Identifying the Water Poor: an Indicator Approach to Assessing Water Poverty in Rural Mexico

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I, **CRYSTAL FENWICK** confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

ABSTRACT

Water scarcity is the focus of considerable research emphasizing the vulnerability of communities to physical water supply. Recent approaches to the determination of water scarcity that incorporate social, economic and political factors with physical measures of water availability include the Water Poverty Index (WPI). Through a rigorous analys that aims to analyze and contrast the results of the WPI with those determined through extensive fieldwork and community consultation, this research aims to fulfil the following core objectives:

1. to determine the impact of scale on water poverty assessments;
2. to test the robustness of the WPI and validate its accuracy as a measurement of water poverty;
3. to assess the ability of the WPI to accurately reflect local perceptions of water poverty.

Mexico has an astounding array of water challenges where even areas with a natural abundance of water face difficulties in the provision of water supply. Particularly compelling is the region of Los Altos. Situated within Mexico's most water-rich state, access to water is exceptionally constrained. This contrast of scale was the incentive for selecting the rural communities of Pozuelos and El Mash to examine water poverty in detail.

A careful examination of water poverty was first undertaken at the state level. Next, water poverty was assessed in the community through an extensive field study, comprising a thorough assessment of infrastructure, water quality analyses, researcher observations, informal interviews and participatory focus groups. These data provided the basis for calculating the WPI at the community scale. Analyses were then undertaken focusing on statistical correlations using Pearson's product moment correlation coefficient informed by researcher observations, regression analyses and community perceptions.

As the only indicator to assess the multiple dimensions of water poverty, the WPI, by definition, is the best tool available. However, the issue of scale continues to be challenging whilst predictions of water poverty are complex and marred by subjectivity. A lack of consensus surrounding appropriate variables is problematic and inhibits

comparisons across localities. Community perceptions of water poverty at the community level differ from results obtained using the WPI further questioning its reliability. Notwithstanding, the WPI highlights the need for a multi-dimensional approach to the determination of water poverty by demonstrating the lack of relationship between water resources availability and overall water poverty across scales. However, this research has demonstrated the complex nature of the WPI rendering its application in practice quite difficult.

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ABBREVIATIONS

AWR	Available Water Resources
BWR	Basic Water Requirement(s)
HDI	Human Development Index
masl	Metres above sea level
PCA	Principal Components Analysis
SWSI	Social Water Scarcity Index
WPI	Water Poverty Index
WSI	Water Stress Index

CHAPTER 1 THE WATER SCARCITY PARADIGM

1.1 Introducing the Problem

Water scarcity is the current focus of considerable research particularly in relation to growing concerns about the impacts of climate change and population growth (Seckler *et al.*, 1998; Vörösmarty *et al.*, 2000). Whilst this research is still subject to debate there is a general consensus that less economically developed regions are especially vulnerable. In 2000, the International Water Management Institute predicted that 1.8 billion people would experience absolute water scarcity by 2025 (IWMI, 2000). More recent predictions suggest that between three and nine billion people will experience water scarcity within the next century (Oki & Kanae, 2006). Much of the current research similarly focuses on water resources availability emphasizing the vulnerability of communities to physical water scarcity. Water resources assessments are often carried out at scales that assume uniform temporal and spatial distributions of population and water (Arnell, 2004; Oki & Kanae, 2006; Shiklomanov, 2000). This approach presents several key problems. Firstly, comparatively little consideration is given to the impact of social, economic and political factors on water scarcity. Secondly, distributions of water and population in reality are not uniform and current assessments mask actual temporal and spatial variability. Finally, undertaking assessments at the macro scale severely masks local variability, and questions the reliability of data at different scales.

Although alternative approaches to the determination of water scarcity have been in existence for some time (Falkenmark *et al.*, 1989), the debate for moving beyond conventional measures of water resources availability and recognizing the multiple dimensions of water scarcity has only recently begun to garner significant attention. However, although many researchers have successfully argued the need to include social, economic and political factors in measurements of water scarcity (Chenoweth, 2008; Feitelson & Chenoweth, 2002; Lawrence, *et al.*, 2003; Molle & Mollinga, 2003; Ohlsson & Turton, 1999), much of this discourse focuses on water management practices and conventional (physical) measures of water resources availability prevail.

More holistic approaches to the determination of water scarcity which incorporate social, economic and political factors with physical measures of water scarcity have been proposed and include the Water Poverty Index (WPI) (Lawrence, *et al.*, 2003).

This research seeks to inform the debate surrounding the assessment of water poverty using the WPI by critically reviewing its use as an assessment tool at the state and household scales in Mexico. Importantly, insufficient research has been undertaken to validate the model and particularly its ability to reflect local realities of water poverty. Furthermore questions surrounding temporal and spatial variability of data and their reliability at different scales are incumbent within the WPI and remain outstanding. Through rigorous analyses that aim to analyze and contrast the results of the WPI with those determined through extensive fieldwork and community consultation, this research aims to fulfil the following core objectives:

1. to determine the impact of scale on water poverty assessments;
2. to test the robustness of the WPI and validate its accuracy as a measurement of water poverty;
3. to assess the ability of the WPI to accurately reflect local perceptions of water poverty.

1.2 Importance of the Study

This study provides valuable insight into questions surrounding the reliability and accuracy of water poverty assessments undertaken using the WPI as well as its application at varying scales. This research seeks to contribute to the debate surrounding the determination of water poverty and the need to consider local social, economic, and political determinants, which influence water supply. Furthermore, it attempts to ascertain the most appropriate scale at which research should be undertaken in order to accurately inform key decision-makers and represent the needs of local citizens. By furthering understanding of community vulnerability to water scarcity and water supply, this research therefore seeks to improve our knowledge of water-health-poverty issues and hence lead to improved public health and livelihoods in developing regions.

1.3 The Research Setting

Mexico currently faces an astounding array of water challenges not in the least because 56% of the country is classified as very arid, arid, or semiarid (Whiteford & Melville, 2002) contributing to over-exploitation of aquifers and a heavy reliance on irrigated agriculture. Even areas with a natural abundance of water are faced with numerous challenges to the provision of community drinking water supply. This situation is particularly compelling in Chiapas, Mexico's most water-rich state but also one of the most marginalized where 31% of all households lack access to a piped water supply and 13% are without access to sanitation (CONAPO, 2006). Access rates are even more limited in the central highlands region of *Los Altos* where 37% of all households lack access to a piped water supply, owing in large part to its considerable rural population. Furthermore, over half the region's population is indigenous and suffers from increased marginalization, evidenced by the fact that ninety-nine of the country's one hundred most marginalized communities are indigenous, seven of which are located in Los Altos. Chiapas is also climatically and topographically diverse with average temperatures varying from a low of 18C to a high of 28C and annual rainfall ranging from a low of 1,200mm to a maximum of 4,000mm depending on region (INEGI Cuéntame, 2010). Los Altos, as the name implies, is characterized by steep inclines that promote water runoff creating additional constraints to the provision of community water supply. It is precisely because of this geographical, cultural and social diversity that the rural communities of *Pozuelos* and *El Mash* were selected from this region to examine water poverty in detail at the local scale.

Perched at 2,500masl in the Municipality of *Chamula*, but geographically closer to the region's capital of *San Cristóbal de las Casas*, Pozuelos is a small rural community of less than 2km^2 though individual households are typically disparate. Home to approximately 435 people who belong to the *Tzotzil* indigenous Mayan group, the population is evenly split between genders and extremely youthful with 64% of all inhabitants under the age of 24 (INEGI, 2010). At a slightly lower altitude of 2,120masl, within the Municipality of *Oxchuc*, the small community of El Mash covers an area of approximately 10km^2 located 7km from the municipal capital of *Oxchuc*. With 360 people who belong to the *Tzeltal* indigenous Mayan group, its population is also evenly split across genders, with more than 68% under the age of 24 (INEGI, 2010). In numbers, El Mash is the more marginalized of the two communities and despite both being classified as highly marginalized (CONAPO, 2006) this is where their similarities end. Pozuelos is more economically affluent than El Mash with higher employment rates and an average daily household income more than twice that of El Mash. They are politically more cohesive and this is reflected in their provision of water supply, a recently constructed network piping safe spring water to individual household taps located within a few metres of each home. To the contrary, El Mash relies on household rainwater harvesting systems during the wet summer months but is forced to rely on unsafe water from ill-managed springs during the drier winter months.

These sites were selected for the compelling reasons given above along with a number of geographical and logistical considerations. There are 13 major hydrological zones within Mexico (CONAGUA, 2008). Chiapas forms part of the eleventh zone known as *Frontera Sur*. Approximately 75% of the state is located within one hydrological river basin with only the coastal zone being divided into a number of smaller basins. For the purposes of this study, it was highly desirable for the two communities to fall within one river basin as this would theoretically require the need to manage only one set of hydrological data, rendering calculations more manageable but also theoretically ensuring a broadly stable environment for comparisons of physical water resources availability. Both communities are located within several hours driving time of the small but important city, San Cristóbal de las Casas, providing the ideal base for this research. San Cristóbal is the site of the historic Zapatista uprising and because of this has become home to a number of important civil society organizations, national and international NGOs and major Mexican universities. Whilst the political environment is now reasonably stable, politics play a large role in civil society. The political history of Chiapas is highly complex and beyond the scope of this research yet inevitably this has played an important role in access to local services. For a detailed account of the indigenous uprising see "The Chiapas Rebellion" (Harvey, 1998).

1.4 Mapping the Thesis

The overarching aim of this thesis is to comment on the practical application of the WPI at both the macro and micro scales. The WPI is a relatively new tool in the equally emerging field of water poverty studies. The concept of water poverty and an indicator approach to its quantification is considered within the constructs of this field.

Chapter 2 sets out the theoretical framework by first describing traditional methods to assessing water scarcity followed by a chronological history of the evolution of water poverty indicators beginning with the inception of water crowding and the Water Stress Index (WSI) in 1989 and culminating in the development of the WPI. A simultaneous review of the key proponents of water poverty research and their criticisms of the various indicators is also provided as well as a detailed review of findings from previous case studies utilizing the WPI. An introduction to a participatory approach to applied development research ensues with a brief consideration of development theory as relevant to the present study and a clear justification for a reflexive and participatory approach to this research.

Chapter 3 focuses on the research methodology employed in this study. This research involves the application of the WPI at the macro and micro scales. An explanation of the WPI equation is presented first then the methodological approach, including data collection, for each stage is explained in detail followed by a brief discussion of the practical applications to undertaking water quality analyses and conducting community focus groups.

The following section, Chapter 4, introduces the focus of the macro scale study, the state of Chiapas, before undertaking a thorough review of each of the core indicators of water poverty, followed by the application of the WPI at the macro scale and the subsequent analysis of results.

Two case studies were selected at the micro scale and are presented in detail in Chapters 5 and 6. In the first instance a thorough introduction to the local region is outlined followed by a detailed presentation of the findings of an intensive data collection process administered in the field within each community. Chapter 7 provides an extensive review of water poverty indicators in both communities and describes the application of the WPI to both sites in detail before presenting a thorough analysis of results in Chapter 8.

Lastly, Chapter 9 summarizes the research findings in an overall discussion of results whilst presenting key recommendations for future research before providing final conclusions to the original research objectives.

CHAPTER 2 THEORETICAL FRAMEWORK

Water Poverty: An Emerging Field

Historically, water scarcity has been defined as a "state of insufficient water to satisfy normal requirements" (Chenoweth, 2008, p.5). With the growing acceptance of water scarcity as a multi-dimensional problem, the term water poverty has grown in popularity and although some (Komnenic, *et al.*, 2009) find the term inappropriate in certain cases, it is now widely used in literature. This general acceptance is a very recent phenomenon and still most commonly used by those with a vested interest in the debate. Recent literature is still marred with confusion surrounding the terms of water scarcity and water poverty and there are as many definitions as indicators drawing even more criticism. We must however bear in mind that each definition, and as a result each indicator, had an original, specific intention unique to its developer. For every author there is a new definition of water scarcity and indicators are viewed from each author's perspective (Seckler *et al.*, 1998). With this in mind, this chapter first considers traditional measures of water scarcity before analysing the rise of the water poverty concept and its related indicators over time followed by a discussion its application in recent case studies.

2.1 Traditional Measures of Water Scarcity

Water scarcity assessments focusing on the physical availability of water resources are numerous particularly amidst growing concerns of climate change. This brief introduction does not attempt to summarise the totality of those assessments but instead, focusing on reports from two well-respected researchers (Arnell, 2004; Shiklomanhov, 2000), attempts to highlight some of the more prominent failings of traditional water scarcity assessments.

According to Arnell (2004, p.34), the first problem with the assessment of traditional measures of water scarcity is the "key assumption… that population changes everywhere within a country at the same rate." According to him "a more sophisticated approach would allow for differential growth rates between urban and rural areas" however "this would not give substantially different results when populations are summed back up to the watershed scale." The second problem with these assessments, are their implicit assumption "that resources in a watershed are equally available throughout" (Arnell, 2004, p.37). The ability to handle temporal and spatial variability of data is a major issue for water scarcity assessments regardless of scale and the limitations of spatial variability in terms of population hold true for water resources availability, particularly in large basins where remote populations may be some distance from the nearest water source. Furthermore, this assumption also fails to address the temporal availability of water particularly relevant given almost half of annual global river runoff occurs between May and August (Shiklomanov, 2000). Shiklomanov (2000, p.12) suggests "the appraisal and assessment of renewable water resources consists of a discovery of water sources, inventory of spatial and temporal (both during the year and over multi-year periods) distributions of river runoff and assessment of water quality" as the "basis for determining the possibilities for water use and production." Unfortunately a lack of water quality data available at the national scale means this factor is not captured as well as spatial and temporal variability.

Shiklomanov documents two facets of water use, the spatial and temporal dynamics, at the global scale. Although he does not provide an explicit formula for his calculations he states that in order to do this he considered "the total withdrawal and consumption for urban population needs (domestic or municipal), industry, (including thermal power), and irrigated farming and agriculture" providing world regional comparisons by "territory and over time" (Shiklomanov, 2000, p.14). Future population estimates are taken from 1994 UN forecasts. It is not clear if population estimates are based on steady rates of growth. At the national level, water use would not be affected by internal migration patterns but this would certainly be a factor for strong consideration at the river basin level, which the author also documents. Shiklomanov estimates "mean value of renewable global water resources to be 42,750km^3" (*ibid.* p.18) which varies by +/- 15-25% in a given year. Temporal fluctuations in a given year are equally impressive with "about 45-55 percent of… runoff occur[ing] during periods of flooding" and "about 46 percent of the annual global river runoff occur[ing] between May and August" (*ibid.*). This is especially important in regions that lack the ability to capture and store water such as Mexico where approximately 67% of all rainfall falls between June and September (CNA, 2006).

Shiklomanov calculated that in 1995 global total water withdrawal was about 3,790km^3/year and consumption 2,070km^3/year, or 61% of withdrawal. He estimated that withdrawals would grow by about 10-12 percent for every 10 years in the future (from 1995) reaching approximately 5,240km^3/year by 2025. Finally he estimated that consumption would rise more slowly increasing only 1.33 times by 2025 from 1995 levels. However it is important to note there exists a massive difference between withdrawal and consumption between regions, which is due for the most part if not wholly to irrigation.

Shiklomanov discusses global water withdrawals compared to available resources further. He calculates what he refers to as specific water availability as a measure of per capita fresh water availability determined by "dividing water resources without consumption by the population… [where] water resources are assumed to be the river runoff formed in the territory of a given region plus half of the river water flow from outside" (Shiklomanov, 2000, pp.26-28). This particular methodology makes the following two assumptions: (i) that 100% of river runoff within a territory is available for use; and (ii) that 50% of all river runoff flowing into a territory is available, implying some sort of equitable share amongst source and recipient territories. This scenario is highly unlikely in practice, for example, the lion's share of resources within the Río Bravo river basin shared between the United States and Mexico, are withdrawn by the United States. Given both of these assumptions are unlikely to be true, it is likely that Shiklomanov's estimates of global and regional reserves are generous. In fact, in his conclusions he states that his own inferences about water availability and resources deficit should probably be considered as "optimistic" (*ibid.* p.31).

A common observation amongst water scarcity researchers is that hydrological data are either absent or unreliable. Whilst improving this situation would be ideal, in the absence of this occurring, it may be wiser to consider alternative methods for determining water availability. In terms of water quality, Shiklomanov recognizes he fails to consider water quality effectively. Yet he states, "every cubic metre of contaminated waste water discharged into water bodies and streams makes 8 to 10m^3 of pure water unsuitable" (Shiklomanov, 2000, p.30). Because of this he concludes, "most regions are already facing the threat of catastrophic qualitative depletion of water resources" and it is his belief that "it is necessary to consider the water supply problems of every region in detail" (*ibid.* pp.30-31). This assertion supports two main issues: (i) the need to consider water quality when calculating water resources availability; and (ii) the need to carry out such studies at the local scale, however uneconomical.

In light of the aforementioned assertions, the inability of traditional water scarcity assessments to handle spatial and temporal variability accurately and the gross negligence of social, economic and political constraints to water supply, traditional water scarcity assessments present serious failings and the impetus for an alternative approach is evident.

2.2 From Water Crowding to Water Poverty: A Chronological Review

Introduced in 1989, the concept of water crowding was first defined as a measure of how many people shared the same flow unit of water placing a clear emphasis on the social demands of water rather than physical stress (Falkenmark & Rockström, 2004).

Falkenmark's attempt to address the humanistic or social aspects of water resources challenges was one of the first holistic approaches to water resource management to be accepted by the scientific community, although only after being adapted from its original form to one more palatable to traditional scientific approaches. Falkenmark, *et al.,* (1989) recognized that aid policies and the response to development needs were historically focused on technological solutions and large-scale projects. Emphasizing the constraints of population growth on water supply, they posited the idea of focusing attention on the need for better demand management strategies as opposed to further supply management techniques. With an emphasis on semi-arid regions of Africa, they categorized water scarcity as either natural or anthropogenic. According to them, aridity and intermittent droughts are two examples of natural water scarcity whereas landscape desiccation and water stress, the latter as a result of too many people sharing a finite volume of water resources, are anthropogenic. Water stress is defined as the number of people that a flow unit of freshwater can sustain. With the idea that freshwater resources are finite, they asked the question: "how many people can be supported by each flow unit within given technological and managerial capabilities?" In their visualization of their concept (Falkenmark, *et al.*, 1989, p.260) they assign a flow unit the arbitrary volume of one million m^3/year. It would appear that linking a volume to the concept of a flow unit would prove to be the unintended precursor of the WSI. Originally known as the 'Falkenmark Indicator', according to Falkenmark & Rockström (2004), this measure was later adopted and modified by the engineering community to express the amount of volume per capita and the WSI was born. Less than $1700m^3$/capita/year for a given region is the conventional threshold used to express water stress whilst less than $1000m^3$/capita/year signifies water scarcity where estimates of water resources are typically derived from mean annual river runoff (Arnell, 2004; Falkenmark, *et al.*, 1989; Falkenmark & Rockström, 2004; Shiklomanov, 2000). Today, the WSI is one of the most widely used indices for measuring water scarcity.

This concept remained largely unchallenged until 1997 when Raskin *et al.* specifically criticized the WSI's inability to consider different patterns of water use (Feitelson & Chenoweth, 2002). Instead, according to Feitelson & Chenoweth (2002, p.265) Raskin *et al.* propose a "use per resource indicator" and suggest including a figure to reflect a country's dependence on transboundary water. Their lack of consideration for water quality and a country's economic capacity is however criticized by Feitelson & Chenoweth (2002).

In 1998, Seckler *et al.* advanced the idea of adopting a demand management approach to water supply in their research report for the International Water Management Institute. They refer to Falkenmark's earlier work as exemplary of historical supply side approaches to constraints of water supply, an indication that Falkenmark's work was never clearly understood. Citing Raskin *et al.*'s advances as another example of a supply side approach, they suggest water scarcity can be viewed as either a problem of supply or demand or both. Advancing a methodology for describing water scarcity as a function of a country's water balance against its projected needs, their approach nevertheless centres on Available Water Resources (AWR) and fails to progress beyond traditional concepts of water scarcity.

Drawing on research by Ohlsson, Turton (1999) expresses water scarcity as a function of adaptive capacity. Discussing the concept of first order and second order scarcities, he describes first order scarcity as a lack of natural capital and second order scarcity as a lack of adaptive capacity such that a society lacks the necessary capacity to deal with first order scarcity. Together, Ohlsson & Turton, (1999) classify the different indices of water scarcity as either first or second generation. According to them, first generation indices, such as the WSI, adopt a supply-side management approach to identifying problems of water scarcity by considering the amount of naturally available water resources to a given population. Second generation indices consider the economic, ecological and social constraints of water scarcity and attempt to measure a population's ability to manage second order water scarcity as a function of these factors. Recognizing the importance of their predecessors and the need for an integrated approach to water management, Ohlsson & Turton (1999) propose combining the widely used WSI with the Human Development Index (HDI) to arrive at a Social Water Scarcity Index (SWSI). Thus, for the first time, the concept of water scarcity expands beyond traditional measures of AWR to include considerations of social and economic capabilities of a population. This work has been cited by Sullivan (2002, p.1200) as "paving the way for the development of a WPI".

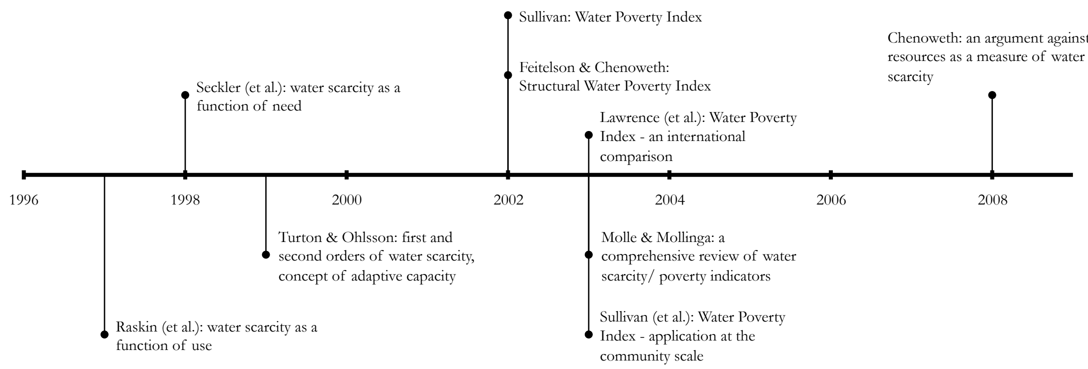

Figure 1 Evolution of water poverty indicators post-Water Stress Index

Feitelson & Chenoweth (2002) provide a comprehensive critique of the above indices beginning with a review of the WSI. According to them, the precursor for the index proposed by Raskin *et al.* (1997) was their critique of the WSI for failing to consider "differences in water use patterns between countries" (Feitelson & Chenoweth, 2002, p.265). However, as previously mentioned, they subsequently criticize this method for not including measures of water quality or economic capacity. They commend the SWSI for its attempt to move away from what they consider to be traditional neo-Malthusian indicators of water scarcity but critique its dependency on a proxy indicator, the HDI, as opposed to including a "causal connection or direct means for assessing adaptive capacity of a society" (*ibid.* p.267). In addition, they highlight the continued lack of consideration for water quality or economic capacity. Instead, they propose their own definition of water poverty as "a situation where a nation cannot afford the cost of sustainable clean water to all people at all times" (*ibid.* p.268). The emphasis on affordability is intentional and they subsequently propose what can otherwise be described as an affordability index constructed from the ratio of a country's ability to pay for water supply and sanitation as a function of their overall cost. They justify this approach by arguing that, "environmental and social dimensions of the sustainability discourse can be conceptually internalized in [monetary] terms" (*ibid.* p.279) Their index advances the definition of water poverty in a new direction and uses a needs assessment approach centred on financial capacity to quantify the adaptive capacity of a country. However, the reduction of water poverty into its main economic components reduces our ability to explore the complexities of water poverty in detail and tells us little about the population in need. It focuses on macro scale water poverty and its utility at smaller scales is questionable. Furthermore, the authors recognize the inability of their index to deal with rural populations, as well as in-stream water use and the ecological value of water.

Sullivan (2002, p.1195) first proposed the WPI as an integrated approach to water poverty (where water poverty is defined as a lack of adequate and efficient water supplies) that "link[s] physical estimates of water availability with socioeconomic variables." She states (*ibid.* p.1197), "the development of a Water Poverty Index is intended to help [the] process of identifying those areas and communities where water is most needed, enabling a more equitable distribution of water to be achieved", one of the most important practical features of any potential water scarcity/poverty indicator. Advancing numerous novel ideas surrounding the identification of water poverty, she discusses the advantages and disadvantages of four possible approaches to calculating a WPI but refrains from recommending any one methodology.

It is not until one year later that a refined version of the WPI including a comprehensive review of water poverty at the international scale is published (Lawrence, *et al.*, 2003). The authors suggest the purpose of the WPI is "to express an interdisciplinary measure which links household welfare with water availability and indicates the degree to which water scarcity impacts on human populations" (Lawrence, *et al.*, 2003, *Introduction*). The authors suggest the water poor can be defined in two ways: those who lack access to water or have insufficient water available to meet their basic needs, and those with insufficient income to access water even when supplies exist. This division highlights that water poverty is not only a function of AWR but also general poverty, a concept commended by Feitelson & Chenoweth (2002). As a result, they propose a composite index, modelled on the HDI, that attempts to describe water poverty by simultaneously assessing it as a function of five key indicators: resources, access, capacity, use and environment, in turn comprised of sub-indices made up of several variables. In theory, variables are weighted according to local preference; in practice no weightings have thus far been applied. Some would argue that as yet there is no evidence to suggest the need for preferential weightings (Lawrence, *et al.*, 2002; Sullivan *et al.*, 2003; Giné Garriga & Pérez-Foguet, 2008). Their concept was developed through intensive consultation and the internal mechanisms of the WPI are described in further detail in the following section.

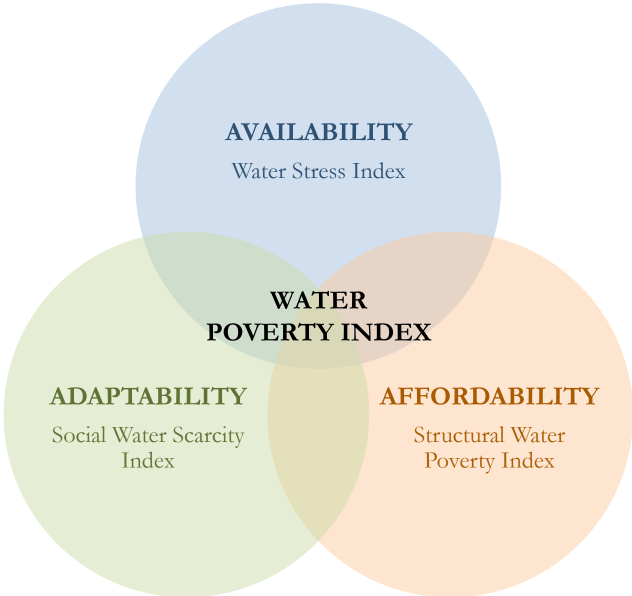

Figure 2 Schema of modern indicators of water poverty

According to Sullivan *et al.*, (2003, p.189), the WPI as described by its authors "was developed as a holistic tool to measure water stress at the household and community levels, designed to aid national decision makers, at community and central government level, as well as donor agencies, to determine priority needs for interventions in the water sector". To do this, the WPI "combines data on local water resources, access, use, social and economic capacity, and water-related environmental quality allowing agencies to monitor progress in water provision at the community level" (*ibid.*). The authors suggest these data could then be "aggregated to provide countries and international agencies with a much more accurate performance indicator to guide policy" (*ibid.*). Despite the recognition of the need to scale up, many models and indices still rely on national or even global data to scale down. Scaling up would provide a much more accurate picture of water scarcity however this approach is hindered by a lack of readily available local data for many regions. The WPI therefore is an extremely valuable tool that could serve to bridge this data gap.

Molle & Mollinga (2003) discuss water scarcity in terms of five types of water use and their five constraints. Through a discussion of the 25 resulting scenarios they highlight the complexity of "the water-society nexus" and, aligning themselves with those who would adopt a more holistic approach, assert "[it] cannot be reduced to a mere question of providing technical and financial means" (*ibid.* p.532). Examining indicators in general before assessing those specifically designed to measure water scarcity, the authors highlight a common critique of composite indicators particularly relevant to the WPI. They assert the weight assigned to sub-indices is "arbitrary" and as a result mask "local differences in the importance of problems" (*ibid.* p.534). Reviewing the works by Raskin *et al.* (1997), Seckler *et al.* (1998) and Feitelson & Chenoweth (2002), they maintain the "Malthusian focus implicit in these approaches of resource/population ratio ignores both virtual water and adaptations" (Molle & Mollinga, 2003, p.535). In their review of Ohlsson & Turton (1999) they highlight the propensity of the use of proxy indicators to produce index "anomalies" necessitating further explanations that are often "site-specific and qualitative" (Molle & Mollinga, 2003, p.535). It would not be inappropriate to apply this critique to the WPI and indeed the authors refer to the "problem of multi-dimensional indices" that "conflate disparate… pieces of information, with arbitrary weights, giving rise to intriguing scenarios" (*ibid.*). In response to the acknowledgment that "the information is in the components" (Lawrence *et al.*, 2003, p.10), Molle & Mollinga (2003) point out these irregularities also exist at the indicator level, presumably as a result of being composite indices themselves whereby an anomalous variable score masks the results of its counterparts. The authors follow their review of water indicators by an assessment of indicators in general and I would direct you to their study for a detailed account (Molle & Mollinga, 2003). Of particular relevance to the WPI's recent momentum is their insight into the contrast of indicator development with the "almost nonexistence of research and knowledge on whether and how indicators influence policy-making at different levels" (*ibid.* p.541) They conclude that differences in responses to water scarcity "may be more easily elucidated through an in-depth qualitative analysis than by plotting a few indicators" yet remind us "[the] main role [of indicators] is to convey messages, convince the public and decision-makers" (*ibid.* pp.542-543). Indeed, this is the argument of Sullivan *et al.* (2003, p.192) who state, "however imperfect a particular index, especially one which reduces a measure of development to a single number, the purpose is political rather than statistical."

Writing on questions of power, Brohman (1996, p.344) remarks, "typically… neither mainstream nor alternative development initiatives have paid much attention to economic, political and sociocultural structures." Whilst conventional water scarcity indicators are not intended to be unique to development, given the potential consequences and likelihood of water scarcity to affect the poor and marginalized within developing economies, it would seem reasonable to apply this critique to conventional methods of determining water scarcity such as the WSI. Water scarcity indicators have clearly moved well beyond the traditional scope of AWR per population base to include more holistic approaches. Many authors now acknowledge the need to include social-adaptive responses, economic and technological considerations in order to accurately assess the complex dimensions of water poverty. As Ohlsson & Turton (1999, p.3) point out, "any discussion aimed at finding appropriate strategies… would benefit from starting off with some reflections on where… a particular country is situated at a given moment." Nevertheless water scarcity is still widely measured using traditional resource-focused methods and specifically the WSI. Yet, traditional measures of water scarcity that focus solely on the physical availability of water resources provide a very incomplete, and potentially inaccurate, picture. Recently, Chenoweth (2008) returned to the forum to revisit the above water scarcity indicators but most importantly to assess the original WSI and its relationship with overall water poverty. Using databases from the UNDP and FAO, he provides compelling evidence there is "no support for the notion that the naturally available water resources of a country have a significant effect on the ability of that country to meet the basic needs of its population" (*ibid.* p.14). Thus the need for an indicator that moves beyond the traditional scope of water scarcity measurements and considers all the dimensions of water poverty in an inclusive, holistic format, such as the WPI.

2.3 Advancing the Water Poverty Index: Evidence from Case Studies

The WPI is designed to operate at a number of scales and enable quick and reliable comparisons of water poverty across space and time. By utilizing a set of standard indicators community or regional performance can be assessed over time and compared to other localities enabling decision-makers to prioritize levels of need. Moreover, the indicators are intended to be flexible and can be modified to meet local needs. Finally, the index addresses the issue of representing qualitative data in an empirical manner.

However, little research has been undertaken thus far to determine the significance of weighting applied to indicators and the integrity of the intended flexibility may need to be compromised in order to provide a common baseline for comparative purposes. Furthermore, the accuracy and indeed appropriateness of representing qualitative data empirically may be questionable. In theory the WPI has the ability to compare performance across localities, but variables are very location specific. It is unclear how potentially different variables, which consequently would affect the indicators, are accounted for. The authors have stated it would not be appropriate to determine one indicator of water scarcity as more important than another and all variables and indicators within the current model are weighted equally. However, the totalizing scoring system masks indicator scores essentially producing misleading results in terms of overall water poverty.

A number of case studies have been undertaken since the WPI was first introduced and an international comparison of 140 countries was undertaken. In the first major study of its kind, the authors conclude that the WPI produces "sensible results" although caution that the WPI is not "definitive" and not "totally accurate" (Lawrence, *et al.*, 2003, p.10). They acknowledge its failure to include a variable that measures investment within the water sector and, having been modelled on the HDI, remind us the WPI is therefore subject to many of the same critiques, in particular, internally correlated indicators. Although they cite this as a known problem of the HDI (and hence the WPI), they justify the trade-off because league tables (rankings) change between countries when indicators are independently analyzed and correlations are in any case imperfect. However, not only is the WPI subject to the same criticisms by its very nature, because the indicator of capacity is modelled on the HDI, there is a strong chance internal correlation will also prove to be problematic. Their analysis shows that WPI is in fact highly correlated with the HDI (r=0.81). Interpreting this correlation coefficient to mean, "65% of the variation in WPI can be explained by the HDI" they suggest, "there are some distinct differences in water issues… compared to general development… measured by the HDI" (*ibid.* p.9). This is a rather optimistic version of events and I would suggest that the high correlation coefficient shows there are important similarities between the WPI and the HDI and such a high correlation coefficient may compromise the overall result. In fact, in their study the indicator of capacity was almost perfectly correlated with the HDI (r=0.94). On the subject of correlations, they show that the WPI is only weakly correlated with the WSI (r=0.35) suggesting it provides added value and unique information to traditional measures of water scarcity, although no mention is made as to whether or not the correlation is statistically significant. Unsurprisingly, indicators of Access and Capacity were highly correlated, each indicator in turn highly correlated with the WPI. The authors anticipated and acknowledge this problem of inter-correlation between indicators and suggest further work is needed. Each indicator and the variables that comprise it are weighted equally. As each indicator is comprised of a different number of variables this may result in an unintentional imbalance. Furthermore, it could be argued that an equal weighting homogenizes problems of water poverty on a global scale that are unlikely to be balanced in reality. Criticising this aspect of the WPI, Feitelson & Chenoweth, (2002, p.268) write: "using a collective expert judgment to determine the weightings of a multi-dimensional index results in an index that is subject to the value judgments of cultural biases of those who created it, *while arbitrarily adopting an equal weighting for all components of an index is a de facto weighting in itself that is no less problematic*" (emphasis added). Finally, the WPI compares relative water poverty by assigning the lowest ranking country on any indicator a score of zero and the highest a score of 1. By its very nature this distorts results between countries. On a large scale (such as 140 countries) these distortions are partially mitigated, but on a smaller scale would necessarily be amplified. The authors argue, "the information is in the components rather than the final single number" (Lawrence, *et al.*, 2003, p.10). However, if that truly is the case, how much confidence can we have in the overall outcome and what purpose does it ultimately serve? Lastly, the authors suggest their results "show few surprises" citing "most of the countries in the top half [of the index] are either developed or richer developing" (*ibid.* p.8).

Sullivan *et al.* (2003) subsequently undertook a pilot study that applied the WPI at the community scale. The authors found their results were in keeping with the general situation of water poverty in the communities as agreed by the study participants. Disseminating their results with pentagram diagrams (where each point represents the score for one of the five indicators), allows users to quickly classify the situation of water poverty in any location without losing its "underlying complexities" appealing especially to policy-makers (Sullivan *et al.*, 2003, p.196). The authors claim the structure of the WPI allows it to be "relevant and applicable at a range of scales" providing a "transparent framework on which decisions in water planning and management can be based" (*ibid.* p.196-197). They caution the need for reliable data and recognize the impact of local politics, which may affect the "comparability of results" (*ibid.* p.197).

Overall, their results were very preliminary and the authors acknowledge the need for further testing "in real implementation over much larger areas, covering whole provinces or substantial parts of countries" (Sullivan *et al.*, 2003, p.198). This is particularly true when utilizing data intended for the national scale. For example, according to one of the original case studies Majengo, Tanzania (an urban community) attained an overall WPI score of 43.8, but at the indicator level scored only 10 for Resources, 32.7 for Access and 15.0 for Use. On the other hand, it had the highest indicator score for Environment at 98.4, which served to artificially inflate the overall WPI score (Sullivan *et al.*, 2003). This distortion is a common problem experienced in additional case studies. Although the index is designed to operate at a number of scales, its relative nature impedes comparisons between studies. Finally, it should be noted that the WPI is not intended to replace more comprehensive integrated water resource management tools but instead to provide a needs-based approach to assessing water poverty enabling decision-making.

Cullis & O'Regan (2004) extend the use of the WPI to devise water poverty maps in their case study of a municipal district in South Africa. Data used to calculate a water poverty index were collected at the lowest level possible and then aggregated at different scales. Although the main objective of this study was the creation of water poverty maps, it nevertheless provides some insight into the WPI. In this study, the number of variables used to calculate each indicator was reduced to one. Although the authors claim this was as a result of their limited timeframe the implications for the WPI are two-fold: (i) the lack of a pre-determined set of variables may hinder its application, and (ii) time may be a critical constraint for undertaking water poverty assessments using the WPI. In terms of socio-economic variables, the authors recommend these should be scaled up "to match the scale of the hydrological and environmental data used" (Cullis & O'Regan, 2004, p.407). They found that data for Use were the most difficult to obtain but in the context of their study suggest this indicator is "one of the most important" (*ibid.*). Even in a less specific context, I agree that readily assessing the proportion of a population that is meeting its basic water requirement (BWR) is of the utmost importance. Although this study included one settlement that had been previously assessed by Sullivan *et al.* (2003), it was not possible to compare overall WPI results as different variables had been used, again highlighting the problems that a lack of pre-defined variables present. Finally, their results show that overall WPI results at the macro scale (in their study, the sub-catchment and place name scale) significantly masked results at the local enumerator scale.

As a follow-up to their earlier work, Sullivan, *et al.* (2006, p.412) appear to rebrand the WPI as "primarily designed for use at the community level" though the authors cite its ability *to be applied to different scales depending on need* (emphasis added). Having endured strong criticism since its inception, the authors make the WPI's ongoing development explicit and suggest "the technique needs to be refined and improved before any scores generated can be taken as definitive" (*ibid.* p.415). Presenting a selection of case studies at different levels they caution users on the impacts of scale. At the community scale, certain variables having been selected for their theoretical impacts did not translate well into practice. Specifically, variables relating to land use designed to assess environmental integrity did not always apply to each setting especially given the marked difference between rural and urban settings. Referencing the study undertaken by Cullis & O'Regan (2004), they reiterate the idea that national level indicators mask local variability and suggest their use for local decision-making is ineffective (Sullivan, *et al.*, 2006). Instead they insist, "using the finest resolution possible [will] produce the most accurate results" (*ibid.* p.420). Lastly, referring to their international comparison (Lawrence, *et al.*, 2003), they admit "to uncertainties in the results" and the need for improved data collection as well as a standardized approach "before definitive comparisons can be made" (*ibid.*). Despite these disadvantages they use the example of the island of Hispaniola (shared by the Dominican Republic and Haiti) to illustrate how the WPI can be effective in highlighting the complexities of water poverty when compared to analyses of AWR alone. With similar water resources, the overall WPI for each country is significantly different (59.4 and 35.1 respectively). Those familiar with the region will no doubt attribute this difference to the marked difference in human development between the two countries and indeed, scores for Access, Capacity and Use are much lower in Haiti than in the Dominican Republic, but so too are scores for Environment. Still others (Molle & Mollinga, 2003) have cited examples of countries assessed in the international comparison where neither the overall WPI nor its indicator scores appear to make sense. On the subject of comparisons, the authors conclude: "there needs to be consistency of data collection, a synchronized definition of variables and standardized procedures for calculating the final index values" (Sullivan, *et al.*, 2006, p.424). However to date most case studies (including the present study) focus on the application of the WPI and the accuracy of its results thus this problem has yet to be resolved. The authors specifically acknowledge the need to improve missing environmental variables and suggest, they "will be incorporated in future revisions" (Sullivan, *et al.*, 2006, p.424). Once again, this has yet to materialize. Commenting on the problem of scale, the authors conclude "values on any measure are really only applicable at the scale represented by the data used to generate them" (*ibid.*) and suggest, for example, census data are the most appropriate for assessing small rural communities. Lastly they remind us, "the disconnection in datasets between hydrological and socio-economic data currently hamper" the ability to apply the WPI to the catchment scale (*ibid.*).

Komnenic, *et al.*, (2009) use the WPI to assess regions purportedly not water poor in a bid to ascertain how it performs under these conditions. The authors interpret the strong correlation between the WPI and Capacity, and the strong relationship between Access and Capacity, as a reflection of the WPI's position that "societies with low income levels and weak health and educational systems are likely to have inhabitants lacking access to safe drinking water" (*ibid.* p.223). As a result of countries in their study with high access rates to safe water and sanitation, for example Serbia and Montenegro with 93% and 87% respectively, being defined as water poor by the WPI (WPI=25.4) they conclude that the concept of water poverty "expressed through the WPI… is neither universally applicable nor suitable for making generalizations" (*ibid.*). Their main problem appears to lie not with the WPI itself, although they do raise a number of important shortcomings, but instead with the term water poverty that they suggest in certain cases is a "crude generalization that may lead to misunderstandings and a misconception of the water challenges a community or society faces" (*ibid.* p.223). Indeed, their position demonstrates this misconception. They reiterate the idea that the WPI's utility lies not within the overall score but instead the individual indicators which they say, "paint a unique and variegated landscape that can be used as a quick scan or diagnosis" a point already acknowledged by the original authors (*ibid.*). Some of their more specific results are more interesting and particularly relevant to this study. The authors found the data collection process to be "slow and painstaking" (*ibid.* p.221) especially in circumstances where the user is unfamiliar with the data. This provides evidence to support earlier comments made in light of Cullis & O'Regan's study (2004) where I suggest a lack of pre-determined variables may hinder the WPI process, a point raised in a subsequent paper (Sullivan *et al.*, 2006), and that time may be a critical constraint. They also raise a number of problems associated with scale such as data-dependency, spatial distortion of results derived from aggregated data, and the masking of local variability inherent in macro scale analyses, again problems previously acknowledged by Sullivan, *et al.*, (2006). Two of their most relevant critiques, especially in light of the present study, centre on the internal mechanics of the WPI. First, they note, "the final value of the WPI heavily depends on the number of countries or communities it is calculated for" (Komnenic, *et al.*, 2009, p.222). This is because of the normalization technique inherent within the WPI that assigns a score of 0 to the lowest ranking country or community and a score of 100 to the highest-ranking community or country. With such a small dataset, having analyzed only four countries, this is in fact the key driver behind the "odd" results for Serbia and Montenegro (*ibid.* p.223). Had it been assessed with a group of developing countries from Sub-Saharan Africa, its resultant WPI score would undoubtedly be much higher. Second, the authors' findings present trends similar to those of Lawrence, *et al.*, (2003) whereby the WPI is most highly correlated with indicators of Access and Capacity and both indicators in turn are highly interrelated. To date neither of these findings has been addressed in a satisfactory manner.

More recently, (Cho, *et al.*, 2009; Giné & Pérez-Fouget, 2009) two case studies have moved away from critiquing the WPI to focus upon its amelioration. In a series of conference papers, Giné & Pérez-Fouget (2008; 2009), propose an enhanced WPI (eWPI) that "emphasize[s] the importance of causality and thus incorporates cause-effect relationships" whilst including "sustainability issues". They define indicators of "pressure, state and societal responses" for each variable used to calculate a water poverty index thus arriving at what they describe as a "causality-issue matrix". In essence, indicator scores for Pressure, State and Response are added to the five existing indicators of Resources, Access, Capacity, Use and Environment to arrive at overall WPI. Although the sub-index calculation is not made explicit, it is presumed to be the same as that within the original WPI. Having devised an alternative model for assessing water poverty, their intention is "not to discuss reliability of results obtained" but "to test the index through its application in a given context, aimed at detecting major shortcomings and pointing out future improvements" (Giné & Pérez-Fouget, 2008). As such they first apply their eWPI to the basin scale to a watershed shared between Ecuador and Peru (Giné & Pérez-Fouget, 2008) then at the community scale in ten communities in Bolivia (Giné & Pérez-Fouget, 2009). Their brief analysis of results adds to the growing body of evidence that suggests overall WPI scores are less meaningful than the individual indicator although they suggest the WPI "can be a powerful tool with potential for wider implementation." Their work also provides valuable insight for the need to conscientiously select variables that describe water poverty at the community level. Some of these suggestions have been incorporated into the present study, for example, the consideration of gender bias through assessing educational levels between men and women. In addition, they provide meaningful direction for future research into the continued use of the WPI. First, they are the first authors to explain the importance of avoiding correlation amongst indicators and variables and the undesirable consequences of interrelationships between indicators on composite indices. Second, they highlight the need for continued research into the issue of indicator weighting and suggest this could be investigated using statistical analyses or participatory methods, but also note, given the importance lies within the individual indicators and not the overall WPI score, a straight average may be suitable. Lastly, they discuss the different aggregation methods available in constructing a water poverty index. The current model favours linear aggregation thus enabling a compensatory approach such that a weakness in one variable may be compensated for in the strength of another. They suggest the need to consider non-compensatory methods in which case a linear approach would not be suitable.

Finally, expanding specifically upon the issue of weighting, Cho, *et al.* (2009) use Principal Components Analysis (PCA) in an attempt to address the problem of indicator weighting subsequently resulting in a reduced number of weighted indicators comprising the WPI, a detailed account of which can be found in their paper. They arrive at a modified WPI (NWPI) that comprises indicators of Access, Capacity and Environment, weighted according to the results of their analysis (0.4, 0.4 and 0.2 respectively). They further reduce their model to include equally weighted indicators of Capacity and Environment justified by statistical tests that suggest these two indicators are most strongly correlated to the primary principal components of the WPI. It should be noted the authors' analysis relies upon data from the original international comparison (Lawrence, *et al.,* 2003). The authors are driven by a desire to find a more cost-effective way of calculating the WPI and although their attempt is admirable, their purely statistical approach to the decision-making process lacks sensitivity towards the realities of water poverty. For example, their exclusion of Use based on incompatible variables and negative correlations with the remaining indicators, although statistically justifiable, is irresponsible and negates what is arguably one of the most important variables of water poverty, the need to assess whether or not a population is meeting its BWR in terms of personal consumption. Second, they fail to address the problem of internal correlation amongst indicators (evidenced by the fact both Access and Capacity are retained in their first modified WPI). Notwithstanding, they suggest applying the same methodology to the sub-indices to determine appropriate weightings for each variable as a possible extension to their study. This would seem to be a more logical approach. Furthermore, given the constraints of the WPI, acknowledged by its developers, these analyses might best be undertaken using data derived at the community scale. Lastly, although they suggest the high correlation between their modified indices and the HDI might be as a result of similarities between variables used to define Capacity and the HDI, they unfortunately fail to extend this further.

From Development Theory to Practice

My research supports a multi-dimensional approach to the assessment of water poverty and using the WPI contributes to the body of growing research that attempts to assess water poverty at various scales. Contrary to most case studies, which are concerned with the WPI's ability to inform wider management policy, my research aims to address the reliability of results by testing the WPI further, analyzing its robustness and assessing its ability to accurately reflect local perceptions of water poverty. Firmly situated within the realm of applied community development research, my study attempts to consider the often-overlooked needs of the development worker and the participating communities themselves, who would no doubt benefit from a simple assessment tool designed to accurately define the water poor. My research therefore focuses solely on the determination of water poor communities or in the words of Giné & Pérez-Fouget (2008), the state of water poverty. Although my research does not purport to influence theories of development, in light of the above approach, it is appropriate to briefly consider the specific notions of development theory that have informed the decision-making process of my work and the broader methodological framework arising from that theory.

2.4 A Brief Discussion of Alternative Development Theory

> "The fact that 'development' as a strategy of modernization has failed to meaningfully take place in a majority of the countries of the Third World is no longer in dispute." (Nabudere, 1997, p.203)

> "With an academic debate on development more for its own sake, and carried on in a language far above the heads of normal practitioners, it would be natural that they would not find any guidance from developmental research." (Närman, 1997, p.221)

Two things are clear from these writings: (i) approaching development through the lens of modernization, predominantly driven by Western ideals, has failed; and (ii) constructs of development theory are often too complicated and too far removed from those closest to the subject matter to enable meaningful discourse. With particular empathy for the latter statement, the following section attempts to describe a small fraction of the history of development theory, focusing on current trends in alternative development theory that aspire to shift the development discourse from theory to practice.

Historically, conventional development theories, encompassing conservative ideologies like neo-liberalism, have attempted to devise a universal approach to problems in third world countries often seeking to impose a westernized solution on what we now recognize as unique, diverse and complex localized problems. This idea is supported by Nabudere (1997, p.203) who in his discussion on the more prominent failings of modernization theories remarks they "have tended to ignore the peculiarities of different countries and cultures seeking to find an existence within the international capitalist system of the world." Furthermore, conventional development theories often approach development in a linear fashion thus ignoring "the many pluralisms of society" (Brohman, 1996, p.325). Instead of meeting the needs of the people, conventional development theories respond to the needs of policy makers and foreign interests.

According to Brohman (*ibid.*) there is a long history of "discipline centrism" in development with the "development process [being] artificially fragmented and compartmentalized to fit the areas of specialization, research methods, and theoretical frameworks of individual disciplines." This is especially true in engineering disciplines, which historically, commonly sought to transpose western modernization without due consideration for the ability of local communities or local environments to sustain modern systems, both in terms of capacity and resources. Interestingly, most efforts to incorporate local knowledge have subsequently come from those seeking to implement appropriate technologies, particularly from within fields associated with agricultural studies.

Recent writings in post-development theory have focused on a number of catch phrases and buzzwords including *beyond development* (Nabudere, 1997), *reflexive development* (Pieterse, 1998) and *development alternatives* (Bebbington & Bebbington, 2000). This writing is indicative of development theory having moved beyond the impasse of the late 1980s/early 1990s, beyond anti-development and post-development critiques, from an economic-centred approach towards new people-centred approaches, under the loosely aligned label of alternative development theory. Alternative development theorists fall broadly within two groups, although overlap between the two is not uncommon (Bebbington & Bebbington, 2000). Critical modernist developmentalists argue the need to remain engaged with market economics whilst promoting the transfer of power to the local people but with little attempt to bridge the gap between practice and theory, thereby remaining firmly within the arena of prescriptive theoretical debate. Popular developmentalists emphasize the need to contextualize development within space and time arguing for stronger linkages between micro and macro scale policies and, citing a stronger need for practice to inform theory remain practically engaged within applied development research.

In seeking to relocate "participation within a radical politics of development", Hickey & Mohan (2005, p.237-238) argue, "that the critical modernist approach… offers the best theoretical home." Whilst critical modernist developmentalism strongly opposes capitalist modernization, rather than reject modernization in its totality, some would suggest retaining "what is worth saving" from conventional development theory and socialism (Peet, 1999, p.208). This construction of a critical modernist approach to alternative development theory introduces a number of interesting concepts particularly adept at rejecting anti-development and encouraging us to remain engaged with development. Advocating the need to "rethink, restructure and rework development", (*ibid.*) Peet combines a number of notions from modernization and embeds them within concepts drawn from Marxist, post-structural and feminist theories to suggest "the crux of an alternative development [should] lie in the production of more goods to satisfy the needs as part of a wider strategy of transforming power relations in society at large." Peet's model of labour would come from those "whose work is connected with the direct reproduction of immediate life" whilst the means of production would be "collectively owned" (*ibid.* p.209).

Bebbington & Bebbington (2000, p.9) also argue there is a need to remain engaged with market economics citing evidence from Andean case studies that suggest, "rural people base much of their choice of crops and crop varieties not on whether they are 'indigenous', 'alternative' or 'modern', but rather on how well suited they are to market conditions." They conclude that by engaging with these "practical challenges" more "we might find that much empowerment passes through a reshaped market that resolves some of the power-based and institutional obstacles to popular participation in economic activities" (*ibid.*).

However, even if progress and the role of markets in development are recognized, other authors would point out "generally, the most basic structural obstacle faced by the poor in Third World societies is the extremely unequal distribution of productive resources and assets" (Brohman 1996, p.272) instead often dominated by the local elite, e.g. land tenure in rural areas. Therefore, material needs and economic growth are meaningless "if the distribution is inadequate and trickle-down effects non-existent" (Närman, 1997, p.222).

Furthermore, Peet (1999) does not reconcile his ideals with practice instead remaining firmly planted in the theoretical arena despite numerous authors highlighting the imperative for practice to inform theory and taking into account experiences of the poor (Brohman 1996; Simon 1997; Nabudere 1997). To this extent, critical modern development remains situated within the arena of prescriptive theoretical debate. To the contrary, Bebbington & Bebbington (2000, p.7) recognize "a closer engagement with the dilemmas encountered in practical attempts to pursue development alternatives" is needed to address some of the weaknesses still prevalent in some versions of alternative development. In support, Närman (1997, p.218) suggests, "we have to account for the gap between action-based and structural constructions of development." Referring to the gap between theory and practice as a problem of relevancy he points out, "research experiences from the field do not always correspond to what the literature is claiming" (*ibid.* p.219). The gap between theory and practice is commonly accepted as one of development's most historically difficult struggles. Theory is often too obscure and too complex for those on the ground, yet practice often fails to inform theory because of its localized context and initial lack of theoretical grounding (Brohman, 1996; Närman, 1997; Bebbington & Bebbington, 2000).

With the universal approach favoured by conventional development theories, discipline centrism and wide gaps between practice and theory, it is not surprising that development is described as having hit an impasse, culminating in an eventual crisis, by the 1990s (Brohman 1996; Nabudere 1997; Närman 1997; Simon 1997). Alternative development theories have thus sought to respond to this crisis by recognizing the many problems of conventional development theories and, in the case of the critical modernist approach, deconstruct the 'old' in order to reconstruct the 'new' (Peet, 1999). However, although critical modernist developmentalists such as Peet advocate a change in the balance of power in favour of local people, this approach still retains a sense of universalism. Moving away from universal approaches Popular Development instead recognizes the need to contextualize development in space and time. Popular Development contrasts with critical modernist developmentalism with the former emphasizing social relations and human nature as unique and diverse and the latter emphasizing material goods and progress. However, both approaches adopt a postmodern critique of conventional development theory and whilst their main focus is inherently different, merging both approaches provides the potential opportunity to address both the complex and diverse political nuances of development, whilst embracing local knowledge and processes of scaling-up.

Specifically, Popular Development (Brohman, 1996) recognizes the complex and diverse nature of third world problems and advocates a more reflexive and flexible approach. Despite earlier criticisms (Bebbington & Bebbington, 2000) it emphasizes the importance of practice informing theory through a process of scaling-up. Furthermore, it emphasizes the need to reconsider those elements traditionally (or often) "excluded from analysis" because their subjective nature is complex or messy. Most importantly, it recognizes that development is first and foremost about people and that reducing it to what can only be measured empirically is to reduce those people at the very heart of development to mere objects (Brohman, 1996, p.327).

> "Many of the errors of development have followed from trying to apply blueprint approaches, which work with controllable and predictable things, to processes with uncontrollable and unpredictable people." (Chambers, 1997, p.190)

Not surprisingly Popular Development shares certain ideals central to a participatory approach (Chambers, 2005) such as "'bringing the actors back' into development work in their own economic, political and sociocultural contexts" and the need for researchers to be self-aware and self-critical in an attempt to avoid "preconceived notions and conceptions" (Brohman, 1996, p.327). Brohman believes "that interdisciplinary approaches to development have yet to gain much respectability in an intellectual environment which tends to favor more 'scientific' and 'rigorous' research in disciplinary specializations" (*ibid.* p.325). My research also aims to adopt a reflexive and interdisciplinary approach to data collection at the community scale that recognizes traditions of the natural and social sciences, their respective roles in development, and more importantly, their ability to inform one another.

As suggested above and proposed again within the framework of my research, central to development are the people themselves, and therefore, it is crucial that development theory understand "what it is to be human" (Brohman, 1996, p.328). Central to human processes are social relations, interactions and societal values, which may be unique to a society or individual and therefore, the appropriateness of a universal approach is raised again. This is particularly relevant in light of the WPI's attempt to compare and contrast communities and regions using similar (or universal) indicators of water poverty. Furthermore, this again underlines the importance, in fact the sheer imperative, of a development approach that not only engages with, but also comes from local people and local knowledge. With most development being carried out by those least in need, myself included, rather than see ourselves as part of the solution, given the authority and power historically granted us, we need to understand our role as part of the problem. As proposed by Chambers (1997), the role of the development worker, or in my case, researcher, should be interpreted as that of a facilitator but, paramount to the success of development, should also be seen as that of a student. This is particularly relevant to strategies devised to assess local perceptions of water poverty, and in particular my role in focus groups designed to elicit the community voice.

Locally developed alternatives focused on bottom-up approaches are however not problem free and often tend to neglect the "larger structural and macro-policy concerns" focusing instead "on isolated problems of survival, ignoring more fundamental issues concerning the systems that generate increasing poverty and inequalities in the first place" Brohman (1996, p.273). To avoid such problems Brohman suggests, "local popular movements need to 'scale-up' their operations to create micro-macro linkages that can affect the overall framework of development" (Brohman, 1996, p.273). Furthermore, a localized, human-centred approach does not preclude the relevance of, and certainly need for, empirical analysis or even extractive data collection, both essential to the success of my research. Instead methods and techniques should be used as appropriate with the decision of what is appropriate and relevant being informed and determined within the local context. In addition, the importance of indigenous experiences cannot be understated. Indigenous forms of knowledge and technology must be recognized as viable options within alternative development as local people often have a better understanding of local complexities and systems. However, historically local populations have been forced to accept a pre-determined blueprint of development thrust upon them through conventional top-down approaches devised by experts and based on western ideals (Brohman, 1996; Chambers, 1997). Indigenous knowledge provides a tremendous opportunity for advancing alternative development approaches with traditional societies often more flexible and amenable to the complexities of local development, leading to more appropriate and meaningful programmes. Local knowledge, however, is not without its disparities and as Simon (1997) and Brohman (1996) remark, we must be aware of its limits and careful not to romanticize its notions. Drawing on writings by Escobar, Simon (1997) points out that indigenous structures are, after all, subject to power relations and external influences.

Finally, in terms of defining development Simon (1997, p.184) reminds us "definitions are contextual and contingent upon the ideological, epistemological or methodological orientation of their purveyors." He then provides his own well thought definition of human development as:

> "[T]he process of enhancing individual and collective quality of life in a manner that satisfies basic needs (as a minimum), is environmentally, socially and economically sustainable and is empowering in the sense that the people concerned have a substantial degree of control (because total control may be unrealistic) over the process through access to the means of accumulating social power" (Simon, 1997, p.185).

Finally, he goes on to state, "given its important qualitative and subjective content, this broad definition naturally defies easy quantification or cardinal measurement" (*ibid.*). These are the dual considerations of this research.

2.5 A Reflexive and Participatory Approach to Applied Development Research

> "The means through which we collect data has an effect on the findings." (Laws, 2003, p.281)

> "The development researcher needs to be more eclectic than is the case with research in more familiar terrains, more sensitive to cultural and ethical issues, and more willing to re-design research strategy as the research project evolves." (Scheyvens & Storey, 2003, p.19)

The idea of reconciling these two statements may at first appear overwhelming, yet they represent the richness, diversity, and above all, uniqueness of development research. Methods in development research have changed over time alongside development theories with methods now as varied, if not more so, than the theories themselves. Development research methods aligned with a modernization approach and focusing on economic growth have come under fire in much the same way as their theoretical counterparts being accused in some academic circles "as totalizing strategies" (Scheyvens & Storey, 2003, p.22). In much the same way that conventional development theories, especially those focused on modernization, have for many years been the dominant theoretical approach to development, empirical and quantitative analyses have been, and in many cases still are, the prevailing scientific methodological approach to research, development or otherwise.

However, as new alternatives to conventional development theories have emerged we have seen a distinct change in methodological frameworks. Research methodologies can be broadly summarised into two categories, early and later approaches, with the former being associated with "economic growth" and "quantitative approaches" whilst the latter is associated with "more humanistic approaches" giving rise to "participatory and qualitative lines of investigation" (Desai & Potter, 2006, p.7). In contrast to advances in development theory whereby new alternatives tend to reject conventional ideas discarding whole notions in their entirety, research methodologies have historically sought to inform one another leading to a diverse methodological toolkit enabling researchers to select those methods and techniques most appropriate to the task at hand.

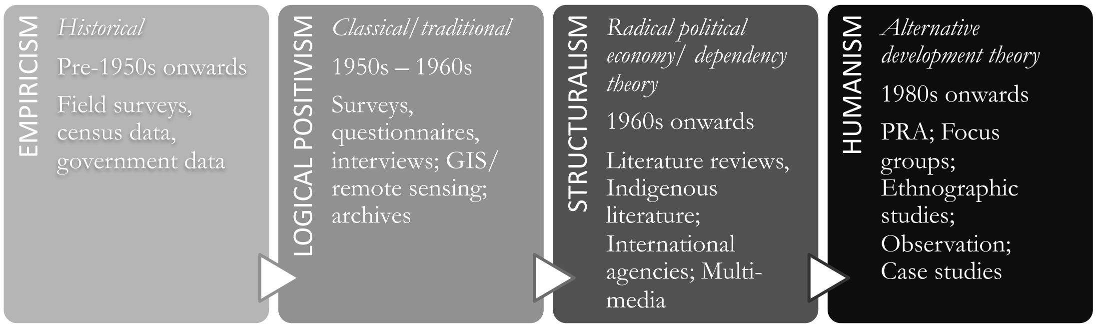

Figure 3 Historical philosophical and associated methodological approaches to development research (Source: Desai & Potter, 2004, p.7)

Critical to development research is the recognition that there is no single universal methodology and some would argue, "singular theories and conceptualizations are too limiting by far" (Desai & Potter, 2006, p.9). There is no justifiable reason why a number of methods cannot be successfully used with the appropriate method being selected for the appropriate problem, and in any case, qualitative and quantitative techniques are not mutually exclusive (Laws, 2003; Scheyvens & Storey, 2003). A single universal methodological framework would be contrary to the very interdisciplinary nature of this, and much, development research. Drawing on themes from both natural and social sciences therefore requires an interdisciplinary methodological framework, based on a reflexive approach and combining a number of quantitative, qualitative and participatory techniques. Applied successfully, an interdisciplinary methodology has the built-in ability to crosscheck information and triangulate results, while the diverse forms of information can be readily disseminated to different audiences (Chambers, 1997; Mayoux, 2006).

My research is predominantly situated within the aforementioned humanist philosophical approach aligned with alternative development theory yet, recognizing the interdisciplinary nature of this research, also draws on other philosophical approaches and their associated methodologies appropriate to the stage of research being carried out. Certain aspects of this research lend themselves naturally to a quantitative (empirical) approach whist others, embedded within the reflexive process and people-centred focus of the research, imply the need for a qualitative approach. For example, the WPI calculated at the state scale (Chapter 4) relies wholly on secondary quantitative datasets such as the national census and government records. Conversely, with few exceptions, data at the household level (Chapter 7) are derived almost wholly from primary sources and approaches to data collection include a number of qualitative and participatory techniques, such as participant interviews and focus groups. Using a variety of methods from different philosophical approaches is in keeping with Laws' advice that "case study research is potentially vulnerable to the charge that the investigator has looked only to see what they wanted to find, [and it] is therefore important to triangulate the research process by looking at the same issues in different ways, collecting data of different kinds from different people" (Laws, 2003, p.348). In terms of qualitative approaches to data collection and analysis more specifically, Mayoux (2006, Chapter 13) describes it as aimed at a "holistic understanding of complex realities and processes where even the questions and hypotheses emerge cumulatively as the investigation progresses." This definition fits well with the overall aims of this research. When deciding to use quantitative versus qualitative methods, Mayoux (*ibid.*) puts forward a series of critical questions for consideration:

> "1. For which questions is quantification needed, and with what degree of precision? For which questions is qualitative information more useful or sufficient; and
>
> 2. For how many people is information required to draw reliable practical conclusions? Which particular people are most important for the analysis or are likely to be able to give reliable information?"

Responses to these questions have been used to inform decisions surrounding the selection of appropriate variables used to calculate a water poverty index as well as the specific methods designed for their data collection.

In addition to considering methodological approaches appropriate for applied development research, due consideration for research type, specifically pertaining to case study research, is also considered. Research or more accurately researchers are often described as 'either/or' encouraged to position themselves within a specific discipline and align themselves with specific types of research. This narrow view leads to preconceived notions and contradicts the very nature of interdisciplinary research.

Nevertheless, it is important to carefully reflect upon one's position associated with different research types. Given the nature and context of this research, it would however be more appropriate to view contrasting research types as a continuum. Using the seven pairs of research types recommended by Blaxter *et al.* (2003, p.23), my research positionality prior to conducting fieldwork is depicted in Figure 4.

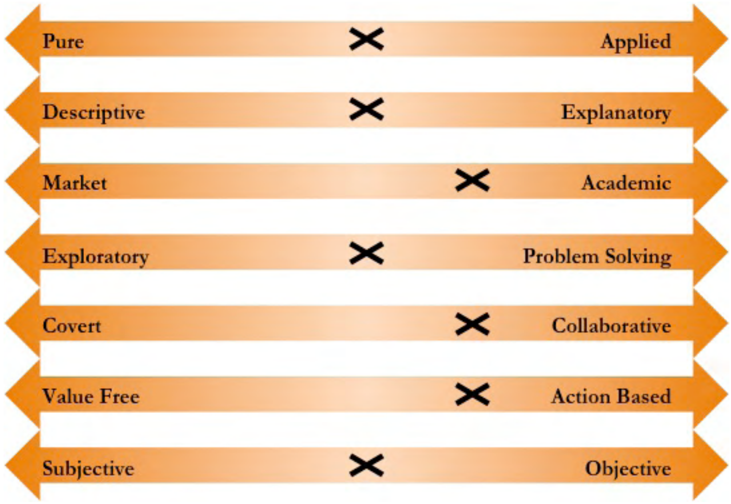

Figure 4 Research positionality continuum prior to conducting fieldwork

There are a number of publications citing numerous research methods applicable to development (Chambers, 1997; Laws, 2003; Desai & Potter, 2003) yet perhaps more importantly a number of factors should be considered before determining the appropriateness of any one method, particularly amongst participatory techniques. Central to development research are "the wishes of the community members" themselves (Laws, 2003, p.350). The level of commitment, time and knowledge of local participants cannot be pre-determined hence the need for a high level of flexibility and reflexivity within the research design process.

With participatory approaches having been developed only recently, they are subject to much debate and contention, in particular the concept of Participatory Rural Appraisal (PRA) as described by Chambers (1997). In terms of the present research, while the history and spread of PRA have been generally informative, it should be made clear that *PRA neither forms part of the specific theoretical framework, nor strictly speaking, the methodological approach*, and therefore this research does not directly engage with the debate surrounding PRA as a theoretical mandate for all development research. In any case, Chambers would describe the end result of PRA as empowerment of the local people and despite a personal empathy for this approach the reality of the context of the present research within the prescribed formula of a PhD thesis is predominantly confined to extractive data collection. For this reason, this research cannot claim to be using a PRA approach. However participatory *techniques*, as alluded to above and currently in use by most development researchers, workers and NGOs, instead are integral to the methodological framework of this research. Notwithstanding, this research aligns itself with certain practitioners who view the participatory approach as a standard for whom the question is not "whether to use PRA processes or methods" but "more how well or badly they will be used" (Chambers, 1997, p.115). Finally, this research borrows *concepts* of PRA critical to the success of participatory techniques, specifically its focus on self-critical behaviour and researcher attitudes, carried out with variable success.

Much of PRA draws upon its predecessor, Rapid Rural Appraisal (RRA). According to Chambers (1997, pp.106-115), "the words 'participation' and 'participatory' entered the RRA vocabulary in the mid-1980s." Many practitioners "consider it important to distinguish between the two" although Chambers believes they are part of a continuum. This research shares the view of some practitioners, as described by Chambers, that "the term RRA should be used for data-collecting activities, while PRA should be reserved for an on-going empowering process." Using these definitions, strictly speaking, this research is more closely aligned with RRA. Nevertheless it is important to note that in reality, "there is an overlap of methods… and the two approaches can be used as part of one another" (Chambers, 1997, pp.106-115).

Describing participation, Chambers (2005, pp.101-110) notes there are any number of definitions of 'participation' and suggests, "it has no final meaning" but is "mobile and malleable." More important than pinning a specific definition on participation is recognizing there are different "types and degrees" instead (*ibid.*). Notwithstanding the aforementioned strict definitions of RRA and PRA, this research draws upon both approaches borrowing methods from each as appropriate to the immediate task at hand. In particular, there is a strong emphasis upon eliciting information regarding water poverty from local people's knowledge in an attempt to (re)construct local realities as a measure of the effectiveness of the WPI to represent community perceptions of water poverty. Likewise, this research draws upon philosophies inherent to PRA approaches that stress behaviour and attitudes, especially those of the researcher, a shift from "appraisal to analysis" and finally "in analysis, from practice to theory, finding what works, and asking why" (Chambers, 1997, pp.106-115). At times, my role will be that of a data collector, eliciting information from local people, for example, when conducting informal interviews. At other times, I will act as a facilitator, for example, when participating in focus groups, providing the tools required to indicate rainfall patterns and/or domestic water availability or well-being rankings to indicate levels of deprivation according to local criteria. Still, at other times, my research will be conducted independently, such as when analyzing water quality under laboratory conditions.

Common Pitfalls of Participatory Research

Recognizing common critiques of participatory approaches, Chambers claims the "rapid adoption of the PRA label" and the rush to go "instantly to scale" without the necessary expertise or qualifications provided the main justifications for much of the earlier criticisms surrounding PRA (Chambers, 2005, p.102). Broadly, he suggests PRA spread too far too quickly, without the understanding needed to employ it effectively (Chambers, 1997, pp.201-211). Brohman (1996) supports Chambers' arguments that it is not participation itself that has failed but the lack of appropriate implementation, if any implementation at all. This may be because of the dominance of development programmes and policies by the state or outside agencies, control of programmes by the local elite, lack of understanding of local structures of society and institutes (hence not reaching the poorest of the poor who are internally excluded), and the failure to consider local complexities (communities are not homogenous). Some would suggest additional areas of debate and contention associated with participatory research include the challenges of measuring the immeasurable and the general reflexivity and openness associated with qualitative development research that can lead to a lack of overall focus (Mayoux, 2006, p.119).

Participatory research designed to assess local priorities emphasizing a bottom-up approach raises questions surrounding micro-macro scale linkages. Brohman (1996, p.251) would argue that participation "as an inherently political act can never be neutral." Additionally, bottom-up approaches to development research are not problem free and often neglect "larger structural and macro-policy concerns" and "ignor[e] more fundamental issues concerning the systems that generate increasing poverty and inequalities in the first place" (*ibid.* p.273).

As this research is concerned with undertaking applied development research, it limits itself to discussing the specific problems associated with the participatory techniques and cultural constraints associated with this project. Specifically, from a more practical perspective Mayoux (2006, p.123) notes "participatory research may raise unrealistic expectations… people may be made more vulnerable by expressing their views and problems publicly. Both factors may lead to unreliable information, and undesirable consequences." Chambers (1997, p.214) also cites the **management of expectations** as one of the more serious and common problems arising with field practice and ethics of participatory techniques. This problem is particularly relevant to my study and inevitable given the context, timeframe and nature of PhD research. Combating this particular problem requires the researcher to be continuously explicit, open and honest with community members and participants and constantly attune to any changes in expectations. Community gatekeepers can assist in managing the overall process and steps taken to mitigate expectations should include participating in community meetings in order to provide a thorough explanation of the purpose of any study before undertaking informant interviews. Brief explanations of the nature of the study and purpose of participation should also be given to each informant prior to beginning each interview. Smaller modifications specific to this research context were also made throughout the research process, including the need to modify certain language i.e. avoiding the term *proyecto* commonly used locally to refer to infrastructure projects.

Other pitfalls of participatory techniques recognized by Chambers (1997, p.214-) and of particular relevance to this research include:

Dominance. Scheyvens & Storey (2003, p.18) note "researchers from the 'first world' will often enter local society further up the hierarchy than their respective position at 'home'… [and] the consideration of this should not only influence the practice of doing research but should explicitly be fed into design." Dominance should be anticipated as an unintentional consequence and constraint to fieldwork especially in light of the status and power often afforded outsiders. Combating dominance requires a sound knowledge of locally accepted behaviour and of participatory techniques appropriate to the local context. Working alongside gatekeepers provides the knowledge and familiarity necessary to help mitigate this problem.

Gender and upper-to-upper bias. Chambers notes that it's often easier to interact with the most visible/accessible community members who often are men or those who are better off. This gender and upper-to-upper bias needs to be carefully offset and taken into consideration during the research design process. In this study, female informants were specifically targeted for their knowledge of domestic water supply and use at the houseld scale and informant interviews were conducted with adult females. It may be easier to combat gender bias as a female researcher creating easier access to certain groups (for example, women and children) than a male counterpart. Lastly, personal perspective, awareness and experience with gender bias in a society where bias against women is perpetuated globally may enable a female researcher to be much more critically aware of any unreported gender bias.

Taking without giving. According to Chambers (1997, p.214-), doing PRA for extractive research raises "ethical questions about unequal relationships and the costs of people's time." Along with managing unrealistic expectations, this was anticipated to be the most challenging aspect of this research, both from a practical and moral standpoint. As described previously, the very nature of this research, confined by the constraints of the PhD process, is extractive and despite a personal empathy with the concept of empowerment, the reality of this research is otherwise. Faced with this dilemma, I can only attempt to be as open and honest as possible about the nature and purpose of my presence and study. Assisted by the community gatekeepers, I will strive to ensure community participants and non-participating community members are fully aware of these limitations.

All of the aforementioned problems were particularly evident in this research. Despite my attempts to manage participant expectations, the nature of my research inevitably raised community hopes, conceivably leading to exaggerated results. Furthermore, a number of authors highlight the problem of power relations, which risk permeating even the best-designed participatory research, manipulating results (Simon, 1997; Mayoux, 2006). Less of a criticism than an inevitable pitfall of participatory research is the need for researchers to offset their biases described by Chambers as "being self-critically aware in our biases and behaviour and learning" (Chambers, 1997, p.115). In fact, Chambers goes on to add "in good PRA, participatory behaviour and attitudes matter more than methods" (*ibid.* p. 212). In short, development research is complex and even the best research techniques cannot withstand the unpredictability and occasionally, unreliability, of results. Human research is fraught with subjectivity from both the research participants and the researcher. The context of a PhD implies time is a critical constraint and unlike less adventurous projects, when all is said and done there is no opportunity to rerun an experiment, return to the laboratory, or revisit archives. In an attempt to respond to all of these dimensions, this research necessarily adopted a reflexive and participatory approach to the assessment of water poverty at the community scale in Mexico, while employing mainly empirical/quantitative methods to its assessment at the state scale.

This chapter has sought to provide a clear and concise theoretical framework within which this research is situated. It has demonstrated some of the failings of traditional measures of water scarcity paving the way for an alternative approach. Describing the inception of water poverty and the WPI through a historical lens and presenting evidence from case studies, which have sought to advance the WPI should provide the reader with the theoretical and practical knowledge of water poverty essential to understanding this research. Equally imperative is an understanding of alternative development theory and this chapter has sought to highlight the impetus for its development and the main tenets supporting a new approach to development research. A sound argument for adopting a reflexive and participatory approach has also been presented as well as a discussion of some of the more common pitfalls associated with this genre of research. The next chapter, Chapter 3, moves beyond the theoretical realm of this research to provide the more practical elements associated with the chosen research methodology.

CHAPTER 3 RESEARCH METHODOLOGY

This chapter provides a simple explanation of the WPI equation before outlining the research methodology used to conduct this research. A detailed explanation of data collection efforts and subsequent water poverty calculation at the macro scale is first provided followed by a similar explanation of methodologies employed at the micro scale. Next the methodology used to analyse water quality at the community scale is explained followed by a summary of the two focus groups conducted in the second of two communities assessed.

3.1 The Water Poverty Index Equation

As discussed in Chapter 2, traditional water scarcity assessments emphasize the vulnerability of communities to physical water scarcity and fail to consider the impacts of social, economic and political determinants, such as poor water quality, access to water, political and institutional arrangements and economic constraints, all major contributing factors to the provision of water. These variables are often qualitative in nature and therefore difficult to value empirically. The WPI attempts to reconcile these elements with physical water scarcity in order to provide a more meaningful and realistic representation of water poverty. It strives to respond to the social needs of water management by ensuring "transparency of the process", by "empowerment of local communities" (Sullivan *et al.*, 2003, p.191) and by utilizing indicators which are determined locally and not by "researchers with no local knowledge" (Sullivan *et al.*, 2006, p.415). Through the use of a set of standard indicators, the authors claim that community performance can be assessed over time and compared to other localities.

The WPI is a composite index based on the HDI expressed as follows:

$$WPI = \frac{\sum_{i=1}^{N} w_i X_i}{\sum_{i=1}^{N} w_i}$$

where, "*WPI* is the water poverty index for a particular location, *Xi* refers to [indicator] *i* of the WPI structure for that location, and *wi* is the weight applied to that [indicator]. Each [indicator] is made up of a number of [variables], and these are first combined using the same technique in order to obtain the [indicators]" (Sullivan *et al.*, 2003, p.192).

Indicator and variable values are normalised such that each score falls between 0 and 100 using the Min-Max normalization technique which assigns the lowest ranking country, state or community a score of 0 and the highest ranking country, state or community a score of 100. Low scores are indicative of water poverty. A full explanation of calculating a water poverty index is described in detail in Chapters 4 and 7 when it is used to assess water poverty at the state and community scale.

3.2 Data Collection and Water Poverty Calculations

Macro Scale Methodology

The WPI was first constructed to develop an international comparison of water poverty across 147 countries (Lawrence, *et al.*, 2003) and later developed for application at the community scale (Sullivan *et al.*, 2003). As a result of the findings of the latter study, it has been suggested that the WPI is more appropriate for use at the community scale. Despite this assertion, the vast majority of studies have since been carried out at the macro (regional, state, country) scale. Also, certain critiques of the WPI and its use at the macro scale, in particular the problem of inter-relation amongst indicators, remain unresolved. Furthermore, AWR continues to be evaluated at the macro scale, or in the case of Mexico at the water basin level. Thus, for the purposes of this study, it is essential that water poverty first be analyzed at the macro scale.

In my research, I have attempted to maintain the integrity of the original WPI by using the same, or very similar, data as those employed by the original authors at the international scale to calculate water poverty at the macro (state) scale. Notwithstanding, some key differences prevail. Namely, the objective of the present study is to calculate water poverty in a national context thus preference was given to readily available nationally sourced data, hence some indicators have been modified in accordance with local methodologies and data availability. A list of indicators used in the original study and those used in the present research is presented in Table 1 below.

Data used to calculate the WPI at the macro scale were derived from three principal sources:

- *Comisión Nacional del Agua* (CONAGUA) [National Commission for Water]
- *Instituto Nacional de Estadística y Geografía* (INEGI) [National Institute of Statistics and Geography]

- *Secretaría de Medio Ambiente y Recursos Naturales* (SEMARNAT) [Secretary of Environment and Natural Resources]

Table 1 A comparison of variables selected for use in calculating the Water Poverty Index at the macro scale

WPI Component	International comparison (Lawrence, *et al.*, 2003)	Mexico (Fenwick, 2010)
Resources	Internal Freshwater Flows External Inflows Population	R1: Ratio of total water withdrawals to available freshwater resources R2: Ratio of treated residual waters to total water consumed
Access	% Population with access to clean water % Population with access to sanitation % Population with access to irrigation adjusted by per capita water resources	A1: % Population with access to piped water A2: % Population with access to sanitation
Capacity	PPP per capita income Under-five mortality rates Education enrolment rates Gini coefficients of income distribution	C1: Per capita income ($MXN) C2: Under-one mortality rate C3: Literacy rate
Use	Domestic water use in litres per day Share of water use by industry and agriculture adjusted by the sector's share of GDP	U1: Domestic water use in litres per day U2: Share of water use by industry adjusted by sector's share of GDP U3: Share of water use by agriculture adjusted by sector's share of GDP
Environment	Water quality Water stress (pollution) Environmental regulation and management Informational capacity Biodiversity based on threatened species	E1: Soil degradation/ erosion E2: Water pollution E3: Urban municipal waste collected as a % of urban municipal waste generated

Specifically, this research relied on three core publications, Estadísticas del Agua en México Edición(es) 2007/ 2008 [Water Statistics in Mexico], II Conteo de Poblacíon y Vivienda 2005 [2005 National Census], Informe de la Situación del Medio Ambiente en México Edición 2008 [Report on the State of the Environment in Mexico] (cited in full in the Bibliography). One of the key reasons Mexico was selected to carry out this research is because of the richness, availability and accessibility of data. When this research began in 2006 not all data were easily accessible but by its culmination in 2010, all of the data had been made available online, a testament to Mexico's adherence to its own access to public information laws and to a culture that promotes the widespread access to information that might otherwise be deemed sensitive in alternative societies. Whilst the mere availability of data does not necessarily imply its reliability, the willingness and amicable nature of the different agencies contacted at various stages of the research contributed greatly to its success and should be commended.

The five indicators of the WPI are comprised of a total of thirteen variables. Data for eleven of the variables (R2, A1, A2, C1, C2, C3, U1, U2, U3 and E3) were reported at the desired scale (state) while data for the two remaining variables were derived from the hydrological administrative unit (RHA). Where necessary a detailed description for these calculations is provided in the relevant indicator section in Chapter 4.

The original WPI methodology normalises variable data using the Min-Max method. This complies with recommendations in the Handbook on Constructing Composite Indicators (Nardo *et al.*, 2008, p.20), which states "normalisation should be carried out to render the variables comparable" although it should be noted that, strictly speaking, this is only necessary when data are reported with different units and/or scales. Using the Min-Max method, each variable score v_i^t for a given state (community or household) *i* at a given time *t*, is modified as follows:

$$v_{ic}^t = \frac{x_i^t - \min(x_c^t)}{\max(x_c^t) - \min(x_c^t)}$$

Adapted from Nardo *et al.*, 2008

where $\min(x_c^t)$ and $\max(x_c^t)$, are the minimum and maximum variable scores across all states (communities or households) *c* at time *t*. The normalised variable score v_{ic}^t thus has a value between the minimum score of 0 and the maximum score of 1. Because the normalization procedure can be sensitive to extreme outliers (Nardo *et al.*, 2008) they are first partially corrected using a methodology similar to that applied in the Environmental Sustainability Index (Nardo *et al.*, 2008, p.84) whereby "any observed value greater than the 97.5 percentile is lowered to match the 97.5 percentile [and] any observed value lower than the 2.5 percentile is raised to the 2.5 percentile."

In the context of the WPI, outlying values are often significant, particularly at the household level although their meaning is most relevant to the specific state, community or household being analyzed and not the group as a whole. Therefore this study also uses the 97.5 and 2.5 percentile as the most appropriate boundaries for variable scores. This method recognizes the importance of outliers by limiting their exclusion to only the most extreme cases while controlling their impact on the normalization procedure.

This same logic is used to calculate a water poverty index at the micro (community) scale.

Variable scores for a particular indicator are summed and averaged to arrive at an indicator score. Indicator scores are then multiplied by 20 and summed to arrive at an overall WPI score between 0 and 100. This last step is presumably esthetical and the present study adopts the view that unnecessary manipulation of data only serves to increase the potential for human error. Therefore, WPI scores presented in this research are reported between 0 and 1 representing the least and most desirable scores respectively. A detailed explanation of each variable, the justification for its inclusion (or exclusion) and its calculation is provided in the relevant indicator section in Chapter 4.

It is difficult to draw precise assumptions about the relationship between indicator scores and overall WPI and what each might say about the other without further statistical analysis. This can be done by undertaking bivariate correlations and using correlation coefficients to assess the strength of associations. Depending on the choice of statistic, data should first be screened for outliers, normality, and linearity. Outliers were identified using box plots constructed in PASW Statistics 18.0 (formerly SPSS) and defined as +/-1.5IQR (with extreme values defined as +/-3IQR). It should be noted that the purpose of removing outliers is solely to account for this sensitivity and improve the accuracy of statistical analyses. Their importance is still noted in terms of individual indicator scores and rankings were therefore not reconstructed on this basis. Normality can be assessed visually by examining histograms. A less subjective test proposes multiplying the standard errors of Skewness (a measure of how the curve deviates to the left and right of its normal centre) and Kurtosis (a measure of how the curve deviates above and below its normal peak) by two to determine the +/- range within which the values for Skewness and Kurtosis should fall if data are distributed normally.

To date most case studies analyzing or using the WPI present correlation matrices in an attempt to demonstrate the strength of relationship between indicators. However it should be noted that this is not necessarily appropriate and in fact, in some cases is wholly inappropriate. Pearson's correlation coefficient (r) is only suitable for describing linear correlations and data must be assessed for linearity in the first instance by examining scatter plots. If a linear relationship does not exist, Pearson's correlation coefficient should not be used. That being said, the WPI is a composite index constructed such that an increase in indicator score corresponds to an increase in WPI score. Thus the relationship between each indicator and overall WPI is considered linear and Pearson's correlation coefficient can be calculated regardless of existing datasets and in this case, r does in fact describe the strength of each relationship. The same cannot however be said for relationships between indicators and their scatter plots must first be assessed. When analyzing small datasets (<50 cases) it is often more appropriate to use Kendall's correlation coefficient (tau-B), which is "better behaved" and whose probability is more reliable under such circumstances (Kinnear & Gray, 1999, p.289). Both statistics have been applied in this research where appropriate.

At the macros scale, the predictive ability of each variable on WPI scores can then be analyzed by running a multiple linear regression analysis, which provides some insight into the contribution of each of the 13 variables on the WPI in the current model and their relationship to one another. As a composite index, the WPI may be susceptible to double-counting as a result of correlated variables. This may be resolved in part or in whole, by the exclusion of highly correlated variables. The determination of which variables to exclude from future calculations can be guided by the results of the aforementioned correlation coefficients as well as the regression analysis. This is in fact the case for water poverty analyses at the macro scale and the application of this approach, and its results, are discussed in detail in later sections.

Micro Scale Methodology

Although data are collected at the household level census information is not reported below the municipal scale therefore calculating a water poverty index at the micro scale required an intense data collection process in both communities. First and foremost this process would not have been possible without the assistance of gate-keepers and translators who assisted in forging community relationships without which entry into the communities would otherwise have been difficult and in the case of Pozuelos most certainly impossible. In the case of Pozuelos, *Pronatura Sur*, a national civil association charged with environmental protection, provided both gate-keeping and translation services[1]. In the case of El Mash, the *Comisión Nacional para el Desarollo de los Pueblos*

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[1] Translation services were provided free of charge by Pronatura Sur in Pozuelos by a male, indigenous community worker from outside the municipality who had an existing relationship with the community. In the case of El Mash,

Indígenas (CDI), the National Commission for the Development of Indigenous Communities (an independent government agency), assisted with site selection and subsequent translation services. A detailed questionnaire comprising 56 questions in total was designed to elicit information relevant to calculating a water poverty index as well as supplementary information regarding community water supply, health and hygiene in general. A copy of the final questionnaire is included in Appendix A. The original survey questions were, for the most part intuitive, yet inspiration was drawn from previous research that relied upon extensive surveys pertaining to community water supply (Drangert, 1993) and from the WPI literature (Sullivan *et al.*, 2003). As fieldwork was conducted first in Pozuelos staff at *Pronatura Sur* reviewed the questionnaire in the first instance and minor revisions were made based on their recommendations. This preliminary review also provided the opportunity to review the use of appropriate language and discuss entry into the community. Arriving at a final version of the questionnaire was however a reflexive process and survey questions changed and developed organically with use and over time such that small variations exist between the first survey employed in Pozuelos and that used in El Mash. This process was taken into consideration when selecting the variables for use in calculating a water poverty index at the community/ household scale and careful consideration was given to ensure the final variables selected for use were as consistent as possible across both sites.

Generally speaking, residents of Pozuelos were comparatively more introverted than those of El Mash and more wary of outsiders despite, or perhaps because of, having been the subject of several anthropological studies and having participated in a development project with *Pronatura Sur*, described in detail below. Thus entry into Pozuelos was somewhat precarious and warranted numerous visits and conciliatory meetings before fieldwork could begin. Once fieldwork began, however, there were no impediments to its progress. Entry into El Mash was very straightforward and participants were ready and willing to the extent that some families were disappointed not to be included in the survey. Surveys were initially undertaken with a pair of appointed community observers (described below) who also served as community guides however as the local terrain became familiar, fieldwork continued independently.

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the services of a female, indigenous community worker from outside the municipality and with no prior relationship with the community were informally sub-contracted from the CDI to act as translator and focus group moderator.

During the period when fieldwork was undertaken, there were 97 households in Pozuelos (as opposed to 101 listed in the 2005 Census). Sample size was determined such that the intended sample size of 49 would allow for a margin of error of 10% and a confidence level of 95%. In actual fact, 44 households were surveyed, increasing the margin of error to 11%. Notwithstanding, a typical statistical approach to sample size calculations cannot be applied accurately to this community given the sample was not random. Instead, the majority of interviewed households comprised those that had a previously existing relationship with Pronatura. Most recently, Pronatura worked with community members to install improved stoves. These are closed units which provide a hotplate surface for cooking, a small entrance at the front of the unit for inserting firewood, and a chimney for extracting smoke outside. The main purpose of these units is to improve the health of family members (specifically to mitigate respiratory illnesses of women and children) predominantly by the addition of a chimney used to extract smoke as opposed to traditional cooking methods carried out over an indoor, open fire. Additionally, less fuel is required to operate these stoves. The recipients of the improved stoves were selected based on their willingness to participate in the study suggesting they may have a higher level of education than alternate households. Furthermore, it is probable that over the course of the working relationship with Pronatura, their presence impacted upon household livelihoods through improved education, by way of training and other immaterial contributions. Therefore, it is conceivable that this particular sample does not represent the community as a whole. However, my observations would suggest that all other facets of household life remain comparatively equal. Certainly in terms of water resources and access to water and sanitation, the community is reasonably homogenous. This is highlighted by the similar findings of the 2005 Census and the present study.

Surveys were carried out over the course of three months between May and early July 2008. Interviews were carried out with adult females across the 44 selected households. Respondents ranged in age from 20 to 74 with a mean age of 41. All but one of the respondents was a housewife with the remaining respondent being the daughter of a widower. The following provides a descriptive overview of participants surveyed.

Table 2 Community demographics in Pozuelos

Identifier	Response	Frequency	Percentage
Gender	Female	44	100
Age (years)	Range	24 - 47	-
	Mean	41	-
Household position	Housewife	43	98
	Daughter	1	2

During the period when fieldwork was undertaken in El Mash, there were a total of 77 households (as opposed to 62 listed in the 2005 Census). In order to achieve a margin of error of 10% and a confidence level of 95%, a sample size of 43 was needed. In actual fact, 45 households were surveyed, leading to a slightly improved margin of error of 9.5%. Contrary to the sample selected in Pozuelos, this sample was completely random. Community members provided me with a hand-drawn map, showing all of the occupied households within the community along with the corresponding names of their respective male heads of household. The households were then numbered in sequential order from M01 to M77. A randomly generated numbers list was created using Microsoft® Excel® 2008 for Mac whereby the number 1 represented household M01, number 2 represented household M02, number 3 represented household M03 and so on and so forth. The first 45 randomly generated numbers (excluding duplicates) were then used to select the sample population. Surveys were carried out over the course of three weeks during the month of August 2008. Initially, two male members of the community observed the survey process, however, as the community's confidence improved with time, subsequent surveys were carried out without supervision. When the two observers were present, they were mindful not to impede the survey process and to mitigate the impact their presence may have, often remaining at a distance. Most respondents generally appeared aloof to their presence. Those who were surveyed independently indicated emphatically they would not have replied any differently had the observers not been present. As a whole, the community was very welcoming and demonstrated a willingness to participate not seen in Pozuelos. In fact, as previously mentioned, several community members were disappointed to learn they weren't included in the sample population. Whilst this reaction is almost certainly due in part to the expectation that something positive would arise from their participation, these generalizations are characteristic of the cultural differences observed in both municipalities as a whole.

Table 3 Community demographics in El Mash

Identifier	Response	Frequency	Percentage
Gender	Female	45	100
Age (years)	Range	19 - 92	-
	Mean	40	-
Household position	Housewife	44	98
	Daughter	1	22

Interviews were carried out with adult females across the 45 selected households. Respondents ranged in age from 19 to 92 with a mean age of 40. The 92-year old respondent is an anomaly with the maximum age otherwise being 67. All but one of the respondents were housewives with the remaining respondent being a daughter who resided at home and answered on behalf of her 74-year old mother. The following provides an overview of participants.

In both communities, where a household was unable to provide an accurate response, unknown values were usually replaced with the community average for the purposes of calculating a water poverty index. This has the effect of exacerbating extreme values, but as the purpose of this study is to analyze water poverty at the community scale, given the choice between excluding entire households from the study completely or removing a small number of extreme outlying values, the latter was considered more desirable.

Only a limited number of studies have been undertaken at the micro (local) scale using the WPI and it is partly for this reason the variables used to calculate the WPI remain very loosely defined. The original authors, following "intensive participation and consultation" with a wide body of experts and interested parties, developed the WPI methodology for use at the community scale through pilot projects (Sullivan *et al.*, 2003, p.189). Recently Giné & Pérez-Fouget (2009) developed an "enhanced Water Poverty Index" subsequently tested at the local scale in Bolivia. The present research draws upon variables used in both of these studies listed in Table 4 as well as alternative variables of relevance to the present case studies. Of particular note is the inclusion of qualitative indicators recommended by the original authors. The selection of variables was based primarily on data availability bearing in mind the intention to create a simple tool for use in field-based assessments. Furthermore, each variable must be *fit for purpose*, which explains the occasional use of different variables between communities. Of significance is the difference in water distribution between Pozuelos and El Mash. Any assessment pertaining to water supply must take these differences into consideration and adapt itself accordingly. Thus whereas water resources availability is calculated based primarily on groundwater recharge in Pozuelos, it is based wholly on precipitation in El Mash a reflection of the first community's reliance on spring water and the second community's reliance on rainwater. Despite these differences, what remains the same is the overall purpose, in this case, to describe quantitative water resources availability. Thus both variables *fit* the community model they attempt to describe whilst corresponding to the overall *purpose* of the WPI.

Table 4 Variables of the Water Poverty Index selected for use at the community scale

WPI indicator	Selected variables
Resources	R1: Quantitative measure of water resources availability R2: Quantitative measure of reliability of water resources R3: Quantitative measure of rainfall variability R4: Qualitative measure of water resources availability R5: Qualitative measure of service reliability R6: Qualitative measure of rainfall variability
Access	A1: % Population with access to piped water supply A2: % Population with access to sanitation A3: Time required for water collection activities A4: Reports of conflict over access to water
Capacity	C1: Average daily household income ($MXN) C2: % Population having completed primary school C3: Ratio of female to male primary school completion rate C4: % Population reporting water-related illnesses C5: % Population having participated in hygiene training
Use	U1: Ratio of domestic consumption to basic water requirements U2: Ratio of livestock consumption to basic water requirements
Environment	E1: Quantitative measure of water quality E2: Qualitative measure of water quality E3: % Population reporting a change in soil fertility E4 % Population reporting a change in tree cover

In general, variable scores are derived in one of two possible fashions, either through calculating an overall community score (as is the case for many of the quantitative indicators) or through averaging household scores (as is the case for the qualitative indicators). Overall WPI scores are however calculated for each household. Where a variable score is calculated at the community scale, each household is attributed the same score. Scores were normalised using the standard Min-Max equation where applicable. In other cases, scores were normalised by assigning categorical scores. For example, where data are presented in the form of a Likert scale, scores are determined by the least and most desirable outcome respectively. Where data are presented in the form of an interval scale, minima and maxima scores are the 2.5 and 97.5 percentiles. The choice of method is reflected within the explanation provided for each variable calculation and the associated equation explained in full detail in the relevant indicator section in Chapter 7. A full description of the choice and impact of normalization technique continues below.

The nature of the WPI, and specifically its choice of data and subsequent normalization technique, requires that data be considered simultaneously in order to arrive at minima and maxima values for each variable. If this step is not carefully considered, comparisons between sites cannot be made. Further still, results are time specific and liable to change if data are modified at a later date. For example, if another community is to be included in the comparison or if longitudinal studies are to be carried out the WPI would need to be recalculated in its entirety.

This dilemma is most prevalent when using interval data but is avoided when using categorical data through question design that integrates categorical scoring, a normalization technique recommended for categorical data. Likert scales, for example, lend themselves easily to this situation. Likewise, certain quantitative measures depicted as percentages or ratios, such as AWR have natural lower and upper boundaries of 0 and 1. In these cases, the user would normally need only be concerned with scale conversion. Although this technique has the advantage of remaining the same over time, it has the disadvantage of creating very disparate scores when only a small number of sites are being analysed as is the case for the present study. Further it must be recalled that indices of relativity are just that, and may not necessarily reflect the actual data. For example, in the case of livestock consumption rates, a score of less than 1 does not necessarily indicate livestock are not achieving their BWR but simply that they are consuming less than the household with the maximum consumption rate.

In situations where natural boundaries are defined by values other than 0 and 1 (as is the case for the Precipitation Concentration Index used to calculate the WPI at the micro scale), the boundaries are nonetheless pre-defined exempting scores from the above pre-requisite, as a community's score is independent of any other site. Categorical data are trimmed to meet the 2.5 or 97.5 percentile. However, the need to define lower and upper values for scalar data using the Min-Max method cannot be avoided in situations where data lack natural or pre-defined boundaries as is the case for three variables used to calculate the WPI at the micro scale: A3, C1 and E1. A3 measures the time in minutes each household spends collecting water. C1 measures average daily household income. E1 measures quantitative water quality (TTC/100mL). It is possible to define boundaries for each of these variables although they would be very subjective and quite possibly site-specific. For example, average daily household income could be designed similar to U1, which considers domestic consumption per capita as a function of a widely accepted minimum standard, the BWR. The minimum standard for C1, might be set at the minimum wage enabling variables scores to be derived from the ratio of actual daily household average incomes to the minimum wage. The problem with this scenario is that minimum wages are site specific and more often than not, to a particular region. Further, one could argue the minimum wage does not necessarily guarantee a good standard of living. So, although the need to normalise this data clearly adds to the complexities of the WPI, it removes site-specific barriers and subjectivity.

With this in mind, water poverty indices were calculated at the household level based on the combined community dataset. Statistical analyses were also undertaken on the combined dataset and are presented in Chapter 8.

3.3 Water Quality Analyses

Water samples were analyzed for pH, turbidity (TU) and the presence of thermotolerant coliforms (TTC) for 31 households in Pozuelos and 11 households in El Mash. Analyses were undertaken using the OXFAM - DelAgua Lightweight Incubator Field Kit. Samples were collected and processed according to the Users Manual (DelAgua Water Testing Limited, 2000). Samples were collected in the field but processed and incubated at home in an area designated for laboratory purposes.

The initial sample size in Pozuelos was intended to mirror the number of households participating in the survey, however preliminary results indicated the absence of significant numbers of TTC. Therefore, in an effort to save time, the sample size was decreased to 31 households, which for a total population of 44 is statistically representative 95% of the time with a margin of error of 10%. Similarly, in El Mash the initial sample size was intended to mirror the number of households participating in the survey, however, due to the number of field hours per day and the distance to the laboratory, it was not possible to collect water samples at the same time as household surveys were conducted. A number of alternative options were considered, including sample preparation in the field, but it was decided that the most appropriate course of action would be to undertake a batch analysis.

To do this, male heads of households were asked to supply me with a 500mL water sample at a specific time and date as agreed in advance. Each male head of household was supplied with a 500mL sealed bottle of spring water. They were instructed to dispose of the water on the morning of the water sampling exercise, paying particular attention to avoid contact with the mouth of the bottle and its cap, keeping them free from debris at all times. They were then instructed to rinse the bottle with water from their household tank at least once before filling the bottle and replacing the cap. Each male head of household was to bring the bottle to an agreed meeting place. The samples were to be taken within the hour immediately preceding their deposition (this would vary depending upon the distance each person was required to travel to arrive at the meeting point). This procedure was attempted several times before being completed with moderate success. Eventually, eleven male heads of household (not necessarily those whose households were surveyed) supplied samples. Clearly eleven samples is not representative of the survey sample size. And in fact, a sample size of eleven amongst a total population of 45 is statistically representative 95% of the time with a margin of error of 26% however much like Pozuelos preliminary results indicated the absence of significant numbers of TTC at the household level. Because each neighbourhood is heavily reliant on local spring water during the dry season, the water quality of each spring was also assessed. Each spring is described in detail in Chapter 5 and results of the water quality analyses are presented in Chapter 6.

3.4 Focus Groups in El Mash

Relationships between myself, the translator(s) and the community/ies were integral to the success of this research. Although the first translator had a pre-existing relationship with the residents in Pozuelos, relationships in El Mash were more successful as evidenced by the higher response rate, richness of data, and overall willingness to participate. One can only speculate as to the reasons behind this overall increased success, which might include: (perceived) cultural differences between the two indigenous groups, gender of the translators, my working relationship with each translator, the nature of the working contract, work ethic, minor variations in the questionnaire used, personal circumstances, etc. It was in part because of the successful relationships between all parties in El Mash that focus groups were targeted within that community and this exercise is outlined briefly below.

Residents were given the opportunity to express their views on water poverty and how it affects their community during one of two focus groups organized separately for female and male heads of households. Forty-eight men and women were randomly selected (24 from each gender) from the 44 households surveyed. Participation rates varied significantly with 23 of 24 women attending, but less than half of all men attending with a further three leaving half way through the daylong session. Initially the women were shy but willing, whereas the men were apathetic with all parties becoming more interested and courageous as the day progressed. A series of planned activities developed around the theme of water were interspersed with icebreaker activities, word games and physical activity (a full outline of focus group activities is attached in the Appendices). As anticipated, the men were more literate[2] than the women and almost everyone in the group spoke Spanish with several men being able to read and write. Alternatively, only two or three women spoke Spanish and none were able to read or write. In fact, few if any, had ever held a marker pen until that date. Although I had intended on passively leading both focus groups this contrast in literacy meant I was forced to adapt a more pro-active role with the women. Instead of providing instructions at the beginning of each task and then adopting the role of observer as intended, and despite the presence of an independent translator and moderator (present only during the female focus group), I participated alongside the women completing the written portion of some tasks and leading some group discussions. However, even if the majority of women had been literate, it seems likely my level of participation would have remained the same due in part to their initial lack of confidence but also their natural tendency to revere outsiders. Suffice to say, as an audience, the women were much more captive than the men. A full discussion of focus group activities and their results is presented in Chapter 7.

Chapter 3 presented a detailed account of the research methodology used in this thesis. Chapter 4 discusses water poverty at the macro scale by first providing background

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[2] It should be noted that the maternal language in El Mash is Tzeltal thus the notion of literacy is not meant to apply to a lack of ability to communicate in Spanish but rather a lack of ability to read and write. Notwithstanding, illiteracy in Mexico is qualified as an inability to read or write in Spanish.

information on the main region of interest, Chiapas, then discussing the five indicators used to calculate the WPI for each state in Mexico including how each indicator and associated variable was calculated. The overall results of the water poverty analysis at the macro scale are then presented followed by a more detailed analysis of the findings, including a major investigation into the failings of the WPI model. Lastly a more explicit discussion of water poverty in Chiapas is presented enabling speculation, and general hypotheses, about water poverty at the community scale.

CHAPTER 4 THE WATER POVERTY INDEX AT THE MACRO SCALE

This chapter undertakes an assessment of water poverty at the macro scale in Mexico. Using the WPI each of Mexico's 33 states is evaluated. Mexico's territory is vast and diverse ranging from desert ecosystems in the north to tropical ecosystems in the south. Culturally and ecologically diverse, each state represents a unique piece of Mexico's rich mosaic. Although aquifers in the north and in the central valley (underlying Mexico City) have been overexploited leaving behind depleted aquifers that have led to the sinking of Mexico City, this study focuses on constructs of water poverty within a water rich state. Chiapas is Mexico's most hydrologically rich state, due in large part to the high volumes of precipitation it receives annually, yet is the second most deprived state and home to many of Mexico's underserved population. Before evaluating indicators of water poverty, a brief description of the geography, demographics and economy of Chiapas, as relevant to this study, is presented below.

4.1 Geography

Covering an area of approximately 73,200km^2, Chiapas is Mexico's tenth largest state representing 3.7% of the country's total land cover (CONAGUA, 2008). Chiapas is bordered by the state of Tabasco to the north, Guatemala to the east, the Pacific Ocean and Guatemala to the south and the states of Oaxaca and Veracruz to the west. Topographically and climatically diverse, 54% of the region is classified as warm-humid, 40% as warm-subhumid, 3% as temperate-humid and 3% as temperate-subhumid. As a result, average temperatures vary significantly ranging from a low of 18C to a high of 28C depending on the region. Annual rainfall also varies dramatically from a low of 1200mm to a maximum of 4000mm (INEGI Cuéntame, 2010). Regional geomorphology is characterized by minor elevations with a relative height greater than 300m and mountains comprising sub-horizontal and monocline folds of sedimentary rocks from the Pliocene to Quaternary epochs (Instituto de Geografía, 2007). The state is divided into nine geographical regions as shown in Figure 5. Pozuelos and El Mash, the two sites selected for study at the micro scale, are located within Region II, Los Altos, and are discussed in detail in relevant chapters that follow.

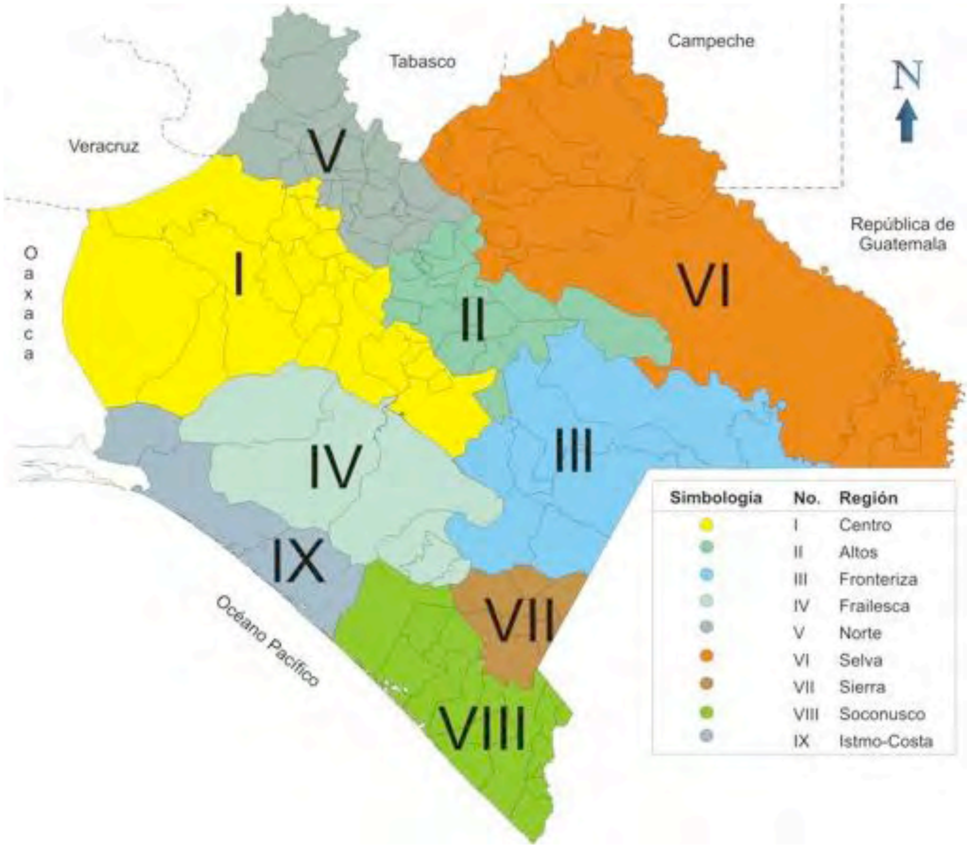

Figure 5 State Map of Chiapas depicting its nine regions (source: Gobierno del Estado de Chiapas, 2005)

As previously mentioned, Chiapas forms part of the eleventh administrative hydrological region (RHA), *Frontera Sur*, and received an average annual precipitation of 1846mm during the period 1971 to 2000 (CNA, 2009). A closer analysis of these numbers reveals that 71% of all rainfall falls between June and October, characterized by a bimodal distribution that peaks in June and September/ October, with one quarter of all precipitation falling in September. Although bimodal distributions of precipitation have been observed in other regions, according to Magaña, *et al.* (1999, p.1578) "in the Tropics, but away from the equator (10° – 20° of latitude), it is only in southern Mexico, Central America, and parts of the Caribbean where a bimodal structure in precipitation is observed." Located at approximately 16° latitude, both study sites are firmly within this zone. The significance of this phenomenon lies not within the peaks of precipitation but instead within the period of relative drought during the months of July and August, known as the midsummer drought (MSD) (Magaña, *et al.*, 1999; Curtis, 2002), which in the case of Chiapas represents a historical reduction in rainfall of 20%. The climatological explanation for this phenomenon is described in detail in Magaña, *et al.*, 1999, the finer details of which are beyond the scope of this study. Of note however is the authors' assertion that "the MSD is part of the annual cycle of precipitation… even after averaging more than 30 yr of station data, its signal is still present" and that its magnitude "is highly variable" (Magaña, *et al.*, 1999, p.1580). In other words, a decrease in rainfall during the months of July and August of variable intensity can be expected in this region and as a result needs to form part of any water assessment exercise.

Table 5 Average monthly rainfall for Frontera Sur over the period 1971 to 2000*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Yr
Rainfall (mm)	106	49	46	61	178	311	224	298	400	255	122	84	2134

Source: Organismo de Cuenca Frontera Sur, CONAGUA, 2009
*excluding 1998, Nov 1995 and 1999; including: Jan 2000

4.2 Demographics

Chiapas is home to approximately 4,293,459 inhabitants living in 118 municipalities comprising approximately 19,350 communities. It is the seventh most populous state in Mexico representing 4.2% of the country's total population (INEGI Cuéntame, 2010). Though population statistics vary according to source and definition, recent estimates suggest 52% of the population lives in a rural setting (defined in this case as locations with less than 2,500 inhabitants, though this figures rises to 66% when locations with less than 15,000 are considered) (INEGI, 2010). This is compared to 24% at the national level. Most of the population, 60%, is between 15 and 64 years of age, 36% is under the age of 15 and only 4% is over the age of 65 (INEGI, 2010).

Of Mexico's total population, 6.1% is indigenous, 13.5% of who live in Chiapas making it the third largest indigenous population in Mexico. The majority of indigenous people in Chiapas belong to one of two Mayan tribes: Tzeltal and Tzotzil, numbering approximately 362,700 and 321,000 respectively. The Chol tribe represents the third largest group with 162,000 people.

Between 25 and 36% of the indigenous group in Chiapas speak only their native language therefore it is not surprising that the illiteracy rate, measured as the percentage of the population, aged 15 or older, unable to read or write Spanish, is high with 21% of the population classified as such. In this regard, Chiapas has the highest illiteracy rate in the country. The gender divide is prominent with 16% of all men being illiterate and 26% of all women. The gender divide favours women however in terms of life expectancy with an average life span of 76 years for women but only 72 for men. With almost 916,300 households housing almost 925,000 families Chiapas has a population density of approximately 5 inhabitants per household. Men head the vast majority of households with only 19% being headed by women.

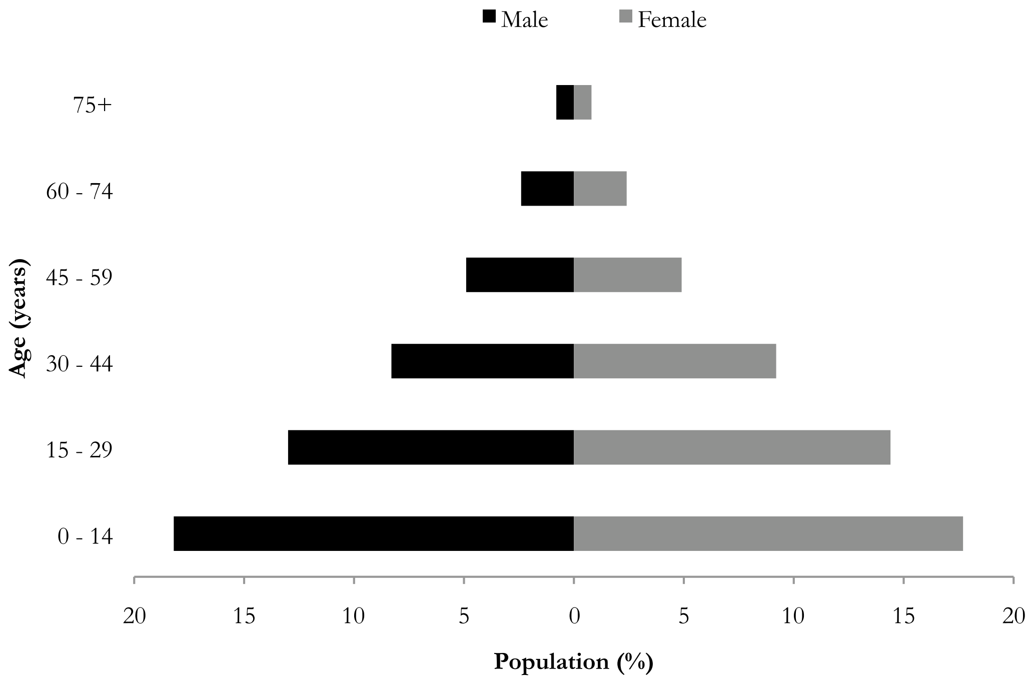

Figure 6 2005 Population pyramid of Chiapas (source: INEGI Cuéntame, 2010)

As previously mentioned 69% of all households purportedly have access to a piped water supply and 87% have access to sanitation (INEGI, 2010; INEGI Cuéntame, 2010). The trend whereby more households have access to sanitation than piped water in Chiapas is likely due in no small part to the tenets of the main social assistance programme *Programa Oportunidades* which stipulate participating households must have a latrine (but, based on observations, with limited regard to their construction, location or maintenance).

A number of the aforementioned factors, derived from census data, are used to calculate what is known in Mexico as the *Índice de Marginación* (or Index of Marginalization) (CONAPO, 2006), an indicator designed to measure marginalization within Mexico at the state and municipal level. The following tables describe marginalization in Chiapas as a function of each variable and then within a national context as it was measured in 2005 (CONAPO, 2006).

Table 6 Factors of marginalization at the state level

Indicator	Chiapas
Total population	4,293,459
Illiterate population 15 years of age or over	21.35
Population 15 years or more not having completed primary school (%)	42.76
Occupants in dwellings with neither drainage nor sanitation facilities (%)	8.07
Occupants in dwellings without electricity (%)	5.88
Occupants in dwellings without a piped water supply within the dwelling or yard (%)	25.90
Dwellings with some level of crowding (%)	60.20
Occupants in dwellings with dirt floor(s) (%)	32.99
Population in localities with less than 5,000 habitants (%)	58.46
Population employed with an income of at least two "minimum salaries" (%)	78.14

Source: Indices de marginación 2005 (CONAPO, 2006)

Table 7 Index of marginalization at the state level

Indicator	Chiapas
Index of marginalization	2.32646
Degree of marginalization	Very high
State ranking	n/a
National ranking	2

Source: Indices de marginación 2005 (CONAPO, 2006)

4.3 Economy

The largest economic sector in Chiapas by work force, employing almost 50% of the economically active population, but one of the smallest in terms of GDP, is the primary sector, dominated by agricultural industries. A number of vegetables and legumes are cultivated locally, including one of the country's most important dietary staples, corn, as well as beans, sorghum, soya, peanuts and sesame. Coffee, cocoa, sugar cane, mango, bananas, and palm oil are also cultivated. Only 4% of all agricultural lands are irrigated, hence the region's dependence on precipitation. Many parts of Chiapas are subject to frequent natural disasters thus the sector can be particularly volatile. The three most important types of livestock currently reared in Chiapas are cattle, pork and chickens. Many farms are small and family-run. Forestry and fisheries are sub-sectors of the primary sector that contribute economically (Gobierno del Estado de Chiapas, 2005; INEGI Cuéntame 2010).

The secondary sector is predominated by small companies and micro-industries, many of which are related to the primary sector (coffee and cocoa bean, dairy, furniture). Two major national companies are present in Chiapas, PEMEX[3] (the national petroleum refinery), and CFE (the federal electrical commission). The production of electricity is purportedly the most important industrial activity within the state, producing 46.7% of all hydro-electricity produced nationally. With 116 oil wells, PEMEX produces an average of 17.6 million barrels of crude petroleum and 223 billion cubic feet of natural gas annually (Gobierno del Estado de Chiapas, 2005; INEGI Cuéntame, 2010).

The most important economic sector is however the service sector. Comprising social and community services, tourism, and banking, it contributes half of the state's GDP. Construction, electricity, gas and water, and agriculture contribute less than 10% of the state's GDP each, with the remainder coming from transportation and communication (9%), manufacturing (3%) and mining (1%). Overall, Chiapas contributes only 1.6% of the nation's GDP (Gobierno del Estado de Chiapas, 2005; INEGI Cuéntame, 2010).

4.4 Indicators of Water Poverty

4.4.1 Resources

This indicator is comprised of two variables. R1 is a measure of AWR however instead of calculating freshwater resources per capita, due consideration is given to whether or not the total volume of freshwater available is sufficient to meet the needs of a particular area, according to current consumption rates. Thus R1 is the ratio of total water withdrawals to AWR, where $R1 \geq 0$:

$$R1 = 1 - (\text{consumptive withdrawals} / \text{AWR}) \qquad \textbf{R1}$$

AWR are reported at the hydrological administrative unit (RHA). There are thirteen RHAs in Mexico, which presume to follow natural hydrological boundaries. To calculate AWR at the state scale it was necessary to assume equal spatial distribution across each RHA. Although states may cross hydrological boundaries, conveniently municipalities do not[4]. Therefore it was possible to calculate AWR for each municipality in Mexico by

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[3] PEMEX (*Petróleos Mexicanos*) is the state owned petroleum company.

[4] A small number of municipalities do in fact cross hydrological boundaries. In these cases, boundaries have been extended or reduced for administrative purposes (CNA, 2008). When calculating total AWR by state, these variations are negligible.

first calculating AWR per km^2 for each RHA, then multiplying this figure by the area of each municipality. AWR by state is therefore equal to the sum of all municipal AWR within that state.

R2 is a measure of water quality. Calculated by determining the ratio of treated residual waters to total water consumed (reported at the state level), it specifically represents the water sector's impact on overall water quality, where:

R2 = total residual waters treated / total water withdrawals **R2**

4.4.2 Access

Access is comprised of two variables, A1 and A2, which represent access to water and sanitation, where:

A1 = % Population with access to piped water **A1**

A2 = % Population with access to sanitation **A2**

Access to a piped water supply is defined as "households with access to a piped water supply within the household, access to a piped water supply outside the household but within the yard/ plot, access to water from a public tap or standpipe, or access to water from another household." Access to sanitation is defined as households with pour or flush toilets, waterless toilets, or unspecified toilets[5] (CONAPO, 2006). Data for both variables are drawn from the national census (CONAPO, 2006) reported at both municipal and state levels.

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[5] A literal translation from the original Spanish text ("*La disponibilidad de excusado o sanitario se clasifica en: disponen de excusado o sanitario: con descarga directa de agua, con descarga manual de agua, sin admisión de agua, y no especificado…*") is used so as not to confuse the reader with the generally acceptable guidelines for access to improved sanitation as defined by various international agencies, including UNICEF (2006). This is because the Mexican government collects data regarding access to sewerage networks ("*drenaje*") separately thus it is not possible to draw any conclusions as to the final disposal of human waste via flush/ pour toilets using the present data in isolation. Furthermore, waterless toilets are not exclusively defined as latrines and researcher observations suggest latrines within the two case study sites do not have any purposeful ventilation thus cannot be considered improved sanitation.

4.4.3 Capacity

Capacity is comprised of three variables representing economic, health and educational well-being. Data for each variable were sourced from the national census. The first variable, C1, is a measure of GDP per capita in Mexican pesos. GDP is most often reported internationally as PPP (purchasing power parity) in US dollars, however, given the present study is undertaken within a single economic market, values as reported in the national currency are used. Given the range of economic disparity across Mexico, one could argue the need for a national PPP. Nevertheless, convention dictates otherwise and to argue the contrary is in any case beyond the remit of this study.

C1 = GDP per capita ($MXN) **C1**

C2 represents health and is a measure of the under-one mortality rate. Infant mortality rates are more commonly expressed as the number of deaths per one hundred children under the age of five; however, Mexico currently uses the under-one mortality rate and as previously mentioned, the objective of this research is to give preference to locally sourced data where available, in part to add meaning to this research in a local context.

C2 = 1 - Under-1 mortality rate (%) **C2**

Finally, the third variable, C3, represents educational well-being and measures literacy. Although a number of indicators representing education were available (including enrolment in primary education), this indicator best represents the nature of education in a water poverty context. Though education enrolment rates are arguably important to combating water poverty, they measure a single point in time and give little indication of the outcome, or completion rates, and in a country such as Mexico, where social assistance is tied to education enrolment, are likely to overestimate the overall educational capacity of society. It is with this in mind that literacy was deemed a better indicator of educational well-being. This indicator measures the percentage of the population who, aged 15 or older, "self declares their ability to read or write a brief note" (CONAPO, 2006).

C3 = % Population aged 15 or more that is literate **C3**

Gini coefficients of income distribution were not included in this study. Although the importance of wealth distribution is duly noted, first and foremost, data are not readily available locally.

4.4.4 Use

This inaccurately named indicator is made up of three variables that consider domestic, agricultural and industrial water consumption each of which is reported at the state scale. The first variable, U1, measures domestic water consumption per capita in litres per day as a ratio of a reference value, known as BWR[6] of 165L/cap/day, where:

U1 = domestic water consumption per capita per day / BWR **U1**

U2 measures water consumption for agricultural purposes as a ratio of agricultural GDP, where:

U2 = agricultural water consumption / agricultural GDP **U2**

U3 measures water consumption for industrial purposes as a ration of industrial GDP, where:

U3 = industrial water consumption / industrial GDP **U3**

4.4.5 Environment

This particular indicator was the most difficult to replicate in a national context. Nevertheless, despite the use of different variables the reliability of the overall indicator remains intact, which is to consider environmental integrity in the context of water poverty. For this purpose, three variables were conscientiously selected given the remit of the indicator and within the constraints of locally available data. Formed of three variables, the first, E1, represents soil degradation/ erosion by measuring the percentage of total area that is free from soil degradation/ erosion. Soil degradation/ erosion is classified locally by process (physical, chemical, wind and water) and degree (lightly, moderately, severely or extremely) and reported at the state scale.

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[6] BWR = basic drinking water requirements [5L], "societal preferences for moderately industrialised countries" for bathing [70L], kitchen and cooking [50L] and "adequate [amounts] for direct sanitation hookups in industrialised countries [40L]" (Gleick, 1996)

$\sum$% of land unaffected by degradation or erosion **E1**

The second variable, E2, is another indicator of water quality but in contrast to R2, which measures the impact of the water sector on overall water quality, E2 measures surface water pollution. Despite geographical disparity amongst the distribution of water quality tests undertaken nationally, this variable nevertheless provides some valuable insight into the problem of surface water pollution faced by Mexico today. Monitoring traditional indicators of pollution such as BOD and COD, surface water is classified as excellent, good, acceptable, contaminated, or heavily contaminated, where:

$\sum$% of water quality test results achieving excellent, good or acceptable **E2**

Water quality test results are reported at the RHA thus the same score was first attributed to each municipality based on its location within a particular RHA and scores were then averaged across municipalities within a given state.

The last variable, E3, is at best a good indicator of water poverty or at worst, an indicator of convenience. Despite efforts to match environmental variables in the present study to those used in the international comparison, comparable data were not available in a form, or at a scale, suitable for this study. The present variable was however meaningfully selected to represent the impact on overall environmental integrity from anthropogenic sources and the link between waste management practices and environmental degradation is generally accepted. It should be noted that although these data refer to urban waste collection only, more than three quarters of Mexico's population resides in an urban setting. Conversely, the lack of waste collection records for the remaining 25% of the population could be indicative of a lack of waste management services in rural communities where solid waste is commonly recycled, sold or burned, the latter posing a significant threat to the environment.

E3 = urban waste collected / urban waste generated **E3**

4.5 The Water Poverty Index

A water poverty index was calculated at the state level in Mexico with WPI scores for each state presented in Table 9 classified in respect of the overall mean. WPI scores range from a low of 0.317[7] to a high of 0.678 with an average score of 0.494 (SD=0.100). Minimum and maximum scores for each indicator are presented in Table 8 along with their respective mean and standard deviation. Based on mean scores states perform best on Access, however this is also the indicator that presents the highest maximum and lowest minimum scores and thus the highest range at 1.00. Environment presents the highest minimum indicator score and with the lowest standard deviation, scores typically remain close to the mean of 0.517. Capacity presents the second largest range of variables at 0.990. The remaining three indicators present a wide range of indicator scores suggesting states are very heterogeneous. Most importantly, accounting for extreme outliers (AWR>15,466L/capita) there is a distinct lack of a linear relationship between AWR per capita and water poverty, as demonstrated in Figure 7. This is a key driver behind the WPI, which argues water resources availability alone is not a good measure of water poverty and that in fact, when socio-economic factors are taken into consideration, the situation changes dramatically.

Table 8 Indicator scores used to calculate the WPI at the macro scale

	Resources	Access	Capacity	Use	Environment	WPI
Mean	0.456	0.675	0.546	0.276	0.517	0.494
SD	0.182	0.222	0.250	0.171	0.148	0.100
Min	0.035	0.000	0.004	0.052	0.272	0.317
Max	0.779	1.000	0.994	0.672	0.868	0.678
Range	0.744	1.000	0.990	0.620	0.596	0.361

In fact, the state with the most AWR, Chiapas, is one of the most water poor (WPI=0.341), with only three states, Guerrero (WPI=0.317), Oaxaca (WPI=0.332) and Hidalgo (WPI=0.340) performing only slightly worse (but when rounded to the nearest significant digit in fact performs the same). The region with the least amount of AWR, Distrito Federal (WPI=0.610), is one of the least water poor, with only three states, Aguascalientes (WPI=0.678), Nuevo León (WPI=0.669) and Coahuila (WPI=0.626) performing better.

[7] The use of three significant digits does not denote accuracy to the thousandth decimal place but instead is required to discern minor differences in score rakings that would otherwise appear the same if rounded to the appropriate decimal place.

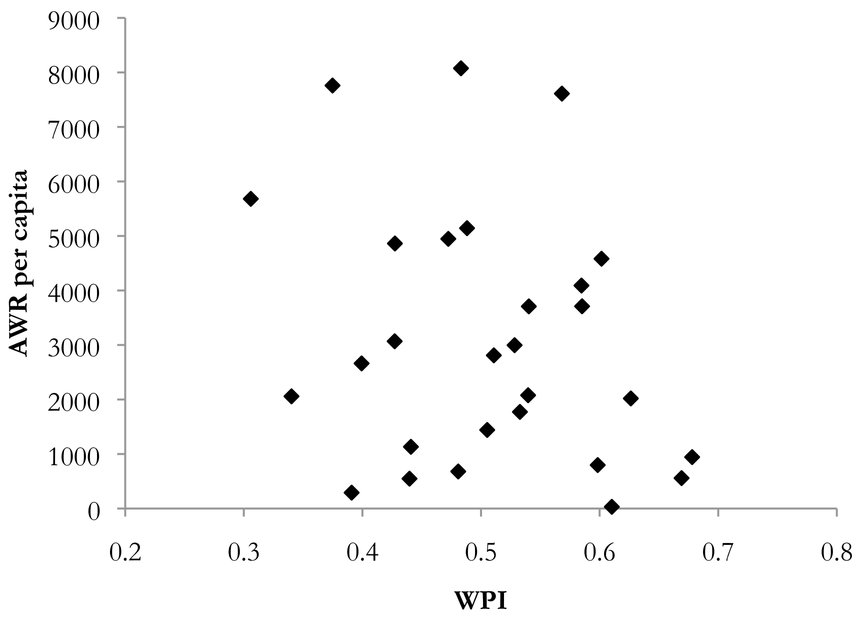


Figure 7 Plot of water poverty scores against AWR per capita (r^2 = 0.1)

Thus it would appear that Resources have little impact on overall WPI seen by examining Figure 8(a)(b). To the contrary, Access and Capacity appear to be closely related with overall water poverty scores, particularly evident in Figure 8(b), which depicts the six states with the greatest WPI scores. To a lesser extent, Environment appears to be related to overall WPI scores whereas Use, much like Resources, appears to have no impact.

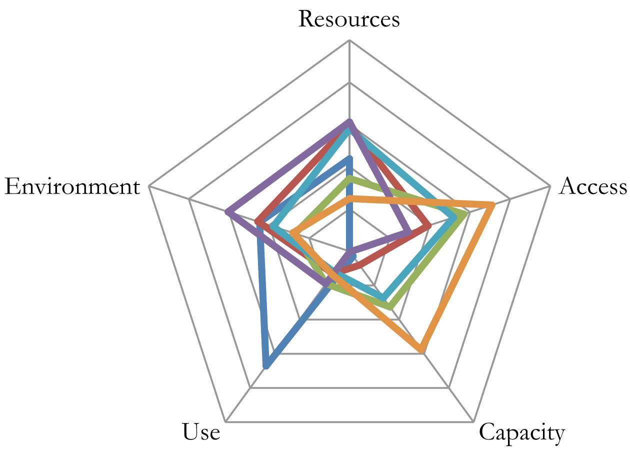
4.6 Analysis of Water Poverty at the Macro Scale

Statistical outliers were only identified in four cases: Guerrero for Access and Use, Sinaloa and Sonora for Use. In a bid to retain as many values as possible, most values were either raised or lowered to meet the lower and upper boundaries of the 2.5 and 97.5 percentiles respectively but in the case of Use, it was necessary to lower original values to the 92.5 percentile. Correcting for outliers typically resolves any problems of abnormality but after adjustments, data for Use remain slightly positively skewed (Skewness=1.054) owing to a very small number of states with much higher scores than the mean. This is not significant enough (2SE=0.828) for the present purposes to warrant further modifications.

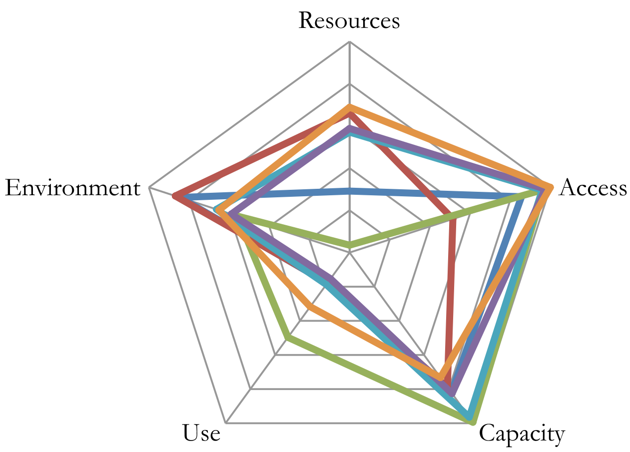
Table 9 Water Poverty Index by state

State	Below Mean (<0.394)	Mean WPI +/- 1 SD (0.394-0.594)	Above Mean (>0.595)
Aguascalientes			0.678
Baja California			0.598
Baja California Sur			0.602
Campeche		0.544	
Chiapas	0.341		
Chihuahua		0.585	
Coahuila			0.626
Colima		0.533	
DF			0.610
Durango		0.568	
Guanajuato		0.441	
Guerrero	0.317		
Hidalgo	0.340		
Jalisco		0.540	
México	0.391		
Michoacán		0.399	
Morelos		0.440	
Nayarit		0.488	
Nuevo León			0.669
Oaxaca	0.332		
Puebla		0.427	
Querétaro		0.505	
Quintana Roo		0.483	
San Luis Potosí		0.511	
Sinaloa		0.551	
Sonora		0.540	
Tabasco		0.413	
Tamaulipas		0.585	
Tlaxcala		0.481	
Veracruz	0.375		
Yucatán		0.427	
Zacatecas		0.427	

Having examined scatter plots for evidence of linear relationships between indicators, only one pair of indicators demonstrates significant linearity, Access and Capacity (r^2=0.5), and two further pairs present evidence of a very small linear relationship, Resources and Use (r^2= -0.2) and Environment and Capacity (r^2=0.2). An absence of linearity does not however imply the indicators are not co-related in some fashion, but simply that their relationship is not linear and should not be described using this method.



(a)



(b)

Figure 8 Pentagram representations of indicator scores for states with below (a) and above (b) average WPI scores

Pearson correlation coefficients for these indicators are shown in Table 10. As anticipated from the Pentagram representations, there is no relationship between Resources or Use and WPI yet Access and Capacity both demonstrate strong positive relationships with overall water poverty while Environment presents a moderately strong positive relationship with WPI. Predictions about relationships between indicators also hold true and Access and Capacity prove to be highly positively correlated whilst Resources and Use are moderately negatively correlated and Capacity and Environment are weakly positively correlated.

Table 10 Pearson's correlation coefficients matrix

Indicator	Resources	Access	Capacity	Use	Environment	WPI
Resources	1.000	-	-	-	-	-
Access	n/a	1.000	-	-	-	-
Capacity	n/a	0.713**	1.000	-	-	-
Use	-0.459**	n/a	n/a	1.000	-	-
Environment	n/a	n/a	0.388*	n/a	1.000	-
WPI	0.048	0.746**	0.887**	0.183	0.532**	1.000

* Correlation is significant at the 0.05 level (two-tailed)
** Correlation is significant at the 0.01 level (two-tailed)

Given the small dataset in question Kendall's tau-b correlation coefficient was also calculated and results are presented in Table 11, which confirm the previous findings but in all cases suggest the relationships are much weaker (save for Resources against WPI which improves slightly but in any case remains insignificant).

Table 11 Kendall's tau-b correlation coefficients matrix

Indicator	Resources	Access	Capacity	Use	Environment	WPI
Resources	1.000	-	-	-	-	-
Access	n/a	1.000	-	-	-	-
Capacity	n/a	0.476**	1.000	-	-	-
Use	-0.281*	n/a	n/a	1.000	-	-
Environment	n/a	n/a	0.290*	n/a	1.000	-
WPI	0.085	0.500**	0.710**	0.184	0.395**	1.000

* Correlation is significant at the 0.05 level (two-tailed)
** Correlation is significant at the 0.01 level (two-tailed)

This analysis forms the basis of an important finding of this study. In a well-constructed composite index, there should be no correlation amongst indicators as this would be akin to double-counting whereby the same body of knowledge unintentionally exerts a disproportionate amount of pressure on the overall index score. A moderate correlation between Access and Capacity is therefore problematic because it implies that each indicator reports similar information, unfairly impacting overall WPI scores. That being said, r^2<0.500 and relatively much less weaker than the correlation between Capacity and overall WPI. The latter relationship is believed to be the more problematic of the two. This was acknowledged by the original authors (Lawrence, *et al.*, 2003) but to date has not been considered further. Because each indicator is itself a composite index statistical analyses must therefore be extended to include variables and Table 12 shows Kendall's tau-b statistic for variables of Access and Capacity.

Table 12 Kendall's tau-b statistic for variables and indicators of Access and Capacity

	A1	A2	Access	C1	C2	C3	Capacity
A1	1.000	-	-	-	-	-	-
A2	0.282*	1.000	-	-	-	-	-
Access	0.641**	0.641**	1.000	-	-	-	-
C1	0.230	0.351**	0.323**	1.000	-	-	-
C2	0.343**	0.504**	0.508**	0.685**	1.000	-	-
C3	0.357**	0.591**	0.579**	0.587**	0.765**	1.000	-
Capacity	0.286*	0.480**	0.476**	0.774**	0.871**	0.781**	1.000

* Correlation is significant at the 0.05 level (two-tailed)
** Correlation is significant at the 0.01 level (two-tailed)

To enable rapid visualization of the data, statistically significant correlations have been colour coded by strength such that red represents $r>0.7$, orange represents $0.6<r<0.7$, yellow represents $0.5<r<0.6$ and green represents $r<0.5$. One of the problems with determining appropriate cut-off points for strengths is that they are based solely on value judgements, an undesirable yet necessary evil. Combined with my knowledge of composite indices, I now reason the following:

1. The most significant correlations are between variables of Capacity with C2 and C3 being very highly correlated, followed closely by a high correlation between C1 and C2 and a moderately high correlation between C1 and C3, which in turn give rise to very high correlations with the overall indicator.
4. Moderately strong correlations between A2 and C2 and C3 are cause for concern and give rise to moderately strong correlations between C2 and C3 and the overall indicator of Access.
5. A1 and A2 are highly correlated with the overall indicator of Access yet because they are only weakly correlated, this is not a cause for major concern.

As suspected, Capacity is indeed the most problematic indicator of the two. The moderately strong correlations between C2 and C3 with A2 may very well be the cause of the inter-correlation between Access and Capacity thus it would seem the most appropriate course of action would be to resolve the problem amongst the variables of Capacity. Nardo *et al.* (2008, p.32) suggest the problem of correlation may be resolved by choosing "only indicators which exhibit a low degree of correlation or to adjust weights correspondingly" especially given the use of equal weights further exacerbates the concept of double-counting. The subject of weighting is highly complex, far more complex than anticipated at the outset of this study and could easily justify an entirely separate thesis. Furthermore, there is no end to the different weighting methodologies in use. Cho, *et al.* (2009) used PCA to determine the indicator weights for their modified NWPI. However, although they recommended extending their analysis to the variable level, to date this research has not been undertaken. Moreover, although their research position within management science implies a certain level of objectivity this is presumably at the expense of in-depth knowledge of the social problems specific to water poverty, hence their removal of Use from the modified index based solely on statistical merit. Although I would agree there currently appears to be a lack of statistical support for its inclusion, I would first be inclined to suggest data should be examined further in an attempt to find a more suitable measure of Use as opposed to excluding the indicator completely. Lastly the aggregation method used to combine variables and indicators may ultimately be inappropriate especially given its condition of "preferential independence" such that: "given the individual indicators {x1, x2,…,xQ}, an additive aggregation function exists if and only if these indicators are mutually preferentially independent (Debrue, 1960; Keeney & Raiffa, 1976; Krantz et al., 1971)" (Nardo *et al.,* 2008, p.103) and "additive aggregation could… result in a biased composite indicator." Given the limited association between the remaining indicators within the WPI, it seems sensible to retain the current model. Thus we are faced with removing variables or modifying their weights.

The decision of which variables to exclude is aided by performing a linear regression analysis and it should be made clear that the regression analysis is used solely for this purpose. I am not interested in the regression equation itself as the model is already defined and furthermore there exists *a priori* knowledge of the model and its workings. Simultaneous inclusion of the variables is selected over a stepwise approach as it corresponds to the WPI model. The predictive ability of each variable on the WPI can be assessed by examining each variable's corresponding beta weight, which expresses the change in the dependent variable (WPI) as a result of an increment of one standard deviation in the independent variable.

Regression coefficients of the simultaneous regression of WPI on its 13 variables are presented in Table 13. Before considering beta weights, it is interesting to examine the unstandardized coefficients (B). This highlights an important problem of using equal weightings in a composite index where an uneven number of variables are used to calculate each indicator. We see that the fewer the number of variables in an indicator, the greater the weight (unstandardized coefficient). This also provides an opportunity to explain the impact of double-counting. Theoretically, C1, C2 and C3 are weighted less than variables of Resources and Access comprised of only two variables each. However, if C1, C2 and C3 reflect the same measure, the weights become additive resulting in a total weight of 0.2 and increased importance being placed upon that variable. Theoretically this is resolved by the classification of variables into indicators where each indicator is given a weight of 0.2, however problems arise when one variable is highly correlated with a variable from another indicator.

Table 13 Regression coefficients of the simultaneous regression of WPI upon its 13 variables

Independen t variable	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	.000	.001		.482	.636
R1	.099	.001	.349	182.831	.000
R2	.100	.001	.253	189.027	.000
A1	.099	.000	.252	216.513	.000
A2	.100	.001	.287	157.512	.000
C1	.067	.001	.179	107.270	.000
C2	.067	.001	.177	45.769	.000
C3	.066	.001	.186	60.641	.000
U1	.065	.001	.150	104.502	.000
U2	.068	.001	.140	123.055	.000
U3	.067	.000	.192	147.979	.000
E1	.066	.000	.161	159.183	.000
E2	.068	.001	.173	130.140	.000
E3	.067	.000	.196	175.061	.000

Returning to the regression analysis to examine the Beta weights, we see that R1 contributes the most to overall WPI and U2 contributes the least notwithstanding all of the contributions are significant ($p<0.01$). However, as variables of Capacity are suspected of double-counting, I shall examine their contribution in detail. We already know that most of the variation in C1 and C3 can be explained by C2 thus it might be prudent to remove both of those variables and retain only C2. We see that of the three variables, C3 contributes the most to WPI followed closely by C1, which supports my decision. Furthermore, this decision does not contradict common sense. However, the removal of these variables has the undesirable effect of creating an imbalance in the number of variables per indicator. It would not be misleading to combine variables of Access and Capacity into one indicator and would have the advantage of reducing the number of overall indicators. In addition, mathematically there is no difference between calculating the average of the sub-index averages or calculating the average of all variables and variables are grouped into corresponding indicators for descriptive purposes alone. Thus, C1 and C3 are removed and C2 is combined with variables of Access to form the indicator AC.

It would of course be prudent to reanalyze correlation effects amongst indicators and overall WPI and between indicators (and variables if necessary) and results are shown in Table 14. Changes made to the WPI have resolved any major issues of inter-correlation between indicators and although AC and Environment are more strongly correlated with overall WPI than the remaining two indicators this is not a cause for concern given $r<0.5$.

Table 14 Kendall's tau-b correlation coefficients matrix after modifying WPI

Indicator	Resources	AC	Use	Environment	WPI
Resources	1.000	-	-	-	-
AC	n/a	1.000	-	-	-
Use	-0.286*	n/a	1.000	-	-
Environment	n/a	n/a	n/a	1.000	-
WPI	0.169	0.508**	0.181	0.472**	1.000

* Correlation is significant at the 0.05 level (two-tailed)
** Correlation is significant at the 0.01 level (two-tailed)

Following the removal of C1 and C3, although all beta weights have increased, those associated with R1 and R2 have increased most (Table 15). This is counter-intuitive given the mounting evidence that water resources availability is not correlated to water poverty (see for example, Chenoweth, 2008). Nevertheless the purpose of this exercise was to mitigate problems of correlation between variables and resolve the potential for double-counting amongst variables of Capacity. We can assess the removal of C1 and

C3 and the newly combined indicator of Access and Capacity on overall WPI scores by conducting a paired samples test and assessing rankings.

Table 15 Regression coefficients of the simultaneous regression of WPI after the removal of C1 and C3

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	.000	.001		.307	.762
R1	.124	.001	.561	228.503	.000
R2	.125	.001	.406	196.629	.000
A1	.082	.001	.268	150.306	.000
A2	.083	.001	.306	123.180	.000
C2	.084	.001	.285	95.727	.000
U1	.081	.001	.240	107.716	.000
U2	.085	.001	.225	135.129	.000
U3	.083	.001	.309	164.226	.000
E1	.082	.000	.258	166.751	.000
E2	.085	.001	.277	135.269	.000
E3	.084	.000	.315	186.376	.000

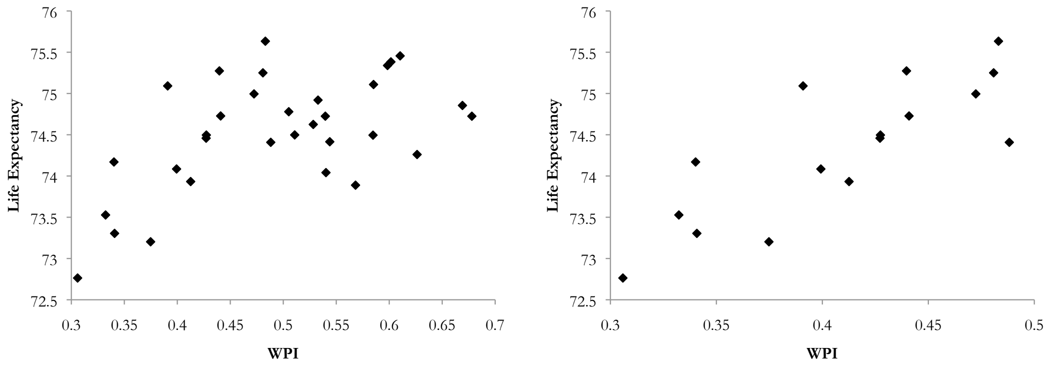
In the first instance, the null hypothesis states there is no difference in means between the paired samples and the removal of C1 and C3 therefore had no impact. The two variables are highly correlated and their coefficient is 0.955. The result of the t-test, $t=2.801$; $df=31$; $p<0.01$, shows the difference in the paired means is significant and the null hypothesis can be rejected (this result improves to $t=5.421$; $df=28$; $p<0.01$ when paired outliers are removed). The removal of C1 and C3 has had an impact. What the t-test doesn't tell us however is how the change impacts overall water poverty between states. The purpose of removing the two variables was to mitigate impacts of double-counting and to remove variables that exerted a controlling force on overall WPI scores. Though their removal necessarily constitutes a change in scores, which has been shown to be significant, we would not necessarily want the overall interpretation of water poverty to change. This impact is assessed by converting the original and new WPI scores to rankings and then measuring the statistical association between both sets, using Spearman's correlation coefficient. I anticipate the two rankings will be highly correlated and indeed $r=0.962$ and is significant at the 0.01 level.

There are numerous considerations that must be made in light of the above statistical analyses. Most importantly, "a statistical model… cannot by itself yield an unequivocal interpretation of regression results: the user must also be guided by a substantive model of causation" (Kinnear & Gray, 1999, p.312). With this in mind, we must undertake one final yet extremely important check before accepting these findings; does the regression equation make sense? In real terms, can water poverty be described in terms other than GDP per capita and illiteracy rates? Although the result might not be desirable, especially given the WPI's aim to describe water poverty as a function of the myriad of socioeconomic variables known to complicate water poverty, the answer is yes especially if alternative variables can be used to describe the same aspect. Given the exceptionally high correlation between all three variables of the original indicator of Capacity, it is probable they describe the same characteristics of water poverty thus the exclusion of two of the three original variables is not untowardly and we have not excluded an indicator of Capacity in totality by their exclusion.

One final but extremely important note must be made concerning multiple regression analyses. Reliability is greatly impacted by sample size and although there is no hard fast rule stipulating minimum sample sizes, a commonly quoted rule of thumb is 10 cases for every independent predictor. With only 32 cases, I recognize that this analysis does not meet this standard and the resultant regression equation may not be reliable or worse still may have been determined by mere chance. These considerations have been weighed, however, one of the main purposes of this analysis is to demonstrate the need for further data exploration and extrapolation, particularly in the presence of highly correlated indicators. Even if we assume the results are unreliable they are nevertheless useful if only for illustrative purposes to highlight the WPI can and should be reduced especially when given the suggestion of double-counting. Lastly, given the results do in fact pass the common sense test, despite what we know about sample size, the possibility still remains that the results are valid.

Returning however to the original model and dataset, it would be useful to compare WPI scores against another indicator as a means of testing, or validating, their descriptive abilities. Such an indicator should measure a concept comparable to the WPI but should not include similar variables so as to avoid double-counting as described above. For example, it isn't useful to compare the WPI against the HDI given the indicator Capacity is based on the HDI. The original authors, however, did just that, arriving at what they describe as a "moderately positive correlation" (r=0.81) between the two indices (Lawrence, *et al.*, 2003, p.9). They describe the effect of this "moderately positive correlation" to mean, "that 65% of the variation in the WPI can be explained by the HDI" (*ibid.*). This is a rather curious assertion and begs the question, what is the purpose of the WPI? With a well-established indicator to describe human development already in place, it would seem more appropriate to analyze factors of water poverty that are not already described by the HDI. There is nothing to stop both indicators being utilized in tandem at a later date. Mexico produces its own composite indicator of well-being, the Index of Marginalization (IoM) (CONAPO, 2006). However, the IoM includes several of the variables used in the WPI such as access to water and sanitation. In order to compare the two indicators, the variables in common would need to be first removed from the IoM (as should have been the case prior to comparing the WPI to the HDI). This is rather complicated and a much simpler approach would be to use an indicator that is linked in concept, but does not have any variables in common with the WPI. As we know that water poverty is intrinsically linked to human development, and in particular health, we might expect to see a positive correlation between the WPI and life expectancy. Figure 9(a) shows a weak positive relationship (r^2=0.3) exists between the two indicators (Kendall's correlation coefficient is also 0.3, significant at the 0.01 level). However, closer examination reveals that in fact a strong positive relationship (r^2=0.7) exists between the two indicators for values of WPI<0.5 (Figure 9(b)) after which point the relationship is non-existent (r^2=0.1). Kendall's correlation coefficients (0.6 and 0.2 respectively) further support this evidence although it should be noted that the reduced number of cases is relatively small (n=16).

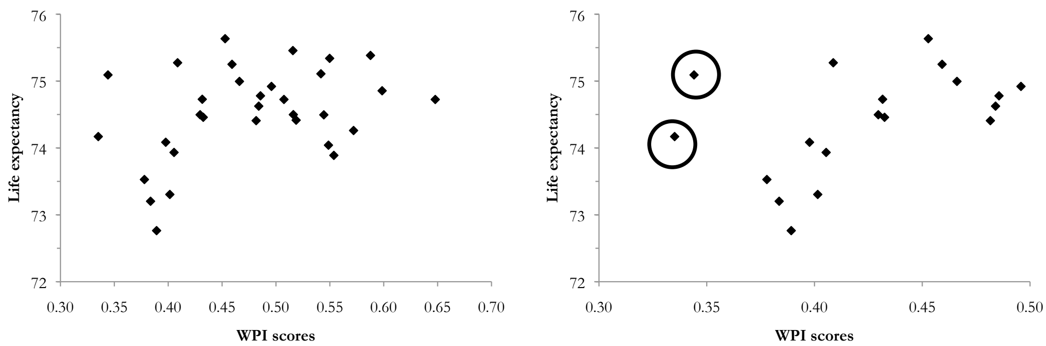
The impact of this relationship is two-fold. In the first instance it provides evidence to support the validity of the WPI and its ability to describe events potentially related to water poverty (notwithstanding the above relationship is not necessarily one of cause and effect). In the second instance, should this relationship be one of causality, which although not proven in the present study is generally intuitive, this evidence would suggest this relationship is most critical in cases of extreme water poverty. To generalize further, this evidence supports the idea that the WPI accurately describes the impact of water poverty on known indicators of health and well-being and is further suggestive of a critical point below which these impacts have the greatest effect.



(a) (b)

Figure 9 Link between water poverty and life expectancy across states for (a) all values of WPI and (b) WPI<0.5

The modified WPI produced as a result of the exclusion of selected variables was also compared to life expectancy in a bid to ascertain whether the association improves or worsens as a result of the modification. Figure 10(a) shows that the relationship does not hold true when all values of the modified WPI are considered (r^2=0.1) or when WPI scores below the threshold of 0.5 are considered (r^2=0.2). However when the two identified outliers are removed from Figure 10(b), r^2 improves to 0.5.



(a) (b)

Figure 10 Link between modified water poverty scores and life expectancy across states for (a) all values of WPI and (b) WPI<0.5 (with outliers encircled)

Broadly speaking, according to the original WPI results, Chiapas can be described overall as water poor and I would not expect overall results at the community scale to differ significantly. Considering each indicator in turn, the WPI suggests that although there is an abundance of natural water resources in Chiapas, the general population has limited access to water and sanitation, is exceptionally limited economically and socially and exhibits trends of poor water use. To the contrary, environmental integrity, including water quality, generally remains intact. Figure 11 shows a breakdown of indicator scores for Chiapas whilst Figure 10 shows a breakdown of variable scores.

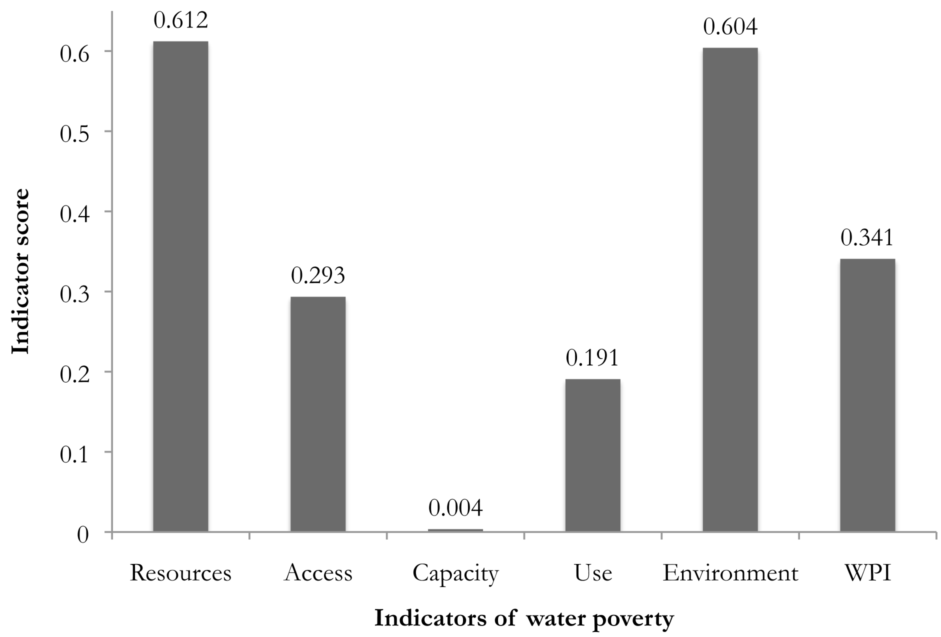


Figure 11 WPI indicator scores for the state of Chiapas

Closer examination of these data suggests that although there is a natural abundance of water (R1=1), very little of it is treated before being returned to the environment (R2=0.2). This is in contrast to variable E2 (0.9), which suggests water quality results are for the most part acceptable, good or excellent. The portion of the population with access to sanitation is considerably higher (A1=0.5) than that with access to a piped water supply (A2=0.05). GDP is negligible (C1=0) and infant mortality (C2=0.01) and illiteracy rates (C3=0) are exceptionally high. Nationally, Chiapas consumes the second least amount of water per capita per day as a function of freshwater resources availability (U1=0.015). Not surprisingly, given most agriculture is rain fed, Chiapas has one of the better ratios of agricultural water consumption to GDP. Notwithstanding, agriculture is not a high-income sector thus almost all states, including Chiapas, score less than 0.4. Chiapas is relatively 'middle of the pack' in terms of industrial water consumption to GDP. Lastly, with a variable score of 0.3, Chiapas is on par with most other states in terms of soil degradation and is in the top-third for urban waste collection. Chiapas fares extremely poorly in terms of relative water poverty amongst states, ranking 1st of all states compared to 4th using the original model (the modified WPI score varies by only 0.02 compared to the original WPI score). Indeed, A2 and C1 are two of its weakest scores suggesting water poverty in Chiapas is severely limited by access to a piped water supply and personal income.

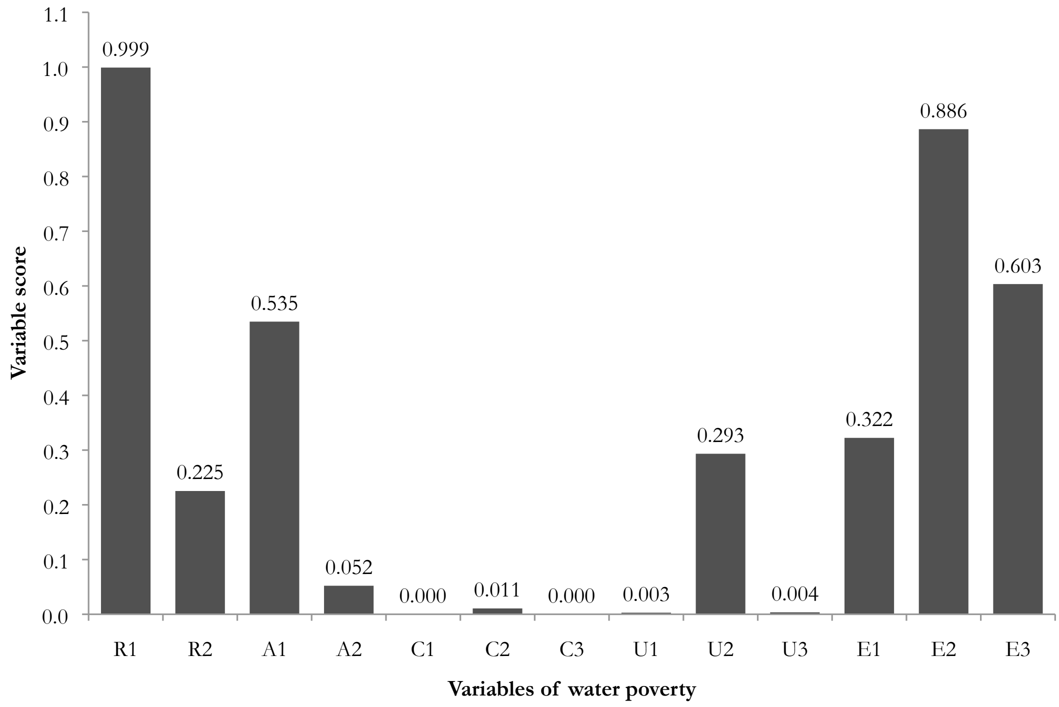


Figure 12 WPI variable scores for the state of Chiapas

Because the WPI measures relative water poverty direct comparisons cannot be made between macro and micro scales. For example, we know that at the state level the population of Chiapas is highly illiterate compared to the rest of the country. We would therefore expect to see high rates of illiteracy in every community. Thus on a relative scale we would not expect to see such extreme variations between scores, nor would we necessarily expect to see such extreme scores, given the population is likely to be more homogenous at the state level than nationally. Nevertheless, having calculated a water poverty index at the macro scale and having examined some of the core results, some initial hypotheses about water poverty at the micro scale can be made. Despite the variation in scale, we might expect to see similar correlations described above. In particular, because the WPI at the micro (community) scale is designed similar to that at the macro (state) scale, we might expect to see a strong correlation between Access and Capacity. However, with a comprehensive database to hand, we can use the above findings to guide variable selection at the micro scale so as to avoid some of the same problems of internal correlation. Given the variation in scale, we might also expect to see discrepancies in indicator and variable scores.

Essentially, although the WPI is useful for describing the general population of a particular region, because it is a measure of relative water poverty it's not possible to use this information to describe water poverty between communities without prior specific knowledge of the communities in question. So, although the present calculation can be used for decision-making nationally, it does not replace the need for a water poverty index at the community scale. This is discussed fully in the following four chapters, which focus on the calculation of water poverty at the micro scale, beginning with Chapter 5, which presents a thorough examination of the local study area.

CHAPTER 5 AN INTRODUCTION TO THE LOCAL STUDY AREA

As mentioned in previous chapters, the state of Chiapas is divided into eight geographical regions. Pozuelos is located in the municipality of San Juan Chamula (023) while El Mash is located in Oxchuc (064), two of eighteen municipalities located within Region II, Los Altos or 'the Highlands' (Figure 13). Covering an area of 3,770 km² and with a population of just under 500,000 the seat of the regional government is located in San Cristóbal de las Casas (078). Its topography is characterized as mountainous with a high number of valleys. Soils are thin and rocky and local relief is characterized by considerable slope. This variable topography has prevented the development of any important surface water networks, having instead developed underground. Local vegetation is composed mainly of oak and pine forests interspersed with one another according to altitude. The region benefits from a temperate climate with a defined rainy season in the summer months and average annual temperatures around 12-18° C (Gobierno del Estado de Chiapas, 2005; Instituto de Geografía, 2007).

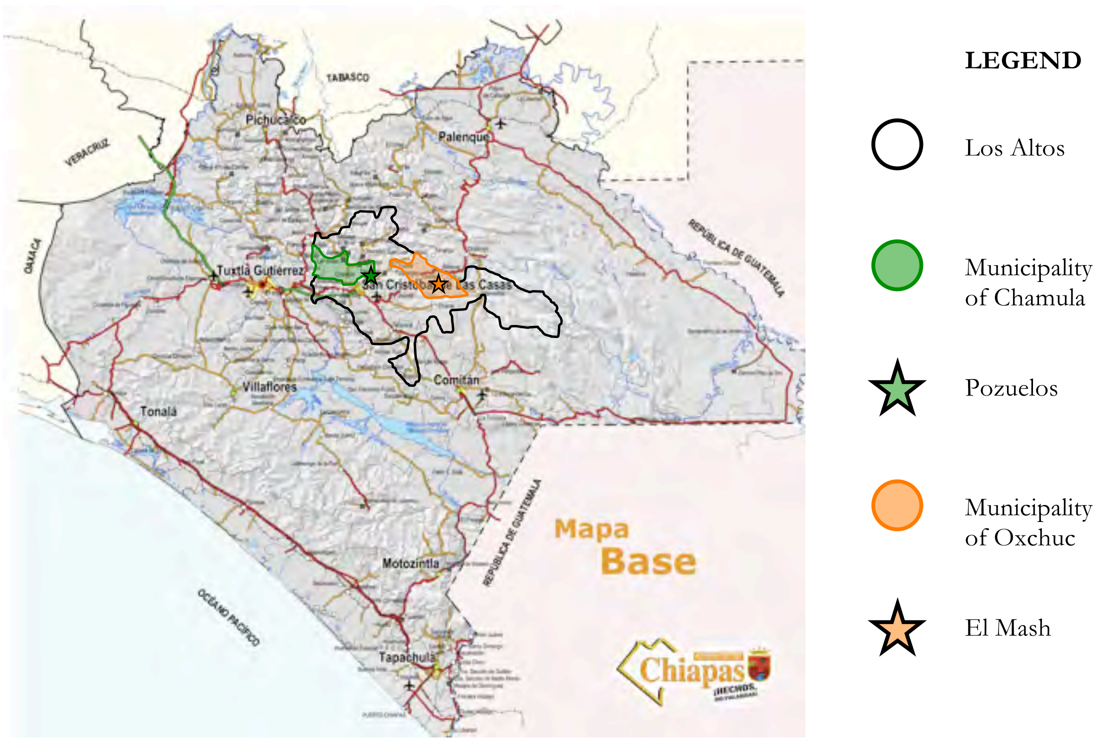


Figure 13 Location of study sites (Source: Gobierno del Estado de Chiapas, 2005)

Bordered by seven other municipalities the Municipality of San Juan Chamula covers an area of 82km^2. Its capital, also known as Chamula, is centred on the geographical co-ordinates of 16°47'N and 92°41'W at an approximate altitude of 2,260masl. Pozuelos is one of 129 communities within the Municipality of Chamula and covers an area of less than 2km^2. Despite the community's small area, individual households are typically spread out such that households do not have more than one or two immediate neighbour(s). Pozuelos is centred on the geographical co-ordinates of 16°46'23"N and 92°37'15"W at an approximate altitude of 2,483masl (Gobierno del Estado de Chiapas, 2005). The average altitude of households surveyed is 2,507masl. Although Pozuelos is equidistant to the city of San Cristóbal de las Casas and the municipal capital, Chamula, the former is more easily accessible. Serviced by numerous private taxis originating in both Pozuelos and San Cristóbal, Pozuelos is accessed predominantly via paved roads and/or roads currently being surfaced with hard standing materials.

The Municipality of Oxchuc, bordered by six other municipalities, is similar in size to Chamula covering an area of 72km^2. Its municipal capital also carries the same name, Oxchuc, and is centred on the geographical co-ordinates of 16°47'N and 92°21'W at an approximate altitude of 1,960masl. El Mash is one of 117 communities in Oxchuc and is located approximately 7km from the municipal capital. Principal access to El Mash is via an unpaved road that originates in the municipal capital. Collective taxis in the form of pick-up trucks service the community with a one-way journey requiring approximately 30 minutes to complete under normal road conditions. It is not uncommon for people to make the journey on foot, despite the distance and variation in topography. El Mash is located at 16°45'57"N and 92°18'03"W at an approximate altitude of 2,120masl. In contrast to Pozuelos, El Mash covers an area of approximately 10km^2. Households are grouped into seven disperse neighbourhoods based on their secondary source of water. These are natural springs located within the vicinity (up to 2km) of each neighbourhood and relied upon during the dry (winter) season, approximately December to May.

Local precipitation is similar to regional patterns and is predominantly distributed over the summer months (Figure 14) (CNA, 2009). The climatological station nearest Pozuelos is located on the nearby peak of Tzonte'witz at the geographical co-ordinates of 16°50'02"N and 92°34'49"W and an altitude of 2800masl. Historical records, kept since 1995, indicate average annual precipitation between 1994 and 2008 was 2135mm (Table 16). The climatological station nearest El Mash is located in the municipal capital of Oxchuc at the co-ordinates 16°47'10"N and 92°20'34"W at an altitude of 1987masl. Records kept since 1970 indicate an average annual precipitation of 1638mm (Table 17).

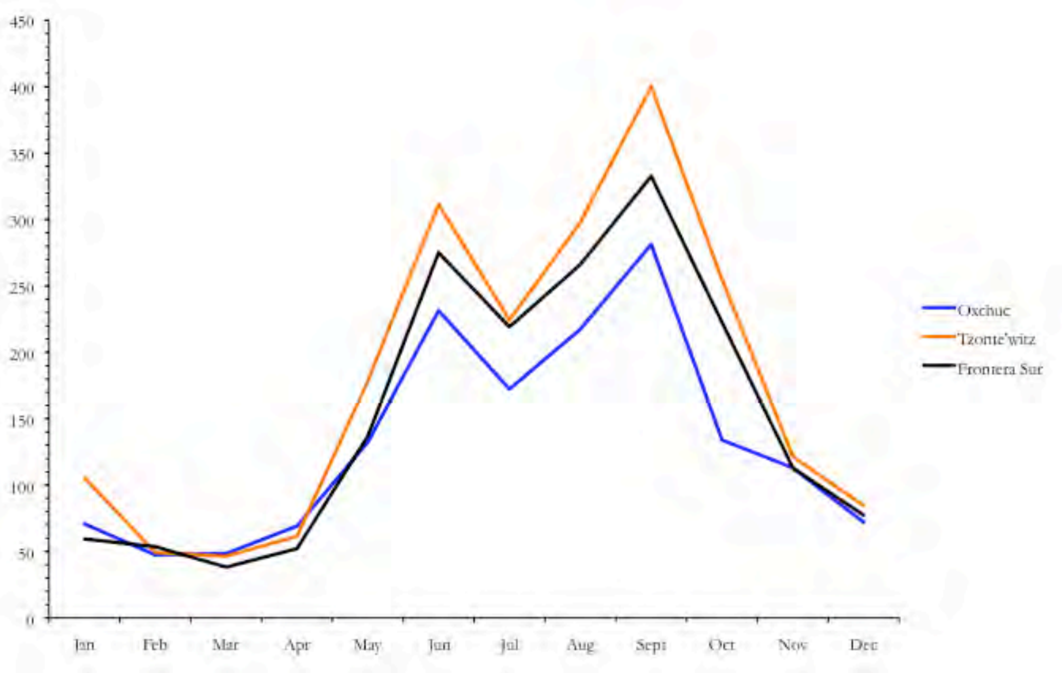


Figure 14 Historical average monthly precipitation (mm) at local and regional scales

Table 16 Average monthly rainfall for Tzonte'witz over the period 1995 to 2008*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Yr
Rainfall (mm)	106	49	46	61	178	311	224	298	400	255	122	84	2134

Source: Organismo de Cuenca Frontera Sur, CONAGUA, 2009
*excluding 1998
Includes: Jan 2009
Excludes: Nov 1995, 1999

Table 17 Average monthly rainfall for Oxchuc over the period 1970 to 2008

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Yr
Rainfall (mm)	71	48	48	69	132	231	172	217	281	182	113	72	1638

Source: Organismo de Cuenca Frontera Sur, CONAGUA, 2009
Includes: Jan 2009
Excludes: Jan 1977; Mar 1977, 1978; Apr 1979, 1996; May 1970; Jul 1981, 1993; Aug 1976, 1998, 2007; Sept 1982, 1990, 1998, 2007; Oct 2007; Nov 1972, 2007; Dec 1976

5.1 Geology

Both study sites are located in the Sierra de Chiapas geological province, described as a mountainous belt of folded and faulted Mesozoic and Tertiary sedimentary rocks that transverses central and northern Chiapas (Duffield, *et al.*, 1984). High peaks, steep terrains and valleys characterize regional topography.

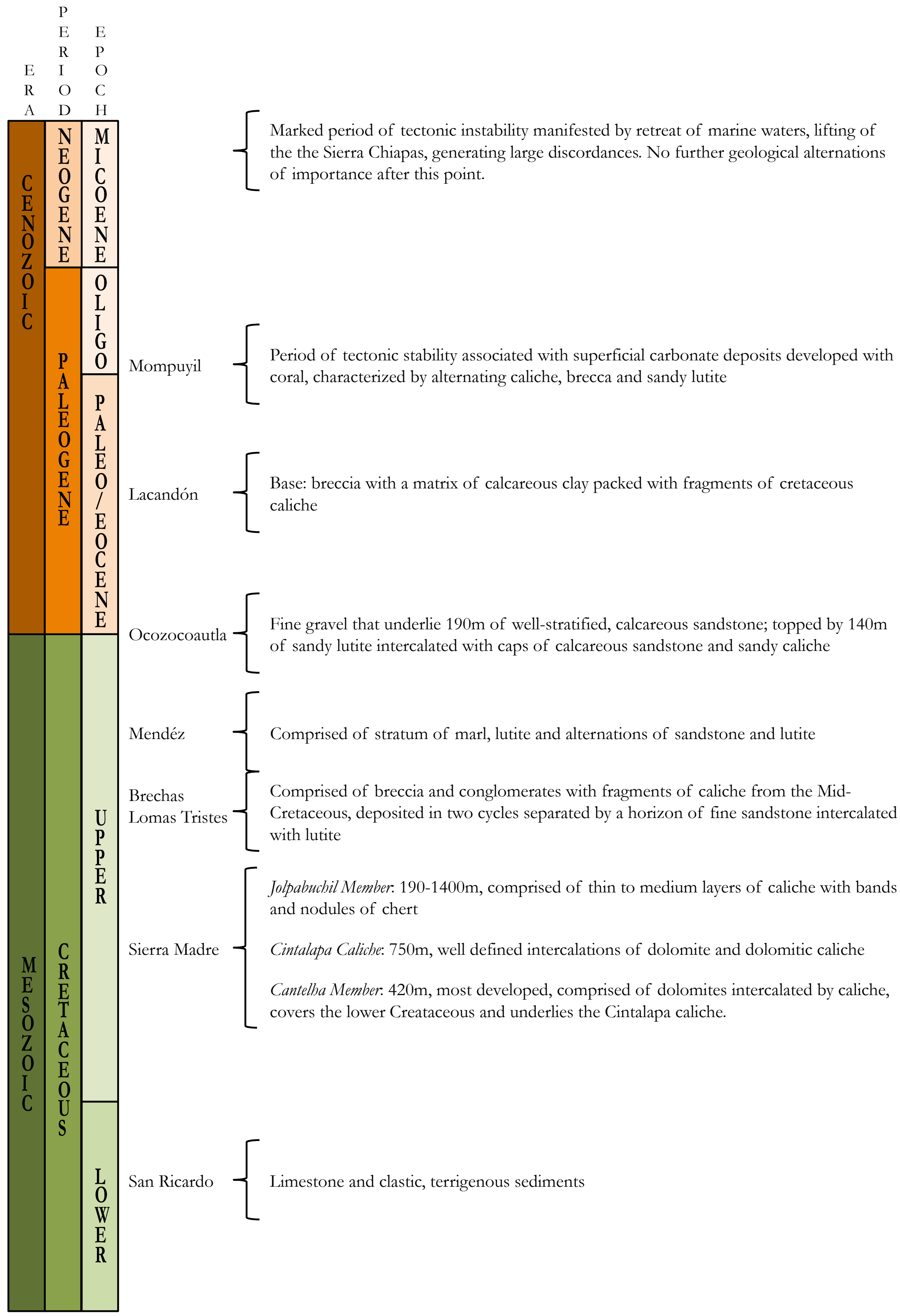
Pozuelos is situated within the Chiapanecan Volcanic Arc (CVA), a "tectonically complex region where three great plates interact: the North American Plate, the Caribbean Plate and the Cocos Plate" (Mora *et al.*, 2007, pp.43-44) located in the strike-slip fault zone. One of the most prominent peaks within the CVA is nearby Tzonte'witz, the site of both springs serving Pozuelos, which covers an area of 16km^2 and whose summit surpasses 2,650masl.

Limestone and dolostone of the Sierra Madre Formation from the Lower and Upper Cretaceous Period characterize the local geology of El Mash. In Pozuelos, younger sedimentary rocks of carbonatic limestone and lutite of the Ocozocuautla-Angostura Formation from the Upper Cretaceous Period characterize local geology (Servicio Geológico Mexicano, 2005). Stratigraphically, the Ocozocuautla-Angostura Formation sits upon the Sierra Madre Formation in turn sitting upon the San Ricardo and Todos Santos formation supported by the Macizo de Chiapas, a granitic basement complex of importance to local hydrogeology. A summary of some of the more important geological characteristics relevant to the local study site of Pozuelos is included in Figure 15.

5.2 Hydrogeology

According to Velázquez Aguirre & Ordaz Ayala (1993, pp.30-31), both sites are located within the Sierras y Valles Del Sureste hydrogeological province comprising an area of 84,280km^2. A translation of their description of this province follows:

> "This hydrogeological province is one of the most privileged in terms of hydraulic richness given it receives the most rainfall in the country, as well as encompassing rivers with some of the highest flows in Mexico, including the Grijalva and Usumacinta. However, despite the abundant rainfall and surface runoff, these are concentrated in one period of the year and [water is] stored mostly in the lower parts [of the province].



Developed from CNA, 2003

Figure 15 Regional geological characteristics of importance

In the Sierra de Chiapas, constituted by a granite mass, the conditions are unfavourable for aquifer exploitation, limiting [water abstraction] to small springs originating in fractured rock. This is the region with the highest rainfall but because of the low permeability of [geological] materials, water drains down both sides of the mountain through streams that descend vertiginously until reaching a more gentle slope, where most of the water infiltrates."

Regional tectonic morphology has been described as two stages of faulting and folding that generated large anticlinal structures that give rise to high limestone terrains with a large development of karstic systems with numerous peaks, towers and drains (Duffield, *et al.*, 1984; Geológico Mexicano, 2005; Mera, 2000; Mora *et al.*, 2007). Karst landscapes are formed through the dissolution of limestone and dolostone producing "landforms such as karren (crevices and channels), dolines and sinkholes (closed depressions) and poljes (large depressions with flat floor)" (IAH Karst Commission, 2009). Karst formations are significant to local water supplies because they impede access, increase variability and, in the case of karst aquifers, increase vulnerability to contamination (IAH Karst Commission, 2009).

Although there is a distinct lack of hydrogeological information available, drainage patterns in Chamula have been described by Mera (1989, p.54). My general observations concur with her description, translated as follows beginning with groundwater and followed by surface water:

"[Groundwater] is located in the karstic areas where water filters through the limestone or through crevices present in the terrain. Due to the large accumulation of water and slow drainage these conditions permit the development of small lacustrine bodies of water used by local populations. This type of drainage limits the distribution of water since there are zones where this does not occur, or to the contrary, favourable conditions exist whereby lands are flooded, limiting agricultural practices. On the other hand surface drainage exists in two forms a) radial, localized in volcanic areas where the quantity of rain received via precipitation drains around intermittent streams of low depth and width whose flow augments during the rainy season; b) the second type of [surface] drainage is slightly associated with groundwater, since water is stored by the limestone rocks when it encounters an impermeable layer, constituted predominantly by lutite; water is distributed along this layer surfacing in areas where there are no porous rocks to absorb it."

To my knowledge, only one hydrogeological study has been published for the region (CONAGUA, 2003). Although the National Water Commission is charged with carrying out studies for every aquifer and hydrogeological unit within the country not all of these studies comprise fieldwork as is the case for the study of the San Cristóbal de las Casas Aquifer that underlies the Municipality of Chamula and eight surrounding municipalities. In fact, according to the CONAGUA (2003) there are no hydrogeological studies for the region although structural surveys were previously undertaken by PEMEX during gas exploration activities. These studies did not include borehole tests and no attempt to estimate hydraulic parameters was made. With such scarcity of information and a clear lack of hydro(geo)logical testing, it would be "adventurous" at best to quantify the hydraulic parameters of any aquifers in the region (CONAGUA, 2003, p.16). Nevertheless, the structural study provides additional information highly relevant to the case study of Pozuelos. Moreover, in the absence of any alternative information, an "adventurous" estimate is the only available measure.

This study (CONAGUA, 2003, p.16) suggests the aquifer in question is situated within unconsolidated clastic materials of sedimentary origin that, because of their lithological characteristics, give rise to an unconfined aquifer of variable depth, ranging from 5m to 17m on average and increasing to 50m to the north of the city of San Cristóbal de las Casas. Lithologically, it forms a part of continental quaternary deposits within the immediate surroundings of the Amarillo y Grijalva River, comprised of narrow terraces of clay, limestone, sand and gravel, and fragments of calcareous rocks, suggestive of high permeability. In general, this sequence corresponds to an aquifer of limited significance, destined mainly for domestic supply in rural communities, through shallow and "mechanical extractions". Its primary source of recharge is precipitation, notwithstanding lateral contributions, from permeable rocks situated at higher altitudes.

5.3 Demographics

Over half of the population of the central region of Los Altos is indigenous. This region presents one of the highest levels of illiteracy within the state at 18% with almost twice as many illiterate females as illiterate males. According to recent census data, 63% of households have access to piped water and 85% have access to sanitation. Seven of the one hundred most marginalized communities in Mexico are located in Los Altos. San Juan Chamula and Oxchuc are ranked 91st and 108th respectively in terms of most marginalized communities at the national level and 10th and 14th at the state level.

At the municipal level, Chamula has a population of 67,085 inhabitants whilst the total population of Oxchuc is 41,423. Both communities exhibit similarly distributed populations across genders with only slightly more females (52%) than males (48%) in Chamula and no statistical difference between genders in Oxchuc. Both populations are exceptionally young with 64% and 65% of all inhabitants under the age of 24 in Chamula and Oxchuc respectively. Similar to state level data, only 5% and 6% of the population is over the age of 60. Of the 129 communities in the Municipality of Chamula, 128 are classified as rural. Only the capital, Chamula, is classified as urban with a total population of 2,959 (INEGI, 2010). Of the 117 communities in Oxchuc, 115 are considered rural. Only two, including the municipal capital with a population of 6,468, are considered urban. Both populations form part of the two largest indigenous groups in Chiapas, the Tzotzil (Chamula) and Tzeltal (Oxchuc) Mayan groups, the Tzeltal being the larger of the two. Of the total population, 83% of Chamulans speak an indigenous language; of these nearly half do not speak any Spanish. In Oxchuc, 82% speak an indigenous language though nearly three-quarters also speak Spanish. Chamula is home to 14,274 households giving rise to a population density of five inhabitants per dwelling. Oxchuc is home to 7,057 households giving rise to a slightly higher population density of 6. There are less male heads of households in Chamula, 80%, than in Oxchuc, 92%. Access to piped water supplies and sanitation facilities differs significantly from state level data. In Chamula 48% of all dwellings are reported to have access to a piped water supply and 83% have access to sanitation facilities. In contrast, only 27% of dwellings in Oxchuc have access to a piped water supply though reportedly 94% have access to sanitation facilities (CONAPO, 2006).

Pozuelos and El Mash are both small, rural, indigenous communities with populations of 435 and 360 respectively (INEGI, 2010). The gender divide within both communities is almost equal with males making up 48% of the population and females 52%. Similarities across population distributions by age continue with 64% and 68% of inhabitants under the age of 24 and only 6% and 5% of inhabitants over the age of 60 in Pozuelos and El Mash respectively. There are 101 households in Pozuelos with a total population density of 4 people per household. There are only 62 households in El Mash where the population density is much higher at 6. The majority, 88% and 84%, of inhabitants in Pozuelos and El Mash speak an indigenous language. Of these, 52% and 44% do not speak Spanish. Heads of households at the community level mirror those at the municipal level, with 80% of all households in Pozuelos and 97% in El Mash headed by men. In stark contrast to municipal averages, some 97% of dwellings in Pozuelos have access to a piped water supply with 96% also having access to sanitation facilities. No dwellings in El Mash have access to piped water supplies although 98% have access to sanitation facilities.

As discussed in Chapter 4 many of these indicators, derived from census data, are used to calculate Mexico's *Índice de Marginación* (Index of Marginalization) (CONAPO, 2006). Tables 18 and 19 describe marginalization at the municipal and community levels as a function of each variable and then as compared either nationally or state-wide (CONAPO, 2006).

Table 18 Factors of marginalization at the municipal level

Indicator	Chamula	Pozuelos	Oxchuc	El Mash
Total population	67,085	435	41,423	360
Illiterate population 15 years of age or over	53.17	51.61	26.49	36.61
Population 15 years or more not having completed primary school (%)	64.71	61.29	45.67	54.49
Occupants in dwellings with neither drainage nor sanitation facilities (%)	11.14	3.96	3.09	1.61
Occupants in dwellings without electricity (%)	7.18	4.95	23.38	54.84
Occupants in dwellings without a piped water supply within the dwelling or yard (%)	33.20	2.00	63.14	100.00
Dwellings with some level of crowding (%)	70.22	75.25	78.84	83.87
Occupants in dwellings with dirt floor(s) (%)	55.65	74.26	82.95	95.08
Population in localities with less than 5,000 habitants (%)	100.00	-	84.39	-
Population employed with an income of at least two minimum salaries (%)	95.61	-	91.20	-
Dwellings without a refrigerator (%)	-	100.00	-	100.00

Source: Indices de marginación 2005 (CONAPO, 2006)

Table 19 Index of marginalization at the municipal level

Indicator	Chamula	Pozuelos	Oxchuc	El Mash
Index of marginalization	1.88198	0.73326	1.78847	1.23813
Degree of marginalization	Very high	Very high	Very high	Very high
State ranking	10	4391/10053	14	2445/10053
National ranking	91	-	108	-

Source: Indices de marginación 2005 (CONAPO, 2006)

5.4 Economy

In the context of this study, the local economy has been described aptly in government publications as follows:

> "The indigenous economy is based on traditional agriculture, using slash and burn techniques for the seasonal production of corn, which is the primary crop followed by the coffee plant and the bean plant. Sheep, cattle and pigs are kept on a small scale, as part of a savings strategy to acquire other goods for consumption that the family does not produce but which are indispensable. Breeding domestic fowl and, occasionally beekeeping, are also undertaken with the same objective, activities that for the most part are managed by women. Tourism has opened new sources of employment whilst at the same time promoting beautiful and colourful indigenous crafts. Indigenous women participate the most in the production and sale of these goods." (Gobierno del Estado de Chiapas, 2005).

Although this description is generally an accurate representation of the indigenous economy and holds for many of the residents of Pozuelos, in reality it requires further explanation in order to accurately represent the residents of El Mash. In El Mash, most people survive simply on subsistence farming as described in the previous paragraph but it should be understood that few, if any, participate in any of the formal economic sectors, instead eking out an existence that only serves to meet, and almost never surpass, the needs of their family. In fact, as will be seen in Chapter 6, families in El Mash who are forced to sell their crops are considered to be some of the least well off. Few if any of the men in El Mash are employed formally, or for that matter, informally. The vast majority of them who manage to find paid employment most often work as peasant farmers. To the contrary, a number of families work in the service sector in

Pozuelos, many who serve the local community, for example, owning and operating small shops. There are a number of skilled workers (builders, gardeners, plumbers, and a candle maker), one or two taxi drivers and even some who are employed formally outside the community.

5.5 Water Supply

The primary source of water in Pozuelos is groundwater captured at two natural springs on nearby Tzonte'witz and distributed via a recently constructed gravity-fed distribution network. The first reservoir is located 10km northeast of the community at an altitude of 2687masl. The second and smaller reservoir is approximately 500m SSW of the first at a slightly lower altitude of 2676masl. A chain link fence protects the first reservoir whilst mesh netting surrounds the second. Water from both reservoirs flows into covered, cement spring boxes with metal screens that trap large and medium size debris at both outflow pipes. Water is then distributed through four-inch stainless steel distribution pipes, with break pressure tanks and air valves distributed intermittently across the network. Designed by a retired American engineer who was a long-time resident and benefactor of the local community, the system is less than five years old and was intended to replace the previous network built with PVC tubing which, according to local residents, was highly susceptible to damage (pers. comm. 1). The municipality provided the necessary funding and the community provided the labour as is customary in small, rural communities.

Each year the community appoints a male member to serve voluntarily as *el patron del agua* (water caretaker) whose primary role is to ensure the regular maintenance of the distribution network. He is officially appointed during the annual changing of the water caretaker ceremony. Every two weeks he visits the reservoirs to remove any debris that may have accumulated. Shutting off the main valve, he also cleans the inside of each spring box using only a deck brush and water. Finally he makes the arduous and precarious journey along the distribution network ensuring the pipes are free from fallen debris and opening and closing the air valves to release any air that may have accumulated in the pipes during the cleaning process (pers. comm. 1).

Plate 1 **Entrance to trail leading to springs serving Pozuelos:** *Littering is prohibited. Punishable by fine and jail within spring zone. Sincerely: Potable Water Patrons, municipal capital*

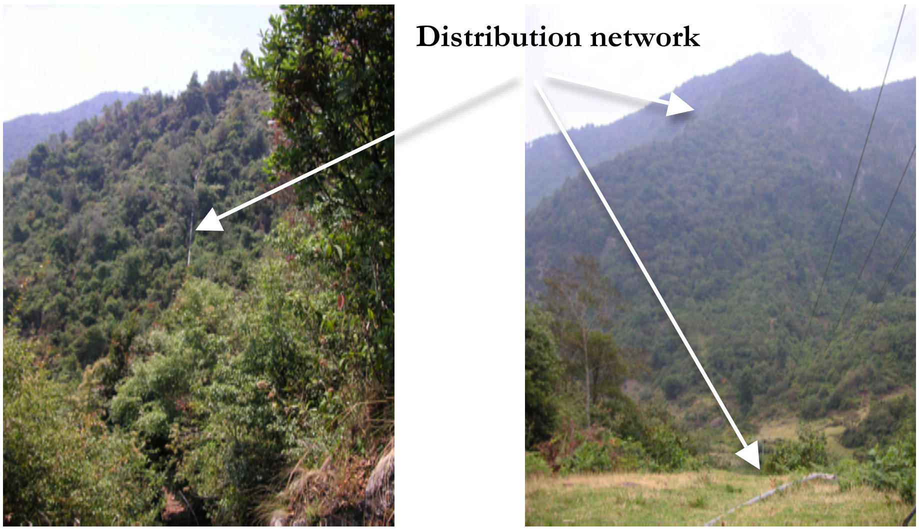


Plate 2 **Examples of topography and distance covered by the distribution supply network from source to site in Pozuelos**

Water is provided free of charge and only in the case of necessary repairs is a voluntary collection undertaken whereby each family (typically the male head of household) contributes financially according to his means. This collection is made after the fact and no finances are kept in reserve for the purpose of repairs and maintenance. Further, community members who may or may not be skilled labourers typically undertake such repairs. The water supply is continuous and is only ever shut off in the case of repairs. That being the case, anecdotal evidence suggests overall water availability decreases significantly during the dry season reducing flow through the network. Three separate bucket flow tests were carried out at the main reservoir giving an average flow rate for the main reservoir of 6.69L/s. As will be discussed later this is insufficient to meet the needs of the community.

Although residents of Pozuelos receive piped water year round, in periods of reduced flow, it is not unusual for women to rely on community water holes predominantly for non-potable uses such as livestock consumption or washing clothes. An example of such a water hole during the dry period can be seen in Plate 3.

Plate 3 Example of water hole most commonly relied upon for non-potable uses during periods of reduced network flow

During times of peak flow, residents commonly fill small plastic tanks known as *tinacos* for water storage. With a 1,700-litre capacity these tanks are not unique to Pozuelos but are found across Mexico. An example of one such tank can be seen in Plate 4.

Plate 4 Example of a 1,700-litre tinaco, commonly used for water storage across Mexico

Residents in El Mash rely predominantly on rainwater though are dependent upon local springs as a secondary source during periods of drought. Approximately three to five years ago, El Mash was the recipient of a government project to supply each household with a concrete water storage tank. Broadly speaking, government-funded projects such as this are sub-contracted to local agents and rarely, if ever, monitored. Thus corruption is rampant and many projects are never completed or are completed to a sub-par standard. Although community leaders must approve a project's completion by signing off on the final contract, many of them are illiterate and largely unaware of the impact of doing so. In many cases, the community will not have been involved in the project planning and remain uninformed of project stipulations and standards. For example, household rainwater tanks in Los Altos normally, as a minimum, should meet the following standards (pers. comm. 2):

- high quality reinforced concrete
- impermeable interior coating
- raised, protected intake, with a removable screen for filtering large debris
- secure metal lid
- overflow valve
- service valve

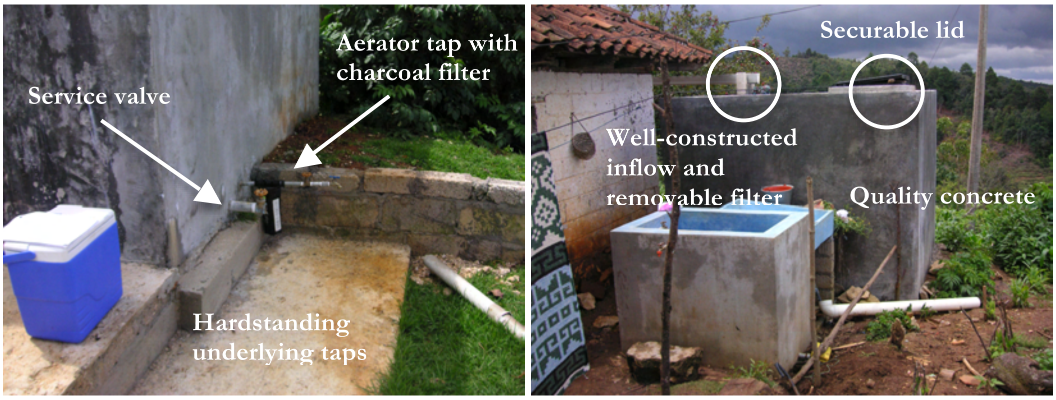


Plate 5 Elements of a well-constructed rainwater harvesting tank (images of tanks constructed as a result of an NGO-led project in Pozuelos)

Despite their age, tanks in El Mash were observed to be cracked and leaking, evidence of the use of poor quality concrete in their construction. Those that had filters had been cemented in during construction impeding their removal for proper cleaning. Taps were often broken and lids non-existent. Furthermore, despite government provision of tanks, residents were left to design their own rooftop catchment. Thus, in one case, the tank had actually been constructed above the eaves troughs rendering it very difficult to capture water. Household roofs were a mix of corrugated steel and clay tiles, and few if any, utilized the entire available surface area of their roof. Clearly most of these problems could have been avoided and are easily remedied, but an unfortunate stipulation in government-funded projects dictates communities may not reapply for assistance in an area, in this case water, where they have already received support until sufficient time (normally ten years) has passed such that other communities have had the opportunity to be served (pers. comm.).

Plate 6 Elements of a poorly constructed rainwater tank (images of tanks constructed during a government-led project in El Mash)

During periods of drought when stored water becomes insufficient to meet household needs, residents rely on a number of local springs. The community is divided into seven distinct neighbourhoods. Divisions are purely geographical and each neighbourhood is associated with one primary spring and in some cases one secondary spring, which may or may not overlap, depicted in Figure 16 in blue. Most springs are small and comprise only basic infrastructure such as a cement spring box and service taps. Each spring is described in detail in the following paragraphs.

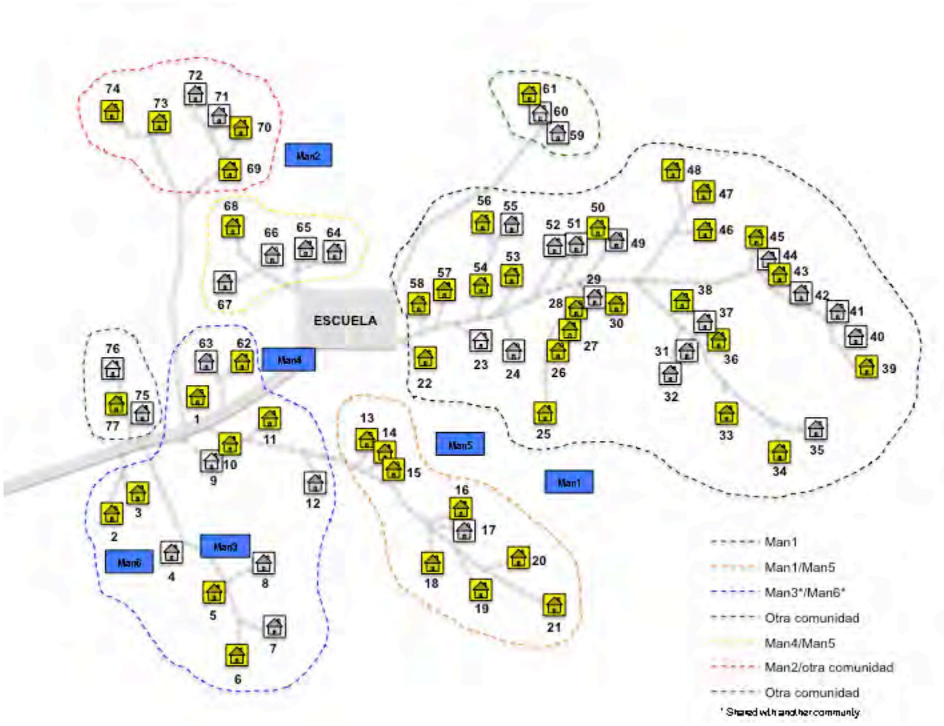


Figure 16 Community map of El Mash depicting neighbourhood divisions and community springs (survey respondents are indicated by a yellow household)

Man1 (Plate 7): This spring is by far the largest in the community and was constructed as part of a neighbourhood-led project completed in January 2006. Two enclosed cement pipes, an inflow pipe and an outflow pipe, service a large cement spring box constructed of stones and mortar capped with cement and a sealed lid. The area is fully enclosed by a chain link fence and access is via one of two gates. The area is overgrown with foliage and at the time of the visit, the ground was damp and muddy. An aboveground tank adjacent to the spring box receives some of the spring box's overflow. The tank is constructed similarly to the spring box and although the area is also enclosed within a chain link fence water otherwise remains open to the elements. At the time of the site visit, the tank was lined with sediment, small rocks and stones and small branches. Moss was growing outside the tank edges whilst algae grew within the tank. Approximately 122 residents use water from both the tank and this area indiscriminately. The spring box has four taps located about 18 inches off the ground although at the time of the visit one tap was in disrepair. Only two of the taps included aerators controlling water flow.

Plate 7 Main spring box (left) and adjacent overflow area (right)

Man2 (Plate 8): The second spring comprises two aboveground spring boxes constructed on top of the site of a natural spring. The area is completely unprotected and both boxes are in poor condition. The older of the two boxes is constructed of stones and mortar topped by a cement lid with a large unprotected opening. Algae were seen growing on all four walls. The second box was built in 2001 and is of cement construction but with no lid. Wood planks cover the top with a small opening to access the water. At the time of the site visit, the ground in the vicinity of the tanks was supersaturated and teaming with algae and insect life. Debris and algae were visible in both tanks and insects were seen striding on the water's surface.

Plate 8 Spring boxes (left) and interior of right-hand spring box (right)

Man3 (Plate 9): A spring box was built in this location in 1998. Cement steps lead down to the bottom of the spring box where two water taps are located. The box also comprises an overflow pipe and a service pipe. The latter was presumably included so that the box could be emptied as required for cleaning yet the box is completely sealed and cannot be accessed. The area surrounding the box is unprotected and vegetation grows on three sides of the tank, including farmed crops. Until three years ago, local farmers used chemical fertilizers. The ground below the spring box was supersaturated. At the time of the site visit, the tank was overflowing and water was running around and over the spring box. The spring is believed to be at low peak from April to July but never dries up completely. The spring box was constructed down slope of households M04 to M08 and their latrines causing severe water quality problems described in detail Chapter 6.

Plate 9 Steps down to taps (left) and overflow pipe (right)

Man4 (Plate 10): This spring refers to a tap stand located within the schoolyard whose source was not investigated. The leaky tap is underlain by hard standing.

Plate 10 Tap stand drawing water from Man4

Man5 (Plate 11): This is a small, unprotected spring borne from under a large rock. Water pools in a small crevice before flowing down slope from the spring. This spring serves as a secondary spring for a small neighbourhood grouping of households.

Residents take water directly from the small pool. Farming activities that include the application of chemical fertilizers to the land are undertaken nearby. Water in the spring was visibly turbid and teaming with insect life.

Plate 11 Source of spring and water hole (left) and close up of turbid water (right)

Man6 (Plate 12): This refers to the site of a spring located within a small cavern providing natural protection. Water falls down a rock face, pooling at the bottom infiltrating rocks. At the time of the site visit the spring was at peak flow and much more accessible than during periods of low flow when residents must crawl inside the cavern to place a hosepipe near the source estimated to be 30-40m from the mouth of the cavern. Water is then siphoned out via gravity.

Plate 12 Inside the cavern where Man6 is borne

CHAPTER 6 LOCAL INDICATORS OF WATER POVERTY

As discussed in Chapter 3, data used to calculate water poverty at the local scale were collected during an intense data collection process in both communities. A detailed questionnaire comprising 56 questions in total was used to assess water poverty at the community scale. The questionnaire (attached in Appendix A) included a number of closed and open-ended questions designed to formulate the basis for a number of quantitative factors impacting water poverty but also included more qualitative questions designed to assess community perceptions of water poverty. The questionnaire was divided into five sections representing each of the five indicators used to calculate water poverty. Beginning with Resources this chapter presents the results of this extensive survey, commenting on findings as appropriate and contrasting both communities throughout.

6.1 Resources

Six facets of water resources were considered: type and volume of household water storage, actual and perceived availability of water during the dry season (November to May), and the respondent's rating of their water service (in terms of reliability and availability). Of the 44 households surveyed in Pozuelos, the majority of respondents use one or more 1,100L plastic tanks to store their water. Some respondents use a combination of both concrete and plastic tanks with the former typically holding 18,000L of water, slightly fewer use only concrete tanks, whilst two use buckets and three do not have any household storage[8]. Of the 45 households surveyed in El Mash, more households use one or more 1,100L plastic tanks to store their water than any other type of storage. A further 38% of households use concrete tanks, 11% use a combination of concrete and plastic tank(s) and 4% of households have no storage.

In terms of volume, the majority of households surveyed in Pozuelos have one plastic tank thus the potential to store 1,100L of water. A further 39% of all households have at least two plastic tanks or some combination of plastic and concrete tanks providing

[8] One household lives on the border of Pozuelos and its neighbouring community of El Pinar and is fortunate enough to be served by both communities, with 2 household taps from El Pinar and 1 from Pozuelos. They reported having year round water service and thus do not need storage. The remaining two households did not have access to storage despite their reported, and observed, needs.

storage capacity ranging from a minimum of 2,200L (two plastic tanks) to a maximum of 22,400L (one concrete tank and four plastic tanks). The five remaining households have no available storage (including the aforementioned households without storage and those whose only available storage is in the form of buckets). In El Mash, total storage volume varies widely across households, ranging from 1,100L for those who have only one plastic tank up to 31,100L for a single household (P050) with two 15,000L concrete tanks and one 1,100L plastic tank. Mean storage volume across all households is 12,350L yet 60% of all households have 11,100L of available storage or less. Clearly 4% of households have no available storage as described above.

Table 20 Type of water storage used by respondents at the household level

	Pozuelos (%)	El Mash (%)
Plastic tank(s)	52	47
Concrete and plastic tanks	21	11
Concrete tank(s)	16	38
None	7	4
Buckets	5	-

Respondents were asked to rate the availability of water from their primary water source during the dry period from November through to May. A five-point Likert scale was used ranging from: none, to very little, to insufficient, to sufficient, to a lot. In this case, the scale is deemed to be of equal intervals thus statistical analyses traditionally applied to interval scales is applicable.

During the months of November and December a large majority in Pozuelos indicated there was sufficient water to meet household needs. Only two respondents in November and one in December struggled to recall the amount of water present in those months. Very few people, less than 7%, considered there to be a lot of water in either month and on the opposite spectrum, six people considered there was insufficient or very little water available in November with this number increasing to nine in December. In January, a marked difference was reported with only 48% of all respondents stating there is sufficient water available for household needs. Half of all respondents, 50%, stated there was insufficient, very little or no water at all available to meet their needs. This trend continues in March and April where the majority of respondents indicate there is very little water available to meet household needs, 71% and 66% respectively with the number of respondents reporting no available water increasing from 9% in March to 23% in April. By May a significant proportion, 30%, of all respondents indicate a total lack of water available for household needs and a further 57% report very little water availability.

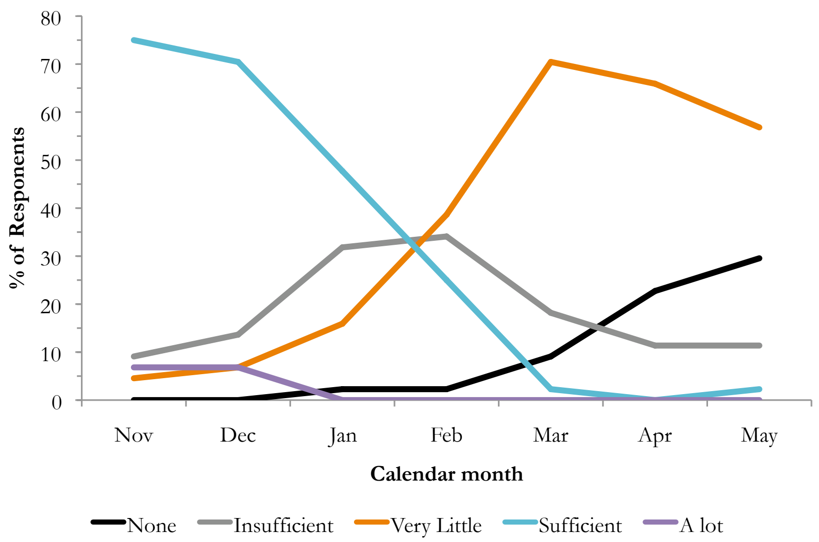


Figure 17 Perceived water availability by month at the household level during the dry season in Pozuelos

In El Mash, the majority of respondents felt there was either insufficient, very little or no water available throughout the entire period surveyed, ranging from a minimum of 66% in December to a maximum of 98% in March. In November 73% felt there was insufficient or very little water available, whilst 16% felt there was sufficient or a lot of water available; one respondent could not remember. In December perceived availability increases slightly with 33% of respondents indicating there was sufficient or a lot of water available, 66% indicating there was insufficient or very little water available; one respondent could not recall how much water was available. A perceived lack of water becomes very apparent in January with 84% indicating there was insufficient or very little water available. In February 91% indicated there was insufficient, very little or no(ne) water available. This trend peaks in March with 98% of all respondents reporting insufficient, very little or no(ne) water available. In April, there is some indication that water availability had recuperated with 93% indicating a limited availability and 7% indicating sufficient availability for their needs. Finally, 80% report a limited availability during the month of May with 20% reporting there is sufficient or a lot of water available.

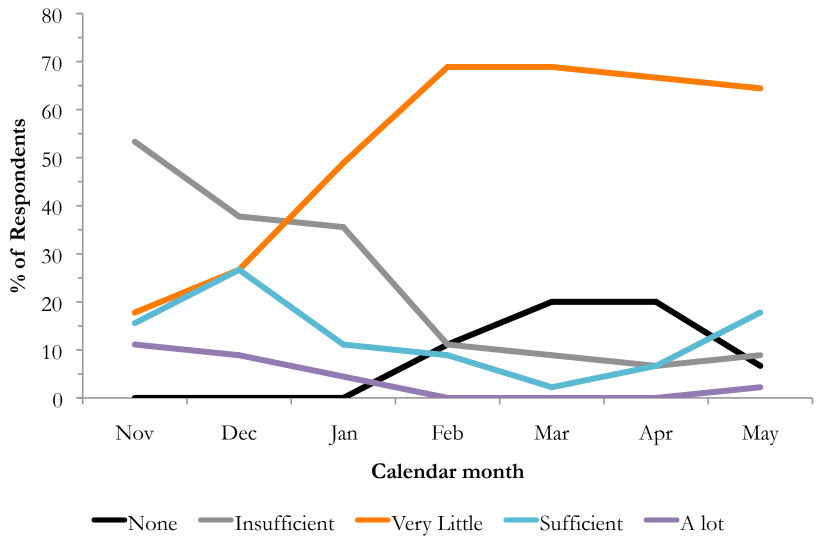


Figure 18 Perceived water availability by month at the household level during the dry season in El Mash

The responses are in keeping with general climatic trends, which show a decrease in precipitation throughout the dry period. When response rates are correlated to volumes of precipitation over the same month, there is little or no correlation (Table 21). However, the water supply system in Pozuelos is spring fed therefore it is reasonable to expect a time lag between precipitation and the availability of water at the household level due to hydrological considerations. Furthermore, it is possible that the memory recall ability of respondents is also subject to a similar time lag, subconsciously relating water availability to precipitation levels after the fact. For example, most respondents also harvest rainwater. Although some households are fortunate to have a large enough storage capacity to maintain separate reservoirs, the vast majority combine tap and rainwater in their household tanks, either voluntarily, or involuntarily, the latter due to poor construction (i.e. tanks without lids). Though instructed to consider their primary water source only, it became evident respondents often considered water availability as a function of the volume of water collected in their tank. Strictly speaking, this is not an unfair interpretation given their propensity to fill their tanks with tap water when possible. In any case, there is a strong correlation between response rates and precipitation when a time lag of one month is considered i.e. January response rates have been correlated with December precipitation and so forth. There is a strong relationship between reports of "a lot" and "sufficient" water available to meet household needs and precipitation. The fact the relationship is positive is indicative of high volumes of precipitation as to be expected. There is an equally strong relationship between reports of "very little" and "no(ne)" water available to meet household needs and precipitation. In this case the relationship is negative, indicative of decreased volumes of precipitation also to be expected. There is no correlation between reports of "insufficient" water available at the household level and precipitation. I would suggest this is because the middle term of a five-point scale with equal intervals would normally represent a neutral response and therefore intuitively bear no relationship to the correlated variable. In the case of this survey, the term "insufficient" bears a negative connotation however there are two factors to take into consideration. In the first instance, for the purposes of statistical analysis the scale has been deemed to be of equal intervals therefore statistically the middle term will be treated as neutral. In the second instance, report rates for this term are typically low, with a maximum number of 15 respondents reporting insufficient water available to meet household needs in February, suggesting the respondents either didn't understand the term correctly, or intuitively viewed the middle term as neutral.

Table 21 Correlation coefficients between perceived water availability at the household level and recorded levels of precipitation

Correlation variables	Pozuelos		El Mash	
	Direct comparison	Time lag of one month	Direct comparison	Time lag of one month
A lot	0.2	0.8	0.5	1
Sufficient	0.1	0.9	0.6	0.8
Insufficient	-0.4	-0.1	0.3	0.9
Very little	-0.2	-0.9	-0.4	-0.9
None	0.4	-0.7	-0.5	-0.8

To the contrary, in El Mash the perception of water availability immediately correlates reasonably well with average monthly perception over the same months. Given the majority of residents rely on rainwater as their primary source of water, one would not expect to see the same correlation when a time lag of one month is applied, yet, as is the case in Pozuelos, the correlation not only exists but is much stronger. There are a number of factors that might contribute to a respondent's perceived time lag in decreasing or increasing water availability. For example, the level at which a respondent considers her tank to no longer contain sufficient volumes of water may vary. The contrary may also stand to be true and respondents may not perceive the immediate impact of precipitation, instead citing increasing water levels only after several days of continued precipitation have generated an overall increase in their water tank, particularly those with large tanks. In addition, water consumption at the household level in El Mash is extremely low therefore it may take some time before water levels are perceived to have decreased after an initial period of rainfall. Further investigation is needed to determine the timeframe within which the correlation exists and at which point it is at its strongest before additional speculation can be made about this relationship.

When asked to rate the quality of their water service in terms of system reliability, the majority of respondents in Pozuelos, 64%, indicated it was bad whilst only 18% indicated it was ordinary and a further 18% indicated it was good. However, when asked to rate water quality, a strong majority of 84% felt it was good/ clean, whilst only 16% felt it was a little dirty or bad/ dirty. The original question pertaining to water quality was open ended to encourage respondents to describe water quality in their own words and to prevent leading. However, it quickly became evident that the main determinant of water quality was its visual properties and respondents associated poor water quality with turbidity or debris. For example, whilst many respondents indicated their water was clean, P003 said her water was a little dirty whilst P004 indicated water drawn from her tap was good, but water stored in her plastic tank had "*bugs inside*". The original question was therefore modified to include visual indicators.

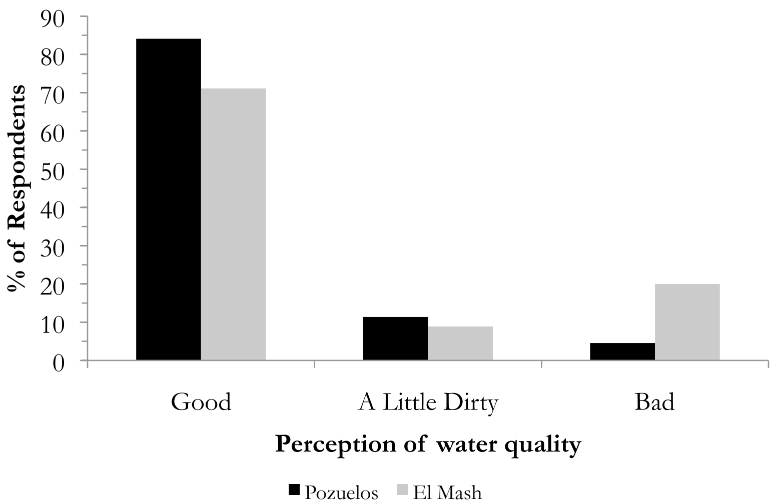


Figure 19 Perceptions of water quality at the household level

In El Mash, a large majority of respondents, 82%, indicated the reliability of their water service was bad whilst only 9% indicated it was ordinary and a further 9% indicated it was good. When asked to rate the water quality of their primary source, a majority of

71% felt it was good/ clean, whilst 29% felt it was either a little dirty or bad/ dirty. Only 67% of respondents felt their secondary source was good/ clean whilst 34% felt it was either a little dirty or bad/ dirty.

6.2 Access

All of the survey respondents in Pozuelos have access to a tap within their yard connected to the public distribution network supplying spring water from nearby Tzonte'witz. This concurs with previously published census data, which indicates only 2% of occupants in Pozuelos reside in dwellings without a piped water supply within the dwelling or yard. The majority of respondents, 93%, harvest rainwater to supplement their needs. Only 2% of respondents resort to using a public waterhole as a secondary source in times of need. However, when asked who the principal water carrier was in the household, 14 respondents provided a valid answer. Further probing revealed some households rely on public waterholes in times of severe hardship, in addition to the primary and secondary sources already listed. This is understandable given water supplied via the public distribution network is contingent upon precipitation, therefore, although rainwater harvesting is common practice both sources have similar patterns of temporal availability. As a result, in times of severe hardship and/ or prolonged periods of drought, some households are forced to rely on public waterholes to meet their needs. In certain cases, this is due to a limited potential to store water. As indicated above, five households are without storage. Additional problems occur in high-density households who may have storage but insufficient volumes to meet their needs. Lastly, anecdotal evidence and personal communication suggest public waterholes are used more frequently than indicated by respondents, particularly for non-potable uses such as washing laundry and/ or watering animals so as to conserve water stored at the household level for potable uses only.

To the complete contrast, of the 45 households surveyed in El Mash, 89% rely on rainwater as their primary source of water whilst 11% rely on spring water. Of the 11% that rely on spring water, two households are without storage hence incapable of taking advantage of rainwater. However, despite having 10,000L concrete tanks for rainwater collection at their disposition, two households (M28 and M30), reportedly use rainwater for purposes other than for human consumption only, for example cleaning, and rely upon spring water as their soul source of drinking water throughout the year. One respondent (M30) mentioned the water from her tank was "dirty" but that the spring water was "clean", a misguided opinion given subsequent water quality analyses. Another household (M57) lives in close proximity of the school and uses the rainwater collected in its tank for human consumption and the rainwater collected in her own 1,100L plastic tank for laundry. The 89% of respondents who rely on rainwater as their primary source of water rely on spring water as their secondary source. The 11% who already use spring water as their primary source have no alternative source.

Of the 14 respondents who stated they participated in water-carrying activities in Pozuelos, men participate in only one household. In the remaining thirteen households, only adult women carry water in five, in a further five all the female occupants carry water, and in three households, women and children of both genders, carry water. The average time required to complete one round trip to collect water including waiting time is 74 minutes with the average household requiring two trips. This is based on information provided by twelve respondents as two respondents, P003 and P007, could not remember the length of time required but both stated the waterhole was "nearby". Household P020 reported the shortest journey of 20 minutes and with three water carriers was only required to make the trip once per day. Four households, P004, P008, P012, and P029, each had the longest travel time of 120 minutes with the number of trips required ranging from one for P008, to two for P012 and P029, to three for P004.

In El Mash, all households rely on either a primary or secondary water source that requires water-carrying activities at least some of the time throughout the year. Both genders participate in these activities in all but ten households and adult males actively carry water in 60% of all households. Some households (M03) are entirely female or do not have a male head of household (M57) whilst other respondents (M27 and M14) indicated the male head of household helped when not working or in one case simply couldn't help as he was required to work outside the community (M11). The respondents gave the impression overall that the community of El Mash generally adopted an egalitarian approach to water carrying activities, and in any case, certainly more so than in Pozuelos. The time required to complete one round trip to collect water including waiting time ranged from 10 minutes to two hours with an average time of 74 minutes. One hour was the most commonly given answer with 42% of all respondents indicating they require 60 minutes to complete one round trip. Five respondents (11%) made at least one daily trip whilst 6 (13%) made on average four daily trips. The majority, 49%, made twice daily trips whilst 27% made three daily trips to collect water.

The vast majority of respondents in both communities (93% in Pozuelos and 100% in El Mash) have access to sanitary installations. In Pozuelos, 84% have access to pit latrines whilst 9% (four households) have access to flush toilets. Still, 7% of all respondents (three households) do not have access to any kind of sanitary installation. These households, P012, P020, and P023 all indicated they practice open defecation. This is in keeping with census data (INEGI, 2010), which suggests 4% of all occupants reside in dwellings with neither drainage nor sanitation facilities. In other words, 17 people of a total population of 435 do not, at the very least, have access to sanitation facilities. The three households without sanitation facilities in this study represent a combined population of ten. The four households with access to a toilet that uses water have septic tanks; two are fully plumbed with all water draining to the septic tank whilst only black water drains to the septic tank in the remaining two households. None of the remaining households have access to any form of water drainage. In El Mash, 98% (44 households) currently have simple pit latrines while 2% (1 household) has a flush toilet connected to a septic tank. This is in keeping with the national census (INEGI, 2010) which indicated only 1.6% of households lacked access to either drainage or sanitation facilities.

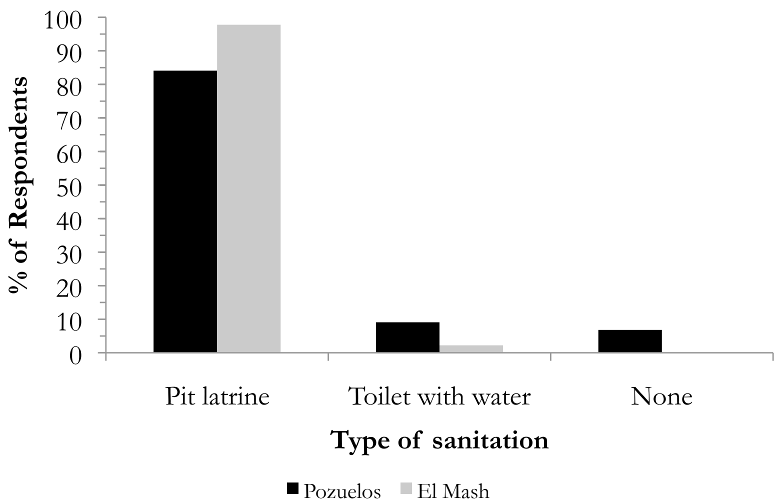


Figure 20 Percentage of households with access to sanitation by type

Most if not all of the households in the community participate in Mexico's welfare programme, Programa Oportunidades. One of the qualifying criteria for the programme is that the household must have its own pit latrine (though the government does not appear to distinguish between simple and ventilated improved pit latrines). Anecdotal evidence suggests that no support is provided however regarding its construction, neither in terms of building materials, building know-how nor maintenance. Thus the majority of latrines in El Mash are very primitive, of timber construction, with pits of unknown dimensions and most likely with unsupported pit walls. I took the opportunity to observe as many pit latrines as possible. These consisted of four timber walls, a timber floor, a timber box seat and a roof made of corrugated steel. Latrines made of timber are often unhygienic due to the difficulty of keeping surfaces clean. Doorframes were often covered with a tarp or old sheet providing some privacy but had only a limited affect against flies and other insects that regularly breed in such areas. None of the latrines included ventilation pipes, although given their poor construction there were ample crevices and cracks between planks. Almost all of the latrines were observed to be in varying states of disrepair, often with rotten floorboards and walls. Many of the pits were full beyond capacity but most of the respondents were unaware of the need to build a new pit once the original pit has reached capacity (dependent upon the volume of the pit and the household population). One household (M61) regularly threw water into the pit after each use.

Figure 21 The *best* of latrine construction and maintenance in El Mash (private latrine)

With little or no guidance regarding pit location, four households (M05, M06, M07, and M08) built their latrines within close proximity of a local neighbourhood spring (Man03). Water quality analyses of the spring's water indicate high levels of thermotolerant coliforms (mean TTC=408/100mL) indicative of faecal contamination, almost certainly as a result of its location immediately downstream of these latrines. As discussed in detail in later sections1, water surrounding the spring contained even higher levels of contamination (mean TTC>13,390/100mL).

Figure 22 The *worst* of latrine construction and maintenance in El Mash (school house latrine)

When respondents were asked whether or not they encountered any conflicts over access to water, a strong majority of 93% in Pozuelos said no. Only 7% indicated they had encountered conflicts from time to time, all of which stated these were mostly "*in the past*" during times of water hardship when certain "*prohibitions*" are implemented at the household level. For example, during the latter stages of the dry season, it is common practice for the community to ban the use of tap water for laundry purposes in a bid to conserve water. In El Mash, although a majority of 73% of all women surveyed reported no conflicts, almost one quarter indicated they had encountered conflicts from time to time. Of these, comments detailing the cause of such conflicts varied, for example, one respondent (M02) reported "*at times* [they] *don't respect the line and there are arguments*", whilst another respondent (M05) suggested there were "*problems between children*." Some respondents commented about the general maintenance and cleanliness of springs. For example, one respondent (M06) reported there were conflicts from time to time when "[they] *leave bags of soap* [behind] *or when it's their turn to clean the tank and they don't show up*." Another respondent (M19) reported, "*other women leave garbage or take more water than they should*." Several respondents (M21, M27 and M34) suggested they argued because, and when, there is insufficient water available at the spring. Interestingly, one respondent (M30) suggested, "*married women have more power* [when accessing water] *because their husbands work*." Some conflicts are clearly geographically and culturally dependant as indicated by two respondents (M70 and M73) who are occasionally required to rely upon a spring outside of their community and who report that conflicts arise when they (residents of El Mash) attempt to use a spring near Oxchuc (the municipal capital). Both respondents commented that the women of Oxchuc don't like them using their spring.

One respondent (2%) reported she encountered daily conflicts over access to water and commented that "*there are women who throw water* [around] *the spring; they waste for waste's sake, nothing more*." Whatever the frequency with which conflicts occur it is clear that all of the comments regarding these conflicts relate to the need to share a water source.

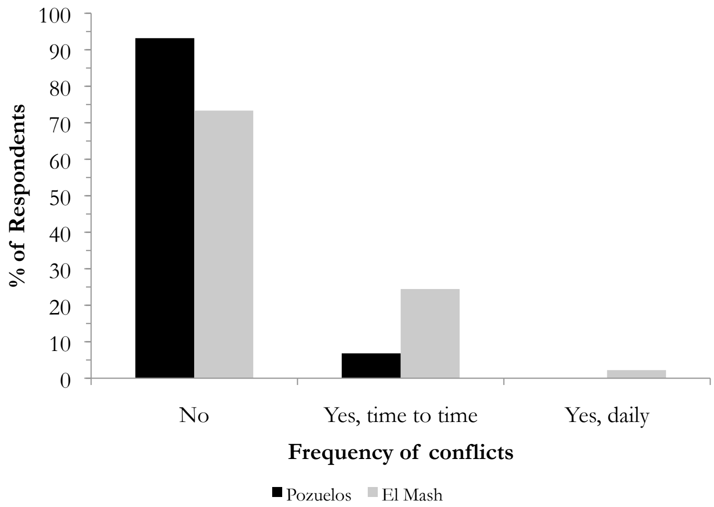


Figure 23 Percentage of respondents and frequency at which they encounter conflicts over access to water

6.3 Capacity

The total household population in Pozuelos captured within the survey sample was 225 ranging from 2 to 11 inhabitants per household giving rise to a mean household density of 5. This is slightly higher than the published census density of 4. Females make up 58% of the population, also higher than the published census data of 48%. The population distribution by age of the survey sample mirrors that of the census data with 64% of the total population being under the age of 24 and 7% over the age of 60 compared with 64% and 6% respectively (INEGI, 2010). In El Mash, the total household population captured within the survey sample was 322 ranging from 2 to 16 inhabitants per household giving rise to a mean household density of 7. Much like Pozuelos, this figure is only slightly higher than the published census density of 6. On average there are 4 females and 3 males per household. Females make up 55% of the total survey population, similar to the published census data of 52%. The population distribution by age of the survey sample mirrors that of the census data with 68% of the total population being under the age of 24 and 6% over the age of 60 compared with 68% and 5% respectively (INEGI, 2010).

Less than half of the surveyed population in Pozuelos (39%) has completed primary school; of these 59% are male and 41% are female. Although three households do not have any occupants who have completed primary school, at least one occupant has completed primary school in 73% of all households and 20% of households are home to at least three occupants having completed primary school. Only 2% or four people (3 males and 1 female) in three different households have completed secondary school and no one has completed tertiary education. In El Mash, One quarter of all households do not have any occupants who have completed primary school. Although 75% of all households have at least one member who has completed primary school they represent only one quarter, 26%, of the total surveyed population. Of these 16% are male and 10% are female. A further 24 males and 17 females across 21 separate households have gone on to complete secondary school, representing 13% of the total population surveyed, whilst 4 males, from two households have also completed tertiary education, including the resident teacher. Compared to Pozuelos, it might appear that on the whole the population of El Mash is better educated given the higher rate of secondary school completion, 2% and 13% respectively. However, not only does Pozuelos have a higher overall rate for primary school completion, 39% compared to 26%, this population is spread across 73% of all households surveyed compared to only 25% in El Mash. This seems to suggest that more residents in Pozuelos achieve basic education but that residents in El Mash who begin education tend to carry on further. Although the issue of education was not studied independently, it is important to note that both communities have their own school. Further the Mexican government currently assists low-income families by providing study grants for each student who remains in school. Interestingly this grant decreases as the level of education increases, perhaps some explanation as to why less children continue onto secondary school in Pozuelos, and equally why many children might remain on in El Mash given the local school was only recently extended to include secondary grades thus the additional income (albeit less than that provided in primary years) might provide a welcome reprieve for families in need.

In Pozuelos, male heads of household practice a variety of trades with more than half being employed as either builders or unskilled labourers. Daily household incomes (defined as income earned from gainful employment) range from zero to MXN$430.00. Of the 44 respondents, only 30 were able to provide any indication of household income whilst the remainder simply didn't know how much their husbands earn. Data are highly skewed and may not be a reliable measure of economic well-being. Many respondents knew exactly how much their husbands earned whereas others could only guess. Further still, many of the incomes are irregular and can vary on a daily basis thus making it difficult to ascertain income levels with any certainty. For example, one respondent (P040) stated her husband worked as an unskilled labourer but was unable to provide further details regarding his income though suggested it was irregular due to his tendency to "*toma mucho*" (drink a lot). Another respondent (P043), indicated her husband worked as a plumber with a daily income of MXN$130 though indicated work was not always available. One quarter of all respondents surveyed receive remittances either at the national (7%) or international level (18%). For example respondent P024, whose husband is an international economic migrant, relies solely on remittances and receives approximately MXN$6,000 - 7,000 "*cada 6 a 7 semanas*" (every six to seven weeks). Though in certain cases remittances clearly contribute significantly to a household's overall income, they are also irregular thus making it difficult to measure their impact on a household's economic well-being. Researcher observations suggest the possibility of a link between the materials used in a household's construction and remittances/ higher daily incomes. Should this prove true, a better measure of economic well-being may therefore be household construction.

The situation is quite different in El Mash where, of the surveyed population, only four male heads of households practice a trade and/or are employed in a skilled position, three as builders and one as the local teacher. A further nine work as unskilled labourers whilst 30 toil as peasant farmers occasionally outsourcing their labour to other landholders but mostly working their own lands. Lastly one individual is considered unemployed. It is difficult to ascertain whether the nature of the question was fully understood in terms of skilled versus unskilled labour and although local definitions might vary from those used in traditional economic assessments, there is nevertheless a 10% difference between the daily wages of those considered builders and those considered unskilled labourers (MXN$100 and MXN$90 per day respectively). We must however bear in mind that the survey was carried out with adult females who may or may not be privy to such information. At best, the response is an accurate representation; at worst it's a guess leading only to speculation about the meaning behind the results. Furthermore, the problem of employment continuity is highly prevalent in El Mash where some respondents (M01) report an average income of MXN$80-$100 yet simultaneously indicate remunerated work is only available "*a veces*" (sometimes). This is particularly relevant to peasant farmers (M02, M047) who are subject to the variability of agricultural work thus who have the potential to earn MXN$60 per day but only "*cuando trabaja por otra gente*" (when [he] works for other people).

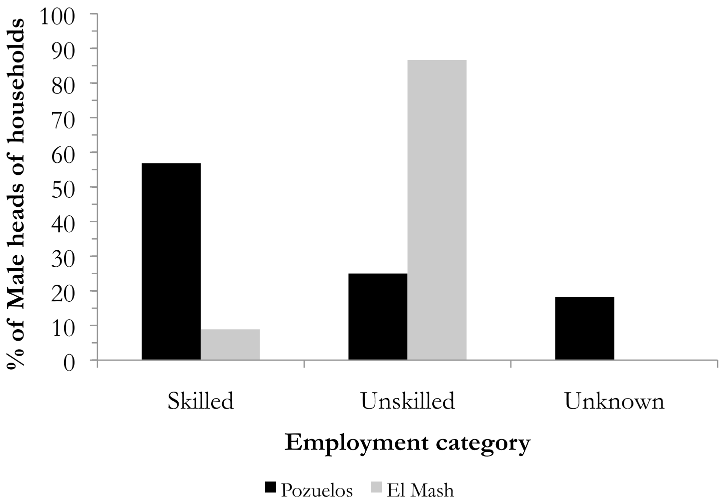


Figure 24 Percentage of skilled and unskilled male heads of households

It is however evident that the income ranges in El Mash are dramatically lower than those in Pozuelos, rising to a maximum of MXN$178 per day in the former and MXN$430 in the latter, with 29% of all households surveyed in El Mash earning no income. Despite the statistical unreliability of data (discussed above), the average household income in Pozuelos is MXN$116 (though corrected to MXN$97 when outliers are removed) compared to only MXN$58 in El Mash. Five households reported receiving national remittances from family members who would otherwise normally be resident in El Mash but have been forced to migrate nationally in search of employment. This is in contrast with the 11 households in Pozuelos currently receiving remittances including eight receiving assistance from international migrants.

The harsh reality is that the majority of respondents in both communities, but especially in El Mash, are reliant upon the limited government social assistance available to them. These programmes, such as Programa Oportunidades for families with school-aged children and *Programa para Adultos Mayores* for senior citizens, exist to supplement a household's income although in reality represent the majority if not all the income earned by many households. In fact, 87% of all households surveyed in El Mash receive some form of government assistance. Of the two households who indicated they don't currently receive assistance, one woman was removed from Programa Oportunidades in 2003 under suspicions of fraud owing to the fact someone else in a neighbouring community shares her name (not an uncommon occurrence). Although the government has since been made aware of the clerical error, at the time of the field study in 2009, she was still waiting to be reinstated. Four additional recipients were unable to provide any information thus when accounted for, the number of people receiving assistance rises to 96%. In Pozuelos, half of all respondents reported they receive some form of government assistance. In reality, this figure is likely to be higher as specific reference to government assistance as a form of household income was made only after many of the surveys had already been completed. In some cases, government assistance may be the only form of income received, as is the case for respondent P013 who receives MXN$500 from each programme.

In terms of basic amenities, 100% of households surveyed in Pozuelos have electricity yet only 49% of all households surveyed have electricity in El Mash. At the time of the study there was an electrification project underway that would ensure all but one household was supplied with electricity. Anecdotal evidence suggests that the reason one household was to remain outside the official electrification project was because the male head of household had elected not to participate in the project's labour force. It is common for any unskilled labour in such projects to be supplied by the community with specialized labour being supplied by the government and/or its sub-contractor. The anecdote was uncorroborated but in any case the house in question was sharing the electrical supply of a family member who lived next door thus, officially or otherwise, all households in El Mash should now be supplied with electricity[9].

Ownership of basic commodities in Pozuelos varied widely with more have not's than haves in all situations except for televisions, with 61% reporting ownership, and improved stoves, with 89% reporting ownership. In the case of the latter, the result is

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[9] This has not been confirmed but the electrification project in question was well underway during the field work phase of this project and certain sectors of the community had begun to receive electricity prior to the completion of said fieldwork thus it is likely that all households have now been connected to the electrical grid.

not surprising, given the survey sample consisted predominantly of those families who participated in the improved stoves' project with the partner NGO. One household (P039) owns a CB radio whilst another (P046) owns a cellular phone.

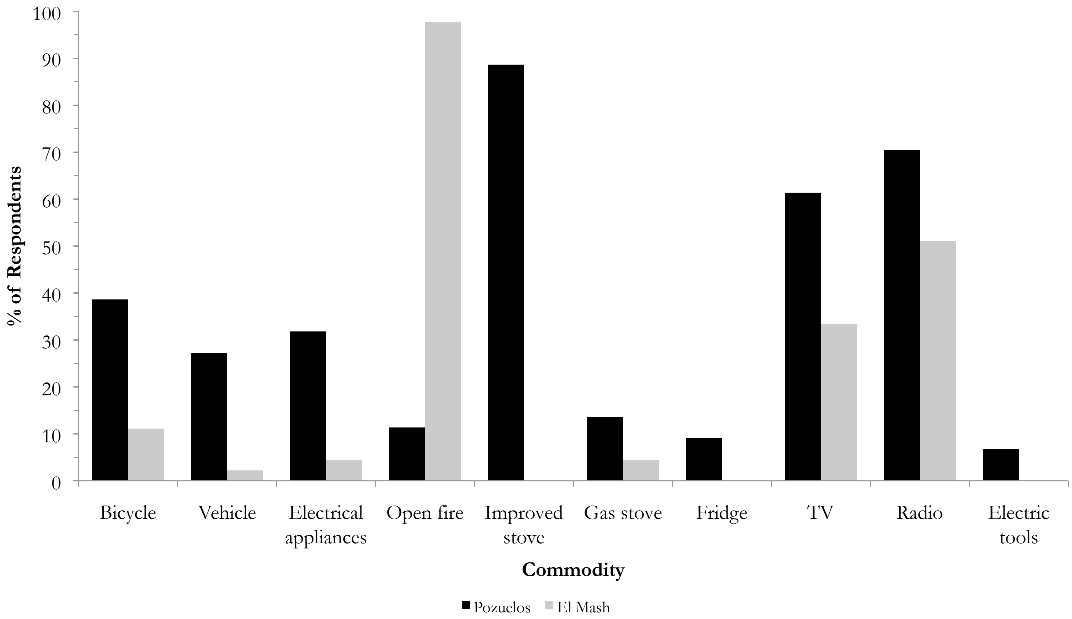

Figure 25 Ownership of selected commodities at the household level

In El Mash, ownership, or more appropriately a lack of ownership, of basic commodities is fairly consistent. Radios are the most commonly owned electrical good, followed by televisions, with 53% and 33% of all households owning one respectively. These figures will undoubtedly rise in light of all households now receiving electricity. Only one household owns a vehicle, while six own a bicycle. Given the poor state and variable topography of the access roads the low level of bicycle ownership is not surprising as many people rely on the well-run taxi service or simply make most journeys on foot. One household owns a blender whilst another owns an iron. Lastly, only two households have gas stoves whilst all (including the two with gas stoves) have open fire pits used for cooking and heating although average daytime temperatures are higher than those in Pozuelos, evident in the choice of building materials, where the walls of the majority of households surveyed in Pozuelos were constructed of brick/ breezeblock or some combination of brick/ breezeblock and adobe or wood. Two houses had walls constructed entirely of cement whilst one had walls constructed entirely of adobe. Roofs were constructed of a variety of building materials ranging from cement (9%) to corrugated galvanized steel sheets (27%) to clay tiles (21%) to clay tiles and straw (2%) or some combination thereof. Though the majority (66%) of households had cement flooring, 32% had floors made of compact dirt, with the majority of those (30%) present in kitchens.

The 2005 Census (INEGI, 2010) indicated 74% of all households had dirt floors. The subsequent decrease can be attributed to the government's *Piso Firme* (hard or solid floor) initiative whose objective is to replace dirt floors with cement in municipalities with 'high' or 'very high' levels of marginalization. Houses in El Mash are typically of wood construction with corrugated sheets of galvanized steel for roofs. Only one household surveyed included bricks/ breezeblock in its construction but not to the exclusion of wood. Further, all but one house had dirt floors in at least one of its two principal rooms with 42% having dirt floors in their entirety, leading to a total of 98% of all households surveyed having dirt floors. In 2005, INEGI reported that 95% of all households had dirt floors. Contrary to Pozuelos, Piso Firme has yet to have a significant impact in El Mash though respondents acknowledged that the existing cement floors were part of an earlier government initiative.

When questioned about the responsibility of water services in their community, 100% of all respondents in Pozuelos indicated there was a water committee/association in their community, many often referring specifically to *el patron* or water caretaker. However, when asked if there was an institution outside the community who was responsible for water, 98% emphatically said "no" or either didn't know. Only one respondent responded affirmatively yet provided no explanation as to who this might be.

The situation in El Mash is different and requires some explanation. Only 69% of respondents indicated the presence of a community water association within the community although 11% recalled the presence of an external entity. The low response rate regarding a community presence as compared to Pozuelos is likely due to the partially decentralized manner in which water is managed, or not, at the community level. As previously explained, El Mash is divided into a number of neighbourhoods, determined mostly by geographical location and as a result, which spring(s) service(s) each household. The majority of respondents, 69% reside in one single neighbourhood with the remaining 31% split across three neighbourhoods and one respondent geographically residing in a neighbouring community but politically affiliated with El Mash (thus not relying on springs within the geographical boundaries of El Mash). In fact, of the 77 households in El Mash, 37 are located within one single neighbourhood grouping, a further 9 are located in a separate grouping but rely on the same spring as the aforementioned 37 households; while the remaining 31 households are located in five other neighbourhood groupings ranging in size from 3 to 14 households. To summarize, 46 households rely on one large spring while 31 households rely on one of four smaller springs or springs not located within the geographical boundaries of El Mash. As you might well imagine, the spring serving the 46 households is not only larger than the other springs but is vastly larger with a different construction and management structure. Thus, it is not surprising that 34 of the 37 respondents who indicated the presence of a community water association reside in that neighbourhood. It is equally unsurprising that 4 of the 5 respondents who are aware of the existence of external agencies related to water supply reside outside this neighbourhood as they are likely more inclined to recall the government project that constructed rainwater tanks for the majority of the community's residents. Although many of the residents across all of the neighbourhoods were recipients of this programme, it seems plausible that those who rely more heavily on rainwater supply, or at least whose secondary supply is unremarkable at best, recall the experience more readily if not perfectly:

> "*Vino alguien de afuera pero no sé de donde*" (An outsider came but I don't know from where).

> "*Vino gente de afuera a ver el pozo pero no se de quien fue*" (People from outside came to see the spring but I don't know who sent them).

6.4 Use

Respondents were asked to approximate how much water their household consumed on a daily basis. They were encouraged to estimate these volumes through the use of familiar household containers often used to store water, such as the commonly used 20L *garrafón* or water bottle. Despite these efforts, of the 44 respondents surveyed in Pozuelos, only 34 ultimately provided information. Water consumption varied across households in Pozuelos from a minimum of 15Lpd to 160Lpd with a mean consumption of 50Lpd. The distribution curve is not normal however this is not unusual, as overall consumption does not take household density into consideration.

When density is considered the distribution curve is still abnormal and accurate generalizations statistically speaking should not be made. Nevertheless it is still important to note that 100% of households reportedly consume less than 40 litres of water per person per day, with all but 3 households reporting an average per capita consumption of less than 25Lpd.

Similar to respondents in Pozuelos, residents in El Mash were encouraged to estimate these volumes through the use of familiar household containers often used to store water. Contrary to Pozuelos, however, there was a 100% response rate in El Mash. Where a range of values was given, the average was taken. For example, a common reply was "*tres a cuatro cubetas* [*de 20 litros*]" (three to four bottles of 20 litres). In this case, the average of 70L was reported. A number of factors may have impacted the high response rate to this and other questions, such as the quality of translation. However, there is no evidence to suggest the responses are more or less accurate than those provided in Pozuelos. In fact, a quick comparison between household consumption rates for domestic purposes and livestock consumption rates would suggest the resident chickens of El Mash are exceptionally well hydrated, or a more plausible explanation that household rates were underestimated whereas livestock rates were overestimated. This isn't surprising and is likely a result of my presence and the purpose of the study. After all, despite the utmost care being taken to manage community expectations, it's understandable that a respondent might modify their response to highlight their need and what better way to highlight this need than to demonstrate the lack of water available for personal use, compromised even further by having to meet livestock needs.

Table 22 Estimated water consumption *per household* at the community level

Statistic	Pozuelos	El Mash
Valid responses	34	45
Unknown	10	0
Mean daily consumption rate	50Lpd	100Lpd
Minimum daily consumption rate	15Lpd	20Lpd
Maximum daily consumption rate	160Lpd	300Lpd

Ideally, one would observe water use over a period of time yet this would have entailed a prolonged community stay, an option that was neither logistically practical nor desirable for the purposes of this study, to study applied methodologies that define the water poor in a simple and practical manner. The need for a prolonged community stay would decry the concepts of simple and practical and certainly condemn the suggestion to include such questions in public censuses as a viable method for collecting water use data in the future. Suffice to say, reported values of water consumption were not independently verified.

Nevertheless, data collected reveal an average daily per capita consumption for domestic needs of 18L (although this is distorted by a few unusually high reported rates). This is sufficient to meet the immediate health needs of the individual (commonly interpreted as 2-5L per day depending on climate). However this is still well below the 50L/p/day recommended by Gleick (1996) to meet overall personal needs of health and hygiene. Surprisingly the average daily per capita consumption in Pozuelos is less than that consumed on average in El Mash where residents do not have access to a piped water supply. Despite a maximum daily consumption rate per capita of 80Lpd, 96% of the population consumes 40 litres or less per day and 73% of the population consumes less than 20 litres per day.

Table 23 Estimated water consumption *per capita* at the community level

Statistic	Pozuelos	El Mash
Valid responses	34	45
Unknown	10	0
Mean daily consumption rate	12Lpd	18Lpd
Minimum daily consumption rate	3Lpd	3Lpd
Maximum daily consumption rate	40Lpd	80Lpd

Total household water consumption ranged from an estimate of 20L to 300L per day. This variation seems odd until you consider the dynamics and circumstances of each family. The first is a family of 6 with no on-site water storage whose female head of household is solely in charge of water collection and required to make two 60-minute return trips per day with two children under the age of five in tow in order to meet her family's needs. Two families estimate they consume 300 litres of water per day, both with access to on-site storage. The first family, a family of nine, has one 10,000-litre concrete storage tank plus one 1,100-litre *Rotoplas* and is thus only required to carry water for part of the year, an activity which requires three to four 60-minute round trips per day, but one in which all family members over the age of five, (of which there are six excluding the husband who works outside the home as one of the three skilled builders in El Mash), participate. The second family, an extended household of 16 combining two generations of one family, 13 of whom are over the age of five, have three 10,000-litre concrete tanks, one 5,000-litre tank solely for washing clothes, and three 1,100-litre Rotoplas. They estimate they are required to carry water for four months of the year an activity that involves one 150-minute round trip per day, but is shared fully by all family members. All things considered, it is no longer odd that the family with the fewest members, no on-site storage, and only one person to undertake water carrying activities consumes the least in contrast to two families with higher densities but with readily available access to on-site water for most of the year, and a large contingency of carriers to quite literally share the load the remainder of the year, who consume the most. The complexities of a community without access to piped water supply are beginning to become evident.

The vast majority of respondents in Pozuelos, 77%, indicated that washing/ cleaning (for example, washing laundry) was the household activity that consumed the most water whilst 75% indicated drinking (or personal consumption other than for cooking) consumed the least. Three quarters of all respondents indicated cooking was the most important household activity that required water whilst 36% said the activity that consumed the most water, washing/ cleaning was the least important (although 23% did not reply). Similarly, the vast majority of respondents in El Mash, 87%, indicated that washing/ cleaning was the activity that consumed the most water in the home, with an equal number responding that drinking consumed the least. Bathing and cooking followed with 5% and 1% respectively. Contrary to Pozuelos, 76% of all respondents in El Mash reported that drinking was the most important household activity (24% responded cooking was the most important with no one suggesting bathing and/or washing/ cleaning was the most important activity). The activity that consumes the most water was also the least important to 67% of all respondents, with bathing and cooking following at 14% and 1%. Once again, these questions elicited a 100% response rate in El Mash.

In Pozuelos, a large proportion, 84%, of all households uses water for industrial activities. Like all communities in the municipality of Chamula, a large majority of the population, and particularly women, continue to wear traditional clothing. Women wear wool skirts while men wear wool vests, useful for insulating against both the cold and heat. Thus in this case industrial refers to the manufacture of clothing at the household level for personal use. Few, if any households, make a living producing clothing, though some households outsource the washing of their fleece, (the step requiring the most water). Regardless of its economic impact, water for this activity is a necessity in Pozuelos and consumption rates vary from 10 to more than 50 litres per use[10].

This activity clearly relies on sheep, and indeed, all but one household rears livestock, including sheep for wool and chickens for eggs and consumption. Livestock activities reportedly account for anywhere from 1Lpd to 40Lpd with the majority of households, 59%, requiring less than 10Lpd, which although being considerably low, is up to one-fifth of total household water use, based on average per person consumption rates.

Table 24 Volume of water per event (L) reported for industrial activities at the household level in Pozuelos

Volume of water (L)	Percent of households
No industrial activity	15.9
10 or less	2.3
21-30	4.5
31-40	6.8
41-50	2.3
50 or more	40.9
Quantity unknown	27.3

No one in El Mash uses water for industrial purposes and this aspect of water consumption was thereafter disregarded in all questionnaires. Livestock activities however are an important part of daily life in El Mash, if only to assure a modest amount of meat and protein is included within their diet. All but three households rear some form of livestock and the vast majority include chickens. A small number of households also rear turkeys and/or ducks and an even smaller number own a cow or two. Livestock activities reportedly consume anywhere from 1 to 40 litres of water per day. Water requirements for livestock however vary from 1 to 103 litres of water per day[11] suggesting a discrepancy between needs and actual use. Much like domestic water consumption the accuracy of the reported values is disputable. Nonetheless it is clear that if domestic water needs are to be met in El Mash, the needs of their livestock need

[10] Use in this context refers to a single clothing-making event. Most respondents in Pozuelos indicated they make clothing at least once and up to three times per year.

[11] Specific values were difficult to ascertain and water requirements would necessarily change depending on region and climate, however, a reasonable estimate of water requirements for livestock and wildlife common to North America were derived from the Ministry of Environment of British Columbia (referenced in full in the bibliography).

also be considered and a household that consumes only 40L of water per day can ill afford the 5L required to maintain 15 laying hens.

Table 25 Estimated water consumption for livestock uses at the community level

Statistic	Pozuelos	El Mash
Valid responses	42	42
Unknown	1	0
Not applicable	1	3
Mean daily consumption rate	11Lpd	8Lpd
Minimum daily consumption rate	1Lpd	1Lpd
Maximum daily consumption rate	35Lpd	40Lpd

Of the three activities requiring water at the household level, 66% of all respondents in Pozuelos reported domestic activities to be the most important with 5% reporting livestock activities to be most important and 30% indicating they felt all activities were equally important. In El Mash, the choice between family and livestock was not difficult and the vast majority, 93% of all respondents, indicated domestic activities were by far the most important activity requiring water in their household while 4% considered both domestic and livestock activities to be equal and one respondent did not reply.

6.5 Health and Hygiene

In Pozuelos, all but one respondent (P022) indicated that household water is treated before (human) consumption. Boiling was the preferred method of treatment for all respondents with 14% of the surveyed population indicating they boiled their water for a minimum of 20 minutes. Of the remaining respondents, 59% indicated they boiled their water for less than 20 minutes and 25% didn't know how long they left their water to boil. Though only one respondent (P003) readily admitted she was unable to tell time, this seems likely to be the case for many other respondents who either didn't know for how long they boiled their water, or who responded with unusual lengths of time, including up to one or two hours (P013, P014, P016, P025, P046). Although boiling for one minute (or three minutes at altitudes greater than 1,600m which is the case of Pozuelos) is sufficient to disinfect water for personal use (CDC, 2009) local health workers typically advocate water should be boiled for 20 minutes hence the magic number of 20 many respondents believed they should adhere to. This in itself puts the accuracy of their responses in doubt. Did the respondents respond with genuine accuracy or did they simply regurgitate the instructions they had previously been given?

Without observational evidence one can only speculate. Further insight into household level water treatment is provided via the numerous comments respondents gave regarding the technique they used to boil water. The specific method used varied across respondents with some removing the water from heat "*as soon as it begins to boil*" (P023, P030, P035, P037, P038, P042,) and others removing it from heat once they noticed a decrease in water levels (P034), the former method being insufficient to disinfect water properly. The comments of one respondent (P009), who indicated "*when* [the water] *begins to boil I wait 3 to 4 minutes*" suggest her method is in line with generally accepted guidelines for disinfecting water via boiling.

Whilst all respondents in El Mash indicated they boiled their water before consumption, boiling times varied with 55% reporting they boiled their water for at least 20 minutes, 31% reporting they boiled their water for less than 20 minutes and 13% not knowing for how long they boiled their water. Again, the importance of the 20-minute mark stems from hygiene education classes provided by the government as part of the Programa Oportunidades previously discussed. Whilst the origin of this time frame is uncertain, having not discussed it in any detail with local health leaders, it would seem probable that this accounts for the entire time frame required for a pot of water to achieve and maintain a rolling boil having started from the moment one places the pot on the open fire. Much like a number of women in Pozuelos, several respondents indicated they were unable to tell time so instead they: "*lo deja hervir hasta que el nivel baja*" (leave it to boil until the [water] level decreases). One respondent indicated she treated her water by "*hechando cloro*" (adding chlorine) but was unable to produce the chlorine upon request. A second respondent was more explicit when explaining how she added chlorine pellets every 20 days to her rainwater tank but again was unable to demonstrate the product upon request. Yet a third respondent outlined how she added chlorine to the water she used for washing clothes and boiled the water to be consumed. It would seem these respondents simply wanted to demonstrate a basic knowledge of health and hygiene. As previously mentioned, the use of a magic number in lieu of step by step instructions puts the accuracy of the responses in doubt and similar to Pozuelos, without direct observations, it is nigh impossible to determine whether or not the respondents replied accurately or simply reiterated the instructions they had previously been provided. On a personal note, I drank numerous cups of coffee in El Mash without once falling ill and my observations suggest the need for water treatment is well and truly understood in El Mash.

No adults were reported to have died prematurely due to diarrhoea or similar illness in either Pozuelos or El Mash. However, 27% of all respondents in Pozuelos and 13% of those in El Mash reported having lost at least one child due to diarrhoea or similar illness. In one case in Pozuelos, seven children within the same household died a premature death. In El Mash all of the reported deaths occurred in different households. One child reportedly died of Hepatitis whilst the remaining children all died with symptoms including fever and/or vomiting. While this information is far from conclusive it would not be unfair to suggest water may have had a role in their deaths. Only 16% of all respondents reported no one in their household had suffered from diarrhoea in the past year whereas 80% responded at least one person had suffered from diarrhoea from time to time. In 4% of all households, both adults and children had suffered often.

Trachoma is known to be prevalent in the region where El Mash is located and although rates of disease are lower in El Mash than other neighbouring communities, at least 13% of all respondents reported that they or a member of their household had been diagnosed (and subsequently operated) for trachoma in the past or was currently living with the disease. Most respondents affected by trachoma were advanced in age with the exception of a young child of 5 who was being treated along with her entire family. One respondent reported being advised by her doctors to "*lavarse con jabón Ariel*[12]" (wash with Ariel soap) though unfortunately didn't seem to understand why.

Despite the prevalence of diarrhoea and trachoma, 84% of respondents indicated they, or members of their household, had never suffered from a water-related illness in the past year. However, the 16% of respondents who responded positively also indicated they had suffered from diarrhoea from time to time or often over the past year. In Pozuelos, 71% of respondents indicated they or a member of their household had never suffered from a water-related illness over the last year (Figure 26). The purpose of this question is to analyze the community's understanding of the relationship between water and water-related illnesses. In this case, 77% of all respondents indicated they or a member of their household suffered from diarrhoea, either from time to time or often, over the past year (Figure 26). If one considers the majority of cases of diarrhoea to be water-related (noting that diarrhoea is also strongly linked to lack of hygiene), one would

[12] A brand of laundry detergent owned by Proctor & Gamble

expect to see a similar response rate for water-related illnesses by members of the community who had a basic understanding of the link between water and diarrhoea. This is clearly not the case in Pozuelos and may be indicative of a lack of knowledge of health-related issues surrounding water quality.

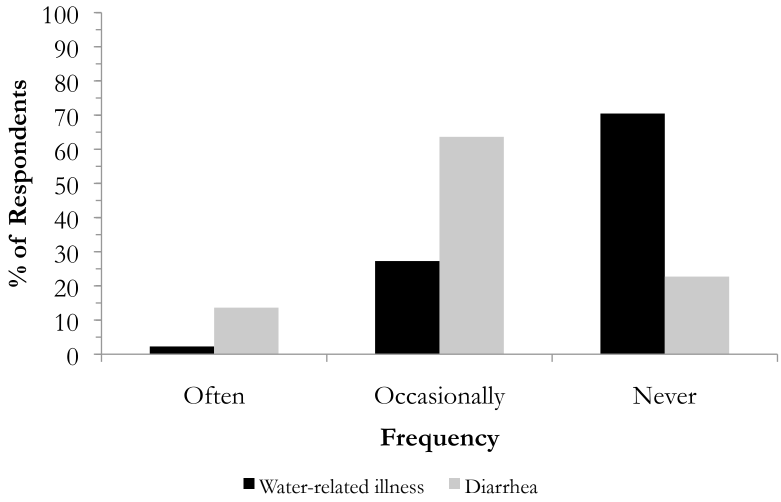

Figure 26 Reported frequency of water-related illnesses compared to diarrhoea suffered by *any* household member(s) at the community level in Pozuelos

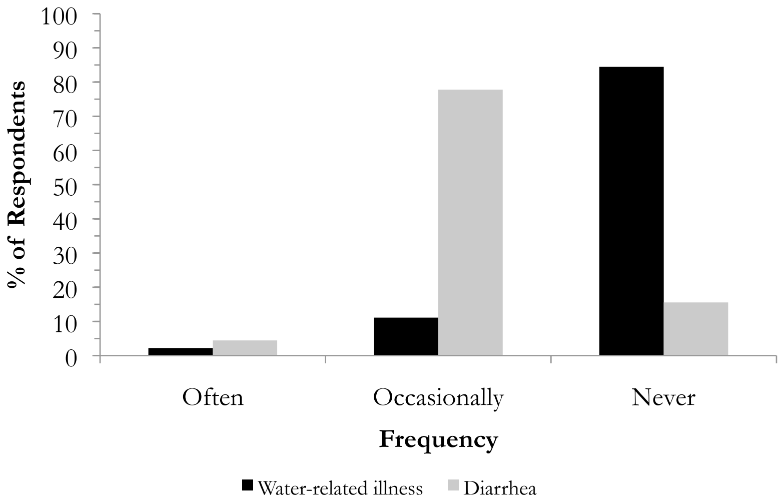

Figure 27 Reported frequency of water-related illnesses compared to diarrhoea suffered by *any* household member(s) at the community level in El Mash

When the respondent or a member of their household falls ill with diarrhoea, 9% rely on traditional herbs and remedies, 62% visit a pharmacy or clinic while 13% do both. The pertinent point here is that El Mash has neither clinic nor pharmacy and people must therefore make the 14km round trip, often on foot, to Oxchuc, the nearest centre offering such services.

Concerning health-related issues related to water quality further, 100% of all respondents in both communities said they practiced hand washing. Of these, 48% of all respondents in Pozuelos and 33% in El Mash reported using soap only sometimes or when their hands were "*visibly dirty*", whilst 43% and 58% respectively, reported always using soap (Figure 28). The remaining 9% in both communities indicated they used water alone. Observational evidence suggests otherwise and when respondents were asked to show me their wash stations, soap was not often present. When asked when they were most likely to wash their hands without any prompting, 43% of respondents in Pozuelos indicated they did so before cooking, 25% reported washing their hands after working whilst 16% said they washed their hands before eating. A further 16% indicated they washed their hands both before and after eating. Only 11% reported washing their hands after using the bathroom.

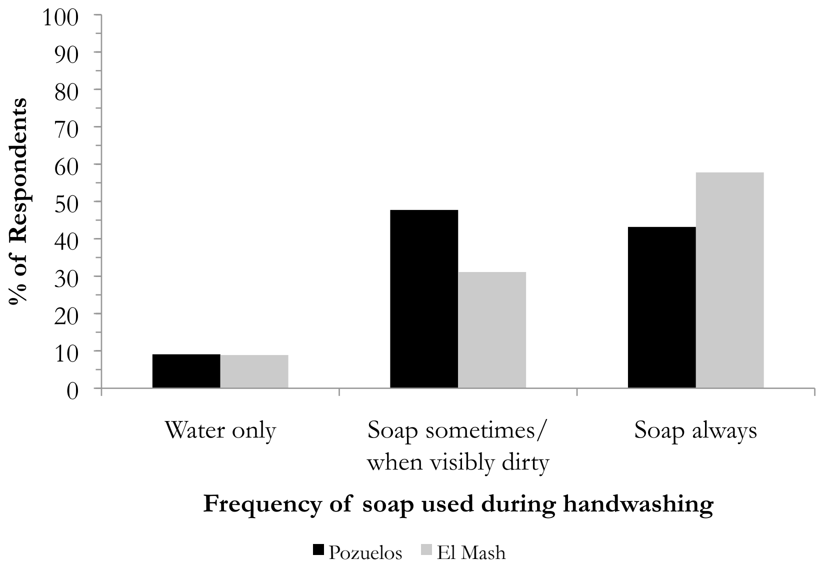

Figure 28 Percentage of respondents reporting the use of soap (and frequency) used for *any* hand washing activity at the household level

Many respondents did not provide any information in terms of the activities with which they associated hand washing. In El Mash, of the four households who only use water, all of them previously indicated either adults or children or both had suffered from diarrhoea from time to time over the past year, with one household also reporting that both adults and children had also suffered from water-related illnesses. Five of the six households with members who had suffered from or were suffering from trachoma indicated they always used soap to wash their hands with the sixth household indicating they sometimes used soap. It is not clear whether this practice was standard or came as a result of their illness. The earlier reference to Ariel soap is interesting because one of the reasons given during informal conversations for not using soap all of the time or even some of the time was that it increased the time needed for hand washing. Comparatively speaking laundry detergent is much more affordable than hand soap and is already a household item thus most households do in fact use laundry detergent for hand washing. If you've ever had the occasion to wash your hands with laundry detergent, you'll agree, it does in fact take much longer to wash your hands and is not necessarily a pleasant experience, especially when more often than not cold water is used.

6.6 Environment

As described in Chapter 3, water samples were analyzed for pH, turbidity (TU) and the presence of thermotolerant coliforms (TTC) for 31 households in Pozuelos and 11 households in El Mash.

In Pozuelos, turbidity results were less than 5 (TU<5) for all samples and is not discussed further here. Mean pH was 7.3 (SD0.5) and ranged from 6.8 to 8.2. Although there are no health-based guidelines for pH, it has been suggested that the optimal range is between 6.5 and 9.5 (WHO, 2003). Data were found to be normally distributed using the tests for Skewness and Kurtosis (Skewness and Kurtosis equal 0.427 and -0.899 respectively, falling within the acceptable ranges of -0.854 to 0.854 and -1.666 to 1.666). Of the 31 water samples collected, valid results for TTC were obtained for 22. Only one sample, from household P024, proved to be significantly contaminated with an average TTC count of 152. The water sample was collected from the household's 18,000L concrete rainwater tank via a garden hose attached to the tank's tap. The respondent reported the hose was normally kept in-situ where the nozzle came into contact with the ground. Given the insignificant amount of TTC found in other samples, this would be the most likely source of contamination despite a tidy yard. There was however insufficient time to repeat the analysis with water sampled directly from within tank.

As previously discussed a sample size of eleven in El Mash would not normally be representative of the survey sample size. However, as is the case for Pozuelos, the vast majority of samples (73%) were free of thermotolerant coliforms. Three samples presented measurable levels of TTC ranging from a minimum count of 1 to a maximum count of 17, not necessarily a cause for major concern in this context. pH varied from a minimum of 6.8 to a maximum of 8.0 and, despite the small number of samples taken, Skewness and Kurtosis numbers suggest the representative curve has a normal distribution with a mean pH of 7.5 (SD0.5). Turbidity results were less than 5 (TU<5) for all samples and is not discussed further here. These results coupled with my observations suggest contamination of rainwater in household tanks is not a major concern in El Mash. However, the same is not true for the six major springs relied upon as an important secondary source of water. Because each neighbourhood is heavily reliant on these springs during the dry season, the water quality of each spring was also assessed and the results of the bacteriological analyses are shown in Figure 29.

Table 26 Percentage of water samples collected at the household level contaminated with Thermotolerant Coliforms

TTC (average no.)	Pozuelos (%)	El Mash (%)
0	22.7	17.8
1-5	22.7	2.2
6-10	2.3	0
11-20	0	4.4
21+	2.3	0
Subtotal	*50.0*	*24.4*
Results not valid	11.4	-
No sample taken	38.6	75.6
Subtotal	*50.0*	*75.6*
TOTAL	100.0	100

Adhering to the previous descriptions of each spring in El Mash, samples were taken from both the spring box (tap) and adjacent overflow area (pool) at Man1. A sample was drawn from each of the two spring boxes at Man2 (left and right). A sample was drawn from the tap at Man3 as well as from water pooled underneath the spring box. Samples were drawn from the tap stand at Man4, the water hole at Man5 and the water pool from within the crevice at Man6. At least two samples were analyzed from each source (and in cases where particularly high levels of contamination were observed four samples were analyzed from each source). pH and turbidity were also analyzed for each sample and in each case the pH was determined to fall within the acceptable range of 6.5 to 9.5 (WHO, 2003). In all cases but one (Man3 pool) turbidity was <5 and is not discussed further. Water pooled underneath the spring box at Man3 was highly turbid but an insufficient volume of water was available to measure turbidity accurately.

Clearly bacteriological results vary depending upon source with TTC counts ranging from 1 to 13390. Quality is best at Man1 and worst at Man3. The variation in quality between spring boxes at Man2 may be as a result of the limited protection afforded by the wood planks covering the right hand spring box and in fact anecdotal evidence suggests animals, including dogs, have been known to drink directly from the left hand spring box. The high contamination at Man3 is no doubt a direct result of the five households and accompanying latrines built directly upslope from the site. Latrine pits were likely dug to depths below the shallow water table at this point and faecal contamination is therefore leaching directly into the spring's underground flow. Water pooled underneath the spring box is much more heavily contaminated than water collected in the spring box, which raises additional questions about latrine construction, surface contamination in the vicinity of the spring and site hygiene. Contamination at Man5 is not surprising as it is an entirely unprotected water hole susceptible to the elements, animals and chemical fertilizers. In fact, of the six sources, those with protection, either manmade or natural (Man1, Man4, Man6) show little contamination compared to those that are not protected (Man2, Man3, Man5), demonstrating the importance of basic infrastructure.

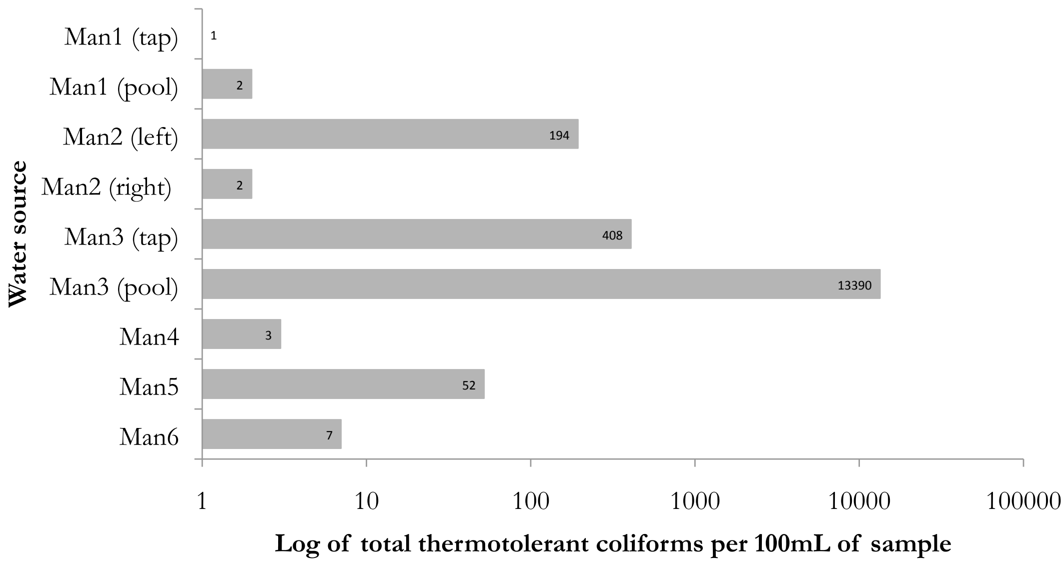

Figure 29 Log scale of (average) total thermotolerant coliforms detected in water collected from springs used for drinking water in El Mash (actual average inside column)

In an attempt to gain some insight into environmental changes across time that may have impacted the community, respondents were asked to comment on whether or not they had observed any changes in soil fertility, land cover or rainfall patterns over the past ten years. The majority of respondents in both communities (68% in Pozuelos and 80% in El Mash) reported having observed a decrease in soil fertility. A slightly smaller number of respondents, 55%, indicated they had observed a decrease in land cover over the last ten years in Pozuelos compared to 78% in El Mash, with 71% of the latter indicating it had decreased a lot. Lastly, 53% of all respondents in Pozuelos reported they had observed a change in rainfall patterns. Though there was a disagreement as to what extent, the majority, 39% reported less rainfall, as opposed to 9% who reported an increase in either rainfall intensity or volume (5% reported having observed a change but were uncertain of just how it had changed). In El Mash, more than half, 62%, of all respondents reported having observed a change in rainfall patterns over the past 10 years, though contrary to Pozuelos, the majority, 43%, said it had increased a lot. The remaining respondents were divided evenly as to whether the rainfall had increased only a little, decreased a lot or decreased a little. Of the respondents who replied rainfall had increased a lot, only one provided any additional information and specified the increase had been only this past year.

Chapters 5 and 6 have provided information essential to understanding local poverty at the community scale. Specifically, Chapter 6 presented the findings of an extensive survey conducted in both communities the results of which are now used to inform the water poverty index constructed for use at the community scale in Chapter 7.

CHAPTER 7 THE WATER POVERTY INDEX AT THE MICRO SCALE

Having examined data collected at the community scale in detail, this information can now be used to calculate a water poverty index at the micro scale. Each of the first five sections below follows the same format as that used to calculate a water poverty index at the macro scale beginning with a descriptive analysis of each indicator followed by a thorough explanation of the justification and method used to calculate each variable proposed in Chapter 3 (Table 4). The results of the WPI are presented in the second half of the chapter, followed by a brief comparison of water poverty between communities whilst results from community focus groups held in El Mash are presented in the final section.

7.1 Resources

According to the WSI, Los Altos would be classified as water scarce as the per capita volume of water available is less than 500m^3/year. However, the WSI takes water for agricultural needs into consideration and as we already know, 96% of crops are rain fed in Chiapas and industrial uses have, in theory, been accounted for in the volume of licensed abstractions. Therefore, if we make the assumption that 100% of the AWR is available for domestic use, each person in the region would theoretically have access to 229 litres of water per day, ample water to meet the daily requirements of even an industrialized country (Gleick, 1996). Thus:

R_p1 = AWR per capita **R_p1**

On a more local scale, the choice of technology (gravity fed piped supply in the case of Pozuelos) must also be taken into consideration thus flow rates are considered in detail. According to Cairncross & Feacham (1993), a diameter of at least 50mm is required for steel pipes to achieve a flow rate of 3.0L/s over a steep gradient. As discussed in Chapter 4, the pipes in Pozuelos have a diameter of four inches or 101.6mm thus this should not be an impediment to overall service. The flow rate required to meet the basic needs of the residents of Pozuelos can be calculated as follows, where D=demand, P=population, and d=day in seconds:

$$Q_p = \frac{D \times P}{d}$$
$$Q_p = \frac{50L/day \times 435 inhabi\tan ts}{86{,}400 s/day}$$
$$Q_p = 0.25L/s$$

Field trials were undertaken 17 May 2008. This date falls midway through the first month of the wet season and would normally be considered representative of the transition period between dry and wet seasons. However, precipitation data from 2008 show it was a particularly wet year and that 386mm of rain fell between January and April, 124mm more than the thirteen-year average for that same period.

Under this scenario, field trials produced an average flow rate of 0.15L/s. Modifying the above equation, we can calculate potential demand based on a flow rate of 0.15L/s as follow:

$$D = \frac{Q_p \times D}{P}$$
$$D = \frac{0.15L/s \times 86{,}400s}{435 inhabi\tan ts}$$
$$D = 30L/person/day$$

Under current conditions (notwithstanding the knowledge that this flow rate is not likely to be representative of the typical transition period from dry to rainy season and in actually fact is likely to be even lower), only 60% of actual demand can be met. Thus:

R_p2 = % of demand (BWR) that can be satisfied with current flow rates **R_p2**

The situation in El Mash is markedly different where households rely on harvested rainwater to meet their daily needs. In this case, there are also two considerations to assessing water resources, though only one strictly applies to physical water resources availability, precipitation. The second consideration is related to infrastructure and more specifically storage capacity yet for the purposes of calculating a water poverty index, both are nonetheless constraints to water supply and hereinafter considered a factor of overall resource availability. There are a couple of ways in which we can consider precipitation as a constraint to water supply. First, let us assume there are no constraints to the community's ability to capture and store rainwater. The first question therefore is, is there sufficient precipitation to meet the needs of the community? In order to determine the amount of rainfall that is actually available for use, or effective precipitation (EP), often defined as the fraction of rainfall that contributes to runoff, we must consider a number of other factors, in this case most importantly, evapotranspiration (ET). Evapotranspiration as defined by Allen *et al.* (1998, Ch.1) is "the combination of two separate processes whereby water is lost on the one hand from the soil surface by evaporation and on the other hand from the crop by transpiration." Evapotranspiration is affected by a number of factors including climate, crop and soil type and can be difficult to measure. In the absence of measured data it is therefore commonly derived from more readily available pan evaporation data typically measured alongside precipitation at climate stations by multiplying said data by the pan co-efficient (K_p). According to Allen *et al.* (1998) pan coefficients vary depending on pan type, pan siting, environment, relative humidity and wind speed but can be affected by other determinants such as whether or not the pan is painted and water level. In the absence of such information, I have adopted a worst-case scenario approach to determining EP whereby $K_p = 1$. In other words, evapotranspiration equals pan evaporation. Historical pan evaporation data for Oxchuc is available from 1973 to 1991 though the dataset is incomplete. In order to maintain integrity across the following calculations, only matching datasets where both pan evaporation (E_{pan}) and precipitation (P) data are complete were used (1974, 1975, 1983, 1984, 1985, 1987, 1988, 1991). With this information, the following calculations can be made, where Q = river discharge:

$$Q = P - ET$$
$$Q = P - (K_p \times E_{pan})$$
$$Q = 1556mm - (1)(1060mm)$$
$$Q = 496mm$$

$$EP = \frac{Q}{P}$$
$$EP = \frac{496mm}{1556mm}$$
$$EP = 0.32$$

Thus approximately 32% of all rainfall is available for use. In order to determine whether or not this is sufficient to meet community needs, it seems logical to consider the month with the least amount of precipitation, February, which receives an average 48mm of rainfall. EP for February is therefore 15mm. With a total survey population of 360, the BWR for El Mash for the month of February, which typically comprises 28 days, is 504 000L or 504m3.

It is first necessary to ascertain whether or not sufficient land is available for the theoretical rainwater harvesting system that would capture rainwater at 100% efficiency.

This can be quickly determined by dividing BWR by EP, in this case equal to 33 600m^2 or 0.0336km^2 less than 0.3% of the community's total area of 10km^2. If a single system were to be constructed, it would need to be 32m deep with a capturing surface of 32m long by 32m wide or some combination thereof. Although this is highly impractical it is not necessarily completely unfeasible. However, a more practical manner in which to view this problem would be at the household level. Assuming an average household population of seven (the survey density of El Mash), each family would require a 10,000L rainwater harvesting tank and a rooftop area of 666m^2. Again, this is not necessarily unfeasible, but as we shall see, it is certainly not the case in El Mash. Thus once again, despite some crude assumptions and bearing in mind a worst-case scenario approach was applied, it is safe to say the amount of precipitation in the region is sufficient to meet the needs of the community from the perspective of physical water resources availability. Thus:

$R_M1 = AWR$ **R_M1**

What has become clear is the constraint of storage on water availability. Thus far, resources have been considered at the community level however as rainwater is harvested individually, these constraints are best considered at the household level. In order to assess resource availability at this scale we need only consider household population in order to calculate BWR and storage capacity. In this manner we can calculate the number of days a family can sustain drought at current storage capacities. For example, two households are considered as follows. The first household, M01, has 3 members and a total storage capacity of 1,100L. Thus with a daily BWR of 150L, they could sustain 7 days of drought. Household M09 has 12 members and a total storage capacity of 20,000L. Thus with a daily BWR of 600L, they could sustain drought for 33 days. Resistance to drought in days varies in El Mash from 0 to 155. This becomes particularly relevant when climate data are examined more closely to reveal that long periods without rain are not uncommon, for example, in 2005, there were 29 consecutive days without precipitation between February and March and only 23mm of rain fell during the period 19 January to 25 March of the same year. To arrive at a variable score, resistance to drought (RD) was normalised across households using the standard Min-Max normalization equation (Chapter 3).

R_M2 = Resistance to drought (days) **R_M2**

The last quantitative variable of resources to be analyzed is that which measures rainfall variability, the Precipitation Concentration Index (Oliver, 1980). PCI is a measure of the concentration of annual rainfall such that a high value (100) indicates most rainfall is concentrated within one month whereas a low value (8.3) indicates low variability or where rainfall is relatively constant from month to month, where pi is the average monthly rainfall and Pa is the average annual rainfall, giving rise to the following equation:

$$PCI = 100\sum \frac{p_i^2}{p_a^2}$$

A slightly modified version of the conceptual scale proposed by Soto *et al.* (2006) is presented in Table 27. For the purposes of normalization minimum and maximum values are therefore defined as 8.3 and 100 respectively.

Table 27 Seasonal Rainfall Variability Scores

PCI	Variability
8.3 – 10	Uniform
11 – 15	Moderately seasonal
16 – 20	Seasonal
21 – 50	Highly seasonal
51 – 100	Irregular

Source: Soto *et al.*, 2006

From the precipitation data presented in Chapter 4, the PCI, for Pozuelos and El Mash respectively, is calculated as follows:

$$PCI = 100\sum \frac{p_i^2}{p_a^2} \qquad PCI = 100\sum \frac{p_i^2}{p_a^2}$$

$$PCI = 100(533824/4553956) \qquad PCI = 100(291906/2683044)$$

$$PCI = 12 \qquad PCI = 11$$

According to Table 27, rainfall variability in both Pozuelos and El Mash is classified as only moderately seasonal.

R3 = Precipitation concentration **R3**

Each of the aforementioned quantitative variables (R1, R2 and R3) has a sister qualitative variable (R4, R5 and R6). The first of these considers water resources availability from the perspective of the survey respondents who were asked to describe typical water availability during a seven-month period intended to represent the dry (or less wet) season (November to May) as either: a lot, sufficient, insufficient, very little or none. Responses were tallied and each household given a score out of seven to reflect the number of months with either sufficient or a lot of water. Scores were subsequently normalised using minimum and maximum values of 0 and 7. Normalised scores were then averaged across households to arrive at a community score. For example, responses provided for two households in each community are listed below.

Table 28 Respondent perspectives of water resources availability for the period November to May

H/H	Nov	Dec	Jan	Feb	Mar	Apr	May	H/H Score	Normalised Score
P026	A lot	A lot	Sufficient	Very little	Very little	Very little	Very little	3	0.4
M05	Insufficient	Insufficient	Insufficient	Very little	Very little	Sufficient	Sufficient	2	0.3

Normalizing scores as described above, the variable score for P026 is 0.4 and the score for M05 is 0.3.

R4 = Perception of AWR during the dry period **R4**

The second variable measures service reliability as perceived by the survey respondents. In this case, respondents were asked to rate their water service as good, ordinary or bad. Household and community scores were calculated in much the same way as R4 and an example is outlined below.

Table 29 Example of scoring qualitative responses to water service reliability

Household	Rating	Household Score	Normalised Score
M15	Bad	0	0
P012	Ordinary	1	0.5
P036	Good	2	1

R5 = Perception of service reliability **R5**

Lastly, survey respondents were asked whether or not they had perceived a change in rainfall patterns over the past decade. Responses were in the form of a yes/no answer with affirmative answers being qualified as either an increase or decrease in the volume of rainfall. Given the area is not prone to flooding and the general consensus appears to be there is a lack of overall water availability, an increase in rainfall is desirable. Therefore, a response indicating there has been an increase in rainfall receives the maximum score of 2, a response indicating there has been no change receives a score of 1 (in respect of the fact that the majority of people believe the business as usual model is not working), and a response indicating there has been a decrease in rainfall receives a score of 0. Much like the previous variables R4 and R5, scores are normalised and averaged to arrive at the community score. Thus, using the same methodology described above, the final derivation for this variable is as follows:

R6 = Perceived change in historical rainfall patterns **R6**

7.2 Access

Quantitative measures of access are very straightforward and households receive a score of 0 or 1 depending on whether or not they have access to a piped water supply and/or sanitation. Community scores are then averaged to reflect the percentage of households with access to each service independent of one another as shown in the equations below.

A1 = % Population with access to piped water **A1**

A2 = % Population with access to sanitation **A2**

Qualitative indicators of access include time spent carrying water and reports of conflicts over access to water. Sullivan *et al.* (2003) recommend assessing the % of water carried by women as well as time spent in water collection activities but insufficient information was available to assess the gender divide in these activities. Notwithstanding only a small number of households are required to carry water in Pozuelos. In El Mash, anecdotal and observational evidence suggest that all household members, males and females alike, participate in water carrying activities. For these reasons, gender is instead considered as a variable of capacity.

Respondents were asked to indicate how much time was required in minutes to complete one round trip, including waiting time, to collect water. They were also asked to indicate how many trips they are required to make each day. This is believed to be a better indicator for use at the household level than distance alone as the essence of time respects each individual's physical ability to complete such a journey. Household scores are equal to the total time in minutes required to complete one round trip multiplied by the number of trips required per day. As per other indicators, scores are then normalised at the community scale. In other words, minimum and maximum scores were defined for each community (thus far, minimum and maximum values have been the same for both communities). The final derived equation follows the same format as previously defined equations.

A3 = Time required for carrying water per trip x number of trips per day **A3**

For the last variable respondents were asked to indicate the frequency with which they experienced conflicts over access to water by selecting one of four possible responses: 'never', 'from time to time', 'often' or 'daily' with each response corresponding to a score of 3, 2, 1 and 0 respectively. Scores were normalised using possible, not actual, minima and maxima scores.

A4 = Frequency of conflicts over access to water **A4**

7.3 Capacity

Six variables were selected to denote Capacity at the community level representing financial and social capacity and health and include a mix of quantitative and qualitative data. The first variable measures household wealth. In the absence of hard data, Sullivan *et al.* (2003, p.194) suggest measuring "ownership of durable items" as a proxy for wealth. Although the use of hard data is desirable, Nardo *et al.* (2008, p.23) advise the use of proxy variables in the absence of other data whilst recommending their "accuracy… be checked" through "correlation and sensitivity analysis". Although income data were collected at the household level in the present study, it is nonetheless interesting to assess its relationship with the ownership of durable items. Survey respondents were asked to indicate whether they owned any of the following: bicycle, vehicle, electrical appliances, gas stove, refrigerator, television, radio or electrical tools. For the purposes of this correlation, households were attributed a score of 1 for ownership and 0 for non-ownership with a maximum possible score of 9. Ownership scores were then normalised using the standard normalization formula. As the presence or absence of dirt floors and building materials are indicators of well-being commonly used in Mexico, these data were also correlated with average daily household income to ascertain whether or not they were good proxies for wealth. For this purpose, households were attributed a score of 0 if dirt floors were present in every room, 1 if dirt floors were present in only part of the household and 2 in the absence of any dirt floors. Households constructed solely of cement or brick/breeze-block were attributed a score of 3, houses constructed of a combination of cement and/or brick/breeze-block and adobe and/or wood were attributed a score of 2, houses constructed of wood were attributed a score of 1 and houses constructed of adobe were attributed a score of 0. Finally, survey respondents were also asked to indicate their average daily household income in Mexican pesos. For the purposes of normalization, minimum and maximum incomes were determined using the lower and upper boundaries identified by the 5th and 95th percentile respectively.

Each of the three scores above were then correlated against average daily household income using Pearson's product moment correlation coefficient. Coefficients were calculated for each community individually and then combined across both communities, the results of which are presented below.

Table 30 Correlation coefficients between average daily household income and selected variables of wealth

Ownership of durable items			Presence of dirt floors			Building construction materials		
El Mash	Pozuelos	Both	El Mash	Pozuelos	Both	El Mash	Pozuelos	Both
0.286	0.539	0.551	-0.222	0.078	0.234	0.117	0.067	0.373

There is a moderately strong positive relationship between ownership of durable items and average daily household income in Pozuelos and both communities combined yet the same relationship is much weaker in El Mash. Overall ownership rates, based on total numbers of owned durable items, are significantly lower in El Mash than in Pozuelos seen in the difference in upper boundaries between communities where P_{max}=7 and M_{max}=3. One explanation for this might be the much higher community average daily household income in Pozuelos of MXN$118, almost twice the daily average of MXN$60 in El Mash. This perhaps suggests that a minimum economic threshold must be met before correlations between ownership and economic well-being can be drawn.

That is not to say that ownership of durable items are not good proxies for wealth, but instead that they need to be selected very carefully and are likely to be site-specific. For example, at the time of the study 50% of households in El Mash did not have electricity but were within an ongoing electrification project. Thus it would be redundant to consider electrical goods as proxies for wealth. Further, as previously discussed, local topography is extremely variable and roads poorly maintained. The road to Oxchuc to the centre of El Mash is a 7km dirt track with a vertical variation of 150m, consequently impacting bicycle ownership, which stands at 13%. The principal road to San Cristóbal de las Casas from Pozuelos is mostly paved (and at the time of the study was undergoing improvements) but steadily declines some 335m from start to finish making the return journey exceptionally difficult and even bicycle ownership in Pozuelos tops out at 40%.

Still, as in most economies there are a certain number of durable items that all families aspire to, and despite their economic status, will go to no ends to acquire. Thus it is for the fifteen households in El Mash, nine of who have low or no regular incomes yet nevertheless own televisions, an ownership rate with no statistical correlation to average daily household income (r=0.02).

In some cases a larger dataset enables analysis of correlations otherwise not possible, for example, in the case where 0% ownership rates exist within one community. This is the situation for households in El Mash with respect to traditional fire pits and improved stoves (as described in Chapter 5). All households surveyed in El Mash currently use an open fire pit contrary to Pozuelos (for reasons already discussed) where the majority of households' surveyed own improved stoves.

Table 31 Pearson correlation coefficients between average daily household income and cooking facilities

Cooking facility	All households	Pozuelos
Improved stove	0.429	0.139
Traditional fire pit	0.429	0.054

It would seem logical for a positive relationship to exist between ownership of an improved stove and average daily income but for the same statistical relationship to exist between ownership of a traditional fire pit and income defies this same logic. There are however two reasonable explanations for this. First it is important to note that as described a number of households within Pozuelos recently participated in an NGO project promoting improved stoves, the vast majority of whom also participated in this study. Second, the average daily household income in Pozuelos is MXN$118, almost twice the daily average of MXN$60 in El Mash. Given 100% of all survey respondents in El Mash use a traditional fire pit and 88% of all survey respondents in Pozuelos use an improved stove, the reasoning behind the first correlation becomes clear. It would seem likely that the second correlation exists because of the 100% ownership rate of traditional fire pits in El Mash, regardless of income. In any case, the correlation coefficient obtained for Pozuelos alone would suggest the absence of a relationship between income and cooking facilities, which is not surprising given prior knowledge of the NGO project. To my knowledge participants were not selected based on income however it is plausible that households with a higher income also have a higher educational capacity and thus, given the option, were more likely to participate in the project. This is supported by the fact that the 12% of participants from Pozuelos in this study who continue to use a traditional fire pit also have daily incomes equal to or less than the community average.

In all cases, it is important to recall that statistical correlations describe relationships of linearity but not cause and effect. Thus it is conceivable that an unknown third variable may be impacting any of these relationships. In the case of the last example, the missing third variable could in fact be the presence or absence of NGO support. Alternatively, cultural preferences are almost certain to play a role. Some households in Pozuelos that have improved stoves also have traditional fire pits citing heating as a key reason for dual ownership. That is to say, the improved stoves are so efficient that only limited heat radiation is available to keep the hearth warm and although women may use the improved stoves for cooking, they continue to use traditional fire pits in order to meet ancillary requirements. This would defeat the primary objective of the improved stove, to improve health and livelihoods in part by limiting the amount of smoke inhaled by women, but is not the subject of this inquiry.

Returning to the focus of this chapter, the first variable is a measure of financial capacity and looks at average daily household income in Mexican pesos. Response rates were highest in El Mash where all but two participants provided income information contrary to Pozuelos where almost a third of all women were unable to provide the same. Where a response was not provided, the community average has been applied, but only after upper and lower boundaries were defined. Thus financial capacity is defined as follows:

C1 = Average daily household income ($MXN) **C1**

The second variable assesses educational capacity by measuring the population as a % of the total reference population that has completed primary school with the reference population changing with scale (household or community). In this case, to avoid mathematical errors in rounding, the community score is calculated independently and not as an average of household scores. Where data permit, this method is preferred. Therefore the applicable definition is as follows:

C2 = % of population having completed primary school **C2**

As proposed by Giné & Pérez-Fouget (2009), this study considers gender inequality within education, but compares primary school completion rates instead of educational levels, whereby:

C3 = ratio of females : males (having completed primary school) **C3**

Not all households have at least one member (male or female) having completed primary school therefore this variable is calculated at the community scale.

Data were collected on the number of childhood deaths per household in an attempt to proxy infant mortality but, without independent verification, remains unreliable. Further, there is no way to determine cause of death or whether it is a function of capacity. Lastly, as the purpose of the WPI is to assess water poverty and not overall human development, variables that impact water poverty directly were considered to be more suitable, or more fit for purpose. It is with this in mind that the next two indicators that assess health were selected. The first aims to assess the percentage of the reference population having reported water-related illnesses in the year immediately prior to the survey. The second aims to assess capacity, or knowledge, pertaining to hygiene by considering the % of the population having participated in hygiene training.

Respondents were asked to indicate how often members of their household (children or adults) suffered from a water-related illness (WRI) during the year immediately prior to the survey. The intention was to assess adults and children under the age of 5 independently however it became clear over the course of the study that children under the age of 5 had come to be interpreted as children of any age. Therefore, answers were subsequently classified solely by frequency. Each frequency was attributed a score of 0, 1 or 2 corresponding to never, form time to time or often respectively. Scores were normalised using possible, not actual, minimum and maximum.

C4 = Frequency of water-related illnesses **C4**

As previously described, the national social assistance programme Programa Oportunidades, is provided to those in need with the caveat that certain conditions be met, for example, participating households must have access to a latrine. Another condition of the programme is that a (female) member of the household attend a hygiene training session often provided at the local school. These sessions address a number of themes, amongst other things water-related hygiene, such as the need to boil water. In theory participation in these sessions should increase capacity in a water poverty context. Therefore, the WPI variable score, C5, can be defined as the % of households within a community where (at least) one member has participated in hygiene training.

C5 = % of households with at least one member with hygiene training **C5**

7.4 Use

Use is comprised of two variables, domestic and livestock water consumption. Though agricultural water consumption is proposed in other studies undertaken at the local scale (Sullivan *et al.*, 2003; Giné & Pérez-Fouget, 2009) and was assessed at the state level in the present study, it is not applicable to the local communities in question who rely solely on rain-fed irrigation. It has already been shown that there is sufficient rainfall to sustain subsistence farming in both communities. Nevertheless, it should also be noted that both communities prohibit the use of water for agricultural purposes. Lastly, although residents of Pozuelos use water for small-scale industrial purposes i.e. to make clothing for their families, it was previously discussed that the volume of water required has a negligible impact when averaged over time. That being said, clothing-making activities are seasonal, tied prominently to sheep-shearing activities, and normally require vast amounts of water at one time. It is clear from conversations with adult females that, as a result, clothing-making behaviours are modified to coincide with water availability. However at present, insufficient data are available to assess the impact this might have on overall water poverty at the household level and therefore is not considered further within this study. There are no other human-induced uses of water to consider.

Respondents were asked to estimate how much water, in litres, their household consumed per day for the purposes of bathing, drinking, cooking and cleaning and/or washing laundry. Where a range was given, i.e. 20-40L the mean volume was taken i.e. 30L. Total household domestic consumption was then compared to a BWR of 50L per person per day. Given the majority of households, if not all, are (according to data collected) consuming insufficient volumes of water to meet their BWR, it should be acknowledged that overall variable scores measure the extent to which water is being under consumed i.e. a score of 1 would indicate each member of the household is consuming at least 50L of water per day with consumption decreasing as scores approach 0. This is in contrast to state variable scores, which measure the extent to which water is being over consumed, i.e. a score of 0 would indicate each state is satisfying its per capita BWR with consumption increasing as scores approach 1. With this in mind, U1 is defined as follows:

U1 = ratio of daily household domestic consumption to daily household BWR **U2**

Similarly, U2 measures the ratio of daily livestock water consumption to basic daily livestock water requirements. Survey respondents were only required to indicate whether or not they needed water for livestock purposes and if so, the total volume of water required each day as the original intended purpose of this question was to assess total daily water requirements for livestock. However, it became evident that volumes were being grossly over-estimated thus a new method for assessing livestock requirements was needed. It was therefore fortunate that most respondents had provided livestock head counts and consumption per animal type. In this way, it was possible to calculate a livestock BWR based on animal type and total head count per household. Similar to U1, the variable scores measure the extent to which water is being under consumed, and a score of 1 would indicate total livestock BWR for that household is being met.

Clearly, like humans, livestock requirements vary depending on size, climate and function. In the absence of available data with respect to the temperate sub-humid climate zone of Los Altos, guidelines published by the Ministry of Environment (1996) were used to determine the daily water requirements for livestock present in the communities of Pozuelos and El Mash. A household without livestock scored the maximum score of 1.0 for this variable.

U2 = ratio of daily livestock consumption to daily livestock BWR **U2**

7.5 Environment

The last indicator to make up the WPI, consists of four variables, one quantitative and three qualitative. The first variable, E1, assesses water quality through standardized testing for the presence of thermotolerant coliform bacteria (TTC). Water quality at the community level has been described in detail in the relevant sections in Chapters 5 and 6 and this section therefore solely addresses the needs of the WPI. The Drinking Water Guidelines proposed by WHO (2008, p.143) recommend "E. Coli or thermotolerant coliform bacteria must not be detectable in any 100-mL sample." In this respect, any variable score charged with assessing water quality should simply correspond to the presence or absence of faecal matter, irrespective of count, whereby a score of 1 would indicate the absence of coliforms and a score of 0 would indicate their presence. However, the purpose of the WPI is to assess relative water poverty and as such its design, or more specifically its statistical validation, is less amenable to either/or questions as demonstrated when considering ownership of cooking facilities. Furthermore, the Drinking Water Guidelines (WHO, 2008, p.143) recognize faecal contamination is widespread in "the great majority of rural water supplies, especially in developing countries." All things considered, it has therefore been determined that the most appropriate way to measure water quality in these circumstances is to compare water quality across households by assessing the overall degree of faecal contamination. In this case a score of 1 indicates the absence of faecal coliforms and a score of less than 1 indicates their presence, with the degree of contamination increasing as the score approaches 0. The standardization methodology previously described is used, whereby E1 is as follows:

E1 = Number of thermotolerant coliforms per water sample **E1**

The second variable measures qualitative water quality and is very straightforward. Respondents were asked to describe the quality of their drinking water as either: good/ clean, a little dirty or bad/ dirty with a score of 2, 1 or 0 being attributed to each response respectively. Similar to other qualitative variables, E2 is therefore defined as follows:

E2 = Perceived water quality **E2**

The third and fourth variables of the Environment indicator are proxies of environmental sustainability recommended by Sullivan *et al.* (2003). The first, E3, considers soil fertility. Respondents were asked to indicate whether or not they had observed changes in soil fertility over the ten-year period prior to the survey. An increase in soil fertility was described as an increase in, or better quality, crops whereas a decrease in soil fertility was described as a decrease in, or lesser quality, crops. To this effect, scores were attributed as follows: 2 for a reported increase in soil fertility, 1 for no change, and 0 for a reported decrease in soil fertility. Incomplete (where the response lacks information as to the degree of change) or unknown responses are excluded prior to calculating the community average. The same approach was used to compile data for the last variable, which aims to assess changes in land cover by asking respondents to indicate whether or not they had observed a change in tree cover (volume of local forests) in the ten-year period prior to the survey. Possible responses and scores are the same as those applied to variable E3 whereby: a score of 2 indicates an increase in tree cover, a score of 1 indicates no change and a score of 0 indicates a decrease in tree cover. Thus, these variables can be represented as follows:

E3 = Perceived historical change in soil fertility **E3**

E4 = Perceived historical change in tree cover **E4**

7.6 The Water Poverty Index

Water Poverty Indices were calculated at the household level for Pozuelos and are presented in Figure 30. WPI scores for Pozuelos range from a low of 0.408 to a high of 0.656 with a mean community score of 0.561 (SD = 0.049). Minimum and maximum scores for each indicator are presented in Table 32 along with their respective average and standard deviation. Overall, the best and worst mean indicator scores for Pozuelos are Access with 0.948 and Use with 0.157. There is little variation amongst the remaining mean indicator scores.

Of the five core indicators, Access presents the highest maximum score of 1.000 whilst Use presents the lowest minimum score of 0.017. Standard deviation is low across all indicators and in all cases is less than 0.15. Use presents the widest range of scores whilst Resources shows the least variation.

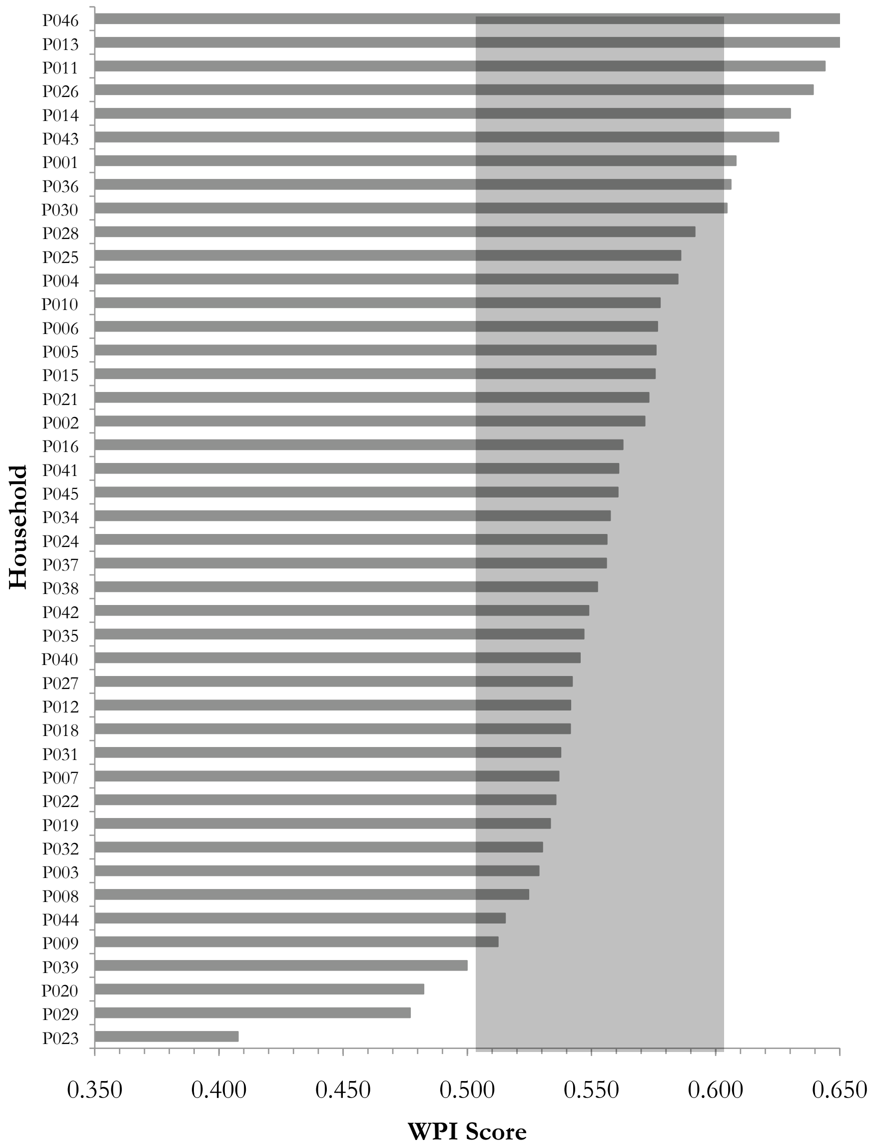

Figure 30 Water Poverty Index by household (Pozuelos) with shaded area representing mean WPI +/- 1 SD

Table 32 Distribution of original indicator scores for Pozuelos

	Resources	Access	Capacity	Use	Environment	WPI
Mean	0.591	0.948	0.562	0.157	0.545	0.561
SD	0.092	0.107	0.087	0.128	0.010	0.049
Min	0.431	0.506	0.382	0.017	0.374	0.408
Max	0.776	1.000	0.747	0.638	0.750	0.656
Range	0.345	0.494	0.365	0.621	0.376	0.248

Household water poverty scores for El Mash are presented in Figure 31. WPI scores range from a low of 0.331 to a high of 0.618 with an average community score almost one full point less than that of Pozuelos at 0.474 (SD = 0.075). Minimum and maximum scores for each indicator are presented in Table 33 along with their respective average and standard deviation. Overall, the best mean indicator score for El Mash is Access with 0.542. This contrasts significantly with a mean score of 0.948 in Pozuelos and is a reflection of their different water supply systems. The lowest mean indicator score in El Mash is Environment at 0.393, contrary to the situation in Pozuelos where Use presents the lowest indicator score. Overall, there is little variation amongst mean indicator scores although the opposite is true for individual indicators.

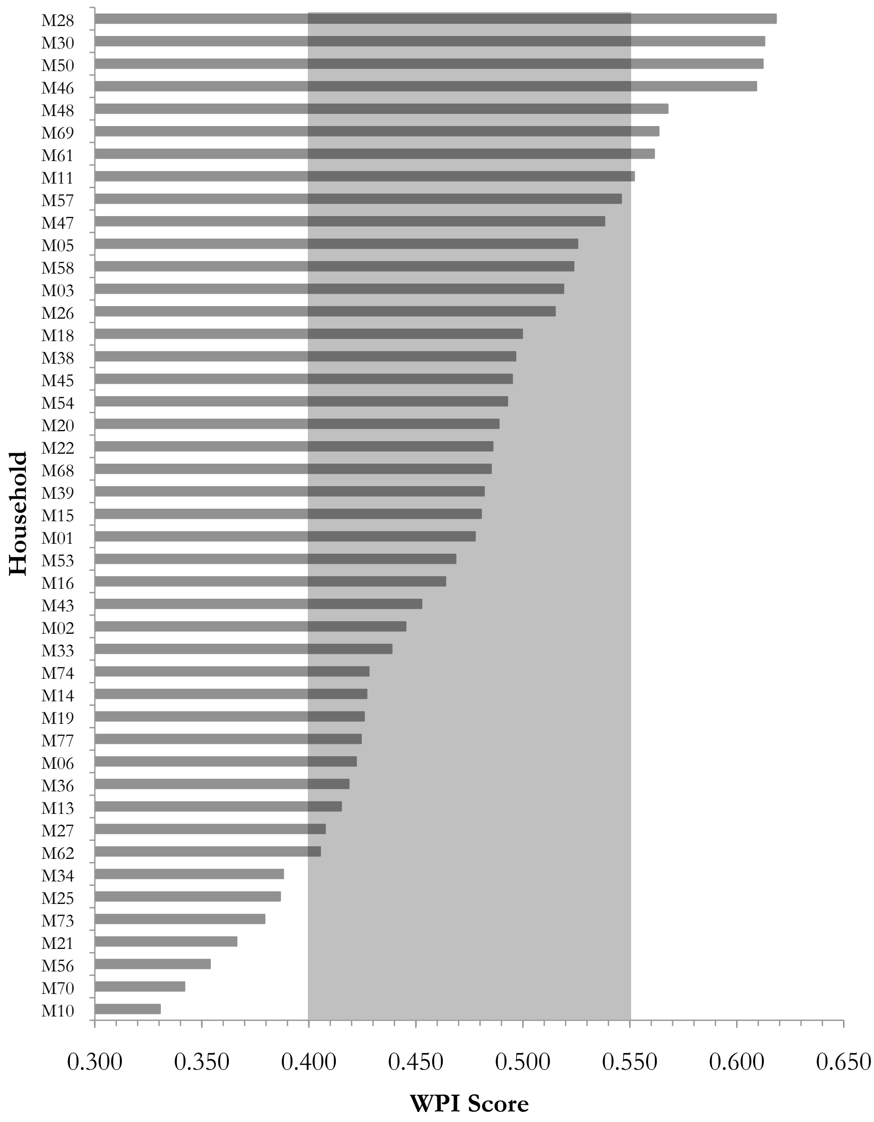

Figure 31 Water Poverty Index by household (El Mash) with shaded area representing mean WPI +/- 1 SD

Table 33 Distribution of original indicator scores for El Mash

	Resources	Access	Capacity	Use	Environment	WPI
Mean	0.538	0.542	0.498	0.400	0.393	0.474
SD	0.110	0.065	0.081	0.244	0.158	0.075
Min	0.362	0.378	0.338	0.036	0.000	0.331
Max	0.828	0.667	0.720	1.000	0.749	0.618
Range	0.466	0.289	0.382	0.964	0.749	0.287

Within El Mash, Use presents the highest maximum score (1.000) and Environment presents the lowest minimum score (0.000). Standard deviations are higher than those in Pozuelos but are still under 0.25. Similar to Pozuelos, Use presents the widest range of variables but Access presents the least. It is anticipated that this contrast in variation between communities will improve statistical analyses of the combined dataset.

Figure 32 shows indicator scores for households with below and above average WPI scores in Pozuelos. Examining these diagrams suggests that Resources is most strongly related to overall WPI scores with $R<0.6$ in all four households with below average WPI scores and $R>0.6$ in all households with above average WPI scores. Similarly, Capacity is strongly related to WPI with $C<0.5$ for households with below average WPI scores and $C>0.55$ for households with above average WPI scores. Access and Environment are only weakly related to WPI, with strong indicator scores for households with above average WPI scores, but variable indicator scores for those below average. Lastly, Use appears to have no relationship with WPI.

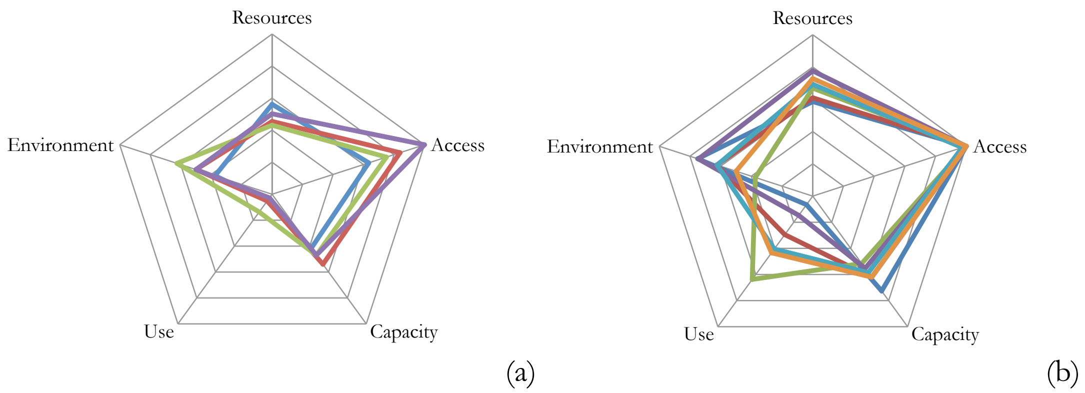

Figure 32 Pentagram representations of household indicator scores in Pozuelos with (a) below and (b) above average WPI scores

Clearly, pentagram representations of indicator scores for households with below and above average water poverty in El Mash (Figure 33) differ significantly from those of

Pozuelos (Figure 30). It is difficult to predict the relationship between indicators and overall WPI scores by examining Figure 33(a) alone, as it appears each indicator is similarly related to WPI scores. However upon examining Figure 33(b), specific trends become more evident. Contrary to Pozuelos, Use would appear to have the greatest impact on overall WPI scores. In fact, the indicator with the greatest impact in Pozuelos, Resources, appears to have the least impact in El Mash. Much like Pozuelos, although to a lesser degree, Capacity appears to be moderately related to overall WPI as does Access although Environment appears to produce variable results and its relationship to the WPI is therefore unclear.

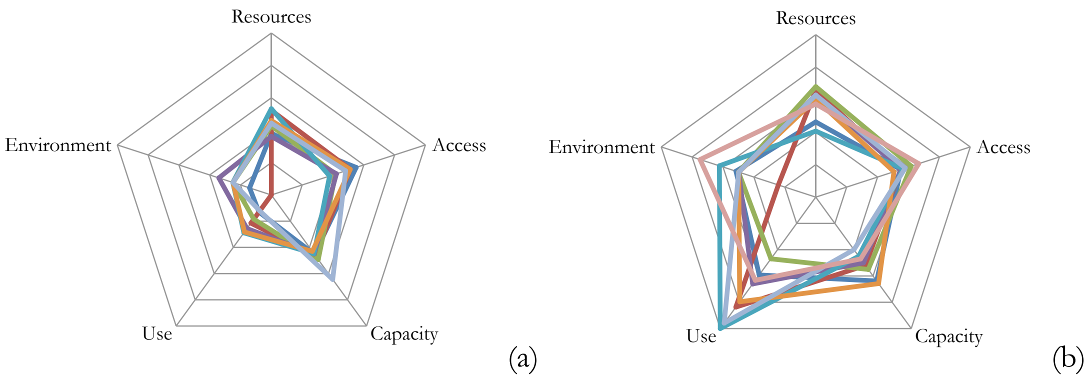

Figure 33 Pentagram representations of household indicator scores in El Mash with (a) below and (b) above average WPI scores

7.7 Comparing Water Poverty across Communities

Overall, Pozuelos and El Mash scored 0.561 and 0.474 for water poverty respectively and, with the exception of a few well-placed households, a comparison of all households' reveals that the least and most water poor households are within El Mash and Pozuelos respectively (Figure 34). This concurs with field observations that suggest El Mash is more water poor than Pozuelos. And in fact an independent t-test[13] confirms the difference in means is significant, two-sample $t(76) = -6.592$, $p = 0$ as expected for two independent populations. However, given the WPI is a scale of relativity and only

[13] The two sample populations exhibit normal distributions and are almost equal in size although after adjusting for outliers Levene's Test is significant ($p=0.007$) and the assumption of equal variances is violated. SPSS computes the t-test under this scenario (results as reported in the main text). Although non-parametric tests are not recommended as a matter of course, because the sample populations violate a key assumption of the t-test, the Mann-Whitney U test was also performed and the null-hypothesis was rejected with the same result ($p=0$).

two communities were analyzed, by design one community must perform better than the other but overall scores provide no indication as to whether or not this order is meaningful nor do they describe the context of water poverty in each community or the cause of variation.

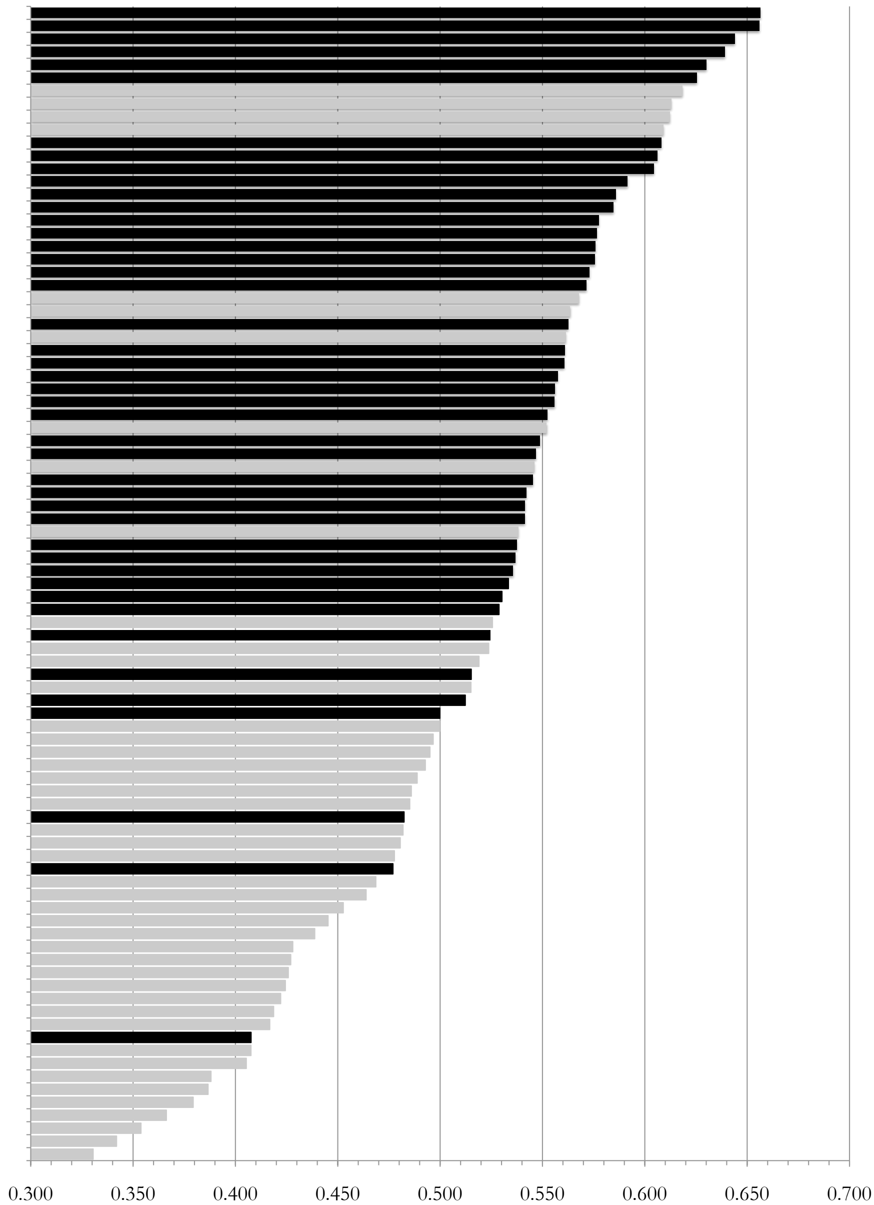

Figure 34 Overall WPI scores for Pozuelos (black) and El Mash (gray)

Indicator scores provide some additional information and, based on mean scores, (Figure 35), suggest Pozuelos experiences comparably high Access scores, average Resources, Capacity and environmental integrity, but low consumption rates whereas El Mash experiences comparably low Access scores, similar Resources and Capacity, slightly higher yet still low consumption scores, and less environmental integrity.

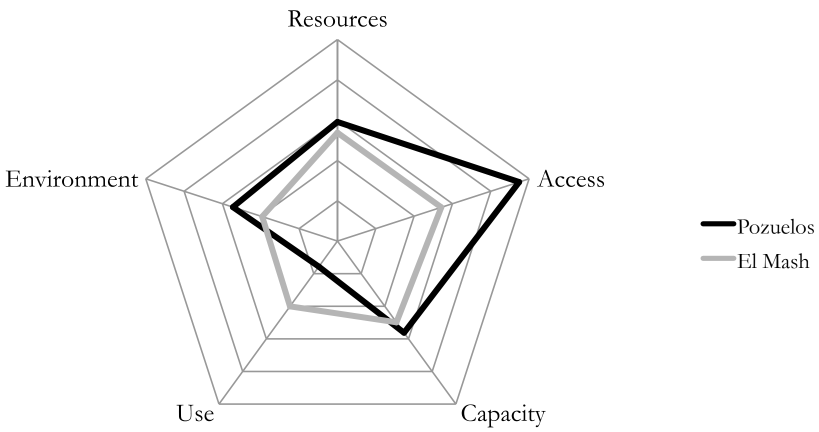

Figure 35 Pentagram representations of mean indicator scores for Pozuelos and El Mash

7.8 The Community Voice

The following section describes the organization and results of two community focus groups held independently with male and female participants in El Mash.

In both sessions, groups were divided into four teams. In general, the women were much more willing to engage in a co-operative process of sharing than the men, who exhibited strong competitive tendencies and who seemed far more preoccupied with what the other team was doing than completing the task at hand. Extreme care had been taken at every step to manage community expectations and although the male community leaders purported to understand my role as researcher in the community, they were obviously concerned with the concept of right or wrong and were inclined to give a more calculated response perhaps intended to appease me in the hope community assistance would be forthcoming. The women on the other hand were less concerned with appearances and spoke with strong, emotional conviction. Though I am not a gender specialist, I note that on the whole, gender bias was not overly explicit[14] in

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[14] By all means this is a relative concept. In the case of El Mash, a lack of explicit gender bias should be interpreted as the ability of women to speak freely regardless of the presence of men, my perception that their opinions and voices were not only heard but valued and observations including the shared role of water carrying activities between men and women. However, it should be noted that women are not allowed to hold roles within the community executive. Furthermore, the idea of explicit gender bias clearly ignores gender biases already implicit in society.

El Mash. Nevertheless, I felt my gender was a factor amongst the women who were seemingly relieved to be heard by someone who, as I perceived it, in their mind might better understand their personal suffering. At the time, despite consciously considering the role of gender, I was less aware of my impact (and that of my interpreter, a young, indigenous woman). Yet upon further reflection, the impact is noticeable and particularly evident in the clarity, accuracy and depth of answers provided in El Mash (as compared to those provided in Pozuelos). If anything, however, I esteem that my gender and the lack of a perceived overt gender bias enabled me to engage more effectively with the women in El Mash, without any obvious detriment to my relationship with the men. The team divisions were purposeful: in the case of the women, in an attempt to ensure one member of each team could speak Spanish and could write (though this was an unattainable goal), in the case of the men, in an attempt to create even-sized groups.

Each team was provided with a box of coloured markers and flip chart paper. Their first task was to pick a team name and create a team poster. The men engaged in the task with humour and vigour devising team names such as "*Los Guerreros*" (the Warriors) and "*El Tigre*" (the Tiger). Exhibiting their passion for their national sport, the remaining team called themselves Pumas after one of Mexico's most popular soccer teams.

The women initially struggled to find their metaphorical voice and were instead assigned colours in lieu of self-assigned group names. However, not to be out done by the men, the women exhibited their creativity during the second task, which was to create diagrams/community maps, identifying local landmarks and areas of interest related to water within their community. The result was a mosaic of colours and smiling faces. The red team's illustration included a green tree, "*uk'um ja'*" (Tzeltal for spring), a rainwater tank, a house and a bowl. The blue team drew wind, rain and trees, a house with a rooftop rainwater harvesting system, leading to a Rotoplas. Another team, inspired by the activity called themselves "*Equipo Manantial*" (Team Spring) and drew a lively picture with a large tree, a rooftop rainwater harvesting system connected to a Rotoplas, a house with an open fire inside depicting a pot for boiling water, two women carrying water from a distant storage tank and rain clouds with the explanation that "*cuando bine nube da enfermedean* [sic]" (when the clouds come they bring sickness). Team Ocean's illustration included "*tokal*" (Tzeltal for clouds), "*tulaja*" (water drops), a river, a flower, a house, a Rotoplas, and a rainwater tank. Strikingly, in the middle of the frame is a pair of "*ojos llorando*" (crying eyes). Although this exercise was intended as more of an ice-breaker activity, it demonstrates a general understanding of the relationship between nature and water and the community's reliance upon various low technologies to meet their needs, especially as a function of domestic activities.

Two of the men's teams presented detailed illustrations of the community (the Pumas having decided to depict their beloved mascot instead). Team El Tigre drew a comprehensive diagram that included a rain cloud, trees and flowers, livestock and wildlife, the principal road, a reference datum, the school, a house and a spring depicted by water flowing from a rock. Los Guerreros depicted similar community attributes, carefully colouring in trees, chickens and water holes and adding a car to the foreground of their diagram. The men's illustrations also demonstrate an understanding of the relationship between nature and water. Their diagrams could be considered more artistic, typical of a landscape artist's rendition, as opposed to the purposeful drawings presented by the women, which emphasized technology.

The next activities concentrated on the concepts of well-being, wealth and poverty as they relate to households and families in El Mash. The main objective of these tasks was to ascertain the community and gender perspective on each concept whilst providing an open forum for discussion. For these tasks the women were divided into groups of two an unavoidable practicality given the translator and I were the only two women able to write in Spanish and it was imperative I maintain a written copy of the outcomes for future analysis. This inevitably diluted the responses to some degree, and despite my best efforts, gave a preferential voice to the few women who understood and spoke Spanish, at least within my group. Nevertheless, and despite any language barriers, it was a valuable exercise though in hindsight had I known my role would be so proactive I would have opted to digitally record both sessions. The men were also divided into two groups for this exercise but unfortunately for no other reason than the loss of several members over the course of the day.

The first of these two conceptual activities entailed compiling a comprehensive list of indicators of well-being. After compiling their lists and after extensive discussions, the women determined further clarification was necessary thus opted to rank the top indicators in order of importance.

Whilst participant numbers were too small to draw any general conclusions about rural well-being in Mexico, they certainly provide valuable insight into the needs, desires and perceptions of this particular community. Table 34 lists the indicators of well-being as defined by the community members of El Mash and ranked in the order attributed to them by the women, followed by the number of times a particular response was given.

Table 34 Local indicators of well-being as defined by the residents of El Mash

Female to male response ratio (no. of groups)		Well-being Indicator	Ranking (women only)	
2	2	Potable water	1st	1st
2	2	Health services	2nd	2nd
2	1	Electricity	2nd	2nd
2	1	Housing/ infrastructure	2nd	2nd
2	2	Roads/ access	2nd	3rd
1	0	Flour mill	2nd	-
2	2	Improved diet	3rd	-
1	1	Education	-	-
1	0	Clothing	-	-
0	1	Employment	-	-
1	0	Gas stove	-	-
1	0	Government assistance	-	-

In total, twelve indicators were proposed. Given the current needs of the community and the overall purpose of this study it is not surprising to see that potable water was mentioned by all four groups and ranked first by both female groups. In the minds of the women health services, electricity and housing are equal; yet only one group of men also mentioned all three indicators, with both having mentioned health services. Roads and diet also figured on all four lists though the women considered them to be slightly less important. One group of women listed ownership (shared or otherwise) of a flourmill as an indicator of well-being but considered it more important than an improved diet. In essence, the two are intrinsically linked, particularly in a community that relies on corn flour for much of its diet. One group of each gender mentioned education, though for the women it did not rank highly. Four indicators mentioned by at least one group of women were not mentioned at all by the men: flourmill, clothing, gas stove, and government assistance. Solely the men mentioned employment. These results are not surprising given their relationship to each gender. The women are the primary household members concerned with food and clothing, and are specifically targeted by Programa Oportunidades whereas the men are typically (or seek to be) employed outside of the home.

If we group related indicators together, we then see that in general two categories of indicators, access to services and infrastructure, figure most prominently, followed closely by food although it is important to note that both infrastructure and food are considered more important than some services.

Table 35 Modified indicators of well-being

Female to male response ratio (no. of groups)		**Well-being Indicator**	**Ranking (women only)**	
Access to services				
2	2	Potable water	1st	1st
2	2	Health services	2nd	2nd
2	1	Electricity	2nd	2nd
1	1	Education	-	-
1	0	Government assistance	-	-
Infrastructure				
2	1	Housing/ infrastructure	2nd	2nd
2	2	Roads/ access	2nd	3rd
Food				
1	0	Flour mill	2nd	-
2	2	Improved diet	3rd	-
1	0	Gas stove	-	-
Economic livelihood				
0	1	Employment	-	-
Integrity				
1	0	Clothing	-	-

In a bid to determine community perceptions of wealth and poverty, groups were asked to contemplate typical wealthy and poor households in El Mash. However, this concept was flawed, and the result revealing, as participants were quick to point out that no one in El Mash is wealthy but instead families exhibited varying degrees of poverty. Thus, the local concept of wealth became less poor. Table 36 lists the indicators of wealth and poverty as defined by the four groups regardless of whether or not they figure on both sides of the wealth-poverty gap.

Table 36 Local indicators of wealth and poverty as defined by the residents of El Mash

Response ratio (F:M)	Indicators of wealth	Response ratio (F:M)	Indicators of poverty
● purple ● brown ● blue ● orange	Car(s)/ airplanes[15]	● purple ● brown ● blue ● orange	Insufficient money
● purple ● brown ● blue ● orange	Nice house	● purple ● blue ● orange	Insufficient clothing
● purple ● brown ● blue ● orange	Sufficient food	● purple ● blue ● orange	Insufficient food (especially meat)
● purple ● blue ● orange	Sufficient clothing	● blue ● orange	No stove (wood fire only)
● purple ● brown	Business	● blue ● orange	No vehicle
● brown ● blue	Employment	● purple ● blue	House in need of repair
● brown ● blue	Piped water supply (in the home)	● blue	Insufficient water/ no piped supply (in home)
● purple ● orange ● blue	Sufficient money/ savings	● purple	Need to migrate for employment
● blue	Access to health care	● purple	Need to sell produce intended for consumption
● blue	Access to public services	● blue	No access to health care
● orange	Better commodities	● brown	No family
● orange	Better land (ranchos)/ livestock	● brown	No land
● brown	Happiness	● blue	No public services
● purple	Radio	● orange	No television
● purple	Television	● brown	Old/ elderly
● blue	Stove	● purple	Peasant farmer
● blue	Travel on deluxe buses	● purple	Reliance on government assistance
		● purple	Reliance on store credit

● (blue) Team 1 - Men
● (orange) Team 2 - Men
● (brown) Team 1 - Women
● (purple) Team 2 - Women

Analyzing the list by gender enables us to make some initial comments about gender-based attitudes. For example, the charts compiled by the men, who were left to their own devices, list indicators of poverty in the first column and indicators of wealth in the second as opposed to the charts compiled on behalf of the women, which list indicators of wealth first and of poverty second. These charts were compiled by the group moderator and I and reflect the order in which the question was asked. Though the men were asked the same question, they elected to contemplate indicators of poverty first. Given earlier comments regarding a distinct lack of wealth in El Mash, this provides additional evidence that the community self-identifies as poor. When the indicators are listed pair-wise (Tables 37 and 38) by gender, it becomes evident that the men have a

[15] Given the absence of wealth within El Mash, some of the men drew parallels between what they perceived as wealth based on images from the popular media

tendency to view indicators of wealth and poverty as opposite poles on the same spectrum. In fact, all but three indicators (employment, better land/ livestock and deluxe travel) figure on both sides of the gap. Furthermore, of the paired indicators, all of them were put forward by at least one team and comprise mostly material goods suggesting a have and have not ideology towards indicators of wealth and poverty. The five top indicators of wealth as described by the men are: sufficient food, clothing, money, a nice house and car ownership. The top five indicators of poverty are: insufficient food, clothing, money, no vehicle, and no stove. Notwithstanding problems of cause and effect, all of the indicators can be categorized as a function of economic or political (access to services) well-being.

Table 37 Local indicators of wealth and poverty as defined by men

Response	Indicators of wealth	Response	Indicators of poverty
🔵 🟠	Sufficient food	🔵 🟠	Insufficient food (especially meat)
🔵 🟠	Vehicles (airplane)	🔵 🟠	No vehicle
🔵 🟠	Sufficient clothing	🔵 🟠	Insufficient clothing
🔵 🟠	Sufficient money/ savings	🔵 🟠	Insufficient money
🔵	Sufficient water/ piped supply (in the home)	🔵	Insufficient water/ no piped supply (in home)
🔵 🟠	Nice house	🔵	House in need of repair
🔵	Access to health care	🔵	No access to health care
🔵	Access to public services	🔵	No public services
🟠	Better commodities	🟠	No television
🔵	Stove	🔵 🟠	No stove (wood fire only)
🔵	Employment		
🟠	Better land (ranchos)/ livestock		
🔵	Travel on deluxe buses		

To the contrary, when a similar attempt is made to list the female responses pair-wise, only the first four indicators comply. The fifth indicator (employment) begins to diverge from this model. Responses elicited from the women diverge even further as they begin to emphasize qualitative indicators of wealth and poverty such as happiness, family, and age, as well as less direct ideals of wealth and poverty such as the need to migrate for employment, and reliance upon government and/or store credit. Interestingly, the relationship between certain concepts and gender is less evident here than when discussing concepts of well-being. For example, none of the female groups mentioned stoves and only one group mentioned clothing, yet both male groups felt the absence of a stove was definitely indicative of poverty, as was insufficient clothing. Neither of the male groups mentioned business ownership and only one mentioned employment yet both female groups associated these indicators with wealth. Participants tended to relate to concepts of well-being on a more personal level, due in part to the question asked: *¿qué significa estar bien*? (literally translated as, what does it mean to be well?), whereas indicators of wealth and poverty were considered in a community context as they applied to households and/or families which might explain why gender stereotypes were more evident in the former exercise. The top four indicators of wealth as proposed by the women are: sufficient food, a nice house, ownership of business and a vehicle. Only one indicator of poverty was proposed by both female groups, insufficient money. Notwithstanding problems of cause and effect all of the indicators can be categorized as a function of economic or social (happiness, family, peasant farmer, elderly) well-being.

Table 38 Local indicators of wealth and poverty as defined by women

Response	Indicators of wealth	Response	Indicators of poverty
🟣 🟤	Sufficient food	🟣	Insufficient food (especially meat)
🟣 🟤	Nice house	🟣	House in need of repair
🟣	Sufficient money	🟣 🟤	Insufficient money
🟣	Sufficient clothing	🟣	Insufficient clothing
🟤	Employment	🟣	Need to migrate for employment
🟣 🟤	Business	🟣	Need to sell produce intended for consumption
🟣 🟤	Vehicle	🟤	No family
🟤	Sufficient water/ piped water supply (in the home)	🟤	No land
🟤	Happiness	🟤	Old/ elderly
🟣	Radio	🟣	Peasant farmer
🟣	Television	🟣	Reliance on government assistance
		🟣	Reliance on store credit

In summary, both groups relate to the concept of well-being on an individual level giving rise to stereotypes of gender roles for some of the less mentioned indicators. Overall both men and women perceive well-being predominantly as a function of access to services and infrastructure. Indicators of wealth and poverty cross the gender divide in terms of stereotypical roles, though a gender divide exists in terms of response type. Men describe indicators of wealth and poverty quantitatively as a function of have or have not pertaining to ownership or possession of material goods. Women on the other hand describe both quantitative and qualitative indicators of wealth and poverty, including both direct and indirect measures of poverty and are less concerned with material goods when compared to men.

The last exercise of the day focused on the concept of water poverty but was approached differently between men and women. In the first instance, there were fewer men than women but more importantly I was the sole moderator during the male focus group. This meant the primary discussion was held in Spanish forcing me to rely upon community members for translation who often were too engaged in their own debate to consider the opinions of those who could not communicate in Spanish. Nevertheless, in my experience, male groups tend to put forward their ideas only after consensus of the wider group. In this case, it is difficult to determine whether consensus was as a result of fair debate, or simply the opinion of those with whom I could readily communicate. It would seem likely that it was a combination of both factors. As mentioned the female focus group consisted of 23 women, only a limited number of who spoke Spanish (though many understood it). As the exercise was undertaken in their maternal language, it was inevitably more inclusive than the male focus group. Furthermore, the trend seen in earlier exercises whereby women considered both qualitative and quantitative sides to a problem, continued in this exercise resulting in an outcome that exhibited more depth and breadth than their male counterparts. For these reasons the outcomes are discussed independently.

The discussion with the women focused on the effects of water poverty, presented simply as, "*no hay agua*" (there's no water), and specifically the impact of water poverty upon their lives. Their initial reaction was equally simple, "*sufrimos*" (we suffer). When queried as to the immediate impacts of water poverty the women described five key situations that render their lives difficult: inability to do laundry, inability to bathe, inability to cook, need to carry water, and thirst. When pressed for further details, it became clear that lack of water initiates a chain of events which gives rise to a number of different circumstances, such as a lack of integrity, poor health, decreased work performance, and loss of earnings ultimately leading to unnecessary suffering.

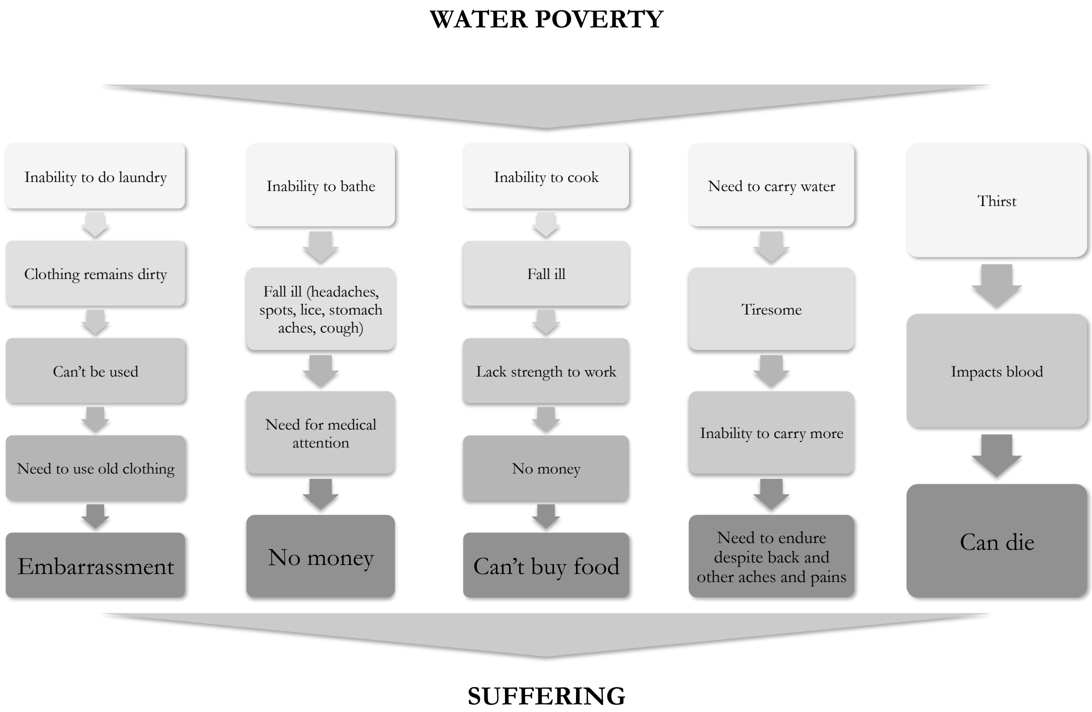

Figure 36 Impacts of water poverty as described by adult females in El Mash

Though the women do not necessarily understand the science behind these impacts (i.e. their perception of problems relating to a lack of water available for consumption or thirst), they were particularly astute at describing the snowball effect of water poverty, especially as it relates to a lack of earnings and health. The most surprising result was the inclusion of the inability to wash laundry as a key impact. Those of us who have lived in Latin America are well aware that pride in one's appearance is very characteristic of the region, for example, the near fanaticism with which certain cultures keep their shoes shined, the collared shirts and dress pants worn by my colleagues on field trips (and their innate ability to remain clean no matter how many dusty hills we may have climbed or how many rain storms we may have endured), to cite a few of my personal experiences across Latin America. Despite my previous knowledge, I wasn't prepared for this pride to extend to rural, indigenous communities to the degree that it did in El Mash. Right or wrong, the reality is "*gringos*[16]" effectively have a carte blanche to disregard cultural nuances, thus I never suffered the inevitable shame a local person might despite wearing my grubbiest pants, least favourite shirt and always wearing a baseball cap on most field trips. Suffice to say my cultural history (dictated by the old

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[16] A word used by Latin Americans to describe foreigners, often negatively.

adage that one should never judge a book by its cover), and personal experiences had clouded my judgement in this respect. In reality, the Tzeltal people of El Mash are no different than their Latino compatriots and pride in appearance is very important to maintaining personal and family integrity. Several respondents made reference to the importance of water for clean clothing during informal household interviews. One respondent specifically stated, "*prefiero lavar ropa antes de bañarme por mi niño que* [debe] *representar*[se] *en la escuela*" (I prefer to do laundry over bathing for my son who needs to present himself [well] at school). Overall, the impacts of water poverty outlined by the women centre on their core domestic activities.

The discussion with the men was not directed yet ultimately focused on the causes and solutions of water poverty. Again their tendency was to reference quantitative or physically tangible aspects of water poverty making specific reference (in no particular order) to:

- Lack of physical resources
- Population density
- Demand which exceeds availability
- Lack of storage
- Water management/ insufficient knowledge

The men clearly demonstrate they are astute in their own right by devising such a list and in fact, if I were to compile a list of the quantitative causes of water poverty in El Mash, it would include some of these same problems. The discussion with the men was extremely straightforward and their ability to assess the problem was evident. Therefore the question that remains is, given such a lucid awareness of the quantitative causes of water poverty in their community, why haven't they attempted to mitigate them? In fact, the discussion turned towards fighting water poverty and specifically identifying local solutions for their localized problem. The men were less adept at defining solutions than defining the problem, but nevertheless came up with the following four ideas:

- Conserving water
- Thinking about traditions
- More storage tanks
- Training

It is common knowledge that paternalism is entrenched in Mexican society and whilst this study acknowledges its importance it is however beyond the remit of the present research. Nevertheless, paternalism has permeated local populations to such an extent that many of them are held prisoner by their lack of desire, not inability, to act. It is with this in mind that the discussion faltered. Having developed a trusting relationship with one of the key participants (who was effectively my gatekeeper to El Mash) and sensing an opportunity to touch upon this problem, I suggested there was a need for them to take ownership of their present circumstances and queried why more had yet to be done. My brashness was well-received and thus ensued a conversation whereby I was initiated into the political discrimination faced by indigenous populations in Mexico, a situation metaphorically and literally reminiscent of the sentiment described in the famous children's song "There's a hole in my bucket[17]."

The perpetual loop of despair described by the men reiterates their desire to access public services and infrastructure for which they require money for which they require work for which they require an education for which they require money for which they require work for which they require certain legal documents for which they require a certain level of literacy to obtain said documents for which they require an education for which they require money… and so on and so forth while the bucket remains unfixed, seemingly forever.

Strikingly, aside from final conversations with the men, the near obscurity of education from all discussions has not gone unnoticed. Although the relationship between marginalization and the inability to read or write Spanish is commonly accepted in Mexico and is one I would not dispute, after two enlightening days of focus groups with both the men and women of El Mash, I'm less convinced that formal education is a good measure of social capacity as put forward by the WPI. I am confident that with the right guidance the residents of El Mash are sufficiently knowledgeable and capable of managing their own water resources. What I am less convinced of is their willingness to do so. Although this is a subjective value judgement (based also on prior experience), it

[17] Apparently of German origin (unconfirmed), the song was popularized in North America through the children's television programme Sesame Street. The song, which has no clear beginning or end, tells the tale of Henry whose bucket has a hole in it and who seeks advice as to how to fix it from his (presumed) partner Liza. Liza recommends a number of fixes but for each fix, Henry has a problematic retort until the point where Liza's last fix requires Henry to fetch water at which point Henry points out, there's a hole in his bucket.

is not without precedent and Närman (1997, p.223) considers "one main dilemma related to development assistance as the passivity created locally." His students provide accounts of "determination among the rural population to deal with their own situation" contrasted by "passivity in just accepting the delivery from outside sources."

Chapter 7 detailed the construction of a water poverty index for use at the community scale followed by a presentation of the overall results obtained from both the WPI and focus groups conducted in the second community of El Mash. Chapter 8 now examines those results in detail.

CHAPTER 8 ANALYSIS OF WATER POVERTY AT THE MICRO SCALE

Following the calculation of a water poverty index at the micro scale in Chapter 7, this Chapter provides a detailed analysis of those results both at the community level and between communities referencing results at the macro scale where applicable. An analysis of selected variables is presented before comparing the results of the WPI obtained in El Mash against the findings of the focus groups conducted there. In principal, the overall analysis (and in particular statistical analyses) follows the same format as that used to analyse the WPI calculated at the macro scale and a basic comprehension of the methods and terminology used is therefore now assumed.

8.1 Pozuelos

Fifteen different households presented outlier values for at least one of the following indicators, Access (x=<0.90), Capacity (0.38=>x=>0.74) and Use (x=>0.29). After recalculation, P023 and P011 presented an extreme value for overall WPI and were therefore removed from statistical analyses undertaken for Pozuelos. Clearly this methodology for removing outliers has the undesirable effect of creating a more homogenous population. However, given my knowledge and experience of the community, I am aware that some of the data collected were at the very least misleading and most likely untrue. It would not be highly unusual for respondents to under or over report certain aspects of community life. For example, as highlighted in Chapter 7, a number of households in Pozuelos were unable to provide accurate or even estimate values for daily household consumption.

After controlling for outliers, data for all indicators but Access proved to be normally distributed. Access however is positively skewed owing to the vast majority (70%) of households that scored a maximum of 1.0 for this indicator. In this instance, there is little that can be done to improve normality without dramatically deviating from the actual data and they are retained in their current form. The impact of such homogenous, abnormal results becomes evident when examining scatter plots. Clearly, Access cannot be linearly correlated with any other indicator or overall WPI scores yet we know a relationship between Access and water poverty exists, and it has been shown to be relevant at the macro scale. On the one hand this is a methodological fault, which adds to the well-known precautionary tale that linear correlation analyses do not preclude the existence of a relationship, simply a linear one. Furthermore, as stated numerous times, even when such a relationship exists, there is no implication of causality. It is only because we are aware of these limitations that we can deduce that a lack of correlation between Access and other indicators and overall WPI in Pozuelos is simply indicative of homogenous variable scores in this community. The size of the dataset is not relevant in this case, as a larger community with similar variable scores would produce the same result. The WPI is however resistant to homogeneity, as uniform data have little impact on actual calculations but instead, we can deduce that Access is not a constraint to water poverty in Pozuelos. On the other hand, this questions the appropriateness of using the WPI to assess water poverty at the household level. As previously explained, most of the data were normalised by assigning categorical scales. For example, there are only two possible options for access to water and sanitation at the household level, yes or no. This results in only two possible scores, 1 or 0, as opposed to assessing access at the community scale, which is based on the percentage of the total population with access to water or sanitation. That being said, assessing water poverty at the community level without considering each household's individual score, eliminates the possibility of analyzing even some of the relationships between indicators within a single community and although this might be desirable for decision-making at the municipal scale, it would be of no utility for decision-making at the community scale. Furthermore, given the present study assesses water poverty in only two communities, application of the Min-Max method would result in one community being assigned the maximum score of 1 and the other the minimum score of 0. This effect is discussed in more detail in following sections describing inter-community results.

After examining the relevant scatter plots, the remaining four indicators show significant positive correlations with overall WPI scores and the resulting Pearson coefficients are shown in Table 39. Kendall coefficients are also calculated, once again because of the small sample size. It should be noted that the Pearson technique should only be used for interval data. As previously described, some of the variable data were in fact ordinal (i.e. preference rankings) converted to scale by assigning categorical scores. Having then been combined with interval data to arrive at an overall indicator score that produces interval data, the use of the Pearson technique is sufficient to describe the association between indicators at present (Kendall's statistic is in fact more appropriate for measuring association between ordinal data but its use in this case is not for that reason).

Table 39 Correlation coefficients between indicators and overall water poverty scores in Pozuelos

	Resources	Access	Capacity	Use	Environment
Pearson	0.567**	0.243	0.366*	0.521**	0.450**
Kendall	0.429**	0.196	0.245*	0.327**	0.341**

* Correlation is significant at the 0.05 level (two-tailed)
** Correlation is significant at the 0.01 level (two-tailed)

As theorized from the pentagram diagrams, Resources is most strongly correlated to overall WPI scores. Capacity, however, is not as strongly correlated as anticipated but instead is statistically the least correlated of all individual indicators to WPI scores. On the other hand, Use, which was believed to have no impact on overall WPI, can be seen to have a moderately positive relationship. Lastly the moderately positive relationship between Environment and WPI was accurately predicted from the pentagram. These relationships differ from those at the macro scale where Resources and Use had no relationship with WPI and Capacity was much more strongly correlated. This variation in results suggests that data selected for use at the community scale are much more appropriate. Further, it highlights that although absolute water resources availability may not be correlated with water poverty, when additional factors such as temporal variation and infrastructure along with perceived water resources availability are considered, the relationship becomes more meaningful. Notwithstanding the inability to consider Access, none of the remaining indicators are correlated thus negating any issues of double-counting. Overall, broadly speaking, water poverty in Pozuelos is similar to that described at the state level barring one important exception, Access. In this case, Pozuelos is believed to be an anomaly.

These results compare well with community observations. Having studied the community intensively, it was clear that Access would not be a major impediment to water poverty. Field tests for flow rates gave some indication that insufficient water was present to meet the community's needs, thus it is not surprising to see that Resources is a moderate constraint to water poverty however, given community perceptions alongside anecdotal evidence, and initial precipitation records, it was originally anticipated that temporal variability of rainfall would have a large impact on water poverty but that is clearly not the case. Given general considerations of capacity and overall livelihoods, it was believed that Capacity would be more strongly related to Pozuelos' state of water poverty, particularly for those households who fared poorly. And yet these results suggest that capacity plays only a limited role in water poverty. Perhaps traditional indicators of well-being are not necessarily good indicators nor representative of overall water poverty but more likely this can be explained by the role of outside agencies in Pozuelos, for example, the work of Pronatura and the community benefactor who designed and helped construct the existing water network. To the contrary, perhaps their involvement is as a result of higher overall capacity, for example as compared to El Mash, which lends itself to a more cohesive and structured community better able to define and respond to its own needs. Based on community observations and in spite of the high propensity for reporting error, it is not surprising to see that Use is moderately correlated with water poverty. Yet because of the high propensity for reporting error, it is difficult to ascertain whether or not this is as a result of genuinely low consumption rates or exaggerated reports. In either case, given the variables used to calculate Use, intuitively one would expect to see some correlation between this indicator and water poverty. The correlation between Environment and water poverty in Pozuelos is similar to that at the macro scale. Variables of Environment are however indirectly related to water poverty thus any attempt to explain this relationship without further investigation would be mere conjecture.

8.2 El Mash

In order to analyze data further, bivariate correlations were constructed and Pearson and Kendall correlation coefficients calculated following a similar methodology to that already described. The only difference lies in the method used to adjust outliers. Data for El Mash are better distributed and anticipated to be more reliable. In fact, only two statistical outliers were identified by PASW where indicator scores for Resources and Access for two individual households were considered too high. Under these circumstances it was sufficient to lower these values to the 97.5 percentile and recalculate WPI scores accordingly. Similar to Pozuelos, none of the indicators are correlated. Only three (Resources, Use and Environment) show strong correlations to WPI scores. Nevertheless, as described in Chapter 3 the WPI is designed such that each indicator is correlated to the overall WPI score and analysis of the correlation coefficients therefore serves to describe the strength of these relationships, presented in Table 40.

Table 40 Correlation coefficients between indicators and overall water poverty scores in El Mash

	Resources	Access	Capacity	Use	Environment
Pearson	0.504**	0.413**	0.084	0.766**	0.634**
Kendall	0.384**	0.229*	0.057	0.555**	0.463**

* Correlation is significant at the 0.05 level (two-tailed)
** Correlation is significant at the 0.01 level (two-tailed)

As predicted by the pentagram representations, Use is most strongly correlated with overall water poverty scores. The relationship between Environment and WPI was unclear, but the correlation is now shown to be strong and positive. The indicator Resources was believed to have the least impact on WPI however it is in fact moderately, positively correlated. Access is much as anticipated albeit slightly weaker, but a lack of correlation between Capacity and WPI was not at all anticipated. The discrepancy between correlations between Access and Capacity and overall WPI scores at the macro and individual community scales might be explained by the datasets in question. The problem with limited variation in categorical scales for some of the variables used to calculate Access was described in earlier chapters and remains true for El Mash with all households scoring 0 in terms of access to a piped water supply and all households scoring 1 in terms of access to sanitation mitigating some of the overall result. Although the variables for Capacity show slightly more variation than the variables for Access, three of the five were assessed at the community scale thus producing one single result for each household.

Some preliminary conclusions about water poverty in El Mash can now be drawn. Based on intensive fieldwork assessments, Access was anticipated to be a major constraint to community water poverty however the WPI suggests otherwise. This might however be as a result of the homogeneity of access to water and sanitation. The strong relationship between Environment and WPI is not surprising particularly in light of exceptionally poor water quality results. The lack of a linear relationship between Capacity and WPI is surprising and although variables at the micro scale vary from those selected at the macro scale, both sets reflect traditional indicators of well-being. Thus again the issue of whether or not traditional indicators of Capacity are truly related to overall water poverty must be considered. Although Resources is significantly correlated with overall WPI scores, it was expected to be one of the major constraints to overall water poverty thus the lack of strength of the correlation is somewhat surprising particularly because of limited storage capacity. Lastly, the strong correlation between

Use and overall WPI scores is intuitive in light of researcher observations. However, after analyzing the data this result is somewhat surprising. Although both communities reported consuming less than the BWR per capita of 25Lpd, many households reported unusually high consumption rates for livestock. This result is indicative of the WPI's inability to accurately reflect local reality and highlights a key problem of the Min-Max normalization technique and the concept of relativity, that is, the inability to penalize unusually high scores. For example, a consumption to need ratio of 1 only scores 0.275 in the present study because a third of all households report overwatering their livestock and some significantly (6:1) so. Thus, it is unusual that the WPI produces the anticipated result (bearing in mind both variables were weighted equally). Broadly speaking, the community of El Mash fits the model of water poverty described at the state level, the single deviation, environmental integrity, being an important one. It is hoped that by analyzing both communities in tandem, the increase in data variation will clarify some of these data problems.

Considering the indicators in both communities that have a significant relationship with overall water poverty scores, the equality of strength for most indicators is of interest. This suggests that the amount of pressure or impact exerted on the overall water poverty scores from each of these indicators is relatively proportionate which is one of the aims of a well-constructed composite index. Further the lack of a distinct relationship amongst indicators is also promising as it suggests that each indicator contributes a different body of knowledge in respect of household water poverty.

8.3 Inter-Community Analysis of Water Poverty

It is hoped that the increased number of cases (n=88) will improve statistical reliability and we can now consider the association between indicators and overall WPI to determine whether or not the combined dataset resolves some of the earlier problems within the individual communities. After adjusting for outliers, one household was removed after it was determined that its overall WPI score was too extreme to be included in the analysis (M10).

Scatter plots of correlations between variables begin to show some interesting results and correlation statistics are presented in Table 41. As anticipated the larger dataset presents different results than those at the individual community level. The correlation between Resources and WPI remains significant, as was the case in both communities but contrary to the result at the macro scale. This reaffirms the idea that variables that consider temporal variability as well as community perceptions of water resources availability offer better insight into water poverty than quantitative measures of AWR alone. Access, which was not significantly correlated to WPI in Pozuelos (r=0.196) but was weakly correlated at the 0.05 level in El Mash (r=0.229), is now highly correlated to WPI in the combined community dataset such that it is the most strongly correlated indicator of all. These results are intuitive and agree with existing knowledge about water poverty. Further they are very closely aligned with the results at the macro scale where r=0.5 and was significant at the 0.05 level. This change in results is likely explained by the increased number of cases and improved variability of data, bearing in mind that access to water and sanitation at the household level is effectively binary data and difficult to correlate when communities present homogenous results of an either/or nature. That being said, given the results are similar to those at the macro scale, this raises doubts about the inclusion of additional quantitative variables at the community scale and, despite the sensibility of variables A3 (time required to collect water) and A4 (conflicts over water) questions their overall impact on this indicator.

Table 41 Correlation coefficients between indicators and overall water poverty scores

	Resources	Access	Capacity	Use	Environment
Pearson	0.552**	0.670**	0.361**	0.140	0.657**
Kendall	0.391**	0.482**	0.261**	0.028	0.479**

* Correlation is significant at the 0.05 level (two-tailed)
** Correlation is significant at the 0.01 level (two-tailed)

Capacity appears to be the most perplexing indicator. At the macro level the association between Capacity and WPI was shown to be very strong, r=0.71, p=0.01. In Pozuelos it was much more weakly associated, r=0.245, p=0.05 and lastly, in El Mash, there was no correlation whatsoever r=0.057 yet in the combined dataset r=0.261, p=0.01. At the macro scale the problem of correlation between Access and Capacity was highlighted and we now know that Capacity scores were impacted by the phenomena of double-counting due to a very high correlation amongst variables. This same relationship has been shown to exist albeit at a much weaker level in the combined community dataset (Table 41) and this specific problem is discussed further below. Data used to calculate Capacity at the community level comprise five different variables, two of which were scored at the community level resulting in only one of two possible scores at the household level and one which was a 3-point Likert scale giving rise to limited variability. However, these variables were then averaged with three others that presented high variability thus it was hoped this impact would be mitigated and with 63 unique scores, Capacity presents the second most variable dataset of the five indicators, more than twice that of Access and Environment. The discrepancy in results between individual communities might well be explained by the homogeneity of the three variables previously described and would therefore question their inclusion in the overall indicator score. It should be noted that the strength of association between indicator scores and overall WPI tells us nothing about the influence of each variable thus at this stage this is mere speculation. Bearing in mind an unusually strong correlation between one indicator and overall index results is not desirable, the current result is in fact acceptable and as is the case for Resources, may well be that more appropriate variables have been selected for use at the community scale. Still, in the context of what we already know about Capacity and the data used to analyze this indicator, further analysis would be warranted.

Although Use was significantly correlated with overall WPI, r=0.327 and 0.555, p=0.05, in Pozuelos and El Mash respectively there is a complete absence of association in the combined dataset. This is admittedly the most curious result as it was anticipated that Use would be an important mitigating factor of water poverty at the community scale as meeting BWR is intuitively a precursor to overall well-being. It should be noted that this result concurs with that previously determined at the macro scale. As previously discussed, the normalization technique called for in constructing a WPI tended to misconstrue data surrounding water consumption. As there is no discrepancy in units for both variables used to calculate the indicator score, Pearson and Kendall statistics were calculated for the **original** dataset, with the only modification being that data were raised or lowered to meet upper and lower boundaries of 0 and 1 respectively as needed. When the new indicator was compared against a recalculated WPI the predicted results are confirmed and the resultant correlations are exceptionally strong, r=0.771, p=0.01 using Pearson's technique and r=0.585, p=0.01 level using Kendall's tau-b statistic.

Although this would appear to provide a neat explanation as to the discrepancy of this relationship across scales, it doesn't explain fully why a positive relationship existed at the individual community level before the data were combined although the change in strength of the relationship goes some way to confirming this idea. Another possible explanation is that each individual dataset balances each other out in the combined dataset effectively nullifying the association of Use and WPI. Cho, *et al.* (2009) elected to remove Use (or assign it a weight of 0) from its modified NWPI for this reason, although their research considered the application of the WPI at the international scale and problems within that dataset are unique. Given what we know about basic water consumption and livelihoods, especially at the household scale, I am inclined to put the burden of error on the data and not the model although this doesn't exempt the model from any responsibility as this once again highlights the general problem of relativity and normalizing data. At the micro scale, where data are comparable and scales are highly uniform, it may be much more appropriate to assess absolute water poverty in which case the unadjusted dataset for Use is preferable. As we know that increased consumption is good only to a certain point, we can set a pre-defined upper boundary. For example, it would be appropriate in the present study to set an upper boundary of 25 for domestic consumption, representative of a BWR of 25Lpd. Thus any household that consumes this level or above is rewarded by receiving a maximum score of 1 and households consuming below this level receive a score commensurate with their consumption as a percentage of the recommended BWR. The same methodology can be applied for livestock consumption although it is more complicated given livestock type and numbers vary by household and the BWR would therefore need to be calculated for each individual household. This is in fact how the original data were calculated in the present study and the strong correlations above reflect this method, although because of the change in methodology, their strengths cannot be meaningfully compared to the strength of association between the other indicators and overall WPI.

Based on the results of all of the correlation analyses undertaken across scales and sites, the association between Environment and WPI appears to be the most convincing. At the macro level $r=0.395$, in Pozuelos $r=0.341$, in El Mash $r=0.463$ and lastly in the combined dataset $r=0.479$ each significant at the 0.01 level. Interestingly, it should be noted that this indicator comprises three qualitative variables at the community level as opposed to the macro scale, which used purely quantitative data. That being said, the data were very similar at all scales potentially arguing that data integrity is an important factor of meaningfully assessing water poverty across scales. Although this research does not focus on existing definitions or overall concepts of water poverty, it is interesting to note that although environmental integrity is often touted as the overarching element of sustainability and one that receives much attention in the popular press, thus far Environment has merited little attention within the constructs of water poverty. Furthermore, data used to comprise variables in this study were, in relative terms, some of the most readily obtainable at both scales. Even at the community level, this information is easily obtainable especially when considering the homogeneity of results of variable E3 and E4 (soil fertility and tree cover respectively), which would imply these data need not necessarily be collected at the household scale and instead could be obtained via community meetings and/ or focus groups. In current times, tree cover can in fact be estimated from publically available satellite images, for example, Google Earth.

An examination of scatter plots suggests Access is positively correlated with Capacity and Environment and negatively correlated with Use. Although these relationships are intuitive, they are cause for some concern, given what we know about composite indices and the desire to avoid co-linearity for the purposes of avoiding double-counting. Using Kendall's technique, $r<0.4$ for all three correlations and significant at the 0.01 although strength is very subjective and specific to the problem being investigated. Given our knowledge of composite indices, the lack of relationship between other indicators, and the unusually high relationship between Access and Capacity at the macro scale, this may be sufficiently strong to warrant further enquiry.

Table 42 Correlation coefficients between Access and select indicators

	Capacity	Use	Environment
Pearson	0.392**	-0.502**	0.479**
Kendall	0.253**	-0.353**	0.325**

* Correlation is significant at the 0.05 level (two-tailed)
** Correlation is significant at the 0.01 level (two-tailed)

Much like at the state level, it would be useful to compare WPI scores against another indicator as a means of testing, or validating, the descriptive abilities of the WPI at the household level. A number of survey questions were designed specifically to elicit data with known links to water poverty. These include data surrounding hand washing activities and frequency of diarrhoea. In the first instance, survey respondents were asked to indicate if they practiced hand washing, and if so, how. Although this was originally an open-ended question, it was exceptionally difficult to explain the intention of the question without leading the respondent. Therefore, the question was modified to offer respondents a choice of responses: soap always, soap sometimes (most often selected by respondents who indicated they washed their hands only when visibly dirty), and water only, with each of the responses being attributed a score from 2 to 0 respectively. Respondents were also asked to report how often they experienced episodes of diarrhoea in the year immediately preceding the survey. Those who responded never were attributed a score of 2, those who responded from time to time were attributed a score of 1 and those who responded often were attributed a score of 0. A definition of diarrhoea was deliberately avoided as the question was originally designed to measure the respondent's knowledge of the relationship between water and diarrhoea hence the simultaneous inclusion of a similar question concerning the frequency of water-related illnesses. It should be noted, there is no correlation between frequency of diarrhoea and frequency of water-related illnesses in either community, perhaps suggestive of a lack of understanding of this relationship. In this case, it was not appropriate to use the Pearson correlation coefficient as it applies to interval data only and given data for hand washing and diarrhoea are ordinal, Kendall's tau-b and Spearman's rho statistics are more appropriate.

We know that improved hygiene – specifically hand washing with soap – is linked to a decrease in diarrhoeal disease (Cairncross, 2003), indirectly linked to the volume of water available for such activities as well as hygiene training. In terms of the WPI at the household scale this equates to different variables within the indicators of Resource, Capacity and Use thus it would seem probable that there would be a positive correlation between incidence of diarrhoeal disease, hand washing activities and overall water poverty. However, Table 43 demonstrates otherwise. Given our knowledge of these relationships, the most likely explanation for this result is unreliable data. In the absence of a reliable indicator to validate water poverty scores at the household level, we must instead consider descriptive analyses.

Table 43 Association between frequency of diarrhoea and hand washing activities with water poverty

WPI	HW	Diarrhoea
Kendall's tau-b	.021	-.001
Spearman's rho	.028	-.005

If performing a multiple linear regression analysis of WPI on its constituent variables at the macro scale was imprudent, undertaking such an analysis at the micro scale would be statistically foolish. Although the rule of thumb was ignored at the macro scale, the difference between the actual number of cases and desirable number of cases was not nearly as vast (32 to 384) as it would be at the micro scale (89 to 1869) and for this reason this step is not performed. A thorough exploratory analysis of the variables is undertaken instead.

8.4 Analysis of Selected Variables

Recall that mean community WPI scores derived from household scale results were 0.561 and 0.474 in Pozuelos and El Mash respectively. These results concur with researcher observations that El Mash is more water poor than Pozuelos. Several researchers, including the original authors, have suggested the merit of the WPI is not within the overall water poverty score but instead within each indicator. Now recall Figure 35 from Chapter 7 that shows mean indicator scores for Resources and Capacity are similar in both communities, Access scores are almost twice as high in Pozuelos as El Mash, Use scores are low in both communities but are twice as low in Pozuelos as in El Mash, and finally Environment scores are moderately higher in Pozuelos than in El Mash. Statistical analyses have attempted to describe the association between these scores and overall water poverty within and across both communities. Results have been shown to vary between independent samples of community households, to present conflicting and complex results that raise doubts about the validity of the WPI model and question the appropriateness of data selection and preparation, to occasionally contradict *a priori* knowledge and ultimately to provide only limited information about the meaning of water poverty at the community scale.

Not only is the WPI a composite index of five key indicators, but also each indicator is in turn a composite index. Perhaps then the full story of water poverty is best appreciated when considering each variable indicator in turn. Figures 37 through 41 compare mean variable scores between communities. Of the 21 variables, El Mash fared better than Pozuelos eight times and worse than Pozuelos twelve times; community scores being tied for one variable. Variables relating to Access and Capacity are most disparate, but many of the remaining variable scores also vary significantly between communities.

Recall that mean Resources indicator scores for Pozuelos and El Mash were 0.591 and 0.538 respectively. At face value, there is little difference between these scores. Yet closer examination of the individual variables reveals a dramatically different story. In terms of resources, both communities scored a maximum of 1.000 for AWR. In terms of reliability, Pozuelos scored much higher than El Mash. Furthermore, because of the difference in water supply systems, R2 is measured at the community level in Pozuelos and, with the exception of network pressure (although impacted by altitude and/or poorly designed infrastructure anecdotal evidence would suggest this is not a major problem overall), impacts each household equally. In El Mash, however, reliability is a function of available household storage therefore each individual household suffers in isolation with R2 scores ranging from 0.000 to 1.000. Consequently, remediation would be significantly different in each community. In the case of Pozuelos, improved flow rates would conceivably resolve the problem for the entire community. That being said, evidence suggests current low flow rates are as a result of actual resources and not infrastructure. Despite sufficient groundwater availability based on aquifer recharge, Pozuelos is geographically and geologically disadvantaged and groundwater is simply not accessible in sufficient quantities to meet community needs, particularly as most runoff heads down slope to be stored at lower elevations. A major fault of the WPI in terms of assessing AWR is that it recommends assessing a community's primary source only and gives little consideration to the type of water supply. In regions such as Los Altos community water supply is complex and it may be the case that a community is forced to rely on several sources to fulfil their needs. Although not ideal, it is nonetheless a viable solution. Such is the situation in Pozuelos where most households now have (rain)water storage tanks alongside household taps. Though most households rely solely on one *tinaco* with a capacity of 1,100L some households recently participated in an NGO-led community project that provided assistance for the construction of large (rain)water storage tanks. As seen in Chapter 6, these are typically of a much better construction than those in El Mash, which were provided by the State Commission for Water and Sanitation (CEAS). Including these larger and newer tanks, total household storage per capita is currently 1,700 litres, sufficient storage to sustain 68 consecutive days of drought (based on a BWR of 25Lpd and assuming no evaporation or leakage). Whilst these figures don't take spatial distribution of storage tanks into consideration, they do suggest that Pozuelos could potentially combat their reduced piped water supply by efficient water storage. As previously described, El Mash was the recipient of a state project to supply each household with a concrete storage tank, essential given their reliance on rainwater as a primary source. Contrary to Pozuelos, the secondary source in El Mash is spring water (much of which is heavily contaminated with faecal coliforms and accounted for in the Environment indicator). Having considered the nuances of each community's water supply system, it is clear that Pozuelos is currently better off than El Mash in respect of quantitative measures of water resources reliability and this is in fact reflected in their disparate R2 scores. There is however little variation in R3 variable scores, which measures the distribution of annual rainfall. This is not surprising given the climatic similarities of both communities.

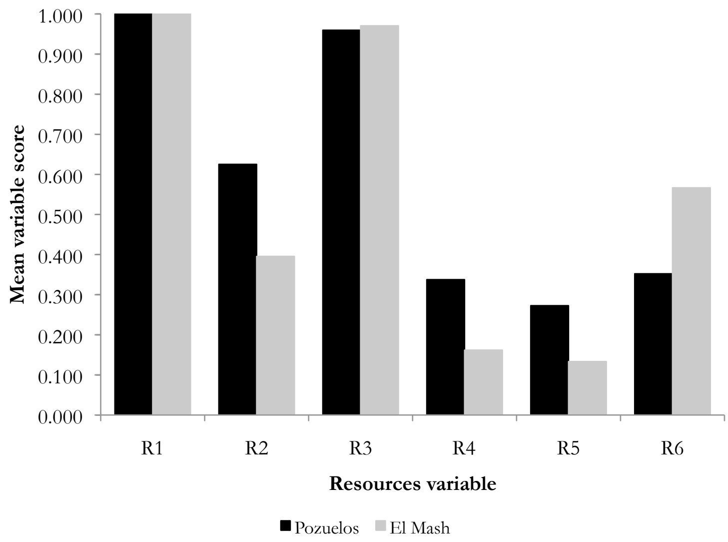

Figure 37 A comparison of mean variable scores for Resources between communities

In terms of qualitative variable scores, commensurate with their quantitative counterparts, El Mash scored much less than Pozuelos for R4 and R5, which measure perceptions of AWR and service reliability respectively. In light of the above descriptions, these results are not at all surprising and indicate residents in both communities are perceptive to their current situation. Although R6 is not directly linked to its quantitative counterpart, it nonetheless strives to assess perception of historical rainfall variability. Pozuelos scored much lower than El Mash indicating most respondents perceived a decrease in rainfall whereas many residents in El Mash perceived an increase or no change. In actual fact, historical rainfall patterns have not varied, however, as discussed in previous chapters, fieldwork was undertaken during a year with higher than usual rates of precipitation so it is conceivable responses in El Mash reflect current and not historical trends. Nonetheless, it is questionable whether or not this particular variable adds value to the overall analysis. One could argue that a community's ability to accurately perceive patterns of precipitation are demonstrative of wider water management capabilities, but should then be classified as a variable of Capacity. A further argument might be made for the inclusion of qualitative variables only when hard data are unavailable. In other words, more qualitative measures can be used as proxies in their absence but that their inclusion otherwise constitutes double-counting. However, qualitative measures of water poverty, especially those that assess community perception, can conceivably be considered as a proxy for variable weights such that a known quantitative variable is modified by community perception. This idea is demonstrated in the section assessing the indicator of Use below.

Access scores between communities vary significantly with mean indicator scores of 0.948 and 0.542 in Pozuelos and El Mash respectively. The most striking difference between variable scores is seen in access to a piped water supply, a reflection of the different community water supply systems and the global community's insistence (impacting user preference) that piped networks are the holy grail of water supply. With this in mind, although this variable accurately reflects the current situation on the ground, it is nonetheless subjective and unfairly penalizes communities that have access to a piped water supply regardless of quality, management or any of the other myriad factors that impact water supply. Likewise, it potentially draws unnecessary attention to communities without access to a piped supply that may otherwise be sufficiently meeting their needs. Defining access to water solely as access to a piped water supply is an exceptionally rigid approach though it is the acceptable definition in a Mexican context hence its inclusion in this index. An entirely separate indicator could feasibly be constructed for the purposes of defining access to water more appropriately. Such an indicator would conceivably combine variables that measure type of water source, potability, distance to source and appropriate infrastructure. Still, strictly speaking, Pozuelos is water rich and El Mash is water poor under the present definition.

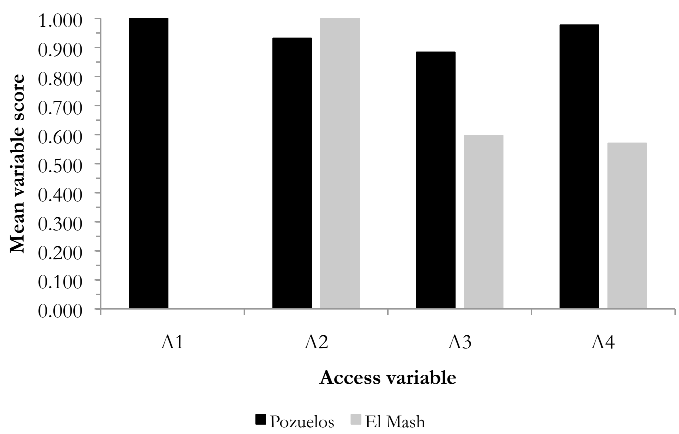

Figure 38 A comparison of mean variable scores for Access between communities

Access rates to sanitation are similar across both communities but given the previously discussed relationship between social services (Programa Oportunidades) and latrines, this is not at all surprising. It is of course important to acknowledge sanitation and hygiene as a measure of overall water poverty and it should be noted that this score accurately reflects local realities however in a national context, this particular variable becomes less meaningful once you consider the main driver behind the high rates of access to sanitation. On the one hand, one might argue that overall outcome is most important; on the other hand one might argue that the outcome is meaningless if the underlying impetus for sanitation development is not understood. Furthermore, this study considered the presence of a latrine to be an indicator of access to sanitation, but did not assess its construction or maintenance. Again this follows the standard definition of access to sanitation in a Mexican context. Strictly speaking, in the case of El Mash where numerous latrines were investigated, most were poorly constructed and informal conversations would suggest householders are totally unaware of management requirements such as the need to monitor pit capacity. Additionally, respondents appeared completely unaware of the importance of appropriate siting, as evidenced by the half a dozen pit latrines built upslope from community spring Man3 in El Mash, undoubtedly the cause of the significant faecal contamination at that source. Once again this is demonstrative of the federal government's paternalistic form of assistance, which solves the problem of provision but fails to educate and consequently does nothing to empower the local population. Similar to A1, access to sanitation might also benefit from being defined by a subset of variables that consider its siting, construction and overall hygiene. Pozuelos scores much better than El Mash for both A3 and A4.

Variable A3 considers the amount of time required to carry water, a problem that is most prevalent in El Mash where all respondents participate in water carrying activities and where distances and travel times to source are much higher. Given almost all residents in Pozuelos have access to water at the household level year round and residents in El Mash are forced to share limited spring water supplies for much of the year, it is not surprising that residents of El Mash experience more conflicts over access to water (A4). In the case of A3 a mean score of 0.884 for Pozuelos fails to describe the situation in sufficient detail. Without prior knowledge, one might presuppose that all households are required to participate in water carrying activities during some part of the year, but that sources are simply located nearby, when in actual fact, only one quarter of all households participate in such activities and distances are variable. This is as a result of a modification made in this study in an attempt to create a single variable that corresponds to water-carrying activities in contrast to the two variables recommended by Sullivan *et al.* (2003) designed to measure time spent in water collection and % of water collected by women. The justification for this modification was the lack of evidence suggesting gender plays a clear role in water carrying activities across the two study sites thus a variable designed to consider gender would add little information. However, it now appears that although a single variable is less complex, it has the undesirable affect of blurring the distinction between carrying and non-carrying households.

Capacity is the second indicator to exhibit similar means between communities with Pozuelos scoring 0.562 and El Mash scoring 0.498. Once again numerically there is only a small difference between the two indicator scores but following previous trends it seems prudent to undertake further examination at the variable level to ascertain any variations and in fact, when doing so, significant differences become apparent. C1 represents average daily household income and C2 reflects the percentage of all household members having completed primary school. Both variables are measured at the household level and reflect the demographic make-up of each community. Neither result is surprising although the difference in scores between communities (Pozuelos scoring higher on both accounts) is much greater than the difference in mean scores. C3 is intended to measure the gender divide in access to education and considers the ratio of females to males having completed primary school reported as a percentage. It can only be measured at the community scale thus producing only two results. Because the WPI is a measure of relativity, the community with the lowest score, in this case El Mash, scores 0 while Pozuelos scores 1. Yet, the actual percentages are very similar at 64% and 69% respectively (bearing in mind this represents the percentage of households with children having completed primary school and excludes households where no children have attended primary school). Although this study compares only two communities, and the result is therefore exaggerated, this situation nevertheless highlights the problem of using relative values. In this case it clearly would make much more sense to measure absolute values. As it stands the impact of this particular variable is nullified by a similar outcome in variable C5 where this time El Mash scores a maximum of 1 and Pozuelos a minimum of 0. C5, which reflects hygiene capacity by calculating the percentage of households with at least one member who has received training, is also measured at the community scale resulting in only two scores. This time the original percentages are more disparate with El Mash scoring 88% and Pozuelos 66%. That being said, even a result of 66% means two-thirds of all households have at least one member with basic knowledge of hygiene and yet because of the concept of relativity, the community still scores 0. Lastly C4, which measures water-related illness at the household level, is comparable between communities. C4 is the only quantitative variable of the five and its reliability is questionable. Ideally health data would be collected from local mobile health units or community clinics but in the absence of such hard data, respondents were asked to comment on their own well-being (as described in Chapters 5 and 6). It would not be surprising for respondents to underreport water-related illnesses for a number of reasons. First, it is generally accepted that a certain level of immunity will be acquired over time such that the human organism adapts to water of a dubious standard and any impacts are dampened (as compared to someone who is not used to consuming the same water). Furthermore, illness is a relative concept and two different subjects will not necessarily feel its impact in the same way. In fact, faced with constant illness, it's conceivable that someone may become psychologically immune to the effects. Lastly, the lack of education evident in both communities may impact the user's overall knowledge and comprehension of water-related illness and/or hygiene. For example, few respondents in El Mash understood the link between trachoma and hygiene, even in households with members who had suffered from the disease. The fact that few respondents indicated they suffer from water-related illnesses may in fact be genuine and a reflection of overall water quality, which in many cases is relatively high. We might however expect to see an increase in reported water-related illnesses in households forced to consume highly contaminated water such as those located near Man3 in El Mash. Eight of the fourteen households in that neighbourhood were selected to participate in the study. Of these, six households reported never suffering from water-related illnesses and only two reported suffering occasionally. This result may however reflect the diligence with which water is boiled before consumption and in fact, all eight of the households indicated they boil their water before use. Thus, if we accept that low incidences of water-related illness are genuine, it would appear this reflects better overall hygiene-related training and the scores are valid. If we don't accept low reports of water-related illnesses and instead presume they are as a result of underreporting, the results are less valid but the context is not completely without merit as they still reflect community perceptions of health. Unfortunately in the latter case, this would result in high variable scores and any meaningful context is lost within the numerical value yet again suggesting scores mask local realities.

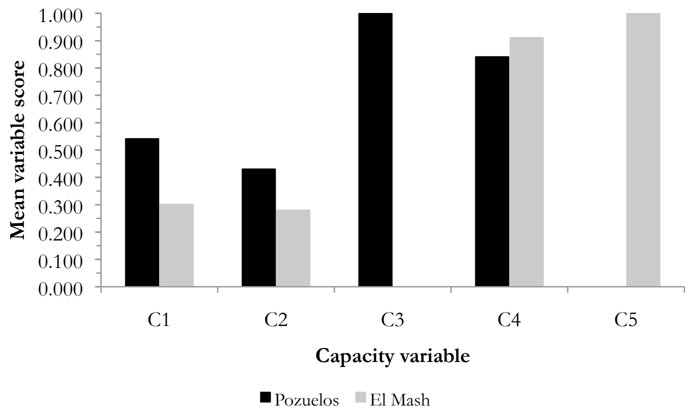

Figure 39 A comparison of mean variable scores for Capacity between communities

Indicator scores for Use show the greatest discrepancy with Pozuelos presenting a much lower mean score (0.157) than El Mash (0.400). Each variable score measures the ratio of water being consumed against a set value intended to represent BWR. Notwithstanding the caveats mentioned in Chapter 6, which describe the subjectivity and reliability of results, these scores suggest that households within both communities are not meeting their basic needs. However, combining data for human consumption with that for livestock consumption is arguable. On the one hand, from purely a human rights' perspective, human consumption is far more important. On the other hand, in communities that rely on livestock for their overall wellbeing, either to help meet their nutritional requirements or economic livelihoods, livestock consumption is equally important. The dilemma of having to choose between domestic and livestock consumption is unlikely one any community would like to face. That being said, this question was in fact put towards both communities. In El Mash 89% of all respondents stated water for domestic use was most important to their household. In Pozuelos, 66% stated it was most important, but 30% indicated all uses were equally important. Therefore, whilst domestic and livestock consumption (or industrial as the case may be), represent competing interests within a household, this is a prime example where it might be appropriate to weight scores differently. Clearly importance is highly subjective but I would argue that it is the community's decision to make. Recalculating mean Use scores weighted by preference (attributing 100% of all those who replied domestic use was most important in both communities and half of those who indicated water was equal across uses in Pozuelos to the U1 weighting and the difference to the U2 weighting), El Mash scores 0.360 and Pozuelos scores 0.207. In terms of comparing both communities, the result is similar yet scores are now less disparate and now include a measure of community perception.

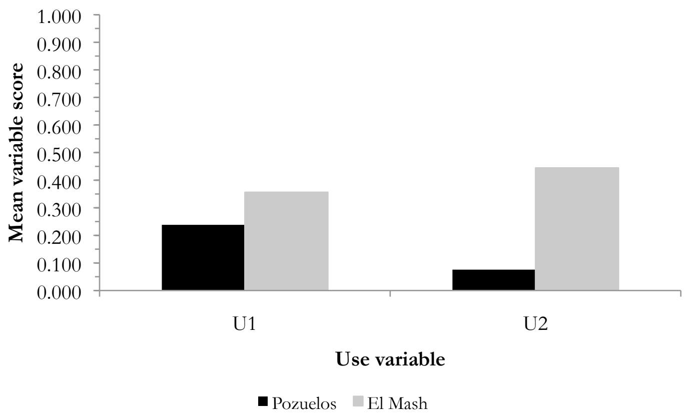

Figure 40 A comparison of mean variable scores for Use between communities

Analyzing the variables of the Environment indicator reveals some questionable choices in data manipulation. Quantitative water quality analyses (E1) suggest water is of a higher quality in Pozuelos than in El Mash and although that is in fact the case, a few considerations should also be made. First, the relative score of each community only enables us to make a statement about which site has better water quality than the other and reveals nothing about the actual bacteriological parameters of water quality. This is after all the objective of a relative scale and care should be made not to draw any specific conclusions about the data used to calculate a score from this statement. In other words, whilst we may make inferences about overall water poverty from the dataset the inverse is not true. In my considered opinion this is a major problem of the WPI in its current form and variable E1 scores highlight this particularly well. For example, despite the aforementioned caveat, with a score of 0.988 one might assume water in Pozuelos to be of a very high quality, with little or no bacteriological contamination. The same logic would therefore suggest a score of 0.714 is representative of light bacteriological contamination. This follows the logic of the predefined scale that stipulates a score of 0 is extremely water poor and a score of 1 is not water poor. In actual fact, water quality analyses described in detail in Chapter 6 support the evidence that Pozuelos has very little if any bacteriological contamination but contradict the severity of water quality in El Mash assumed from the variable score.

Not one spring in El Mash was found to be completely free from bacteriological contamination. Instead, average thermotolerant coliforms counts ranged from a low of 2 to a high of 408 in water used for consumption. In an attempt to remain faithful to the current model for calculating a water poverty index, the decision was made to normalise the original data such that a TTC of 448 scored the minimum score of 0 and a TTC of 0 scored the maximum score of 1. Thus households in El Mash who rely on Man5 with an average TTC of 52 receive a relative score of 0.870, which could be interpreted, albeit erroneously, of little or no bacteriological contamination. Part of the problem lies in the nature of the variable being measured. As we know faecal contamination is not normally tolerated at any level in drinking water although certain allowances for rural communities where it is often difficult to ensure water sources remain 100% free from contamination are often made (WHO, 2008). The earlier justification for not simply quantifying the presence or absence of thermotolerant coliforms explained in Chapter 6 is now brought into question. Although one might argue that a score of 1 for Pozuelos and a score of 0 for El Mash might better reflect actual water quality, as we've already seen, it can be very difficult to assess associations amongst binary data and neither method is satisfactory. It may be preferable to measure water quality at the community level as a function of the number of households with access to a non-contaminated source. For example, 95% of all households in Pozuelos rely on a water source with counts of 5 TTC per 100mL or less compared to 51% in El Mash. However, once again the real problem lies in the idea of calculating relative water poverty as these data still produce a binary result and assign scores of 1 and 0 to Pozuelos and El Mash respectively and again the evidence for calculating absolute water scarcity is mounting. E2 measures respondents' perceptions of water quality and when compared to E1 scores would seem to suggest respondents have a good grasp of overall water quality within each community. However, it should be noted that respondents typically defined water quality by its visual characteristics (good/clean, a little dirty, bad/dirty) and in reality this is not a good indicator of bacteriological contamination. Nevertheless, the fact that many more respondents deemed their water to be of good quality in Pozuelos than in El Mash is telling. Given the similarity in scores between E1 and E2 in both communities, the addition of E2 to the present study likely creates the effect of double-counting although for the first time, this is desirable. The purpose of assessing perceptions of water quality is an attempt to include the community's voice in any measurement of water poverty. Had community perception been better or worse than actual results, this would have been reflected in water poverty scores by mitigating the impacts of E1 accordingly. An alternative to including variables that measure community perception directly would be to weight quantitative values according to community perception as was suggested for variables of Use. For example, 84% of all households in Pozuelos perceive water quality to be good whilst only 56% of households in El Mash perceive water quality to be good. Therefore weights of 0.84 and 0.56 could be applied to E1 scores giving rise to scores of 0.830 and 0.400 respectively indicating actual water quality results have been decreased to reflect the 16% and 44% of households in each community which feel their water quality is not of a sufficiently high standard. If everyone believed their water was of a sufficiently high standard, E1 scores would not change and water quality would reflect quantitative values only.

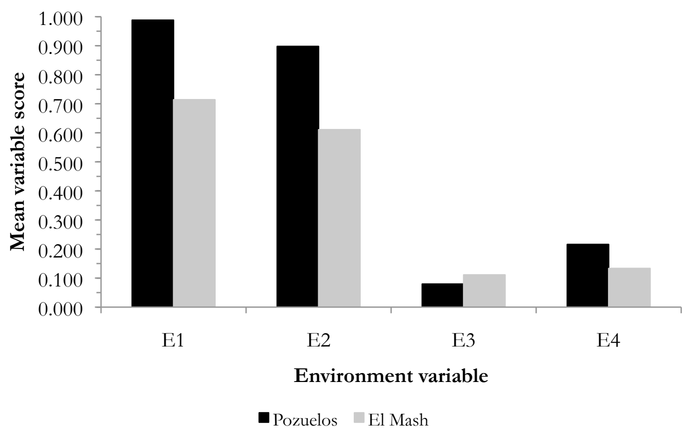

Figure 41 A comparison of mean variable scores for Environment between communities

The last two variables of Environment are designed to measure soil fertility and tree cover, variables suggested by Sullivan *et al.* (2003) as indicative of overall environmental integrity. Both variable scores reflect community perception only as no hard data exist to measure either variable at the local scale. Although respondents in Pozuelos felt that tree cover had not declined as much as in the area surrounding El Mash (possibly a reflection of the fact that El Mash is located within a region of high logging activity), overall environmental integrity appears to be quite low in both communities. As the original data were in the form of a Likert scale, categorical scores were assigned to each category to arrive at a variable score. Because the assignment of categorical scales serves the dual function of converting data into numerical form whilst simultaneously normalizing them for direct inclusion into a composite index it is no surprise that variable scores converted from Likert scales typically reflect the original data more accurately than interval data, which have undergone in some cases vast transformations in a bid to conform to the concept of relativity.

Overall, water poverty scores for resources concur with researcher observations between communities, however, it is already becoming evident that mean indicator scores at the community level disguise important characteristics of variables. In the case of Access, mean indicator scores do indeed reflect the situation on the ground accurately whilst further analysis of variable scores reveals their nature, notwithstanding the usual caveat that causality is not implied. Capacity is one of the most complex indicators and has produced confusing results at all scales. Some of these problems have already been discussed. One of the most pertinent problems in relation to studies undertaken at the micro scale is the problem of relativity, which entails the need for a complete dataset of all communities being assessed at the outset without which variables will be subject to the time constraints of the Min-Max methodology leading to erroneous results. In the present study, it was possible to assess water poverty both independently and jointly yet this demanded 12 months of extensive research in the field simply to assess two communities. Ensuring data are available for each community at one single moment in time is a monstrous task and highly unlikely. There are 18 municipalities within Los Altos. Two of these, San Juan Chamula and Oxchuc comprise 129 and 119 communities respectively. Chiapas is home to a further seven regions each with similarly high numbers of communities. Any decision-making would be marred by the logistical nightmare of collecting data in each of these communities rendering the idea of comparing relative water poverty almost impossible. Thus the impetus for reducing the number of variables used to calculate water poverty at the micro scale. As seen, variables of Use are difficult to assess accurately and in their current form represent community perceptions of consumption, believed to exaggerate actual consumption. The argument against evaluating different uses of water equally is valid but may be resolved using community perceptions of importance as variable weights.

It is not appropriate to measure relative water quality and doing so masks local realities leading to mean indicator scores that blur actual results. Neither of the suggested solutions to this impasse is satisfactory and both have significant drawbacks. Similar to assessments of Use variable scores designed to measure water quality may improve by weighting scores based on community perceptions of overall water quality derived from

E2. Variables developed to assess environmental integrity are useful and data are readily available, however, results cannot be independently verified at the community scale.

This chapter presented a thorough statistical and descriptive analysis of the WPI, its indicators and variables at the macro and micro scale, including inter-community analysis. A number of key findings from this analysis enable meaningful reflections about the WPI and are presented in the following chapter.

8.5 Community Perceptions of Water Poverty: Do the Numbers Add Up?

Having discussed the scientific merit of this study's findings, I now turn my attention to conceivably the most important test used to assess the WPI, its ability to accurately describe local realities of water poverty. This discussion concerns El Mash alone as in-depth focus groups developed to elicit community perceptions of water poverty were not undertaken in Pozuelos. According to the WPI, El Mash is water poor, and more so than Pozuelos. First and foremost, the community upholds this overall result. Rounding figures to the nearest tenth, average indicator scores show limited variation with Resources, Access and Capacity producing a score of 0.5 and Use and Environment producing a score of 0.4. Thus average indicator scores tell us very little about the constraints to water poverty in this community and would seem to suggest no single indicator is responsible for the current state of affairs. From a management perspective it would therefore be difficult to determine where efforts need to be concentrated in order to improve the current situation. Further statistical analyses suggest Use is most strongly correlated with WPI followed by Environment, Resources and Access, the latter less significantly correlated than the former three. It should be noted that the impact of storage on water poverty was considered under the umbrella indicator of Resources. Capacity is not at all correlated with WPI ($r<0.1$) scores. Although we are reminded that the purpose of the WPI is "political rather than statistical" (Sullivan *et al.*, 2003, p.192) it is impossible to derive meaning from the indicator scores alone thus we are left with no choice but to seek out a mathematical justification for the current state of affairs.

At this stage it would be most relevant to compare community perceptions of water poverty with results obtained from the WPI. The idea of water poverty was discussed with men and women separately resulting in totally different ideas that describe the causes of water poverty in the community. Notwithstanding discussions with the wider group may very well lead to different results, if we combine the causes listed by the men and women in Chapter 7 into one matrix, we arrive at the following results: Resources and Use are equally responsible for water poverty each defined by four causes, the former put forward entirely by the men and the latter put forward entirely by the women. Access and Capacity are also equally responsible for water poverty but to a much lesser degree each defined by one cause, the former put forward by the women and the latter put forward by the men.

Thus when ranking indicators by the strength and significance of their correlation with WPI (notwithstanding the WPI does not purport to explicitly define the causes of water poverty) we see that the WPI relates water poverty to Use, Environment, Resources, and Access. When ranking indicators by their perceived relationship to water poverty, we see that water poverty is related to Resources and Use, then to a less degree, Access and Capacity. The women accurately identified the main component of water poverty as suggested by the WPI and this is not surprising given the relationship between the WPI and domestic activities. The men adopted a more traditional view of water poverty, suggesting the cause of their current state of water poverty is almost wholly related to a lack of available resources and/ storage. Given my knowledge of the community I would suggest the results put forward by the women are more accurate. Nevertheless, neither result corresponds exactly with the findings of the WPI though at the same time, the results aren't dramatically disparate either. Of course, perceptions of water poverty are relative and reflect to a certain degree the community's overall capacity to understand and discuss what is know to be a complicated concept. That being said, the results of the two focus groups would all seem to suggest the community does have a sound general understanding of water poverty and general poverty as it impacts their community. What the WPI however fails to do accurately is account for such a discrepancy between genders and further research to this effect would be warranted.

Other results arising from the two focus groups seem to suggest that access to health services is a major contributing factor to well-being and general poverty in the community. The importance of the lack of access to health services to the community might be an indication of overall poor health (although survey results do not reflect this assertion). In terms of the variables used to define Capacity at the macro scale, this would suggest that the exclusion of all other indicators, save for child mortality, would be a prudent choice. Of course there is no scientific evidence to support this assertion given the WPI was constructed differently at the two scales and there was no suggestion of double-counting amongst indicators at the community level, thus no statistical justification for excluding any variables. That being said, in light of the WPI's desire for simplicity, the results from the community focus groups might very well be a useful tool for reconstructing a simplified water poverty index based on perceptions of water poverty such that each variable reflects the importance of water poverty to the community. Alternatively, these results could be used to refine indicator weightings in response to a participatory approach to this problem. These would inevitably provide site-specific products, however, it has already become clear that no one methodology can claim to describe water poverty in its totality thus the need to find alternative complementary techniques in order to accurately assess water poverty in a manner satisfactory to all concerned parties, specifically water managers, policy makers, communities, and academia.

Having presented the results of an extensive study of water poverty at the macro and micro scale, designed to assess the impact of scale on the WPI, to assess its reliability and robustness, and to assess its ability to represent local perceptions of water poverty, Chapter 9 discusses these results in the context of the overall study before providing final conclusions to the original aims of this research.

CHAPTER 9 CONCLUDING DISCUSSION

This chapter seeks to bring the findings of this thesis together to provide a single, unified account of the overall results and analyses of this research and to resituate these findings within the original framework of this project. Beginning with a discussion of the study's core findings, this chapter then address the practical application of the WPI before citing key evidence to support the exclusion of resources as an indicator of water poverty. Next this chapter provides recommendations for future research before discussing some of this study's limitations finally culminating in a concluding statement that aims to correspond to each of the study's three original objectives.

9.1 Discussion of Study Results

At the macro scale, a high degree of correlation between indicators of Access and Capacity proved to be as a result of the high degree of correlation between its variables rendering the indicator unsuitable for use in a composite index. Multiple linear regression analysis helped to identify variables C1 (per capita income) and C3 (literacy rate) as the main predictors of the WPI and support substantive evidence for their exclusion. A paired samples test between original and modified WPI scores, calculated after their exclusion, suggests the difference in means is significant and the removal of both variables impacts overall WPI scores. However, Spearman's rho statistic, $r=0.962$, significant at the 0.01 level, comparing sets of rankings of original and modified WPI scores shows water poverty by state is unchanged. Original WPI scores are weakly ($r^2=0.3$) correlated with values for life expectancy but this improves to $r^2=0.5$ for WPI<0.5 suggesting there is a critical point below which water poverty impacts well-being. There is no correlation between modified WPI scores and life expectancy when the full dataset is used, however, when the partial dataset is considered (WPI<0.5) and controlled for outliers, r^2 improves to 0.5 once again.

In general WPI scores tell us little about actual water poverty and only limited information can be gleaned from its indicators. To arrive at meaningful interpretations of water poverty it is necessary to analyze the variables used to calculate a water poverty index. Even still, only limited hypotheses can be made across scales as the current model used to calculate a water poverty index is relative and results are only meaningful within the context under which they originate. The sheer number of variables used to assess water poverty at either scale only exacerbates this problem, creating dichotomies between variables that might otherwise not exist and homogenizing entire communities and even states to the extent that meaningful discourse surrounding water poverty is impeded. Water poverty is a complex beast but attempting to capture every possible factor only serves to multiply these complexities further. Instead, a more sustainable and logical approach would be to reduce the number of variables to the minimum number of variables that describe the maximum variance in water poverty.

At the micro scale most of my study's findings relate to the WPI model and data selection. Specifically the concept of calculating relative water poverty has proven to be problematic at the micro scale especially when small datasets, such as the present study where n=2, are being analyzed. The intended use of the Min-Max method is to normalise data with otherwise incompatible scales and/or units to *relativize* data, I might add erroneously. The argument for calculating relative water poverty is weak especially given the limitations placed on data, for example, the subsequent inability to compare different regions or even different communities that were not assessed in tandem. The problem of relativity impacts the WPI's ability to accurately reflect local realities of water poverty as evidenced by the indicators of Access (particularly access to water and sanitation), Use and the assessment of water quality. Some questions have been raised as to the appropriateness of calculating water poverty at the household scale as opposed to the community scale. Although logistically it is much more difficult to assess each individual household, similar data collection requirements exist at both scales. Certain variables however lend themselves more readily to a community evaluation, such as soil fertility and tree cover. When variable scores failed to accurately reflect household realities of water poverty, this was most often as a result of the general failings described above and not the inability of data derived from a smaller scale to add meaningful detail to water poverty analyses. For example, the need to *relativize* carefully collected data at the household scale can have the impact of increasing homogeneity across communities and interesting detail is lost as a result. This adds to the growing criticism surrounding the utility of WPI scores and questions the need for a composite index. Although inferences about water poverty can be made from the data used to comprise the selected indicators, the inverse is not true. And in fact, inferences made from indicator scores are dubious, especially when they reflect the mean value of a dataset, and the need to examine variables to garner a true appreciation of water poverty at the micro scale is increasingly imperative.

There are however some positive findings arising from analyses at the micro scale. Compared to the macro scale, data selected for use at the micro scale would appear to be more appropriate for use in a composite index. This is evidenced by the relatively even strength of correlations between indicators and overall water poverty scores and the lack of significant correlation amongst indicators. Furthermore, meaningful assessments of water resources availability can be made at the micro scale and are improved with the inclusion of variables that consider phenomena not previously assessed such as temporal variation of precipitation and water infrastructure. Notwithstanding these variables are exceptionally localized and may rely on qualitative data which might be less reliable. The inclusion of qualitative data generally produced varying results. In some instances, their inclusion did not appear to add value to overall water poverty scores. However the importance of community perception should not be dismissed and some suggestions have been made as to how to improve their utility in a composite index, for example, using perceived results to weight quantitative measures of the same variable. This might enable comparisons between absolute water poverty and community perceptions of water poverty. Lastly the indicator of Environment was most consistently correlated with WPI across scales despite problems surrounding the assessment of water quality at the micro scale. Although this finding is consistent with other studies, it has not yet been considered in further detail and would benefit from additional investigation.

9.2 The Application of the Water Poverty Index in Practice

These results can be combined with those from earlier case studies and theoretical critiques of the WPI to arrive at a number of core findings. The internal mechanism of the WPI is subject to serious failings. Particularly problematic is the high correlation between the indicator of Capacity and WPI, and the strong interrelationship between indicators of Access and Capacity. This is as a direct result of modelling Capacity on the HDI and leads to the double-counting of variables designed to assess Capacity, clearly compromising the WPI. Reducing the variables to just one measure of Capacity mitigates this problem. Combining the remaining variable with those designed to measure Access alleviates the internal imbalance across indicators and simplifies the model even further without compromising the substantive determination of these two indicators. The resultant WPI is statistically different to the original model but their corresponding rankings remain highly correlated suggesting comparable results

The problem of weighting has been raised numerous times (Feitelson & Chenoweth, 2002; Molle & Mollinga, 2003; Giné & Pérez-Foguet, 2008; Cho, *et al.*, 2009) but as yet has not been resolved in a satisfactory manner. This study continues the tradition of weighting indicators equally but acknowledges the need to investigate this aspect further. Some options have been proposed in this regard (Giné & Pérez-Foguet, 2008) and although this study lends its support to the idea of selecting weights through a participatory process, recognizing this is a time consuming process that will produce locally-specific results, ultimately advocates the benefits of a straight average. Statistical methods should not be used as the sole method for determining weights but as a tool to aid the decision-making process and should in all cases be supported by substantive knowledge of the problem being studied.

Independent of the problem of weighting, it is generally accepted that meaningful discourses of water poverty are best derived from the indicators and not the overall WPI. It should be noted that this has always been the position of the developers since the WPI's inception (Lawrence, *et al.*, 2003). This is supported by evidence from case studies that demonstrate macro scale results hide micro scale realities (Cullis & O'Regan, 2004), reiterated by more recent findings (Komnenic, *et al.*, 2008; Giné & Pérez-Foguet, 2008) as well as the present study. However, Molle & Mollinga (2003) respond to this assertion by suggesting similar irregularities exist within the indicators themselves. Clearly this makes sense given the indicators, also composite indices, would be subject to the same internal problems as the WPI. In particular, the concept of relative water poverty constructed as a result of the choice of normalization technique implicit within the WPI model at the variable level has the tendency to distort results especially for small datasets such as those analyzed in Komnenic, *et al.* (2008) and the present study. Konmenic *et al.* (2008, p.222) describe the cause of this phenomenon accurately and states: "the final value of the WPI heavily depends on the number of countries or communities it is calculated for."

The developers (Sullivan *et al.*, 2003) suggest a standardized set of indicators would enable comparisons across time and space, for example, between communities. However, the normalization technique currently in use prevents longitudinal studies regardless of the indicators selected for use. Instead a standardized scoring system that sets acceptable minimum and maximum scores might alleviate this problem. Nevertheless, a standardized set of indicators does not yet exist and differences between locales would likely impede its creation. For example, the developers (Sullivan *et al.*, 2003) recognize the difficulty in translating theoretical constructs, however well designed they might be, into practice especially between rural and urban settings where individual variables may not apply to both sites. This idea is supported by the present study where substantial differences between study sites proved somewhat problematic to the selection of variables, for example, the difference in water supply systems that equate to inherently different *needs*. Inevitably, some concessions must be made increasing data distortion and further masking local realities of water poverty necessitating further explanations. Molle & Mollinga (2003, p.535) note these explanations are often "site-specific and quantitative."

The above findings give rise to the idea that any meaningful discussion surrounding water poverty should include the examination of variables especially where datasets are susceptible to distortion. Moving the discourse to the variable level would diminish the purpose of the WPI, which according to the developers is "political, rather than statistical" (Sullivan *et al.*, 2003, p.192). Their desire to create a simple indicator of water poverty with the aspirations of opening up political discourse, does not preclude the need for sound scientific evidence in support of the results, including potentially, the use of statistics to validate the internal mechanisms of any such indicator. Examining the WPI at the variable level has a number of advantages and would diminish some of the core problems that arise when using composite indices and could conceivably pre-empt the need to combine data using the aggregation methods implicit within the WPI. For example, the need to normalise data, producing relative measures of water poverty, would be mitigated. Although equal weightings already provide for a transparent process, transparency would be increased further enabling a more direct comparison of results, or at the very least, would render the decision of whether or not a particular variable is comparable possible. Concentrating efforts on the collection of data and not their aggregation might alleviate some of the time constraints critical to this exercise rendering the process less "painstaking" (Komnenic, *et al.*, 2008, p.221). Reducing the number of selected variables through a substantive and statistical decision-making process would further help this problem and the PCA advanced by Cho, *et al.* (2009) might prove much more useful in this context.

9.3 The Exclusion of Resources as an Indicator of Water Poverty

Some progress has already been made in respect of refining the variables necessary to calculate water poverty and the idea that AWR be excluded from such analyses is now discussed. A valid argument for its exclusion can already be made given some of the failings of traditional assessments of water scarcity (that apply equally to variables used to measure quantitative water availability within the WPI) that were discussed in Chapter 2. Considering two major assessments of AWR undertaken at the international scale (Arnell, 2004; Shiklomanov, 2000) the failings of traditional water resources assessments become evident and a major justification for the development of the WPI is based on this notion. More recently, Chenoweth (2008, p.5) provided compelling statistical evidence to support the argument that "the naturally available water resources of a country do not have a significant effect on the ability of that country to meet the basic needs of its population." This provides a clear argument for the exclusion of variables that purportedly measure AWR within the WPI. Indeed, this study has shown there is no relationship between the indicator of Resources and WPI at the macro scale ($r<0.1$). It is only when variables that attempt to describe the temporal variability of water resources and community perceptions of AWR are included that results at the micro scale improve ($r=0.4$). Thus it is apparent that quantity has little impact on water poverty after all. This result would not surprise researchers that focus on the water-health nexus of water poverty and has in fact already been put forward by Cairncross (2003) in his editorial that accurately deconstructs long-held myths about water supply. Supported by sound evidence, Cairncross (2003, p.193) asserts: "the idea that global and local water shortages are to blame for the fact that over a billion people lack water supplies turns out to be a myth."

9.4 Future Recommendations for an Ameliorated Water Poverty Index

A comprehensive review of existing literature has shown the main purpose of indices and especially the WPI is to impact policy. There is now overwhelming evidence that the overall index score is purely political in nature with little scientific merit rendering the choice of a composite index to calculate water poverty scientifically questionable. Furthermore, the indicators used to calculate the WPI are themselves composite indices subject to the same conditions, biases and failings as the overall WPI. It is therefore clear that in order to create a more meaningful discourse surrounding water poverty, analytical efforts should be concentrated on the selected variables used to calculate a water poverty index and neither the indicators nor the overall WPI score.

In the first instance, it has been shown that more variables does not necessarily provide additional detail but instead adds to the logistical problems, creates confusion and alters individual results such that they are no longer discernable in a wider amalgamated portrayal of water poverty. Thus the number of selected variables should be reduced to the minimum number of variables required to describe the maximum variance in water poverty. This would assist in the development of a set of core variables and increase opportunities to make comparisons between sites. There is already substantial evidence to support the removal of physical measures of water resources availability concentrating instead on temporal and spatial variability of water supplies. Shifting the focus of the WPI to its constituent parts mitigates most, if not all, of the serious failings of the internal mechanisms implicit within the current model. Moreover, a move towards calculating absolute water scarcity as opposed to relative water poverty will remove previously discussed problems and improve overall functionality enabling longitudinal studies, the addition of new sites without compromising previous calculations and the genuine ability to compare water poverty between sites.

This does not however preclude the need to examine variables further and the same rigorous analysis as that undertaken at the indicator level must be performed to resolve potential problems of accountability in terms of inter-relationships between variables thus avoiding double-counting and the need to obviate any normalization techniques that might potentially lead to the distortion of data. In terms of reducing the number of variables to a manageable number, statistical approaches designed for this purpose have been proposed and include PCA to identify key variables that best represent the core indicators described by the original WPI. Such a reduction in variables would not only impact the overall index, but alleviate many of the logistical problems described in this study and others such as the amount of time consumed in collecting and ultimately analyzing data.

The problem of weighting has been highlighted as a major problem by many researchers and although this study opted to replicate the original model by using equal weighting it is recognized as an outstanding problem that needs to be addressed in future research. Although many researchers recognize the importance of capturing the community voice this study has shown the WPI is unable to capture local perceptions of water poverty in a satisfactory manner. Developing weightings based on community perceptions of water poverty is a viable solution to both of these problems. However, community perception is relative and liable to be site specific thus its inclusion in any calculation might compromise the ability to compare (absolute) water poverty across sites with any scientific certainty. Nevertheless, future research into this specific problem is considered essential for the future of the WPI.

9.5 Limitations of a Participatory Approach

My research positionality prior to conducting fieldwork (Figure 4) inevitably shifted as the research progressed. Although I had aspired to remain more qualitative in my approach (conducting research that was descriptive, exploratory, and collaborative), my position shifted from descriptive to explanatory, from exploratory to problem solving, and from collaborative to covert. This is partially as a result of problems I encountered with the WPI model, resulting in a marked shift towards problem solving as I grappled with the internal mechanics of a poorly designed composite index. In my attempt to correct some of the more prominent failings of the WPI model, my position became increasingly more explanatory rather than exploratory. Although I attempted to retain an overall element of exploration in terms of applying the WPI at the community level, truthfully this exploration was forceful developing as a result of the lack of pre-determined variables. Most of these shifts are as a result of having adopted a reflexive approach towards conducting research and in my opinion remain value free such that the outcome is neither 'better' nor 'worse' because of these shifts. However, my greatest shortcoming likely stems from my own research bias. At the outset I anticipated a largely collaborative effort towards my research, especially in terms of my third objective, which aimed to assess community perceptions of water poverty and necessitated input from the community itself. As the WPI model proved to be far more complicated and cumbersome than expected, my *modus operandi* reverted to earlier learnings and I began occupying a more familiar space, that of the empiricist or positivist.

This shift, along with other uncontrollable factors, had a direct impact on the focus groups I conducted in El Mash. In particular, the sessions were rushed and too much information was crowded into a rather short period of time. Clinging to my own research bias, I conducted my fieldwork in a linear fashion, insistent that the WPI be calculated at the community scale prior to engaging the community in specific discussions concerning water poverty. Ironically, this was in an attempt to avoid researcher bias as it was my belief that in order to accurately compare community perceptions with the results of the WPI, the two needed to be wholly independent. In part, this remains true as the WPI asserts its ability to be utilised by virtually anyone implying only a limited amount of required knowledge. Yet calculating the WPI without first debating the constructs of water poverty with each community meant my position shifted from moderately objective to highly subjective. Subjectivity is inherent within the WPI and engaging with the community first would not have removed all subjectivity but it is fair to say that the subjectivity of a wider group would have led to better objectivity overall.

In terms of PLA more generally, critiques have been made against this approach suggesting "it can perpetuate power differences within the community… those with the strongest voice are likely to be heard" (Laws, 2003, p.350). This is relevant to both focus groups I conducted. In the first instance, I hadn't anticipated such a large participation rate amongst the women. Secondly, I failed to take into consideration the high level of illiteracy prevalent amongst them. Consequently, I was forced to adopt a far more proactive role than originally anticipated. In some circumstances, for example when discussing the concept of well-being, my translator/assistant and I led the groups. As a result, in my group, I was forced to rely upon a single participant for Tzeltal-Spanish translations. Inevitably this gave rise to certain voices being heard more strongly than others. This was also a key problem during the male focus group. Due to circumstances beyond my control, which left me without an assistant/translator, during discussions with the wider group, I was again forced to rely on one participant who was fluent in both written and spoken Spanish. Fortunately, more men than women spoke Spanish and although certain voices dominated, the majority of voices were still heard.

Reverting to the use of questionnaires, Chambers (1997, pp.190-210) would say "[they], select and simplify reality, often mislead, and reconfirm the realities of uppers, missing local complexity and diversity." However, I would argue the use of questionnaires enables the researcher to fulfil the role of student far more successfully. In this case most bias entrenched within the process of conducting surveys can be attributed to the research assistants/translators. In fact, in Chapters 7 and 8 I suggest response rates, and accuracy and clarity of information vary between communities as a result of my relationship with each of my research assistants/translators and indirectly their gender.

Although it would be unfair for me to describe problems in my working relationship with my research assistant/translator in Pozuelos solely as a function of gender bias and power, it is worth noting he was male, indigenous, older and a more experienced community worker than I and I attribute some of our strife to his reluctance to 'taking orders' from a young, white, female researcher with less local knowledge. During interviews, I struggled to ensure he understood the importance of translating *verbatim* as opposed to relating events according to his own perception and opinion. Furthermore, his own bias was evidenced in his reluctance to ask some of the already agreed upon questions. For example, it was clear he believed women would not be able to accurately estimate the amount of water used at the household level and despite my insistence that he encourage the informants to associate volumes of water with nearby containers, response rates were particularly low. This contrasts with my experience in El Mash, where I had a healthy, enjoyable relationship with my research assistant/translator. Female, young, indigenous and obviously impressionable she was ready and willing to accept her role and contribute additional information, such as personal opinions, only when encouraged to do so. She proved invaluable when organizing the focus groups, though I might add, my rush to complete those exercises was also due in part to her time constraints (and in fact, as previously mentioned, she withdrew her services only days before the male focus group was scheduled to take place).

In addition to my personal relationships with each research assistant/translator, it's also worth noting cultural nuances between the Tzotzil and Tzeltal tribes, the former often described as conservative and troublesome (at least within the Municipality of Chamula), the latter described as warm and co-operative. These descriptions generally held true during the year I lived in Chiapas both from a personal perspective and that of the media. It is not possible to raise concepts of idigeneity without acknowledging the extensive body of work by Tuhiwai Smith. Citing her now, I acknowledge this thesis' failure to engage with themes of power or the indigenous struggle.

> "Whilst it is more typical (with the exception of feminist research) to write about research within the framing of a specific scientific or disciplinary approach, it is surely difficult to discuss research methodology and indigenous peoples together, in the same breath, without having an analysis of imperialism, without understanding the complex ways in which the pursuit of knowledge is deeply embedded in

> the multiple layers of imperial and colonial practices" (Tuhiwai Smith, 1999, p.7).

Returning to some common pitfalls associated with participatory research outlined in Chapter 2 (management of expectations, dominance, gender and upper-to-upper bias, and taking without giving), as anticipated the management of expectations and taking without giving proved to be the most difficult constraints to this research. Community gatekeepers and especially my research assistants/translators proved invaluable at managing community expectations. In this respect, the more experienced community worker in Pozuelos was particularly adept at ensuring the community executive and participants were consistently aware of the nature of this research. It helped in no small part that he worked for Pronatura, the NGO with an existing presence in the community. Furthermore, Pronatura also employed a father and son from within the community and Pozuelos had already participated in several academic research projects. This level of awareness enabled a (mostly) problem free entrance and exit to the community. Moreover, in my opinion there is little new information I could provide to the community relating to their community water supply system. In contrast, though it was not an impediment to my research, it was more difficult to manage expectations in El Mash where neither the community nor my research assistant/translator had prior experience with research projects. This led to a certain amount of internal conflict, whereby I relished the level of interest the community afforded my presence and research, yet despite my concerted efforts to manage expectations I was aware this was a result of unmet hope. Contrary to Pozuelos, in El Mash I did have important information requiring immediate attention – specifically the results of my water quality analyses indicating several springs, and one in particular, were heavily contaminated with thermotolerant coliforms. Though I would have preferred releasing this information to the community as a whole, I was at least able to disseminate my findings to the community executive. In some way, this small act served to assuage my own misgivings about unmet expectations within El Mash.

The problem of taking without giving proved nigh impossible to mitigate. It is not possible to comment on this constraint to participatory research, especially that conducted within the academic arena, without providing my own personal opinion on this matter though it is a highly emotional subject and completely beyond the remit of 'a' thesis. That in itself is a major subject of contention and one that has given me serious cause to reflect on a career in international development research. It is not possible to come away from this research without some misgivings and in fact notions of guilt. In retrospect, I feel that what began as a selfless attempt at contributing to rural livelihoods ultimately become a rather selfish initiative in no small part due to the constraints placed upon a PhD student. Despite attempts to secure funding to return to my study sites and disseminate my findings more fully, my requests were rejected, unbelievably, citing a lack of bearing on the research. It is this belief system that perpetuates failures in development research and as institutes of excellence I would urge all universities and institutes of higher education participating in development research to seek novel but appropriate ways to overcome this barrier and strive to 'give back' what can only be perceived as rightfully 'theirs'. In this respect, following the final submission of this thesis, I have committed to providing a fully translated executive summary of my findings to both participating communities, Pronatura and, at their request, CONAGUA.

Lastly, returning to the idea that theory is often too obscure and too complex for those on the ground, yet practice often fails to inform theory because of its localized context and initial lack of theoretical grounding (Chapter 2), I acknowledge I have not attempted to influence development theory through my own practice in part because of my own initial lack of theoretical grounding. Although I was fully aware of this concept in principle, rising to the challenge proved to be more difficult than anticipated. Notwithstanding this study continues to push the agenda of water poverty to the fore and contributes to the growing body of knowledge supporting the need for a mutli-dimensional approach to the assessment of water poverty. Furthermore, one can only "welcom[e] error as an opportunity to do better" (Laws, 2003, p.349).

9.6 Conclusions

In response to questions surrounding temporal and spatial variability of data and their reliability at different scales, the first objective was to determine the most appropriate scale for undertaking water poverty assessments carried out by calculating, comparing and contrasting the WPI at the household and state scales. As the only indicator to consider social, economic and physical dimensions of water poverty in tandem, the WPI is by definition the best tool available. Nevertheless this research has sought to demonstrate its complex nature rendering its application in practice quite difficult. Its inability to accommodate local variations in the dimensions of water poverty easily further demonstrates its failure to accurately reflect local realities of water poverty and importantly its ineffectiveness at comparing water poverty across localities. Notwithstanding since its inception it has garnered a lot of interest. At worst it has enabled the debate surrounding water poverty to continue in a meaningful and constructive way; at best it has served to highlight the inappropriateness of defining water poverty by a single number. In this case it would appear the whole is not better than the sum of its parts.

The issue of scale continues to be problematic and a response to the first objective is akin to asking the oft used question when such a response is variable and not forthcoming, how long is a piece of string? In essence, the most appropriate scale is the one the user wishes to assess with the implicit understanding that data used to undertake the assessment correspond to that scale. In this context, the data determine the most appropriate scale. In practice, this is rarely possible due to the discrepancy between natural and political boundaries, the former representing the scale at which water resources are typically analyzed, the latter representing the scale at which socio-economic data are most often assessed. That being said, natural boundaries of water resources such as the catchment area are often subject to dramatic temporal and spatial variation as is the present case thus jeopardizing accuracy regardless of attempts to maintain integrity across scales. Some of these problems may be mitigated by incorporating questions designed to elicit information about the various dimensions of water poverty in future household censuses, although reliability of data will continue to be problematic. In this regard, it is important to address whether the issue of scale is about precision of data or the ability to include more data, the response being subject to value judgements as again this can only be defined by the user. The user will often be faced with including data that originate from different natural scales and must give thoughtful consideration to this scenario when interpreting the results.

In response to a lack of research, the second objective sought to address knowledge gaps in the WPI by testing its robustness and validating its accuracy to successfully predict community water poverty by undertaking rigorous analyses of the WPI at the state and community scales. Similar to the concept of water poverty the response to the second objective is marred by vast subjectivity as demonstrated by the value judgments required to determine the most appropriate scale at which to undertake assessments. Furthermore, despite its attempts to address the various dimensions of water poverty there is a lack of consensus surrounding what indicators should be included in the, or for that matter any, WPI. This is not surprising given the level of contention surrounding the subject of water resources owing in part to the divergent interests of concerned parties. In any case, indicators of water poverty between two rural communities in the same state have been seen to be so vast that it's hard to comprehend how they could be defined by a single set of indicators destined to represent all rural communities let alone cross the urban-rural divide. In the second instance, accuracy is not necessarily gained by going into further numerical detail and instead such level of detail may serve only to decrease any added value lost by covering up difficult questions that might best be answered through meaningful discourse. This is exemplified by the differences observed between measured and perceived water poverty at the community scale. Thirdly, the aforementioned lack of, and difficulty in defining, indicators inhibits comparisons across localities in turn contravening not only its robustness but also its main purpose. Even so, previous assertions that the WPI is nonetheless a useful (if not precise) tool for guiding water management policy are not easily ignored. Assuming the user fully appreciates the complexities and subjective nature of the WPI and can dedicate the resources required to define a set of appropriate indicators, I would suggest there is strong potential for the WPI to be used a tool for guiding water management policy yet I'm less convinced of its ability to accurately, or more appropriately meaningfully, define water poverty at the community scale. I also note the majority of case studies thus far have been within a purely academic circle and I doubt the capacity of the WPI to position itself as a local resource anytime soon.

In response to questions about its ability to accurately represent local realities, the third objective aimed to assess the ability of the WPI to reflect local perceptions of water poverty by analyzing and contrasting the results with locally defined variables determined through extensive fieldwork and community consultation. The ability of the WPI to reflect local realities of water poverty was carefully assessed but instead of arriving at a concrete answer only gives rise to further questions. As mentioned, indicators of water poverty between two communities in the same state have been seen to be so vast that it would be difficult to capture both realities of water poverty with a single set of indicators and within the constraints of the internal mechanisms of the WPI. Thus, the first question is not can the WPI reflect local realities of water poverty but instead, **which** WPI reflects local realities of water poverty. The insinuation that modifications would be required in order to assess local realities of water poverty is intentional: modifications of scale, modifications to indicators, modifications in data collection, the list is almost endless. Thus, the second question becomes why? If such an effort is required to analyze different communities, different regions, different scales, different data and so on and so forth, what is the utility of an index, particularly one that recognizes most of its value can be found within the indicators themselves and not the overall index score?

In reality, indices are well-suited to the needs of politicians, managers, media and the general public, who are perhaps less interested in the nuances of a particular story than its bottom line. Thus any indicator of water poverty needs to balance these competing interests. That being said, although the WPI as a tool remains ambiguous, it is evident that the concept of water poverty is much more meaningful than earlier discourses designed to focus on physical water scarcity alone and continues to attract the attention of researchers with diverse backgrounds and interests. Consequently, I readily support the need for continued research into the amelioration of a water poverty index as in any case, it is now clear that the WPI, despite its shortcomings, provides a better picture of water poverty than measures designed to assess AWR alone.

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APPENDIX A SURVEY QUESTIONNAIRE

ENCUESTA SOBRE LA ESCASEZ DEL AGUA
El Mash, Oxchuc, Chiapas, México

Información General

Encuestador(a)
____

Fecha ______________________________ Código de vivienda __________________________

Posición GPS y altitud ____

Nombre del/de la entrevistado/a ____

Hombre		Mujer	

Edad _________________________ Posición en la vivienda ______________________________

Numero de personas que viven actualmente en la vivienda:

Edad	Hombres	Mujeres
0 a 5		
6 a 17		
18 a 24		
25 a 44		
45 a 60		
60+		

Numero de personas que migraron de la vivienda:

	Hombres	Mujeres
Nacional		
Internacional		

Sección 1 – Recursos – Estas preguntas se aplican a la temporada SECA

1) ¿Cual es su fuente principal de agua domestica durante la temporada seca?

____

Seleccione una de las siguientes fuentes:

1.	Entubado (privado)	2.	Entubado (publico)	3.	Fuente de la vivienda	4.	Pozo profundo (privado)
5.	Pozo profundo (publico)	6.	Pozo (privado)	7.	Pozo (publico)	8.	Pequeña presa
9.	Tanque (conteniente)	10.	Estanque natural	11.	Manantial	12.	Arroyo/ riachuelo
13.	Río	14.	Camión de agua (gobierno)	15.	Vendedor de agua	16.	Aguas pluviales

2) ¿Cuanto agua esta disponible para su vivienda durante la temporada seca?

noviembre

Mucho		Suficiente		Poco suficiente		Muy poco		Ningún	

diciembre

Mucho		Suficiente		Poco suficiente		Muy poco		Ningún	

enero

Mucho		Suficiente		Poco suficiente		Muy poco		Ningún	

febrero

Mucho		Suficiente		Poco suficiente		Muy poco		Ningún	

marzo

Mucho		Suficiente		Poco suficiente		Muy poco		Ningún	

abril

Mucho		Suficiente		Poco suficiente		Muy poco		Ningún	

mayo

Mucho		Suficiente		Poco suficiente		Muy poco		Ningún	

3) ¿Por lo general cómo considera es la disponibilidad de agua en temporada seca?

Muy bueno		Bueno		Regular		Malo	

4) ¿Como es la calidad de su agua en temporada seca?

____

5) ¿Usa algún método de tratamiento de agua en su vivienda?

Sí		No	

6) ¿Cuál método y como lo hace?

___

7) ¿Si hierve su agua, cuantos palos de leña utiliza cada vez?

	palos por día

Sección 2 – Acceso

8) ¿Quien(es) es/son la(s) persona(s) principalmente encargado de acarrear el agua en su vivienda?

	Hombres	Mujeres
Adultos		
Niños		

9) ¿Cuanto tiempo (en minutos) necesita normalmente para acarrear el agua (de su fuente principal en temporada seca) por un solo viaje incluyendo el tempo para hacer la cola?

	Minutos

10) ¿Cuantos viajes hace al día?

	Día

11) ¿Tiene acceso a instalaciones sanitarias?

Sí		No	

Seleccione una de las siguientes opciones:

1.	Excusado (seco)	2.	Excusado (agua)	3.	Letrina (seca)	4.	Hoyo
5.	Otro (especificar)						

12) ¿Tiene acceso al drenaje?

Sí		No	

Seleccione una de las siguientes opciones:

1.	Red pública	2.	Fosa séptica
3.	Conexión directa al agua (especificar)	4.	Conexión directa a la tierra (especificar)

13) ¿Tiene algún conflicto sobre el acceso al agua?

Sí		No	

14) ¿Con que frecuencia tiene conflictos sobre el acceso al agua?

1.	Jamás	2.	De vez en cuando	3.	A menudo	4.	Diario

Sección 3 – Capacidad
Educación

Indica el nivel de educación de cada persona en su vivienda quien haya completado por lo menos la escuela primaria:

	Primaria completa	Secundaria incompleta	Secundaria completa	Educación superior incompleta	Educación superior completa
Hombres					
Mujeres					

15) ¿En que profesión trabaja su esposo/ sus hijos/ sus hijas?

____

16) Tiene acceso a la energía eléctrica?

Sí		No	

17) ¿Tiene piso de tierra en algún cuarto de su casa? ¿En donde?

Cocina		Dormitorio		Otro	

18) Material de construcción del techo:
____

19) Material de construcción de las paredes:
____

20) ¿Cuáles son sus ingresos diarias/ semanales/ mensuales? ¿Cuánto gana su esposa por día/ semana/ mes? ¿Participa en algún programa estatal (Programa Oportunidades)?

____

21) ¿Recibe algún envío de dinero de alguien que vive a fuera?

Nacional		Internacional	

22) ¿De los siguientes productos, cuales tiene en su vivienda?

Bicicleta		Vehículo		Electro-domésticos	
Fogón abierto		Fogón mejorado		Estufa de gas	
Refrigerador		Televisión		Radio	
Herramientas de trabajo (especificar)		Otros 1 (especificar)		Otros 2 (especificar)	

23) ¿Hay un comité de agua formal en su comunidad?

Sí		No	

24) ¿Hay instituciones a fuera de su comunidad que son responsables del agua?

Sí		No	

25) ¿Hay alguien en su vivienda que alguna vez ha participado en un programa de capacitación del uso de agua o higiene?

Sí		No	

26) ¿Cuantos veces en el último año alguien en su vivienda ha tenido la diarrea?

Adultos (más de 15 años)					
Muchas veces		De vez en cuando		Nunca	

Niños y menores de 5 años					
Muchas veces		De vez en cuando		Nunca	

27) ¿Qué hace cuándo alguien sufre de la diarea ?

____

28) ¿Se murió alguien en su vivienda de la diarrea?

Adultos	
Menores de 5 años	

29) ¿Cuantos veces en el último año se enfermó alguien en su vivienda debido al agua?

Adultos					
Muchas veces		De vez en cuando		Nunca	
Menores de 5 años					
Muchas veces		De vez en cuando		Nunca	

30) ¿Alguien en su familia ha sufrido de la trachoma?

____

____

31) ¿Su familia lava sus manos?

Sí		No	

32) ¿Cómo y cuando se lava sus manos?

____

____

Sección 4 – Uso

33) *Aproximadamente*, cuanto agua se consuma *en temporada seca* en su vivienda por día (en litros o en cubetas)?

	Litros/ cubetas

34) Ordena las siguientes actividades domesticas en orden ***del consumo de agua actual*** en su vivienda:

Agua para tomar		Bañarse/ baño		Cocinar		Lavar ropa/ limpiar casa	

35) Se usa agua (de la fuente principal en temporada seca) por sus animales de traspatio?

Sí		No	

36) Estimar el volumen del agua consumido en litros/ cubetas por día.

____

37) Ordena las siguientes actividades por su importancia familiar:

Agua para tomar		Bañarse/ baño		Cocinar		Lavar ropa/ limpiar casa	

38) Ordena las siguientes actividades ***por su importancia familiar*** cuanto al uso del agua (*más importante, importante, un poco importante, no importa*):

Domestica		Industrial		Agricultra		Animales	

Sección 5 – Ambiente

39) Ha observado un cambio en la fertilidad de sus tierras en los últimos diez años?

Sí		No	

40) Estimar el cambio:

Cambio	Mucho	Algo	Un poco
Aumento			
Disminución			

41) Ha observado un cambio en la cobertura de sus bosques en los últimos diez años, por ejemplo, menos leña disponible para el combustible?

Sí		No	

42) Estimar su cambio.

Cambio	Mucho	Algo	Un poco
Aumento			
Disminución			

43) Ha observado un cambio en el nivel de precipitación en los últimos diez años?

Sí		No	

44) Sí si, estimar el cambio.

Cambio	Mucho	Algo	Un poco
Aumento			
Disminución			

Comentarios/ observaciones:

____

____

____

____

____

____

APPENDIX B FOCUS GROUP ACTIVITY PLANS

Taller con las Madres de Familia

El Mash, Municipalidad de Oxchuc, Chiapas

Sábado el 25 de octubre del 2008

10h00 – 17h00 (hora local)

Hora	**Actividad**	**Duración**
9h00	Recepción y bienvenido • Distribución de gafetes • Presentación de las promotores, los objetivos del taller y las actividades a seguir	20 min
9h20	Juego de presentación • "Pelota Caliente". Todas las mujeres forman un circulo. La que tiene la pelota se presenta al grupo: *Me llamo…, Vine al taller porque…* • Materiales: pelota.	45 min
10h05	Formación de grupos • Cada mujer esta dado un numero entre 1 y 4 y se forman en grupos según su numero. Cada grupo tiene que escoger su nombre de grupo y preparar su pancarta. El tema es el "Agua". Cada grupo tendrá la oportunidad de presentarse al grupo entero y explicar porque escogieron su nombre. • Materiales: plumones, papel.	15 min
10h20	"Trazando la Comunidad" (Community Mapping) • Cada grupo debe dibujar su comunidad lo más completo posible e incluir los monumentos que son más importantes para ellas. • Hay que incluir los recursos de agua (manantiales, ríos, etc.) • Materiales: plumones, papel y etiquetas decorativas.	60 min
11h20	Presentación del trabajo • Cada grupo debe escoger una porta voz quien tendrá 5 minutes para explicar su mapa al grupo entero.	20 min
11h40	"Calendario Estacional" (Seasonal Calendar) • Cada grupo debe creer un calendario (según los meses del año) que representa los días de lluvia por mes. • Materiales: plumones, papel, etiquetas adhesivas. Cada etiqueta represente un día de lluvia. Por ejemplo, si en el mes de enero hay 10 días de lluvia, pondrán 10 etiquetas.	60 min
12h40	Presentación del trabajo • Cada grupo debe escoger una porta voz quien	20 min

	tendrá 5 minutes para explicar su mapa al grupo entero.	
13h00	**ALMUERZO**	**60min**
14h00	DINAMICA - "Canasta de silla"	30 min
14h30	"Indicadores Locales" (Local Indicators) • Los cuatro grupos se reforman en dos grupos. Cada grupo debe discutir el concepto del "*bienestar*" en su comunidad. *"¿Que significa estar bien, que necesita para estar bien?"* Deben escribir o dibujar una lista de las cosas que representen el bienestar (que sea dinero, que sea salud, que sea familia, etc.) • Materiales: plumones y papel.	30 min
15h00	"Coloquio" (Group Discussion) • Cada grupo tendrá 10 minutes para presentar su lista al otro grupo y explicar/ defender su lista. Habrá 10 minutos para conversar sobre los acuerdos o las diferencias.	30 min
15h30	"Una vida sin agua" (Key Probes) • Siempre en dos grupos, cada grupo debe discutir la pregunta *"¿Que pasa cuando no hay agua?"*. El trabajo debe hacerse a través de una diagrama causal. Por ejemplo: Cuando no hay comida → tengo hambre → me hace falta fuerza → no puedo trabajar. • Materiales: plumones y papel.	30 min
16h00	"Coloquio" (Group Discussion) • Cada grupo tendrá 10 minutes para presentar su lista al otro grupo y explicar/ defender su diagrama. Habrá 10 minutos para conversar sobre los acuerdos o las diferencias.	30 min
16h30	Dinámica de conclusión – "Papa Caliente" • La persona quien tiene la pelota escoge otra mujer y la pregunta algo; la pelota sigue a la mujer que contesta • Preguntas posibles: ¿En que mes llueve más? ¿Para ti, que necesita para estar bien? ¿Qué aprendió hoy? Que le gustó? ¿Qué no le gustó?	30 min

Taller con las Padres de Familia

El Mash, Municipalidad de Oxchuc, Chiapas

Sábado el 8 de noviembre del 2008

10h00 – 17h00 (hora local)

Hora	**Actividad**	**Duración**
10h00	Recepción y bienvenido • Distribución de gafetes • Presentación de la promotora, los objetivos del taller y las actividades a seguir	15 min
10h15	Juego de presentación • "Pelota Caliente". Todas los hombres forman un circulo. El que tiene la pelota se presenta al grupo: ***Me llamo __________ lo que más me gusta de El Mash es __________.*** • Materiales: pelota.	15 min
10h30	Formación de grupos • Se dividen en grupos según el color de su gafete (negro, verde, rojo, celeste). Cada grupo tiene 15 minutos para escoger su nombre de grupo y preparar una pancarta. • Materiales: plumones, papel.	15 min
10h45	"Calendario Estacional" (Seasonal Calendar) • Cada grupo debe creer un calendario (según los meses del año) que representa los días de lluvia por mes. • Materiales: plumones, papel, etiquetas adhesivas. Cada etiqueta represente un día de lluvia. Por ejemplo, si en el mes de enero hay 10 días de lluvia, pondrán 10 etiquetas.	60 min
11h45	Presentación del trabajo • Cada grupo debe escoger una porta voz quien tendrá 5 minutes para explicar su mapa al grupo entero.	20 min
12h05	"Indicadores Locales" (Local Indicators) • Cada grupo debe discutir el concepto del "*bienestar*" en su comunidad. *"¿Que significa estar bien, que necesita para estar bien?"* Deben escribir o dibujar una lista de las cosas que representen el bienestar (que sea dinero, que sea salud, que sea familia, etc.) • Cada grupo debe discutir lo que significa estar *rico* y estar *pobre*. Deben escribir o dibujar una lista de las cosas que representen estas temas. • Materiales: plumones y papel.	60 min

13h05	Presentación del trabajo • Cada grupo debe escoger una porta voz quien tendrá 5 minutes para explicar su mapa al grupo entero.	20 min
13h25	**ALMUERZO**	**60min**
14h25	DINAMICA - "Beach Ball Brainstorming" • El moderador anuncia un tema (AGUA). La pelota se pasa de persona a persona. El que tiene la pelota tiene que decir algo relacionado con el tema y pasar la pelota a alguien otro.	15 min
14h45	"Coloquio" (Group Discussion) • Describir el problema de agua en la comunidad • ¿Cómo esta afectado la comunidad e/o su familia? • ¿Cómo resolverá la situación usted?	60 min
15h45	Clausura del Taller – preguntas	15 min

APPENDIX C WPI RESULTS MACRO SCALE

Estado	Resources	Access	Capacity	Use	Environment	WPI	AWR (m3/year)	AWR per capita	WPI Rank	AWR Rank
Guerrero	0.4379	0.0000	0.0293	0.6716	0.4472	0.3172	17696369051.7	5681	1	28
Oaxaca	0.6006	0.3913	0.0811	0.1317	0.4565	0.3323	54166977752.3	15446	2	30
Hidalgo	0.3446	0.5693	0.3259	0.1896	0.2716	0.3402	4827218346.2	2058	3	11
Chiapas	0.6121	0.2935	0.0036	0.1907	0.6041	0.3408	114421218586.7	26650	4	32
Veracruz Ignacio de la Llave	0.5800	0.5183	0.2731	0.1232	0.3793	0.3748	55172141381.3	7760	5	31
México	0.2492	0.7087	0.5770	0.1375	0.2822	0.3909	4084465469.2	292	6	10
Michoacan de Ocampo	0.4952	0.7074	0.3048	0.1725	0.3166	0.3993	10557849593.4	2662	7	21
Tabasco	0.6045	0.5172	0.4395	0.1219	0.3800	0.4126	38688577540.6	19442	8	29
Puebla	0.5276	0.6196	0.3138	0.1190	0.5559	0.4272	16514836537.6	3068	9	27
Yucatán	0.4437	0.4804	0.4608	0.2347	0.5175	0.4274	8843468603.5	4862	10	18
Morelos	0.2315	0.7066	0.5926	0.2735	0.3945	0.4397	883960775.4	548	11	3
Guanajuato	0.2581	0.6949	0.4200	0.3689	0.4625	0.4409	5540322948.0	1132	12	14
Zacatecas	0.4489	0.6762	0.4163	0.3226	0.4978	0.4724	6765407535.4	4947	13	15
Tlaxcala	0.5172	0.8775	0.4537	0.1191	0.4367	0.4808	726249246.5	680	14	2
Quintana Roo	0.5494	0.3636	0.7572	0.0524	0.6931	0.4831	9168514736.4	8076	15	19
Nayarit	0.5398	0.7536	0.4694	0.2143	0.4637	0.4882	4884132925.4	5143	16	12
Querétaro Arteaga	0.3304	0.6034	0.5941	0.2913	0.7068	0.5052	2303426256.1	1441	17	7
San Luis Potosí	0.6360	0.6545	0.4503	0.1954	0.6179	0.5108	6773372796.2	2810	18	16
Colima	0.2907	0.9149	0.6688	0.2518	0.5381	0.5328	1006829523.0	1773	19	5
Sonora	0.0391	0.8685	0.7629	0.6716	0.3562	0.5397	7175225195.3	2996	20	17
Jalisco	0.4715	0.8342	0.6487	0.2062	0.5378	0.5397	14033197254.6	2078	21	25
Campeche	0.4908	0.5654	0.6453	0.4783	0.5396	0.5439	14984278524.8	19854	22	26
Sinaloa	0.1805	0.6804	0.5688	0.6671	0.6569	0.5507	9672843129.9	3708	23	20
Durango	0.7793	0.7041	0.5727	0.4005	0.3843	0.5682	11485654005.0	7611	24	22
Tamaulipas	0.5512	0.8845	0.7468	0.2244	0.5164	0.5847	12371007206.8	4091	25	24
Chihuahua	0.5339	0.7450	0.7726	0.5065	0.3681	0.5852	12027327221.1	3710	26	23
Baja California	0.2913	0.8564	0.8198	0.1791	0.8453	0.5984	2268950871.5	798	27	6
Baja California Sur	0.6608	0.5146	0.7883	0.1764	0.8681	0.6016	2347038743.2	4583	28	9
Distrito Federal	0.0350	0.9658	0.9942	0.4969	0.5595	0.6103	273739214.9	31	29	1
Coahuila de Zaragoza	0.5882	0.9746	0.8259	0.1536	0.5895	0.6263	5039416267.2	2020	30	13
Nuevo León	0.5706	0.9597	0.9645	0.1875	0.6630	0.6691	2344560977.1	558	31	8
Aguascalientes	0.6887	1.0000	0.7324	0.3173	0.6513	0.6780	1005482925.1	944	32	4

Estado	Resources	Access	Capacity	Use	Environment	WPI Score	Life Expectancy (2005)	Index of Marginalization (IoM)	HDI Mexico 2000	Falkenmark
Aguascalientes	0.6887	1.0000	0.7324	0.3173	0.6513	0.6780	74.7246	-0.9535	0.8201	943.7468
Baja California	0.2913	0.8564	0.8198	0.1791	0.8453	0.5984	75.3393	-1.2534	0.8221	797.6712
Baja California Sur	0.6608	0.5146	0.7883	0.1764	0.8681	0.6016	75.3832	-0.7195	0.8167	4582.5385
Campeche	0.4908	0.5654	0.6453	0.4783	0.5396	0.5439	74.4151	0.5588	0.8153	19853.8266
Chiapas	0.6121	0.2935	0.0036	0.1907	0.6041	0.3408	73.3045	2.3265	0.6926	26650.1249
Chihuahua	0.5339	0.7450	0.7726	0.5065	0.3681	0.5852	75.1088	-0.6841	0.8193	3710.4843
Coahuila de Zaragoza	0.5882	0.9746	0.8259	0.1536	0.5895	0.6263	74.2605	-1.1371	0.8281	2019.6442
Colima	0.2907	0.9149	0.6688	0.2518	0.5381	0.5328	74.9199	-0.7379	0.8061	1772.5997
Distrito Federal	0.0350	0.9658	0.9942	0.4969	0.5595	0.6103	75.4559	-1.5049	0.8715	31.3888
Durango	0.7793	0.7041	0.5727	0.4005	0.3843	0.5682	73.8888	-0.0188	0.7904	7610.8440
Guanajuato	0.2581	0.6949	0.4200	0.3689	0.4625	0.4409	74.7277	0.0919	0.7605	1132.1078
Guerrero	0.4379	0.0000	0.0293	0.6716	0.4472	0.3172	72.7636	2.4121	0.7195	5680.6490
Hidalgo	0.3446	0.5693	0.3259	0.1896	0.2716	0.3402	74.1699	0.7506	0.7483	2058.0642
Jalisco	0.4715	0.8342	0.6487	0.2062	0.5378	0.5397	74.7249	-0.7687	0.8008	2078.3416
México	0.2492	0.7087	0.5770	0.1375	0.2822	0.3909	75.0918	-0.6221	0.7894	291.5914
Michoacan de Ocampo	0.4952	0.7074	0.3048	0.1725	0.3166	0.3993	74.0850	0.4565	0.7486	2662.0412
Morelos	0.2315	0.7066	0.5926	0.2735	0.3945	0.4397	75.2737	-0.4435	0.7893	548.0571
Nayarit	0.5398	0.7536	0.4694	0.2143	0.4637	0.4882	74.4081	0.1905	0.7669	5142.9032
Nuevo León	0.5706	0.9597	0.9645	0.1875	0.6630	0.6691	74.8550	-1.3261	0.8425	558.3229
Oaxaca	0.6006	0.3913	0.0811	0.1317	0.4565	0.3323	73.5277	2.1294	0.7062	15446.1770
Puebla	0.5276	0.6196	0.3138	0.1190	0.5559	0.4272	74.4581	0.6348	0.7575	3067.8857
Querétaro Arteaga	0.3304	0.6034	0.5941	0.2913	0.7068	0.5052	74.7792	-0.1417	0.8020	1441.3178
Quintana Roo	0.5494	0.3636	0.7572	0.0524	0.6931	0.4831	75.6336	-0.3157	0.8195	8075.7879
San Luis Potosí	0.6360	0.6545	0.4503	0.1954	0.6179	0.5108	74.4979	0.6557	0.7667	2810.0454
Sinaloa	0.1805	0.6804	0.5688	0.6671	0.6569	0.5507	74.0412	-0.1482	0.7828	3708.2838
Sonora	0.0391	0.8685	0.7629	0.6716	0.3562	0.5397	74.6249	-0.7495	0.8176	2996.0925
Tabasco	0.6045	0.5172	0.4395	0.1219	0.3800	0.4126	73.9327	0.4622	0.7661	19441.7991
Tamaulipas	0.5512	0.8845	0.7468	0.2244	0.5164	0.5847	74.4949	-0.6834	0.8026	4090.6196
Tlaxcala	0.5172	0.8775	0.4537	0.1191	0.4367	0.4808	75.2504	-0.1292	0.7629	679.8769
Veracruz Ignacio de la Llave	0.5800	0.5183	0.2731	0.1232	0.3793	0.3748	73.2028	1.0767	0.7437	7759.5613
Yucatán	0.4437	0.4804	0.4608	0.2347	0.5175	0.4274	74.4964	0.4314	0.7708	4861.8589
Zacatecas	0.4489	0.6762	0.4163	0.3226	0.4978	0.4724	74.9950	0.1600	0.7539	4946.5870
2.5 Percentile	**0.0381**	**0.2274**	**0.0235**	**0.1040**	**0.2798**	**0.3289**				
97.5 Percentile	**0.7091**	**0.9803**	**0.9712**	**0.6716**	**0.8504**	**0.6711**				
92.5 Percentile				**0.6149**						

Estado	R1	R1 Normalised Xmin=0, Xmax=.9863	R2	R2 Normalised Xmin=0.0397, Xmax=0.7686	WPI component score
Aguascalientes	0.3784	0.3837	0.7617	0.9938	0.6887
Baja California	0.0000	0.0000	0.4630	0.5827	0.2913
Baja California Sur	0.8300	0.8415	0.3885	0.4801	0.6608
Campeche	0.9587	0.9720	0.0466	0.0095	0.4908
Chiapas	0.9853	0.9990	0.2034	0.2253	0.6121
Chihuahua	0.5720	0.5799	0.3942	0.4880	0.5339
Coahuila de Zaragoza	0.6150	0.6236	0.4413	0.5527	0.5882
Colima	0.0000	0.0000	0.4620	0.5813	0.2907
Distrito Federal	0.0000	0.0000	0.0905	0.0699	0.0350
Durango	0.8643	0.8763	0.5354	0.6823	0.7793
Guanajuato	0.2674	0.2711	0.2178	0.2451	0.2581
Guerrero	0.7593	0.7698	0.1167	0.1060	0.4379
Hidalgo	0.5159	0.5230	0.1604	0.1661	0.3446
Jalisco	0.7389	0.7492	0.1805	0.1938	0.4715
México	0.3262	0.3308	0.1615	0.1676	0.2492
Michoacan de Ocamp	0.5199	0.5271	0.3763	0.4633	0.4952
Morelos	0.0000	0.0000	0.3760	0.4630	0.2315
Nayarit	0.7570	0.7675	0.2664	0.3120	0.5398
Nuevo León	0.1393	0.1412	0.7921	1.0000	0.5706
Oaxaca	0.9799	0.9935	0.1905	0.2076	0.6006
Puebla	0.8491	0.8609	0.1808	0.1943	0.5276
Querétaro Arteaga	0.5576	0.5654	0.1090	0.0954	0.3304
Quintana Roo	0.9498	0.9630	0.1383	0.1358	0.5494
San Luis Potosí	0.8032	0.8144	0.3721	0.4576	0.6360
Sinaloa	0.0526	0.0533	0.2632	0.3076	0.1805
Sonora	0.0000	0.0000	0.0965	0.0781	0.0391
Tabasco	0.9898	1.0000	0.1916	0.2090	0.6045
Tamaulipas	0.6948	0.7044	0.3288	0.3980	0.5512
Tlaxcala	0.6089	0.6174	0.3427	0.4170	0.5172
Veracruz Ignacio de la	0.9168	0.9295	0.2071	0.2304	0.5800
Yucatán	0.8753	0.8874	0.0158	0.0000	0.4437
Zacatecas	0.7891	0.8000	0.1107	0.0978	0.4489
2.5 Percentile	**0.0000**		**0.0397**		**0.0381**
97.5 Percentile	**0.9863**		**0.7686**		**0.7091**

Estado	A1	A1 Normalised Xmin=77.5609, Xmax=95.2334	A2	A2 Normalised Xmin=67.6435, Xmax=94.8811	WPI component score
Aguascalientes	95.4679	1.0000	95.7777	1.0000	1.0000
Baja California	90.6592	0.7412	94.1000	0.9716	0.8564
Baja California Sur	81.2423	0.2083	89.9943	0.8209	0.5146
Campeche	87.3116	0.5517	83.4081	0.5791	0.5654
Chiapas	87.0118	0.5348	69.0549	0.0521	0.2935
Chihuahua	90.3267	0.7224	88.5424	0.7676	0.7450
Coahuila de Zaragoza	94.8905	0.9806	94.0147	0.9685	0.9746
Colima	93.4908	0.9014	92.9251	0.9285	0.9149
Distrito Federal	94.5318	0.9603	94.0897	0.9713	0.9658
Durango	88.3174	0.6087	89.4131	0.7996	0.7041
Guanajuato	86.9797	0.5330	90.9746	0.8569	0.6949
Guerrero	70.7804	0.0000	62.7822	0.0000	0.0000
Hidalgo	86.9572	0.5317	84.1640	0.6068	0.5693
Jalisco	92.6570	0.8542	89.8126	0.8142	0.8342
México	89.1903	0.6581	88.3204	0.7594	0.7087
Michoacan de Ocamp	90.4280	0.7281	86.3392	0.6867	0.7074
Morelos	91.0454	0.7630	85.3441	0.6502	0.7066
Nayarit	90.9779	0.7592	88.0071	0.7479	0.7536
Nuevo León	95.1653	0.9961	92.7805	0.9232	0.9597
Oaxaca	89.9216	0.6994	69.9004	0.0832	0.3913
Puebla	90.2239	0.7165	81.8704	0.5226	0.6196
Querétaro Arteaga	86.0407	0.4798	87.4336	0.7269	0.6034
Quintana Roo	81.7202	0.2354	81.0290	0.4917	0.3636
San Luis Potosí	91.9144	0.8122	81.1647	0.4967	0.6545
Sinaloa	89.0619	0.6508	86.9732	0.7100	0.6804
Sonora	93.1703	0.8833	90.8903	0.8538	0.8685
Tabasco	91.9900	0.8165	73.5729	0.2180	0.5172
Tamaulipas	94.0612	0.9337	90.3884	0.8354	0.8845
Tlaxcala	91.0655	0.7642	94.6208	0.9908	0.8775
Veracruz Ignacio de la	92.6486	0.8537	72.6181	0.1829	0.5183
Yucatán	79.5294	0.1114	90.7736	0.8495	0.4804
Zacatecas	86.3066	0.4949	90.9902	0.8575	0.6762
2.5 Percentile	**77.5609**		**67.6435**		**0.2274**
97.5 Percentile	**95.2334**		**94.8811**		**0.9803**

Estado	C1	C1 Normalised Xmin=31.6331, Xmax=144.9131	C2	C2 Normalised Xmin=12.6749, Xmax=24.0130	C3	C3 Normalised Xmin=2.7409, Xmax=20.2137	WPI component score
Aguascalientes	85.6361	0.4767	14.9205	0.8019	4.1618	0.9187	0.7324
Baja California	92.9661	0.5414	13.3810	0.9377	3.0849	0.9803	0.8198
Baja California Sur	89.1975	0.5082	13.7297	0.9070	3.6207	0.9496	0.7883
Campeche	121.6783	0.7949	17.5731	0.5680	10.2026	0.5730	0.6453
Chiapas	31.6332	0.0000	23.8919	0.0107	21.3501	0.0000	0.0036
Chihuahua	102.9125	0.6292	15.1141	0.7849	4.4229	0.9037	0.7726
Coahuila de Zaragoz	98.2797	0.5883	13.5742	0.9207	3.2856	0.9688	0.8259
Colima	70.0204	0.3389	14.0556	0.8782	6.4245	0.7892	0.6688
Distrito Federal	185.5000	1.0000	12.8710	0.9827	2.5947	1.0000	0.9942
Durango	65.0110	0.2946	17.8515	0.5434	4.8368	0.8800	0.5727
Guanajuato	52.0322	0.1801	18.1122	0.5204	10.4368	0.5596	0.4200
Guerrero	39.4488	0.0690	24.4299	0.0000	19.8838	0.0189	0.0293
Hidalgo	41.5787	0.0878	18.7303	0.4659	12.8031	0.4241	0.3259
Jalisco	69.4983	0.3343	15.2459	0.7732	5.5589	0.8387	0.6487
México	51.3494	0.1740	16.0223	0.7048	5.3234	0.8522	0.5770
Michoacan de Ocam	39.9025	0.0730	19.4277	0.4044	12.5802	0.4369	0.3048
Morelos	64.8783	0.2935	15.0259	0.7926	8.1264	0.6918	0.5926
Nayarit	42.0895	0.0923	17.0028	0.6183	8.0237	0.6977	0.4694
Nuevo León	133.1304	0.8960	11.9995	1.0000	2.7833	0.9976	0.9645
Oaxaca	32.5238	0.0079	21.9056	0.1859	19.3466	0.0496	0.0811
Puebla	50.7610	0.1689	20.1226	0.3431	12.7096	0.4295	0.3138
Querétaro Arteaga	83.2803	0.4559	16.8122	0.6351	8.1360	0.6912	0.5941
Quintana Roo	107.4936	0.6697	14.6937	0.8219	6.5830	0.7801	0.7572
San Luis Potosí	57.2026	0.2257	17.9316	0.5364	9.9245	0.5889	0.4503
Sinaloa	55.1135	0.2073	15.9636	0.7099	6.4243	0.7892	0.5688
Sonora	85.4365	0.4750	14.1433	0.8705	3.7329	0.9432	0.7629
Tabasco	47.6332	0.1412	18.2200	0.5109	8.5688	0.6665	0.4395
Tamaulipas	83.0564	0.4539	13.9409	0.8883	4.5194	0.8982	0.7468
Tlaxcala	37.3448	0.0504	17.9318	0.5363	6.6836	0.7744	0.4537
Veracruz Ignacio de	44.2058	0.1110	20.3891	0.3196	13.4212	0.3887	0.2731
Yucatán	59.1338	0.2428	17.1381	0.6064	10.8948	0.5333	0.4608
Zacatecas	39.6675	0.0709	19.1029	0.4331	7.1966	0.7450	0.4163
2.5 Percentile	**32.3234**		**12.6749**		**2.7409**		**0.0235**
97.5 Percentile	**144.9135**		**24.0130**		**20.2137**		**0.9712**

Estado	U1	U1 Normalised Xmin=0.9685, Xmax=3.9216	U2	U2 Normalised Xmin=0.0089 , Xmax=.3644	U3	U3 Normalised Xmin=1.0948 , Xmax=38.5350	WPI component score
Aguascalientes	1.7716	0.2720	0.0540	0.1270	21.8000	0.5530	0.3173
Baja California	1.4546	0.1646	0.0320	0.0649	12.6192	0.3078	0.1791
Baja California Sur	1.8600	0.3019	0.0257	0.0474	7.8333	0.1800	0.1764
Campeche	2.6537	0.5707	0.0052	0.0000	33.4519	0.8642	0.4783
Chiapas	0.9770	0.0029	0.1132	0.2933	11.4278	0.2760	0.1907
Chihuahua	2.3640	0.4725	0.0639	0.1547	34.5000	0.8922	0.5065
Coahuila de Zaragoza	1.1870	0.0740	0.0298	0.0589	13.3684	0.3278	0.1536
Colima	1.7469	0.2636	0.0691	0.1694	13.1600	0.3223	0.2518
Distrito Federal	2.0491	0.3659	0.6000	1.0000	5.7643	0.1247	0.4969
Durango	1.6481	0.2301	0.1231	0.3213	25.4333	0.6501	0.4005
Guanajuato	1.9462	0.3311	0.0495	0.1141	25.8571	0.6614	0.3689
Guerrero	1.5140	0.1847	0.2959	0.8074	52.4333	1.0000	0.6640
Hidalgo	1.1610	0.0652	0.0536	0.1257	15.2393	0.3778	0.1896
Jalisco	1.7199	0.2544	0.0716	0.1764	8.1278	0.1878	0.2062
México	1.5283	0.1896	0.0416	0.0921	5.9947	0.1309	0.1375
Michoacan de Ocamp	1.1335	0.0559	0.1129	0.2925	7.4321	0.1693	0.1725
Morelos	2.5883	0.5485	0.0526	0.1230	6.6750	0.1490	0.2735
Nayarit	1.8055	0.2834	0.0987	0.2527	5.0915	0.1067	0.2143
Nuevo León	1.9476	0.3316	0.0099	0.0029	9.6325	0.2280	0.1875
Oaxaca	0.9394	0.0000	0.0899	0.2277	7.3667	0.1675	0.1317
Puebla	1.1423	0.0589	0.0553	0.1304	7.3761	0.1678	0.1190
Querétaro Arteaga	2.8951	0.6524	0.0415	0.0917	5.9533	0.1298	0.2913
Quintana Roo	1.2146	0.0834	0.0351	0.0738	0.2643	0.0000	0.0524
San Luis Potosí	1.1506	0.0617	0.0482	0.1106	16.5955	0.4140	0.1954
Sinaloa	3.2005	0.7558	0.1445	0.3815	33.4400	0.8639	0.6671
Sonora	6.4055	1.0000	0.0828	0.2079	33.0818	0.8543	0.6874
Tabasco	1.4935	0.1778	0.0438	0.0982	4.4497	0.0896	0.1219
Tamaulipas	1.6840	0.2423	0.0398	0.0870	13.9741	0.3440	0.2244
Tlaxcala	1.2690	0.1018	0.0650	0.1577	4.7588	0.0979	0.1191
Veracruz Ignacio de la	1.3006	0.1125	0.0980	0.2506	1.3359	0.0064	0.1232
Yucatán	2.1568	0.4024	0.0507	0.1177	7.9806	0.1839	0.2347
Zacatecas	1.3457	0.1277	0.1081	0.2792	22.1000	0.5610	0.3226
2.5 Percentile	**0.9685**		**0.0089**		**1.0948**		**0.1040**
97.5 Percentile	**3.9216**		**0.3644**		**38.5350**		**0.6716**

Estado	E1	E1 Normalised Xmin=27.2383, Xmax=94.4960	E2	E2 Normalised Xmin=45.0500, Xmax=100	E3	E3 Normalised Xmin=.7840, Xmax=.9764	WPI component score
Aguascalientes	49.2100	0.3267	79.8100	0.63258	0.9753	0.9945	0.6513
Baja California	94.1000	0.9941	86.6700	0.75742	0.9349	0.7844	0.8453
Baja California Sur	95.8600	1.0000	86.6700	0.75742	0.9469	0.8468	0.8681
Campeche	58.1000	0.4589	99.4327	0.98968	0.8168	0.1704	0.5396
Chiapas	48.9200	0.3224	93.7600	0.88644	0.9001	0.6034	0.6041
Chihuahua	33.7200	0.0964	82.7146	0.68543	0.8461	0.3225	0.3681
Coahuila de Zaragoza	79.6600	0.7794	87.9182	0.78013	0.8242	0.2090	0.5895
Colima	47.7200	0.3045	79.8100	0.63258	0.9143	0.6772	0.5381
Distrito Federal	72.8800	0.6786	28.0000	0.00000	0.9800	1.0000	0.5595
Durango	40.1000	0.1912	97.6715	0.95763	0.7848	0.0042	0.3843
Guanajuato	38.6500	0.1697	81.7252	0.66743	0.8899	0.5505	0.4625
Guerrero	51.7300	0.3641	84.8033	0.72345	0.8329	0.2541	0.4472
Hidalgo	57.9200	0.4562	64.7524	0.35855	0.7810	0.0000	0.2716
Jalisco	48.1403	0.3108	79.6165	0.62905	0.9136	0.6736	0.5378
México	43.0590	0.2352	55.3054	0.18663	0.8657	0.4246	0.2822
Michoacan de Ocamp	46.5197	0.2867	77.4206	0.58909	0.7982	0.0740	0.3166
Morelos	48.8282	0.3210	73.8100	0.52338	0.8492	0.3390	0.3945
Nayarit	59.8555	0.4850	85.2140	0.73092	0.8177	0.1753	0.4637
Nuevo León	60.4079	0.4932	86.3012	0.75070	0.9273	0.7450	0.6630
Oaxaca	58.5756	0.4659	93.5237	0.88214	0.7881	0.0215	0.4565
Puebla	56.2626	0.4315	80.5247	0.64558	0.8976	0.5907	0.5559
Querétaro Arteaga	60.3733	0.4927	93.5144	0.88197	0.9275	0.7459	0.7068
Quintana Roo	68.9490	0.6202	100.0000	1.00000	0.8723	0.4590	0.6931
San Luis Potosí	62.7036	0.5273	98.4048	0.97097	0.8524	0.3555	0.6179
Sinaloa	51.4971	0.3607	95.2500	0.91356	0.9180	0.6964	0.6569
Sonora	73.4962	0.6878	50.0000	0.09008	0.8399	0.2907	0.3562
Tabasco	32.3782	0.0764	93.7600	0.88644	0.8181	0.1772	0.3800
Tamaulipas	47.1103	0.2955	94.7628	0.90469	0.8511	0.3489	0.5164
Tlaxcala	28.4083	0.0174	70.7560	0.46781	0.9427	0.8250	0.4367
Veracruz Ignacio de la	40.1412	0.1918	90.8061	0.83269	0.8058	0.1134	0.3793
Yucatán	23.2081	0.0000	100.0000	1.00000	0.8903	0.5524	0.5175
Zacatecas	57.9924	0.4573	89.3931	0.80697	0.8281	0.2291	0.4978
2.5 Percentile	**27.2383**		**45.0500**		**0.7840**		**0.2798**
97.5 Percentile	**94.4960**		**100.0000**		**0.9764**		**0.8504**

Code	Description	Level
R1	Ratio of total water withdrawals to available fresh water resources	RHA
R2	% of treated residual waters compared to total water consumed	State
A1	% of occupied h/h with access to sanitation	Household
A2	% occupied h/h with access to piped water supply	Household
C1	GDP per capita; proporationately scaled; Xmax = 187.50; Xmin = 28.57	State
C2	Under-1 mortality rate (inverse)	Household
C3	% of population over-15 that is literate	Household
U1	Public consumption as a ratio of BWR of 165l/cap/day	State
U2	Agricultural consumption as a ratio of Agricultural GDP	State
U3	Industrial consumption as a ratio of industrial GDP	State
E1	% of total land area free from any form of soil degradation	State
E2	Water quality (% of test results for surface waters obtaining excellent, good or acceptable 2006	RHA
E3	Ratio of urban waste collected to urban waste generated 2006	State

APPENDIX D WPI RESULTS MICRO SCALE

Household	Resources	Access	Capacity	Use	Environmen	WPI	Individual Ranking	Joint Ranking
M01	0.623	0.640	0.390	0.469	0.266	0.478	22	24
M02	0.540	0.512	0.460	0.198	0.516	0.445	18	19
M03	0.662	0.506	0.600	0.561	0.266	0.519	33	39
M05	0.712	0.579	0.553	0.519	0.266	0.526	35	42
M06	0.459	0.579	0.407	0.524	0.141	0.422	12	13
M10	0.378	0.551	0.453	0.130	0.141	0.331	1	1
M11	0.463	0.551	0.638	0.592	0.516	0.552	38	57
M13	0.487	0.484	0.450	0.064	0.591	0.415	10	11
M14	0.478	0.506	0.555	0.130	0.466	0.427	15	16
M15	0.580	0.640	0.555	0.161	0.466	0.481	23	25
M16	0.793	0.566	0.470	0.150	0.341	0.464	20	21
M18	0.718	0.506	0.400	0.534	0.341	0.500	31	34
M19	0.400	0.467	0.720	0.325	0.216	0.426	14	15
M20	0.434	0.596	0.400	0.673	0.341	0.489	27	30
M21	0.362	0.423	0.450	0.256	0.341	0.366	4	4
M22	0.570	0.506	0.473	0.381	0.499	0.486	26	29
M25	0.460	0.512	0.430	0.282	0.249	0.387	6	6
M26	0.497	0.429	0.338	0.812	0.499	0.515	32	37
M27	0.403	0.535	0.567	0.159	0.374	0.408	9	9
M28	0.573	0.667	0.470	0.633	0.749	0.618	45	83
M30	0.628	0.579	0.400	0.959	0.499	0.613	44	82
M33	0.525	0.417	0.438	0.191	0.624	0.439	17	18
M34	0.444	0.482	0.644	0.121	0.249	0.388	7	7
M36	0.515	0.618	0.484	0.228	0.249	0.419	11	12
M38	0.450	0.506	0.570	0.458	0.499	0.497	30	33
M39	0.557	0.596	0.494	0.265	0.499	0.482	24	26
M43	0.459	0.596	0.460	0.500	0.249	0.453	19	20
M45	0.534	0.596	0.550	0.172	0.624	0.495	29	32
M46	0.406	0.566	0.450	1.000	0.624	0.609	42	80
M47	0.528	0.596	0.435	0.633	0.499	0.538	36	49
M48	0.629	0.551	0.500	0.660	0.499	0.568	41	67
M50	0.602	0.506	0.658	0.796	0.499	0.612	43	81
M53	0.626	0.506	0.527	0.185	0.499	0.469	21	22
M54	0.562	0.551	0.574	0.278	0.499	0.493	28	31
M56	0.427	0.417	0.493	0.184	0.249	0.354	3	3
M57	0.828	0.551	0.442	0.410	0.499	0.546	37	54
M58	0.603	0.596	0.534	0.387	0.499	0.524	34	40
M61	0.657	0.551	0.520	0.837	0.242	0.561	39	64
M62	0.579	0.596	0.550	0.036	0.266	0.405	8	8
M68	0.506	0.581	0.542	0.331	0.466	0.485	25	28
M69	0.680	0.618	0.550	0.469	0.500	0.564	40	66
M70	0.522	0.512	0.460	0.215	0.000	0.342	2	2
M73	0.533	0.378	0.448	0.289	0.250	0.379	5	5
M74	0.406	0.573	0.382	0.529	0.250	0.428	16	17
M77	0.402	0.596	0.543	0.334	0.249	0.424	13	14
P001	0.609	1.000	0.555	0.126	0.750	0.608	38	79
P002	0.776	0.884	0.434	0.138	0.625	0.571	27	68
P003	0.586	0.909	0.530	0.120	0.500	0.529	8	43
P004	0.693	0.750	0.600	0.256	0.625	0.585	33	74
P005	0.717	1.000	0.516	0.147	0.500	0.576	30	71
P006	0.752	1.000	0.605	0.025	0.500	0.577	31	72
P007	0.586	0.825	0.516	0.257	0.500	0.537	12	47
P008	0.586	0.929	0.554	0.055	0.499	0.525	7	41
P009	0.586	0.868	0.530	0.079	0.499	0.512	5	36
P010	0.669	1.000	0.590	0.129	0.499	0.578	32	73
P011	0.776	1.000	0.553	0.147	0.744	0.644	42	87
P012	0.609	0.506	0.520	0.448	0.624	0.542	15	51
P013	0.693	0.974	0.586	0.405	0.623	0.656	43	88
P014	0.609	1.000	0.621	0.295	0.625	0.630	40	85
P015	0.645	1.000	0.705	0.028	0.500	0.576	29	70
P016	0.478	1.000	0.740	0.095	0.499	0.563	26	65
P018	0.562	1.000	0.521	0.126	0.498	0.541	14	50
P019	0.645	0.929	0.515	0.079	0.499	0.533	10	45
P020	0.431	0.750	0.470	0.137	0.624	0.482	3	27
P021	0.609	1.000	0.470	0.161	0.625	0.573	28	69
P022	0.514	0.951	0.553	0.161	0.499	0.536	11	46
P023	0.562	0.634	0.416	0.052	0.374	0.408	1	10
P024	0.562	1.000	0.656	0.161	0.402	0.556	22	60
P025	0.478	1.000	0.540	0.288	0.623	0.586	34	75
P026	0.669	1.000	0.516	0.638	0.374	0.639	41	86

Household	Resources	Access	Capacity	Use	Environmen	WPI	Individual Ranking	Joint Ranking
P027	0.586	1.000	0.590	0.161	0.374	0.542	16	52
P028	0.609	1.000	0.592	0.257	0.499	0.592	35	76
P029	0.455	0.839	0.540	0.051	0.499	0.477	2	23
P030	0.538	1.000	0.740	0.120	0.624	0.605	36	77
P031	0.478	1.000	0.563	0.022	0.624	0.538	13	48
P032	0.514	1.000	0.436	0.077	0.624	0.530	9	44
P034	0.562	1.000	0.520	0.081	0.624	0.558	23	61
P035	0.645	1.000	0.382	0.208	0.499	0.547	18	55
P036	0.776	1.000	0.510	0.120	0.624	0.606	37	78
P037	0.514	1.000	0.486	0.155	0.624	0.556	21	59
P038	0.514	1.000	0.747	0.126	0.374	0.552	20	58
P039	0.502	1.000	0.470	0.028	0.499	0.500	4	35
P040	0.562	1.000	0.642	0.148	0.374	0.545	17	53
P041	0.538	0.974	0.690	0.104	0.499	0.561	25	63
P042	0.431	1.000	0.558	0.131	0.624	0.549	19	56
P043	0.586	1.000	0.726	0.066	0.749	0.625	39	84
P044	0.514	1.000	0.545	0.017	0.499	0.515	6	38
P045	0.562	1.000	0.572	0.045	0.624	0.561	24	62
P046	0.728	1.000	0.620	0.434	0.499	0.656	44	89
.5 Percentil	**0.544**	**0.50639**	**0.394**	**0.212**	**0.266**	**0.447**		
7.5 Percenti	**0.776**	**1.00000**	**0.738**	**0.835**	**0.732**	**0.638**		

HH	Resources	Access	Capacity	Use	Environmen	WPI	HWFreq	Diarrea	WRIllness
M10	0.378	0.551	0.453	0.130	0.141	0.331	1.000	0.500	1.000
M70	0.522	0.512	0.460	0.215	0.000	0.342	0.000	0.500	0.500
M56	0.427	0.417	0.493	0.184	0.249	0.354	1.000	0.500	1.000
M21	0.362	0.423	0.450	0.256	0.341	0.366	1.000	0.500	1.000
M73	0.533	0.378	0.448	0.289	0.250	0.379	1.000	0.500	0.500
M25	0.460	0.512	0.430	0.282	0.249	0.387	0.500	0.500	0.500
M34	0.444	0.482	0.644	0.121	0.249	0.388	0.500	0.500	1.000
M62	0.579	0.596	0.550	0.036	0.266	0.405	0.500	0.500	1.000
M27	0.403	0.535	0.567	0.159	0.374	0.408	1.000	1.000	1.000
P023	0.562	0.634	0.416	0.052	0.374	0.408	0.500	0.000	0.500
M13	0.495	0.484	0.450	0.064	0.591	0.417	0.500	0.500	1.000
M36	0.515	0.618	0.484	0.228	0.249	0.419	0.000	0.500	1.000
M06	0.459	0.579	0.407	0.524	0.141	0.422	1.000	0.500	0.500
M77	0.402	0.596	0.543	0.334	0.249	0.424	0.500	0.500	1.000
M19	0.400	0.467	0.720	0.325	0.216	0.426	0.500	1.000	1.000
M14	0.478	0.506	0.555	0.130	0.466	0.427	1.000	0.500	1.000
M74	0.406	0.573	0.382	0.529	0.250	0.428	0.500	0.500	0.500
M33	0.525	0.417	0.438	0.191	0.624	0.439	0.500	1.000	1.000
M02	0.540	0.512	0.460	0.198	0.516	0.445	1.000	0.500	1.000
M43	0.459	0.596	0.460	0.500	0.249	0.453	1.000	0.500	1.000
M16	0.793	0.566	0.470	0.150	0.341	0.464	0.500	0.500	1.000
M53	0.626	0.506	0.527	0.185	0.499	0.469	1.000	0.500	1.000
P029	0.455	0.839	0.540	0.051	0.499	0.477	0.000	0.500	1.000
M01	0.623	0.640	0.390	0.469	0.266	0.478	0.500	0.500	0.500
M15	0.580	0.640	0.555	0.161	0.466	0.481	0.500	0.500	1.000
M39	0.557	0.596	0.494	0.265	0.499	0.482	1.000	0.500	1.000
P020	0.431	0.750	0.470	0.137	0.624	0.482	1.000	0.500	1.000
M68	0.506	0.581	0.542	0.331	0.466	0.485	1.000	0.500	1.000
M22	0.570	0.506	0.473	0.381	0.499	0.486	1.000	0.500	1.000
M20	0.434	0.596	0.400	0.673	0.341	0.489	1.000	0.500	1.000
M54	0.562	0.551	0.574	0.278	0.499	0.493	0.000	0.500	1.000
M45	0.534	0.596	0.550	0.172	0.624	0.495	1.000	0.500	1.000
M38	0.450	0.506	0.570	0.458	0.499	0.497	1.000	0.500	1.000
M18	0.718	0.506	0.400	0.534	0.341	0.500	0.000	0.500	1.000
P039	0.502	1.000	0.470	0.028	0.499	0.500	0.500	0.500	0.500
P009	0.586	0.868	0.530	0.079	0.499	0.512	1.000	0.500	1.000
M26	0.497	0.429	0.338	0.812	0.499	0.515	1.000	0.500	0.000
P044	0.514	1.000	0.545	0.017	0.499	0.515	1.000	0.500	0.500
M03	0.662	0.506	0.600	0.561	0.266	0.519	1.000	1.000	1.000
M58	0.603	0.596	0.534	0.387	0.499	0.524	0.500	1.000	1.000
P008	0.586	0.929	0.554	0.055	0.499	0.525	1.000	0.500	1.000
M05	0.712	0.579	0.553	0.519	0.266	0.526	0.500	0.500	1.000
P003	0.586	0.909	0.530	0.120	0.500	0.529	0.500	1.000	1.000
P032	0.514	1.000	0.436	0.077	0.624	0.530	1.000	0.500	0.500
P019	0.645	0.929	0.515	0.079	0.499	0.533	1.000	0.500	1.000
P022	0.514	0.951	0.553	0.161	0.499	0.536	0.000	0.500	1.000
P007	0.586	0.825	0.516	0.257	0.500	0.537	0.500	1.000	1.000
P031	0.478	1.000	0.563	0.022	0.624	0.538	1.000	0.500	1.000
M47	0.528	0.596	0.435	0.633	0.499	0.538	0.500	0.500	1.000
P018	0.562	1.000	0.521	0.126	0.498	0.541	1.000	1.000	0.500
P012	0.609	0.506	0.520	0.448	0.624	0.542	1.000	0.000	0.500
P027	0.586	1.000	0.590	0.161	0.374	0.542	1.000	0.500	1.000
P040	0.562	1.000	0.642	0.148	0.374	0.545	0.500	0.500	1.000
M57	0.828	0.551	0.442	0.410	0.499	0.546	1.000	1.000	1.000
P035	0.645	1.000	0.382	0.208	0.499	0.547	0.500	0.500	0.500
P042	0.431	1.000	0.558	0.131	0.624	0.549	1.000	0.500	1.000
M11	0.463	0.551	0.638	0.592	0.516	0.552	1.000	1.000	1.000
P038	0.514	1.000	0.747	0.126	0.374	0.552	1.000	0.500	1.000
P037	0.514	1.000	0.486	0.155	0.624	0.556	0.500	0.500	0.500
P024	0.562	1.000	0.656	0.161	0.402	0.556	0.500	1.000	1.000
P034	0.562	1.000	0.520	0.081	0.624	0.558	0.500	0.500	0.500
P045	0.562	1.000	0.572	0.045	0.624	0.561	1.000	0.500	1.000
P041	0.538	0.974	0.690	0.104	0.499	0.561	1.000	0.000	1.000
M61	0.657	0.551	0.520	0.837	0.242	0.561	1.000	0.000	1.000
P016	0.478	1.000	0.740	0.095	0.499	0.563	0.500	0.500	1.000
M69	0.680	0.618	0.550	0.469	0.500	0.564	1.000	0.000	1.000
M48	0.629	0.551	0.500	0.660	0.499	0.568	1.000	0.500	1.000
P002	0.776	0.884	0.434	0.138	0.625	0.571	0.500	1.000	0.500
P021	0.609	1.000	0.470	0.161	0.625	0.573	0.500	1.000	1.000
P015	0.645	1.000	0.705	0.028	0.500	0.576	0.500	0.000	1.000
P005	0.717	1.000	0.516	0.147	0.500	0.576	0.000	1.000	1.000
P006	0.752	1.000	0.605	0.025	0.500	0.577	0.500	1.000	1.000
P010	0.669	1.000	0.590	0.129	0.499	0.578	0.500	0.500	0.500
P004	0.693	0.750	0.600	0.256	0.625	0.585	0.500	0.500	1.000
P025	0.478	1.000	0.540	0.288	0.623	0.586	0.500	0.500	0.500
P028	0.609	1.000	0.592	0.257	0.499	0.592	0.500	0.500	1.000
P030	0.538	1.000	0.740	0.120	0.624	0.605	0.500	0.500	1.000
P036	0.776	1.000	0.510	0.120	0.624	0.606	0.500	0.500	1.000
P001	0.609	1.000	0.555	0.126	0.750	0.608	0.500	1.000	1.000

HH	Resources	Access	Capacity	Use	Environmen	WPI	HWFreq	Diarrea	WRIllness
M46	0.406	0.566	0.450	1.000	0.624	0.609	1.000	0.500	1.000
M50	0.602	0.506	0.658	0.796	0.499	0.612	0.500	0.500	1.000
M30	0.628	0.579	0.400	0.959	0.499	0.613	1.000	0.500	1.000
M28	0.573	0.667	0.470	0.633	0.749	0.618	1.000	0.500	1.000
P043	0.586	1.000	0.726	0.066	0.749	0.625	1.000	0.000	1.000
P014	0.609	1.000	0.621	0.295	0.625	0.630	1.000	0.000	1.000
P026	0.669	1.000	0.516	0.638	0.374	0.639	0.000	0.500	0.000
P011	0.776	1.000	0.553	0.147	0.744	0.644	1.000	1.000	1.000
P013	0.693	0.974	0.586	0.405	0.623	0.656	1.000	0.500	1.000
P046	0.728	1.000	0.620	0.434	0.499	0.656	1.000	0.500	1.000
2.5 Percent	**0.434**	**0.511**	**0.403**	**0.025**	**0.374**	**0.536**			
97.5 Percer	**0.776**	**1.000**	**0.740**	**0.947**	**0.749**	**0.655**			

Household	R1	R1: Normalised Xmin=0, Xmax=1	R2	R2: Normalised Xmin=4.40, Xmax=93.333	R3	R3: Normalised Xmin=8.3, Xmax=100	R4	R4: Normalised Xmin=0, Xmax=7	R5	R5: Normalised Xmin=0, Xmax=2	R6	R6: Normalised Xmin=0, Xmax=2
P001	1.000	1.000	60.000	0.625	12	0.960	4	0.571	0	0.000	1	0.500
P002	1.000	1.000	60.000	0.625	12	0.960	4	0.571	2	1.000	1	0.500
P003	1.000	1.000	60.000	0.625	12	0.960	3	0.429	1	0.500	0	0.000
P004	1.000	1.000	60.000	0.625	12	0.960	4	0.571	1	0.500	1	0.500
P005	1.000	1.000	60.000	0.625	12	0.960	5	0.714	2	1.000	0	0.000
P006	1.000	1.000	60.000	0.625	12	0.960	3	0.429	2	1.000	1	0.500
P007	1.000	1.000	60.000	0.625	12	0.960	3	0.429	1	0.500	0	0.000
P008	1.000	1.000	60.000	0.625	12	0.960	3	0.429	1	0.500	0	0.000
P009	1.000	1.000	60.000	0.625	12	0.960	3	0.429	1	0.500	0	0.000
P010	1.000	1.000	60.000	0.625	12	0.960	3	0.429	2	1.000	0	0.000
P011	1.000	1.000	60.000	0.625	12	0.960	4	0.571	2	1.000	1	0.500
P012	1.000	1.000	60.000	0.625	12	0.960	4	0.571	1	0.500	0	0.000
P013	1.000	1.000	60.000	0.625	12	0.960	4	0.571	2	1.000	0	0.000
P014	1.000	1.000	60.000	0.625	12	0.960	4	0.571	0	0.000	1	0.500
P015	1.000	1.000	60.000	0.625	12	0.960	2	0.286	0	0.000	2	1.000
P016	1.000	1.000	60.000	0.625	12	0.960	2	0.286	0	0.000	0	0.000
P018	1.000	1.000	60.000	0.625	12	0.960	2	0.286	0	0.000	1	0.500
P019	1.000	1.000	60.000	0.625	12	0.960	2	0.286	2	1.000	0	0.000
P020	1.000	1.000	60.000	0.625	12	0.960	0	0.000	0	0.000	0	0.000
P021	1.000	1.000	60.000	0.625	12	0.960	4	0.571	0	0.000	1	0.500
P022	1.000	1.000	60.000	0.625	12	0.960	0	0.000	0	0.000	1	0.500
P023	1.000	1.000	60.000	0.625	12	0.960	2	0.286	0	0.000	1	0.500
P024	1.000	1.000	60.000	0.625	12	0.960	2	0.286	0	0.000	1	0.500
P025	1.000	1.000	60.000	0.625	12	0.960	2	0.286	0	0.000	0	0.000
P026	1.000	1.000	60.000	0.625	12	0.960	3	0.429	0	0.000	2	1.000
P027	1.000	1.000	60.000	0.625	12	0.960	3	0.429	0	0.000	1	0.500
P028	1.000	1.000	60.000	0.625	12	0.960	4	0.571	0	0.000	1	0.500
P029	1.000	1.000	60.000	0.625	12	0.960	1	0.143	0	0.000	0	0.000
P030	1.000	1.000	60.000	0.625	12	0.960	1	0.143	0	0.000	1	0.500
P031	1.000	1.000	60.000	0.625	12	0.960	2	0.286	0	0.000	0	0.000
P032	1.000	1.000	60.000	0.625	12	0.960	0	0.000	0	0.000	1	0.500
P034	1.000	1.000	60.000	0.625	12	0.960	2	0.286	0	0.000	1	0.500
P035	1.000	1.000	60.000	0.625	12	0.960	2	0.286	0	0.000	2	1.000
P036	1.000	1.000	60.000	0.625	12	0.960	4	0.571	2	1.000	1	0.500
P037	1.000	1.000	60.000	0.625	12	0.960	0	0.000	0	0.000	1	0.500
P038	1.000	1.000	60.000	0.625	12	0.960	0	0.000	0	0.000	1	0.500
P039	1.000	1.000	60.000	0.625	12	0.960	3	0.429	0	0.000	0	0.000
P040	1.000	1.000	60.000	0.625	12	0.960	2	0.286	0	0.000	1	0.500
P041	1.000	1.000	60.000	0.625	12	0.960	1	0.143	0	0.000	1	0.500
P042	1.000	1.000	60.000	0.625	12	0.960	0	0.000	0	0.000	0	0.000
P043	1.000	1.000	60.000	0.625	12	0.960	3	0.429	1	0.500	0	0.000
P044	1.000	1.000	60.000	0.625	12	0.960	0	0.000	0	0.000	1	0.500
P045	1.000	1.000	60.000	0.625	12	0.960	2	0.286	0	0.000	1	0.500
P046	1.000	1.000	60.000	0.625	12	0.960	2	0.286	1	0.500	2	1.000
M01	1.000	1.000	60.000	0.625	11	0.971	1	0.143	2	1.000	0	0.000
M02	1.000	1.000	60.000	0.625	11	0.971	1	0.143	0	0.000	1	0.500
M03	1.000	1.000	100.000	1.000	11	0.971	0	0.000	0	0.000	2	1.000
M05	1.000	1.000	50.000	0.513	11	0.971	2	0.286	2	1.000	1	0.500
M06	1.000	1.000	4.400	0.000	11	0.971	2	0.286	0	0.000	1	0.500

Household	R1	R1: Normalised Xmin=0, Xmax=1	R2	R2: Normalised Xmin=4.40, Xmax=93.333	R3	R3: Normalised Xmin=8.3, Xmax=100	R4	R4: Normalised Xmin=0, Xmax=7	R5	R5: Normalised Xmin=0, Xmax=2	R6	R6: Normalised Xmin=0, Xmax=2
M10	1.000	1.000	30.875	0.298	11	0.971	0	0.000	0	0.000	0	0.000
M11	1.000	1.000	31.714	0.307	11	0.971	0	0.000	0	0.000	1	0.500
M13	1.000	1.000	0.000	0.000	11	0.971	0	0.000	0	0.000	2	1.000
M14	1.000	1.000	33.333	0.325	11	0.971	4	0.571	0	0.000	0	0.000
M15	1.000	1.000	5.500	0.012	11	0.971	0	0.000	1	0.500	2	1.000
M16	1.000	1.000	100.000	1.000	11	0.971	2	0.286	1	0.500	2	1.000
M18	1.000	1.000	40.667	0.408	11	0.971	3	0.429	1	0.500	2	1.000
M19	1.000	1.000	42.857	0.432	11	0.971	0	0.000	0	0.000	0	0.000
M20	1.000	1.000	61.000	0.636	11	0.971	0	0.000	0	0.000	0	0.000
M21	1.000	1.000	22.222	0.200	11	0.971	0	0.000	0	0.000	0	0.000
M22	1.000	1.000	44.444	0.450	11	0.971	0	0.000	1	0.500	1	0.500
M25	1.000	1.000	30.000	0.288	11	0.971	0	0.000	0	0.000	1	0.500
M26	1.000	1.000	50.000	0.513	11	0.971	0	0.000	0	0.000	1	0.500
M27	1.000	1.000	44.400	0.450	11	0.971	0	0.000	0	0.000	0	0.000
M28	1.000	1.000	33.333	0.325	11	0.971	1	0.143	0	0.000	2	1.000
M30	1.000	1.000	50.000	0.513	11	0.971	2	0.286	0	0.000	2	1.000
M33	1.000	1.000	20.182	0.177	11	0.971	0	0.000	0	0.000	2	1.000
M34	1.000	1.000	53.200	0.549	11	0.971	1	0.143	0	0.000	0	0.000
M36	1.000	1.000	14.800	0.117	11	0.971	0	0.000	0	0.000	2	1.000
M38	1.000	1.000	24.667	0.228	11	0.971	0	0.000	0	0.000	1	0.500
M39	1.000	1.000	24.667	0.228	11	0.971	1	0.143	0	0.000	2	1.000
M43	1.000	1.000	0.000	0.000	11	0.971	2	0.286	0	0.000	1	0.500
M45	1.000	1.000	44.400	0.450	11	0.971	2	0.286	0	0.000	1	0.500
M46	1.000	1.000	33.333	0.325	11	0.971	1	0.143	0	0.000	0	0.000
M47	1.000	1.000	66.667	0.700	11	0.971	0	0.000	0	0.000	1	0.500
M48	1.000	1.000	25.000	0.232	11	0.971	4	0.571	0	0.000	2	1.000
M50	1.000	1.000	155.500	1.000	11	0.971	1	0.143	0	0.000	1	0.500
M53	1.000	1.000	36.364	0.359	11	0.971	3	0.429	0	0.000	2	1.000
M54	1.000	1.000	40.000	0.400	11	0.971	0	0.000	0	0.000	2	1.000
M56	1.000	1.000	12.500	0.091	11	0.971	0	0.000	0	0.000	1	0.500
M57	1.000	1.000	4.400	0.000	11	0.971	7	1.000	2	1.000	2	1.000
M58	1.000	1.000	49.400	0.506	11	0.971	1	0.143	0	0.000	2	1.000
M61	1.000	1.000	40.000	0.400	11	0.971	4	0.571	0	0.000	2	1.000
M62	1.000	1.000	36.364	0.359	11	0.971	1	0.143	0	0.000	2	1.000
M68	1.000	1.000	42.200	0.425	11	0.971	1	0.143	0	0.000	1	0.500
M69	1.000	1.000	46.000	0.468	11	0.971	1	0.143	2	1.000	1	0.500
M70	1.000	1.000	63.429	0.664	11	0.971	0	0.000	0	0.000	1	0.500
M73	1.000	1.000	43.500	0.440	11	0.971	2	0.286	0	0.000	1	0.500
M74	1.000	1.000	33.294	0.325	11	0.971	1	0.143	0	0.000	0	0.000
M77	1.000	1.000	43.500	0.440	11	0.971	0	0.000	0	0.000	0	0.000
2.5 Percentile	**1.000**		**4.400**		**11.000**		**0.000**		**0.000**		**0.000**	
97.5 Percentile	**1.000**		**93.333**		**12.000**		**4.000**		**2.000**		**1.000**	

Household	A1	A1: Normalised Xmin=0, Xmax=1	A2	A2: Normalised Xmin=0, Xmax=1	A3	A3: Normalised Xmin=24.50, Xmax=360.00	A4	A4: Normalised Xmin=0, Xmax=3
P001	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000
P002	1.000	1.000	1.000	1.000	180.000	0.537	3.000	1.000
P003	1.000	1.000	1.000	1.000	147.000	0.635	3.000	1.000
P004	1.000	1.000	1.000	1.000	360.000	0.000	3.000	1.000
P005	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000
P006	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000
P007	1.000	1.000	1.000	1.000	147.000	0.635	2.000	0.667
P008	1.000	1.000	1.000	1.000	120.000	0.715	3.000	1.000
P009	1.000	1.000	1.000	1.000	90.000	0.805	2.000	0.667
P010	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000
P011	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000
P012	1.000	1.000	0.000	0.000	240.000	0.358	2.000	0.667
P013	1.000	1.000	1.000	1.000	60.000	0.894	3.000	1.000
P014	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000
P015	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000
P016	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000
P018	1.000	1.000	1.000	1.000	20.000	1.000	3.000	1.000
P019	1.000	1.000	1.000	1.000	120.000	0.715	3.000	1.000
P020	1.000	1.000	0.000	0.000	Not applicable	1.000	3.000	1.000
P021	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000
P022	1.000	1.000	1.000	1.000	90.000	0.805	3.000	1.000
P023	1.000	1.000	0.000	0.000	180.000	0.537	3.000	1.000
P024	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000
P025	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000
P026	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000
P027	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000
P028	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000
P029	1.000	1.000	1.000	1.000	240.000	0.358	3.000	1.000
P030	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000
P031	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000
P032	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000
P034	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000
P035	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000

Household	A1	A1: Normalised Xmin=0, Xmax=1	A2	A2: Normalised Xmin=0, Xmax=1	A3	A3: Normalised Xmin=24.50, Xmax=360.00	A4	A4: Normalised Xmin=0, Xmax=3
P036	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000
P037	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000
P038	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000
P039	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000
P040	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000
P041	1.000	1.000	1.000	1.000	60.000	0.894	3.000	1.000
P042	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000
P043	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000
P044	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000
P045	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000
P046	1.000	1.000	1.000	1.000	Not applicable	1.000	3.000	1.000
M01	0.000	0.000	1.000	1.000	60.000	0.894	2.000	0.667
M02	0.000	0.000	1.000	1.000	120.000	0.715	1.000	0.333
M03	0.000	0.000	1.000	1.000	240.000	0.358	2.000	0.667
M05	0.000	0.000	1.000	1.000	30.000	0.984	1.000	0.333
M06	0.000	0.000	1.000	1.000	30.000	0.984	1.000	0.333
M10	0.000	0.000	1.000	1.000	180.000	0.537	2.000	0.667
M11	0.000	0.000	1.000	1.000	180.000	0.537	2.000	0.667
M13	0.000	0.000	1.000	1.000	270.000	0.268	2.000	0.667
M14	0.000	0.000	1.000	1.000	240.000	0.358	2.000	0.667
M15	0.000	0.000	1.000	1.000	60.000	0.894	2.000	0.667
M16	0.000	0.000	1.000	1.000	160.000	0.596	2.000	0.667
M18	0.000	0.000	1.000	1.000	240.000	0.358	2.000	0.667
M19	0.000	0.000	1.000	1.000	180.000	0.537	1.000	0.333
M20	0.000	0.000	1.000	1.000	120.000	0.715	2.000	0.667
M21	0.000	0.000	1.000	1.000	240.000	0.358	1.000	0.333
M22	0.000	0.000	1.000	1.000	240.000	0.358	2.000	0.667
M25	0.000	0.000	1.000	1.000	120.000	0.715	1.000	0.333
M26	0.000	0.000	1.000	1.000	120.000	0.715	0.000	0.000
M27	0.000	0.000	1.000	1.000	90.000	0.805	1.000	0.333
M28	0.000	0.000	1.000	1.000	20.000	1.000	2.000	0.667
M30	0.000	0.000	1.000	1.000	30.000	0.984	1.000	0.333
M33	0.000	0.000	1.000	1.000	360.000	0.000	2.000	0.667

Household	A1	A1: Normalised Xmin=0, Xmax=1	A2	A2: Normalised Xmin=0, Xmax=1	A3	A3: Normalised Xmin=24.50, Xmax=360.00	A4	A4: Normalised Xmin=0, Xmax=3
M34	0.000	0.000	1.000	1.000	160.000	0.596	1.000	0.333
M36	0.000	0.000	1.000	1.000	90.000	0.805	2.000	0.667
M38	0.000	0.000	1.000	1.000	240.000	0.358	2.000	0.667
M39	0.000	0.000	1.000	1.000	120.000	0.715	2.000	0.667
M43	0.000	0.000	1.000	1.000	120.000	0.715	2.000	0.667
M45	0.000	0.000	1.000	1.000	120.000	0.715	2.000	0.667
M46	0.000	0.000	1.000	1.000	160.000	0.596	2.000	0.667
M47	0.000	0.000	1.000	1.000	120.000	0.715	2.000	0.667
M48	0.000	0.000	1.000	1.000	180.000	0.537	2.000	0.667
M50	0.000	0.000	1.000	1.000	240.000	0.358	2.000	0.667
M53	0.000	0.000	1.000	1.000	240.000	0.358	2.000	0.667
M54	0.000	0.000	1.000	1.000	180.000	0.537	2.000	0.667
M56	0.000	0.000	1.000	1.000	480.000	0.000	2.000	0.667
M57	0.000	0.000	1.000	1.000	180.000	0.537	2.000	0.667
M58	0.000	0.000	1.000	1.000	120.000	0.715	2.000	0.667
M61	0.000	0.000	1.000	1.000	180.000	0.537	2.000	0.667
M62	0.000	0.000	1.000	1.000	120.000	0.715	2.000	0.667
M68	0.000	0.000	1.000	1.000	140.000	0.656	2.000	0.667
M69	0.000	0.000	1.000	1.000	90.000	0.805	2.000	0.667
M70	0.000	0.000	1.000	1.000	120.000	0.715	1.000	0.333
M73	0.000	0.000	1.000	1.000	300.000	0.179	1.000	0.333
M74	0.000	0.000	1.000	1.000	150.000	0.626	2.000	0.667
M77	0.000	0.000	1.000	1.000	120.000	0.715	2.000	0.667
2.5 Percentile					**24.500**			
97.5 Percentile					**360.000**			

Household	C1	C1: Normalised Xmin=0, Xmax=200	C2	C2: Normalised Xmin=0, Xmax=95	C3	C2: Normalised Xmin=0.635, Xmax=0.692	C4	C4: Normalised Xmin=0, Xmax=2	C5	C5: Normalised Xmin=0.660, Xmax=0.884
P001	50.000	0.250	50.000	0.526	0.692	1.000	2.000	1.000	0.660	0.000
P002	55.000	0.275	37.500	0.395	0.692	1.000	1.000	0.500	0.660	0.000
P003	70.000	0.350	28.571	0.301	0.692	1.000	2.000	1.000	0.660	0.000
P004	116.000	0.580	40.000	0.421	0.692	1.000	2.000	1.000	0.660	0.000
P005	116.000	0.580	0.000	0.000	0.692	1.000	2.000	1.000	0.660	0.000
P006	100.000	0.500	50.000	0.526	0.692	1.000	2.000	1.000	0.660	0.000
P007	116.000	0.580	0.000	0.000	0.692	1.000	2.000	1.000	0.660	0.000
P008	116.000	0.580	18.182	0.191	0.692	1.000	2.000	1.000	0.660	0.000
P009	100.000	0.500	14.286	0.150	0.692	1.000	2.000	1.000	0.660	0.000
P010	150.000	0.750	66.667	0.702	0.692	1.000	1.000	0.500	0.660	0.000
P011	100.000	0.500	25.000	0.263	0.692	1.000	2.000	1.000	0.660	0.000
P012	80.000	0.400	66.667	0.702	0.692	1.000	1.000	0.500	0.660	0.000
P013	116.000	0.580	33.333	0.351	0.692	1.000	2.000	1.000	0.660	0.000
P014	116.000	0.580	50.000	0.526	0.692	1.000	2.000	1.000	0.660	0.000
P015	200.000	1.000	50.000	0.526	0.692	1.000	2.000	1.000	0.660	0.000
P016	200.000	1.000	66.667	0.702	0.692	1.000	2.000	1.000	0.660	0.000
P018	116.000	0.580	50.000	0.526	0.692	1.000	1.000	0.500	0.660	0.000
P019	80.000	0.400	16.667	0.175	0.692	1.000	2.000	1.000	0.660	0.000
P020	0.000	0.000	33.333	0.351	0.692	1.000	2.000	1.000	0.660	0.000
P021	0.000	0.000	33.333	0.351	0.692	1.000	2.000	1.000	0.660	0.000
P022	100.000	0.500	25.000	0.263	0.692	1.000	2.000	1.000	0.660	0.000
P023	116.000	0.580	0.000	0.000	0.692	1.000	1.000	0.500	0.660	0.000
P024	116.000	0.580	66.667	0.702	0.692	1.000	2.000	1.000	0.660	0.000
P025	120.000	0.600	57.143	0.602	0.692	1.000	1.000	0.500	0.660	0.000
P026	116.000	0.580	100.000	1.000	0.692	1.000	0.000	0.000	0.660	0.000
P027	50.000	0.250	66.667	0.702	0.692	1.000	2.000	1.000	0.660	0.000
P028	150.000	0.750	20.000	0.211	0.692	1.000	2.000	1.000	0.660	0.000
P029	80.000	0.400	28.571	0.301	0.692	1.000	2.000	1.000	0.660	0.000
P030	200.000	1.000	66.667	0.702	0.692	1.000	2.000	1.000	0.660	0.000
P031	116.000	0.580	22.222	0.234	0.692	1.000	2.000	1.000	0.660	0.000
P032	83.000	0.415	25.000	0.263	0.692	1.000	1.000	0.500	0.660	0.000
P034	80.000	0.400	66.667	0.702	0.692	1.000	1.000	0.500	0.660	0.000
P035	40.000	0.200	20.000	0.211	0.692	1.000	1.000	0.500	0.660	0.000
P036	40.000	0.200	33.333	0.351	0.692	1.000	2.000	1.000	0.660	0.000
P037	116.000	0.580	33.333	0.351	0.692	1.000	1.000	0.500	0.660	0.000
P038	320.000	1.000	70.000	0.737	0.692	1.000	2.000	1.000	0.660	0.000
P039	100.000	0.500	33.333	0.351	0.692	1.000	1.000	0.500	0.660	0.000
P040	116.000	0.580	60.000	0.632	0.692	1.000	2.000	1.000	0.660	0.000
P041	90.000	0.450	100.000	1.000	0.692	1.000	2.000	1.000	0.660	0.000
P042	116.000	0.580	20.000	0.211	0.692	1.000	2.000	1.000	0.660	0.000
P043	430.000	1.000	60.000	0.632	0.692	1.000	2.000	1.000	0.660	0.000

Household	C1	C1: Normalised Xmin=0, Xmax=200	C2	C2: Normalised Xmin=0, Xmax=95	C3	C2: Normalised Xmin=0.635, Xmax=0.692	C4	C4: Normalised Xmin=0, Xmax=2	C5	C5: Normalised Xmin=0.660, Xmax=0.884
P044	140.000	0.700	50.000	0.526	0.692	1.000	1.000	0.500	0.660	0.000
P045	130.000	0.650	20.000	0.211	0.692	1.000	2.000	1.000	0.660	0.000
P046	150.000	0.750	33.333	0.351	0.692	1.000	2.000	1.000	0.660	0.000
M01	90.000	0.450	0.000	0.000	0.635	0.000	1.000	0.500	0.844	1.000
M02	0.000	0.000	28.571	0.301	0.635	0.000	2.000	1.000	0.844	1.000
M03	0.000	0.000	100.000	1.000	0.635	0.000	2.000	1.000	0.844	1.000
M05	100.000	0.500	25.000	0.263	0.635	0.000	2.000	1.000	0.844	1.000
M06	65.000	0.325	20.000	0.211	0.635	0.000	1.000	0.500	0.844	1.000
M10	0.000	0.000	25.000	0.263	0.635	0.000	2.000	1.000	0.844	1.000
M11	178.000	0.890	28.571	0.301	0.635	0.000	2.000	1.000	0.844	1.000
M13	50.000	0.250	0.000	0.000	0.635	0.000	2.000	1.000	0.844	1.000
M14	50.000	0.250	50.000	0.526	0.635	0.000	2.000	1.000	0.844	1.000
M15	50.000	0.250	50.000	0.526	0.635	0.000	2.000	1.000	0.844	1.000
M16	0.000	0.000	33.333	0.351	0.635	0.000	2.000	1.000	0.844	1.000
M18	0.000	0.000	0.000	0.000	0.635	0.000	2.000	1.000	0.844	1.000
M19	170.000	0.850	71.429	0.752	0.635	0.000	2.000	1.000	0.844	1.000
M20	0.000	0.000	0.000	0.000	0.635	0.000	2.000	1.000	0.844	1.000
M21	50.000	0.250	0.000	0.000	0.635	0.000	2.000	1.000	0.844	1.000
M22	50.000	0.250	11.111	0.117	0.635	0.000	2.000	1.000	0.844	1.000
M25	25.000	0.125	50.000	0.526	0.635	0.000	1.000	0.500	0.844	1.000
M26	33.000	0.165	50.000	0.526	0.635	0.000	0.000	0.000	0.844	1.000
M27	125.000	0.625	20.000	0.211	0.635	0.000	2.000	1.000	0.844	1.000
M28	0.000	0.000	33.333	0.351	0.635	0.000	2.000	1.000	0.844	1.000
M30	0.000	0.000	0.000	0.000	0.635	0.000	2.000	1.000	0.844	1.000
M33	0.000	0.000	18.182	0.191	0.635	0.000	2.000	1.000	0.844	1.000
M34	160.000	0.800	40.000	0.421	0.635	0.000	2.000	1.000	0.844	1.000
M36	0.000	0.000	40.000	0.421	0.635	0.000	2.000	1.000	0.844	1.000
M38	100.000	0.500	33.333	0.351	0.635	0.000	2.000	1.000	0.844	1.000
M39	0.000	0.000	44.444	0.468	0.635	0.000	2.000	1.000	0.844	1.000
M43	60.000	0.300	0.000	0.000	0.635	0.000	2.000	1.000	0.844	1.000
M45	150.000	0.750	0.000	0.000	0.635	0.000	2.000	1.000	0.844	1.000
M46	50.000	0.250	0.000	0.000	0.635	0.000	2.000	1.000	0.844	1.000
M47	0.000	0.000	16.667	0.175	0.635	0.000	2.000	1.000	0.844	1.000
M48	100.000	0.500	0.000	0.000	0.635	0.000	2.000	1.000	0.844	1.000
M50	100.000	0.500	75.000	0.789	0.635	0.000	2.000	1.000	0.844	1.000
M53	50.000	0.250	36.364	0.383	0.635	0.000	2.000	1.000	0.844	1.000
M54	90.000	0.450	40.000	0.421	0.635	0.000	2.000	1.000	0.844	1.000
M56	40.000	0.200	25.000	0.263	0.635	0.000	2.000	1.000	0.844	1.000
M57	0.000	0.000	20.000	0.211	0.635	0.000	2.000	1.000	0.844	1.000
M58	50.000	0.250	40.000	0.421	0.635	0.000	2.000	1.000	0.844	1.000
M61	120.000	0.600	0.000	0.000	0.635	0.000	2.000	1.000	0.844	1.000

Household	C1	C1: Normalised Xmin=0, Xmax=200	C2	C2: Normalised Xmin=0, Xmax=95	C3	C2: Normalised Xmin=0.635, Xmax=0.692	C4	C4: Normalised Xmin=0, Xmax=2	C5	C5: Normalised Xmin=0.660, Xmax=0.884
M62	150.000	0.750	0.000	0.000	0.635	0.000	2.000	1.000	0.844	1.000
M68	100.000	0.500	20.000	0.211	0.635	0.000	2.000	1.000	0.844	1.000
M69	60.000	0.300	42.857	0.451	0.635	0.000	2.000	1.000	0.844	1.000
M70	100.000	0.500	28.571	0.301	0.635	0.000	1.000	0.500	0.844	1.000
M73	60.000	0.300	41.667	0.439	0.635	0.000	1.000	0.500	0.844	1.000
M74	45.000	0.225	17.647	0.186	0.635	0.000	1.000	0.500	0.844	1.000
M77	90.000	0.450	25.000	0.263	0.635	0.000	2.000	1.000	0.844	1.000
2.5 Percentile	**0.000**		**0.000**		**0.635**				**0.660**	
97.5 Percentile	**200.000**		**95.000**		**0.692**				**0.844**	

Household	U1	U1: Normalised Xmin=0.128, Xmax=1.6	U2	U2: Normalised Xmin=0.114, Xmax=3.333	U1 (not normalised)	U2 (not normalised)	Use	Amended WPI
P001	0.480	0.239	0.156	0.013	0.480	0.156	0.558	0.496
P002	0.480	0.239	0.233	0.037	0.480	0.233	0.597	0.525
P003	0.480	0.239	0.074	0.000	0.480	0.074	0.517	0.510
P004	0.800	0.457	0.292	0.055	0.800	0.292	0.946	0.611
P005	0.480	0.239	0.292	0.055	0.480	0.292	0.626	0.443
P006	0.200	0.049	0.119	0.001	0.200	0.119	0.259	0.356
P007	0.480	0.239	1.000	0.275	0.480	1.000	0.980	0.630
P008	0.200	0.049	0.313	0.062	0.200	0.313	0.356	0.474
P009	0.360	0.158	0.114	0.000	0.360	0.114	0.417	0.484
P010	0.480	0.239	0.177	0.020	0.480	0.177	0.569	0.562
P011	0.480	0.239	0.292	0.055	0.480	0.292	0.626	0.559
P012	0.520	0.266	2.143	0.630	0.520	1.000	1.000	0.593
P013	1.320	0.810	0.085	0.000	1.000	0.085	1.000	0.561
P014	0.800	0.457	0.542	0.133	0.800	0.542	1.000	0.554
P015	0.120	0.000	0.292	0.055	0.120	0.292	0.266	0.368
P016	0.280	0.103	0.393	0.087	0.280	0.393	0.476	0.505
P018	0.480	0.239	0.157	0.013	0.480	0.157	0.558	0.442
P019	0.280	0.103	0.292	0.055	0.280	0.292	0.426	0.438
P020	0.520	0.266	0.137	0.007	0.520	0.137	0.589	0.493
P021	0.520	0.266	0.292	0.055	0.520	0.292	0.666	0.625
P022	0.520	0.266	0.292	0.055	0.520	0.292	0.666	0.554
P023	0.200	0.049	0.292	0.055	0.200	0.292	0.346	0.470
P024	0.520	0.266	0.292	0.055	0.520	0.292	0.666	0.497
P025	0.920	0.538	0.234	0.037	0.920	0.234	1.000	0.573
P026	1.600	1.000	1.000	0.275	1.000	1.000	1.000	0.605
P027	0.520	0.266	0.292	0.055	0.520	0.292	0.666	0.562
P028	0.480	0.239	1.000	0.275	0.480	1.000	0.980	0.549
P029	0.240	0.076	0.200	0.027	0.240	0.200	0.340	0.529
P030	0.400	0.185	0.292	0.055	0.400	0.292	0.546	0.518
P031	0.160	0.022	0.188	0.023	0.160	0.188	0.254	0.462
P032	0.200	0.049	0.453	0.105	0.200	0.453	0.426	0.521
P034	0.280	0.103	0.304	0.059	0.280	0.304	0.432	0.539
P035	0.720	0.402	0.158	0.014	0.720	0.158	0.799	0.591
P036	0.400	0.185	0.292	0.055	0.400	0.292	0.546	0.546

Household	U1	U1: Normalised Xmin=0.128, Xmax=1.6	U2	U2: Normalised Xmin=0.114, Xmax=3.333	U1 (not normalised)	U2 (not normalised)	Use	Amended WPI
P037	0.520	0.266	0.256	0.044	0.520	0.256	0.648	0.447
P038	0.480	0.239	0.155	0.013	0.480	0.155	0.558	0.576
P039	0.120	0.000	0.292	0.055	0.120	0.292	0.266	0.500
P040	0.160	0.022	1.000	0.275	0.160	1.000	0.660	0.526
P041	0.400	0.185	0.188	0.023	0.400	0.188	0.494	0.497
P042	0.480	0.239	0.188	0.023	0.480	0.188	0.574	0.534
P043	0.320	0.130	0.116	0.001	0.320	0.116	0.378	0.545
P044	0.160	0.022	0.156	0.013	0.160	0.156	0.238	0.347
P045	0.160	0.022	0.333	0.068	0.160	0.333	0.327	0.387
P046	1.320	0.810	0.302	0.058	1.000	0.302	1.000	0.522
M01	0.920	0.538	1.402	0.400	0.920	1.000	1.000	0.558
M02	0.440	0.212	0.708	0.185	0.440	0.708	0.794	0.742
M03	3.200	1.000	0.508	0.122	1.000	0.508	1.000	0.744
M05	1.000	0.592	1.545	0.445	1.000	1.000	1.000	0.705
M06	0.960	0.565	1.667	0.482	0.960	1.000	1.000	0.734
M10	0.320	0.130	0.531	0.130	0.320	0.531	0.586	0.664
M11	0.400	0.185	N/A	1.000	0.400	1.000	0.900	0.751
M13	0.200	0.049	0.370	0.080	0.200	0.370	0.385	0.562
M14	0.400	0.185	0.357	0.076	0.400	0.357	0.579	0.629
M15	0.400	0.185	0.556	0.137	0.400	0.556	0.678	0.632
M16	0.520	0.266	0.222	0.034	0.520	0.222	0.631	0.678
M18	1.600	1.000	0.333	0.068	1.000	0.333	1.000	0.815
M19	0.680	0.375	1.000	0.275	0.680	1.000	1.000	0.652
M20	1.400	0.864	1.667	0.482	1.000	1.000	1.000	0.775
M21	0.680	0.375	0.556	0.137	0.680	0.556	0.958	0.763
M22	0.160	0.022	2.500	0.741	0.160	1.000	1.000	0.770
M25	0.440	0.212	1.250	0.353	0.440	1.000	1.000	0.744
M26	1.200	0.728	3.000	0.897	1.000	1.000	1.000	0.716
M27	0.480	0.239	0.370	0.080	0.480	0.370	0.665	0.651
M28	0.520	0.266	3.333	1.000	0.520	1.000	1.000	0.655
M30	2.720	1.000	3.067	0.918	1.000	1.000	1.000	0.741
M33	0.360	0.158	0.833	0.223	0.360	0.833	0.777	0.659
M34	0.320	0.130	0.476	0.113	0.320	0.476	0.558	0.509
M36	0.280	0.103	1.250	0.353	0.280	1.000	0.780	0.680

Household	U1	U1: Normalised Xmin=0.128, Xmax=1.6	U2	U2: Normalised Xmin=0.114, Xmax=3.333	U1 (not normalised)	U2 (not normalised)	Use	Amended WPI
M38	1.320	0.810	0.459	0.107	1.000	0.459	1.000	0.728
M39	0.280	0.103	1.487	0.427	0.280	1.000	1.000	0.712
M43	0.120	0.000	N/A	1.000	0.120	1.000	0.620	0.634
M45	0.400	0.185	0.625	0.159	0.400	0.625	0.713	0.683
M46	1.600	1.000	6.250	1.000	1.000	1.000	1.000	0.667
M47	0.520	0.266	3.333	1.000	0.520	1.000	1.000	0.781
M48	0.600	0.321	3.333	1.000	0.600	1.000	1.000	0.733
M50	1.000	0.592	3.333	1.000	1.000	1.000	1.000	0.715
M53	0.440	0.212	0.625	0.159	0.440	0.625	0.753	0.692
M54	0.320	0.130	1.487	0.427	0.320	1.000	1.000	0.705
M56	0.520	0.266	0.444	0.103	0.520	0.444	0.742	0.731
M57	0.320	0.130	2.333	0.689	0.320	1.000	1.000	0.725
M58	0.640	0.348	1.487	0.427	0.640	1.000	1.000	0.727
M61	1.120	0.674	N/A	1.000	1.000	1.000	1.000	0.694
M62	0.160	0.022	0.278	0.051	0.160	0.278	0.299	0.575
M68	0.240	0.076	2.000	0.586	0.240	1.000	1.000	0.740
M69	0.800	0.457	1.667	0.482	0.800	1.000	1.000	0.723
M70	0.680	0.375	0.291	0.055	0.680	0.291	0.826	0.777
M73	0.280	0.103	1.639	0.474	0.280	1.000	1.000	0.712
M74	0.720	0.402	2.222	0.655	0.720	1.000	1.000	0.752
M77	0.400	0.185	1.667	0.482	0.400	1.000	1.000	0.770
2.5 Percentile	**0.128**		**0.114**					
97.5 Percentile	**1.600**		**3.333**					

Household	E1	E1: Normalised Xmin=0.000, Xmax=388.000	E2	E2: Normalised Xmin=0, Xmax=2	E3	E3: Normalised Xmin=0, Xmax=2	E4	E4: Normalised Xmin=0, Xmax=2
P001	0.000	1.000	2.000	1.000	1.000	0.500	1.000	0.500
P002	0.000	1.000	2.000	1.000	0.000	0.000	1.000	0.500
P003	0.000	1.000	1.000	0.500	1.000	0.500	0.000	0.000
P004	0.000	1.000	2.000	1.000	0.000	0.000	1.000	0.500
P005	0.000	1.000	2.000	1.000	0.000	0.000	0.000	0.000
P006	0.000	1.000	2.000	1.000	0.000	0.000	0.000	0.000
P007	0.000	1.000	2.000	1.000	0.000	0.000	0.000	0.000
P008	1.000	0.997	2.000	1.000	0.000	0.000	0.000	0.000
P009	1.000	0.997	2.000	1.000	0.000	0.000	0.000	0.000
P010	1.000	0.997	2.000	1.000	0.000	0.000	0.000	0.000
P011	9.000	0.977	2.000	1.000	1.000	0.500	1.000	0.500
P012	2.000	0.995	2.000	1.000	1.000	0.500	0.000	0.000
P013	3.000	0.992	2.000	1.000	0.000	0.000	1.000	0.500
P014	0.000	1.000	2.000	1.000	0.000	0.000	1.000	0.500
P015	0.000	1.000	2.000	1.000	0.000	0.000	0.000	0.000
P016	1.000	0.997	2.000	1.000	0.000	0.000	0.000	0.000
P018	3.000	0.992	2.000	1.000	0.000	0.000	0.000	0.000
P019	2.000	0.995	2.000	1.000	0.000	0.000	0.000	0.000
P020	1.000	0.997	2.000	1.000	1.000	0.500	0.000	0.000
P021	0.000	1.000	2.000	1.000	0.000	0.000	1.000	0.500
P022	1.000	0.997	1.000	0.500	0.000	0.000	1.000	0.500
P023	1.000	0.997	1.000	0.500	0.000	0.000	0.000	0.000
P024	152.000	0.608	2.000	1.000	0.000	0.000	0.000	0.000
P025	3.000	0.992	2.000	1.000	0.000	0.000	1.000	0.500
P026	2.000	0.995	0.000	0.000	0.000	0.000	1.000	0.500
P027	1.000	0.997	1.000	0.500	0.000	0.000	0.000	0.000
P028	1.000	0.997	2.000	1.000	0.000	0.000	0.000	0.000
P029	1.000	0.997	2.000	1.000	0.000	0.000	0.000	0.000
P030	1.000	0.997	2.000	1.000	1.000	0.500	0.000	0.000
P031	1.000	0.997	2.000	1.000	0.000	0.000	1.000	0.500
P032	1.000	0.997	2.000	1.000	0.000	0.000	1.000	0.500
P034	1.000	0.997	2.000	1.000	0.000	0.000	1.000	0.500
P035	1.000	0.997	2.000	1.000	0.000	0.000	0.000	0.000

Household	E1	E1: Normalised Xmin=0.000, Xmax=388.000	E2	E2: Normalised Xmin=0, Xmax=2	E3	E3: Normalised Xmin=0, Xmax=2	E4	E4: Normalised Xmin=0, Xmax=2
P036	1.000	0.997	2.000	1.000	0.000	0.000	1.000	0.500
P037	1.000	0.997	2.000	1.000	0.000	0.000	1.000	0.500
P038	1.000	0.997	0.000	0.000	0.000	0.000	1.000	0.500
P039	1.000	0.997	2.000	1.000	0.000	0.000	0.000	0.000
P040	1.000	0.997	1.000	0.500	0.000	0.000	0.000	0.000
P041	1.000	0.997	2.000	1.000	0.000	0.000	0.000	0.000
P042	1.000	0.997	2.000	1.000	0.000	0.000	1.000	0.500
P043	1.000	0.997	2.000	1.000	1.000	0.500	1.000	0.500
P044	1.000	0.997	2.000	1.000	0.000	0.000	0.000	0.000
P045	1.000	0.997	2.000	1.000	0.000	0.000	1.000	0.500
P046	1.000	0.997	2.000	1.000	0.000	0.000	0.000	0.000
M01	363.000	0.064	0.000	0.000	0.000	0.000	2.000	1.000
M02	363.000	0.064	2.000	1.000	1.000	0.500	1.000	0.500
M03	363.000	0.064	2.000	1.000	0.000	0.000	0.000	0.000
M05	363.000	0.064	2.000	1.000	0.000	0.000	0.000	0.000
M06	363.000	0.064	0.000	0.000	0.000	0.000	1.000	0.500
M10	363.000	0.064	1.000	0.500	0.000	0.000	0.000	0.000
M11	363.000	0.064	2.000	1.000	2.000	1.000	0.000	0.000
M13	53.000	0.863	2.000	1.000	1.000	0.500	0.000	0.000
M14	53.000	0.863	2.000	1.000	0.000	0.000	0.000	0.000
M15	53.000	0.863	2.000	1.000	0.000	0.000	0.000	0.000
M16	53.000	0.863	1.000	0.500	0.000	0.000	0.000	0.000
M18	53.000	0.863	1.000	0.500	0.000	0.000	0.000	0.000
M19	53.000	0.863	0.000	0.000	0.000	0.000	0.000	0.000
M20	53.000	0.863	0.000	0.000	0.000	0.000	1.000	0.500
M21	53.000	0.863	1.000	0.500	0.000	0.000	0.000	0.000
M22	2.000	0.995	2.000	1.000	0.000	0.000	0.000	0.000
M25	2.000	0.995	0.000	0.000	0.000	0.000	0.000	0.000
M26	2.000	0.995	0.000	0.000	1.000	0.500	1.000	0.500
M27	2.000	0.995	1.000	0.500	0.000	0.000	0.000	0.000
M28	2.000	0.995	2.000	1.000	0.000	0.000	2.000	1.000
M30	2.000	0.995	0.000	0.000	1.000	0.500	1.000	0.500
M33	2.000	0.995	2.000	1.000	0.000	0.000	1.000	0.500

Household	E1	E1: Normalised Xmin=0.000, Xmax=388.000	E2	E2: Normalised Xmin=0, Xmax=2	E3	E3: Normalised Xmin=0, Xmax=2	E4	E4: Normalised Xmin=0, Xmax=2
M34	2.000	0.995	0.000	0.000	0.000	0.000	0.000	0.000
M36	2.000	0.995	0.000	0.000	0.000	0.000	0.000	0.000
M38	2.000	0.995	2.000	1.000	0.000	0.000	0.000	0.000
M39	2.000	0.995	2.000	1.000	0.000	0.000	0.000	0.000
M43	2.000	0.995	0.000	0.000	0.000	0.000	0.000	0.000
M45	2.000	0.995	2.000	1.000	1.000	0.500	0.000	0.000
M46	2.000	0.995	2.000	1.000	1.000	0.500	0.000	0.000
M47	2.000	0.995	2.000	1.000	0.000	0.000	0.000	0.000
M48	2.000	0.995	2.000	1.000	0.000	0.000	0.000	0.000
M50	2.000	0.995	2.000	1.000	0.000	0.000	0.000	0.000
M53	2.000	0.995	2.000	1.000	0.000	0.000	0.000	0.000
M54	2.000	0.995	2.000	1.000	0.000	0.000	0.000	0.000
M56	2.000	0.995	0.000	0.000	0.000	0.000	0.000	0.000
M57	2.000	0.995	2.000	1.000	0.000	0.000	0.000	0.000
M58	2.000	0.995	2.000	1.000	0.000	0.000	0.000	0.000
M61	12.000	0.969	0.000	0.000	0.000	0.000	0.000	0.000
M62	363.000	0.064	2.000	1.000	0.000	0.000	0.000	0.000
M68	53.000	0.863	0.000	0.000	1.000	0.500	1.000	0.500
M69	388.000	0.000	2.000	1.000	1.000	0.500	1.000	0.500
M70	388.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
M73	388.000	0.000	2.000	1.000	0.000	0.000	0.000	0.000
M74	388.000	0.000	2.000	1.000	0.000	0.000	0.000	0.000
M77	2.000	0.995	0.000	0.000	0.000	0.000	0.000	0.000
2.5 Percentile	**0.000**							
97.5 Percentile	**388.000**							

Code	WPI Indicator	Description	Level (P/M)
R1	Quantitative measure of water resources availability	Available water resources per capita	Community
R2	Quantitative measure of reliability of water resources	% of demand (BWR) that can be satisfied with current infrastructure	Community/ Household
R3	Quantitative measure of rainfall variability	Precipitation Concentration Index	Community
R4	Qualitative measure of water resources availability	Perception of available water resources during the dry period	Household
R5	Qualitative measure of service reliability	Perception of service reliability	Household
R6	Qualitative measure of rainfall variability	Perceived change in historical rainfall patterns	Household
A1	Access to piped water	% Population with access to piped water supply	Household
A2	Access to sanitation	% Population with access to sanitation	Household
A3	Time required for water collection activities	Time required for carrying water per trip x number of trips per day	Household
A4	Conflict over access to water	Frequency of conflicts over access to water	Household
C1	Average daily household income ($MXN)	Average daily household income ($MXN)	Household
C2	Education	% of h/h population having completed primary school	Household
C3	Access to education by gender	Ratio of female to male primary school completion rate	Community
C4	Water-related illnesses	Frequency of water-related illnesses	Household
C5	Hygiene capacity	% Population having participated in hygiene training	Community
U1	Domestic consumption	Ratio of actual domestic consumption to basic water requirements	Household
U2	Livestock consumption	Ratio of actual livestock consumption to basic water requirements	Household
E1	Quantitative measure of water quality	Measure of Thermotolerant Coliforms per 100mL of sample	Household/ Community
E2	Qualitative measure of water quality	Perception of water quality	Household
E3	Soil fertility	% Population reporting a change in soil fertility	Household
E4	Tree cover	% Population reporting a change in tree cover	Household

APPENDIX E WATER QUALITY ANALYSES

WATER QUALITY RESULTS - EL MASH

Household	Mean pH	TU	TTC 1	TTC 2	Mean TTC
M53	7.7	<5	0	0	0
M69	7.4	<5	8	21	14.5
M5	7.9	<5	1	0	0.5
M31	7.8	<5	0	-	0
M65	8	<5	0	-	0
M74	8	<5	17	-	17
M33	8	<5	0	-	0
M47	6.8	<5	0	-	0
M63	<6.8	<5	0	-	0
M37	8.1	<5	0	-	0
M57	<6.8	<5	0	-	0
M16	8	<5	0	-	0
M2	<6.8	<5	0	-	0
M10	<6.8	<5	0	-	0
M4	7.9	<5	7	-	7
M49	8.2	<5	0	-	0
MEAN	**7.8**	**<5**	**2**	**7**	**2**

Spring	Mean pH	TU	Sample 1	Sample 2	Sample 3	Sample 4	Mean TTC	Std Dev
Man1 (pool)	7.7	<5	3	1			2	1
Man1 (tap)	7.7	<5	1	1			1	0
Man2 (left)	7.6	<5	209	179			194	21
Man2 (right)	7.6	<5	3	1			2	1
Man3 (L-tap)	7.6	<5	>357	358	440	700	499	179
Man3 (R-tap)	7.5	<5	180	199			190	13
Man3 (R-tap2)	-	<5	>353	434	460	500	465	33
Man3 (pool)	-	-	9,530	17250			13390	5459
Man3 (flow)	7.5	<5	675	945			810	191
Man4	7.7	<5	1	4			3	2
Man5	7.4	<5	58	70	44	37	52	15
Man6	7.6	<5	6	7			7	1
School	7.8	<5	0	0			0	0

WATER QUALITY RESULTS - POZUELOS

HH	pH	TU	TTC1	TTC2	TTC3	TTC Avg	Comments
P001	8.2	<5	0	0	-	0	Tank (unfiltered)
	8.2	<5	0	0	-	0	Tank (filtered)
P002	7.2	<5	0	0	-	0	
P003	8.2	<5	0	0	-	0	
P004	7.6	<5	0	0	0	0	Tinaco
	-	<5	0	0	0	0	Garrafón
P005	7.6	<5	0	0	0	0	Tap
P006	8.2	<5	0	0	0	0	R/W tank (mix)
P007	7.2	<5	0	0	0	0	Bottle (piped)
P008*	8.2	<5	-	-	-	-	R/W tank (r/w)
	7.2	<5	-	-	-	-	Tap
P009*	7.2	<5	-	-	-	-	Tinaco (piped)
P010*	7.2	<5	-	-	-	-	Tinaco (piped)
	7.2	<5	-	-	-	-	Tap
P011	7.2	<5	7	8	13	9	Tinaco (piped)
P012	6.8	<5	2	2	2	2	Tap
	8	<5	0	1	0	0	R/W tank
P013	7.2	<5	4	3	3	3	Tap (through hose)
P014	8.2	<5	0	0	0	0	R/W tank (mix)
P015	8.2	<5	0	0	0	0	R/W tank (mix)
P016	Same supply as P015		-	-	-	-	
P018	6.8	<5	2	5	1	3	Tap
	7.4	<5	0	0	0	0	Container
P019	7	<5	2	2	3	2	Tap
P020	6.8	<5	2	0	1	1	Tap
	6.8	<5	2	3	-	3	Tap
	-	<5	3	1	-	2	Tap
P021	6.8	<5	0	0	-	0	Tinaco
	6.8	<5	4	10	-	7	Tap (through hose)
P022	6.8	<5	2	0	-	1	Tap (through hose)
P023	6.8	<5	2	0	-	1	Tap (through hose)
	7.2	<5	0	0	-	0	Tinaco
	7.4	<5	0	0	-	0	R/W tank
P024	8	<5	149	155	-	152	
P025	6.8	<5	2	3	-	3	
P026	6.8	<5	2	2	-	2	
P027	6.8	<5	1	1	-	1	
P028**	7.2	<5	0	2	-	1	
P029**	7.2	<5	2	1	-	2	Tap (through hose)
P030**	7	<5	0	0	-	0	Tap (inside kitchen)
P031**	7	<5	1	4	-	3	Tap
P032**	7.4	<5	0	0	-	0	Tap
P034***							
P035***							
P036***							
P037***							
P038***							
P039***							
P040***							
P041***							
P042****							
P043***							
P044***							
P045***							
P046***							

* TTC not analysed
** Results not valid
*** Not sampled