DISCRIMINANT ANALYSIS OF WATER TRADE AMONG IRRIGATION FARMERS IN THE LOWER ORANGE RIVER OF SOUTH AFRICA

R.M. Armitage[1] and W.L. Nieuwoudt[2]

This study found that a water market emerged within the Lower Orange River for river water rights. The market emergence is attributed to the scarcity of water in this region and the demonstrated demand by farmers for a change in the allocation of these rights. Transfers were facilitated by authorisation of the Department of Water Affairs and Forestry permitting transfers of water rights, and the enabling environment defined by the regional Water Affairs office. Improving water trade could be achieved by the delegation of authority to the regional Department of Water Affairs to approve transfers, extending support to market transfers of canal water, and ensuring that water extraction is closely monitored as river water use increases in future. A discriminant analysis indicated that water rights transferred from farmers with potential to irrigate wine grapes, raisin grapes, and field crops to farmers with potential to irrigate table grapes, representing the highest valued use of the water. Farmers stated that the proposed new Water Law created much uncertainty about their water rights, stifling water market activity, and that it will lead to underinvestment in irrigated agriculture. Overcoming such institutional and legal barriers for market performance will require that water use allocations be specified for reasonable periods, be inherently secure, and water trading be permitted through the relevant legislatures.

DISKRIMINANT-ANALISE VAN WATERHANDEL ONDER-BESPROEIINGS-BOERE IN DIE BENEDE-ORANJERIVIER GEBIED VAN SUID-AFRIKA

Hierdie studie het bevind dat daar 'n mark vir rivierwaterregte in die Benede-Oranjerivier ontwikkel het. Hierdie ontwikkeling word toegeskryf aan die skaarste van water in hierdie gebied en die bewese aandrang onder boere vir verandering in die toewysing van hierdie regte. Oordragte is moontlik gemaak deur magtiging van die Departement van Waterwese en Bosbou wat oordragte van waterregte goedgekeur het, en deur die bemagtiging omgewing soos gedefinieër deur die streekskantoor van Waterwese. Verbeterde waterhandel kan bewerkstellig word deur die delegering van gesag na die Departement van Waterwese in die streek om oordragte goed te keur, deur steunverlening aan markoordragte van kanaalwater, en deur die versekering dat wateronttrekking noukeurig geëvalueer word namate die gebruik van rivierwater in die toekoms toeneem. 'n Diskriminant-analise het getoon dat die oordrag van waterregte van boere met potensiaal om wyndruiwe, rosyntjiedruiwe, en saaigewasse te besproei gegaan het na boere met potensiaal om tafeldruiwe te besproei, wat die hoogste waarde-gebruik van die water verteenwoordig het. Boere het gesê dat die voorgestelde nuwe

[1] *Post-graduate student, Department of Agricultural Economics, University of Natal, Pietermaritzburg.*

[2] *Professor, Department of Agricultural Economics, University of Natal, Pietermaritzburg.*

Waterwet baie onsekerheid oor hulle waterregte geskep en watermarkaktiwiteit onderdruk het, en dat dit sal lei tot onderbelegging in besproeiingslandbou. Om sulke institusionele en wetlike struikelblokke vir markprestasie te oorkom, sal dit nodig wees dat toewysings van watergebruik vir redelike tydperke gespesifiseer word, dat dit inherent seker moet wees, en dat waterhandel deur die betrokke wetgewers toelaat moet word.

1. INTRODUCTION

The current South African water economy exhibits extreme competition between users, inelastic supply of water, high and increasing demand for water, and increasing social costs (Backeberg, 1994). Demand on water supplies continues to mount owing to population and economic growth, industrialisation and urbanisation, and the need to address inequity in water allocation and environmental demands. Water scarcity in South Africa has historically been resolved with the exploitation of new water sources through water management institutions concerned primarily with the construction of storage and conveyance facilities (Walmsley, 1995). However, since many water sources have been fully appropriated given current technologies, and the remaining water sources are becoming prohibitively expensive to exploit, these supply side responses to water scarcity are becoming increasingly inadequate (Conley, 1993 and Backeberg, 1994). The reassessment of the current water law to yield a new Water Act is a reflection of the need for new water management institutions and allocation systems better suited to future needs of the country.

Fifty-one percent of all water consumption in South Africa occurs in irrigated agriculture, prompting the observation that this sector will be the primary source to satisfy demand through water savings (Water Research Commission, 1996). Increasing food demand in the future arising out of population growth, higher standards of living and increased per capita consumption will mean that irrigated agriculture will also have to meet the challenge of producing more food for consumption. Mitigating the reduction in irrigation water for farmers will require an enabling environment through institutional reform that allocates water in an efficient and flexible manner (Backeberg, 1997). Markets are the classical economic institution for allocating scarce resources efficiently and flexibly, (Griffin & Boadu, 1992), and evidence from a number of countries including Chile, Mexico, Australia, and the United States has shown that water markets are an effective mechanism for improving irrigation water allocation and its use (Easter, 1996).

This paper draws from the substantial literature on water markets, and follows an approach similar to Hearne (1995) and Michelsen (1994) in their respective studies of water markets in Chile and the US. A 'water market' that emerged in

the Lower Orange River was chosen for analysis, as this area exhibits one of the highest incidences of market trading of water rights in South Africa. The purpose of this research is to investigate how water markets can lead to more efficient allocation and use of irrigation water. Specific aims are to

(1) evaluate the market for 'outer land' water rights that has emerged in two state irrigation schemes in the Lower Orange River, in an attempt to understand the institutional, administrative and transaction characteristics of such a market,

(2) determine factors that discriminate between Buyers and Sellers of 'outer land' water rights in the sample survey,

(3) ascertain sample farmers' responses to the proposed new Water Law, and

(4) provide policy recommendations.

2. TRADABLE WATER RIGHTS

2.1 Requirements for a market in tradable water rights

An efficient water market requires:

(1) Well defined rights that are completely specified in the unit of measurement, reliability and priority, creating certainty in what is being traded and predictability in the reallocation process.

(2) Enforceable water rights that secure the net benefits flowing from the use of the water right for the right holder.

(3) Transferable water rights that create exposure to the opportunity to realise higher valued alternatives. Water rights should ideally be separated from land to enable transfers to take place independently of land ownership or use (Anderson, 1983 and Pigram, 1993).

(4) Constitutional guarantee of title ownership and legal sanction of water transfers by the relevant Government jurisdiction, to provide for secure water rights, and

(5) an efficient administration system to maintain the proper chain of title over the water rights (Simpson, 1992).

2.2 Incentives for water market allocation

Cummings & Nercissiantz (1992) explain that an unfettered water market will result in an economically efficient allocation, with water placed in uses most highly valued by society in a flexible manner. The implicit value endowed in water within a market creates a built in incentive to conserve water voluntarily without having to raise water charges (Thobani, 1995). As such, water markets allow decentralised information to be brought to bear on water management decisions, enabling a farmer to apply first hand knowledge to determine how much water to apply and which crops to produce (Anderson & Leal, 1989 and Pingali & Rosegrant, 1995). Water market allocation provides maximum flexibility in responding to changes in crop prices and water values as demand patterns and comparative advantage change and crop diversification progresses (Rosegrant & Binswanger, 1994). For flexibility to exist it is not required that all water be subject to reallocation. A tradable margin constituting only a small part of total water supply within each major water using area that is subject to low cost reallocation is sufficient (Howe *et al.*, 1986). By assuring access to secure supplies of water, markets also stimulate employment and investment through increasing producer incentives to make long term investments in production technology (Easter & Hearne, 1995 and Thobani, 1997). The fact that people with no water rights or poor financial situations have low bargaining power does not disqualify the merits of a water market. Water services should not be subsidised or market values of rights distorted to achieve social objectives, but rather appropriate payment systems such as lifeline rates and grant funding should be considered (Backeberg, 1996).

Within a market environment for a natural resource such as water, individual users face the opportunity cost of selling the resource through the market, and may have incentive to maintain or improve resource quality. However, this may not always hold true for water, especially flow resources. As Booker (1990) notes, water has public good attributes while efficient markets require that resources be rival and excludable, and use values well known. Efficiency requires that external effects of the transfer be internalised in the transfer process. Accounting for negative third-party impacts in the transfer decision entails procedures to identify and value impacts, by either including affected parties in the transfer process or securing compensation once external effects become evident (Saliba, 1987). Experience from Chile, Mexico and the United States, shows that market transactions do not take place under conditions of perfect competition, necessitating a role for public institution performance in the protection against monopoly development, third party impairment from water trades and to resolve conflicts amongst water users (Rosegrant & Binswanger, 1994).

3. WATER RIGHTS TRADING IN THE LOWER ORANGE RIVER

3.1 The study area

The study was conducted among irrigation farmers in the Boegoeberg and Kakamas Irrigation Schemes along the Orange River between Boegoeberg to Augrabies in the Northern Cape Province, in November 1997. The study area can be divided into two river reaches. The first stretches from Boegoeberg to Upington and incorporates the Boegoeberg Irrigation Scheme. The second stretches from Upington to Augrabies and incorporates the Kakamas Irrigation Scheme. The area is arid; precipitation declines from 400mm to less than 200mm per annum in the West. The hottest conditions and highest evaporation rates in South Africa are experienced in this area (McKenzie *et al*., 1991 and National Regional Development Programme, 1991).

3.2 Water rights allotments in the Boegoeberg and Kakamas Irrigation Schemes

The quantity of the annual basic water quota, specified as a certain volume per ha per year, was set by the Department of Water Affairs and Forestry (DWAF) according to hydrological conditions and anticipated water demand for the coming water year. Farmers paid an annual levy for their water rights depending on whether the water was extracted from the canal or river. Canal water rights are extracted directly from the canal, and are primarily gravity fed onto 'inner land'[1]. River water rights on the other hand are extracted by direct pumping from the river by the right holder, and are primarily used to irrigate 'outer land'. River water comprised approximately 26 percent of total irrigation water supply in the Boegoeberg and Kakamas Irrigation Schemes, while canal water comprised approximately 74 percent. Farmers paid R450.45 per ha for canal water and R24.50 per ha for river water in the 1997 water year (Department of Water Affairs and Forestry, 1997c).

3.3 The institutional arrangements facilitating water trading in the Lower Orange River

Development of the water market was achieved within a centralised non-market water allocation system that was highly controlled and regulated by the DWAF. Trading of water rights emerged despite a significant extent of bureaucratic regulation imparted on the market. While some regulation of water trades is desirable within the context of a water market, much of the regulation governing transfers of water rights in the Lower Orange River served to

increase transaction costs unnecessarily. The institutional arrangements facilitating market development are discussed below.

Initial allocations of water rights in the study area were contingent to land characteristics of individual farms. 'inner land', was allocated a canal water right under the initial settlement of the irrigation scheme in 1933. 'Outer land', was allocated a river water right by the state from October 1977. Individual farmers had to apply to the regional DWAF to incorporate the 'outer land' water right into their property. This involved a bureaucratic process in which farmers were required to obtain a cultivation certificate from an appointed soil scientist from the Department of Agriculture, serving as proof as to the extent of their property's 'outer land' that was irrigable, within 2km of the river, and not higher than 60m than the river. The application for incorporation and soil scientist's report would be evaluated by DWAF head office in Pretoria. Following approval, a river water right coupled to the land area specified by the cultivation certificate up to a maximum of 30 ha, which included the 'inner land' area irrigated from the canal, would be granted to the farmer by the regional DWAF office. In addition, any 'outer land' that was purchased from the state subsequent to 1977 was entitled to a basic water right quota from the river of 30 ha in its entirety, provided it met with the above provisions. The bulk of irrigable 'outer land' in the two irrigation schemes received a river water right in this manner. However, some farmers found it uneconomic to develop their 'outer land' for irrigation purposes owing to the unsuitability of this land in supporting cropping enterprises. This generated a bank of unused water rights that expedited the subsequent reallocation of water from low to high potential 'outer land' through the market. The Department of Water Affairs and Forestry (1997c) estimate that between 15 to 20 percent of 'outer land' water rights were unused prior to the development of the water market.

Secondly, the unit of measurement of 'outer land' water rights was completely specified as a diversion right of 15000m3/ha/year. Individual farmers' river water rights were found to have a high-implied reliability, since a river water quota of 15000m^3/ha/year was effectively declared in each year since river water quotas were initially allocated in 1977. Only in 1993 was a restriction placed on water extraction, with a 50 percent reduction in water quotas for the first four months of the year due to severe drought. This was restored to its original value for the remainder of the year after favourable rains. The specification of all irrigation water rights as proportional, allowed the extent and risk associated with restrictions to be spread equally among all rights holders. Irrigation rights also enjoyed high priority, assuring irrigators of rights senior to industrial water rights, and junior only to basic human water requirements and stock watering requirements. This created certainty among parties as to exactly

what was being traded, and predictability in the outcome of the reallocation process.

Thirdly, 'outer land' water rights were transferable between irrigation properties, and trades legally sanctioned by way of Government Notice 966 of 19 May 1989. The Minister delegated to certain officials the authority to permit water allocated to one piece of land to be used on another piece of land, in circumstances where a policy had been determined by the Minister to handle such applications. This enabled water to be temporarily or permanently transferred from one property to another, by means of lease agreement or sale of the water rights. However, before individual transfers could proceed, a number of bureaucratically determined conditions had to be satisfied. As a result of these regulations, water transfers were not simple voluntary trades between two parties, but rather negotiated transfers between the two parties and bureaucratic authorities. In the consideration of applications for the permanent transfer of water rights from one owner's land to another; It had to be technically possible to supply water to the property to which the scheduling was to be transferred, and all costs, if any, inherent in moving the point of supply had to be borne by the buyer; There had to be sufficient irrigable land on the property to which the water was being transferred; The regional DWAF Office, Department of Agricultural Development, and local extension officers had to support the transfer from an agricultural perspective, and; The property from which water rights were transferred could not be encumbered by the Land Bank, or no objection to the permanent transfer of the water indicated by the Bank (Department of Water Affairs and Forestry, 1989). The transferability of 'outer land' water rights among irrigable properties created exposure to farmers with poor 'outer land' soils to realise higher valued alternatives through the transfer of these rights to table grape farmers with more fertile 'outer land'. However, the coupling of 'outer land' water rights to land prevented any transfers of irrigation water to higher valued urban uses, eliminating the potential to generate water savings within the agricultural sector that could be reallocated to urban uses.

The controlled allocation environment in which water rights were allocated as well as constitutional guarantee of title ownership of water rights provided for water rights that were wholly enforceable and secure, assuring that the benefits from the use of the water were secured for the right holder. Water transactions were first initiated in late 1994, and were driven by the desire of large-scale table grape producers to expand their operations. These farmers typically possessed considerably more high potential 'outer land' suitable for cultivation than their basic water right encompassed, generating a gradual escalation in demand for water rights for this land. Increasing water demand culminated in the DWAF notifying farmers within the two irrigation schemes of their opportunity to,

firstly, incorporate a basic water right into their 'outer land' and develop this land for irrigation purposes, and secondly, to purchase any additional water rights for irrigable 'outer land' from other farmers with unused water rights. Facilitating water rights sales between farmers, represented a shift in policy by the DWAF to reallocate existing but unused water rights. Such a change aimed to encourage economic growth within the irrigation schemes without the need for new claims to be made on the river.

The administrative function performed by the regional DWAF office was central in the successful establishment and functioning of the water market. The transfer process as specified by the DWAF was clearly defined and well understood by potential market participants. The transfer process was however guided heavily by bureaucratic regulation. Farmers were required to prove any land for which an application had been filed to purchase water rights was suitable to irrigation. A potential buyer was required to obtain a cultivation certificate for the land he intended to buy water rights for. Both buyer and seller were required to file a joint application, with the services of a lawyer at a cost to the buyer, with the regional DWAF office, to have the water rights permanently transferred from the seller's property to that of the buyer's. The application was submitted to the DWAF head office in Pretoria for consideration and approval. Following approval to transfer the water, the regional DWAF office would conclude the transaction, and the transfer of the water right would be formally registered. This supervising and recording function of the DWAF was important in maintaining the correct chain of command over water rights and ensuring transfers were concluded within three to six months. In addition the DWAF performed an important role as provider of market information, matching potential sellers and buyers. In most instances, sellers actively sought out potential buyers for their water rights. On the other hand, transaction costs may have been unnecessarily high as a result of the elaborate bureaucratic conditions that had to be satisfied before transfers could proceed, and in the approval process governing water rights trades.

Sellers faced transaction costs of R200 to R600 per transaction, stemming primarily from the cost of hiring a soil scientist to assess the 'outer land' for which they were applying to incorporate an 'outer land' water right, and to a lesser extent from the effort in completing and filing the transfer application. Buyers faced higher transaction costs of R2000 to R6000 per farm arising primarily from the legal cost involved in the application and transfer process, and to a lesser extent from the cost of a soil scientist to assess the land for which they were applying to buy water rights, and the effort in filing the application. In addition, the onus was on the buyer to bear any infrastructure costs needed in transferring the water to the future point of use. This generally involved the cost

of electricity, pumps and pipes, and represented a significant investment on the part of the buyer. The high fixed transaction cost in the transfer process arising from legal fees may have ruled out small transfers. As a result the market is quite imperfect.

Finally, the specification of water rights as diversion rights, allowed for transfers within the Lower Orange River for the full quantity for the water right allocation. Since no return flow had been calculated and implemented for water rights within the Lower Orange irrigation schemes, there was no onus on buyer or seller to determine the effects of the transfer on the other water users. This enabled transfers to be achieved through administrative procedure with no lengthy adjudication processes, to ensure there were no adverse impacts associated with each particular transfer.

4. DATA COLLECTION AND CHARACTERISTICS OF RESPONDENTS

A survey of 54 irrigation farmers was conducted during November 1997. The target population was identified with the assistance of the regional DWAF office and was composed of three separate strata. The first stratum, Buyers, consists of all 11 farmers in the study area who had bought water rights. A random sample of 25 farmers (40 percent) was drawn from the population of 63 farmers who had sold water rights to other farmers. This stratum, stratum two, represents the Sellers. Stratum three, the Control, encompasses all 18 farmers who had river water rights but had not engaged in any water trading activity. A questionnaire was completed by individual farmers during personal interviews conducted in the survey. Nine, 21 and 14 usable questionnaires were obtained from strata one, two and three respectively. The non-usable questionnaires were due to missing values or farmer absenteeism during the survey period. As a consequence, the descriptive results that follow represent the population parameter estimates for the Buyer and Control groups, while the descriptive for the Seller group represent the estimated population parameter estimates.

Eight of the nine Buyers were located in the second river reach from Upington to Augrabies, while all 21 Sellers and all but one of the Control farmers were located in the first reach from Boegoeberg to Upington. Table 1 summarises the general size characteristics of the three strata. Table 1 shows that Buyers generally have larger farms with more irrigated land than the other two strata, as well as proportionally more arable land that can be developed for irrigation purposes.

Table 1: Farm characteristics of survey farmers in the Lower Orange Region, November 1997

	Ave.Farm Area	Ave. Arable Area	Ave. Irrigated Area
Buyers (n=9; N=11)	1280.56 ha	449.22 ha	166.55 ha
Sellers (n=21; N=63)	132.05 ha	70.67 ha	52.71 ha
Control (n=14; N=18)	87.50 ha	45.64 ha	34.71 ha

A cropping programme summary of the survey farmers is presented in Table 2. The data in Table 2 show that 64 percent of Buyers' irrigated land is under table grapes, 16.5 percent under raisin and wine grapes, and 18.2 percent under horticultural crops (date, vegetable, melon and citrus). The Sellers and Control farmers are more diversified, with more than 50 percent of their irrigated land under field crops (wheat, maize, cotton, and lucerne), and the remainder under raisin and wine grapes.

Table 2: Irrigation crop use percentages of survey farmers in the Lower Orange Region, November 1997

	% Irrigation Crop Use				
	Table Grapes	Raisins & Wine Grapes	Field Crops	Horticultural Crops	Total
Buyers (n=9; N=11)	64.0	16.5	1.3	18.2	100.0
Sellers (n=21; N=63)	0.3	44.0	54.0	1.7	100.0
Control (n=14; N=18)	2.0	36.0	56.0	6.0	100.0

Significant differences are also apparent in the irrigation systems used by the three groups of farmers. A summary of irrigation system use in Table 3, shows that Sellers and Control farmers employ flood irrigation systems exclusively, while Buyers use primarily micro systems (54 percent), and to a lesser degree flood systems (30 percent) and drip systems (16 percent).

Table 3: Irrigation system use percentages of survey farmers in the Lower Orange Region, November 1997

	Micro	Drip	Flood	Macro	Total
Buyers (n=9; N=11)	54.0	16.0	30.0	-	100.0
Sellers (n=21; N=63)	0.5	-	96.0	3.5	100.0
Control (n=14; N=18)	3.0	3.0	94.0	-	100.0

Table 4: Comparative descriptive statistics of water trades by sample buyers and sellers of water rights in the lower Orange River, November 1997

BUYERS (n=9; N=11)	Min	Max	Mean	Sum	Std dev	Nature
No. of water contracts per Buyer	1.00	14.00	4.33	39.00	5.27	Permanent sale
Water volume traded per Buyer	10.00 ha	452.80 ha	119.47 ha	1075.20 ha	164.78	"
Water volume traded per transaction	7.60 ha	64.40 ha	27.57 ha	-	17.26	"
Ave purchase price per ha per transaction	R800.00/ha	R5000.00/ha	R3386.20/ha	-	755.44	"
Total ave purchase price per ha	**-**	**-**	**R3296.04/ha**	**-**	**-**	**"**
SELLERS (n=21; N=63)	**Min**	**Max**	**Mean**	**Sum**	**Std dev**	**Nature**
No. of water contracts per Seller	1.00	2.00	1.19	25.00	0.40	Permanent sale
Water volume traded per Seller	10.00 ha	100.00 ha	28.09 ha	589.80 ha	20.15	"
Water volume traded per transaction	9.60 ha	100.00 ha	23.59 ha	-	19.33	"
Ave sale price per ha per transaction	R3000.00/ha	R4600.00/ha	R3440.00/ha	-	473.46	"
Total ave sale price per ha	**-**	**-**	**R3529.93/ha**	**-**	**-**	**"**

Table 5: Combined descriptive statistics of water trades by sample buyers and sellers of water rights in the lower Orange River, November 1997

BUYERS + SELLERS (n=30)	Min	Max	Mean	Sum	Std dev	Nature
No. of water contracts per individual	1.00	14.00	2.13	64.00	3.15	Permanent sale
Water volume traded per individual	10.00 ha	452.80 ha	55.50 ha	1665.00 ha	97.89	"
Water volume traded per transaction	7.60 ha	100.00 ha	26.02 ha	-	18.05	"
Ave transaction price per ha per transaction	R800.00/ha	R5000.00/ha	R3407.21/ha	-	655.99	"
Total ave transaction price per ha	-	-	R3378.89/ha	-	-	"

5. RESULTS

Descriptive information summarising the comparative transaction details of the sample Buyers and Sellers of water rights, are presented in Table 4 below.

Table 4 shows that all water trades were permanent in nature. No temporary water trades had taken place. Sample Buyers of water rights entered into more contracts per individual (4.33) than the sample Sellers of water rights (1.19), and exhibited a greater range in the number of contracts per individual (13) as opposed to the Sellers (1). The lower number of water contracts per Seller is borne out by the fact that Sellers of water rights tended to sell their 'outer land' water right or portfolio of 'outer land' water rights to a single Buyer, whereas the larger Buyers invariably had to purchase water rights from a number of Sellers, all selling a fairly uniform volume of water. This latter point is emphasised in Table 4 by the fact that the average volume of water traded per transaction by sample Buyers (27.57 ha) is only slightly higher than that of the sample Sellers (23.59 ha). However, the sample Buyers of water rights traded a greater volume of water (119.47 ha) per individual than Sellers (28.09 ha), and exhibited a greater range in the volume traded per individual (442.80 ha) than the sample Sellers (90.00 ha). Table 4 shows that the purchase price of 'outer land' water rights for Buyers ranged from R800 to R5000/15000m^3/ha, while the sale price for Sellers ranged from R3000 to R4600 15000m^3/ha. Finally, the mean purchase price paid by Buyers was R3296.04/15000m^3/ha, while the mean sale price received by Sellers of water rights was R3529.93/15000m^3/ha.

Table 5 summarises the transaction details of the sample Buyers and Sellers of water rights in aggregate.

Table 5 shows that volume traded per individual ranged from 10.00 ha to 452.80 ha, with a mean of 55.50 ha. Water volume traded per transaction ranged from 7.60 ha to 100.00 ha, with a mean of 26.02 ha. Finally, the sale price for 'outer land' water rights ranged from R800 to R5000/15000m^3/ha[3] with a mean sale price of R3378.89/15000m3/ha. A cursory examination of land prices within the study area found that dry land suitable for irrigation and for which a farmer could obtain water rights sold for R1000 to R2000 per ha, while undeveloped arable land coupled to a water right generally sold for R6000 to R10000 per ha. This information confirms that the trading value of 'outer land' water rights is approximately R4000[4] per ha.

Net present value analysis of the sale price of 'outer land' water rights was used to calculate the shadow price of 'outer land' water rights in the Lower Orange River. The results of this analysis are presented in Table 6.

Table 6: The sale price and estimated shadow price of 'outer land' water rights in the Lower Orange River, November 1997

	MIN	MAX	AVE
Sale price of 'outer land' water rights (R/15000m3/ha)	R800.00	R5000.00	R3387.89
Estimated shadow price of 'outer land' water rights using a 10 % discount rate (R/15000m3/ha/annum)	R104.50*	R524.50	R362.39
Estimated shadow price of 'outer land' water rights using a 15 % discount rate (R/15000m3/ha/annum)	R144.50	R774.50	R531.33

* R104.50 = {(R800 * 10%) + R24.50}

In Table 6, the rental value of 'outer land' irrigation water was calculated as the sale price, multiplied by the real discount factor, plus the annual tax for 'outer land' water rights. The annual tax on river water for 'outer land' of R24.50 per 15000m^3/ha was added to calculate the shadow price of water before tax. Real discount rates of 10 and 15 percent were used in the calculation. According to Nieuwoudt (1987), the rental rate of return on farmland is about 4.6 percent. However, higher discount rates of 10 and 15 percent for water right quotas were used in this analysis, and can be attributed to uncertainty surrounding water rights. This follows Ortmann (1987), who used a capitalization rate of 15 percent for sugar quotas in an analysis of land rents and production costs in the South African Sugar Industry. The higher discount rate for sugar quotas than for land is attributed to uncertainty about losing the quotas, since such quotas may be abolished. Similarly, uncertainty about water rights is expected to lead to a higher discount rate for water than for land.

The data in Table 6 show that the rental value of 'outer land' water on the Lower Orange River is estimated to range from R104.50 to R524.50/15000m^3/ha per annum using a 10 percent real discount rate, and from R144.50 to R774.50/15000m^3/ha per annum using a 15 percent real discount rate. The average rental values of irrigation water using a real discount rate of 10 and 15 percent were calculated as R362.39 and R531.33/15000m^3/ha per annum respectively.

Torell *et al.* (1990) calculated an average market rental value for water in storage that ranged from R92.43/15000m^3/ha[5] (or $1.52/acre/foot) in Oklahoma to R507.72/15000m3/ha (or $8.35/acre/foot) in New Mexico in the Ogalla aquifer in the Western US over the period from 1979 to 1986. From these data it cannot be concluded that average water values in the Lower Orange River are

significantly different from the values in the Western US, given the range in prices in both countries, uncertainty about the discount rate, and differences in time periods and land use.

Of the 1075.20 ha of land for which the sample Buyers had purchased water rights, Table 7 summarises the existing and the additional future intended development of this land. Table 7 shows that water rights have been purchased almost exclusively for viticulture, particularly table grape production. Existing table grape production amounts to 8.1 percent of the land area for which water rights were purchased, while future intended table grape production accounts for an additional 51.5 percent of this land. Future intended raisin and wine grape production amounts to approximately 23.3 percent of this land area.

Table 7: Existing and future intended use of purchased water rights by buyers (n=9; N=11), November 1997

Existing Development		
Crop	**Micro irrigation (ha)**	**Drip Irrigation (ha)**
Table Grapes	117.4	15.0
Raisins & Wine Grapes	10.0	9.0
Vegetables	-	80.0
Additional Future Intended Development		
Table Grapes	513.8	40.0
Raisins & Wine Grapes	170.0	80.0
Citrus	30.0	-

Of the reported 589.80 ha of water rights that were sold by the 21 Sellers, 370.20 ha had been used as grazing land and a further 219.60 ha was unutilized. The discrepancy in selling area and buying area is explained in that only a random sample of 40 percent of the Sellers was drawn, while the entire population of Buyers were surveyed. The Buyers generally purchased water rights from multiple Sellers. Sellers were also able to sell water rights to farmers in the Middle Orange River, and may have under-reported water rights sales in the survey.

5.1 Responses to water trading activity

Farmers were requested to motivate the reason for engaging in or abstaining from water rights transactions. The nine Buyers all revealed buying water rights to irrigate crops on previously unscheduled land, while 3 farmers also bought water rights for the additional reason of securing a higher degree of water supply availability for dry periods. Table 8 displays the reasons of the 21 Sellers

for selling 'outer land' water rights. Table 8 shows that 10 of the 21 Sellers sold water rights because of poor 'outer land' soils coupled to the water right, while five sold water rights because of steep slopes on their 'outer land'.

Table 8: Reasons for selling water rights reported by sellers (n=21; N=63), November 1997

Reason for selling water rights	No. of farmers
Water unused because of poor soils on land coupled to the water right	10
Water unused because of steep slope on land coupled to the water right	5
Farm has enough water for its operations	3
Too expensive to develop the land coupled to the water right	2
Farmer perceives he will lose unused water rights under the new water law	1

The reasons for Control farmers not engaging in water market transfers are displayed in Table 9. Table 9 shows, as expected, that farmers who did not buy additional water rights generally did not require any additional water for their farm operations, while farmers who did not sell water rights were commonly using the water right in their farm operations, or retained the rights to maintain a higher degree of water supply availability.

Table 9: Reasons for not buying or selling water rights by Control farmers (n=14; N=18), November 1997

Reasons for not buying water rights	No. of farmers
No additional water required for farm operations	11
Prices of water rights too high	4
No one is willing to sell their water rights	1
Reasons for not selling water rights	**No. of farmers**
Entire water right used in farming operations	9
Excess water retained to maintain a higher level of water supply security	6
No one wants to buy water rights	1

No renting activity for temporary transfers of 'outer land' water rights had developed in the study area. Farmers' incentives to rent in water rights for 'outer land' for temporary periods of time may have been reduced by the high fixed costs involved in developing 'outer land' for irrigation purposes. Higher transaction costs faced by Buyers, especially the associated fixed cost component of hiring a lawyer in the transfer process, may have prevented market

participation of certain farmers, by driving a wedge between buying and selling prices. This would have been significantly larger for small transactions of water rights.

Monitoring of river water extraction does not appear to be a critical issue at present on the Lower Orange River. From the sample of farmers in the survey who responded to the question on river water extraction (n=30), 83 percent stated that farmers did not have unlimited access to river water during times of water abundance. A further 83 percent stated the DWAF monitored their water extraction, while the remainder were unsure as to who performed the monitoring function. Fifty-five percent believed that monitoring was performed by the inspection of pump meters, while the remainder were unsure as to the method of monitoring. Seventy-two percent of farmers believed it was not possible to withdraw more river water than their specified right without any resulting penalties. However, 40 percent of farmers were unsure as to what these penalties would be, while 27 percent believed farmers would have to pay a higher levy for any water extracted above their quota, 13 percent believed offenders would be formally charged, and 20 percent believed farmers' sluice gates would be closed for a period. In addition, 80 percent of sample farmers reported having good information about water availability in future months, while all farmers reported being unable to claim compensation for pollution or reduced flow as a result of the actions of another party. The study shows that although rights are enforced, a high percentage of farmers (40 percent) were unsure of penalties resulting from over-extraction. This may be due to the majority of farmers with river water rights either irrigating only a fraction of the land coupled to the water right or not making use of the water right at all. This buffer of unused rights may mean that monitoring of river water extraction is not a critical issue to farmers. This situation may change in the future as more river water rights are exercised, requiring more intensive monitoring of pump meters and the existence of a transparent penalty structure.

5.2 Discriminant analysis

Discriminant analysis was used to differentiate between those respondents who had bought water rights (Buyers) and those who had sold water rights (Sellers). The dependent variable in the analysis, **Bght,** was constructed using one (1) for farmers who had bought water rights and zero (0) for farmers who had sold water rights.

The set of discriminating variables on which the two groups are expected to differ was assembled following Manley (1994), and are presented in Table 10.

Table 10: Definition of variables included in the discriminant analysis between buyers and sellers of water rights along the lower Orange River, November 1997

Variable	Definition
Bght	= 1 if respondent bought water rights, 0 otherwise.
Tblgp	= 1 if respondent grows table grapes, 0 otherwise.
Retrn	A proxy variable calculated as the ratio of farm gross margin (R) from irrigation enterprises to total farm irrigation water requirement (m3).
Iritec	= 1 if respondent uses micro and/or drip irrigation, 0 otherwise.
Incont	Ratio of actual irrigated area to total farm size.
Potdev	Ratio of undeveloped arable land to total arable area.
Usear1	= 1 if respondent is located in the River reach from Upington to Augrabies and uses 50 percent to 75 percent of his arable land, 0 otherwise.
Usear2	= 1 if respondent is located in the River reach from Upington to Augrabies and uses 25 percent to 50 percent of his arable land, 0 otherwise.
Usear3	= 1 if respondent is located in the River reach from Upington to Augrabies and uses 0 percent to 25 percent of his arable land, 0 otherwise.
Vine	=1 if respondent grows wine and/or raisin grapes, 0 otherwise.

In discriminant analysis the objective is to weigh and linearly combine the variables so that the groups are forced to be as statistically distinct from one another (Klecka, 1975).

Market proponents contend that water rights will move from lower to higher valued users through the market mechanism. It is thus hypothesised that water rights will transfer from farmers growing primarily wine and raisin grapes (**Vine**) to farmers growing table grapes (**Tblgp**). The estimated return (**Retrn**) per unit of water applied is expected to be an important discriminating variable, with water rights gravitating to the most effective users of water. In a market, both buyers and sellers have an incentive to adopt water saving technology as water has an opportunity cost. Any transaction costs of water right transfers may drive a wedge between the prices faced by Sellers and Buyers, resulting in Buyers being more frugal users of water and having somewhat greater incentive to make use of micro and drip irrigation systems (**Iritec**). An institutional control variable, **Incont**, measuring the ratio of actual irrigated area to total farm size was included in the analysis. The ratio of this control variable is influenced by the initial bureaucratic allocation of water rights to 'inner' and 'outer land', as well as the subsequent reallocation of water to undeveloped 'outer land' through the market. No *a priori* expectation is associated with this variable.

Buyers were also expected to have proportionally more arable land than Sellers that could be developed for irrigation purposes (**Potdev**). The availability of high potential 'outer land' is expected to be an important factor in influencing farmers' decisions regarding water trading activity. Buyers are hypothesised to be located in the river reach from Upington to Augrabies and be using only a fraction of their available arable land (**Usear1, Usear2, and Usear3**).

The results of the discriminant analysis undertaken to determine which variables distinguish between Buyers and Sellers are presented in Table 11.

Table 11: stimated discriminant function between Buyers and Sellers of water rights along the Lower Orange River, November 1997

Explanatory variable	Standardised Coef.	F – value
Tblgp	0.760	18.33*
Retrn	0.730	14.87*
Usear2	0.612	6.69*
Usear1	0.610	6.47*
Incont	0.596	6.53*

* denotes statistical significance at the 1 percent level of probability

F-value	15.5*
Wilks' lambda	0.061
Canonical correlation	0.97

The most significant variable discriminating between Buyers and Sellers was whether the farmer grew table grapes (**Tblgp**) or not. This shows that water rights moved from potentially lower valued users, with the opportunity to cultivate only wine grapes, raisin grapes and field crops, to table grape farmers representing the highest valued use of the water right. The second most important variable was the estimated return per unit of water applied, (**Retrn**), showing that water gravitated to those farmers best able to utilize the water in their farm operations. These two variables have a correlation coefficient of 0.17. The location of the farmer in the river reach from Upington to Augrabies, and whether he was utilising 25 to 50 percent (**Usear2**) or 50 to 75 percent (**Usear1**) of his arable land respectively were the next most significant variables respectively. **Incont**, the ratio of actual irrigated land to total farm size was the least significant variable discriminating between Buyers and Sellers. The overall F-value of 15.5 indicates that the four retained independent variables together distinguish significantly between Buyers and Sellers. The Wilks' Lambda of 0.061 and canonical correlation coefficient of 0.97, indicate the function is effective in classifying respondents correctly.

The discriminant analysis results suggest that irrigation techniques used by Buyers and Sellers were not significant in directing the transfer of water rights. This may be attributed to the opportunity cost for water being similar for Buyers and Sellers, and because irrigation systems are adopted largely for practical reasons. Flood irrigation systems appear almost exclusively in the 'inner land', where soils have a high clay content and water holding capacity. These lands are generally within the flood zone of the river, where the risk of damage to micro and drip systems from periodic flooding is high and existing canal infrastructure is in place to allow for easy delivery of the water. The predominance of micro and drip systems on Buyers 'outer land' is explained by the lower clay content and water retention capability of this soil which demands more efficient water application techniques as a result. Micro irrigation is also favoured for its important cooling effect on the table grape crop. As a result, 'outer land' is generally amenable mainly to micro and drip irrigation using water pumped directly from the river, while 'inner land' is amenable to flood irrigation systems using gravity fed water from existing canal infrastructure.

5.3 Farmer responses to the proposed new Water Law

The recent acceptance of the new Water Law Principles (Department of Water Affairs and Forestry, 1997b) that will form the basis of the new water legislation by the DWAF has created much uncertainty among irrigation farmers, and will certainly impact on some of their investment, production, and financing decisions. A five category scale, ranging from 'strongly disagree' through to 'strongly agree' with a given statement (Table 12), was used to elicit farmers' perceptions on the influence of the proposed new water law on their farm operations and water trading activity.

Within the study area, the proposed water legislation has already had a negative influence in bringing water transfers among farmers to a standstill. This is reflected in Table 12 with 88 percent of sample farmers recording that the proposed amendments to the water legislation had created widespread uncertainty pertaining to water market transfers, and 80 percent believing the new legislation will lead to fewer water market transactions.

According to the White Paper on Water Policy (Department of Water Affairs and Forestry, 1997a), all water will be transformed into 'public property whose allocation and right of use shall be subject to Government control'. The National Water Bill (Department of Water Affairs and Forestry, 1997b) further states that there can be 'no private ownership of water, only authorisation for a use right' for water that shall not be held in perpetuity. Existing water users will have to apply for registration of their use, which on approval will be converted into a

rolling water use license granted on a five year cycle with a maximum length of forty years. At the end of this period license holders will have to apply for license renewal which will be considered along with new applications. Existing water rights may only be recognized to the extent that they are 'beneficially used in the public interest', where the public interest is defined by Government.

Table 12: Responses of sample farmers to statements regarding the proposed new Water Law, November 1997

Statement (n=44)	strongly disagree	disagree	uncertain	agree	strongly agree
The proposed legislation has increased uncertainty pertaining to water market transfers	2	-	3	10	29
The proposed legislation will lead to fewer water market transactions	3	-	6	15	20
You will have less incentive to invest in irrigation technology	4	4	5	10	21
Selling some of your water use rights to another farmer will negatively influence the success of reregistration of your water use rights	4	6	8	10	16
Free unrestrained trading of water use rights is good for farmers	2	-	2	15	25

By invalidating individual ownership of water the new Water Law severely attenuates water rights and moves away from the present permanent land-linked water rights to a time limited water use allocation, without compensation or recognition that water rights were paid for by the owner in the capitalised land value. For farmers who have purchased water rights, this attenuation of these property rights may be unconstitutional, since the constitution states that 'Property may only be expropriated only in terms of law of general application for a public purpose or in the public interest; and subject to compensation'. Table 12 shows that 59 percent of sample farmers believed that under the new water law, any sale of water to another farmer may jeopardise the success of their application for reregistration of their water use rights.

The National Water Bill (Department of Water Affairs and Forestry, 1997b) states that water licenses will be issued for a specific quantity, storage capacity, percentage of flow, rate of abstraction or quantity per ha. The water licenses will

not assure the supply or quality of the water, and water use licenses may be temporarily controlled, limited or prohibited. This effectively eliminates private control over water management. Since all existing rights may not necessarily be recognised under the new water legislation, (i.e. unused water rights), and applications for renewal will not necessarily be approved is of great concern to survey respondents, since production in the Lower Orange Region is totally dependent on water available for irrigation. This effectively transfers the power of decision from the individual user to the Government, and empowers the Government with total control over farming operations, since it decides how long a farmer can farm; 5 years or 40 years. This has negative implications for land values if a farmer's application for renewal is not granted, resulting in an effective nationalisation of property. The authorisation of only temporary use rights will effectively reduce the collateral value of irrigation properties, negatively affecting farmers' credit worthiness, and distort farmer incentives to make more productive and sustainable use of available water (Burger, 1997). Table 12 shows that 71 percent of respondents believed they would have less incentive to invest in irrigation technology under a situation of temporary water use allocations. In any event, investments in expensive irrigation technologies are unlikely under a system of temporary use allocations that may be controlled, limited or prohibited. Increased centralist intervention in water management may place irrigation farmers under increased financial pressure resulting from higher tariffs and levies, and excessive regulation of water usage. Land values could decline in the long term as a result of excessive taxation of water usage and restricted scope for increased profitability.

The proposed new Water Law makes Government exclusively responsible for water allocation, and advocates public interest above private interest in the evaluation of efficiency, equity and sustainability objectives by the Government as custodian of the nation's water resources (Backeberg, 1997). However, there are no clear cut criteria on which Government can base decisions regarding the 'optimal use' of water, and any decisions taken in the public interest will be subject to political bias. The new Water Law proposes that provision may be made for market trading of water use allocations in limited areas, but this will be subject to central control with particular attention paid to whether equity objectives and fair resource allocations are achieved by the market. This will result in a trade off between equity and efficiency in water allocation and use. Government's role as the custodian of the public trust in managing, protecting and determining the use of water will be the foundation of the new water law (Department of Water Affairs and Forestry, 1997a). In contrast, 90 percent of survey farmers supported a water market providing for unfettered trading of water use rights.

5.4 Water trading under the proposed new Water Law

Where water trading is permitted under the new Water Law, it is important that the institutional environment promote the market system. However, it can be argued that several principles on which the Water Law will be based are inhibiting to market development. Firstly, while water use allocations will be well defined in the unit of measurement and enforceable, the reliability of each use allocation will be highly variable since they will not be held in perpetuity and will not give a guaranteed assurance of supply or quality. In addition, any water use allocation may be temporarily controlled, limited or prohibited. This will create substantial uncertainty over the security of water rights and may preclude any trading of water use rights. Secondly, although water use allocations may be made transferable, any transfers will essentially be limited to rentals for the duration of the temporary water use allocation, thus eliminating the potential benefits accruing from permanent water transactions. Lastly, the reality of no private control over water management and temporary water use allocations facing irrigation farmers will stifle farmer incentives to buy or sell water rights in certain instances. Farmers will not have sufficient incentive to invest in water saving irrigation technology and other production inputs if uncertainty about water ownership arises. The risk associated with the costly investments in the establishment of table grapes of approximately R100000/ha, will be substantially increased if water rights are less secure. Incentives to purchase water rights for arable land to be developed and equipped with costly irrigation systems will be severely distorted, as will producer incentives to change to more efficient irrigation techniques or less water intensive crops and use the conserved water to expand production or sell to another user.

The success of market like allocation mechanisms under the new Water Law will require legal recognition of water transfers, along with a local water management authority such as a Water User Association or Department of Water Affairs office to define the transfer process, record transfers, and prevent and resolve conflicts among members. Importantly, water trading will depend on whether water use allocations are allocated for reasonably long periods of time, and the extent to which use rights are given the certainty and definition needed for a market. This will depend on (1) the extent to which individual use rights are legally recognised, (2) minimal government interference in these rights, and (3) the willingness of legislatures to define the scope of the public interest in the water resource. Clearly detailed definition of both current and future public interests in water supplies is unlikely from Government given the current emphasis on protecting expanding public interests. As a result, public interests will remain ill-defined and flexible, in turn leading to lack of definition and certainty of individual use rights. In Mexico, active development of water

markets has taken place despite all water being declared as public property, partly because water use rights have been specified for up to 50 years in length on a volumetric basis separate from land rights (Easter, 1996).

6. CONCLUSION

A survey of 54 irrigation farmers in the Boegoeberg and Kakamas Irrigation Schemes in the Lower Orange River conducted in November 1997 found that a water market for river water rights had developed. Market development for this particular category of irrigation water rights can be attributed to the scarcity of water in this arid region and increasing demand for river water rights by table grape farmers wanting to expand production. The large number of willing sellers, and the role played by the Department of Water Affairs and Forestry in administering market transfers, thereby minimising transaction costs and time, facilitated the emergence of the market.

While water rights for 'outer land' in the Lower Orange River transferred for a price, they did so within a regulated overall non-market allocation environment controlled by the DWAF. The water market that emerged was not fully developed since only the reallocation of unused 'outer land' water rights was facilitated through the market function. No inter-sectoral trading was permitted, nor market transfer of canal water enacted. Although water rights and land were not used in fixed proportions, allowing a farmer to save water and irrigate a larger area or transfer the saved water through the market, no transfers of conserved water had developed in practice. A possible reason for this is that farmers prefer to retain conserved water for water supply security. No temporary water transfers had taken place, which may be explained by the high fixed costs involved in transporting the water to the 'outer land' and developing this land for irrigation purposes, and the high fixed transaction cost of hiring a lawyer in the transfer process.

While participation in the market proved successful in transferring 'outer land' water rights, a number of institutional responses to the *status quo* regarding water trading could strengthen the market and extend its applicability to include all categories of irrigation water rights. These include:

(1) Allowing farmers to develop land without the need to obtain a cultivation certificate. In this way the market will determine which land will be developed for irrigation and farmers can expand production using conserved or purchased water. It would be expected that water rights would transfer to the highest valued uses generated from the more productive soils.

(2) Reducing the bureaucracy involved in obtaining approval of water rights transfers, by eliminating the approval necessary from the Department of Water Affairs and Forestry head office, will improve the ease with which market transactions occur. However this may be tempered by providing the regional Department of Water Affairs and Forestry office with the authority to supervise transactions, and to prevent and resolve conflicts among users.

(3) Continuing the administrative function performed by the regional Department of Water Affairs and Forestry office in recording and monitoring water transfers. The extension of this support to allow for the reallocation of canal water and any conserved water, through permanent or temporary transactions, as and when the demand arises will promote the resultant market.

(4) Over time, the restriction that water transfers occur only within the irrigation sector could be relaxed by separating water rights from land use to allow for inter-sectoral trading of water rights. This would allow potential sellers to sell water to higher valued municipal or industrial uses and receive effective compensation while at the same time generating the expected water savings within the irrigation sector.

Changes in the pattern of water use in the study area resulting from water market activity may create marginal impacts on lower basin water users and the environment. Agricultural users in lower basins may face increased water salinity as a result of increased upstream irrigation water use. Instream flows to sustain the environment, the reserve to meet basic human needs, and normal flow to satisfy equity objectives given the past exclusion of millions of people from water in South Africa must be considered. For these reasons, trading of water use rights in the future will only take place over and above the Reserve; which constitutes basic human needs, instream flow requirements, and international obligations. Procedures to identify negative external effects of a transfer and to resolve conflicts among users by the regional DWAF, along with the definition of a transparent channel for airing grievances arising from water trading activity, may become necessary as water demand rises.

A discriminant analysis found that water rights moved from potentially lower valued users with the potential to grow wine grapes, raisin grapes, and field crops to potentially higher valued users with the potential to grow table grapes. These farmers had the highest estimated return per unit of water applied showing that water rights gravitated to the most effective users of water. Water rights were found to transfer to farmers in table grape producing areas who had

undeveloped arable land that could potentially be developed for irrigation purposes, from farmers in areas with areas with lower soil potential for crop production.

The study found that most survey farmers believed the proposed new Water Law has led to widespread uncertainty about water rights transfers and that it will lead to fewer water market transactions in future. As a result of the proposed authorisation of only temporary water use allocations, the majority of survey farmers believed they would have less incentive to invest in irrigation technology. Farmer incentives to cultivate undeveloped land and establish costly irrigation systems will also be distorted. Similarly, incentives to change to more efficient water application techniques to generate water savings that may be used to expand production or sold to potential buyers of water rights will be distorted. This in turn debases the enabling environment necessary for the establishment of water market activity. Overcoming such institutional and legal barriers for market performance will require that water use allocations be specified for long periods of time, as in Mexico, with an expiry date closer to 40 years, be inherently secure, and water trading be permitted through the relevant legislatures.

NOTES:

1. *Arable land between the river and the canal.*

2. *Land adjacent to, but inland from the canal.*

3. *The majority of water rights sold for R3000/ha or R3500/ha. The variation in market prices may be the result of market information imperfection for the R5000 transfer, or the result of a family transfer for the R800 transfer.*

4. *This figure was calculated as R6000 - R2000 = R4000.*

5. *In this calculation an exchange rate of R5.00 = $1.00 was used (1997).*

REFERENCES

ANDERSON, T.L. (1983). *Water rights:scarce resource allocation, bureaucracy and the environment*. Pacific Institute for Public Policy Research, San Francisco.

ANDERSON, T.L. & LEAL, D.R. (1989). Building Coalitions for Water Marketing. Journal of Policy Analysis and Management, Vol 8, No 3: 432 - 445.

BACKEBERG, G.R. (1994). *Die politieke ekonomie van besproeiingsbeleid in Suid-Afrika*. Unpublished PhD Thesis, Department of Agricultural Economics, University of Pretoria.

BACKEBERG, G.R. (1996). *Discussion of water law principles*. Gauteng Workshop, Pretoria.

BACKEBERG, G.R. (1997). *Water institutions, markets and decentralised resource management : Prospects for innovative policy reforms in irrigated agriculture.* Presidential address at the 35th Annual Conference of the Agricultural Economics Association of South Africa, Osner Conference Centre, East London.

BOOKER, J.F. (1990). *Economic allocation of Colorado river water : Integrating quantity, quality, and instream values*. PhD Thesis, Department of Agricultural and Resource Economics, Colorado State University.

BURGER, W.J.J. (1997). *Personal communication*. Oranje Boere-Unie, Watersake Komitee.

CONLEY, A.H. (1993). South Africa's water management : Burning questions and key trends. *Water, Sewerage and Effluent,* 13(1):38-43.

CUMMINGS, R.G. & NERCISSIANTZ, V. (1992). The use of water pricing as a means for enhancing water use efficiency in irrigation : Case studies in Mexico and the United States. *Natural Resources Journal*, (32):731-755.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY. (1989). *Government Notice 966.* Pretoria.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY. (1997a). *White Paper on a National Water Policy for South Africa*. Pretoria.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY. (1997b). *National water bil*l : Fourth Draft for Discussion.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY. (1997c). Upington Regional Office. *Personal communication*.

EASTER, K.W. (1996). *Market approaches to water allocation : What have we learned*? 5th Joint Conference on Agriculture, Food and the Environment, Padova, Italy.

EASTER, K.W. & HEARNE, R.R. (1995). Water markets and decentralised water resources management : International Problems and Opportunities. *Water Resources Bulletin*, 31(1):9-20.

GRIFFIN, R.C. & BOADU, F.O. (1992). Water marketing in Texas : Opportunities for reform. *Natural Resources Journal,* 32:265-288.

HEARNE, R.R. (1995). *The market allocation of natural resources: Transactions of water use rights in Chile*. PhD Thesis, Department of Agricultural and Applied Economics, University of Minnesota.

HOWE, W.H., SCHURMEIER, D.R. & SHAW, W.D. (1986). Innovative approaches to water allocation : The potential for water markets. *Water Resources Research*, 22(4):439-445.

KLECKA, W.R. (1975). *Statistical package for the social sciences SPSS*. Second Edition. McGraw Hill, New York.

MANLEY, B.F.J. (1994). *Multivariate statistical methods : A primer.* Second Edition. Chapman and Hall, London.

MCKENZIE, R.S., SCHAFER, N.W. & STOFFBERG, F.A. (1991). *Water resources of the Orange River*. Proceedings of the Fifth South African National Hydrological Symposium, Stellenbosch: 6.3.1 - 6.3.10.

MICHELSEN, A.M. (1994). Administrative, institutional, and structural characteristics of an active water market. *Water Resources Bulletin*, 30(6):971-982.

NATIONAL REGIONAL DEVELOPMENT PROGRAMME. (1991). *Development region B : Regional profile and development guidelines*. Vol 2.

NIEUWOUDT, W.L. (1987). *Presidential address at the 25th Annual Conference of the Agricultural Economic Association of Southern Africa*, Indaba Hotel, Johannesburg.

ORTMANN, G.F. (1987). Land rents and production costs in the South African sugar industry. *The South African Journal of Economics*, 55(3):249-258.

PIGRAM, J.J. (1993). Property rights and water markets in Australia : An evolutionary process toward institutional reform. *Water Resources Research*, 29(4):1313-1319.

PINGALI, P.L. & ROSEGRANT, M.W. (1995). Agricultural commercialisation and diversification. *Food Policy,* 20(3):171-187.

ROSEGRANT, M.W. & BINSWANGER, H.P. (1994). Markets in tradable water rights : Potential for efficiency gains in developing country water resource allocation. *World Development*, 22(11):1613-1625.

SALIBA, B.C. (1987). Do water markets work? Market *Transfers and Trade-Offs in the Southwestern States. Water Resources Research*, 23(7):1113-1122.

SIMPSON, L.D. (1992). *Conditions for successful water marketing.* World Bank Technical Paper No 249:97-101.

TORELL, A., LIBBIN, J. & MILLER, M. (1990). The market value of water in the Ogalla Aquifer. *Land Economics*, 66:163-174.

THOBANI, M. (1995). *Tradable property rights to water*. World Wide Web, The World Bank: http//www.worldbank.org/html/fpd/notes/34/Thobani34. html.

THOBANI, M. (1997). Formal water Markets : Why, when, and how to introduce tradable water rights. *The World Bank Research Observer*, 12(2):161-179.

WALMSLEY, J.J. (1995). Market Forces and the Management of Water for the Environment. *Water South Africa,* 21(1):43-50.

WATER RESEARCH COMMISSION. (1996). *Policy proposal for irrigated agriculture in South Africa.* WRC Report No KV96/96.