Unreliable water supplies and household coping strategies in peri-urban South Africa

Batsirai Majuru

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Abstract

Many developing countries face severe challenges with the reliability of water supplies. These supplies are often characterised by intermittence, low pressure and poor water quality. Despite its contribution towards water-related illness and the significant coping burden it imposes on households, water supply reliability remains a difficult attribute to measure. A key challenge is the lack of a universal definition of water supply reliability. The issue of unreliability in water supply and the financial cost it imposes on households is of profound relevance in South Africa – a country whose social policies include a Free Basic Water policy which entitles all households to a free lifeline supply of 6,000 litres per month. This thesis examines household experiences of unreliable water supplies and in particular, explores the question as to what constitutes a reliable water supply, and household responses to unreliable water supplies.

The analysis draws on literature reviews and a household survey conducted in peri-urban communities in the Limpopo Province of South Africa in 2012. A systematic review of definitions and assessment criteria used in studies of water supply reliability demonstrates that there is no consensus on what constitutes a reliable water supply. Assessment criteria also vary greatly, with the most common criterion in urban settings being the duration and/or continuity of supply in hours per day. In rural settings, the proportion of functional water systems is commonly assessed. A discrete choice experiment was conducted to elicit households' preferences for a reliable water supply. Results indicate that overall, households value notification of interruptions and having water available for longer durations during the day, and would be willing to pay for these improvements. However, there is some heterogeneity in these preferences as wealthier households, who have drilled their own wells and are no longer dependant on the public supply are less willing to pay for improvements in the water supply.

Findings from a systematic review of household strategies to cope with unreliability reveal that relatively wealthy households incur significant direct costs from strategies such as drilling wells and installing water storage tanks, poor households expend time and energy in collecting water from other sources. Income, level of education, land tenure and extent of unreliability are the main determinants of which strategies are adopted. Results from the survey in Limpopo highlight that Free Basic Water is not actually free; households spend significant proportions of their income on buying water, drilling wells and treating the water prior to consumption. Coping costs increase with wealth status and are higher in communities without alternative water sources such as springs. Notably, for many households the lifeline supply of 6,000 litres per month is unmet.

The findings from this thesis highlight the need for consensus on the definition, and assessment approach for water supply reliability. Further, the analysis of households' responses to unreliable water supplies in South Africa draws attention to how poor reliability negates the Free Basic Water policy. Without reliable water supply services, the objectives of improving public health and promoting equity cannot be met.

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Acronyms

AfDB	African Development Bank
ADB	Asian Development Bank
DWA	Department of Water Affairs
DCE	Discrete choice experiment
DfID	Department for International Development
FBW	Free Basic Water
JMP	Joint Monitoring Programme
MDGs	Millennium Development Goals
RDP	Reconstruction and Development Programme
SPSS	Statistical Package for the Social Sciences
TUT	Tshwane University of Technology
UEA	University of East Anglia
UNC	University of North Carolina
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
WHO	World Health Organisation
WSA	Water Service Authority
WSP	Water Service Provider

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1 Introduction

This introductory chapter provides a brief overview of the problem of poor reliability of water supplies in developing countries. It outlines the research needs, as well as the thesis objectives. The scope and definitions of terms used throughout the thesis are also outlined, and the chapter concludes with an overview of the thesis structure.

1.1 Background and rationale

By 2012, 116 countries – representing an estimated 89 % of the world's population – reportedly had access to improved water sources (WHO/UNICEF, 2014). Seemingly, the Millennium Development Goal (MDG) target to halve the proportion of the world's population without access to safe drinking water by 2015 had already been met. South Africa is one of the few countries in sub-Saharan Africa classified as having already met the drinking water target in the Joint Monitoring Programme's (JMP) 2014 update (WHO/UNICEF, 2014). However, the laudability of this achievement may be debatable when confronted with the local reality of unreliable water supplies; with taps running dry for weeks on end [Appendix 1.2 (Majuru et al., 2012)].

The problem is not unique to South Africa alone; the subject of poor reliability of water supplies in developing countries is one that is all too familiar. Even where basic water supply infrastructure exists, in many developing countries water services are characterised by low pressure, intermittent supply and poor water quality (Vásquez et al., 2009). A third of hand-pumps in rural parts of sub-Saharan Africa are reported to be non-functional (Rural Water Supply Network, 2009), and in urban parts of south and south-eastern Asia piped water is available for only a few hours each day (IBNET, 2011).

Piped water supplies may be contaminated due to fluctuating pressure in distribution systems, or poor storage and handling practices during supply interruptions (Kumpel and Nelson, 2013) or households may be forced to revert to unsafe water sources [Appendix 1.1 (Majuru et al., 2011)], resulting in diarrhoeal illness. But the impacts of unreliable household water supplies are not limited to health; livelihoods are affected (Hunter et al., 2010), and households incur significant costs that arise from the coping strategies employed to avoid or mitigate these consequences (Pattanayak et al., 2005).

Despite its significance, water supply reliability is not addressed in the current MDG indicators; a major obstacle to its inclusion being the lack of consensus on the definition and assessment criteria for reliability of water supply (WHO/UNICEF, 2012). While much has been written on the subject, the notion of reliability in water supply has remained rather nebulous. For the households that are continually faced with the task of obtaining sufficient quantities of safe water, what constitutes a reliable supply?

An equally important issue is how households respond to, or cope with unreliability. Most studies on this topic have focused on assessing coping costs as indirect estimates of willingness to pay for water service improvements (Widiyati, 2011, Mycoo, 1996, Dutta and Tiwari, 2005) and have been conducted mainly in urban settings. Overall, these studies have highlighted that households are willing to pay for improved and more reliable water services, although the amount varies widely.

However, the dominance of this ‘means to an end’ approach, in which household coping strategies are assessed for the sole purpose of determining willingness to pay for improved services, has meant that relatively little attention has been devoted to understanding the underlying perceptions of water supply reliability that enable the adoption of specific coping strategies, and much less so the policy arena in which water services are located. Further, few studies have drawn on any structured research into household strategies to cope with unreliable water supplies in peri-urban and rural areas. This thesis examines household experiences of unreliable water supplies in South Africa, and in particular, explores the notion of reliability in water supply, and household strategies to cope with unreliable water supplies.

1.2 Study objectives and methods

The absence of an agreed upon definition of water supply reliability has important implications on monitoring of progress on the global development agenda, and the ability to translate the findings of such monitoring into effective policy interventions. Without a clear indication of the extent of the problem and where the most affected areas are, it is difficult to target interventions to mitigate the effects of unreliable water supplies. Further, knowledge of the extent of unreliability is of limited relevance if it is not completed by an understanding of what unreliability in water supply means to households, and how they cope with it. What deficiencies in the supply are they compensating for; in what ways do they compensate; and how effective are these compensating / coping strategies? Such knowledge is relevant to both practice and policy in the interdisciplinary areas of water, health and development, where it can contribute to the formulation of improved policy, and evidence for practice.

The objective of this study is to investigate households' experiences of and responses to unreliable water supply. Specifically, the study seeks to address the following questions and sub-questions:

- What is a reliable household water supply?
  - How is reliability defined and assessed?
  - What attributes of water supply reliability do households value?
- How do households respond to unreliable water supplies?
  - What coping strategies do households employ?
  - What are the costs of coping with unreliable water supplies?

The study uses a combination of literature reviews and empirical survey data from peri-urban communities in South Africa to address the research questions. The reviews of both grey and peer reviewed literature provide a broader research context for the study, focusing on the assessment of water supply reliability, and household responses to unreliable water supplies. Analyses of the survey data allows for a more localised, and perhaps more nuanced perspective. Discrete choice analysis is employed to assess household preferences for water supply reliability. The survey dataset includes information on household coping strategies and coping costs, which are also analysed. This quantitative data is complemented by qualitative data from key informant interviews with water supply technicians in the study area. The data from the interviews are used to provide a service provider perspective of the water supply systems and problems with water provision in the study area.

1.3 Contribution of the thesis

The need for consensus on a definition and assessment approach for water supply reliability is articulated in the 2012 update on the MDG target for drinking water, and efforts are underway to refine the monitoring indicators for the post-2015 development agenda (WHO/UNICEF, 2012). The review of definitions and assessment for water supply reliability represents a timely contribution to the ongoing policy debate about indicators in the post-2015 development agenda. Related work in this area has reviewed reliability only in part; within a broader concept of water security (Bradley and Bartram, 2013), and as a component of a monitoring index (Kayser et al., 2013). The review presented herein – to my knowledge – is the first to focus solely on reliability.

The discrete choice experiment complements the review by providing a user perspective of the concept of reliability in water supply. As will be covered more extensively in Chapter 5, the few discrete choice surveys that have focused on water reliability have been conducted mainly in developed countries. The even fewer studies that have been conducted in developing countries have been in urban settings. The discrete choice experiment in Chapter 6 contributes to the thin empirical literature in non-urban settings in developing countries.

If effective interventions are to be designed to target the consequences of unreliability, an understanding of household responses to unreliability is required (Kudat et al., 1993). To my knowledge, the review in Chapter 7 is the first to synthesise existing literature on household strategies to cope to with unreliable water supplies. As with the discrete choice experiment, the survey of coping strategies in Limpopo adds to the limited literature covering this topic in non-urban settings in developing countries.

1.3.1 Why South Africa?

The setting of the survey in South Africa provides a particularly interesting vantage point for several reasons. In 2010, 97 % of the country's population was reported to have access to basic water supplies. However, as stated in the Department of Water Affairs' 2009/2010 report, these figures "only reflect infrastructure provided and do not reflect quality of ongoing service provision" (Department of Water Affairs, 2010a). Peri-urban and rural communities in particular are still challenged by significant problems in the quality of water services (Statistics South Africa, 2011), and provide an opportune setting for studying household water supply beyond the dichotomous view of whether or not access is provided.

South Africa's legislative and policy framework for water services is widely lauded as being among the most progressive in the world (Tissington et al., 2008). Driven by equity concerns in the provision of water services, the country's Free Basic Water policy provides each household with a free minimum water allowance of 6,000 ℓ per month (Department of Water Affairs, 2007). The uniqueness of the policy, Szabo (2009) notes, lies in that the water is actually free, unlike in other settings where the term is used loosely to describe a fixed fee for the first units of water. Ostensibly, the Free Basic Water policy guarantees that the minimum water requirements of the poorest households – most often in peri-urban and rural communities – are met. But when the water supply is unreliable, how 'free' is Free Basic Water?

1.3.2 Previous work

The study is largely driven by my previous experience in working on water and health in South Africa. As a masters' student, my dissertation was part of a larger project that had been commissioned by the South African Water Research Commission. The overall aim of the project was to measure the benefits of water supply and sanitation service provision, since the end of apartheid (Jagals, 2012).

My MSc dissertation assessed whether upgrading water supply systems in rural communities in Limpopo Province improved water service attributes of access (distance and time to source), availability (quantity of water available and reliability of supply) and potability (microbial water quality) (Majuru, 2010). Although there were remarkable improvements in access to water sources (distances and collection times greatly reduced), the associated benefits, such as having sufficient quantities of water and improvement in water quality were minimal (Majuru et al., 2012). The water supply was unreliable, and in the most affected communities diarrhoeal illness rates were relatively high (Majuru et al., 2011). The role that poor reliability played in undermining the impact of these water supply interventions drove my interest in the topic.

1.4 Scope and definitions of terms

This study uses literature reviews and empirical analyses to addresses reliability of water supply and households' responses within a number of boundaries. First, the literature on water supply in developing countries is often interspersed with terms such as *sustainability* and *reliability* and other synonyms. Although these terms are often used interchangeably in the literature, a distinction is made between the two in this thesis, to avoid ambiguity. Sustainability, in the context of this thesis, refers to the capacity of water supply systems to continue to provide intended health, social and economic benefit to recipients in a manner that has no significant environmental, economic and social adverse effects (Barnes, 2009). The term encompasses aspects such as the renewability of the water resource, financial, administrative and technical capacities in managing the resource, as well as cultural and political dimensions (Carter and Rwamwanja, 2006). The scope of this thesis is limited to quality of the water supply service i.e. *reliability* and focuses on the operational performance of water supply and the ability of the supply to meet household water needs. While Chapter 2 outlines the reasons behind poor water supplies in the communities surveyed, a full discussion of why water supplies in developing countries are unreliable lies beyond the scope of this thesis.

The study is limited to domestic water supply in developing countries. ‘Developing countries’ are as defined by the World Bank’s country classification for 2011 (World Bank, 2011). Although the empirical work presented is based exclusively on data collected from South Africa and may be site-specific, the implications of the findings can be understood as broadly applicable to developing country settings.

The term ‘peri-urban’ as used in this thesis refers to communities that are in a sense, transitional between rural and urban. In such communities, the population density may be higher than is typical of rural communities, with livelihoods characterised by a mix of small-scale agriculture, informal economies and migrant labour. The presence of urban characteristics such as paved roads, street lighting and sewerage may also be low (Iaquinta and Drescher, 2000, United Nations Children’s Fund, 2012).

1.5 Structure of thesis

The nine chapters in this thesis are organised into four parts. Part 1 is an introduction to the thesis, and provides some background to the study. The two main research questions are addressed in Parts 2 and 3, and Part 4 concludes the thesis.

The present chapter has given an overview of the study; outlining the gaps in existing knowledge and study objectives. The following three chapters in this part of the thesis continue to sketch a background of the thesis. Chapter 2 sets the scene by providing an overview of the existing policy and institutional frameworks contextualising water supply services in South Africa. It further describes the study communities in the Limpopo Province of South Africa, and their water supply systems. The findings from key informant interviews provide useful insights of the context of water supply problems in the study communities. An overview of the data and methods used in the study, as well as the sampling procedures, data handling and methods of analysis is presented in Chapter 3. Key variables used in the analyses of survey data are also introduced. In Chapter 4, the demographic characteristics of the study sample, as well descriptive statistics of the key variables are presented.

Part 2 addresses the question as to what constitutes a reliable water supply. Chapter 5 considers this question in a broader context, through a literature review of the definitions and assessment criteria used in studies on water supply reliability. The review highlights that despite the importance of the subject and the number of studies that have been conducted, consensus on what is meant by water reliability and how it should be assessed is lacking. Chapter 6 presents a more local perspective, exploring household preferences for water supply reliability in the study communities in Limpopo. Most notably, the results of the discrete choice analysis are useful in highlighting the value that households place on notification of interruptions.

Part 3 is aimed at investigating households' responses to unreliable water supplies. Chapter 7 begins with a conceptual background around coping with unreliable water supplies, noting some of the early work on the topic. The literature on household coping strategies is then examined, including the factors that influence choice of coping strategy, costs of coping and welfare outcomes associated with coping. Chapter 8 presents the results of the survey on household strategies to cope with unreliable water supplies in Limpopo, including household coping costs, and the ability of household to meet minimum water requirements. The chapter explores whether Free Basic Water is in fact 'free', and the extent to which 'basic' water requirements are being met.

Part 4 gives an overview of the thesis, in which the study objectives and related main findings are reviewed, as well as its strengths and limitations of the study. The synthesis chapter, Chapter 9, offers comment on the implications of the work presented, and some recommendations for future research.

2 Setting the waterscape

Before turning to the existing state of water supplies services in the study area, it is important to outline the context within which these services are located. This chapter outlines the history of water supply services in rural South Africa, and provides a brief background of the policy, legislative and institutional frameworks that have shaped water supply services in the country. The chapter serves as policy reference point for the empirical work presented in the thesis. The study area is then described, and the chapter concludes with an overview of the state of water supplies in the area.

2.1 An overview of water supply services in South Africa

The Republic of South Africa was established in 1994, when the apartheid era of white minority rule was abolished. In the 2011 census, the country's population was estimated at just below 52 million (Statistics South Africa, 2012b), and the Human Development Index ranking for 2012 is 121 out of 187 countries. GDP per capita (PPP) was US$9,594 and life expectancy for both men and women was 53.4 (United Nations Development Programme, 2013). The country boasts the largest and most industrialised economy in Africa, with an estimated two thirds of the population now living in urban areas.

Despite being one of the emerging economic powerhouses along with China, Brazil, Russia and India, huge socio-economic inequalities exist between urban and rural areas. In 2010, 66 % of households in urban areas sourced their main income from wages and salaries, compared to 43 % in rural areas. A third of rural households depended on remittances and social grants or pensions, and two thirds survived on less than $2 a day (Turok, 2012). As in most other countries, a major reason for these inequalities is the differences in economic opportunities in urban and rural areas, and particularly in South Africa, the aftermaths of the apartheid era.

2.1.1 The legacy of apartheid

When the country's first democratically elected government came into power in 1994, they inherited substantial backlogs in public services, of which water supply is a prime example. An estimated 12 million people – close to one third of the country's population – were without adequate supply to drinking water (Republic of South Africa, 1994).

The majority of those without water supply services were in rural areas formerly known as ‘homelands’ or ‘reserves’. These homelands were administrative territories created by the apartheid government in which the country’s African ethnic groups were made to settle in (Van Koppen et al., 2005). Much of the land in the rural areas was infertile, limiting the potential for self-sustaining economic activity.

Control over water resources was unequally divided between the white central government and the black ‘homelands’, which comprise most of rural South Africa. While the central government invested heavily in infrastructure and services in white communities, the black rural areas remained largely underdeveloped (Tissington et al., 2008). In these areas, the management of water supply was under partial control of local chiefs and tribal councils. Because of the systematic underdevelopment and consequent poverty in these areas, water and other public services were heavily reliant on whatever finances were provided by the central government (Cothren, 2013).

2.1.2 Legislative, policy and institutional framework

Since 1994, water service provision in the country has focused on extending water services to rural areas where they were previously non-existent, and improving / upgrading existing water services that are rudimentary. To facilitate this process, the government set about establishing various legislative, policy and institutional frameworks for water services as summarised in Table 2.1.

The Reconstruction and Development Programme (RDP) is viewed as the major statement of intent by the post-apartheid government in tackling the huge inequities that existed in the country. As the blueprint for socio-economic development, the RDP aimed to redress social, economic and spatial inequalities that existed in various public services, infrastructural development etc.

Table 2.1: Main legislative and policy documents relating to the provision of water supply services in South Africa

Document	Brief description of objective
White Paper on Reconstruction and Development Programme (1994)	Sets out the framework for socio-economic policy in post-apartheid South Africa
White Paper on Water Supply and Sanitation Policy (1994)	Sets out policy and institutional goals related to water services
Constitution of the Republic of South Africa (1996)	Establishes access to water as a human right, and binds national, provincial and local government to the realisation of the right
Water Services Act(1997)	Legislates access to water by clarifying the role of water services institutions
National Water Act (1998b)	Governs water resource management by legislating the way in which water resources are protected, used, developed, conserved, managed and controlled
Municipal Structures Act (1998a)	Provides for the establishment of municipalities in accordance with the requirements relating to categories and types of municipality and to provide for an appropriate division of functions and powers between categories of municipality. The Act allocates the responsibility for water services to the District Municipality or the local municipality if authorised by the Minister of Provincial and Local Government.
Municipal Systems Act (2000)	Outlines the specific duties of and requirements for municipalities, and distinguishes between the functions of a water service authority and that of a provider. It also identifies the importance of alternative mechanisms for providing municipal services and sets out certain requirements for entering into partnerships.
Strategic Framework for Water Services(2003)	Sets out the national framework for water services, including norms for water service coverage and quality and aligns policies, legislation and strategies in the provision of water services
Free Basic Water Implementation Strategy (2007)	Targets water needs of poor household by guaranteeing a free minimum quantity of water
National Water Services Infrastructure Asset Management (IAM) Strategy (2010b)	Establishes DWA as sector leader in guiding and empowering water service institutions in management of water service infrastructure and assets, and ensuring optimal utility from water service infrastructure through reliable and sustainable service provision
National Water Services Regulation Strategy (draft) (2010c)	Establishes DWA as national regulator of water services, whose objective is the protection of the consumer and public interest

The RDP set out a three-phase programme for universal water services in South Africa. In the immediate term, the programme aimed to ensure that all households had access to at least 20-30 litres of water per capita per day (ℓcd), and within 200 m. Thereafter, the medium term goal was to provide on-site supply of 50-60 ℓcd and in the long term, supply on demand (African National Congress, 1994). The White Paper on Water Supply and Sanitation Policy gave effect to the RDP immediate term goal of supplying 20-30 ℓcd within 200 m, as a minimum standard for basic water supply (Smith, 2009). The right to water is enshrined in the constitution, whose Bill of Rights state that everyone has the right to have access to sufficient water (Republic of South Africa, 1996). The Constitution binds national, provincial and local government to realise this right.

Along with water policy and legislation, the institutional frameworks for provision of water services in South Africa also underwent transitions. While water services were heavily centralised under the apartheid government, the present day approach is to shift the delivery and management of these services from national to local government. The national government has the responsibility of establishing frameworks that enable the realisation of the right to water, while local government is tasked with the actual delivery of water to communities (Gowlland-Gualtieri, 2007).

At the level of local government, Water Service Authorities (WSAs) are responsible for ensuring access to water services within their area of jurisdiction. A WSA may be a metropolitan, district or local municipality, or a rural council. The operational responsibility of providing water services in the WSA’s area of jurisdiction lies with a Water Services Provider (WSP). WSAs may perform the functions of the WSPs themselves, contract an external entity to act as WSP or set up a joint venture with another water services entity to provide water services (Republic of South Africa, 1997). For instance, the City of Cape Town acts as both the WSA and the WSP within its area of jurisdiction, while in Durban, Ethekwini Metropolitan Municipality is the WSA and Umgeni Water is the WSP.

Under the mandate of the Constitution and the Water Services Act, the national Department of Water Affairs (DWA) monitors the performance of all water service institutions. The specifics of this role have been somewhat unclear until the recent drafting of the National Water Services Regulation Strategy (Department of Water Affairs, 2010c). The main objective of the Strategy is stated as “the protection of the consumer and public interest” (Department of Water Affairs, 2010c). The Strategy outlines DWA’s role as the national regulator of water services, and tasks the departments with providing support and encouragement for performance improvement of WSAs. WSAs themselves have a regulatory function at local level, by ensuring good performance of their WSPs who are tasked with the operational responsibility of providing water services.

The decision surrounding the institutional arrangements for the provision of water services is governed by Section 78 of the Municipal Systems Act, which describes the process of delineating or appointing a WSP. Essentially, the process entails a status quo assessment of the municipality's infrastructure, water resources, financial resources and institutional capacity. Internal service delivery mechanisms are then assessed, and a decision is then made as to whether the services should be provided internally or externally (Tissington et al., 2008).

2.1.3 Funding mechanisms

With the devolvement of power to local government, municipalities now bear the financial and technical responsibility of providing water services. Much of the focus has been on eliminating backlogs in water services. While most urban municipalities can generate sufficient revenue from internal tariff cross-subsidies, in rural municipalities where a substantial proportion of households may be poor the situation is problematic.

Unlike many other countries in sub-Saharan Africa that have relied strongly on donor funding, South Africa has largely funded water supply and sanitation programmes itself (Water and Sanitation Program, 2011). To facilitate the elimination of service backlogs, the national government provides various grants, the main ones being the Municipal Infrastructure Grant (MIG) and Equitable Share (EQ). The Municipal Infrastructure Grant (MIG) is a conditional grant for capital investment. Specifically, the grant is designed to fund the capital costs of providing basic service infrastructure for poor households, with the ultimate goal of removing backlogs in basic water services by 2013 (Department of Water Affairs and Forestry, 2002).

The Equitable Share (ES) is intended to subsidise operating costs, particularly for poor households. The subsidy contributes to the general operating budget of municipalities in which the operational costs of delivering water services exceeds the amount that is billed to poor households. The grant is unconditional, thus municipalities are not obliged to report how it is allocated or spent (Department of Water Affairs and Forestry, 2002, Tissington et al., 2008).

2.1.4 Free Basic Water services

The implementation of the subsidies for poor households is through the Free Basic Water (FBW) policy. Prior to 2001 when FBW was implemented, all water consumed had to be paid for, which meant that even with the extension of water services to previously un-serviced areas, the services remained out of the reach of poor households.

FBW was introduced to ensure that all households, particularly the poor, households have access to water supplies. Under the policy, each household receives a 'basic' supply of 6,000 litres of water free of charge each month. Assuming an average household size of 8 persons, this equates to 25 litres per capita per day (ℓcd), and consumption above this amount incurs charges (Department of Water Affairs, 2007). In rural areas and informal settlements where the common mode of supply is communal taps, it is assumed that households are unlikely to use over 6,000 ℓ per month, thus water is not charged for.

In essence, the FBW policy subsidises the operation and maintenance costs of providing a *basic water supply service*, which is defined as the provision of *basic water supply infrastructure*, its sustainable operation and the communication of good water-use, hygiene and related practices. The sustainable operation is qualified as the availability of water for at least 350 days per year, with interruptions not exceeding 48 consecutive hours per incident (Department of Water Affairs, 2003).

Basic water supply infrastructure is in turn defined as infrastructure necessary to supply 25 ℓ of potable water per capita per day, within 200 m of the household and at a minimum flow rate of 10 ℓ/min in the case of communal water supplies. In the case of yard or household connections, the quantity is 6,000 ℓ of potable water supplied to each formal connection per month (Department of Water Affairs, 2003).

At the time of writing (May 2014), the Department of Water Affairs is in the process of reviewing its water policies, including the Free Basic Water policy (Department of Water Affairs, 2013). The proposed changes would see a shift from providing the basic allocation to all households, to a targeted approach in which the Free Basic Water is provided only to indigent households.

2.1.5 Cracks in the rural water service pipeline

With these policy, legislative and institutional frameworks in place, it is perhaps unsurprising that South Africa's approach to water resources and service provision has been widely lauded as being among the most progressive in the world (MacKay et al., 2004, Movik, 2011, Tarmann, 2000). However, closer scrutiny suggests that the situation on the ground is rather complex. In theory, access to water is recognised as a human right, and equity in service provision is emphasised as being imperative to alleviating poverty, improving health and promoting economic development. In reality, controversies exist over whether these policies have actually translated into tangible improvements, particularly for previously marginalised poor rural households.

The reasons for these controversies are diverse, but perhaps of greater interest to the study presented herein are those relating to FBW and the reliability of rural water supplies. The definition of basic water services sets out criteria for quantity, distance, quality and reliability, and the Department of Water Affairs (DWA) is tasked with the overall monitoring and national regulation of the water services. In reality, such regulation on the part of DWA appears to predominantly focus on the monitoring of water quality in urban areas, and much of the regulation of other aspects of water services is left to local municipalities (Tissington et al., 2008).

In turn, the overriding concern of rural municipalities appears to be meeting the distance criterion by providing infrastructure within 200 m. In some rural communities of Limpopo, the 25 ℓcd allocation is not met, water supply is unavailable for weeks on end and the quality of water consumed at the point of use does not meet national drinking water quality standards, but the majority of taps are within 200 m (Majuru et al., 2012). According to the Department of Water Affairs, although 97 % of the country population were reported to have access to basic water supplies by 2010, "the figures only reflect infrastructure provided and do not reflect quality of on-going service provision" (Department of Water Affairs, 2010).

Although the microbial quality of water supplied at the communal taps generally meets national standards, the quality at the point of use often does not, due to re-contamination of the water during transportation, handling and storage. The DWA maintains that its responsibility in relation to monitoring of water quality ends at the tap as the point of use, and in the case of communal water sources the responsibility of ensuring safe water quality beyond the point of collection lies with the Department of Health (Swart, 2013). However, it is not clear how, and the extent to which this responsibility is carried out by the Department of Health.

In relation to water quantity, it is perhaps worth reiterating here that the 25 ℓcd allocation was only intended as an initial target to ensure that there was “some for all, rather than all for some” (Republic of South Africa, 1994), particularly for rural areas that had previously had no water services at all. Thus, rural water supply projects were to be constructed in consultation with communities and with the capacity for upgrading, in accordance with communities’ desires for higher levels of service (Department of Water Affairs, 2003, Republic of South Africa, 1994).

However, in many rural water supply projects the 25 ℓcd has become a *de facto* maximum; projects are constructed with permanent assumptions of 25 ℓcd and relatively constant populations (Bond and Dugard, 2008). The potential for service upgrade is limited by the use of small pipes, low abstraction capacity in the case of groundwater resources and communal sources. In some municipalities, even households that can afford to upgrade to a higher level of service such as a yard or in-house connection are discouraged from doing so as it diverts the focus from meeting backlogs in basic services (Tissington et al., 2008). As a result of these frustrations, vandalism and hosepipe connections from the communal taps are not uncommon.

In a country in which an estimated 10 % of the population were living with HIV in 2013 (Statistics South Africa, 2013a), the adequacy of the FBW allocation for basic domestic needs, let alone the increased hygiene needs of those who may be ill, has been heavily criticised (Smith, 2009).

The potential for productive use of water and livelihoods under this 25 ℓcd allocation is also slim. The limited evidence on water and livelihoods suggests that a supply of 50-150 ℓcd within 150 m is the level of service at which significant productive use of water occurs (Smits et al., 2010). Even then the water supply has to be reliable, which has been difficult to achieve in rural water supplies in the country.

The often cited reason for unreliability of rural water supplies is the limited potential for cost recovery from largely poor households. Although funding such as the Municipal Infrastructure Grant and Equitable Share can still be drawn from national government, municipalities are increasingly being urged to become financially self-sufficient and implement cost-recovery mechanisms (Tissington et al., 2008). Ironically, while allowing for productive uses in water supply is likely to improve the ability of rural households to pay for water services or at the very least contribute towards the maintenance of the water supply systems (International Water Management Institute, 2006), there is a reluctance to move these households up the service ladder.

The resulting implication is that by restricting rural / peri-urban households to the minimum level of service, this perpetuates the cycle of households not being able to generate livelihoods from the water supply, poor or even no cost recovery for water service providers, and unreliable water services. Thus, for many rural households, the viability of free basic water supply services as a poverty alleviation and health promotion mechanism is yet to be proven.

2.2 The study area

The study is set in the Vhembe District of Limpopo Province, in the northern parts of South Africa (Figure 2.1). The district is largely rural, and consists of two territories that were the former homelands of Venda and Gazankulu. According to the 2011 census, the estimated population of the province is just over 5,4 million (Statistics South Africa, 2012b), making up almost one tenth of the country's total population.

Figure 2.1: Map of South Africa and location of Limpopo Province
Source: http://www.bbc.co.uk/news/world-africa-11532759

The median age in the province is 22 years; slightly below the national median of 25. A quarter of the persons aged 15 years or older are functionally illiterate i.e. they either have no schooling, or their highest educational attainment is less than Grade 7, which is the highest level of primary schooling in the country.

The average household size in the province is 3.8 (Statistics South Africa, 2012a). Households in the province have the lowest average annual income of R56,844 (US$6,633), compared to the national average of R103,204 (US$12,042[1]). A third (33.1 %) of this income is from social grants[2] and almost one fifth (17.7 %) is from remittances[3] (Statistics South Africa, 2013b).

Access to piped water in the yard/ dwelling in Limpopo Province is among the lowest in the country. While results from the 2011 census indicate that 73.4 % of the country's population had piped water within the yard / dwelling, in Limpopo Province just over half (52.3 %) of households have piped water in the dwelling or yard, 33.7 % have piped water outside the yard, and the remaining 14 % are reported to have no access to piped water (Statistics South Africa, 2012b). Diarrhoea remains the leading cause of death among children aged under 5 in the country, and in Limpopo Province accounted for 22 % of deaths in the period 2006-2009 (Statistics South Africa, 2012e).

2.2.1 The study communities

The communities in which the study was conducted are located in the peripheries of Makhado town, formerly known as Louis Trichardt. The town lies at the foot of the Soutpansberg Mountain Range, on the main route linking South Africa to Botswana, Mozambique and Zimbabwe.

Rainfall is low and temperatures relatively high in the areas west of Makhado and north-west of the mountain range, with the vegetation mainly being savannah plains and thorn bushveld. East of the town, temperatures are mild and rainfall relatively high, with lush sub-tropical vegetation. Game and cattle ranching, forestry and farming of sub-tropical fruits such as avocados, litchis and bananas are the main agricultural activities (Makhado Municipality, Unknown).

[1] Exchange rate in 2012 of US$1: ZAR8.57
[2] Social grants refer to welfare support for older persons, people with disabilities, war veterans, care dependents, foster children and general child support.
[3] Remittances refer to money transfers from family members

The three study communities can be described as transitioning from rural to peri-urban. Formerly part of the Venda 'homelands', the communities now fall under the jurisdiction of the greater Makhado Local Municipality, and have strong urban influences. Due to the close proximity and ease of access to Makhado town, the communities are expanding rapidly. Settlements are relatively dense, as an increasing number of people opt to commute from these areas to work in Makhado town centre.

2.2.2 Communities 1 and 2

Communities 1 and 2 are located in the areas known as Sinthumule-Kutama, approximately 9 kilometres south-west of Makhado town. The area is dry, and comprises about 19 villages spread over 19,000 hectares of flat plain (Wainwright, 1983). The groundwater is saline and has high nitrate concentrations (Wainwright, 1983). High calcium and magnesium content also make the water hard, and incrustation of water pipes is a recognised problem in the area (du Toit, 2002).

Water sources in the study communities are generally those classified as improved sources, according to the WHO/UNICEF Joint Monitoring Programme for water and sanitation (WHO/UNICEF, 2011). Shared water supplies in the area are in the form of communal taps (Figure 2.2). The water supply is drawn from groundwater that is accessed through several boreholes that have been drilled around the communities.

Figure 2.2: A communal tap in Community 1
Source: Author

From these boreholes the water is pumped to three reservoirs in the area. The water is then chlorinated while in the reservoirs, before being distributed under gravity feed to communal taps though a network of pipes. There are 28 communal taps in Community 1, and 57 in Community 2. Vhembe District Municipality is the water service authority, and Makhado Local Municipality is the water service provider. This means that while Vhembe District Municipality is responsible for providing access to water services in the area, the operational responsibility of delivering the water supplies lies with Makhado Local Municipality. Because the supply from the communal taps is intermittent, the two communities also have water delivered by a municipality tanker each week. The tanker draws treated water from Makhado town on a given day and, over several trips, delivers water around the communities. Households queue up at designated spots and collect water from the tanker in an assortment of containers; including 20-ℓ plastic jerry cans, buckets and 5-ℓ bottles.

Figure 2.3: Drilled well and storage tank in Community 2
Source: Author

Some households in the area have privately set up boreholes in their yards. Water abstracted from these boreholes is pumped to a storage tank (Figure 2.3), which may be connected to a yard tap or to taps in the house. Due to the high salinity of the groundwater, some of these households who have privately drilled boreholes rely on municipal tanker supply for their drinking water, and use the water from the boreholes for domestic purposes other than drinking.

2.2.3 Community 3

Community 3 (C3) is located north-east of Makhado town, in the area known as Tshifhire-Maleula. The area is hilly, with lush vegetation, numerous springs and frequently enveloped in mist rolling off the tops of the Soutpansberg mountain range.

Public water sources are communal taps and protected springs. The community has a small treatment plant (Figure 2.4) which draws raw water from a river in the area. The water is diverted to a weir close to the plant, from where it is pumped up for treatment.

Figure 2.4: Water treatment plant in Community 3
Source: Author

There are 27 communal taps in the area. Because of the hilly terrain, the municipal supply does not reach some of the households that higher up along the hills. These households rely on protected springs as their main source of water. ‘Private supply’ in Community 3 consists of households with municipal connections into the yard / house, or those that have privately connected pipes from the protected springs in the area to storage tanks in the yard.

2.2.4 Water supply problems in the study communities

From interviews with water supply technicians in the study communities, several factors affecting the water services were cited. In Communities 1 and 2, the main problem cited was that the boreholes that supply water to the community reservoirs often do not function well. Depending on the size of the reservoir, filling it up can take up to four days if there are problems with one or more of the boreholes. According to the technician, none of the boreholes can go for three months without breaking down. Once broken down, repairs are often late in coming. The boreholes are managed by the Vhembe District Municipality (Makhado Municipality, 2012).

Apart from the machinery breaking down, vandalism and theft of cables and transformers linked to the pumping devices are also common. Further, because the groundwater in the area is hard, water pipes often become blocked from the build-up of minerals.

In Community 3, the major problem cited was that the plant capacity is only 864 ℓ, which is insufficient to supply the entire community. In order to boost the water supply, staff at the treatment plant work in 24-hour shifts. Even then, the water is not enough to meet the needs of the estimated 12,900 people living in the community. Further, there are not enough booster pumps in the distribution network to ensure that the water is of sufficient pressure to reach households located further up on the hills.

As in Communities 1 and 2, vandalism and theft of plant machinery and cables also pose significant problems for the community's water supply. Many of the copper faucets on the communal taps and other metallic parts in the distribution network are stolen and sold to scrap metal dealers.

Agricultural activities and waste management practices in the area also impact on the operation of the treatment plant. Many households in the area cultivate avocados for commercial purposes. However, because the terrain is hilly, a lot of the surface run-off that occurs in the rainy months of November to March ends up in the river from which the plant's raw water is drawn. The water becomes highly turbid, which the plant is not designed for. Treatment is suspended until most of the sediment has settled in the bottom of the weir and the water is clearer. At the time of the interview, the water in the weir was indeed muddy (Figure 2.5) and plant operations had been suspended until the mud settled.

Figure 2.5: Weir in Community 3
Source: Author

In relation to waste management, the major issue cited is that waste material such as plastic bags and disposable nappies end up in the river, and consequently block pipes at the canal. At the time of the interview, the community had recently been without water, due to pipes in the weir being blocked, and the pumps that draw water into plant not working properly. The Department of Water Affairs' Vhembe District office had been informed, and they in turn had sent out a contractor to fix the problem. The contractor had unblocked the pipes, but replaced the pumps with those that were equally faulty. From the time that the pipes got blocked to the time the problems with the contractor were resolved, the plant had not been operating for six weeks.

Conclusions

This chapter has outlined the transitions that have taken place in relation to water service in South Africa since 1994. These transitions have been facilitated by legislative, policy and institutional frameworks which seek to achieve the goal of universal and equitable access to water in a progressive manner, particularly in rural communities. Laudable as these reforms are, their implementation has been problematic. The chapter locates these problems within the Free Basic Water policy which appears to have stagnated at providing basic water supply infrastructure with the quality of services receiving less consideration.

3 Methods

This chapter lays out the general research strategy and techniques applied in addressing the empirical component of the study. The survey design, sampling process and key variables are described. Some general information about data collection and analyses is outlined; the specific methods are detailed in each chapter as appropriate. The chapter concludes with an outline of the preliminary statistical analyses for the key variables.

3.1 Background

The data for the study were collected alongside that of a larger multi-country study funded by the United Kingdom's Department for International Development (DfID) in Ghana, South Africa and Vietnam. My involvement in the DfID study and how it relates to the study presented herein are outlined in the following sections.

The DfID study was aimed at assessing whether at-house / in-house water supplies have significantly greater health, social and economic benefits than shared / communal water supply (Evans et al., 2013). Of key interest therefore, was the relationship between water source (in / at-house or off-site), usage and selected health and socio-economic outcomes.

This relationship is complex and often is mediated by various factors. In my involvement with the DfID study, I specifically sought to address the role that water supply reliability plays in this relationship. I contributed to the design of the study and the development of survey instruments. The same survey instruments were used in the data collection in the three study countries. I was responsible for the management of the fieldwork in South Africa, where I assisted in training the fieldworkers and then supervised the data collection and management.

The data for the study were collected in collaboration with Tshwane University of Technology (TUT), a South African university based in Pretoria. Under the collaboration TUT provided local support relating to liaison with communities and recruitment of field assistants. My current involvement with the DfID study is in data analysis, writing the report to DfID (Evans et al., 2013) and subsequent publications.

The DfID study upon which this thesis is built essentially tests the association between level of water service (at / in-house and communal water supplies) and selected health, social and economic outcomes in the three study countries. The empirical work presented in this thesis is complementary to the DfID survey in South Africa, and explores reliability in more detail, by exploring households' preferences for reliable water supplies, strategies to cope with unreliable supplies and the consequent implications for the country's Free Basic Water policy.

3.2 Research strategy

The study design was a mixed-methods cross-sectional survey, utilising a variety of data collection techniques. Quantitative research methods used were: structured and semi-structured questionnaires on household characteristics, health, coping strategies and coping costs; and discrete choice surveys to elicit households' preferences for reliable water supplies. Qualitative methods were used to collect background information on the study area, and included key informant interviews with operators of water treatment plants, and structured community observation sheets.

Designing a research study entails a number of decisions and is often a balancing act of competing needs, a prime example being the need to balance project resources with the scope of enquiry. While it would have been ideal to investigate water supply reliability over a longer period of time in each of the three study countries, this was not feasible within the project budget. Due to the same practicalities, the study presented in this thesis is embedded within the broader design of the DfID study. The study also draws on some of the complementary data from the DfID study, such as households' socio-economic profiles and existing water services.

3.2.1 Sampling

The basic sampling unit in the study was the household, as all members of the household would likely share the same water sources. The term 'household' requires some clarification here, as it can have significant implications on measures such as water consumption and household wealth.

In the study setting, households can be made up of nuclear, multigenerational or extended families. Owing to migration to urban areas, a number may be further classified as 'split households', in which family members who would 'normally' be living in the same residence actually live elsewhere. In the survey, a household was defined as a group of people who lived and ate together. To account for visitors or migrant family members, persons usually residing in the house for less than six months of the year were excluded from the analyses.

3.2.1.1 Sample size

Because the DfID study had multiple outcomes of interest (binary, count and scalar), the sample size was computed to account for these different outcomes. A sample size of 200 households was deemed sufficient to detect an outcome affecting 10 % of the population using a power of 80 %, and a significance level of 5 %. A detailed explanation of the approach used in determining this sample size is included in Appendix 3.1.

With the difference between in / at-house and communal water supplies underpinning the study, sampling from a general population would unlikely provide sufficient resolution for this comparison. The need to sufficiently balance this mix in level of service with ability to generalise findings was met through semi-purposive selection of the study site, followed by stratified random selection of households.

3.2.1.2 Site selection

Selection of the study site was based on a number of methodological and practical considerations. The criteria for selecting the study site were as follows:

- Representation of peri-urban and / or rural areas in which people are provided with a variety of water supply service levels and technologies i.e. private and shared water supplies;
- The location of homes and water source points used by the community have been or can be readily mapped;
- Established working relationships with a core institution;
- Permission to access and work in the area is granted by the appropriate local authorities, community members generally willing to participate in the study.

Of key importance in the DfID study was that the selected site would exhibit the various levels of water services i.e. shared / communal water supplies, in-house connections or yard connections, while still being broadly comparable to other poor communities in the country and region.

Vhembe District, located in the Limpopo Province of South Africa, was an opportune setting for a number of reasons. The province itself is mainly rural, and until fairly recently, had substantial backlogs in water and sanitation service provision (Department of Water Affairs, 2011, van der Merwe, 2011). According to the results of the 2011 census, 43.5 % of households in Vhembe District have access to piped water in the yard /dwelling compared to the national average of 73.4 %. The majority (44.8 %) access water outside the yard/dwelling and the remaining 11.7 % have no access to piped water (Statistics South Africa, 2012a).

An understanding of the local context is a key component in any field study and perhaps more so when working across cultures and languages. I have previously been involved in environmental and epidemiological research in various parts of the district through Tshwane University of Technology in South Africa, where I obtained my previous qualifications. In the process, I had also visited the study communities investigated in this thesis and owing to their variability in environmental factors which likely affect water access such as elevation and terrain, as well in levels of water service, had identified them as potential study sites.

3.2.1.3 Sampling frame and household sampling

The sampling frame for the survey was two village clusters in the peripheries of Makhado town, in Vhembe District. Sinthumule in the south-west of Makhado town comprises approximately 10,000 households spread out over 9 communities. Tshifhire-Maelula is situated north-east of the town, and is essentially one large village of approximately 1,000 households.

The survey was preceded by another survey conducted by the collaborating institution, Tshwane University of Technology in 2011. During this time all households and communal water sources were mapped using Global Positioning System (GPS) devices. Where possible, an indication of the water source (in / at-house) was provided. The coordinates from the mapping exercise were then used to generate unique identities for the households and water sources.

The identities generated from this preceding study were used to facilitate sampling of households. Households were selected through stratified random sampling to include households using public water supplies and those using private supplies. Owing to the practical logistics of carrying out the survey and the related transport costs, the decision was made to include only a sub-sample of the nine communities in Sinthumule. Two communities were randomly drawn from the nine communities in Sinthumule. From these two communities (Community 1 and Community 2) 100 households were randomly selected, and an additional 100 randomly selected from Tshifhire-Maelula.

3.3 Data collection

A combination of quantitative and qualitative approaches was employed to collect data, so as to provide a comprehensive picture within the setting studied. For the quantitative component, the household surveys were the data source. These surveys were supported by key-informant interviews, as well as community observation checklists.

3.3.1 Household surveys

The survey was in two parts. Part 1 related to household demographics, history of water services in the community, reliability of the water supply, perceived risks from the water supply, strategies to cope with unreliability of the water supply and the coping costs. Part 2 was a discrete choice experiment of households' preferences for water supply reliability, and included sections on the respondents' characteristics, an introduction to the choice experiment and the choice sets.

These instruments were designed using a number of sources. The starting point for gathering the study population's perspective and experience of water supply services, and the legislative frameworks guiding these services was published and grey literature, including water policy documents. Other resources were survey instruments used in previous studies and the World Bank's Living Standard Measurement Survey (LSMS) guidance manual (Grosh and Glewwe, 2000).

The original surveys instruments were compiled in English. They were then translated into the local language of TshiVenda by a field assistant, who is fluent in both English and TshiVenda, and has basic understanding of the key concepts of the subject under investigation. The TshiVenda versions of the survey instruments were then back-translated by a professional translation service, to determine whether the content matched that in the original survey instruments.

To evaluate the survey instruments, preliminary drafts were circulated among individuals from the collaborating institution for review during the design phase. Cognitive interviews were conducted with the fieldworkers during their training, and a field test of the instruments was also run prior to the implementation of the survey.

3.3.2 Key informant interviews

Key informant interviews with water supply technicians in the study communities were valuable in balancing the picture of water supply services in the communities, providing some insights into the water problems from the supplier perspectives. 'Key informant' as used in this sense refers to individuals interviewed owing to their first-hand knowledge about the topic under investigation. As the persons tasked with the operation of water supply systems in the communities, the technicians were deemed knowledgeable on the operational problems facing the water supplies.

The interviews were semi-structured, with a set of key themes used as a general guide. These themes included: a description of the water supply technician's job responsibilities; how water is supplied to the study communities; challenges encountered in their role as water supply technician; reasons underlying these challenges and potential solutions to the problems in the water supply.

As an opening question, the technicians were asked to provide some background about themselves and their job in the municipality. The sequencing of the themes to be covered was flexible, and generally determined by the flow of the interview. At the end of each interview, the opportunity to raise issues of potential relevance that had not been covered in the interview was provided. Interviewees were asked: "Is there anything that we did not discuss that you would like to share?"

Separate interviews were conducted with the technicians in the two village clusters. The interviews were conducted through face to face interaction, and recorded on a digital recorder. Prior to the interview, the purpose of the study was explained, as well as the interviewees' rights and assurances in line with principles of research ethics. It was also made clear that their identities would remain anonymous in all publications ensuing from the study. Such anonymity was maintained by not naming the interviewees, and not naming the communities that they work in; the communities are referred to as Communities 1, 2 and 3 throughout the thesis. The interviews were conducted largely in TshiVenda, with the field assistant acting as the English-TshiVenda translator.

3.3.3 Community observations

A profile of each community was compiled prior to commencing fieldwork. Structured observation sheets were used to collect data on the status, extent and usage of communal water supplies, solid waste disposal facilities and general housing and environmental conditions in the area. As with the key informant interviews, these observations mainly served the purpose of providing context and texture to the data collected from the surveys.

3.3.4 Fieldworkers

Fieldworkers were recruited from the study area. Amongst the requirements for recruitment were fluency in both local TshiVenda language and English, literacy and numeracy skills sufficient for the data collection requirements of the study, and an understanding of the cultural norms and appropriate behaviours in the study sites. I delivered training on ethics requirements, consent, the survey instruments and field risk assessment. Training methods used included Round Robin discussions, vignette case studies, group discussions and role plays.

3.3.5 Ethics and household recruitment

Ethical approval to conduct the study was granted by the research ethics committees of the University of East Anglia (Appendix 3.2a) and Tshwane University of Technology (Appendix 3.2b). Formal permission to work in the area was obtained from the local tribal council. A meeting was held at the Sinthumule-Kutama Tribal Council, during which the overall purpose of the project was explained to the tribal leadership in the area and community members who were in attendance.

Before commencing work in each of the three communities that were finally selected for inclusion in the study, informal meetings were held with the community headmen. This was mainly to establish rapport and provide an opportunity to address any further questions or queries that communities may have had.

At the households, voluntary and informed consent was sought from an adult normally responsible for dealing with water supply-related issues; usually the female spouse in the household. It was made clear to respondents that their participation in the study was entirely voluntary, and that although permission to work in the communities had been granted by the respective tribal leadership, this did not mean that households randomly selected for the study were obliged to participate. No incentives were offered to households participating in the study.

3.3.6 Survey procedures

This survey was conducted from September to December 2012. This period covers the two seasons of spring, when the weather is relatively dry and warm, and mid-summer, when it is hot, humid and raining.

The survey was conducted during the same period as that of the DfID study, and where possible, amongst the same households. The actual survey visits to the households were however lagged, to allow respondents time between the two surveys. Where a household decided that they no longer wished to take part in the reliability survey, they were replaced with the next one in the list.

The survey was administered through face to face interviews. The questionnaire was piloted on four households; two with private supplies and two with shared water supplies. Of key interest in the pilot was to afford the fieldworkers an opportunity to identify and comment on feasibility and ease of use of the survey procedure and instruments. Minor modifications to the instruments were made thereafter, relating mainly to the wording in the local TshiVenda language.

I was also supported by a field assistant from the collaborating institution, who assisted in liaising with community leaders and the field logistics of transporting fieldworkers to and from study sites and management of water quality sampling. During data collection, fieldworkers checked responses for logic, and if unclear, verified the answers with the respondent. At the end of each day I checked the completed survey forms for gaps and inconsistencies. Where gaps or inconsistencies were found, fieldworkers were asked to re-visit the household to fill in or verify the information. Re-training was conducted at periodic intervals, as each of the fieldworkers was sometimes confronted with unique challenges. Highlighting these challenges and resolving them as a group meant that the team could learn from each other.

3.3.7 Key variables

A number of key variables are used in much of the empirical work presented in this thesis. These key variables and the methods used in the data collection are outlined below.

3.3.7.1 Water use

Water use is a variable of key interest in both the broader DfID study and the study reported herein. In the context of the DfID study, the difference between in / at-house and communal access to water supply was hypothesised to have an influence on the quantity of water used, and consequently on hygiene and health as well as livelihood or productive use of water. However, a key mediator in this relationship is the reliability of the water supply, and how it influences the quantity of water used.

Data on water use were derived from the DfID survey database. The data were collected using a combination of direct observation and prompted recall methods. For households using communal water supplies, respondents were asked to show the fieldworkers the containers that the water was stored in. From this, the capacities of the containers could be recorded. Respondents could then give an estimate of the number of containers of each capacity that were used in the household each day. An estimate of household water use was then derived by multiplying the number of containers by the capacity (often 20-ℓ plastic jerry cans).

For households using in / at-house water supplies however, this was more complicated. Many of the households had drilled their own wells and set up storage tanks with connections to yard or in-house taps, with no meters. The few that had yard taps connected to the municipal supply either did not have meters or if they did, the meters did not work. To help respondents in these households estimate their water consumption, prompts were used during the survey interviews. Respondents were asked about the capacity of their storage tanks and how often these tanks were filled. For instance, a 2,500-ℓ storage tank that was filled every 10 days implied that the volume used by the household used each day was about 250 ℓ.

3.3.7.2 Household socio-economic status

An assumption made in the design of the study was that in / at-house connections in the communities studied are costly and often only available to the wealthier households. Thus socio-economic status was deemed an important confounder that the analyses had to take into account.

A number of variables from the DfID survey database were used as proxy indicators of households' socio-economic status. These were: household income, household wealth index and a household crowding index.

Household income

In many developing country settings household income may have multiple streams of income from for instance, the informal economy, self-employment and causal labour (Howe et al., 2012). In addition, households may also receive remittances from family members, or social grants, as was the case in the communities studied. The measurement of income therefore had to take these multiple sources into account.

In the survey, respondents were asked to estimate i) wage earnings from labour services; ii) revenue from renting out land e.g. farming or grazing land; iii) revenue from property rentals; iv) remittances from family members v) social grants such as pensions, child support etc. and vi) any other sources of income otherwise not covered. Where other adult household members were present at the time of the interview, they could also provide some answers on what activities they engaged in and the amount of income they brought into the household.

Household wealth index

The second socio-economic indicator used was the wealth index. The wealth index approach arises mainly from the Demographic and Health Surveys (DHS) (Filmer and Pritchett, 2001, Rutstein and Johnson, 2004), and is now commonly used in low and middle income countries where income data may not be readily available or reliable. In the DfID survey data were collected on households' ownership / presence of key assets and amenities shown in Table 3.1.

Table 3.1: Asset-based indicators of household socio-economic status

Household assets	Household amenities
Radio / radio cassette player	Type of flooring
Television	Type of roofing
Mobile phone	Electricity
Refrigerator	Number of rooms used for sleeping
Washing machine	
Car	
Bicycle	
Stove (gas, electric or kerosene)	

The underlying principle in asset-based measures of socio-economic status is that ownership of certain assets provides some insight into households' wealth. The asset variables as well as variables relating to household amenities such as toilet facilities and electricity are then aggregated into a single composite index for each household.

In relation to possessions such as cars, radios, televisions etc., a key issue that Howe et al.(2012) raise is the quality, or functionality of the items. Ownership of a washing machine may suggest that a household is wealthy, but the washing machine may be very old or non-functional. To address this quality issue, the assets listed in the survey were only those that were functional.

Household crowding

The household crowding index measures household space in relation to the number of inhabitants, and has been viewed as a proxy indicator of household socio-economic status. In the DfID survey, respondents in each household were asked about the number of rooms used for sleeping, excluding the times when there were visitors staying over.

3.3.7.3 Coping cost

Households respond to unreliable water supplies through various coping strategies. Parallel to this is the costs that are associated with the various coping strategies. Direct coping costs refer to expenditures arising from installing fixtures to augment the water supply such as drilled wells, electric pumps and storage tanks, purchase of water and treatment of water.

In the case of fixtures, data were collected on the year in which fixtures were installed, the initial cost of purchasing and installing the fixture as well as the running costs. For household who bought water from neighbours, data were collected on the unit cost e.g. the cost of a 20-ℓ container of water, and the estimated total amount spent on water each month. A similar approach was followed in the case of expenditures on bottled water; data were collected on the typical capacity of the water bottles, the unit cost of each bottle and an estimate of the total spent on bottled water each month.

Respondents in each household were also asked about water treatment practices; specifically the type(s) of treatment as well as the frequency of treatment. Data were collected on the approximate amounts spent on chlorination products each month, as well as cost of purchasing filtration devices and the replacement of filters, as a running cost.

3.4 Data management and analyses

Survey data were entered into Epi Info 7 (Centers for Disease Control and Prevention, 2012) and SPSS 18 databases (SPSS Inc., 2009). During the data entry, data were checked further for quality, and any noticeable inconsistences were raised with the fieldworkers.

A key consideration in the data management was that household data from the two surveys had to be matched. The household identifiers used were the same as those used in the DfID survey database to facilitate this matching.

Data from the household surveys were cleaned and checked prior to analysis. The checking process related mainly to missing data, creation of new variables and consistency checks with the DfID dataset. The checks and analyses were done in SPSS 18 (SPSS Inc., 2009) and Stata 12.1 (Stata Corp, 2011).

3.4.1 Preliminary steps for key variable data

The preliminary procedures applied to key variable data relate mainly to handling missing data and the creation of composite variables for use in subsequent analysis. These procedures are outlined in the sections that follow, while the details of their application in the analyses are provided in the appropriate chapter.

3.4.1.1 Imputation of missing data

In a typical household survey dataset, there may be unit non-response, in which data for a sampled household may be completely missing. There may also be item non-response, in which data may be missing for specific variables (Yan and Curtin, 2010). While there was no unit non-response observed in the study's dataset, item non-response was problematic in some key variables. Missing data for these key variables were imputed using single and multiple imputation techniques. The rationale behind using these imputation approaches is outlined in Appendix 4.1.

Single imputation was applied for the variable relating to the year when fixtures were installed / capital costs incurred, with missing values replaced with the mid-point of the earliest reported installation date (1981) and the latest reported installation date (2012), which was 1997.

Multiple imputation was applied for the other variables with missing data; namely water use, household income and the capital and running costs of fixtures. The method employed in the multiple imputation was derived from Rubin (1987). An initial step in multiple imputation is to explore the patterns and mechanisms of missingness. The proportions of missing values for each of the key variables are reported in Section 4.3 of Chapter 4.

The next step is to build the imputation model. The imputation model is the same model that would be used in the analyses. Thus, for each of the key variables to be imputed, independent variables were selected that would reasonably be expected to be related to key outcome variables. Pairwise correlations were run in Stata for each of the outcome variables, and other variables with a correlation of p value < 0.10 with the key variable to be imputed were included in the imputation model. These included: indicators of socio-economic status, such as education, household crowding and assets owned; number of people living in a household; and type of water supply. Stata offers a suite of commands which can be used in multiple imputation, whose basic steps are outlined as:

1. Re-shaping the dataset so that it can accommodate the imputed variables to be filled in
2. Registering the variable to be imputed
3. Specifying the number of imputations to be run, which in this case was 15 imputations for each of the key variables. The rule of thumb is between 5 to 20 imputations (Baraldi and Enders, 2010), with a complete dataset being generated each time.
4. Running the imputation model with the specified number of imputations. Essentially the analyses were performed within each of the 15 datasets, and the resulting parameter estimate from each dataset then pooled by averaging into one estimate. The pooling accounts for variation from both within and between imputed datasets.

As will be shown in the next chapter, some of the variables to be imputed were not normally distributed. Imputing these variables directly would have resulted in biased estimates, as many of the popular multiple imputation procedures assume that data are normally distributed (Sterne et al., 2009). The variables were transformed to their natural logarithm prior to imputation, and transformed back to their original scale after the imputation.

3.4.1.2 Water use

After the multiple imputation, the average of estimates from each of the 15 imputation datasets was used to calculate daily per capita water use. This was done by dividing the estimated (and imputed) amount used in household each day by the number of persons living in the household.

3.4.1.3 Indicators of socio-economic status

Total household income

The total monthly income of each household was calculated by adding up the incomes from the various sources. The aggregate was then used to construct income quintiles for the survey sample.

Household wealth index

The wealth index was constructed using Principal Component Analysis (PCA), which is essentially a data reduction technique that summarises variability among variables (Howe et al., 2012). The underlying concept is that PCA analyses all the variance in a given set of variables, then reorganises it into sets of ‘principal components’ which account for the majority of the variability in the data. The components themselves are linear combinations of the original variables which are multiplied by a weight or eigenvalue which describes the principal component. Much of the variance in the data is explained by the first component, with the subsequent components accounting for progressively lower proportions of the remaining variability. Since most of the variance is captured by the first component, the common practice is to use only this first component in the wealth index.

In the context of the household asset and amenity variables presented earlier in Table 2.1, the application of PCA reduces the variables into a single composite wealth index. The wealth index was created following the method of Filmer and Pritchett (2001). PCA was performed in SPSS, and the first component retained. The index was computed using the score command, to produce an index for each household. As with the household income data, quintiles were then constructed in order to categorise households in various socio-economic groups.

Following Balen et al. (2010),Cronbach’s alpha statistic was used to determine the internal consistency of the wealth index. In this context, the test can be used to determine the extent to which the variables included in creating the index measure a single latent concept or variable i.e. wealth.

Household crowding index

The number of rooms used for sleeping provides some indication of the extent of crowding in households. The household crowding index was calculated by dividing the number of household members by the number of rooms normally used for sleeping.

3.4.1.4 Coping costs

The total coping costs for each household were estimated by summing up the various cost components. The costs of capital expenditures such as those relating to drilling wells, installing electric pumps and storage tanks and connecting pipes to yard / in-house taps were annuitized to reflect the monthly coping costs. Annuitizing essentially spreads the capital cost of fixtures over their useful lifespan. The method of annuitizing costs applied herein is derived from Drummond et al. (2005) and the Centers for Disease Control and Prevention (2013).

In annuitizing the capital costs of fixtures, the following assumptions were made:

- The useful lifespan of a fixture would be 32 years
- The scrap value in relation to the initial value is 10 %
- The base discount rate is 8.5%

The lifespan of the water supply fixture is based on the oldest recorded fixture in the survey. The scrap value of 10 % is arbitrary; most existing studies do not provide detail on the scrap value used, and simply state that parameters used in the amortisation were based on ‘expert knowledge’ or ‘field notes’ [see for instance Altaf (1994) and Pattanayak et al.(2005)]. The base discount rate of 8.5% was obtained from the South African Reserve Bank (2013). The capital costs were annuitized using the formulae outlined in Figure 3.1. An initial step was to determine the present value of the fixture’s scrap value. The scrap value in this sense relates to the resale value of a fixture such as a tank, pump, etc. after its useful lifespan. This scrap value was subtracted from the purchase cost of the fixture. The difference between these two costs (purchase cost minus the present value of the scrap) was divided by the annuity factor.

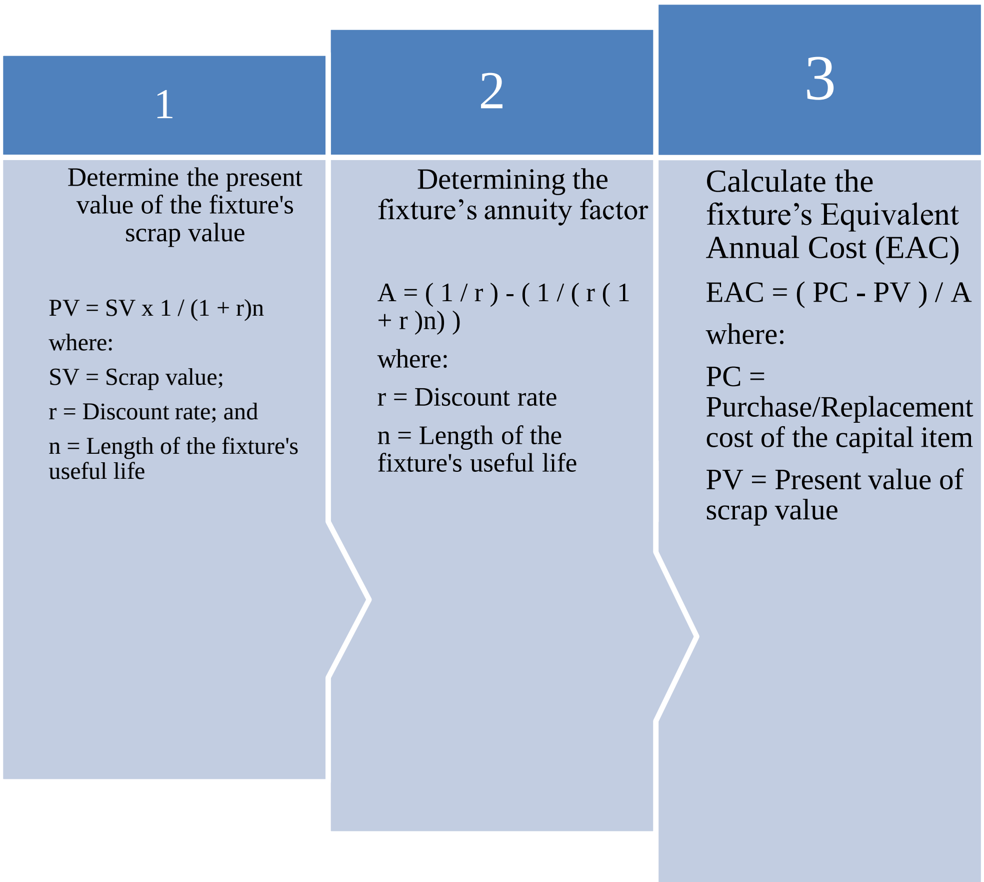

Figure 3.1: Steps in annuitizing capital costs of coping

Source: Cost analysis (Centers for Disease Control and Prevention, 2013)

Sensitivity analyses were performed in order to determine the effect of varying some of these assumptions on annuitized cost figures. The discount rate and scrap value in the model were modified to observe the effect on the cost figures (Table 3.2).

Table 3.2: Scenarios used in sensitivity analyses of coping costs

Scenario	Discount rate (%)	Scrap value (%)
1	8.5	5
2	8.5	10
3	8.5	15
4	8.5	20
5	7	5
6	7	10
7	7	15
8	7	20
9	10	5
10	10	10
11	10	15
12	10	20

The results from these sensitivity analyses models were compared to the results from the base model. The annuitized coping costs were divided by 12, to obtain an estimate of the monthly capital cost of the fixtures. Similarly, the annual running costs of the fixtures were divided by 12, to obtain an estimate of monthly running costs. These were summed up, together with any monthly costs from purchasing water or water treatment products where relevant, to make up the total coping costs for each household.

3.4.2 Interview data analyses

Recordings of the key informant interviews with water supply technicians were transcribed and translated by professionals at the Wits Language School Translation and Transcription Services located at the University of the Witwatersrand in South Africa. Where applicable, the interviewee responses in TshiVenda were translated into English.

Each of these transcripts was examined line by line, and the data organised according to the themes outlined in the interview guide. Together with the data from the community observations, these interviews are not a direct contribution to the results of the study, but serve mainly to provide some context to the water supply problems in the study communities. These were reported in the second section of Chapter 2, which set the scene for the study and described the study communities and their water supplies.

Conclusions

This chapter has outlined the methods used in the study, including the research strategy and data collection methods. The key variables used in the thesis were presented, namely water use, income, coping costs and indicators of socio-economic status. In the chapter that follows, the characteristics of the study sample are presented, as well as the descriptive statistics of the key variables.

4 Sample characteristics and key variables

This chapter outlines the characteristics of the study sample, as well as descriptive statistics of the key variables introduced in the previous chapter (Chapter 3). The demographic and socioeconomic characteristics are presented, as well as a profile of the water supplies in the study communities. Throughout this chapter and other analyses chapters (Chapters 6 and 8), the results for Communities 1 and 2 are presented jointly.

4.1 Sample characteristics

The demographic characteristics of the study sample are summarised in Table 4.1. A total of 197 households participated in the survey, with the sample evenly split between Communities 1 and 2 and Community 3.

Table 4.1: Characteristics of study sample

Sample characteristics	*n*	%
Total sample size	197	100
Community		
1	34	17
2	65	33
3	98	50
Main water supply, private	74	37.6
Main water supply, shared		
Neighbour’s private supply	8	4.1
Communal tap	107	54.3
Protected spring	6	3.0
Municipal tanker	2	1.0
Electricity	187	94.9
Gender of main respondent, female	154	78.2
Mean age of main respondent	41	
Highest level of education, main respondent		
Never attended school	39	19.8
Primary (Grade 7)	32	16.2
Lower secondary (Grade 9-10)	42	21.3
Upper secondary (Grade 11-12)	64	32.5
Tertiary	20	10.2
Mean household size	6	
Household members with diarrhoea in the last 2 weeks	15	8

Households using communal water supplies made up the majority (62 %) of the sample, and almost all households surveyed (94.9 %) had electricity. Just over three quarters (78 %) of the main respondents were female. The mean age was 41 years, and the majority had completed secondary schooling.

4.2 Current water supply

In the sections that follow, the characteristics of the water supply are presented, relating mainly to the reliability and households' perceptions of their water supply.

4.2.1 Water sources

The main water sources in the study communities are shown in Table 4.2.

Table 4.2: Main water sources

	Communities 1 and 2		Community 3	
	n	%	*n*	%
Private supply				
Drilled well with yard / house tap	26	26.3	-	-
Municipal or spring connection with yard / house tap	-	-	48	49.0
Communal supply				
Communal tap	66	66.7	41	41.8
Neighbour's yard tap	5	5.1	3	3.1
Municipal tanker truck	2	2.0	-	-
Protected spring	-	-	6	6.1

Private supplies in Communities 1 and 2 are drilled wells with taps in the yard and / or house, while in Community 3 the private supplies are municipal or spring connections. In both clusters the main water source for households using communal supplies are communal taps.

The alternative water sources are presented in Table 4.3. Almost three quarters (71.7 %) of households in Communities 1 and 2 rely on neighbours' drilled wells as their alternative water source.

Table 4.3: Alternative water sources

	Communities 1 and 2		Community 3	
	n	%	*n*	%
Communal tap	9	9.1	2	2.0
Neighbour's yard tap / drilled well	71	71.7	21	21.4
Rainwater harvesting	-	-	-	-
Municipal tanker truck	5	5.1	-	-
Protected spring	-	-	79	80.6
None	19	19.2	7	7.1

Note: Totals do not add up to 100 % as households may use more than one alternative source

In Community 3, the majority (80.6 %) of households rely on the protected springs in the area as their alternative source. While 19 % of the households in Communities 1 and 2 report that they rely solely on their main water source, the proportion in Community 3 is smaller, with 7 % reporting that they do not use an alternative water source.

4.2.2 Reliability of the current water supply

Households using private water supplies report an average of 2 breakdowns in the water supply system each year, while those using communal supplies as their main source report 3 breakdowns a year (Table 4.4).

Table 4.4: Reliability characteristics of water supply, by type of supply

	Private supply		Communal supply	
Characteristic	*n*	mean	*n*	mean
Hours of water supply during the day	74	17.4	122	15.0
Days of water supply during the week	74	5.8	122	3.8
Time taken to restore water supply (downtime)	72	20.1	118	36.8
Number of breakdowns in the year	74	1.5	117	2.7
Prior notification of interruptions (%)				
Always	41	-	116	5.7
Sometimes		-		1.6
Never		55.4		87.0
Flow rate (%)				
High	73	68.9	123	52.0
Moderate		23.0		35.0
Low		6.8		13.0

The average time taken to restore the water supply after breakdowns amongst households using private supplies is reported as just under 3 weeks, while for households using communal supplies the average is just over 5 weeks. Households using private water supplies report having water available for 17 hours a day, while those using communal supplies report an average of 15 hours a day. For both private and communal supplies the flow rate is generally rated as high.

Table 4.5: Reliability characteristics of main water supply, by community cluster

	Communities 1 and 2		Community 3	
Characteristic	*n*	mean	*n*	mean
Hours of water supply during the day	98	14.1	98	17.7
Days of water supply during the week	98	3.5	98	5.5
Time taken to restore water supply	94	41.5	96	19.7
Number of interruptions in the year	95	2.6	96	1.8
Prior notification of interruptions (%)				
Always	99	2.0	85	5.1
Sometimes		-		2.0
Never		70.7		79.6
Flow rate (%)				
High	99	47.5	97	69.4
Moderate		33.3		27.6
Low		19.2		2.0

On average, households in Communities 1 and 2 report having water available from the main source for 14 hours a day, while in Community 3 water is available for about 18 hours a day (Table 4.5). Breakdowns in the water supply system in Communities 1 and 2 take almost 6 weeks to repair on average, and just under 3 weeks in Community 3. The majority of households report that they are never notified of any interruptions in the water supply. In all three communities the flow rate is generally rated as high.

4.2.3 Multiple source use

The majority of households (86.8 %) rely on more than one water source. The reasons for using multiple water sources are presented in Figure 4.1.

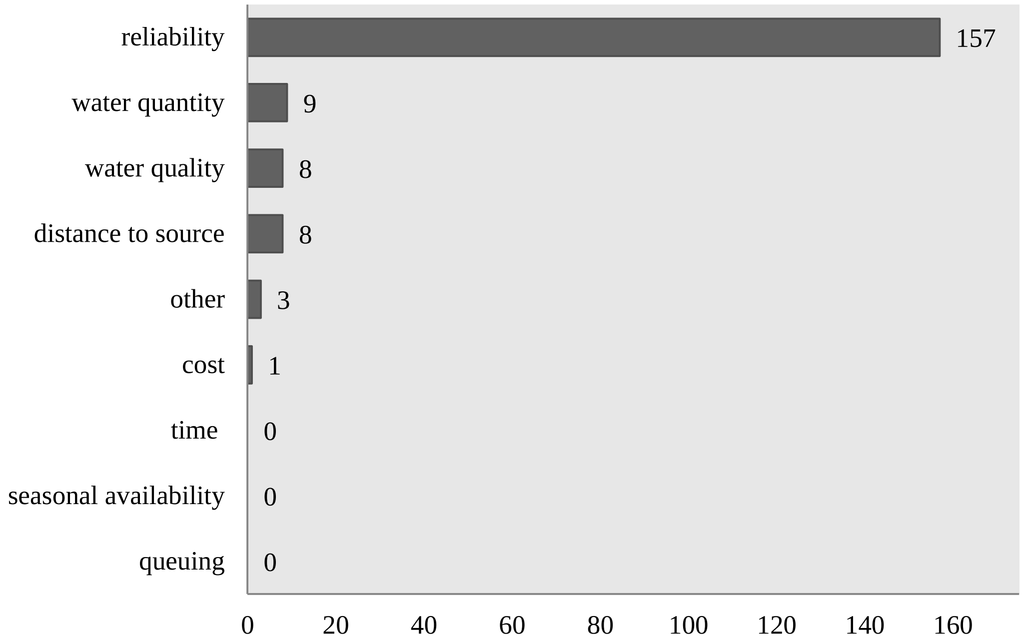

Figure 4.1: Reasons for using multiple water sources

Among 157 (92.8 %) of the households, poor reliability of the main water supply is cited as the reason for using more than water source. Other reasons include the quantity of water available, the quality of water and distance to the water sources.

4.2.4 Perceptions of the water supply

Of the 197 households surveyed, almost two thirds (65 %) rate their main water supply as being very unreliable, while about one quarter (24 %) rated their water supply as being very reliable (Figure 4.2).

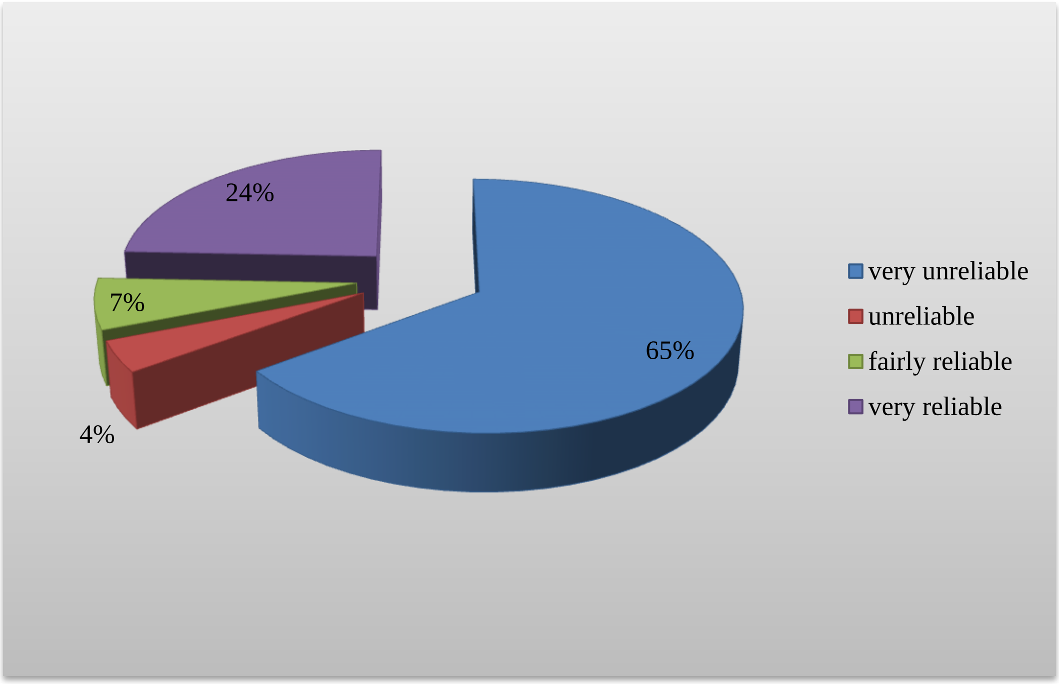

Figure 4.2: Ratings of the reliability of the main water supply

The main concerns that households have with their water supply relate to the quantity of water supplied and the time it takes to collect it (Figure 4.3). About two thirds (65.3 %) of households are very concerned about getting enough water to meet their day to day requirements.

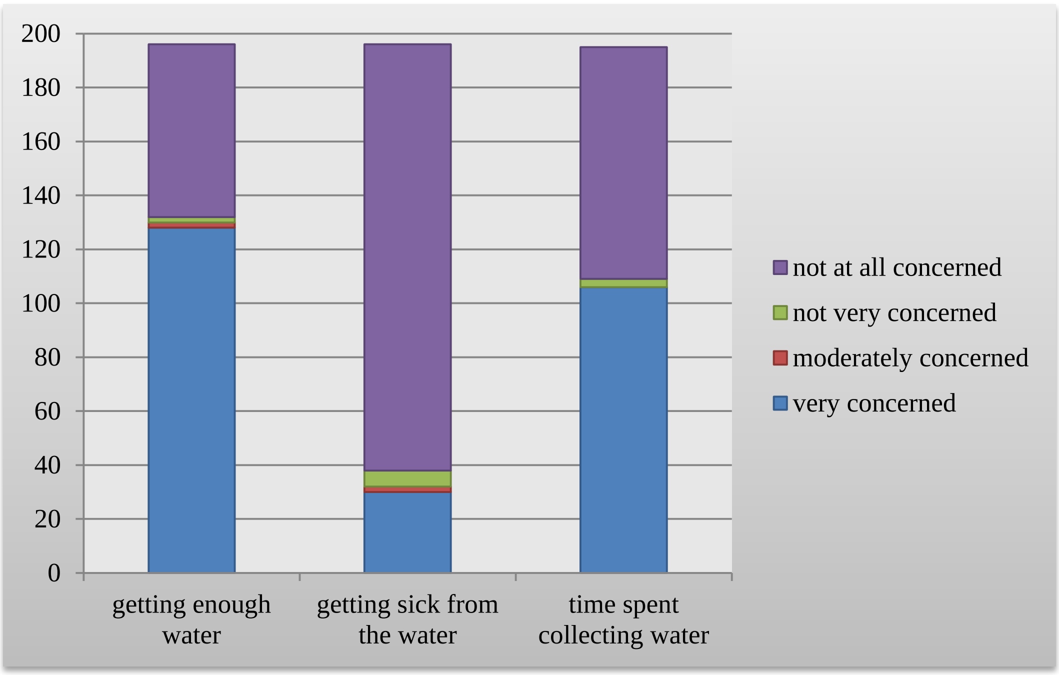

Figure 4.3: Household concerns with the main water supply

The second greatest concern is the amount of time it takes to collect water; 54.54 % of households report that they are very concerned. Getting sick from the water ranks as the least of households' concerns; 80.6 % report that they are not at all concerned.

4.3 Key variables

The descriptive statistics of key variables introduced in Chapter 3 are summarised in the sections below. Detailed results of the imputation for water use, income and initial and running costs are provided in Appendix 4.

4.3.1 Water use

Table 4.6 presents the summary statistics for non-imputed and imputed water use data. Respondents found it difficult to estimate their households' water consumption in 39 (52.7 %) of households with private supplies and 15 (12.2 %) of those with shared water supplies, bringing the total of missing values to 54 (27%).

Table 4.6: Summary statistics of water use data

Variable	*n*	Mean	Standard deviation	Median	Proportion of missing values (%)
Non-imputed household water use	143	90.1	52.3	75.0	27.4
Imputed household water use	197	88.7	46.7	80	-

Note: Water use is in litres (ℓ) per household per day

The parameter estimates from the non-imputed and imputed datasets are fairly similar. The mean water use in the non-imputed dataset is 90.1 ℓ per household per day, while in the imputed dataset the mean is 88.7 ℓ per household per day. Assuming an average household of 6 people from Table 4.1, this equates to just below 15 ℓ per capita per day.

4.3.2 Household socio-economic status

4.3.2.1 Household income

In 7.6 % of all households, respondents preferred not to say, or were not sure of the households' total monthly income. The mean household income in the non-imputed dataset is just under R2,295 per month (Table 4.7). At the exchange rate of R8.57 per United States (US) dollar in 2012 (South African Reserve Bank, 2014), this is approximately US$268 per month.

Table 4.7: Summary statistics of household income data

Variable	*n*	Mean	Standard deviation	Median	Proportion of missing values (%)
Non-imputed household income	182	2,295.1	2,237.3	1,760.0	7.6
Imputed household income	197	2,233.7	2,168.1	1,740.0	-

Note: Household income is in South African Rand (ZAR) per month

The mean household income in the imputed dataset is slightly lower at R2,234 or approximately US$261 per month at an exchange rate of R8.57:US$1.

4.3.2.2 Household asset index

The weights of the variables used in the construction of the wealth index are shown in Table 4.8. Variables that reflect a lower wealth status contribute negatively to the index score. For example, having a mud / earth floor and a metal or corrugated iron roof decreases a household's index score. Conversely, variables that reflect a higher wealth status contribute positively to the index; examples being having electricity, owning a television and owning a refrigerator.

Table 4.8: Weights of variables included in asset index

Household asset / amenity	Weight
Earth/ mud floor	-.220
Wooden tiles on floor	.111
Metal or corrugated iron roof	-.282
Number of rooms used for sleeping	.664
Electricity	.582
Radio / cassette player	.387
Television	.648
Mobile phone	.426
Refrigerator	.674
Washing machine	.461
Car	.483
Bicycle	.281
Stove	.551

Notes: Extraction Method: Principal Component Analysis, no rotation. Variance explained: 22.72 %

The wealth index is derived from the first un-rotated component / factor, which accounts for approximately 23 % of variation in the data. The variables used in the construction of the index produce a Cronbach's alpha of 0.56, which is somewhat below the conventionally accepted range of 0.70 to 0.95 (Tavakol and Dennick, 2011).

Following Balen et al. (2010) the wealth index scores were grouped into quintiles representing: (1) least wealthy; (2) below average (3) average; (4) above average and (5) most wealthy households. The summary statistics of these wealth quintiles are presented in Table 4.9 below.

Table 4.9: Summary statistics of wealth index scores, by wealth quintile

	Wealth index score					
Wealth quintile	*n*	Mean	Standard deviation	Median	Minimum*	Maximum*
1	39	-1.5	0.9	-1.2	-3.36	-0.56
2	40	-0.3	0.2	-0.3	-0.51	0.03
3	46	1.6	0.1	0.2	0.04	0.27
4	34	0.5	0.1	0.5	0.31	0.70
5	37	1.2	0.4	1.1	0.72	2.28

Note: *Second decimal point added to indicate cut-off points in each quintile

The wealth distribution for the overall sample is roughly even, with approximately 20 % of households in each quintile. The index scores for the least wealthy households (wealth quintile 1) ranges from -3.36 to -0.56, with an average of -.1.5. Amongst the households categorised as most wealthy, the minimum index score is 0.72, and the average 1.2.

4.3.2.3 Household crowding index

The summary statistics for the household crowding index are presented in Table 4.10.

Table 4.10: Summary statistics of household crowding index data

	n	Mean	Standard deviation	Median
Household crowding index	196	1.7	0.8	1.5

The index was derived by dividing the number of people in each household by the number of rooms used for sleeping. On average, households have two people sleeping in a room.

4.3.3 Coping cost

The coping costs are reported in two parts. The first part presents the summary statistics of the non-imputed and imputed initial and running costs for households with private supplies. In the second part, the annuitized initial and running costs are presented, as well as the costs incurred by households without private supplies.

4.3.3.1 Initial and running costs of fixtures

The initial and running costs incurred by households with private supplies are summarised in Table 4.11.

Table 4.11: Summary statistics of initial and running cost data

Variable	*n*	Mean	Standard deviation	Median	Proportion of missing values (%)
Non-imputed year fixture installed	31	-	-	-	58.1
Imputed year fixture installed	74	-	-	-	-
Non-imputed initial cost	18	8,685.0	11,986.7	1,975.0	75.7
Imputed initial cost	74	7,341.2	11,000.9	1,275.5	
Non-imputed running cost	24	1,283.8	1,856.5	425.0	67.6
Imputed running cost	74	815.7	1,768.6	52.5	

Note: Costs are in South African Rand (ZAR)

Of the 74 households with private water supplies, 43 (58 %) could not recall when the fixtures were installed. Three quarters of the respondents did not know or could not recall the initial costs of installing the fixtures and 68 % did not know or could not recall the running costs.

The year of installation was imputed as 1997; the mid-point between the earliest recalled installation date (1981) and the latest recalled date (2012). Both the initial and running cost data are highly skewed. In the imputed dataset the mean installation cost is R11,000, against a median of R1,275; approximately US$1,284 and US$149 respectively. Similarly, the mean running costs in the imputed dataset are R816 (US$95) and the median costs R53 (US$6).

4.3.3.2 Total coping costs

The monthly coping costs are summarised in Table 4.12. For households with private supplies, these costs include the annuitized initial and running costs, as well as the costs of any other coping strategies such as buying bottled water, chlorination etc. For households without private supplies, the costs included are those incurred from buying water from neighbours, buying bottled water and chlorination.

Table 4.12: Summary statistics of total coping cost data

Variable	*n*	Mean	Standard deviation	Median
Households with private supply	74	139.1	209.4	22
Households with communal supply	123	45.7	60.7	20
All households	197	81.3	144.6	21

Note: Costs are in South African Rand (ZAR) per month

The average coping costs for households with private supplies are R139 a month (approximately US$16 at a 2012 exchange rate of R8.57: US$1), while the median costs are much lower, at R22 (US$3). Households with communal supplies spend R46 (US$5) a month on coping costs on average. Their median coping costs are in fact similar to those of households with private supplies, at R20 (US$2) a month.

4.4 Discussion

The objective of this chapter was to present the social and demographic characteristics of the study sample as well as summarise the key variables relevant to the thesis.

The results regarding the reliability of the water supplies are generally consistent with the results for the Limpopo Province. Results of the 2011 General Household Survey (GHS) (Statistics South Africa, 2011) indicate that households in the province experienced the highest number of interruptions in 2010, with 81.2 % of households having their water supply interrupted. The province also had the second highest duration of interruptions in the country, with interruptions likely to last 15 days or longer.

Households are least concerned about getting sick from drinking water, which would suggest that they perceive the water to be generally of good quality. Supporting evidence of this can again be drawn from the GHS (Statistics South Africa, 2011), which shows that household water treatment has been steadily declining in Limpopo Province since 2006.

The Free Basic Water (FBW) policy allows for 6,000 litres per household per month, based on an average household size of eight and 25 ℓ being available to each individual daily (Department of Water Affairs, 2003). This translates to 150 ℓ a day for a household of 6 persons. Households in the study communities use an average of about 90 ℓ per day; well below 150 ℓ.

In terms of socio-economic status, the average household income of R2,234 per month equates to R26,808 per annum, which is below the district's average of R49,440 and the province's average of R56,841 from the 2011 census (Statistics South Africa, 2012a). The census report for the province does not distinguish between urban, peri-urban and rural households. It is plausible that the reported annual income for the sample may be similar to that of other peri-urban households in the province. Further, under-reporting remains a significant issue in surveys of income (Moore et al., 2000). Although care was taken to probe respondents about the different streams of income, and where possible, obtain income information directly from household members engaged in income-generating activities, it is not excluded that the income data may have been under-reported. The item non-response rate of 7.6 % for income data is relatively low, compared to the non-response rates of 10-20 % that have been reported in for instance the South African Social Attitudes Survey (Human Sciences Research Council, 2010) and the 2007 Community Survey (Porter et al., 2013).

The proportions of missing data for initial and running costs of fixtures are rather high. The summary statistics for these costs and results ensuing from analyses of total coping costs for households with private supplies therefore need to be interpreted with caution as they are to a large extent based on imputed data. Given that for many households the installation of such fixtures represents a once-off expenditure, it is plausible that they may have indeed forgotten how much money was spent. To the author's knowledge, no studies have been published that report on households' capital expenditures related to coping with unreliable water supplies in the country. This makes it difficult to determine (i) typical response rates when eliciting such information in surveys; (ii) data collection techniques that can improve the quality of information obtained and response rates; and (iii) estimates of what might reasonably be lower and upper boundaries of the costs.

Little insight can be drawn from studies conducted in other countries. In their eminent study of coping costs in Nepal, Pattanayak et al. (2005) state that: "In general, most parameters used in the calculations (e.g., lifespan estimates) are based on average statistics from our sample or from other studies in Nepal (when none was available from our survey) or our field notes (based on our discussions with key informants or experts)." No detailed information is provided in their study nor indeed in many other studies, of the response rates and recall issues that arise in the collection of such data. In many developing countries household water management is a gendered phenomenon in which the responsibility lies mainly with women (Porter et al., 2013), hence the decision to target senior females / female spouses in the interviews. However, it is plausible that higher item response rates could have been achieved if senior males / male spouses had been targeted for the particular questions, as they are more likely to be in paid employment (Statistics South Africa, 2012c) and possibly be responsible for high-cost investments such as drilling wells and purchasing storage tanks.

The mean initial and running costs are much larger than the median costs, indicating that the cost data are positively skewed. These results are expected, as the costs of drilling wells in Communities 1 and 2 can be reasonably expected to be much higher than the costs of setting up pipe connections to the springs in Community 3.

Conclusions

The chapter has presented the characteristics of the study sample, including descriptive characteristics of the households surveyed, water supply in the communities, as well as summary descriptives of the key variables. Overall, the results of this chapter highlight that while households have access to improved water sources, the majority perceive their water supply as being unreliable, and water use is generally below the recommended minimum of 25 ℓcd. In the following chapters, the issue of unreliability in water supply is explored in more detail; reviewing the definitions and criteria used in assessing reliability (Chapter 5), and eliciting households' preferences for reliable water supplies (Chapter 6).

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5 Reliability of water supplies in developing countries: A review of definitions and assessment approaches

Unreliable water supplies in developing countries are a widely recognised concern. However, unreliability means different things in the variety of literature on water supplies, and no unified definition or assessment criteria exist. This chapter reviews definitions of water supply reliability used in existing literature, as well as the various ways in which it is assessed.

5.1 Introduction

In recent years there has been growing criticism of the approaches used in measuring progress towards Millennium Development Goal target 7c, which aimed to halve the proportion of worlds' population without access to an improved drinking water source by 2015. Among the major criticisms is the way in which key concepts of safety and access are addressed and measured (see for instance, Clasen (2012), Devi and Bostoen (2009), Onda et al. (2012) and Dar (2009)). Further – and of main interest in this review – is the acknowledgement in the MDG update that reliability is not addressed in the existing indicators (WHO/UNICEF, 2012).

Although unreliability of water supplies in developing countries is widely recognised as a significant concern, robust literature on the scope of the problem remains lacking. No unified definition or standard way of measuring water supply reliability exists (WHO/UNICEF, 2012), and the data that is available is often sketchy (Kleemeier, 2010). Much of the often-cited data on the reliability of water supplies in urban areas is from the World Bank's International Benchmarking Network for Water and Sanitation Utilities (IBNET, 2011). The database contains information on duration of supply in hours per day and / or proportion of residential customers receiving intermittent supply from utilities in 85 countries. Because the data is as reported by the utilities themselves, the quality of the data depends greatly on the accuracy of this reporting (WHO/UNICEF, 2011).

Systematically collected data on the reliability of water supplies in rural or peri-urban communities is even more limited. The most often cited figures are from the Rural Water Supply Network(Rural Water Supply Network, 2009), which are themselves a compilation from various sources and report only on functionality of handpumps in sub-Saharan Africa. Thus, the little systematic data that is available is often limited to specific communities, regions or water supply technologies and is sometimes not necessarily nationally representative. Further, various reports use their own definitions of reliability and indicators, with the result that aggregation of data across studies is difficult.

Safe, reliable water supplies play an important role in achieving the benefits of water supply improvements (Hunter et al., 2010) and monitoring of progress in this regard depends greatly on the quality of indicators used. The aim of this chapter is to provide a review of the various definitions and assessment criteria of water supply reliability currently used in the literature. It is hoped that this summary will contribute to the identification of clear definitions and assessment criteria that can be used to evaluate the reliability of water supplies in developing countries.

5.2 Methods

Water supply reliability as considered in this review is distinguished from sustainability. While the terms are often used interchangeably in the literature, in this thesis sustainability is distinguished as the capacity of a water supply to continue to provide intended health, social and economic benefit to recipients in a manner that has no significant environmental, economic and social adverse effects.

A scoping search was conducted prior to the actual search for the review to identify the various terminology used in relation to reliability in the water supply literature. Literature searches for grey and published literature were then conducted in a number of databases and websites shown in Table 5.1.

Table 5.1: Databases and search engines used

Academic	Search engines	NGO / Donor Agencies
CINHAL EBSCOHost	Google Scholar	Asian Development Bank (ADB)
MEDLINE Ovid	Google Web	African Development bank (AfDB)
ProQuest Dissertations and theses		Inter-American Development Bank (IDB)
PubMed		Department for International Development (DFID)
Scirus (Elsevier)		United States Agency for International Development (USAID)
Scopus		Water Aid
Web of Knowledge		World Bank
		World Health Organisation (WHO)

The search terms used were:

"water supply" OR "safe water" OR "drinking water" OR "domestic water" OR "household water" OR “water point” AND reliab* OR sustainab* OR availab* OR function* OR regular OR access OR intermitten* OR interrupt* OR constant OR continu* OR consistent OR “operation and maintenance” OR breakdown

Papers retrieved from the search were screened for relevance according to the following criteria:

- Report on reliability of domestic water supply
- Based on primary data from developing countries
- Report on operational reliability of water supply, not water scarcity, e.g. due to drought
- Provide a definition and / or assessment criteria of reliability

The full texts of papers whose abstracts met the criteria were retrieved and reviewed in detail. The reference lists of these included studies were also checked for potentially relevant studies. Data were also extracted from major national surveys of the Asian Development Bank (ADB) and Pan American Health Organisation (PAHO) Evaluation of Drinking Water and Sanitation Services (Evaluation 2000). Developing countries (low and medium income) were defined as per the World Bank classification(2011).

5.3 Results

Seventy-eight documents were reviewed for this assessment and 34 were found to be relevant. Amongst those excluded, reasons included lack of clarity on both how reliability was defined and consequently assessed and results being presented as an overall index of sustainability, from which data on reliability could not be extracted. Two of the papers (Zerah, 1998; 2000) were based on the same study and were regarded as one study for the purposes of the review.

Of the 34 studies reviewed, half were carried out in sub-Saharan Africa (Tables 2a-c). The data from PAHO covered 19 countries in Latin America and the Caribbean region, while that from ADB covered 40 utilities in Lao, Malaysia and Vietnam. Sixteen of the studies evaluated reliability in rural settings, 13 in urban and 5 in both rural and urban settings. The ADB survey data from south-east Asia was for utilities in urban areas, whereas that of PAHO covered both urban and rural areas.

5.3.1 Definitions of reliability

Definitions or descriptions of reliability are explicitly stated in seven of the studies. A comprehensive list of these studies and others in the review is given in Tables 5.2-5.4.

Table 5.2: Studies in urban settings

Author(s), year	Study objective(s)	Setting, year of study and sample	Methods	Definition of reliability/synonym	Type of supply	Estimates of (un)reliability
Aderibigbe et al. (2008)	Determine the availability, adequacy and quality of water supply	Urban Nigeria 750 female respondents randomly selected from 3 communities	Descriptive cross-sectional study, using structured questionnaires	None stated	62.9 % of respondents house connection	15 % had water more than 3 times a week 30.1 % had water 2 or 3 times a week 54.9 % had water occasionally or once a week
Andey & Kelkar (2009)	Evaluate influence of continuous and intermittent water on domestic water consumption	Urban India, 4 cities; Ghaziabad: 35 households out of 48; Jaipur: 195 households out of 206; Nagpur: 214 households out of 330; Panji: 51 households out of 120 households	Six measurements repeated times over 1 year for both modes of supply. Average consumption calculated from meter readings, duration of survey and number of people in households	None stated	Piped supply	Ghaziabad: 10 hours/day Jaipur: 3 hours/day Nagpur: 16 hours/day Panji: 5 hours/day
Asian Development Bank, (2007)	Help water utilities southeast Asia to assess their performance	Urban southeast Asia 2005 40 water utilities; 17 from Vietnam, 17 from the Philippines, 5 from Malaysia and 1 from Lao PDR.	Water utility questionnaire	None stated	Piped supply	24 hours a day on average for Malaysia and Lao; 23 hours a day on average for Vietnam and the Philippines

Author(s), year	Study objective(s)	Setting, year of study and sample	Methods	Definition of reliability/synonym	Type of supply	Estimates of (un)reliability
Ayoub & Malaeb (2006)	Investigate impact of intermittent supply on water quality	Urban Lebanon 2003-2004 181 water samples	Quantitative. Samples collected from water network before storage in household tanks and after storage from household tanks	None stated	Piped supply	Once every two days
Baisa et al. (2010)	i) Develop a model describing the optimal intertemporal depletion of each household's private water storage if it is uncertain when water will next arrive to replenish supplies ii) evaluate the potential welfare gains that would occur if alternative modes of water provision were implemented	Urban Mexico 2005 data	Model calibrated using data from the Mexican National Household Survey of Income and Expenditure survey	None stated	Piped supply	1 day per week: 2.8% 2 days per week: 2.1% 3 days per week: 3.8% 4 days per week: 0.2% 5 days per week: 1.3% 6 days per week: 0.2% Daily at limited hours: 21.6% Daily at all hours: 68.0%

Author(s), year	Study objective(s)	Setting, year of study and sample	Methods	Definition of reliability/synonym	Type of supply	Estimates of (un)reliability
Caprara et al. (2009)	Investigate the relationship between the socio-economic characteristics and community practices that take place indoors (e.g. garbage disposal, water storage practices) affecting Ae. aegypti.	Urban Brazil 2005	Mixed methods. Purposive sampling of 6 blocks in city of Fortaleza 204 households total 51 middle class households 153 under-privileged households	None stated	Piped supply	*Middle class:* 2-5 dys/wk: 0; 6 -7 dys/wk: 39 (100%); 3-12 hrs/dy: 23 (59%); 13-24 hrs/dy: 16(41%) *Under-privileged class:* 2-5 dys/wk: 30 (21.4%); 6-7 dys/wk: 110 (78.6%), 3-12 hrs/dy: 37 (26.4%), 13-24 hrs/dy: 103 (73.6%)
Gulyani et al. (2005)	Examine current water use and unit costs in three Kenyan cities and test the willingness of the unconnected to pay for piped water, yard connections, or an improved water kiosk (standpipe) service	Urban Kenya 2000 674 households interviewed in 22 sites in the three urban areas	Cross-sectional survey using structured questionnaires	None stated	House connection Yard tap Kiosk	House connection: 36%<8hrs/dy, 28% 8-16hrs/dy, 36%>16hrs/dy Yard tap: 47%<8hrs/dy, 32% 8-16hrs/dy, 21%>16hrs/day Kiosks: 36%<8hrs/dy, 54% 8-16hrs/dy, 10%>16hrs/dy.

Author(s), year	**Study objective(s)**	**Setting, year of study and sample**	**Methods**	**Definition of reliability/synonym**	**Type of supply**	**Estimates of (un)reliability**
Howard (2002)	Develop a model of water supply surveillance for urban areas of developing countries that provides reliable assessment of water supplies, with particular emphasis on the urban poor	Urban Uganda 1997-200 1,652 water points in 10 locations	Multi-criteria zoning to identify vulnerable communities and structured observation of water points and structured questionnaires	Discontinuity was defined as being the physical absence of water flowing from the source	Piped water Point sources: protected springs boreholes/ tubewells with handpumps, dug wells with handpump	309 (18.7%) water points had discontinuity. Piped: 245 (25.7%); Protected: 33 (6.7%) Unprotected: 31 (15.1%). Discontinuity occasional (70%) seasonal interruption relatively common and daily/monthly interruptions far less common.
Mycoo (1996)	Provide a demand-oriented perspective on water provision for domestic users, examining cost recovery potential based on household willingness to pay more for an improved service and water pricing	Urban Trinidad Stratified sampling of 6 settlements (total of 420, sampling rate 0.34%). Criteria: location, elevation and slope, income, housing and land tenure, level of service and the number of hours of water received.	Cross-sectional survey using contingent ranking, contingent valuation and observed behaviour of the household in producing water	None stated	Piped: House connection Yard tap Communal tap	4S% of customers receive a 24 hour supply seven days a week

Author(s), year	Study objective(s)	Setting, year of study and sample	Methods	Definition of reliability/synonym	Type of supply	Estimates of (un)reliability
Pattanayak et al. (2005)	Evaluate how coping costs and willingness to pay vary across types of water users and income	Urban Nepal 2001 Clustered sampling (probability-to-size), 1500 households in five municipalities of Kathmandu Valley	Mixed methods cross-sectional survey using 17 purposive, open-ended discussions, 2 focus groups, and 150 pre-tests in designing the survey instrument	None stated	70% piped, 30%: private wells, public taps, stone spouts, and water vendors. About 1% of the connected households share a connection with other households	Water was available from private connections on average about 2 hours per day in the wet season and 1 hour per day in the dry season
Shah (2003)	Establish the value of water supply services to people of Zanzibar Town by measuring willingness to pay for reliable water services, to provide basis for change of the financing policy for water supply services management.	Urban Zanzibar 300 households out of 10 Shehias; (0.94 % of the town's households). In some instances household shad to be targeted to balance political affiliations	Cross-sectional survey using structured questionnaire	Availability of water at a point of consumption (household or public stand-pipe) for 24 hrs a day, 7 days a week, 365 days a year.	Piped supply	20.7 % had 'no problem' with supply, 27% had water for 1-5 hrs/dy; 24.3% for 5-10hrs/dy; 13% 5-10hrs/dy; 12.7% for 15-24 hrs/dy; 0.3% did not respond and 0.7% did not know
Thompson et al. (2000)	Assess changes in domestic water use	Urban Kenya, Tanzania, Uganda 1997 Unpiped households: 99 Piped households: 349	Cross-sectional follow up study, 30 years later, using semi-structured interviews, observation, interviews with key informants, , field observation, review of secondary literature	None stated	Piped in house connection	Water available 24hrs/dy: 56%, <12hrs/dy: approximately 40%; 1-5hrs/dy: approximately 20%

Author(s), year	Study objective(s)	Setting, year of study and sample	Methods	Definition of reliability/synonym	Type of supply	Estimates of (un)reliability
Virjee & Gaskin (2010)	Ascertain the willingness to pay for changes in the level of service experienced by users	Trinidad and Tobago 2003 The Central Statistical Office's Continuous Sample Survey of Population sampling method was used to randomly select 1419 households, using a two-stage stratification scheme based on geography and labour force characteristics	Cross-sectional multi-part survey	None stated	WASA in-house piped connection only; WASA in-house connection + secondary source; No in-house connection	Water available 24hrs/dy, 7dys/week: 27%, Almost 30% received no water from WASA at all during the time of the survey. 68% had water storage tanks on their premises with an average installed capacity of 610 gallons. As a result of these coping mechanisms, 82% of those with tanks had a 24-hour water supply
Widiyati (2011)	Present evidence of willingness to pay to avoid costs associated with intermittent water supply from Bandung Municipality in Indonesia	Urban Indonesia 2011 200 people interviewed in survey	Cross-sectional survey using structured questionnaires	None stated	Piped	24 hour supply: 60% For about 40%: water is rationed from 1hour every 2days to about 18 hours per day. Mean hours of supply in actual study was 2.4 based on a numbered scale of 1: ≤3hrs/day, 2:3-6hrs/dy, 3: 7-10hrs/dy, 4:11-13hrs/dy, 5:other

Author(s), year	Study objective(s)	Setting, year of study and sample	Methods	Definition of reliability/synonym	Type of supply	Estimates of (un)reliability
Zérah (1998, 2000a)	*Study 1:* Measure the costs of unreliability *Study 2:* understand the household demand for a service by assessing the actual behaviour adopted by households when they have to cope with an inadequate service.	Urban India 1995 Two stratified sample of 678 households in four zones of urban Delhi	Cross-sectional survey using structured questionnaires	A service is reliable if it is provided in time, and with the quality and the quantity required	Piped	On average, 13hrs/dy, about 40 % have water around the clock about 13 % do not get water at all; High pressure: 8.5%; Average pressure: 49.1% Low pressure: 32.9%; No pressure: 9.5% >12hrs: 50.3%; 6-12hrs:8.6%, 2-6hrs: 28.2%, ≤2hrs: 12.8%
Zérah (2002)	Determine the level of service provided by the Vijayawada Municipal Corporation (VMC); assess the existing households' coping strategies; evaluate the cost of water supply and sanitation and measure the level of satisfaction of the inhabitants of Vijayawada	Urban India 2002 167 households in 15 wards (out of 50 wards) and in neighbouring villages of Vijayawada	Cross-sectional survey using structured questionnaires	None stated	Piped connections, private boreholes, public taps	Municipal water connection: 3.83 hours of supply in summer, 3.73 in winter. Private boreholes: On average, households spend almost 2 hours to pump water.Public taps: water is available every day in winter in 93% of the cases and in 96% of the cases in summer. Otherwise water is available on alternate days. In winter and in summer, supply is similar (around 6 hrs).

Table 5.3: Studies in rural settings

Author(s), year	Study objective(s)	Setting, year of study and sample	Methods	Definition of reliability/synonym	Type of supply	Estimates of (un)reliability
Admassu et al. (2003)	Assess utilisation, functionality, community participation and sustainability of water projects	Rural Ethiopia, 2001-2002 11 randomly selected peasant associations, making a total of 768 households and 114 site observations	Descriptive cross-sectional study using structured questionnaires, observation and 4 focus group discussions	Functioning: proper physical state of water supply projects in relation to their present working condition at the time of the survey	Protected spring, hand-dug wells with pumps	52 out of 442 source points not functioning. (11.76%)
Arnold et al (2013a)	Assess existing water infrastructure, determine the reliability of water sources, assess the water quality available for domestic use, and evaluate community awareness as related to water, sanitation, and hygiene.	Rural Ghana, 2008-2010 8 villages selected on basis on participation in previous community development projects and request by villagers	Cross-sectional surveys in summers of 2008-2010m using sanitary surveys, conversations with villagers, 1 focus group, key informant interviews and water quality testing	None stated	Standpipes, boreholes, dug wells and shallow wells	One third of standpipes not functioning at time of survey,

Author(s), year	**Study objective(s)**	**Setting, year of study and sample**	**Methods**	**Definition of reliability/synonym**	**Type of supply**	**Estimates of (un)reliability**
Davis et al. (2008)	Explore the contribution of various types of post-construction support (PCS) to the sustainability of rural water supply systems in Bolivia	Rural Bolivia 2005 99 communities	Cross-sectional mixed methods using household survey, system operator survey, focus group with village leaders, focus group with women, focus group with village water committee	None stated	94 % had house connections or yard taps 27 % had public taps 8 % had wells	Breakdowns as reported by operators: mean 2, household members: mean 3, women's focus groups: mean 2.9 Typical duration of breakdowns (dys) operator: mean: 4.2, household members: 9.8, women's focus groups mean 15.8. Systems received prior to 2000, range between 5 and 8 years in age
Gleitsmann et al. (2007)	Assess the impact of stakeholder participation on the management of water sources; examining i) choice-of technology preferences ii) water use patterns for domestic and agricultural purposes among stakeholders	Rural Mali 2004 3 communities, 30 women, 60 men Consultation with World Vision and village representatives led to selection of a representative cross section that included all ethnic groups	Mixed methods case study using focus groups, key informant structured and unstructured interviews	Success was defined as a pump that was in-use by the community.	Wide-diameter wells and boreholes with handpumps	Success rates of different manual pumps in the study area: UPM 4/21 (19%); India-Mali 6/11 (55%); Vergnet 6/7 (86%) Total 16/39 (41%) If WHO minimum flow rate guidelines of 13 l/min are applied, success rate:4/39 (10%).

Author(s), year	Study objective(s)	Setting, year of study and sample	Methods	Definition of reliability/synonym	Type of supply	Estimates of (un)reliability
Hoko & Hertle (2006)	Evaluate the sustainability of a rural water point rehabilitation project that was carried by a local NGO	Rural Zimbabwe 144 water points Mwenezi: 37 Gwanda: 41 Bulilima: 38 Mangwe: 28	Cross-sectional quantitative study using structured observation of water points and structured questionnaires	None stated	Boreholes with handpumps	Water points not working in Mwenezi: 4%, Gwanda: 17%, Bulilima: 13% Mangwe: 25%. Operation of the water points deemed difficult by a minimum of 19% (Mwenezi) to a maximum of 64% (Mangwe) of respondents.
Jiménez & Pérez-Foguet, (2011)	Establish relationships between technology, functionality and durability of rural water points	Rural Tanzania 2005-2006 5.921 water points 15 districts covering 15 % of rural population	Quantitative cross-sectional survey (Water Aid data)	None stated	Handpumps 2,326 (39.3%) Motorised pumping systems 2,180 936.8%) Gravity fed 1,263 (21.3%) Other (protected springs, rainwater-harvesting, windmill powered water point): 152 (2.6%)	*

*Functionality: Handpumps 45.31%, gravity -fed systems: 48.61% motorised pumps 44.36%, other systems: 36.18% Aggregated functionality: 45.4%.

Handpump functionality dropped from 61% in first 5yrs to 6% in the 25yr period: Motorised systems started at 77% and dropped to 13%, gravity fed systems 66% to 20%. Aggregated rate: 35-47% working 15 yrs after installation.

>30% of WP become non-functional after the first 5yrs and after this the functionality rate decreases at a slower rate (another 30% become non-functional in following 15yrs) - handpumps show least favourable functionality rate; gravity-fed show irregular trend between periods but best performance in the long-run; motorised pumping systems have a very good performance in the first period and maintain a similar descending slope as others in the long term

Author(s), year	**Study objective(s)**	**Setting, year of study and sample**	**Methods**	**Definition of reliability/synonym**	**Type of supply**	**Estimates of (un)reliability**
Kleemeier (2000)	Explore the assumption about the link between participation and sustainability by presenting findings from a study of operation and maintenance on rural water supplies that were constructed under a program widely praised for its exemplary approach to community participation	Rural Malawi 1997-1998 Sample includes schemes from all three of Malawi's administrative regions. Sample limited to schemes that originally had less than 120 km of pipeline. 17 schemes visited for one day and a follow-up visit to four of the schemes	Cross-sectional survey involving discussion with water schemes' monitoring assistant, main committee, tap committees, repair teams and observation of schemes	None stated	Piped- communal taps	Overall, 66% of the taps supplied water a minimum of 50% of the days in the previous 3 months. In 4 of the smallest schemes (13-37 taps), 80% or more of the taps supply water on a regular, if not continuous basis
Majuru et al (2012)	Assess the impact of unreliability on water service indicators of distance to source, water quantity and quality	Rural South Africa 2007-2008 3 communities of which one was a control/reference community, 114 households in total	Quasi-experimental with repeated cross-sectional surveys of water supplies and daily symptom diaries over 56 weeks	None stated	Piped- communal taps Drilled wells with handpumps Water tanks	Handpumps: broke down for about 2 weeks every 3 months; 83% ; Tanks: water ran out after 2 weeks: 50% Communal taps Community 1: 2 breakdowns 89%, Community 2: 4 breakdowns: 58%
Moon (2006)	Assess the role of private sector participation in developing and sustaining rural water schemes	Rural Tanzania 2004-2006 6,812 distribution points in 3 regions and 1 district in another region	Quantitative cross-sectional survey (Water Aid data)	'Functionality' is the ratio of functional systems within the population.	Four commonly used extraction systems in the study area: pump and engine, Afridev handpumps, Tanira handpumps, and gravity systems.	Pump and engine schemes have a functionality rate of 48% and the others vary between 60% and 70%

Author(s), year	Study objective(s)	Setting, year of study and sample	Methods	Definition of reliability/synonym	Type of supply	Estimates of (un)reliability
Musonda (2004)	Identify factors that contribute to the promotion of sustainability of rural water supplies in Zambia	Rural Zambia 2001 16 water points in Mazabuka District	Mixed methods cross-sectional survey with structured questionnaires and observations	None stated	Hand-dug well and boreholes with handpumps	8 functioning out of 16, 3 in disrepair for 2 months, 1 in disrepair for 4 years, 1 very difficult to operate, 3 functioning but had problems. Five years was the average age for functional handpumps, as they had been constructed between 1995 and 2000. All semi-functional handpumps had been constructed between 1980 and 1996
Norwegian Agency for Development Cooperation (2008)	Carry out a descriptive based analysis of Norad's previous support to the WSS sectors in partner countries, with emphasis on Kenya and Tanzania during the period 1975 - 1995	Rural Kenya and Tanzania	Archive search and literature study, single and group interviews cross-sectional field work	None stated	Kenya: piped water supply Tanzania: Handpumps, gravity schemes	*Rukwa:* between 65 % and 74 % of 2,000 water points still operating and in daily use. *Kigoma:* between 76 % and 78 % of 800 water points still working and in daily use. *Kenya:* 16 towns, 91 % of water points still working and in daily use.

Author(s), year	Study objective(s)	Setting, year of study and sample	Methods	Definition of reliability/synonym	Type of supply	Estimates of (un)reliability
Schweitzer (2009)	Evaluate the efficacy of community management in sustainability of rural water supply	Rural Dominican Republic 2008-2009 Stratified random sample of 64 water systems built in the DR by initiatives of the National Institute of Potable Water (INAPA, 23) and Peace Corps (41) out of a total cohort of 185 (118 PC and 67 INAPA)	Mixed methods using secondary data analysis observation (participant and non-participant) focus group/key informant interviews household surveys formal versus informal interviews	None stated	INAPA (21): Public or shared taps 1%, Patio connections 77%, Household connections 9%, Multiple connections 14%; Peace Corps (40):Public or shared taps 6%, Patio connections 68%, Household connections 8%, Multiple connections 18%.	Systems with major repairs within last month: INAPA: 80 %, Peace Corps 45% Days per week with water INAPA: 5.7, Peace Corps: 6.2 Hours per day with water INAPA: 11.4, Peace Corps: 16.6 Average system age (years) INAPA: 5; Peace Corps: 6.85

Author(s), year	Study objective(s)	Setting, year of study and sample	Methods	Definition of reliability/synonym	Type of supply	Estimates of (un)reliability
World Bank – Netherlands Water Partnersrhip (2009)	Investigate how the provision of support to communities after the construction of a rural water supply project affected project performance in the medium term	Rural Peru, and Ghana. Peru mid-2004, Ghana late 2004 Peru: 99 villages, 25 households on each village, 1,360 male and 1,089 female respondents	Cross-sectional mixed methods using household survey, system operator survey, focus group with village leaders, focus group with women, focus group with village water committee	None stated	Handpumps, public taps and house connections	∞

∞Peru: Taps working (operator data): FONCODES Average: 95%; SANBASUR Average 93%; Average hours of operation/day (household data): FONCODES: 18.8; SANBASUR: 19.9; Average major unplanned interruptions in water supply service for at least one day in past 6 months (operator data): FONCODES: 89%; SANBASUR: 59%; (Leaders): FONCODES: 70%; SANBASUR: 55%; Average system age: FONCODES: 7.57 years; SANBASUR: 6.13 years; Average number of days to fix major problem operator: FONCODES: 4.53; SANBASUR: 1.06; leaders: FONCODES: 2.08; SANBASUR: 2.58

Ghana: % of villages where all project handpumps are working (89): Brong Ahafo: 88; Volta: 92; % villages with working systems that had a breakdown in last 6 months (57): Brong Ahafo: 58; Volta: 55; Average years since completion: Brong Ahafo: 6.2; Volta: 5.8 (Average 6); Median days to repair the system last time it broke (reported by hhs) (20): Brong Ahafo: 18; Volta: 22

Table 5.4: Studies in both urban and rural settings

Author(s), year	Study objective(s)	Setting, year of study and sample	Methods	Definition of reliability/synonym	Type of supply	Estimates of (un)reliability
Akosa (1990)	Develop of a Data Envelopment Analysis method to combine assessment of technical, financial, economic, institutional, social and environmental aspects of water supply and sanitation projects	Rural and urban Ghana, 1986-1988 6 water supply projects over a 30-month period	Cross sectional surveys with Observation, records from treatment plants, interviews with plant operators	None stated	Piped Drilled wells with handpumps Hand-dug wells with handpumps	*

*Accra-Tema Water Supply: Power outages involved 193 faults lasting a total of 707 hrs 7mm in 3 years (1986-88). Frequency of fault: 1 fault in 5.67 days. Duration: average 3.67 hrs/fault. Plant down time: 2.7%.

Borehole Water Supply: 21.7% down time.

Package Plant Water Supply: 20.3 % down time. % of time when plant was operating with inadequate supply of chemicals (including periods of chemical rationing) 58.7%.

2500 Drilled Wells Water Supply: Target established is 90% of pump operational at all times. Achievement is 85% of all handpumps operational. Down time is 15%.

3000 Drilled Well Water Supply: Target established is 90% of pumps operating at all times. Achievement is 40% of all hand pumps operational. Down time is 60%.

Hand Dug Well: Pump down time is calculated as 2.3% but water is available through the hatch

Author(s), year	Study objective(s)	Setting, year of study and sample	Methods	Definition of reliability/synonym	Type of supply	Estimates of (un)reliability
Asian Development Bank (2009)	Assess project performance and identify lessons for maximizing the development effectiveness of water supply and sanitation interventions, by conducting rigorous impact evaluation	Rural and urban Punjab, Pakistan. 7 randomly selected districts of the 30 covered by the Punjab Rural Water Supply & Sanitation Project (PCWSSP) and the Punjab Community Water Supply & Sanitation Project (PCWSS). 115 subprojects were identified using stratified random sampling, A total of 1,301 treatment households covered by a project and 1,301 comparison households outside the projects	Mixed methods using key informant interviews, focus group discussions, and household surveys. Comparison communities identified using district census reports. Community-level parameters used for matching: i) total village area ii) number of households with potable water iii) average household size iv) literacy rates.	None stated	92 % of the project communities had a community water supply system, while 8% of comparison communities did. 24% depended on hand pumps in project areas and 54% than in the comparison communities 40 % served by tube wells in project communities and 24 % in comparison communities	89% PCWSSP functional, and 68 % of PRWSSP Households receiving water received on average 5 hours of supply per day. 18 % of households in project areas used suction machines to deal with low pressure. Down time less than 3 days for 2/3 of major repairs
Bourgois et al. (2013)	Survey of the quantity and quality of existing water access points in three districts in Sierra Leone	Rural and Urban Sierra Leone 2,859 drinking water access systems in 3 districts	Survey of water points and interviewers with local leaders of villages	Rate of functionality defined as access to water throughout the year and a working pump	Spring box : 2 bore hole : 499 Hand dung well : 2028 Open well : 330	30 % of the finished, complete borehole systems were non-functional due to a broken pump

Author(s), year	Study objective(s)	Setting, year of study and sample	Methods	Definition of reliability/synonym	Type of supply	Estimates of (un)reliability
O'Hara et al. (2008)	Quantify current level of access to safe water and sanitation in rural and urban communities across the Republic of Kazakhstan.	Rural and urban Kazakhstan 2005 7,515 people (0.05% of the population)	Cross-sectional in-depth questionnaire survey administered to7,515 people; 250 semi-structured interviews with individuals from urban and rural settlements, as well as officials working in various organisations concerned with water supply and health issues; and 16 focus group discussions with a range of stakeholder groups	None stated	Piped	Urban dwellers report service cuts on 6 days a month for 8-10 hours per day. Rural dwellers report cuts of 15-16 hours on an average of 21 days a month. People living in upper floors of high-rise buildings have cut-offs due to low pressure

Author(s), year	Study objective(s)	Setting, year of study and sample	Methods	Definition of reliability/synonym	Type of supply	Estimates of (un)reliability
Pan American Health Organisation (2001)	Monitor and evaluate the situation of drinking water and sanitation in the Region of the Americas	Rural and urban parts of the Americas*	Questionnaires collation of information already existing in the countries, through consultations of documents and reports of entities of the sector and government institutions, results of household surveys, applied research and Sectoral Analysis or other pertinent studies conducted in the sector.	None stated	Piped and un-piped	Urban systems provided with water intermittently: 0 -100% Urban population provided with water intermittently: 0-99.9 % Rural systems in operation: 6-100%

*Countries covered in the survey were: Anguilla, Antigua & Barbuda, Argentina, Bahamas, Barbados, Belize, Bolivia, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, French Guiana, Grenada, Guadalupe, Guatemala, Guyana, Haiti, Honduras, Montserrat, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Saint Kitts & Nevis, Saint Lucia, Suriname, Trinidad & Tobago, Turks & Caicos Islands, Uruguay, Venezuela and Virgin Islands

These definitions vary considerably, including: "the ratio of functional water systems in the population" (Moon, 2006); "the physical absence of water flowing from the tap" (Howard, 2002); "availability of water at a point of consumption (household or public stand-pipe) for 24 hours a day, 7 days a week, 365 days a year" (Shah, 2003) and "a service is reliable if it is provided in time, and with the quality and quantity required" (Zérah, 1998).

Although none of the definitions are shared by more than one study, there is some degree of commonality in the features used by the different studies as part of their definition. One is to define reliability in terms of the water supply system and how it works (3 out of 7 studies) (Admassu et al., 2003, Howard, 2002, Moon, 2006). The other defines reliability in relation to the extent to which the needs of water users are met (2 out of 7 studies) (Zérah, 1998, Zérah, 2000a, Gleitsmann et al., 2007).

5.3.2 Assessment of reliability

The criteria used to assess reliability also differ somewhat. For example, Akosa (1990) quantifies reliability as the "fraction of the time when the service is available to the user", while Kleemeier (2000) reports on the "proportion of taps supplying water at time of survey and preceding 3 months". Some assessment criteria are shared by more than one study and seem to be related to the setting i.e. rural or urban.

The assessment criteria used in urban settings are presented in Table 5.5. The most common criterion used to assess reliability of water supplies in urban settings is duration of supply in hours per day. This criterion is used in 12 of the 18 studies reporting on urban settings (Andey and Kelkar, 2009, Asian Development Bank, 2007, Baisa et al., 2010, Caprara et al., 2009, Gulyani et al., 2005, Pan American Health Organization, 2001, Pattanayak et al., 2005, Shah, 2003, Thompson et al., 2000, Virjee and Gaskin, 2010, Widiyati, 2011, Zérah, 2002, Zérah, 1998, Zérah, 2000a, Jiménez and Pérez-Foguet, 2011).

Table 5.5: Assessment criteria for reliability of urban water supplies

	Aderibigbe et al. (2008)	Akosa (1990)	Andey & Kelkar (2009)	Asian Development Bank (2007)	Ayoub & Malaeb (2006)	Baisa et al. (2010)	Caprara et al. (2009)	Gulyani et al. (2005)	Howard (2002)	Mycoo (1996)	Pan American Health Organisation (2001)	Pattanayak et al. (2005)	Shar (2003)	Thompson et al. (2000)	Virjee & Gaskin (2010)	Widiyati (2011)	Zérah (1998, 2000a, 2002)
Frequency of supply per week*	✓				✓												
Frequency of supply in days per week						✓	✓								✓		
Duration of supply in hours per day			✓	✓		✓	✓	✓			✓	✓	✓	✓	✓	✓	✓
Fraction of the time water is available		✓															
Frequency and length of service interruptions										✓							
Interruption in supply in the previous week									✓								
Pressure										✓							✓
Proportion of systems with intermittence											✓						
Proportion of population served by intermittent systems											✓						

*Unit not specified

Amongst the literature covering rural settings, 7 studies (Admassu et al., 2003, Arnold et al., 2013a, Asian Development Bank, 2009, Davis et al., 2008, Jiménez and Pérez-Foguet, 2011, Pan American Health Organization, 2001, World Bank - Netherlands Water Partnership, 2009) report on the proportion of water sources functional at the time of the survey (Table 5.6). Downtime (duration of breakdowns in the water supply system) is reported in 5 of the studies (Arnold et al., 2013a, Asian Development Bank, 2009, Davis et al., 2008, Majuru et al., 2012, World Bank - Netherlands Water Partnership, 2009). In the study by Davis et al. (2008) the authors note that discrepancies in the reported duration of breakdowns may have been due to respondents classifying events of low pressure that resulted in limited or no supply as breakdowns.

Three of the studies report on ease of operation of handpumps. In a study in Mali, Gleitsmann et al. (2007) report that some households had stopped using the handpumps altogether due to - amongst other reasons - difficulty in manually operating the pumps. This difficulty in operating handpumps is also reported in a study of the sustainability of rehabilitation of rural water systems in Zimbabwe by Hoko and Hertle (2006). In some instances up to 100 strokes were required before water was discharged from handpumps, and up to 64 % of respondents reported having difficulty in using the handpumps. Similarly, Musonda (2004) finds that women and children in particular sometimes had difficulty in collecting water from handpumps because they were too stiff to operate.

Table 5.6: Assessment criteria for reliability of rural water supply

	Admassu et al. (2003)	Arnold et al. (2013b)	Asian Development Bank (2009)	Bourgois et al., (2013)	Davis et al. (2008)	Gleitsmann et al. (2007)	Hoko & Hertle (2006)	Jiménez & Pérez-Foguet (2011)	Kleemeier (2000)	Majuru et al. (2012)	Moon (2006)	Musonda (2004)	Norwegian Agency for Development Cooperation (2008)	O'Hara ett al. (2008)	Pan American Health Organisation (2001)	Schweitzer (2009)	World Bank – Netherlands Water Partnership (2009)
Age of water supply system					✓											✓	✓
Breakdowns in previous 6 months					✓												✓
Breakdowns in study period										✓							
Down time		✓	✓		✓					✓							✓
Duration of supply hours per day			✓													✓	
Duration of supply days per week																✓	
Duration of supply interruptions in hours/day and days/week														✓			
Ease of operation of handpumps							✓					✓					
Flow rate						✓											
Hours/days water was available per week		✓															

	Admassu et al. (2003)	Arnold et al. (2013b)	Asian Development Bank (2009)	Bourgois et al., (2013)	Davis et al. (2008)	Gleitsmann et al. (2007)	Hoko & Hertle (2006)	Jiménez & Pérez-Foguet (2011)	Kleemeier (2000)	Majuru et al. (2012)	Moon (2006)	Musonda (2004)	Norwegian Agency for Development Cooperation (2008)	O'Hara ett al. (2008)	Pan American Health Organisation (2001)	Schweitzer (2009)	World Bank – Netherlands Water Partnership (2009)
Lifespan of water system (proportion functional over a period of time)								✓			✓	✓	✓				
Number of pumps in use at time of survey						✓											
Proportion of taps supplying water at time of survey and preceding 3 months									✓								
Proportion of functional water sources at time of survey	✓	✓	✓	✓	✓			✓							✓		✓
Proportion of non-functional water sources at time of survey							✓										
Sources with major repairs within last month																✓	

5.3.3 Lifespan of water supply systems

Five studies assess reliability in relation to the age of water supply systems. Kleeimeier (2000) evaluated the Malawi Rural Piped Water Scheme Program and reports that although the smallest and newest schemes were performing well 3 to 26 years after completion, overall almost half of the schemes were performing poorly. In a survey of 16 water points in a district in rural Zambia, Musonda (2004) found that 10 years was the average age for functional handpumps, whereas semi-functional hand pumps were approximately 13 years old or more. Functional handpumps were those that typically served 360 people, whereas non-functional ones were those that had served about 506 people. This correlation between age and functionality of water supply systems is also reported by Moon (2006). Anecdotal evidence from the study suggests that hand pumps require major rehabilitation after 7-8 years. Most pump and engine systems have significant maintenance costs within a few years but a few seem to work after 30 years, while gravity systems seem relatively unaffected by age.

Jiménez and Pérez-Foguet (2011) surveyed water points in 15 districts covering 15 % of the rural population in Tanzania. They find that functionality rates did not vary greatly between hand pumps, gravity-fed systems and motorised pumping systems. Functionality of hand pumps dropped from 61 % in the first five years of installation to 6 % over a period of 25 years. In the same period, motorised pumps dropped from 77 % to 13 %, while gravity-fed systems dropped from 66 % to 20 %. The aggregated functionality for three technologies was 35-47 % of functional water points after 15 years. The authors conclude that generally 30 % of water points became non-functional within the first five years of operation, after which period the decrease in functionality is at a slower rate.

In contrast, Bourgois et al. (2013) find that the performance of older systems is significantly better than that of newer ones. In their survey of water points in three districts in Sierra Leone, 73 % of the water systems that were 22 years old were functioning at the time of the survey, compared to 40 % of those that were a year old.

5.4 Discussion

The review has explored definitions of and criteria used to assess water supply reliability, and noted some reports on the lifespans of various water supply technologies.

Only about a fifth (7/34) of studies in the review give explicit definitions of reliability. These definitions vary, but two common features appear to underlie these definitions; the functionality of the water supply system itself, and the extent to which it meets the needs of water users. The most common criterion used to assess water supply reliability in urban settings is the duration / continuity of supply in hours per day, whereas in rural settings the proportion of functional water systems is more commonly used. Results from four out of five studies reporting on the lifespans of water supply systems indicate a correlation between age and functionality; older systems are less likely to be functional. These results are contradicted in one study which finds better functionality amongst older systems.

Before discussing the implications of these findings, there are some limitations to the review that should be noted. The first of these arises from the lack of consensus on what is meant by water supply reliability. Studies use various terms synonymous to reliability, and although efforts were made to capture this variation in terminology in the search terms, it is likely that there are some that were missed. The studies retrieved must be considered in the light of this limitation. Although the literature reviewed is by no means exhaustive, it does cover a range of grey and published literature, including literature from key agencies in the water sector and some results from multi-country monitoring activities.

Turning now to the results of the review, an interesting finding is that the geographic distribution of studies appears to be biased towards sub-Saharan Africa, as half of the studies reviewed were from there. Notably, this is in contrast to the number of studies from the same region on how households cope with unreliable water supplies (Chapter 7). The spread between rural and urban settings is somewhat more even.

The two features underlying the definitions of reliability are reflective of the conundrum that characterises the assessment of other features of water supply. Should the definition and subsequent assessment be based on a *binary* approach of whether the supply is reliable, accessible or safe, or rather one that better reflects the *quality* of these water supply features?

The results indicate that current practice appears to favour assessment criteria based on the former in rural settings, and the latter in urban settings. The most common assessment criterion that is reported in rural settings is the proportion of water sources that are functional at the time of the survey. Given that the majority of studies reviewed are from sub-Saharan Africa where the majority of rural dwellers rely on handpumps (WHO/UNICEF, 2011), it is likely that the assessment approach might have been shaped on this basis.

There are some challenges that the approach presents. First, although handpumps are quite common as the supply technology in rural areas, there are some countries that are making significant progress in 'moving up the service ladder' by providing piped technologies, either at communal points, within yards or within the home, South Africa being an example (see Tissington et al., (2008)). In these settings water supply systems may not stop functioning completely, but gradually deteriorate in performance (Lockwood et al., n.d.), and failure to take this into account would yield inaccurate estimates of the real situation on the ground.

Further, these 'snap-shots' of the proportion of functional systems do not always take into whether the breakdown is short-term, pending repair, or if the water source is completely non-functional (Koestler et al., 2010, Lockwood et al., n.d.). The difficulty in operating handpumps that is noted as a significant problem in three studies perhaps alludes to the limitations of considering reliability of handpump supplies as a binary issue of whether or not the pump works.

The dominance of a particular assessment criterion in a particular setting should also not be assumed to mean that it is necessarily the most appropriate. For instance, although duration of supply appears to be the de facto assessment criterion in urban settings, evidence suggests that for instance, adequate flow rate is also of importance to water users (Davis et al., 2008), and that pressure fluctuations in piped systems can negatively affect water quality and subsequently health (Klasen et al., 2012, Lechtenfeld, 2012). Taking this into account plus the range of assessment criteria found in this review, the findings point towards reliability of water supply being a multi-attribute concept.

Conclusions

The review has shown that there is a lot of variation in the definitions and assessment criteria used in studies on water supply reliability in developing countries. That said, there is some degree of commonality in the assessment criteria used, depending on the setting. Many of the studies conducted in urban settings report on duration of supply in hours per day, whereas in rural settings the proportion of functional water supply systems is more commonly reported.

Although these particular criteria dominate in the existing literature, care should be exercised to not assume that they are necessarily the most appropriate. First, the heterogeneity in the definitions and assessment criteria used is perhaps indicative of a multi-attribute nature of the concept of reliability. Failure to take this into account in the assessment process – regardless of setting – would likely yield an inaccurate depiction of the situation. Secondly, the reliance on a binary indication of functionality in rural settings may not take into account the changing landscape of water supply technologies in these areas, where supply systems may not necessarily fail altogether but perform at a sub-optimal level. Thirdly, there is no indication that the perspectives of water users – those actually faced with unreliable water supplies – are taken into account when deciding upon assessment criteria. The next chapter addresses this issue by assessing households' preferences for reliable water supplies.

6 Preferences for reliability of water supply in Limpopo

This chapter builds on the systematic review presented in Chapter 5 and empirically explores the question as to what constitutes a reliable water supply. A discrete choice experiment is applied to elicit households' preferences for reliability of water supplies. It addresses three main points in households' preferences: i) the attributes of reliability that are of interest to households and their relative importance, ii) how much households would be willing to pay for these attributes, and iii) the proportion of households who will accept hypothetical water services, if given specific levels of reliability.

6.1 Introduction

Understanding preferences for reliable water supplies is important for several reasons. First, households' preferences for water supplies can have a significant impact on the willingness to use water services. With increasing emphasis on involving users in decision-making about services, eliciting preferences is an important step towards designing appropriate services (Yang et al., 2006). Further, as efforts to develop indicators to succeed those of the MDGs gather momentum, it should be highlighted that the primary challenge presented by water supply reliability is how to define and assess it in a framework that is cognisant of:

- the multi-attribute nature of water supply reliability
- the various water supply technologies
- the feasibility and cost of assessment
- the role of water supply reliability as a predictor of health, social and economic outcomes

Evidently, the development of this framework and subsequent definition and assessment criteria requires the continued collaborative efforts of those providing water supplies, funders and monitoring agencies. Further, understanding the value water users place on various attributes of reliability is necessary to better tailor assessment criteria that broadly recognise user perspectives. Amongst the studies reviewed in the previous chapter, little account is given as to how the criteria used to assess reliability were arrived at, or water users' preferences for reliability.

The 2013 update on the MDG target for water and sanitation outlines proposed definitions and targets for the post-2015 agenda. Amongst these is the proposed definition of "Intermediate drinking water supply at home" as "the use of an improved source that is on the premises and from which water is "available in acceptable quantities at least 12 of the past 14 days" (WHO/UNICEF, 2013). But even in this report it is not evident how this definition was arrived at, nor the extent to which it matches water users' own perceptions or definitions of unreliable water supply. Are there other attributes not reflected in this definition that would constitute unreliable water supplies, from the perspective of the user? How closely is what is measured in global monitoring programmes indicative of water users / households actual experience? If indeed the adage that what gets measured gets improved is true, then greater emphasis should be given to understanding households' own preferences for water supply reliability, and where improvements can be targeted.

6.1.1 Eliciting preferences

Preferences can be elicited through various qualitative and quantitative techniques. The former typically entails surveys of sample households and key informants, or group-based approaches such as community meetings or focus groups (Ryan et al., 2001). A major limitation of this technique is that is that it essentially produces a list of preferences, with no indication of how they are prioritised (World Health Organization, 2012).

Quantitative approaches include ranking, rating as well as choice-based techniques. Essentially, in ranking exercises respondents assign an ordinal ranking a given set of options, and in rating exercises a numeric or semantic scale is assigned to given criteria or scenarios. However, the limitation that these approaches present is that they do not provide information on strength of preference or trade-offs that respondents may be willing to make.

6.1.2 Why a discrete choice experiment?

Discrete choice experiments (DCEs) are a powerful choice-based approach aimed at assessing stated preferences for a given phenomenon, as a function of the phenomenon's characteristics. The approach is based on the economic theory that users' decisions with regards to goods or services are based primarily on the characteristics or attributes of those goods or services. DCEs have been applied widely in transport, health and environmental economics (World Health Organization, 2012).

As applied to this study, the technique is based on the premise that the reliability of water supplies can be described by attributes of reliability, and the extent to which households value the reliability of water supplies depends on levels of these attributes.

In the discrete choice survey, respondents are presented with a number of choice sets, each describing a series of attributes at different levels. By varying the levels of attributes in the various choice sets and asking respondents to make their choices again, the relative importance that individuals place on these attributes can be determined (Phillips et al., 2006). If there is a cost attribute included in the DCE, the preferences can be quantified in monetary terms i.e. a monetary value attached to them.

When well-designed and conducted, DCEs can provide information on:

- The characteristics of a water service that are most important for households
- How much households are willing to pay for water services of given attributes and attribute levels
- How characteristics such as sex, socio-economic status, community etc., can influence preferences for water services
- What proportion of households would be interested in defined services levels

6.2 Objectives

The discrete choice experiment sought to address the following questions:

- Which attributes of water supply reliability are of importance to households?
- How much are households willing to pay for improvements in these attributes?
- Do preferences and willingness to pay for attributes differ between various subgroups?
- What proportion of households would be interested in water services of defined level of reliability?

Understanding the preferences of households is useful for policy and planning in water supply services. Optimal levels of water supply reliability can be determined, and through willingness to pay estimates, some insights into the monetary value of the levels of reliability can be drawn.

6.3 Methods

Several stages are involved in the design of discrete choice experiments (DCEs). These are: identifying the attributes; assigning attribute levels; designing the choice sets and generating the questionnaire.

6.3.1 Establishing attributes and assigning attribute levels

To establish the attributes and levels, the findings from the review of definitions and assessment criteria for reliability (Chapter 5) were integrated with the findings of a purposive literature search on DCEs on water supply improvements, water supply service benchmarks in South Africa and discussions with researchers from the collaborating university who themselves reside in the vicinity of the study communities. The search terms, databases, characteristics of the studies, attributes and levels identified from the DCE literature are tabled in Appendix 6.1.

Three attributes were identified from the literature search: availability of supply during the day (in hours per day); availability of supply during the week (in days per week) and prior notification of water supply interruptions. From the Strategic Framework for Water Services (Department of Water Affairs, 2003) and the guide for water supply service levels(Department of Water Affairs, 2000), 3 attributes were identified that were thought to be potentially relevant to the respondents and the water supply policy in the country (Table 6.1). The Strategic Framework for Water Services sets out norms for water service coverage and quality, as well the roles of various spheres of government, while the guide serves to assist local government in the selection of appropriate levels of water services.

Table 6.1: Attributes and levels from water service benchmarks

Attribute	Service benchmark	Interpretation
Downtime (time taken to repair breakdowns)	Not to exceed 48 consecutive hours (2 days)	Maximum downtime is 2 consecutive days
Flow rate	10 ℓ/min	Ideally 2 min to fill up a 20-ℓ container
Number of breakdowns	Availability of water for at least 350 days per year	Maximum 15 days without supply; with a maximum downtime of 2 days, translates to about 8 breakdowns

Note: South African water service benchmarks from the Department of Water Affairs (2000, 2003)

One of the attributes that had initially been included was ‘ease of operation’ of hand-pumps. After discussions with environmental health researchers from the local university this attribute was dropped, as it was established that there were no longer any hand-pumps in the study area. The attributes and levels finally included in the choice experiment were those thought to be of practical relevance to respondents as well as reflective of the existing water policy, and are shown in Table 6.2.

Table 6.2: Attributes of water supply reliability and their levels

Attribute	Level			Expected sign
Availability of water supply during the day	Low* ≤ 8 hours a day	Moderate 9-16 hours a day	High ≥ 17 hours a day	Positive
Availability of water supply during the week	Low* < 2 days a week	Moderate 2-4 days a week	High > 4 days a week	Positive
Time taken to repair breakdowns	Short* < 3 consecutive days	Moderate 3-5 consecutive days	Long > 5 consecutive days	Negative
Number of breakdowns in water supply system per year	Low* < 5 interruptions	Moderate 5-8 interruptions	High >8 interruptions	Negative
Prior notification of when water supply will be interrupted	Never*	Sometimes	Always	Positive
Flow rate	Low*	Moderate	High	Positive
Cost of the proposed water service per month	R0	R30	R60	Negative

Note: *reference category used in the regression models; cost included as a continuous variable

Altogether, three attributes were identified from the literature search and another three from the water policy documents. A cost attribute with a monthly cost of a water service ranging from R0 (free) to R60 was included, bringing the total number of attributes in the choice experiment to seven. The levels for the cost attribute were intended to cover the possible range of water supply situations households may be in. At the time of the survey in 2012, the average annual price of a loaf of white bread in peri-urban or rural areas was R8.95; thus R60 was roughly comparable to the price of half a dozen loaves of bread (National Agricultural Marketing Council and Department of Agriculture Forestry and Fisheries, 2012).

The theoretical validity of the choice analysis is assessed by determining whether the signs of the estimated coefficients are consistent with a priori expectations (Mangham et al., 2009). The expected signs of the coefficients for each of the attributes are shown in the last column of Table 6.2. The signs of the coefficients were expected to be positive, with the exception of time taken to repair breakdowns, number of breakdowns and monthly cost of the service. For instance, households would be expected to prefer shorter repair times, fewer breakdowns and lower water prices, all indicated by a negative sign on the coefficients for these the attributes.

6.3.2 Designing the choice sets and generating the questionnaire

With seven attributes and each of them with three levels, the design would generate 2,187 scenarios are possible. A fractional factorial design was used to reduce this to a more practical number. An D-efficient design (Kuhfeld, 2005) was generated in SAS 9.3 software(SAS Institute Inc, 2010), resulting in 18 scenarios. The questionnaire was first compiled in English, translated into the local language of TshiVenda, and thereafter back-translated into English to verify linguistic and contextual accuracy. An example of the English version of a choice scenario is shown in Figure 6.1.

Characteristic	Service A	Service B	Your Current service
 **Availability of water supply during the day**	Moderate Water available 9-16 hours per day	Low Water available 8 hours per day and less	
 **Availability of water supply during the week**	Moderate Water available 2-4 days per week	High Water available more than 4 days per week	
Time taken to repair breakdowns	Long More than 5 consecutive days	Short Not more than 2 consecutive days	
Number of breakdowns per year (12 months)	Moderate 5-8 interruptions	High More than 8 interruptions	This is the service your household currently experiences
Prior notification of when water supply will be interrupted	Always	Never	
 **Pressure**	High	Moderate	
 **Cost of the proposed water service per month**	R30	R0	
If you had the option to choose, which of the three services would you opt for? **(please tick one)**	☐	☐	☐

Figure 6.1: An example of the choice scenario

Respondents were asked to consider a choice set with two hypothetical choice alternatives, along with an opt-out alternative if they did not prefer any of the hypothetical alternatives. This opt-out alternative was the current water supply.

6.3.3 Administering the choice survey

The survey was administered through face to face interviews with trained interviewers. The survey was pre-tested on four households; two with private supplies and two with shared water supplies. Minor modifications were made thereafter, relating mainly to the wording in the local TshiVenda language. The survey began with a warm-up exercise, in which respondents were introduced to the choice situation and the attributes and levels were explained. The interviewers then went through an example of a choice scenario with the respondents, and answered any questions that arose. The attribute levels for the 'current service' were based on respondents' reviews in Part 1 of the survey and are summarised in Chapter 4. These were read out to the respondents as they went through the DCE questionnaire. Respondents were given the choice to either read the questionnaire themselves or have it read out by the interviewer. To aid in comprehension, respondents who chose to have it read out to them were still shown copies of each of the choice scenarios during the interview.

6.3.4 Analysis

In each choice scenario, a respondent *n* faces a choice among *J* = 3 alternatives; two hypothetical water supply reliability options and their current supply reliability, with *T* = 18 such choice scenarios. The 3 alternatives in each scenario are described in terms of the reliability attributes shown in Figure 6.1. A respondent *n* faces attributes of alternative *j* in choice scenario *t* that are represented by the vector V_{njt}. The respondent *n* derives a certain level of utility from each of the three alternatives in the choice scenario, and in the case of alternative *j*, this utility is expressed as:

$$U_{njt} = \beta_n V_{njt} + \varepsilon_{njt} \quad (1)$$

where β_n is a coefficient vector relating the respondent *n* and the alternative V_{njt} to their utility for that alternative. ε_{njt} is an unknown random component denoting factors that influence utility but are not captured in $\beta_n V_{njt}$.

In each of the 18 choice scenarios, the respondent chooses the alternative with the highest utility. The researcher cannot observe the respondent's utility but can observe their choice. Therefore, the probability that respondent *n* will choose alternative *j* is that alternative *j* has a higher utility than alternative *i*; i.e. choose *j* if $U_{njt} > U_{nit}$.

6.3.4.1 Conditional logit model

Households' preferences were estimated using McFadden's (1973) conditional logit model in Stata 12.1 (Stata Corp, 2011) using the equation:

$$
\begin{aligned}
V = \beta_0 &+ \beta_{1\_available \leq 8\,hrs/day} + \beta_{2\_available\ 9-16hrs/day} \\
&+ \beta_{3\_available\ >16hrs/day} + \beta_{4\_available\ <2days/week} \\
&+ \beta_{5\_available\ 2-4\ days/week} + \beta_{6\_available\ >4days/week} \\
&+ \beta_{7\_breakdowns<\ 3days\ to\ repair} \\
&+ \beta_{8\_breakdowns\ 3-5days\ to\ repair} \\
&+ \beta_{9\_breakdowns>5days\ to\ repair} + \beta_{10\_breakdowns<5/year} \\
&+ \beta_{11\_breakdowns\ 5-8/year} + \beta_{12\_breakdowns>8/year} \\
&+ \beta_{13\_notification\ never} + \beta_{14\_notification\ sometimes} \\
&+ \beta_{15\_notification\ always} + \beta_{16\_pressure\ low} \\
&+ \beta_{17\_pressure\ moderate} + \beta_{18\_pressure\ high} + \beta_{19\_cost/month} \\
&+ \varepsilon
\end{aligned} \tag{2}
$$

Where V is utility derived from a water service scenario, the betas (β) are the coefficients indicating the strength of preference for attribute levels in the service and ε is the error term representing unobservable factors. McFadden's conditional logit model is based on the assumption that the error terms ε between service scenarios are independent and identically distributed (iid). Thus, the odds of choosing between two alternatives are assumed to be independent of the presence or absence of a third alternative (Independence of Irrelevant Alternatives (IIA)).

Although all households in the study communities in theory receive Free Basic Water services (see Chapter 2), many households incur water related costs, depending on the strategies they engage in to cope with the unreliable water supply. Estimates of the monthly coping costs for each household were included in the analysis as the costs of the current water supply.

6.3.4.2 Analysing preferences for subgroups

Preferences for water supply reliability are likely to differ across population groups, depending on various factors, such as the existing water situation, socio-demographic characteristics, and perceptions of the water quality (Nam and Son, 2005). Among the households surveyed, intuition suggested that the preferences would differ among households with private water supply and those with shared supplies, as well those in Communities 1 and 2 and those in Community 3. As described in Chapter 2, households with private supplies were those who had either drilled their own wells in Communities 1 and 2; or paid for a municipal yard connection or set up a yard connection from the springs in Community 3. These investments may be indicative of household's valuation of improved water services (Nam and Son, 2005). Further, because households in Communities 1 and 2 incurred significantly higher coping costs compared to those in Community 3, it is plausible that this could have an influence on their preferences (Nam and Son, 2005). To investigate how preferences for water supply reliability differ over the groups, the same model was run for subgroups of households with private versus communal supply; and households in Communities 1 and 2 versus Community 3.

6.3.4.3 Willingness to pay

The inclusion of the cost attribute in the choice experiment enables the estimation of the monetary value of each of the attributes i.e. how much money a respondent was willing to pay for an improvement in an attribute of their water supply. This was estimated as a ratio of an attribute coefficient to negative coefficient of the cost attribute. The equation for estimating willingness to pay for a generic attribute *x* is shown below as:

$$wtp_x = -(\beta_x/\beta_c) \tag{3}$$

where βx is the coefficient for attribute *x* and βc is the coefficient for the cost of the water service per month. After estimation for all attributes in the overall model, similar analyses were performed to investigate how willingness to pay varied amongst the subgroups. Confidence intervals were estimated using the Delta method (Hole, 2007).

6.3.4.4 Predicting choice probabilities

Of further interest was the impact of various water supply reliability improvements by testing 'what if' scenarios. In other words, this was the change in the probability of choosing a baseline service alternative because of a change in the level of one or more of the reliability attributes. The averages of the reliability attributes of the current water supply and the median coping costs reported in Chapter 4 were used to construct a base service alternative. Two hypothetical services alternatives were also constructed, with the levels for the reliability set to ‘high’ and ‘moderate’ for the other, and three levels of potential monthly service costs: R0 (free), R30, and R60. This resulted in one base alternative and 6 hypothetical alternatives (Table 6.3).

Table 6.3: Service scenarios used in predicting uptake of water supply services

Attribute	Base alternative	1	2	3	4	5	6
Availability of water supply during the day	9-16 hours a day	9-16 hours a day	9-16 hours a day	9-16 hours a day	≥ 17 hours a day	≥ 17 hours a day	≥ 17 hours a day
Availability of water supply during the week	> 4 days a week	2-4 days a week	2-4 days a week	2-4 days a week	> 4 days a week	> 4 days a week	> 4 days a week
Time taken to repair breakdowns	> 5 consecutive days	3-5 consecutive days	3-5 consecutive days	3-5 consecutive days	> 5 consecutive days	> 5 consecutive days	> 5 consecutive days
Number of breakdowns in water supply system per year	< 5 interruptions	5-8 interruptions	5-8 interruptions	5-8 interruptions	>8 interruptions	>8 interruptions	>8 interruptions
Prior notification of when water supply will be interrupted	Never	Sometimes	Sometimes	Sometimes	Always	Always	Always
Flow rate	High	Moderate	Moderate	Moderate	High	High	High
Cost of the proposed water service per month		R0	R30	R60	R0	R30	R60

The method used to calculate the probability of uptake of water services follows that of Ryan et al. (2008). The indirect utility of each of the service alternatives was calculated by adding up the coefficients of the relevant attribute levels derived from the conditional logit analysis. The probability of taking up e.g. service alternative 5, a highly reliable service that is provided at a cost of R30 per month, versus the base (current) service would be given by

$$P = e^{service5} / (e^{service5} + e^{current}) \quad (4)$$

Where P is the probability of taking up service alternative 5, *service5* is the indirect utility of service alternative 5 and *current* is the indirect utility of the current service. The predicted measures provide an estimate of the percentage of the sample that would prefer a service that offers the presented attribute levels to the current service.

6.4 Results

The majority (41.7 %) of households with private supplies prefer their current service. In contrast, most households using communal supplies prefer the hypothetical Services A and B.

Table 6.4: Frequencies of service options chosen, by type of supply and community cluster

	Service A	Service B	Current service
Type of supply			
Private	364	405	551
	(27.6 %)	(30.7 %)	(41.7 %)
Communal	993	1,056	159
	(45.0 %)	(47.8 %)	(7.2 %)
Community cluster			
Communities 1 and 2	720	759	298
	(40.5 %)	(42.7 %)	(16.8 %)
Community 3	637	702	412
	(36.4 %)	(40.1 %)	(23.5 %)

Looking at the options by community cluster, 83 % of the choices made by households in Communities 1 and 2 are for the hypothetical Services A and B. In Community 3, about three quarters of the choices made are for the hypothetical services.

6.4.1 Preferences for the overall sample

Table 6.5 presents the estimated coefficients and standard errors from the conditional logit model for the overall sample. The odds ratios and confidence intervals can be found in Appendix 6.2. The model is significant (P < 0.001) as indicated by the likelihood ratio test. All coefficients are significant, with the exception of 'availability of water supply during the week'. The coefficients are relative to the reference category for each attribute, which is 'low', as shown in Table 6.2.

Table 6.5: Water supply preferences for overall sample

	Coefficient	Standard error
Availability of water supply during the day		
9-16 hours a day	0.2548^{***}	0.0604
More than 16 hours a day	0.3788^{***}	0.0569
Availability of water supply during the week		
2-4 days a week	0.0210	0.0577
More than 4 days a week	0.1135	0.0595
Time taken to repair breakdowns		
3-5 consecutive days	0.0584	0.0602
More than 5 consecutive days	-0.2299^{***}	0.0572
Number of water supply system breakdowns per year		
5-8 breakdowns	0.3262^{***}	0.0603
More than 8 breakdowns	0.3202^{***}	0.0577
Prior notification of water supply interruptions		
Sometimes	0.3448^{***}	0.0602
Always	0.6238^{***}	0.0544
Flow rate		
Moderate	0.1685^{**}	0.0629
High	0.1199^{*}	0.0605
Price	-0.0257^{***}	0.0010
N	9,036	
Pseudo-R^2	0.2138	
Likelihood ratio degrees of freedom	13	

Note: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Compared to the current service, households are more likely to choose a service option with the following attributes, in order of preference:

- there is prior notification of interruptions in supply;
- water is available for a longer duration during the day;
- time taken to repair breakdowns is shorter;
- the flow rate is higher; and
- the service cost is lower.

The significant coefficients generally bear the expected signs, with the exception of number of breakdowns, whose positive sign implies that more breakdowns would be preferable. Households are willing to pay R14.71 (US$2[4]) for water supply that is available for more than 16 hours a day (Table 6.6).

Table 6.6: Willingness to pay estimates for overall sample

	WTP	95 % confidence interval
Availability of water supply during the day		
9-16 hours a day	9.90^{***}	5.28 - 14.51
More than 16 hours a day	14.71^{***}	10.25 - 19.18
Availability of water supply during the week		
2-4 days a week	0.82	-3.58 - 5.21
More than 4 days a week	4.41	-0.17 - 8.99
Time taken to repair breakdowns		
3-5 consecutive days	2.27	-2.31 - 6.85
More than 5 consecutive days	-8.93^{***}	-13.27 - -4.59
Number of water supply system breakdowns per year		
5-8 breakdowns	12.67^{***}	7.95 - 17.39
More than 8 breakdowns	12.43^{***}	7.95 - 16.92
Prior notification of water supply interruptions		
Sometimes	13.39^{***}	8.84 - 17.95
Always	24.23^{***}	19.87 - 28.59
Flow rate		
Moderate	6.55^{**}	1.69 - 11.40
High	4.66^{*}	0.02 - 9.29

Note: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$; WTP estimates are in South African Rand (ZAR)

[4] Exchange rate in 2012 of US$1: ZAR8.57

Households are willing to pay R8.93 for a service in which breakdowns are repaired within 2 consecutive days, compared to one in which it repairs taken more than 5 consecutive days. Prior notification of supply interruptions is highly preferred, and households are on average willing to pay R24.33 for a service in which they are always notified, compared to one which they are never notified.

6.4.2 Preferences by type of water supply

The coefficients and willingness to pay estimates according to type of water supply are presented in Tables 6.7 and 6.8 respectively. Having water available for a longer period during the day and notification of interruptions in supply are particularly important to households using communal water supplies. The willingness to pay estimates are R16-R19 and R23-R35 respectively (Table 6.8).

Table 6.7: Preferences by type of water supply

	Private supply		Communal supply	
	Coefficient	Standard error	Coefficient	Standard error
Availability of water supply during the day				
9-16 hours a day	-0.0601	0.1116	0.4032***	0.0743
More than 16 hours a day	0.2777*	0.1079	0.4527***	0.0692
Availability of water supply during the week				
2-4 days a week	-0.2224*	0.1126	0.0554	0.0697
More than 4 days a week	-0.0611	0.1140	0.1380	0.0733
Time taken to repair breakdowns				
3-5 consecutive days	0.3730***	0.1127	-0.0573	0.0732
More than 5 consecutive days	0.1998	0.1054	-0.3728***	0.0701
Number of water supply system breakdowns per year				
5-8 breakdowns	0.3135**	0.1115	0.3568***	0.0742
More than 8 breakdowns	0.1038	0.1112	0.4249***	0.0689
Prior notification of water supply interruptions				
Sometimes	-0.1159	0.1129	0.5665***	0.0734
Always	0.0858	0.1064	0.8545***	0.0651
Flow rate				
Moderate	0.1290	0.1214	0.1625*	0.0761
High	-0.0115	0.1173	0.1010	0.0728
Price	-0.0303***	0.0020	-0.0245***	0.0012
N	2,704		6,332	
Pseudo-R^2	0.1873		0.2549	
Likelihood ratio degrees of freedom	13		13	

Note: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

For the households using private water supplies, several of the significant coefficients bear signs that are opposite to what might be expected: availability of water supply during the week; time taken to repair breakdowns and number of breakdowns.

Table 6.8: Willingness to pay estimates, by type of water supply

	Private supply		Shared supply	
	WTP	95 % confidence interval	WTP	95 % confidence interval
Availability of water supply during the day				
9-16 hours a day	-1.98	-9.20 - 5.24	16.49***	10.47 - 22.51
More than 16 hours a day	9.16*	2.10 - 16.22	18.51***	12.73 - 24.30
Availability of water supply during the week				
2-4 days a week	-7.34*	-14.64 - -0.03	2.27	-3.32 - 7.86
More than 4 days a week	-2.02	-9.38 - 5.35	5.64	-0.35 - 11.64
Time taken to repair breakdowns				
3-5 consecutive days	12.31***	5.10 - 19.51	-2.34	-8.20 - 3.52
More than 5 consecutive days	6.59	-0.22 - 13.40	-15.25***	-20.83 - -9.66
Number of water supply system breakdowns per year				
5-8 breakdowns	10.34**	3.17 - 17.52	14.59***	8.36 - 20.82
More than 8 breakdowns	3.42	-3.74 - 10.59	17.37***	11.61 - 23.13
Prior notification of water supply interruptions				
Sometimes	-3.82	-11.16 - 3.52	23.17***	17.24 - 29.09
Always	2.83	-4.07 - 9.73	34.94***	29.10 - 40.78
Flow rate				
Moderate	4.25	-3.65 - 12.16	6.65*	0.43 - 12.86
High	-0.38	-7.96 - 7.20	4.13	-1.73 - 10.00

Note: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$; WTP estimates are in South African Rand (ZAR)

Amongst the households using shared water supplies, the signs on the significant coefficients are as expected, with the exception of number of breakdowns.

6.4.3 Preferences by community cluster

Tables 6.9 and 6.10 present the coefficients and willingness to pay estimates for Communities 1 and 2 and Community 3. Households in Communities 1 and 2 are more likely to opt for a service in which:

- Water is available for longer periods during the day (more than 8 hours);

- Water is available for more than 4 days a week;
- They are notified prior to interruptions in the water supply;
- The flow rate is not low (moderate or high)
- The service cost is low

Table 6.9: Preferences by community cluster

	Communities 1 and 2		Community 3	
	Coefficient	Standard error	Coefficient	Standard error
Availability of water supply during the day				
9-16 hours a day	0.3268***	0.0897	0.1365	0.0828
More than 16 hours a day	0.5773***	0.0924	0.2450**	0.0762
Availability of water supply during the week				
2-4 days a week	0.1160	0.0878	-0.1376	0.0805
More than 4 days a week	0.4859***	0.0939	-0.1459	0.0811
Time taken to repair breakdowns				
3-5 consecutive days	0.0944	0.0952	0.0964	0.0797
More than 5 consecutive days	-0.0694	0.0903	-0.2364**	0.0754
Number of water supply system breakdowns per year				
5-8 breakdowns	0.2415**	0.0932	0.3565***	0.0804
More than 8 breakdowns	0.3028**	0.0926	0.2285**	0.0783
Prior notification of water supply interruptions				
Sometimes	0.5767***	0.0955	0.1159	0.0802
Always	0.8127***	0.0863	0.4220***	0.0728
Flow rate				
Moderate	0.2992**	0.0970	0.1092	0.0853
High	0.2698**	0.0969	0.0328	0.0821
Price	-0.0296***	0.0015	-0.0216***	0.0014
n	4,162		4,874	
Pseudo-R^2	0.3685		0.1065	
Likelihood ratio degrees of freedom	13		13	

Note: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

In Community 3 however, the number of days that water is available during the week and the flow rate do not seem important.

Table 6.10: Willingness to pay by community cluster

	Communities 1 and 2		Community 3	
	WTP	95 % confidence interval	WTP	95 % confidence interval
Availability of water supply during the day				
9-16 hours a day	11.02***	5.03 - 17.02	6.33	-1.19 - 13.85
More than 16 hours a day	19.47***	13.11 - 25.84	11.36**	4.32 - 18.41
Availability of water supply during the week				
2-4 days a week	3.91	-1.88 - 9.71	-6.38	-13.72 - 0.96
More than 4 days a week	16.39***	10.02 - 22.76	-6.77	-14.10 - 0.56
Time taken to repair breakdowns				
3-5 consecutive days	3.19	-3.11 - 9.48	4.47	-2.77 - 11.71
More than 5 consecutive days	-2.34	-8.31 - 3.63	-10.97**	-17.80 - -4.13
Number of water supply system breakdowns per year				
5-8 breakdowns	8.15*	1.85 - 14.44	16.54***	8.97 - 24.10
More than 8 breakdowns	10.22**	3.90 - 16.53	10.60**	3.46 - 17.73
Prior notification of water supply interruptions				
Sometimes	19.45***	13.24 - 25.67	5.38	-1.86 - 12.61
Always	27.42***	21.41 - 33.42	19.57***	12.79 - 26.35
Flow rate				
Moderate	10.09**	3.59 - 16.59	5.06	-2.79 - 12.92
High	9.10**	2.71 - 15.50	1.52	-5.96 - 9.00

Note: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$; WTP estimates are in South African Rand (ZAR)

In both clusters the signs for the number of breakdowns are positive, implying that more breakdowns would be preferred. Households in Communities 1 and 2 are willing to pay R19.45 a month for a service in which they are sometimes notified of interruptions, and R27.42 for one in which they are always notified.

6.4.4 Predicted choice probabilities

Table 6.11 shows the predicted probabilities of choosing a supply option with given reliability characteristics over the current supply. The most preferred service option is one in which the service is provided for free; and the probability of uptake decreases as the water service costs increase.

Table 6.11: Predicted choice probabilities for hypothetical service options versus the current service

	Free	R30	R60
Service option 1			
Water available more than 16 hours a day			
Water available more than 4 days a week			
Breakdowns repaired in 2 days	83.3%	69.8%	51.6 %
Not more than 4 breakdowns a year			
Always notified of interruptions to supply			
Flow rate high			
Service option 2			
Water available 9-16 hours a day			
Water available 2-4 days a week			
Breakdowns repaired in 3-5 days			
5-8 breakdowns a year	81.1 %	66.5 %	47.8 %
Sometimes notified of interruptions to supply			
Flow rate moderate			

Note: Service costs are in South African Rand (ZAR) per month

A service in which all reliability characteristics are set to 'high' and the service is free would be preferred by 83 % of households, whereas the same service provided at a cost of R60 a month would be preferred by 51.6 %. Even with all attributes set to 'moderate' (Service option 2), 81 % of households would still prefer this service if it were provided for free.

6.5 Discussion

A discrete choice experiment was conducted to elicit preferences for reliability of water supply in peri-urban communities in Limpopo, South Africa. The study is amongst the few that focus specifically on water supply reliability (Hensher et al., 2005, MacDonald et al., 2003), and also adds to the relatively small literature on rural / peri-urban preferences in developing countries.

The few studies of households' preferences for water supply reliability have found that decreases in water supply reliability were undesirable (Griffin and Mjelde, 2000, Howe et al., 1994, Koss and Khawaja, 2001), and that households were willing to pay for reduced duration and frequency of supply interruptions (Hensher et al., 2005, MacDonald et al., 2003). The results of the choice experiment for the overall sample are generally in line with these previous findings: households prefer to have water available for more hours during the day; breakdowns repaired within shorter periods; higher flow rate and lower service costs.

Similar to the findings of Hensher et al. (2005), households greatly value notice of water supply interruptions. The willingness to pay estimates for water being available for longer periods of the day of R17-R19 (about USD2 at the 2012 exchange rate of USD1: ZAR8.57) for households using communal supplies and R9 (approximately USD1) for households using private supplies are comparable to those reported by Kanyoka et al. (2008). In their study of preferences for multiple use water services in rural Limpopo, the authors report willingness to pay estimates of R15 (just under USD2) for households using communal supplies and R7 (just under USD1). While these amounts may seem small, they do not necessarily reflect a low valuation of the water supply. As Carter et al. (2010) note, spending priorities as well as genuine inability to pay may mean that there may be a mismatch between households' willingness to pay estimates and their actual demand for improved supplies.

When extending the analysis to subgroups of private versus communal water supply and Communities 1 and 2 versus Community 3, the results are rather mixed, indicating heterogeneity in preference. For the subgroup using private water supplies in particular, the directions of preference for several attributes are contrary to theoretical expectations. There are two possible explanations for this. First, it should be borne in mind that households categorised as having 'private' water supplies have either drilled their own wells and set up high-capacity storage tanks (Communities 1 and 2) or have a municipal yard connection / set up a connection from a spring, with a high-capacity storage tank.

Such investments afford these households a considerable degree of autonomy, and would likely result in low preference for improvement in the reliability of the supply. As Table 6.4 shows, almost 42 % of the options selected by this sub-group are for the current service, implying that they are less willing to consider other service options. Such influence of the current supply has been found in other studies. In Mexico, (Soto Montes de Oca and Bateman, 2006) find that households with better levels of water supply prefer to maintain the status quo. Similarly, Virjee and Gaskin (2010) report significant reductions in willingness to pay for service improvements in Trinidad and Tobago. They surmise that continued unreliability of the supply resulted in households no longer believing that the services could improve and increasing investment in coping strategies that award them immunity from the unreliability of the supply.

The second explanation, and linked to the first, is that some households using private water supplies, particularly those that have drilled their own wells may have had weak preferences for some of the attributes, and thus had little incentive to make trade-offs in the choice sets presented. By taking on the role of both producer and consumer (Humplick et al., 1993), such households may have effectively 'exited' the water supply system (Zérah, 2000a), and may be indifferent to any proposed improvements.

The results of the analyses for the Communities 1 and 2 versus Community 3 show similar heterogeneity in preference and willingness to pay, with some attributes being insignificant for Community 3. Again, this could be explained by the coping strategies employed in the two clusters. Households in Communities 1 and 2 have either drilled their own wells or buy water from those that have the wells, both of which represent significant initial or ongoing costs. In contrast, households in Community 3 face the lower costs of installing storage tanks and setting up connections from springs, or only the opportunity cost of walking to the nearest spring or neighbour's yard tap. This difference in main coping strategies, and more importantly, associated coping costs, may well influence households' preferences.

The attribute relating to number of breakdowns was consistently positive in both the overall and subgroup models. A possible explanation for this may lie in the current (existing) water supplies in the studies. Households using communal supplies as their main source may perceive their current water services as always worse than the attribute levels presented in the hypothetical service options, resulting in the observed positive coefficient for an otherwise negative attribute. As shown in Table 6.4, the current service option is the least popular amongst households using communal water supplies. Further, households using communal water supplies have water available 4 days a week, on average. Because they may not always be aware of the reasons underlying the unavailability of water on the other 3 days, they may generally perceive all episodes of day to day unavailability as breakdowns, in which case the attribute levels in the choice experiment would still be better than the perceived current levels.

The number of days water is available appears to be of relatively little importance in the models for the overall sample and for private versus communal supply. Commenting on similar findings, (Virjee, 2005) suggests that this may suggest that the way in which households use water does not require daily supply. Households using private supply are unlikely to fill up their storage tanks on a daily basis. Similarly, households using communal supplies may not necessarily go and collect water everyday.

Unsurprisingly, the predicted uptake rates of hypothetical services decreases with an increase in the service cost. It is however interesting to note that the differences in the uptake rates for a ‘highly reliable’ Service option 1 and a ‘moderately reliable’ Service option 2 are very small. This could again be a reflection of the perception that any service option other than the current one is better.

There are a number of limitations in the discrete choice experiment reported that should be noted. First, although the attribute levels included are validated in literature and tractable with existing water policy, the design of the experiment would likely have benefited from focus group discussions with a sub-sample of the households. This could perhaps have aided in determining any potential influence of the current water supply situation and adapting the choice experiment to better assess this influence.

From an analytical perspective, the conditional logit model has been considered restrictive in its assumption that the odds of choosing between two alternatives are independent of the presence or absence of a third alternative (IIA). More recently, it has been argued that the violation of the IIA assumption may not be much of an issue if, as in this case, the objective is to estimate individual’s average preferences (Cushing and Cushing, 2007). The violation is however more of a concern when predicting uptake rates. Thus, applicability of the uptake rates presented herein may be limited. The second major assumption in the conditional logit is that differences in preference arise only from differences in the probability of selecting choice alternatives. To minimise this bias, sub-group analyses were performed to assess the difference in preference.

Conclusions

The limitations of the survey notwithstanding, there are some implications from the study that are worth noting. First, many stated preference studies focus on cost as the main determinant of water demand (Jones et al., 2006). The results of this choice experiment highlight that households are not only interested in the cost of water supply services, but also in reliability attributes such as notice of interruptions, duration of supply each day and time taken to repair breakdowns.

Secondly, the evaluation of preference over subgroups highlights the need for targeted and prioritised approaches to service improvements. Households using communal supplies have relatively higher demand for service improvements, and improvements would do well to target them. Priority could also be given to improving services where alternative water sources such as the protected springs in Community 3 may not be available.

In the following chapters, the question as to what happens when water supplies are unreliable is tackled. Chapter 7 reviews the existing literature on household strategies to cope with unreliable water supplies, followed by empirical analyses of coping strategies among the study communities in Limpopo in Chapter 8.

7 Household responses to unreliable water supplies: A review

Households employ a variety of strategies to mitigate and / or cope with the risks that unreliable water supplies pose. This chapter reviews these coping strategies, including the related coping costs, their distribution across socio-economic groups and the effectiveness of coping strategies in meeting household water requirements.

7.1 Introduction

With the Millennium Development Goal era drawing to an end, emphasis has been growing on the importance of reliable water supplies in meeting critical health goals (Clasen, 2012, Hunter et al., 2010) and the development of indicators of reliability as part of the post-2015 strategy (WHO/UNICEF, 2012). An equally important issue is how households are actually responding to unreliable water supplies. Although there is a growing body of literature on this matter, much of it is focused on assessing household costs of coping with unreliable of water supplies as indirect estimates of willingness to pay for improved water supplies (Widiyati, 2011, Mycoo, 1996, Dutta and Tiwari, 2005). The usefulness of this approach may be limited if household responses to unreliable water supplies are to be understood beyond their implications on water demand and pricing options in service improvements. For instance, the association between reverting to untreated water sources during supply interruptions and diarrhoeal illness (Hunter et al., 2009, Majuru et al., 2011) has been documented.

To the best of my knowledge there has not been an attempt to review existing literature on how households cope with unreliable water supplies. Consequently, the review sought to address the following questions:

- How do households respond to unreliable water supplies?
- What factors influence the choice of coping strategies?
- What are the financial costs of coping strategies?
- What health and social outcomes are associated with coping with unreliability?
- How effective are these strategies e.g. are water quantity, quality and pressure needs met?
- How are coping strategies distributed across socio-economic groups?

In attempting to answer these questions, the review identifies what is known and what is missing from the literature on coping with unreliable water supplies in developing countries. Before turning to the methods used to address the review questions above, an overview of the conceptual background surrounding the notions of ‘reliability’ and ‘coping’ in the context of water supplies is provided.

7.2 Conceptual background of reliability and coping

As is pointed out in the 2012 update on the MDG water target, although the general consensus is that reliability is an important aspect of water supply, there is yet no agreement on how it should be defined or consequently measured (WHO/UNICEF, 2012). ‘Reliability’ as considered in this review is a feature of water supply that is made up of several attributes. These attributes include: consistency with which water is supplied, e.g. 24 hours a day, everyday, or for part of the day on some days; the predictability of the supply, e.g. supply that is not continuous, but provided at regular intervals, or not continuous and at irregular intervals; the pressure of the supply, e.g. pressure fluctuations may result in limited or no supply. This definition also extends to breakdowns in the supply systems itself, which are distinguished in this review from intermittent / discontinuous supply, which may be more indicative of sub-optimal functionality than complete non-functionality.

Amongst the early attempts to systematically describe and analyse the impact of unreliability was a study funded by the World Bank to assess the extent of private costs that Nigerian firms incurred due to deficiencies in public services (Lee and Anas, 1992). The methodology from this study was subsequently applied on household water supplies in India, Pakistan and Turkey around 1990-1992. From the three case studies, the authors suggested a conceptual framework and methods for analysis of unreliability of water supply and its impact on households (Humplick et al., 1993, Madanat and Humplick, 1993) and summarised the households’ responses to unreliability and their costs (Kudat et al., 1993). This conceptual framework was later applied in another World Bank-funded study conducted in Azerbaijan in 1994 by Kudat et al. (1997) and has shaped much of the often-cited work on the topic.

In their conceptual framework, Kudat et al. (1993) and Humplick et al. (1993) posit that as a commodity, water has three main attributes: quantity, quality and pressure. Where the water supply does not meet the optimum levels of these three attributes, the supply is said to be unreliable, and households will adopt strategies to mitigate risks from this unreliability. These activities can be broadly categorised as extending on the concept of ‘exit, voice and loyalty’ (1970). Faced with chronic unreliability, households may ‘exit’ the unreliable water system by adopting strategies such as drilling wells, installing large capacity storage tanks or even relocating to areas where water supply is more reliable. The 'voice' strategy includes complaints and protests to water utilities or local authorities. Households could also be loyal, and engage in accommodative strategies such as rescheduling activities to when water is actually available, collecting from alternative sources and consuming less water.

The authors also suggest that factors associated with the choice of coping strategies can be grouped into three levels: (i) household level e.g. socio-economic status, gender, age structure; (ii) settlement level e.g. water service level, formal / informal settlement and (iii) national level e.g. urbanisation, privatisation of water supply sector, regulatory and policy framework (Humplick et al., 1993, Kudat et al., 1997). Subsequent studies have drawn upon the work of Kudat et al., focusing mainly on measuring the costs of coping strategies (Choe et al., 1996, Zerah, 1998, Zérah, 2000b) as indirect estimates of willingness to pay for more reliable services.

7.3 Methods

Literature searches were conducted in CINAHL EBSCOHost, Embase Ovid, PuBMed Central, Scopus, ScienceDirect, Scirus and Web of Knowledge. The search terms used were:

> TITLE-ABSTR-KEY("water supply" OR "safe water" OR "drinking water" OR "domestic water" OR "household water" OR "water point") and TITLE-ABSTR-KEY(reliab* OR sustainab* OR availab* OR function* OR regular OR access OR intermitten* OR interrupt* OR constant OR continu* OR consistent OR "operation and maintenance" OR breakdown) AND TITLE-ABSTR-KEY(cope OR coping OR "coping strategies" OR avert OR "averting behaviour" OR respond)

Searches were also conducted in Google and Google Scholar search engines, where the first 50 hits were checked for potentially relevant papers. Papers obtained from the search were screened for relevance according to the following criteria:

- Report strategies employed to cope with unreliable domestic / household water supply
- Collect and report data on developing countries
- Based on empirical research

Although the scarcity of water resources contributes to unreliability of water supplies the world over, in many developing countries a significant proportion of the problem lies in decaying infrastructure, rapid growth of settlements and poor water management. Thus, the review focuses on responses to unreliability relating to the performance or functionality of water supply systems and distribution networks. Developing (low and medium) countries were defined as per the World Bank classification (2011). Studies that only listed coping strategies with no other accompanying coping-related information such as costs, determinants of coping etc. were excluded. Full texts of papers whose abstracts and titles met the criteria were retrieved and reviewed in detail for study quality and findings. The reference lists of relevant papers were also checked for other potentially relevant papers.

7.3.1 Quality appraisal

Study quality appraisal was in two parts; a general appraisal tool adapted from Hellenbrandt et al. (2011) that was applied to all studies, and an additional appraisal tool developed by the Swedish Environmental Protection Agency [SEPA (2006)] for studies that use econometric valuation techniques. Hellenbrandt et al.'s (2011) tool is largely based on assessment criteria suggested in the Cochrane and EPPI frameworks, which they adapted to suit the heterogeneity in study outcomes and study design encountered in their own review. The appraisal in this review is similarly broad, and considers the clarity of research objective, clarity of methods used, description of water supply conditions, reporting of results, researcher bias, and any other issues that may influence study quality. Based on these criteria, the risk of bias was categorised as high, moderate or low. A copy of this tool is attached as Appendix 7.1.

The SEPA (2006) tool is aimed at assessing the quality of valuation studies and considers bias in two parts: the quality of studies in general, regardless of the valuation technique, as well as factors related to specific valuation techniques. Study quality was assessed using a modified version of the generic component of this tool, following the example of (Söderqvist and Soutukorva, 2009). Using this tool, economic valuation studies were classified as being of high, moderate or low quality. A copy of this tool as applied in the review is attached as Appendix 7.2.

7.4 Results

A total of 1,398 papers were found from the database search (Figure 7.1). Of these, 357 were duplicates and the majority focused on agricultural or industrial water supply, or reported on coping with water scarcity from drought, climate change, and thus did not meet the inclusion criteria. Four studies were found from perusing reference lists of other studies, bringing the total number of studies reviewed to 23.

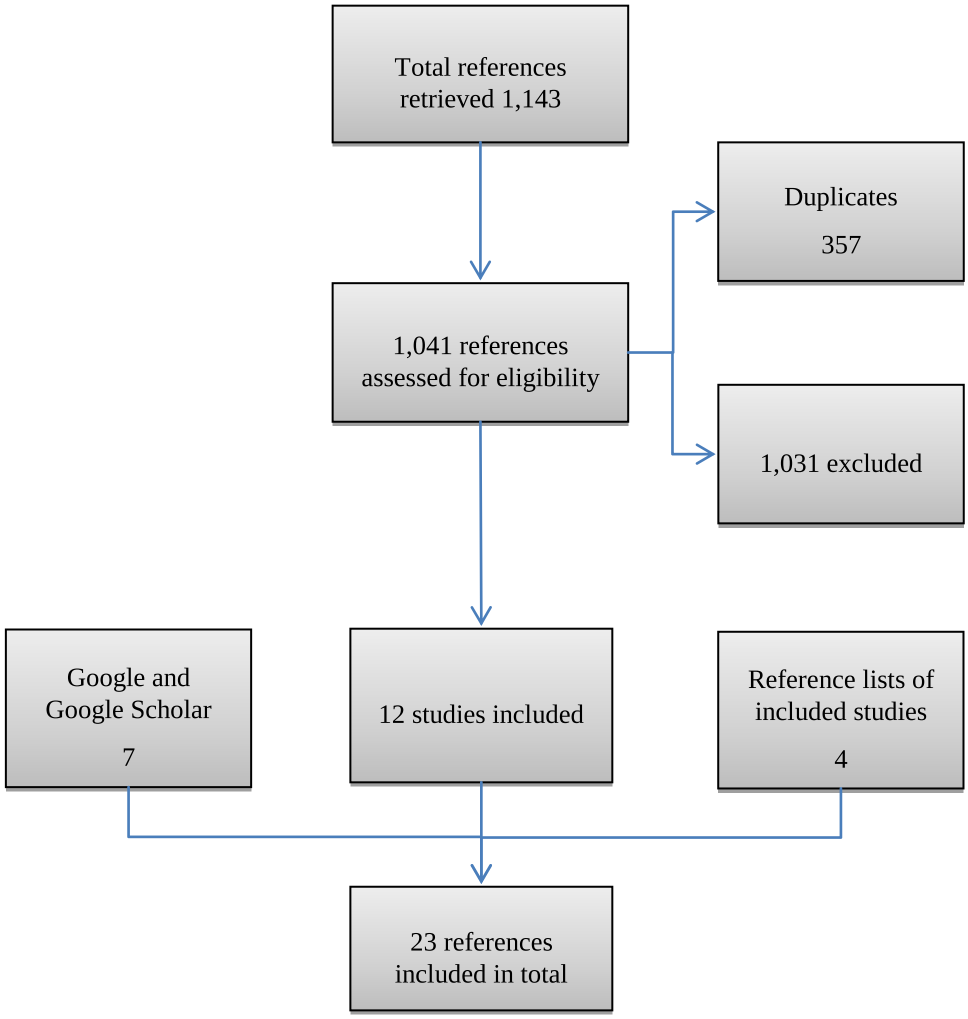

Figure 7.1: Flow chart of study selection process

Almost half (47 %) of the studies were carried out in South Asia (Figure 7.2; Tables 7.1-7.3). Of the 23 studies reviewed, 19 were conducted in urban settings, 2 covered both rural and urban areas, and 2 conducted in a rural setting (Tables 7.1-7.3). All studies reported on cross-sectional data and a third estimated willingness to pay for improved / more reliable water services. Six studies simultaneously measured coping costs and used them as indirect estimates of willingness to pay.

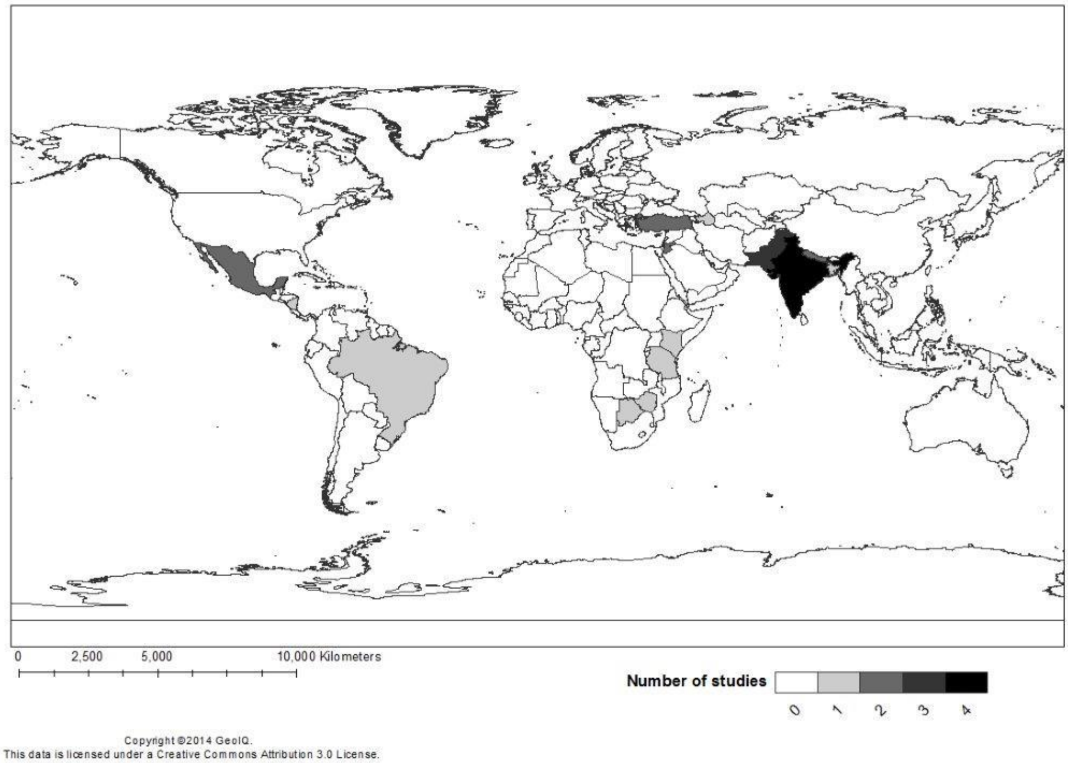

Figure 7.2: Geographic distribution of studies included in review

Using the generic appraisal tool adapted from Hellenbrandt et al. (2011), 11 of the studies were categorised as having low risk of bias, 10 moderate risk and 2 high risk. Common sources of possible bias were in the methods used to address study objectives and the subsequent reporting of results not being clear. For instance, three of the studies (Chaminuka and Nyatsanza, 2013, Potter and Darmame, 2010, Olsson and Karlsson, 2010) use convenience or snowball sampling techniques without any clear justification for doing so. Such samples are prone to selection bias as they are unlikely to be representative of the population (Sedgwick, 2013).

The SEPA appraisal tool (Appendix 7.2) was applied to the 8 studies that apply valuation techniques. Six of the studies were categorised as moderate quality and two as low quality. Among the sections that scored least were those relating to reporting of statistical uncertainty and non-response. Six of the studies do not report confidence intervals and standard errors of the estimated economic values, and half of the studies provide no information on the response rate.

Table 7.1: Studies conducted in urban settings

Author(s), year	Study objective(s)	Setting, type of supply and sample	Findings
Baisa et al., (2010)	Estimate the welfare costs of unreliable water supply	Urban Mexico, Piped supply Model calibrated for Mexico City using data from the Mexican National Household Survey of Income and Expenditure	Common storage tank capacity was 750 ℓ Normalising delivery time across time and households had large social gains and average total lifetime gains of 9,382 pesos ($833) per household
Caprara et al., (2009)	Investigate the relationship between socio-economic characteristics and community practices affecting *Aedes aegypti* vector ecology	Urban Fortaleza, Brazil, 2005 Piped and unpiped supply Purposive sample of 204 households, with mixed methods descriptive case study approach	Water was stored in roof tanks, drums and other containers. Poorer households could not afford roof tanks with lids or mesh and thus provided breeding areas for dengue
Chaminuka & Nyatsanza, (2013)	Assess the causes and extent of water shortages and coping mechanisms used by affected residents in Harare	Urban Zimbabwe Piped supply Convenience sample through a snowballing techniques 40 respondents in total	Coping strategies included collection from boreholes, rainwater harvesting in the rainy season, drilling wells, collecting water from neighbours with wells
Choe et al., (1996)	Estimate the real costs of an intermittent supply and predict how much people would pay for a continuous full-service metered supply	Urban Dehra Dun, Utter Pradesh, India, 1995 Random-stratified cluster sample of 1,100 households drawn from the 1995 electoral roll	Coping strategies included storage in tanks, enhancing pressure and improving water quality Coping costs matched willingness to pay estimates Coping costs were at least as great as the amount paid in water billings Households with piped supply invested in storage tanks, while those without spent time queuing for water
Dutta et al., (2005)	Examine how much money people in unplanned areas are willing to pay to support a policy that provides them with a better and reliable water supply	Urban India 28.92 % had piped supply Multistage stratified random sampling, with 650 interviews conducted in 4 unplanned settlements	Coping strategies included drilling wells, installing booster pumps, storage Average annual coping cost was 3,112 Rupees

Author(s), year	Study objective(s)	Setting, type of supply and sample	Findings
Gerlach & Franceys, (2009)	Investigate the status of water supply service and regulatory arrangements with respect to poor and vulnerable consumers	Urban Jordan, 2005 Piped in-house, tanker trucks in event of distribution problems. Semi-structured interviews with key stakeholders, survey of 10 households each in 9 selected poor neighbourhoods and small-scale surveying of private water tanker operations	Household coping strategies are: buying water from private tankers, buying from neighbours; storing water in the home; collecting from wells, springs and buying bottled water, scheduling major household activities to when water is available and generally limiting water use Households using bottled water report buying an average of 31.6 l per week at an average price that corresponds to 24 times the price per cubic metre for water taken from the network. Lower-income households are supported through more frequent supplies of 2–3 days per week, but have limited storage capacity. With as little as 0.13 m^3 household-level storage per person available amongst this group, 4% of the total sample have less than 30 lpcd, and 8% no more than 50 lpcd, unless additional supplies are bought in.
Gulyani et al., (2005)	Examine current water use and unit costs and test the willingness of the unconnected to pay for piped water, yard connections, or an improved water kiosk (standpipe) service	Urban Kenya, 2000 Piped in-house; yard taps; standpipe, vendors, groundwater 674 randomly selected households were interviewed in 22 sites in the three urban areas	Average capacity of a private water storage system was about 1,058 ℓ and the average investment for such a system was about Ksh 5,399 (US$72)
Humplick et al., (1993); Madanat & Humplick, (1993)	Present a model and methods for analysis of households' responses to unreliable water supply	Urban Pakistan and Turkey 1990-1992 Piped and unpiped supply Case studies with a detailed sample of 30 households in Istanbul, Turkey and less detailed but larger sample of 900 in Faisalabad, Pakistan	High income households have the most options Low income households spend a higher proportion of their income on coping costs

Author(s), year	Study objective(s)	Setting, type of supply and sample	Findings
Jamal & Raman., (2012)	Explore impacts of gas and water supply crises and document coping strategies	Urban Bangladesh, 2010 Type of supply not clear Participatory rural appraisal applied to urban setting	Household coping strategies are drilling wells, collecting from shared sources, buying water and treating water. Middle income families spend up to Tk1,500 on buying water each month Community strategy is to raise funds for a tube well to be constructed.
Kudat et al., (1993)	Assess households' responses to unreliable water supply	Urban India, Pakistan and Turkey 1990-1992 Piped and unpiped supply Case studies of 30 households in Istanbul, Turkey, 900 in Faisalabad, Pakistan and 1,011 in Jamshedphur, India	Suggested quantity, quality and pressure as key reliability attributes Categorised coping strategies into enhancement and accommodating strategies Low income households are unable to invest in facilities to improve supply, and reduce water use instead
Kudat et al., (1997)	Present a methodology for a Social assessment for the World Bank's Greater Baku Water Supply Rehabilitation Project	Urban Baku, Azerbaijan, 1994 Piped supply Rapid user surveys with 150 respondents and 400 respondents, consultations, stakeholder workshop	Female headed households had more difficulty coping, expended more labour than capital Average tank storage capacity was 948 cm^3 and cost $94 at the time Boiling was most common treatment Opportunity cost of time spent collecting was 4-16 % of household income Low income households more likely to adopt accommodative than enhancement strategies
Mycoo, (1996)	Examine cost recovery potential based on household willingness to pay more for an improved service and water pricing	Urban Trinidad Piped supply Stratified sample of 420 households, stratified according to slope, land elevation and income. Survey of households and interviews of professionals in the water sector	Most common tank capacity was 420 gallons with capital and maintenance monthly costs estimated at TT$67 Households paid private water trucks about TT$150 per trip to fill up the tanks when water supply was off for several days and their reserves were exhausted

Author(s), year	Study objective(s)	Setting, type of supply and sample	Findings
Pattanayak et al. (2005)	Evaluate how coping costs and willingness to pay vary across types of water users and income	Urban Nepal, 2001 70% piped; 30%: private wells, public taps, stone spouts, and water vendors. About 1% of the connected households shared a connection with other households Clustered sampling (probability-to-size), 1500 households in five municipalities of Kathmandu Valley	Coping costs (1) were equivalent to 1% of current incomes - majority attributed to time spent collecting water; (2) were correlated with but were significantly lower than WTP; and (3) varied across households with different socioeconomic profiles
Potter & Darmame, (2010)	Examine potential social equity dimensions in the use of water within Greater Amman	Urban Jordan, Greater Amman Piped supply Snowball sample of 25 low income and 25 high income households	High income households had average storage capacities of $16.24m^3$, compared to low income households whose average storage capacity was $3.12\ m^3$
Subbaraman et al., (2013)	Evaluate an informal water distribution system in Kaula Bandar (KB), a non-notified slum in Mumbai	Slum in urban India Informal system of water hoses delivering water to households A Baseline Needs Assessment survey of 959 households in 2008 and a Seasonal Water Assessment in 2011, in which 229 samples were collected for water quality testing over three seasons	Alternative sources during system failures are at least one kilometre away, private tankers are also used Extra costs of water during system failures average US$8.42 per 1,000 ℓ. 95 % of households use less than 50 ℓ of water per capita per day during system failures
Vásquez et al., (2009)	Elicit household willingness to pay responses for safe and reliable drinking water in Parral, Mexico	Urban Mexico Piped supply Stratified random sample of 398 households in 6 geographic zones	Combined expenditure on tap and bottled water was 7.49 % of reported median income

Author(s), year	Study objective(s)	Setting, type of supply and sample	Key findings
Vásquez, (2012)	Investigate the relationship between perceptions of water supply reliability and household expenditures on water storage devices in León, Nicaragua	Urban Nicaragua, 2009 Piped supply Stratified random sample of 891 households in 8 geographic zones	Perceptions of water supply reliability are the main determinant of household expenditures on water storage devices. Findings also indicate that perceptions of water supply reliability are associated with service performance (as measured by daily hours with water supply) and assessment of service hours relative to peers Income and home ownership also positively impact those expenditures.
Virjee & Gaskin, (2010)	Ascertain the willingness to pay for changes in the level of service experienced by users	Trinidad and Tobago, 2003 Piped in-house; Piped in-house + secondary source; no in-house connection The Central Statistical Office's Continuous Sample Survey of Population sampling method was used to randomly select 1,419 households, using a two-stage stratification scheme based on geography and labour force characteristics	68% had water storage tanks on their premises with an average installed capacity of 610 gallons., thus 82% of those with tanks had simulated a 24-hour water supply 58% of poorer households had water storage tanks compared to 84% of wealthier households Households with coping infrastructure (storage tanks) had a lower demand for service changes. Households with no in-house piped supply had highest WTP, possibly because of the utility derived from having water close by

Author(s), year	Study objective(s)	Setting, type of supply and sample	Key findings
Zérah, (1998, 2000a)	*Article 1:* Measure the costs of unreliability *Article 2:* Estimate the household demand for a service by assessing the actual behaviour adopted by households when they have to cope with an inadequate service	Urban India, 1995 Piped Two stratified sample of 678 households in four zones of urban Delhi	Annual coping costs were 15.7% of monthly income for households in the lower income bracket and 1.4% for higher income households Bills to the water utility were less than a sixth of coping costs Aggregated coping costs were almost twice the expenditure of the utility on water supply, while revenue to the utility was 8.5 times lower than the coping costs High income, very low reliability and ownership of houses influenced adoption of tubewells as coping strategy Probability of rescheduling activities increased if reliability was low and households had low incomes Average storage capacity was 200 ℓ for households with a tank with tubewells, 150 ℓcd for households with tanks linked to municipal water and 30 ℓ for households with handpumps or who collect from outside sources. Households with incomes above Rs. 8,000 had storage capacity of 203 ℓ, and households with income below Rs. 3,500 stored 100 ℓ

Table 7.2: Studies conducted in rural settings

Author(s), year	Study objective(s)	Setting, type of supply and sample	Key findings
Ngwenya & Kgathi, (2006)	Investigate access to potable water in HIV/AIDS related home-based care households in five rural communities	Rural Botswana Piped supply; piped yard taps; communal standpipe Two- stage stratified random sampling involving 39 caregivers, using structured and informal interviews, participant observation	Water was purchased from donkey-cart owners at P5 for 20 ℓ. To economise on water use, households reduced the number of meals in a day and frequency of baths for bed-ridden HIV/AIDS patients
Olsson & Karlsson, (2010)	Investigate how poor women cope with water problems and constraints to women accessing water	Rural Zanzibar Piped supply; piped yard taps; communal standpipe Snowball sampling, with key informant, individual and group interviews with 19 participants	Main alternative sources when tap was not available were untreated Women of lower socio-economic status felt that they could not voice their thoughts on how the water situation could be improved

Table 7.3: Studies conducted in both urban and rural settings

Author(s), year	Study objective(s)	Setting, type of supply and sample	Key findings
Altaf, (1994)	Describe household response to inadequate public piped water supply systems and to highlight the economic implications of their efforts to improve level of service and reliability	Rural and urban Punjab, Pakistan Public piped water systems and those without Stratified random samples of 968 urban and 756 rural households	Households using handpumps as a back-up to the public connection incur costs of Rs 36-Rs 66 per month, Households using a motor pump as a back-up incur costs of over Rs 80 per month
Katuwal & Bohara, (2011)	Estimate the effect of wealth, education, information, gender, caste/ethnicity and opinion about water quality on drinking water treatment behaviours	Rural and urban Kathmandu, Nepal, 2005 Piped and unpiped supply Authors used from a 2005 survey by the Central Bureau of Statistics with 2,000 households	Wealthier households increased boiling and filtering, instead of using one treatment method Exposure to information increased treatment behaviour by 21 % Increase in household size increased cost of treatment, leading to use of cheaper methods or less frequent treatment Probability of treatment decreased by 11 % if household head was male

7.4.1 Coping strategies

Three main categories of coping strategies were identified from the review: enhancing and conserving quantity of water available, improving the quality of water and enhancing flow rate. A fourth category is also considered: collective action and voice. Although there is some overlap between these categories, each is considered in turn.

7.4.1.1 Enhancing and conserving water

The storage of water is reported in the majority of the studies (Table 7.4). Storage vessels vary from large capacity overhead tanks to smaller vessels such as pots and buckets. While overhead tanks can fill up automatically whenever the municipal supply becomes available (Choe et al., 1996), the storage process for smaller vessels can be tedious. In Fortaleza, Brazil, Caprara et al. (2009) report that households got up at dawn when the municipal water supply became available in order to start filling up drums, pots and buckets. Households may spend 38 minutes storing water (Zérah, 2000a), or several hours (Olsson and Karlsson, 2010) if the water is to be collected from an alternative source over several trips.

Table 7.4: Coping strategies identified from the literature

	Altaf (1994)	Baisa et al. (2010)	Caprara et al. (2009)	Chaminuka & Nyatsanza, 2013	Choe et al. (1996)	Dutta et al. (2005)	Gerlach & Franceys, 2009	Gulyani et al. (2005)	Jamal & Rahman. 2012	Kudat et al. (1993)	Kudat & Musayev, (1997)	Katuwal & Bohara, (2011)	Mycoo (1996)	Ngwenya & Kgathi, (2006)	Olsson & Karlsson, 2010	Pattanayak et al. (2005)	Potter & Darmame, 2010	Subbaraman et al., 2012	Vasquez et al. (2009)	Vasquez (2012)	Virjee & Gaskin (2010)	Zerah (1998; 2000)
Install storage tanks	✓	✓				✓	✓	✓		✓	✓		✓		✓	✓	✓		✓	✓	✓	✓
Store water in buckets, bottles etc			✓	✓			✓			✓	✓	✓			✓		✓	✓				✓
Collect water from alternative sources				✓	✓		✓		✓	✓	✓	✓		✓	✓	✓		✓				
Drill wells, install hand pumps	✓			✓					✓	✓	✓					✓						✓
Purchase water			✓				✓		✓	✓	✓		✓	✓		✓	✓		✓			
Install electric pump	✓				✓		✓			✓							✓					✓
Treat water (boil/ filter/ chlorinate)	✓				✓				✓	✓		✓	✓		✓	✓	✓		✓		✓	✓
Recycle water										✓												✓
Use water sparingly							✓			✓					✓			✓				
Harvest rainwater				✓											✓							

	Altaf (1994)	Baisa et al. (2010)	Caprara et al. (2009)	Chaminuka & Nyatsanza, 2013	Choe et al. (1996)	Dutta et al. (2005)	Gerlach & Franceys, 2009	Gulyani et al. (2005)	Jamal & Rahman. 2012	Kudat et al. (1993)	Kudat & Musayev, (1997)	Katuwal & Bohara, (2011)	Mycoo (1996)	Ngwenya & Kgathi, (2006)	Olsson & Karlsson, 2010	Pattanayak et al. (2005)	Potter & Darmame, 2010	Subbaraman et al., 2012	Vasquez et al. (2009)	Vasquez (2012)	Virjee & Gaskin (2010)	Zerah (1998; 2000)
Reschedule activities							✓						✓		✓							✓
Protest / complain									✓	✓	✓		✓									✓
Move to another house/ area										✓												✓
Install extra storage space										✓												
Reduce baths and/ or alter diet										✓				✓								

In a number of studies the households tried to conserve their stored water by carrying out domestic activities requiring a lot of water on the days when water was available (Gerlach and Franceys, 2009, Mycoo, 1996, Ngwenya and Kgathi, 2006, Zérah, 2000a). Water conservation strategies included reducing intake of fresh fruit and vegetables that would need to be washed, reducing frequency of bathing and laundering (Kudat et al., 1993) and flushing toilets only once a day (Chaminuka and Nyatsanza, 2013).

Ngwenya and Kgathi (2006) investigate water access in households caring for family members with HIV/AIDS related illnesses in rural Botswana. Carers in households that did not have means of transport (donkey carts, wheelbarrows, bicycles etc) to enable them to collect water from alternative sources limited their domestic water use. This entailed reducing the number of meals cooked per day, reserving potable water for drinking only by family members, reducing the number of baths given to the ill family members and keeping soiled laundry until there was water available to wash it.

7.4.1.2 Improving water quality

Of all the possible responses to unreliable water supply, household water treatment is perhaps the most researched, both in developing and developed countries. Unreliable water supplies often lead to poor water quality in various ways. Intrusion of contaminants into pipes can occur when the flow rate is low or supply cut off, or when water collected from alternative sources is unsafe or re-contaminated during collection and storage (Kumpel and Nelson, 2013).

Water treatment through boiling, filtration or use of chemical treatment products is reported in twelve studies (Table 7.4). Of these, boiling and filtering appear most common, with households using either one of the two methods or both (Dutta and Tiwari, 2005, Katuwal and Bohara, 2011, Pattanayak et al., 2005). In Kathmandu, Nepal, (Katuwal and Bohara, 2011) find that households tend use more than one method if they are wealthier. The authors also note some urban-rural differences in treatment behaviour, with the proportion of urban households that boil water higher than those in rural areas.

7.4.1.3 Enhancing flow rate

There is some overlap in the needs that some coping strategies fulfil. For instance, the installation of overhead tanks enables households to store large quantities of water and also have such water flow into the water supply pipes at a reasonable pressure (Choe et al., 1996, Zérah, 2000a). Other pressure-enhancing strategies are installing electric pumps to convey water from storage tanks or installing motors directly onto municipal water connections to boost the flow rate (Zérah, 1998).

7.4.1.4 Collective action and voice

The strategies reviewed above have focused on action undertaken within the household. Another route of action can be collective action amongst households and 'voice'; defined by (Zérah, 2000b) as "complaints, demonstration and associations".

In their study of strategies to cope with unreliable gas and water supplies in Dhaka, Bangladesh, Jamal and Rahman (2012) find that in addition to adopting various coping strategies at household level, community action was sought through contributing towards the establishment of a tube well. Households in Turkey, are reported to have created joint community actions and pressured for better services, although no further details are provided (Kudat et al., 1993).

7.4.2 Factors influencing choice of coping strategies employed

Income, education and land tenure are reported to be significant determinants of choice of coping strategy in eight of the studies. Households that are relatively wealthier, more educated and/ or own the property they live on are more likely to drill wells and/or install storage tanks (Caprara et al., 2009, Choe et al., 1996, Kudat et al., 1993, Kudat et al., 1997, Pattanayak et al., 2005, Virjee and Gaskin, 2010, Zérah, 2000b, Vásquez, 2012).

Katuwal and Bohara (2011) focus on water treatment as a coping strategy in Nepal and find positive associations with wealth, education, gender, caste/ethnicity and perceptions of water quality. Of the 2,000 households surveyed, 40 % used filtration methods and 34 % boiled water.

Extent of unreliability also plays a role, as a quarter of households with tube-wells in the study by Zerah (2000b) had very limited duration of supply (less than 4 hours day). Vásquez (2012) also finds perceptions of water supply reliability to be the main determinant of expenditure on water storage devices; households with lower perceptions of the reliability of their supply spending more on storage devices than those with higher perceptions. However, these perceptions are themselves mainly influenced by how households assess the reliability of their supply relative to that of their peers.

7.4.3 Costs of coping

Thirteen of the studies report data related to the costs of coping with unreliable water supply. These costs typically arise from installation and maintenance of storage facilities, time spent collecting water from alternative water sources, drilling wells and installing pumps, purchasing water, household water treatment and treatment of water related disease. As shown in Table 7.5, the actual components of the total coping costs vary widely.

Table 7.5: Coping costs and their components

	Altaf, 1994	Choe et al. (1996)	Dutta et al. (2005)	Kudat & Musayev, (1997)	Gerlach & Franceys, 2009	Mycoo (1996)	Pattanayak et al. (2005)	Vásquez et al. (2009)	Vasquez (2012)	Zerah (1998)
Capital cost of infrastructure	✓	✓	✓	✓		✓	✓			✓
Operation of infrastructure	✓	✓	✓				✓			✓
Maintenance of infrastructure	✓	✓	✓			✓		✓		✓
Installation of water storage vessels	✓		✓		✓	✓	✓		✓	✓
Water treatment			✓				✓			✓
Treatment of water related illness										✓
Income losses due to illness										✓
Opportunity cost of water collection		✓		✓			✓			✓
Purchasing water			✓	✓	✓	✓	✓	✓		

Coping costs range from average monthly costs equivalent to 1 % of monthly income in Nepal (Pattanayak et al., 2005) to 15.7 % for households in the lower income bracket in India (Zerah, 1998). In Zimbabwe, buying water from vendors can cost as much as $1 for each 20-ℓ bucket (Chaminuka and Nyatsanza, 2013). Coping costs range from being at least as great as amounts paid in water bills (Choe et al., 1996) to as much as six times the bill amounts (Zerah, 1998). In two studies (Altaf, 1994, Zerah, 1998) aggregated coping costs exceed the water utility's full cost of supply. In Amman, Jordan, Gerlach and Franceys (2009) report average weekly expenditures on bottled water that are 24 times the price per cubic metre of water from the supply network.

It is worth bearing in mind that the household responses considered in this review are in relation to *deficiencies* in water supply services and not the lack of service provision altogether. In other words, the households are connected to or have access (in theory) to a formal service, which is or has become deficient. Thus, in some studies households still incur water utility bills, in addition to their coping costs. For instance, although some households in the study by (Chaminuka and Nyatsanza, 2013) went for more than a month without municipal water supply, they were still required to pay fixed water charges which are mandatory for households with piped supply.

7.4.4 Coping costs and willingness to pay

Of the thirteen studies reporting on coping costs, eight include surveys of willingness to pay for improved/ more reliable water services. Key work in this area includes the study by Pattanayak et al. (2005) in Kathmandu, Nepal. They find that coping costs are correlated to willingness to pay estimates as well as water bills across the income distribution. Mean willingness to pay is reported to be almost 6 times greater (US$17) than mean coping costs (US$3), confirming their hypothesis that coping costs are a lower bound for willingness to pay. The reasons for this divergence, the authors note, are that: i) the coping costs they estimated do not include lost wage income, cost of illness and pain and suffering and ii) the willingness to pay estimates do not necessarily reflect the true willingness to pay due to the hypothetical nature of the contingent valuation questions. They thus suggest that future studies of coping costs could serve as a screening tool in cost-benefit analyses of water supply improvements; coping costs that exceed the cost of water service improvements would be indicative of cost-beneficial policy. Four other studies compare coping costs to willingness to pay estimates (Table 7.6).

Table 7.6: Willingness to pay and coping

Author(s), year	Water service improvement	Elicitation format	Coping cost - willingness to pay difference
Altaf, 1994	(1) In the rural area with sweet groundwater: extra 4 hours of supply from the existing piped water system (2) In the rural area with brackish groundwater and in the urban area: an improved system which would supply clean and safe water continuously with adequate pressure and reliability	Not reported	Rural area with sweet groundwater = +Rs 22 Rural area with brackish groundwater = +Rs 15 Urban area = +Rs 46
Choe et al., 1996	(1) Improve quality, by enhancing water purification and repairing leakage (2) Increase quantity, by adding more tube-wells and overhead tanks (3) Improve reliability, by adding additional power generators.	Referendum question was followed by an open-ended question to estimate the WTP	Individual connection = -Rps 0.11 Public tap users = +Rps 39.45 All = +Rps 7
Dutta et al., 2005	(1) Longer hours of service that would gradually move from intermittent to continuous scheme (2) Good quality water with no health risk of contamination	Split bidding game, with different subgroups facing starting point in increasing or decreasing order - the starting bid being 3 times higher or lower than the actual cost. The bidding game was followed by a final open-ended question on households' maximum willingness to pay	+Rs 158
Mycoo, 1996	(1) Better reliability: no disruptions and a 24 hour per day supply (2) Better pressure: no drops in volume of water per second/minute in tap (3) Better water quality: clear, odourless, good taste (4) A service upgrade (relevant to standpipe and yard tap users)	Respondents were shown a payment card of the prices charged by WASA to domestic users on a quarterly basis, and were instructed to use these in guiding their responses and indicate the maximum amount they were willing to pay per month	No significant difference +TT$0.14

Results vary: Altaf (1994), Choe (1996) and Dutta (2005) report coping costs that are significantly higher than willingness to pay estimates in India. In a survey conducted in

1994, Mycoo (1996) found that coping costs equalled willingness to pay estimates in Trinidad; the monthly capital and maintenance costs of storage tanks in Trinidadian dollars were $66.86 and estimated willingness to pay of $67.

A later study in 2003 by Virjee and Gaskin (2010) in Trinidad and Tobago did not compare willingness to pay estimates to coping costs, but to the average water bills in the sample. Willingness to pay amongst households with piped connections and storage tanks or secondary water sources was lower than the average water bills. In the study, 68 % of households had invested in storage tanks, with capacities averaging 610 gallons, leaving them with little need for service improvement. However, households without piped connections were willing to pay 10 % more than the average water bills for a service improvement that included an upgrade to a piped connection. The authors highlight that might be indicative of scope sensitivity, as the utility derived from having their own piped supply would have been larger.

7.4.5 Distribution of coping strategies across socio-economic groups

Pattanayak et al. (2005) find that collecting water from alternative sources constituted 56 % of total coping costs for poor households (classified as households in the lowest four income deciles), compared to 34 % of wealthier households in Kathmandu, Nepal. Katuwal and Bohara’s (2011) study in the same city finds that wealthier households in the first and second wealth quartile households were more likely to use more than one treatment method.

In another study, female-headed households are found to have more difficulty coping and were more likely to expend labour than capital through collecting water from other sources (Kudat et al., 1997). In Delhi, India, households were more likely to drill their own well if their monthly income was 8,000 Rupees, reliability was low and if they owned the residential property(Zérah, 2000a).

Although almost all households in the studies reviewed store water, income appears to be a significant determinant of storage capacity. Gerlach and Franceys (2009) find that few low-income households in Jordan had access to large storage devices. Average storage capacity per capita amongst these households was 64 ℓ, and a minimum of 13 ℓ.

7.4.6 Health and social outcomes related to coping

No studies were found whose primary focus is specific health and / or social outcomes related to coping. However, some of the studies draw attention to linkages between water storage practices and dengue vectors (Caprara et al., 2009), microbial regrowth in storage containers (Gerlach and Franceys, 2009), and the cost of water-related illness (Zérah, 1998, Dutta and Tiwari, 2005). Caprara et al. (2009) report that households in lower income areas stored water in open containers such as barrels, drums and pots, which provided breeding sites for *Aedes aegypti* mosquitoes.

Another important issue that arises from the literature concerns gender and household responses to unreliable water supplies. Again, none of the studies reviewed directly sought to investigate this in depth. However, in the literature reviewed there are several references to women and children primarily bearing the burden of collecting water from alternative sources (Chaminuka and Nyatsanza, 2013, Ngwenya and Kgathi, 2006, Olsson and Karlsson, 2010). Chaminuka and Nyatsanza (2013) found that in Harare, Zimbabwe, when the piped supply was unavailable women got up at 4 am to queue for water from boreholes in the area. In Zanzibar, women complained about having 'head pains' and chest pain from carrying water from alternative sources (Olsson and Karlsson, 2010).

Baisa et al. (2010) calibrate a model of depletion of stored water to assess the welfare effects of unreliable water supply in Mexico City. Households in their sample store water in overhead tanks when it is available, and purchase water from tanker trucks when the storage tanks are depleted. Amongst their findings is that significant welfare gains can be derived if the city's water utility provides equal quantities of water at regular intervals, compared to the existing supply that is discontinuous and irregular, with no additional infrastructure or price increases.

7.4.7 Effectiveness of coping strategies adopted

None of the studies in the review sought to assess the effectiveness of coping strategies in meeting household water needs or any other outcome. However, some insights can be drawn from studies comparing coping strategies to water quantities stored. Installing storage tanks allowed households to store greater quantities of water, and where these were set up as overhead tanks or there were electrical pumps, households had the added advantage of improved flow rate. Zerah (2000b) report storage capacities of 200 ℓcd for households with storage tanks relying on tubewells, 150 ℓcd for tanks linked to municipal water and 30ℓcd for households using communal handpumps or other unpiped sources.

Three studies report on the perceived effectiveness of having large-capacity storage tanks. Respondents reported having continuous water supply and sufficient pressure through the installation of overhead storage tanks of average capacities of 400-500 gallons (Altaf, 1994), 948 m^3 (Kudat et al., 1997) and 620 gallons (Virjee and Gaskin, 2010).

Perhaps the most important question to be answered regarding the voice strategy is whether it is effective in pressuring water utilities to improve services. Although none of the studies seek to address this question, Zérah (2000b) notes that after demonstrations over water and electricity in Delhi in 1998, bottled water companies and water vendors emerged, although no supporting evidence is provided. Prior to these demonstrations, the use of the 'voice' strategy was rare. Possible reasons are that households may not believe that anything would come out of it, or may lack structures necessary to voice their concerns in an organised manner (Chaminuka and Nyatsanza, 2013, Zérah, 2000b).

7.5 Discussion

The chapter reviewed 23 studies relating to household strategies to cope with unreliable water supplies in developing countries. To my knowledge, no other studies have attempted to synthesise the literature on this issue.

Before discussing the implications of the literature reviewed, it is important to note some limitations. In the most fundamental sense the review is limited by the current lack of a universally agreed upon definition of water supply reliability. Although efforts were made to capture the various terminology used in the literature on reliability in the search terms, the studies retrieved must be considered in the light of this limitation. In addition, there may have been studies assessing some coping behaviours that do not state this in the abstract of the paper and would consequently be missing from the review.

Secondly, the literature on coping with unreliability is widely dispersed across various disciplines, as evidenced in the sources we searched. While this is not necessarily a limitation, it does bring up significant variations in the reporting structure and consequently makes it difficult to synthesise results in a systematic manner. In this review, a thematic approach was used to analyse the literature. The heterogeneity in study methods and reporting of study outcomes also makes appraisal of study quality through common appraisal tools less useful. Although efforts to mitigate this have been made by adapting some existing appraisal tools, this only allows for broad indications of study quality.

The above notwithstanding, the results of this review have several implications for both research and practice in the water supply sector. From a methodological perspective, two issues are worth noting. First, given that reliability of supply is particularly problematic in both south Asia and sub-Saharan Africa (WHO/UNICEF, 2011), one might expect that studies on coping from both these regions would be widespread. However, almost half of the studies reviewed on household coping strategies are from south Asia compared to four from sub-Saharan Africa. Further, only 4 of the 23 studies cover rural settings. This suggests geographic bias at a regional level, towards south-Asia; and at a country level, towards urban areas. The reasons for the south-Asia focus are not clear, but in the latter, a possible explanation may lie in that a number of studies reviewed were mainly aimed at assessing demand for improved water services. The perception that willingness and / or ability to pay amongst rural households is low (Abramson et al., 2011) may influence whether studies are conducted in these areas.

Secondly, the literature reviewed herein is characterised by a reliance on mainly small-scale cross-sectional studies. Although such studies have been useful in describing the typology of coping strategies and their determinants, clear evidence on issues related to health and social welfare is scarce. The health and social issues identified in this review are rather anecdotal, partly because they are not the central focus of many studies, or rigorous scientific approaches are not applied.

These methodological limitations make it close to impossible to address the question as to how effective various coping strategies are; a matter of key relevance for policy and practice in the water sector. It is plausible that coping strategies may be ineffective or even counter-productive (Few et al., 2004). For example, some urban households in Zimbabwe have resorted to digging shallow wells, whose contamination is now thought to have exacerbated the 2008-2009 cholera outbreak in the country (Chambers, 2009, Mangizvo and Kapungu, 2010). There is therefore a need to step up research into large scale, rigorous evaluations of what strategies work, why they work, at what cost, and in what contexts.

This is not to say that smaller studies should be abandoned. On the contrary, one can argue their importance in bringing to light some of the more nuanced or less explored issues around households' coping strategies and their outcomes. Notable examples are the studies by Chaminuka and Nyatsanza (2013), Kudat et al. (1993) and Ngwenya and Kgathi (2006), which point to potential relationships between coping strategies and outcomes in sanitation practices, nutritional status and HIV. However, the need for more rigorous approaches in these small-scale studies is emphasised as well.

Results from eight studies support Kudat et al.'s (1993) theory that low income households are more likely to engage in 'accommodative' strategies by spending time collecting water from alternative sources, than enhancing strategies such as drilling wells or installing storage tanks. While it is somewhat obvious that households with higher income would have more coping options, the key implication is the added vulnerability of relatively poor households to unreliable water supplies (Vásquez, 2012). The broader consequences extend towards undermining poverty alleviations mechanisms through losses in labour productivity, erratic school attendance particularly for girls, reduced potential for productive water uses (Kudat et al., 1993), as well negative mental health outcomes (Wutich and Ragsdale, 2008).

The results also suggest that wealthier households drill wells or install storage tanks that practically afford them continuous supply and are, by implication, able to 'look after themselves' (Gerlach and Franceys, 2009). In many developing countries self-supply initiatives such as households drilling wells (Oluwasanya et al., 2011), and local water enterprises such as water kiosks (Opryszko et al., 2009) are increasingly being promoted. However, regulation of these initiatives is generally weak (Gerlach and Franceys, 2009), and concerns have been raised of their implications on groundwater levels (Grönwall, 2010, Zérah, 2000b), water quality (Oluwasanya, 2009, Stoler et al., 2012), health (Risebro et al., 2012) and affordability (Opryszko et al., 2009).

The findings on coping costs and willingness to pay for improved reliability are worth noting. In some of the studies, households' coping costs are at the minimum, the equivalent of bills from water utilities, or even greater and willingness to pay for improved public supplies is low among relatively wealthier households. This represents a significant diversion of potential revenue for the many water utilities in developing countries that are already struggling to recover revenue from water users.

Also of interest is that strategies such as communities setting up communal water supplies are relatively uncommon. Such community action would be perhaps indicative of a willingness to seek collective and long-term solutions that would provide economy of scale, particularly for households of lower socio-economic status. Some insights on this matter can be drawn from Manzungu et al. (2012), who warn that collective action may not be easily achieved where the state has previously assumed the role of service delivery, as in the studies reviewed herein. Further, collective action may require levels of social cohesion and trust that other households will pay their contribution (Fjeldstad, 2004) that should not be assumed to exist. A potential area of enquiry therefore could be the conditions necessary for households to seek collective action.

Developing feasible solutions is perhaps a more challenging task than diagnosing the nature and extent of the problem. Strategic action is required to implement effective measures to alleviate the problems posed by unreliable water supplies.

In the immediate to medium term, there is an urgent need to develop a sound decision base for coping strategies that can be promoted that promote good health, while being environmentally sustainable and applicable at scale. In parallel, such evidence needs to be translated to mitigatory action that can be undertaken at both the water supplier and household level. For instance, water utilities may benefit from developing contingency measures to supply water to communities during water supply interruptions. In particular, the findings by Baisa et al. (2010) on the welfare gains of supplying water at regular intervals are worth noting as a potential short-term solution where continuous supply may not be immediately feasible. As poor households are often the ones least able to cope, such interventions could be targeted towards mitigating water supply shortages amongst these sections of the society. At household level, effective mechanisms of disseminating information and education on best practice coping strategies that are locally relevant are key.

It is also important to acknowledge that in many developing countries the delivery of basic services and politics, governance and institutions are intricately linked (National Agricultural Marketing Council and Department of Agriculture Forestry and Fisheries, 2012). Thus, lasting solutions are likely those that also address the improvement of water service delivery at various spheres of government.

Conclusions

The review of how households in developing countries cope with unreliable water supplies has shown that households engage in a variety of strategies, with storage being a common one. The factors influencing the choice of strategies vary, but income, level of education, tenure and extent of unreliability appear fairly significant. The costs of these coping strategies vary widely, and are in some cases comparable to water utility bills.

The evidence that is available indicates that the poorest sections of society suffer most from the impacts of unreliable water supplies and are least able to develop effective coping strategies. Consequently the poorest sections of society may be missing out on the health and other benefits of access to safe water supplies even when they are reported as being served by improved supplies, and efforts aimed at mitigating unreliability of water supplies would do well to target them. The following chapter provides an empirical assessment of households' coping strategies, and the implications on the Free Basic Water Policy in South Africa.

8 Household responses to unreliable water supplies and Free Basic Water in Limpopo

This chapter builds on the systematic review in Chapter 7 by providing empirical evidence of household responses to unreliable water supplies. The chapter examines household strategies to cope with unreliable water supplies, as well as the factors associated with the adoption of these strategies. The crucial question of Free Basic Water is examined, taking into account the costs of coping, and the quantity of water households are able to obtain.

8.1 Objectives

The overall aim of this chapter is to assess the implications of unreliable water supplies for households in Limpopo. The specific objectives are to:

- Describe household coping strategies
- Identify factors associated with coping strategies
- Describe the distribution of coping strategies across population groups
- Explore the implications of household coping strategies in the context of Free Basic Water, by assessing:
    - The costs of coping with unreliable water supplies
    - Whether the Free Basic Water allocation is met

The last of these objectives is of particular relevance to policy, as it considers the issue of unreliable water supplies in the broader national context of the Free Basic Water policy. Specifically, the objective is to answer the question as to whether water is actually free, and whether the 25 ℓ per capita per day (ℓcd) water allocation is actually being met amongst the households studied.

8.2 Methods

Details of the questionnaire design, sampling and survey procedures have been presented in Chapter 3. The analyses presented in this chapter also draw on the key variables presented in Chapters 3 and 4; namely indicators of household socio-economic status, household coping costs and water use.

8.2.1 Data collection

The survey instrument comprised several sections relating to the household demographics, socio-economic status, water use, strategies to cope with unreliability, and the coping costs. For respondents that reported treating water amongst their coping strategies, follow up questions were asked about the treatment method(s) used and the frequency of treatment.

8.2.1.1 Coping costs

The methods used to derive monthly costs of having a drilled well and / or storage tank have been described in Chapter 3. Other cost data that were collected were those relating to buying water from neighbours, treating water through chlorination and buying bottled water. For households that reported buying water from neighbours, questions were asked about whether they paid for the water or got it free, the mode of payment i.e. charged per container of water or a flat rate, and the estimated total spent each month on buying water. Questions were also asked about the costs of treating water; the amount spent on purchasing filter equipment; the costs, if applicable, of replacing filters; and the amount of money spent on chlorinating products. For households that bought bottled water, data were collected on the number of bottles bought each month and the price of each bottle of water.

8.2.1.2 Cost of illness

Data were also collected on the occurrence of water-related illness, namely diarrhoea in the household, as well as the costs of treatment. Respondents were asked if anyone in the household had experienced diarrhoea in the last two weeks. A household member was considered to have had an episode of diarrhoea if they had passed three or more loose stools within a 24-hour period (World Health Organisation, 2014). Where diarrhoea was reported, follow-up questions were asked about the treatment method (if any); the costs related to travel when seeking treatment; the cost of the treatment itself, as well as any primary daily activities (e.g. schooling, work) that were missed during that time.

8.2.2 Analysis

Analyses were performed in SPSS 18 (SPSS Inc., 2009) and Stata 12.1 (Stata Corp, 2011), and graphs plotted in Excel 2010 (Microsoft, 2010) and Stata (Stata Corp, 2011).

8.2.2.1 Assessing the distribution of coping strategies

Household coping strategies and the related costs were anticipated to differ, depending on the wealth status of the household as well as the community that they were in. To investigate these differences, the coping strategies were grouped by wealth status and community.

8.2.2.2 Factor analysis of coping strategies

Because several of the coping strategies were highly correlated (Table A8.1.1, Appendix 8.1), factor components were used in the analyses instead of the original variables. Factor analysis is a multivariate statistical technique which identifies a set of underlying factors that explain relationships among correlated variables (Heck and Thomas, 2009). Because the extracted factors are usually fewer than the original set of variables, it can be applied as a data reduction technique. Factor analysis was done in SPSS (SPSS Inc., 2009), and Principal Component Analysis (PCA) was used for extraction of the factors and equamax rotation. The equamax rotation is orthogonal and derives non-correlated factors. Items with factor loadings greater than 0.5 were retained for further analysis.

8.2.2.3 Determining factors associated with coping strategies

To identify the factors associated with the various coping strategies, linear regression was performed in Stata (Stata Corp, 2011) for each of the components derived from the PCA. Backward stepwise regression models were used to select potential explanatory variables, with significance level for removal set to 0.05. This technique is useful in creating simple models using variables that make most valuable contribution to the relationship under consideration (Portney and Watkins, 2000). The final models included significant variables identified from the stepwise regression procedures, as well as the indicators of socio-economic status, which were included as control variables and household perceptions of the water supply.

8.2.2.4 Assessing the 'free' and 'basic'

The question of what the implications of unreliable water supplies are on the Free Basic Water policy was considered from the perspective of whether water in three study communities is actually free, and whether households are able to obtain the basic minimum of 25 ℓ per capita per day. The three outcomes of interest were the costs of water-related illness, the costs of coping with unreliable water supply, and average per capita water use.

The monetary costs of illness comprise the travel costs to a health facility / practitioner for both the household member who was ill and anyone accompanying them, as well as the costs of consultation at the facility / practitioner, and any medicines prescribed. Where any of the costs were covered by some form of health insurance, this was deducted from the cost of treatment / medication, to give the out-of-pocket expenses incurred by the household.

Coping costs comprise the aggregate monetary costs of having a drilled well and / or storage tank, buying water from neighbours, chlorinating water and buying bottled water for each household each month. As with the coping strategies, the distribution of these costs was assessed by wealth status and community. The Kruskal-Wallis test was used to compare coping costs across groups, as the coping costs were not normally distributed. Sidak, Bonferroni and Scheffe multiple comparison tests were conducted to examine differences in means between each pair of grouping variables.

Water use data were compared to the water service benchmark specified in the criteria used to define Free Basic Water. This benchmark is set at 6,000 ℓ a month for a household of 8 people; essentially translating to the 25 ℓ for each household member a day (Department of Water Affairs, 2003, Department of Water Affairs, 2007). Assuming that all households employ at least one strategy to cope with the unreliable water supplies, effective coping would be defined as achieving average per capita water use of at least 25 ℓ per day, at zero cost.

Linear regression models were used to identify the determinants of coping costs and water use, using log transformed variables of household monthly coping cost and household water use. Backward stepwise regression with significance level for removal set to 0.05 was used to identify variables for inclusion. The final models included the variables identified from the stepwise regression; indicators of socio-economic status as control variables; perceptions about the water supply; and community.

8.3 Results

The coping strategies adopted by households in the three communities are presented in Figure 8.1. Most households engage in several strategies, with the most common being storing water in vessels such as buckets, drums etc., as well as harvesting rainwater in the summer.

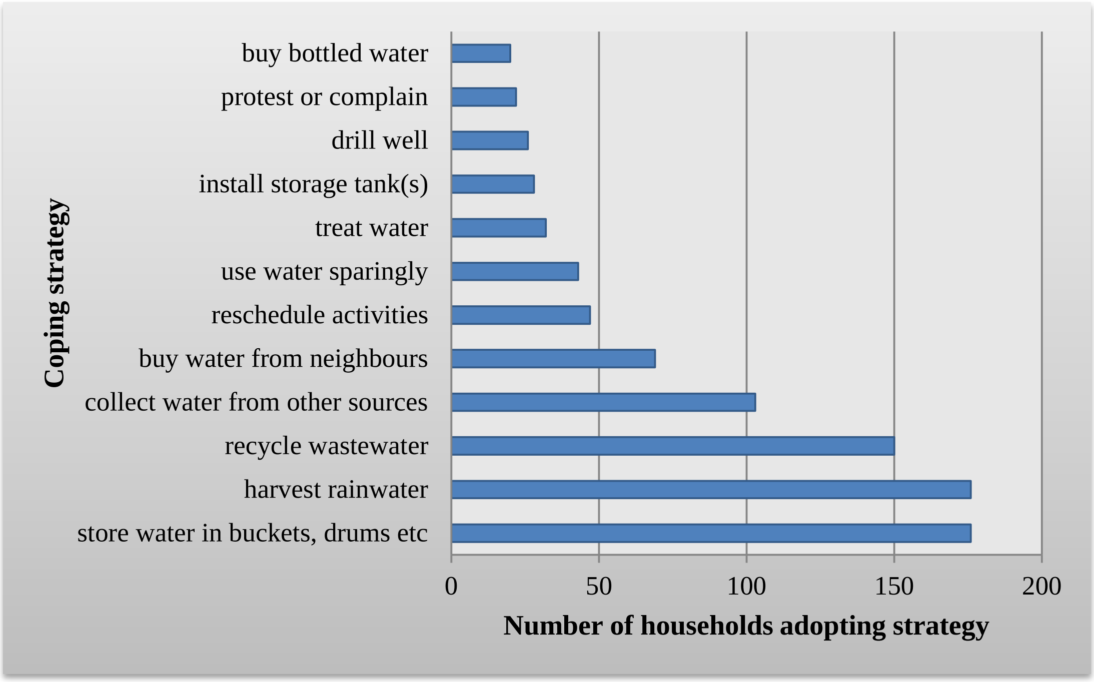

Figure 8.1: Household strategies to cope with unreliable water supply

A typical set-up for harvesting rainwater is to place drums or buckets at the edge of a gutter, as shown in Figure 8.2.

Figure 8.2: Harvesting rainwater

Source: Author

Collecting water from other sources is distinguished from buying water from neighbours, in that the water is obtained for free i.e. without payment. Recycling wastewater includes re-using laundry water for bathing, mopping floors, cleaning toilets etc. Only when the water is very greasy, soapy or dirty is it used to water flower or vegetable patches. Amongst the households that report using water sparingly, this is mainly by skipping baths, dry bathing or simply wiping with a wet towel. Rescheduling domestic activities typically entails postponing laundry washing and thorough mopping of floors until more water is available.

Water treatment is reported by 16 % (32) of the households. The treatment methods are presented in Figure 8.3.

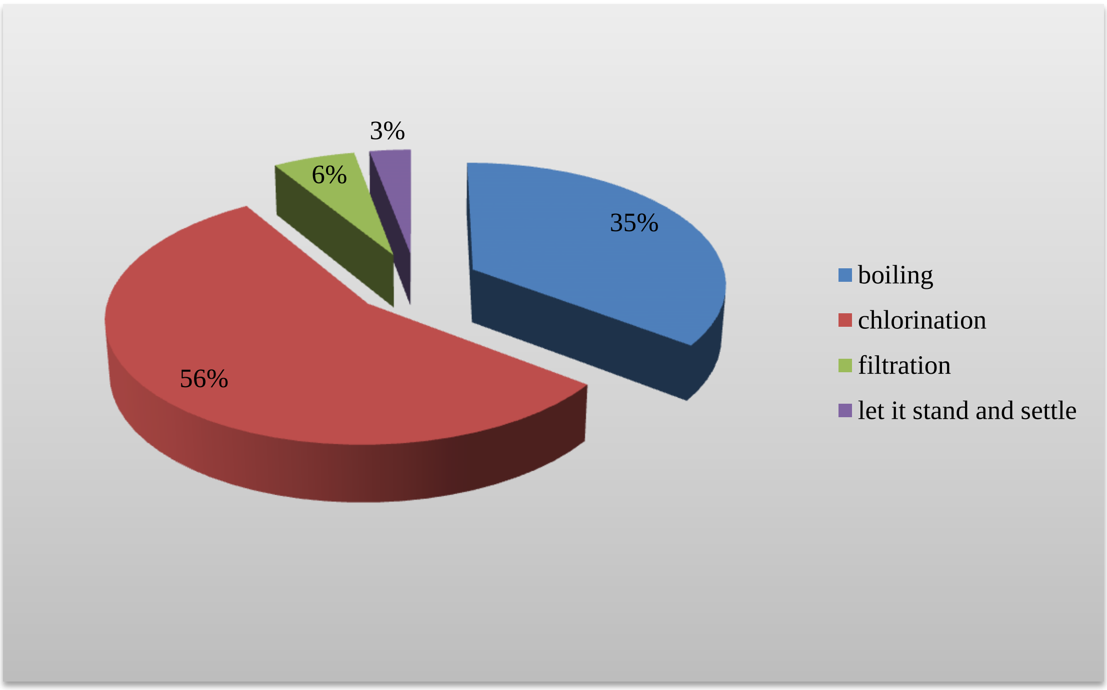

Figure 8.3: Household water treatment methods

The most common treatment method is chlorination, by adding bleach solution to water. None of the households practise solar disinfection. A few households (6 %) report filtering water when it is particularly turbid, by sieving it through kitchen towels or muslin cloths.

8.3.1 Distribution of coping strategies across population groups

Figure 8.4 shows the distribution of the various coping strategies by wealth status. While the majority of strategies are employed by households across all wealth groups, drilling wells is exclusively done by the wealthiest households; i.e. households in quintile 5. Storage tanks are installed by households whose wealth status is categorised as average, above average and wealthiest.

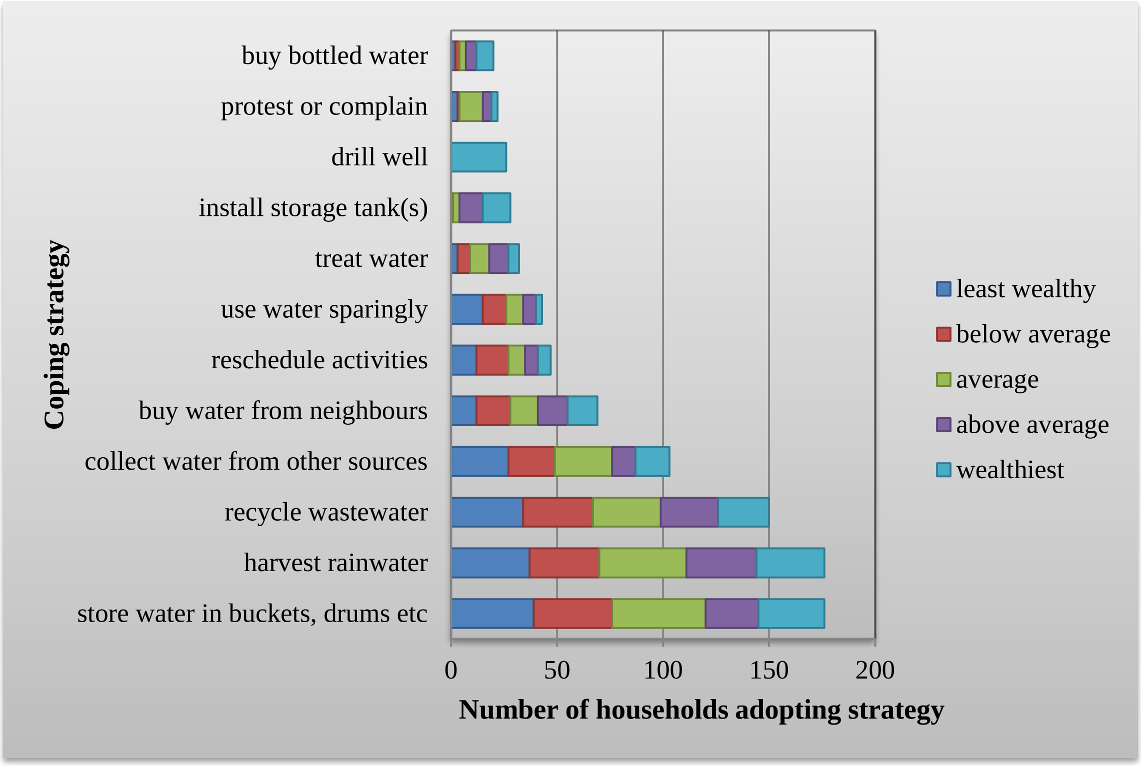

Figure 8.4: Household coping strategies, by wealth status

When looking at the coping strategies by community, Figure 8.5 shows that there is a fairly even spread of the strategies across the three communities. However, collecting water from other sources is most prevalent in Community 3.

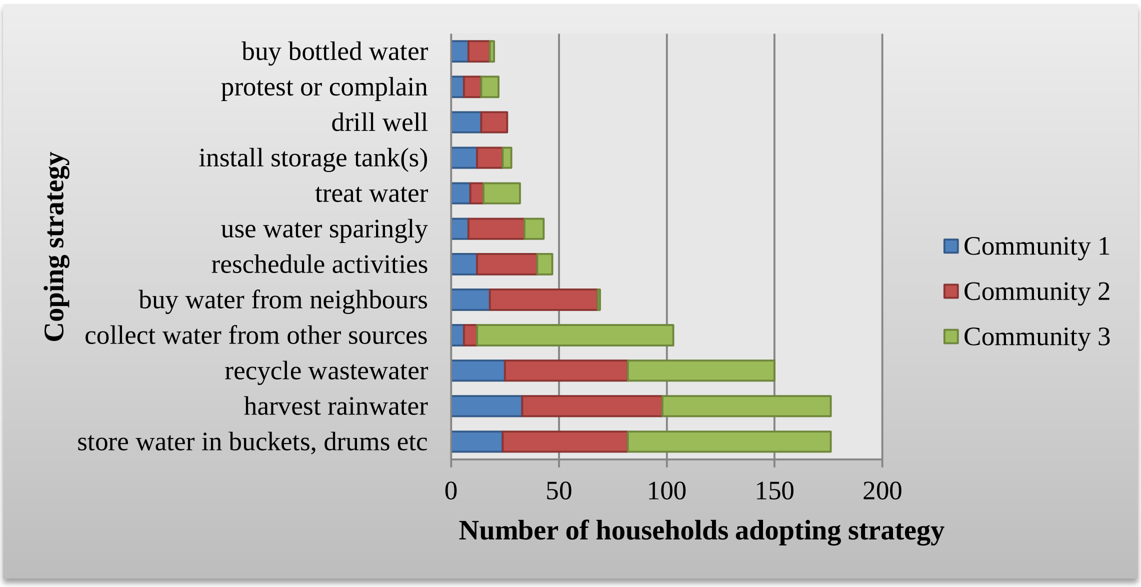

Figure 8.5: Household coping strategies, by community

Conversely, buying water from neighbours is most prevalent in Communities 1 and 2, with only one household in Community 3 reporting that they buy from neighbours. Preliminary discussions with the local headmen and informal discussions with respondents revealed that in Community 3, the chief had forbidden the sale water. Thus, although some households have spent money in setting up the connections from the springs and storage tanks, they cannot charge neighbours who come to collect water from them. Drilling wells is reported only in Communities 1 and 2, and buying bottled water is also more prevalent in these two communities than in Community 3.

8.3.2 Coping components

Four components were extracted from the data on coping strategies, and together these four components represent 64.5 % of the variance in the original variables. The rotated component matrix of the variables is shown in Table 8.1.

Table 8.1: Rotated component matrix of coping strategy variables

	Component			
Coping strategy	1	2	3	4
Drilled well	.930	-.014	.009	-.139
Storage tank	.891	-.052	.058	-.158
Treat water	.110	.120	-.275	-.659
Store water	-.792	.146	.073	.081
Buy water from neighbours	-.036	.849	.122	.187
Buy bottled water	.426	.218	-.269	.271
Collect water from alternative sources	-.366	-.813	-.049	-.021
Recycle waste water	-.139	.089	.802	.109
Harvest rainwater	.176	.232	.713	.022
Use water sparingly	-.190	.619	.156	.243
Reschedule household activities	-.268	.663	.220	-.184
Protest/complain to local authority	-.072	.188	-.080	.685

Notes: Extraction Method: Principal Component Analysis. Rotation Method: Equamax with Kaiser Normalization. Variance explained: 64.48 %.

Factor 1 is associated with drilling wells and installing storage tanks, with scores of 0.930 and 0.891 respectively. This component was named drilling and storing. Factor 2 was named buying and accommodating, and is associated with buying water from neighbours (0.849), using water sparingly (0.619) and rescheduling activities (0.663). Factor 3 is associated with recycling wastewater and harvesting rainwater, and was named recycling and harvesting, while Factor 4 is protesting / complaining to local authorities.

8.3.3 Factors associated with coping strategies

The results of the linear regression for each of the coping factors are shown in Table 8.2. Drilling wells and / or installing storage tanks are positively associated with a higher wealth status and a perception that there is a problem with the quality of the water. There is a strongly negative association between drilling wells and /or installing storage tanks and being in Community 3, compared to Community 1. Buying water from neighbours, using water sparingly and rescheduling activities (Factor 2) is marginally associated with more people in the household having episodes of diarrhoea; has a strongly negative association with being in Community 3; has a moderately negative association with problems with water quality being a reason for using multiple sources; and is marginally associated with a decrease in the number of days that water is available per week.

Recycling wastewater and harvesting rainwater is marginally associated with a higher household crowding index; is negatively associated with being very concerned about the time spent collecting water; and also negatively associated with the perception that there are generally no problems with the water supply. Protesting or complaining is marginally associated with lower household incomes and longer time taken to repair breakdowns.

Table 8.2: Linear regression of factors associated with coping strategies

	Drill wells/ storage	Buy water and accommodating	Recycling and harvesting	Protest/ complain
Least wealthy [a]				
Below average	-0.0148	-0.0739	-0.0255	-0.2238
	(-0.3429 - 0.3132)	(-0.3683 - 0.2205)	(-0.4712 - 0.4202)	(-0.7291 - 0.2814)
Average	-0.0077	-0.1875	-0.1808	0.1821
	(-0.3445 - 0.3291)	(-0.4761 - 0.1010)	(-0.6218 - 0.2603)	(-0.3121 - 0.6763)
Above average	0.5697**	-0.1686	0.1917	-0.0622
	(0.1782 - 0.9612)	(-0.5070 - 0.1697)	(-0.3403 - 0.7237)	(-0.6471 - 0.5227)
Wealthiest	0.4689*	-0.2631	-0.3137	0.3121
	(0.0376 - 0.9002)	(-0.6383 - 0.1121)	(-0.8931 - 0.2656)	(-0.3285 - 0.9527)
Household crowding index	-0.0522	-0.1444	0.3059*	0.0384
	(-0.2412 - 0.1367)	(-0.3120 - 0.0233)	(0.0507 - 0.5610)	(-0.2488 - 0.3256)
Household income	0.0498	0.0122	-0.0272	-0.2313*
	(-0.0999 - 0.1995)	(-0.1233 - 0.1477)	(-0.2339 - 0.1794)	(-0.4626 - -0.0000)
Community 1[a]				
2	-0.4073*	-0.0963	0.4218	0.1671
	(-0.7575 - -0.0570)	(-0.4256 - 0.2330)	(-0.0730 - 0.9166)	(-0.4068 - 0.7411)
3	-0.7155**	-1.5300***	0.4539	0.0196
	(-1.2208 - -0.2102)	(-1.9720 - -1.0881)	(-0.0185 - 0.9264)	(-0.5461 - 0.5853)
No of household members reporting diarrhoea	-0.0235	0.1759*	0.0014	-0.0905
	(-0.2055 - 0.1585)	(0.0177 - 0.3342)	(-0.2391 - 0.2420)	(-0.3605 - 0.1795)
Water quality problem	0.2531*			
	(0.0073 - 0.4988)			
Availability of water, in days per week		-0.0469*		
		(-0.0931 - -0.0006)		
Not at all concerned about time spent collecting water[a]				
Moderately concerned		-0.1560	0.2822	
		(-1.3486 - 1.0365)	(-1.0598 - 1.6242)	
Very concerned		-0.0378	-0.5708**	
		(-0.2583 - 0.1827)	(-0.9252 - -0.2164)	
Reason for multiple source: water quality		-0.7234**	0.0981	
		(-1.2240 - -0.2228)	(-0.6457 - 0.8419)	
No problem with water supply			-0.5386*	
			(-0.9904 - -0.0867)	
Time to repair breakdowns				0.0049*
				(0.0003 - 0.0096)
n	167	160	165	160
R^2	0.2998	0.7586	0.3205	0.1499

Note: 95 % confidence interval in parentheses; [a]base category, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

8.3.4 Coping and Free Basic Water

The following sections present the results of the assessment of water-related illness, coping costs and their distribution across populations groups and water use.

8.3.4.1 Water-related illness

Among the households surveyed, 15 (7.6 %) reported at least one episode of diarrhoea within the preceding two weeks. Almost half of these cases are reported in Community 2 (Figure 8.6). In relation to wealth status, the highest number of cases (4) is reported amongst the least wealthy households, compared to only one among the wealthiest.

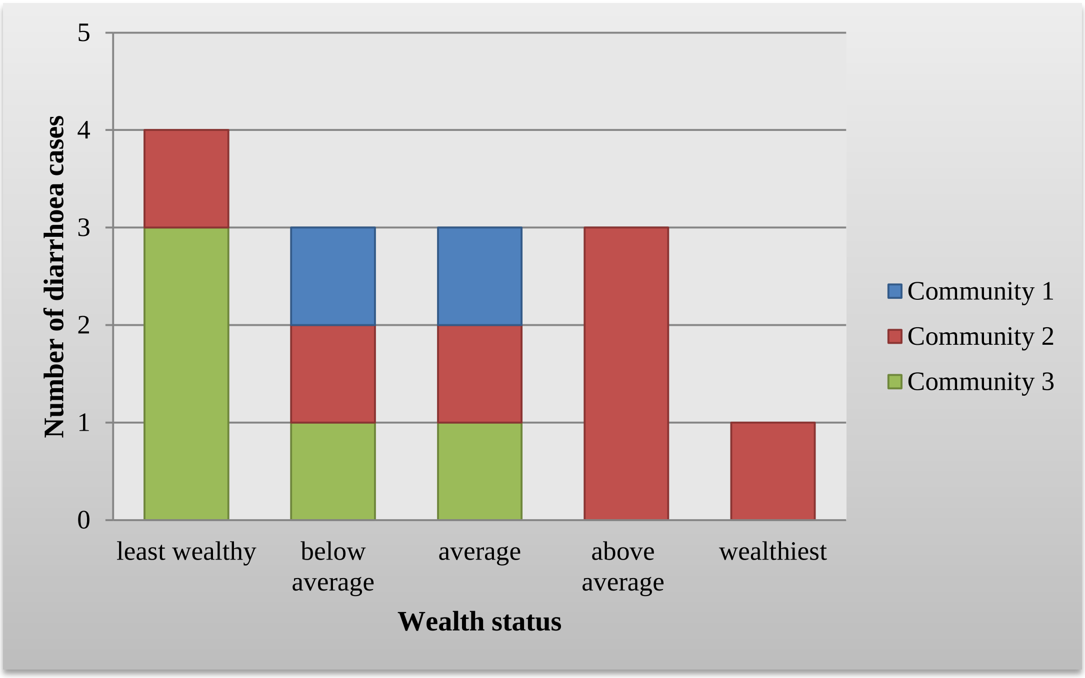

Figure 8.6: Number of households reporting diarrhoea, by wealth status and community

With regards to the treatment method, five (5) households reporting using no treatment; five (5) went to a local clinic, three used oral rehydration therapy, and two (2) altered their normal diet until the diarrhoea had cleared up. Among those that went to the local clinic, no treatment costs were charged. In terms of transport costs, two (2) households reported that they walked to the clinic and thus incurred no transport costs, two (2) got a lift to the clinic from neighbours and one (1) spent R50 (approximately US$6 at a 2012 exchange rate of US$1: ZAR8.57) on transport to and from the clinic.

8.3.4.2 Is Free Basic Water actually 'free'?

The total monthly coping costs comprise the costs of drilling wells, installing storage tanks, buying water from neighbours, chlorinating water and buying bottled water. The costs for each of these coping strategies are presented in Table A8.1.2 in Appendix 8.1. The aggregate monthly coping costs in each wealth quintile are summarised in Table 8.3. Median coping costs range from R0 to R89, for the least wealthy to the wealthiest households.

Table 8.3: Monthly household coping costs, by asset quintile

Wealth status	Mean	Median	Standard deviation	Minimum	Maximum
Least wealthy	26.54	0.00	48.98	0	200.00
Below average	47.30	13.00	94.21	0	545.00
Average	44.39	14.50	67.08	0	310.00
Above average	145.15	69.00	214.65	0	1,097.00
Wealthiest	158.27	89.00	191.82	0	662.00

Note: Coping costs are in South African Rand (ZAR)

Results of the Kruskal-Wallis test indicate a significant difference in coping costs across the wealth quintiles, with $F(4,191) = 8.00$ and $p = 0.00$. Post-hoc analysis using the Sidak, Bonferroni and Scheffe methods showed that coping costs are significantly lower at the 0.05 level amongst least wealthy households (wealth quintile 1), below average (wealth quintile 2) and average households (wealth quintile), compared to the above average (wealth quintile 4) and wealthiest households (wealth quintile 5) for all methods.

The distribution of the coping costs across the three communities is summarised in Table 8.4. The lowest costs are incurred by households in Community 3, who have median costs of R1, compared to the R105 and R100 in Communities 1 and 2 respectively.

Table 8.4: Monthly household coping costs, by community

Community	Mean	Median	Standard deviation	Minimum	Maximum
1	162.56	105.50	156.54	0	574.00
2	134.94	100.00	184.69	0	1,097.00
3	17.47	1.00	55.10	0	417.00

Note: Coping costs are in South African Rand (ZAR)

Results of the Kruskal-Wallis test indicate that these differences are significant, with $F(2,194) = 23.93$ and $p = 0.00$. Sidak, Bonferroni and Scheffe results confirm that coping costs are significantly lower in Community 3 compared to Communities 1 and 2 at the 0.05 level.

Figure 8.7 presents the median coping costs as a proportion of the median household income for each month. Overall, the median household income per month is R1,760, and R21 (median value) is spent on coping costs each month, which comes to 1.2 % of the monthly income spent on coping costs.

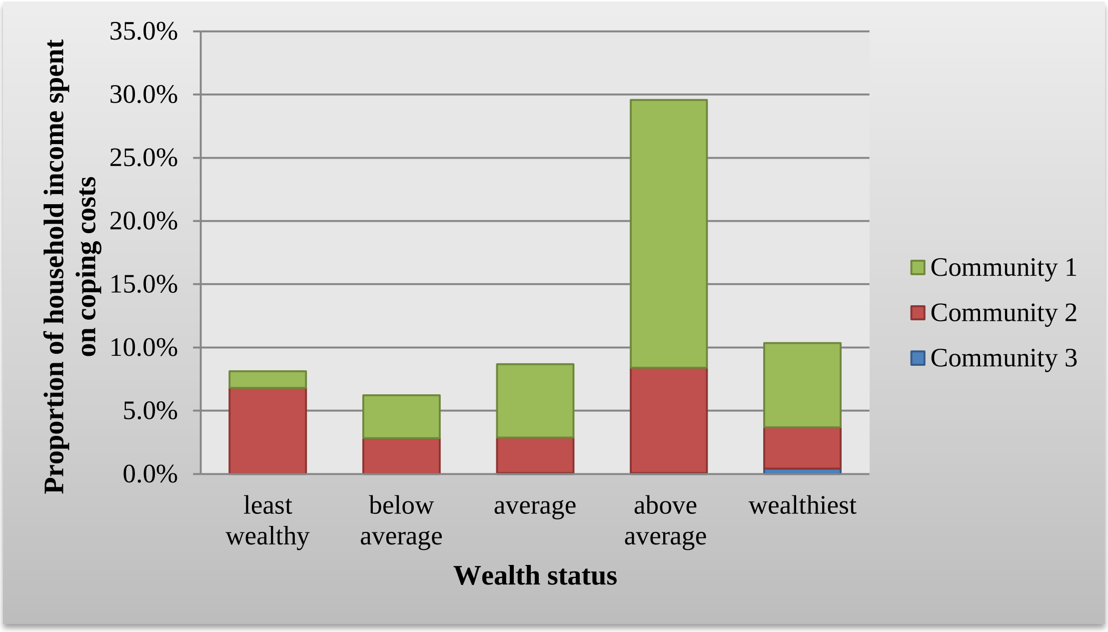

Figure 8.7: Median coping costs as a proportion of median household income, by wealth status and community

However, as Figure 8.7 shows, when examining the distribution of these coping costs by community, households in Communities 1 and 2 incur coping costs of between 1.3 and 21.2 % of their monthly income overall. There is an overall increase in the proportion of household income spent on coping costs, with a higher wealth status. The least wealthy households in Communities 1 and 2 spend 1.3 and 6.8 % of their income on coping costs, while those in the above average wealth category spend 8.3 and 21.2 % respectively. In contrast, the least wealthy and below average households in Community 3 incur no coping costs, while those in the average to wealthiest categories incur costs that are less than 0.5 % of their monthly household income.

In order to provide some insight into the household determinants of coping costs, Table 8.5 presents the results of a linear regression of log-transformed coping costs, socio-economic indicators, perceptions about the water supply and community.

Table 8.5: Determinants of aggregate household monthly coping costs

	Coefficient	95 % Confidence interval
Least wealthy [a]		
Below average	0.5211	-0.1425 - 1.1847
Average	0.6157	-0.0057 - 1.2371
Above average	1.5682***	0.8716 - 2.2649
Wealthiest	1.5340***	0.7908 - 2.2773
Household crowding index	0.1461	-0.1319 - 0.4241
Household income	0.0009	-0.2935 - 0.2954
Community 1 [a]		
2	-0.1577	-0.8675 - 0.5521
3	-3.1450***	-3.8094 - -2.4806
Diarrhoea in the household in last 2 weeks	-0.2609	-1.0182 - 0.4963
Availability of water, in hours per day	-0.0403*	-0.0751 - -0.0054
Availability of water, in days per week	0.1219	-0.0147 - 0.2585
Time to repair breakdowns	0.0061*	0.0010 - 0.0112
Reliability of water supply expected to be worse in the next two years [a]		
Better than it currently is	0.2601	-0.4526 - 0.9727
The same	0.3460	-0.2134 - 0.9055
Do not know	0.7565*	0.0806 - 1.4325
Not at all concerned about time spent collecting water [a]		
Moderately concerned	-1.0945	-2.9120 - 0.7231
Very concerned	0.7743**	0.2863 - 1.2622
n	183	
R^2	0.6349	

Note: [a]base category, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Coping costs increase with a higher wealth status, uncertainty about how reliable the water supply in the future (the next 2 years), the time taken to repair breakdowns and households being very concerned about the time spent collecting water. However, households in Community 3 are more likely to have significantly lower coping costs compared to those in Communities 1 and 2. Further, coping costs increase as the number of hours that water is available each day decreases.

8.3.4.3 Is 'basic' actually basic?

Although households employ a variety of strategies to cope with unreliable water supplies, only 34 households (17.3 %) are able to meet the minimum water use benchmark of 25 ℓ per capita per day (Figure 8.8).

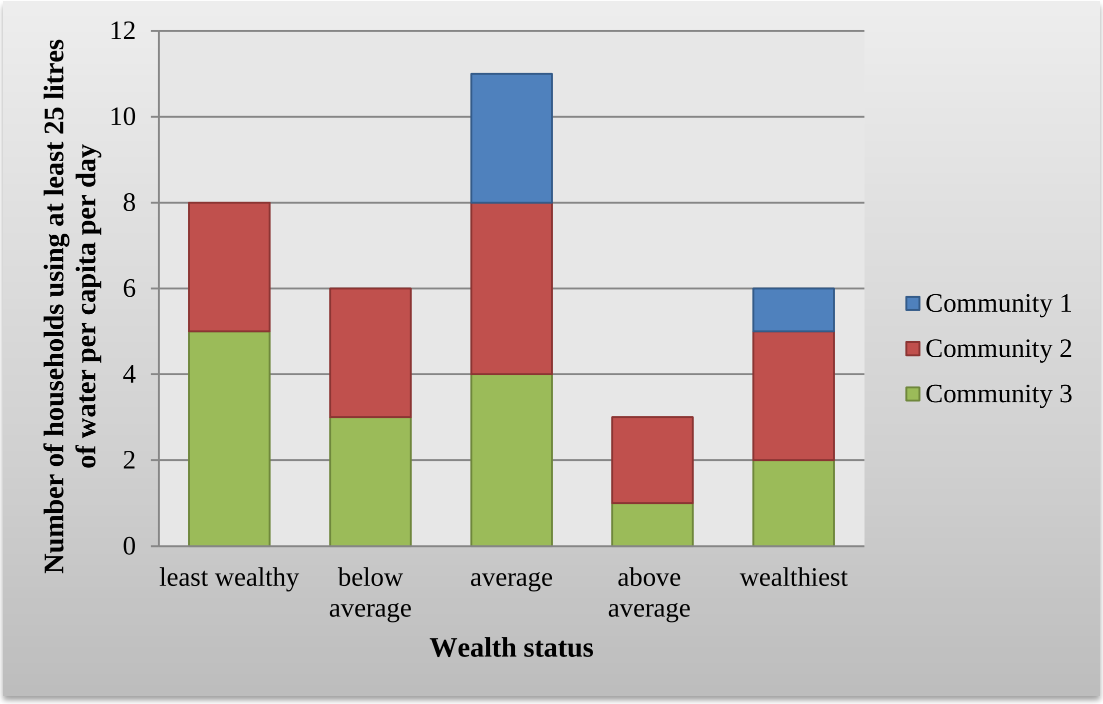

Figure 8.8: Number of households meeting water use benchmark, by wealth status and community

Across the three communities, the highest proportion of households in which the benchmark is met is in Community 2, where 23.1 % of households have a daily per capita use of at least 25 ℓ. When looking at the results by wealth status, the highest proportion of households meeting the 25 ℓ benchmark are those in the average wealth category.

The overall determinants of household water use are presented in Table 8.6. Household water use increases with a higher wealth status and the number of years that the household has lived on their premises. There is also a positive association between household water use and the household crowding index.

Table 8.6: Linear regression of determinants of household water use

	Coefficient	Confidence interval
Least wealthy [a]		
Below average	0.0811	-0.1554 - 0.3176
Average	0.1877	-0.0458 - 0.4213
Above average	0.2512	-0.0109 - 0.5132
Wealthiest	0.4072**	0.1228 - 0.6916
Household crowding index	0.2403***	0.1438 - 0.3368
Household income	0.0209	-0.0748 - 0.1166
Community 1 [a]		
2	0.0394	-0.1889 - 0.2677
3	-0.1441	-0.4530 - 0.1647
Diarrhoea in the household in last 2 weeks	-0.2955	-0.5926 - 0.0016
Number of years household has lived on the premises	0.0078*	0.0018 - 0.0139
Monthly coping cost	-0.0092	-0.0730 - 0.0545
Coping factors		
Drill wells, storage tanks	0.0086	-0.1044 - 0.1216
Buy water, reschedule, use sparingly	-0.0312	-0.1722 - 0.1099
Recycle, harvest	-0.0285	-0.1065 - 0.0496
Protest, complain	-0.0104	-0.0817 - 0.0609
n	164	
R^2	0.2728	

Note: [a]base category, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

8.3.4.4 How much does the basic water supply cost?

If only 34 (17.3 %) of households can actually meet the benchmark minimum of 25 ℓcd, how much are they paying, in terms of coping costs? Overall, the median coping cost for households that use at least 25 ℓcd is R30 per month. However, these costs range from R0 in Community 3 to R168 in Community 1 (Table 8.7).

Table 8.7: Median coping costs for households who meet and those who do not meet the 25 ℓ per capita per day benchmark

	Community 1		Community 2		Community 3	
Wealth status	≥ 25 ℓcd	< 25 ℓcd	≥ 25 ℓcd	< 25 ℓcd	≥ 25 ℓcd	< 25 ℓcd
Least wealthy	-	20.00	30.00	100.00	0.00	0.00
Below average	-	63.50	30.00	75.00	0.00	0.00
Average	168.00	83.00	15.00	75.00	25.00	0.00
Above average	-	275.00	45.00	100.00	39.00	9.00
Wealthiest	15.00	199.50	100.00	115.00	167.50	8.00

Note: Coping costs are in South African Rand (ZAR); costs are per household per month

Across the three communities, the median costs for households that meet the 25 ℓcd benchmark are R124 in Community 1, R35 in Community 2 and R1 in Community 3. By wealth status, median coping costs for households using at least 25 ℓcd are R0.50 for the least wealthy; R11 for those below average; R34 for the average; R40 for the above average; and R73 for the wealthiest. Coping costs for the least wealthy and below average households in Community 3 (n = 8) are R0; i.e. these are the households that do have free (R0) and basic (≥ 25 ℓcd) water.

Overall, households that use less than 25 ℓcd pay R106 in coping costs in Community 1, R100 in Community 2 and R1 in Community 3. By wealth status, the median coping costs for households using less than 25 ℓcd are R0 for the least wealthy; R15 for those below average; R10 for the average; R100 for those above average; and R89 for the wealthiest.

8.4 Discussion

This chapter set out to examine household strategies to cope with unreliable water supplies, factors associated with the adoption of these strategies, as well as the coping costs and quantity of water obtained, within the context of the Free Basic Water policy. The key findings of the chapter are: the high prevalence of rainwater harvesting as a coping strategy across all three communities; the significantly lower coping costs incurred by households in Community 3; the very small number of households that meet the minimum water use benchmark of 25 ℓ per capita per day; and consequently the even smaller number of households that do in fact have Free Basic Water, defined as zero coping costs and water use of at least 25 ℓcd.

There are some limitations to the findings presented in this chapter that should be noted. First, the coping costs presented in this chapter are limited to the direct monetary costs only, and do not include opportunity costs of time lost by households, or the indirect costs on livelihoods. Further, the costs of household water treatment relate only to the costs of bleach solutions, and do not include the energy costs of boiling water. Thus, the full economic costs of coping may well be higher than those presented herein.

The data presented herein (coping costs, water use, diarrhoea and reliability of the water supply) are based on self-reports from the household respondents and may be subject to recall bias. It was not possible to triangulate the self-reported with, for instance, financial records of coping expenditures, water meter readings, microbiological diagnosis of diarrhoea or water utility records of service performance. To try and minimise the potential bias, prompted recall techniques were used in the survey, where instead of asking respondents to simply state e.g. the amount of money spent on buying bottled water, prompts such as the number of water bottles bought, their capacity and the price per bottle were provided. Similar prompted recall techniques were also used in the household water use survey questions. With regards to the diarrhoea data, the survey employed a specific case definition to reduce subjectivity in the self-reports and potential bias. However, it should be highlighted that while the quality of the water supply service can have a significant impact on health outcomes such as the occurrence of diarrhoea, other factors such as sanitation also play a major role. Thus, the observed diarrhoeal prevalence cannot be attributed entirely to unreliability in the water supply.

Water use, handling practices and water-related illness may be influenced by seasonal changes (Brown et al., 2013). Thus, the study period may have been too short to observe these seasonal influences and other contextual factors that impact on coping behaviours.

Turning now to the findings, the relatively low prevalence of household water treatment (16 %), suggests that households do not hold the perception that the water is of poor quality. As reported in Chapter 4, 80.6 % of households report that they are not at all concerned about getting sick from their drinking water, and household water treatment has generally been declining in the Limpopo Province (Statistics South Africa, 2011).

Unsurprisingly, drilling wells is done by only the wealthiest households in Communities 1 and 2, given the high costs associated with this coping strategy. Households in

Community 3 would have no need to drill wells because of the availability of springs in the area, from which they either collect water directly or set up pipe connections to the yard. The community's hilly terrain would also likely be a deterrent to drilling wells.

As has been noted in the literature, the analysis of the determinants of household coping strategies is complicated by the fact that households often employ several strategies, and some more than others. Analysing each of the strategies individually would require insight into the sequence in which they adopted, which is rather complex (Zérah, 2000a). Existing studies provide only a descriptive analysis of the distribution of strategies across population groups (e.g. Caprara et al., (2009); Choe et al., (1996) and Kudat et al. (1993); focus their analysis on the determinants of a particular coping strategy (e.g. Vásquez (2012) and Zérah (2000a)) or analyse the determinants of the aggregate coping costs (e.g. Pattanayak et al., (2005). The use of the extracted principal components in the analysis thus represents a novel approach in the analysis of household strategies to cope with unreliable water supplies. This approach allowed two distinct advantages. As an exploratory technique, it revealed underlying patterns in the adoption of coping strategies. Second, as a data reduction technique, it simplified analysis which would have otherwise been tedious with 12 coping strategy variables, and likely compromised variance estimates in the regression analyses (Portney and Watkins, 2000).

Interestingly, the factors extracted from the principal component analysis are broadly in line with the concept of 'exit, voice and loyalty' (Hirschman, 1970, Zérah, 2000a) outlined in the systematic review of coping strategies (Chapter 7). Factor 1, drilling wells and installing storage tanks, corresponds with the 'exit' concept; households exit the unreliable water supply system by becoming producers of water themselves or having as little reliance on the unreliable supply as possible by storing large quantities of water. Factor 2 (buying water, rescheduling activities and using water sparingly) and Factor 3 (recycling wastewater and harvesting rainwater) are broadly representative of 'loyalty'; households accommodate unreliable water supplies by working their water use and domestic activity around it. The last of these, the 'voice' option is evidenced in Factor 4; the households that protest or complain to the local authorities.

Turning to the determinants of coping strategies, the positive association between Factor 2 (buying water, rescheduling activities and using water sparingly) and diarrhoea in the household is worth noting. A possible explanation is that cost could be a limiting factor in the quantity of water that households can buy – hence the need to use it sparingly – and consequently in hygiene practices such as hand-washing and bathing. The relatively small sample size limits the ability to conduct sophisticated analyses of the diarrhoea data, such as determinants of diarrhoea occurrence and age-specific estimates.

Recycling wastewater and harvesting rainwater (Factor 3) is positively associated with the household crowding index. This suggests that households of a lower socio-economic status (indicated by a higher household crowding index) are more likely to be ‘loyal’ and accommodate unreliable water supplies, and supports the findings of the review in Chapter 7.

Protesting and / complaining to local authorities (Factor 4) is associated with lower household income. As the findings in this chapter suggests that households of a higher socio-economic status are more likely to ‘exit’ the unreliable water supply by drilling their own wells, it perhaps makes sense they would not be willing to engage with the local authorities by voicing their problems. The association between protesting and / or complaining and with the length of time taken to repair breakdowns also makes intuitive sense; as shown in Chapter 4, breakdowns could take over a month before they were repaired, during which time households would likely get frustrated and approach local authorities.

Unsurprisingly, the lowest coping costs are reported in Community 3, as pipe connections from springs would be relatively cheap compared to drilling wells, and also because even when households collect water from their neighbours they are not charged for it. Perhaps worth bearing in mind when considering the annuitized monthly coping costs for households with drilled wells (Appendix 8.1) is that they may actually be offset by the income that comes from selling water to neighbours. Although such data was not collected in the survey itself, it is plausible that a reasonable proportion of these costs could be recovered in this way. A simple projection is that if a household sells water to two neighbours, at an overall price of R70 per month each, the income generated is R140; over half of the households’ median coping costs.

According to the results of the 2010/2011 Income and Expenditure Survey, the proportion of household income spent on water supply and miscellaneous services related to their dwelling annually is on average 3.1 % for the country as a whole, and 1.4 % for households in Limpopo Province (Statistics South Africa, 2012d). While coping costs among the three communities are overall comparable to these figures (1.2 % of household income), the proportion of household income spent on coping costs in Communities 1 and 2 specifically is much higher.

Amongst the determinants of coping costs is uncertainty about the reliability of the water supply in the next 2 years. This finding is generally in line with Kudat et al.'s (1993) hypothesis that household expectations of unreliability induce them to employ more permanent, and usually more costly coping strategies. Also noteworthy is the strongly negative association between coping costs and being in Community 3. Much of the existing analyses of the determinants of coping costs focus on socio-economic factors; observed and reported quality of the water supply; and other household characteristics as determinants of coping strategies and the ensuing costs. The results of the analysis of determinants demonstrate the influence of environment i.e. the presence of springs in Community 3, on household coping costs. This is an issue that received very little attention in the literature, with the exception of the early studies on coping by Humplick et al. (1993) and Kudat and Musayev (1997). These studies do not present any empirical evidence of this relationship, but do highlight it in their framework of assessing household strategies to cope with unreliable water supply.

While households in Community 3 are seemingly at an advantage in relation to the lower coping costs they incur, this does not seem to necessarily translate to higher water use than households in Communities 1 and 2. The low proportion of households that actually meet the 25 ℓ per capita per day minimum is consistent with the findings from another survey conducted in the north-eastern parts of the province (Majuru et al., 2012). Amongst the determinants of increased water use is a higher crowding index. A high crowding index suggests a lower socio-economic status, but also relates to a high number of household members, which is known to have a positive association with water use (Nauges and Whittington, 2010).

Conclusions

Much of the analyses of household coping costs have been aimed at indirectly estimating willingness to pay for more reliable water supplies. The application of such information is often in settings where costs recovery or pricing options are under consideration, where coping costs are used as a lower bound of willingness to pay

(Pattanayak et al., 2005). However, the Free Basic Water policy presents a unique context, in which the goal is to in fact provide a specific allocation of water for free.

The median coping cost in Communities 1 and 2 is about R100 a month, and only 8 households out of the 197 surveyed have Free Basic Water; i.e. spend R0 on coping costs and use at least 25 ℓ of water per capita per day. This finding raises some critical questions about the effectiveness of not only household coping strategies, but also the Free Basic Water policy, in enabling households to meet basic water needs.

9 Discussion and conclusions

9.1 Overview

Access to adequate quantities of safe and reliable water supplies is essential to the attainment and maintenance of good health. Yet, as the Millennium Development Goal era draws to a close, a sobering reality is that although many developing countries have made significant progress in extending access to water supply services, these supplies are unreliable.

The primary objective of this thesis has been to improve understanding on how households in developing countries experience, perceive and respond to unreliable water supplies. The thesis draws on a combination of structured literature reviews and analyses of primary data from a case study in South Africa to address two main questions: what is a reliable water supply, and how do households respond to unreliable water supplies. The specific questions that the thesis sought to address are:

- What is a reliable household water supply?
  - How is reliability defined and assessed?
  - What attributes of water supply reliability do households value?
- How do households respond to unreliable water supplies?
  - What coping strategies do households employ?
  - What are the costs of coping with unreliable water supplies?

The thesis presents a diverse set of findings concerning improved understanding of water supply reliability as a concept, and household experiences of unreliable water supplies. In locating the empirical analyses in peri-urban South Africa, the study is well-placed explore the implication of unreliable water supplies on the country's Free Basic Water policy.

The main findings of the thesis have been summarised within the respective results chapters: General Results (Chapter 4); Definitions and assessment criteria for water supply reliability (5); Household preferences for water supply reliability (6); Review of household coping strategies (Chapter 7) and Coping with unreliable water supplies in Limpopo (Chapter 8). This chapter synthesises the main findings from these chapters to answer the two main research questions of the study. These findings are presented at a broader, international level, drawing from literature reviews; and at a local level, from the results of the survey in South Africa.

9.2 Summary of main findings

Chapter 5 and Chapter 6 highlight some important conceptual points relating to the question as to what is meant by a reliable water supply. The first of these is that **water supply reliability is a concept that encompasses several attributes,** as evidenced in the myriad of assessment approaches that are found in the literature review. Although 'snapshot' approaches such as duration of supply each day and functionality at the time of the assessment have become common, long-term aspects such frequency of breakdowns in a given time period are as important. Unfortunately, **the articulation of reliability as a multi-attribute concept is neither clear nor consistent** in the existing literature**.** Consequently, evaluation approaches are largely ad-hoc.

While households would generally prefer water supplies that are reliable, the high value placed on prior notification of interruptions suggests that they would be tolerant of water supplies that were frequently interrupted, provided that there is some pattern or degree of predictability in the interruptions. Presumably, the significance of such notification lies in enabling households to adapt through appropriate coping strategies (Hensher et al., 2005). Taken together, the findings from the discrete choice experiment in Chapter 6 and coping survey in Chapter 8 support the idea that household coping costs arise mainly from the uncertainty of not knowing when next water will be supplied (Baisa et al., 2010).

Unsurprisingly, **household coping strategies are strongly influenced by socio-economic status, and of course, the extent of unreliability**. In both the review in Chapter 7 and the survey in Chapter 8, the adoption of particular coping strategies is shaped by inequalities relating to wealth status, level of education and housing tenure. However, the combination of ad-hoc evaluation approaches and lack of prioritisation of health linkages has meant that beyond typologies of coping strategies, related coping costs and determinants, current understanding of the wider implications of unreliable water supplies – including health – remains largely anecdotal.

The survey findings in Chapter 8 are therefore important in shedding light on other issues related to household coping strategic that have received less attention. The first of these is that **environmental conditions account for substantial differences in coping costs.** The stark difference in coping costs between Communities 1 and 2 and Community 3 highlight environmental conditions as a strong determinant of coping costs. Unlike households in Communities 1 and 2 who spend substantial amounts of money on either drilling wells or buying water, households in Community 3 spend considerably less in setting up pipe connections from springs to storage tanks, or simply collect water from the springs at no financial cost.

The second – and the most critical – is that **poor reliability negates the Free Basic Water policy.** Coverage data on access to basic water services mask the impact of unreliable water supplies on households. While in theory, households in the communities surveyed do not pay for basic water supply services, in reality, substantial amounts are spent on drilling wells, buying water and on treating the water prior to consumption.

9.3 Contribution of thesis and significance of findings

This thesis has sought to contribute to improved understanding of water supply reliability in developing countries and households' coping strategies. From a policy perspective, both international and local definitions and assessment approaches are important in priority setting (Evans et al., 2013). An important contribution of this thesis is the presentation of the concept of water supply reliability, both in terms of assessment approaches in literature and households' preferences.

At the time of writing, South Africa's water policies, including the Free Basic Water policy are under review (Department of Water Affairs, 2013). Although exploratory in nature, the findings from the survey offer timely and equally sobering insights into the realisation of the Free Basic Water policy on the ground. To date, studies of the Free Basic Water policy have mainly been centred around low income urban households and the adequacy of the 25 ℓ per capita day / 6,000 ℓ per household per month allocation, and the steep tariff structure for water use beyond the 6,000 ℓ (Bond and Dugard, 2008, Mosdell and Leatt, 2005, Smith and Green, 2005, Smith, 2010).

The basis for these existing approaches is that households are actually receiving the free basic allocation of water, but it is inadequate, and that tariff structure prohibits consumption beyond this basic allocation. The survey findings on water use and coping costs are therefore crucial in highlighting that not only are peri-urban / rural unable to even meet the minimum water allocation of 25 ℓcd, but are also essentially paying for the little water that they can get.

9.4 Limitations

There are some caveats to be noted in this study. The work presented herein relates primarily to operational unreliability of water supplies, and does not extend to unreliability resulting from seasonal shortages factors or drought. It must be noted however, that the two may be strongly correlated. The empirical findings in the thesis are based on data from peri-urban communities in the northern parts of South Africa. Given the differences in socio-economic conditions and the quality of the water supply services, these findings may not be readily generalised to more urban settings. Preferences and willingness to pay for reliability of water supply in particular, differ depending on the existing quality of water service provision and households' socio-economic status (Soto Montes de Oca and Bateman, 2006). There are however, broad similarities between patterns of water use and the reliability of the water supply between the communities studied herein and those previously studied in other parts of the province (Majuru et al., 2012, Majuru et al., 2011). This suggests that the findings in this thesis may have wider resonance with these communities.

A second limitation to the survey is the use of a cross-sectional design. Although the study was conducted over a time period that covered two seasons (late spring to mid-summer), this was not sufficient to compare seasonal variations in water use and coping behaviour, which would likely have significant implications on the coping costs and diarrhoeal incidence. It is also important to note that this study examined household experiences of unreliable water supplies based primarily on reported data on service quality, coping costs and diarrhoeal illness. As with most self-reported studies, the results must be considered alongside the possibility of upward or downward bias.

A major limitation with regard to the reviews on assessment of reliability and coping strategies relates to the nature of the literature on water supply reliability. With the various terminology used, it is possible that not all studies that meet the inclusion criteria may have been identified. This partly emanates from the fact that the terminology around water supply reliability varies greatly. To identify all potentially relevant studies would have required the application of all possible terminologies in the searches, and would have required the screening of tens of thousands of studies. Further, much of the literature on water supply reliability is based on single-case studies with no uniformity in reporting across studies. This makes the application of a quality appraisal tool difficult.

9.5 Implications for policy and practice

The findings of this thesis have a number of important implications for both policy makers and practitioners alike. Definitions and approaches to monitoring are of critical importance in policy, as they can determine how matters are prioritised (Evans et al., 2013). At the most fundamental level, **the need for consensus on assessment of reliability is apparent**. Based on the findings from Chapters 5 and 6, a reasonable approach could be to adopt a multi-criteria indicator that takes into account both the long-term and day-to-day reliability of water supplies.

Setting out definitions and assessment criteria does not, on its own, enable water supplies to be reliable; it must be translated into the appropriate regulatory measures. Chapter 4 highlights that although South Africa's water policies set out clear criteria for the provision of basic water services including reliability, in practice, the scope of regulation is largely limited to water quality in urban areas. Admittedly, lack of capacity and monitoring structures and resources contribute greatly to this problem, not only in South Africa, but in developing countries in general. This implies a need for renewed focus on **strengthening institutional capacities for peri-urban and rural water service provision**.

A second implication is that **water supply reliability should gain greater prominence as a key determinant of health.** Beyond institutional limitations, it is evident from the literature that unlike water quality-health linkages which occupy a defined space in the water discourse, the main discourses that define reliability problems have been largely framed within the context of operation and maintenance and cost recovery, with no clear articulation of the links to health. There is a need for this paradigm to shift to one in which water supply reliability is prioritised as a key component of mainstream health and economic development policies.

The objective behind seeking household perspectives is to understand household behaviours, and in turn, what the impact of potential service changes or improvements might be. It is perhaps all too easy to conclude from the estimates of willingness to pay (Chapter 7) and coping costs (Chapter 8), that households *can* afford and *should* pay some amount towards their water supply services. However, it is important to note that coping strategies such as drilling wells represent high capital, long-term investments which are irreversible, even if water supply services were to improve. Barring dramatic and urgent improvements in the reliability of water supply services, it is likely that households become less willing to accept and pay for public water services (Altaf, 1994).

The analysis of households' responses to unreliable water supplies in South Africa and implications on the Free Basic Water policy offers some important lessons in this regard. By focusing primarily on the *quantitative* aspect of water service provision (i.e. extending service), it has meant that the country has managed to achieve almost universal provision of water supply services, with the poor – for whom the policy was intended – not deriving maximum benefit from water services. This draws attention to how poor water services can undermine social policies that would be otherwise transformative in enhancing livelihoods of the poor. Without reliable water supply services, the objectives of improving public health and promoting equity cannot be met.

9.6 Further work

It is fairly likely that for the foreseeable future households in developing countries will continue to be confronted with the challenge of obtaining sufficient quantities of water, ensuring that such water is safe for consumption, and achieving these two objectives at a reasonable cost. While the goal of providing universal access to safe and reliable water supplies remains, strategic action is required in the interim to alleviate the problems posed by unreliable water supplies. Potential avenues of enquiry and action are outlined below.

- At the time of writing, South Africa's water policies are under review. Among the proposed changes is that the Free Basic Water allocation of 6000-ℓ be made available only to indigent households, while everyone else will be required to pay (Department of Water Affairs, 2013). This underscores the need for improved understanding of who the indigent households are, where they are and their needs.
- While the finding that socio-economic factors are key determinants of household coping strategies is unsurprising, it is the wider implication on poverty alleviation and social equity that should be a primary concern. Parallel to the need for understanding of poor households is the monitoring that not only takes into account reliability of water supply, but is also disaggregated to enable focus on inequalities and effective targeting of the most vulnerable populations.

- The findings in Chapter 8 highlight that apart from socio-economic status, environmental conditions are important mediating factors in how households cope with unreliable water supplies. As a priority, attention should be given to circumstances where low socio-economic status and unavailability of alternative water sources intersect.
- There is therefore an urgent need to develop a sound decision base for coping strategies that can be promoted that promote good health, while being environmentally sustainable and applicable at scale.
- Analyses of water supply reliability have largely focused at the household level. A more holistic understanding of the impacts of unreliable water supplies can be facilitated by research conducted in other spheres of activity. How, for instance, do schools, workplaces and healthcare facilities cope with unreliable water supplies, and what are the health, social and economic implications within those spheres?
- The high value that households place on prior notification of interruptions warrants further examination of what the implications are for situations in which fully reliable water supplies are not a feasible option. How do health, social and economic outcomes in these situations compare to those in which supply interruptions are random?

There are important ways in which further work may improve upon the design and scope of the survey in South Africa. The first of these is the replication of the study with a larger sample, and over a longer period of time; allowing more refined analyses of health outcomes and to better capture the effects of seasonality. Secondly, with the review of the Free Basic Water under consideration, it may be valuable to determine how coping costs of peri-urban households that are supposedly receiving Free Basic Water compare to (i) the costs of providing reliable public water supplies and (ii) the bills that are paid by urban households with piped water supplies.

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Appendix 1.1: Health impact of small-community water supply reliability

Appendix 1.2: Water service benchmarks and reliability

Appendix 3.1: DfID project inception report

Appendix 3.2a: Ethics approval from University of East Anglia

Appendix 3.2b: Ethics approval from Tshwane University of Technology

Appendix 4: Imputation procedures

There are several mechanisms underlying missing data. Data is said to be missing completely at random (MCAR) if the probability of an observation being missing has no relationship with the variable itself or any other variable in the analysis (Allison, 2001). In other words, the missing data is unrelated to the study variables. If the probability of an observation being missing is related to the values of some other variable i.e. the missingness can be predicted from other variables in the dataset, the data is missing at random (MAR). Finally, data may be missing not at random (MNAR), if the probability that an observation is missing is related to the value of the observation itself; the missingness depends on unobserved data. Such missing data raises the concern of drawing invalid inferences from analyses, and essentially threatens the integrity of a study.

Handling missing data

An easy solution for missing data would be to maximise data collection in the first instance. However, in reality this is not always possible. Difficulty in recalling information (such as costs of drilling wells, which may have been done years ago) and unwillingness to disclose information such as income, are common (Groves et al., 2009). Allison (2001) outlines a good method for handling missing data as one that:

- Minimises bias
- Makes maximum use of the available information
- Produces good estimates of uncertainty

Based on these criteria, three main options for handling missing data considered were: 1) dropping variables with too many missing values from the analyses; 2) analysing only cases that have complete data i.e. dropping the households that had some item non-responses; or 3) imputing the missing data.

The first option – omitting variables with missing data from analyses – was not viable, as the variables that did have missing values were those that were key in the analyses. Given that the proportion of data missing was large, complete case analyses (option 2) was also not viable, as the size of the sample analysed would have been considerably reduced, and consequently the statistical power (Baraldi and Enders, 2010). A further consideration in complete-case analysis was that unless the data were missing completely at random, results obtained from such analyses would have been biased (Altman and Bland, 2007).

Imputation was considered the most viable option. It is a technique in which missing data on a variable is replaced by a value drawn from an estimate of the variable's distribution (Donders et al., 2006). The imputation can be in several ways. Single imputation typically uses a single estimate such as the sample mean or median. Although the relative simplicity offered by this approach is attractive, the use of a single estimate such as a mean often attenuates overall correlation estimates and variability of data and may produce biased mean estimates (Baraldi and Enders, 2010).

Multiple imputation of missing data

Multiple imputation was developed by Rubin (1987). The technique uses a specified regression model to impute missing values; essentially filling in values given the values for the other variables in the model. Multiple imputation generally assumes that data are MAR, and can also be applied on data that is MCAR.

A distinct advantage of multiple imputation lies in its maximum use of available data, which consequently preserves statistical power. Further, the pooling of parameter estimates from each multiple datasets generated accounts for variation from both within and between imputed datasets (Baraldi and Enders, 2010).

The detailed results of the imputation for water use, income and initial and running costs are outlined in the sections below.

Household water use

Linear regression of household water use with non-imputed data

```
. reg lnwater i.washingmachine i.car max_people i.currrent_pubpri i.drilled_well
i.education crowding

      Source |       SS       df       MS              Number of obs =     143
-------------+------------------------------           F( 10,   132) =    4.83
       Model |  11.6972395    10  1.16972395           Prob > F      =  0.0000
    Residual |  31.9458404   132  .242013943           R-squared     =  0.2680
-------------+------------------------------           Adj R-squared =  0.2126
       Total |  43.6430799   142  .307345633           Root MSE      =  .49195

------------------------------------------------------------------------------
        lnwater |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
----------------+-------------------------------------------------------------
1.washingmach~e |   .2979487   .1488695     2.00   0.047      .0034701    .5924272
          1.car |   .0304254   .1244702     0.24   0.807     -.2157889    .2766396
     max_people |    .107238   .0224382     4.78   0.000       .062853     .151623
1.currrent_pu~i |   .0655579   .1153081     0.57   0.571     -.1625329    .2936488
 1.drilled_well |   .0391015   .2110228     0.19   0.853     -.3783224    .4565255
                |
      education |
             1  |  -.1212153   .1472187    -0.82   0.412     -.4124285    .1699979
             3  |  -.1401734   .1244264    -1.13   0.262     -.3863012    .1059544
             4  |  -.0451894    .120066    -0.38   0.707     -.2826919    .1923131
             5  |  -.1201534    .181167    -0.66   0.508     -.4785196    .2382128
                |
       crowding |   .0138526   .0639456     0.22   0.829      -.112638    .1403433
```

```
         _cons |   3.727959   .1575362    23.66   0.000     3.416337    4.039581
------------------------------------------------------------------------------
```

Imputation procedure: linear regression of log-transformed water use data

```
. mi impute truncreg lnwater i.washingmachine i.car max_people i.currrent_pubpri
i.drilled_well i.education crowding, add(15) rseed(2232) ll(2.995732) ul(5.598422) force

Univariate imputation                      Imputations =       15
Truncated regression                             added =       15
Imputed: m=1 through m=15                      updated =        0

Limit: lower =     2.995732            Number truncated =        1
       upper =     5.598422                        left =        0
                                                  right =        1

------------------------------------------------------------------
                   |               Observations per m
                   |----------------------------------------------
          Variable |   Complete   Incomplete   Imputed |     Total
-------------------+-----------------------------------+----------
           lnwater |        143           54        53 |       197
------------------------------------------------------------------
(complete + incomplete = total; imputed is the minimum across m

 of the number of filled-in observations.)
```

Linear regression of household water use with imputed data

```
. mi estimate: reg lnwater i.washingmachine i.car max_people i.currrent_pubpri
i.drilled_well i.education crowding

Multiple-imputation estimates                     Imputations     =         15
Linear regression                                 Number of obs   =        196
                                                  Average RVI     =     0.4047
                                                  Largest FMI     =     0.5088
                                                  Complete DF     =        185
DF adjustment:   Small sample                     DF:     min     =      36.15
                                                          avg     =      83.04
                                                          max     =     120.97
Model F test:       Equal FMI                     F(  10,  161.1) =       4.48
Within VCE type:          OLS                     Prob > F        =     0.0000

------------------------------------------------------------------------------
        lnwater |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
----------------+-------------------------------------------------------------
1.washingmach~e |   .3140712   .1308466     2.40   0.019     .0528075    .5753349
          1.car |   .0259636   .1172346     0.22   0.825    -.2080135    .2599406
     max_people |   .1044825    .021612     4.83   0.000     .0616942    .1472709
1.currrent_pu~i |   .1003848   .1080126     0.93   0.357    -.1161714    .3169409
 1.drilled_well |   .0616926   .1807337     0.34   0.735    -.3048009     .428186
                |
      education |
             1  |  -.0847564   .1381631    -0.61   0.541    -.3592699    .1897571
             3  |  -.1397083   .1212286    -1.15   0.252     -.379904    .1004874
             4  |  -.0494941   .1202604    -0.41   0.682    -.2891918    .1902036
             5  |  -.0854089   .1640808    -0.52   0.604    -.4114951    .2406772
                |
       crowding |   .0216527   .0611774     0.35   0.724    -.0994643    .1427697
          _cons |   3.687413   .1544538    23.87   0.000     3.380409    3.994417
------------------------------------------------------------------------------
```

Household income

Linear regression of log-transformed household income with non-imputed data

```
. reg lnwincome i.washingmachine i.car max_people i.currrent_pubpri i.drilled_well
i.education crowding
```

```
      Source |       SS       df       MS              Number of obs =     183
-------------+------------------------------           F( 10,   172) =    1.97
       Model |  16.8976763    10  1.68976763           Prob > F      =  0.0391
    Residual |  147.407347   172   .85701946           R-squared     =  0.1028
-------------+------------------------------           Adj R-squared =  0.0507
       Total |  164.305023   182  .902774854           Root MSE      =  .92575

------------------------------------------------------------------------------
      lnwincome |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
----------------+-------------------------------------------------------------
1.washingmach~e |   .6087177   .2205672     2.76   0.006     .1733507    1.044085
          1.car |  -.0361544   .1976315    -0.18   0.855    -.4262497    .3539408
     max_people |   .0880654   .0386371     2.28   0.024     .0118013    .1643294
1.currrent_pu~i |  -.1488574   .1703024    -0.87   0.383    -.4850092    .1872944
 1.drilled_well |  -.5035258   .2549902    -1.97   0.050    -1.006839   -.0002128
                |
      education |
             1  |  -.0341386    .232148    -0.15   0.883    -.4923643    .4240872
             3  |   .0254363    .215341     0.12   0.906     -.399615    .4504876
             4  |   .0005043   .1950662     0.00   0.998    -.3845275    .3855362
             5  |  -.0222356    .302573    -0.07   0.942      -.61947    .5749988
                |
       crowding |   .0490981   .1088334     0.45   0.652    -.1657229    .2639191
          _cons |   6.889812   .2635478    26.14   0.000     6.369608    7.410017
------------------------------------------------------------------------------
```

Imputation procedure: truncated regression of log-transformed income data

```
. mi set mlong

. mi register imputed lnwincome
(14 m=0 obs. now marked as incomplete)

. mi impute truncreg lnwincome i.washingmachine i.car max_people i.currrent_pubpri
i.drilled_well i.education crowding, add(15) rseed(2232) ll(0) ul(9.862665) force

Univariate imputation                     Imputations =       15
Truncated regression                            added =       15
Imputed: m=1 through m=15                     updated =        0

Limit: lower =          0           Number truncated =        2
       upper =   9.862665                       left =        1
                                               right =        1

------------------------------------------------------------------
                   |               Observations per m
                   |----------------------------------------------
          Variable |   Complete   Incomplete   Imputed |     Total
-------------------+-----------------------------------+----------
         lnwincome |        183           14        13 |       197
------------------------------------------------------------------
(complete + incomplete = total; imputed is the minimum across m

 of the number of filled-in observations.)
```

Linear regression of log-transformed household income with imputed data

```
. mi estimate: reg lnwincome i.washingmachine i.car max_people i.currrent_pubpri
i.drilled_well i.education crowding

Multiple-imputation estimates                    Imputations     =         15
Linear regression                                Number of obs   =        196
                                                 Average RVI     =     0.0778
                                                 Largest FMI     =     0.1512
                                                 Complete DF     =        185
DF adjustment:   Small sample                    DF:     min     =     125.81
                                                         avg     =     163.97
                                                         max     =     180.86
Model F test:       Equal FMI                    F(  10,  181.3) =       1.91
Within VCE type:          OLS                    Prob > F        =     0.0464

------------------------------------------------------------------------------
      lnwincome |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
----------------+-------------------------------------------------------------
1.washingmach~e |   .5592816   .2142895     2.61   0.010     .1359126    .9826505
```

```
         1.car |  -.0227053   .1961352    -0.12   0.908    -.4105113    .3651006
    max_people |   .0871452    .037762     2.31   0.022     .0126321    .1616583
1.currrent_pu~i |  -.1469546   .1712856    -0.86   0.392    -.4854948    .1915857
 1.drilled_well |  -.4651853   .2493881    -1.87   0.064     -.957418    .0270475
               |
     education |
             1  |  -.0239977   .2294946    -0.10   0.917    -.4768315    .4288361
             3  |   .0255133   .2118883     0.12   0.904    -.3927037    .4437303
             4  |  -.0044317   .1925373    -0.02   0.982    -.3843399    .3754765
             5  |  -.0288361   .2925948    -0.10   0.922    -.6078813     .550209
               |
      crowding |   .0509024   .1071003     0.48   0.635    -.1604366    .2622415
         _cons |   6.889869   .2579092    26.71   0.000      6.38086    7.398877
-------------------------------------------------------------------------------
```

Initial costs of fixtures

Linear regression model of log-transformed initial costs with non-imputed data

```
. regress lninitial_cost lnimp_inc i.education i.community_id i.fixtures fac1_1 fac4_1
crowding
note: 10.fixtures omitted because of collinearity

      Source |       SS       df       MS              Number of obs =      18
-------------+------------------------------           F( 13,     4) =   28.46
       Model |  67.3078659    13  5.17752815           Prob > F      =  0.0027
    Residual |  .727814856     4  .181953714           R-squared     =  0.9893
-------------+------------------------------           Adj R-squared =  0.9545
       Total |  68.0356808    17  4.00209887           Root MSE      =  .42656

------------------------------------------------------------------------------
lninitial_~t |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   lnimp_inc |  -.2126975   .3126255    -0.68   0.534    -1.080685      .65529
             |
   education |
          1  |   .7838198   .4968574     1.58   0.190    -.5956775    2.163317
          3  |    .701825   .8313722     0.84   0.446    -1.606434    3.010084
          4  |   1.694776   .4761464     3.56   0.024     .3727819     3.01677
          5  |  -1.785516   .6639226    -2.69   0.055    -3.628861    .0578285
             |
community_id |
          1  |  -.0617503   .6361631    -0.10   0.927    -1.828022    1.704522
          2  |   1.620537   2.002883     0.81   0.464    -3.940358    7.181431
             |
    fixtures |
          4  |   -1.01305   .7137026    -1.42   0.229    -2.994606    .9685061
          5  |   2.325802   1.055132     2.20   0.092    -.6037149    5.255318
          8  |   .4944514   .9844939     0.50   0.642    -2.238942    3.227845
         10  |          0  (omitted)
             |
      fac1_1 |   1.983163   .6240054     3.18   0.034     .2506459    3.715679
      fac4_1 |  -.1991177   .1781051    -1.12   0.326    -.6936168    .2953813
    crowding |   -.211179   .2198653    -0.96   0.391    -.8216229    .3992649
       _cons |   6.019216   2.585538     2.33   0.080    -1.159387    13.19782
------------------------------------------------------------------------------
```

Imputation procedure: truncated regression of log-transformed initial costs

```
. mi set mlong

. mi register imputed lninitial_cost
(56 m=0 obs. now marked as incomplete)


. mi impute truncreg lninitial_cost lnimp_inc i.education i.community_id i.fixtures
fac1_1 fac4_1 crowding, add(15) rseed(2232) ll(3.912023) ul(10.4631) force
note: 10.fixtures omitted because of collinearity

Univariate imputation                         Imputations =       15
Truncated regression                                added =       15
Imputed: m=1 through m=15                         updated =        0
```

```
Limit: lower =     3.912023           Number truncated =        1
       upper =      10.4631                       left =        0
                                                 right =        0

-------------------------------------------------------------------
                   |               Observations per m
                   |----------------------------------------------
          Variable |   Complete   Incomplete   Imputed |     Total
-------------------+-----------------------------------+----------
    lninitial_cost |         18           56        56 |        74
-------------------------------------------------------------------
(complete + incomplete = total; imputed is the minimum across m
 of the number of filled-in observations.)
```

Linear regression model of log-transformed initial costs with imputed data

```
. mi estimate, esampvaryok: reg lninitial_cost lnimp_inc i.education i.community_id
i.fixtures fac1_1 fac4_1 crowding

Multiple-imputation estimates                   Imputations     =         15
Linear regression                               Number of obs   =         73
                                                Average RVI     =     2.3223
                                                Largest FMI     =     0.9079
                                                Complete DF     =         58
DF adjustment:   Small sample                   DF:     min     =       4.88
                                                        avg     =      19.02
                                                        max     =      49.59
Model F test:       Equal FMI                   F(  14,   38.1) =      57.54
Within VCE type:          OLS                   Prob > F        =     0.0000

------------------------------------------------------------------------------
lninitial_~t |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   lnimp_inc |  -.4178345   .0979366    -4.27   0.008    -.6713895   -.1642796
             |
   education |
          1  |   1.294531   .2200038     5.88   0.000     .8291635    1.759898
          3  |   2.268075   .4368552     5.19   0.003     1.171122    3.365028
          4  |   1.780565   .1968819     9.04   0.000     1.365889     2.19524
          5  |  -.7939998   .2672696    -2.97   0.010    -1.368864   -.2191356
             |
community_id |
          1  |  -.4307327   .2432452    -1.77   0.090    -.9338276    .0723622
          2  |  -.2647642   .7736697    -0.34   0.737    -1.906948     1.37742
             |
    fixtures |
          4  |   -1.43222   .4067652    -3.52   0.001    -2.253647   -.6107923
          5  |   .7984005   .4898291     1.63   0.113    -.1992816    1.796083
          6  |     .12378   .5181503     0.24   0.812    -.9171671    1.164727
          8  |  -1.213167   .4333523    -2.80   0.025    -2.224014   -.2023196
         10  |          0  (omitted)
             |
      fac1_1 |   .9545215   .2403548     3.97   0.006     .3778756    1.531167
      fac4_1 |   -.343155   .0567432    -6.05   0.000    -.4590293   -.2272807
    crowding |  -.3240747   .0964112    -3.36   0.004    -.5302104    -.117939
       _cons |   10.45729   1.140379     9.17   0.000     7.788383    13.12621
------------------------------------------------------------------------------
Warning: estimation sample varies across imputations; results may be biased.
         Sample sizes vary between 73 and 74.
```

Running costs of fixtures

Linear regression model of log-transformed running costs with non-imputed data

```
regress lnwrun_cost lnimp_inc i.car max_people number_of_tanks i.change_source
reliability_days_per_week i.education i.fixture i.community
note: 8.fixtures omitted because of collinearity
note: 2.community_id omitted because of collinearity

      Source |       SS       df       MS              Number of obs =      26
-------------+------------------------------           F( 14,    11) =    3.89
       Model |  181.009451    14  12.9292465           Prob > F      =  0.0146
    Residual |  36.5759867    11   3.3250897           R-squared     =  0.8319
-------------+------------------------------           Adj R-squared =  0.6180
       Total |  217.585438    25  8.70341751           Root MSE      =  1.8235

------------------------------------------------------------------------------------------
              lnwrun_cost |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
--------------------------+---------------------------------------------------------------
                lnimp_inc |  -1.255239   .7348881    -1.71   0.116    -2.872716    .3622393
                    1.car |     3.3379   1.094812     3.05   0.011     .9282354    5.747565
               max_people |   .7505018   .2530031     2.97   0.013     .1936457    1.307358
          number_of_tanks |   .7301365   2.891983     0.25   0.805    -5.635075    7.095348
          1.change_source |   .5975455   1.435236     0.42   0.685    -2.561387    3.756478
reliability_days_per_week |   .8231816   .3629249     2.27   0.044     .0243892    1.621974
                          |
                education |
                       1  |  -1.843604   1.397026    -1.32   0.214    -4.918438     1.23123
                       3  |  -8.756502   1.928544    -4.54   0.001     -13.0012   -4.511805
                       4  |  -2.658224   1.546353    -1.72   0.114    -6.061725    .7452768
                       5  |  -2.058064    2.77792    -0.74   0.474    -8.172224    4.056097
                          |
                 fixtures |
                       4  |   .4318066   2.269049     0.19   0.853    -4.562336     5.42595
                       5  |  -4.165671   2.897988    -1.44   0.178     -10.5441    2.212758
                       8  |          0  (omitted)
                      10  |   1.364387   3.960209     0.34   0.737    -7.351974    10.08075
                          |
             community_id |
                       1  |   2.138882   1.592203     1.34   0.206    -1.365533    5.643297
                       2  |          0  (omitted)
                          |
                    _cons |   5.283938   5.776214     0.91   0.380    -7.429423     17.9973
------------------------------------------------------------------------------------------
```

Imputation procedure: truncated regression of log-transformed running costs

```
. mi set mlong

. mi register imputed lnwrun_cost
(48 m=0 obs. now marked as incomplete)

. mi impute truncreg lnwrun_cost lnimp_inc i.car max_people number_of_tanks
i.change_source reliability_days_per_week i.education i.fixture i.community, add(15)
rseed(2232) ll(0) ul(8.89563) force
note: 8.fixtures omitted because of collinearity
note: 2.community_id omitted because of collinearity

Univariate imputation                    Imputations =       15
Truncated regression                           added =       15
Imputed: m=1 through m=15                    updated =        0

Limit: lower =           0          Number truncated =        5
       upper =     8.89563                      left =        5
                                               right =        0

------------------------------------------------------------------
                   |               Observations per m
                   |----------------------------------------------
          Variable |   Complete   Incomplete   Imputed |     Total
-------------------+-----------------------------------+----------
       lnwrun_cost |         26           48        48 |        74
------------------------------------------------------------------
(complete + incomplete = total; imputed is the minimum across m of the number of filled-
in observations.)
```

Linear regression model of log-transformed running costs with imputed data

```
mi estimate, esampvaryok: reg lnwrun_cost lnimp_inc i.car max_people number_of_tanks i.change_source
reliability_days_per_week i.edu
> cation i.fixture i.community

Multiple-imputation estimates                   Imputations     =         15
Linear regression                               Number of obs   =         70
                                                Average RVI     =     0.4813
                                                Largest FMI     =     0.6229
                                                Complete DF     =         53
DF adjustment:   Small sample                   DF:     min     =      13.87
                                                        avg     =      36.29
                                                        max     =      49.59
Model F test:       Equal FMI                   F(  16,   47.8) =      10.90
Within VCE type:          OLS                   Prob > F        =     0.0000

------------------------------------------------------------------------------------------
              lnwrun_cost |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
--------------------------+---------------------------------------------------------------
                lnimp_inc |   .0090745   .2170253     0.04   0.967    -.4568021    .4749512
                    1.car |   1.358044   .4429358     3.07   0.004     .4586135    2.257474
               max_people |   .5346517   .1092444     4.89   0.000      .309981    .7593224
          number_of_tanks |   1.403041   1.049349     1.34   0.189    -.7172926    3.523375
          1.change_source |   .8925055   .5512028     1.62   0.117    -.2380128    2.023024
reliability_days_per_week |   .4456877   .1415198     3.15   0.004     .1551124    .7362631
                          |
                education |
                        1 |  -.8652044   .6447433    -1.34   0.187    -2.166071    .4356624
                        3 |  -4.311931   .8669633    -4.97   0.000    -6.097771   -2.526091
                        4 |  -1.461293   .6310662    -2.32   0.026    -2.739052   -.1835349
                        5 |   -1.06437   .9086264    -1.17   0.251    -2.920349    .7916094
                          |
                 fixtures |
                        4 |  -.6029637   1.528376    -0.39   0.695    -3.673432    2.467504
                        5 |  -2.369712   1.747998    -1.36   0.182     -5.89217    1.152745
                        6 |  -1.995852   2.288108    -0.87   0.388    -6.604769    2.613065
                        8 |  -1.462433   2.043774    -0.72   0.478    -5.573685    2.648819
                       10 |  -2.143235   1.964598    -1.09   0.281    -6.104734    1.818264
                          |
             community_id |
                        1 |   .5284437   .7929517     0.67   0.508    -1.065054    2.121941
                        2 |          0  (omitted)
                          |
                    _cons |  -.3289534   2.344675    -0.14   0.889     -5.08564    4.427733
------------------------------------------------------------------------------------------
Warning: estimation sample varies across imputations; results may be biased.  Sample sizes

         vary between 70 and 74.
```

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Appendix 6.1: Results of structured search of discrete choice studies of reliability water supply

Table A6.1.1: Literature search terms and databases

Database	Date of search	Type of search	Search term	Hits	Notes
Science Direct	06/04/2013	title, abstract, key	"water supply" OR "domestic water" OR "household water" OR "drinking water" OR "safe water" AND Conjoint OR "conjoint analyses" OR "conjoint measurement" OR "conjoint studies" OR "conjoint choice experiments" OR "part-worth utilities" OR "functional measurement" OR "pairwise comparisons" OR "pairwise choices" OR "discrete choice experiments" OR "discrete choice modelling" OR "discrete choice conjoint experiments" OR "stated preference"	10	-
Scirus	06/04/2013	title	"water supply" OR "domestic water" OR "household water" OR "drinking water" OR "safe water" AND Conjoint OR "conjoint analyses" OR "conjoint measurement" OR "conjoint studies" OR "conjoint choice experiments" OR "part-worth utilities" OR "functional measurement" OR "pairwise comparisons" OR "pairwise choices" OR "discrete choice experiments" OR "discrete choice modelling" OR "discrete choice conjoint experiments" OR "stated preference"	3	-
		keyword	As above	20	-
Scopus	06/04/2013	title, abstract, key	"water supply" OR "domestic water" OR "household water" OR "drinking water" OR "safe water") AND (conjoint OR "conjoint analyses" OR "conjoint measurement" OR "conjoint studies" OR "conjoint choice experiments" OR "part-worth utilities" OR "functional measurement" OR "pairwise comparisons" OR "pairwise choices" OR "discrete choice experiments" OR "discrete choice modelling" OR "discrete choice conjoint experiments" OR "stated preference" OR "choice modelling" OR "choice model"	78	-

Appendix 6.1: Results of structured search of discrete choice studies of reliability of water supply

Database	Date of search	Type of search	Search term	Hits	Notes
Google Scholar Search 1	06/04/2013		"water supply" OR "domestic water" OR "household water" OR "drinking water" OR "safe water" AND Conjoint OR "conjoint analyses" OR "conjoint measurement" OR "conjoint studies" OR "conjoint choice experiments"	3,530	Could not search using the entire search term as in other databases -first 100 results exported to endnote
Search 2	06/04/2013		"water supply" OR "domestic water" OR "household water" OR "drinking water" OR "safe water" AND "part-worth utilities" OR "functional measurement" OR "pairwise comparisons" OR "pairwise choices" OR "discrete choice experiments"	4,600	-first 40 results exported to endnote
Search 3	06/04/2013		"water supply" OR "domestic water" OR "household water" OR "drinking water" OR "safe water" AND "discrete choice modelling" OR "discrete choice conjoint experiments" OR "stated preference" OR "choice modelling" OR "choice model"	4,910	-first 100 results exported to endnote

Table A6.1.2: Study characteristics

Authors and date	Study setting	Study participants	Objective of the study	Number of attributes	Number of choice sets in fractional factorial	Number of choices made by each respondent	Administration of questions	Choice of attributes was based on
Haider & Rasid, (2002)	Canada	100 respondents from 50 randomly selected streets	Elicit preferences for municipal water supply options	3	18	9	Door-to-door interview of household heads	-
Hensher et al., (2005)	Australia	211 urban households	Establish the willingness to pay to avoid interruptions in water service and overflows of wastewater	6	-	6 for drinking water service and 6 for waste water service	Choice experiments were mailed out to respondents, who were then contacted by phone and interviewed about the choice experiments	Focus group discussions

Appendix 6.1: Results of structured search of discrete choice studies of reliability of water supply

Authors and date	Study setting	Study participants	Objective of the study	Number of attributes	Number of choice sets in fractional factorial	Number of choices made by each respondent	Administration of questions	Choice of attributes was based on
Kloos & Tsegai, (2009)	South Africa	475 urban & rural households	Detect households' preferences for water services	5	6	6	Sample was split into 2 groups; households with in-house /yard connection, and those using shared supply	Focus group discussions
Kanyoka et al., (2008)	South Africa	169 rural households	Assess the household demand for multiple use water services in the Sekororo-Letsoalo area	6	12 and 9	3	Sample was split into 2 groups; households with in-house /yard connection, and those using shared supply	Focus group discussions

Authors and date	Study setting	Study participants	Objective of the study	Number of attributes	Number of choice sets in fractional factorial	Number of choices made by each respondent	Administration of questions	Choice of attributes was based on
Macdonald et al., (2005)	Australia	337 urban households	Estimate residential customers' willingness to pay (WTP) for higher customer service standards regarding continuity of water supply	5	-	6	An independent market research firm using a drop-off-pick-up method	Consultation with industry representative and focus groups
Snowball et al., (2008)	South Africa	71 urban households	Elicit household willingness to pay for water service improvements in Grahamstown West	6	13	13	'Drop off and collect' method; 13 choice cards of which each questionnaire contained 3 cards, and respondents instructed to choose their most preferred alternative within each set	Interviews with the local council and water supply officials and the municipality's database of water complaints

Appendix 6.1: Results of structured search of discrete choice studies of reliability of water supply

Authors and date	Study setting	Study participants	Objective of the study	Number of attributes	Number of choice sets in fractional factorial	Number of choices made by each respondent	Administration of questions	Choice of attributes was based on
Tarfasa& Brouwer, (2013)	Ethiopia	145 urban households	Assess household WTP extra for improved water supply services in an urban centre in Ethiopia	3	12	12	In person interviews	Authors mention that the experiment was designed in collaboration with the office responsible for maintaining and operating the water system in the city and collecting water fees from connected domestic households

Appendix 6.1: Results of structured search of discrete choice studies of reliability of water supply

Authors and date	Study setting	Study participants	Objective of the study	Number of attributes	Number of choice sets in fractional factorial	Number of choices made by each respondent	Administration of questions	Choice of attributes was based on
Yacob et al., (2011)	Malaysia	230 households	Assess community preferences and values relating to water service improvement	4	5	5	Assess community preferences and values relating to alternative water service management	Literature, government annual reports, brochures, and expertise judgments
Yang et al., (2006)	Sri Lanka	1,800 households in 3 coastal towns	Evaluate the factors that drive customer demand for alternative water supply and sanitation services in Sri Lanka	5	27	There were 27 choice tasks grouped into 9 blocks; each respondent saw one block of 3 choice tasks	In person interviews	Focus groups, purposive interviews and meetings with officials

Table A6.1.3: Study characteristics of contingent valuation studies

Authors and date	Study setting	Study participants	Objective of the study	Proposed water service change(s)	Methodology	Administration of questions	WTP / WTA
Howe &Griffin Smith, (1993, 1994)	USA	Approximately 284 respondents	-Compare the attitudes of the water-using public, water officials, and elected officials toward the risk of water supply shortage -Measure what water users would be willing to pay for differing levels of reliability; -Develop a methodology for incorporating water users' valuation of reliability in system design	"Standard annual shortage events": i.e. droughts of sufficient severity and duration that residential outdoor water use would have to be restricted to 3 hours every third day for the months of July, August, and September The probability of the standard annual shortage event was labeled P*s*, with the reliability of the system (relative to that event) given by (1 - P*s*). For Boulder, P*s* •	Respondents were first asked to indicate (yes/no) whether or not they would be willing to accept the lower level of R (higher P s) with a concurrent reduction in their monthly water bill. Those who responded "yes" were then asked what the required reduction in their monthly bills would be. This was their "willingness to accept compensation"	Mail survey	-Customers' views of risk of water shortage differed from those of public and elected officials -Customers were less willing to accept a reduction in reliability from the current level of 1/300 to 1/100 and WTA was \$4.53/month for residential and \$6.53/month for commercial Customers' WTA for a reduction in reliability from current level of 1/300 to 1/50 was \$5.44/month

	1/300	for residential, and $8.08 for commercial customers -WTP for an increase in reliability from 1/300 to 1/600 was $4.67/month for residential customers and $16.03/month for commercial customers -WTP for increase in reliability 1/300 to 1/1000 was $5.32/month for residential and $18.02/month for commercial customers

Authors and date	Study setting	Study participants	Objective of the study	Proposed water service change(s)	Methodology	Administration of questions	WTP / WTA
Koss & Khawaja, (2001)	USA	3,769 surveys across ten water districts in California	Estimate households' value of water service reliability	Occurrence of water shortages of a given frequency and severity i.e. Shortage/ reduction from full service of 10 – 20%, frequencies / of once every 30, 20, 10, 5 or 3 years	Double-bounded dichotomous choice	Combined mail / telephone survey	-WTP varies from $11.67/month to avoid a 10% shortage once every 10 years, to $16.92/month to avoid a 50% shortage every 20 years -Respondents are willing to pay more for larger shortages and for shortages that occur with higher frequency

Authors and date	Study setting	Study participants	Objective of the study	Proposed water service change(s)	Methodology	Administration of questions	WTP / WTA
Soto Montes de Oca & Bateman, (2006)	Mexico	1,424 household responses; of which 716 were presented with the maintenance scenario and the remaining 708 households faced the improvement scenario.	Investigate the influence of baseline supply quality and income distribution upon stated preferences in Mexico City	a) High quality service: no supply interruption, no smell, no taste, no discolouration and higher flow rate b) Maintenance of the current water service quality	Single dichotomous choice question	Telephone survey	Richer households enjoying higher baseline service levels would prefer programs to maintain the status quo, while poorer households enduring lower initial quality of service would prefer schemes which improve the quality of supplies

Authors and date	Study setting	Study participants	Objective of the study	Proposed water service change(s)	Methodology	Administration of questions	WTP / WTA
Vasquez et al., (2009)	Mexico	398 households	Investigate households' willingness to pay for improved water services in the mid-sized urban area of Hidalgo del Parral in Chihuahua, Mexico	Reduced water contamination (microbes, bacterium, and heavy metal) and either *unreliable*: with the time they have to access tap water remaining approximately the same, OR *reliable*: having tap water 24 hours per day every day of the year.	Referendum	In-person interviews	Households have a median WTP for safe and reliable drinking water at least 45.64% above their current water bills. Validity findings include significant scope sensitivity in WTP for water services.

Appendix 6.2: Odds ratios of preferences for reliability of water supply

Table A9.2.1: Water supply preferences for overall sample

	Odds ratio	Confidence interval
Availability of water supply during the day		
9-16 hours a day	1.290***	1.146 - 1.452
More than 16 hours a day	1.461***	1.306 - 1.633
Availability of water supply during the week		
2-4 days a week	1.021	0.912 - 1.144
More than 4 days a week	1.120*	0.997 - 1.259
Time taken to repair breakdowns		
3-5 consecutive days	1.060	0.942 - 1.193
More than 5 consecutive days	0.795***	0.710 - 0.889
Number of water supply system breakdowns per year		
5-8 breakdowns	1.386***	1.231 - 1.560
More than 8 breakdowns	1.377***	1.230 - 1.542
Prior notification of water supply interruptions		
Sometimes	1.412***	1.254 - 1.589
Always	1.866***	1.677 - 2.076
Flow rate		
Moderate	1.184***	1.046 - 1.339
High	1.127**	1.001 - 1.269
Price	0.975***	0.973 - 0.977
N	9,036	
χ^2	1407	
Likelihood ratio degrees of freedom	13	

Note: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table A9.2.2: Preferences by type of water supply

	Private supply		Communal supply	
	Odds ratio	Confidence interval	Odds ratio	Confidence interval
Availability of water supply during the day				
9-16 hours a day	-0.942	0.757 - 1.172	1.497***	1.294 - 1.731
More than 16 hours a day	1.320**	1.068 - 1.631	1.573***	1.373 - 1.801
Availability of water supply during the week				
2-4 days a week	0.801**	0.642 - 0.998	1.057	0.922 - 1.212
More than 4 days a week	0.941	0.752 - 1.176	1.148*	0.994 - 1.325
Time taken to repair breakdowns				
3-5 consecutive days	1.452***	1.164 - 1.811	0.944	0.818 - 1.090
More than 5 consecutive days	1.221*	0.993 - 1.501	0.689***	0.600 - 0.790
Number of water supply system breakdowns per year				
5-8 breakdowns	1.368***	1.100 - 1.702	1.429***	1.235 - 1.652
More than 8 breakdowns	1.109	0.892 - 1.379	1.529***	1.336 - 1.750
Prior notification of water supply interruptions				
Sometimes	0.891	0.714 - 1.111	1.762***	1.526 - 2.035
Always	1.090	0.884 - 1.342	2.350***	2.069 - 2.670
Flow rate				
Moderate	1.138	0.897 - 1.443	1.176*	1.013 - 1.366
High	0.989	0.786 - 1.244	1.106	0.959 - 1.276
Price	0.970***	0.966 - 0.974	0.976***	0.973 - 0.978
N	2,704		6,332	
χ^2	366.7		1,177	
Likelihood ratio degrees of freedom	13		13	

Note: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table A9.2.3: Preferences by community cluster

	Communities 1 and 2		Community 3	
	Odds ratio	Confidence interval	Odds ratio	Confidence interval
Availability of water supply during the day				
9-16 hours a day	1.387***	1.163 - 1.653	1.146*	0.975 - 1.348
More than 16 hours a day	1.781***	1.486 - 2.135	1.278**	1.100 - 1.483
Availability of water supply during the week				
2-4 days a week	1.123	0.946 - 1.334	0.871*	0.744 - 1.020
More than 4 days a week	1.626***	1.352 - 1.954	0.864	0.737 - 1.013
Time taken to repair breakdowns				
3-5 consecutive days	1.099	0.912 - 1.324	1.101	0.942 - 1.287
More than 5 consecutive days	0.933	0.782 - 1.114	0.789***	0.681 - 0.915
Number of water supply system breakdowns per year				
5-8 breakdowns	1.273**	1.061 - 1.528	1.428***	1.220 - 1.672
More than 8 breakdowns	1.354**	1.129 - 1.623	1.257***	1.078 - 1.465
Prior notification of water supply interruptions				
Sometimes	1.780***	1.476 - 2.146	1.123	0.960 - 1.314
Always	2.254***	1.903 - 2.669	1.525***	1.322 - 1.759
Flow rate				
Moderate	1.349**	1.115 - 1.631	1.115	0.944 - 1.318
High	1.310**	1.083 - 1.584	1.033	0.880 - 1.214
Price	0.971***	0.968 - 0.974	0.979***	0.976 - 0.981
n	4,162		4,874	
χ^2	1,114		378.5	
Likelihood ratio degrees of freedom	13		13	

Note: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Appendix 7.1: General study appraisal tool

Table A7.1.1: Assessment criteria and scoring method

Criterion	Score as	Categories	Score
Clarity of research objective	done’ if objective is clear, specific and addressed by methods and results	Done	2
	partial' if the above is covered in part only	Partial	1
	‘not done’ if there are problems with the above	Not done	0
Clarity of study methods	‘done’ if, for each variable of interest, sources of data and details of methods of assessment (measurement) are described	Done	2
	‘partial’ if these methods are described in part only	Partial	1
	‘not done’ if these methods are not well described	Not done	0
Description of conditions	‘done’ when water supply conditions and unreliability of supply are well described, and have been well investigated on the ground	Done	2
	‘partial’ when these factors are described in part only	Partial	1
	‘not done’ when these factors are not well described	Not done	0
Reporting of results	‘done’ if results reported match objectives	Done	2
	‘partial’ when only one of the above is met	Partial	1
	‘not done’ if none of the above are met	Not done	0
Researcher bias	‘ok’ if study funding and financial interests of authors declared, no bias is apparent and selection of case/ survey is justified	Done	2
	‘partial’ if funding or financial interests not declared, but selection of case/survey is justified	Partial	1
	‘not done’ when funding and financial interests not declared, selection of case/survey not justified, potential bias evident	Not done	0
Other validity issues	‘done’ if there are no other issues around validity (sample size, sampling strategy)	Done	1
	‘not done’ if there are additional validity issues	Not done	0

Criterion	Score as	Categories	Score
Summary of validity	High quality		10 - 12
	Moderate quality		7 - 9
	Poor quality		6 or less

Table A7.1.2: Appraised studies

Author(s), year	**Clarity of research objective**	**Clarity of study methods**	**Description of conditions**	**Reporting of results**	**Researcher bias**	**Other validity issues**	**Summary of validity**
Altaf, (1994)	2	1	1	2	2	1	9
Baisa et al., (2010)	2	2	2	2	1	1	10
Caprara et al., (2009)	2	2	2	2	2	1	11
Chaminuka & Nyatsanza, (2013)	2	1	1	1	0	0	5
Choe et al., (1996)	2	2	2	1	2	1	10
Dutta et al., (2005)	2	2	2	2	2	1	11
Gerlach & Franceys, (2009)	2	2	2	1	2	0	9
Gulyani et al., (2005)	2	1	2	1	2	1	9
Humplick et al., (1993); Madanat & Humplick, (1993)	2	1	2	1	1	0	7

Author(s), year	**Clarity of research objective**	**Clarity of study methods**	**Description of conditions**	**Reporting of results**	**Researcher bias**	**Other validity issues**	**Summary of validity**
Jamal & Rahman, (2012)	1	0	1	1	1	0	4
Katuwal & Bohara, (2011)	2	2	2	1	1	1	9
Kudat et al., (1993)	2	1	2	1	1	0	7
Kudat & Musayev, (1997)	2	1	2	1	1	0	7
Mycoo, (1996)	2	2	2	1	2	1	10
Ngwenya & Kgathi, (2006)	2	2	2	2	0	0	8
Olsson & Karlsson, (2010)	1	1	2	2	1	0	7
Pattanayak et al., (2005)	1	2	2	2	2	1	10
Potter & Darmane, (2010)	2	1	2	2	2	0	9
Subbaraman et al., (2013)	2	2	2	1	2	1	10
Vásquez, (2012)	2	2	2	2	2	1	11
Vásquez et al., (2009)	2	2	2	2	2	1	11

Author(s), year	Clarity of research objective	Clarity of study methods	Description of conditions	Reporting of results	Researcher bias	Other validity issues	Summary of validity
Virjee & Gaskin, (2010)	2	2	2	2	2	1	11
Zérah, (1998, 2000a)	2	1	2	2	1	1	9

Appendix 7.2: Adapted SEPA study appraisal tool

Table A7.2: Adapted SEPA assessment criteria and scoring method

Check questions	Altaf, 1994	Choe, 1996	Dutta (2005, 2006)	Kudat and Musayev, 1997	Mycoo, 1996	Pattanayak, 2005	Vasquez, 2009	Virjee & Gaskin, 2010	Yes	Not clear	No	Comment
Earlier reviews												
1. Has the study been subject to external review?	2	2	2	2	2	2	2	2	2	1	0	
1a. If "yes", in what way?	Journal peer review	Organisation report review	Journal peer review	Organisation report review	Thesis examination	Journal peer review	Journal peer review	Journal peer review				
Bias												
2. Who conducted the study? **Lead study authors in relation to funding**	University of Karachi researcher	UNC, EHP and independent consultant	PhD candidate	World Bank representativ e	PhD candidate	Non-profit research organisation	University academic	PhD candidate				
3.Who was the principal/funder of the study? **Have the principal funders been declared?**	2	2	2	2	2	2	2	2	2	1	0	
Valuation method												
4. What valuation method was used? **Is the valuation method specified?**	0	2	2	0	2	2	2	2	2	1	0	
	Averting expenditure, contingent valuation	Contingent valuation, averting expenditure	Contingent valuation, averting expenditure		Contingent ranking, contingent valuation, household production function	Contingent valuation, averting expenditure	Contingent valuation, averting expenditure	Contingent valuation				
Sensitivity analyses related to results from statistical/econometric analyses												
5. Was the statistical uncertainty of the estimated economic values reported in terms of, for example, confidence intervals or standard deviations?	0	0	2	0	0	0	2	0	2	1	0	

Check questions	Altaf, 1994	Choe, 1996	Dutta (2005, 2006)	Kudat and Musayev, 1997	Mycoo, 1996	Pattanayak, 2005	Vasquez, 2009	Virjee & Gaskin, 2010	Yes	Not clear	No	Comment
6. Was there a sensitivity analysis indicating what is reasonably the *lower* boundary of the estimated economic values?	0	2	1	0	2	2	2	2	2	1	0	
7a. If "yes", fill in this lower boundary..		Average coping costs for Individual piped connection shared with other households: 2.10 Rupees; Average coping costs for households using tubewells: 1.23 Rupees. Average willingness to pay for households with existing piped connections is 40 Rupees for partial service by government	Willing to pay for single quality reliable supply: US$4.35		Monthly willingness to pay by income quintile: Poorest 20%: $28; Second quintile (low income): $50	Average monthly coping costs of poor households (lowest 4 deciles of income distribution): connected to the public network incurred average costs: US$1.38; Not connected to the public network: US$1.40; Average for poor households: US$1.39	Median WTP (Mexican pesos) for a reliable system with safe water with 80% certainty: 92.74; with 90% certainty correction: 54.77	Willingness to pay of 99 Trinidad and Tobago dollars per quarter for households with a piped connection and secondary water source				

Check questions	Altaf, 1994	Choe, 1996	Dutta (2005, 2006)	Kudat and Musayev, 1997	Mycoo, 1996	Pattanayak, 2005	Vasquez, 2009	Virjee & Gaskin, 2010	Yes	Not clear	No	Comment
7b. If "yes", what factors were considered in the sensitivity analysis?		Water service levels, service provider	Single quality improvement, with provision of potable water that meets standards of the World Health Organisation		Income distribution	Income distribution, water service connection status	Referendum valuation with 80 % and 90% certainty correction applied on willingness to pay estimates	Water service connection status				
8. Was there a sensitivity analysis indicating what is reasonably the *upper* boundary of the estimated economic values?	0	2	0	0	1	0	2	2	2	1	0	

Check questions	Altaf, 1994	Choe, 1996	Dutta (2005, 2006)	Kudat and Musayev, 1997	Mycoo, 1996	Pattanayak, 2005	Vasquez, 2009	Virjee & Gaskin, 2010	Yes	Not clear	No	Comment
8a. If "yes", fill in this upper boundary.		Average coping costs for Individual piped connection exclusively for own use: 2.11 Rupees Average coping costs for households using public taps or neighbours: 43.65 Rupees. Average willingness to pay amongst households with existing piped connection with full service provided by a private contractor is $44 Rupees	Willing to pay for dual quality reliable supply: US$6.78		Monthly willingness to pay by income quintile: third quintile (middle-income): $55; fourth and fifth quintile (high-income): $41	Average monthly coping costs of non-poor households: connected to the public network incurred average costs: US$3.72; Not connected to the public network: US$4.90; Average for poor households: US$4.00	Median WTP (Mexican pesos) for a reliable system with safe water with no certainty correction: 229.75; for open-ended question: 111.31	Willingness to pay of 175 Trinidad and Tobago dollars per quarter for households with no in-house connection				
8b. If "yes", what factors were considered in the sensitivity analysis?		Water service levels, service provider	Dual quality improvement, with separate provision of potable and non-potable water		Income distribution	Income distribution, water service connection status	Open ended valuation, no certainty corrections	Water service connection status				

Check questions	Altaf, 1994	Choe, 1996	Dutta (2005, 2006)	Kudat and Musayev, 1997	Mycoo, 1996	Pattanayak, 2005	Vasquez, 2009	Virjee & Gaskin, 2010	Yes	Not clear	No	Comment
Are future values discounted?												
9. If the valuation study estimated future economic values, did the study report how these values were converted into present values?	Yes	Yes	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Yes	No	Not clear	Not applicable
9a. If "yes", how was the selected discount rate motivated?	Not motivated	Assumed a 12% real interest rate based on the current market price of capital investments	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable				
9b. If "yes", what was the size of the discount rate that was used?	^10%	^12%	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable				
Primary data or secondary data												
10. Were primary data used?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Not clear	
11. If secondary data were used, was the quality of the original data collection evaluated?		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable				
11a. If "yes", what was the result of this evaluation?		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable				
12. If secondary data were used, was it a main purpose of the original data collection to collect the data that were used in the valuation study?		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable				
13. If secondary data were used, was the relevance of using it for the valuation study evaluated?		Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable				
Survey, population and sample												
14. Was a target population defined?	2	2	2	2	2	2	2	2	2	1	0	

Check questions	Altaf, 1994	Choe, 1996	Dutta (2005, 2006)	Kudat and Musayev, 1997	Mycoo, 1996	Pattanayak, 2005	Vasquez, 2009	Virjee & Gaskin, 2010	Yes	Not clear	No	Comment
14a. If "yes", how was the target population defined in time and space, and what was its size?	Households with inadequate public piped water supplies	Dehra Dun, Utta Pradesh, India. Estimated population in 1995 was 290,000	People living in unplanned areas in Delhi, India. Estimated population in Delhi at time of study was 14 million	Baku, Azerbaijan	Urban households in Trinidad	Kathmandu, Nepal	Chihuahua, Mexico	Trinidad & Tobago				
15. Was a frame population/sampling frame defined?	2	2	2	1	1	2	2	2	2	1	0	
15a. If "yes", how was the frame population/sampling frame defined in time and space, and what was its size?	Sampling frame in urban area was 436 enumeration blocks of approximately 200-250 households. In the rural area the sampling frame was a sweet groundwater zone and a brackish groundwater zone	A total of 15,288 households were registered under the 52 selected polling booths. Approximately 8.6% of households from each polling booth were randomly selected	Unplanned residential areas that come under E, F, G, and H classes inside Municipal Corporation of Delhi jurisdiction. Size 4.9 million	Study refers to Zones I-IV, but it is not clear whether these are the sampling frame	Capital region, which consists of 14 sub-regions. 6 sub-settlements were chosen; Goodwood Park, Alyce Glen, St Barbs, Barataria, Valsayn and Malabar. Estimated population in Trinidad 1991 was 1.28 million	All households had previously been enumerated. Five municipalities: Kathmandu Valley, Kathmandu, Lalitpur, Bhaktapur, Kirtipur, and Madhyapur in 2001	Parral, Chihuahua State, Mexico. Estimated population in 2005 103,519 inhabitants. The city was stratified into six geographical zones and 70 households randomly selected from a list of mailing addresses in each zone	Trinidad & Tobago, with 1.3 million residents in 340,000 households				

Check questions	Altaf, 1994	Choe, 1996	Dutta (2005, 2006)	Kudat and Musayev, 1997	Mycoo, 1996	Pattanayak, 2005	Vasquez, 2009	Virjee & Gaskin, 2010	Yes	Not clear	No	Comment
16. Were potential differences between the target population and the frame population/sampling frame reported?	0	0	0	0	1	0	2	0	2	1	0	
17. How did the study take into account potential differences between the target population and the frame population/sampling frame?					Not clear		Not clear					
18. What was the sample size?	756 rural and 968 urban, totalling 1,724	1,100 households	650 households	400 households	420 households	1,500 households	398 households	1,419 respondents				
19. What type of sampling procedure was used for constructing the sample?	Random-stratified clustered sampling	Random-stratified clustered sampling	Multistage stratified random sampling	Not specified	Cluster stratified random sampling	Clustered random sampling	Stratified random sampling	Stratified random sampling				
20. Was the sampling procedure a probability sampling?	Yes	Not clear	Not clear	Not clear	Not clear	Not clear	Not clear	Not clear	Yes	No	Not clear	
21. On the whole, did the study meet the criteria that define a survey?	Yes	Not clear	Not clear	Not clear	Not clear	Not clear	Not clear	Not clear				
22. If "no" to question 21, was the purpose of the study of a kind that does not motivate a survey? (For example, it might not be necessary to carry out a survey if the study was not aiming at computing estimates which are representative for a population.)		No	No	No	No	No	No	No				
23. If aggregate economic values for a population were estimated, was this estimation consistent with the sampling procedure and the definition of the population?	Yes	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Yes	No	Not clear	
The design of the data collection work												
24 Were focus groups (or the like) used for developing and testing the survey instrument?	1	2	2	0	0	2	2	1	2	1	0	`

Check questions	Altaf, 1994	Choe, 1996	Dutta (2005, 2006)	Kudat and Musayev, 1997	Mycoo, 1996	Pattanayak, 2005	Vasquez, 2009	Virjee & Gaskin, 2010	Yes	Not clear	No	Comment
25. Was a pilot study carried out for testing the survey instrument?	1	2	2	0	2	2	2	2	2	1	0	
Data collection method												
26. What data collection method was used?	Person to person interviews	Person to person interviews	Person to person interviews	Person to person interviews	Person to person interviews	Person to person interviews	Person to person interviews	Person to person interviews				
27. When was the data collection carried out?	1988-1990	September 1995 to March 1996	Not reported	July 1994	March-May 1994	2001	Not reported	May – June 2003				
Non-response												
28. Was there a report on non-response?	0	1	0	0	2	0	1	2	2	1	0	
30. How was unit non-response defined?		Zero bids in the contingent valuation were reported			Item non-response was 35 out of 420, plus another 25 that were excluded from the analysis for reasons not specified.		Authors report response rate of 94.76% but not clear whether this is unit or item non-response	Not clear				No report on unit non-response, but one on item non-response
31. What was the size of the unit non-response (in per cent)?		3.50%	Not reported	Not reported	See previous comment		See previous comment	12.50%				
32. Was a follow-up study of non-respondents carried out?	0	0	0	0	0	0	0	0	2	1	0	

Check questions	Altaf, 1994	Choe, 1996	Dutta (2005, 2006)	Kudat and Musayev, 1997	Mycoo, 1996	Pattanayak, 2005	Vasquez, 2009	Virjee & Gaskin, 2010	Yes	Not clear	No	Comment
33. According to the study, how are valuation results affected by the non-response?		Not reported	Not reported	Not reported	Not reported	Not reported		Not clear. Authors mention that non response is due mainly to errors in the CSO-supplied listing records and the difficulty in accessing some remote areas.				
34. If values at a population level were estimated, did such estimations take non-response into account?					1				2	1	0	
Survey instrument												
Was there a copy of the complete survey instrument?	0	0	2	2	2	0	0	0	2	1	0	
Access to data												
Did the study mention that it is possible to get access to the data used?	0	0	0	0	0	0	0	0	2	1	0	
Validity tests												
37. Was there any test of internal validity?	0	0	0	0	2	2	2	0	2	1	0	

Check questions	Altaf, 1994	Choe, 1996	Dutta (2005, 2006)	Kudat and Musayev, 1997	Mycoo, 1996	Pattanayak, 2005	Vasquez, 2009	Virjee & Gaskin, 2010	Yes	Not clear	No	Comment
37a. If "yes", what test was carried out?					Convergent validity in the positive relationship between coping cost and WTP	Convergent validity in the positive relationship between coping cost and WTP	As a measure of construct validity, WTP for safe and reliable water was found to be positively related to income					
37b. If "yes", did the test indicate the presence of internal validity?					2	2	2		2	1	0	
38. Was there any test of external validity?	0	0	0	0	0	0	0	0	2	1	0	
38a. If "yes", what test was carried out?												
38b. If "yes", did the test indicate the presence of external validity?									2	1	0	
Natural scientific/medical basis												
39. Was any expert in natural sciences/ **water supply/resources** involved in the valuation study?	2	2	2	1	1	2	1	1	2	1	0	
Total score	**12**	**21**	**21**	**10**	**23**	**20**	**26**	**20**	**42**	**21**	**0**	

Rating:

Poor	0-14
Moderate	15-28
Good	29-42

Modifications to the questions are indicated in bold font

Appendix 8: Correlation of coping strategies, and components of coping costs

Table A8.1.1: Correlation matrix of coping strategies

	Drilled well	Storage tank	Treat water	Store water	Buy water from neighbours	Buy bottled water	Collect water from alternative sources	Recycle waste water	Harvest rainwater	Use water sparingly	Reschedule household activities	Protest/ complain to local authority
Drilled well	1.0000											
Storage tank	0.8721***	1.0000										
Treat water	0.1563**	0.1755**	1.0000									
Store water	-.06915***	-0.6131***	-0.0709	1.0000								
Buy water from neighbours	-0.0977	-0.0855	-0.1214*	0.2191***	1.0000							
Buy bottled water	0.2662***	0.2482***	0.0798	-0.1562**	0.1407**	1.0000						
Collect water from alternative sources	-0.3181***	-0.2223***	-0.0477	0.1640**	-0.7473***	-0.1836***	1.0000					
Recycle waste water	-0.1336*	-0.0791	-0.1410**	0.2312***	0.2362***	-0.0879	-0.0579	1.0000				
Harvest rainwater	0.0861	0.0935	-0.0263	-0.0127	0.2191***	0.0617	-0.2641***	0.3469***	1.0000			
Use water sparingly	-0.1697**	-0.1799**	-0.1661**	0.1825**	0.4363***	0.0258	-0.3071***	0.1805**	0.1825**	1.0000		
Reschedule household activities	-0.1831***	-0.1937***	-0.0205	0.1934***	0.4129***	-0.0699	-0.3237***	0.2016***	0.1934***	0.4539***	1.0000	
Protest/complain to local authority	-0.1383*	-0.1443**	-0.0688	0.1225*	0.1789**	0.0409	-0.1130	0.0850	0.0703	0.2028***	0.0662	1.0000

Notes: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table A8.1.2: Components of coping costs

		Community 1	Community 2	Community 3
buy water from neighbours	median	70.00	70.00	50.00
	n	17	50	1
treat water	median	15.00	14.50	12.00
	n	6	4	9
install storage tank(s) / drill well	median	237.63	219.92	9.56
	n	14	12	48
buy bottled water	median	30.00	20.00	25.50
	n	8	9	2

Note: Coping costs are in South African Rand (ZAR)