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A Framework for Valuing Water Demand Management: Literature Review

Report 1 of 3

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About This Report

Title

A Framework for Valuing Water Demand Management

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Abstract

Beacon's water research has successfully demonstrated the potential benefits of a water-efficient approach through analyses of the potential of packages of measures, and discussions and workshops with a range of councils. This work made explicit the 'what' and the 'how' for water demand management (WDM), with the remaining question, 'why' (would an organisation adopt WDM) requiring research. It was clear that a rigorous economic analysis of the value of water demand management was needed to help councils and water authorities to demonstrate the value of such an approach to decision-makers and communities.

To do this Beacon commissioned work from Market Economics in three parts:

- A literature review;
- The creation of a comprehensive conceptual framework; and,
- A case study to test the framework utilising data from Tauranga City Council.

This is the first part of the work.

Reference

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1 Introduction

Water can be deemed an essential environmental resource. From an anthropogenic perspective, its most important role lies in human sustenance. Humans utilise water directly for many purposes; municipal water supply, sanitation, irrigation, transportation, industrial water supply, energy generation (hydro-electric), and recreation, for example. In recent years, with the rise of environmental ethics, the value of water has been given a broader definition with a more systematic and integrated approach. The idea that the value of water is determined solely through the interest of humans is increasingly questioned. Water plays an absolutely necessary and irreplaceable role in many ecosystem services, such as habitat creation, nutrient cycling, the hydrological cycle, and climactic regulation, to name a few.

The Total Economic Value (Direct-use, Indirect-use, and Non-use values) is often overlooked and unrecorded in economic accounts. Water has many unique characteristics that make it difficult to trade on regular markets. Exclusive property rights cannot be assigned because of its physical attributes, in particular its highly fluid nature and role in the hydrological cycle. Secondly, water can be utilised as a non-rival good, where one's use does not preclude another's use of that resource, such as with non use values like recreation and aesthetics. Thirdly, due to the large amount of interdependency with uses of water, such as hydroelectricity generation impacting recreation, externalities can be associated. When externalities are present, the full cost of an activity may not be visible or taken into account by the producer or consumer. Lastly, economies of scale in the supply of water lead to imperfect competition, where limited competition and monopoly suppliers can significantly influence the pricing of goods. And a market relies on competition for the efficient pricing of goods.

A common theme running through a survey of water management literature is that water management problems involve decisions about how water should be best allocated to receive the greatest public return from scarce resources. The full value of water needs to be recognised to allow informed decisions for public policies related to water supply and quality. This is of particular importance, because these policies can have significant economic consequences for households, communities, farms and industry (Young, 2005). If water is allocated to less valued uses, water quality will decline, ground water basins are often over exploited, public amenity values can receive minimal attention, and floods and droughts can destroy property and take a severe toll on life (Young, 2005).

This value case will discuss the definition of value as well as the commonly identified values of water including direct, indirect, non-use, economic, social and cultural values. Economic valuation and non-market economic valuation will be introduced incorporating and addressing the limitations of valuing such a unique resource. Finally, a number of valuation methods will be reviewed.

2 The Value of Water

2.1 What is Value?

In ethics, value is a property of an object, whether physical or abstract, representing that object's degree of importance. People in different cultural settings communicate their sense of value in multi-layered ways. It is, for example, embodied in their institutions and taboos, in their principles of right conduct, and in their habitual forms of cooperation (O'Connor, 2002).

Most modern Western ethical theories share the assumption that value must ultimately be reduced to matters of interest or concern to humans (Routley and Routley, 1995). Hence objects do not have value by themselves; value is injected by anthropogenic beliefs and perceptions. Or in other words, something has value if, and only if, it is perceived as contributing to the welfare of someone. In recent years, however, and particularly as a result of a rise in environmental ethics, the idea that values are determined solely through the interests of humans has been increasingly questioned (Routley and Routley, 1995). This leads to the idea of intrinsic value, or value that an object has 'in itself,' or 'for its own sake'. Many now argue that ecological resources or systems, such as water, possess this type of value. As an example, reference can be made to the recent branch of ecological philosophy known as deep ecology (Harding, 2002). Although there is certainly room for debate on the concept of intrinsic value, the very nature of the concept, in that it is independent of human reference, means that it is difficult (if not impossible) to describe and evaluate. For this reason the focus of this literature review is on values referenced from a human perspective.

In order to further understand the types of values that can be attributed to ecological resources, such as water, it is helpful to refer to the typology of use and non-use values as applied in the Total Economic Valuation methodology (Pearce et al., 1989; Pearce and Turner, 1990; Perrings, 1995a, 1995b). Beginning with the first type of value: use values are those relating to its present or future use. Use values can be further categorised into direct-use, indirect-use and option values. Direct-use values are those based on conscious use of a resource in consumption or production activities, for example in the case of water, use of water drinking, irrigation, industrial processing and hydro-electric power generation. Indirect-use values, on the other hand, are associated with resource functions that indirectly contribute to human welfare or life-support. For water this includes, for example, the contribution made by clouds to climate regulation, and the role of water in sustaining vegetation and, hence, oxygen production. Option values recognise that individuals who do not presently use a resource may still value the option of using that resource in the future.

Non-use values (originally theorised by Krutilla, 1967) greatly expand the definition of value for ecological resource into social and cultural considerations. Non-use values apply when individuals who do not use or intend to use a good but would nevertheless feel a deprivation if the asset were to vanish or be withdrawn (Young, 2005). The sub-category, existence values, are values individuals may place upon the conservation of an environmental resource, which will never be used personally or by future generations. Bequest value refers to preserving a resource for use by future generations. Altruistic values are derived from the value individuals place on an environmental resource that they themselves may never use, but for which they are concerned about the availability to others in the current generation.

2.2 Commonly Identified Values of Water

In itself water can be viewed as an important ecological resource or asset. This resource has the potential to be used for, or converted into, many beneficial goods and services, such as drinking water, cleaning products, recreation and transport services and so on. Any consideration of the value of water must also take account of the role played by water in complex ecological systems. These systems provide numerous beneficial services to humans such as waste assimilation, climate regulation and atmospheric regulation. Often it is difficult to isolate the functions (and hence value) of water in the provision of such services. Further, as will be seen from the discussion of valuation techniques below, there are very limited techniques thus-far developed for valuing these *in-situ* functions (refer particularly to damage cost, alternative costs and avertive expenditures methods).

Table 1 provides a summary of some of the many important values that are attributed to water resources according to the typology described above. Among the most-obvious direct-use values of water are those associated with agricultural irrigation and industrial and municipal supply. The first category, irrigation, is important as it provides for a means of production of agricultural commodities in situations where production would otherwise be limited, while the second category encompasses a wide group of situations where water is used as in input in the production of goods and services in other than agricultural activities. Included in the third category, municipal supply, are both indoor (sanitation, drinking, cooking) and outdoor (lawns, gardens, washing) residential use, as well as a number of commercial uses primarily for human consumption and sanitation (e.g. by restaurants, hotels and offices). Other direct-use values of water range significantly in nature and include electricity generation and transport and navigation values. The recreational and aesthetic values received directly from water and water-bodies are also increasingly recognised. Water bodies such as lakes, rivers, and streams have broad potential for inexpensive leisure activities, adventure activities and serve as a basis for much domestic and international tourism.

In addition to the direct values, water provides significant indirect values, predominantly through its role in the provision of ecosystem services. As described above, these values are often difficult to identify and evaluate as a result of the complexity of systems. Clearly water has a significant role in the ecosystem services of waste treatment and assimilation since it has the unique property of being a nearly universal solvent. Water also helps to transport waste and processing of waste into a less undesirable form. In addition, water has a critical role in the provision of habitat and life-support to wildlife, the provision of nutrient cycling and processing functions and in helping to regulate climate. The final indirect value identified, ecosystem support, is important as it indicates that there are many other values provided by ecosystems, all of which are critically dependant on the provision of water.

Lastly, one must note that water has significant social and cultural values. Maori, for example, respect the different forms of water and feel that each form has its own life force. In some instances recognition of the value is regardless of any use of the resource and therefore the social and cultural values might be aligned with non-use values under the use and non-use typology. Maori values related to water and water management are outlined further below.

Direct Use Value
Irrigation for agriculture
Industrial water supply
Municipal water supply
Energy resource (hydro0electrical
Transport and navigation
Recreation and amenity
InDirect Use Values
Waste treatment
Wildlife harvesting
Nutrient cycling
Climate regulation
Ecosystem support
Option Values
Potential future uses of direct and indirect uses
Non-Use Values
Bequest values
Existence values
Altruistic values

Table 1: Values of Water

Adopted from Young (2005) and Birol et al (2006).

2.3 Introduction to Maori Values of Water

Maori participation in water planning and management is particularly important to the New Zealand context because, as New Zealand's indigenous people, their access to water could be marginalised by the interests of the majority (Bennett, 2007). A number of values guide the Maori perspective of, and interactions with, water. These values are described below.

Mauri

Mauri can be translated as life force, life essence, vital essence or spark of life (Bennett, 2007; and Williams, 2006). All things have Mauri as given during the conception of all Living things. "The key to the Maori view towards environmental issues is the importance of not altering mauri to the extent that it is no longer recognisable" (Williams, 2006). Mauri can be altered by human activities (Huakina Development Trust v. Waikato Valley Authority, 1987). For example, a shoreline can lose its mauri when polluted with rubbish and sewage waste. Mauri can also be lost physically through eutrophication. Drownings or frequent mishaps are examples of spiritual pollution. Bodies of water that have been spiritually polluted are regarded as tapu, and cannot be used for any purpose (Williams, 2006, p.75). Damage to mauri can also occur through unsustainable practices, such as overfishing. In the Manukau claim (Waitangi Tribunal, 1985), the Waitangi Tribunal ruled that the claimants' traditional fisheries were severely depleted by activities such as overfishing, which eroded their traditional use, rights and responsibilities.

Maori are hostile to the deliberate mixing of waters with different mauri (Williams, 2006). For example the Tainui people opposed the piping of the Waikato river to move ironsand to the Glenbrook steel mill and then discharged into the Manukau harbour. The mauri of the two water bodies were incompatible and the mauri of the Waikato would have been deliberately polluted (Oliver, 1991).

Mahinga Kai

Mahinga kai are the "areas and locations where food of any sort and type is gathered, grown or hunted including forests, lakes, rivers, streams, swamps, wetlands, [and] traditional gardening plots…" (Harmsworth, 1995, p. 70) and Mahinga kai is critical for sustaining life. Most of the mahinga kai types are water bodies. Multiple claims made to the Waitangi Tribunal have concerned the loss and degradation of mahinga kai (Waitanga Tribunal, 1985, 1989, 1991).

Kaitiakitanga

Kaitiakitanga is described as "... the burden incumbent on tangata whenua (i.e. tribal members in a particular area) to be guardians of a resource or taonga for future generations" (Durie, 1998, p. 23).

Ki uta ki tai

Ki uta ki tai translates to 'from the mountains to the sea' (Bennett, 2007). It refers to the flow of water in a catchment, and the interconnectedness between water and land. Ki uta ki tai conveys the need for management of entire catchments (Tipa & Teirney, 2003), rather than by arbitrary political partitions.

Rahui

A rahui is a temporary restriction imposed on a land or water area to prevent people from access in order to allow species to be and allow them to grow unmolested (Williams, 2006; Bennett, 2007; and Mead, 2003). The two most common instances when a rahui is applied are after a drowning or to conserve a natural resource of value to the community (Bennett, 2007).

Taonga

Taonga, or treasures (Kawharu, 1989), is a term used to refer to a number of things such as natural resources, spiritual values, cultureal aspects, and people (Bennett, 2007). Rivers, fisheries and the mauri of rivers have also been deemed as taonga (Bennett, 2007; Waitangi Tribunal, 1985, 1989).

3 Economic Valuation of Water

3.1 Introduction to Economic Valuation

A common theme running through a survey of water management literature is that water management problems involve decisions about how water should be best allocated so as to receive the greatest public return from scarce resources. Included is theory around how to proportion inputs in a production process, which products and how much of each with scarce inputs, and how to allocate use of resources between present and future generations (Varian, 1997). Such issues are amenable to enquiry according to an economic framework.

For many, economic valuation means foremost, and sometimes exclusively, the value of produced goods and services as determined by markets (O'Connor, 2007). It is thus often upon these values that many decisions about resource management and allocation have been made. However water, like many other ecological resources, possesses a number of characteristics which mean that it is not suitable to market valuation. Described below are a number of characteristics associated with water that explain why, for the most part, water is not traded on regular markets and why regular markets cannot efficiently allocate and value water:

- Lack of exclusive property rights
  Exclusive property rights are fundamental to market valuation: if beneficiaries cannot be limited to those that have not paid for the costs or production the 'free rider' problem (Wills, 1997) exists and the market cannot allocate goods efficiently.

  The physical nature of water, for example the large extent of water bodies and mobility of water in the hydrological cycle, make it difficult and costly to exclude beneficiaries. Consider, for instance, the difficulty in limiting the experience of the aesthetic values of a river, or excluding discharges from using the capacity of the ocean to assimilate waste.

- Non-Rival Goods
  Non-use values of water, as well as some use values such as recreational and aesthetic values, are largely non-rival. That is, one person's use does not preclude enjoyment by others.

  Non-rival goods or services, and the consequences of decisions about production and consumption, tend to be shared by many, making it difficult for the market to provide the optimum quality or quantity of the good or services, in light of all users. Non-rivalry requires multilateral coordination between producers and consumers. If non-rival goods are also non-excludable, ruling out exclusive property rights and market deals, market coordination of production and consumption of that good is practically impossible (Wills, 1997).

- Externalities
  There is a large degree of interdependency in the uses of water. For example, hydroelectricity generation can impact on recreational values (positively and negatively). Such interdependencies may be associated with ‘externalities’ in the market. In other words, the full costs of economic activity may not be revealed or fully taken into account in producer or consumer decisions, resulting in less than optimal outcomes for society.

- Imperfect Competition
  Markets rely on competition in suppliers to efficiently price goods. However the significant economies of scale tend to result in limited competition and monopoly suppliers for uses that require the capture, storage and delivery of water.

The identification of such limitations has led to the pursuit of methods to ‘internalise the environment’ in economic valuation practices. The underlying principle is that although we cannot introduce all ecological goods and services into markets, nevertheless actual market transactions can be extrapolated in various ways to provide estimates, in monetary terms, of the values associated with some environmental goods (O’Connor, 2002, 2007). The common rationale to monetary valuation of non-market benefits is that it provides a common and understandable measure through which different objectives can be traded-off.

3.2 Economic Welfare Theory and Non-Market Valuation

Above we have described a number of the important values associated with water. Resource and environmental economists that provide monetary estimates of non-market values do not purport to measure or evaluate these values per se, but rather attempt to assign monetary measures to potential policy changes or other actions impacting on the services or functions provided by the resource in questions (Pearce, 1993). Always the preoccupation is with human action and human induced change, and the possible repercussions of this back on present and future human society (O’Connor, 2007).

The adoption of an opportunity-cost analytical framework is implicit in most monetary valuation studies of ecological resources. It involves: (a) developing ways of estimating in monetary terms the ‘opportunity cost’ associated with alternative uses of resources, which means assigning monetary values to ecological goods and services (and also ecological bads); and (b) choosing the course of action that is judged to be the ‘best’ for society based on this evaluation (O’Connor, 2002). The assignment of monetary values (Step a) can be approached in two distinct ways (O’Connor, 2007):

- On the ‘supply side’ through estimates of economic costs – that is, the reduction in welfare received as a result of a change in the quality or quantity of a good or service.

- On the 'demand side' through estimates of economic benefits – that is, the change in welfare as a result of some improvement in the quality or quantity of a good or service.

These benefits and costs are typically measured by either willingness to accept (WTA) compensation or willingness to pay (WTP) (Young, 2005). The former defines the minimum amount of compensation required in order for an individual to forego an improvement in welfare that would otherwise be received, or alternatively, the compensation required for an individual to accept a cost that would otherwise not be received. The latter measure, by contrast, refers to the maximum amount that a person would be willing to pay in order to either receive a benefit or avoid a cost as applicable to the circumstances. The selection of either WTA or WTP as the appropriate measure will depend on existing institutional entitlements, specifically whether the person in question has an existing right to either receive a benefit or avoid a cost. A variety of methods are available for quantifying these values, for example travel cost method, hedonic pricing and contingent valuation. These are discussed further below.

Once benefits and costs categories have been decided and evaluated in monetary terms, the standard cost-benefit analysis turns to principles of economic efficiency in order to evaluate the alternative courses of action (Step b). Strictly speaking, the definition of economic efficiency, also termed Pareto optimality, is satisfied when resources are allocated such that no further reallocation is possible that would provide gains in production or consumer satisfaction to some firms or individuals without simultaneously imposing losses on others (Young, 2005). Inherent in the concept are a number of assumptions including (Wills, 1997; Young, 2005): (a) individual preferences count, or in other words, what the individual wants is assumed good for the individual; (b) the economic welfare of society is based on the economic welfare in aggregate of its individual citizens; and (c) a change that makes everyone better off with no person worse off constitutes a positive change in total welfare. In reality few policy changes or resource management practices would meet the strict Paretian standard of improving the welfare of many while making no person worse off. To overcome this difficulty welfare theorists apply the compensation test. Here, if beneficiaries could in principle compensate losers and still be better off, the change is deemed acceptable, whether or not the compensation actually takes place (Young, 2005). In relation to the Paretian standard it should also be noted that applied cost-benefit analysis typically examines fairly large increments of change and assesses simply whether the movement is in the direction of Pareto improvement. Where an action generates incremental benefits in excess of costs it is termed Pareto superior as it is superior to the existing situation (Young, 2005)

Finally, it is worth noting the extent to which standard cost-benefit analysis is able to deal with the future. As with other ecological resources, decisions regarding the management and allocation of water bring to the forefront a need to reconcile future and present preoccupations (O'Connor, 2002). Depending on the values that are chosen for analysis, a valuation undertaken from the perspective of the current generations may entail, by default, consideration of benefits and costs for future generations. These considerations occur particularly in relation to the non-use categories of values as described above. In addition there is some attempt in established cost-benefit methodologies to extend conventional cost-benefit analysis across time by including costs and benefits that occur in the future, but at a 'discounted' value. This practice allows for consideration of future interests but assumes that these interests are of lesser weight to those of the present.

3.3 Issues and Limitations around Monetary Valuation

The application of cost benefit valuation techniques to ecological resources is to transpose traditional economic valuation methodology into arenas for which it was not originally devised. There are a number of issues and limitations apparent in this approach, some of which are outlined below:

- Conditions required for monetary commensurability
  The comparison of benefits and costs relies on an assumption of commensurability in monetary values. The necessary conditions required for monetary commensurability are, however, very strict and have little chance of occurring in the real world (O'Connor, 2002). The conceptual basis behind the idea of relative prices is typically the idea of the 'general equilibrium' situation in a perfectly competitive marketplace. Here the price that a buyer is willing to pay represents, by hypothesis, the value of the marginal unit of that good by comparison with other goods available within the market (O'Connor, 2002). For a variety of reasons these equilibrium conditions may not be satisfied and hence commensurability in monetary values will not exist.

- Scientific uncertainties
  Science has a limited ability to understand the future consequences of ecological resource use. Where systems under consideration are complex, and environmental consequences are long-lived (e.g. impacts on ecosystem functioning as a result of water quality degradation), scientific uncertainties are particularly high. In these situations the evaluation of opportunity costs becomes difficult and often arbitrary (O'Connor, 2001)

- Incomparability in costs and benefits
  In addition to the issues identified above regarding money commensurability and estimation difficulties, it is important to note that costs and benefits identified may not be directly comparable. This occurs because benefits and uses of water incorporate a number of dimensions – namely quantity, quality, timing and location. It is thus highly likely that different types of value estimates will incorporate fundamental dimensional differences making direct comparisons of value difficult. In regards to this issue, the concept of water quality is particularly challenging. Notably water is not necessarily consumed in the process of being used, and can be in whole or in part reused (Gibbons, 1986). A further complication arises as a result of the difference between average and marginal values. Although most valuation techniques focus on assessing changes in marginal value, in some situations average values are estimated. Young (2005) also distinguishes between private and social prices in valuation estimates, with the difference between the measures relating to whether or not subsidies, taxes or other government influences are included in the price.

- Difficulty in assessing every potential cost/benefit
  In an ideal cost-benefit analysis every positive and negative consequence of an action would be taken into account. Inevitably this is impossible due to the complexity of the situation and limitations in the availability of resources for a study.

- Importance of base assumptions
  Even if it is assumed that monetary values are commensurable, and that we can ignore uncertainties relating to the future consequences of ecological resource use, the results of any particular valuation exercise are highly dependent on the initial assumptions and parameters employed (O'Connor, 2002). Among the most important assumptions made will be those around the identification of possible benefits and costs, the allocation of entitlements and 'property rights', elasticities of substitution between different forms of capital, and appropriate discounting rates for future values.

- Institutional structures and power relations
  Existing institutional structures and power relations inevitably influence the base assumptions discussed above, as well as cost benefit analysis in general. These influences manifest in a variety of ways. For one, the costs and benefits identified in any valuation exercise, and the relative emphasis placed on either 'supply-side' or 'demand side' considerations, are closely related to the institutional and power relations involved (O'Connor, 2007). Take for example a community concerned with the discharge of effluent. In this situation it is environmental effects that motivate the evaluation exercise, and hence these will be well-represented in the costs identified. If, on the other hand, the situation involved an absence of acceptance that future generations have an entitlement to quality water resources, it may indeed be efficient or optimal to delete or degrade irreversibly the water resources. This example illustrates that so-called optimal choices in welfare theory actually depend on prior resolution of entitlement or property rights issues. Furthermore, the persons (present or future) to whom these entitlements currently sit can influence greatly the results obtained from a non-market valuation technique. Important in this regard is that an individual's willingness to pay and willingness to accept (supply and demand) is highly dependent on his or her income and thus existing property rights. Therefore cost-benefit analysis entails an assumption that individual preferences should be weighted according to the existing distribution of income and in turn implies acceptance of existing societal distribution of property rights (Wills, 1997).

3.4 Economic Valuation as Scenario Analysis

Of the issues and limitations of monetary valuation identified above, the last two issues are perhaps the most important. Together these issues highlight that, despite the apparent mathematical formalism of the valuation task, the process of monetary evaluation is itself a normative exercise. Inherent to the valuation exercise are decisions around what benefits or costs are relevant for consideration; whether current incomes and distributions are fair and appropriate for use in measuring values; and what is, or might be, fair or unfair between generations (Holland, O'Connor and Neil, 1996). Clearly a transparent valuation exercise begins by defining clearly any assumptions made in regards to these questions, thus highlighting that the valuation exercise is but one scenario among many possible alternatives. Having defined this, particular scenario investigations can be made about what commitments this scenario does or might entail.

An approach to sustainable water management involving analysis of two or more scenarios was recommended by O'Connor (1997), on the basis that it provides a robust evaluation of water use benefits while taking account of fairness and stewardship concerns in water distribution. In terms of the types of scenarios to be investigated he notes that one scenario, the reference scenario, could potentially be framed as a 'business-as-usual' scenario involving trends in water use that are potentially unsustainable. Another scenario could then be constructed as a comparison involving satisfaction of specific sustainable water management criteria.

4 Applied Methods of Non-Market Monetary Valuation

4.1 Introduction to Applied Methods of Monetary Valuation

This section of the literature review provides a brief overview of applied methods of non-market monetary valuation. These methods are grouped and described according to the types of water values (e.g. industrial water supply, waste treatment) in relation to which the methods are best applied. On the basis that the purpose of this research is to assess integrated water management applied predominantly in an urban context, the focus of the section is specifically on values important to urban situations, i.e. industrial water supply, municipal water supply and waste treatment. It is nevertheless recognised that integrated water management requires careful consideration of the way in which water use policies or actions, even those confined to a specific location or scale, may impact on a whole range of water values. For this reason a summary table is also provided in Section 4.5 of applied methods of non-market monetary valuations with consideration of techniques applied both within and outside of the urban context.

4.2 Valuing Water in Municipal Uses

Applying the same categorisation as used by Young (2005), municipal water use encompasses those uses in which water is primarily for human consumption and sanitation. It therefore includes a number of quite distinct types of use. The most important is residential (i.e. household or domestic) water use for both indoor (e.g. bathing, drinking and cooking) and outdoor (e.g. watering gardens, cleaning and filling swimming pools) purposes. Although there has been some limited separate treatment by economists, water uses by non-manufacturing businesses (e.g. restaurants, hotels and offices) and some public or government water uses (e.g. for maintenance of public buildings and grounds) may also be analysed in the same manner as residential water use (Gibbons, 1986; Young, 2005).

In order to value residential water use, most studies rely on consumption and price data from water supply agencies (Young, 2005). Important to note is that this data is likely to encapsulate value added to the water by water supply agencies through the quality treatment and transport of the good. However in most valuation studies it is the value of raw water 'at-source' or 'instream' which is important, as it provides a means of comparison of benefits and costs against other types of water use (e.g. by agriculture, industry and the environment). Another important consideration is that not-all types of residential uses are supplied and/or priced by water supply agencies.

4.2.1 Demand Functions for Municipal Water Use

The usual approach to valuing residential/municipal supply is through the construction of economic demand functions (Gibbons, 1986; Young 2005). Other possible methods are described in Table 2 below. For an in-depth analysis of the demand function approach, readers can refer to authors such as Hanemann (1998), Howe (1998) and Arbues et al (2003) among others. In short, water demand functions describe the relationship between the quantity of water taken and the price of water, and are based on the hypothesis that consumers adjust water consumption behaviour and modify water using appliances in response to changes in water price.

A simple demand function is presented in Figure 1 below. According to this figure, a consumer's willingness to pay for an incremental increase in supply of treated and delivered water from Q_1 to Q_2 is represented by the area under the demand curve ABQ_2Q_1 (although the actual price paid by the consumer is the water price multiplied by the quantity). Now in order for the value imputed to be comparable with other instream uses, it is necessary to subtract the costs of water treatment and transportation. In Figure 1 these costs are represented by the line P_2B. Overall the value of municipal water, net of utility costs, is therefore represented by the triangle ABC.

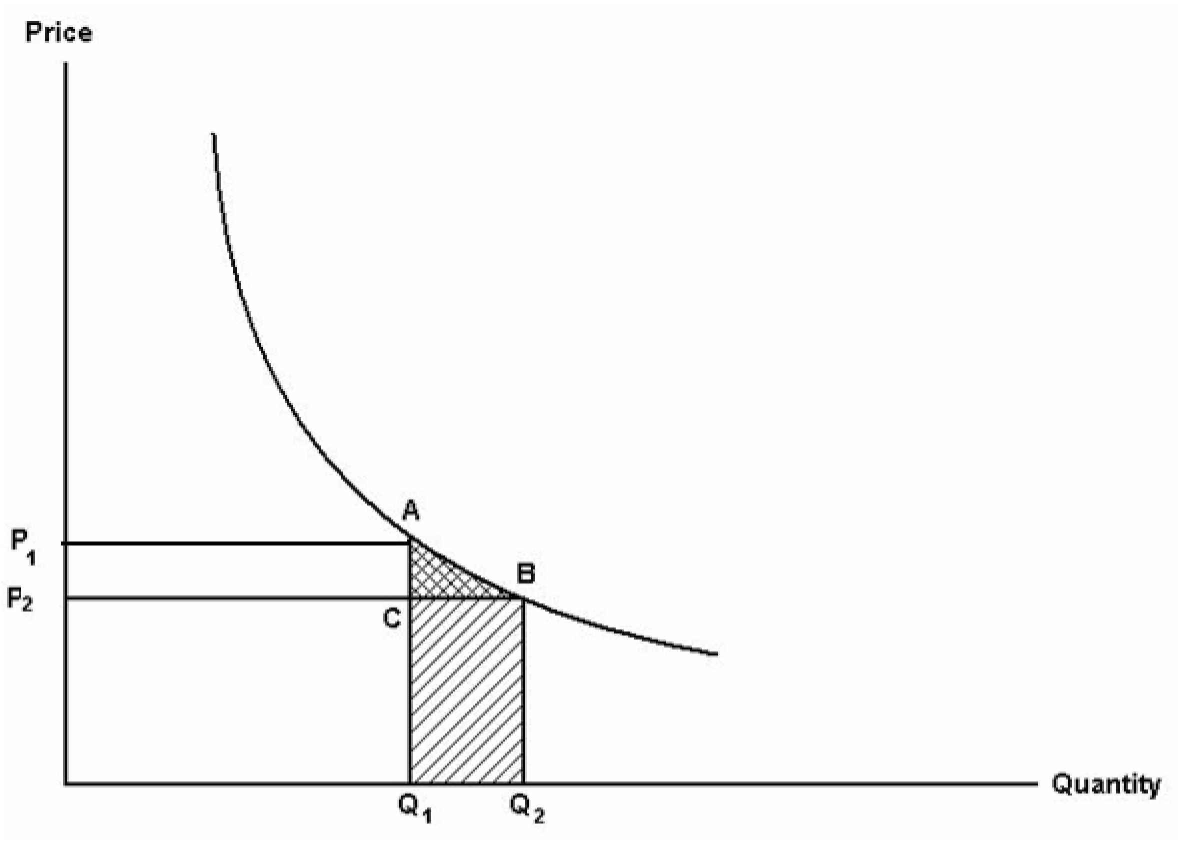

Figure 1: Consumer Water Demand Curve

An important point to note is that while a demand curve will vary depending on the unique combination of demands represented and various other circumstances specific to the situation, a demand curve will typically follow a hyperbola-type shape. This means that for a certain minimum level of water supply or quantity, the price that consumers would be willing to pay nears infinity. This result reflects that a small portion of water demand is for uses which there are no substitutes and that are of great necessity to consumers (Gibbons, 1986).

In order to derive the shape of a specific demand curve, economists will typically rely on application of econometrics. The details of this procedure are not described here, except so far as to note that this allows for inclusion of a variety of demand parameters such as prices of related goods, incomes of domestic water consumers, climate, and municipal water conservation policies[1]. It can also be noted that analysts continue to debate the best specification of the demand function according to these parameters (Young, 2005).

In terms of limitations, one of the major difficulties in applying the demand function approach is that sufficient data on prices and water use for developing reliable water demand function is difficult to obtain.

4.2.2 Expressed Preference Methods

Expressed preference methods are a class of non-market valuation techniques which involve the direct questioning of populations for preferences regarding proposed environmental policy changes or other actions (Young, 2005). Only occasionally are expressed preference methods, namely contingent valuation and choice modelling, used in the valuation of municipal water. A description of these methods is provided below.

4.3 Valuing Water in Industrial Uses

In an industrial context water is used for cooling and condensation, washing raw materials and equipment and conveying other production inputs. Water may also be incorporated into the final product itself. Although water is not necessarily consumed in industrial processes, industrial water use invariable involves some degradation in water quality. The degree to which these residuals can be treated or released into water bodies has significant implications for industrial water use. Understanding the role of water reuse is also very important in the context of valuations in the industrial context.

Unlike municipal water uses, the values associated with industrial water use are seldom measured by a demand function (Gibbons, 1986). There is generally a lack of suitable empirical data for estimating water demand functions for industry. This is primarily because, even in those industries where enormous quantities of water are used, the market price of water tends to

[1] ***For an introduction to econometric analysis readers may refer to Meadows and Robinson (2007).***

be dwarfed by other costs of production (e.g. raw materials, energy, labour). As a result decisions on water use tend to be secondary to other profit-maximising considerations by firms (Gibbons, 1986). In this section we therefore describe alternative methods for measuring the value of industrial water uses. This description is however preceded by a short summary of the way in which economic welfare theory is expanded from the subject of an individual to a firm.

4.3.1 Valuing Producers' Uses of Water

Industrial water uses can be distinguished from municipal/residential water use in that the good is classified as an intermediate or producers' good, as opposed to a final consumption good (refer to Young (2005)). The basic principle behind estimating the economic benefits or values of an unpriced producers' good entails isolating the portion contributed by the good to the total output of the industrial process, from the contributions of all other inputs that go into the production process (Young, 2005). To date, the development of suitable methodologies for measuring such values has received relatively little attention. (Young, 2005).

In order to develop a theoretical measure of welfare changes for firms based on changes in the quantity or quality of an unpriced input (e.g. water), economists typically derive what is termed a Value of Marginal Product (VMP) function. The method used to derive this function is complex and dependent on a number of assumptions. Reference can be made to authors such as Varian (1997) for a full description. Essentially the function describes, for any given value of input of the subject good (i.e water), the amount in which the value of the firms' output will increase should the amount of the input of the good increase by one unit while all other inputs remain unchanged. The function is therefore used to measure producers' benefit or willingness to pay for changes in the quantity of the subject input.

4.3.2 The Basic Residual Method

The basic residual method is the most frequently used method for approximating VMP, although typically in the case of irrigation for agricultural crops as opposed to industrial uses (Young, 2005). According to the residual method, the value of VMP is estimated through valuing water as the remainder of net income after all other relevant costs are accounted for. The theoretical basis for this approach can be derived from either the product exhaustion theorem or the theory of economic rents (refer to Young (20050)).

There are a number of obstacles to reliably estimating industrial demand or willingness to pay for water. For one, accurate specification of the appropriate production function is a major issue in applying the residual method (refer to Young (2005)). Furthermore, obtaining enough observations to develop and reliably estimate industrial water demand functions is expensive and time consuming. Other limitations centre on the validity of the theoretically assumptions underpinning the methodology. According to Young (2005), the method is best applied where the production process is simple, stable over time, and water represents a significant contribution to the value of production.

4.3.3 Econometric Estimates of Production Functions and VMP

Although infrequently applied, occasionally production demand functions are derived by fitting production data with economic techniques. The VMP functions can then be derived to provide measures of water demand and hence value. To date the approach has mainly been used to study agricultural water use. As water typically represents only a small element of the costs in industrial enterprises, and data is hard to obtain, few estimates of the value of water via the econometric production function approach have been undertaken (Young, 2005).

4.3.4 The Alternative Cost Method

The alternative cost method is suitable for use only in a narrow range of situations. Nevertheless, where estimates of VMP prove difficult due to a lack of data or other reasons, the alternative cost method might potentially provide an attractive alternative. Essentially the method rests on the principle that, from a social accounting stance, the maximum willingness to pay for a provision of a good or service is no greater than the estimated cost of providing that good or service via some other process or technology.

The alternative cost method is easily misused and should be applied with caution. The main weakness is that it is generally possible to conceive of some alternative that would be more expensive that the proposal being evaluated, thereby inevitably producing an estimate of cost savings and net benefits (Young, 2005).

A very specific type of alternative cost approach recommended by Gibbons (1986) for an industrial context it to examine the value internal water recirculation. It is hypothesised that industry would be willing to pay only up to what it would cost to produce water of a similar quality through treatment and reuse. In the typical case, the average cost of recycling rises as the degree of recycling goes up. This means that the marginal cost increases over the range of recycling possibilities.

4.3.5 Hedonic Pricing Methods

Hedonic pricing methods are occasionally used for inferring producers' valuation of water. The method relies on the market prices of one good, usually real estate, to estimate the value of a nonmarket amenity that influences the price of the market good (Colby, 1989). Essentially it's based on Lancaster's theory that any good can be described by a collection of characteristics (Lancaster, 1966). The price of the good depends on these characteristics. For example the price of a house will reflect its characteristics (e.g. number of bedrooms, number of bathrooms, size of section etc.). Milliman (1959) and Hartman and Anderson (1962) were some of the early users of HPM. They used land differentials to determine the value of irrigation water. HPM has also be applied to valuing the access to surface and ground water (Miranowski and Hammes, 1984; Gardner and Barrows, 1985; Ervin and Mill, 1985; King and Sinden, 1988) both in quality and quantity.

4.4 The Value of Water for Waste Treatment

Water quality is one of the critical dimensions of water demand, with different water uses requiring different levels of water quality, and producing varying degrees of water degradation (Gibbons, 1986). The capacity of water bodies to assimilate and dilute wastes thus represents significant economic value in itself. The values of water for waste treatment (i.e. the benefits provided by the resource) are usually calculated as either waste-treatment costs foregone or damages avoided (and conversely, if the question relates to the loss of waste treatment value as a result of water degradation, the costs can be estimated from the costs of waste treatment and the costs of damages incurred). It is important to note that, since different types of pollutants involve different waste-treatment process and can result in different adverse effects, the value of water for waste treatment is also specific to the pollutant(s) considered. Pollutants are typically allocated to two categories: point source and non-point source. Point source pollutants consist predominantly of liquid industrial and municipal wastes and effluent from treatment plants. Non-point source pollutants include runoff from agricultural and urban lands, seepage of chemicals into the water table and salinity from natural sources.

4.4.1 Alternative Costs Methods

The alternative cost framework has already been outlined above. In regards to the value of water for water treatment, the approach involves estimating the costs required to provide water treatment functions via alternative mechanisms (methods of treating and reducing wastes entering a stream).

4.4.2 Damage Cost Methods

Damage cost methods can be used to infer the value of water for waste treatment. The approach involves measurement of the resource costs brought on by an ecological change. The general principle is that the affected individual or household would be willing to pay up to the amount of expected damage in order to avoid them. The cost-of-illness method is a subset of the damage cost methods. It uses data on costs of mediation, visits to doctors, time lost from work etc to infer costs of damages to human health. This method does not account for the disuitility of those who are ill, nor does it consider the avertive or defensive measures taken by individuals to prevent illness (Birol, Karousakis, & Koundouri, 2006).

4.5 Other Non-Market Valuation Techniques

4.5.1 Stated preference techniques

Unlike many of the methods described above, stated preference techniques (also termed expressed preference techniques) do not rely on any market transactions to infer value. The two most commonly applied stated preference techniques are contingent valuation and choice experiment method (choice modelling).

- Contingent valuation method (CVM)
  The researcher creates a hypothetical or experimental situation where individuals reveal the values they would place on a resource. Participants reported values are 'contingent' upon the conditions of the situation created by the researcher. Individuals are either interviewed or given a questionnaire in which they are asked to state their maximum WTP or minimum willingness to accept (WTA) compensation. The method is frequently used in the assessment of recreational and amenity values. It is also one of the few techniques available for considering non-use values of a resource. CVM also has the advantage of accommodating for environmental changes that have not yet occurred (i.e. ex ante valuation). Hence CVM offers the largest scope and flexibility out of the revealed preference techniques.
  On the other hand, CVM has been criticised for a lack of validity and reliability. This method is vulnerable to information bias, design bias, hypothetical bias, yea-saying bias, strategic bias (free-riding), substitute sites and embedding effects (Birol, Karousakis, & Koundouri, 2006) (Blamey, Gordon, & Chapman, Choice modelling: assessing the environmental values of water supply options, 1999). In response the U.S. National Oceanic and Atmospheric Administration (NOAA) has constructed a set of best practice guidelines for implementing CVM (Arrow, Solow, Portney, Learner, & Radner, 1993).

- Choice Experiment Method
  Choice experiment method (CEM) is built upon Lancaster's theory of value (Lancaster, 1966). CEM starts with random utility models (RUMs). RUMs assume the respondents have perfect discrimination ability, as they are discrete choice economic models (Manski, 1977). A choice experiment utilises carefully designed tasks to reveal factors that influence choice (Birol et al., 2006). A profile or a number of profiles is created for an environmental resource based upon its attributes. For example, one attribute that could describe coastal waters is bathing water quality. This attribute could be split into levels of high, medium, and low and assigned monetary values. The respondent is then presented with choices or a multitude of scenarios to establish WTP.

  CEM has similar advantages to CVM as it can be used for any environmental resource and to estimate non-use values. CEM, however, can also estimate specific attributes of a resource rather than just the resource as a whole. CEM does not have some of the biases that come along with CVM, such as strategic bias and yea-saying bias (Birol et al., 2006).

In the last decade, CEM has been applied to use and non-use valuations of wetlands in Australia, Sweden, and Malaysia (Morrison, Bennet, & Blamey, 1999; Carlsson, Frykblom, & Liljenstolpe, 2003; amd Othman, Bennett, & Blamey, 2004). CEM has also been used to estimate the value of improved water quality, water supply and other water services. Willis et al. (2002) investigated the preference trade offs for water company customers concerning water supply reliability and wetland conservation. Abou-Ali and Carlsson (2004) examined the effects of improved health status through increased water quality in Cairo, Egypt. Hensher et al. (2004) utilised CEM to find the amount customers were WTP to have reliable water services, including waste water overflow. Finally, Blamey et al. (1999) used CEM to assess the environmental values of water supply options.

4.5.2 Avertive expenditures method

The avertive (avoided cost) expenditures method looks at household behaviours in response to the degradation of a good. For example, avertive or defensive behaviours to avoid the adverse impacts of water contaminants (Um, Kwak, & Kim, 2002; Abdalla, 1994; and McConnell & Rosado, 2000). Some examples of these behaviours could include buying non-durables (bottled water), liming to reduce water acidification, and changing behaviour to avoid exposure to the contaminant (e.g. boiling water for cooking and drinking or reducing the frequency or length of showers if a volatile organic compounds are present) (Birol, Karousakis, & Koundouri, 2006). The avertive expenditures method has many limitations, as it cannot consider more than one avertive behaviour at a time. Also, a combination of avertive behaviours might have additional synergistic effects. For example, the purchase of bottled water could have additional taste benefits. An avertive measure usually does to fall on a continuous spectrum, it tends to be a discrete decision, such as whether or not to buy a water filter. Lastly, avertive expenditures do not include all the costs related to pollution and are therefore only able to provide a lower bound estimate of the cost of a damaged environmental asset.

4.5.3 Travel Cost Method

The travel cost method (TCM) is often used to estimate values associated with recreation. It utilises the time and travel cost expenses that people are willing to incur to visit a site to hunt, swim, fish, hike, or birdwatch for example. WTP is estimated based on travel cost and number of trips. This method can be used to estimate the economic benefits and costs resulting from changes in access cost for a recreational site, elimination of an existing recreational site, addition of a new recreational site, and changes in the environmental quality of a site (Birol et al., 2006).

This method has certain disadvantages and limitations. Defining and measuring the opportunity cost is complex because there is no consensus on an appropriate measure. When substitute sites are taken into account such as in the random utility approach to TCM, information can be collected on the value of the characteristics of a site in addition to the value of the site in question (Birol, Karousakis, & Koundouri, 2006). TCM can only estimate the value of a resource in situ or on site. It does not measure non-use values.

Valuation Methods	Description of Method and Data Sources	Potentially useful for valuing:	Advantages	Disadvantages
Production Functions	Primary or secondary data on industrial/agricultural inputs and outputs analysed with statistical techniques	Irrigation for agriculture, industrial water supply, municipal waters supply	Based on observable data from firms using water as an input. Relatively inexpensive. Can be used for evaluating a variety of scenarios	Diffcult to apply where production process is complex. Not suitable for use where water contributes only a small portion of the value of an output. Based on complex assumptions/ theoretical foundations
Water Demand Functions	Primary or secondary data on water use and price used to construct water demand functions.	Municipal water supply	Use of real market data. Relatively inexpensive.	Can estimate use values only. Difficult to obtain suitable data for derivation of a function.
Travel Cost Method	Application of econometric analysis to infer the value of recreational site attributes from varying expenditures incurred by consumers in travelling to the site	Recreation and amenity	Use of real market data. Relatively inexpensive.	Can estimate use values only. May have substantial data requirements. Requires estimates of value of travel/leisure time. Cannot predict
Hedonic Property Value Method	Revealed preference approach using econometric analysis of data on real property transactions with varying availability of water supply or quality.	Irrigation for agriculture, industrial water supply, municipal waters supply, recreation and amenity	Use of real market data.	Can estimate use values only. Rquires extensive house market data. Cannot predict the changes in use values due to environmental changes without prior information. Current evidence suggests it is not suitable for use in benefits transfer. Difficulty in detecting small effects of environmental quality factors on property prices. Connection between implicit prices and value measures is technically complex. Ex post valuation.
Avertive Expenditures Method	Revealed preference method using reductions in the costs of actions taken to mitigate or avoid incurring an external cost as a partial measure of the benefits of policies from reducing the externality.	Potentially some indirect-use values	Modest data requirements. Use of real market data	Can estimate use values, but problems arise when (i) individuals make multiple averting expenditures (ii) there are secondary benefits of an averting expenditure and (iii) averting behaviour is not a continuous division but a discrete one (e.g. Dual flush toilet is either purchased or not)
Damage Cost Methods	Maximum willingness to pay given as monetary value of damages avoided	Waste treatment, potentially other indirect-use values		Estimates do not capture full losses from environmental degradation. Limited to assessment of current situation. Ex post valuation. Does not measure non-use values.
Replacement Cost Method	Value attributable to cost savings from next best alternative source of service (e.g. electricity, transportation)	Irrigation for agriculture, industrial water supply, waste treatment, some indirect-use values	Based on observable data from actual behaviour and choices. Relatively inexpensive. Provides a lower bound WTP if certain assumptions are met.	Need for easily observable behaviour on averting behaviours or expenditures. Estimates do not capture full losses from environmental degradation. Several key assumptions must be met to obtain reliable estimates. Limited to assessment of current situation. Ex post valuation. Does not measure non-use values.
Contingent Valuation Method	Expressed preference method using statistical techniques for analysing responses to survey questions asking for monetary valuation of proposed changes in environmental goods or servies.	Recreation and amenity, non-use values	Can estimate both use and non use values. Suitable for valuing environmental changes irrespective or whether or not they have a precedence. Completed surveys give full profile of target population. Does not need observable behaviours (data). Technique is not generally difficult to understand. Enables ex ante and ex post valuation.	Relatively expensive due to the need for thorough survey development and pre-testing . Complex and multi-dimensional scenarios may be too much of a cognitive burden for respondents. The concept of diversity may similarly be difficult to put across to respondents. Subject of varying biases. [2] Controversial for non use value applications.
Choice Modelling	Expressed preference method using statistical techniques to infer willingness to pay for goods or services from survey questions asking a sample of respondents to make choices among proposed policies.	Recreation and amenity, non-use values	Can be used to measure the value of any environmental resource without need for observable behaviour (data), as well as the values of their multiple attributes. Can measure non use values.	Technique can be difficult to understand. Expensive due to the need for thorough survey development and pretesting. Controversail for non use value applications. Not as widely tested as CVM.
Basic Residual Method	Constructed models for deriving point estimates of net producers' income or rents attributable to water via budget or spreadsheet analysis	Irrigation for agriculture, industrial water supply	Based on observable data. Relatively inexpensive.	Can estimate use values only.

Table 2: Methods of Non-Market Valuation[2]

Adopted from Young (2005), Birol et al. (2006) and Nijkamp, Vindigni, & Nunes (2008)

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[2] Various biases include interviewing bias, starting point bias, non-response bias, strategic bias, yea-saying bias, payment vehicle bias, information bias, and hypothetical bias.

5 Beyond Monetary Valuation

With time and budgetary constraints it is not possible to provide an in-depth review of techniques alternative to monetary valuation that may provide assistance to decisions makers, specifically in relation to water use and integrated water management. Nevertheless it is worthwhile identifying two tools in particular, which have the potential to be helpful for integrated water management and decisions involving water resources more generally: stakeholder mapping and multi-criteria analysis. These tools can be applied in a complimentary manner to the methods of monetary valuation described above during the process of setting and evaluating comparative scenarios.

5.1 Stakeholder Mapping

Stakeholder mapping, which is based on institutional analysis, uses interviews, focus groups, literature reviews and the like to identify distinct categories of users or potential beneficiaries. Their input helps to define questions for analysis, validate assumptions and identify potential scenarios.

5.2 Multi-Criteria Analysis

A great number of multi-criteria analysis (MCA) methods have been developed in recent years. Often these approaches involve monetary valuations set alongside other methods of for identifying and evaluating consequences of alternative courses of action (O'Connor, 1996).

As opposed to the cost-benefit approach described above, MCA assumes that, while the effects of alternative courses of action or policies may be comparable in various ways, these effects cannot be reduced to a single unit of measurement (e.g. money in the case of cost-benefit analysis). A theoretical justification for the use of MCA is the existence of 'weak comparability' in the consequences of action. This means that there is not a single principle of comparison by which all different actions can be ranked (O'Neil, 1993). MCA therefore does not provide a unique criterion for choice, but instead helps to frame a problem of arriving at a political compromise decision (Munda, 1995).

The theoretical and technical foundations to CBA can be complex due to the large range of information categories that analysts may attempt to bring together. However described simply, the MCA approach involves: (1) identification of alternative courses of action; (2) identification of a set of evaluation criteria; and (3) evaluation of each potential action according to the identified criteria.

6 Conclusion

The effective implementation and justification of integrated water management requires above all an understanding and appreciation of the many important values attributable to water. This initial literature review has therefore concentrated on an examination of water values and the various economic theories and techniques applied in their valuation. One, not surprising, finding is that economic valuation is often mistakenly conceptualised as the value of goods and services as determined by markets. This is important because many water values, like those of other ecological resources, are not easily captured by regular market mechanisms and is often regarded as a common good. This applies particularly in regards to the indirect use values provided through water's role in the provision of ecosystem services, such as waste treatment and nutrient cycling, and also in regards to the non-use values provided by water. Even in regards to direct use values, typically the type of values most amenable to market valuation, there are a number of characteristics which make water difficult to effectively price and allocate.

The recognition of the many limitations of market valuation with respect to environmental goods and services has led to the development of methods to 'internalise the environment' in economic valuation exercises. The adoption of an opportunity-cost framework is implicit in most of these exercises. This process requires estimation, usually in monetary terms, of the 'opportunity cost' associated with alternative uses of resources. This requires assignment of monetary values to improvements (or reductions) in ecological goods and services. A variety of techniques can be applied in these regards depending on the type of value in question, for example developing demand functions for municipal water use, alternative cost methods and hedonic pricing methods. Various limitations are associated with each technique.

The next step in the project will be to develop a conceptual framework for identifying the various costs and benefits applicable to a given water demand management technology/practice. Although in the development of this framework, particular attention will be given to the values of water as described in this literature review, the framework will also allow for the inclusion of wider benefits and costs arising from water demand management, for example synergistic reductions in energy use.

The proposed framework will be developed from the perspective of scenario analysis. The use of the scenario approach recognises that any attempt to predict the future is impossible, and therefore any assessment of the future (particularly long term) costs or benefits of a particular water demand technology/practice are subject to the particular assumptions that are made regarding the future. The scenario approach also recognises that the results of a valuation exercise are dependent on a variety of other assumptions employed, for example in the identification of benefits and costs relevant for consideration, the appropriate discount rate for the future, and so on. The advantage of the scenario approach is that it makes these assumptions implicit and open for debate. Ideally the assumptions employed in each scenario would be developed through consultation with stakeholders, although time and budgetary constraints are likely to limit this in practice.

Rather than applying a strict monetary valuation, the proposed framework will be based around multi-criteria valuation. This recognises that while monetary valuation techniques are useful, it is unlikely that all of the individual benefits and costs associated with a water demand management technique will be amenable to assessment in monetary terms. Alternative criteria and indicators will therefore be developed for evaluating benefits and costs where necessary.

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