water rights, as evinced in these licences, is that certain rights are reserved by the government. Under the current governance regime in the Gnangara case, it can be argued that retention by the government of certain aspects of water rights is consistent with sustainable management. Unfortunately, however, the implementation of the government's retained rights in this case has not given rise to sustainable management of the groundwater system. A more effective approach by the relevant agencies would be to limit extractions to

sustainable levels, and to grant property rights to these sustainable extraction volumes that are more robust and readily transferable than is currently the case. Even though the Western Australian government signed the National Water Initiative in 2006, the current property rights situation remains a long way from facilitating markets in groundwater. Other aspects of the legislative environment give rise to additional impediments to trading.

Legal impediments to groundwater trading

Amendments made to the Act in 2001 allow trading but do not facilitate it. The amended Act allows for a licensee to “transfer the license or ... water entitlement” to another location and/or user (Gov. WA 2011, p. 118), and also provides for shorter-term ‘agreements’: temporary leases of all or part of a licensed entitlement. A number of requirements of the Act impose restrictions of the transferability of licences in this case.

Transfers and agreements may be made only “to a person who holds, or is eligible ... to hold, a licence of the same kind” (Gov. WA 2011, p. 118). Eligibility to hold a licence generally requires that a person own or occupy the land to which the licence relates. Exceptions to this requirement are made where a third party establishes eligibility by gaining permission to use the land from an owner or occupier, and where legal ‘persons’ – including public utilities for example – are authorised “under a written law” to undertake licensable activities on the land (Gov. WA 2011, p. 101). In the context of transfers between individual water users, this means that the recipient must usually own or occupy the land on which the water is to be used, or have written permission from the owner (and occupier, if relevant) to use the land for “the things that may be done under the licence” (Gov. WA 2011, p. 101). The licence eligibility requirement on buyers is a substantial constraint on the transferability of the already attenuated right conferred by the licence. By limiting trading opportunities to buyers having legal access to the land where the transferred pumping right would be used, the current system imposes limitations on both would-be sellers and buyers. It precludes such actions as acquiring entitlements in advance of land when establishing a business, and the retention of licences by those who sell their land or whose leases expire, for example (DoW 2009b).

Neither short-term agreements nor longer-term transfers can be made without the approval of the Minister (effectively the Department). Approval is granted at the Minister’s discretion, and after consideration of “all matters the Minister considers relevant” (Gov. WA 2011, p. 120, 121). This Ministerial approval requirement gives rise to an application process for

water transfers. Applicants for either type of exchange are currently required to provide five pages of information, including details of both the existing and proposed water uses. There is no provision for the separate submission of information by buyer and seller, nor for electronic submission, inhibiting the transacting parties' ability to preserve confidentiality of the personal and business information required by the application process. Application fees for both transfers and agreements are currently \$200 and are non-refundable. In addition, transfer applicants are required to provide evidence that stamp duty on the transfer price has been paid to the Office of State Revenue (unless the transfer results from sale of associated land). Applicants thus face significant and potentially substantial transaction costs in financial terms as well as otherwise. These arise not only from the application process itself, but also from uncertainty as to the nature and extent of the "matters the Minister considers relevant" to the decision whether to grant approval. An additional layer of uncertainty is contributed by the fact that transfers and agreements allowed by the Act can be prohibited by local by-laws. The Act itself states that its permission to transfer does not apply where such local prohibition exists. The time and effort required to negotiate this range of barriers seem likely to ensure that only the most motivated buyers and sellers would choose to bear the costs.

Haddad presents 12 conditions which together "describe a niche in which a market may arise" (noting that these do not represent "a causal chain that, if intact, leads to the formation of a market") (1996, p.97). Two of Haddad's conditions directly address the legal environment: the "right to transfer" and the "stability of law" (1996, p. 101).

An implementable right to transfer requires that not only property rights, but also any laws protecting the environment and/or third parties, should all "provide an opportunity for transfer" (Haddad 1996, p. 119). Laws of this type may constrain the types of trades considered acceptable from the point of view of environmental and other externalities. The former state policy on tradeable water entitlements noted that "trades are subject to the provisions of the Environmental Protection Act" (WRC 2001, p. 4). This text was removed in the 2010 replacement policy, although the new policy states that where the proposed transfer is "considered a 'significant proposal' under the Environmental Protection Act 1986 [it] must be referred to Environmental Protection Authority for assessment" (DoW 2010d, p. 7). This provision would constitute an impediment – albeit an appropriate one – to environmentally-damaging transfers of groundwater use, although indications are that there has been no instance of such a referral in practice (Gardner 2012; EPA 2012). The 2010

replacement policy on entitlement transactions notes that “[t]he department will seek to address issues” relating to transfer applications with reference to the stipulations made in the Act regarding the initial granting of licences (DoW 2010d, p. 11). These include “whether the proposed taking and use of water” is “in the public interest”, “ecologically sustainable”, “environmentally acceptable”, and may be detrimental to other current or future “needs for water” (Gov. WA 2011, p. 103). If observed as criteria in the transfer approval process, these stipulations could be sources of uncertainty for prospective buyers and sellers. The overriding issue, however, is that in many instances in the Gnangara case, many of these stipulations of the Act have not been effectively observed in the process of issuing licences. Their implementation as part of the transfer approval process would provide the Department with one means of redressing some impacts of existing over-allocations. It would also represent an attenuation of the “right to transfer” condition Haddad describes. The recommendation here is that the environmental protection provisions of the Act should be implemented in the initial licensing process; they would then – if also used in the review of transfer applications – represent a lesser constraint on the transferability of the licensed water use right.

Haddad's “stability of law” condition states that the stability of a legal environment is an important factor in the development and persistence of a market: “[i]f the buyer perceives a significant risk that the rules will change before delivery is completed, a different contract, or none at all, may be pursued” (Haddad 1996, p. 119). Fisher concurs: “those trading or intending to trade [should] have confidence in the legal structure out of which [transactional] arrangements evolve” (2006, p. 1). Stability of law increases in importance with the longevity of the transferred rights; it will be of less concern to transferees of single-year leases, for example.

There is no question as to the general stability of the broad legal environment in the GGS case. High-level legal constructs such as the concept of private property, or the right to trade it, are not foreseeably threatened. Nor is there doubt as to the enforceability of Western Australian law in general. Of more relevance to the GGS case are the stability of the specific laws that pertain to the allocation and trading of groundwater in the area, their implementation in the licensing and allocation processes, and the current low levels of monitoring and enforcement of compliance with those allocations.

A stipulation of the National Water Initiative was that Western Australia would work towards replacing the 1914 Act. New legislation remains pending and may be completed by late 2012. Trading is expected to be facilitated within the new legislative framework, partly through provisions for “a system of secure and fully tradeable water access entitlements” decoupled from the ownership and/or use of land (DoW 2009b, p. 9). In this sense, the present legal context for trading in the GGS cannot be seen as stable. For at least two reasons, however, this does not represent an inhibition to market formation. First, the main legal instability is likely to be in the direction of improvements to the current trading environment. The second reason is that trading in GGS groundwater is currently so *ad hoc* and constrained that it would be unlikely to suffer from perceptions of instability of law that arise from the potential for legislative reform. Indeed, favourable comments from the Gnangara Sustainability Strategy could have the opposite effect, by instilling increased confidence in the future prospects for a groundwater market. (A converse effect of this might be that prospective trades are postponed pending the realisation of expected reductions to transaction costs.) There is no reason to suppose that a new legislative framework would be insufficiently stable over the relevant time-frame.

Policy Context

The majority of the policies discussed here are those of the Department or its predecessors. The Economic Regulation Authority has exclusive jurisdiction over water pricing; the Gnangara Sustainability Strategy did not consider pricing, despite its primary purpose of addressing the sustainability of a resource currently being used at no cost other than the costs of pumping (there is no licence fee nor any volumetric or other ongoing fee for groundwater use in the GGS area).

Operational policy 5.13 – ‘Water entitlement transactions for Western Australia’ is the current state policy concerning the transfer of water entitlements. Policies on water trading are generally related to placing restrictions on trading activity. Policies concerned with the granting of licences and entitlements also affect the subsequent tradeability of those assets. There are currently no policies directly encouraging trading in groundwater use rights. We discuss restrictions first, then move to licensing policies, including the treatment of unused entitlements. Finally, we address problems arising from the passive nature of policies on groundwater trading in this case.

Restrictions on trading

All but two of the eight management areas shown in Figure 1 are in turn divided into management sub-areas. Groundwater transfers between sub-areas are not permitted. This limits the potential range of value-creating transactions, thus limiting the potential for improvements in both economic efficiency and environmental protection. By limiting potential benefits, this restriction also impedes market development. A recently replaced policy held that trades between sub-areas could be allowed, in cases where the transaction would “result in the source area returning to a more sustainable allocation position and where demand in the receiving area will remain below sustainable yield” (WRC 2001, p. 3). The 2010 replacement policy removed this reference to inter-area transfers, noting only that transactions must remain within sub-area boundaries, further stipulating that even these intra-area transactions “may be constrained by geophysical limitations” (DoW 2010d, p. 6). This policy change removes the potential for an important use of transfers – that of reallocating extraction to reduce environmental impacts – and the associated potential for welfare-enhancing transactions (see Skurray *et al.* 2012). Under the new policy, transactions within over-allocated sub-areas may be approved where the Department concludes that “the transaction will result in the same or reduced impacts” (DoW 2010d, p. 9).¹⁴

In the Gnangara case, the large number, and in many cases the small size, of the management sub-areas mean that the above policy requirements present problems. Of the 51 superficial aquifer management sub-areas in the GGS, a number are as narrow as one kilometre in places (DoW 2009a). Further, the current areas are largely based on land-ownership boundaries (DoW 2008a); they therefore, to some extent, are congruent with historical land use boundaries. They were not designed to reflect hydrogeological realities, or to minimise transaction costs of transfers with net economic and environmental benefits.¹⁵

¹⁶ Given the size and origins of these area boundaries, preventing the exchange of water entitlements between sub-areas eliminates much of the potential for gains from trade, by limiting the number and diversity of potential transacting parties. Poorly delineated trading areas could also be a source of transaction costs, by increasing regulatory concern about the potential impacts of even intra-area trades, and thus increasing the tendency for case-by-case review of proposed transactions. With increasing aquifer transmissivity, the importance of trading area boundaries for transaction costs changes. One of the primary purposes of trade in water-use rights is to enhance the economic efficiency of user adaptations to reduced supplies, by providing the opportunity for trade with areas having surplus water or where lower values are placed on water. Even between contiguous over-

allocated GGS management sub-areas, the elimination of cross-boundary trading opportunities is a constraint on the potential for beneficial reallocation – and relocation – of extraction. Inter-area transfers may require administrative review.

There are environmental, hydrological, and social reasons to place limits on the geographic scope of groundwater transfers. Reducing the potential for spatial concentration of the impacts of pumping is an example (Skurray and Pannell 2012 provide a discussion). Larger management areas have greater potential for the concentration of effects. The current restriction on inter-area transfers in the GGS, combined with the somewhat *ad hoc* and path-dependent origins of the management areas, result in a system which is highly restrictive without yielding the benefits which should accompany those restrictions. It is possible that the legislative reform process may result in design improvements to the existing management areas and sub-areas, making them more hydrogeologically relevant, and more useful in a trading context. Until then, the current restriction on inter-area transfers remains a major constraint to the development of effective trading in the groundwater system.

A prospective purchaser of GGS groundwater is required to hold a licence already, or to undergo an assessment process in order to be granted a new licence reflecting the purchase. Where a purchaser has an existing licence, the Department assesses "the outcomes of the transaction, usually the impacts of increasing the existing water entitlement, and whether these impacts are acceptable" (DoW 2010d, p. 5). If per-area allocation limits were environmentally sustainable, adhered to during the licensing process, and enforced through effective monitoring of consumption, trades within a given management sub-area should not require such intensive assessment. The type of system-wide reduction in extractions recommended in the 2009 Gnangara Sustainability Strategy draft report would be a step towards addressing the first of these criteria, and thus also toward curtailing the costs currently imposed by administrative review of intra-area transfers. We contrast the Gnangara institutional context with that described by Colby: "[e]fficient trading mechanisms are more readily implemented when there is a strong political or legal mandate to cap resource use and trades are perceived as a means to ease adjustment to use limits" (2000, p. 638).

Even where management sub-areas incorporate hydrologically sensitive ecosystems (and depending on the size of the sub-area) administrative review requirements could be minimised by the use of appropriate management tools. Locations at which additional

groundwater extraction would pose risks to hydrologically vulnerable ecosystems could be identified and made public. Users would be informed in advance that transactions would not be permitted to increase licensed extraction in those areas, obviating the application and review processes for such transactions. Firm policies such as this, properly enforced, could reduce administrative review costs while improving the transparency of the system to users. The Department's current per-trade assessment process appears inconsistent with the purpose of the management sub-area allocation limits and with its restriction of inter-area trades. With appropriate management area boundaries, the current restrictions on trading would ideally obviate the need for trade-by-trade departmental review.

The Department's power of administrative review not only imposes transaction costs, but creates the opportunity for approval of inappropriate transactions. Extensive regulator discretion may reduce the perceived consistency and transparency of the process while also reducing the quality of environmental management relative to a well-designed and less review-intensive system.

To some extent the requirement for per-trade departmental approval arises from the close relationship between licences and licensed uses. A purchase of land, for example, requires that the purchaser take over the existing water licence or apply for a new one. Where the purchaser maintains the existing land use, the Department is required to grant approval. Even in this case, however, the transfer process is not unencumbered; sellers must have met all licence conditions – something over which the buyer has no control – and the transfer application must still be submitted for approval. This case-by-case process, in which the Department interposes itself even between buyers and sellers of land, potentially transforming the transacted asset in the process, highlights the inefficiency of the current system.

Policy requires trades not to cause “unacceptable impacts (ecological or social)” whether they be caused directly, or through the spatial concentration of extraction (DoW 2010d, p. 7). The policy document does not define these impacts; applicants are nonetheless responsible for demonstrating that such impacts will not occur. The 2009 Gnangara Groundwater Areas Allocation Plan notes that “[t]he department uses internal policy to manage trading around environmentally sensitive areas” (DoW 2009a, p. 54). This policy offers guiding principles for assessing transfer applications, in which approvals “should generally be approved subject to the normal assessment process” for transfers of water use away from sensitive

“high risk” groundwater-dependent ecosystems, and “generally not be approved” in the reverse direction unless the applicant demonstrates that adverse impacts would not occur (DoW 2005, p. 7). These are appropriate goals.¹⁷ As well as on environmental grounds, the Department may refuse approval of a trade to prevent “speculation and market manipulation” (DoW 2010d, p. 9).

These requirements, in combination, give the Department wide latitude in approving or denying trades, and could represent significant sources of uncertainty to prospective buyers or sellers of groundwater use rights. Specifically, the appearance to the user of unpredictability in policy implementation may be cause for concern.

Licensing policies and processes

Allocation limits represent the volume of water deemed available for licensed use within a groundwater management area. Allocation limits exist for each sub-area in the Mirrabooka, Leederville, and Yarragadee aquifers as well as the superficial aquifer. Each licence specifies the groundwater sub-area and the aquifer from which water may be taken under the licence. In principle, further licences are not issued once the allocation limit is reached. These limits, however, are not strictly binding on the issuer; the Department may use “internal operational policy” to assess applications for licensed water use in excess of a sub-area's allocation limit (DoW 2009a, p. 51). The internal policy is entitled “extenuating circumstances for granting water entitlements resulting in allocation limits being temporarily exceeded” (DoW 2008b, p. 1). The document appropriately notes that exceeding sub-area allocation limits ought to be considered a temporary measure, on the basis that doing so could “set a precedent” and “encourage similar applications that would further exacerbate the situation” (DoW 2008b, p. 6). The document suggests, however, that such exceedances should instigate “a review or amendment of the limit” or a survey aimed at recouping unused entitlements in the area (DoW 2008b, p. 6). The former of these options is of clear concern and would have the effect of removing the temporary nature of the exceedance. This process has the potential to cause a ‘ratcheting up’ of allocation limits. Indeed, the point is made in the document that “[i]f the precautionary principle was used in setting the allocation limit then it is reasonable to amend that limit” (DoW 2008b, p. 6). Putting aside the unconditional nature of this statement, it is also contrary to the very intent of the Precautionary Principle (e.g., Myers 1993). This is clearly an issue of concern with regard to the functioning of any market in groundwater entitlements. It is important for the operation of a trading scheme that allocation limits be binding on the Department in the licensing process; the issuance of new licences in a fully or over-allocated groundwater area would

undermine the integrity of any trading scheme. At August 2009, 17 of the 51 superficial aquifer management sub-areas were over-allocated in terms of licensed extraction, down from 19 sub-areas in February 2008 (DoW 2008a; 2009a). In 2009, six of the eight sub-areas in the Leederville aquifer also had total licensed entitlements in excess of the sub-areas' respective allocation limits (DoW 2009a). At April 2012, the Department's online register lists two licences (issued to the Water Corporation to take water from the Yarragadee aquifer in the Gnangara Confined sub-area) having a combined total of 15.4 GL. As the Department's 2009 allocation plan gives a figure of 14.7 GL for the licensed entitlements for this sub-area/aquifer combination, it appears the smaller of these two licences (0.7 GL) was issued since the allocation plan was published. The plan lists the allocation limit for this sub-area and aquifer as 5.15 GL per annum (DoW 2009a). Such flexibility in the allocation limits would need to be remedied before any trading scheme could begin effective operation. Indeed, it should be rectified well in advance of the attempted implementation of trading, in order to bolster confidence in the allocation system as a basis for the market.

Although allocation limits may deliberately be exceeded, and despite the current over-allocation of many groundwater areas, departmental staff expressed considerable confidence in these allocation limits as the basis for determining the acceptability of impacts of a proposed trade. This confidence is supported by the assertion that licences are granted only within allocation limits, and only if the expected impacts of extraction are considered acceptable. Such confidence in the hydrological soundness of the initial licensing process seems inconsistent with the level of scrutiny that applications for intra-area trades in fact receive.

As well as in the licensing process, allocation limits must also be binding on groundwater users. The 2001 policy on trading noted that “[a]ccurate measurement of use is a pre-requisite for trades” (WRC 2001, p. 3). This statement was removed from the 2010 replacement document. Monitoring and enforcement of licensed water use have been weak. Without metering, establishing compliance is labour intensive and approximate. Malcolm notes that, prior to the Gnangara metering program, there had been “no measurement or estimation of private abstraction” (2004, p. 2), although inspection and survey procedures were used to identify non-compliance issues (WRC 2003). While metering began in 2005, it is by no means comprehensively implemented: of 1,682 licences in a sample of 15 GGS groundwater sub-areas, only 36% were reported as metered (DoW 2010a). Enforcement of

licensed consumption for the remaining 64% of these licensees, is left to compliance inspections. Priority for these inspections will be given “where aerial photography fails to identify whether the licensed water entitlement is being used as per the terms and conditions of the licence” (DoW 2009a, p. 53). The relatively new metering program begins to address this serious shortcoming, although there are indications that enforcement remains inadequate, even in cases where metering demonstrates exceedance of licensed entitlements. The low levels of enforcement have attracted media attention (Towie 2010; Mercer 2012). Naturally, failure to enforce usage limits reduces the potential for the development of effective trading and would seriously undermine confidence in the validity of any trading or transfer scheme.

Entitlements are conditional upon their being used. One Departmental staff-member suggested a connection between this policy and the fact that licences are granted at no cost. An entitlement (or part thereof) is considered unused if not used for more than three consecutive years, although shorter periods may apply (WRC 2003). In groundwater management areas where less than 70% of the “sustainable limit” has been allocated, departmental policy is not to actively pursue the recovery of unused entitlements (WRC 2003, p. 6).¹⁸ In management areas that are more than 70% allocated, policy is to “actively seek out” unused entitlements, and to request explanation. Where a licensee fails to demonstrate extenuating circumstances, policy is to “aim to recoup” the unused amount (WRC 2003, p. 7). As an alternative to recouping the unused entitlement, the Department has the option of obtaining “a commitment from the licensee to utilise the entitlement within an agreed timeframe” (WRC 2003, p. 9). This approach appears to encourage the consumption, rather than the conservation, of groundwater, with the potential result that efficiency of use is substantially reduced. Recouped entitlements are not eligible for compensation. Trading of unused “sleeper” entitlements (i.e., by the original owner) is generally prohibited, although unused allocations resulting from efficiency improvements are tradeable and will not be recouped by the Department (WRC 2003). The Department will not recoup paid-for entitlements from transferees (except in exceptional circumstances), even if they are unused (WRC 2003). The justification is that, unlike the original owner who obtained it at no cost, transferees have paid for the usage right.

The 2003 policies on unused entitlements have the stated aim of establishing “confidence and reliability in water usage in the lead up to trading in licence entitlements” (WRC 2003, p.

7), a goal which appears to remain distant and is, in any case, likely to be inconsistent with some elements of the policies and processes discussed above.

Policy passivity

One group of transaction costs arises from the passive nature of trading policies; no policies exist to encourage groundwater users to trade. The resulting absence of any facilitating market infrastructure means that very few resources are available to assist prospective sellers or buyers. There are no water brokers and no public databases of buyers, sellers, or prices. The Department's website directs interested buyers to its online register of licences to "locate and contact potential water licensees [...] interested in trading their water allocations" (2010e, p. 6). The register is a complete listing of licensees per area, providing no indication as to which of these may be a willing seller or may have surplus entitlement.¹⁹ Potential sellers are advised that they may "wish to advertise [their] water entitlement in local papers" (2010e, p. 6). As Brajer et al. emphatically observe, "the fact that there are many potential sellers of water rights is immaterial to me if I am unaware of their existence, and/or if it is inordinately costly for me to learn of their existence" (Brajer et al 1989, p. 497, quoted in Haddad 1996). The regulator has an important role in establishing or commissioning facilitating infrastructure, and in promulgating advice as to the available sources of market information, whether those sources be private (e.g., brokers), public, or non-government in nature.

Information on prices reached in the few transfers that have occurred is inaccessible. The 2001 policy on trading acknowledged that "price and other market information are essential to ensure water trading occurs efficiently and equitably" (WRC 2001, p. 8). That policy further stated that "[p]rice data will be publicly available and published periodically by the Commission" (WRC 2001, p. 6). Despite these 2001 policy statements, it has not been possible to obtain any of this information from the Department without resort to a request under the Freedom of Information Act 1992. The Department still appears to consider this information legally protected and confidential. Indeed, the Department noted in 2010 that policy was "being revised to take out the inconsistency with the law" (DoW 2010b). This suggested that part of a then nine-year-old policy, rather than belatedly being implemented, was instead to be abandoned. The resulting November 2010 policy document includes no mention of price information or its importance or publication. This was a retrograde step in terms of market development and facilitation.²⁰ Whether the expected future legislative reform will remedy this drawback is as yet unknown. Depending on the nature of the anticipated transaction, it may not be necessary to publish all price information; in a

contractual market it may be sufficient to make available a minimum of non-specific or aggregated price data by which buyers and sellers may be guided.

In his conditions for a market to form, Haddad outlines a requirement for appropriate “performance evaluation and incentives” on the part of the relevant oversight institutions (1996, p. 115). It would undoubtedly be helpful for institutions to engage in regular “review and self-evaluation” with respect to their roles in facilitating transfers, and for high-level institutional staff to have the necessary incentives to oversee and improve the administration of a trading scheme (Haddad 1996, p. 115). In the GGS case, trading is not sufficiently well-developed, nor is it a sufficiently operationalised organisational objective, for this requirement to be met. Further, it seems clear that there is a lack of organisational expertise with regard to markets, and to the implementation of economic instruments more generally. This lack of expertise may reflect, and be reinforced by, an organisational culture more closely aligned with command-and-control regulation than with the implementation of market-based management tools.

Haddad outlines two further desirable qualities of the institutions overseeing a trading system:

- that the organisation should have no policies, requirements, or attitudes that are in conflict with its role as a facilitator of trading; and
- that oversight bodies should not cause “unintended hindrances to transactions” (Haddad 1996, p. 115).

From the discussion above, it is clear that, in the GGS case, the Department of Water does exhibit some of these internal conflicts. The 2001 policies on trading were strongly countered by various subsequent departmental procedures, as well as by aspects of the organisational culture. The general passivity of policies – and/or their insufficient or lacking implementation – also conflicts with the Department's stated objectives regarding water trading. This factor also generates Haddad's unintended hindrances, through such manifestations as “poor or ill-defined procedures, or insufficient resources” (Haddad 1996, p. 115).

Concluding Remarks

The Gnangara case highlights opportunities for substantial improvements in the legislative and regulatory environments if groundwater transfers are to be used as an effective management tool. Perhaps the primary concern in the current legislative environment is the weakness of property rights to groundwater use. It would be possible to create a more conducive trading environment by decoupling licensed water entitlements from the land use for which the licence was originally granted. This would not necessitate a change to the underlying Crown ownership; that is, it would not be necessary to move to a Texas-style “right of capture” regime in which ownership of groundwater rests with the owner of the land through which it is extracted. There is certainly scope, however, for improvement in the nature of groundwater rights as tradeable assets in the GGS case.

The requirement for per-transaction application to the Department, the associated forms and fees, and the uncertainty regarding approvals, together constitute substantial transaction costs to potential sellers as well as buyers. The implementation of this statutory requirement also imposes a substantial burden on the Department. By the Department's own admission, “[t]he current transfer mechanism for licences is cumbersome” (DoW 2009b, p. 13). By contrast, a statutory requirement imposed on the Department to promote and facilitate water trading would ease transaction costs within the current system, and would be in keeping with the requirements of the National Water Initiative.

A major impediment to effective trade in the current environment is that there is no publicly-available price information. Due to the various constraints discussed in this paper, the market is so thin that prices for exchanges are established case by case between the buyer and seller. In some cases, the Department is not informed of the final price for a particular transaction, and so could not publish it even if systems were in place to do so. Informal trades and the withholding of price information from the Department may be responses to impediments such as those discussed here, and to others real or perceived. It is not, of course, the Department's active policy to discourage the development of a market price. Its policies taken as a whole, however, do have this effect. To develop conditions for a price to arise, it will be incumbent upon the Department to develop policies to facilitate trading, and to implement those already in place or recently superseded. The changes made in the transition from the Water and Rivers Commission's 2001 policy to the Department's 2010 policy on water entitlement transactions can be considered retrograde.

Potential gains from trade are substantially reduced in this case due to a number of aspects of the management boundaries, combined with the restriction on transfers between zones. There is a relationship between water licences and land uses, and a partial coincidence between management area and land-use divisions, reducing the scope for trade between use types. The small size of several of the sub-areas is a factor. In combination, these aspects have the effect of limiting the number, range, and nature of potential transacting parties, and consequently constraining the range of respective private valuations held for the traded good by participants in the market.

The great number of impediments to efficient trading that pertain to the current management regime may be concealing significant demand for water-rights transfers between users and usage-types, thereby reducing the economic efficiency of water use in the region. The absence of an institutional environment suited to the development of a market in groundwater rights leaves agencies without the option to use trading as part of the management of reductions in Gnangara groundwater use – reductions that appear to be necessary and imminent.

Despite policy statements dating back to 2001, we conclude that there remains very substantial scope for improvement in both the legal and policy environments of the Gnangara groundwater system if effective trading in groundwater usage rights is to be developed. Where transfer approval procedures are able to protect against external damages, the resulting transaction costs would appropriately reflect the various benefits - both public and private - which may be vulnerable under a proposed water transfer (Colby 1996). We suggest that the transaction costs exhibited in the Gnangara case do not arise from such a system. Norgaard notes that "sustainability is difficult, i.e. transaction costs will be high" (2010, p 1225). We point out that the current institutional context in the Gnangara case has not resulted in sustainable management of the groundwater resource, and that the impediments it poses to groundwater trading do not arise from a demonstrated political or organisational intent to implement sustainable management. Effective groundwater trading schemes are rare worldwide; the approach employed here and some of the conclusions reached will be relevant to other cases.

Notes

- 1 Skurray et al. (2012) provide background on the Australian water reform process.
- 2 Having described many of its shortcomings, Glennon points to the current situation in the American West as the result of "water allocated through the political process", noting that it "inevitably goes to the most powerful economic and political interests in the state" (Glennon 2009, p. 314). Absent the political power enjoyed by agricultural interests in many jurisdictions, for example, beneficial reallocation by the public sector would be more feasible. Glennon observes that the current reality, however, is that "[h]eavy-handed government mandates would generate bitter political controversy and endless litigation..." concluding that "state legislators will not impose costly changes on the farming community" (Glennon 2009, p. 306).
- 3 Noting the "cultural, spiritual, religious, environmental, and economic value[s]" of water, Glennon envisages a "regulated market with state responsibility" for third-party (including environmental) protection (2009, p. 310). In a comparable vein, the National Research Council points out that the desired goal is not the promotion of water transfers for their own sake, "but to use them to accomplish better overall water management" (1992, p. 3). Haddad "characteriz[es] markets as policy tools used to achieve specific social goals that may fall short of Pareto-efficient allocation" (1996, p. 99).
- 4 The term 'policy-induced transaction costs' is due to Colby (1990).
- 5 While Haddad's case-studies are long-term, inter-regional transfers, his analysis is also pertinent to the development of markets in other types of transfers.
- 6 The National Research Council notes, for example, that "pre-1980 Arizona ground water law [...] did not recognize hydrologic surface-ground water relationships and thus allowed virtually unrestrained ground water pumping" (1992, p. 200).
- 7 It should be noted that policy rigidity is not necessarily unhelpful; an inflexible policy which spelled out the requirements of sustainable groundwater extraction from a given aquifer, for example, would be of value. Crase et al (2002) identify policy flexibility as a source of transaction costs in water markets.
- 8 There is "direct connection" between the Leederville and superficial aquifers where the confining formation has eroded; there is a window of "hydraulic connection" between the Yarragadee and Leederville aquifers where the South Perth Shale is absent (Salama 2005, pp. 30-31). Carbon dating has shown that water in the Yarragadee Aquifer is more than 36,000 years old; geochemical analysis indicated "very little [...] mixing of waters between these aquifers" under the extraction and recharge conditions current at the time (Salama 2005, p. 42).
- 9 The Department of Water notes that these percentages assume that "water use corresponds to total of licensed entitlements" (DoW 2009a, p. 28) For unmetered use, this cannot be verified.
- 10 Glennon provides a dramatic illustration of the 'right of capture' which applies to groundwater in Texas, under which "each Texan [land-owner] is free to pump [...] unlimited amounts of groundwater, regardless of the consequences to neighbors" (2009, p. 129). The rule of capture confers an "absolute right" on land-owners to withdraw water from beneath their land,

circumventing “[s]everal normal constraints of prior appropriation”, including those against wasteful use and injury to third-parties (Slaughter 2009, p. 336).

11 Where these are not the same entity, water trading may result in a different outcome from that which Vaughan and Emerson suggest, namely that “water users can be confident of access to water in times of scarcity”. In a drought, for example, some users may lose the use of water since the owner may choose to sell the use (or ownership) rights elsewhere.

12 While the Act specifies the preconditions for “compensation for damage due to exercise of Minister’s powers”, it does not describe how compensation would be calculated, noting only that “[l]ocal by-laws may prescribe [...] how compensation is to be assessed” and providing for the arbitration of disputes as to the amount (Gov. WA 2011, pp. 125-126).

13 As at March 2012, the final Gnangara Sustainability Strategy report had not yet been released, despite the publication in July 2009 of the ‘draft for public comment’ version, and in November 2009 of the ‘analysis of public submissions’.

14 In over-allocated contexts, trading offers agencies an opportunity to reduce overall consumption, by requiring the surrender of part of the transacted right. While it does not require this itself, the 2010 policy notes that water management plans may stipulate that approval of transactions in over-allocated areas be contingent upon the surrender to the Department of a percentage of the transacted entitlement.

15 The groundwater areas in the GGS are of varied origins. The Mirrabooka and Gwellup areas were established in relation to public water supply. The 1975 establishment of the Swan area was related to vineyards in the region. The Wanneroo area was proclaimed around horticultural land uses. The Gnangara area – at the height of the Gnangara groundwater mound hydrologically – is state land. The Perth area encompasses urban areas, parks, etc.; many of the sub-areas in the Perth groundwater area are based on local municipal boundaries. Some areas – Swan and Wanneroo, for example – reflect the historical uses of the different soil types in the region.

16 Describing the development of water rights and management regimes in the American West, Libecap credits “institutional path dependence” with increased present day transaction costs in water markets, an illustration of “how past arrangements to meet conditions of the time constrain contemporary economic opportunities” (2011, p. 64).

17 This policy was promulgated by the Water and Rivers Commission in conjunction with the Department before legislation abolished the Commission and transferred its functions to the Minister for Water Resources.

18 Policy on unused entitlements interchanges the terms ‘sustainable yield’ and ‘sustainable limit’, but does not define either.

19 Alternatively, buyers may submit a data request to the Department for a similar list of licensees within their area. This presents a potential barrier to those averse to seeking contact with government agencies.

20 Indeed, the National Water Commission’s latest Australian Water Markets Report notes that “there is no legal requirement for entities involved [...] to report sale prices to [the Department], and there is no means of verifying the accuracy of declared sale prices” (NWC 2011, p. 205).

Acknowledgements

The authors are grateful to two anonymous reviewers, and to the editor, for their helpful comments and suggestions, which improved the paper. Professor Alex Gardner, Faculty of Law, University of Western Australia, kindly provided information on the relevant legislation. The authors are grateful for funding from the National Centre for Groundwater Research & Training which is an Australian Government initiative, supported by the Australian Research Council and the National Water Commission.

References

ABS (Australian Bureau of Statistics), 2002. Regional Population Growth, Australia and New Zealand, 1991 to 2001 [online]. [Accessed May 2012].

ABS (Australian Bureau of Statistics), 2012. Regional Population Growth, Australia, 2010-11 [online]. [Accessed May 2012].

Akteruzzaman, M., Kondo, T., Osanami, F. and Doi, T., 1998. Structure of the Groundwater Market in Bangladesh: A Case Study of Tubewell Irrigation Investment. *Water Resources Development*, 14, 55–65.

Bauer, C., 2004. Results of Chilean water markets: Empirical research since 1990. *Water Resources Research*, 40.

Bell, S. and Quiggin, J., 2008. The limits of markets: the politics of water management in rural Australia. *Environmental Politics* 17: 712-729.

Bjornlund, H., 2003. Efficient Water Market Mechanisms to Cope with Water Scarcity. *Water Resources Development* 19, No. 4: 553–567.

Brajer, V., Church, A., Cummings, R. and Farah, P., 1989. Strengths and Weaknesses of Water Markets as They Affect Water Scarcity and Sovereignty Interests in the West. *Natural Resources Journal*, 29, 489-509.

Brewer, J., Glennon, R., Ker, A. and Libecap, G., 2007. Water Markets in the West: Prices, Trading, and Contractual Forms. *Arizona Legal Studies*.

Colby, B.G., 1990. Transactions costs and efficiency in western water allocation. *American Journal of Agricultural Economics*, 72, 1184–1192.

Colby, B.G., 1996. Markets as a response to water scarcity: policy challenges and economic implications. In: D. Hall, ed. *Advances in the economics of environmental resources*, vol 1. JAI Press Inc., Greenwich, CT. pp. 211-224.

Colby, B.G., 2000. Cap-and-Trade Policy Challenges: A Tale of Three Markets. *Land Economics* 76: 638-658.

Crase, L., Dollery, B. and Lockwood, M., 2002. Transaction Costs Emanating from Policy Flexibility in Water Markets. In: D. Brennan, ed. *Water policy reform: lessons from Asia and Australia*. Proceedings of an International Workshop held in Bangkok, Thailand, 8 – 9 June 2001.

Crase, L., Pagan, P. and Dollery, B., 2004. Water markets as a vehicle for reforming water resource allocation in the Murray-Darling Basin of Australia. *Water Resources Research* 40.

DoW (Department of Water), 2005. Managing abstraction in areas of declining water levels affecting groundwater dependent ecosystems on the Gnangara

Mound. Allocation note. Department of Water, Government of Western Australia, Perth.

DoW (Department of Water), 2008a. Gnangara groundwater areas - Water management plan. Draft for public comment. Department of Water, Government of Western Australia, Perth.

DoW (Department of Water), 2008b. Extenuating circumstances for granting water entitlements resulting in allocation limits being temporarily exceeded. Operational policy. Department of Water, Government of Western Australia, Perth.

DoW (Department of Water), 2009a. Gnangara groundwater areas allocation plan. Water resource allocation and planning series. Department of Water, Government of Western Australia, Perth.

DoW (Department of Water), 2009b. Discussion Paper: Water Resources Management Options. Department of Water, Government of Western Australia, Perth.

DoW (Department of Water), 2010a. Aggregated data on selected superficial aquifer groundwater sub-areas: Licences to take groundwater from the superficial aquifer on Gnangara Mound. Personal Communication. Department of Water, Government of Western Australia, Perth.

DoW (Department of Water), 2010b. Personal Communication. Senior Legal Officer, Department of Water, Government of Western Australia, Perth.

DoW (Department of Water), 2010c. Complete list of all conditions on the subject licences and number of licences. Personal Communication. Department of Water, Government of Western Australia, Perth.

DoW (Department of Water), 2010d. Operational policy 5.13 Water entitlement transactions for Western Australia. Department of Water, Government of Western Australia, Perth.

DoW (Department of Water), 2010e. Water licensing frequently asked questions. Department of Water, Government of Western Australia, Perth.

DoW (Department of Water), 2012. The Water Register. Available via <http://www.water.wa.gov.au/ags/WaterRegister/>. Department of Water, Government of Western Australia, Perth. Accessed April 2012.

EPA (Environmental Protection Authority), 2012. Personal Communication. Assessment and Compliance Services Division, Environmental Protection Authority, Government of Western Australia, Perth.

Evans, R., 2007. The Impact of Groundwater Use on Australia's Rivers: Technical report. Land & Water Australia, Australian Government, Canberra.

Fisher, D.E., 2006. Implementing the National Water Initiative: A Generic Set of Arrangements for Managing Interests in Water. Kelvin Grove: Queensland University of Technology.

Froend, R., Loomes, R., Horwitz, P., Bertuch, M., Storey, A. and Bamford, M., 2004. Study of ecological water requirements on the Gnangara and Jandakot mounds under section 46 of the Environmental Protection Act. Task 2: determination of ecological water requirements. Water and Rivers Commission, Government of Western Australia, Perth.

Gardner, A., 2012. Personal Communication, Faculty of Law, University of Western Australia, Perth.

GCC (Gnangara Coordinating Committee), 2009. Gnangara sustainability strategy - Draft for public comment. Department of Water, Government of Western Australia, Perth.

Glennon, R., 2009. *Unquenchable: America's water crisis and what to do about it*. Island Press, Washington, DC.

Gomez-Limon, J. and Martinez, Y., 2006. Multi-criteria modelling of irrigation water market at basin level: A Spanish case study. *European Journal of Operational Research*, 173, 313–336.

Gov. WA (Government of Western Australia), 2011. Rights in Water and Irrigation Act 1914 (amended), Version 08-h0-00. Government of Western Australia, Perth.

GSST (Gnangara Sustainability Strategy Taskforce), 2009. Gnangara sustainability strategy situation statement. Department of Water, Government of Western Australia, Perth.

Haddad, B.M., 1996. Evaluating the Market Niche: Why Long-Term Rural-to-Urban Inter-regional Markets for Water Have Not Formed in California. PhD dissertation. University of California, Berkeley.

Haddad, B.M., 2000a. Economic Incentives For Water Conservation On The Monterey Peninsula: The Market Proposal. *Journal Of The American Water Resources Association*, 36, 1–15.

Haddad, B.M., 2000b. Rivers of gold: designing markets to allocate water in California. Island Press, Washington DC.

Hartman, L.M. and Seastone, D.A., 1965. Efficiency Criteria for Market Transfers of Water. *Water Resources Research*, 1.

Howe, C., 1997. Increasing efficiency in water markets: examples from the western united states. In: Anderson T, Hill P, editors. *Water marketing, the next generation*. Rowman & Littlefield, Lanham, MD.

Howe, C., 2002. Policy issues and institutional impediments in the management of groundwater: lessons from case studies. *Environment and Development Economics*, 7, 625–641.

Kaiser, R. and Phillips, L., 1998. Dividing the waters: Water marketing as a conflict resolution strategy in the Edwards Aquifer region. *Natural Resources Journal*, 38, 411–444.

Libecap, G.D., 2006. Assigning property rights in the common pool: Implications of the prevalence of first-possession rules. *Sharing the Fish*, February 26-March 2, 2006, Fremantle, Western Australia.

Libecap, G.D., 2011. Institutional Path Dependence in Climate Adaptation: Coman's "Some Unsettled Problems of Irrigation". *American Economic Review* 101: 64-80.

Malcolm, J., 2004. Audit of Compliance Report - Environmental Management of Groundwater Abstraction from the Gnangara Groundwater Mound July 2000 – June 2003. Appendix 3 to Environmental Management of Groundwater Abstraction from the Gnangara Mound: July 2000 - June 2003 Triennial Report - Water and Rivers Commission. Report by the Environmental Protection Authority under section 48(1a) of the Environmental Protection Act 1986. Perth.

McCann, L., Colby, B., Easter, K., Kasterine, A. and Kuperan, K., 2005. Transaction cost measurement for evaluating environmental policies. *Ecological Economics* 52: 527– 542.

Mercer, D., 2012. Bore users let off amid record fines. *The West Australian*, 13th March.

Myers, N., 1993. Biodiversity and the Precautionary Principle . *Ambio* 22, 2-3, *Biodiversity: Ecology, Economics, Policy*: 74-79.

National Research Council, 1992. Water transfers in the west: efficiency, equity, and the environment. National Academy Press, Washington DC.

Norgaard, R.B., 2010. Ecosystem services: From eye-opening metaphor to complexity blinder. *Ecological Economics* 69: 1219–1227.

NWC (National Water Commission), 2011. Australian water markets report 2010–11. NWC, Canberra.

Ostrom, E., Burger, J., Field, C., Norgaard, R. and Policansky, D., 1999. Revisiting the Commons: Local Lessons, Global Challenges. *Science* 284: 278-282.

PWC (PricewaterhouseCoopers), 2006. National Water Initiative water trading study - final report. The Department of the Prime Minister and Cabinet, Australian Government, Canberra.

Salama, B., 2005. Interconnectivity Between the Superficial Aquifer and the Deep Confined Aquifers of the Gnangara Mound, Western Australia. *Water, Air, and Soil Pollution: Focus*, 5, 27–44.

Skurray, J.H. and Pannell, D.J., 2012. Potential approaches to the management of third-party impacts from groundwater transfers. *Hydrogeology Journal*. Available from: <http://dx.doi.org/10.1007/s10040-012-0868-9> [Accessed 30th May 2012].

Skurray, J.H., Roberts, E.J. and Pannell, D.J., 2012. Hydrological challenges to groundwater trading: Lessons from south-west Western Australia. *Journal of Hydrology* 412–413: 256–268.

Slaughter, R., 2009. A Transactions Cost Approach to the Theoretical Foundations of Water Markets. *Journal of the American Water Resources Association* 45 (2): 331-342.

Sturgess, G., 1997. Transborder Water Trading among the Australian States. In: T. Anderson and P. Hill, eds. *Water Marketing, the Next Generation*. Rowman & Littlefield, Lanham, MD.

Supreme Court of Ohio, 2005. McNamara v. Rittman. 107 Ohio St.3d 243, 2005–Ohio–6433.

Taylor, R., 2010. MP Washer turns tap on politics of WA water. *The West Australian*, 18th August, 21.

Towie, N., 2010. Bore users escape fines. *The Sunday Times*, 18th September.

Vaughan, B. and Emerson, P., 1997. Protecting the Edwards Aquifer: An Efficient and Ecological Alternative. In T. Anderson and P. Hill, eds. *Water Marketing, the Next Generation*. Rowman & Littlefield, Lanham, MD.

Vaux, H. and Howitt, R., 1984. Managing Water Scarcity: An Evaluation of Interregional Transfers. *Water Resources Research*, 20, 785–792.

WRC (Water and Rivers Commission), 2001. Statewide Policy No.6 - Transferable (Tradeable) Water Entitlements for Western Australia. Water and Rivers Commission, Government of Western Australia, Perth.

WRC (Water and Rivers Commission), 2003. Statewide Policy No. 11 - Management of Unused Licensed Water Entitlements. Water and Rivers Commission, Government of Western Australia, Perth.

Young, M. and McColl, J., 2009. Double trouble: the importance of accounting for and defining water entitlements consistent with hydrological realities. *The Australian Journal of Agricultural and Resource Economics*, 53, 19–35.

Zekri, S., Kotagama, H. and Boughanmi, H., 2006. Temporary Water Markets in Oman. *Agricultural and Marine Sciences*, 11, 77–84.