CHAPTER 3: DEMAND MANAGEMENT AS A TOOL FOR EFFICIENT WATER ALLOCATION AND USE

3.1 Introduction

Due to the nature of water resource's and the importance of water for the perpetuation of life; interventions through supply or demand management are required in order to meet the associated social and economic goals, such as: efficacy, economic efficiency, equity, environmental impacts, fiscal impacts, political and public acceptability, sustainability and administrative feasibility (Hassan, 1997b). For a greater discussion on these goals, see appendix 1.

However, as supply-side interventions are becoming increasingly costly and less viable, water demand management interventions are being adopted at a global level, to meet increasing demands (Haasbroek and Harris, 1998; Darr et al, 1976; Hassan, 1997b; Tate and Kassem, 1992; World Bank, 1995). Simply put, water demand management aims to achieve the efficient allocation and use of water resources. This includes interventions at three levels of water management, namely, allocation, application and productivity (Ashton and Turton, 1999).

The ability of water management institutions to adopt and adapt to these changing philosophies will inevitably determine the success or failure of demand management strategies. What constitutes water demand management? What set of tools are available for applying water demand management (WDM)? Will these tools address the limitations of water scarcity and is there a role for WDM in the future? This chapter aims to address some of the frequently asked questions surrounding WDM, with specific focus on the role of water pricing and value for the South African water sector.

This chapter is structured as follows. The first part outlines the approaches to water demand management by identifying non-market and market mechanisms. The second part introduces the concept of water demand curves and elasticities and their role in assisting decision-making for water management. The third part develops the argument into a discussion on the value of water.

3.2 Water demand management

As the marginal costs of water supply options become increasingly higher in the face of declining supply availability and accessibility and water utilities focus on cost recovery requirements above subsidisation needs, water demand management is proving to be a preferred and practicable solution. Rising regional water scarcity in many parts of the world further exacerbates the water supply problem as countries become more hesitant to offer water to neighbouring regions and more determined to secure their own positions thereby reducing their water shortage risks. Economic development activities pressurise the system further but also provide advanced technology options and economies of scale that support the underlying methodology for water demand management (Goldblatt et al, 2000; Haasbroek and Harris, 1998).

Defined by Goldblatt et al (2000), water demand management is "a management approach that aims to conserve water by controlling demand which involves the application of selective incentives to promote efficient and equitable use of water". This approach encourages water to flow to its highest value use and to be allocated equitably between user groups.

Water demand management approaches provide a means by which user demands may be satisfied without resorting to costly and timely supply-side development. It aims to build efficiency into the system by modifying demand. This incorporates both technical efficiency and economic efficiency, the former targeting the technical aspects of water allocation between user groups and various sectors, the latter targeting the maximisation goals of the benefit-cost ratio between various demand management options (Goldblatt et al, 2000). Two approaches to demand-side management have been identified, the use of market and non-market incentives to influence user behaviour. The most popular market incentive depends on pricing (water tariffs) followed by water markets, auctioning and pollution charges. Non-market incentives such as restrictions, education and persuasion, and quotas and norms may also prove beneficial, but have generally been evaluated in conjunction with pricing changes, as a result their direct impacts are often difficult to identify (Winpenny, 1994). WDM provides a set of management tools through which conservation policy goals can be achieved such as:

- Waste reduction
- The use of water based on economic efficiency principles
- The application of water efficient methods and appliances

- Identification of behaviour altering incentives
- Service cost recovery
- Allocation priorities and movement from low value users to high value users
- The role of the private sector
- Decentralisation of management and control
- The use of economic instruments such as prices and markets to achieve efficient allocation of the resource
- The use of other instruments such as regulation, moral suasion, and technology to reduce water loss and waste

Water demand management is superior to approaches based on supply augmentation as it provides clear economic, financial and environmental benefits, while attempting to relate the value of water to the cost of provision. It also negates the need for future new supply developments by reducing water waste, inefficiencies and loss. In turn, environmental disturbances are minimised and capital resources are 'freed up' for investment in other priority areas (Haasbroek and Harris, 1998; Winpenny, 1994). As a result, water demand management addresses efficiency and equity goals. The Southern Africa Water Demand Management Declaration of March 1999 (Appendix 2) depicts the intentions of water demand management for the SADC region (Goldblatt et al, 2000), in turn emphasising the role for WDM in the region.

3.3 Non-market mechanisms in WDM

Non-market mechanisms are used to influence consumer behaviour without resorting to pricing or market mechanisms and to reduce losses and waste through conservation measures. They include repair and maintenance of infrastructure, moral suasion, public education, standard setting and the establishment of norms.

3.3.1 Restrictions and sanctions

Although pricing policies are increasingly being adopted to address issues of water resource management, they still play a relatively minor role in water shortage management. Drought management is more commonly dealt with through direct legislation such as daily service interruptions or various systems of quantity rationing. These forms of regulation serve to curb water demand and use by limiting the quantity of water used, the time-period of allocation, or the specific category of water use.

Restrictions prove to be valuable mechanisms for curbing water demand, however the effects are short lived. Once restrictions and sanctions are removed, water use patterns tend to return to their former levels due to the observations that the underlying consumer behaviours that drive these demands remain unchanged, as do the requirements of existing water-using fixtures (Goldblatt et al, 2000). Hence water demand management principles based solely on regulatory mechanisms tends to achieve short-term goals.

A series of water demand management country studies were carried out for Southern Africa under the guidance of the International Union for the Conservation of Nature during 1998. From these country studies, it is evident that restrictions have been widely used within the region during times of severe water shortages. Zimbabwe enforced restrictions on the rights to redistribute water during 1992. Botswana enforced restrictions on the uses of water for construction purposes and household irrigation during the 1980's. South Africa also imposed restrictions during its drought periods specifically targeting household use by setting times for irrigating gardens or complete bans on irrigation for recreation or aesthetics during 1984, (Arntzen et al, 1998; Buckle, 1998; Gomes et al, 1998; Haasbroek and Harris, 1998; Goldblatt et al, 2000).

Woo (1992) recognised that there was very little empirical evidence on the effects of water service interruptions and developed and urban water demand model that included the effects of daily service interruptions in Hong Kong. The model was estimated using monthly per capita data for Hong Kong for the period 1973 – 1984. Aggregate data was used as information was lacking for consumption by rate class breakdowns such as commercial and residential. Residential and non-residential water consumption was billed under inverted block rates and flat charges per cubic meter respectively. Six regression models were estimated including the double log and linear functions eliminating the possibility of spurious results. The Hausman specification test was applied to remove any biases or inconsistencies caused by endogenous price variables. The double-log and linear models were shown to be plausible models for explaining per capita water use in Hong Kong. The findings indicated that the effects of service interruption on per capita consumption were significantly small. Furthermore, the own price and income elasticities estimated were –0.3840 and 0.2776 respectively, indicating that price responsiveness was highly significant and that "price does matter, even for Hong Kong consumers whose use patterns are unrelated to residential and agricultural irrigation." A price increase of 16 to 30 per cent would have achieved the same consumption results as the service interruptions.

3.3.2 Quotas and norms

Quotas and norms may be set to achieve allocative efficiency goals in the face of scarcity. Both fixed quotas and penal tariffs may be used to enforce rationing. In Israel, water consumption fell by 70 percent over the period 1962 to 1982. The reason was the use of a comprehensive system of norms taking into account "best practice technology". Users who exceeded these limits were fined accordingly Arlosoroff (1985) in (Haasbroek and Harris, 1998). Large water savings have also been recorded in Tianjin, China through recycling and norms based on water audits Bhatia et al (1993) in (Haasbroek and Harris, 1998).

3.3.3 Education and moral suasion

The raising of public concern through exhortation and appeals is often used in conjunction with other approaches, particularly for the management of drought, hence it is difficult to quantify their individual impacts (Winpenny, 1994). Water use awareness and efficiency education for irrigation agriculture has not been widely evidenced despite the demands of this sector on water and its inherently low water application efficiencies (Goldblatt et al, 2000).

Three extensive programs were implemented in selected areas within South Africa as pilot studies for future work on water demand management. The first approach to water management was to upgrade the existing earth-lined irrigation canal system belonging to the Blyde River Irrigation Board, by replacing it with a buried pipeline, thereby reducing leakage losses (Ballot, 1997).

The second approach was the implementation of a twelve-point demand management plan for the Greater Hermanus region, as follows:

- Intensive communication campaign
- Education and water audits at school
- Water loss management
- Clearing of invasives in the catchment
- Water wise gardening
- Water wise food preparation
- Domestic water saving initiatives
- Regulations

- Assurance of supply tariffs
- Escalating seven-step block rate tariffs
- Informative billing
- Masakhane metering project

This integrated demand management approach to water conservation proved to be highly successful (Haasbroek and Harris, 1998).

The third approach to water demand management was the multi-agency Working for Water programme. A comprehensive initiative aimed at clearing invading water 'thirsty' alien plants over a period of 20 years. The initiative recognised that exotic plants had invaded about ten million hectares of South Africa's land surface due to the careless introduction of these plants for commercial gain. These plants impact on the environment by obstructing rivers, increasing soil erosion, threatening indigenous biodiversity and absorbing water on a perennial basis. The Working for Water Program has hired many disadvantaged citizens and provided them with a wage to remove these invasive woody species. The program is however, wrought with various controversies as many indigenous trees are removed along with exotics. This approach is sometimes confused with supply-side management but for the purposes of this study supply-side management is regarded as any means by which water supply is augmented through large infrastructural projects such as the building of dams. Demand management is explained as any approach that increases the availability of water through managed responses in its use and application hence the working for water programme is a good example of a demand managed approach to extending the available supply of water.

3.3.4 Technology improvements

Water efficiency may be greatly improved through the introduction and application of water saving technologies ranging from crop selection and irrigation system changes in agriculture, to the choices of cooling systems in industry and the fitting of low water use appliances in households. The feasibility of improved technology being implemented is however often limited by capital constraints (Goldblatt et al, 2000; Haasbroek and Harris, 1998).

3.3.5 Water loss control

Many of the water systems are characterised by leakages and 'lost water'. Through the control and estimation of this unaccounted-for water, water may be saved at the level of the water service provider. Approaches to water loss control include ongoing leakage detection, ongoing program repair, water audits, pipe replacement and water meter management (Goldblatt et al, 2000).

3.3.6 Water re-use and recycling

The treatment and re-use of wastewater 'frees up' water that would otherwise be 'useless' to certain sectors, thereby reducing the need to augment supplies through costly supply-side management approaches. Water re-use and recycling can be achieved in numerous ways such as through:

- Re-use plants[5],
- The use of wastewater as cooling water in power plants,
- The diversion of industrial and toxic waste water away from main water courses,
- Specialised treatment of wastewater,
- Specialised treatment of effluent with strict quality controls,
- Water mixing that combines wastewater with water from other sources,
- Using waste-water for irrigation.

Many opportunities exist for the re-use and recycling of wastewater within the agricultural, industrial and domestic demand sectors (Arntzen et al, 1998; Buckle, 1998; Haasbroek and Harris, 1998; Gibbons, 1986; Goldblatt et al, 2000; Gomes et al, 1998).

3.4 Market mechanisms in water demand management

Economists frequently prefer to use market mechanisms for allocating goods and services. Water demand management recognises two market-orientated approaches to managing water. The first is the establishment of a water market in which water as a commodity or the right to use water itself may be traded. The second is the selection and implementation of a pricing mechanism that will fully reflect the opportunity costs and scarcity value of water to society. Pricing mechanisms cover a wide range of values for

[5] For an explanation on re-use, see definitions

water resources and readers needs to be mindful of the distinction between a market price for water rights and consumer tariffs aimed at some level of supply cost recovery.

3.4.1 Water markets and tradable water rights

Historically, water has not been allocated through markets. Coase (1960) in (Munasinghe, 1986) stated that market allocations of resources would be efficient under two conditions. First, property rights need to be clearly defined and well protected. Clearly defined rights are those that are exclusive, specific, enforceable and transferable. Second, transactions costs must be zero or negligible (for further discussion see: Meinzen-Dick et. al, 1997; Rosegrant and Binswanger, 1994; Hassan, 1997; Algharianí, 1994). Despite the recognition that transactions costs in water markets are rarely zero, markets in tradable rights are believed to offer a number of significant benefits:

- Water markets promote flexibility in water use and in response to changes in demand patterns and comparative advantages, with regard to crop prices and water prices. They also help to establish an explicit value for water and provide incentives for efficient use, thereby recognising the full opportunity cost of water (Rosegrant and Binswanger, 1994; Gardner and Miller, 1985).
- Water markets empower water users to make decisions that will maximise their utility and achieve greater social gains. They do however need to develop acceptable definitions of the conditions that trigger service and availability interruptions, as water is not stochastic over time and space (Rosegrant and Binswanger, 1994; Hamilton et al, 1989).
- Where the security of a right to tenure is established, investments in water saving technology will be encouraged (Rosegrant and Binswanger, 1994). Hamilton (1989) however, found that the effectiveness of efficiency gains was dependent on the nature of the alternative use and the corresponding length of tenure. For interruptible water markets that allowed trade between irrigation agriculture and hydroelectric power, a long-term contractual commitment of at least 25 years was required.
- The externalities associated with degradation are internalised (Rosegrant and Binswanger, 1994).

Although persuasive arguments are offered for water markets, their establishment is also subject to a number of critical conditions such as:

- The existence of water rights and some levels of initial allocations that are well-defined and specified in a unit of measurement (Armitage et al, 2000).
- A difference in values for water among users.
- Enforceable water rights that secure the transfer of benefits from the water-use to the rights holder (Armitage et al, 2000).
- Transferable rights (Pigram, 1993; Armitage et al, 2000).
- Technical and physical infrastructure that will allow for the transfer of water from one user to another. Volumetric measuring will allow flexible deliveries in line with demand changes over space and time. The technology need not be extremely sophisticated (Roome, 1995; Meinzen-Dick et. al, 1997).
- The establishment of various supporting institutional and legal frameworks that facilitate the negotiation process, administration duties and a guarantee of title ownership (Meinzen-Dick et. al, 1997; Armitage et al, 2000; Simpson, 1992).
- The existence of voluntary and willing sellers and buyers (Roome, 1995).
- Political support and the establishment of mechanisms to minimise social and environmental impacts (Hassan, 1997a).
- Constraints of scarcity.

The establishment of markets for water has not been met with overarching enthusiasm. Fears of monopoly formation and the limitations of many administrative bodies to handle negotiations and market establishments are some of the concerns. In many countries existing water laws state that water cannot be transferred between sectors, that it must rather be utilised in the purpose and sector for which the right was obtained (Kessler, 1997). Characklis (1999) validated that this ban on inter-sectoral trade or leasing "handcuffed" markets ability to adapt efficiently during periods of drought and suggested that by eliminating this distinction between rights, trade between all affected participants would be encouraged, thereby increasing responsiveness to water scarcity threats. Consequently, many markets function at the margin due to high transaction costs, inadequate infrastructure, poor legal frameworks, and political and social resistance (Montginoul et. al, 1997).

Existing water rights generally form one of three userfructuary systems: riparian rights (link ownership of water to the ownership of adjacent or overlying lands); appropriative rights (acquisition of a right by a priori use over time); and public allocation (water distribution by administrative bodies), (Sampath, 1992; Rosegrant and Binswanger, 1994). Despite limitations in the transferability of these rights in most countries, many have managed to establish markets for water and water rights. Groundwater markets are well established in parts of Asia (Winpenny, 1997); informal water markets and trading, mainly in underground water, is expanding in many developing countries such as Tamil Nadu, Pakistan, Indonesia and Jordan. These spontaneous markets usually reflect 'spot-market' trading of given quantities at given points in time (Meinzen-Dick et al, 1997; Shah, 1991; Chaudhry, 1990; Rosegrant and Binswanger, 1994). Surface water markets exist in some of the western States in the USA such as New Mexico and California; in parts of Australia and in Chile. Progress is also being made in the UK to encourage farmers to trade with others within their districts (Winpenny, 1997; Meinzen-Dick et. al, 1997; Kessler, 1997).

A limiting factor to these emerging markets is the presence of transaction costs (costs of technology, analytical skills, institutional, and legal frameworks). Rosegrant and Binswanger (1994) argue that where the value per unit of water is high for different uses then the gains from trade should offset the transaction costs involved. Hamilton et. al. (1989), concur with this idea that markets facilitate the provision of compensation unlike centrally controlled allocation; and they propose that the level of compensation for the trade should be greater than the income lost by moving the water from its prior use to its current use. Therefore, the value generated by the water use in the new sector must be greater than the income lost including all transaction costs by the water used in the old sector. Markets permit the transfer of water across sectors, districts and time and it is expected that buyers and sellers will have good knowledge about the value of water to their production processes. This in turn is expected to reduce the information costs of the transaction unlike the case where marginal cost pricing is used to allocate the resource (Meinzen-Dick et. al, 1997).

Markets for transferable water rights still face the challenge of incorporating environmental protection and public interest criteria. Externalities such as pollution, overdraft, lower water tables, and waterlogging have yet to be addressed, although theoretically the market system should account for the costs associated with these externalities.

The majority of existing literature on water markets tackles transactions among agricultural users or those transactions between agriculture and urban or municipal users. The study by Hamilton (1989) was one of the first to address the use of water markets to meet hydro-electric demands. Shah (1985 and 1989) in Winpenny (1994) discussed the relevance of groundwater markets, recognising the non-sustainable implications of aquifer depletion. Another, large operating markets scheme was established in the United States – the Colorado-Big Thomson scheme. This scheme negated the necessity to develop further supply-side solutions and effectively addressed supplemental irrigation needs (Howe et. al, 1986).

The new South African Water Act provides a policy framework for water markets in the country, as a means to address issues of water allocation and demand, however it remains unclear regarding the legal transfers of water use licences, relying on a fairly regulated approach to markets that is expected in turn to increase transaction costs (Louw et al, 2000; NWA, 1998). Trade is also dependent on the premise that allocations come from the same source, particularly for the purposes of cross-sectoral trade (Louw and Van Schalkwyk, 2000), and that allocations are value driven. The Water Act also implies that rights must be assigned and water allocated under the perception of fairness, a process inherently depending on the preparation of a water balance per catchment, negotiations on lawful apportionment, and decentralised management. This process may also require some changes to be made in the interests of equity, after which 'free functioning water markets' should be allowed to operate (Backeberg, 1996; Armitage et al, 2000).

Within South Africa water trading in irrigation agriculture exists at an informal level in the north-eastern part of the country, the prices at which water is traded are negotiated by individual farmers and vary accordingly. Discussions are currently underway with the Department of Water Affairs RSA on how to establish water markets under their demand management strategy. Water use along the Orange River has been evidenced by water transfers since the 1980's and indicates transaction costs varying between R2000 and R6000 per farm of 30 hectares, with an allocation of 15000 meters cubed per hectare, excluding the cost of electricity, irrigation infrastructure and brokers fees (Armitage, 1999). The farm survey done by Louw and Van Schalkwyk (2000) revealed that farmers along the Berg River also participated in water trading and paid about 6 cents per meter cubed of water for permanent water transfers. Temporary water transfers were however, carried out frequently on a 'good-will' agreement basis and did not have transaction costs associated. For the purposes of the study, temporary transaction costs of 3 cents per cubic meter were assumed.

The establishment of water permits (transferable right to water use), water banking (the storing of water for the purposes of critical need driven demand) and water auctions (sales of water by authorities to the highest bidders) are also approaches to creating markets under the realm of water demand management. Algahaiani (1994) proposes the use of water banking to Libya based on purely technical reasons, a number of banks have also been established in the USA and have proven to be very successful in meeting demands during periods of drought (Keller et. al, 1992; Kennedy, 1991; Vaux, 1991: in Winpenny, 1994). Water auctions are however very rare as they do not actually transfer legal entitlements to the consumer. Environmental and third party externalities are not reflected in the auction prices. An example of a water auction can be found in Simon et al (1990) in (Winpenny, 1994).

3.4.2 Economic supply pricing of water resources

The notion that cheap water will be wasted and that the correct pricing of the resource will instead lead to it being treated as a precious and efficiently used commodity lies behind the value of pricing in water demand management. Numerous approaches to this question of efficient pricing have been addressed including delivery cost pricing, electricity and pumping cost-based pricing (for groundwater exploitation), marginal cost pricing, opportunity cost pricing, scarcity value, marginal value pricing and value added. Each approach has its shortcomings and South Africa now, not only has to find a way of measuring consumption and valuing its water resources, but must also address the welfare pressures of a large population living without basic domestic supplies and sanitation facilities.

Water tariffs refer to a monetary charge placed on the user for withdrawing water from the bulk supply of water or water services. This usually relates to surface water and government supply-schemes. Depletion of ground water sources does not currently carry a user cost in South Africa. The concept of pricing becomes extremely complex as use activities are considered. In many cases such as industrial use, water is returned to the overall supply and where this water conforms to quality standards, it may be reused. Consequently, charges may take the form of direct extraction charges, coupled with pollution charges and rebates for efficient use. A further distinction also exists between the pricing of water based on water service charges and the pricing of water rights.

Three types of pricing are generally recognised: financial pricing, economic pricing and environmental pricing. Financial pricing focuses on operation, maintenance, servicing and capital investment cost recovery. It is usually reflected in average costs. Economic pricing signals the opportunity cost of water and its consequential costs of allocation between users. It also recognises the costs associated with long-term investment planning, to current and future generations such as opportunity and marginal costs. It, therefore, reflects the scarcity value of water. Environmental costs include the costs associated with the externalities of water use.

Pricing proves to be a valuable tool in determining the willingness to pay of various users. The adoption of a pricing policy does however depend on a number of "trade-offs" such as: economic efficiency goals, investment information, administrative and transaction costs, and equity goals. Pricing also proves to be inappropriate on the grounds of efficiency in the face of resource superabundance (a "free good"), (Hanke and Davis, 1973). Pricing is also limited where it is used in direct opposition to existing policies such as the subsidisation of water intensive agricultural inputs. Questions arise as to whether users should be expected to pay for investment costs as well as maintenance and operation costs and the debate extends to the burden of costs associated with environmental externalities.

Current thinking recognises the existence of numerous criteria and requirements for the setting of water tariffs, some of which are not consistent with others, they are the following (Munasinghe, 1986):

- Economic resources must be allocated efficiently within the water sector,
- Fairness and equity considerations must be met whereby, costs are allocated among water consumers according to the degree to which they impose on the system; price stability needs to maintained from year to year; and water needs to be supplied at a minimal level to consumers who cannot who are unable to pay the full costs.
- Enough revenue to cover the financial requirements of water supply utilities must be raised by water prices,
- Customers need to be able to understand the tariff and billing structures for pricing,
- Political goals also need to be addressed such as the application of subsidies for certain sectoral growth.

Based on these policy goals a myriad of pricing structures have emerged as follows:

3.4.2.1 Financial cost recovery

Historically water has been regarded as a 'free' good and as a result, the provision thereof has been heavily subsidised in many countries, particularly in the agricultural sectors. Users have not been impelled to apply water efficiently, to allocate water between uses rationally or to conserve unutilised quantities of the resource. The recognition of the scarcity value of the resource and the increasing demands for competing use have initiated a move to establish the true economic price of water, thereby reflecting both the opportunity cost and the shadow price of the resource. Water charges are based on the premise of collection, where markets do not exist and administered prices are not used. This is relatively easy for uses that are metered on a regular basis such as industrial, commercial and domestic use. However, extra costs become apparent for uses where water is not metered such as groundwater abstraction and direct precipitation storage.

Historical pricing structures have emphasised cost recovery, among other deficient regimes, such as average cost pricing and flat-rate pricing. The use of tariffs is widespread in many countries, but cost recovery pricing does not from part of demand management (OECD, 1987). Cost recovery fails to incorporate the costs associated with investments as they usually try to recover the delivery costs of the service, depending on central bodies such as governments to subsidise the fixed capital costs. Average cost pricing does not distinguish between the costs of supply of old water projects and new water projects. While flat-rate pricing regimes tend to subsidise peak load and remotely located consumers by failing to adjust for distance, location, seasonal and temporal change impacts on the costs of delivery (Dinar and Subramanian, 1998; Hassan, 1997b; OECD, 1987; Munasinghe, 1988). Cost based pricing is reliant on the underlying country priorities. Failure to monitor consumptive and non-consumptive use and adjust charges accordingly for a resource that clearly has recycling and recovery potential further limits the gains from historical pricing regimes.

3.4.2.2 Delivery cost pricing

Delivery cost pricing refers to the pricing of water based on the costs of delivery. Some existing water pricing methods include (Dinar and Subramanian, 1998; Sampath, 1992; Tsur and Dinar, 1995):

Volumetric: These charges are based directly on the volume of water consumed. These volumes may be determined by the time of known flow or the time of uncertain flow or may be a charge based on a minimum volume whether used or unused.

Output: Charges may be based on the level of output produced through the applications of water. For example, irrigators may be charged a water fee per unit of a particular crop.

Input: Charges based on inputs are the reverse of that above. Here water users are charged per unit of certain inputs used.

Per unit area: In this case water is charged per unit area irrigated and may differ according to the choice of crop irrigated, the season of the year and the choice of irrigation method.

Flat-rate charges: Flat rate charges are based on any number of components such as the number of residents, number and type of water-using fixtures, the number of taps, number of rooms in the house, the width of inflow pipes, measures of property value or even ground value. They often consist of a flat charge for a minimum level of consumption. These systems violate the principals of allocative efficiency, as they do not encourage the use of water in its highest value use. They are however very easy to administer and are fairly simple for consumers to understand, without the need for strict monitoring. Flat-rates also assure a relatively good return of revenue to the water supply institutions (OECD, 1987).

Decreasing block rate tariff: This tariff system is based on the premise that succeeding blocks of units of water are sold at lower prices and usually include some level of minimum charge based on customer and capacity costs. The limitation of this approach is that in some instances it may result in inappropriate cross-subsidisation, whereby excessive water use for luxury purposes such as garden watering or swimming is charged a lower rate than prudent users (OECD, 1987).

Increasing block rate tariff: These tariffs work in the opposite direction to the above-mentioned tariffs and the rate increases for each additional block of water consumed. This approach is aimed at keeping consumers within the lower brackets of quantity demanded.

Two-part tariffs: A combination of flat-rate pricing and average cost pricing form the basis of two-part tariff structures. The flat-rate depends on the characteristics of the consumer such as the size of meter or the number of water outlets. The second part of the tariff is usually a single rate based on the volume of water consumed. Revenue obtained from the volume charge must however, be managed carefully. If it is too low then consumers will be encouraged to overuse the water resource, if it is too high then consumers will be discouraged from demanding the resource and revenue streams to cover the associated costs will become uncertain (OECD, 1987).

Hanke and Davis (1973) recognised that water rates tended to be uniform over space and as a result, delivery costs could not be flat-rates but were valued according to certain variables. They proposed that water commodity prices for urban demand should be varied according to rate zones, based on the consumers distance from the source centre and area demand density. These rate variations were expected to address equity and efficiency goals.

A review of demand management issues for Canada by Tate and Kassem, (1994), recognised that water metering used in conjunction with demand based pricing policies lowered demand by more than 30% of pre-metered levels. The municipal sector was advised to recover the full cost of service provision, while integrating water supply and waste treatment into one service. For smaller communities dependent on subsidies it was proposed that these subsidies be given directly to the consumers. For the case of the industrial sector it was recognised that the prices paid for water should reflect the cost of providing the resource. For water intake, economic rent principles are used for pricing and on the discharge side sewer surcharges, effluent discharge fees and marketable effluent permits were recommended as management instruments.

3.4.2.3 Average cost pricing

Average cost pricing is based on the premise that all costs associated with water delivery are added together and are then divided by the total number of units expected to be sold within the financial year. As a result, all water consumers bear the costs of peak load users throughout the year (OECD, 1987). Where sectors are institutionally underdeveloped, average cost pricing is used as it is simpler, although marginal cost pricing is superior. Average cost pricing tends to be the most widely used policy where meters and commodity charges are established in municipal zones, Hanke and Davis (1973). This approach is regarded as insufficient because historical average costs do not reflect marginal historical or future opportunity costs and are thus inconsistent with the efficiency concept. Gibbs (1978) further purported that the use of the average price per unit of water was limited and tended to overestimate response changes when used in demand models.

3.4.2.4 Marginal cost pricing

Marginal cost pricing is defined in economic theory as a pricing rule whereby "firms or government-owned enterprises set price equal to marginal cost", where marginal cost is the addition to total cost resulting from each additional unit of output (Mansfield, 1994). Facilitated by perfectly competitive conditions and the absence of externalities, economic theory further stipulates that these market prices will reflect social values.

According to Sampath (1992) if long-run marginal cost pricing of water is adopted for the irrigation sector then the resulting social benefits will all be optimal. This will however require the absence of externalities, increasing returns to scale and monopoly power. Furthermore, marginal cost pricing is believed to facilitate improved environmental management through the direct conservation practices of farmers wanting to reduce their overall costs. Sampath (1992) reviews the status of irrigation water pricing and the necessary cost recovery in developing countries finding that the pricing policies are predominantly based on financial and not economic considerations. Price setting levels are aimed at maintenance and cost recovery inhibiting aims to meet the best efficient use objectives for the scarce resource, water. Irrigation charges further diversify between countries and regions within these countries by taking the following forms: demand charges based on volume, water rate per hectare based on the crop irrigated, land taxes based on the provision of irrigation facilities, betterment levies, irrigation and maintenance cess' and other indirect financing mechanisms. Based on the above observations it is evident that most developing countries do not follow marginal cost pricing principles nor optimal pricing procedures. The reasons for this behaviour may be due to a number of socio-political, physical and administrative constraints. Many "indirect beneficiaries" other than the irrigation farmers, such as consumers gain from irrigation and Sampath (1992) proposes that it may not be equitable to allocate the full costs of irrigation water to the farmers alone. Variable pricing systems also carry large administrative costs; they may facilitate efficiency but may not be politically or administratively feasible. Where water has formerly had 'no price' complex cultural issues arise through the introduction of price, furthermore, price elasticities of demand for water are indicated to be low efficiency pricing gains may be negligible. Water pricing is not only used to determine efficiency but may also be required to meet policy objectives of conflict resolution, income redistribution and rural development. Finally, Sampath (1992) indicates that deviations from marginal cost water irrigation pricing may not necessarily be inefficient, in cases where "rainfall, water supply, crop production functions and effective demand" are evident at certain levels he recognises that market clearing prices may differ from marginal cost.

Winpenny (1994) defines long-run marginal cost pricing where price equals marginal cost or supply, in other words where the marginal benefit of consumption is equated with the marginal cost of supply. This form of pricing is regarded as the most common but relies upon metering and the proportionate volumetric charges; these charges should also include all related environmental costs and benefits to be strictly economically efficient.

While reviewing the potential for marginal cost pricing in water resource management Hanke and Davis (1973), recognised that marginal cost pricing was the most effective form of pricing to achieve the efficient allocation of natural resources. Furthermore, that marginal cost pricing will achieve social welfare maximisation where the difference between total revenue plus consumer surplus and opportunity cost is the greatest. Thereby optimal output from an existing water facility may be achieved while determining future investment capabilities. Hanke and Davis (1973) clearly identify the marginal cost concept as that of marginal opportunity cost, maintaining a useful distinction, especially for the case of water. Where water use is defined by a plethora of competing users, its price should reflect, delivery, maintenance and treatment costs but also the costs of not using the resource in its best alternative use. A number of areas were identified that could respond favourably to revised pricing strategies namely, municipal water services, industrial and municipal sewerage, navigation, flood damage reduction and shoreline protection.

Municipal water service revenues were predominantly derived from flat rate charging systems, in cases where certain municipalities were partially or wholly un-metered. They found that this approach did not lead to conservation practices and that efficiency gains were lost resulting in the marginal opportunity cost of water provision bordering on a zero value. Furthermore water is mobile and is characterised by variability over time consequently it was recognised that capacity costs vary according to seasonal fluctuations in demand and it was proposed that seasonal peak load rates should be introduced where marginal opportunity costs showed large seasonal variations. Lastly, declining block rate structures were criticised in the face of increasing long-run marginal costs and it was proposed that municipal pricing structures should reflect the "different conditions under which water is consumed".

Gibbs (1978) identified two formulations of the price of water. The second formulation was the marginal or block price defined as the 'price of the last unit of water purchased. He further stated that the use of marginal price in water demand studies was more accurate than the use of average price as the former allowed for analysis of consumer responses to changes in the price structure.

Marginal cost pricing is not widely used amongst the OECD countries (OECD, 1987). The reasons for this are as follows:

- Long-run marginal costs are difficult to determine as they can fluctuate over time and vary according to the time-span over which they are estimated.
- Differentiation between users is difficult resulting in surplus revenue received from some groups and subsidisation of others.
- Charges would vary across regions and are dependent on accurate demand forecasts and investment decisions.

In spite of these shortcomings, many countries have implemented various forms of marginal cost pricing such as increasing block rate tariffs and decreasing block rate tariffs. Herrington, (1980), used 'present worth difference methodology' to determine the marginal cost of wholesale water deliveries in Peru. Hanke (1981) in (OECD, 1987), used a similar method to determine the marginal capital costs of a New York water utility. Both Japan and France have allowed marginal cost pricing to influence tariff design (OECD, 1987).

The Malthusian perspective on resource scarcity predicts absolute physical scarcity in the near future as the resource is depleted this is mainly due to the 'limits to growth' theoretical constraints imposed on an economy. Ricardo however, recognises these limitations but stipulates that markets will react to increasing prices as the resource becomes scarcer and in so doing will encourage resource substitution, efficient use and recycling (Turner et al, 1994). Marginal cost pricing, however, does not account for the shadow price of the resource that in turn reflects the opportunity costs of competing uses for the resource. It implicitly assumes that water is abundant and has an opportunity cost of zero (Hassan, 1997b). Consequently, opportunity cost pricing is regarded as the best pricing approach when attempting to reflect the economic value of water.

3.4.2.5 Opportunity cost pricing

The opportunity cost of water equals the measure of the scarcity value of water to society. Where sectoral differences and interdisciplinary uses are evident, the water should be allocated where the opportunity cost of water is lower than the value of water in the selected use. The opportunity cost of a resource is defined by the World Bank (1993) as, "the value of a good or service forgone, including environmental goods and services. This occurs where a scarce resource is used for a particular purpose and not for its next best alternative use."

Market prices for water may diverge significantly from their shadow (economic opportunity cost) prices due to the existence of distortions such as monopoly practices, external economies and diseconomies, taxes and subsidies (Munsasinghe, 1988). Furthermore, the use of shadow pricing allows the water sector to address social and political goals across sectors and within the water sector itself, that strict efficiency goals overlook (Munasinghe, 1988). For example, a study by Hanke and Davis (1973) indicated that industrial sewerage charges were reported to be much lower than municipal water charges and hence proposed that this price discrimination be corrected by implementing charges that reflected the opportunity costs of pollution.

Irrigation water pricing is of vital importance in arid and semi-arid regions according to (Hamdy et al, 1994), as it has the potential to influence water allocation between competing users, water conservation practices, additional revenue generation, cropping patterns, income distribution, efficiency in water use and various environmental impacts. They propose that water should be regarded as an economic good with an opportunity cost derived from future use expectations.

Alghariani (1994), supports the need for opportunity cost pricing in recognising that where water supplies are subsidised, their prices are lower than their opportunity costs and allocations and uses tend to be inefficient. The role of pricing is further recognised to generate revenue that will cover operation and maintenance costs and must be derived under principles that consider food security, rural incomes and basic needs. Furthermore, property rights among water users must be clearly defined for the correct pricing policy.

In the case of Botswana however, the ability-to-pay principal is still utilised and those who can afford to pay the full cost price of water do so and those who cannot do not. This applies to water consumption for basic needs (Masedi, 1996).

(Hamdy et al, 1994), state that the price of water should include the scarcity value of water and not just cover the direct costs of production, with special attention being paid to pollution, over-exploitation and social aspects of equity.

(Prasad and Rao, 1991) reviewed the pattern of financial returns to irrigation systems in India by focussing on large-scale canal irrigation projects. Finding that the collection costs of water rates approached the revenues realised, providing poor returns on investment. State determined water rates were also much lower than the implicit pricing or shadow prices for water perceived by farmers. In concluding it was proposed that water rates should cover the operation and maintenance costs of water delivery during the initial introduction of water rates.

It is important to determine between the economic costs or benefits foregone in using water in one particular use versus the actual value of water. Monetary values are not easily assigned to the worth of non-consumptive functions. Human life and ecosystem sustainability are considered to be 'priceless' to many and are consequently particularly difficult to value. Consideration needs to be taken of these implications when planning any demand management strategy.

3.4.3 Full cost pricing of water resources

The ultimate goal in pricing strategies is to understand the full-cost of water supply and the full-value of water in use, including the implications for these different prices on different user groups. Rogers et al. (1998) in (Rogers et al., 2001) identify the various levels of water pricing, outlines in figure 3-1. The costs of water reflected in pricing often relate specifically to the costs of supply such as operation and maintenance costs, and capital charges, hence water is under priced. The full economic costs need to be included in these estimates, such as the opportunity costs of water and economic externalities, giving the full economic cost of water. Environmental economic takes this theory one step further and recognises the impacts on the environment not just those on social and economic capital, so environmental externalities also need to be included if one is to reflect the "true" full cost of water supply. The full value of water refers more to the use value of water and incorporates re-use and recycling aspects. The economic values for water are identified below to which intrinsic value is added. Figure 3-1, re-iterates the complexities water managers face when striving to price water so that the full costs and benefits are captured.

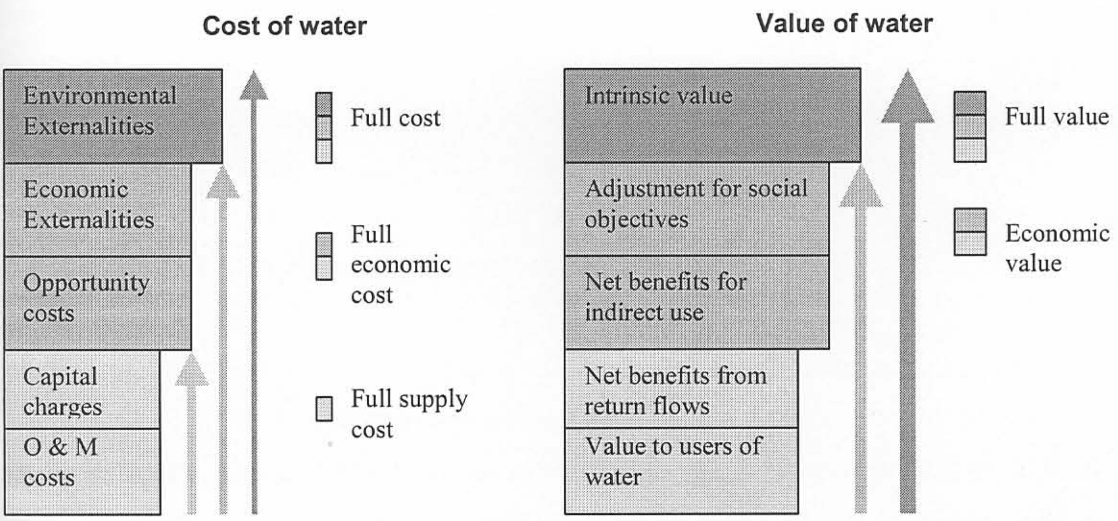

Figure 3-1: Underlying principles for the cost and value of water
Source: Based on Rogers et al., 2001.

3.5 Summary

Markets in tradable water rights are regarded to some extent to be superior to pricing mechanisms as they reduce information costs and may be politically more feasible. By bringing together users with expert knowledge of water use in their respective applications and the productivity values thereof, the market would inherently capture the information costs involved in negotiation further reducing the transaction costs. Where rights to water exist, this process merely formalises these rights and does not necessarily threaten user groups through unplanned price adjustments or hikes (Rosegrant and Binswanger, 1994). Fundamental to the understanding of water markets and pricing strategies is knowledge on the demand and supply of water; the number and type of users; the willingness to engage in market transactions; consensus on prices and price structures; and the nature of demand and the demand curve. The following chapter proceeds to introduce the theory of demand for water and its use in understanding the behavioural consumption patterns of the water consumer.