The Role of the Engineer in International Development

A Case study in Water Supply Service Delivery Models in Sierra Leone

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Ph.D Research
The Edinburgh of University
2013

ABSTRACT

The eradication of global poverty is central to the concept of sustainable development. In developing nations the lack of essential infrastructure and technologies, which are necessary to provide people with their basic human rights, offer a central role for the engineer. These needs are increasing as new global threats, such as the pressures caused by population growth, the harmful effects of climate change or the increasing frequency and intensity of disasters, have only heightened the difficulties which threaten the world's poorest nations.

Decades of development practice has allowed the profession of engineering to engage with many of these global issues. Over this period the engineering approaches, particularly in Sub-Saharan Africa, have gradually moved from high impact and short-term disasters relief interventions to long-term endogenous solutions. This change in overall aims has raised awareness of the sustainability of current engineering interventions. Many of the results are not entirely positive. For example, in water supply engineering, certain national estimates of sustainability of hand-pump wells for countries in Sub-Saharan Africa can range from 30-80%. The role that the engineer could provide in addressing the concerns of poorer nations has not yet been fully realised.

This thesis evaluates the current engineering models of service delivery that are used by Non-Governmental Organisations (NGOs) in developing nations. These models of technology transfer are supposed to provide communities in developing nations with a sustainable access to technologies that can provide for their basic rights. It is from within these models that engineers, who in many cases are foreign to the socio-cultural systems of the host nation, perform their engineering function and activities. The field research focuses on a case study of water supply engineering projects that have been carried out within the rural District of Tonkolili in Sierra Leone.

To address the complex socio-cultural and socio-technical systems in Sierra Leone this field research adopted a combination of qualitative and quantitative assessment methods. This involved investigating both the technical and social sustainability issues found in Sierra Leone. The research visits were both inductive and deductive. They covered 150 spatially distributed villages in the rural district of Tonkolili. The methodologies used as part of this study involved; interviews, focus group discussions, community mapping, transect walks and technical observations, to provide a broad understanding of the sustainability issues affecting engineering projects.

A total of 309 hand-pump wells, pulley systems and borehole water points were evaluated as part of the research. The study investigated the technical, socio-technical and socio-cultural consequences of these technology transfers - as well as the current condition of the social support mechanisms that are designed to sustain the water schemes. The results of the technical observations demonstrated that there are a diverse range of failures, from extreme to moderate, that have occurred at many of the water points. During the field visits observations of water supply solutions found to have urgent technical problems were frequent occurrences. The majority of the water points (96%) were found to have at least one technical failing that required immediate maintenance or further engineering assistance.

The social research also indicated that, of the 4,700 individual categories monitored, a significant proportion (49%) were technical problems that were within the capacities of village members to address locally. These technical problems found to be ignored by the host communities. The NGO trained support mechanisms, which were designed to provide sustainability to the systems, for innumerable reasons, were unable to operate effectively. The breakdown in function of these supporting systems highlighted the serious weakness of current service delivery models in their ability to achieve sustainable engineering solutions.

Investigating the relationship between the households and the water points suggests that the communities are not acting rationally towards their water sources. The majority of households were found to have unsafe water practices regardless of the provision of their improved sources. For example, many households that had access to improved water sources were found to still use their unimproved sources (30%). Many more (53%) complemented, and mixed, their unimproved water with water from their improved wells. This attitude towards safe water suggested that there were fundamentally flawed assumptions about how communities would receive and interact with their technologies.

These household decisions, and the associated technical concerns, are directly attributable to the actions of the engineers from the project implementing development agencies. The results of these misinterpretations have undermined the long term sustainability of water supplies in Sierra Leone. The research indicated that to address sustainability the engineering profession is at a crossroads in determining its future in international development. Engineers have the capacity to acknowledge that the complexities of development limit their efficacy and therefore seek support from other professions. This would narrow the scope of their interventions. They are also capable of actively seeking the opposite; to broaden the scope as well as the responsibilities, expectations and skills of the engineers. It is this decision that will define the role of the engineer in international development.

DECLARATION

I hereby declare that this thesis came into shape solely by myself under the supervision of Dr. Blanca Antizar-Ladislao; and the work involved herein was accomplished by myself, except where due reference has been made. Moreover, this thesis contains no material, which has been accepted for the award of any other degree or professional qualification.

Unless otherwise stated all photographic evidence and site pictures used in this research are the property of the author. These were taken with explicit permission from those who were photographed either by the research assistants, Alannah Dela Hunty and Jack Barrie, or by myself, as part of the field research proceedings.

Paul Byars

ACKNOWLEDGEMENTS

This research would not have been possible without the assistance of my research supervisor Dr Blanca Antizar-Ladislao. Her patience, understanding and encouragement has been unwavering throughout my studies - and is the only reason that this thesis could be completed at all.

I would like to offer special thanks to the field research assistants; Jack Barrie and Alannah Dela Hunty, who volunteered for months in the collection of the field data in Sierra Leone. Their enthusiasm, integrity and generosity made working on many chapters and sections in this thesis possible.

The field research would also not have been possible without the assistance of Alfred Sesay and Sheiku Kamara who were perfect guides, translators and men. I could not have asked for better. This thanks is also extended to Abdullahi Kamara and Joseph Turay for their tireless enumeration work on the quantitative surveys.

A particular mention is given to the field staff of Concern Worldwide - Sierra Leone for their support for this research, and in offering their team house used for accommodation for the duration of the field visits. The number of people that assisted in Concern are too numerous to mention, and every one of them are amazing people, but particular thanks is paid to Marianne Byrne, Marie Rongeard and Patrick Barasa for their support - of both me and my work. Special thanks is given to Rosalind McCollum, for giving me inspiration, friendship and love exactly when I needed it, and in larger quantities that I could ever have hoped.

I would like to thank my parents, who loved and supported me regardless of my continuous ups and downs. I would also like to thank my wonderful siblings: Margaret, John-Patrick, Anthony, Catherine, David, Clare, Sr Maria Grace of the Incarnation - for being unceasing in their encouragement of my work. Every one of them had to make some form of sacrifice because of my travels and I cannot thank them enough. I would also like to thank Eadaoin and Niamh (and Tobias, Rosin and Lucas) for being a wonderful new part of my family.

Many parts of this research were positive, but given some of the harder experiences, there were times when I needed to be both counselled and protected. For this I would like to thank Edinburgh Universities Counselling service - as well as the work of countless Dominicans and Jesuits priests. In particular the time, energy and love offered to me by Fr Robert Gay-Op and Fr Bruno Clifton. They helped me finish this research in one piece and without losing myself in the process.

I would like to acknowledge the financial assistance given to me by the Engineering and Physical Sciences Research Council (EPSRC) as well as the Humanitarian Innovation Fund (HIF).

Special thanks must also be given to the innumerable students and colleagues who have made working on this research a pleasure. Once again there are too many to name, but a special mention is given to Jonathan Choksey, Ruan Roux, James Watt, Douglas White, Angus McBride, Chris Hutchens, Miriam Hansen, Colin Brett and Barry Lovern. Additionally I would like to thank Engineers Without Borders - Edinburgh branch, the SEED research group and the Edinburgh DIEM members for their assistance over the years of the research.

This study would not have been possible without the guidance of so many development practitioners. This list is extensive, but special thanks is given to Liam McCarton, Dave Stanley, Franck Flachenberg, Dualta Roughneen, Per Anderson, Sean O'Haigan, Charles Mutai, Charles Omona and Zenebe Mekonnen. Their mentoring and support, and those of so many others, made many parts of this research possible. It has been my greatest honour to work with so many people that are so selflessly dedicated to alleviating the suffering of others.

Most importantly, a special thanks is given to people of Tonkolili in Sierra Leone. Through this research I have met so many people that have faced immense adversity - but with a dignity and grace that has been a marvel to behold. I have been humbled and awed by so many acts of generosity and kindness in so many of the villages that I have visited. Every day in Sierra Leone was a gift and it would not be possible to repay even a small amount of what I received from each of the visited communities.

Finally, I would like in particular to thank the children, from every visited village, in Sierra Leone. They made each of the site visits a joy. These children taught me that Sierra Leone does have diamonds of great worth, and that they have the potential to bring the country out of the depths of its poverty, but these diamonds are not stones.

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NOTATION

ABET	American Accreditation Board for Engineering and Technology
ADB	African Development Bank
AFRC	Armed Forces Revolutionary Council
AIDS	Acquired Immune Deficiency Syndrome
ATT	Appropriate Transfer of Technology
CAWST	Centre for Affordable Water and Sanitation Technology
CDF	Civil Defence Forces
CFR	Case Fatality Ratio
CHC	Community Health Centres
CHP	Community Health Post
CIA	Central Intelligence Agency
CLTS	Community Led Total Sanitation
DFID	Department for International Development
ECOMOG	Economic Community of West African States Monitoring Group
EU	European Commission
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
GBV	Gender Based Violence
GDP	Gross Domestic Product
GNI	Gross National Income
GPS	Global Positioning System
GOSL	Government of Sierra Leone
GUI	Graphical User Interface
HDI	Human Development Index
HIV	Human Immunodeficiency Virus
ICE	Institute of Civil Engineers
IDP	Internally Displaced Person
ITK	Indigenous Technical Knowledge
IMF	International Monetary Fund
JMP	Joint Monitoring Project
KAP	Knowledge Attitudes and Practices
LTT	Linear Transfer of Technology
M&E	Monitoring and Evaluation

MCHP	Maternal and Child Health Posts
MDG	Millennium Development Goals
MICS	Multiple Indicator Cluster Surveys
NBA	Needs Based Approach
NGO	Non-Governmental Organisation
NPFL	National Patriotic Front of Liberia
O&M	Operation and Maintenance
ODA	Official Development Assistance
OECD	Organisation for Economic Co-operation and Development
PHU	Peripheral Health Unit
PTA	Parent Teach Association
RBA	Rights Based Approach
RUF	Revolutionary United Front
RWH	Rainwater Harvesting
RWSN	Rural Water Supply Network
SALWACO	Sierra Leone Water Company
SATT	Synergistic Approach to Technology Transfer
SLA	Sierra Leone Army
SODIS	Solar Disinfection
TUI	Text-Based User Interfaces
UK	United Kingdom
UN	United Nations
UNAMSIL	United Nations Mission to Sierra Leone
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNHCR	United Nations High Commissioner for Refugees
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
VDC	Village Development Committee
VLOM	Village Level Operation and Maintenance
WATSAN	Water and Sanitation
WCED	World Commission on Environment and Development
WHO	World Health Organisation
WSP	Water and Sanitation Program
WUC	Water User Committee

CHAPTER 1: SCOPE OF THE RESEARCH

Part 1: Introduction

1.1.1 Engineering and Sustainable Development

Engineering has made huge advancements in technical innovation over the previous centuries of professional development. The engineer can be credited for addressing some of the greatest problems faced by humanity. These include finding technical solutions for complex and often interconnected issues including energy, waste, transport, habitation, health, communication, water and sanitation (UNESCO, 2010). The technical innovations that have been designed to address these problems, particularly in the previous decades, have exhibited the value of the engineering profession in increasing global prosperity and well-being.

> *"Countless committees, task forces, panels, and commissions have already addressed the need and eloquently emphasized that the competitiveness of the country and therefore the general standard of living hinges on the ability to educate a large number of sufficiently innovative engineers"* (Tryggvason and Apelian, 2006).

A list of current engineering outputs and innovations are seemingly endless. The civil engineering profession, which is of particular importance to this research, can demonstrate innumerable infrastructure and construction projects to act as examples of their diverse technical capacities; these include dams, skyscrapers, bridges, water supply networks, sanitation systems and irrigation schemes. The technical progress in many areas has been made due to a culmination of dedication, rigour and rationality that has exemplified the core functionality and excellence of the profession (Jowitt, 2003).

For all these technical advancements, inspiring and sophisticated as they are, the world still faces substantial, and in many cases worsening, global challenges (UN, 2012a). The interaction of these problems including; population increases, climate change, peak oil-prices, global recessions and an increase in rural-urban migrations, have created a perfect storm that have exposed the global community to increasing difficulties and hardships. Those that are worst affected by these events are those that already live in conditions of extreme poverty. The growing understanding of how these events will shape a common future has raised awareness of the potential role that engineering can take in the alleviation of global poverty (WCED, 1987a). This reasoning has coincided with an increasing valuation and objective focus on the concept of 'sustainable development'. The sustainable development movement, though concerned with environmental wellbeing and economic growth, is also directly linked to addressing the suffering caused by extreme poverty:

> *"Sustainable economic development is directly concerned with increasing the standard of living of the poor, which can be measured in terms of increased food, real income, education, health care, water supply, sanitation, and only indirectly concerned with economic growth at the aggregate"* (Barbier, 1987).

However the actual scope, scale and interconnectedness of poverty related issues are yet to be fully understood by the profession of engineering. Regardless of the sophistication of the technical artefacts produced by the engineer, the majority of these design solutions have only addressed the needs of the industrial and post-industrial nations. Much of the developing world remains without sustainable access to some of the most fundamentally basic engineering services and infrastructure.

1.1.2 Current Understanding: Development and the Role of the Engineering

The magnitude of technical problems found within developing countries, which urgently require the services of an engineer, are overwhelming. The extent of these problems is on a scale that is difficult to comprehend. Examples include the 780 million people that are without access to an improved drinking water source, the 2.5 billion people that are without improved sanitation and the 1.2 billion people that are still without access to electricity (UNICEF and WHO, 2012). Almost all of these populations, who live without these basic services, are residents of the 'developing countries'. These are defined as nations that have an underdeveloped industrial base and have a low scoring in the Human Development Index (HDI) relative to other countries (UNDP, 2011). It is anticipated that, for many of the world's poorest populations, there will be a decline in the current levels of development progress (IPCC, 2007a; World Bank, 2012a). This will be caused by external influences and pressures such as global climate change and the depletion in natural resources. Many of these problems have been caused by the actions of the industrial and post-industrial nations, particularly during the historical periods of industrialisation (IPCC, 2007b). This has only increased the importance of finding sustainable engineering solutions to address technical problems.

> *"Amongst the greatest challenges we face in the world today are those of delivering growing, secure and affordable supplies of clean water and of energy, to meet the needs and expectations of an expanding population, whilst reducing our CO_2 emissions and the human contribution to climate change. The implementation of innovative engineering solutions is fundamental to addressing these challenges, whilst also offering exceptional opportunities for*

> *economic growth to the nations which are able to deliver them"* (Brown and Rudolph, 2004).

The importance of having sustainable engineering practices in international development are continually stated by a host of development practitioners, economists, policy makers, think-tanks and government agencies (Rogers et al., 2008; WCED, 1987b). Highlighting the importance of engineering in developing countries is usually made by commentators who refer explicitly to the number of global infrastructural, technical or systematic problems that have affected the progress of developing nations (Guthrie et al., 2008; Juma, 2006). Publications such as these can be seen as important as they highlight the link between reaching development targets and having continual engagement with trained engineering professionals, however they do not determine how an engineer should operate within the context of extreme poverty.

The assumption that an engineer, who has been trained in the tertiary educational institutions of post-industrial nations, is fully prepared to work in every aspect of engineering in developing countries can be dangerously misleading (Bourn and Neal, 2008). There will always be a role in developing countries for engineers that are trained external to the realities of extreme poverty, particularly on large scale or technically complicated projects - where the engineering demands are similar to those found within the developed nations. However, these are not the primary engineering interventions that are required in developing nations (Hazeltine et al., 1998). As Schumacher, an economist that had a foundational role in the conception of the appropriate technology movement, stated:

> *"The heart of the matter, as I see it, is the stark fact that world poverty is primarily a problem of two million villages, and thus a problem of two thousand million villagers"* (Schumacher, 1973).

Rural development not only challenges the existing practices of the engineer but it is also where many of the most basic needs of the poor have not been addressed or understood (Chambers, 1993). The communities that continually struggle with the vicious realities and cycles of extreme poverty are, in most cases, broadly geographically distributed. Their lack of wealth, education and local support systems means that they face continual adversity in their struggle for survival (Chambers, 1983). It is not only a lack of wealth or poor socio-economic status that the world poorest face - but a denial of their basic human rights. Poor rural populations do not have the economic capacities or financial support necessary to fund large scale or complicated 'traditional' engineering solutions that could be made available in urban or peri-urban environments. The limitations and context of rural poverty is comparatively different to the conditions that an engineer is trained or prepared to address. Therefore it is in this context where the profession of engineering can be pushed to its full capacity and where the role of the engineer requires introspective analysis.

1.1.3 Key factors in the Transfer of Technology

The engineering that will be investigated in this research is specifically designed to address the problems of those that are the most marginalised and in need of technical assistance. The organisations that are primarily responsible for addressing global poverty, as well as implementing engineering projects in developing countries, are known as the International Non-Governmental Organisations (NGOs). These development agencies are mainly private initiatives and are normally autonomous, non-membership based, relatively permanent and usually not-for-profit organisations (Desai and Potter, 2013). They are intended to be intermediary within the context of which they operate. They are, in most cases, staffed by professionals who work with grassroots organisations in a supportive capacity (Desai and Potter, 2013). Each of these development organisations has their own unique methods of delivering services to their beneficiaries.

In this research the method of providing a technical artefact is defined as being a 'technology transfer'. This concept describes an exchange of technologies between two independent cultures through the medium of the NGO. The particular focus of this study will be on the provision of ‘improved sources’ of drinking water supplies. Improved sources are defined by the Joint Monitoring Project (JMP) as being; tube-wells, boreholes protected dug wells, protected springs or rainwater (WHO and UNICEF, 2012).

1.1.4 The Sustainability of Engineering Interventions

This research is intended to challenge the existing methods of technology transfer and propose a new paradigmatic approach to engineering. It is intended that this will provide a further realisation of the role of the engineer in international development. The suggestion that there is any need for the engineering profession to alter their practices, or that their role requires any form of self-examination, can be viewed as contrary to certain elements of the supporting literature.

There are many positive examples of current models of technology transfer. For example, a basic overview of the globally monitored indicators in water supply would refute any need for further investigation into the professions actions. In 2012 an international declaration announced by the UN heralded the achievement of the MDG goal for water supplies (UN, 2012a). As the UN news centre reported:

> *"the goal of reducing by half the number of people without access to safe drinking water has been achieved, well ahead of the 2015 deadline…*[by 2015] *some 92 per cent of the global population will have access to improved drinking water"* (UN, 2012b).

There has been a growing body of literature that contests the reaching of this international milestone. An increasing number of reports on the sustainability of water supply projects in developing countries can differ dramatically from the United Nations account of events. The most extreme reports are mainly found in Sub-Saharan Africa. In this continent the figures on the functionality of water supply problems vary with each country. Additionally many of these nations have reported their own unique issues with their water schemes. In 2010 the Rural Water Supply Network (RWSN) estimated that of the twenty selected countries evaluated in Sub-Saharan Africa the majority had severe problems with sustainability of their interventions. In this report it was suggested that Sierra Leone, Côte d'Ivoire and the Democratic Republic of Congo were found to have over 65% of their water points rated as 'non-functional'. The average non-functional status for all their surveyed countries was 36% (RWSN, 2009a). Many of these results have been confirmed by other independent water supply analysts. In Suttons' survey of 11 countries in Sub-Saharan Africa the percentage of functioning water systems in rural areas was reported to range from 35–80% (Sutton, 2004). A study in South Africa documented that as many as 70% of the boreholes in the Eastern Cape were not functional (Mackintosh and Colvin, 2003). A survey of 7,000 wells and boreholes in Tanzania found that, on average, 45% were in operation, and only 10% of systems that were 25 years or older were still functioning (Haysom, 2006).

There has been a recent focus on understanding the magnitude and scale of these problems by using satellite mapping techniques and Global Positioning Systems (GPS). A comprehensive water point mapping exercise in Sierra Leone indicated that the non-functionality of public water points is high. It was also found that this failure rises rapidly the age of the intervention. Among water points built five years before the survey 31% were said to be impaired and 17% were found to be broken down (Hirn, 2012). Many of these results differ from the projected image that the NGOs portray of their systems. These depictions can be compared to actual the conditions of water points that can be continually observed in many parts of Sub-Saharan Africa (Figure 1).

Figure 1: A common sight in hand-pump well success - Mabai, Sierra Leone

Each of the reports on sustainability that have been highlighted above has used a different criterion to determine classifications of functionality. Each of the reports and research findings offer no overall consensus or definitive statements on the causations of the problems. Additionally each of the reports differs in their monitoring techniques while simultaneously exploring the subject on different geographical scales. Regardless, the increasing numbers of reports, which are accumulating on an annual basis, suggest that there is severe and widespread failure occurring in many fundamentally basic engineering projects.

This research is specifically focused on investigating the role of the engineer in these problems. As this study is intended to be holistic it would be insufficient to only view the technologies with regards to their practical failings (Bourn and Neal, 2008). Instead it is the root causations of the problems, and their relationship to the engineering profession, which are important to define and understand. For there to be a credible suggestion of how the profession should progress in this regard, and to offer alternative approaches to engineering practices, a forthright and layered investigation into current engineering projects in international development is required. This research will focus on a single case study, carried out in the Sub-Saharan African country of Sierra Leone, to assess the current impact of the profession in developing nations.

1.1.5 Sierra Leone: Selection of the Research Case Study

For this research to address the widespread sustainability issues outlined above it would be ideal to provide a definitive answer to *'the role of the engineer in international development'*. Realistically this is too broad a question to answer in a single thesis. The diversity in populations, cultures and societies in each nation, and also within each country, are substantial. As Chambers found, through studying the work of field researchers in developing nations, within any given 'developing country' the differences between each spatially separated rural community, and the resulting quantity of information that could be gathered; technically, anthropologically or sociologically, would overwhelm any meaningful conclusion (Chambers, 1983).

Therefore, instead of basing the research in a number of locations, the Sub-Saharan African country of Sierra Leone was chosen as the basis for this study. The selection of any country in the developing world, to act as a reliable case study, has its advantages and disadvantages. A conscious effort was made to select Sierra Leone, based on a number of its social, economic, cultural and even metrological attributes. Certain aspects of the decision making process are discussed as follows:

- ***Economic Situation****:* Sierra Leone is currently defined as having the majority of its population living in extreme poverty and in need of external assistance (IMF, 2012; UNDP, 2011; World Bank, 2012b). Sierra Leone does not have the economy to construct or support its own large rural infrastructure projects (GOSL, 2009; IMF, 2005). Neither could it provide the required financial capital to technically advanced multinational companies to resolve the countries problems on its behalf (GOSL, 2009). The lack of commercial viability of water supply in rural areas means that participation of large multinational companies is unlikely (Prasad, 2006). Realistically, Sierra Leone will not have access to either multinational companies, or a technically capable private sector, in the immediate future. They are dependent on innovative solutions, and the involvement of non-state actors, to resolve their current rural water supply problems.

- ***Rural-Urban Distinction:*** Globally there has been an increase in migration of people from rural to urban environments in the last decade (UN, 2012c). The world is currently close to peak rural populations with urban populations continuing to grow. Regardless of the increases in urban expansions, Africa is only likely to reach a 50% urbanization rate in 2035 (UN, 2012c). Given the rate of growth and geographic expansion of urban environments in the developing world there can be a lack of clarity about what can still be regarded as a ‘rural’ area. This is due to hybrid urban-rural settings of certain towns, suburbs and peri-urban settlements which encapsulate the urban sprawl. Comparative to other nations Sierra Leone has few large cities and limited sprawl outside the Western Area (IMF, 2005; World Bank, 2004). In Sierra Leone there remains a clear distinction between rural and urban centres. Research in these environments is clearly identifiable as being 'rural', and not with some underlying urban complexities that could skew results.

- ***Ethnic Formation:*** Most of the tribes in Sierra Leone are settlers, as opposed to nomadic people, and have been resident in their areas for centuries (Ferme, 2001; Kup, 1961). Their cultural practices are more definable because there is not constant mass migration of the communities (Ferme, 2001). This movement is typical of nomadic pastoralist tribes who require mobilisation for the feeding of their livestock or for continual access to water (Omar, 1992; Sheik-Mohamed and Velema, 1999). Certain Sierra Leonean tribes, such as the Fula and the Mandingo are traditionally traders, rather than pastoralists, and are regularly settled into their host culture. Having stable traditions, which can be verified without extensive anthropological research into how practices change in different geographies, is important for determining current, but also historic precedent, for defining water practices.

- ***Water Resources****:* Sierra Leone is water rich and therefore does not have a resource limitation which could have adversely influenced, or even invalidated, the results of the studies in water poor areas (UNICEF, 2011a). Field research in water deprived countries, such as Malawi or Botswana, can have yearly rainwater yields that are exceptionally low (Calow et al., 2010). This could mean that technical errors that are not environmentally dependent could be overlooked because of the precedence of the issues related to available water quantities. Countries which are resource poor with regards to water can have more extreme reactions directly related to restrictions at their sources (Calow et al., 2002). This can move discussion away from technical issues, into more political spheres, thereby limiting the analysis on engineering.

- ***Local Context****:* The historical context of Sierra Leone is important for evaluating the role of the engineer in international development. The history of Sierra Leone, from colonisation, to independence, to the conflict of the Mano River War, has created a holistic, and occasionally dramatic, case study in water supply interventions. It is reasonable to suggest that many of the elements that caused the war, or were damaged by the conflicts proceedings, remain context specific. Utilising a case study with such an intense period of conflict is not dissimilar to the host of developing countries that have experienced some form of recent humanitarian or environmental disaster (Beasley, 2009; Meredith, 2006; White et al., 2001). Regardless of its history of conflict Sierra Leone has remained peaceful for over a decade, and the nation is clearly moving towards development programming rather than the disaster relief phases that marked the post-conflict years (IMF, 2005). However, there is still the potential for violence, a scenario that can either be mitigated or exacerbated by the assistance of the international community (Hanlon, 2005; Richards, 2005).

- ***Humanitarian Assistance****:* Finally, the Mano River War resulted in a large humanitarian response with multinational donors and organisations responding on an immense scale. This level of sustained international support is not present in the more stable economies of certain developing countries. The introduction of the NGOs and their methods of service delivery were supposed to fill the gaps left by weak, or non-existent, public and private sectors (Desai and Potter, 2013; OECD, 2009a). Prior to the development agencies intervention in water supplies; years of neglect, lack of investment, poor maintenance and infrastructural damage, had essentially destroyed all progress in the sector (ADB, 2011; GOSL, 2009). The vacuum of technical support filled by humanitarian agencies has created an ideal case study where the mandates, visions, rhetoric and practices of engineering in NGOs, over the previous decade, can be analysed and evaluated. As the conflict had eroded or destroyed the capacities of state, as well as private sector involvement, the majority of case studies are directly attributable to the working practices of international NGOs (Hirn, 2012). These case studies can be critiqued in relation to development agencies without considering indirect factors that could be suggested to impact the project, such as competition from existing private-sector actors, or viewing failures as only indicative of state problems, such as corruption.

CHAPTER 1: SCOPE OF THE RESEARCH

Part 2: Research Aims, Objectives and Methodology

1.2.1 Aims and Objectives of the Research

The overall aim of this research is to better understand, explore and progress the role of the engineering profession that is engaged in the alleviation of global poverty.

The objective is to explore the current impact that the profession has made on development targets. This can be achieved through an observation of the professions existing practices and its current technical outputs. The focus of this research is on engineers that operate outside their normal contextual environment. As development agencies are specifically mandated to address the root causes of poverty then it is the engineering practices of these organisations that will be the primary focus of the field research.

The exploration of current and previous engineering activities in the developing world can offer important insights into new methods of development practice for engineers. It is intended that an exploration of engineering in this way can not only highlight current limitations with existing practices but it can also be used to determine the potential future choices for the development engineering sector.

1.2.2 Systems Analysis of Engineering in International Development

This research will consider the two most fundamental outputs of an engineering intervention: the technologies themselves and the mechanisms that provide them with sustainability. However there are two further elements that need to be considered in the analysis of engineering practices. These provide a ‘systems’ view to development and encompass two separate components: the (i) socio-technical and (ii) the socio-cultural aspects of technology transfer. A description of these elements is as follows:

A ‘system’ refers to an entity that is made up of interrelated parts. Positively or negatively interacting with any component within this system will not only have an effect on the altered component but the entire system as a whole. The ‘social systems’, which are also referred to in sociology as the ‘social structure’, is a term that is used to refer to patterned social arrangements in a society. These patterns are both emergent from, and determinant of, the actions of the individuals within the society. The relationship that the village communities have with their technologies forms what can be considered to be a 'socio-technical system'.

"For the analysis of functioning artefacts in context the combination of 'the social' and 'the technical' is an appropriate unit of analysis. At the level of social functions, a range of elements are linked together to achieve functionally, for example, technology, regulation, user practices, markets, cultural meaning, infrastructure, maintenance networks and production systems. This cluster is called a 'socio-technical systems', thus highlighting that social and technical aspects are strongly interlinked" (Geels, 2005).

The socio-cultural system of a society refers to the combined interactions of the social and cultural elements and structures. The ‘cultural system’ is a term used to define the interaction between different cultural elements such as arts, beliefs, knowledge and practices. Within these cultural systems there is a distinction between ‘material culture’ and ‘non-material culture’. This is a distinction that is important for engineering projects. A ‘non-material culture’ refers to intangibles such as language, traditional practices and rituals. A ‘material culture’ refers to physical artefacts that are constructed and produced by society. It is the concept of ‘material culture’ which suggests that an individual’s relationships and perceptions of an artefact are socially and culturally dependent (Appadurai, 1988). Therefore the artefacts of the water supplies and their associated socio-technical systems are a component of a much larger socio-cultural system.

1.2.3 The Methodology of the Thesis

The NGO provided engineering projects in developing countries are intended to operate within complex environments, authoritative hierarchies and multifaceted systems. Additionally much of the complexity arises primarily due to the context of poverty. This context does not have the capacity to be easily contained, rationalised, or explained. Furthermore, in all development projects, this context is the single most important aspect of the intervention and it affects all programming activities. The problems associated with poverty cannot be isolated or disassociated from this contextual background. Engineering solutions, as important as they are in achieving national health targets, are only one aspect of the complex socio-cultural fabric of developing nations. For this study the need to introduce other parameters, such as ‘science’ and ‘technology’ further increases the complexity of the subject matter.

“Neither science, technology nor development demonstrates simple properties that define them once and for all. The sources of all knowledge and the artefacts or processes that derive from them are complex and context bound. The is no scientific method to translate nature into knowledge, and no technological method to translate knowledge into artefacts, much as there is no singular developmental approach to reduce inequality by identifying it, or promote growth by forecasting it”(Smith, 2009).

The known complexity of these systems does not diminish the responsibility in analysing the problems associated with poverty. As Schön, a theorist on the practice of reflective professional learning, explained:

> "*In the varied topography of professional practice, there is a high, hard ground overlooking a swamp. On the high ground, manageable problems lend themselves to solution through the application of research-based theory and technique. In the swampy lowland, messy, confusing problems defy technical solution. The irony of this situation is that the problems of the high ground tend to be relatively unimportant to individuals or society at large, however great their technical interest may be; while in the swamp lie the problems of greatest human concern"* (Schön, 1992).

This thesis is engaged with what Schön refers to as 'the lowlands': the disordered, complex and sometimes brutally violent problems that are caused by the wide ranging and overlapping social issues of extreme poverty.

1.2.4 Layout of the Thesis

To address the complexity in the research a broad range of sources, and research approaches were utilised. This combines both qualitative and quantitative methods which have been used for analysis and discussion purposes. This thesis draws from a range of ethnographies, technical observations, field manuals, discussion groups, individual interviews, reports, datasets, survey methods, research papers and contextual analysis to provide an insight into engineering in development. Given the range and the diversity of information the research, and in order to provide a narrative flow, certain elements have been grouped together into sections within the broader scope of the thesis chapters. This thesis is divided into six chapters with thirteen individual elements (Figure 2).

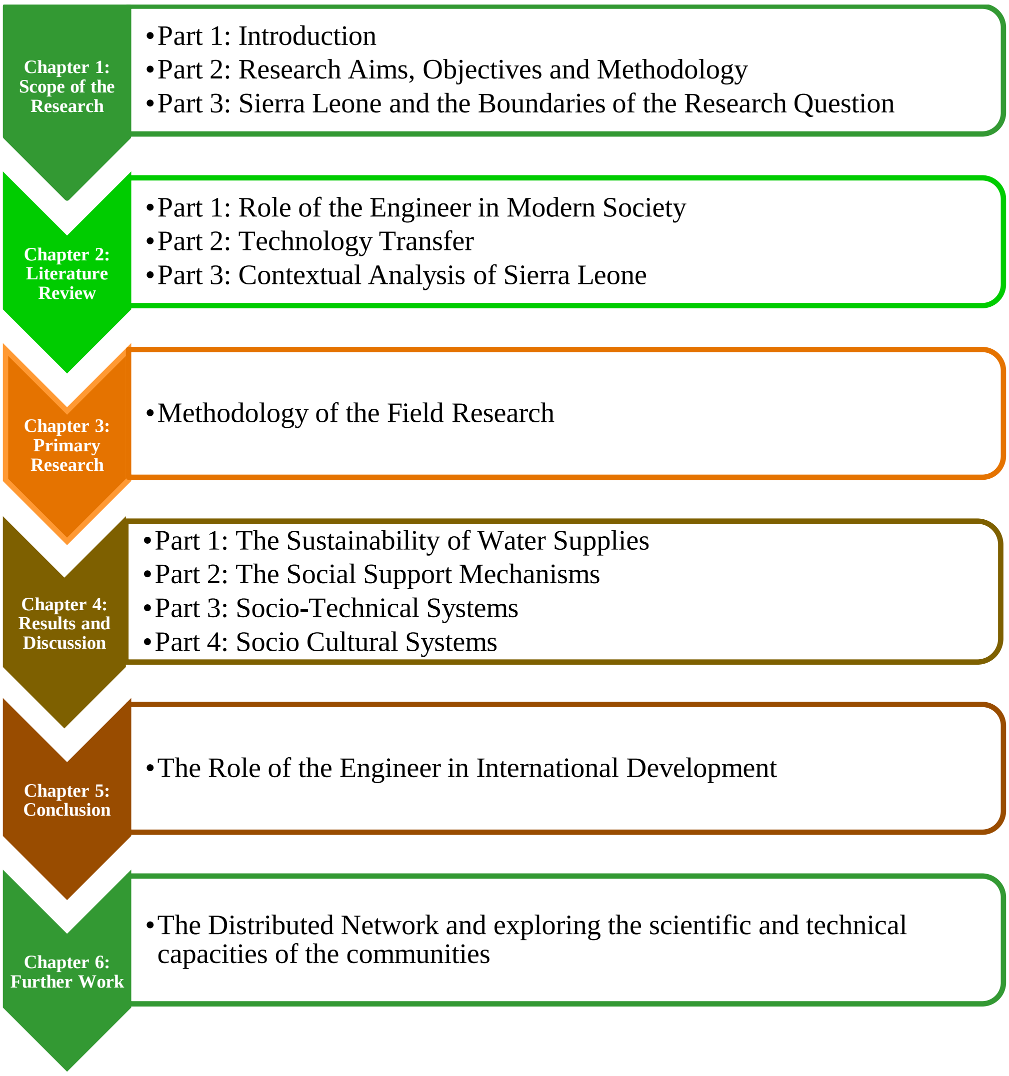


Figure 2: Layout of the thesis

Chapter 1: The first chapter provides an overview and scope of the research including the introduction, aims and objectives and boundaries of the field visits. The following chapter will define the parameters of the research question.

Chapter 2: The second chapter presents a critical review of the literature grouped into three sections. The first part addresses the role of engineer in modern society. This includes its historical formation as well as the narrow and broad definitions of the profession. The second part reviews the models of technology transfer used to provide technical solutions to communities in the developing world. The final part explores some of the fundamental historic, demographic, economic and political context of Sierra Leone which is important for contextualising the primary field research. The three parts of this chapter are discussed independently and utilise a range of secondary supporting information.

Chapter 3: The third chapter explores the methodologies adopted in the primary field research in Tonkolili, Sierra Leone. This includes both quantitative and qualitative research methodologies including; data collection methods, survey types, data enumeration processes and the method of analysis

Chapter 4: The fourth chapter explores the technical, social, socio-technical and socio-cultural aspects of the technology transfer process in Tonkolili District, Sierra Leone. Though these chapters consist of both 'results' and 'discussions' their length and their unique focus require a brief introduction to provide a contextual understanding of the topic. Therefore each of the chapters has an introduction before a presentation of the results. The first two chapters also include a grading system for understanding the information gathered in Sierra Leone. The first part addresses the functionality of water supplies in Sierra Leone by focusing on the condition of the projects witnessed in 150 villages in Tonkolili. The second part explores the social support mechanisms designed to sustain these interventions by investigating the three main support elements: the Water User Committees (WUC), the hand-pump technicians and the spare part supply chains. The third part explores the relationships that households have with their water supply technologies. This includes whether the failure in the understanding of the technical properties of these artefacts has resulted in sustainability problems. The fourth and final part explores opportunities that have been missed or overlooked in engineering practices in Sierra Leone. This part investigates the lack of technical immersion, the inability for current models of service delivery to benefit from existing practices of the beneficiaries, as well as the failure of the engineering approaches to address negative socio-cultural norms within the communities.

Chapter 5: This concluding chapter presents how the role of the engineer can be affected by the case study in Sierra Leone. It concludes that the history of the profession can have contributed to the conditions observed in the case study. This could result in consequences for the profession and introduce choices regarding the future of engineering.

Chapter 6: The final chapter discusses the areas that are important for further study, but were not part of the primary research objectives of this thesis.

CHAPTER 1: SCOPE OF THE RESEARCH

Part 3: Boundaries of the Research Question

1.3.1 Parameters of the study

Exploring the role of the engineer within the complex, disparate and diverse environments of a nation such as Sierra Leone requires certain boundaries to be set. The limitations imposed on this study are intended to allow for concise conclusions about the profession of engineering without resulting in a distortion or oversimplification of the realities of poverty. The first step in answering the research question is to set boundaries so that not every variation of engineering practices or technological innovations requires an explanation or justification for their exclusion. These were chosen based on: (i) practical experience in the field, (ii) an overview on the resources and time available for this study, and (iii) an overall review of available literature on development engineering. To provide an accurate evaluation there are five limitations that have been placed on the research question.

1. **The Engineers:** The focus is on the technical practices of engineers that are not from within the socio-cultural systems (*i.e.* not from the developing country that hosts the projects).
2. **International Development Agencies:** The research investigates engineering projects that are implemented by Non-Governmental Organisations (NGOs).
3. **Technology Transfer:** The technical research explores technology transfer projects between developed and developing nations. The chosen technology was household water supply systems.
4. **Rural Poverty:** This research purposefully targets rural communities rather than urban or suburban environments.
5. **Socio-Political Elements:** The thesis does not explicitly target the political elements within engineering projects in international development.

The selection of these five limitations narrows the research objectives to specific fields. The reason for these choices will be discussed as follows:

1.3.1.1 The Engineers in International Development

The primary audience of this research are those who provide, or are seeking to provide, assistance from outside their normal socio-cultural norms. However, as this research will be based on rural development, certain aspects of this study could be applicable to national staffs of NGOs that operate over rural-urban disparities in their own country. The primary focus is on engineering technology transfer projects that take place over a rich-poor divide. The engineers that are engaged in development work have technical objectives to achieve but a broader interpretation of the term 'engineer' is required to determine the ethics, limitations and untapped potential in engineering practices (Newberry, 2007).

The preclusion for any nation, region, community or individual requiring an engineering intervention, as opposed other mechanisms such as an educational or social-policy solutions, is that the issue must be solved by the inclusion of a technical artefact. This does not mean that multi-disciplinary actions are not considered, particularly concerning the complexity of development issues, or that they cannot complement engineering functions, but that it is not considered an engineer's responsibility if there is no necessity for a technical artefact to be present. The role that the engineer provides with regards to the artefact is in the design or overseeing the implementation of a technical solution to suit and to solve the problem. This role is not defined as being the individual that actually constructs the artefact (*i.e.* the construction workers) nor does it extend to those responsible for its operation (*i.e.* the users) of the artefact. It also does not include those responsible for maintenance (*i.e.* the technicians).

1.3.1.2 Engineering in the International Development Agencies

There are a number of engineers, who operate outside their socio-cultural systems, which engage in engineering in developing nations. For example in Sierra Leone these engineers are found to practice within a range of diverse sectors including: heavy metal mining, road network construction, large scale energy systems (including dams and electricity grids), Information and Communications Technology (ICT) networks and defence infrastructure installations (ADB, 2011). These engineers are usually employed by engineering firms, consultancies and contractors. These are private sector operatives, and though their practices can increase the welfare and quality of life for the countries in which they operate, they are primarily profit driven and are not explicitly mandated to address poverty. The responsibility for poverty reduction is provided by not-for-profit enterprises including Non-Governmental Organisations (NGOs), grassroots organisations and advocacy groups (Desai and Potter, 2013). These are funded by the international donor community and private investors. They are specifically mandated to eliminate extreme poverty and are therefore heavily invested in sustainable development. It is the engineering capacity of these organisations, and the technology transfer that they engage in with their beneficiaries and host communities, that is the focus of this research.

The numbers of engineers that work within international NGOs are very few in comparison to the scale of the problems. It is estimated by UNESCO that Sub-Saharan Africa alone needs 2.5 million engineers in order to resolve its technical problems. Sub-Saharan Africa is only one region of the developing world that requires engineering support (UNESCO, 2010). In developing countries the shortfall in technically competent staff on a national level cannot be resolved by the quantity of engineers working within development agencies. This realisation is exacerbated by the low numbers of expatriate engineers that are likely to enter into development as a full-time engineering career choice (Lamb and Long, 2004).

1.3.1.3 Household Water Supply and Technology Transfer

It is not possible to analyse the broad spectrum of technologies that have, or could be, provided to developing countries. There are an entire range of engineering projects which NGOs currently provide to communities in developing nations that could potentially be discussed. These include infrastructure provision – such as bridges, schools, box-culverts or health clinics, but they also include technology transfer projects – such as water supply technologies (*i.e.* tubewells), sanitation solutions (*i.e.* pit latrines), and energy systems (*i.e.* micro-hydro systems).

To provide an analysis of technologies it is better to address one aspect of engineering rather than continually alternate between different technologies. A misconception about the ‘complication’ of the artefacts that the NGOs provide can result in the technology transfer not being regarded as a complex process. The development agencies usually provide ‘low’ technologies to achieve poverty alleviation targets. The definition of a ‘low technology’ is one that can be manufactured with little capital investment, can normally be understood by one individual, and usually do not need a technical specialists or process of compartmentalisation in order to construct (Hazeltine et al., 1998; Schumacher, 1973). The properties of many of these artefacts have been understood and have been used by post-industrial countries for decades, if not for centuries. The lack of complication in these technologies can give the mistaken impression that engineering in development could only involve a linear process of technology transfer – and that the benefits of this transfer would be immediately apparent to the project beneficiaries. The reality of development practice suggests otherwise and this linear approach will be discussed in detail. The relationships that new technologies can have with their host communities can very often be unquantifiable and of an indeterminate and dynamic nature. Therefore it is better to use the technology, in this case the provision of a domestic water supply, as a focal point, and infer the success and failure of these transfers from the communities’ reaction to these technical solutions, than attempt to discuss multiple intervention types within a complex system. This study will focus solely on the engineer's role in household water supply. The water supply technologies in each case can differ, and include communal systems, but the resulting investigation is into the access to improved sources that is available to each household.

To resolve and address basic water related issues, in any given country, the need for some form of engineering is unquestionable. Water related problems cannot be resolved without the inclusion of some form of infrastructure into development programmes (Harvey and Reed, 2004; WPP, 2012). Therefore it is guaranteed, in at least one aspect of service delivery, that there is a role for the engineer within these projects.

There were three further reasons for specifically selecting water supplies:

- Firstly, the investigation into water supplies schemes provides clear advantages for the purposes of this research. Their construction, over consecutive decades of development, has left a legacy that can be easily identified and evaluated. The majority of systems in developing countries are provided by, or implemented in partnership with, the International NGOs. Unlike larger construction projects, such as schools or bridges, many of their technical properties can be assessed during a single site visit.

- Secondly, the selection of 'household' water supplies, rather than the water used for industrial, commercial or agricultural purposes, provides a direct correlation between health and the human right to water, without the necessity to explore communal water rights (El Hadji Guissé, 2005). There are specific guidelines to how much water each person is entitled to, for household and drinking purposes, which are not clearly stated for other usages (Howard and Bartram, 2003). This narrows the research objectives and focus.

- Finally, as the household water supplies are a human right, and the local government within developing countries are unable to provide many of these solutions to their people using their own resources, there is a clear role for the international NGOs in assisting with these problems (Filmer-Wilson, 2005). Additionally reaching water supply targets has been an explicit goal for the NGOs donor bodies. For example the need to water is addressed in the Millennium Development Goals (UN, 2012a).

The water supply projects themselves have a range of technical, environmental, and institutional factors to consider (Panthi and Bhattarai, 2008). Though the focus of the research is water supply technologies, it is intended that the conclusions are applicable to more than a single field of engineering in development.

1.3.1.4 Rural Poverty and International Development

For this research the rural areas in developing countries, as opposed to urban, suburban, peri-urban or townships were selected. This decision was made for two reasons:

- Firstly, water supply development in rural areas has been chronically under-addressed. It is reported by the Joint Monitoring Project (JMP) that 780 million people require access to safe drinking water (UNICEF and WHO, 2012). The same report also suggested that the number of people in rural areas using an unimproved water source in 2010 was five times greater than those in urban environments. The nature of rural development, with regards to its isolation from urban cores and its extreme poverty, are major contributors to the slow uptake of water supplies.

- Secondly, the solutions that are available to urban centres are very different to those that are applicable in a rural environment. Piped water networks, centralised treatment systems or large scale water storage solutions, such as those utilising dam and reservoir technologies, are not cost effective on smaller and more spatially distributed scales (Skinner, 2003). For this reason solely focusing on urban infrastructure provision would play a detrimental part when considering the role of the engineer in international development. The type of engineer that can address urban concerns is too easily identifiable with current 'post-industrial' engineering practice (Jenkinson, 2011). Successful project implementation on large scale, capital intensive and 'high' technologies necessitate an engineering education that is not dissimilar to those that are currently produced globally at leading tertiary educational institutions. Urban water supply provision in developing countries is no less prone to cultural miscommunications, corruption and technical incompetence than their rural counterparts, but the scale makes the exact nature of these issues harder to define.

It is within the rural areas, where many of the needs are the most extreme, and the technical options more limited, that new engineering innovation is required. It is also within these disparate regions where the role of the engineering professions can be challenged and the concept of what 'engineering' can achieve can be progressed in new and unexplored directions (Chambers, 1993).

1.3.1.5 Socio-Political Aspects of Development Engineering

In Sierra Leone the Ministry of Energy and Water Resources (MoEWR) are the current custodians of the nation's Water Law. They have oversight over the sector agencies through their Water Department. This includes (i) the National Water Resources Board (NWRB) who provides regulation and oversight for water resources management and (ii) the Energy and Water Regulatory Authority (EWRA) who are responsible for economic regulation of water and related sanitation delivery (GOSL, 2009). The existing socio-political involvement of government institutions in the communities will be discussed as part of this research discourse, but the socio-political context of water supplies will not be addressed in isolation as is not the focus of this research. It is understood that government institutions have a key role to play in rural water supply programmes, especially in providing an enabling role as policy-makers, facilitators and regulators.

> *"National and local government institutions are generally the most important stakeholders if services are to be sustainable. The role of government in rural water supply must be clearly defined at all levels and understood by all stakeholders"* (Harvey and Reed, 2004).

Though it has been emphasised that government institutions are invaluable to the sustainability of water supply programmes the purpose of this research is not to fully engage in the socio-political elements of water supplies in Sierra Leone. The main reason for not investigating the socio-political elements of water supply projects is that in countries like Sierra Leone, where the majority of the infrastructure is heavily donor subsidy driven, it is the model of technology transfer across socio-cultural divides that requires revision and analysis (World Bank, 2009). This process of service delivery is shared with the government institutions, through a process of capacity building, so that the scale of interventions can increase and the development practices attempted by the international NGOs can continue once the development agencies pull out (Abrams, 1996). This can already be observed in Sierra Leone, as it can in many parts of Sub-Saharan Africa, as government bodies have directly adopted the practices of development agencies. Therefore their success and failures can mimic the results of the NGOs (Harvey, 2008). Their current role in service provision of water supplies (*i.e.*, working with contractors to engage in construction, setting up community structures to support water supplies and providing the technologies spare arts) is closer to the existing practices of NGOs rather than as a separate entity operating within the sector (Figure 3). The government bodies do not work with enough sufficient differences from their NGO counterparts to warrant a different approach to their activities.

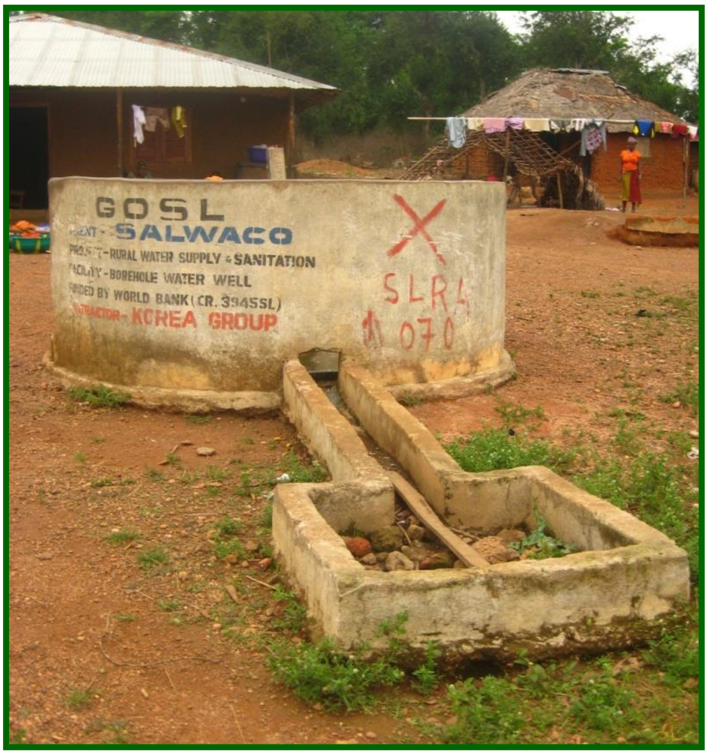


Figure 3: Government of Sierra Leone (GOSL) built borehole - Mathonkara

For this reason having a functional, ethical and sustainable model of service delivery is a necessity. Separating the socio-political elements and the local government actions from the models of technology transfer is not intended to diminish their role in rural water supplies. Instead it is done so that a better understanding of the methods of technology transfer can be formed prior to the hand-over of this process to the local government bodies.

CHAPTER 2: LITERATURE REVIEW

Part 1: The Role of the Engineer in Modern Society

2.1.1 Introduction - The Definition of the Engineer

The first part of the literature review will discuss the current role of the profession of engineering as it has evolved in modern and technically advanced societies. It is intended that this will provide an understanding of the term 'engineer', and therefore make an exploration of their role in international development feasible. It is not possible to offer an authoritative explanation for the role of the 'engineer' in modern society as there are no fixed, unanimous or definitive statements on the professions purpose. The term 'engineer' has evolved over time and has consistently taken on new meanings, and new branches of practice, to suit both ever-changing circumstances, and the technical necessities that have been caused by the demands of post-industrialisation living. Tracing historical exactness for a definition of 'the engineer' is difficult because engineering, as a subject, does not have the same level of historically introspective analysis and internal debate as the learned professions - divinity, medicine and law (Ballard, 1978; Carassa and Stracca, 1984; Stanley, 1978).

The lack of self-reflective understanding in the profession is rapidly changing. Engineering is now at the forefront of worldwide changes due to technological progress becoming more central to the understanding of global prosperity (Tryggvason and Apelian, 2006). The introduction of the concept of sustainable development, borne from the concepts of modernity and post-modernity, has radically changed the methods and functions of engineering (Rogers et al., 2008). It has had consequences for current engineer's practices, across all fields, as it has allowed for analysis and discussion on the non-technical aspects of engineering projects. As such, the socio-cultural and environmental properties of engineering artefacts, which were largely ignored during the historical period of industrialisation, are no longer considered neutral (MacKenzie, 1996; Winner, 1980). Scientific supported theories which have identified global threats to prosperity; particularly climate change, non-renewable resource use and population growth, has meant that the engineer can no longer act with impunity of the consequences of their practices (Azapagic and Perdan, 2011; Singleton and Hahn, 2004). Sustainability as Jowitt described:

> *"…defines the context in which technical and other analyses disciplines are applied and the emergent properties that arise from their application"* (Jowitt, 2003).

The arguments for sustainable development have necessitated more introspective thinking about the role that engineering plays on the global stage.

2.1.2 The History of the Profession of Engineering

Before the introduction of the current descriptions of the 'engineer' it is important to provide a brief historical overview on the formation of the profession. This is important as it indicates the original purpose of the profession and their function in society that they were designed to accommodate. The consensus on the beginnings of engineering, as a profession, can be contradictory and have been heavily debated. The philosopher Michael Davis, in his book *'Thinking Like an Engineer'* contests two of the most popular conceptions about the ancestry of engineering:

1. The earliest human ancestors built tools, which has parallels to engineering innovation, and are therefore engineers
2. That the organisational activities taken to build large constructs, such as the pyramids would have parallels with modern engineering practices, and could therefore be referenced as work of an engineer.

According to archaeological research, during the Palaeolithic Period, generally referred to as the Stone Age, the first handcrafted tools began to emerge (Brose and Wolpoff, 1971). These were hand-crafted technical solutions to problems such as piercing, cutting and cleaving required for the skinning of furs and the eating of meat. Therefore by assigning this innovation in tradecraft to engineering, many authors conclude that these Stone Age people were the first engineers. For example, the UNESCO report on engineering indicates that many of the contributors make continual reference to these pre-historic events as the root of engineering (UNESCO, 2010). Davis argues that these authors would make the mistake of attributing engineering to the creation of *"mere technology"*. Davis also observes that engineers are not usually involved in manual labour, as those of the Palaeolithic era would have been, but in the preparing orders for others to carry out (Davis, 1998).

Therefore, by this logic, the history of engineering would begin much later than the Palaeolithic Period, such as in the building of schemes large enough to credit the involvement of an engineer. Archaeological evidence suggests that there are many projects that would have allowed for this type of 'engineering', such as the Step Pyramid at Ṣaqqārah, Egypt or the Pharos Lighthouse of Alexandria (Finch, 1951; Kirby, 1990). Davis also argues that this too is incorrect as it would attribute the history of engineering to that of architects ('*arkhitektn'* or 'master builders' in Ancient Greek). He notes that the word 'engineer' only entered common usage 400 years ago in France, whereas the word 'architect' has a much older etymology. The professions of architecture and engineering are sometimes historically indistinct, and have often shared practices - such as the development of mathematical measurement techniques to provide two-dimensional records of three-dimensional spaces, but the two professions have had quite different evolutionary backgrounds (Davis, 1998; Saint, 2007).

Regardless of what pedigree commentators on the origins of engineering claim, there is common consensus that the word 'engineer' was originally used as a military term. The etymology of the word 'engineer' is attributed to the Latin word *'ingenium'* used in 1250 to mean *'of innate quality or a clever invention'*. The term *'engines'* was the name first given to these clever inventions; complicated devices used for useful purposes. The first people to be called 'engineers' were the French soldiers, in Old French – *'engigneor'*, who operated their armies 'engines of war' which were predominantly catapults or artillery. These '*engigneors'* were not necessarily responsible for designing or building their armies engines. In 1676 the *Corps de Génie* - Engineering Corps were formed as a special unit in the French army, responsible for all military constructions. Later, in 1716, the French military established the *Corps des Ponts et Chaussées* - the Bridge and Highways Corps (Artz, 1966). These engineers were primarily intended for military purposes, such as the building of fortifications and mines, but the transferable skills they acquired, such as the ability to build roads and bridges, became as crucial for commerce as it was for military functions (Brunot and Coquand, 1982).

Over the following decades 'civil engineering' was formed as certain engineer's technical practices necessitated a split from the military operations. By 1747 the *Corps des Ponts et Chaussées* formed the *Ecole Nationale des Ponts et Chaussées* - National School of Bridges and Highways (Artz, 1966). It trained both 'civil' and 'military' engineers and taught subjects like materials, machines and hydraulics (Finch, 1951; Kirby, 1990). In 1771, under the direction of John Smeaton, the first man to call himself a civil engineer, the United Kingdom followed suit, forming the Society of Civil Engineers (Norrie, 1956). Most European countries adopted these practices and 'civil engineering' became a formal profession. They were not the only technical professions, as the architects were still responsible for much of the built environment projects.

Engineers and architects shared some aspects of their work as both professions prepared, instructed and implemented projects by utilising construction drawings (Saint, 2007). At an early stage in the evolution of engineering there formed some important distinctions between their practices and that of the architect that determined their future roles in society. The advantages gained from the military heritage of the civil engineers, rather than a legacy of trades and craftsmanship, ensured that they could replace architects in large civilian projects (Davis, 1998).

There were three significant developments that gave engineers precedence over architects in large civilian projects:

- Firstly, engineers were originally trained in the art of war and understood the importance of speed and reliability in their constructions. Architects were skilled labourers, such as timber craftsmen and stone masons, who had worked to achieve their 'master builder' status through apprenticeships. These builders were more akin to artists in that their methods were often used to express aesthetic creativity. They developed these qualities in their designs of their buildings, which required skilled labour, and time, to construct. Therefore they adopted slower methods and were less concerned about the pure functionality of their work (Davis, 1998, 1996).

- Secondly, unlike architects, the first engineers were trained as army officers. These officers were regarded as 'well-disciplined men' and were capable of holding positions of key responsibility. As such they would have been well versed in giving orders to large groups of both skilled and unskilled men. These abilities would have been immensely beneficial when managing large civilian projects. This type of work would have presented problems for architects who, given their skilled labour intensive practices, would only have been capable of carrying out much smaller, or less complex, projects (Davis, 1996).

- Finally, the origins of engineering coincided with the Age of Enlightenment and the end of the Scientific Revolution. Engineering came to prominence in society around the time that Newton's *"Philosophiæ Naturalis Principia Mathematica"* introduced the laws of motion and the formation of classical mechanics (Newton et al., 1726). The professions embrace of this paradigm allowed for an adoption of a scientific process that could be applied to construction projects (Hall, 1961). As the internal structure of engineering was not as dependent on previous years of incremental improvements in practice, as the architects had been, engineers were capable of utilising these scientific breakthroughs and seamlessly incorporating them into their practices. Engineers developed calculation and design methods that negated the need for rules of thumb or empirical formulas. Problems that required a scientific solution could now be resolved methodically by an engineer to provide constructions that were reliable, safe and offered substantial financial savings on material and labour costs. (Davis, 1996)

The combination of these three aspects allowed for construction projects that were in the interests of the general public. The service provided by engineers offered both a rational reason (speed, reliability, and cost savings) but also a moral reason (safety, value for money, ensured quality) for their participation in large scale projects. Though there were similarities in their practices, the pre-historic and ancient history linkages to engineering did not offer these two core rationalities, and therefore could be argued to not be classified as engineering. Current definitions of engineering, with its formal curriculums, examinations, certifications, standards of practice and codes of ethics, directly identifies with these historical roots that were first established in 1716. The profession has since split into further categories of specialisation, such as mechanical, chemical and electrical engineering, which allows the professions to focus on specialised technical aspects without sacrificing their common engineering attributes.

2.1.2.1 The Misconceptions of the Engineering Profession

It is important to state the historical formation of the engineer. It is equally important to understand certain descriptions that are inconsistent with the current formation of the profession. In 1933 the engineer John Waddell wrote a paper offering vocational guidance to engineers. He defined engineering within the context of scientific and artistic development:

> *"Engineering is the science and art of efficient dealing with materials and force…it involves the most economic design and execution…assuring, when properly performed, the most advantageous combination of accuracy, safety, durability, speed, simplicity, efficiency, and economy possible for the conditions of design and service"* (Waddell et al., 1933).

Engineering being presented as an 'art' or 'science' is a common perception of the field, often from social commentators from within the profession. As the civil engineering observer, Florman states:

> *"[engineering is] the art or science of making practical application of the knowledge of pure sciences"* (Florman, 1996a).

Ferguson, a historian of technology, asserted that much of engineering activities are non-verbal and intuitive practices, rather than a continual dependency on sets of equations and calculations. From this he asserts that engineering design is an art, and not a science (Ferguson, 1992). The description of engineering design as an art derives criticism from commentators such as Kasher who suggest that, though engineering often involves *'creativity and innovation'* and sometimes *'beauty and elegance'*, it uses dramatically different methods for classification and evaluation than those used in art (Kasher, 2005). This is confirmed by one of the broadest artistic philosophical theories: the institutional theory of art (Dickie, 1974). Though certain aspect of engineering, such as the design elements, usually contains fundamental artistic concepts, the expression '*engineering is an art'* does not describe the role of the entire profession.

The most notable confusion with the profession is caused by the identity of the engineer being merged with the role of a scientist. This can be a misappropriation sometimes fuelled by engineers themselves (Bush, 1945). Certain descriptions of the occupation can describe engineering as an *'applied science'* (Bunge, 1966; Kline, 1995). Since its inception engineering has undoubtedly made use of scientific studies, theories and advancements in order to successfully operate and progress. The labelling of engineering as an 'applied science' is fundamentally misleading for two reasons: firstly science can be argued to always be applied, or always have an application, and secondly engineering still happens when there is no scientific theory governing a course of action, or when scientific reasoning cannot be used to explain the outcome of a given scenario.

In this first instance, the rationalisation of an 'applied science' relegates certain sciences, or aspects of scientific thinking, normally referred to as the 'pure sciences', to be classed as 'non-functional' science. This suggests that certain parts of science have no application in the real world. This is apparently contradictory, as Feibleman states:

> *"The logical evidence in favour of the hypothesis is contained in the very nature of pure science itself. Any discovery in pure science that gets itself established will have gained the support of experimental data. Thus here must be a connection between the world of fact, the actual world, in other words, which corresponds to sense experience, and the laws of pure science. It is not too difficult to take the next step, and suppose that the laws, which were suggested by facts in the world corresponding to sense experience, could be applied back to that world."* (Feibleman, 1961)

As he goes on to suggest, the distinction between pure and applied sciences are distinct, but they gradually merge into each other (Feibleman, 1961). Even within the scientific community the concept of applied science is disputed - as the Biologist Thomas Henry Huxley stated:

> *"I often wish that this phrase, "applied science", had never been invented. For it suggests that there is a sort of scientific knowledge of direct practical use, which can be studied apart from another sort of scientific knowledge, which is of no practical utility, and which is termed "pure science". But there is no more complete fallacy than this. What people call applied science is nothing but the application of pure science to particular classes of problems"* (Huxley, 1880).

In the second instance, engineering has been shown to operate outside normal scientific structures. Kuhn's model of scientific revolutions does not offer a clear indication of where the practice of engineering is supposed to operate (Kuhn, 1970). Engineering regularly uses established theories but generally for application and not to reinforce or challenge existing scientific paradigms. Most importantly the engineer is still required to make assumptions and decisions where scientific theory is incomplete or inconclusive. It is therefore outside Kuhn's model of normal, revolutionary or new-normal science. It is argued that engineering, particularly at the senior levels of decision making, operates in a realm of ‘post-normal’ science where:

> *"facts are uncertain, values in dispute, stakes high and decisions urgent"* (Funtowicz and Ravetz, 1993).

Therefore engineering and science exist in tandem, and are part of the same spectrum of activity, but they refer to two different practices, formations and purposes. Engineering, as a profession, regularly adopts scientific methods and principles in order to successfully operate (*i.e.* it applies science) but the profession is neither a function of science nor confined by the boundaries of existing scientific hypotheses. Science, like art, is a tool for the engineer in the construction of their methods, tools and technologies.

2.1.3 The Engineer – The Two Definitions of the Engineer

This study is focused on the external and contextual application of engineering in society, and not with the internal operations, formations and evolution from within the profession. Therefore the nature of a professions in general, with their internal classifications, distinctions, codes of practice and regulation (Larson, 1979) will not be discussed in-detail in this research. As discussed previously the engineer’s role has evolved to suit the requirements of the societies in which the engineer operates. It was found in the literature that the current definition of the profession falls within two categories:

1. The narrow definition – which is linked to the function of the profession

2. The broad definition – which considers the context of the engineer and their purpose within society at large

Understanding both these expressions is important to determining the role of the engineer in international development. The full explanation of these definitions will be provided in more detail.

2.1.3.1 The Engineer – The Narrow Definition

The narrow explanation defines the profession with regards to an engineer's practice. This is usually defined as a culmination of their activities. For example Florman suggests that*:*

> *"Engineers are what they are. And, to a great extent engineers are what they do. The ultimate expression of an engineer is to enumerate all the products and processes created by engineers and to describe the activities by which these products and processes are achieved."* (Florman, 1996b).

The need to associate engineers directly to their working practices, rather than on broader terms, is clearly evident in many of the descriptions of the profession. This is particularly common with encyclopaedic references and educational material. These basic definitions are occasionally propagated by engineering institutes with the intention of attracting people to the field. Many of these definitions normally use one, or more, of these three techniques in the rationalisation of the profession:

- ***Engineering problems:*** an overview of the technical problems that an engineer solves (*i.e.* the construction of particular structures, machines or manufacturing processes)
- ***Knowledge systems:*** a reference to the application of knowledge used by the engineer to develop solutions to technical problems (*i.e.* the application of either technical, scientific or mathematical knowledge)
- ***Method used for solving technical problems:*** a description of the methods used to address the problems (*i.e.* design, development, invention or implementation).

Depending on their purposes, each commentator offers different variations in their choice of describing the engineer. However, the narrow definition has one overarching conclusion, engineers are almost always regarded as 'technical problem solvers' (Mourtos et al., 2004). It rationally follows that each engineer's individual discipline is determined by the type of problems addressed, and the methods that are used to solve them. Using this logic means that certain activities can be established as 'engineering' practices, through consensus of engineering institutions, whereas other practices can become debatable. For example, the historical notion of an engineer being someone who 'operates' an engine would, at the very least, broaden the profession to every car or mobile phone owner in the world. The inapplicability of this description of the engineer is clear, and it would be unlikely for this notion to be condoned as being ‘engineering’. There are however more contentious issues. These evolve around the classification of the tasks concerned with the 'maintenance' of an artefact. This technical activity being defined as an engineering practice is open to interpretation, particularly in the United Kingdom. The flexibility of this practice has allowed countless technical professions to align themselves to engineering. This increases their status and is used by corporate bodies, such as British Gas - who suggest they have over 1000 'engineers' rather than 'heating technicians', to advertise their technical strengths. This remains an important societal consideration for both industrial and developing nations alike, but is out-with the scope of this thesis to discuss in detail (British Gas, 2013; Davis, 1996).

Regardless of the knowledge systems utilised or the methods adopted, engineering’s primary ethos is in finding solutions to technical problems. These are issues that can only be resolved by the inclusion of a technical artefact. Artefacts, from the Latin '*arte factum'* - made with skill, vary in scale, manufacturing and construction processes, as well as inherent complication. The technical requirement, as provided by the properties of the artefact that is deemed necessary for construction, determines the specialisation or field of engineering that participates. Examples include the construction of a hydraulic dam and the Civil Engineer or the creation of a computer processor and the Electronic Engineer. With the oldest engineering professions, such as civil and mechanical, completed artefacts are usually physical constructs. The developments in certain engineering fields have moved towards providing more metaphysical solutions to problems. Certain technical problems require a solution that is not tangible to human senses, such as a developing technical processes or creating new methods of organisation (Jowitt, 2003). This has blurred the simple definition of an engineer’s role being simply focused on the creation of a physical construct. Metaphysical artefacts require technical knowledge and application, and are still covered under the definition of 'technical problems which require an engineer’s participation'. These apply wider definitions to ‘technology’ than purely physical constructs but do not offer a wider interpretation of ‘engineering’.

The narrow definition for the engineer exists because of the practical need to relate the activities of the engineer to the definition of the profession (Florman, 1996b). This is required for four reasons:

1. Due to its practical application, the narrow definition offers clear distinctions between the different fields of practice, such as mechanical, civil, chemical and environmental engineering
2. As an umbrella term, it is used to explain how disparate professions, such as chemical and electronic engineering, are associated with each other (Burghardt, 1995).
3. The narrow definition is also regularly used to differentiate the occupation from other technical professions, most notably the practices of architecture (Saint, 2007).
4. It also allows a clear differentiation between engineering support roles, such as engineering technologists or technicians (Kirkpatrick, 1985).

2.1.3.2 The Engineer – The Broad Definition

As seen from the historical description of the profession engineering has its evolutionary roots firmly in functionality; however a broader definition of the profession is required to determine their role within society. During the formation of the engineering institutes there were attempts to broaden the definition of the profession. These were intended to provide contextualisation of the engineer's activities, to include the social aspects of their practices. This went as far back as 1828 when Tredgold of the Institute of Civil Engineers (ICE) stated: *"Engineering is the art of directing the great sources of power in nature for the use and convenience of man".* This original quote is generally misinterpreted as a moral endeavour due to the misappropriation of *"convenience".* Tredgold's quote was generally referring to the advancements of British industrial and commercial interests rather than ethical considerations about humanity in general (Mitcham and Munoz, 2009).

Debates that started in the 1970s slowly changed the perspective of the role of engineering in society. The catalyst was a resurgence of Malthusian concepts of global instability by the Club of Rome (Meadows et al., 1974). Forty year later their predictions were found to be ultimately inaccurate about population growth and the dramatic depletion of resources. However the debates that surrounded analysing society's tendency for the rapid consumption of non-renewable resources introduced the concept of sustainable development. The UN commissioned Brundtland Report, known as 'Our Common Future', was designed to allow global collaboration on sustainable development. The simplest explanation of sustainable development offered in this report is:

> *"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs."* (WCED, 1987a).

It is centred on three aspects of sustainable development which include; economic growth, environmental protection and social equality. The economic sustainability approach focuses on maximising income while maintaining constant or increasing stock capital (Pearce and Atkinson, 1993), the environmental protection sought to maintain the resilience and robustness of biological systems (Redclift, 1987) and the socio-cultural sustainability was focused on maintaining the stability of social and cultural systems (Barbier, 1987).

Ethical arguments in engineering arose with the realisation of the impact that construction, tools and technologies had on both the localised and global environment. Scientific research into sustainability, including aspects such as the monitoring of the climate change, water and air pollution and resource depletion, suggested that the engineering of the natural environment was capable of causing significant, and sometimes irreversible, damage. The 'non-neutrality' of engineering practice became paramount to the understanding of the professions ethical responsibilities and expectations (Martin and Schinzinger, 1996; Newberry, 2007). In 1979 the American Accreditation Board for Engineering and Technology (ABET) determined engineering to be:

> *"…the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind"* (ABET, 2013).

The focus on the engineer's role in safeguarding and increasing the welfare of mankind offered a broader interpretation of the profession, and a context for their work, than simply stating an engineer's operational capacities. The introduction of sustainability necessitated a change in the practices of engineering. As the Brundtland Report suggested

> *"The concept of sustainable development does imply limits - not absolute limits but limitations imposed by the present state of technology and social organization on environmental resources and by the ability of the biosphere to absorb the effects of human activities"* (WCED, 1987a).

Therefore a redefinition of the purpose of engineering, for future generations, was required. Sustainability necessitated a revaluation of Tredgold's original mandate in order to respond to the new roles and responsibilities that would be required for achieving global sustainability:

> *"Engineering is the art of working with the great sources of Power in Nature for the use and benefit of society"* (Jowitt, 2003).

Engineering, as a profession, had made ethics central to its purposes. The aspiration to benefit society requires an introspective look at engineering practices, in all their areas of technical problem solving.

2.1.4 The Definition of the Engineer

The definition of the role of the engineer adopted for this thesis will draw from both the narrow and the broad aspects. There is no definitive statement, but both aspects are crucial to understanding the role of the engineer in any context. These two synergetic components will provide a framework for reference when exploring the role of the engineer in international development.

A narrow definition is required as it provides a structure of reference that can be used to determine if it is a role suited to that of an 'engineer' rather than that of another profession. This is necessary due to wide spectrum of problems faced by an engineer in developing countries. The constant demands and needs of poverty can push the boundaries of what could, or perhaps should, be expected from the profession (UNESCO, 2010). The importance of the engineering profession not being classed as an 'art' is crucial in development for making the distinction between local and traditional artisans, such as blacksmiths and mechanics, and engineering (Richards et al., 2004). Not classifying engineering as a 'science' highlights the importance of understanding the social aspects and context of the technical design and implementation stages of development practice.

The broad definition of the engineer is used to provide the contextualisation of the engineers' role in society, particularly as they relate to sustainable development. Therefore this research has indicated that there are two dimensions to the engineer that explains their role: firstly their operational capacities (function), and secondly their meaning and contribution to society as a whole (ethics). These are intended to be co-equal aspects and work in synergy to determine the role of the engineer in any given environment. It is not a coincidence that the engineered artefacts that the engineers produce can be understood by using the same logic. As Binford discussed, artefacts themselves have two dimensions – firstly their function and secondly their social meaning and symbolism (Binford 1965). The engineer, as a precursor to their artefacts, can also be shown to have these same two dimensions.

One final aspect of the role of the engineer, which is not discussed in detail, in this chapter or in this research, is the inherent attributes or characteristics of engineering practice. These are sometimes referred to in the definition of the engineer. There are many possible considerations, as Waddell states:

> "*...accuracy, safety, durability, speed, simplicity, efficiency, and economy...*" (Waddell et al., 1933).

These attributes are not considered as external to the definition of the engineer, but are seen as products of the interplay between the two core mechanics of the profession: functionality and ethics. For example; constructing an artefact efficiently is both a product of an engineer's function, as well as an expression of their ethical commitment to their client. A discussion on each of these engineering characteristics and application within the profession are outside the scope of this thesis.

2.1.5 Colonialism and Engineering

The profession, as defined originally by the narrow definition, and later by the broader definition, can be seen clearly in the practices of engineering during the early years of its formation. Historically examples are frequent, particularly from analysing the industrial and post-industrial eras, but the period of colonisation is also a key example of the early stages of engineering development and maturation. As discussed before the links between the modern concept of 'engineering' and its historical basis started in roughly 1676 (Artz, 1966). The European Colonial Period, of which Spain, Portugal, France, Great Britain and the Netherlands were the initial participating empires, followed later by Germany and Belgium, developed concurrently to the history of the engineering profession (Gann and Duignan, 1975). Starting in the 16^{th} century throughout Africa, Asia and the Americas the process of decolonisation did not happen for the majority of the nations until the end of World War II.

This period of history is of importance because of the change in attitude to modern engineering approaches, but also for the legacy of artefacts that remains in the 21^{st} century. Throughout many parts of Africa there are widespread examples of engineering activities that were constructed by the colonial powers. In many ways these typify the application of the 'narrow' definition of engineering in that their use and purpose was dependent on functionality and utility over increasing welfare and benefiting the societies that they were based within. In the early stages engineers were used for mapping the sovereign territories and build basic infrastructure. Later they were used to utilise the natural resources of the colonised nations (Lucena and Schneider, 2008; Rostow, 1959). Their involvement in Africa included a host of engineering interventions such as canals, bridges, telegraph networks, maritime ports, roads, mining infrastructure and railways (Rostow, 1959).

> *"Although working under different economic and political relationships between Empire and colonies, these engineers shared a primary concern: permanent transformation, i.e. the attempt to transform nature into a predictable and lasting machine (infrastructure) that could be controlled and would last to ensure their imperial patrons a return on investment and display superiority over indigenous technology."* (Lucena and Schneider, 2008)

As could be anticipated there have been both positive and negative impacts of such engineering interventions. The benefits offered by many of these projects, which would have been unprecedented in the local histories of many of the colonies, would have been considerable. Roads that were impassable in certain seasons would have allowed for continual movement of people and goods (Barwell et al., 1985). The wealth and income generation for villages that have been located close to these roads remains would remain evident as far as the 21st century (Bryceson et al., 2008). Villages and communities which are based closer to road constructions have better access to education, health and livelihoods than their more isolated counterparts (Howe et al., 1984; Platteau, 1996). Rivers and streams, which would have otherwise have severely restricted movement, would have become for the first time traversable. Bridges built during the colonial periods would have benefited from the progress in mathematics and scientific progress that engineering at that point had achieved. Examples, such as the Victory Falls Bridge, which crosses the Zambezi River as was built in 1904 (Figure 4), typifies the examples of engineering seen during this period and were scattered throughout the colonies of the European powers (Winchester, 1938).

Figure 4: Victoria Falls Bridge - Source: UN World Tourism Organisation (UNWTO)

Railways and ports would have offered unprecedented access to the land for those involved in the transfer of goods between and within nations (Gann and Duignan, 1975). Though it is unlikely that the local populations would have benefited from the large ports and, to a lesser extent certain nationalised railways, there would have been clearly observable changes in the local economies, labour availability and cultural practices (Gann and Duignan, 1975).

Solely looking at the benefits offered for the communities that are resident would be to hide the true extent of the engineering problems with the colonial and post-colonial periods of infrastructure provision. The issues do not lie with the engineer directly but in the aims and objectives of the colonial powers themselves. Regarding these aims however the engineering profession played an important role. A determining factor in colonisations strategies was whether the countries were determined as being for settlement (such as in the case of the United States of America or Australia) or they were not (such as the case of the Congo and Sierra Leone). In the latter case extractive states were built. Instead of investing in institutions and encouraging outside investment the primary objective was to transfer natural resources to urban centres for extraction (Acemoglu et al., 2000).

In many parts of the world the colonial powers sought for trade links with other nation states and the construction of infrastructure to suit these objectives (Gann and Duignan, 1975).

Examples such as the Suez Canal, built by French engineers, which linked Europe to Eastern Asia without the need to travel around Africa offered examples of progressive engineering interventions that distributed and facilitated the creation of wealth (Mitchell, 1988). These advancements primarily increased the wealth of the colonial powers that participated in their construction. In most cases Africa was not considered as a trading partner to these powers and the interactions, including the majority of the construction activities, were designed with the explicit purpose of extracting resources from many of the colonised nations. Additionally many sites of importance were chosen not only for their economic importance, but also for their naval and military significance (Hoskins, 1944).

The extractive nature of the colonial and post-colonial periods is evident in many of the geographical layouts of the road and railway networks in the extractive states. The key purpose of the interventions were to take African resources and minerals from the mines, mills and fields to the ports and railways stations where the majority of the wealth was extracted to the metropolis (Acemoglu et al., 2000). The importance of road networks to the development of a country, regardless of their intended purposes, cannot be overstated:

> *"Transport facilities provide the initial stimulus for increased production in agriculture, industry, trade, and tourism. The ability, therefore, to provide and operate transport facilities at reasonable cost determines, in large measure, the success or failure of social and economic activities."* (Jalloh, 1998)

The road networks, though indirectly beneficial for local communities that were settled next to, or migrated to these routes, were not designed to link villages and towns together. In Sierra Leone, for example, the road transport network was developed at the start of the 19th Century by the colonial administration for the primary purpose of transporting palm oil to the railway stations (Jalloh, 1998). This could be argued to be true for many developing nations under colonial administration in Africa. The evidence supporting this claim can be observed in post-independence layout of the road network in areas such as West Africa (Figure 5). Prior to 1960 the provision of roads throughout West Africa can be shown to be sparse (Club, 2009). Furthermore, it can be seen that many of the roads primary purposes were to link the countries to their central hub, usually the capital city, which was also usually centred around ports. The lack of linking roads between nations (such as the lack of roads between Ghana and Côte d'Ivoire) also indicates the historical antagonisms of the colonials powers independent from the needs of the colonised countries (OECD, 2009b).

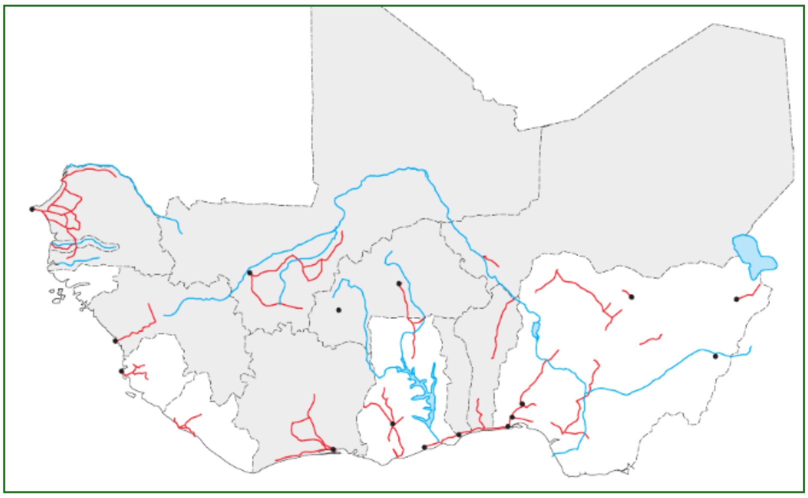


Figure 5: Post Independence (1960) - Main Paved or Partially Paved Roads in West Africa

In a similar vein almost all of the bridges that were constructed in Africa were usually only built in areas where it was deemed as a necessity for the movements of goods or for the strategic military purposes of the colonisers. Heavy metal mining and deforestation were only possible because of these infrastructure projects. The environmental damage caused by this period, particularly in West Africa, was extensive. Only about 8 million ha of West African forest remained in the mid-eighties which is over 80% deforestations from what existed prior to the pre-colonial era (Rompaey, 1993). Though should be emphasis on how the ethical development (the 'broad' definition of the engineering profession) was not yet understood there should also be an appreciation of how the technically focused 'narrow' definition was also similarly unrealised in its potential. Vital elements of engineering practice, now utilised when engaging with host populations, were never explored or researched. These included the notions of utilising indigenous knowledge, local participation and ensuring environmental sustainability. All of which were exempt from operational practices (Fairhead and Leach, 1997).

Of all the inhumane practices of the colonial period the slave-trade remains the most ethically devastating. The original purpose of many African ports were specifically for enhancing the effectiveness of the slave trade. In the 18th Century 75% of all Africa's exports were enslaved humans. At its peak this resulted in over 80,000 Africans enslaved per annum (Hochschild, 2005). The enslavement of people and the growth of the slave population in Africa continued apace for the whole of the nineteenth century (Lovejoy, 1989). Millions were displaced, enslaved and abused over almost three centuries of this trade. This period was of particular importance to the British Empire and its colonies. In the United Kingdom the 1672 Royal African Charter allowed for trading in Africa, which included the slave trade, though for a time was primarily based from London. In 1698 this London 'monopoly' was broken and Bristol and Liverpool participated in the trading of slaves (Richardson, 1975; Tallon, 2007). Scotland participated after the 1707 Act of the Union with England through the general trade of British Empire (Anstey, 1975). Merchant slave ships left from Port Glasgow and Greenock for what was known as the 'triangle trade' between Africa and the Americas (Sheridan, 1958).

Engineering and architectural reminders in cities throughout Europe remain today. The slave ports of London, Bristol, Liverpool and Glasgow all benefited from development and expansions during colonisation. Though the enslavement of other humans was only one sector of 18th and 19th Century markets that utilised these ports - the value of this particular trade was significant for the European empires (Lovejoy, 1989). There were also indirect developments that utilised the trade such as the sugar warehouses in Greenock (Figure 6) where sugar was produced through the efforts of slave labour (Graham and Whyte, 2007).

Figure 6: Sugar Warehouse in Greenock, Scotland. Source: Dave Souza

The legacy of the slave trade in Africa can also be observed in the slave forts and holding warehouses in many nations, primarily in West and Central Africa (Clair, 2006; Lawrence, 1964). Many of the trade castles and forts of West Africa were built for entirely utilitarian purposes - again emphasising functionality for the slave traders over any form of ethics. They were as serviceable as holding places for livestock (Lawrence, 1964). The morally degraded conditions of many these historical artefacts can still be observed today.

2.1.6 Colonialism and Engineering - Conclusion

It can be shown that the initial use of engineering in Africa was not primarily for the benefit of the occupants and instead was used to fulfil the desires of the colonial powers. This has implications for the current practicing of engineering in Africa. There are three important points which are important for this study:

1) The purpose of raising these points is not to apportion blame for issues that are ethically, contextually and historically complex. The engineering profession certainly cannot be held solely responsible for the extent of the Western Powers abuse of the world's poorest countries. Realistically however, without the technical facilitation of the engineers of that time, such exploitation would not have been possible. It should be equally important to state that though there were those that sought only to enhance the extraction of local resources, and would have been indifferent to the needs of those they were exploiting, it is also fair to assume that there would also have been engineering objectors and abolitionists. Such a conclusion is possible by observing the growth in ethical awareness over centuries of practice and the progression towards a broader definition of the profession in modern society. However, this is not to downplay the importance of the colonial period in the formation of engineering. Like other historical periods, most notably industrialisation, this era was instrumental in the development of the engineering profession. Colonisation, it has been argued, was allowed to "*shape engineering education to help meet these* [colonial] *ends."* (Lucena and Schneider, 2008). Additionally the historical background of colonisations offers an important indicator of how engineering, alongside the other professions of 21st century society, has matured in both its ethical and operational practices.

2) The legacy of many engineering artefacts and constructions built over centuries is not unnoticed by the indigenous populations of colonised countries. This extends beyond the arguments about slavery and extraction damaging the economic and social wellbeing of a country (see: Lovejoy 1989; Nunn 2007). Instead for many parts of engineering the era has resulted in a more direct impact on daily living in poor nations. For example during research visits it was noticed that individuals in Freetown, Sierra Leone often expressed their dissatisfaction concerning the road layout in Freetown. This normally arose when utilising public transport as road transport was often badly designed, poorly implemented and incomplete in many areas throughout the city. Constant references are made to the *'mess'* that the *'British'* left them with in their design of Freetown. Regardless

of their historical accuracy of Britain's engineering involvement in Freetown, or lack thereof, their legacy still shapes public perception of the profession. The same argument can be applied to the ports, bridges, road networks and railways which were never originally designed to enhance local welfare. Therefore an engineer operating in a developing country does not do so against an empty backdrop of constructed works. Instead the historical legacy of what engineers have or have failed to contribute to the local society remains an element, sometimes large, occasionally insignificant, but mostly unquantifiable, that still influences engineering activities in this context.

3) Road networks are not the only omission of care by the colonial administrations. Throughout Africa there was also the notable exclusion of many engineering projects designed to explicitly deal with the poverty of the indigenous populations. This was either in preventing health issues developing (such as the construction of sanitation systems or the introduction of water supplies and treatment) or in increasing local welfare (such as constructing facilities that would enhance the economic activities of the local markets). In this regard it is perhaps unrealistic to expect such developments for those in the colonised countries at this time when the poorest of the colonial nation states, even at the end of the colonial period, were experience similar problems in their own countries.

Like other historical periods the engineering ethics of the colonial and post-colonial eras were a product of their time. The profession did not act alone in its practices but was instead complicit in its approach with a range of other actors including prominent scientists, geographers, politicians and economists of that era. For the colonial empires to function entire sections of society had to participate in conjunction and in partnership with the engineering efforts. The purpose of including this particular argument in this study is to show that 'development engineering' in its modern conception is in many ways dichotomous with the engineering that proceeded it. The development engineering of the modern era is a realisation of the 'broad' definition and not, as would be the case in the engineering of the Industrial Revolution, a natural evolution of the profession.

2.1.7 Engineering and International Development

Though it could be argued to be dichotomous with the colonial periods of engineering this realisation of the 'broad' interpretation was itself an evolving process. The most significant departure from the periods of colonial engineering was the sudden and widespread provision of technologies and infrastructure that were made available to what was known as the 'Third World nations' following World War II. At this stage the purposes of these interventions were for the post-colonial nations to achieve some form of 'modernity'. This process of providing modernity could be seen, historical, as the missing link between the post-colonial periods and the poverty alleviation orientated engineering observed in modern society. This change in practices, from both the former colonial empires and from the new world powers, was mostly attributable to the Cold War.

> *"Engineers from the US and USSR were motivated by ideologies of modernisation in spite of their political differences. After 1945, many American and Soviet engineers came to believe that it was possible to develop and modernise the world through science and technology, i.e. to move 'traditional' societies from their current stage of backwardness and launch them through a stage of 'take-off' by implementing large development projects (dams, steel mills, urbanisation). Their hope was that these countries could join the superpowers in a 'modern' stage of consumer capitalism (US) or industrialised socialism (USSR)."* (Lucena and Schneider, 2008)

This, as yet, was not primarily focused on poverty alleviation but instead had political overtones. Instead of address global poverty as an objective in itself the world superpowers primarily sought to expand their capitalist or communist agendas (Lucena and Schneider, 2008). As almost an echo of the original historical split in engineering (from military to civil engineering) it could be argued that it was first from within the industrial-military complex that the origins of *'development engineering'* began. Seeking to link technologies to local context resulted in investigating technologies that were of simple design, easy to maintain and operate, and could be deployed throughout the 'Third World' (Williamson, 2009). At the close of the 1960's 'first development decade' the concept of development engineering had progressed from the idea that large infrastructure projects were the solution to achieving 'modernisation'. Instead there was a new focus and realisation. The priority became on diffusing technical information and on providing technical expertise to suit local contexts (Darrow et al., 1986). Regardless of these advances by the end of the 1960's the concept of technology transfer in the developing nations was still only considered as having a marginal role in normal scientific engineering education (Lucena and Schneider, 2008).

In 1973 the arrival of Schumacher's *"Small is Beautiful"* coincided with the United Nations shift in the approach to development to *'fulfil basic needs'* by explicitly addressing the social issues of poverty (Anand and Ravallion, 1993; Schumacher, 1973). Appropriate Technology, as a movement, introduced to the general public the theory of adaptation existing technologies or innovating new *'intermediate'* solutions that would allow for the eradication of the social problems of development. The growth in the sector was seen in the number of established 'appropriate technology' groups in the late 1970's and the growing, albeit brief, impetus for technological change (McRobie, 1981). The decline in the Cold War and the rise of neo-liberal economics ensured that the appropriate movement declined as a popular approach. The attention that was previously given to the eradication of poverty struggled to survive due to the geopolitical fights for economic competitiveness. These neo-liberal economics resulted in what was described as the 'lost decade in development' (Drabek and Laird, 1997).

The importance of appropriate technology only emerged once again through the discourses in the early 1990's due to the discussions around Sustainable Development (SD). Through numerous summits and conferences throughout the decade the issues of SD and the growing awareness of social and environmental issues of past industrialisation efforts, shaped the role of the engineer (Clapp, 1994). The core concept of SD became incorporated into traditional engineering practice. By doing so engineers became 'central players' in the continuation and development of this concept. The profession expanded its understanding of the 'welfare of mankind' to include previously unrecognised elements of engineering - most notably the new emphasis on environmental engineering being an active, rather than reactive, field of practice (Clapp, 1994; Vesilind et al., 2010). At the end of the century, and entering a new millennium, the concept of sustainability became intrinsically linked to the United Nation's Millennium Development Goals (MDG). The eradication of extreme poverty became a global goal involving the entire spectrum of technical and non-technical professions (UN, 2012a). For the engineering profession the concepts of Appropriate Technology, and the organisations that maintained the philosophy of *'small being beautiful'*, once again emerged as a potential solution to the rural and urban poverty of the developing nations.

The focus on many engineering projects in the developing world has been on specifically addressing poverty alleviation either directly or indirectly. This is not to suggest that the extractive industries, or organisations seeking a return on capital investments, have declined. Instead many projects are built with the active participation of the host nations based on their own identification of their needs - both socially and economically. A comparative example (Figure 7) would be the difference in road infrastructure left by colonial powers (1960), to post-independence (1975) to a more recent example (2005). Through policy reforms many of these roads have been built with assistance or as contracted work by international organisations working in partnership with local governments. There remains issues of road construction quality, maintenance schedules and the sparse distribution of the networks however there remains much growth in the sector (Gwilliam and Foster, 2008).

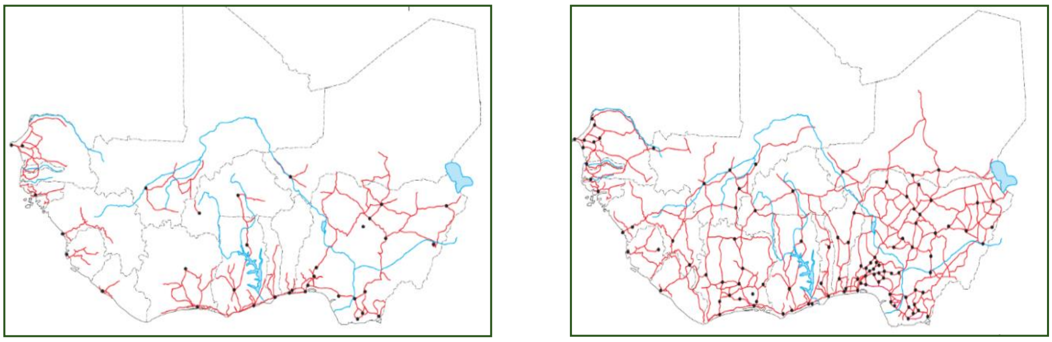


Figure 7: Main Paved or Partially Paved Roads in West Africa 1975 (Right) & 2005 (Left)

Private sector engineering firms and companies in developing countries now operate within established ethical codes of practice. They can be held legally responsible for misconduct in all areas of their operational procedures (Galloway, 2007). Given the context of many developing countries, particularly the widespread institutional corruption that plagues poor nations, it is also true that these procedures are not always applied. However, even with this caveat, the international organisations remain a far cry from the selective, destructive and unchecked abuses carried out by the colonial powers and facilitated by the engineers at the time (Fairhead and Leach, 1997; Luke and Riley, 1989; Sibanda, 1979; Stanley and Stanley, 2014). Though operating in parallel to *'development engineering'* these private sector involvements in Africa are not the subject of this study. As stated before, this research investigates the role of the engineer specifically with regards to the direct objective of the alleviation of poverty in Africa.

2.1.8 Non-Governmental Organisational Structures and Engineering

Since the 1970's there has been a radical growth in organisations whose sole purpose is to develop solutions to a range of poverty related problems (Desai and Potter, 2013). Though they are not solely confined to engineering projects there has been an abundance of infrastructure activities that have been the cornerstone for development interventions and programming (Calderon and Serven, 2010). Though NGOs, by their very nature, are not intended to be an extension of foreign policies it would be unrealistic to suggest that the donor bodies who provide financial assistance to these organisations do so for wholly altruistic reasons (Donini, 2010; Edwards and Hulme, 1996). These agencies, for these interventions, have very specific mandates that ensure that their justification for such work is for the specific purposes of ensuring that there is the continued reduction in global poverty. Their primary purpose is for the continued betterment of the welfare of mankind.

Development aid agencies, the Non-Governmental Organisations (NGOs), all share a common goal of addressing global poverty. Their approaches to addressing these issues are varied resulting in a host of different organisational and management structures. They also vary in their operational practices and their mandates regarding their beneficiaries. Some organisations have a specific technical focuses such as Water Aid, Practical Action or Engineers Without Borders (EWB). Others, such as Concern Worldwide, Mercy Corps, Oxfam and Save the Children, approach the issues of poverty more holistically by engaging in multiple sectors in development simultaneously. These, usually larger organisations, also engage in engineering approaches to development, but alongside non-engineering interventions such as urban health monitoring or rural agricultural development. Given the spread of management and organisational variations providing clarity on exactly where the engineer fits within any given organisation would require an exact depiction of the NGO in question. Firsthand experience working with these agencies has indicated that individual organisations can have different approaches to engineering in each of the separate developing countries within which they operate (*i.e.*, some work entirely through existing engineering firms in one country while in another they take direct responsibility for the delivery of construction services). A single organisation can also approach engineering projects differently within a single country (*i.e.*, they engage in school construction using a different engineering and community management approach to that used for building communal water points).

To offer some level of clarity to the role that an engineer takes within an NGOs management structure a standard model of how NGOs operate within developing countries is required. This model only considers the operational management activities of in-field agencies rather than the overall structure of the originations. Therefore it does not include the headquarter management structures (such as public relations, human resources and grant partnerships). The outlines of field based structures discussed here is not intended to be specific to a single organisation – but are an amalgamation of management structures of different groups. For the purposes of this research the model is also based only on NGOs that, in at least some part of their development programming activities, participate in engineering activities.

The most common trait within international NGOs is to have the organisation split into two sections known as programmes and systems. The programmes teams are responsible for identifying projects, finding funding, engaging with communities, implementing project activities, developing donor relationships, monitoring and evaluating project success, reporting on projects and in engaging with local stakeholders. The systems components are mainly dependent on the running of the organisation. This consists of the finance, procurement, logistics, fleet management, communications, information technological support and security. The systems components usually ensure that all programming activities are successful and receive the necessary support to be operational.

Engineering within NGOs depends, as all NGO activities do, on engaging with both of these core sectors in order to operate successfully. The 'engineering' element of NGOs usually crosscuts through many different programming sectors. The number of programming sectors depends on the mandates and philosophical approaches of different organisations. Some have only a single focus, such as Mary's Meals which engages solely in education; whereas others have many, such as Mercy Corps which has over thirty two programming sectors. Providing a simple conceptual analysis of NGOs a standard model would most likely present four key thematic areas that most organisations programme within (Figure 8). An overview of the different sectors is as follows:

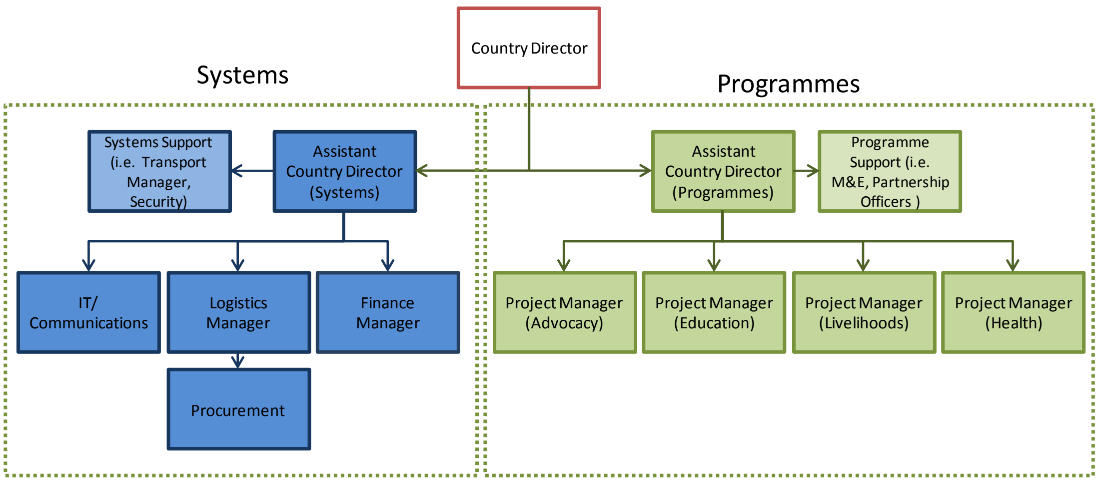


Figure 8: Simplified NGO Organisational Model

Education – This sector considers all aspect of education including elements such as increasing school enrolments, school feeding, improving quality of education, adult literacy, and government education support. In engineering this programming sector includes school construction and associated facilities (Freeman et al., 2014; UNICEF, 1998). This can include latrine structures and water points particularly to address menstrual hygiene issues for young women (Kulanyi, 2015; Truyens et al., 2013).

Health – Primarily focused on wellbeing and includes child and maternal health support, vaccination campaigns, family planning activities, infectious diseases campaigns and hygiene teachings. The engineering elements are many and include all elements of water and sanitation construction as well as including health clinic, maternal wards and hospital construction (Cross and Coombes, 2013; Mara et al., 2010).

Livelihoods – These programming activities are intended to improve income generation. These include improving market access, micro-credit loans, agricultural support and education, skills and vocational training, and the provision of equipment and tools. The engineering support for livelihoods include projects such as road construction, bridge building, construction of box culverts and income generating buildings. Sanitation marketing and provision of water treatment works are considered as livelihood projects (Cross and Coombes, 2013; Mintz et al., 2001).

Advocacy and Capacity Building – This sector includes all aspects of awareness raising and the strengthening of civil society. This includes issues such as increasing governmental capacities, campaigning for human rights issues, electoral monitoring, addressing gender based violence and the lobbying of governments on a range of issues. The engineering element of this sector is much less construction intensive, but would include support and assistance to governments engaged in large scale or widespread construction activities for developing contractual documents and running internationally accepted bidding procedures.

Other programmes in development crosscut between the different sectors. Issues such as gender inequalities or HIV/Aids awareness are not always contained within a single sector and influences all elements of programming activities (Piot et al., 2008; Pronyk et al., 2012). As many NGOs engage in multiple sectors then their engineering divisions deal with multiple sectors simultaneously. The engineering teams usually work in partnership with different programming sectors to achieve their goals. For example many NGOs would have the simultaneous construction of schools, health clinics and footbridges which would come from three of their respective thematic sectors.

2.1.9 Engineering Input to Programming Activities

The sector of Water and Sanitation is particularly important for this research. Smaller organisations, such as Living Water or Pump Aid, are able to operate with only a WATSAN (Water and Sanitation) focus. Larger organisations usually have a WATSAN component as part of their existing sectors but, most commonly, under the management of health co-ordinators. Though the construction activities of humanitarian agencies are varied almost all the major NGOs encountered in Sierra Leone had an engineer or the engineering team specifically for the WATSAN construction.

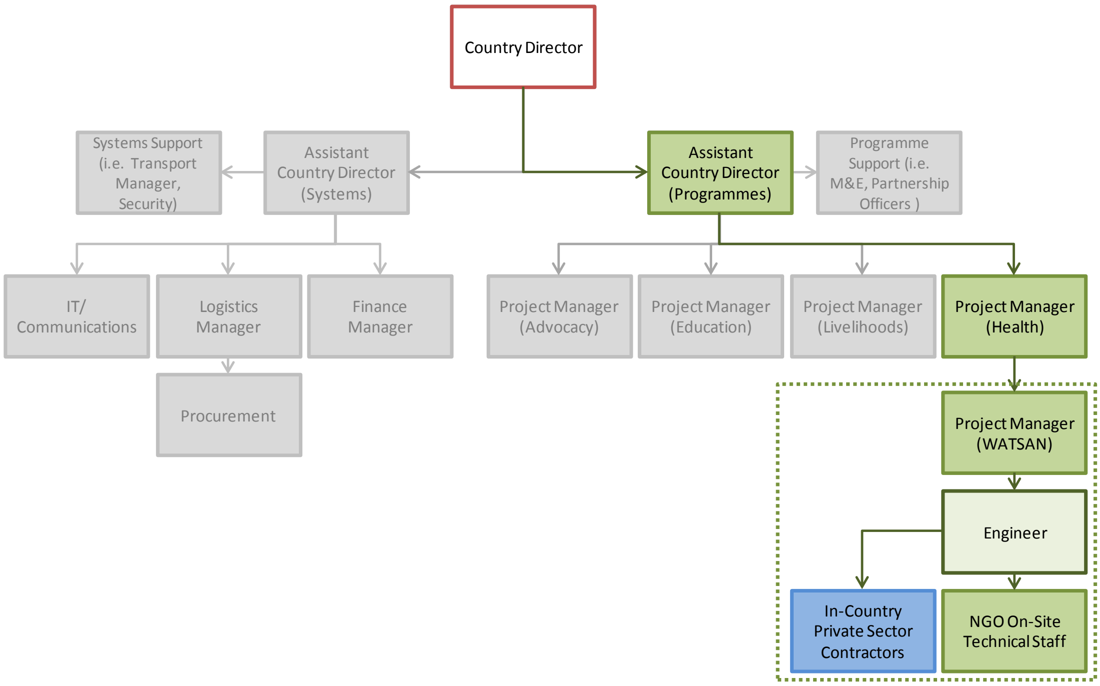


Figure 9: NGO Organisational Model Showing the WASH Sector

It was common to find that the project manager for the health team would be responsible for a wide variety of projects and would not be limited to water and sanitation alone. Therefore almost all important decisions regarding water supplies and sanitation would be made by the WATSAN project manager (Figure 9). From firsthand experience this manager was usually found to be either an expatriate engineering staff member or a non-technical staff member who depended on an engineering co-ordinator for their construction work. Normally this co-ordinator, unlike the WATSAN engineering project manager, would have had oversight over a number of engineering projects and would not be confined solely to the health sector.

During the research visits in Sierra Leone it was found that the specialisations and qualifications of the WATSAN personnel varied greatly. The majority of the larger NGOs were found to have employed highly qualified expatriate staff. A minority were content with utilising only local engineers for some, or occasionally all, of their constructed works. Certain smaller NGOs used engineers as short term consultants for contract management or for supervision during the construction phases. Some NGOs emphasised a 'software' orientated approach to water supply and sanitation and only invested in non-technical parameters - such as raising awareness about personal hygiene and hand washing.

2.1.10 Conclusion - NGOs and the Engineer

The exploration of the history of development has indicated that the engineering profession has become an integral part in offering humanitarian assistance to developing nations. This has only been possible due to the philosophical change in attitudes of the profession from having a 'narrow' and functionality based focus to progressing to a much needed 'broader' approach encompassing the social nature of development issues. This realisation has allowed the role played by the engineer to be pivotal in the success of many development programmes. However, as the post-colonial period shows, this maturation is historically a more recent phenomena. Similarly the NGO sector, comparative to other established professions is, of itself, exceptionally new and only gained prominence in the period following World War II. As this study will argue, there is still much more progress needed in both the narrow and broad realisations of the engineering profession, in order for it to fulfil its full potential in alleviating the suffering of poverty.

Establishing that engineers have a fundamental role in development does not indicate how effective the profession has been, or will continue to be, with regards to this responsibility. Though presenting a standard model of a management structure can indicate where an engineer would usually be placed within these systems as there are too many differences in NGOs operational practices to define which good practices align with the correct management of the profession. It is also too complex to draw conclusions about alterations of existing approaches - beyond the usual difficulties in managing engineers within any organisation. Therefore the approach of an organisations towards engineering, rather than their structural management, is of importance to this study in determining the success of the role of engineers in international development.

2.2.1 Service Delivery Models

The second part of the literature review will explore the concept of ‘service delivery’ as it relates to NGOs practices in rural water supplies. The role that the engineer provides in the provision of household water supply technologies depends on the model of service delivery that the Non-Governmental Organisations (NGOs) have strategically selected. These are an expression of the development agencies attitudes and ethical commitment towards their beneficiaries. The engineer may not be responsible for defining the overall approach to the technology transfer – but their participation in these programmes establishes the strategic vision of their organisations. Technology transfer refers to the diffusion of a technical innovation within the households, communities and villages of the project beneficiaries. The background inequalities of technical sophistication between the two societies and the disparate differences in socio-cultural structure creates, as Rogers explains - a *'heterophilous diffusion of innovation'* between the two parties (Rogers, 2003). Further investigation into the implications of these cultural differences will be discussed in the following chapters.

The models of service delivery used by NGOs have been given different names. These include; 'models of community-based management', 'private sector engagement' or 'models of self-supply' (Harold and Stef, 2011). Many of these descriptions can cover the specifics of certain approaches but there are broader categories that can be used to define the entire spectrum of technology transfer.

The NGOs, both international and national, which are capable of providing and implementing water supply programmes, operate under different developmental mandates. Each of their relative organisational sizes, financial funding, technical skills and management capacities can dictate their abilities with regards to technology transfer. Therefore their output in developing countries offers a broad spectrum of different project types. The background research into secondary data concerning development practices, which was complimented by the field research in Sierra Leone, found that almost all of the strategies adopted by NGOs can be placed into three thematic categories. These can be considered as two polemic extremes to approaching the problems of development and a third option which is a synergetic combination of both approaches. A new terminology is required to group fundamentally similar approaches together and to understand where they stand relative to each other. The three categories are defined in this research as being:

1. The Linear approach to Technology Transfer (LTT)
2. The Appropriate approach to Technology Transfer (ATT)
3. The Synergetic Approach to Technology Transfer (SATT)

The terms adopted here were developed to provide clarity to the concepts explained in this research. However the concepts have been established in field activities and have evolved over decades of development practice. They are all, to different degrees, a combination of 'top down' and 'bottom up' approaches to international development. They are also responsible for determining the practices of the engineer, who has a central role, whether actively or unwittingly, in the NGOs implementation of rural development projects.

2.2.2 Linear Approach to Technology Transfer

The linear model is the most straightforward mechanism of technology transfer. In the provision of water supplies the primary, and usually only, objective of this approach is to provide an improved source to a village by simply constructing a water supply solution. Of the three categories of service delivery this is the most 'top down' approach to development. The model exists because, regardless of the service approach that is utilised, the communities will still require a technical artefact to resolve their water supply problems. This is an uncomplicated approach and involves directly providing the artefact to suit the health 'needs' of the communities. To achieve linearity and simplicity the water supply 'problems' are addressed in isolation from the wider context of poverty.

> *"Engineers in particular tend to see demand as directly proportional to consumption; consequently, water supply schemes are designed according to volumes of water supplied per household. The cost of these schemes, maintenance and financial sustainability of the schemes are often side-lined"* (Harvey and Reed, 2004).

For example, a linear approach would depend on a Needs Based Assessment (NBA) to assess if a community has access to water supplies (Kirkemann and Martin, 2007). A water supply solution would be provided if the assessment indicated that the community coverage is currently without access to an improved source of drinking water.

This model of service delivery is akin to the pre-development and neo-colonial, if not colonial, theories regarding the best methods of assisting rural communities:

> *"The idea of a linear trajectory from one stage to another, from pre-technological to technological, from traditional to modern, from indigenous to scientific is implicit within most mainstream development thinking, and was implicit – if perhaps considered less of a priority – in most colonial thinking. Colonial and development thinking, so different in terms of aim and ideology, are stitched together by the shared idea of the application of technology."* (Smith, 2009)

A continuation of the linear practice could be argued to largely ignore the key lessons learnt during the UN Water Decade (Bendahmane, 1993). In Sierra Leone a purely linear approach to development is not the normal practice for most of the programmes of the large NGOs. It is commonly found in the operational output of smaller international organisations, local NGOs, grassroots organisations, religious groups and private individuals. Due to the number of these organisations present in Sierra Leone these actually have a substantial percentage of the total constructed water supplies in-country.

The model of service delivery could be viewed as a direct interpretation, without any recognition of the contextual subtleties, for achieving the targets of the Millennium Development Goals (MDGs). The MDGs do not, by themselves, stipulate supporting measures that must be put in place to provide 'sustainable access to improved sources of drinking water' to communities (Garriga and Foguet, 2010). Therefore, to those using a purely linear approach, any other considerations that are not specifically 'water related' are seen as secondary objectives, if they are considered at all (RWSN, 2009b). The long term sustainability of the water supplies are dependent on local markets, other organisations or local government bodies to resolve, rather than being worked into the programming strategies of the implementing organisation. The capacities of the socio-cultural systems to sustain the water schemes, or withstand the shock of costs that maintenance may occur, are not a feature of this implementation practice.

In this model the water supply needs are identified by external expertise regardless of the opinions of the communities. This 'technical core' is located external to the communities and is essential for all aspects project support, growth and sustainability. Project implementation only requires community permission, rather than their understanding, to proceed. The solutions are capital intensive and, given the socio-economic conditions of the village communities, are required to be heavily subsidised by the implementing organisations (Wood, 1994). Participation of the villages in this linear model is limited to assisting the implementing organisation with the labour intensive parts of the projects - such as providing food for technicians or assisting with basic construction tasks.

The flow of information concerning all aspects of the projects is in one direction - directly from the technical core to the communities. This method is not dependent on local feedback and therefore largely ignores indigenous knowledge input. Local knowledge is viewed as detrimental to the project purposes and, to technical experts operating within this model, would be considered a barrier to success. The choices for technologies are made by the service provider on behalf of the communities. This limits the participatory role of the communities and imposes the limitations of the host organisations onto their programming outputs.

The quality of service is dependent on the limited capacities of the implementing organisations which vary between different actors. Some agencies are capable of providing high quality services and others, who lack sufficient engineering technical skills, struggle to provide basic services. The linear approaches do not exhibit technical imagination and are usually the most straightforward response to providing 'improved sources of drinking water'.

2.2.2.1 Examples of Linear Approach to Technology Transfer

A linear approach is an exceptionally common method of transferring a technology to developing communities. This approach to development has been heavily criticised by rural water supply specialist the Rural Water Supply Networks (RWSN). In their widely distributed publication on 'the myths of rural water supply' they debated independent actions of small NGOs as being dangerous and not in the best interests of the communities they were serving.

> *"In many countries, improving rural water supplies is an endeavour whereby almost anyone can decide to 'do- good'. An NGO or project can turn up in a particular village and 'improve the water supply' as they see fit…Funding agencies and do-gooders can pursue their own interests, or what they consider to be right, rather than those of the rural people they are trying to serve."* (RWSN, 2009b).

The transfer of 'low technologies' into a foreign socio-technical system can be indistinguishable from the outputs of the other models of transfer. As it is the same technical output (*i.e.* providing a hand-dug well) the approach can produce the same observable artefacts as the broader intervention strategies, particularly immediately after their construction. The differences are only observable through intangible indicators such 'participation', 'ownership' and even 'sustainability'. There are occasional differences observed in the technical conditions from projects attempted by inexperienced development organisations attempting engineering projects. As their numbers of interventions are low they do not have sufficient practical experience in engineering construction. For example in the village of Makonolina in Sierra Leone a communal hand-pump well that was built by a small organisation can be shown to have a concrete screed finishing that was poorly implemented – a situation that would not have arisen from a competent service provider that had a very basic understanding of concrete mixing (Figure 10). Though certain organisations can be capable of providing high-quality artefacts their inability to address larger socio-cultural or socio-technical issues that affect the sustainability the projects is of more concern to the success of projects than short-term benefits.

Figure 10: Community well - Makonolina

The LTT approach, depending on the mandates of the implementing organisations, can also involve implementing the provision of 'high' technologies such as localised treatment plants. The LTT models transfer of 'high' technologies to communities involves a more complicated delivery mechanism, as the construction is more 'technical expert assisted' implementation, but the resulting technologies are no more capable of being sustained at the local level than their lower tech counterparts. These 'high' technologies are very often portrayed as being 'silver bullets' to the problems of development. The properties of these innovations may present those that are outside a socio-cultural system, such as the general population of a 'developed' country, with a supposed solution to the water supply problems in developing nations. To the techno-centric value systems of many post-industrial nations these can appear to be a straightforward route for achieving international goals. Organisations that promote these technologies consciously choose to omit the realities of poverty, or provide an evaluation of other technologies that can achieve the same without the capital expenses. The most notable examples are the LifeStraw, the lifesaver bottle and Q-drums (Smith, 2007). These are only a few of the thousands of technologies that can supposedly offer solutions to the safe water problems of the developing world.

Solutions like these have achieved international media attention because of their ability to display properties that can be misinterpreted as short-cuts to achieving global targets. The LifeStraw, for example, has won several major innovation awards on the basis of the solution being capable of addressing global water problems (Vestergaard-frandsen, 2013). That the solutions require heavy capital investment, would create a culture of dependency on the interventions and only address problems that could be solved using locally available materials combined with labour intensive (not capital intensive) construction, are issues that are constantly omitted from how they are publically portrayed. These solutions are often, in reality, a straw-man fallacy masquerading as engineering solutions. These 'high' technology and linear interventions have exceptionally poor success rates - though not through failures in the functioning of the technologies themselves. For example an Ethiopian based controlled study of the LifeStraw suggested an immediate limitation of the technology:

> "*Five months after distribution, 34% of participants reported use of LifeStraw during the past week; even fewer (13%) reported drinking with it consistently. Of the remaining participants, at least half had discontinued use at the beginning of the follow-up period"* (Boisson et al., 2009).

As Paul Hetherington, a spokesman for the charity Water Aid UK, reported in the international media:

> *"It is something that may well have very useful applications in an emergency scenario. But it's not a development tool; it doesn't really solve the problem of getting water to people"* (IRIN, 2008).

Regardless of their relative success in laboratory conditions – these solutions undermine the complexity and the contextual reality of poverty.

2.2.2.2 The Advantages of Linear Approach to Technology Transfer

The LTT model can be viewed as an unethical approach to international development but the model does have positives that have sustained its usage. These advantages can appeal to donors and NGOs that do not have the capacity to understand the wider and more complex context of poverty.

As a model of technology transfer the project objectives are relatively straightforward to rationalise to those outside the environment of poverty. Therefore the projects have clear aims and objectives. This, it could be argued, is due to their over-simplification of the actual problems. Their narrow expression of water needs allows donors, particularly small fundraising groups, to grasp the fundamentals of what is being attempted by the implementing organisations. This makes project achievements relatively straightforward to share with stakeholders. As long as the focus is on the short term gains, instead of long term sustainability, the monitoring and evaluation of these programmes and achievement of project aims can be relatively simple to achieve.

As the model is linear in approach, and defines its objectives achieved through verifications of basic indicators, increasing the scale of these inputs would only require larger financial contributions and more implementing agencies to carry out the distribution of the technologies. As the model does not perceive that further social development is required, either from the communities or from the engineer, then it is the economics that is regarded as being the main limiting factor in increasing coverage. Therefore their lack of success can be determined as being a 'lack of political will-power' rather than inconsistencies in the model of transfer itself (Grayman et al., 2012).

The approach also provides a limitation to information pathways that can otherwise complicate commitments to the communities. The linear approach knowingly omits indigenously known information that could be detrimental to the projects core objectives (Cooke and Kothari, 2001). Though this practice would omit any valuable information that is known within the communities, the advantage is it would also disregard local practices and opinions that are dangerous, irrational or those that are not supported by scientific evidence. The more complex approaches, which are inclusive and invite the local culture and knowledge into their projects, have to maintain this commitment throughout their programming. This increases complexity and can cause difficulties when attempting even basic tasks (Briggs, 2005). The linear model circumvents this approach by disregarding local knowledge and operating independent of indigenously established knowledge institutions.

Finally, the LTT system clearly indicates where both the engineering support and the private sector activities should be focused. All technical support would be based at the 'technical core'. This allows the project proposals to be designed without the need for any project altering community input. Their project funding does not allow for technical choices to be made by communities. For example, the funding for a lifestraw projects would only include the quantity of solutions that are to be manufactured and the cost of the distribution of these solutions to a broad geographical area. In this case the long-term sustainability would only be offered by continually duplicating the funding proposals to compensate for damaged, malfunctioning or misplaced lifestraws.

2.2.2.3 The Disadvantages of a Linear Approach to Technology Transfer

A fully LTT approach has considerable flaws that undermine much of the positive aspects of a linear project. Though this concept of the technology transfer is simple to rationalise it is usually an oversimplification of the complex problems faced by the communities. Issues that are indirectly related to water supply, such as gender inequalities, household water practices or the capacities and willingness of the communities to sustain the interventions, are usually omitted from the scope of the problems.

As the model is normally fully subsidised by the donors the approach is almost always highly capital intensive. Given the financial capacities of the communities a local ‘scaling-up’ of this approach is unlikely. The scale and coverage of these interventions is directly comparable to the financial investment into the technologies that are made by donors. These donors are external to the socio-cultural systems of the beneficiaries. Therefore they have no control or executive decision making power in the process. This disempowerment can reduce the status of the communities to that of ‘victims’ rather than ‘actors’ in their own development (Kirkemann and Martin, 2007). LTT projects can actively create a culture of dependency whereby the organisations have made rural communities indefinitely dependent on their continued support. It would be cynical to suggest that this is the explicit purpose of certain organisations; however it is still the case that creating this culture is financially advantageous to the implementing bodies. Regardless of the true intentions behind the provision of this engineering assistance - the creation of dependency is a rational consequence of the linear model.

The intervention technique also poses considerable ethical questions about engineering practice. The most notable is the use of manipulation, the lowest form of participation:

> *"Participation is undertaken in a manner contrived by those who hold power to convince the public that a predefined project or program is best"* (Duraiappah et al., 2005).

The linear diffusion of both 'high' and 'low' technologies assumes that the engineer knows what is best for the communities, usually without any appreciation of the context. Therefore, when resistance is met, the only option is for the engineer to convince the communities that a concept, that is outside their normal practices, is the most suited to their needs – regardless of local practices or other technical options that are available. The portrayal of a single technical solution being the only option available is almost always factually incorrect (Lantagne et al., 2006; Skinner, 2003). This therefore becomes the manipulation of community needs to suit the capacities of the implementing organisation.

As the low technology interventions can be intermittent in communities (*i.e.* not part of a larger health programme) there are few considerations given for the social support mechanisms that could be designed to sustain the technical systems. The linear and 'low technology' water points are highly vulnerable to any missing links in private sector responses and local skilled personnel shortages. A small implementing organisation that has both the willpower and capacity to continually resolve maintenance problems that arise, due to their full subsidy practices, places a considerable burden on their operational activities while simultaneously increasing the local dependency on their presence. An organisation that either does not intend, or does not have the capacity, to provide long term sustainability shifts this responsibility to an unprepared community. This raises serious ethical questions about their practices.

2.2.2.4 The Role of the Engineer and the Linear Approach To Technology Transfer

As the linear model of technology transfer is relatively straightforward then so too are the corresponding responsibilities of the participating engineers. For the engineering design component the problems of water supplies are treated in isolation of a wider context. The engineer can conceive technical 'solutions' that can be designed entirely independent to the context. Their design criteria is based on empirical measurable values – such as intended target population, anticipated quality of water expected, technical limitations such as topography and financial resource available. The engineer would not be required to consider the condition and capacities of existing social support mechanisms, socio-cultural response issues or local limitations that will affect the long term sustainability of the intervention. The engineers either make, or are provided with, assumptions about how these heterophilous cultures will respond to their technologies. In certain cases the design of the technical component may not involve the input of the engineer until the empirical information of the project has already been gathered and the engineers 'technical skills' are deemed necessary. The engineering of the linear approach is measured solely on the number of interventions built, and therefore the only measure of success for an engineer is in the number of constructed or manufactured solutions.

The role of the engineer, as defined from this model of technology transfer, would require no alteration to the existing engineering practices. The ability to isolate problems means that any sufficiently qualified engineer, within their own socio-cultural system, has the ability to transfer their skills into international development. This assumes that they would need no adaption of their professional practices to reflect the conditions of their new context. If such an eventuality was possible then the combination of supposed ‘transferable skills’ and a centralised ‘technical core’ would mean that the deficit of engineers in development could be realistically filled (UNESCO, 2010). The reasons that this has not materialised is that the realities of poverty are, first and foremost, utterly dependent on the contextual background upon which they exist:

> *"... technology always operates in a context of some kind and that this context ought to be uppermost amongst factors affecting the design or choice of particular technologies"* (Willoughby, 1990).

As the definition of the engineer is based on two concepts; functionality and morality, the linear approach fails the profession in both categories. It is possible for the linear models to produce projects that can be determined as being successful immediately following their construction. However these projects would not offer any real measure of sustainability in their ‘whole life’ design. The linear model also has the ability to create cultures of dependency and make their technology transfer reliant on external controlled financial support. Therefore the role of the engineer, as defined by the linear model, does not conform to the standards that should be accepted of the profession. Therefore further paradigms of technology transfer are required.

2.2.3 Appropriate Technology Transfer Model

The Appropriate Technology Transfer (ATT) model is almost diametrically opposed to the values and practices of the LTT approach to development. The term ‘ATT’ refers to a blanket definition to any of the organisations that seek to empower the communities to respond to their own problems by designing and providing solutions that are suited to local conditions. The term ‘appropriate technology’ and the associated social movement originated from the work of the economist E.F. Schumacher and his concept of ‘Intermediate Technology’ (Schumacher, 1973). The introduction of this concept created a social ‘paradigm shift’ of practices that occurred in rural development during the 1980s and 1990s.

This signalled a change from the previous years of top-down methodologies in rural development. During this period technology transfers gradually became more focused on bottom-up or grassroots methods of service delivery (Farrington et al., 1998; Rondinelli, 1993)

Unlike the linear model the appropriate technologies are designed to function by making the communities as self-sufficient as possible with regards to their water supply problems:

> *"Systems independence relates to the ability of a technological device to stand alone, to do its job with few or no other supporting facilities or devices to aid in its function"* (Wicklein, 1998).

These projects are not defined by offering a single solution to water supply problems, but encompass various technical solutions, and therefore there are no two implemented projects that are identical - though the overall technical service provision, such as an organisation specialising in building gravity fed water supply systems, may be the same.

> *"Technology should not be predetermined in any rural water supply programme, and the final choice of technology should be made by the community from a range of feasible options. Though they still involve an engineer making technical judgements based on local conditions, the technical solutions are designed to be as self-sustaining and as inclusive of local participation as possible"* (Harvey and Reed, 2004).

The ATT models embraces rather than shuns local knowledge. This allows local input to be transformative the final design of the technical artefacts. The opinions of the beneficiaries are considered to be crucial to the development of the project objectives and solutions (Murphy et al., 2009; Wicklein, 1998). In many cases local manufacturing processes as well as materials and design ideas have been incorporated into the final construction of the artefacts (McRobie, 1981; Wicklein, 1998).

The sustainability of this model of transfer depends on the type of project that is being implemented. There are two possible variations:

Firstly there are technologies that are not dependent on continual technical support upon the completion of their construction. These can be sustained at village level using local materials and maintenance (Colin, 1999). having technologies that can be fully maintained using local resources would stipulate, given the technical capacities of communities in the developing world, that the solutions are exceptionally simple. They can have no, or very few, sophisticated working components that require them to be continually resupplied. The use of these technologies limits the options that are available at the local level - particularly with the complexities that can arise through water contamination (Murphy et al., 2009). Their technical simplicity can also have inherent technical design constraints such as low flow rates, low yield, poor quality and continual local maintenance requirements (Wicklein, 1998).

Secondly there are technologies that continually require some level of technical support in order to be successful. the reliance on continual outside support pushes the ATT model towards being a linear approach to development. There are normally mitigating circumstances for an ATT organisation to provide a 'high' technology. Even although they might provide the solution in such a way that is consistent with the ATT approach, they would still be vulnerable to criticism associated with creating dependency cultures. However this is not intended as a criticism as some needs, particularly with certain water contaminants, require an appropriately designed solution. This does not mean that this justifies a blanket solution, such as the lifestraw, to cover every eventuality:

> *"The notion of appropriate technology suggests that all alternatives should be researched for 'best fit.' The impression that advanced technology is invariably inappropriate for the Third World is an exaggerated and misleading interpretation of the intent of appropriate technology. It is not realistic to suggest that the development of the Third World should be based almost entirely on technological monoculture"* (Akubue, 2000).

2.2.3.1 Examples of Appropriate Technology Transfer Model

There are many examples of ATT programmes including rope pump projects, self-supplied pulley wells, rainwater harvesting tanks and point of collection water treatment designs. The work of Sutton into self-supply solutions has indicated that ATT projects are feasible and have the potential to provide long term advantages. These projects usually display high levels of innovation and creativity on behalf of the implementing organisations (Nyundu and Sutton, 2001; Sutton, 2009). In recent years one of the most prominent engineering innovations in the ATT approach is found outside water supply technologies - instead it is found in the provision of sanitary solutions. This has been the progressive development of Community Led Total Sanitation (CLTS). The unique intricacies of this methodology will not be discussed in this research. However the approach has been championed as an 'appropriate' method of technology transfer (Kar and Bongartz, 2006; Kar, 2003). Communities are facilitated to conduct their own appraisals of their sanitary conditions. Using 'triggering sessions' the CLTS method uses a localised desire for change to mobilise the communities to provide basic technical solutions to suit their hygiene needs. This same process of self-supply has not yet been replicated in water supplies (Harvey, 2011).

With regards to ‘high’ technical ATT approaches, many of these can be necessitated by the fully realised needs of the communities with regards to their water supplies – such as the provision of centralised treatment plants, gravity fed schemes and small scale piped networked systems (Furber, 2013). These ‘high tech’ approaches, where possible, use local construction methods and the entire process can be rationalised to the project participants. These projects very often display inventive solutions that present excellent case studies in engineering innovation.

2.2.3.2 Advantages of the Appropriate Technology Transfer Model

The appropriate technology movement, in theory, offers a diverse range of technical choices to the communities. The ability to allow the communities to make observable differences to the designs of their technologies has been a central argument in increasing community ownership towards the technical solutions (Murphy et al., 2009). The ideology of the ATT model has incorporated many of the lessons that were learned over the course of the UN water decade (Carter et al., 1993).

As the technologies of the ATT approach use local resources for their construction and maintenance they significantly reduce their dependence on subsidies by external donors. This in turn reduces the reliance of communities for continued external support and diminishes the dependency culture that forms during the linear interventions (Murphy et al., 2009). It also provides, depending on the resources used, a reduction on the environmental costs of providing and transporting spare parts. Technologies that were constructed on this ATT model have the concepts of local sustainability built into their design. Therefore this empowers local participants and elevates their status to being ‘actors’ in their own development (Kirkemann and Martin, 2007). The community participation is attempted to be as inclusive as possible and therefore plays to one of the main strengths of the rural poor - the widespread availability of manual labour (Chambers, 1983; Schumacher, 1973).

The conscious effort to include contextual social factors into the designs means that other indirect influences can be influenced as a function of how water supplies are provided. The targeting of women, for example, can be used to address empowerment issues that are otherwise missed during a linear approach to development (Cornwall, 2003).

2.2.3.3 The Disadvantages of the Appropriate Technology Transfer Model

As the ATT model of service delivery adopted most of the progressive development ethics and ideologies it would be supposed that this model would be the mainstream approach to development engineering practice. The reality is that the opposite has occurred – projects that are dependent on a fully ATT approach to development are the least considered model in engineering. Over twenty years ago Willoughby, in his critique of the appropriate technology movement, identified a key paradox:

> *"The Appropriate Technology movement is thus an enigma. On one hand it may be seen as one of the most promising sources of hope that the constellation of contemporary global problems may be overcome. On the other hand the fact that after more than two decades it has failed to become the dominant mode of technological practice raises a shadow of pessimism over this hope"* (Willoughby, 1990).

The appropriate technology movement did not fully succeed in its paradigmatic shift of culture and policy. There is no reason to suggest that the largest NGOs have entirely rejected the ideology - but evidence suggests that they do not have the capacities to commit to large scale ATT implementation in water supply technology transfer. Therefore the comprehensive adoption of this strategic approach is left to small and technically proficient organisations such as Practical Action and Engineers Without Borders rather than being a mainstream practice of the large organisations (Helgesson, 2006; Olley, 2012).

There are fundamental problems with using ATT that confines the model to being more of a theoretical panacea or a utopian model for development, rather than being a considered approach:

> *"[Appropriate Technology] represents a shift from the preoccupation with the centralized, technically oriented solutions of the past decades that failed to alter life prospects for a majority of the peasants and small farmers in the world"* (Agrawal, 1995).

The efforts involved in inviting local indigenous knowledge and design ideas into the projects mean that they are more complex and can have more issues than simply providing predetermined solutions (Briggs, 2005). The resources, including both time and money, which are used to provide full participation in projects, can stretch the capacities ATT organisations regardless of their size. The demands of providing differing technical solutions in a development context, with the limitations of resources that are available, mean that many organisations are only capable of providing an occasional ATT type project – rather than being a mainstream choice for technology transfer.

For any NGO to be fully capable of providing the ATT model they would need to have a considerable percentage of their organisations with technical skills and strong engineering capacities. Given the shortage of engineers that are available in development it is unlikely that there would ever be sufficient technical personal to address the human resources requirements necessary for large organisations to implement an ATT model. Additionally, most international organisations are multi-disciplinary and are funded to respond to a range of developmental problems, and rarely have mandates to address purely technical issues. Therefore they are unlikely to ever adopt such a techno-centric response to development problems. There are private sector groups that have the unique specialisations required to fulfil the technical requirements of the ATT model but would have to compete with the much larger NGOs for both finances and human resources. As the head of one technical organisation stated during an interview for this research:

> *"In some cases, the private and government sectors maybe weakened because the best staff are poached by NGOs who offer better pay and conditions. There are blurred lines between private sector and NGOs – both bid for contracts, but NGOs are often able to subsidise their bids in hidden ways from their unrestricted donations budgets."*

There are also operational problems with the technology transfer model when practiced in development. Participation for communities that cannot offer monetary support requires an alternative, the use of local labour. Therefore, as the alternative LTT model requires less active participation, the required outcomes are much less attractive to the project beneficiaries than projects by an NGO implementing a capital intensive model of service delivery. For example, a community that has an option for a borehole water point would be less interested in a pulley well system. Community enthusiasm further diminishes when the LTT model can provide a fully subsidised system when the ATT approach would involve intense labour and the possibility of contributing towards the capital costs. In these situations the only method for the ATT approach to be successful is to have no others organisations or projects operate within the locality. For the ATT projects to remain sustainable, through the use of labour and local subsidies, this would have to be an indefinite arrangement.

The most important disadvantage of the ATT approach is the inability to bring many of the solutions to scale (Smits and Suazo, 2010). It is possible to have a successful project in one location the alteration of one of the many factors that contributed to this success, such as the size of the community, the local availability of resources, the education of project participants, can influence the outcome in another village. Villages that do not have similar characteristics as the piloted village cannot be fully assisted.

2.2.3.4 The Role of the Engineer in the Appropriate Technology Transfer Model

The role of the engineer within the ATT model depends on the type of project that is being attempted. Unlike the technically standardised approaches of the LTT model the ATT technical solutions cannot be developed independent of the context and therefore, to some degree, necessitate an engineer's presence for the development and design of the project. This can vary with the complexity of the project being implemented. Low technologies would have fewer problems in this regard, but are vulnerable to the other social issues, as discussed before.

Complicated technical solutions for providing safe water, such as localised piped network systems in large rural communities, could take months of planning and years of work. Given the budgetary and skilled personnel requirements the solutions would only be able to address water supply issues in a single villages at a time and would therefore not be replicable on a larger scale. It is possible using the LTT model to delegate certain tasks to locally trained staff and thereby reduce the participation of a tertiary educated engineer. The demands of the ATT model in the more complicated technical interventions mean that this offsetting of responsibilities is not possible during the design and implementation stage. The level of local expertise, particularly in niche, but low technology, interventions that are foreign to the local culture – such as water treatment processes, piped water designs or gravity flow systems, would mean that the host communities would still require the constant participation of an engineer during the initial construction, design and implementation stages. This need for technical assistance could be offset in a well-designed programme by not requiring longer term and sustained assistance, but the initial stages of the process would require the full attention of the engineer. As large organisations operating in Sierra Leone deal with hundreds, if not thousands, of villages, it is unlikely that they would make this commitment to training the required number of engineers needed for a solution such as this (UNESCO, 2010).

Furthermore, adopting a philosophy which encompasses local design ideas is admirable, however the reality is that most community members do not have sufficient technical skills to make reasonable input into the designs of solutions. Realistically only minor design recommendations could be considered and this process would still require an engineer to decide on behalf of the community the course of action that is to be taken. Additionally, for the inputs that can be considered, even simple re-working of design ideas would take continual effort. Each community can have different needs based on their local social, cultural, geographical, political and environmental circumstances. The constant technical changes would necessitate continual engineering participation during the designs stages.

The ‘high’ and ‘low’ technology transfers of the ATT model are dependent on access to a sufficient number of engineers to be successful. However, there are more limiting problems than just the number of technical personnel participating. It is also dependent on the type of training the engineer has received. The ATT model is based on a philosophy of “appropriateness” a concept that has not been well understood by the engineering profession. Even at the peak of the movement there was little engineering focus on the values of what was being portrayed. In Willoughby’s critique of the appropriate technology movement he explains that:

> *“Within engineering circles it appears that many of the best aspects of appropriate technology are understood simply as good, intelligent engineering”* (Willoughby, 1990).

This poses the question – why would an engineer knowingly design an ‘inappropriate’ technology? Could not all engineering interventions be stated as being appropriate, within regards to many of their properties, to the engineer that designed them? Would engineers implementing an LTT approach not also consider their technologies to be 'appropriate'? Whose version of ‘appropriateness’ is relevant; the engineer that can appreciate the technical capacities of the problems, or the communities that form the socio-cultural systems themselves - but who are usually unaware of the full context of both their water supply issues and the solutions that are available? There are no simple answers to these questions, but training an engineer that is capable of addressing the subtleties of these problems is a difficult process.

Engineering education in the industrial and post-industrial nations is primarily centred on ‘goal orientated design’ and in providing a functional solution to a technical problem (UNESCO, 2010). The social contexts of problems are usually the responsibilities of other societal sectors and professions, but which work in partnership with the engineering functions, to provide an optimal solution. This allows an engineer that works within their own socio-cultural system to have the capacity to design, construct and alter their nations built environment without an overemphasis on the social context. In simple terms – they are the section of their own socio-cultural system that is specifically trained to provide technical solutions within their local environment. There are design standards, regulations, local policies and laws concerning certain practices – but these are developed for the engineering profession - by the engineering profession, or at least with engineering input (Martin and Schinzinger, 1996).

> *"Scientists, engineers and technologists are members of communities and all that [this] entails: rules, norms and institutions. They are trained to be members of epistemic communities and are measured against the rules of those communities; they adhere to prevailing methods of enquiry; try to conform to indicators of excellence; and communicate using rhetorical devices born out of their communities"* (Smith, 2009)

Engineering education within the industrial and post-industrial nations is primarily concerned about conformity to these standards (Jenkinson, 2011). This training ensures that, through formal education and chartership, engineers operate within the boundaries set by their professions (Davis, 1998). This is not intended as a criticism of the engineering profession as it has proven to be an effective method of ensuring stability, quality, safety and efficiency of engineering solutions. The limitations of this education are found when trying to directly solve rural problems using engineers that have been educated within these defined 'engineering communities'. In the ATT model the achievement of a project is more concerned with its method of delivery rather than achieving 'goal orientated' functionality. The context is considered as important, if not more so, than the delivery of a technology and is stoically defended:

> *"Appropriate technology may not be efficient from an engineering standpoint, but it is pedantic and unrealistic to describe any technology that enhances the capacity to satisfy community goals and aspirations as inefficient"* (Akubue, 2000).

This is a role that is currently unsuited for engineers trained in the developed nations (Passino, 2009). This can explain why there are so few ATT projects attempted by international NGOs in the developing world or, specifically for this research, in Sierra Leone.

2.2.4 The Synergetic Approach to Technology Transfer

The international development agencies that have provided the majority of the water supply technologies in Sierra Leone have not depended on either the LTT or ATT approaches. These two models instead represent the two extremes of technology transfer. The LTT movement is geared towards one aspect of the engineer, their affinity to engineering functionality, but it knowingly reduces social responsibility in a development context resulting in a fundamental lack of ethical considerations. The opposite is true of the ATT approach which, through its adherence to high social standards and development ethics excels in its appreciation of the context of poverty, but it is prone to functionality problems caused by the inability to scale the approach to suit numerous and widely distributed rural communities.

The sustainability of both approaches is also questionable. The LTT approach is heavily capital intensive. The extension of services is solely dependent on the availability of financial resources and would require constant monetary assistance for long term maintenance and support. Furthermore, only providing a technical artefact with no other considerations is an approach that is guaranteed to develop serious technical difficulties, which are inevitable in any engineering project, at some stage in the future. The sustainability of the ATT model is also questionable, but for different reasons. With the exception of infrequently observed 'high' technology interventions the ATT projects are not usually as highly capital intensive as LTT programmes. However they are always dependent on having a skilled human resource base for their continued success. For the approach to be successful on a large scale would require a continual availability of engineers that have sufficient appreciation for the concepts and values of the ‘appropriate technology movement’. The shortage of this key resource undermines the success of the ATT approach in achieving technical objectives. In conclusion, the sustainability of the two approaches is, at the very least, dependent on either one of two resources: (i) financial capital or (ii) skilled technical personnel. For a developing nation to rely solely on these two approaches to technology transfer would mean that their rural water supplies would depend on the two resources that actually define their poverty. This is without considering other known issues with NGOs operational practices such as the organisations structure designed to accommodate engineering, the local conditions, the local supply chains and the availability of unskilled labourers.

The field research indicated that most of the largest development agencies operating in Sierra Leone have attempted to combine both approaches into one cohesive implementation strategy. Therefore a further definition of technology transfer is produced. This thesis defines this model as the Synergetic Approach to Technology Transfer (SATT). The conceptualisation of this model has evolved through developmental practice and has never been explicitly stated in the secondary literature. Its purpose has been to attain the strengths of the other two approaches while simultaneously cancelling their weaknesses. This model has been developed either through an informed decision making process, or has become an evolved consensus through the attempts to apply the ATT approach to pre-existing development activities. In many ways its formation coincided with the ATT movement but differed in its application of the 'appropriate' ideology:

> *"Most water and sanitation agencies within developing country governments are striving for a high degree of standardization as a partial answer to their managerial, administrative and financial problems. They may well be right to resist any attempt to encourage a very flexible approach to participation on a community-by-community basis. Flexibility at the regional, district or branch level may well be practicable, but to regard each scheme as a fresh planning exercise would strain even the most efficient bureaucracies"* (Feachem, 1980)

The SATT model is a rational solution based on the limitations of the available capital and skilled human resources of both the communities and the implementing organisations. To address the weaknesses in linear approach there has been inclusion within the SATT model for social support mechanisms – such as the training of community management committees, collection of tariff schemes and the training of local technicians. The SATT model has attempted to maintain what can be perceived as the strengths of the LTT approach – such as limiting the number of technological interventions attempted and in seeking to standardise the technical approaches that have been used. The SATT model, in theory, also incorporates certain elements of the ATT approach. It has attempted to achieve this by allowing an increase in participation, promoting self-reliance through the community management structures, while also engaging with indirect water supply issues - such as gender inequalities at the source. As certain SATT models are more 'linear' with regards to technical standardisation they can still allow a ‘technical core’ to make the vital hardware decisions on behalf of the communities. This allows the projects community mobilisation, or ‘software’ units, of the water supply projects to provide the social measures – such as sensitising the communities to the technologies, developing the community water committees or training maintenance staff. This means that the role of the engineer in the SATT approach, when the participating engineer comes from outside the socio-cultural systems, is more compatible with their existing education that they received in developed nations. There is still technical choice, but the process is more valued than the actual decision:

> *"Often environmental, technical and financial factors severely constrain the range of possible technologies. Even where there is little realistic choice, however, the importance of the discussion lies as much in the process (sharing the decision-making) as in the final ability to choose"* (Harvey and Reed, 2004).

2.2.5 The Polarities and the Synergetic Approach to Technology Transfer

Evaluating the success of the SATT model in development practice is a difficult process. It is not, of itself, a new paradigmatic vision for achieving rural development objectives. Instead it is a combination of two already existing approaches. It appears that it has been rationally and logically conceived during the attempts to provide an improved source of drinking water over large geographical areas while also simultaneously attempting to adhere to fundamental development ethics. Therefore the model exists between the polar extremes of the ATT and LTT models (Figure 11).

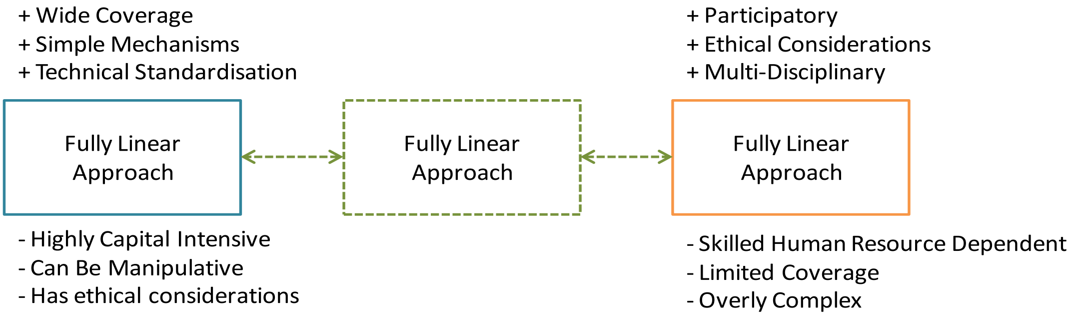


Figure 11: The Synergetic Approach to Technology Transfer

The complexity involved in analysing this model is due to the different adherences, by different organisations, to their own unique methods of technology transfer. The SATT model is not always a decisive middle ground between the ATT and LTT approaches. Some organisations prefer an almost totally LTT model but with certain limited concessions that allow it to address the outstanding sustainability issues. Other organisations have a more rigorous ATT approach, but restrict certain technical choices that are given to the communities by standardising of their provided technologies. A clear evaluation is further complicated by the same organisations opting for a strategy during a project, such as building communal wells, while simultaneously providing water points using a different value system in another, such as constructing health clinic wells. This can happens due to pressures by donors to adopt new ethical values system. It can also be caused by the introduction of new programme staff who have their own ethical considerations. It was also noted in Sierra Leone that certain NGOs have adopted a linear approach in one regard, such as the supplying the same pulley wells systems across their entire village, and have yet apply the values of ATT when they complement the supplies with other technologies, such as water storage devices or sanitation technologies. Additionally many of the villages can have multiple interventions by different organisations which have used different technology transfer strategies for each of their projects. The complexity offered by these competing case-studies can disguise the actual weaknesses of the SATT approach.

It is from the SATT approach to technology transfer that policies and institutional frameworks are built. These include the participation with the local government, private sectors and manufacturers of technologies. Harvey and Reed mention five models of service delivery within this framework: community management, public-private, manufacturer-NGO, primary healthcare, least subsidy, and government service (Harvey and Reed, 2004). The only observed model in Sierra Leone was the community managed model. This is known to be the most dominant service delivery model used by organisations (Harvey and Reed, 2004). The specifics of each of the alternative methodologies within the SATT system will not be discussed in this thesis - but the implications of many of the results of the field research apply directly to the other alternative support models.

Comparing the different theories, using an arbitrary scale, suggests that the SATT model has been the most rational choice for development agencies (see Figure 12). The 'ideal' model SATT has evolved to offer the most advantageous benefits to communities, implementing agencies and donors. Therefore, as this is the best conceptualisation of current practices, this research will primarily investigate household water supply technologies that have been provided by international NGOs that have adopted the SATT model of service delivery.

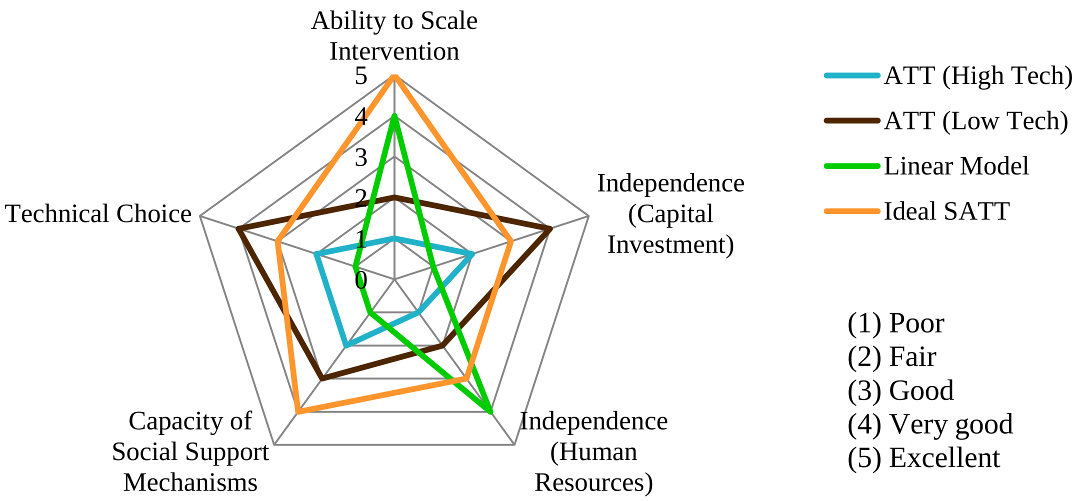


Figure 12: Comparison of the service delivery models

2.2.6 Conclusions - The Models of Service Delivery

The understanding of these different models has implications for the study of the role of the engineer in international development. The engineer's roles and responsibilities, which has resulted in both their practices and in certain project types, are determined by the type of technology transfer model that the implementing agencies strategically choose. Any alterations to the role of the engineer would have to specifically address the models of service delivery. The main reason for introducing and addressing the three approaches formally is that any suggested alternative would have to be a paradigmatic shift in practices and not a re-wording of existing engineering technology transfer models.

The chapter has also indicated that the success of a model cannot only be assessed with regards to the functionality of the technologies immediately after their construction. This is important as otherwise, based solely on achieving functionality and despite its ethical limitations, the LTT approach would be the only valid engineering method in rural development. Instead project success should be measured by also evaluating the social support mechanisms and the interaction of the socio-cultural and socio-technical systems to fully understand the success of the intervention.

Finally, the SATT model is also the most dominant approach to technology transfer by the international development agencies. Most of these NGOs would resist the label of having a 'linear' approach to their development practices. The same organisations would also concede that many of their limitations mean that their transfers are not fully 'appropriate'. Without further transparency and accountability by the implementing organisations it is difficult to determine which approaches were fully LTT or ATT. Therefore the field research has investigated each of the water supply projects that were observed in Sierra Leone as though they were provided using the Synergetic Approach to Technology Transfer.

2.3.1 Sierra Leone and the context of poverty

The final part of the literature review explores the background context to which water supply projects in Sierra Leone are supposed to operate. The objective is to present the varied and complex environment that acts as a backdrop to the research carried out for this thesis. To avoid generalising the 'developing world' this research has focused on a series of case studies carried out in a single district, Tonkolili, in Sierra Leone. There are an extensive range of problems, such as health issues like HIV/AIDS or legal issues, such as community land tenure disputes for agriculture, which rural communities have to contend with (Chambers, 1983). Many of these issues, though severe in themselves, would only have a minor, or potentially negligible, influence on household water supply. Therefore some narrowing of focus is required which does not involve an oversimplification on the context of poverty, but is also manageable and rational in its scope. This requires a selection of key influences which were clearly identifiable during primary research in the field – made through observation and in-country experience as well as informal discussions and interviews. These aspects have been focused on for this contextual analysis.

2.3.2 The Republic of Sierra Leone

Sierra Leone, officially the Republic of Sierra Leone, is a country in Sub-Saharan Africa (Figure 13). It is located in Western Africa but below the Sahel Region (Figure 14)

Figure 13: Map of Sierra Leone in Sub Saharan Africa

In 2012 the West African nation was estimated to have a population of 5,485,998 people. The populations sizes are calculated with regards to trends in growth and is available in the World Banks central micro-data catalogue (World Bank, 2004). Sierra Leone is bordered by the nations of Guinea, to the northeast, and Liberia, to the southeast. Both of these neighbouring countries have had significant impact in the recent history of Sierra Leone. The country is divided into four regions, Northern, Eastern and Southern Provinces and the Western Area. The Western Area (or Freetown Peninsula) is the smallest region and contains the nation's capital, Freetown, as well as the surrounding sub-urban area and towns. The Western Area is the only region where the majority of the population are urban dwellers. The other three provinces have primarily rural populations (Figure 14). The rural areas constitute approximately 60.7% of the population; however the size of urban populations has steadily increased in recent years whereas the rural populations have had more moderate growth (World Bank, 2011).

Figure 14: Location of Sierra Leone in West Africa

World demographic indicators of the World Bank estimate that 41.9% of the Sierra Leonean population are below the age of fourteen. The median age for the country is just over nineteen years. Only a small percentage of the population (3.7%) are over the age of sixty-five. In all age categories women are the largest group (a ratio of 0.943 males to females). The Sierra Leone population is generally exceptionally young, as a point of reference, the median age in the United Kingdom is over forty years of age and only 17.3% of the population are under the age of fourteen. Inadequate Sierra Leonean health levels in some of the most basic mortality indicators, including life expectancy, explains the demographic differences in this area (World Bank, 2011).

Sierra Leone has a diverse ethnic background having eighteen different tribes (Devis, 1973). The post-war census of Sierra Leone (World Bank, 2004) states that the largest ethnic groups are Temne (35%) and Mende (31%). Other large tribes include the Limba (8%), Kono (5%) and the Krio (2%). The Krio (also referred to as Creole) are the descendants of the slaves resettled from Nova Scotia, the West Indies and England. The Krio are mainly concentrated in the Western Area (in Freetown and neighbouring towns) though their influence, particularly with regards to the countries lingua franca, can be found throughout the country (Hair, 1998). Each of the eighteen tribes has their own unique history, traditions and customs. Certain smaller tribes, such as the Mandingo, a branch of the Mandinka people, and the Foulah, a branch of the Fulani, are spread throughout Sierra Leone and into neighbouring countries (Devis, 1973). The Temne, the most dominant ethnic group in Sierra Leone, are predominantly found in the Northern Provinces and the Mende, the second largest, are found in the Southern and Eastern Provinces. A map of the ethnic groups is shown in Figure 15. The Temne has been specifically highlighted as this tribe was the main focus of the field research.

The relationships of the different tribes, and the clans within these tribes, is outside the scope of this thesis to discuss in detail. There has been historical intertribal tensions, some of which was manipulated during the Mano River War, but there is not sufficient evidence from firsthand experience of the communities to suggest that current tribal problems have sufficient impact on engineering in Sierra Leone. Similarly the inequalities between tribes - such as with the smaller groups like the Mandigo and the Foulah, were not found to significantly impact the success of projects. Reviewing urban water and sanitation projects in Freetown would require detailed historical analysis of the relationship between the Krio and the other tribes. However, as this thesis is concerned only with rural Water supplies, and the

Krio are predominantly found within Freetown and its surrounding areas, this tribal inequality will not be investigated in detail.

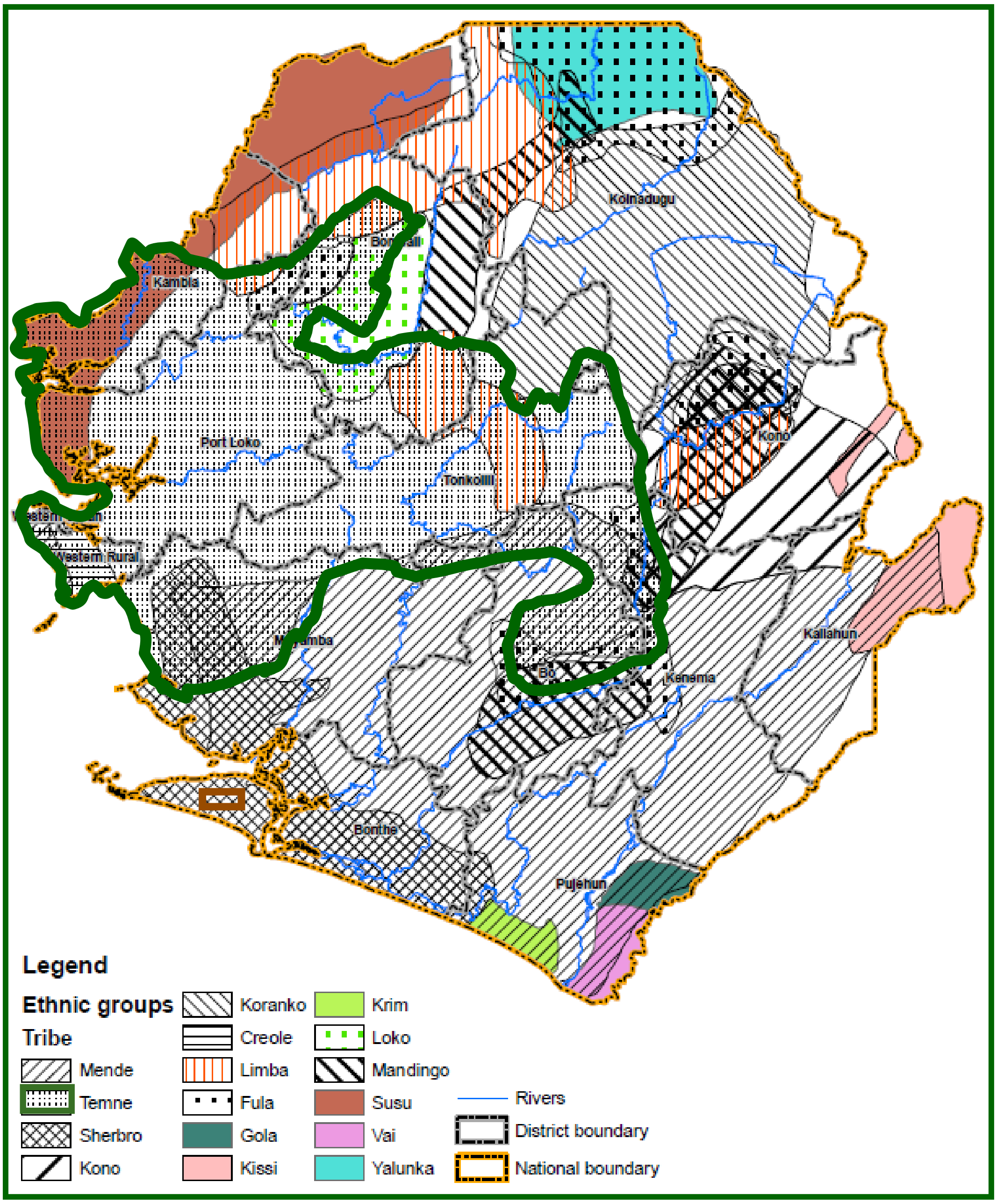


Figure 15: Map of Sierra Leone (the Temne population has been highlighted in green)

Most individuals in Sierra Leone speak one or more of the sixteen native and unique languages (Sengova, 1987). Due to their prominence in the media, in literacy, and in formal education, the five most commonly used languages in Sierra Leone are; English, Krio, Limba, Mende, and Temne. Though English is used for various formal areas such as business, education, government administration, the judiciary and international communication, it is rarely spoken by individuals in the rural areas. In Sierra Leone it is Krio that is the lingua franca, though it is the first language of less than 10% of the people, but is spoken by almost 95% of the population (CIA, 2012). Krio, the language, has its roots in the Atlantic slave trade as a form of 'pidgin' English. As this forms the basis for the Creole, much of the sayings and expressions can be interpreted by an English speaker without the need for extensive linguistic support.

According to the American Central Intelligence Agency the main religions in Sierra Leone are: Islamic beliefs (60%), Indigenous beliefs (30%) and Christian beliefs (10%) (CIA, 2012). Defining the religious adherence of Sierra Leoneans is complicated by the widespread practice of syncretism - the mixing and melding of different religious ideologies and traditions (Stewart, 1994). Adherence to local belief systems, such as witchcraft and sorcery, are evident in local practices, regardless of the professed religion of the individuals. This process offers an inclusive approach to religion, but tracing a common spiritual or religious reasoning behind a practice is open to misinterpretation or misrepresentation, partly because the beliefs of an individual can very often be contradictory with regards their simultaneously held creeds.

2.3.2.1 Colonial history of Sierra Leone

It is thought that Sierra Leone has been inhabited for over 2,500 years however there is no formal documentation or written history prior to the colonial period. Additionally there is little archaeological evidence to base historical theories upon. Historians explore the pre-colonial period by the investigation of ethnographical and logistical studies of current populations that live in the country (d'Azevedo, 1962). Understanding their history becomes clearer in the 1500's, as contact with the European countries instigated a dramatic change in culture in Sierra Leone. Several accounts of the first explorations of the country by the European powers exist. These explorers first sighted the coast of Sierra Leone in 1446. Sixteen years later a Portuguese explorer named Pedro de Sintra mapped the hills surrounding what is now Freetown Harbour, naming the shaped formation the 'Serra de Leão' (Portuguese for Lion Mountains). The Italian rendering of the name given to this geographic formation is 'Sierra Leone' (Kup, 1961). The finding of this port initiated the arrival of European traders, trading posts as well as the introduction of the slave trade. The American slave trade had its origins in Sierra Leone in the 1560s and by the 18th Century the British and Portuguese slaving settlements lined the coast (Wylie, 1973). With the abolishment of the slave trade in both America and Britain came the resettlement of freed slaves in Sierra Leone and the creation of a British Colony. The capital Freetown was constructed in 1791 by over 1,100 former American slaves from Nova Scotia. The settlement in Freetown was heavily populated by the Krios (also called Creoles) descendants of freed slaves from around the world who settled in Freetown between 1787 and 1855 (Hair, 1998; Peterson, 1969).

Prior to independence the British colonial rule in Sierra Leone had a crucial role in exploiting the country for its resources (Rodney, 1972). Much of the colonial infrastructure was constructed to be primarily extractive, as roads and rail networks were linked to Freetown, rather than act as feeder transport for towns and villages, and they facilitated the continual extraction of resources from the country. The colonial period had little impact on increasing water supply coverage in Sierra Leone, but the impact of the slave trade, the introduction of a new social elite and the focus on a specific method of providing infrastructure all contributed to the problems that arose during post-colonialism and independence. It is possible to suggest that the direct influences of both the slave trade and colonial rule diminished over time, but their legacy had terrible consequences that were partially responsible for the brutal war that followed independence from British colonial rule (Shaw, 2002).

2.3.2.2 The Mano River War

The Mano River War; sometimes referred to independently as the civil wars in Sierra Leone and Liberia, was an eleven year war that began in Sierra Leone on March 23rd 1991. Colliers book 'the bottom billion' states four traps that purposefully hinder the development and prosperity of a country. Throughout the years of the Mano River War the Republic of Sierra Leone became well integrated into three of these traps: (i) bad governance in a small country, (ii) the conflict trap and (iii) the natural resource trap (Collier, 2007). For geographical reasons the fourth trap does not apply as Sierra Leone could technically not be 'landlocked with bad neighbours'. However, it was Sierra Leone's proximity to their volatile neighbour Liberia, separated only by the porous border of the Mano River, which instigated the eleven year civil war. In 1991 Liberia was in the midst of its own civil conflict (referred to as the First Liberian Civil War) and the warlord Charles Taylor had been successful in the coup d'état which saw the sitting president of Liberia, Samuel Doe, assassinated. It was over the Mano river that the Revolutionary United Front (RUF), led by Fodah Sankoh, with support from the special forces of Charles Taylor’s National Patriotic Front of Liberia (NPFL), entered Sierra Leone in an attempt to emulate Taylor's success in Liberia, and overthrow the Sierra Leonean government of Joseph Momoh. It is well known that this coup attempt was a thinly concealed effort by Taylor to control the natural resources in Sierra Leone (Gberie, 2005).

It was through previous pre-war decades of poor governance that Sierra Leone had become unstable. The events that transpired in the eleven years of conflict had their roots in years of violent coups, political corruption and scandal. Since independence from British colonial rule in 1961 many years of political mismanagement and electoral violence had taken their toll. The most notable example was the regime of Siaka Stevens who for seventeen years, beginning in 1968, corrupted, eroded or destroyed the capacity of every state institution in his power (Reno, 1995). When Siaka Stevens stood down in 1985, the leadership was given to Major General Joseph Momoh who, as a president, was often described as weak, inept and inattentive to state affairs (Tuchscherer, 2006). The resulting mismanagement and corruption effectively destroyed civil society in Sierra Leone. The RUF's original mandate was supposedly to:

> *"...mobilise a socially-excluded youth underclass into a Museveni-style 'people's army' in an attempt to overthrow a corrupt one-party regime government, the All-Peoples Congress* [APC] *of President Joseph Momoh"* (Richards, 1999).

Though not specifically addressed by Collier's 'traps' it is also argued that the legacy of both the slave trade and colonial exploitation contributed indirectly to the collapse of the state (Richards, 2005; Shaw, 2002; William, 2006). At the start of the civil war a combination of factors including, but not limited to, widespread frustrations of both the rural and urban youth, the migration of the educated professionals to developed countries, and the continued political upheaval culminated in a situation that rapidly descended into civil unrest. By 1991 the machinations of what would become a brutal war machine were finally set into motion.

The resulting war gained international notoriety and media attention for its extreme violence, most notably the practices of murder, cannibalism, sexual violence, abductions, torture, bodily mutilation, as well as the recruitment and use of child soldiers (Taylor 2003; Zack-Williams 2001). Terror tactics of the RUF included the hacking off of arms and legs of individuals, leaving almost 20,000 people disfigured (Dufka, 1999). As Collier noted, the longer Sierra Leone stayed in a state of conflict the more players became established that benefited from the violence and the resulting situation became intractable (Collier, 2007). Throughout the war there were attempts at peace, such as the Abidjan Peace Agreement on 1996, the Conakry Agreement in 1997 and the Lomé Agreement 1999. Each of these in turn failed, because of the actions of invested parties intent on violence, and the war continued (Alao and Ero, 2001). Sierra Leone's wealth in natural resources did not alleviate the suffering and was regarded as a catalyst for much of the conflict. Their rich resources, in particular the alluvial diamonds in the Kono and Kenema districts, became the focal point of the war (Campbell, 2004). The RUF had originally stated 'revolutionary' ideals but this ideology was abandoned and the control of the diamondiferous areas became one of the main objectives of the conflict. Diamonds were not the only area of exploitation as gold, bauxite and titanium dioxide mines were also targeted. Other acts of pillaging such as looting of property and forced agricultural labour also provided methods of extracting riches from the local population (Richards, 1996).

Due to its intricate complexities, the specific details of the war cannot be described in this study in detail. The eleven years that Sierra Leone was engaged in the Mano River War resulted in a host of actors and events and each played a principal role over the course of the conflict. This included; the in-fighting and corruption of the Sierra Leone's Army (SLA), the participation of the Nigerian led multinational force of Economic Community of West African States Monitoring Group (ECOMOG), the coups and military rule of the National Provisional Ruling Council (NPRC), the involvement of the South African paramilitary group Executive Outcomes (EO) and the final coup of the conflict of the Armed Forces Revolutionary Council (AFRC). Each of these actors and organisations made their own contribution, either by commission or omission, to the decline of Sierra Leone and the continuation of the conflict. Several events, from the failed peace accords, to the brutality of certain RUF campaigns, most notably the extreme violence linked with "Operation Pay Yourself" and "Operation No Living Thing", were hallmarks of a country that had collapsed (Clapham, 2001; Dufka, 1999; Meredith, 2006).

Though the conflict actively dismantled many parts of civil life, it did give rise to new organisations that formed in response to the conflict. One of the most significant was the formation of the militias known as the Civil Defence Forces (CDFs). These armed groups assembled, through a process of local institutionalisation, as a response to the attacks by the RUF and SLA on unguarded towns and villages (Hoffman, 2012). The largest local militia faction was from the Mende tribe, originally known as the ‘kamajoisia’, but later as the ‘Kamajors’, other ethnic groups responded with their own militias. The CDF was formed by a combination of participants from many of the different ethnics groups. The Kuranko's had the ‘tamaboro’, the Temne had the ‘gbethis’ and ‘kapras’, and the Kono with the ‘donsos’ who all fought with the explicit goal of creating a democratically elected government. The idealism of the CDF can be seen as commendable but they were also responsible for their own participation in certain war crimes and atrocities (Dufka, 1999; Hoffman, 2012).

It was not until 1999 when the Lomé Peace Agreement was signed, and the UN established some enforcement of the accord through the United Nations Mission to Sierra Leone (UNAMSIL), that the hostilities reduced. In 2001 the number of UN forces present in Sierra Leone involved over 17,500 combatants, and was at the time the highest troop deployment anywhere in the world, however the fighting still continued, particularly with RUF factions that remained in control of the diamondiferous areas (Olonisakin, 2008). It was not until the deployment of the British military in Operation Palliser, which provided the support for the failing UNAMSIL mission, that acted as a catalyst for the end of the war (Dorman, 2007; Williams, 2001). A combination of this robust overseas military support, Guinean military involvement on the Sierra Leone borders and new UN resolutions, effectively ended the conflict and forced the RUF into the signing of a new peace treaty (Adebajo, 2002). The UN resolution had restricted the illicit diamond trade (Resolution 1306) and was designed to specifically target and limit Liberian support for the RUF through the expulsion of its members from their country (Resolution 1343). It also created an end of Liberia's financial support for the RUFs cause. On the 18 January 2002, President Kabbah declared the eleven-year long Sierra Leone Civil War officially over. The wars legacy had left the country in ruins. As the historian Meredith states:

> *"Over a period of eleven years some 50,000 people had died, 20,000 were left mutilated and more than three quarters of the population had been displaced. And, according to a UN report, of all the world's countries Sierra Leone had reached the very bottom of the league for human development."* (Meredith, 2006).

Figure 16: Location of the Signed Peace Agreement: Ferry Junction

2.3.2.3 Post Conflict Sierra Leone

The end of the conflict had left Sierra Leone in extreme state of both economic and social collapse. The impact that the war had on the indicators monitored by the Human Development Index (HDI) were dramatic. The country's Gross Domestic Product (GDP), mortality of its citizens and national literacy rates were some of the lowest in the world. The life expectancy of Sierra Leoneans was the lowest in the world at 40.2 years for women and 37.6 years for men. Their adult literacy was less than 36% for those above 15 years, and the educational system had received no expenditure on education in decades (UNDP, 2002). Their dependency on Official Development Assistance (ODA) was one of the highest percentages of GDP in the world at almost 28.7% (UNDP, 2002). Their reliance on foreign aid, the breakdown of normal civil society, and their lack of local and professional technical expertise, necessitated the need for foreign agencies to intervene on their behalf.

The lack of qualified technical staff in Sierra Leone has its own history that pre-dated the conflict. Where it is true that the war had left a dramatic shortage of highly educated indigenous people, but the large scale emigration of the educated elite, including those such as doctors, lawyers and engineers, started decades before the civil war. The presidency of Siaka Stevens in 1967 and what is referred to as his “seventeen-year plague of locusts” was a central contributor to the departure of many skilled personnel (Hirsch, 2001). Until Stevens reign the western styled universities of Freetown were known as the ‘Athens of Africa’ and were responsible for producing renowned academics in West Africa (Paracka, 2001). During Siaka Stevens regime the universities were starved of funds and many professors compromised their integrity by joining the cabinet. Corruption became institutionalised throughout the education sector. Professionals that were capable of standing up to Stevens, particularly his implementation of a one state party, were forced to deal with exaggerated treason charges, unfair trials and many faced execution (Forna, 2002). He specifically overlooked educated, qualified and productive individuals preferring to appoint those that could be corrupted or manipulated. The situation left little options for the educated elite and they migrated to other countries. The following reign of President Joseph Momoh and the ensuing violence did not slow down, but instead increased, the human capital flight (often referred to as the “brain drain”) as those with technical skills and knowledge fled the conflict. It is estimated that the emigration rate of tertiary educated Sierra Leoneans was 49.2% (Docquier et al., 2009). This was one of the highest global migrations for a country of its size. Sierra Leone was left, both before and after the Mano River War, without a much needed educated professional class. The conflict also caused infrastructure damage to the universities like Fourah Bay College and Njala University (UNESCO, 2012; World Bank, 2007). Engineering, given its intense training and need for prolonged education, suffered with the rest of the professions that required support from state institutions.

The rural provinces did not, historically, have the same dependency on formally educated professionals as the Western Area. The conflict did however dramatically influence the organisation and function of rural civil society. Due to the warring factions specifically targeting rural communities, the conflict period caused severe devastation to the internal relationships and the social cohesion in the rural areas (McIntyre et al., 2010). As the African Development Bank reported *"[the] once-vibrant regional trading hubs have contracted"*. The consistent attacks against the rural populations, from all the militant participants in the war, clearly disrupted the fragile internal networks of trade, commerce and agriculture that the communities depended on for their survival (ADB, 2011). The looting, pillaging and destruction of both private and communal properties drove large sections of the rural populations from their villages and communities. Hundreds of thousands of people became Internally Displaced Persons (IDPs) in their own country. At the peak of the conflict in 1994 there were over 782,000 displaced individuals and this averaged at over 650,000 people throughout the war. At the signing of the Lomé peace accord in 1999 over 490,000 Sierra Leoneans had become refugees in nearby countries such as Guinea, Côte d'Ivoire and Ghana. The combined number of displaced people at any given time throughout the war constituted almost a quarter of the entire population of Sierra Leone (UNHCR, 2002). The widespread abduction and use of children as soldiers, sex slaves or as forced labourers, by most of the militant participants in the war, further destroyed communal relations. It was well reported that the forced recruitment strategies used by the armed forces were designed to explicitly sever ties of the child to their family, community and society (Rosen, 2005). The disarmament process took place in 2002, however many young men and women could not, or would not, return to their villages (Ginifer, 2003). The breakdown of civil society constricted the flows of monetary support, and ruined networks that were necessary for the survival of the villages, including both physical constructs, such as dirt roads for the mobilisation of goods, and societal constructs, such as community education frameworks.

By the end of hostilities in 2002 Sierra Leone had spent almost a decade as a "failed state" - one that is unable to deliver essential service required by its population. As the report by the Organisation for Economic Co-Operation and Development (OECD) into 'state rebuilding in fragile situations' stated:

"In the absence of a willing and capable state, particularly in weak-capacity post-conflict countries, the strategy often deployed is the use of non-state entities (ranging from private corporations to donor-funded NGOs) to fulfil some of the responsibilities of the state during a period in which the state is focused elsewhere" (OECD, 2009a).

The end of the conflict heralded the arrival of hundreds of the global and regional Non-Government Organisations (NGOs) and the creation of many smaller grass-roots, civil society organisation and local NGOs. These would act as implementing agencies for the foreign aid money that was available for disaster relief and post-war reconstruction. Depending on their sizes and mandates, the NGOs varied in both scale and capacity. There was representation from almost all of the largest International NGOs. Their programmes encompassed a range of governance, health, livelihoods, advocacy and educational projects.

2.3.3 Contextual Analysis of the Field Location - Tonkolili

This research is primarily interested in a single geographical area, Tonkolili District, in Sierra Leone and, as such, the specific context of its demographic formation, culture and tradition are important for this study. Tonkolili is one of fourteen districts in Sierra Leone, and one of five districts in the Northern Province. Geographically Tonkolili is over 2,704 square miles and has an estimated population of 345,884 people, over 6.6% of Sierra Leone's total (Figure 17)

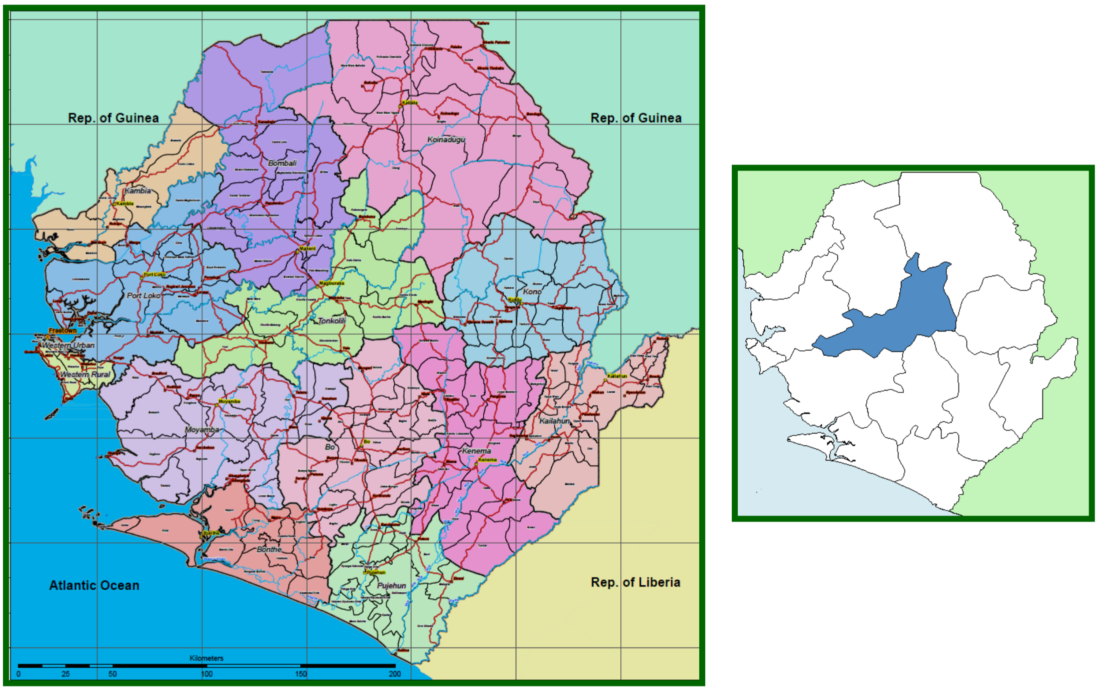


Figure 17: Map of the districts in Sierra Leone – Tonkolili as the central district

In relative terms, Tonkolili is the most central district in Sierra Leone and is landlocked on all sides by seven other districts. Its capital is Magburaka which has an estimated 16,313 people. Other towns are much smaller, with the second largest township, Yonibana, having an estimated population of 3,589 people (World Bank, 2004). The district consists of eleven chiefdoms, and each of these chiefdoms consists of not more than one or two large towns (those with more than 2,500 people). The majority of villages within the chiefdoms consist of settlements which accommodate less than 500 people. Villages are widely spatially distributed throughout the districts. Their formation is dependent on a number of factors including access to land, water, roads, agriculture as well as social and traditional centres (John, 1963).

The conflict was particularly devastating for certain districts and communities in Tonkolili. The leader of the RUF, Foday Sankoh, was born in Masang Mayoso in Tonkolili. Not far from this village was one of the central bases for the RUF, referred to as their base camp or training base, which was named Camp Charlie. This base was situated in the Malal Hills in Tonkolili (Richards, 1999). As the proximity to the hills increases, during travel through Malal Mara region on research visits, the legacy of devastation and historical violence inflicted on the local population becomes more noticeable. Many villages have spent over a decade recovering from the conflict but certain infrastructural ruins remain, including those of communal building such as schools, and individual constructions such as houses. Tonkolili was not one of the diamondiferous areas that were fought over during the Mano River War, however its central location, between Kono and Freetown, made it an important through route for every military faction that sought control of the natural resources.

2.3.3.1 Contextual Analysis of the Field Location - The Temne

Most of the residents in Tonkolili are Muslim in religion and Temne by ethnicity. As the following researches surveys and interviews are predominantly focused on the Temne people, a brief description of the tribe is required. There is no archaeological record for the present-day Temne before contact was made by the European civilisations. Ethnographical studies suggest that Temne migration originally came from the northeast of Sierra Leone, from the Fouta Djallon plateau area in the Republic of Guinea (d’Azevedo, 1962). During slave trade and colonisation by the Europeans and Americans hundreds of thousands of Temne were shipped to the Western world as slaves. There are also reports that the Temne were heavily involved in the profitable trading of slaves with the Western powers (Wylie, 1973).

In the post-colonial period the Temne were, and remain, predominantly farmers, fishermen and traders. Their farming is primarily subsistence farming of dry and wet rice (Spencer et al., 2009), as well as various secondary crops such as sorghum, millet and groundnut (Peace Corps, 1978). As the Temne are mainly based in the Northern Region, and without access to the sea, their fishing methods involve primarily fresh water fishing in the interior rivers and permanent fish ponds. Post-war efforts by certain Non-Governmental Organisations have focused efforts on food security which involves increased rice yield storage and the constructing permanent fish ponds for the production of fish such as Tilapia. Fisheries provide 80% of the total animal protein into the national diet (ADB, 2011). Temne trading mainly focuses on local resources, such as the trading of palm oil, gold and farmed goods, though they have a long history of trading into the interior of West Africa (McGowan, 2009).

The social structure and organisation of the Temne is based on a hierarchy of elders. This has implications for the management of communal water supplies. The introduction of the British administration during colonisation appointed the chiefdoms as units of the local government and their basic structure still exists today (Jackson, 2006; Kup, 1961; Manning, 2009). The British district commissioners were noted to work with, and through, the paramount chiefs. This hierarchical oligarchy has several layers. Each village has an elected headman and these are responsible to the section chief. The section chief is in charge of a small cluster of villages. There are eighty such sections in total in Tonkolili. These sections chiefs fall under the authority of the paramount chief who led their respective chiefdom ward. Each paramount chief is elected for life from hereditary families known as 'ruling houses' and on appointment to their post become nonpartisan Members of Parliament.. (Jackson, 2006). In Tonkolili the eleven chiefdoms are responsible to a single paramount chief, referred to as *bai* in the Temne Language (Biyi, 1913). The Temne do not have women chiefs, though this practice is not homogenous throughout all the tribes in Sierra Leone (McFerson, 2011). The chiefs are responsible for taxes, local police, dispensing local justice (through local courts) and control of the land (Jackson, 2006; Manning, 2009; Richards, 2005). The chiefs are also responsible for certain religious affairs and their post are closely linked to the functions and practices of the secret societies.

2.3.3.2 The Secret Societies

Many aspects of the traditions, culture and practices of the rural populations in Sierra Leone are carried out overtly, but there are certain aspects that are secretive and intentionally hidden from outside observers. The most notable practice is the role and practices of members of the ancient cultural institutions known as the 'secret societies'. The uniqueness of these societies and their impact on rural culture and tradition at village level, and their importance to later chapters exploring the social aspects to water supplies, has necessitated an explanation in this research of their formation and purpose. There are several secret societies in Sierra Leone (such as the Wunde, Gbangbani, Yassi and Ojeh) but the most important leading societies are the Poro, a male only society, and the Bondo, the accompanying female society, referred to as the Sande in the Southern Provinces. Initiates from these societies are distributed throughout the country, as well as through the neighbouring countries of Liberia, Côte d'Ivoire and Guinea. Many of the communities have their own Poro and Bondo congregations, and initiation into one allows for the participation into others (Lavenda and Schultz, 2008).

The anthropologist Fanthrope, in a report for the United Nations High Council for Refugees (UNHCR), states that the primary purpose of the societies is to canalise and control the powers of the spirit world which are captured in specific artefacts such as masks:

> *"the secluded rites of passage into adulthood are better understood as lessons in reflexivity: learning how to nurture powers contained in masks and medicines teaches initiates to recognize and regulate corresponding powers within themselves and thus adhere to culturally prescribed behavioural norms specific to their sex*" (Fanthorpe, 2007)

The gender specific nature of the societies is noteworthy, particularly in a country with a poor record of gender equality. The mystical powers of the societies are regarded as being sex-specific, and their control requires a separation of both males and females (Fanthorpe, 2007; Shaw, 1985). It is noted that the nature of the societies is exceptionally egalitarian between genders, and the practices of one society is independent, though supposedly equal, to that of the other. The Poro and the Bondo are sodalities that are responsible for initiating young men and women into adulthood (Lamp, 1978). For the men this training includes learning about leadership and forming a part of the patriarchy, for women it involves learning about being a dutiful mothers and wives. It is from within these societies that bush-craft skills are learned, including basket weaving, animal trap building and bridge building (Little, 1949).

Two of the most important laws of the societies, which give rise to the function of secrecy, are that initiates cannot speak of society affairs to those that have not been initiated and that societal practices cannot be witnessed by those that are not part of their society. As Fanthrope states, the 'secret' aspect of the societies are somewhat of a misnomer, as the initiates of the leading societies do not hide their membership as instead, when rituals and rites are taking place, any non-initiates must conform to a ritual curfew and either leave the area or retreat into their settlements (Fanthorpe, 2007). The secrecy aspect of the societies does lead to problems regarding the exact definition and quantification of this aspect of Sierra Leonean culture. Full details and definitions of each of the different society's initiation ceremonies, rites and rituals are suspect to multiple and often contradicting stories and reports. Some interviews and field research for this study that concerned aspects of witchcraft or specific rituals were very often dramatized, or possibly sensationalised, as part of the discourse. Anthropologically it is well accepted that the Poro and Bondo's function are more closely related to preparing a role for the individual in community life than some of the more dramatic interviews may suggest. The secrets, as MacCormack states when viewing the role of the Sande (Bondo) and women-hood are:

> *" [a] secret in the sense that it owns knowledge so valuable that it must be guarded against debasement and transmitted only in ritual situations to initiates properly prepared to receive it"* (MacCormack, 1979).

The role of preparing and supervising individuals gives the societies vital control over the sexual, social and political conduct of their initiates. Even though almost all aspects of the secret societies practices, rituals and rites are hidden, their direct impacts on the social, cultural and political activities in rural areas are explicit, and demonstrate the concealed power of the societies in Sierra Leone.

Certain practices, such as cannibalisation and human sacrifices, were commonly reported throughout the Mano River War, and were often linked, perhaps mistakenly, to the practices of the leading secret societies, both in Sierra Leone and Liberia (Richards, 2009). There may be some element of truth in these stories, but it is likely that the physical act of cannibalism is not common practice in the post-war secret societies. The background research does indicate that the act of 'eating' a human has a symbolic meaning, and is not necessarily interpreted literally (Shaw, 1997). Other elements, which were directly linked to certain society's practices, such as the 'bullet-proofing' of troops using sorcery, particularly among the Civil Defence Forces such as the Kamajor, have their roots firmly in societal witchcraft (Muana, 1997). This resulted in many commentators stating that the rise of the local militias in the rural areas as being a *'poro thing'* (Ellis, 2001; Sawyer, 2005) though the extent of this has since been disputed (Hoffman, 2012).

In peacetime the secret societies of Sierra Leone are not without controversy. The historically documented Bundo initiation ceremony includes Female Genital Mutilation (FGM) and is still carried out by the female secret societies (Koso-Thomas, 1987). The prevalence rate of this practice is stated to be almost 94% in Sierra Leone (Sipsma et al., 2012). This practice in itself denotes a cause for concern and an indication of the societies control in the rural areas. However it is the inability of the political parties to directly address the issues, for fear of isolating their political bases, which indicate the strength and influence of these sodalities on the political spheres in Sierra Leone (Fanthorpe, 2007).

Witchcraft and sorcery form an everyday part of living in rural Sierra Leone (Ferme, 2001; Shaw, 1997). The use of "taboos" as forms of protections or nomination of prohibited items, which can be placed on anything or anybody, is an important theme in village culture. As with most traditional beliefs, the question should not be whether the statements about practices are objectively true, that by washing in a particular way a body can actually be made bullet proof, or that eating fruit marked as a taboo will lead to physical harm, but that they are subjectively true and have very real consequences. Viewing the practices subjectively can provide meaning to otherwise illogical behaviour. For example, the Kamajors participated in the conflict dependent on the knowledge that their 'protection' through ritual cleansing and abstinence from sex would protect them from bullets. Similarly areas or artefacts that are protected by taboos are consciously avoided, even by those not in the societies, through fear of something less tangible than a direct threat. During site visits for this research, the local guides warned against photographing specific areas and artefacts that were protected by taboos. They warned only of mystical repercussions, rather than more practical notions, such as an attack by local population for insulting their traditional beliefs.

There is a spiritual aspect to the societies, but they cannot be dismissed as being simply a quasi-religious or cult following, and their impact extends beyond religious rituals including judicial, education and health functions. The health issues associated to the use of 'local medicine' as opposed to seeking 'western' solutions to ailments is a common problem (MacCormack, 1992). This had led to competing information, between traditional healers and local district health practitioners, about the cause of a patient's health issues. The ability for the societies to influence indigenous knowledge on practices related to health, through their informal capacity and formation as an educational institution, is one of the most important considerations of the impact of the societies on water supply projects. There is historical president, both in noting that the societies competed for information on health, and for the western powers to attempt to use traditional health networks in the rural areas, in reports carried out in pre-independent Sierra Leone (Little, 1949).

Many of the site visits carried out for this research encountered continual direct and indirect involvement with the societies. Rituals and practices, such as the returning of the young women (the *'sowees'*) from their years training within the societies bush, to the inauguration of the new paramount chief in Kholifa Mabang, to the constant reminders of the societies presence due to taboos placed on various crops, water points and pathways, were a clear indication of the impact and power of the societies on rural life.

2.3.3.3 Households and Communities: Definition of Terms

This research will make explicit reference to 'households' and 'communities'. It is important to describe these relations with regards to the contextual analysis of Sierra Leone and more specifically the Temne tribe:

Households: In Sierra Leone, as with almost all countries, their society consists of the smallest social unit being classed as 'the family' (Martinson, 1970). As Richards notes, *"family structure (lineages) is the foundation of social organization in rural Sierra Leone"* (Richards et al., 2004). An individual's water supply practices are representative of their function and role within this larger societal unit. Understanding the internal familial relationships in Sierra Leone is a complex process because 'family' encompasses many examples of matrilocal, conjugal and consanguineal groupings. There several variations in the terminology of relationships which are inclusive of an individual being included in a 'family'. For example, individuals are very often caller brother *(*Krio: *broda)* or sister *(*Krio: *sista)* and yet are as distant to their immediate family as second, or sometimes third, cousins, and usually several places removed. Three further issues distort an exact definition on what is locally considered to be 'members of a family'. The first is that many families in the rural area do not have a conjugal or 'nuclear family' structure. Polygamy is widely practiced among the Islamic and Indigenous religious practitioners in Sierra Leone (Bledsoe, 1990). Therefore 'families' are dynamic groupings, particularly when the central male figure divorces, moves away or dies. This creates a matrilocal family structure often leaving disparate groupings of unrelated widows and step-siblings in the one house. Vernon Dorjahns' pre-war work on Temne household sizes indicated that there were over 15 grouping that could describe their household's typology (Dorjahn, 1977). Secondly, the eleven year conflict forced the migration of many families, in many cases destroying their societal ties to each other; and some of these have never recovered. This has resulted in unrelated individuals being resident in one household. Added to the burden of displaced families is the number of widows and orphans that are directly attributable to the conflict. Though some people were found to live with distant relatives, there are also communal adoptions, with individuals staying with unrelated families, yet with no record of adoption proceedings. Finally, Sierra Leone has an established historical legacy of patronage systems (Dorjahn and Fyfe, 1962; Hoffman, 2003; Labonte, 2011). This brings together individuals for different purposes, such as for labour or for protection, and further extends the number of individuals defined as being 'in the family' where no clear consanguineal linkages exists. The original purpose of certain parts of the research methodology was to explore family relationships to water; however the variations in definitions would have made this term too complex a unit to analyse. This research used the selection of 'households' as the unit to be surveyed, as this was determined to be more rational, and the groupings were more inclusive, without requiring exclusions of particular individuals. Even with this unit there is confusion regarding the terminology, in particular the definition of the 'household' *(*Temne: *ataruŋ,* pl. *akaruŋ)* and the 'house' *(kafus,* pl. *tafus)*. The 'households' are an umbrella groupings of different 'houses'. As Dorjan states

> *"…a large ataruŋ was generally a production unit, but its members were often divided into two or more tafus, or consumption units"* (Dorjahn, 1977).

Figure 18: Typical Temne household - Rogberka

Traditionally built 'households' include more than one 'house'. The smallest possible unit to investigate was the 'household' rather than the family, and this encompassed more than a single 'house' in each block. When counting 'houses' as structures, each 'households' (*ataruŋ)* is counted, rather than the individual *'tafus'*. This is because it is not clear to an outside observer which rooms are used as *'tafus'* and which are used for other purposes, such as stores. For clarity during interviews and discussions, any confusion in terminology was clarified as being *"people under this roof"* rather than *"people in this house"*. This was particularly important for defining who the *"head of the household"* was, and who was responsible for the individual actions of the 'houses'.

***Community*:** The definition of 'community' is defined by residential terms (Richards et al., 2004). It was clear from the site visits that certain villages did not have harmonious social groupings. Some villages had split their communities into several sections, for their own reasons. The rationale behind these divisions was not immediately obvious, and was not simply based on the village populations becoming too large. Analysing and understanding the history of each community, would introduce an unnecessary level of complexity to the research. Therefore, unless the divisions were named (usually a divided village will share the same name, but have different numerical values after), then the grouping of households in one immediate geographical area, clustered under the one name, and participating under a definable social hierarchy, is termed the 'community'.

Figure 19: A view of the village from outside -Mamanor

2.3.4 Water Supplies in Sierra Leone

As there are thousands of water supply projects in Sierra Leone a reliance on secondary data is required. Two data sets were used for this research to complement the primary field research:

- **STAT-Wash Database** (gathered in 2012): GPS Monitored information for 28,000 water points in Sierra Leone. Does not include villages without
- **InterAide Water Point Mapping** (gathered in 2010): Water point information on 2,859 villages in three sections including Tonkolili. Includes villages without water points. Does not include GPS values

A brief description of these two data sets used for this research, including their strengths and weaknesses, are provided in Appendix A.

2.3.4.1 Common Water Supply Systems in Sierra Leone

This research focuses on three main water supply intervention types carried out by both state and non-state actors operating in Tonkolili. Given the availability of groundwater these services usually include the provision of hand-dug wells (either hand-pump wells or pulley wells) and drilled boreholes systems. These hand-dug wells are generally protected from groundwater contamination and surface water runoff by a lining which extends from the surface to below the water table. These sources usually have a headwall which is raised above ground level. They frequently include a platform to divert spilled water away from the well. Ideally all protected wells should be covered, so that foreign contaminants cannot enter into the water. The STAT-Wash database estimated that the combined total of hand-dug wells and boreholes constitute an estimated 70.56% of all water supply systems in Sierra Leone (Hirn, 2012). Protected sources differ from what are considered to be 'traditional wells'. These well types are locally built systems which are usually unlined, are without a raised headwall and have no drainage facilities. They also, typically, have an inadequate water point cover. Technical assessments of these facilities are not included in the secondary data or in this research.

One alternative water supply technology, which was regularly found to be in working order, and was also plentiful within certain localities, was large scale piped water networks. According to the water point mapping of the STAT-Wash Database it was estimated that there are 7,566 standpipes in Sierra Leone (Hirn, 2012). These systems are always attached to larger centralised piped networks and water catchment areas such as dams. Due to the high capital costs projects such as these are mainly used to service high density populations. For this reason they are typically based in urban or peri-urban environments such as Magburkha, Makeni and Freetown. Occasionally the tap-stand posts are found in rural settlements around these urban centres. They are not part of mainstream rural development practices of NGOs and are not part of the ATT, LTT or SATT models. These systems utilise a much broader engineering methodologies than those used in more rural environments. They also differ in their implications of their use. For example they include taxation payments for water usage which does not apply in more rural situations.

2.3.4.2 Water Resources in Sierra Leone

Unlike many of the climatically drier countries found in Sub-Saharan Africa the water resources that are available in Sierra Leone, particularly from precipitation, are plentiful. According to the Food and Agriculture Organization (FAO) the country has internal renewable sources estimated to be 160 km^3 per year, with surface water accounting for over 93% of these sources. Internally produced groundwater is estimated to be 50 km^3 per year with 80% being an overlap between surface and groundwater. The total actual renewable resources are 30,960m^3/year/inhabitant (Karen, 2005). It is estimated that the rainfall in Sierra Leone averages 2,526 mm/year. This annual amount ensures that Sierra Leone has one of the highest average rainfall levels in the world – as it ranks 12th out of 178 recorded countries (World Bank, 2012b). The depth of rainfall has a high annual average but the pattern of precipitation is uni-modal, with the country experiencing two climatic variations - the wet and the dry seasons. Most of the rainfall occurs in the wet season, between late April and early November, peaking in July and August. The availability of rainwater reduces substantially in the dry season with rainfall becoming erratic resulting in months without rain. It is estimated that the total renewable water resources that is withdrawn by the local population accounts for less than 0.2% of the total resources. This is accounting for the combined usage for irrigation, livestock, municipality usage and industry purposes. Currently the total water withdrawal per person in Sierra Leone is only 86m^3/year (Karen, 2005).

The climatic variations caused by the dry season can cause technical challenges for achieving annually sustained water supply targets in Sierra Leone. However, even at peak drought periods, each village does have locally available water resources, albeit much of what is available is from untreated and unimproved sources such as rivers or traditional water sources.

2.3.4.3 Historical water supplies in Sierra Leone

There is little historical evidence of communal and rurally constructed water supplies during the period that Sierra Leone was a protectorate of the British Empire. This was typical approach to infrastructure by the colonial powers. During this period, even within the urban areas of Sierra Leone, there was insufficient coverage of water and sanitation facilities.

"The European empires generally refused to provide modern sanitation in native neighbourhoods, preferring to use racial zoning and cordons sanitaires to segregate garrisons and white suburbs from epidemic disease" (Davis, 2007).

As mentioned before, the colonial period in Africa was devastating for the colonies. Sierra Leone was exploited over centuries by different colonial administrations. It was noted during the site visits that there were some examples of infrastructure designed to complement defunct colonial train lines. These were found along the areas where tracks used to exist such as in Kumrabai Junction (Figure 21).

Figure 20: Water Supply used by the defunct railway system, Kumrabai Junction

During the post-colonial periods the technologies would have been transferred directly to the communities in a 'linear' approach. This linearity would have been due to the colonial administrations indifference towards the social and cultural context of dwellers in rural Sierra Leone. There were some observed examples of old pre-conflict constructed piping networks in some of the larger rural villages. These used submersible pump systems for groundwater extraction. The majority were decentralised solutions, as they were unconnected to larger piped infrastructure, in each of the villages (Figure 21).

Figure 21: Example of a pre-Mano River war piped system - Kumrabai Station

All of the observed systems had not operated in years and most were in a definitive state of deterioration Therefore little reliable information could be attained from the success of these types of engineering technologies. The infrequency of observed colonial period artefacts, and their location near former colonial infrastructure, suggests that they were not provided to address the severe lack of safe water coverage in the country. Instead the most transformational changes in water supply service delivery in Sierra Leone came through the distinct phases of international donor support that have taken place over the previous four decades. These phases that have affected both Sierra Leone but also many nations in the developing world, .

2.3.4.4 The UN Water Decade, Water Supply and Sierra Leone

The most notable increase in water supply projects in the developing world, and in a post-independent Sub-Saharan Africa, was due to the UN's International Drinking Water Supply and Sanitation Decade (1981-1990). This period brought a change in technological development to water supplies across all of Sub-Saharan Africa. The Water Decade heralded substantial investment into new approaches for small scale water supply technologies. The implementation agencies adopted and developed new technologies to suit the ambitious target of '*providing safe water and sanitation to everyone by 1990'*. These new technologies were created to involve more 'appropriate' designs. The introduction of the Water Decade coincided with the peak of the 'appropriate technology movement'. This movement had developed in response to the 1970’s global energy crisis. This introduced the ATT approach to development practice. In the 1980’s it was estimated that there were over 1000 specifically ‘appropriate technology’ orientated groups globally active (Jéquier and Blan, 1984). Though, as discussed in the previous section, the ATT movement declined as the primary NGO implementation strategy its concepts allowed SATT model to benefit from advancements made in low-cost technologies. The methods adopted by the appropriate technology groups had resulted in innovative approaches to hand-pump designs. Many of the technical solutions were low in capital cost, offered ease of installation, could be widely manufactured and were efficient at water lifting (Reynolds, 1992). The designs claimed to be 'user friendly' and were reported to be widely accepted by their host communities. The largest water scheme service providers, in particular the international project implementing NGOs, opted for these new technologies as a method of assisting their beneficiaries. Hand-pump designs, particularly those of the India MK II, the Afridev and the Kardia became increasingly popular throughout the developing world (Reynolds, 1992; Wood, 1994). These technologies, combined with the wide availability of shallow groundwater resources, ensured that the installation of wells and boreholes became common practice in Sub-Saharan Africa (Harvey and Reed, 2004).

In Sierra Leone the first UN water decade provided considerable progress in achieving their nationwide water targets. From 1981-1990 national coverage was increased from 2% of the population to 35%. Between 1991 and 2001 this fell to 15% due to the damage caused to infrastructure during the conflict period (UN, 2007).

The lack of investment into new infrastructure and the inability to maintain existing supplies was the most obvious direct impact that the war had on household water in Sierra Leone. However there was a host of other indirect implications that the conflict had on rural communities and their relationship to their drinking water. Prior to the conflict, water supply projects in rural areas were not common. The lack of technical support that was available for the communities in the interior, as evident by the infrequent availability of improved water supply sources pre-1990s, meant that before the war the majority of the country would have been dependent on unimproved sources (Hirn, 2012). The widespread destruction and pillaging by many of the factions in the war, most notably the RUF, SLA and the CDF, resulted in a high percentage of the few water supply resources that built pre-war in rural communities being destroyed. In the supporting literature there is not the same amount of specific information, denoting damage inflicted on rural water points, as there is to damage caused to infrastructure around Freetown. Many documents, like the African Development

Banks account of infrastructure only recount general, but extensive, damage to rural properties (ADB, 2011). There are reports that suggest that throughout the conflict period village water supplies, both improved and unimproved, were specifically targeted as acts of war. There are references to these acts the Poverty Reduction Strategy Paper (PRSPs) and in many community interviews (World Bank, 2009). These informant interviews suggested that many water points were used as locations for executions or mass burials.

2.3.4.5 The Millennium Development Goals, Water Supply and Sierra Leone

At the advent of the new millennium the failure of the UN water decade to provide the global target of *'providing everyone with water'* prompted a second international response intended to reduce water poverty (Carter et al., 1993). This second UN international response came through the establishment of the Millennium Development Goals (MDGs). These targets were not limited to only addressing water goals, as had happened in the UN Water Decade, and were instead inclusive of many simultaneous poverty reduction targets. All 193 United Nations member states agreed to achieve these goals by the year 2015. For water supplies the most notable target was Goal 7, designed to provide international environmental sustainability. This goal included an explicit mention and targets for water supply coverage for the new millennium: to halve, by 2015, the proportion of the population without sustainable access to safe drinking water (Target 7c). It was declared by the UN in March 2012 that this global target had been reached (UN, 2012b).

Post-war Sierra Leone (2002-2005) benefited from the intense donor attention as funds for disaster and humanitarian relief seen an exponential increase. This was partly attributable to the intense international media attention on the conflict brought about by the violence of the RUF. In the post-war period there were a large number of water supply systems that were provided. The rural programmes progressed as road access increased across the country. Immediately after the war an increasing number of implementing international NGOs sought disaster relief funding and implemented large scale development programmes. The primary response to water supplies was in community focused WASH (Water, Sanitation and Hygiene) programmes. These were designed specifically to increase access to communal sources of drinking water in Sierra Leone. These WASH programmes had, and have continued, to provide hand-dug wells, protected well sources and boreholes. It was also found that donor money was provided for building school infrastructure, whether primary, secondary or tertiary facilities (MEST, 2007). Many of these would also include funds for water supply systems. Additionally newly provided health infrastructure, referred to as Peripheral Health Units (PHUs) -which include a range of different facilities such as:

Maternal and Child Health Posts (MCHPs), Community Health Post (CHPs) and Community Health Centres (CHCs), also included water points as part of their infrastructural programming. These additional constructions increased the coverage of improved water supply solutions and technologies.

Following the post-war period (2005-onwards) there was a steep decline in interventions, as both donor and media attention shifted elsewhere. However, the renewed international commitment brought about by the MDGs ensured an increasing interest in water supplies coupled with an increase in donor funding. This funding (2005-onwards) will not be finished until 2015, when all the targets are supposed to be reached and reviewed. As of 2012 the Joint Monitoring Project Report indicated that Sierra Leone was unlikely to meet its national target (UNICEF and WHO, 2012). Therefore the history of water supply technologies falls within four categories, pre-war (until 1991), the conflict period (1991-2001), the post-war recovery period (2001-2005) and the development phase (2005- onwards).

2.3.4.6 Phases in the Service Provision of Water Supplies in Sierra Leone

Plotting the data, made available from the STAT-Wash Dataset, confirms the four phases of historical service provision of water supplies in Sierra Leone (see Figure 22). The conflict years did not provide widespread coverage, but these results claimed dramatically after the war, with a further increase in NGO programmes due to the financial pledges of the MDGs.

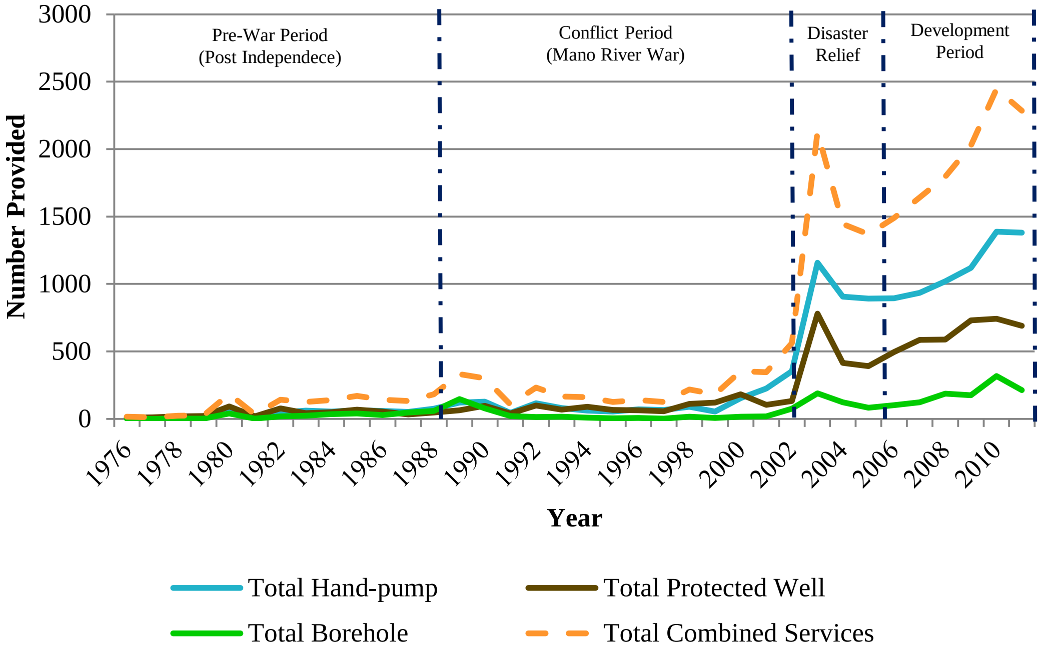


Figure 22: Installation of water points by year constructed

According to the STAT-Wash Database, the total number of water supply systems in Sierra Leone, as of July 2012, was estimated to be 28,845, of these 10,051 are regarded as *'hand-dug well with pump',* 8,350 are *'protected wells with no pump'* and 1,952 are boreholes. Since the end of the Sierra Leone civil war, there has been strong growth and involvement by NGOs in the water supply sector (Table 1).

Table 1: List of water points by implementing agencies

	Total (Including Protected Wells)	2012- Under construction	Total (Excluding Protected Wells)	2012- Under construction
Community	584	55	249	30
Donor	255	6	201	6
Government	1950	171	1867	153
Major NGO	4621	152	3958	115
Other	1526	118	1276	95
Private	6641	169	745	90
Religious Group	1588	50	1032	39
UN Agency	2160	84	1808	77
Unknown	1028	92	867	77

The STAT-Wash database estimated that there were 6,641 private donor (local investment) built sources, yet the vast majority of these (5,869) are termed as 'protected sources' which are defined as lined wells, but without headwalls, lifting technologies, drainage or spillways. All the protected sources technically contribute to the MDG targets of *'providing access to improved sources of drinking water'*, but they do vary significantly in cost, function and technical capacity, both to build and to maintain, than the borehole and hand-pump well systems. Privately built protected well systems have little regulation and safety standards in their construction. Privately built boreholes and hand-pump wells are mainly found in the wealthier regions of Sierra Leone, in particular the Western Area and in the city Bo in the Southern Region. Community built rural wells are similarly mainly restricted to the richer districts and households in Sierra Leone (World Bank, 2012b).

The contributions of private groups and government sectors, such as SALWACO (Sierra Leone Water Company), are still dwarfed by the combined activities of the international development organisations, religious groups and UN agencies (Table 1). The combined external contributions have provided a total of 11,178 water points in the country. The 'other' category highlighted in (Table 1) represents the water supply projects by smaller local organisations and programme partners. In many of these cases the water supply projects are financed, supported, and managed by the international NGOs who in-directly operate through their smaller and national implementing partners.

2.3.5 Current Overview of Sierra Leone

Sierra Leone's recent history has implications for its current development programming. In terms of economic development the country has gradually progressed and improved since the end of the conflict. After two peaceful elections, in 2007 and 2012, and growth in many of their industrial sectors, the country has gradually begun to leave the 'disaster' phase and enter into a period of 'development'. The sustained peace since the war has seen the repatriation of ex-combatants and child soldiers into normal civilian life, and the return of many people that were displaced; both internally in Sierra Leone, and those that were refugees in other countries. Sierra Leone is currently entering the development phase, and has seen some clear progress in certain sectors; however their current development status remains as one of the poorest lower income countries in the world. Using the United Nations Human Development Index (HDI) as a basis for explaining poverty, there are three main components that can be used as indicators of a countries wealth: their national income, education, and health. Using this ranking Sierra Leone is currently placed at 180 out of 187 countries on the listing (UNDP, 2011) but he end of the conflict has seen Sierra Leone's HDI ranking increase by 2.65% per annum.

According to the HDI, which measured the indicators in 2011, the life expectancy of a Sierra Leonean is still ranked as the lowest in any part of the world (an average of 47.8 years). The severe lack of sophisticated health systems in the rural areas contributes substantially to these statistics. The interventions of NGOs have provided a sizable increase in primary health care, including the participation in the rehabilitation of 867 Peripheral Health Units (PHUs), however the rural areas are still bereft of senior medical personnel and are still dependent on external support and capacity building for the recruitment of medical staff (World Bank, 2009). Due to Sierra Leone's tropical climate there are high risks of infections and diseases which in turn lead to high incidence of mortality. Having inadequate water and sanitation facilities is one of the largest contributing factors in Sierra Leone having the lowest life expectancy in the world (GOSL, 2009). Sierra Leone also has one of the highest rates of infant mortality and deaths in the world, with 128 deaths per 1000 births, and under-five mortality rate, 217 deaths per 1000 children (UNICEF, 2011b).

Education in Sierra Leone has improved considerably after the war. Primary school education has been strongly supported by the local government, international donors and the implementing agencies. As the recent Multiple Indicator Cluster Surveys 4 (MICS4) have suggested, there has been a strongly improved increase in school enrolment since the end of the war - with over 74% in attendance at primary school level. The gender parity at primary school level is roughly equal (1.04). Secondary schools have not received the same attention, partly because there is no human right to secondary education to prompt action, and only 37% of the population that are at secondary school age are in education. The disparities between gender at secondary level are significant with 33.2% of girls attending, compared to 39.9% of males. Attendance at secondary schools drops dramatically with the wealth index quintiles, reaching as low as 14.4% for girls and 22.2% for boys (UNICEF, 2011b). Similarly the rural areas have a disproportionally low representation with regards to access to secondary school education, with most of the senior secondary years being taught in only the largest of the towns found in the rural areas.

The financial situation in the country has seen strong growth in recent years, though the overall income is still ranked as one of the lowest in the world. In 2012 the World Bank Report on world development stated that Sierra Leone's Gross National Income (GNI) per capita was $340 (this was calculated using the Atlas method). This ranks the country 209 out of 216 global economies. In the same time period they have seen their gross domestic product increase by 4.9%. However Sierra Leone remains highly dependent on Overseas Development Aid (ODA). During the period 2007-2011, an average of $453.79 million per annum was injected into the economy from a host of international and private donors through both grants and loans. For the period 2008-2012 Sierra Leone's net ODA received, as a percentage of GNI, is estimated to be 24.4% (OCED, 2012).

2.3.6 Conclusion of the Contextual Analysis

Sierra Leone remains one of the poorest low income countries in the world. As a summary: the current poverty of Sierra Leone had many of its roots in the historical abuses of the European and American powers. This culminated in decades of governmental corruption, mismanagement and finally, in the Mano River War. In each historical aspect there is more detail, context and interactions that could be reasonably accounted for in this research. The purpose of the contextual analysis is to demonstrate that the water supplies in Sierra Leone, which have been provided through the assistance of international NGOs in the past decade, have been supplied against a complex and difficult contextual background. Many of the elements are interdependent and interrelated. Understanding the current conditions of water supply projects for this study was not done without an appreciation to the challenges faced by the implementing organisations. Therefore the current water supply problems in Sierra

Leone cannot be summarised with only a simple statistic that states the percentage of the population *"lacking access to improved water"*. The contextual analysis is important for three reasons:

Firstly, this context should have been understood by the implementing organisations and engineers. Therefore it is an important counter-argument for allowing the problems with the water supplies to being solely attributable to the Mano River War. It was from within this tumultuous context, not despite of the environment, that engineering projects were required to be successful. The Mano River War, as devastating and traumatising as the event was, cannot be regarded as the sole causation of the majority of the technical problems witnessed at the water points in Sierra Leone. It is because of their conflict history that the majority of international interventions were provided. In accepting the international donor communities money the NGOs had committed themselves to providing *"sustainable access to safe water"* to their beneficiaries. Therefore it is not a sufficient defence to blame the extent of project failures on the nature of the conflict. It is undoubted that the contextual background of Sierra Leone, and not just its conflict history, created limitations for the success of water supply projects. These limitations should have been accounted for and reflected in the programming practices of the NGOs.

Secondly, the contextual analysis has shown that the country has entered into a phase of development and therefore certain projects, particularly those implemented in the previous five years, cannot be determined as being "disaster relief" projects. These projects should be capable of being assessed comparative to the projects of other developing nations and with regards to their long term sustainability.

Finally, the contextual analysis is important for this research as it provides a broader application from the outputs of the research findings. Having a tumultuous period of history is not abnormal for developing nations. Though each situation is unique to each nation, they have disruption to their services in common. This means that the lessons that can be learned from the NGO interventions in one post conflict case study, particularly during the development phases following the post-war recovery, can have implications for many other developing nations. This would not be possible if a more stable case study was chosen.

Therefore the contextual analysis has indicated that being able to provide a sustainable level of service depends on the ability of the NGO to summarise the context, design projects that understand the limitations of their environment, and, for engineering water supply projects, in the correct selection of the model of technology transfer.

CHAPTER 3: PRIMARY FIELD RESEARCH

Methodology of Field Research

3.1.1 Key Informant Interviews: Engineers and Criteria for Selection

The original exploration of this research topic was dependent on discussions regarding the experiences and attitudes of engineers actively engaged in the sector. Engineers from a range of different NGO backgrounds were contacted throughout the course of this study. Senior water and sanitation project managers that oversaw engineering projects were also included in the interviews. The criteria for selection required the candidate to have over three years experience in working as an engineer in development. This reasoning was based on many discussions with a number of field workers. The most significant majority were short-term relief workers with experiences between one and six months. It was found that engineers with less than three years of experience often had opinions that were usually heavily imbalanced towards their current placements. Using the opinions of a significant number of short term volunteers often resulted in an uneven discussion on development engineering. The short term volunteers were very often recent graduates or engineering students and were usually not yet engaged in development as a full time career. Engineers with more experience were found to have more balanced viewpoints such that they measured their opinions against the context of development from their years of their previous experiences in engineering. The average number of years of in-field practice for interviewees quoted in this research was seven years.

Though the case study for this research was carried out in Sierra Leone the interviewees shared experiences from many other nations as well. Their previous experience in working in developing countries and communities included: Afghanistan, Brazil, Burkina Faso, Cambodia, Cameroon, Central African Republic, Chad, China, North Korea, Ethiopia, Ghana, Guatemala, Haiti, Kenya, Laos, Liberia, Mali, Mongolia, Nicaragua, Niger, Nigeria, Philippines, Romania, Rwanda, Sudan, Tanzania, Uganda, Uzbekistan, Western Sahara and Zambia. All of the engineers quoted in this research worked for prominent INGOs and development agencies in their engineering activities.

3.1.1.1 Methodology of the Key Informant Interviews

All the responses to the key informant interviews were qualitative in nature. Their interviews were a combination of unstructured discussions exploring personal experiences in development. There were also semi-structured discussions which explored specific findings from the primary data collection in Sierra Leone. These semi-structured interviews were transcribed and then approved by the interviewee. The transcribed notes will not be included in this research as it would be possible to identify organisations through them. Minor corrections have been made regarding the language of certain quotes as some correspondents did not have English as their first language. The unstructured interviews were carried out *in-situ* in Sierra Leone and were therefore based on correspondence that was noted at the time.

The results of these interviews will be used throughout the exploration of the field study in Sierra Leone to provide a broader scope to the findings. Quotes used from these sources have been confirmed and verified by the interviewees.

3.1.1.2 Key Informant Interviews: Limitations and Use of Materials

Though the interviews were successful it was decided that the primary research methodology adopted in this study would not depend solely on the opinions of the NGO engineers. This is not to claim that it is not possible to engage successfully with these individuals. Instead it ist in recognition of the difficulties of linking existing water supply infrastructure to the engineers that participated in their construction. Without verification of opinions it is difficult to draw meaningful conclusions regarding engineering.

This was not the only limitation on communicating directly with NGO engineers. An additional burden has been placed on many engineers in that much of their work requires strict confidentiality. Almost all engineers interviewed during the research periods requested for their experiences to be shared but that their names and organisations should be kept anonymous. The reasons for this insistence was due to the complex nature of many developing countries. Unstable regions, untrained construction partners, forced compromises due to lack of resources, ethical dilemmas caused by corruption, lack of control over engineering proceedings are all just some of the hallmarks of working in many of the world's poorest nations. This is particularly heightened in post-disaster recovery and post-conflict relief efforts. Furthermore, given the relationship between the donor community and the NGOs, many of the interviewees were acutely aware that the problems they experienced in engineering are only a single component of the multi-sector responses (Pronyk et al., 2012) by development agencies. Unreserved expositions of failure in one area of programming, such as engineering, could have a significant impact on other unrelated fields.

To entirely ignore the feedback of the engineers would be to lose the value and importance of their statements. For this reason some of the interviews, quotes and opinions have been included in this study. In agreement with the need for maintaining confidentiality no information will be provided that could conclusively identify any of the parties involved in the interviews.

Though the interviews were useful in providing informed opinions on the development activities of large NGOs the lack of actual confirmation on best practices resulted in inconclusive statements. For the few results that could be verified the need to maintain confidentiality meant that they could not be utilised to support arguments and theories of practice. An alternative approach was sought which would allow for an exploration of the success of engineering in a developing nation without depending solely on the available secondary information.

3.1.2 Aims and Objectives of the Field Research

The methodology that was adopted to be the corner-stone of this thesis was an independent primary field research study of water supplies in Tonkolili District in Sierra Leone. The overall aim of this placement was to provide a reliable dataset of information to indicate the sustainability of water supplies in the research area. The objectives of this placement were as follows:

- To explore the context of rural poverty, and its connection to water supply engineering
- To create a technological definition of success and failure in NGO provided water supplies
- To determine the causation of any observed technical problems, which are directly attributable to poor applications, or omissions, of engineering practice
- To analyse the social support systems that are included to support engineering service delivery models and are designed to offer sustainability to the water supply projects

It was intended that fulfilling these objectives would provide the foundation to exploring the current impact that the engineer has, or the potential that the profession could have, on addressing the problems of rural poverty. It was expected that, through the exploration of current engineering practices, new technical solutions, paradigms and options in engineering practice could be developed. The differences that exist between current engineering practices, and this new paradigm, could offer an innovative insight into the role of the engineer.

3.1.3 Pre-Survey Period and Inductive Research

The information gathered and analysed for this thesis originates from research carried out during a six-month placement in Tonkolili district and other, smaller supporting trips that were carried out post-placement in the same sections. This remains only a small component of the total interviews, surveys, evaluations and case-studies that took place in-country during the course of this research. Prior to the placement for data collection, that was used to support arguments in this thesis, almost thirteen months were spent working internally with other development agencies, local partners and different communities in various regions in Sierra Leone. These initial placements formed the basis of future research. As a notation for this thesis: any activities that took place before the final six month placement in Tonkolili (named the *'survey'* period*)*, is described as the *'pre-survey'* period. The *'pre-survey'* field work was mainly based around the Southern district of Pujehun, though additional activities were also based in the urban slums of Freetown in the Western region. Pujehun offered similar characteristics to Tonkolili, in that it involved working with the rural poor in evaluating their water supply problems. There were substantial cultural differences between the two regions as the dominant tribe in this area is Mende, unlike the Temne of the Northern Regions. The placements indicated that there were pragmatic anthropological differences between the tribes, the technical findings, with regards to the success of water supplies in Pujehun, differed only marginally from those in Tonkolili. This is more indicative of the practices of NGOs than the differences between the culture of the Temne and the Mende.

The methodology of research used during initial pre-survey period was different to that utilised in the final placements. The focus was more on 'action based learning' rather than 'learning by observation' (Pedler, 2011; Trehan and Pedler, 2011). This method of learning comprised of being an active agent in Sierra Leone's water supply issues, rather than being a passive observer. Due to direct engagement in the water sector, in providing new water sources, the pre-survey period did not offer an overview of other organisations service delivery practices in Pujehun. Any observations that were made were as a 'participant-observer' in the working practices of the host organisations (Kluckhohn, 1940). This meant that the lessons learned from the pre-survey research were highly susceptible to the individual traits and irregularities of these organisations. This gives rise to a range of ethical problems inherent with this approach (Jarvie, 1969).

The experience gained on the pre-survey placements was invaluable but the nature of the observations would have skewed any meaningful conclusion. When viewed rationally, the most noteworthy findings of these placements could be argued to be localised issues, rather than indicative of the development engineering culture as a whole. Observing any organisation at a single phase in their operations is not entirely conclusive of their practices, or of the definable and sustained impact of their intervention. Mainstreaming issues currently affecting the whole country, like corruption, or shortages of qualified technical staff, leave a single organisation highly susceptible to criticism that, without a full appreciation of their own context, could be unfairly warranted.

It is also important to note that the purpose of this research is solely on *‘engineering in development’*, and not to provide a commentary on entire range of other sectors that are engaged in the field. When presenting some of the findings of this research to the one of the largest UK base development agencies the response was: *"we are seeing similar problems and failures throughout all our other project areas"*. In this sense, engineering is not alone in facing difficulties in operating in a development context. Presenting the engineering problems discussed here as the only issues confronting NGOs would be misleading. Similarly an overemphasis on the failings of any single institution would only be limited to a single sector. Criticism, which cannot verify whether other actors have made the same mistakes, would have attracted negative donor attention to the organisation that has been singled out. This would affect projects across all their programmes, potentially harming unrelated activities that are currently beneficial to the rural communities. For these reasons it was deemed that the results of the research carried out during the initial *'pre-survey'* placements were highly sensitive. The findings from this period will remain confidential to the agencies, although key lessons learned during the course of these placements were incorporated into the final survey period.

The results of the pre-surveys including; discussions, technical observations, meetings and interviews formed a foundation for the final research period. Therefore, in hindsight, the pre-survey period was mainly focused on inductive surveys (*i.e.*, focused on learning about the context and relationship of both Sierra Leone and their water supplies rather than focusing on a particular element of engineering practice). The ‘survey period’ utilised both the results and the experience gained in these thirteen months, and became a deductive study into the research objectives into water supplies in Sierra Leone.

3.1.4 Context of the Methodology

The action based learning methodology of the pre-survey period was abandoned to focus on a case study overview and evidence based research into organisational practices in Tonkolili (Bulmer, 1984). This offered the freedom to focus on research aims, rather than project implementation determined goals. The inductive *'pre-survey'* work with the communities in Sierra Leone, specifically in investigating their water supplies, had demonstrated the interconnected nature of water to different levels of their societal structures. To accurately address the nature of household water supplies it was found that research questions would have to be directed at a number of different levels in each of the communities' indigenous social structures. This involved separating the research into three different aspects through focusing the investigations on a household, communal and a technical basis.

Very few of the visited water supplies were the personal property of any individual household. Certain households had a 'caretaker' responsibility, but were not owners of the property. The vast majority of the water supply systems, particularly those that were provided by the major NGOs, were provided as communal systems (MacDonald et al., 2005). These were observed to have local by-laws and customs designed to enforce the standard of community ownership (Harvey and Reed, 2004). These by-laws are not legally binding, and would not be used in a court of law, instead they are agreed upon and enforced from within the communities. The Sierra Leone by-laws will be discussed in more detail in Chapter 4: Part 3. This meant that questions regarding sustainability had to be addressed to the community, rather than to households, and could not be reliant on any individual's insights or observations. The main research focus was on addressing how households worked together to address problems with sustainability. Although the community were deemed responsible for the water supplies, there were, in almost all cases, elected groupings of community members who shared more responsibilities than others in this regard. To construct an accurate picture of their contributions to sustainability then these groups were required to be specifically targeted, and where possible, invited to share in a more in-depth dialogue about water supplies. These three groupings were, (i) the key actors in community decision making; such as chiefs, headmen, and village elders, (ii) the Water User Committees (WUC) that were responsible for the operation and maintenance of the water supplies and (iii) the hand-pump technicians responsible for repairs. Each of these required different methods of dialogue to explore their function within the support systems. For checks and balances additional representation was given to a random selection of community members, who were not participants in any of these 'executive' positions, to look at the interactions of the decision making groups with the average community member. Each survey category was explored separately and each with their own independent methodology for data collection.

3.1.4.1 Overview of the Main Survey Period

Providing only a brief, but numerically quantitative, insight into the communities' water supplies would have substantially diminished the methodology of using only one country to act as the case study. It would have sacrificed the ability to do in-depth explorations instead providing only superficial surface level observations. Pursuing a high number of completed surveys, rather than attempting to receive quality of information, would have resulted in conclusions that would have been more statistically accurate, but offer fewer abilities for analysing the nature of water supply interventions. Furthermore, a purely quantitative methodology would have been on a much smaller scale than is capable by the large donor agencies, such as the World Bank, which were involved in water mapping during the same period (Hirn, 2012). Instead, the methods utilised in this study systematically addressed different levels of community participation in the water supplies. The combination of research methods, and the care taken to explore untapped areas of potential, which were identified during the course of the interviews, resulted in a very gradual exercise, with long survey periods and durations of stay in each of the villages. A total of 150 villages were visited over the course of the field research. The location was spread over seven of the eleven chiefdoms: Kholifa Mabang, Kunike Barina, Kunike Kholifa Rowalla, Kuniki, Yoni and Malal Mara and included several districts within these communities (Figure 23). The list of communities can be found in Appendix B.

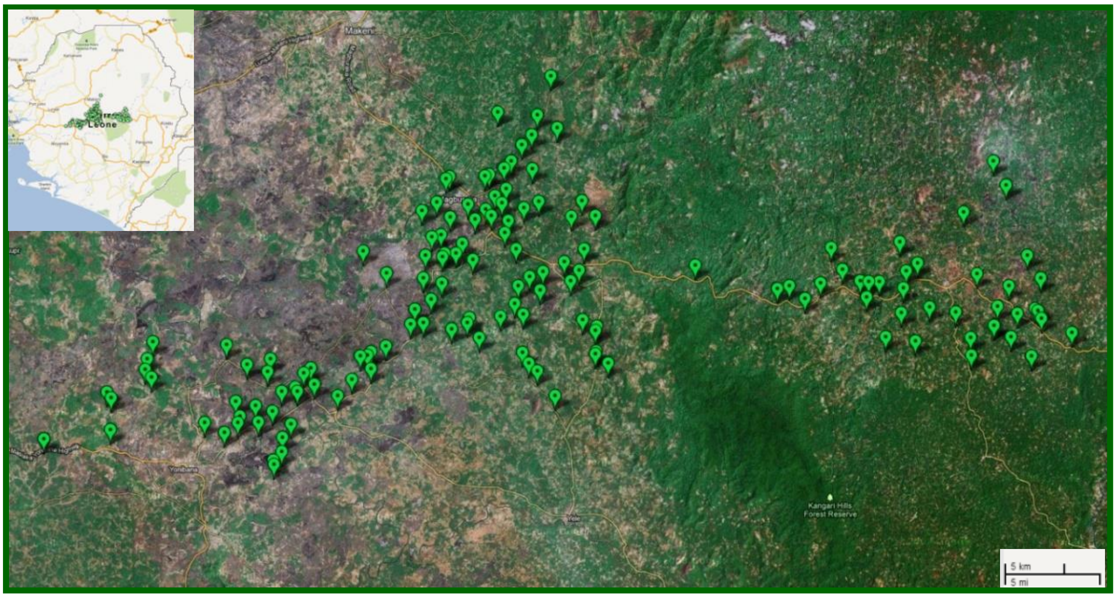


Figure 23: Location of village community surveys carried out in Sierra Leone

For the first three months of investigations each of the villages were given several hours solely dedicated to community profiling. When combined with the survey and interview exercises this usually resulted in a single village being visited over the course of one day. Additional participation activities, such as the focus group discussions, involved returning to the same villages, and spending another day interviewing community members. The variations in adopted methodologies, and the desire to have accuracy in the data collection process, gave rise to unique ethical situations.

3.1.4.2 Ethical Considerations

As outsiders and guests of the surveyed villages there were important ethical considerations for carrying out the field research. These changed depending on the type of surveys or discussions being attempted. The ethical approaches adopted required the field researchers to consistently show the highest standard of professional conduct at all times when on community visits.

All the surveys, including communal, technical and household, required informed verbal consent before proceeding. When entering a village a meeting was requested in a public location, normally at the headman's house or in local communal buildings designed for this purpose. These included the *'court barray'* or *'palaver huts'*. The village headman or chief, and any associated key informants, such as the head of the women's groups or youth leaders, were invited to a brief meeting. These meetings introduced the purpose of the research visit. It was made clear that the purpose was only *'to explore the NGOs or Government provided water supplies and their impact on the village'*. It was also made apparent that the actions of the research team in the communities were in no way indicative of the village receiving, or being declined, any form of future water supply service. It was also stressed that if they are willing to participate in the surveys they should be aware that attempting to manipulate the proceedings to suit their villages own agenda would result in the research results being voided. Permission was requested from the village chief, elders or village representative, to ask questions about their communities. Consent was also requested for other project objectives; such as to carry out household surveys, to provide support for the technical assessments, and to provide local guides for visiting the unimproved sources. These requests were never denied in any village that were covered in the survey period. There were few case studies where the village elders attempted to manipulate proceedings, but the range of survey activities ensured that they had little impact on the visit. For example certain elders would attempt to inflate the number of people supposedly living within their village. Their assumption being that if we were gathering information for a new project, rather than for research purposes, they could benefit from misdirected aid. These attempts were usually thwarted by both, practical observations and other members of the community that preferred a more honest approach to the discussions.

It was also agreed, with the village elders or their representatives, that the research team required confidence during household interviews and that the nature of these conversations was to remain private. Additionally, the research team was available for questions or issues that were raised throughout any part of this introduction.

There were separate ethical considerations given to the household surveys, and particularly for responses to certain questions that were deemed necessary for survey purposes. The household surveys were directed at the person responsible for the household affairs. These were over the age of eighteen and therefore capable of giving informed consent. If this individual was unavailable, then it was asked if someone could represent the house on their behalf. The use of a proxy was noted as part of the surveys. Like the community surveys, the reason for the visit was described to the head of household, or to their proxy. Their permission was asked before the surveys could commence, and they had the option of raising questions before, during and after the survey activities. As with the community surveys there were no declinations by households, however there was refusal by certain individuals for photographs of their household, their water facilities or pictures of members of household. As the pictures were not essential to the results, then this did not diminish the required output of the interviews. It was also made clear to the households that their information would remain confidential and this anonymity has been respected in this study. No personal details were recorded, although, for analysis purposes, the GPS information was taken. This again required informed consent from the head of the household. Children were spoken to, with regards to one question on water collection, in the presence of the household adults. There were no abstentions from participating in the surveys, but it was clear that certain questions made some individuals uncomfortable, or they were not willingly answered in the presence of other household members. These were normally linked to questions on gender issues or income. If it was not possible to receive an answer for a question in an isolated environment then it was marked as unanswered and the survey continued.

The Focus Group Discussions (FGDs) also presented their own ethical considerations. The practical ethical considerations of the FGDs included informed consent from the groups in participating in the activities. The nature of Sierra Leonean culture means that in many cases the older men traditionally speak on behalf of their group. This can mean that lesser heard opinions and information can be missed as female and younger members will not volunteer information on their own accord. The splitting of the groups by gender avoided male dominated responses. Additionally certain questions were sometimes purposely directed at younger participants. Given the purposeful, gentle, but firm, nature of how these questions were asked, the responses were not challenged but instead respected by the groups.

Finally the technical surveys also presented certain ethical issues. As discussed before, the main reason why the pre-survey research information was not included was that it over-exposed the service deliverer responsible for their construction to contextually deprived criticism. The same considerations are required for the agencies that built the water supplies in Tonkolili. The purpose of the research placement was to discuss issues with the sustainability of solutions, not to create an inquisition into failure, or to apportion blame for the problems. This would only diminish the impact of the conclusions and detract from the results being indicative of a sector wide approach to engineering. Therefore, though the organisations responsible for the construction are known, this information will remain confidential.

3.1.4.3 Selection of Villages for Surveys

Given the nature of the conditions in Tonkolili there were several constraints to the field research. These were caused by the availability of financial resources and research time as well as the local conditions. This research is primarily focused on the technical aspects of the engineering carried out during the developmental programming. It is not intended to speak conclusively about sociological or anthropological aspects of communities in Tonkolili, though the research does touch on both of these thematic areas. Therefore the prime directive is to assess the technologies, in as much qualitative and contextual detail as possible, without over expending resources on individual case studies. A balance is required between seeing enough iterations of successful and failed projects and in seeing too many projects in not enough detail or too few in too much. There were two issues that influenced the selection of the villages used in this thesis. The first was the recognition that the availability of research resources was finite. This was coupled with geographical terrain problems, as the topography of the research area is primarily swamp-land and dense bush-land, and is exceptionally difficult to traverse with roads becoming occasionally dangerous to use (Figure 24).

Figure 24: Example of road conditions - Kono Highway

The road condition led to an increase in expenditure the further into rural areas that the research probed. The more remote villages were found to have increasingly diminishing returns on technical observations. The further a village was from an urban centre the less likely that they had received an improved source of drinking water. Villages that do not have, and have never had, an improved source of drinking water are not part of this survey as they can offer no information, except by omission, on the impact that water supply engineering has had on their community.

Secondly, though it would be rational to select a single section, and attempt to analyse each of the different communities within these predefined areas, this methodology also provided problems. By design in some instances, and chance in others, certain sections were shown to fall under the responsibility of a single NGO who were the sole provider of water supplies in the area. Therefore any conclusions drawn would not be indicative of wider NGO activities, but heavily biased towards the practices of a single organisation. A more balanced view was required on the causation of water supplies problems.

The methodology used to resolve both of these issues was to target existing infrastructure, which would allow a large percentage of the transport activities to take place on traversable roads, but also allow the selection of villages to cut through different sections. Research efforts were focused on two main roads, although the majority of the interviews were on branches off these routes. Although it is stated that some of the villages are classed as being ‘off the main road’, which may indicate a non-remote village, in reality many required several hours of travel in a vehicle to reach. Occasionally additional parts of the journey were only traversable by foot.

One final aspect in the selection of villages was the omission of large settlements. These included groupings with over two thousand people. These villages could not be fairly evaluated with the same methods that are used to explore smaller settlements. Given the number of interactions between individual households in these dynamic groups they are comparatively more difficult to explore than smaller villages. Therefore the nature and causation of their problems are harder to define and the results could not be included in this research. Additionally, though research was based from Magburkha, certain villages could not be targeted in its immediate surroundings due to the construction of a water supply dam in the village and tapped water, through communal pipe stands, to these villages.

3.1.4.4 The Methodologies of the Field Research

The final surveys methods used fell into three categories, with different methodologies adopted in each section. These included:

Mixed Survey Methodologies: the household and communal surveys consisted of a mixture of qualitative and quantitative research methodologies. These also included token representation, pictorial assistance, multiple choice questions, as well as both structured and semi-structured interview questions (David and Sutton, 2010). The array of questions supported multiple hypothesis related to water supplies. The KAP (Knowledge, Attitudes and Practices) survey forms can be found in Appendix C. The community survey forms can be found in Appendix D.

Technical Surveys: these consisted of technical observations of measured water point components and included on-site judgements of conditions. These surveys involved little dialogue with the communities. There was no pre-existing standards used for the formation of these surveys, instead they were dependent on on-site experience of engineering construction and literature reviews into technical failure of water points. The Hand-Dug Well forms can be found in Appendix E. The borehole forms can be found in Appendix F.

Focus Group Discussions (FGD): these are a form of qualitative research which sought to understand the community’s perceptions, opinions and beliefs about the water supply interventions, their social support structure, and their sustainability. These used full-discussion techniques (Greenbaum, 1997; Morgan, 1996). The questions were designed to result in open-ended responses to the questions. They were also designed to be more flexible to allow for the inclusion of every participant in the groups. To avoid confusion, or the discussions departing from the topic, there was also an inclusion of a mix of structured questions. The FGD villages, and the index for the results, can be found in Appendix G.

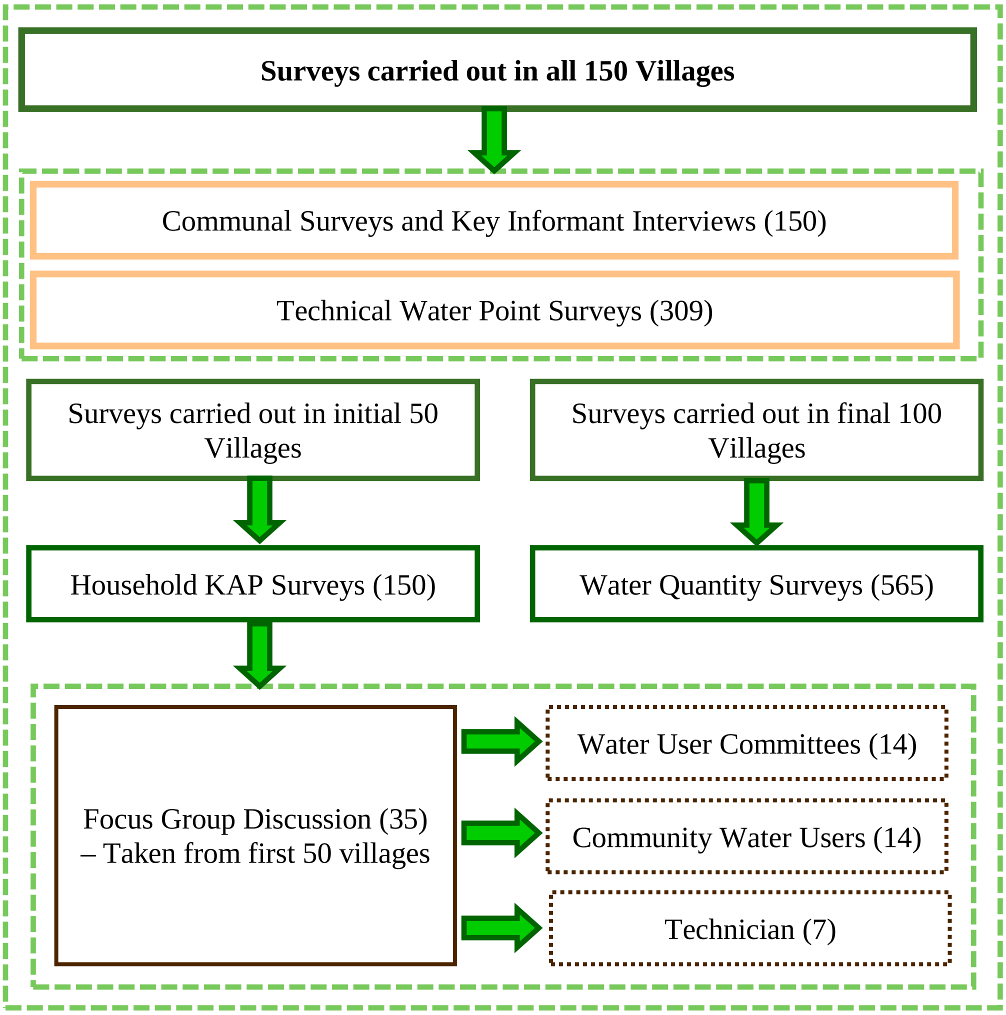


Figure 25: Diagram showing main survey period

Community Interviews: Village Surveys

The communal surveys were always the first surveys carried out in each village. These were used to explore communal relationships with their technologies. This survey was primarily a quantitative survey, so that comparisons could be made to other communities' practices. A total of 150 villages were studied during the course of the placement, with one communal survey per village. The communal questions were asked publicly, usually directed to the village headman or spokesmen. The methodology used purposive sampling, as it was judged that these individuals would hold specific knowledge on the issues (David and Sutton, 2010).

Usually there was a single informant that was the focus of the interviews, but the responses also normally involved a range of different participants offering their suggestions (Figure 26). If a question had multiple answers, the noted response was usually that selected by the chief or headman, as this was most likely the response that would be used for communal decisions. This also provided clear demonstrations of community dynamics regarding how decisions are made. The communal survey was used to determine the geographic and demographic information about the village. Additional communal aspects were explored by asking about their capacities with regards to their water supply, including their participation in the previous NGO projects. The most important questions were focused on each of the communities' social supporting mechanisms. This included the formation of their Water User Committees (WUC), their tariff systems and the technical support that is currently available at the local level.

Figure 26: Example of community input in the communal surveys- Mamanor

Communal Interviews: Focus Group Discussions

In the majority of villages there are certain members that are responsible for the upkeep of the social support systems which cover the operation and maintenance capacities towards their water supplies. These village members were specifically sought for their participation in the FGDs. A total of 14 community 'full group discussions', which included not more than 10 people per group were carried out. This number was consistent with FGD methodologies in chairing groups (Greenbaum, 1997). These villages were selected after the first month of communal, household and technical surveys. This used the initial research data to identify villages that could provide a unique perspective on the sustainability of their water supplies. The FGDs differed from the communal surveys as they were not inclusive of the entire community, but were only for those that were officially stated as being part of the villages Water User Committee (WUC). These members were not usually present during the communal surveys, as most village members are usually on their farms during the daytime hours.

An added incentive was required to bring community members from their work, particularly as the research was not intended to directly benefit the community, as would be the case if it was part of a baseline for implementation of project activities. Therefore the village members were provided with food and drink for their efforts, to compensate for the time that they would spend off their farms. This offer was made after the establishment of participants in the group discussions, to avoid individuals putting themselves forward that were not on the original board. The food was prepared in generous proportions, with more than the participants being served. This is an encouraged procedure as it facilitates the success of the FGDs (Greenbaum, 2000). All FGDs were completed in a timely and organised manner. The FGDs were designed to explore the relationship with the communities and their organisation, operational abilities, structure as well as specific activities such as their tariff systems, private sector engagement and meetings. The questions were designed to challenge the rhetoric of what is stated about their function and purpose by those that are responsible for creating the groups. The FGDs also evaluated the perceived successes and failures of the groups. The majority of the FGDs were split by gender resulting in seven male only groups and seven female only groups. This allowed for an exploration of gender roles as they related to water supplies. These were moderated by both male and female expatriate staff. This was used to determine if there was bias based on the sex of the moderator (Gurney, 1985; McKeganey and Bloor, 1991; Warren and Rasmussen, 1977). The full results of these discussions can be found in Appendix H, I and J.

Figure 27: Example of the mixed Focus Group Discussion - Ferry Junction

Household Interviews: KAP and Water Quantities Surveys

The household surveys were the longest component of the individual interviews, averaging over an hour each, and covering a wide range of technical, social and demographic aspects. They were used to test hypothesis of household water usage. The questions were explorative of household Knowledge, Attitudes and Practices (KAP) as it related to water (Duncker, 2001). This covered aspects like water supply, treatment, storage and usage. The surveys also included additional sections related to the technologies such as household hygiene, education, livelihoods and communication. Due to the duration of time required for these surveys, and the resources that were available to complete them, these could not be proportionally distributed. These used an 'availability' or 'opportunity' sampling methodology (Schutt, 2008). Three surveys were asked at each village, regardless of the size of the village, and taken from randomly selected households using a basic ‘spin the bottle’ technique. A total of 150 KAP surveys were carried out in 50 villages. This was to provide some level of triangulation between responses. As they do not use proportional distribution they cannot be conclusive, or be calculated probabilistically, for household practices in each village. However they do describe the sample. The trends that were presented in the data were instrumental in the questions used in the technical and communal surveys. They were also used to inform themes and questions that were raised during all the FGDs. Finally certain information, which was taken from the KAP surveys, has been used to compare the responses with trends in national secondary data on household practices.

It was not possible to use probability distribution on the household KAP surveys, as this would have involved multiple trips to the same village. To have the results as probability distributed, and to have meaningful conclusions, would require several hundred completed forms. This would have resulted in fewer technical observations, the prime directive of the research, and fewer communities would have been visited. Much of the information in the KAP surveys was replicated in secondary data, though not always from surveys in Tonkolili – and therefore could be used as confirmation of results.

The KAP survey did raise one question, related to sources used by households, that was not replicated in secondary research. Given its unique, and critical impact on water supply projects, this question was required to be asked in a statistically relevant way, to show that the results were indicative of the entire survey catchment area, and not only certain households within the surveyed location. These household were selected using a more rigorous method of selection including probability distributions as well as random distribution methods when in the village. This resulted in 568 surveys being completed in 100 villages (with an estimated total population 48,174). This number of surveys provided a confidence ratio of 95%, a degree of accuracy of 0.05, and a probability of success of 0.5. This also included a design effect factor of 1.5, information provided by an expert in Monitoring and Evaluation (M&E) projects in Tonkolili. The resulting surveys were distributed equally throughout the villages and therefore each household had an equal chance of being selected for the survey.

The method used for in the ‘water quantity distribution’ question involved a simple procedure. The purpose of the question was to determine the amount of water taken from each of their available sources. The need for this alternative approach to answer this question arose because of the inaccuracies of numerical values and nominal descriptions found in the pre-survey testing. For example, the summation of percentages, for numerically stated results, rarely resulted in a total of ‘100%’. Similarly the results for certain spoken responses (i.e. ‘some of the time’, ‘all of the time’ or ‘never’) were obscure. For example certain individuals stated ‘all of the time’ for all of their source choices. The analysis of this response made an interpretation of these results nonsensical. For this survey, instead of depending on the households to provide exact percentages that could be used to describe their sourced water quantities (*i.e.* the percentage of water taken from each source) they were presented with a fixed number of 'tokens' (thirty black-eyed beans of the same size) which represented their total water collected each month. They were asked to distribute these tokens over pictures of their different sources (Figure 28). After this distribution was achieved an interpretation of their results was read back to them. If they confirmed the interpretation the results were then noted. It was infrequent to observe a household member that did not understand the question or what was expected of them with regards to the tokens. This 'token distribution method' was used throughout the field research. It was also used for questions on gender equity of tasks at the sources. It is important to note that this method does not provide an accurate description of the water taken from each source – as this could only be achieved by measuring the total water quantity at each collection period over a long duration. Instead it offers an indication of where households believe to be the location of their sources, and the household's perception on the scale of the quantities collected from these water points.

Figure 28: Example of water quantity question in the household interviews - Maworro

Household Interviews: Focus Group Discussions

The household interviews also had their FGDs, designed to complement findings in their household surveys. A total of thirteen of these groups met. They were used to determine, independently, the relationship and opinion they had, as a group, on both their Water User

Committees and their technicians. These FGDs involved the selection of ten random members of the communities, split equally between the genders, to be invited to the discussions. These are classed as mini-groups (Morgan, 1996). Participants in these talks shared in the incentives of the food that was provided for all the FGDs. Like the community FGDs they included a separation of gender (five males and five female groups). When saturation of responses had been reached, after several group discussions, certain village groups were combined together to determine if there were different dynamics when the genders were mixed. The FGDs with the communities had a much wider distribution of age categories, as their selection was not confined to those that had already been selected for participation as a member of the Water User Committee or in the role of village technician. The questions that were asked during these discussions were the least structured. The number of questions, and the complexity of the answers, varied depending on the capacities of each group. This process was the most inductive aspect of the survey period and was designed to explore potentially missed opportunities in current research. The lack of structure in the questioning reflected the lack of obligations expected of household members who are not included in the formal water point committees or have been given advanced technical training. An overview of the responses, grouped by thematic points can be found in Appendix H.

Technical Surveys: Borehole and Well Observations

With regards to traditional engineering practice, the technical surveys were the most straight-forward aspect of the field research. A total of 309 village wells, 17 of them boreholes, were included in this study. The process of evaluating each water point depended on visiting each source with a list of criteria. It then involved the noting and marking what was observed. The only information that required the participation of the communities or individuals was the verification of dates of construction, and the confirmation of the implementing agency. These were occasionally marked on the water point and did not require an individual's input. The water point mapping included both boreholes and hand-dug wells, though a different classification system was used for both. The technical assessment forms went through several iterations before they were finalised. Instead of re-visiting the villages to complete the forms the water points were extensively categorised, photographed and mapped. Therefore the minor changes were taken from this library of documentation. These changes were necessitated by incomplete or inaccurate information available at the sources. The lack of village documentation about the sources, which could have been given to the communities by the implementing organisations, severely limited the types of questions that could be asked, particularly regarding maintenance histories and alterations to the structure. Using a nominal grading (i.e. the water point is 'poor'), without a predefined standard of the terminology, also presented problems. This methodology was too open to interpretation as certain construction patterns differ with each project with a range of different omissions and technical considerations. Too many technical variations in water supply designs prevented this from being a consistent approach. Instead a checklist of components, and a pre-defined criterion of their condition, was developed that allowed observations to be addressed, though not graded in-situ. The analysis and calculations about the water points overall condition were carried out during the post-survey period. The exact definition for how this survey was developed, and the reasons for the categorisation, will be explored in the following chapter.

Technical Interviews: Focus Group Discussions

The interviews with the technicians involved more engineering dialogue than in other community meetings. These were much smaller groupings, and therefore as Greenbaum's methodology defined, could therefore be classed as a 'mini-group' (Greenbaum, 1997). A total of eight technician FGDs were completed. The main objective of these groups was to explore the nature and duration of their technical training; their associated abilities to resolve maintenance issues, and the technical problems that they anticipated that were outside their capacities to resolve. Other aspects of the discussion involved gender roles in the selection of technicians. The level of training by the technicians strongly influenced the extent of detail covered in these meetings and the type of questions that could be asked. For this reason the discussion questions were not fully structured.

The technician interviews were highly susceptible to gender bias. Several group discussions had no women present, as no women were trained. Several villages had women that were trained as technicians, but were not invited to the group discussions. These discussions did not continue until these women were invited to the meetings.

Figure 29: Technician Focus Group Discussion- Kumrabai Station

3.1.4.5 Field Staff and Photographic Documentation

For this research to be carried out both accurately, efficiently and ethically a range of local and international intermediaries were used. Each of these people had a different number of functions that allowed for the success of the field research activities. There were four different categorisation of individuals that contributed to the success of this project; (i) the social and cultural assistants, (ii) the local interpreters and data enumerators, (iii) the technical assistants and (iv) the local guides. With the exception of the local guides, all these members were brought from outside the villages to provide assistance for the research. The Sierra Leonean assistants were trained in-country, with a period of field training which included visiting test-case villages. The results of these test periods are not included in the final data. There was additional assistance provided from expatriate volunteers for the duration of the project. These two members added their own experience, one a gender specialist and the other a water engineer, to the research proceedings. Each had their own background in development field research. The social and cultural assistant, a Sierra Leonean staff member, was responsible for community introductions, professional conduct of the local staff and ensuring traditional etiquette was observed at all times in the villages.

As discussed before, the research for the placement was 'deductive' as it sought to explore the reasons behind the failures that had occurred with the water supplies. The pre-survey period had made it apparent that water supply failure had occurred on a national scale.

Statements about 'failure' bring controversy. Without proper documentation the examples explored in this thesis could be declared as 'worst case scenarios' rather than indicative of the nature of engineering in Tonkolili as a whole. To avoid accusations of over-emphasising water supply failures part of the technical surveys included photo documentation. This created a library of information that could be linked to the surveys. Additionally, for added verification, geographical information was taken using Global Positioning Systems (GPS) hardware. This verifiable evidence-based framework has presented a reliable basis for discussions on water supply problems.

3.1.4.6 Informal Data Collection

There are dangers associated with blindly focusing on survey objectives, even when utilising various methodologies to explore the realities of rural poverty. As Chambers states:

> *"Under pressure of the immediate need to keep the survey running, its objectives slide out of sight; the means - the collection of information - become the end. There is neither time, energy nor resources to explore new questions or notice the unexpected"* (Chambers, 1983).

The final component of the surveys involved profiling certain aspects of the villages through photographic evidence. This data collection process was the most inductive aspect of the community visits as it provided information on previously unheard situations. Originally intended as a photo-documentation of the village's unimproved sources, the unexpected enthusiasm of most of the locally appointed guides presented an unanticipated, but invaluable, perspective of village life. These walks around the villages, and their peripheries, were unstructured. The only overall objective was to locate the village's unimproved sources - though there were no directions on the routes. It was during this period that some of the most unique findings of this research were made. This was partly due to the informal nature of the walks around the villages. Their unstructured nature permitted the opportunity for the guides to lose their apprehension, or perhaps inhibitions, about the purpose of the research visits. This allowed for open dialogue about their experiences with their water. This type of participatory approach to research is strongly supported by investigators into rural development (Chambers, 1983).

The flexibility of this approach to discretely explore each community's tacit relationships to water and technology was the most valued component of the placement period. Where possible certain events, or evidence highlighted by the guides, were documented by photographical evidence. Important considerations were noted down after the field visits, and not in-situ, as it would have changed the dynamics of the informal data collection process.

3.1.4.7 Data Enumeration and Methods of Data Analysis

The data was gathered in different forms, and digitised by entering the information in databases, spread sheets and report documents. All survey data was originally gathered using printed hard-copies of the surveys. Multiple demands on the research time that was available in each of the villages meant that the recruitment of local data enumerators for carrying out household surveys was required. The training for the enumerators involved information on how to successfully input data into the hard-copy forms and how, if necessary, to correct mistakes. The data was inputted into digital from separately. This was done by expatriate staff with highly competent computer literacy skills. To minimise errors, and to easily resolve corrections, the information was collated into a Microsoft Access Database. This limited errors by reducing the number of inputs required by the enumerator. The ability to quickly input data and review the trends in results ensured that the information could be analysed in-situ. This permitted modifications and adaptations to be made to the research objectives if necessary.

The quantitative field research was relatively simple to input into the computers but there was still the introduction of human errors into the final data. To have an understanding of the scale of these errors then double data entry was carried out on 10% of the final datasets. The differences between the two sets were less than 1% of the inputted information. As this was not a considerable error margin then the entire dataset was not re-entered. Therefore there remains a small margin of error in the digital data that was used in this study.

The qualitative data, in particular the results of the Focus Group Discussions, were transcribed differently. Given the reliance on translators, the information was already a summary of information presented by the households or community. The exact word-for-word translation was not deemed necessary. There was a limited ability to receive new information from an exact translation as it presented linguistic and grammatical differences that are beyond the scope of the research to understand. To provide verification of the group discussion responses an attempt was made to digitally record the conversations. This resulted in several problems, including; the inability to correctly position the recording devices to pick up all discussion members points, the fact that the majority of the conversations were in Temne, and the ambient noise caused by the village settings. This resulted in this method of data collection being abandoned. Instead the discussions involved note-taking by expatriate staff to record the proceedings. This involved on-going translation by experienced community mobolisers. These were manually typed into documented forms. The resulting records were organised thematically on the points raised by the FGDs.

The quantitative data was analysed using Microsoft Excel, Minitab and Google Fusion. The Minitab included an Analysis of Variance (ANOVA) test for the household data on distances to improved sources (Iversen and Norpoth, 1987). The GPS information was mapped using Garmin e-trek monitoring equipment. The information on household, water supplies and village centres were mapped using Google Earth. All village locations are given in Appendix A. The calculations of distances used in this research use the haversine formula to calculate lengths. Given the limitations of the method these distances are accurate to within 0.5% of their stated distance (Gellert et al., 1989). As exact values are not required then this error is within acceptable margins.

3.1.4.8 Known Problems and Mitigation in the Field Research

The research used experienced translators for the field research and yet there will always be errors associated with their involvement (Desai and Potter, 2006; Temple and Young, 2004). The majority of the conversations, interviews and surveys were carried out in Temne, the local dialect. This meant that there was two translation errors, firstly in the inability to verify that the questions were correctly asked, and secondly to check that the responses were accurately recorded. It was clear that certain questions needed repetition in order for the communities to understand what was being asked. It was also evident that some summarisation of the responses was given, as the translated answers were usually shorter than what was said during the interviews. An exact word-for-word translation of what was said was too time-consuming; therefore some form of compromise was required. To reduce misrepresenting community responses in these questions several steps were taken:

- Firstly, it was ensured that the translation activities were carried out by experienced local staff members that understood the necessity of accurate responses (Desai and Potter, 2006). Their prior experience, in education and agriculture, as well as working with major international NGOs, meant that they maintained a high level of professional conduct with regards to their translation responsibilities.

- Secondly, the training for the translators was extensive. This involved a briefing in the questions that were to be asked; including any inputs that they may suggest that would enhance the performance of the discussions and surveys. One of the difficulties, whose impact on the translations of the interviews is harder to verify or quantify, was the influence of leading questions. Several efforts were made to limit the ability for a question to be suggestive of an expected response. Though attempts were made at carefully structuring questions, such as having the discussion questions semi-structured allowing for multiple responses, this could be nullified by a mistranslation of the question. Where possible, questions were modified to reduce the amount of clarity that was required. If this was not possible, as some questions were too open to a leading interpretation or mistranslation, then the results were not used. After several surveys and focus groups the data was reviewed and, if necessary any differences in trends between the outputs of the different translators were questioned and addressed.

- Finally, alternative options were given for the community for the translation of responses, such as speaking in either English, a rural practice which was uncommon, or Krio, which was more regular. As Krio is a form of Pidgin English many of the details can be understood without extensive use of a translator's skill. This option was seldom used in the household KAP surveys, but was very common in the FGDs, particularly when community members felt the need for their opinions to be clearly understood. The mixture of people present during the group discussions meant that there was a high probability of one member speaking some form of English or Krio. This was used on occasion, but the majority of the group discussions were usually carried out in Temne. Though certain members of the groups may be able to communicate adequately in a second (or third) language for much of the interview, this requires extra effort on their behalf. This can result in impoverished accounts and make the value of the data uncertain (Marshall and While, 2006). Additionally this shifted the translation responsibilities to a member of the community who would have the ability to direct proceedings.

Another issue that affected field research was the expectations of the communities. Pre-survey investigations into community water supplies had indicated that communities and households were liable to attempt to influence the outcome of the surveys if they felt that it could provide them with new infrastructure. It was their expectation was that they could potentially receive a new water supply if questions were answered in the correct fashion. This is a situation that is not uncommon in development research activities (Desai and Potter, 2006). This was mitigated by a number of decisions:

- Firstly, as described before, the communities were given a full introduction to the purpose of the research. This arrangement was referred to when questions about new supplies were discussed.

- Secondly, questions were generally phrased so as to avoid confusion or the suggestion of a promise about introducing new water supply sources.

- Finally, if neither of these criteria resolved the issues the surveys were designed so that they are not dependent on a single source of information. Triangulation between different survey practices ensured that any influence that was asserted would only impact a minority, and not the entirety, of the survey questions.

There was the occasional example of certain community members aggressively attempting to assert their control over proceedings: such as during the pilot testing of the surveys in the village of Malon. If they would not adhere to the conditions of the initial agreement that were made between the research group and the community leaders, then the surveys were still attempted, to avoid creating a dangerous situation, but due to their bias the gathered information the results were not included in the final survey datasets.

CHAPTER 4: RESULTS AND DISCUSSIONS

Part 1: The functionality of Water Supplies in Sierra Leone

4.1.1 Introduction

4.1.1.1 Sustainability of Water supply systems in Sierra Leone

Through an analysis of the secondary data, when compared to the results of the primary field research, it was found that there is a current inability to contextualise and present the scale of the problems associated with water supplies in Sierra Leone. Organisations and research groups have increasingly sought to raise the awareness of the serious sustainability issues, but the frequently differing terminologies have resulted, in many cases, in contradictory statistics. This chapter will explore the current understanding of functionality of water points and present a new method for contextualising failure.

One of the most prominent preliminary results found was from the Rural Water Supply Network (RWSN). This organisation suggested that up to 63% of the systems in Sierra Leone were impaired. This was an estimate taken from UNICEF summaries, the Joint Monitoring Report (2004) and the MICS (2005) data (RWSN, 2009b). This inherits the errors and uncertainties of the original collection methods. Furthermore it generalises certain factors technical that can be observed in Sierra Leone providing a very limited definition of 'functional' water supplies.

More in-depth analysis of failure has been surveyed by NGO water specialists such as the French organisation Inter Aide. There survey of water supplies, carried out in 2010, investigated schemes three regions in Sierra Leone resulting in information from a total of 2,859 villages. Their conclusion suggested that the average failure of hand-dug wells was 71% and boreholes 33%%. With the Inter Aide data it is unclear how systems are regarded as being 'non-functional' as their definition of the term only considers two factors: (1) if the hand-pump or pulley system is functional and (2) if there is seasonable availability of water.

The STAT-Wash database, carried out in 2012, with support from the World Bank, WSP and MoEWR provided much more survey details on water supplies. It contains the most comprehensive national statistics on functionality. This includes almost all the water points in Sierra Leone and also includes verifiable GPS data to track their information. Their results for functionality are tiered into three definitions (i) functional, (ii) partly damaged and (iii) non-functional. The failure rate of systems is more conservative than the results of organisations such as RWSN and Inter Aide. The data indicates that 35.9% of systems in Sierra Leone (of the 11,383 hand-pump and borehole systems) are non-functioning. A summary of the data can be shown in Table 2.

Table 2: Functioning well systems (hand-dug and borehole) in Sierra Leone

	Period Date	Total Constructed	Total Partly Damaged	Total Broken Down
Development Period	2005-2012	6,743	**15.6%**	**18.3%**
Post War Period	2002-2004	2,025	**18.4%**	20.1%
Conflict Period	1991-2001	805	**21.0%**	22.1%
Pre-Conflict Period	Before 1991	959	**14.3%**	19.7%
Unknown Year		851	**12.6%**	28.1%
Total		**11,383**	16.1%	**19.8%**

An overview of this reported failure, sorted by the year that they were built, is provided (Figure 30).

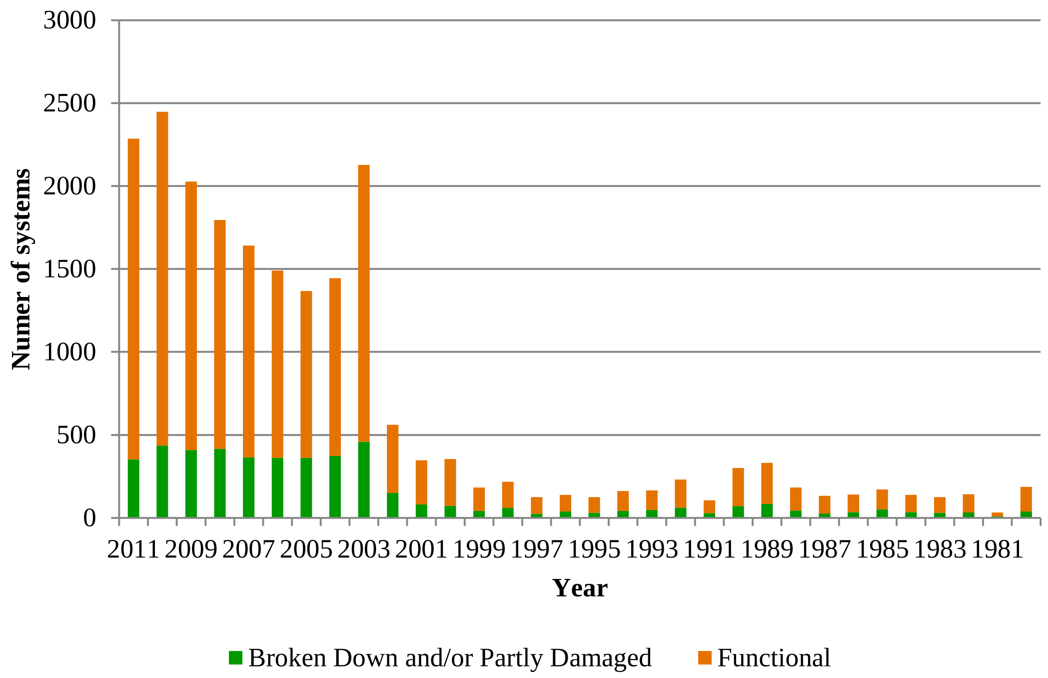


Figure 30: Functionality of water supplies shown by their year they were built

As would be expected, the water supply systems built during the conflict era were more likely to be both damaged and to be broken down. The STAT-Wash data also indicated that systems built in the immediate aftermath of the conflict also had a higher than average percentage of the problems. This data only presents a snapshot of functionality at the time the survey was undertaken. There can be no projection about the probability of a given system failing during a given time period - as this would require an exact time when the systems stopped working. This information is difficult to find at village level. The only projection that is available is from 2011, when 2,285 systems were built, as this was the year before the STAT-Wash survey. The dataset shows that 352 of these newly constructed systems were not working in 2012. This data suggests a failure rate of 15.4% in the first year of construction. Regardless of the scale of this survey there is a limit to defining causation or the implications of the NGOs actions. This is caused due to the definition of 'failure' used to define the sustainability of the water points.

The need for triangulating results, and having independent verification of the secondary data, is shown when comparing the surveys of Inter Aide with the larger dataset from the STAT-Wash Database (see Table 3).

Table 3: Comparison of data Inter Aide and STAT-Wash Database for the same year

	Borehole				Hand Dug Well			
Survey Method	**Completed**	**Not Completed**	**Functional**		**Completed**	**Not Completed**	**Functional**	
Inter Aide (2010)	89	1	49	55%	545	47	128	23%
STAT-Wash (2012)	155	3	108	70%	702	47	384	55%

There are significant differences in both the reported number of constructed systems and the total numbers that are considered to be 'functioning'. There are several rational reasons that could be raised explaining the differences in information:

i) The Inter Aide survey was carried out two years before the STAT-Wash investigations. As there has not been a momentous construction activities in this time period it does not explain the significant differences in the reported number of constructed wells.

ii) The two datasets used different methodologies and would have been susceptible to different biases, such as human reading errors. The scale of the differences between the final data is too extreme to seriously consider this as being the sole reasons for the non-parity of information.

iii) The Inter Aide survey states that functional hand-dug well systems, in Tonkolili, in 2010 are half of the value of those in the STAT-Wash Database reported in 2012. This means that either there has been a sustained period of rehabilitation of sources in these two years, of which there is no evidence, or there is a difference in the methodology for defining when a water point can be classed as 'functional'.

The conclusions that are drawn from comparing this secondary information are that both the reports are prone to error, with different adherences to standards for both approaches. It is likely that the STAT-Wash database collection methods were more inclusive of systems that could be defined as being 'hand-dug wells' than the Inter Aide report. This could include water points that the Inter Aide Report would define as unimproved. The most important problems are related to the different definitions of 'functionality' found in these reports.

4.1.1.2 Defining 'Non-functioning' systems

The Inter Aide survey was one of the first of its kind in Sierra Leone. Their information classifies their surveyed systems as being '*working'*, '*not working'* or as having *'seasonal' problems'*. The classification of *'not working'* is defined as the well system having a hand-pump or pulley system problem and/or no water all year long. Their *'seasonal'* categorisation is for a well that provides water, but not for the full duration of a year. There are practical problems with applying this method in defining sustainability in that it is too narrow. For example; their data on Kumrabai Junction, in Mabang Chiefdom, shows that there is a 'broken pump' but Inter Aide have still classed the well as 'working' (Figure 31).

Figure 31: The problems determining 'functionality' at water points - Kumrabai Junction

It is likely that the community continues to use their well with a broken pump, but through the use of the manhole cover, with a rope and bucket. Their binary description of 'working' does not allow for a technical intermediate state. The information provided by Inter Aide does not discuss other technical problems that can occur about the sources that are not hand-pump or pulley technology related. This includes components such as the well lining or the headwall. It also offers no indication of other well properties that may be missing or damaged, such as the spillways, aprons or the fencing.

The STAT-Wash dataset provides several more criteria for understanding the problems with the water points (Table 4 & Table 5). This provides more in-depth information which is inclusive of damage to the apron, pump, pipes and concrete. It also provides options to highlight any other failure that may have occurred, which are not included in this listing. The dataset does include more options for listing observed technical issues than the Inter Aide data, however the results do not include aspects of the wells that are currently considered to be standard engineering construction practices of improved sources (DFID, 1999). These include spillways, soak-ways and fences. Additionally the results are intended to evaluate hand-pump wells and can be incomprehensible when applied to different technologies, such as the pulley systems. Certain indicators of technical problems are randomly mentioned in the datasets, such as issues with source leakage, but the continual evaluation of these indicators is inconsistently monitored.

Table 4: STAT-Wash database classification of failure (general problem area)

Problem Type	Occurrences (no.)
Well related	1,660
Pump related	3,251
Pipe related	114
Concrete Structure	15
Apron related	1,121

Table 5: STAT-Wash database classification of failure (specific problem area)

Problem Type	Occurrences (no.)
Pump damaged	2,212
Well damaged	1,128
Apron Damaged	1,101
Well polluted	659
Pump damaged	589
Pump stolen	473
Other	952

Like the Inter Aide information on functionality the results of these statistics provide very dubious conclusions about the current causes of problems with well systems. Though the information is extensive, the sheer quantity of data can introduce a form of statistical myopia, and actually disguise the true nature of the problems. For example in 1,128 cases the results of the STAT-Wash information described the systems as having 'well damage' (Table 5). The interpretation of such a term could vary substantially between different well systems. Some could indicate a complete collapse of the well lining whereas others, using the same classification, could refer to only a minor fault such as a hairline fracture in the well cover. There are no intermediate stages in the classification system; therefore they offer no technical standard outside the arbitrary and binary classification of systems as being: 'functional' or 'non-functional'.

4.1.1.3 A New Theory in the Definition of Non-Functional Water Points

This research proposes a new method for defining sources as being non-functional. The basic theory behind the provision of water supply services to the rural communities of Sierra Leone is that the villages have an inability to improve their access to safe sources of drinking water without external assistance. This socio-economic evaluation presents a framework and rationality by which the success of water supplies can be fairly evaluated. This evaluation also suggests the financial capacities of the communities for sustaining the intervention. Due to the application of a SATT model, the majority of the NGO provided water supply systems are expected to be sustained at the local level. This is emphasised through the creation of social support mechanism such as tariffs schemes and the training of local technicians for the explicit purposes of maintaining the sources at the village level (Harold and Stef, 2011; Harvey and Reed, 2004). Therefore, if the socio-economic capacities of the communities have been fairly evaluated; the limit to each community's continued participation is dependent on the associated cost of repairing any faults not exceeding the cost of a new system. There should also be an observable range of factors which can be shown to be within the capacity of the communities to address, and which their social support mechanisms are designed to accommodate, and problems that place an unfair burden on their socio-economic capacities. Therefore this necessitates a more specific definition of technical failures than referring to the water supplies as having simply 'well damage' or other basic nominal descriptions.

The research that was carried out in Sierra Leone specifically addressed the need for a new framework for defining functionality. For this conceptualisation the case-study that was used to determine the condition of water supplies in Tonkolili explicitly focused on hand-dug well systems. Hand-dug systems include both hand-pump and pulley well technologies. These are the most typical water supply sector interventions made by NGOs and include over 90% of the water points in Sierra Leone. However it does not include drilled wells such as boreholes. These were evaluated as part of this research, but to avoid confusion will not be considered as part of this chapter's investigation into the success and failure of water supplies. Boreholes are a more recent intervention in Tonkolili (68.9% have been built after 2005) and their long term sustainability cannot be evaluated at this stage. Boreholes also have different technical components, and evaluation criteria, that are not applicable to hand-dug wells. This makes direct comparisons about their conditions difficult to monitor.

4.1.1.4 Components of the well systems

Hand-dug wells consist of more than a single component which can have technical issues. Problems with hand-dug wells are not merely limited to the functionality of the hand-pump or pulley technology alone. Due to the varied nature of designs for water supplies there is also no fixed international standard for well components. Since the UN water decade in the 1980s there have been several developments in well systems (Bauman 2000, Skinner 2003). This has resulted in the designs evolving over time and certain components becoming more standardised during this process. The standardisation provides a mechanism for comparing the sources to each other. The main areas of the well system fall under these ten categories:

1. ***Lining* -** If the well is correctly lined it is enough to raise the standard of the well from unimproved to an improved source (UNICEF and WHO, 2012). The well lining ideally extends from the ground surface to the water table. Its purpose is to retain the soil at the sides of the well and prevent infiltration from surface water near the ground level (Collins, 2000; OXFAM, 2008).

2. ***Head wall* -** the purpose of the head wall and apron is to prevent infiltration of surface water into the well. The well wall is usually, though not always, an extension of the well lining (Boschi, 1982; Collins, 2000).

3. ***Well cap (cover slab)* -** The cover slab is placed at the top of the headwall, ensuring that surface water and external contaminants do not enter the well water. The slab should be sealed to the headwall, to prevent well contamination, but also to stop the cap moving, and potentially causing harm (Boschi, 1982; Brikké and Bredero, 2003; UNICEF, 2009a).

4. ***Well Apron* –** This is the area around the well. This prevents the contamination of the well by surface water. It prevents ponding, erosion and provides a safe environment for

the users. It allows the area around the well to be easily cleaned. Ideally it should slope towards the drainage channel around the edge of the apron (Brikké and Bredero, 2003; Collins, 2000; Smet and Wijk, 2002).

5. ***Spillway and runoff area* -** the purpose of the spillways is to collect water from the drainage channel and carry it to a soak pit which dissipates the water into the ground (Skinner, 2012).

6. ***Drainage area*** - the drainage area surrounds the well and is designed to collect wastewater allowing it to run into the spillway (Brikké and Bredero, 2003; UNICEF, 1999; USAID, 2010)

7. ***Manhole cover* -** the manhole cover is designed to allow access for maintenance. It can be designed to allow a pump system to revert to an improved pulley system in the case of an emergency. Most NGOs provide a manhole cover, however some are capped (sealed with concrete) to avoid tampering (Collins, 2000; Smet and Wijk, 2002).

8. ***Hand-pump or pulley systems* -** There are a range of differing technologies that fall under this category such as piston, direction action and suction pumps. In the case of pulley wells; this includes the windlass or bicycle pulley mechanism (Brikké and Bredero, 2003; Collins, 2000; Erpf, 2002; Harvey and Reed, 2004).

9. ***Lifting systems*** – this includes all system used for raising the groundwater such as; the rising pipes, washers, cylinders, bearings, connector rods, cylinders and in the case of pulleys; the rope and bucket (Erpf, 2002).

10. ***Fence*** – this is a locally built structure designed to protect the source from contamination by animals, or falls and accidents by the host population, particularly children (DFID, 1998; Wagner and Lanoix, 1961).

The purpose of assessing the individual components of the well systems is to allow the entire approach of service delivery in the water sector to be contrasted and compared. There are two complications with this analysis:

- Firstly, different water points were shown to differ in designs, particularly older models, and omit aspects that are now considered standard practice for well construction (Collins, 2000). For example, older well designs did not originally include spillways, drainage channels or manhole covers. An omission can have a severe impact on the sustainability and safety of the well, though the extent depends on the type of component which is absent (Figure 32). The components of the wells have evolved since the UN's water decade and now include areas that were not present in historical designs (Watt and Wood, 1979). These parts are now deemed necessary for the continued functionality, sustainability and safety of the water point (DFID, 1998).

Figure 32: Severe erosion on older well type caused by lack of drainage - Patifu

- Secondly, some well designs combine certain technical areas. Examples include the fencing and the draining system, which can be combined as a single unit to divert the flow of waste water. Where technical areas are combined then they are assessed on their ability to complete their unique function. For example a concrete fencing that acts as a drainage channel would be independently assessed in its ability to achieve success in each role independently.

However, separating the water supplies into individual criteria would be a redundant process unless a method can be developed which allows any 'well damage' that is observed to be contextualised. This method should also allow for a form of categorisation that should be relative to the condition of other existing water supplies in Tonkolili.

4.1.1.5 Technical Grading Scale

Current monitoring targets have created a definition whereby water points can be *'considered potentially safe'* (Sphere, 2011; UNICEF and WHO, 2012). To quantify how far short of current standards the hand-dug well systems in Tonkolili actually are, then an evaluation of the inverse is required; a way in which a hand-dug well could be *'considered potentially unsafe'*. This can be combined with the theory of the community's needs and capacity for preventative and corrective maintenance of the water supply intervention. This results in a grading system which can determine, in general terms, the financial costs and human resources that would be required to return the source to its 'safe' condition. It is important to establish at this stage that the grading system presented in this chapter is not intended to be a measurement of the magnitude, or impact, of the risk at the water points. A full technical analysis, combined with an extensive review of important water quality indicators, would have to be considered to determine the actual risk to the communities (Godfrey et al., 2011; Onda et al., 2012). This would be intensive in both, time and financial resources, and without an abundance of both, it would not offer an understanding of the scale of water supply problems in Sierra Leone. The alternative is to use the assumption that any failure, no matter its magnitude, probability, or impact, introduces an equal amount of risk at the source. Therefore the water point can be classified as 'potentially unsafe' until repairs are carried out.

There are other considerations that have to be acknowledged that directly affect the nature of an 'assumed safe' source that are not rationalised by only viewing the individual well components. These are technical considerations and are not fully part of the social support mechanisms designed to sustain the source (investigated in the following chapter). The number of people using the sources, the amount of time that the sources are in use, the location of the sources (in particular the proximity to high risk structures such as latrines) and the groundwater quality, also have to be considered as part of the technical evaluation into the water points (Davis and Lambert, 2002; DFID, 1998; Harvey and Reed, 2004). These categories have been included as part of the technical evaluation process.

A full technical assessment of the water point would involve taking each technical item apart to assess the actual functionality of the component. It would also involve comparing detailed technical build specifications, such as; the thickness of cassions, design of steel re-enforcement and depth of digging. As there are widespread variations in technologies and water point designs each of the individual technical components can have different materials prices as well as different logistical and labour costs for repairs. If providing financial accuracy and an exact pricing list was required then the number of different designs would necessitate unique survey criteria at each source. This would make the results incomparable with each other. Theoretically, if it was possible to provide this attention to detail in Sierra Leone, then a costing value could then be compared to other evaluations for repairs but even for a small number of case studies this would result in huge capital costs for the technical surveys. It would also be an exceptionally difficult process and liable to error. Furthermore achieving the exact pricing would be exacerbated by the condition of many of the water supply systems in Sierra Leone. Many of the observed sources were found to be beyond rehabilitation, and getting accurate estimates for repairs would be unrealistic.

Therefore a system of evaluation is required that allows for both extremes of technical issues, from the critical to the marginal, to be taken into consideration. Simultaneously a degree of accuracy is required for an evaluation that does not result in unrealistically large survey expenses or becoming limited to assessing a small number of water points. The field research indicated that a grading system is required that provides an understanding of the financial capabilities of the host community. This should also include an understanding of local human resources that are necessary for the repair of water points.

4.1.2 The Grading System

This chapter presents a grading system that can be used to evaluate the success and failure of water supply systems in Sierra Leone. It is important to define how these water points can be objectively assessed. This involves separating the criteria for the wells into individual sections, assessing them independently, and using only quantitative measurements and a pre-defined assessment criterion. From this sufficient information can be gathered that can be used to define the quality of the existing well construction, the current functionality conditions of the systems, and the probability that the community can resolve any maintenance issues for themselves. This grading falls into five categories and is dependent on both the financial resources required to resolve problems and the availability of technical assistance (Table 6).

Table 6: Grading scheme that uses the 'communities' capacity to repair'

	Community Capacity	Financial Resources	Min. Required Technical support
Grade A	Dramatically exceeds communities financial capacity and requires advanced technical support	*over $5,000*	Civil Engineer
Grade B	Exceeds communities capacity and requires advanced technical support	*$500 - $4,999*	Civil Engineer
Grade C	Potentially within communities capacity, but resolution requires a functional tariff scheme and an skilled technician	*$100 – $499*	Highly trained technician
Grade D	Within communities capacity, would require a tariff system, though could be resolved by a break-and-pay system. Needs a trained local technician	*$25-$99*	Local technician
Grade E	Fully within communities capacity to resolve locally with little or no technical support	*$0 - $24*	Community committee or caretaker

An overview of examples of what is applicable in each grading is outlined below:

- **Grade A:** *(Extreme failure):* this is the most dramatic of all failure modes. Wells that fall under this category have, in most cases, clearly noticeable defects (Figure 33). The systems are usually completely non-functioning, and in many scenarios, have been for a long while. The cost of remediation for the wells is comparable to replacing the well system entirely. In some cases, particularly in the areas of highly contaminated water or incomplete systems that have been left unfinished, the wells may offer continual danger to the community. Before a new system can be provided, wells of a Grade A failure would have to be dealt with to ensure that any associated risks of the previous systems are mitigated. For example this could involve either the dismantling and back filling the well, or providing a complete water treatment system capable of dealing with water quality issues.

Figure 33: Example of Grade A failing (A) Patifu (B) Masokoh

The failings shown above are primarily concerned with the collapsing of the well lining. In Patifu the water point had not only been found to be without water, and have significant damage to the casings, but the water point was located next to a school community with little cover provided to stop accidental falls. In Masokoh the water point exhibited one of the most common failure types for water points of this type. This pulley well system had a brickwork lining. In this instance the lining collapsed due to the proximity to the roots of a tree.

- **Grade B:** *(Severe failure):* this is the highest level of failure for systems where the option of rehabilitating the well remains, though the price of a repair would still be comparable to providing a new system (Figure 34). Failure in this category usually affects a significant component of the well system, usually structural in nature. Wells that are classed as having 'severe failure' offer significant risk to its host community. The defects of a Grade B failure will continue to offer risk to their hosts, such as standing groundwater being able to enter through the partial collapse of a well wall. Extreme seasonal failure will also contribute to the Grade B categorisation of the well. Like Grade A failure, the cost of repairing these wells will exceed the financial capacities of the community. Much of the rehabilitation would also require an engineer, as steel reinforcement design, for example is beyond the capacities of the NGO technicians. Severe failure, like extreme failure, usually indicates poor engineering practices in the manufacturing and construction process.

Figure 34: Example of Grade B failing - Romankro

- **Grade C:** *(Significant failure):* This is the first mode of failure that has a parallel with existing standards. Wells that fall under this category have exceeded the standards laid out in the SPHERE guidelines (Sphere, 2011). For example the wells that fall into this category would not have sufficient yield to supply the communities with water all year round, and may require added depth (and extra casings) to their wells system. Technical failures, such as the piping or hand-pump rusting, may contribute to the system not working (Figure 35). There may also be issues with certain important, but inexpensive external components of the well, such as the spillways, aprons and well walls. Communities with a functioning tariff system, which has been operating successfully for a number of years, should potentially be able to afford the costs of fixing these well problems.

Figure 35: Example of Grade C failing - Mabang

- **Grade D:** *(moderate failure):* Wells that fail in this category will have only temporary, rather than permanent, issues (Figure 36). The reasons for these wells not working would only be a minor defect usually caused by wear and tear on fast moving parts (such as a rusted chain, broken seals or damaged, but repairable, pipes). Structural damage would be minimal, no more than hairline cracks present, which require simple rehabilitation. The remedial action for these should not require expensive solutions. Inexpensive fencing would be considered a Grade D problem. Providing solutions to any of these problems should not exceed the financial capacity of the communities, even without a properly functioning tariff system. The remedial actions should also be within the capacity of an NGO-trained local technician to repair.

(A)  (B) 

Figure 36: Example of Grade D failing - (A) Mafanta (B) Masang Junction

- **Grade E:** *(mild failure):* This grading of failure is used as a counterpoint to 'extreme' failure. Though it could be argued that wells that fail in this grading are being judged harshly, technical solutions such as these would not be acceptable in a developed country. Mild failure is typified as having superficial structural and mechanical problems (Figure 37). Examples of this include; exposed formwork or surface level rusting of components such as the man-hole covers hinges. Water schemes that have incomplete fencing or spillways that are incompletely constructed would also constitute a Grade E failure.

Figure 37: Example of Grade E failing - Mathombo

- **No Failure:** It is possible to have water supplies that have no known defects or parameters that have failed. These were only noted on new constructions which were less than three months old and were not within the catchment area of 150 villages surveyed and the 309 water points evaluated for this study (for example Figure 38) but the option remained a possibility.

Figure 38: Example of a water point with 'no failure' - Rowunkor

The criteria of each of the well components were combined with the definitions given for each of the categorisations of failure. The information used to design the grading system was taken from multiple technical reports, handbooks, site reports, engineering guidelines and well training manuals. This results in a matrix of indicators that can provide an overview of the condition of the water points at the time of the survey. The table demonstrating the grading criteria can be found in (Table 7). A full explanation of the grading choices, their sources, and the cost and technical support analysis can be found in Appendix K. There are some important considerations:

- Firstly as can be shown in Table 7 certain categories do not have a high classification of failure. For example a missing spillway cannot be classed as Grade A or B as it is not expensive to replace and does not require advanced technical assistance to construct or maintain.

- Secondly, certain categories can have multiple failure types at each point. For example; the cover slab can have steel reinforcement damage causing it to sag, it can have a range of different erosion types, and can be cracked to various extents. Multiple failings in a single category have been considered as part of the evaluation process.

- Finally the majority of the issues can be assessed using simple quantitative measurements at the source. These have been used to create the survey forms.

Table 7: Grading System for determining the functionality of water points

Item		Grade A	Grade B	Grade C	Grade D	Grade E
1. Structural Components	1.1 Lining *(cassion)*	Collapsed or no lining	Inadequate, damaged or missing lining (cassion)	Finger-width (or larger) damage to lining	Hairline cracks on lining	Dirty lining
	1.2 Well Wall *(Parapet)*	Complete Collapse	No wall or sizable failure affecting formwork	Finger-width (or larger) fissures in wall	Hairline fissures or cracks	Dirty well wall
		-	-	Significant gap between the headwall and cover	-	-
	1.3 Cap *(Well Cover)*	-	Missing or severely damaged cover	Finger-width or larger cracks	Hairline cracks	Exposed Rebar
		-	-	Severe Ponding on Cover	Mild ponding on cover	Slight ponding on cover
		-	Sagging of the cap	-	-	Dirty Cap
	1.4 Apron *(Slab)*	-	No well apron	Severely limited or damaged apron	Minor cracks	Dirty Apron
		-	Sagging well area	Severe Ponding	Mild ponding	-
		-	-	Severe Erosion	Mild Erosion	-
	1.5 Spillway and Soak-way *(drainage channel)*	-	-	No Spillway or soak-way	Damaged Spillway or Inadequate spillway or soak-way	Blocked or dirty Spillway or soak-way
	1.6 Drainage Area *(Drain)*	-	-	No drain	Damaged drain	Dirty drain
	1.7 Manhole Cover *(Inspection cover)*	-	-	Missing manhole cover or Sealed Manhole	Damaged/rusted manhole cover	-
	1.8 Fence	-	-		No fence	Porous fencing or missing gate

2. Mechanical Components	2.1 Hand-Pump System		Failed pulley system	Missing hand-pump (in their entirety)		Noise pollution
		-	-	Rusted or Severely Damaged Components	Damaged or missing fast-moving replaceable parts	Un-greased pump
		-	-	Permanent Concrete Security	Missing security cover	-
	2.2 Lifting system	-	Missing/No lifting system or Rusted/damaged pipes	Damaged Single Component (*i.e.* cylinder)	Superficial damage (pipes), or unclean pipes	-
3.Topography	3.1 Proximity to structures	Proximity to expensive permanent or immovable high risk structure	Proximity to permanent movable high risk structure	Proximity to temporary high risk structure	-	-
	3.2 Flooding	Well dramatically below floodplain	Well just below floodplain	-	-	-
4. Available Water Quantity	4.1 Seasonal availability	No water all year (12 months)	Water not available between 6-12mths	Water not available between 3-6mths	Water not available between 1-3 mths	Slight water shortages for less than a month
	4.2 Technical Operation	-	Pump required to be in operation more than 10hrs	Pump required to be in operation more than 6hrs	Pump required to be in operation more than 4hrs	-
	4.3 Yield per person	No water (0L/ person/day)	Only the emergency amount available (7L/person/day)	Between minimum standard and the human right to water (7/l/p/d and 40/l/p/d)	-	-
5. Water Quality	5.1 Quality	Highly contaminated water source on one or more dangerous contaminants	Fail Sphere Standards for water quality	Fail basic WHO Standards for water quality	Fail main WHO Standards for water quality	Higher than intended values in WHO standards for any parameter

4.1.2.1 Unmonitored Grading Criteria

The grading system was designed to be inclusive of the major indicators of failure. There were two aspects that could not be monitored by only visiting the source once during the process of evaluation. These are: (1) the measurements of the yield at source and (2) the quality of the water.

The yield at source depends on periodic testing throughout the year to indicate how much water is available (WPP, 2012). This would require monitoring the height of the water table at key stages; such as before users had withdrawn water, to evaluate the recharge of the system. This could not be carried out once, but would require several measurements over both wet and dry seasons. It would also have to consider the flow-rate of the technology used, and the duration of time that the source was in use per day. None of these calculations can be determined by visiting the sources only once. As it was out with the scope of this research to spend several weeks, months or years, studying a single source, then this aspect will not be included in the analysis.

The linkages between developmental service delivery of water supplies and their water quality are important aspects of engineering in developing countries (Onda et al., 2012). The exploration of water quality requires a rigorous and precise scientific methodology to provide accurate findings. To provide a degree of accuracy, and a conclusion on the viability of results, the water testing would have to be taken at key seasonal periods, such as the peak seasons in the wet and dry seasons (CAWST, 2009). Additionally, periodic bacteriological testing would be required to explain whether the contaminants that are found within the systems were from either the ground or surface water rather than introduced by the users through rope-and-buckets (CAWST, 2009). This would explain whether findings were common or isolated occurrences. Limited conclusions can be made from using a single measurement taken from a source at a random point in time. Water quality monitoring is important, and is logically included as part of the grading system. Correctly evaluated it would provide information on failure that is not rationalised in other evaluated categories, such as hazards in the groundwater (Godfrey et al., 2011; Onda et al., 2012). The time, money, and independent focus required for monitoring this aspect of the grading would diminish the attention that can be given to other technical areas. Including water quality results would have more accuracy with regards to exact risk, albeit only defining the findings of the survey period, but they would not offer an indication of the causation of the problems, or provide a summary of the technical systems as a whole.

4.1.2.2 Limitations of the Grading System

The classification system allows for an overview of the water supply situation in Tonkolili. It is intended to provide a macro-orientated view of the problems. Unfortunately each water system is not an exact replica of a fixed and pre-defined standard. Therefore to include the variation in hand-dug well designs the system has to allow for approximations. By doing so the grading system is vulnerable to human error caused by poor assumptions.

Many of the properties describing the condition of the technical artefacts fit their exact description but others require an in-situ judgement in order to determine their place on the grading scale. The most common issue was found when observing and grading concrete fractures in the well systems, specifically the well cover, headwall, apron and lining. The larger the fractures sizes, the higher the material costs for rehabilitation. The size of the fractures could also result in higher costs due to the associated technical skills which are required for correcting the problems. In reality it would require a complete stress analysis of the hand-dug well to accurately determine if structural failure could occur from these fractures. Additionally it would also involve hydrological data to assess whether the integrity of the apron, lining, headwall or well cover had been breached by these fissures. This would be required to determine if it was these fissures that were responsible for failure as opposed to other contamination transmission routes. As the cost of this level of analysis would be too high to carry out on a large scale, an approximation which could determine the most probable scenario is required. This results in describing the factures by their observed length. These fractures sizes ranged from ‘hairline’ to ‘finger-width’ to ‘larger than finger-width’. Small and non-invasive fractures were ignored. Theoretically only cracks that were likely to cause water to enter from exposed and unprotected areas, such as on the casing or headwall, or fissures that could potentially cause structural damage, were included. As this is difficult to define then this method of observation is susceptible to human error, and could potentially be influenced by bias. It would also, at best, only provide an approximation of the true extent of the problems. Regardless, any damage would still require repair, and could be deemed as *‘potentially unsafe’* until such rehabilitation is undertaken. To reduce bias the majority of the sources, and any relevant well components, were fully documented with photographs. This ensures that decisions can be independently verified during the process of analysis.

It was not possible to observe the interior of several of the hand-dug wells. This was either because there was no manhole cover, the manhole access was sealed off, or the cover was so rusted that access to the interior was unavailable. The inability to observe the interior of the well resulted in the manhole receiving a ‘Grade C’ classification of failure. This is because it would result in issues with maintenance. The casings and the condition of the piping were marked as ‘not observed’. Having the inability to observe the casings and piping of certain wells reduces the accuracy of the measurements; however this grading scheme is not dependent in the cumulative sum of individual components, but on the most severe individual problem. Some elements of these wells were discounted, but the remainder of the hand-dug wells components were able to be assessed to provide a grading. Additionally certain well components, such as the cylinder head, were reported by local technicians to be damaged. Verification of this would have required pulling up the piping and lifting systems to confirm. As the classification of ‘Grade C’ groups all known issues with the pumping mechanisms, an exact definition of the causation was surplus to requirements.

4.1.2.3 Providing a Final Graded Mark for Water Points

The overall goal of the grading system is to class the evaluated hand-dug wells at the maximum level in which it has failed. This means that a well that consists of only ‘Grade E’ problems, but has a single ‘Grade A’ problem would still be classed as a ‘Grade A’ failed well. The most significant failure categorisation would always take precedent over lesser technical issues. This is consistent with the rational of the grading as it is based on the host community’s capacities to repair, and the technical assistance that they require.

It observed that many water points have failure grading in more than a single area. Multiple failures of ‘Grade C’ would not result in a ‘Grade B’ failing because they would both ultimately necessitate different responses. For example, a well missing pipes, pumping mechanism and a manhole cover (all ‘Grade C’ failures), would require each of these components to be replaced, but not the replacement of an expensive element or a skill dependent contribution (which would be a more typical response to a ‘Grade B’ failure). This is a limitation of the grading system as multiple Grade C’s would not result in an up-marking of its grading, though repairs could, in theory, cost more to rehabilitate the system than a Grade B situation (Figure 39).

Figure 39: Multiple Grade B and C failings on the one source Mabum Station

The frequency of this occurrence is offset by using an exponential increase in financial costs between each grading criterion, rather than a linear increase. This allows for the summation of multiple occurrences to cost less than the minimum of the next classification. Given that approximations used to calculate costing it is still theoretically possible, though infrequent, that the multiple costs of failure on one Grade would add up to the minimum of those Graded higher in severity. As the grading is only an approximation of costing, then this level of accuracy is not required.

4.1.3 Application of the Grading System

4.1.3.1 Results of the Field Survey on Water Points

In total 295 water points, involving over 4,700 individual evaluation checks, were assessed as part of the technical survey into hand-dug wells. Of these 211 were hand-pump well systems and 84 were pulley wells. As defined by the maximum grading of each of the observed water points: the majority of the wells (36%) are classed as Grade C failures. This was followed by Grade B (33%) and Grade A (27%). Very few wells only had a Grade D failure (4%) and only 2 (1%) had only Grade E issues. None of the wells exhibited a maximum of "no failure" as every water point had some defect. This is partly attributable to the exactness of the Grade E criteria. The results are shown in Figure 40 below:

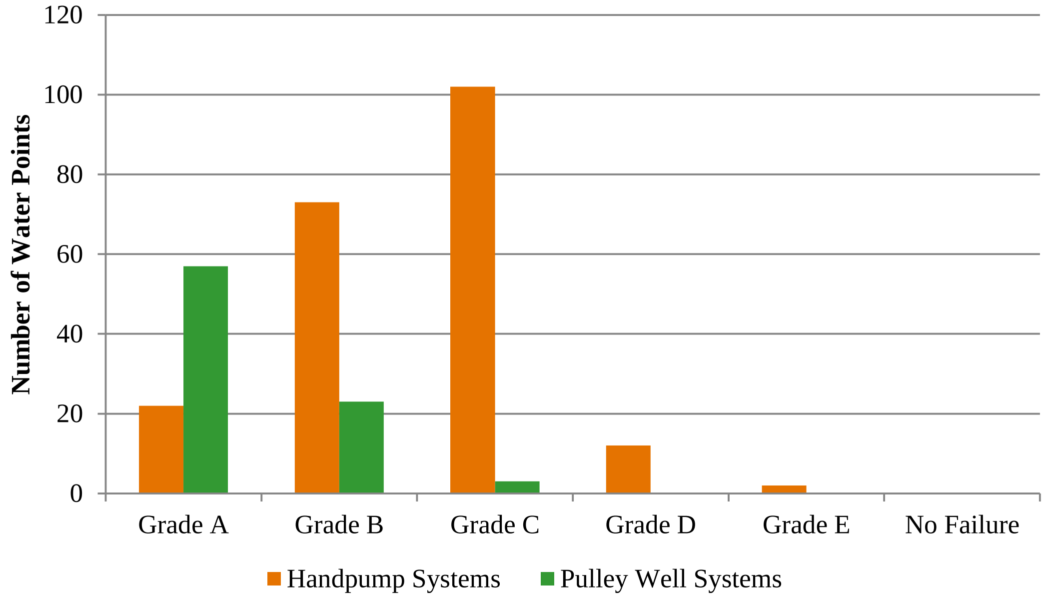


Figure 40: Overall failure grades of pulley and hand-pump systems

The mechanisms of failure are dependent on the well type. A summary of the data can be found in Appendix L. There are some general comments on the water sources. None of the wells exhibited only the classification of *'no failure'* but there were many examples of satisfactory technical aspects. Out of the 4,700 individual evaluated criteria that were monitored 41% offered no contribution to issues at the source. However, over the 295 water points that were evaluated there were examples of every type of technical problem presented in this chapter.

A total of 82 case studies identified 122 forms of extreme failure. This means that 40 wells had multiple 'Grade A' problems at the source (see Figure 41). Similarly there were 161 cases studies of wells which were identified to have 332 forms of significant 'Grade B' failures. This statistic alone indicates considerable engineering service delivery problems.

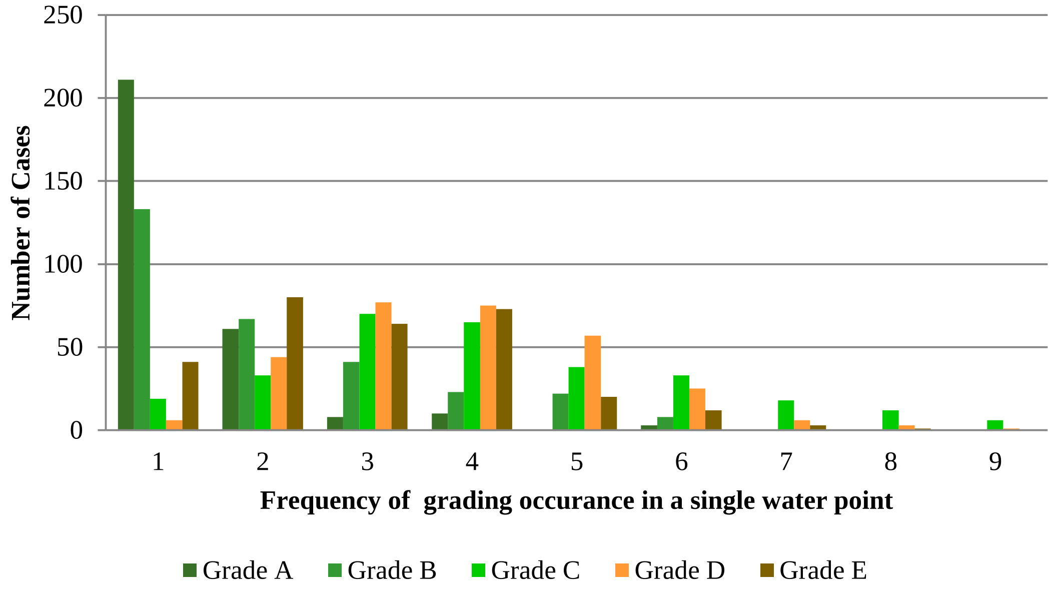


Figure 41: The frequency of modes of failure

The most common problems were found to be within the capacity of the community to resolve, with a tariff system, or less. Over 2,300 monitored indicators could have been resolved using local resources and skill (Figure 42). Successful local maintenance was found to be less likely if more extensive failure had not been addressed. For example a spillway would not be addressed if the well lining had collapsed.

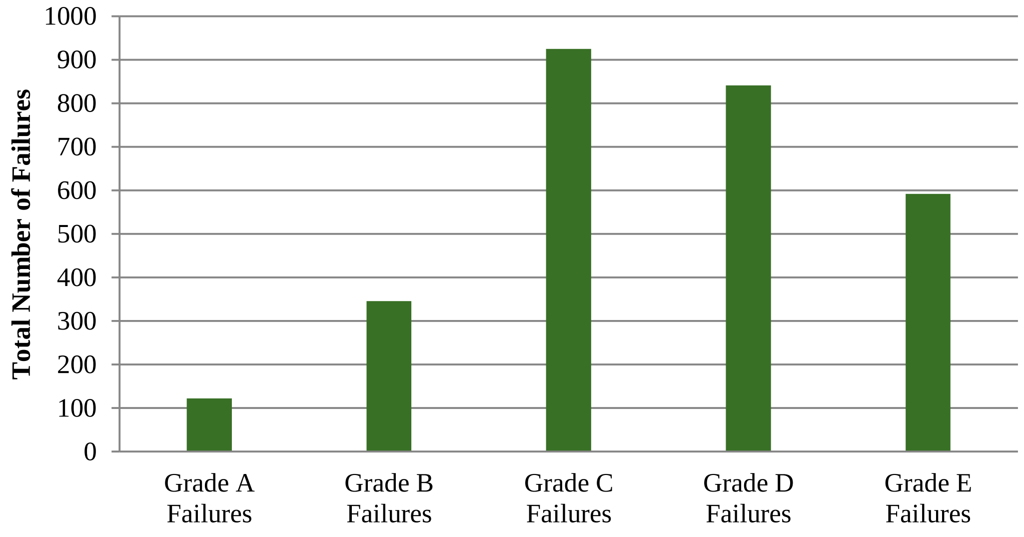


Figure 42: Total number of failures per grading

It was also noted that A Grade A or B failure does not necessarily suggest that the well was not be used regardless of its safety. A total of 52.8% of the Grade A and B classed wells were still in use at the time of the survey, but that maintenance in other areas, such as fencing or spillways, were usually not provided. This suggests that as the magnitude of the failures increase, the responsibility that the community feels to the continual upkeep of the source diminishes.

It was noted that the service delivery models used by the local government, such as SALWACO - who provided fourteen of the hand-pump water points covered in the survey, exhibited the same ratios of grades as the NGO provided systems. This remains only a small sample but it is consistent with the theory that the local government replicates the patterns of the NGOs in their models of service delivery. It also indicates that, through the sharing of technology transfer methodologies, they inherent the weaknesses of the NGOs delivery model.

The dates that the water points are constructed also provide an insight into the functionality of water supplies over time. It is important to note that this does not provide information on the year it failed. The results can be shown in (Figure 43)

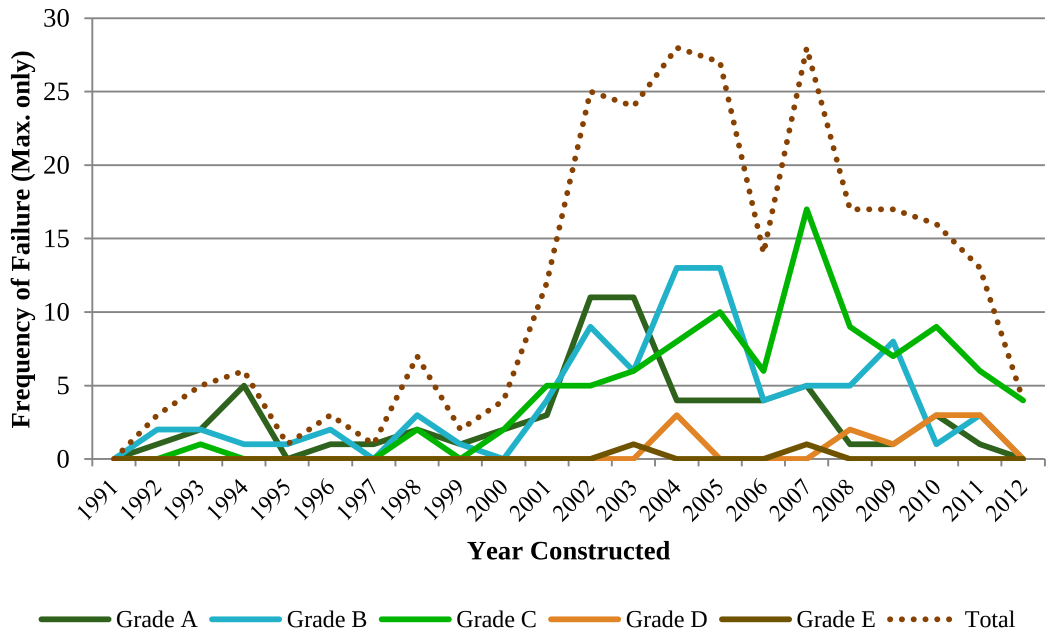


Figure 43: Maximum failure by date of year constructed

It can be observed that Grade A and B type failures were unlikely to occur immediately after construction. There were very few examples of newly constructed wells that develop serious issues. This addresses the problems in the STAT-Wash database – as it is not the non-functionality that is important immediately following construction, but the condition of the systems in their entirety.

The most important indicator of failure is the increase in Grade C classifications over time. This grading peaks after five years of construction (as is shown in the year 2007 in Figure 43). After this the probability of developing a Grade A or B classification becomes more common as the frequency of having a maximum grading of C slowly decreases. This indicates that there is a correlation between the different grading classifications. It also suggests that the probability of the water point developing a more serious technical issue increases over time. This is not unanticipated, as structural damage caused by minor and unaddressed components, such as hairline fractures, can become exacerbated over time, and therefore become more extreme in their failing. The grading system models this process, and therefore provides some form validation in describing the conditions of water supplies.

4.1.3.2 Results - Pulley Wells in Tonkolili

As the two types of well under evaluation are different they each have unique aspects that require consideration (Figure 44). An overview of the results of the pulleys can be found in Appendix L. There are several aspects of the pulley wells which require attention:

Pulley Well Lining: These well types were found throughout Tonkolili (Figure 44). The most common cause of failure (58.2% of the Grade A problems) in these well systems was the condition of the well lining. Several of these water points had used some form of cement block-work and stone lining to construct. These had either eroded or collapsed thereby limiting the success of the well. This resulted in dry sources with no yield at even the peak of the wet season for 12% of the pulleys and only marginal water yield for a further 31.3%.

Figure 44: Interior of pulley wells in Tonkolili

Pulley Windlass Systems: It would be biased to assess a pulley wells simply for not being a hand-pump well. The pulley systems were assessed with regards to the functionality of the pulley systems that they had installed. The functionality of the lifting system replaced the indicators for the hand-pump system. Only 15 of the 82 pulley well windlass systems (18%) were operational at the time of surveying. Most users used rope and bucket systems to withdraw water.

Spillways, Fences and Manholes: The most frequently observed problems were with the lesser technical components. The surveys on the pulleys suggest that 44.6% of the spillways were non-existent and 30.1% were severely damaged. Only 1.2% of the wells were found to have adequate fencing. It was also noted that in 25.3% of the sites there was no observed manhole cover on the wells. Without this component the well becomes an open and 'unimproved' source of water. Considering damaged manhole covers in this statistic the vast majority (64%) of the sources were shown to require, at a minimum, a new manhole cover for protection.

The pulley well systems were an attempt to provide a technical solution that conforms to a more ‘appropriate technology’ approach of SATT. The pulley wells systems could theoretically have proven successful – conforming to many of the development ideals. Low cost, easy to maintain, few moving parts and built using locally available labour the intervention achieves most of the goals of the appropriate technology movement. They are not fully ATT as, according to the STAT-Wash database, the same approaches and model of technology were found in a further 98 villages. These pulley well technologies were not adapted to suit local conditions in each village, as would be anticipated of a full ATT model; therefore they have a linear element to their distribution. The grading results have shown that this strategy did not result in positive gains and the vast majority of the systems were in irreparable condition.

4.1.3.3 Results - Hand-Pump Systems in Tonkolili

The hand-pump wells were responsible for a more complex array of failures and problems These pictures indicate Grade A failures in linings and being built below floodplanes (Figure 46). Others indicate complete hand pump systems with damaged linings and in severe damage to the well cover (Figure 46). An overview of the results of the hand-pump systems can be found in Appendix M. Some of the most important results are discussed briefly here:

Figure 45: Examples showing Grade A hand-pump well failures

Figure 46: Examples showing Grade B hand-pump well failures

Lining and the Well Cover: The most significant contribution to the failures was from the lining. Unlike the pulley wells there were few examples of stone lined systems. All the sources had originally used concrete linings and cassion rings. A small minority of these (4.3%) had since developed serious problems and collapsed. A further 26 wells (12.3%) had developed serious problems with one or more cassions. These contributed to 29% of the Grade A problems and 24.3% of the Grade B. The well cover was also a significant contributor to the well problems with 2.8% having serious problems, and 5.2% having significant failure.

Handpumps: A total of 53 (25.1%) of the handpumps were noted to have problems that would require them to be replaced (severe erosion or missing hand-pump). A further 19 (9%) required individual parts to be replaced.

Pipes: Several water lifting systems were in immediate need of attention 29 (13.7%) lifting technologies, including all the required technical components, required replacing. Thirty of the piping systems required several parts to be replaced, usually the result of rusting on the pipes, potentially caused by iron in the groundwater.

Location: Nine locations for the water points (4.3%) were deemed to be too close to permanent high risk structures, including latrines and livestock shed. This was a very small minority, and it is difficult to assess whether the other structures were placed post-construction of the water point.

Water availability: Seasonal problems were common with the hand-dug wells. Eleven (5.2%) of the water points had shortages that extended beyond the dry season. A further 20.5% of the water points experienced some form of seasonal shortages limiting supply for up to three months. There were two examples of wells that never had any water, because of problems during the sinking of the well, but were capped regardless.

Security: A total of 48 (22.7%) water points were noted to have a concrete security cover sealing the hand-pump in place. This indicates that the practice is not an infrequent occurrence. The majority of sources (71.6%) did not have any form of protection to reduce theft. Twelve of the total wells had some form of security to safe guard the well.

In technical terms the provision of hand-pump wells fared better than their pulley counterparts. The choices of water lifting technologies were clearly pre-determined by the organisations. Similarly the blueprint for the entire systems was also similar for each organisation. Many of these solutions incorporated local fencing and labour – while the majority had some form of social support mechanism such as Water User Committees (WUC). Therefore the synergy between LTT and ATT approaches were more balanced in the hand-pump systems. This offers a complete demonstration of the Synergetic Approach to Technology Transfer. The technical problems have not been as severe as those of the pulley wells systems but there are many examples of poor engineering practice in design and construction methods as well as the technical sustainability of the solutions.

4.1.4 Technical Summary of Water Supplies in Tonkolili

The variety of different technical categories identified, the intermediate nature of failures that has occurred at each source, and the range of graded problems has justified the use of multiple indicators and a quantitative grading system for evaluating the water supplies. The variation of failures were spread over the entire geographical area in Tonkolili (Figure 47)

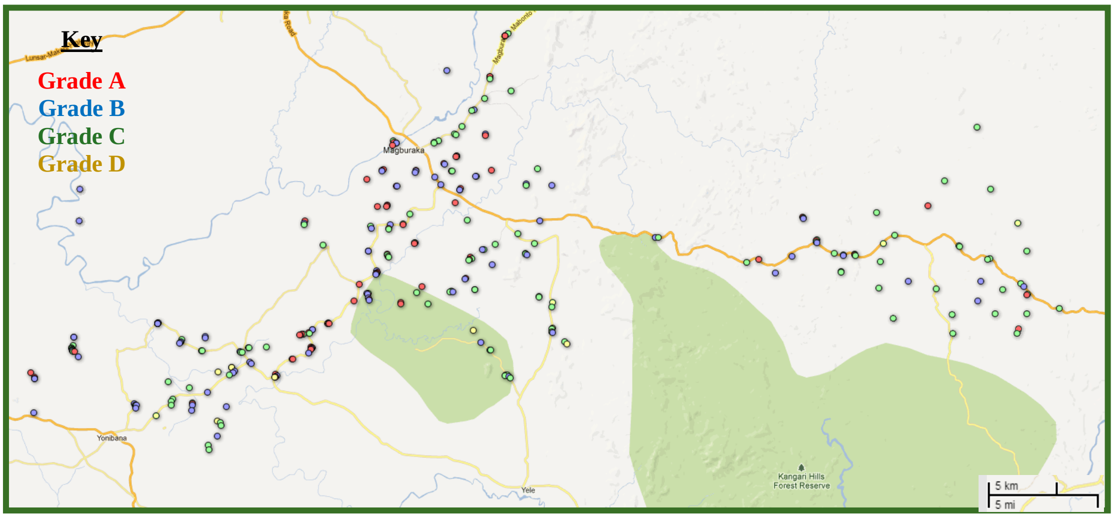


Figure 47: Spread of different well grading of water-points in Tonkolili District

The conclusion drawn from the site visits indicate that Tonkolili water supply systems are in a state of disarray, with extreme, severe and significant failures common throughout the chiefdoms. The pulley well systems were a considerably poor technical choice for Sierra Leone, and the communities have clearly not responded positively to the intervention. These systems have indicated that attempting to scale an appropriate technology over a broad geographical region cannot be applied linearly.

Technical water supply issues are common in water schemes found throughout rural Tonkolili. Though the Grade A and B failures indicate a poor level of engineering practices, as well as an indication of the technical capacities of the implementing agencies, there are further implications for the water supply sector. That such conditions were frequent indicate that there are poor feedback mechanisms between the implementing agencies and their beneficiaries. It also suggests that there is poor use of internal regulation and monitoring by NGOs, little quality control over services, and there has been a lack of accountability for the spending of certain donor resources. The misconceptions, or underestimations of functionality, partly caused by the inadequate monitoring, have supported the incorrect assumption that these technologies are providing sustainable access to water for the communities.

4.1.5 Discussions of the Technical Conclusions with Engineers

During the investigation of the water points development engineers were asked explicitly for their reasoning on the lack of sustainability of water supplies. The purpose of these discussions was to determine their reasons to why such failure had occurred and if it affected their own countries of practice. In these discussions the initial focus of the responses to 'why' was usually on the failings of the technologies themselves:

> *"The symptom of source failure may be due to a poorly functioning technology, the inability of the community to perform routine maintenance, a problem with the initial water point or a lack of local water resources"*

> *"[There is a] lack of professionalism and quality control in the drilling and hand-pump supply sector, which leads to poor workmanship and little comeback for the end user for non-functioning services"*

Discussing the findings of the research placements in Sierra Leone did not result in shock from any of the interviewees. It was in this area specifically where confidentiality had to be maintained. Many responses indicated that engineers had either worked on projects that had similar limitations or that they had previously witnessed poor quality engineering work. Some stories surpassed the case study presented here in presenting shocking and disturbing technical problems. Certain engineers explained stories where the impact of failure (*i.e.*, outbreaks of illness or death) were known and linked directly to an engineering intervention.

Some of the most experienced field engineers immediately recognised the broader scope of the problems and the context upon which theses technical constructs are supposed to remain sustainable:

> *"Digging deeper there may be many secondary reasons: inappropriate technology used, a lack of proper investigations when setting a water point, climate or land use change, a lack of community involvement, or an unsuitable water management structure imposed. Again there may be many plausible reasons why this culture developed, leading back to donor priorities and government policies."*

The management practices of NGOs and their relationship with the donors, particularly the scheduling of funding cycles, was also often raised.

> *"[There is a] lack of good writing, data management and documentation also inhibits learning and growth. The reporting that does exist tends to be donor-focused, donor-driven and inevitably biased towards only reporting successes and focusing on narrow metrics, such as beneficiaries – and this can often lead to perverse incentives that undermine long term sustainability of WASH services"*

The discussions were always inconclusive to providing an exact cause for failure with one engineer stating that *"any attempt to ascribe simple answers is at best naive"*. The complexity was seen in the range of responses: weak economies, corruption, lack of life cycle costing knowledge, highly dispersed populations, weak communications and transport infrastructure, weak local and national government capacities and difficulties in supplying, monitoring and enforcing WASH service provision.

Though a counter-strategy for responding to these problems highlighted in this chapter would be to provide a higher quality of service delivery, and adopt a minimum engineering standard towards water points, there is more to the problems witnessed in Sierra Leone than the poor designs of water point infrastructure. As one engineer stated:

> *"The issue may be more than simply the quality of the work but also how the work is done and the perception and efficacy of the development nexus on a broader assessment."*

The responses of the engineers indicated that there was a tendency to focus the roots of these problems on the weaknesses of 'top-down' and macro-level approaches. Whereas it is undoubted that there are issues with governance, population disparities and the economy of Sierra Leone, such a top-down emphasis on research is not the only method of investigating the issues. The distributed nature of the failure encountered indicated that there are individual, micro and cumulative interactions of the host communities that may have perhaps the most significant roles in the problems that have occurred.

The grading system has revealed the possibility that there is a direct correlation between the actions, or inactions, of the communities and the technical failures witnessed. Therefore the inability, incapacity or unwillingness of the host communities to repair the water supply sources has indicated a serious cause for concern. This lack of sustainability has not been anticipated in the design of the water supply projects. Therefore the social elements of these artefacts were also explored to understand the extent of their involvement in the technical failings.

CHAPTER 4: RESULTS AND DISCUSSIONS

Part 2: The Social Support Mechanisms

4.2.1 Introduction

4.2.1.1 The Sustainability Mechanisms

Hand-pump water supply systems, and to some extent the pulley wells, given their fundamental technical properties, are unable to attain any order of sustainability without some form of external support (Skinner, 2003). Even though technical maintenance can offer one aspect of attention for the social support mechanisms there are a host of other communal issues that require internal management. This is so that the source can provide equitable and safe access to the villages (Harvey and Reed, 2004). This is not a new concept, as the practice of the NGOs creating support mechanisms within the community structures has been developed over years of implementation (DFID, 1999; IRC, 2003). The success of these social support mechanisms is a fundamental aspect of the Synergetic Approach to Technology Transfer. Regarding their technical capacities, the social mechanisms are intended to provide an "enabling environment" for the water supplies that will allow them to be continually operated without the constant need for external technical assistance. The developments in hand-pump technologies since the UN Water Decade allowed for many innovations in water supply technologies that could be maintained at the village level (as indicated in the previous chapter). There are many types of social support systems that were created during these decades that were intended to provide sustainability to a water supply source (Bendahmane, 1993).

This chapter will address three of the most common social support elements that were found to be implemented or trained by NGOs operating in Tonkolili:

1. Water User Committees (WUC)
2. Hand-pump technicians
3. Spare part supply chains

It has already been defined in the previous section (see Chapter 4: Part 1) that 83.6% of the technical problems could, or should, have been resolved locally, assuming the support mechanisms were functional and operating as expected. Therefore the scale of the problems witnessed in Tonkolili suggests that there are considerable issues with either one, or all, of the social supporting roles.

This chapter will make explicit reference to the results of the Focus Group Discussions. The full transcripts, which have been categorised by thematic topics, can be found in Appendix H, I and J. As there are too many individual points to explicitly reference then only quotes that were taken directly from the meetings will be stated in detail. Other references will use a square bracket coding denoting the location, FGD and gender of participants. The index list of the corresponding village information can be found in Appendix G.

4.2.2 The Water User Committees

4.2.2.1 Introduction

Water User Committees (WUCs) are found to be operational in Sierra Leone under different names – from "stakeholder committees" to "water management groups". These names sometimes indicate slightly different objectives and their formational structure can be dependent on the organisations that trained them. For example, some groups had technical maintenance staff as part of their committees, while others operated independently. Regardless of their given names, the resulting groups should display similar functions with regards to the sustainability, safety and continued access to water supplies for their communities. The term "Water User Committees" in this study will act as an umbrella name for all the community decision making groups which were found at each water source in Tonkolili.

The creation of water management groups have become an established practice in water supply interventions since the promotion of community participation in the 1980's (IRC, 2003). Prior to this period many of the water systems were found to be "supply driven" and were managed by government institutions (Harvey and Reed, 2006a). The low rate of rural water coverage prior to the 1980's is an indication of the limited capacities, motivations and commitments of the local governments. The decentralisation of Operation and Maintenance (O&M) allowed the governments to give, or potentially, shift, responsibility of the sources to the communities themselves (Harvey and Reed, 2006a).

The community surveys in Tonkolili indicated that there were established committees at the majority (94%) of the villages interviewed. This was even true with regards to water points that had failed in their first year of service, as well as those that had remained non-functional for long durations. Each user committees were found to differ in their formations function, size, gender distribution, capacities and motivation. The WUC normally oversaw a number of water points in their village and some of their powers extended beyond the water points into other areas of water collection. In many cases the selection process for WUC members included people that were already part of the village decision making processes and hierarchies. The WUCs were also found to be independent for different project types, such as school, health clinic and community wells. The majority of WUCs were formed to fulfil specific objectives – these were found to be as follows:

- ***(A) Ownership:*** The committees are usually established at the conception of the project . Initially they are responsible for determining, on behalf of the community, the location of the project sites (Smet and Wijk, 2002). They are also expected to provide certain initial costs. This occasionally includes monetary support, but in-kind contributions, such as accommodation and food for technicians and the provision of local materials, were found to be the most common involvement. After the construction of the well systems they are formally handed over to the communities, the WUC are there to take responsibility of the system (Arlosoroff et al., 1987; Schouten and Moriarty, 2003). This involves making any of the important decisions concerning the water sources in maintenance, upgrading, enhancing or even abandoning the source.

- ***(B) Community Access*****:** Given the ethics of development, the water supply systems that are provided by the international donor community are intended and expected to be available to all in the villages (Harvey and Reed, 2006a). The WUC is responsible for ensuring that all members have continued access to the sources. In times of water scarcity the WUC are also responsible for the development and usage of water management plans. This will involve locking sources to ensure proper recharge of the supplies. This will limit community access for shorter periods.

- ***(C) Operational Management:*** This covers all aspect of community management for the operation of the systems; this includes setting up and enforcing community by-laws, it also includes the creation and enforcement of tariffs schemes (Harold and Stef, 2011; Harvey and Reed, 2004). The management of the water points also involves working with the community to provide members for any unskilled labour which includes: the cleaning of well areas, headwalls, hand-pumps as well as the unblocking of spillways and well aprons. Depending on the community training, the WUC committees may also be responsible for the chlorination of water points. This task is sometimes shared by the technicians; however the WUC is usually responsible for ensuring that these tasks are carried out. The WUC should also be responsible for ensuring that fencing is always in place (Brikké and Bredero, 2003). This involves the use of local labour for the provision of local materials (usually bush-poles or bamboo). The fencing is required to be non-porous, gated and protected from domestic animals, such as dogs, goats, pigs and ducks.

- ***(D) Financial Management:*** There are several aspects of water point sustainability that require financial management from the communities. These include the collection and monitoring of funds from tariff systems and the fines that are taken from violation of by-laws. The WUCs are responsible for ensuring that there are sufficient funds to pay for the upkeep and repair of the system (McCommon et al., 1990; Schouten and Moriarty, 2003). For accountability and transparency the WUC should have sufficient backdated accounts of any money that is taken and any transfers that are made. Though the WUC would not be responsible for the maintenance activities themselves, they have a responsibility for bringing any mechanical issues to the attention of the technicians. Financing of any problems and ensuring the fund-raising capacity for any additional monetary resources which exceed collected tariff amounts should be their primary responsibility (McCommon et al., 1990). They are also responsible for the safe storage of any spare parts and tools which are required for the maintenance of the systems.

- ***(E) Local Government Contact:*** The committees are, in many cases, designed to act as an advocacy group to their local government agencies - as they are supposedly responsible for their countries rural water supply. This communication should, theoretically, reduce the village's dependency on the international NGOs. In Sierra Leone, after the Local Government Act (2004), the responsibility of water supplies in the rural areas was devolved to local councils. They are supposed to be assisted by SALWACO (Sierra Leone Water Company), which was previously responsible for water supply in the whole of Sierra Leone. Water and Sanitation is regulated at the local level through the District Health and Management Team (DHMT) that are established to deal with health issues.

- ***(F) Hygiene Promotion:*** Water User Committees are usually developed as part of a holistic health response in the rural villages. Therefore the same committees are sometimes used to provide health and hygiene promotion activities in the communities. The training, when provided, can govern all aspects of water such as: use, collection, transport, storage and consumption. The WUC should also be responsible for providing community education on areas such as: water borne diseases and vectors, risks related to contaminated sources, transmission routes and the safe and proper use of hand-washing facilities. Some of the committees have a shared involvement with other health initiatives, depending on their core functions.

These seven attributes are known by the communities and can be stated by the WUC groups. The cholera outbreak in Sierra Leone resulted in many NGOs asking the WUC's to restate their roles and responsibilities towards water and sanitation in the villages. Many of these results were posted on the walls of the villages as a reminder of the communities of their function and commitments (Figure 48).

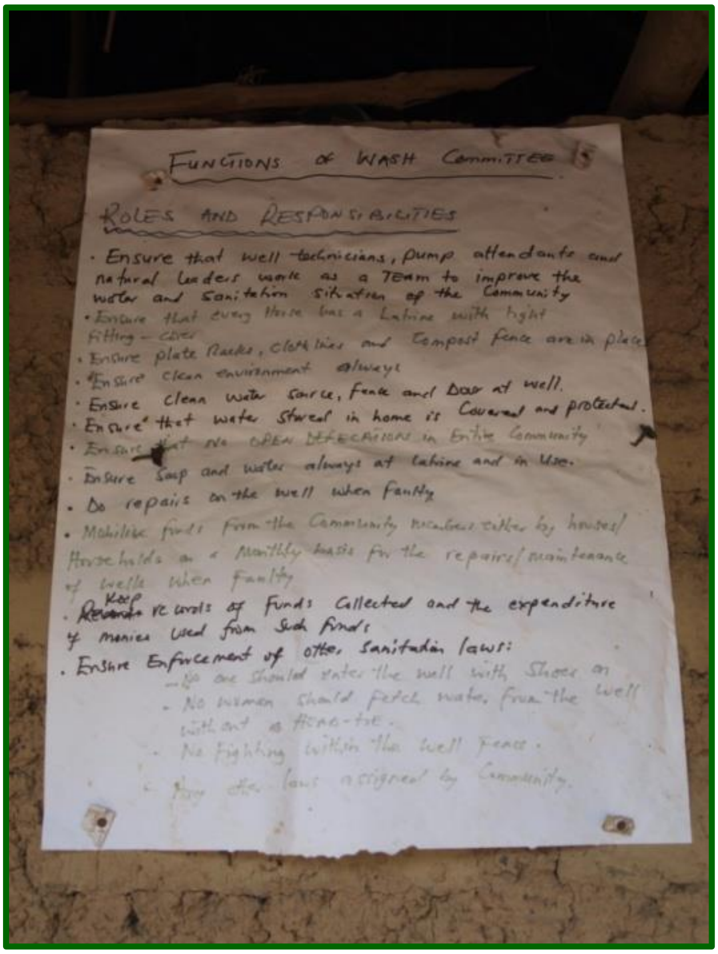


Figure 48: Example of the declaration of the responsibilities - Bonkababy

4.2.2.2 Formation of the Water User Committees in Tonkolili

The Focus Group Discussions (FGDs) were carried out as explained in the methodology and were complimented by the communal surveys of the 150 villages (Chapter 2). Of the 150 villages surveyed, 141 had user committees. The reasons for not having a committee depended on certain local situations. Some water sources were old and therefore the committees had not functioned for a long time, some systems had failed and their committees did too, and some LTT projects never appointed or trained a committee. The size and gender distribution of committee members varied. It was found that the average number of male committee members was 5.35 (with a median of 4) people and the female average was 4.42 (a median of 3) people. The largest observed committee had 40 individuals. There appears to be no correlation between the number of wells (working or non-working) and the size of committees. As they are essentially volunteers this should not matter, though it is likely that the number of members could add levels of bureaucracy to the proceedings that are not necessary.

Most of the eighty two committee members interviewed as part of the fourteen FGD, both male and female, were reported to be older than thirty years of age. The female members were older, averaging forty-two years, while the men averaged thirty-eight years. Only five of the committee members interviewed were under the age of twenty-five. The youth were found to have a disproportionate representation within the committees, given their numbers in the villages, as well as their demographic size (see Chapter 2). The ages of the committee members were found to be important given the attitudes towards the water supplies that were found in the interviews.

Committee positions were selected and appointed by the community. In the majority of cases these positions were held until the person moved to another village, became too old, or died. Many of the committees had an option for voting out someone that does "not work" on the upkeep of the water supplies. The committees' opinion of someone that is "not working" is unclear. During the FGDs it was asked of the committee members to state their roles and responsibilities with regards to their hand-dug well. Based on the committees stated tasks that they were elected to achieve, and compared to the list of unresolved issues with the systems (see previous chapter), it should be expected that at least one individual should have been declared as "not working" on the committee. None of the committees suggested that the reasons for the number of Grade C failures being so commonplace were because of anyone on the committee "not working". The only noted case of village members replacing individuals in community positions was in the case of Kumrabai Station, where the previous committee members were accused of stealing money from the tariff system. However, failures to carry out their duties, with regards to the committees" self-proclaimed roles and responsibilities, were clearly not sufficient for a member to lose their positions on the executive board.

4.2.2.3 The Focus Group Discussions with the Water User Committees

The most distinct trend when meeting with the committees was their general apathy towards their water supplies. They were notably subdued when questions were presented concerning any aspect of their sources. There was a clear distinction between pre-interview discussions, which usually involved animated talks about superficial issues (such as the current success of a football team in the English Premier League) and the demure attitude to their water supplies. Additionally other cultural and social interests received more animated responses, such as discussions on land tenure for women, or local political issues, rather than discussion on their on-going and clearly visible water problems. The lack of emotive responses was particularly acute with the female committees. It was theorised during the FGDs that this might be interviewer bias because of gender. The format of the FGDs was changed so that different communities groups were interviewed by a different gender of interviewees. This had no noticeable impact on the results and the women remained unanimated regardless. The committees that had working sources displayed very little pride in their systems. No references were ever made to the successes or failures of water points of other villages in the region. Certain water supply issues were continually raised during the course of the interviews, but the interviewees did not appear overly enthusiastic or concerned about the technical issues, with the implications that their condition was a concern for NGOs and Governments, and usually the implementing agency that built the supplies.

This general lack of interest in the topic was also observed from the randomly selected Villager Water Users (VWU) that participated in the FGDs. These FGD participants did not appear to have any measurable expectations for the running of the WUCs. Additionally, there were no individuals or groups that expressed disappointment or frustration about the functioning of the WUCs, nor any suggestions of improvements to the practices of the committees.

4.2.2.4 The Water User Committees and their Functional Abilities

Six of the core attributes of the WUCs will be discussed in more detail – as they are linked to the sustainability of the technologies and are therefore crucial to understanding engineering in development. The seventh element (F) relates to hygiene promotion, and though fundamental to the on-going success of the technical intervention, does not directly affect the sustainability of the artefact.

(A) Community Ownership of the Water Supplies

The location of the water sources was rarely raised as an issue in the community discussions. However having a surveyed response which determines the satisfaction of each household with regards to the wells location, particularly many years after implementation, is difficult. Maintaining community access to the water point is of more important note. For example in Mayatha, it was noted that community members on the periphery of the village were excluded from using the improved source because they had an on-going dispute with the chief, and the well system was regarded as being his property. This may not be an uncommon practice, but remains difficult to trace in the FGD or communal surveys as these were normally carried out by speaking directly to the community spokesperson. These would very often be the chiefs or village elders, or within the hearing range of senior community members. This aspect will be discussed with regards to the socio-cultural systems in Sierra Leone in the following chapters.

Figure 49: The locked and controlled well - Mayatha

There are a number of factors to consider when defining the communities expressions of ownership regarding their hand-dug well. The most straightforward method is to discuss directly with the community about whether they feel as though they own the source. The community surveys explored this explicit understanding of ownership. All of the communities thought that the well systems were their property. However, the numbers were drastically different when questions were asked about whose responsibility it was to alter or modify the well. The majority (60%) thought that this was the remit of the NGOs and 37% thought it was the Government's responsibility. Only 3% believed the chiefs and elders, and the community itself, had any responsibility in this regard.

There are also indirect methods for monitoring the communities' feelings of ownership. The communities care and attention, or neglect, can be monitored by the observable conditions of the systems. The interviewed WUCs repeatedly stated, in all the FGDs, that their responsibilities included fencing the systems, unblocking spillways and ensuring that the headwall, apron and well walls were kept clean. All of these responsibilities require little or no monetary or technical support, and can be achieved by an individual or by mobilising community members.

The lack of fencing was the most clearly visible problems with the systems. Of the 292 wells that were observed 64.7% had no fence. 8.2% of the fences would not keep out a goat or pig - and was therefore either in a state of disrepair or poorly constructed. A further 16.5% were missing a gate to protect the systems. This is important because some of the fencing is permanent, normally concrete or mud brickwork surrounding the wells. It would normally be provided as part of the system by the constructing agency. Therefore this would only require a gate to make them fully safe from domestic animals. Of all the observed sources only 5.48% of the fences were adequately provided. It is noted that some of these villages provided not only excellent fencing, but ones that integrated cultural techniques in their manufacturing processes. Unfortunately these were rare and were an exception and not the rule. Most of the fences that were regarded as being satisfactory were provided as part of the well system. The most significant response came from participants in the Matukuto 2 focus group. The site visit clearly demonstrated they had the materials to make a fence (Figure 50). The male committee stated that they had *"not built the fence because the wells will not be repaired otherwise"* [MTU/M/6]. They had purposely agreed, by consensus of all those on the male committee, to neglect their duties with regards to the fencing. Their strategy for doing so was that the NGOs in the area would only assist them if the condition of the well looked sufficiently bad. As they felt that they were without a legitimate channel for support this was decided as a viable option.

Figure 50: The missing fence - Matukutu 2

The interviewed water users randomly selected in Matukuto 2 offered no objections to the practices of the WUC in this regard. This is disturbing for four reasons;

1. The committees are actually increasing risk taking behaviour, because though their hand-pump was not-functioning, their systems were still in use,
2. It shows that the committees are actively engaged in manipulation of their sources in order to illicit a response from NGOs,
3. This action demonstrates a worrying state of dependency and corresponding lack of ownership of the solutions by the community
4. The results also show that the committees can neglect their duties at will, without any issues being raised by the communities.

The strategy and approach taken in Matutuko 2 can be argued to have worked, as a major NGO repaired the system in the following months, whereas others that have been maintained have not received the same attention. The same precedent for the WUC not fulfilling their duties can be found in both the activities of unblocking of spillways and the cleaning of the wells (Figure 51).

(A)  (B) 

Figure 51: Some examples of dirty wells systems (A) Matuku, (B) Mathinka Bana

It is difficult to assess if a water point has been regularly cleaned, as not all problems are clearly observable and certain water points do not have build-up of lime scale, animal defecation or algae growth. There were many blatant examples of systems that are unhygienic. It was noted that 68.1% of the well systems were classed as unclean because of some observable source of dirt found at the water points. These were only noted if there were considerable unhygienic conditions (Figure 51). This included the largest component of the well, the well apron (39.1% of the total wells), the drainage area (22.8%) and the well wall (19.7%). It is also noted that many of the spillways are blocked (24.5%); this differs from having a damaged spillway, as it does not require construction activities, but labour intensive cleaning.

(B) Community Access

The Water User Committee are supposed to, theoretically, ensure that every person in the village has equal access to the water sources. The majority of the 150 villages surveyed were said to be controlled by the chief and village elders (66.7%). The committees were said to control the source in only 14.7% of the cases. An additional 15.3% of the sources were said to be controlled by an individual, though this number usually included people which sat on the committee boards, such as chairpersons and youth leaders. Only 1.3% of the villages felt as though the community itself controlled the sources.

The FGDs included questions on “undesirables” or people that are intentionally prevented from using the sources for whatever reasons. Examples included small children, old people, the blind and anyone that is sick. The WUC defended and justified their actions in this regard mainly through health and safety reasons, either for the individual using the source, or for other users that might be harmed by the undesirable person’s presence. Exhibiting community spirit, some villages indicated that the community provide water on behalf of those not deemed capable of using the sources. When probed deeper, particularly regarding water collection of an old person, there was no definitive answer on *"how old?"* or *"what if the person wants to get the water for themselves?"* which suggests that the decisions are made in a case by case basis in each scenario. There was sufficient evidence to suggest that the WUC felt it was in their power to restrict access to certain members of the community.

The power over sources is only a considerable threat when individual community members take exception to an individual that has a problem which is not clearly understood by those who control the sources. The most notable example in Sub-Saharan Africa is the role of HIV/AIDS. Though HIV/AIDS are not reported to be as prevalent in Sierra Leone as it is in other parts of Sub-Saharan Africa, there are still 63,000 people, estimated to be between the ages of 15-49, that suffer from the illness (UNAIDS, 2012). Each of the FGDs surveyed communities was asked if they would allow a person with HIV/AIDS to use the source. Most would reply that they *"do not know anyone with HIV/AIDS"*. When they were asked what they would do if they knew someone that did, then the answer was to restrict this person from using the sources. Reasons for this were numerous and varied, from the rational *"people with HIV are sick, are more likely to have diarrhoea, and shouldn't be fetching water"* [MTB/F/12] to the irrational *"people with HIV spit and this spreads the disease"* [MAG/M/4]. The majority (97%) would restrict a person with HIV/AIDS from using the sources. The 3% that would not restrict water access had been recently sensitised on HIV/AIDS issues by their NGO. There were positive case studies such as in Mamanso Khafla where they stated that *"[we] are aware that people with HIV/AIDS must not be stopped from using the water"* The training received by those in Mamanso Khafla was not only provided to this village, and the same response should have been given in the surrounding villages. There is therefore either a noted disconnect between the training provided for the WUC and those for HIV/AIDS practices, or the communities that have been sensitised about HIV/AIDS are wilfully ignoring their education in this regard. Fully understanding that the communities relationship to HIV/AIDS is out-with the scope of this research, but it is important to note that sources of water can be used assert bias. This is a crucial aspect discussed in the following chapters.

Sierra Leone has a high religious tolerance and a syncretic belief structure (see Chapter 2). There were no noted cases of people being isolated or ostracised from a water supply because of adhering to one of the mainstream religions in the country. The secret societies present a different obstacle, though these are not normally regarded as religions entities, but rather as cultural institutions. All of the interviewed villages would restrict a "practising" society member from using their sources. Though most of the individuals in the communities are society members, it was established that society members can be either practising or non-practising at different periods. Particular reference was made to "sowes" practicing members of the female Bundu society. In Matukuto there were specific names given for Poro and Bundu society members that were refused access. These included "sowes", "sokos" and "mircles". The individuals in the communities that were "practicing" were known by name, and refused access. It was also noted in Magbeseh 2 that the village appeared to be actively aggressive against certain secret society's practices. They fully restricted certain society member types from using their water sources. This suggests that participation in these solidities is not harmonious and there are internal politics influencing different practices. It may also suggest that certain internal elements of the societies may compete against each other (such as the different Poro, Wunde, Gbangbani male societies). As discussed in Chapter 2, the rules and regulations of the Secret Societies prohibit the true nature of what is happening being easily discerned.

There is sufficient evidence to suggest that the water points are an active artefact in internal village disputes, and the WUC provides a role in restricting access to certain individuals for both social and cultural reasons. It is also clear that they can be used to reinforce entrenched biases. The nature of these restrictions cannot be ignored and will have an important impact on the socio-cultural activities of the engineers.

(C) Operational Management

To manage the operation of the water scheme the WUCs would require, at the very least, regular meetings. The communal surveys indicated that the majority of the meetings took place monthly (30.7%) and also between 1-3 months (18.8%). A quarter of those asked about their meetings times suggested that they would only meet to discuss the water points when they required repair (25%). There were also those that claimed to meet weekly (9.3%). Probing the weekly meetings further revealed that water, hygiene and sanitations aspects were included as part of normal community meetings, rather than their water systems being an area of discussion in itself. This probing was prompted by village spokespersons that said they met as regularly as once per week, but their village wells had clearly not been functioning in many years, which made it unclear as to which aspects of their water points they were discussing. This suggested the water supply was only one of many topics that the village committees dealt with, and was an extension of their existing powers. The remaining committees had not met in six months (4.3%), not met in a year (7.9%) or had never met before (2.1%).

An established practice for the Water User Committees in Sierra Leone is to create by-laws for their water supply systems. Theoretically this is to ensure that the system is properly operated and treated by users. It is the responsibility of committees to establish the regulations and these are normally based on community inputs. The by-laws are theoretically supposed to keep order at the sources while also providing an income for on-going operation and maintenance schemes. This monetary collection is independent of the tariff schemes - which will be discussed later in this chapter. The amount charged by the committee on community members is dependent on an agreed fee, which in all cases is made by community consensus. This scheme may possibly work in Sierra Leone's densely populated urban areas, given its observable widespread popularity at highly contested sources in the slums in Freetown. In a rural setting the results are suggested to be much less effective. The focus groups were able to name several of their by-laws. The majority of the groups had certain by-laws in common: *"no children under five using the source"*, *"no woman to use the source with untied hair"*,*" no using the source out of hours", "no shoes to be worn at the source"*, *"no quarrelling at the well"* and *"no skipping queues"*. Additional, more unconventional, rules included *"no sweating"* [FER/M/1], *"no people with HIV"* [KUM/M/2],*"no spitting"* [MAG/M/4], *"no dirty containers or rope"* [MAM/M/7]. The sizes of fines were usually around 1000-2000le (~12-20 pence). Additional punishment included confiscating the water container until the owner paid the fines. Only Matukuto 2 reported having made financial savings from the fines. This amounted to 30,000le (£4.60) over several years, and was given to the WUC treasurer; however there were no records of where, when or why the fines were levied. None of the villages had any fixed notice of the by-laws and fines, either written on a formal document, or displayed in a public place. The committee of Mamilagbla claimed that there results were at one point written down, but they were later destroyed in a fire.

The interview in Mathinka Bana demonstrated the ineffectiveness of their monitoring of their regulations. It also presented a case study which contradicted the stated aims of their by-laws. Their regulations stated that people using the water points should have their hair tied back and should not wear shoes at the source. They also claimed that having children at the sources was prohibited. The wording of these by-laws was confirmed by all of the committee members present. During the course of the interviews with the male committee members several women, with untied hair, wearing their shoes and accompanied by small children, proceeded to use the water source. This was done in a clear line of sight of the location where the discussion groups were talking. Though there was a general feeling embarrassment, it was abundantly clear that in Mathinka Bana the by-laws were known, but not observed, by regular well users. The fines were not an enforced practice.

Kumrabai Junction had a system of fining those that did not provide labour for the wells. This included a heavy fine of 5000le (£1.30) for those found not to be working on the fencing or on cleaning and weeding at the sources. Given the unclean and unfenced condition of the wells both at the time of the interviews, and in repeated visits over the next five months, it was clear that there was no enforcement of these fines. The pattern of observing individuals that transgressed the most common bylaws was repeated at almost every visited source, which presented enough evidence to suggest that they are not strictly adhered to, or respected, by individual households in the communities.

(D) Financial Management

During the surveys it was found that unless fines are large enough or levied often enough, the by-laws are ultimately a very weak method of collecting resources for the maintenance of the water point. In Ferry Junction it was decided by the WUC that the village borehole would have its repair costs covered by fines from the by-laws. After three years the committee reported that they had taken a total of 2000le (~20 pence) in fines. This amounts to two offences, and the amount collected could not repair even the most marginal of technical problems at their source. Instead the most successful committees raised funds for repairs from collecting household tariffs. The FGD indicated that many of the communities had, at some stage, a collection scheme however, the majority were not successful.

The reasons for halting a functioning tariff system varied between communities. In Kumrabai Junction there was a reported total of 60,000le (~£9.25) collected by each household at 500le (~8 pence) per month. This money was then stolen by those responsible for the collection. However, with roughly thirty households in the village, the resources could have been only collected for no more than four months. Kumrabai station collected for longer, for three years, though in smaller increments of 300le. This money was also reported to be stolen by the chairman. The system was also abandoned after the incident. In Mathinkabana they started a tariff system in 2004, again it only operated for three months before the collection stopped. In this time it had collected 25,000le (~£3.85). Though money was not stolen in this instance the threat of corruption, or someone *"eating the money"* [MTB/M/5] - the Krio expression most readily used to explain fraud, was allegedly enough to stop people paying. It was found that there was little community trust about these shared resources. Magbontho's tariff system was reported as being "not currently collected". Both of their wells were reported to have been provided in 2001 and yet the reported total that was collected in over ten years was little more than 30,000le (~$4.60). At the time of the discussions they had not collected in eight months. Mamillagbla originally attempted to collect 1000le (~16 pence) per household per month; though the system stopped working and they no longer collect the money.

Matukuto 2's situation was more complex. The amount that was previously collected was 500le (~8 pence) per household per month. Local disputes over payments resulted in only those with immediate proximity to the well paying for the system. They had originally attempted to charge every household but there were disagreements, with those of the peripheries of the village preferring to collect from closer, unimproved, water sources rather than pay to use the communal systems. A naturally occurring technical problem with the pipes resulted in the system being abandoned by the entire village. Money that was collected prior to this time was given to the technicians to address a problem with the pipes. New pipes were bought, but they were not long enough. The technicians requested more resources, but the village lost confidence in them and the tariff system was abandoned.

The community survey research in the 150 villages indicated the same patterns as the FGDs. The tariff systems were normally collected at a household level. The average tariff for the 150 villages surveyed was 1250 le (~19 pence), with the mode and median both being 500le (~8 pence). The updated survey inquired, in more depth, about the frequency of collections. There were 40 villages that claimed to have a tariff system. Those that collected regularly every month constituted only 32.5% of those surveyed. A small percentage (5%) collected but it was either irregular, or did not include all the households in the village. The largest majority (62.5%) had a tariff system, but did not currently collect.

The impact of the amounts collected by the average village requires perspective. The money is required to provide maintenance capacities at a local level. Applying the standards (Sphere, 2011) which many international NGOs and government agencies use as guidelines then there should be no more than 250 people per source. Larger villages should, ideally, have multiple systems. Combining the Sphere standards with information gathered in the household surveys, which indicated that each household had 13 people, indicates that each water point should be supported by 19 households. The technical grading system (see the previous chapter) has already demonstrated that the failure of systems can vary in scale. It was established that Grade C failure should ideally be “on replaceable parts” for which costs the community is expected to cover. Grade A and B technical failure should result in cost comparable to the replacement of the entire systems and is not included in this discussion. With Grade C failure a common problem is the replacement of the pump technology. The average price of an India MK II (the most popular pump) in Freetown is 2.5 million Leones (~£365). At current rates of collection the 19 households would have to collect, uninterrupted, for 22 years to be capable of replacing their hand-pump. In Sierra Leone replaceable parts, such as cylinders, cost around 800,000le (~£124). At current tariff rates this could require up to a decade of undisturbed collection to replace. Pipes are also regularly a source of problems that require replacement. This is not including their internal mechanism which may also require attention. The average depth of a well can be assumed to be 10m. For PVC pipes this would cost, on average, 270,000le (at 90,000le for 3m ~£13.5) and steel pipes around 375,000le (125,000le for 3m ~ £19). Fast moving parts, which are usually bought as a group which includes: bearings, axle bar, chain, seals, nuts and bolts, costs roughly 180,000le (~£27.30). To address the problems the pipes and fast moving parts would require a non-interrupted tariff collection of almost two years. The problems would also have to be a single occurrence and have a return period of less than two years in order for the tariff systems to cope. None of these prices for replaceable parts raised here include the labour or transports costs for the goods and are only for the material resources themselves.

The realisation of the true capacity of the tariffs has resulted in most of the communities abandoning the system and reverting to a system that only pays when the well breaks. Out of the 150 surveyed villages, 40.69% would, theoretically, wait until the well breaks before attempting to pay for repairs. The village of Mathinkabana provides a typical case study that arises with problems using this locally devised strategy. In this village there are five wells systems and yet only one of them is working. Their tariff system, established in 2004, had only collected 25,000le (~£3.85) before people lost confidence in the system. To use the grading system established in the previous part of this chapter - the current village water status shows that three of the wells can be classed as grade B and the other two as grade C. The most notable water point is the central well in the village which mostly has Grade C type problems. Though it is currently operational it has severely rusted pipe system. The WUC, with assistance from the technicians, estimated that the piping issue would cost 150,000le (~£23.30) to correct. This in itself is a cause for concern because a realistic valuation of the problem would be closer to 500,000le (~£77.60) for three 3m PVC pipes plus transport and labour costs. The WUC sought income from each household but found that people were not able to present enough resources up-front. Even though they did not intend to use a tariff system, they were even unwilling to contribute regularly through incremental payments after the well became damaged, as they had promised. The discussions indicated that they had resolved to seek assistance from the NGOs instead of continuing to collect finances to address the issue. Their abandonment of any realistic collection schemes indicates an increase in dependency on the communities on external support.

Though 59.3% of the communities claimed that they would not wait until the well broke before addressing the problems, 42.9% of these, (or 24.8% of the total villages surveyed), also had no tariff systems. Therefore they would not pay to upkeep their system and not contribute to repairs if it broke. This is the most alarming statistic as it indicates a fundamental rejection of the technology and a lack of integration into normal community practices.

The user committees are designed to collect financial resources from the communities, either from the tariff systems or through the by-laws. The WUCs are also, theoretically, supposed to have records of the amounts collected. None of the villages in the FGDs could present reliable income and expenditure information concerning their water sources. Many of the user committees had “treasurers” but they could not present recently updated accounts. Given the thefts of collected resources which were reported to have occurred in several of the villages, and the resulting abandonment of the tariff system, the lack of trust in the financial management of the WUCs must be a central issue in the failure of these systems.

Many of the NGOs have hand-over ceremonies for the water points, which supposedly provide the communities with documentation regarding their wells. None of the 150 interviewed communities could provide supporting or updated information regarding the problems with the sources. Issues such as: when problems had occurred, quotes for repairs, causes of the technical problems, amount of resources prioritised from the tariff to address the issue or technical persons contacted, were not available locally. Very few communities claimed to have the original hand-over notes, though some villages did suggest that they were available somewhere in the village, but no actual examples were ever presented. The lack of transparency, and the resulting trust issues, will be a considerable factor in the abandonment of the improved water systems.

(E) Local Government Contact – Socio-Political Interaction

The group discussions with both the WUCs and the well user groups indicated that local government support for their water supplies was uncommon. Many of the 150 villages that were interviewed found the question amusing, resulting in some villages, such as in Mumunta, in Kholifa Mabang, in outright laughter. Though many villages indicated that the thought of expecting support from their local government was incredulous a large percentage (37%) of the villages thought that they should take the responsibility for modifying or fixing their wells. Many more (60%) thought that this responsibility lay with the NGOs. A small minority (3%) regarded the technical faults as their own problem and one that could be resolved internally.

4.2.2.5 The Sustainability of Water User Committees

The WUCs in Tonkolili have a unique role to play in the sustainability of water supplies. Development agencies and NGOs, as Harvey suggested, adopted the practise because of their "project approach" to development (Harvey and Reed, 2003). This allowed the implementing agency the ability to construct sources but also provide:

> *"a convenient concept for shifting responsibility for on-going O&M* [Operation and Maintenance]*, and hence sustainability of services, from facility-provider to end-user"* (Harvey and Reed, 2006a).

The WUCs assessed in Tonkolili can be shown, in many cases, to have neglected or ignored the authority and responsibilities that has been given to them over their water supplies. To proportion blame on the communities for this, except in clear cases of individual abuse – such as wilfully prohibiting a member from using a source, would be unethical. The WUCs, as Harvey suggested, can be a western world's "cultural idealisation" of how low income communities should sustain and operate their water supplies (Harvey and Reed, 2006a). The development of these committees can be shown to be flawed- though whether this makes these management committees dispensable, particularly with regards to the need for having a local body that can achieve the core objectives of the WUCs, is a separate matter. Though success has not been achieved in the WUCs, without some form of local stakeholders' involvement the water supplies would return to a neo-colonial and fully LTT approach to water supply and technology transfer.

4.2.3 Hand-Pump Technicians

4.2.3.1 Introduction

Local technicians are trained to maintain water supplies at the local level (Colin, 1999). They are also, in most cases, responsible for the routine chlorination of the sources (Smet and Wijk, 2002). In certain villages in Tonkolili these individuals were occasionally considered to be members of the WUC. In general they were seen as an external supporting role to these management groups. Working in conjunction with the WUC they should be capable of addressing certain types of technical problems. In reference to the previous chapter, only technical problems that were assessed as being Grade C or below are considered to be within the technician's capacities to resolve, and therefore the meetings did not hold individuals accountable for problems that were beyond their capacity to resolve. Furthermore as the tariff systems outlined above were found to be so inadequate and incapable of resolving a Grade C issue, and the Grade E failures are usually considered functions of the WUC, then only Grade D failures –*i.e.* those that require a small amount of financial resources to resolve, were discussed with the technicians.

Successful local maintenance was found to depend on the technician's relationship with their WUC, their own technical skills, their access to spare parts and the availability of tools for maintenance. Of the 150 villages surveyed 67 (44.7%) had a local technician. The average number of technicians was three per village. This is consistent with NGO trainings which usually trained village technicians in clusters. The technician discussions were carried out independent of the meetings with the user committees and water user groups. There were notable issues in both the formation and effectiveness of the technicians.

The technicians are trained by many of the implementing agencies, but are also trained through cluster training offered by technical specialist NGOs that are not directly involved in WASH implementation projects in each village. The interviewed technicians were trained by some of the larger international NGOs. There were found to be no examples of small NGOs and grassroots trained technicians. The length of training varied between each of the technicians. Some were trained over a longer periods such as in Matatuka 2 where the training took place over several months. The remainder of the technicians had received less than three days training. In Malagbla, for example, the technicians had only received their training in a day. All the technicians that were interviewed were aware that they needed more training and were usually acutely aware of their lack of skills with regards to maintenance. Unlike the WUCs focus groups, which were difficult to elicit responses, the technicians engaged well with the topic, though there were variations in enthusiasm in certain villages. On average the technicians were more acutely aware of the technical failings and shortcomings of their water points.

The stated tasks and responsibilities of the technicians varied between the communities that were interviewed. Given the timing of their trainings, which was usually carried out when the wells were built, it is likely that the exact outcomes of their trainings had been forgotten.

There were certain shared training experiences. All of the technicians were taught to loosen the pumps and take apart the pump-head, to sort out and clean the pipes, to organise the fencing and to grease the pumps. Some technicians were responsible for the chlorination of the wells; other communities had different members within their WUC provide this service.

The technicians that were interviewed during the FGDs exhibited very poor practical skills. Each discussion involved a technical explanation of the parts of a well. The majority were unable to name basic components, or even their hand-pump type. They were also asked to name the price of a new hand-pump, the costs of spare parts or the prices of tools. It was clear that they had no concept of the prices, as they ranged from the costly (7,000,000le ~£1780) to the ludicrously expensive (17,000,000le ~£2620). The average price of a new hand-pump well in Freetown is closer to 2,500,000le (~£385). None of the technicians could name the prices for any spare parts, or the costs of buying toolkits. Only in Kumrabai Junction was there an accurate estimate for procuring a new chain for their well, but this was because another technician had offered to sell them the unneeded parts for their system. The opinions of the technicians were similar to that of spare parts costing found in the community surveys . Of the first 50 villages interviewed, 96% could not name a spare part supplier and 70% did not know how far they would have to travel to collect spares.

4.2.3.2 Technicians and Water Point Treatment

Water points should be regularly chlorinated, particularly if the users are using the emergency manhole cover (rope and bucket systems) for water withdrawal. Finding out if a water points has been successfully chlorinated is not as clear as asking the village spokesperson if their water point has been given treatment, such as the results for the STAT-Wash database (Figure 52). Instead it depends on asking further information - including the frequency of treatment and the quantities of chlorine used.

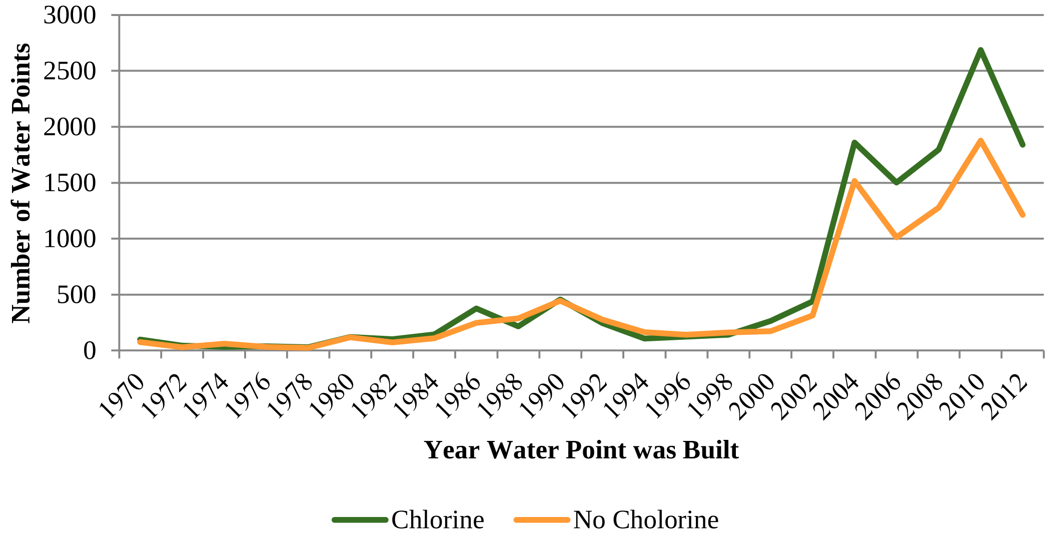


Figure 52: Rates of chlorination of water points (STAT-Wash information)

Many of the villages were found to have different strategies related to the water treatment of the water points. The interviewed technicians regularly had problems with the dosages and practices of chlorination. In Matotuka the three technicians could not agree on either the quantity of dosages, or the times when a well should be chlorinated. The same was true of Magbontho, where their two technicians varied in their understandings between the correct timings and dosages. All of the technicians had not chlorinated their wells in over a year. In Kumrabai Junction the technicians knew how often they should chlorinate, and yet had still not done so in over a year. In the 150 visited villages 64.43% claimed to have chlorinated their wells but the results also indicated that 45.8% of these 96 villages which claimed to have chlorinated had not carried out the procedure in years. This should have been less of an issue for hand-pump systems but the method of access, particularly for broken hand-pumps, should have necessitated more frequent treatment (Figure 53). Certain villages, such as Mayinkoko and Makombor, had not treated their source in over 4 years, and they had the mistaken belief that doing it once, following the construction of their water point, was sufficient. There were several villages (24%) that had not treated their water in over three months. Only seven villages (7.3%) claimed to provide treatment to their source on a monthly basis. The remaining 22.9% claimed to chlorinate their wells between one and three months. These numbers dramatically altered in the aftermath of the cholera outbreak in 2012 but the lack of practice in treatment ensured that it was the NGOs that had to carry out the majority of the shock treatment, instead of depending on or strengthening existing responses.

Figure 53: Example of a non-chlorinated well - Kumrabai Station

The dosages of chorine that were used differed between communities. Forty one villages (43.2%) did not know how much chlorine to use. The same number of villages (43.2%) used a fixed amount of chlorine and empirical formulas for selecting their dosage amounts. They often used a fixed number of tablespoons of chlorine, regardless of the amount of water in the wells, as the procedure of treatment. There were several reports of chlorination being abandoned because people got sick from the water. Several of the villages (13.7%) would follow the correct procedure and measure the depth of the water before making an estimate about the amount of chlorine to use.

4.2.3.3 Technicians and the Water User Committees

The Water User Committees are supposed to work in partnership with the technicians to repair the systems by providing external support such as fund-raising and providing non-skilled technical labour. In the sixty-seven villages that had hand-pump technicians around 15% of the committees did not have any confidence in their maintenance capabilities. The most dramatic example, during the FGD field research, was in Mathinkabana, which had six trained technicians. The discussion with the technicians was interrupted by an irate community member who used the opportunity to lambast the participants for their technical shortcomings. Mathinkabana presented a common situation where the technicians were given resources to fix a technical problem, but were unable to do so; though it is evident that the problems were out-with their trained technical capacities to resolve. Mathinkabana, for example, had three Grade B failed wells.

The opposite viewpoint was also true of the relationship between the WUC and the technicians. In Kumrabai Junction the technicians struggled to make their opinions about the necessary repairs for the water supplies registered by their WUC. The technicians were acutely aware of the limitations of the tariff system and reckoned that the amounts would need to be increased to 10,000le (~£1.50) per household each month until both of their non-functioning wells could be repaired. Additionally one Kumrabai Junction technician's also displayed a rare show of technical innovation by proposing a method for building the fencing for the well using locally available materials and construction techniques. These ideas were ignored by the local WUC, as they would have been required to increase funds or source new labourers for the task, even though it could have allowed for sustainability and even provided a longer term solution to the fencing for the wells.

The majority of the village community groups (85%) did express that there were no problems with their technicians – even though many of their water points had clearly not been maintained to any level of satisfaction. As with their opinions of the WUC, the views of the randomly selected community members suggested little with regards to dissatisfaction with the practices of their technicians. Again, as with the WUC, the responsibility for selecting the technicians is regarded as being part of the communities' role in the water supplies. This can explain their lack of dissatisfaction in the technician's role in maintaining their hand-pumps. As the technicians are, theoretically, selected democratically by all the village members, then any dissatisfaction would result in internal criticism of their choices. It is also true, given the small sizes of villages that the technicians are family members of those being interviewed, and therefore the community members were found to be less likely to publicly criticise them. This dynamic, such as in Mathinkabana, can be shown to alter if the community invests money in repairs which is felt to be squandered by the technical staff.

4.2.3.4 Technicians Assistance on the Procurement of Spare Parts and Tools

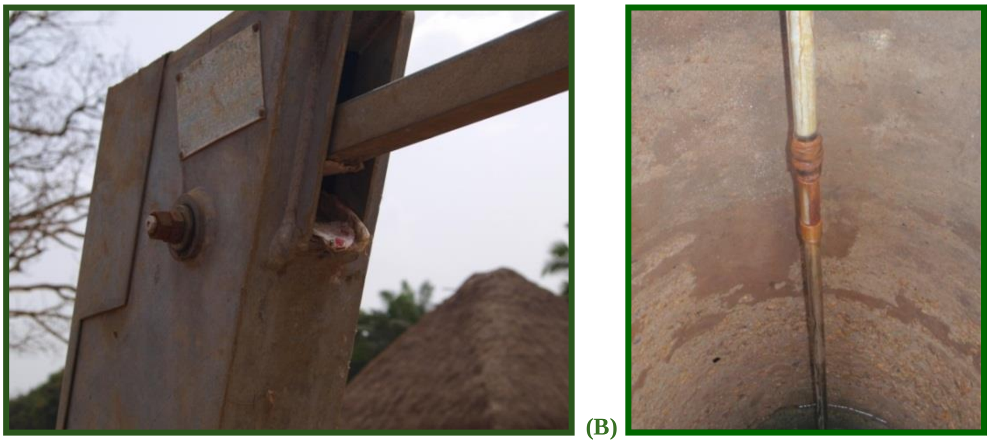
Making correct use of the spare parts and tools is defined as being the responsibility of the technicians. Only two villages of the 150 had a store of certain spare parts for their well system. The technicians are supposed to offer guidance to the WUC on spare parts. There were evidently problems with this responsibility as only 4% of the villages could correctly identify where spare parts are available (Freetown or Conakry) and none of the villages could name a private-sector supplier. The majority (77.3%) of the responses from the communities “didn’t know” where spare parts could be bought and a further 22.7% of the responses suggested a near-by town, where spares parts are unavailable.

Finding local tool-kits for fixing the well systems was similarly limited. Most of the communities (87%) did not have their own tool-kit. Of the 13 villages that did have access to tool-kits a further four of these were incomplete. Many of these kits were provided by the constructing agency rather than procured independently. These kits were usually found to be shared with other communities in the local region. However this, like the tariff system, is highly susceptible to corruption and theft. One international organisation had provided a full tool-kit to a MHCP in Kumrabai Station. This kit was allegedly stolen without anyone claiming responsibility. It was provided to the community to service a cluster of nearby villages. The community spokespersons in Kumrabai Station had argued that they had loaned it to another nearby village, and the tools had gone missing in transit. Other villages suggested that the community had sold the tools. Neither argument can be proven, but what can be observed is that neither Kumrabai Station, nor the surrounding villages, was willing to procure a new tool-kit. Every technician in this cluster complained about the lack of tools and the resulting inability to repair their sources. The WUC have not provided the necessary assistance in this regard and do not appear to be under pressure to do so, either by their technicians or their communities.

4.2.3.5 Sustainability and the Local Technicians

The importance of having locally available technicians is a fundamental component of Village Level Operation and Maintenance hand-pumps (Colin, 1999). Without their inclusion the concept is redundant. The case studies indicate that those found in Tonkolili are usually poorly trained. The case studies suggested that where certain technical problems were within their limited technical capacities, the failings of the WUC meant that there was usually insufficient money or willpower for repairs regardless. The legacies of failed attempts to correct issues, when money was available, or not actually necessary, are of more important note. The advantage of using the technical grading system is that it allows technical problems which could be resolved locally, with very little financial input, to be highlighted. The significant numbers of Grade D and E technical issues suggest that the village technicians are not responding to their responsibilities as they should.

It is important to note that though the technicians do not have the explicitly stated skills, when it comes to resolving technical issues, it is clear that they have the inductive capacity to resolve certain technical problems. There were many examples of local *'bush jobs':* a Krio expression suggesting the use of locally available materials to temporarily maintain the systems (Figure 54).



(A) **(B)**

Figure 54: Examples of '*bush jobs*' (A) Mathinka Bana (B) Malongba

Examples include the binding of damaged pipes or locally built manhole covers or using local materials to reduce noise levels at the pump. These solutions are unlikely to sustain the water points in the long term, but can resolve immediate operational issues. There is enough evidence to suggest that the technicians either do not have sufficient influence to motivate the WUC to repair the water points, or they themselves are indifferent to the technical problems affecting their water supplies.

4.2.4 Spare Part Supply Chains

4.2.4.1 Introduction

The final aspect of the social support mechanisms is the spare part supply chains in Sierra Leone. According to Harvey and Reed the overall goal of an effective and sustainable supply chain is to ensure that spares are available, accessible, affordable and appropriate (Harvey and Reed, 2006b). The private sector is necessary because of the NGOs dependency on imported technologies:

> *"In order to ensure that these requirements are fulfilled, there must be a sustainable chain of incentives from the manufacturer to the eventual customer. The majority of handpumps found in Sub-Saharan Africa outside South Africa are manufactured in India, meaning that, in general, pumps and components must be imported"* (Harvey and Reed, 2006b)

Unlike the WUC and Local Technicians the private sector component is not a function of individual villages. The supply chains are instead a regional issue which affects all of the chiefdoms and sections in Tonkolili. As many of the interventions involve technological components that are not locally available then the systems are dependent on this external supporting mechanism to provide sustainability to the artefacts.

4.2.4.2 Results of the Spare Part Supply Chain Investigation

The field results indicate that; any village in Tonkolili that requires spare parts would have to travel considerable distances in order to resolve their technical problems. Though some villages did mention that they could collect spare India MK II parts from urbanised centres in the rural areas such as Magburakha, Mile 91 or Makeni, the actual visits to these potential suppliers suggested otherwise. Visiting suppliers that were based in these large rural townships indicated four crucial results:

1. There are very few stores, if any, that stocked hand-pump components in many of the larger towns (populations over 3,000 people). There was usually no more than one supplier that could be identified. There are an abundance of other hardware suppliers such as for car repairs, bicycle spare stores and mobile phone warehouses but very few that supported parts for rural water supplies.
2. The few stores that did stock well parts are forced to sell the entire technical system (i.e. hand-pump, pipes, risers, bolts etc.) as they claimed that they could not make a profit on individual parts.
3. The store owners admitted that they rarely ever sold the hand-pumps. The hand-pumps were usually neglected at the back of the stores or hidden behind other merchandise.
4. Additionally the rurally located store owners did not have the capacity to stock technical components of lesser used well types, such as the Afridev, Kardia or the winch mechanisms of the pulley systems.

For a community to address individual technical problems, such as replacing cylinders or pipes, they would realistically need to travel to Freetown. In the whole country this is the only area where hand-pump technologies are guaranteed to be available. Almost all the suppliers are based on one road in the centre of Freetown called Regent Street. In this area it is possible to find both the entire hand-pump systems but also dealers that sell a small selection of spare parts. It was noted that several have outlets in other parts of Freetown. To trade in hand-pumps, even with these outlets, some form of travel to the centre of Freetown is required.

All of the main hand-pump suppliers, a combined total of twelve, were visited. The findings of these can be shown in (Table 8). The supplier's survey was not concerned with the centralised stock buyers who procured hand-pumps in bulk for the implementation activities of NGOs. These suppliers are available for large implementation activities of the NGOs but are not open to the public and do not trade in individual pumps.

Each supplier was asked for an estimated price for their hand-pumps and their spare parts. To identify any bias due to an expatriate engineer asking for technical information, a follow-up meeting was carried out independently by a Sierra Leonean volunteer who requested the same information, under the guise of a local person looking for prices to repair their village well. There were no distinct differences between the prices quoted, though they did vary marginally in certain circumstances, suggesting that these were set prices that were not dependent on the ethnicity or background of the buyer.

Table 8: Results of the Private Sector Spare Part Supply Chain

	Guru Nanak	Jeety Trading	ALZ	Hema Trading	Ali and Son	Hema Trading	Brilliant Building	Pawan Putrah	Sun City	Aztec Shop	Fawaz building materials	Starlight
Freetown Address	8 Ecowas street	10 Ecowas street	22 Ecowas street	29 Ecowas street	8 Ecowas street	7 Ecowas street	3 Ecowas street	2 Ecowas street	6 Ecowas Street	42 Ecowas Street	30 Ecowas Street	24 Ecowas Street
Pumps Stocked	India MK II	Afridev India MK II	India MK II	India MK II	India MK II	None Stocked	India MK II	India MK II	India MK II	None Stocked	India MK II	India MK II
Order	In Stock	In Stock	In Stock	In Stock	In Stock	3 weeks	In Stock	In Stock	In Stock	3 weeks	In Stock	In Stock
Cost of Pump	2.5M Le - (5 pipes and cylinder)	2.8M Le - (6 PVC pipes)	2.5M Le - (8 PVC pipes)	3.5M Le (stainless steel pipes)	No Price Given	No Price Given	2.5M Le - (5 PVC pipes)	2.9M Le - (4 PVC pipes)	2.5M Le - (6 PVC pipes)	14M Le - (5 PVC pipes)	2.4M Le - (4 PVC pipes)	2.7M Le - (4 PVC pipes)
Pipe Costs	Included in Price	Included in Price	Included in Price	Included in Price	No Price Given	No Price Given	130,000 le for 3m of PVC	-	PVC/ Steel 90,000 Le	-	-	-
Sell Parts Separately	No	No	No	No	No	No	No	No	No	No	No	No
Spares*	No spares	No spares	No spares	No spares	No spares	No spares	No spares	FM Parts	Cylinders (800,000le)	FM Parts	No spares	No spares
Cost of Spares	Does not stock spares	Does not stock spares	Does not stock spares	Does not stock spares	Does not stock spares	Does not stock spares	Does not stock spares	Stores FM spare parts (400,000le as a group)	Stocks FM spare parts (180,000le)	150,000 Le	Does not stock spares	Does not stock spares
Tool Stocks	No tool stocks	No tool stocks	No tool stocks	No tool stocks	No tool stocks	No tool stocks	Toolbox 120,000le	No tool stocks	No tool stocks	850,000le for tool box	No tool stocks	No tool stocks
Price list	No pricelist	No pricelist	No pricelist	No pricelist	No pricelist	No pricelist	No pricelist	No pricelist	No pricelist	No pricelist	No pricelist	No pricelist
Nationality of Owner	Lebanese Owners	Indian	Lebanese	Indian and Lebanese	Sierra Leonean	Indian and Lebanese	Indian Owners	Not Known	Not Known	Not Known	Lebanese	Lebanese
Price Difference Check	No Difference	Higher + 200,000 Le	No Difference	Higher (+ 500,000 Le)	No Difference	No Difference	No Difference	Lower (- 150,000 Le)	Higher + 100,000 Le	No Difference	No Difference	No Difference

* FM Spares = Fast moving spares (all or any of: bearings, axle bar, chain, seals, nuts and bolts)

There are a number of important aspects related to water supplies which was determined by these visits, and that would have an implication for those coming from rural areas and were attempting to fix their wells:

Given the quality of infrastructure of the roads in Sierra Leone, particularly around the Freetown peninsula, travel from the edges of Tonkolili to Regent Street in Freetown could take at least a day (using local transport) to complete. The travel is expensive, and without contacts to provide housing, would need to consider additional provisions for accommodation. Additionally finding the stores would require the ability to navigate around the complex layout of Freetown. None of the stores provided transport of materials to villages which, considering the weight of certain components, and the lack of transport capacitates of rural villagers, is a substantial cost consideration.

The stores did not usually openly display hand-pumps, nor were there any hand-pump specialists that only traded in this commodity. The request to actually see hand-pumps usually involved arduous trips to warehouses rather than an evaluation of displayed models that were readily available for inspection. The hardware stores primary trade appeared to be in construction commodities for urban settlements in Freetown and in providing mining materials to gold and diamond prospectors. It was apparent that rural water supplies are not considered a substantial source of income and are low on the priorities of the hardware stores.

Many of the store managers admitted that there was not a good trade in individual hand-pump technologies. 'Brilliant Building' and 'ALZ' claimed that they sell less than five pumps per month. The highest selling supplier surveyed was 'Pawan Putrah' who suggested that they sold on average ten per month. Furthermore they reported that the majority of their clients were private citizens from the urban areas around Freetown rather than people from the rural communities. Considering the number of faults on the water points, at a national level, these few stores should be inundated with technical requests for spare parts and new hand-pumps.

Certain hand-pumps technology designs had no spare parts available at all. Hand-pumps such as the Kardia, Costallen and Inka were not stocked. The only hand-pumps and spares that were available, at the time of the surveys, were the India MK II and the Afridev.

Though many of the store managers were helpful, it was clear that they required an exact definition of a part that required replacement. They could offer assistance on the goods they had available, but many did not fully understand the specifics of certain problems. This is important given the lack of technical knowledge of the technicians (as outlined above). The hardware merchants were liable to suggest procuring multiple items that could resolve general issues. This option would not be available to a community that has no financial flexibility due to the rigidity of their tariff schemes. The problems with the pump technicians not being able to name the price of hand-pumps would be aggravated by the fact that store owners do not have list of prices. As one warehouse owner suggested, *"you will never find a price list from any supplier in Freetown".*

It was also apparent that certain technical components would only be sold as sets. The Grading system, as outlined in the previous Chapter, assumes that certain components can be bought independently but the private sector inquiries suggested that this is not always the case. In many examples if was found that entire hand-pump systems were being sold instead of individual parts. The majority of the suppliers (75%) only sold their pumps as complete kits. It was possible to buy pipes independently, though these are used for a number of hardware activities and are not necessarily linked to the spare part supply chain for the hand-pumps. Even the 'fast moving spares' had to be bought as a collection of commodities from many of the suppliers.

Finally, it was clear from the study into the warehouse suppliers that the stores were primarily interested in selling new equipment, not in repairing existing infrastructure. The majority of the store owners did not see market potential in fixing the sources.

The condition of the spare part supply chains in Sierra Leone, at a national level, undermines every aspect of the sustainability of rural water supplies in the country. Though it is realistically possible to procure spares the barriers presented to an individual representing a rural population are considerable. For maintenance activities to be successful there would have to be a number of conditions that are met:

1. The water point that requires repairs would have to be the right type of technology.
2. The village tariff system would have to allow for flexibility in pricing changes.
3. The parts needing replaced would have to not be part of a set.
4. The financing plan would need to have factored in all the costs of travelling, accommodation and transport of the goods.

The probabilities of a rural village underestimating or missing one of these factors are high. Even if a single village in Tonkolili happens to have a working tariff systems and sufficiently skilled technicians to identify the problems, which as outlined in the previous section is unlikely, they would still face significant problems when attempting to resolve any of their water point issues. The frequent examples of failed maintenance activities, such as in Mathinkabana, where the technicians sought to engage with the private sector, have not happened for irrational reasons.

4.2.5 Grading the Social Support Mechanisms in Sierra Leone

The social support mechanisms of water supplies in Sierra Leone can be measured as either passed or failed in a number of categories. However, there are also, like the technical grading system, intermediate steps which indicate that there are a range of diverse problems. As there should be a number of social support systems operating simultaneously then some form of perspective is required for analysing the systems as a whole. Once again a grading system has been developed to provide an overview of the situation in Sierra Leone. This uses many of the same methods adopted in the technical grading system (see Table 7). Unlike the technical grading system, the reference point cannot be based on ‘expenditure to repair’, and therefore be a logarithmic scales of costs. Instead they are based on assumptions made about the likelihood that a system will be capable of being sustained and that access will be maintained for each user. Each grade considers the necessity for training, or re-training, of each social groups involved in sustaining the water supplies. Therefore the following guidelines were developed to provide an overview of the systems in Tonkolili:

- **Grade A (Social) –** *Extreme Failure* – Extremely high probability of serious sustainability issues developing at the water point. May require damage control to minimise existing damage. Long-term training, rather than retraining, is required. The issues may be beyond the capacity of a water supply intervention to resolve.

- **Grade B (Social) –** *Severe Failure* –High probability of sustainability issues developing at the water point. Requires complete retraining of social support mechanisms where necessary. Issues should be resolvable at the local level, but with continued support over a long duration

- **Grade C (Social) –** *Significant Failure* –Mild probability of the water point developing sustainability issues. Requires some retraining of social support mechanisms. Issues should be resolvable at the local level and should be resolved within a short duration.

- **Grade D (Social) -** *Moderate Failure* – Low probability of water point developing sustainability issues. Requires refresher course of social support mechanisms. Issues should be resolvable at the local level and should be resolved immediately after support.

- **Grade E (Social) -** *Mild Failure* – Very low probability of water point developing sustainability issues. Single discussions or distribution of learning materials should remind the social support mechanisms of their responsibilities.

The criterion uses quantitative, but basic, information provided by the communities about the functioning of their social groups. In-depth qualitative analysis is meaningless when displayed for each village, as it allows too many variations in outcomes. Outlines of the individual categories are indicated in Table 9. The functioning of the spare part supply chains have been omitted from the final calculations as, given their regional coverage, there was uniformity about their problems which would result in every grading having a minimum of 'Grade B' problems. There are also more functions for the WUC, rather than the technicians, which can be graded using surveys. This is not biased because the WUC has more responsibilities towards the sustainability of the systems than the technicians – though the importance of their roles for the sustainability of the technical artefact is equitable. These were analysed together as each aspect contributes to the overall sustainability of the water supplies.

Table 9: Grading system for determining the sustainability of the support mechanisms

Item		Grade A	Grade B	Grade C	Grade D	Grade E
Ownership	Restriction	One individual or household controls the well..	Particular group (*i.e.* ethnic, gender, cultural) is restricted from using well.	Marginalised group restricted (*i.e.* individuals with HIV/AIDS restricted)	Individuals restricted (*i.e.* individuals classed as insane, witchdoctors)	-
	Perceptions of ownership	-	-	Perceptions of ownership being directed at implementing agency	Perception of the well making community hesitant to modify well	-
Maintenance	Spare parts & tools	No access to spares or tools	Restricted access to spares or tools	Overly expensive spares or tools	Broken, missing or damaged tools or access	Poorly managed or stored spares or tools
	Technical maintenance	-	No technician in wide area capable of fixing Grade E technical failure or above	No technician in wide area capable of fixing grade D technical failure or above	No technician in wide area capable of fixing grade C technical failure or above	-
Treatment	Frequency	-	No treatment of well system	Irregular treatment	Seasonal treatment	Only monthly treatment
	Levels of treatment	-	Dangerous levels of chlorine or no treatment of the wells.	Insufficient or wildly varying dosages of chlorination.	Partially accurate or empirical dosages of treatment	Insufficient record keeping of dosages
Water Management Committee	Water User Committees	No Water User Committee	User committee wilfully negligent. Committee openly corrupt	Significant gender imbalance). Reactive user committee	Dysfunctional user committee. Long periods between meetings.	Irregular meetings. Inconsistencies in minutes
	Tariff	-	No tariff System	Inadequate tariff system Incapable of correcting a grade D failure or above.	Partial tariff (reactive) Incapable of correcting a grade C failure or above.	No tariff from certain households
Institutional Support	Private Sector or Government	Severely disruptive or dangerous involvement	No supporting organisation	Weak institutional support	Limited support	-

4.2.6 Results of the Grading Analysis

The responses to the community surveys were compiled and analysed using the grading system. The results were calculated by grouping community answers on specific topics together and counting their total contribution to the social mechanisms sustainability. This research focused on 100 villages as their communal surveys were expanded to include all graded aspects, which were designed after the input from the FGDs, and after visits to the initial 50 villages. As with the technical grading, the maximum failure of any component is of key concern (Figure 55).

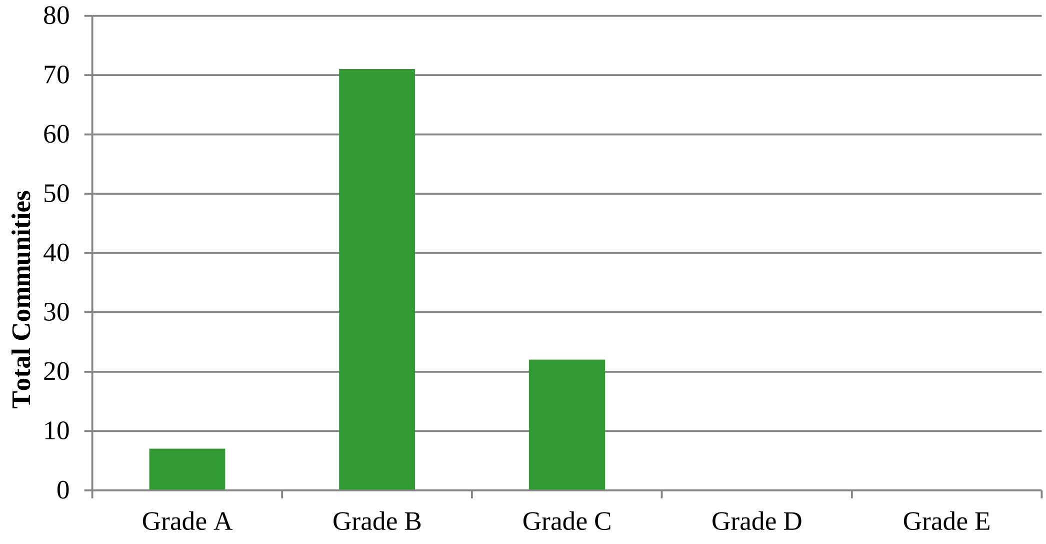


Figure 55: The communities maximum failed grading

The results suggest that for the communities surveyed in Sierra Leone there is a high probability of their sources falling into disrepair. There is substantial re-training required for the WUCs and technicians. The NGO response should have been to revaluate the success of current training. Within the context of rural Sierra Leone the WUCs and technicians are incapable of providing sustainability to the water supplies.

Certain villages received a 'Grade A' classification because of their purposeful restrictions to certain community members from participating in their access to water supplies (Figure 56). Certain discriminations can be addressed in the short and medium term, such as providing HIV/AIDS sensitisation to raise awareness of the disease, but deeper rooted social issues cannot reasonably be expected to be altered over the course of water supply provisions.

The technical maintenance capacities of the technicians and WUCs tariff systems were found to be the weakest aspects of the social support mechanisms (Figure 56). Therefore it is required that there is a rethinking on their conception, implementation and applicability in solving the sustainability problems of the communities.

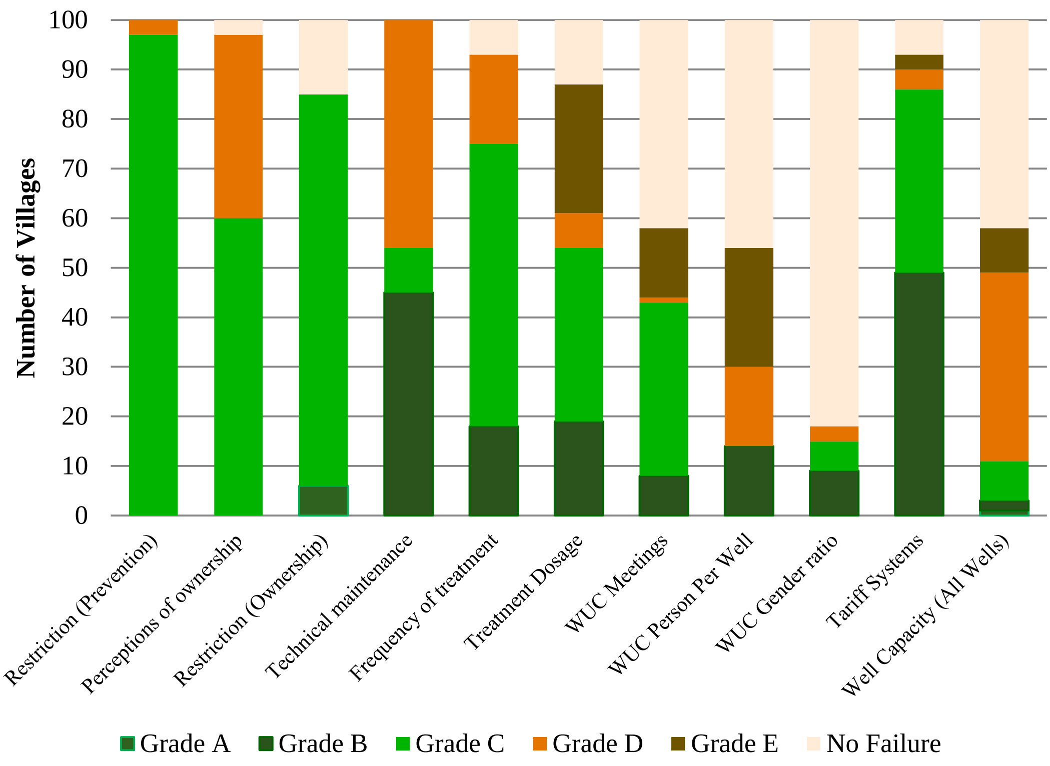


Figure 56: Total grading by individual category

4.2.7 Questions Raised from the Social Support Mechanisms

The three social support mechanisms, which were analysed in this chapter, were found to significantly undermine sustainability of the water supplies in Tonkolili. This explains the prevalence of Grade C, D & E technical failures outlined in the previous chapter. The WUCs were found to contribute to the decline of water supplies as they were unable to provide the minimum required support to achieve sustainability. The vast majority of WUCs were found to have failed in all areas of their stated objectives. Their inability to correctly provide funds for repairs through tariff schemes and by-laws suggests a serious cause for concern. This would have undermined the capacities of the technicians, but they were found to be mostly technically incapable regardless.

The results have shown that the private sector response have been inadequate to sustain the systems. There are several organisations that have suggested that the reason that the tariff systems fail, or the technicians lose credibility, is that the spare part supply chains are defective and that this undermines the entire process (Harvey and Reed, 2006b; Oyo, 2002). Questions are asked, for logical reasons, of the implementing agencies which have provided water supplies without any realistic chances of the systems being maintained or sustained for future generations. There have been recent moves, by large organisations such as UNICEF, to provide spare part supply chains, and to decentralise donor procured spare part warehouses. This would theoretically increase local access for communities and address one or more of the spare part problems (such as fixed costs, storage of lesser used technologies or the provision of potentially lower prices). However this procedure could be argued to be addressing only the symptoms of the problems, and not the causation of the issues.

The three social support mechanisms outlined in this chapter are not independent. To repair a well the technicians needs both the WUC, for their fundraising capacities, and the private sector, for their provision of the necessary spare parts. The same is true of the WUC, which requires working water points to remain legitimate. That the private sector requires both the input of the WUCs and technicians appears to be less well understood by the organisations intent on addressing the issue. The private sector response cannot be forced, but is instead a natural response to the simplest of market dynamics - supply and demand. If the private sector in Sierra Leone felt that there was profit to be made then it would respond accordingly, as it already does in so many areas. As has already been discussed, certain 'foreign' technologies, including mobile phone, car parts and bicycle repairs, were available in abundance in some of the most remote areas. The private sector response to these technologies has thrived without, or possibly despite, the actions of the development agencies.

The Synergetic Approach to Technology Transfer (SATT) is dependent on these social mechanisms being fully operational for the model to claim to have achieved 'appropriateness' rather than 'linearity' towards technology transfer. They therefore present ethical questions about the delivery of water supplies.

The WUCs were found to be relatively indifferent to their constructed sources, as evident by their lack of care and attention, as well as their general lack of enforcement of regulations at the water points. It was observed that the villages are not fully taking responsibility and ownership for their engineered solutions. This results in their function to providing sustainability for their systems as being negligible. There practices ask crucial questions about water supply in Sierra Leone: Why is water such a passive issue for most communities as evident by the apathetic replies of the WUCs? Why are the community members not upset by the condition of their systems and the failures of the WUCs? Why do households in the community not aggressively demand the sustained right of access to safe water from either their WUC or even those that they think are responsible for their implementation?

Similarly questions can be asked of the technical support. Why are there not competitive technical services being offered to the communities when there are for other technology repairs services such as mobile phones? Why have the communities not pushed their technicians for further training, or prioritised it during the FGDs as being a necessity? Why do the technicians not have even basic information on the costing of hand-pumps (which can be found from suppliers as shown in Table 8), when they have information on other aspects of living in Freetown?

Additionally the private sector has not been established or developed in any rural region in Sierra Leone. Again this asks questions about water supplies in Sierra Leone: how, with the number of repairs required throughout the country, can the market not fulfil a pivotal role in Tonkolili? Why is this activity not seen as profitable and is shunned by most hardware merchants? Why is there no demand or expectations on the private sector - yet there is a clear market potential in the rural areas? Why are other technologies such as mobile phones and bicycles, which have less importance to human survival, more heavily prioritised in the markets in rural Tonkolili?

It can be concluded, by the analysis of the social support mechanisms, that there are substantial problems with how the socio-technical systems in Tonkolili have responded to their water supply technologies. Each of the technologies practical contributions to community life, as well as their importance to survival, has been shown to be undervalued in almost all the interviewed communities. This has considerable repercussions for the success of the technical interventions.

4.2.8 Discussions on the Social System with Engineers

The social support mechanisms were discussed with engineers at length. Instead of a common consensus there were clear disparities and polarisation of opinions about whether such inclusions to water supply projects warranted the participation of engineers. Emphasis was primarily on the practical engineering activities and in improving the technical capacity of the organisation:

> *"I see in other organisations that there are managers from more policy or advocacy backgrounds who rightly focus attention on the human capacity, economic and socio-political issues of development but at the expense of getting the basics right in terms of good quality engineering – this can lead to poor borehole design and construction and poor pump quality control and installation."*

> *"[...] the development of technical skills is often not prioritised. However, I think this is not limited to NGOs, across the water sector, within government and private sector, technical skills are rarely prioritised. The reasons for this are complex and relate in part to donor expectation."*

The problems with the social mechanisms are very often attributed as being the responsibility of non-engineering management staff that are supposed to work with engineers. The focus of these discussions was usually around whether the engineering needs were understood and addressed by the implementing organisations:

> *"In several large NGOs I have worked with, there is a culture perpetuated that the engineering is known and easy and senior managers often lack the capacity to evaluate whether the engineered solutions are fit for purpose."*

A lack of understanding of what 'engineering needs' is compounded by the number of sectors engaged in by the NGOs. There can be confusion over which elements are actually considered 'engineering' activities. For example the Country Director for one major organisation working in Sierra Leone insisted that they were *'not really doing any engineering'* despite the fact that a large proportion of their annual budget was in construction. The reason for this was that their management sectors did not have a specific mention of 'engineering' and therefore the number of minor construction projects were arriving simultaneously from different divisions within the organisation. Their engineering co-ordinator was not impressed by this statement.

Many discussions with engineers resulted in what could be regarded as open hostility towards management staff that did not understand the practical and technical needs of the profession:

> *"[...] NGOs, as they move from service delivery to 'rights-based programming' and working through local and national partners, tend to be increasingly populated by non-technical and non-experienced personnel. They are coming increasingly from a social studies background. This forms an education not on the practical realities of human and social interaction, but on ideals and ideology rather than quality professional experience grounded in the reality of life. "*

Speaking directly to NGO staff that managed engineers an opposing view was presented of the profession. To many programme staff members their engineers were considered too preoccupied with the technical aspects and not enough attention was given to the 'software' elements of construction. The information gathered for this chapter was only possible through conversations from a number of NGO programme managers. Almost every management individual expressed surprise that an engineer would prioritise the successes and failures of the social mechanisms when studying the impact of engineering projects in Sierra Leone. This was in itself an interesting conclusion about external perceptions of the profession when operating in development.

The current situation in Sierra Leone has indicated that without some form of progression the in-field engineers will continue to make flawed assumptions about the relationships that rural communities have with their water. The questions raised by the social support mechanisms about the socio-technical systems of Tonkolili require addressing to better understand the scope of what would be expected of the profession.

CHAPTER 4: RESULTS AND DISCUSSIONS

Part 3: The Socio-Technical Systems

4.3.1 Introduction

4.3.1.1 Assumptions of the Socio-Technical Systems

The failures of both the technical systems and their social support mechanisms suggest that there are deeper underlying causations for the problems experienced in the communities in Tonkolili. The previous chapters have shown that these issues are not unique to only one area or to one community. The failures are also not confined to one organisation or to one service provider. It has been noted that though a well-constructed water point is less likely to develop serious technical failures it is still liable to suffer substantial sustainability issues due to the weakness of the social support mechanisms. This investigation explores the social and cultural assumptions and the engineering decisions that have been made, without the input of this profession, which have had a direct impact on the sustainability of the systems.

The most important conclusions that were reached in the previous chapters is that the majority of the issues could be resolved at a local level if there was sufficient willpower to contend with the faults from within the communities themselves. At the very least there should have been more indications during the FGDs and communal and household surveys of resentment, anger or dissatisfaction from within the communities themselves. This emotive response could have been directed at the parties they feel that are responsible for their water supplies – the governments, NGOs or even their own local authoritative hierarchies. The apathy found in the discussions, combined with the demonstrated lack of urgency in responding to ever increasing technical problems, suggest that there is a common and tacit reasoning behind the lack of motivation. Concluding that rural Sierra Leoneans are somehow incapable of showing passionate responses to their problems would be a denial of local cultural attitudes found in normal living. Sierra Leoneans are also not unwilling to address perceived communal threats as this would be denial of an eleven year of conflict which bears witness to the contrary.

None of the discussions, community groups, surveys or interviews, both from within or outside the villages, indicated that the reasoning behind the failures was known explicitly by one individual. Multiple reasons were given for water supply failure not being addressed, but none were true in all scenarios, or were entirely consistent with human behaviour –

especially in accordance with basic human survival instincts. Older community members and Sierra Leoneans based outside the communal systems, which were usually urban based dwellers, would dismiss the roots problems as being caused by “laziness” - the rural community members were failing to fulfil their obligations due to mere idleness. This is contradicted by the labour intensive lifestyles needed for survival in the villages.

Confining the explanations of the problems to being to one of ‘sloth’ would be unsuited to the development ethos of the international organisations. Doing so would place the burden of responsibility for failures entirely on individuals within the communities. Therefore an alternative approach is used by development organisations to rationalise the frequency of such events. Interviews with practitioners from the development agencies, who are usually individuals that come from outside the rural socio-cultural systems, would summarise that the failure of water supplies as being caused by scientifically irrational indigenous beliefs. They would usually refer to a casual, vague or simplified explanation of indigenous practices that must be responsible for households abandoning their improved water supplies.

These views have an uncanny resemblance to those held by Rudyard Kipling, a colonial era and imperialist British poet, in his poem the “White Man’s Burden”. In this he states:

> “*And when your goal is nearest/The end for others sought/ Watch sloth and heathen folly/Bring all your hopes to nought”* (Kipling, 1899).

These descriptions appear to offer a rationalisation for the failure occurring in projects. The field research found that the concepts of ‘sloth’ and ‘heathen folly’ are not explanations of the root causes of the problems. Even if they were partially true, which they will be in certain circumstances, they would only be symptoms of underlying issues. They are not explanations of why such attitudes have formed or why the local indigenous knowledge systems have not encompassed such important technologies. The tendency for experts to resort to these fallacies means that there is no single spokesperson capable of providing an unbiased definition of causation. The societal practices of those in Tonkolili are best explored through an analysis of the practices of the households as the local socio-technical system is both influenced by, and influences, the household and communal attitudes towards their technologies.

When providing an artefact to a socio-technical system an engineer has to make assumptions about how the users will interact with the solution. This is applicable over the life expectancy of the artefact. These estimates must include the theoretical value that individuals, households and communities are expected to place on the technology. Given the amount of donor funding invested in water supplies in Sierra Leone, and the manner in which projects have been implemented, it is fair to suggest that the expectations are that communities would both use, and value, the provided water sources. It is also clear that the NGOs and government agencies expect that these wells would form a fundamental component of the rural socio-technical systems. The service delivery models have assumed that people would be both willing and able to support these systems indefinitely. The previous chapters have suggested that this level of support by the communities and the corresponding ownership of the technologies has not materialised. Therefore there have been fundamental mistakes made by the engineers about the nature of the socio-technical systems in Tonkolili.

4.3.1.2 Technology Transfer in the Communities and the Mobile Phone

The suggestion that the societal practices of the communities are a form of Ludditism, and that they have rejected technical modernity, is evidently untrue. In none of the case studies were the water supplies shown to be vandalised (*i.e.* wantonly damaged) by the host villages. The community studies found no examples of villages that would object to the construction of a new water point. Additionally, at no stage in the interviews was there a display of hostility towards the topic of water supplies and their associated technologies. Regarding 'technical modernity' the communities themselves were shown to have allowed other technical artefacts - such as transport vehicles (in Krio: *Poda Poda's*), battery powered torches, and power generators - to have a central role in community living. The most notable 'high technology' encountered during the field research was the widespread use of mobile phone technologies. The success of this technology in integrating seamlessly into rural socio-technical systems invites a comparative study to the NGO provided water supplies.

After the conflict period, and during the arrival of the NGOs who engaged in relief and development programmes, there was also an increase in private sector responses to provide Information Communication Technologies (ICTs). This included internet and satellite coverage - but the largest growth area was mainly focused on the mobile phone market (Mayer and Figueredo, 2009). These private sector organisations rapidly expanded their coverage to the rural areas by installing communication towers throughout the dense bush terrain (Pushak and Foster, 2010; Touré, 2007). The different networks have continually competed against each other for market sector control and there currently remains heavy competition in the country, as witnessed from the aggressive marketing campaigns. The mobile phone market, and the associated micro-economy it has created, is continually growing and expanding in Sierra Leone.

Given the differences in service delivery methods of the two technologies, as well in as the manufacturing process of the different artefacts, a direct comparison regarding service coverage to rural populations is not possible. For example a relatively large population in Sierra Leone can be covered with a single telecommunication tower regardless of their spatial distribution. Each phone subscriber would only need to be within the wide range of a centralised tower. To achieve the same population coverage with water supplies would either require a vastly more expensive centralised system, or hundreds of smaller communal systems. An exploration into the uptake of mobile phones is relevant to this study as an indirect comparison to the problems of water supplies. They both present examples of technologies which are not designed locally and yet are expected to function and remain sustainable within the rural socio-technical systems. The two technical interventions in Sierra Leone have similar limitations regarding the creation and establishment of market and spare part supply chains in a country recovering from conflict. The main beneficiaries, customers and users for both technologies are from populations that are severely illiterate and have low economic prospects. Where the mobile phone market has grown stronger over the years, without requiring any foreign aid, water supplies have clearly struggled to be valued in communal living. However there is a positive relationship that households have with their phones, for those who have them, that can be compared to the negative attitudes to the water supplies. It is on this basis that a comparison can be made.

The KAP surveys indicated the relationship that certain rural households could have with their mobile phones. The 150 surveys indicated that 55% of the households had a mobile phone. Of those that did not have access to a phone 8% would share phones with a neighbour. Most of the households that had a phone had only one mobile phone (59%). A quarter of the phone owning households had two phones (25%). A smaller amount had three phones (10%) and the remainder had more than three (6%). The majority (85%) of those interviewed said that they had bought their phone themselves. Of those that used the phone, but did not purchase them, included those that had been gifted (10 %) or rented (5 %) their mobile. Renting the phone cost 2,100le per month on average, though there were exceptions, this value was constantly repeated suggesting a fixed rate. These phones differed in prices, the average being around 150,000le. As the 150 household surveys were not carried out using probability distributed methods they cannot conclusively explain the widespread adoption of mobile phones in Sierra Leone. Therefore a larger dataset of information is required. The World Bank Indicators estimated in 2011 that there are 2,175,000 mobile phone subscriptions in Sierra Leone or 35.6 phones per 100 people (World Bank, 2012b). Though this shows a large increase in uptake this remains one of the least covered countries in Sub-Saharan Africa (Mayer and Figueredo, 2009; Rotberg and Aker, 2013). The rate of service delivery (Figure 57) can be compared to the Ministry of Water Resources and Energy's datasets on water supply coverage (Hirn, 2012).

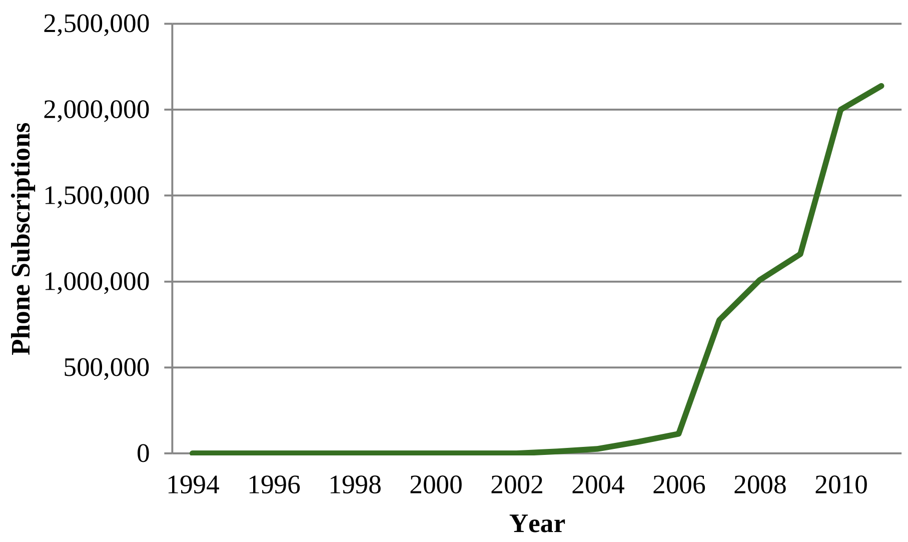


Figure 57: Number of new mobile phone subscriptions per year

Unlike the provision of water supplies, there are no dramatic drops in service delivery, or hikes caused by new donor initiatives, instead there has been steady growth over the previous decade. With an average yearly growth of 35% there is a continued expansion of the sector and this is expected to increase in future (World Bank, 2012b). The rate of growth has however declined, as would be expected, but the market still remains strong (Figure 58). Phones remain relatively inexpensive, but the socio-economic conditions of Sierra Leone, which has low economic growth, naturally limits the number of people that are capable of procuring their own phone or paying for the running costs in a poor economic climate (Aker and Mbiti, 2010; Touré, 2007).

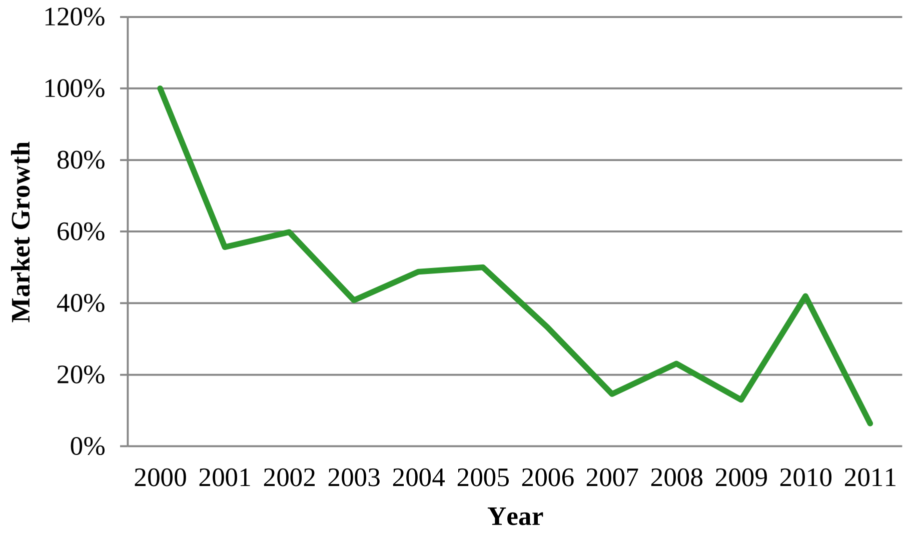


Figure 58: Average growth of mobile market per year

The amount of money invested into the continual use of mobile phones in Sierra Leone is the only reason that the private sector can participate and remain competitive in the market. As these are profit-making enterprises their nationwide presence indicates that there is financial gain in the sector (Mayer and Figueredo, 2009). This profit is not only in the urban areas but also found within rural communities. The continued growth and fierce competition of the network suppliers indicates that the networks have remained profitable since their introduction.

As the phones require sizable, and regular, financial contributions to operate then a comparisons to the community tariff schemes for water supplies are inevitable. The 83 households that owned a phone paid an estimated average of 33,000le per month on phone credit (Figure 59). Local rural business involved buying larger quantities of credit selling the balance through the phones micro-crediting capacities. This explains the higher transfer amounts which would otherwise skew the results. The results are far higher than the minimum expected by the NGOs from the community tariff systems. It is important to state that the same households were unlikely to provide an average of 500le per month for their water supplies.

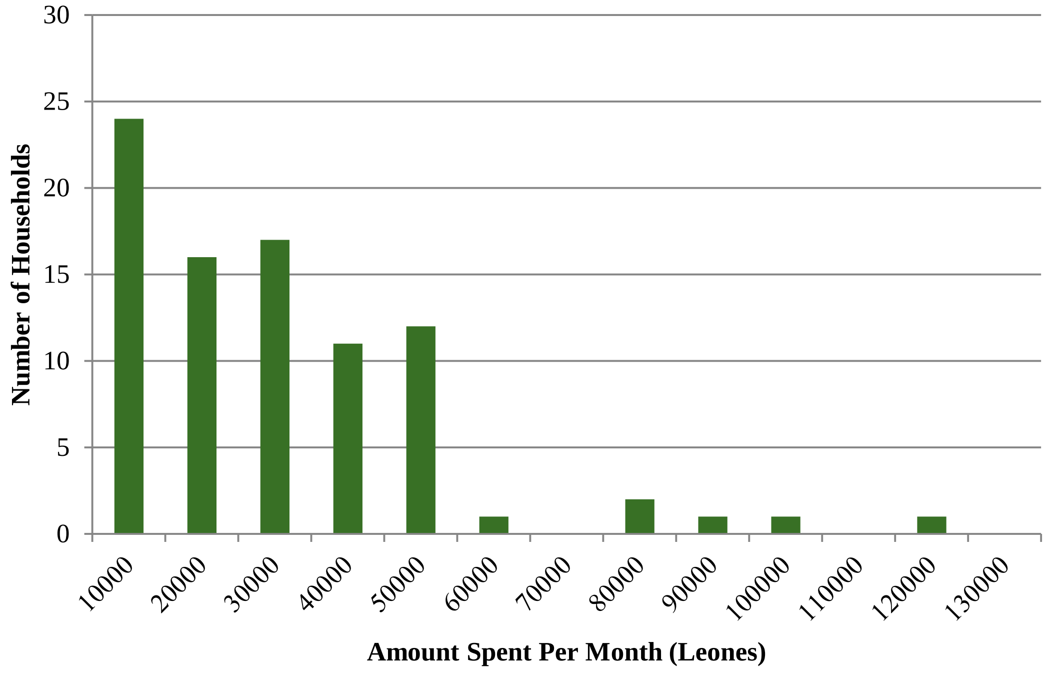


Figure 59: Amount spent of phone credit per month in eighty-two households

Compared to their local knowledge about the water supply private sector, many of the households could not only name the price of a new phone, but also knew store locations or individual sellers where competitive prices for the phones could be attained. These questions were often debated at the household and community level between participating survey members. This indicates that there was competition at the local market level. It was also apparent that the households could make distinctions between brands of phones and had preferences for different technology types. This was usually due to the phones build specifications and additional hardware features. The use of combination torch/phone models and multi-SIM phones are a common preference, and a technical response to local conditions that has been identified and capitalised upon by local entrepreneurs.

Given that mobile phone technologies are 'high technologies' their maintenance requires more technical skill than a 'low' technology such as a hand-pump. Regardless of the limited number of repair options that could be maintained locally the surveys indicated that not only had many phone owners had their phones repaired but they understood both the locations of repairmen, as well as the estimated costs of spares. As with procurement of new phones, there were several competitive prices named for addressing technical faults. This can be compared to the knowledge gaps of the technicians about the suppliers of the wells.

There are also comparisons with the average villager's willingness to pay. The surveys indicated that should a 'significant problem' occur 94 % of those that owned a phone would be willing to save for a new phone and only 6% would not consider a replacement. Questions that challenged the eventuality of minor and reparable damage to the phone indicated further insights - the majority of phone users (88%) would fix their phones by saving money that would be specifically used for this purpose. The remaining 12% would immediately attempt to resolve the problems with their cash reserves. Repairing phones locally was also common – a total of 44% of the households surveyed had previously repaired their phone. The average cost of this maintenance was 34,000 Le. The average repair cost, per phone owning household, was higher than the total communal amounts collected for the water supplies in almost all the individual villages.

Figure 60: Mobile phone seller and charging station - Mabanabom

Mobile phones were available in all major towns and cities. Certain smaller sellers had specifically targeted rural markets. Over a third (34.7%) of the interviewed households had salespersons that either sold phones at the local communal markets or had purposely brought their wares to the villages to sell independently. There are further micro-economic ventures that have grown to capitalise on the growth of the mobile phone sector. They include replaceable parts for the phones but they also include phone accessories and aesthetic paraphilia that are not necessary for the mobiles operation. The household surveys indicated that these items are regularly procured. This includes items such as batteries (52.3%) chargers (47.4%), cases (46.2%), ringtones (17.9%) and adaptors (7.7%). Therefore it can be concluded that the private sector is not only present, but flourishing in many of the rural areas.

The field visits demonstrated that mobile phone technologies have integrated into community living in Sierra Leone. They are now considered a valued commodity in household living. The household investment into mobile phone technologies, and the care and attention that they have provided to their upkeep, suggests that these are given higher priorities than their improved water technologies. The differences in practices, particularly in financial investment, are staggering. The 82 interviewed households that had phones would have had enough financial resources to sustain their water supplies indefinitely - if only the money was directed towards this technology.

The mobile phones, though often shared, are an individual's property. This relationship is not the same for communal properties such as water points. This feature has an undoubted impact on the ownership at household level. This, in itself, is not the only explanation of why mobile phones are given such importance. Water supplies, it could be argued, are not failing solely because they are a communal property. There were many witnessed examples in almost all the villages of successful communal properties – including mosques, schools, health clinics, palaver huts, football pitches, farms, churches and storehouses. Sierra Leone is noted for being collectively orientated rather than focused on individualism (Hofstede, 2005). Therefore it is the features of the artefacts themselves, rather than their communal nature, that are a cause for concern.

It is a valid argument to suggest that the mobile phone, as an accessible 'high technology', offers an aspect of Western modernity that is within reach of rural dwelling individuals. The 'low technology' of the hand-pump does not offer this level of technical excitement. The only parallels with Western civilisations water supplies are a tenuous historical link rather than a direct comparison to the current practices of the post-industrial nations. Regardless of this conception of modernity it could be argued that water supplies should offer something more profound and valued than any ideals of technical sophistication. They offer a service for which a mobile phone cannot directly provide – the continued health and wellbeing of the user. That the households are unable to interpret the technology in this way suggests that there are fundamental problems regarding how the technologies are understood at the micro-level.

4.3.1.3 The Technical Properties of Artefacts

The technologist MacKenzie suggested that there were sociological properties to artefacts which can be used to determine *"whether they work, how well they work and how safe they are"* (MacKenzie, 1996). He optioned three important ways in which an individual learns and understands the properties of technologies (or the artefacts) that they use. The three methods, and their explanation, are as follows:

- Inductive Reasoning – properties learnt from using or testing the technologies
- Deductive Reasoning– inferred properties from theories or models
- Authoritative Reasoning – depends on trust to inform people of their properties

As MacKenzie explained - this list is not extensive (MacKenzie, 1996). A further process will be added which is important to engineering practices - learning through design. This 'constructionism' is the innovative process whereby the properties are understood through the evolution of the technology and through continual invention (Dahlbom et al., 2001; Papert, 1986). Though this list is not exhaustive the questions raised by the analysis of these four points are sufficient to challenge the fundamental misconceptions about water supplies provided by NGOs in Sierra Leone.

Technologies do not require all of these four reasoning's to be affirmed simultaneously for them to be successfully used. Only one of these four categories needs to be confirmed for a user to appreciate the properties of a given artefact and to successfully operate the technology. A mobile phone, for example, is best understood through induction alone. Regarding the deductive capacity of users and phones - there are a disproportionate number of mobile phone users, even in developed countries, who can understand the technical concepts and the internal workings of a mobile phone, when compared to the total number of actual users. The mobile phone is designed and built using a combination of different forms of electrical, electronic and mechanical engineering. The phones are a single unit of a much larger ICT network of infrastructure (Sage, 2000). Understanding the phones functionality to this degree of accuracy does not infer substantial, if any, benefits to the operation of the technology. As a 'high' technology a mobile phones technical complication, combined with the use of theories that depart from the macroscopic mechanics of Newtonian physics, ensures that only highly educated and skilled engineers can participate in the actual design process of the phones. The surveyed households adopted the phones in Tonkolili without requiring participation in their construction and, in many cases, without fully acknowledging the origins of the technologies. Additionally, authority is not required as its use does not depend on any external expert's opinion to inform a user of the phones functionality. In Sierra Leone it can be shown that a user can determine and appreciate the phones properties without any external guidance.

Mobile phones are best understood through induction - through users both operating and testing the phones for themselves. Even though many of the cheaper and 'simple' phones most common in the household surveys use Text based User Interfaces (TUI), rather than the smartphones Graphical User Interfaces (GUI), people in rural Sierra Leone have found methods of using the technologies without being able to read, or without having the capacity to read in English. Though illiteracy presents an obvious disadvantage, and could prevent the extent of market coverage, it did not appear to deter users from either procuring or using a phone. Therefore the 'inductive' aspects depend on the user being able to discern the core functionality and purpose of the technologies, which is to enhance their communication with others (Scheele, 2006). A user being able to fully determine all of their phones additional features is not obligatory, though it would be advantageous, for certain aspects of its use. This is a very basic observation - mobile phone users believe that when they are talking on their phones the person they are communicating with is both sending and receiving information – but the implications for inductive reasoning are important. It suggests that some form of feedback is required from the technology. This verification can be immediate, because of a human's biological capacity for speaker recognition through voice biometrics or deferred, when communicating with an unknown individual. If there is, theoretically, any doubt then this can be verified by communicating in-person at a later stage - to confirm that the communication actually took place. This feedback can be immediate - but would require another actor to confirm its validity. Once this assumption has been confirmed then future practices, such as using the phone for business or recreational purposes, can be rationally adopted.

4.3.2 Inductive Reasoning

The most important consideration of the improved water supplies is to challenge the assumption that, like mobile phones, they can be understood through induction alone. The water supplies are viewed as 'low' technologies, and have an uncomplicated method of operation. Therefore they require little complex inductive reasoning for a user to determine their practical function. The basic use of a hand-pump well mechanism is simple: by pulling the hand-pump handle the water point will produce water. Pulley systems require a similar, if not more basic, inductive process. Water extraction can usually be understood immediately - by using the hand-pump or pulley at the source. In this sense, the inductive reasoning is faster than the mobile phones. As handpumps and pulleys have only one moving part then it requires no other actor to affirm its functionality.

Determining this 'inductively learned knowledge' as being the most important aspect of improved water points is critically flawed. The distinction between an 'improved' and an 'unimproved' sources are important (UNICEF and WHO, 2012). The knowledge that is important for a user to have is not that the sources provides a supply of water, but that the water that is provided is safer, or at least significantly healthier, than other 'unimproved' sources which were previously used by the households. Using communication technology as a comparative case study of this fallacy would be akin to suggesting that a user determining a mobiles phones definition of 'functionality' as being an 'artefact that was capable of producing noise'. There is a distinction between a technologies 'function' and 'proper function' (Scheele, 2006; Vermaas and Houkes, 2006). The reasons for NGOs providing supply systems to communities are that the sources of water are 'considered safe'. In certain extreme situations, most notably in disasters relief for drought, the provisions of safe drinking water can be designed to address water needs where people are liable to die of dehydration (Davis and Lambert, 2002). This would be a 'need' that is understood at a physiological level (Maslow et al., 1970). This is not the case in Sierra Leone as it has an abundance of water resources (see Chapter 2). Rural dwellers have continual access to water from unimproved sources regardless of its quality. In the developmental programming in Tonkolili it is the health benefits of water, rather than for addressing dehydration, which are desired. This is the fundamental basis for the provision of the water supplies, and the foundation upon which sustainability is intended to be built.

4.3.2.1 The Results of the Household Water Quantity Surveys

There may have been an initial enthusiasm for the provision of water supply systems, but there are clear indications from the monitored technical and social factors (see Chapter 4 Parts 1 & 2) which suggest that this positive momentum is not sustained in the long term – particularly when the household are required to financially support their systems. This would suggest that they are not responding scientifically rationally toward their water supplies. In total 565 households were evaluated using probability distribution methods and the token distribution questions (see Chapter 3). The results suggest that the use of unimproved sources remains exceptionally common in Tonkolili by those that have access to improved sources.

Figure 61: Household water quantity survey

To spatially illustrate this point a village, named Kumrabai Junction in Mabang Chiefdom, had all of their water points, unimproved and improved, fully spatially mapped (Figure 64). The case study survey was more intensive than the proportionally distributed methods – taking almost a week of research. In 2007 this community had received two improved sources of drinking water provided by NGOs (Figure 62).

Figure 62: Two 'improved' sources - Kumrabai Junction

This village was selected because of the minor technical problems that were facing their improved sources. This would have made them more inconvenient to use than they would be if they were fully functional – but they are still capable of supplying the village with an improved source of drinking water. The hand-pump wells only had minor damage to the hand-pump lifting mechanism. They could still provide water, and were seen to do so, through the inspection (manhole) covers. Therefore they required the same type of access as local unimproved wells, but with slightly more effort, as they have a deeper shaft, smaller opening for access and a higher headwall. The significant difference is that the lined wells fulfil all the criteria for being an ‘improved source of drinking water’ even without a functioning hand-pump. Kumrabai Junction is also located in an area with a high water table and the two wells were reported to have never have gone dry. The site visits indicated that the unimproved sources were still in use – note the water collected buckets at the sources (Figure 63). The final results were mapped using the GPS co-ordinates (see Figure 64).

Figure 63: Examples of traditional 'unimproved' sources - Kumrabai Junction

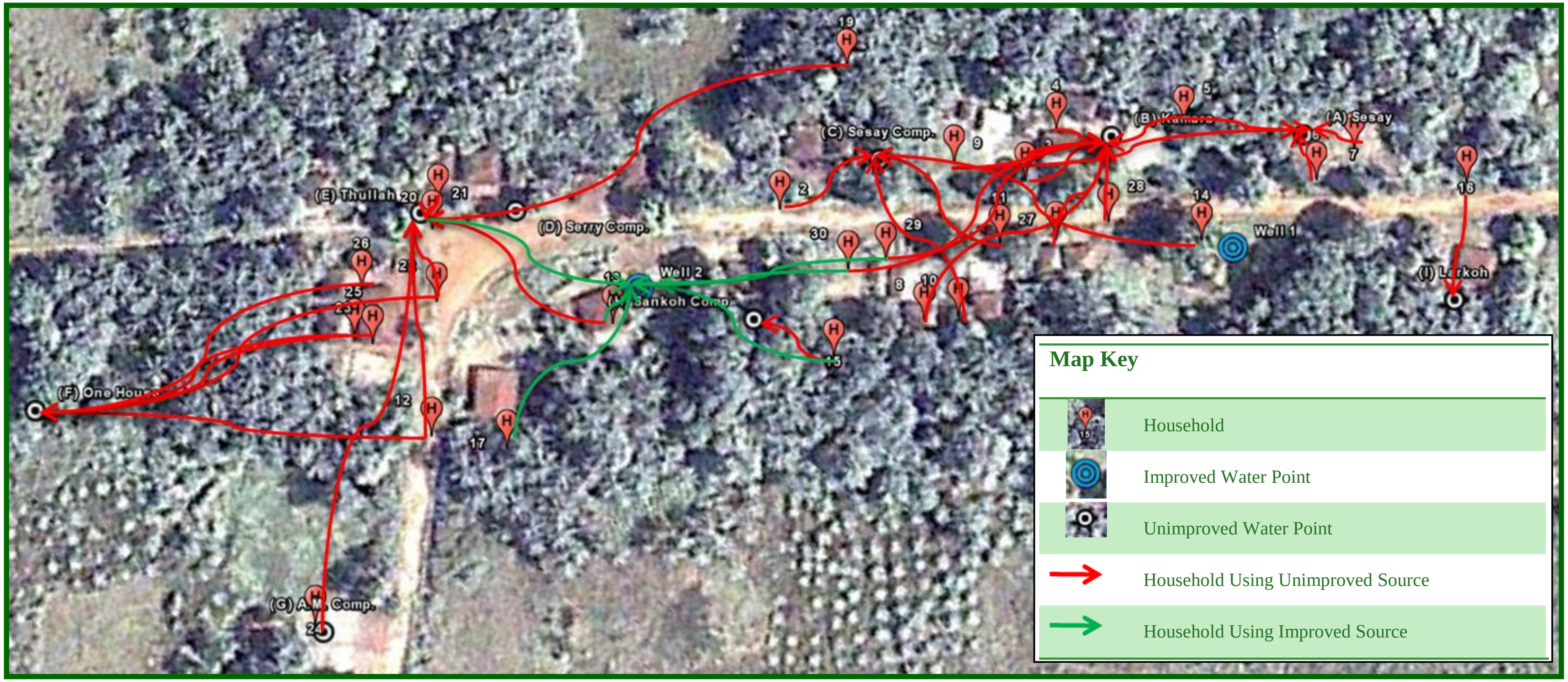


Figure 64: Use of water from households using improved or unimproved sources - Kumrabai Junction

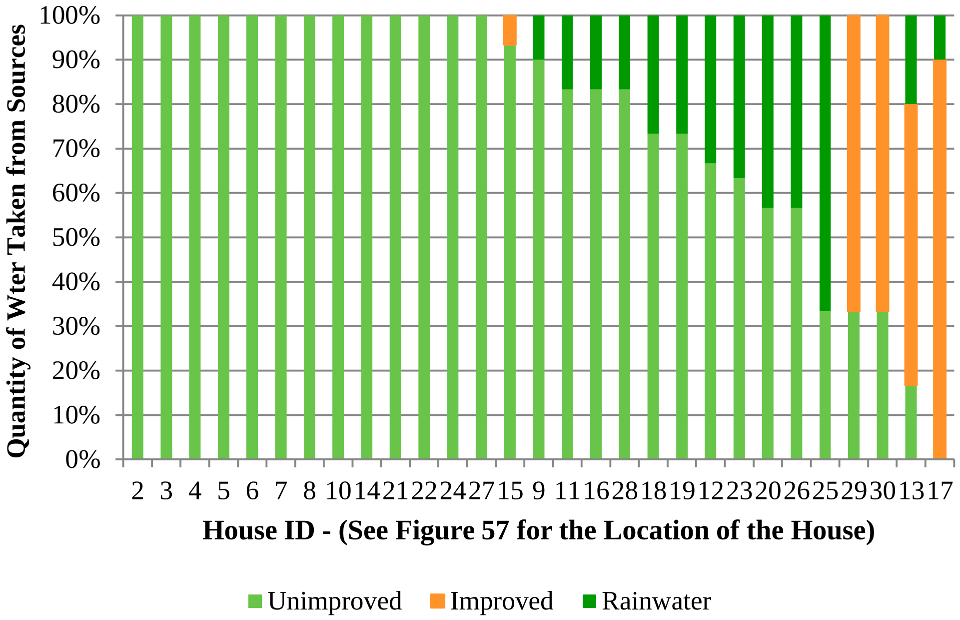


Figure 57 (continuation): Use of water sources – Kumrabai Junction

The site visits indicated that the traditional, unlined and unimproved sources were preferred as a source of drinking water over their alternative protected and lined solutions. The survey of the use 'household water sources' was carried out in all the communities to determine the parity with the case study in Kumrabai Junction (Figure 65). It is important to note that all of the villages studied in the survey areas had previously received access to an improved source of drinking water, and are therefore not conclusions drawn from households without access to an 'assumed safe' source.

As an additional consideration the results discuss here also omit villages that only had access to a 'Grade A' well. Villages that only have this access would, by default, only use unimproved sources that would negatively skew the results. The water quantity surveys indicate that the communities in Tonkolili continue to use unimproved sources of drinking water despite their access to improved sources (Figure 65). The majority of the households (53.4%) were found to use both source types. A total of (29.9%) of the households were found to ignore their improved source entirely, and only take water from unimproved sources. Only a minority (16.7%) used their source as anticipated, and only took water solely from improved sources.

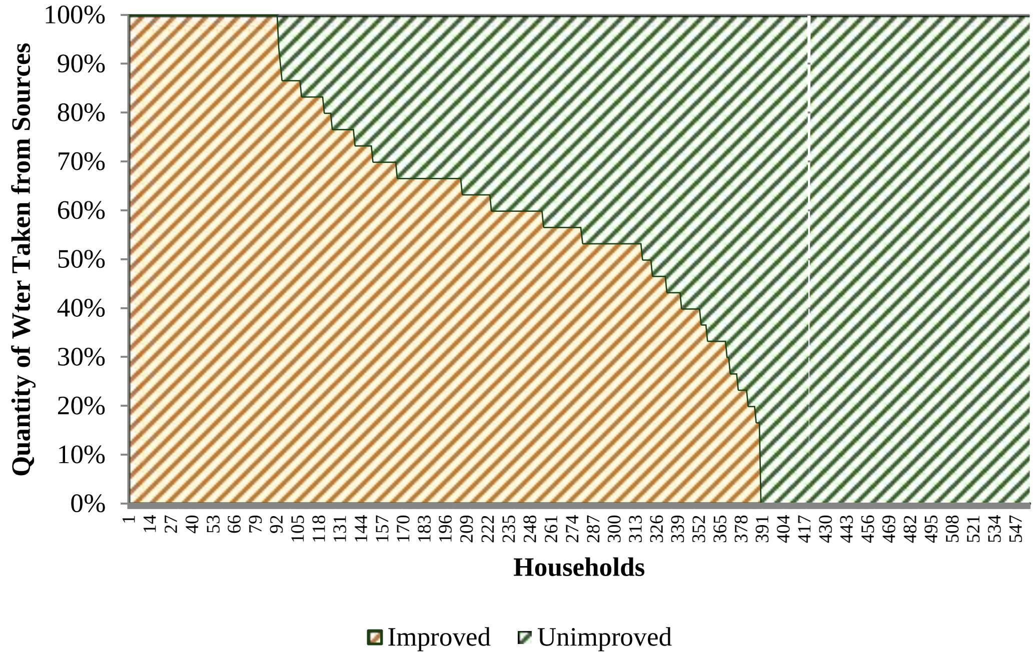


Figure 65: Source of household water in the dry season for all households

The results can be shown to affirm that contaminated water is used regardless of whether there is an improved source of household water (Figure 65). The complex nature of the socio-technical systems can raise multiple explanations for these events occurring. These false conclusions can disguise the true nature of the problems. There are three important fallacies that have to be addressed:

A. Unsafe water is gathered, but is only used for domestic purposes, and not used for drinking purposes. There is therefore a minimal actual threat to the households. The households who use the unimproved sources are only those that do not have any access to the safe water points.

B. The researched examples are worst case scenarios because it uses dry-season data- and therefore is only rationalising practices of households dealing with water shortages

C. These practices can be rationalised by other scenarios, which have been anticipated – most notably the location of the sources to the households, and are therefore not dependent on the relationship between the technologies and the households.

(A) The unimproved sources: drinking or domestic water supplies

Using an unimproved source of water for certain applications, such as bathing or domestic chores, are unlikely to cause the same health issues as consuming the water. This changes if water supply is scarce (Jofre et al., 2010). Infections such as trachoma, an eye infection causing blindness, can be caused by sharing and reusing for washing hands and face water contaminated with pathogens specific of skin and eyes. Given the abundance of water resources in Sierra Leone water scarcity is not a central issue.

There are some possibilities of safe water practices in this regard particularly in the cases of households complementing their sources with water from unimproved wells. In this situation it is possible that the drinking water is only taken from the improved source. The deficit, which is only used for non-consumption purposes, could theoretically be taken from more plentiful sources such as rivers and streams. This would not be an ideal situation, but it is certainly better than drinking from the unimproved sources. The suggestion that this is in-fact the practices of the household would be credible if they were shown to display household water storage facilities that would be capable of coping with multiple source management. The observations in the 150 household surveys strongly suggested that this was not the case (Figure 66). The entire household storage of water was primarily a single container (53.7%) or two containers (19.8%). The majority of these containers would also be used for the collection of water from the sources. This invites further contamination into the water storage cycle. The containers themselves were often dirty (50.5%) or unprotected as they had no cover (47.5%). The condition of storage does not diminish, but perhaps strengthens, the concept that people in Tonkolili are not providing safe water to their households.

Figure 66: Typical example of observed household water storage containers

Finding supporting evidence that the unimproved sources were used for drinking purposes, and not for domestic use alone, was verified by the guides during the water source walks. Each surveyed community were asked to guide the field researchers to their used drinking water sources. Additional confirmation was required from the guides at each site to verify that it was actually used for drinking purposes. Occasionally water sources were passed that was used for other purposes, such as making palm oil, bathing or washing clothes. The distinctions between the two types of sources were highlighted by the communities themselves. Their function was usually determined by local conditions – such as proximity to plantations for palm oil, or depth of water for clothes washing (Figure 67).

Figure 67: Women using water for non-domestic purposes - Mayinkoko

Finally, the visits to the unimproved locations also involved many indirect observations of users drawing and drinking from unimproved water sources. In the picture below of the woman in Mayatha a local bowl, used for drinking purposes can be observed (Figure 68). These events happened without fanfare, and were normally observed from people that were met at the sources, rather than the guides – who could be suggested to be manipulating events. This suggested that the practices were routine rather than occasional occurrences.

Figure 68: Woman using unimproved water source for drinking - Mayatha

(B) Seasonal water shortages, rainwater and unimproved access

The condition of the water supplies from many poor practices in construction has resulted in 55% of the wells reporting some form of shortages during the dry season. However, isolating the 224 households that have continual access to an improved source of water did not result in significantly different practices at the water point (Figure 69). There is an improvement with those only using improved sources (20.5% - an increase of 3.5%) but the majority of the users with access to an improved source mix their water (50.4%), or continued to only use their unimproved sources (29.0%).

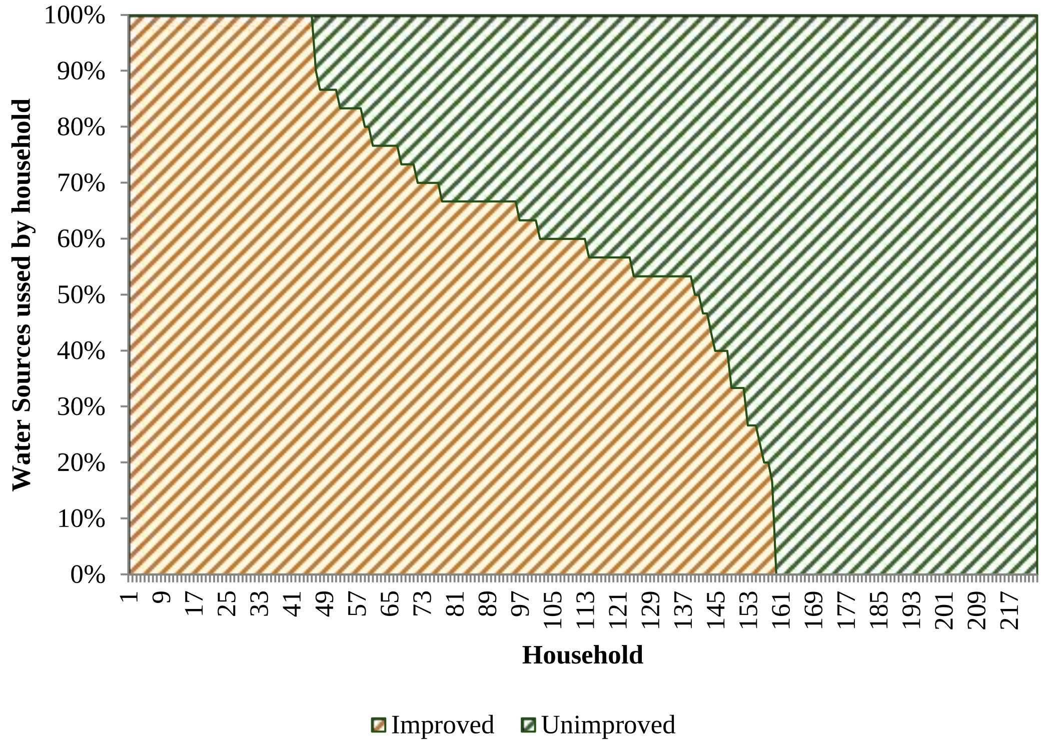


Figure 69: Water quantities of households with seasonal access

The results of the water quantities of households in the wet season are more complex. The suggestion that water is collected in larger quantities and from safer sources in the wet season is at least partially true. The reported safe and unsafe water practices appear to be dramatically different from those taken in the dry season (see Figure 70) with 55.7% of water coming from improved sources and only a minority of the water being mixed (21.3%). There are still large numbers of households that have access to an improved water source that continue to abandon their source (23.1%). However, these numbers are dependent on rainwater being regarded as an improved source of drinking water. Including rainwater in the 'unimproved' classification demonstrates both the importance of this resource in rural Tonkolili, but also the frequency of its use in households.

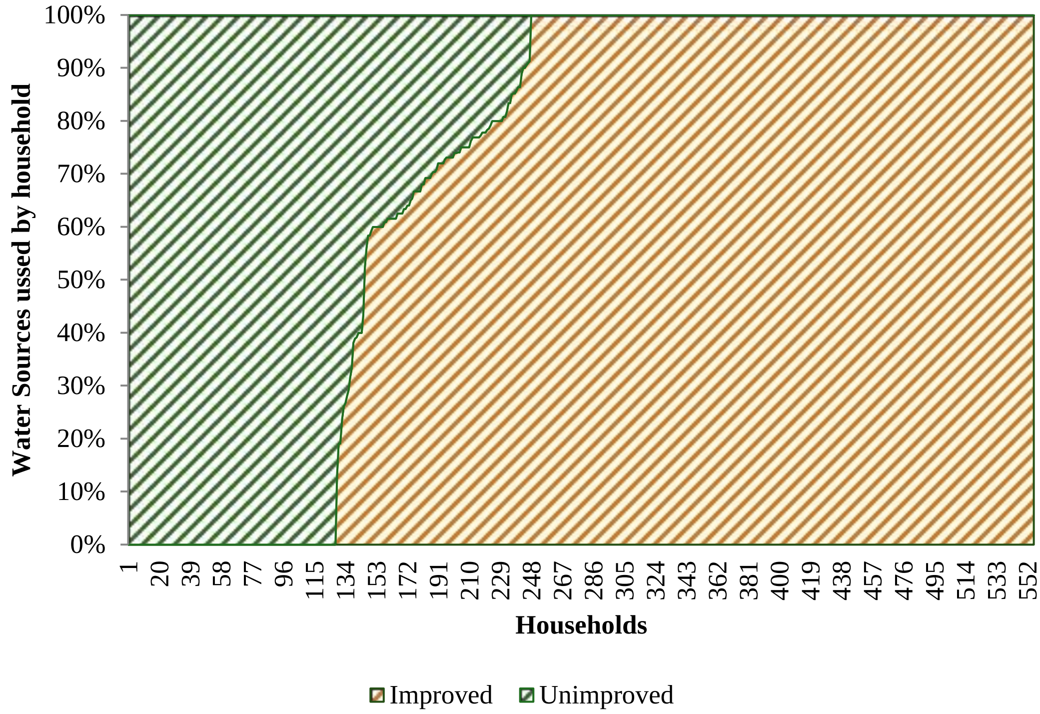


Figure 70: Water quantities of households - rainwater considered improved

With the exception of two (0.4%) of the 565 surveyed households almost all community members used rainwater collection. The implications of these practices have substantial consequences for the socio-cultural systems of the communities. This will be discussed in more detail in the following chapter.

Given the unsafe condition of the majority of the storage containers used for rainwater collection, combined with the basic mechanisms used for rainwater harvesting - which excludes first flush systems, basic filtering or downpipes to protect the water - it is unclear how their methods could be described as being ‘assumed safe’ (Figure 71 & Figure 72). Though, in according to UNICEF and WHO guidelines, this can be considered as being an ‘improved source’ there must rationally be more sophisticated technical standards for the collection practices for the method to be ‘assumed safe’.

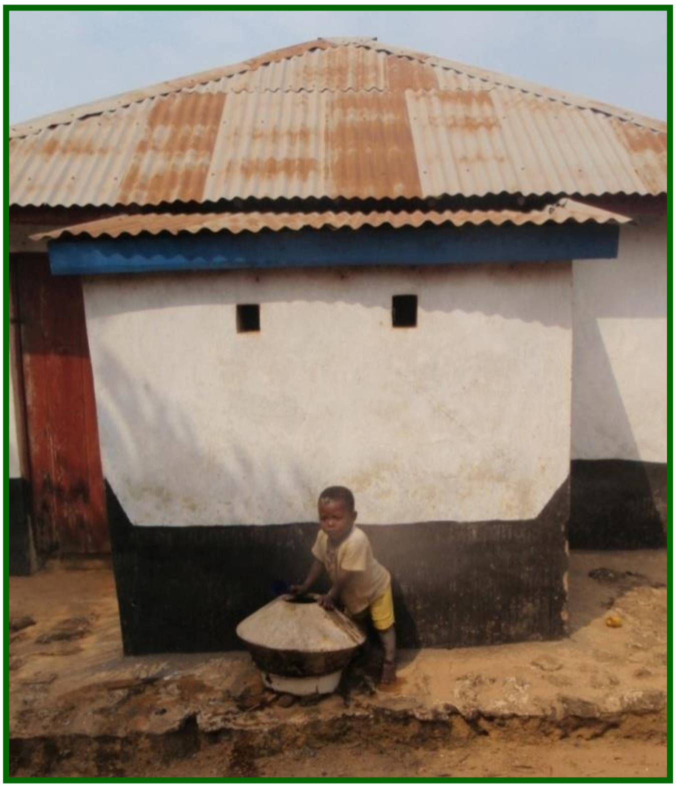


Figure 71: Child drinking from rainwater storage - Makone Yambie

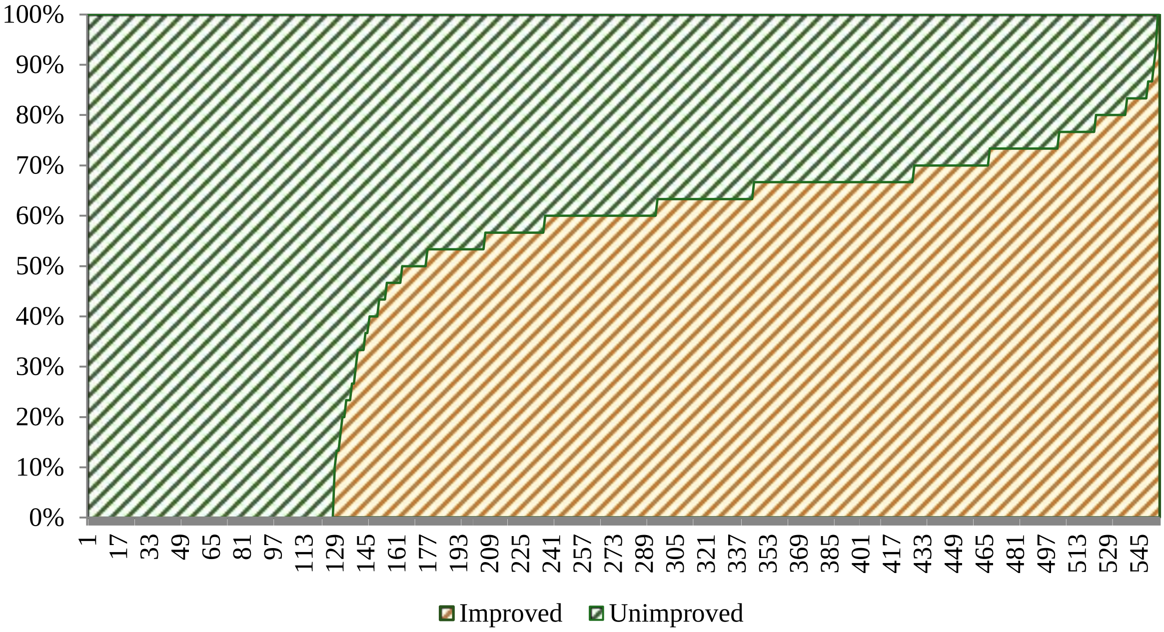


Figure 72: Water quantities of households - rainwater considered unimproved

The differences between the dry and the rainy seasons suggest that there are changes in the patterns regarding how water is gathered and used in these periods. There is however insufficient evidence to suggest that this change is made because water is reprioritised at the household level as being ‘safe’ in the wet season. The high water tables and quantity of water available in the wet season will mean that certain collection methods, such as rope and bucket systems, require less energy for collection. There would also be fewer queues at sources, or waits for water recharge, which can explain the increase in the use of sources. Regardless of the abundance of water available in the wet season there were still household that continued to use unimproved sources to complement their main source of water. The water quantity results suggest that water is gathered opportunistically from any source. Therefore it is the convenience of collection methods offered to the user, rather than the safety of the source, that determines its usage.

(C) Water Practices and Technical Failure

The final aspect concerning the use of water supplies is the location of the households to their improved and unimproved sources. There are various reports stating that the optimum sustainability of water supply technologies requires households to have few choices in alternative water sources (Breslin and WaterAid, 2003; Harvey and Reed, 2004; Nyundu and Sutton, 2001). However, there are few findings that discuss how the technology transfer should be approached when water is abundantly available and a restriction of access is not a possible solution. The most significant reason for not being able to use a source is simply that the source is not available or too far out of reach.

The Sphere standards state that there should be no more than 250 people per source (Sphere, 2011). Comparing these numbers to the census average per households as well as to the number of working water supplies suggests that 35% of the communities in the 150 villages would be without continual access to improved water regardless of their preferences or practices. In the 52 villages the averaged underserved population per village was 171 people (and a median of 131 people). Regardless, the majority of the villages (65%) had sufficient water access and these sources were not over-exploited. These numbers would be much lower if all the water sources were operational (*i.e.* no Grade A or B failures) as 84% of the communities would have sufficient access. This partially explains why certain households can only use unimproved sources even in the wet season – as there is no alternative choice available.

It would be logical to conclude that, with certain sources over utilised, there should be a tendency for users closer to the source to exploit this resource, and users further away to depend on unimproved sources. The Joint Monitoring Project of UNICEF and WHO have stressed the importance of distance to water sources as one of their few monitored indicators (UNICEF and WHO, 2012). Their assumption is that the households distance to the water point is one of the most significant factors when a user decides to use a source. The household data suggests that the farthest an individual would travel, while only collecting from improved sources, was 370 meters. Only 9 out of 565 houses were further than this distance from a source. This is due to the size of villages and the centralised location of wells in the communities. Households in villages with access to an improved source of drinking water, that were either working or in a reparable condition, were spatially mapped against their closest improved source. These were compared to the decisions made for their selection of sources. Given the relative inaccuracy of the water quantity results due to them being approximations rather than measured quantities, the decisions are simplified into four categories of access (fully improved, over 50% improved, under 50% improved and fully unimproved). Analysing the results in Minitab using log-normal distributions and comparing the probability density functions, suggested that there is no difference between the decisions based on the distance to the sources alone F(555,3)1.66, p=0.175. The results are compared as follows (Figure 73):

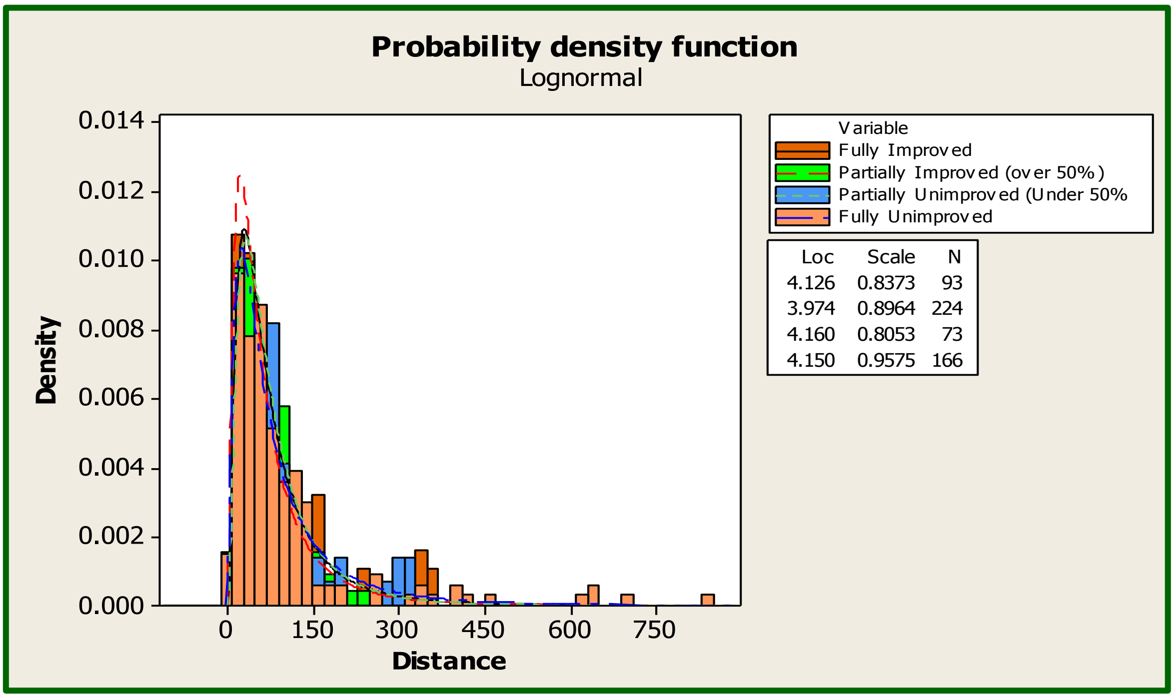


Figure 73: Choice of source compared to the distance to improved source

The results show that the probability of using a particular source type, based on distance alone, is not statistically significant. This indicates that it is not the only consideration given by a household when using a source. Therefore their decisions are influenced by a number of complex social, technical and cultural factors. The 150 KAP surveys of the households asked the water users for their reasons for choosing their sources. Multiple explanations and answers for each source were allowed. For the reasoning that has been outlined in the previous section rainwater has been excluded due to difficulties in categorising it as an improved and unimproved source. Rainwater selection decisions have been evaluated independently. The majority of the users of improved sources suggested that it was the quality of the water that they preferred (70.4%). This does not necessarily mean that they believed the water was safe, as 'safety' was never described. Instead it was the taste that was considered preferential for their choice of unimproved sources. Only one of the households suggested that they used their source solely for health reasons. A smaller minority (24%) thought that their improved source was reliable whereas sixteen (10.7%) of the households claimed to use the improved sources because it was the only option available to them.

The responses given for those using unimproved sources were more complex. The majority thought that the reliability of the source was the most important feature (51.3%) followed by their unimproved source being their only option (32%). Surprisingly, a small minority (17.3%) thought that the quality of their unimproved water was superior to their improved sources. Rusting pipes, chlorination or algae may be the cause for preferring the taste of their unimproved water points. Other stated rationalities were again more linked to convenience than safety including: least busy (14.7%), suit their house’s needs (12%) or that they were closer than their improved source (10.7%). Three of the households (2% of the total) claimed to have used their unimproved sources because they were prevented from using their improved water point. Rainwater was used mainly because of the proximity to the household (40.7%) though a similar number of the surveys (38%) suggested that people enjoyed the quality and taste of rainwater.

The water quantity surveys and KAP surveys suggest that many of the interviewed households regard the convenience of using an unimproved source enough to outweigh any of the additional efforts – financially, socially or physically - that come with using an improved source of drinking water. There is little evidence to support the theory that a significant proportion of the water users have understood, through induction alone, the actual purpose of their water supply technology.

4.3.3 Deductive Reasoning

The inability for inductive reasoning to result in the communities only taking a safe course of action with regards to their water suggests that there is a fundamental knowledge gap that is critically missing. This should not be an extraordinary assertion as it conforms to normal human behaviour patterns. It is as applicable for industrial nations as it is for developing states. The concept of 'safe water' is based on an established scientific theory and is founded on an understanding of multiple microscopic biological and chemical interactions. It cannot be inferred, without misrepresentations that could lead to harmful practices, by inductive reasoning alone. The best examples of these practices can come from the historical exploration of case studies which mirror the current situation in Sierra Leone.

There have been many examples of historical water supply systems, particularly those of ancient Rome, that were capable of providing large quantities of water to cities (Hodge, 2002). However, as evident by the number of deaths throughout history that are linked to water, the relationship between the bodies health and safe water were not understood until the period known as the scientific revolution. The most notable breakthrough in reducing mortality rates related to water was in the development of the concept known as 'germ theory' (Goldstein, 2010). The 1854 cholera epidemic in Broad Street in Soho, London, was a catalyst for the growing understanding of the effects of contaminated water (Johnson, 2006). This was the fourth cholera outbreak in a decade and it killed approximately 600 Londoners. Previous cases in London (1848–49 and 1853) had killed 14,137 and 10,738 people respectively. It was estimated that during the 19th century Cholera had, globally, killed tens of millions of people. The English physician, John Snow, was a sceptic of the popular miasma theory which was used at the time to explain the transmission routes of the disease. Miasma theory suggested that it was 'bad air' or 'noxious pollution' which had caused the disease. Using mapping techniques Snow was able to trace the contamination of Cholera to a hand-pump on Broad Street. This pump had been constructed near a cesspit which introduced faecal bacteria into the water supply. The hand-pump was disassembled following the publication of his findings. Though Snow was capable of showing the communities that they had contacted the disease through this mechanism, he was not able to prove that it was the water that was the source of the illness (Hempel, 2006; Vinten-Johansen and Zuck, 2003). The scientific theory of Germs, at this point in history, had not yet been established. Due to pressure from the local council the pump was reassembled and the reasoning behind Snow's faecal-oral transmission routes were ignored. There are direct parallels between the council opting for 'convenience' that they valued, instead of opting for 'safety' that they did not yet have the capacity to understand, and the current practices of the households in Sierra Leone.

In 1866 cholera returned to London. It did not affect certain populations that had access to a newly constructed sewerage system. These sewers were conceived by the prominent engineer Joseph Bazalgette. The cholera outbreak did however kill nearly 4,000 people that were not covered by this system. Referring to the concept of engineering operating in a paradigm of 'post-normal science' the sewerage system built by Bazalgette was designed to address miasma theory, not germ theory. The Metropolitan Board of Works tender for the *"merciful abatement of the epidemic that ravaged the Metropolis"*, accepted a scheme to implement sewers, though not explicitly for health reasons. The mounting sewage and waste runoff in London had, at the time, resulted in a constant negative impact on the civil and social life on the Londoners. The House of Commons finally took action after their members complained that the smell was interfering with their work (Halliday, 1999). Though the London sewers were an engineering feat of great importance, without an established recognition of germ theory, it can only be classified as an 'unintended consequence' that it had reduced the impact of cholera (Merton, 1936).

The full explanation of germ theory was finally established in the late 19th century through advancement by scientists such as Louis Pasteur and Robert Koch (Metchnikoff et al., 1971). This definition of transmission became the dominant scientific theory for explaining the spread of disease. Future engineering progress into water supply innovation depended on these advancements. From these theories new methods were established that allowed for the filtering and purifying of water, thereby making it fit for human consumption. Over the following years, decades and centuries that followed these breakthroughs the scientific theory of germs became an established concept in the sciences (Goldstein, 2010). The theories were disseminated through existing national and international educational institutions. The concept of 'safe water' is currently taught as an elementary component of the physical sciences of biology and chemistry. Based on public perceptions of safe water, this education has informed the socio-cultural and socio-technical systems and practices in all of the developed nations. The concept of 'safe water' is now regarded as common knowledge in many developed countries. In these nations knowingly drinking impure water would be considered foolish. Intentionally giving contaminated water to another, or perhaps more importantly, to a child, would be considered a crime of reckless endangerment, negligence or grievous bodily harm. Furthermore, a sufficiently educated person from these countries, given a choice between the indefinite use of their phone and drinking contaminated water, or having pure water, but an inability to use a phone, would be expected to opt for the safe water choice.

There are three important historical lessons that are understood from these case studies that are relevant to this research:

1. Without an understanding of the mechanisms of disease, by a host community, there is only a limited impact that awareness raising can bring (such as Snow’s efforts with the local council and the hand-pump).
2. Technology transfers in water supply should require basic scientific concepts to be understood by some, if not all people, in a socio-technical system. Without this knowledge external influences and pressures placed on committees and councils will result in unsafe practices.
3. Finally, seeking an explanation for causation is not – as Kipling described it – ‘heathen folly’. Miasma theory was not a religious concept, but a flawed scientific theory. It was a natural human response to rationalising why such non-linear events have occurred using the information and tools that are locally available.

This case study of cholera, and the spread of the disease itself, has a direct parallel to the existing situation in Sierra Leone. In 2012 the country experienced the worst outbreak of the disease since its records began and the worst in West Africa in a decade (GOSL, 2012). The epidemic in Sierra Leone, which had its origins in the Marbella slum of the nation's capital, resulted in over 22,500 cases and 293 deaths (GOSL, 2012). The disease did not spread instantaneously but developed over a number of months (Figure 74). The onset of the ‘rainy season’ introduced a sudden upsurge in both cases and fatalities. The international donor community quickly responded to the rapid increase in cases by making funds available to the operational development agencies. The NGOs developed targeted responses for affected communities which included shock chlorination of their water points, the provision of oral rehydration therapy and sensitisation programmes (WHO, 2009). The impact of these interventions was successful in reducing the Case Fatality Ratio (CFR) from a high of 8.5% to an average of 1.3%. This was not an engineering response to a humanitarian crisis. Instead it only indicates the strengths of the public health responses and the effectiveness of NGOs in certain disaster relief situations.

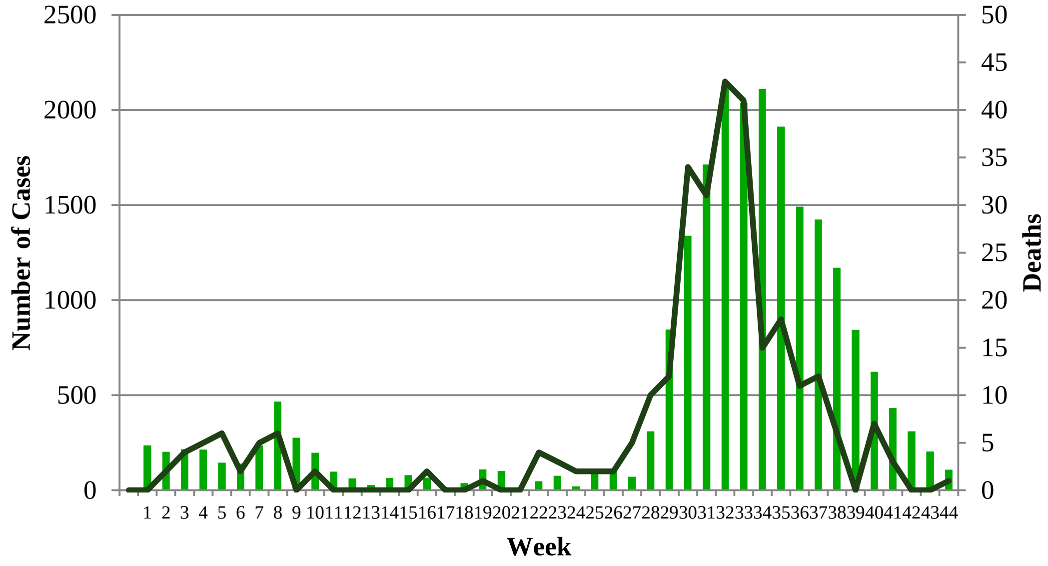


Figure 74: The trends of cases and deaths caused by cholera in Sierra Leone (2012)

Schumacher strongly supported the argument that there is a missing 'knowledge factor' that is omitted from developmental programming and which is responsible for failing projects (Schumacher, 1973). For deductive reasoning to be successful there must be the capacity of the user to deduce, through an understanding of their scientific models, the function of their artefact. This depends on some form of formal education having sufficiently presented the correct, and usable, information. This presents one of the most challenging problems of working in a developing country, the interaction between the locally available information, referred to as indigenous knowledge, and the scientific knowledge of the communities themselves (Agrawal, 1995; Briggs, 2005; Chambers, 1983; Smith, 2009). It is beyond the scope of this research to argue the epistemological or practical differences between both knowledge types. It is sufficient to note that there are substantial differences between what is known to have been understood - using either 'traditional' or 'scientific' deductive methods to explore the natural world, in every nation (Agrawal, 1995).

The concept of 'safe' water in the communities indicates that there are problems with their understanding of this knowledge. The FGDs and the KAP surveys both suggested that there were missing links in the perceptions of safe drinking water. The extent of this problem was not immediately clear through the responses given in the initial KAP surveys. The results showed (Table 10) that the aesthetic properties of water were the most important aspect when considering a choice of source.

Table 10: Household descriptions of 'safe water'

Parameter	No. of Responses	Percentage of total
Water that is clean/clear (transparent)	82	54.7%
Water that has no taste	66	44.0%
Water that has no colour	53	35.3%
Water without Dust/Particles or Rust	16	10.7%
Water that is treated	11	7.3%
Has no germs (Concept Not Known)	9	6.0%
Has no germs (Right Description)	8	5.3%
No Response	6	4.0%
From a covered source	5	3.3%
Has no germs (Wrong Description)	5	3.3%
Water that has no smell	4	2.7%
Water that is cold	3	2.0%
Comes from an Improved Source	2	1.3%
Does not contain salt	2	1.3%
Water that Provides Health	1	0.7%

The problems arise when an individual uses the same classification of 'safety' to encompass water taken from unimproved sources. For example, few of the observed and used unimproved sources had discolouration or provided water that was not transparent – an indicator used by some to denote safety. The taste of the water can also be a dangerous indicator to use. Taste is subjective to the preferences of the user. People can prefer a taste based on what they have been accustomed to drinking. Reasoning based on aesthetic properties alone can also be used to reject improved sources. For example; chlorinated water can have a distinct taste, water that contains iron can be coloured though not be harmful for consumption and turbid water can be safe while also being clouded in appearance. There were individual examples of people not using improved water sources for these reasons alone.

There were only a few descriptions (14.7% of the total responses) that explicitly referred to bacteria or germs in the household surveys. These were separable into three categories where the description of germs was found to be; (i) understood, (ii) not defined or (iii) misunderstood. A liberal allowance was given when confirming that the notion of germs was understood at the household level. For example, mentioning that germs caused harm, were not visible to the human eye or were living organisms was sufficient for the assumption that there was some form of scientific knowledge in the household.

The twenty eight FGDs with the Water User Committees and the User Groups offered a similar experience when discussing the nature of safe water. The initial responses were mainly concerned with the aesthetic properties of the water before any scientific concepts were raised. These were usually provided as an afterthought. Further probing of the definitions indicated that in the majority of cases the word used to describe 'germs' was actually that used to describe insects or visible (though small) contaminants. The most common term used was *'nictoro'* (Temne). The direct translation of the term is 'mosquito larvae'. Other definitions included local words for 'butterflies', 'worms' and 'flies'. All of these definitions for germs were found to be dependent on some form of visual verification to confirm their existence. Therefore size of bacteria was raised in the FGDs. The most common response was for them to demonstrate their supposed sizes using blades of grass or roots of plants. These were usually around 1cm long or less but they were always visible to the naked eye. The focus groups were each asked about the colour of germs. For this there were mixed responses – with each group optioning different colours – red, black and white were the most common. One participant in Kumrabai Station suggested that some were yellow – *"because they caused Yellow Fever"* [KST/T/18]. The household KAP surveys suggested that there should be certain individuals that actually have some form of scientific knowledge about germs– but there were never any counter-arguments to challenge the general consensus on the more popular definitions in the FGDs.

The suggestion that scientific knowledge has to be held by all members of a socio-technical system for the users to participate in safe water practices would be flawed. Even using a conservative estimate, it would not be expected that the populations of the post-industrial nations would depend on every individual having detailed, or even basic, scientific knowledge on the theories of 'safe water'. What is required is that there are sufficient members who do understand the terms and who have formed knowledge networks which safeguard the integrity of this information. This network of information has allowed for the concept of 'safe water' to influence the attitudes and practices towards water supplies at a societal and cultural level. This reasoning is also combined with the concept of 'authority', in that the networks determine which participants are 'experts' and whose opinions can be trusted, based on who understands the most about the science of water. This authority is established through formal institutions and educational centres. This process of information sharing and peer-to-peer reviewed networks allows for redundancies for uninformed individuals. Therefore a participant can be a member of a network, and be influenced by the attitudes and practices of those around them, without having ownership of the entirety of the knowledge themselves. The case study in 'germ theory' in Tonkolili suggests that a similar network for scientific knowledge does not exist in rural Sierra Leone.

Therefore there are two conclusions drawn from the research in Tonkolili which suggests that:

- Scientific knowledge about germs is not held by the majority and therefore, in its absence, the guiding paradigm is an indigenous concept of 'safe water'.
- The interviews and discussions also suggested that local 'experts', who do have some form of scientific knowledge, do not have sufficient understanding of the concepts or authority to challenge the behaviour of those around them.

The main institutions that are responsible for the dissemination of scientific knowledge, in both the developed and developing nations, are secondary educational institutions. It is in this regard that Sierra Leone is most disadvantaged. The 150 household surveys, which represented 2,795 people, explored the number of people with scientific education. Having secondary school level teaching, or above, qualifies as being scientifically educated. In total 50 people had some exposure to scientific education (39 males and 11 females). This represents less than 1.8% of the total inhabitants in the surveyed households. This is less than the number of people that would be expected to be attending secondary level education as the scientific courses are not available in every school. As discussed in the contextual analysis, Sierra Leone does not have the infrastructure capable of providing secondary school education to many of the rural communities. Not only are there few facilities for teaching scientific theories but the pedagogy of teaching only allows for didactic lessons - instead of using the more beneficial experimental learning methodologies (Freire, 1970). The combination of problems ensures that properly educated individuals are few. Those that are educated have usually not been taught using the most efficient, informative or accurate methods. This means that they are unable to contest contradictory theories that arise when using indigenous knowledge alone to describe water safety.

Using deductive reasoning to determine the functionality of a water source is compounded by the vast number of co-existing theories that can be used to explain the 'cause and effect' of contaminated water. General statements, based on empirical observations, are made about events that have occurred. These are usually scientifically inaccurate. This knowledge gap forms due to the non-linear relationship between contaminated sources, clean water and the health of the user (Cairncross et al., 1980). The inability to isolate the effects of drinking impure water allows for simultaneous, and often contradictory, descriptions of causation to occur. This is caused by the complex transmission routes for diseases and infections, combined with varying symptoms in different people due to immunity differences. For example research has indicated that diarrhoea is more likely to be caused by poor hand-washing and inadequate sanitation than by water supplies alone (Curtis and Cairncross, 2003; Fewtrell et al., 2005). In Tonkolili poor hygiene is coupled with other aspects of contamination such as; poor cooking practices, animal vectors that carry disease, the use of bush-meat and squalid living conditions. Even if the water supplies were capable of providing a clean source of water, against this sanitary backdrop, the result would only provide a percentage reduction in the total illnesses of a household. This slight deficit in illnesses is difficult to determine by an individual that uses empirical evidence alone.

Using scientific reasoning to explain the nature of ‘safe water’ can be contested by indigenous information formed through incorrect empirical observations. For example several of the communal surveys involved discussions with older individuals in the communities. These elders had usually been drinking from their unimproved water sources for decades. These informal discussions usually involved continual references to their health being verifiable proof that the actions of using their unimproved sources were not harmful. As with the explanation of ‘germs’ the concepts of the ‘immune system’ - the ability for the body to become accustomed to certain local bacteriological contamination, were lost in translation. The relationships between the exceptionally short life expectancy in Tonkolili, including the high infant mortality, and the illness caused by the water sources could not be made using empirical evidence alone. Only in extreme circumstances was the feedback on water instantaneous. This resulted in people being sick immediately after consuming water from their unimproved sources. Unfortunately this was also applicable to improved water sources, as there were several reports of people abandoning their safe water supplies because of over-chlorination, which had resulted in illnesses.

4.3.3.1 Misinterpreting Inductive and Deductive Reasoning

The argument for the omissions of deductive reasoning is one of the most substantial for the sustainability of water supplies in Tonkolili. It is the knowledge factor which, as Schumacher stressed, *"is so conspicuously missing"* (Schumacher, 1973). It also offers a theory as to why the NGOs provided the water supplies using the flawed methods that they adopted in Sierra Leone. Water supplies in many other nations in Sub-Saharan Africa, and throughout the developing world, would not be expected to have the same problems that were found in the case studies in Tonkolili. The difference between Sierra Leone and other nations is their abundance of water resources. In nations where water resources are scarce the communities will seek to resolve their issues as a matter of survival. They are doing this only to addresses a physiological need (Maslow et al., 1970). A logical rationalisation of their practices would be that they are only using their improved sources. This would be the same regardless of whether they knew about 'safe water' or not. Therefore they would have no need for deductive reasoning. These systems would only require the inductive capacities of the communities for the supplies to be successfully valued and maintained. In retrospect these countries, like Bazalgette's sewerage systems, are dependent on 'unintended consequences' of the action to achieve their health benefits.

Requiring this local appreciation attitude to be a standard response across all programme areas in all countries is a gross misinterpretation of human behaviour. In this regard the capacity of development agencies for multi-national responses and internationally standardised services, the very strength of the NGOs, has been used against them to the detriment of the water sector in Sierra Leone. Learning through authority and design are similarly incapacitated due to the lack of deductive reasoning.

4.3.4 Authoritative Reasoning

The poor coverage of formal secondary school education within the rural communities is a well-known problem for development organisations. The lack of scientific knowledge within the communities affects all aspects of their health programming and is not limited to the water supply sector alone. It would be out-with the capacity, even with the combined efforts of the largest NGOs, to provide secondary school education to all the communities in rural Sierra Leone. Even the actions of the local government are severely restricted by the lack of finances that are available from international donors in this regard. Primary school education is determined as being a human right – which prioritises literacy and numeracy (UN, 1989a). Secondary education is not supported in the right of the child and is therefore without international monetary support and backing. This means that the successes of the projects that are dependent on some form of scientific education usually rely on some form of authoritative teaching. Unlike deductive reasoning, depending on authority to understand the properties of an artefact does not require a person to understand the nature of the technology; instead it requires an individual to trust the opinions and advice of an expert. There are two aspects of authority that are considered in this research:

1. Direct Authority – i.e. using community sensitisation campaigns
2. Indirect Authority –i.e. using local agents to spread information

Using authority directly requires organisations to rely on the strength of their relationships with the communities. This can be used to influence how they will engage with their provided services. There are many examples of authoritative messages, covering a broad range of health issues, which are spread by NGOs. These usually display simple messages of the behaviour that they are intending to promote or discourage. These advocacy projects are referred to as ‘sensitisation’ campaigns. They are designed to make community members more aware of health issues, without requiring them to understand the exact nature of the propositions. For example the posters shown below (Figure 75) suggest that people should only use improved sources of water to prevent diarrhoea but are left without an explanation as to why.

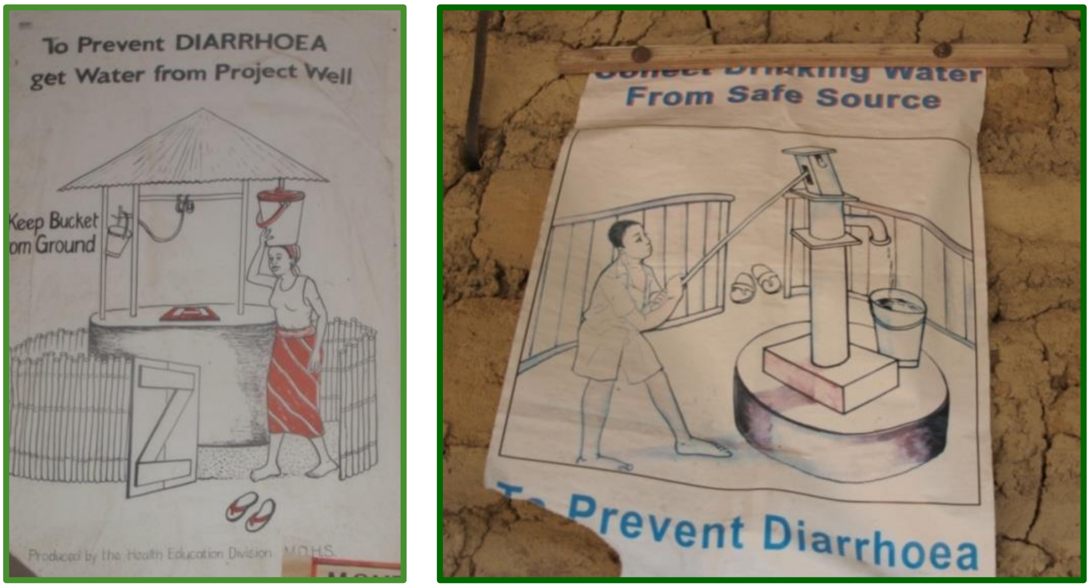


Figure 75: Posters for only using an improved source

There are a number of problems with the utilisation of direct authority:

- Direct authority works best, for example in the United Kingdom where there are health messages on the relationship between smoking and cancer, if the intended audience already understand the fundamentals behind the concepts. These messages can therefore act as reminders of social and personal responsibilities - and therefore further information is not necessarily required. As explained in the exploration of deductive reasoning - scientific concepts such as ‘germs’, ‘pathogens’ and ‘bacteria’ are poorly understood at the local level. This shortage of strong educational foundations undermines the success of direct authority as the majority of the messages will be unheeded or misunderstood.

- The NGOs are theoretically transitory and are only intended to provide a short term service to communities (Desai and Potter, 2013). After 2002, and without precedent, NGOs appeared in huge numbers in Sierra Leone (see Chapter 2: Part 3). Since then the number of operational agencies implementing projects has slowly declined. As they are not an established component of the socio-technical systems then they are perceived as only short term intermediaries by the host communities. Though this is beneficial from a withdrawal perspective an NGO can vastly overestimate their authority on community matters. This is important for water supplies as the health message requires a response that is uninterrupted by alternative practices.

- Water supplies are only one aspect of community living that is prioritised by NGOs. The streams of information and social campaigns are among a host of other issues that are funded by international donors that NGOs seek to resolve. The same health clinics which display posters regarding improved water supply also provide information on everything from breast feeding, HIV/AIDS treatment, polio vaccinations and sanitation campaigns. Similarly communal areas can have information on domestic issues such as the awareness campaigns for Gender Based Violence (GBV) and sexual exploitation. They also usually contain a host of information on local governance such as the election of local councillors, presidential election information or votes for chiefdom leaders. The information about water supplies can be effectively lost in this myriad of information (Figure 76).

Figure 76: Example of peripheral health clinic posters

There are various in-direct routes for providing information to communities. Using local social hierarchies, such as chiefs or woman leaders is one utilised method. Others involve using the NGO established committees, such as the Water User Committees (WUCs) and Village Development Committees (VDCs). Chapter 4: Part 2 has already stressed the lack of effectiveness of the WUCs in many of these areas.

Using indirect authority to provide health messages can also introduce misinformation if the concepts are not clearly understood by the facilitators. The shortage of basic scientific understanding displayed in the FGDs has resulted in a proliferation of incorrect information. In certain cases this could be seen as an extension of a NGOs authority on water and hygiene practices. There were examples of NGO facilitators and mobilisers providing mixed, or potentially wrong, information about safe water sources. The village of Rogbesseh, as an example of this point, abandoned their rainwater collection practices because of the opinions of a representative from one of the largest international NGOs.

4.3.5 Reasoning by Design

The final aspect of the water supplies is the involvement of the households in the design of their solutions. This is of importance to engineers as it is a method by which the profession has grown to understand and accept new technologies - and without being limited to the progress of existing scientific theories (see Chapter 2). Within any socio-technical system innovative experimental design leaps are required for technological advancement. The practice of experimentation and testing the design of new technological ideas provides its own aspect of understanding (Dahlbom et al., 2001). It can be used to determine a technologies function and role in society without fully understanding the scientific workings. Additionally the design elements in development practice, referred to as ‘participation in the design stages’ is supposed to create ownership from within the community for their artefact (Murphy et al., 2009).

The KAP surveys indicated that, though many of the households (99%) claimed to have participated in the water supply projects, their inputs were limited to certain areas. The main forms of participation were:

- 94% provided materials –usually sand and ball-stones
- 93% provided some form of labour – such as carrying materials
- 27 % provided access through their land to the construction site
- 30% provided the land that the well was built upon

When asked whether they would participate more in future projects the majority (99%) said ‘yes’. Their suggestions for how they could participate more, if a future water scheme was to be provided, only emphasised existing participatory expectations and did not include being more involved in the design of the systems. Most of the households (96%) claimed that they did not participate with regards to the design elements. Those that felt that they had influenced the design were those that had provided the location for the water point. They did not have any meaningful impact in altering the actual technical specifications of the artefact. According to these discussions the households feel that the NGOs function is to provide pre-conceived technologies that are already determined by the organisations before their arrival in the villages.

Prior to the NGO involvement in the village water supplies, and due to widespread failures of the system, many of the villages have constructed and used their own unimproved water supplies. The largest visited water points were usually village ‘scoops’ – hand-dug ponds that were shallowly excavated to around one or two meters. These were constructed using local tools and suggested little towards the villages having advanced indigenous technical skills. Many of the local ‘scoops’ included basic stairs dug into the topsoil to attain access. The swamplands usually had a sectioned area which was used for water collection. The location of these sources was based on locally known information about surface water flow but their choices were not always topographically logical.

Figure 77: A typical unimproved 'scoop' - Robis

Several villages had ‘traditional’ hand-dug wells solutions. These ‘traditional’ wells varied in their design elements and in the sophistication of their construction techniques. The vast majority were unlined holes that had no protection from contamination caused by surface runoff. There were some exceptions as certain sources had components that would reduce the danger at the source through the use of locally built linings, spillways, covers and headwalls. All of the observed locally built sources used rope and bucket systems as their solution to water lifting. There were no observed examples of locally built windlass mechanisms or hand-pump designs.

The construction of the traditional sources offered an indication of the communities design aspirations for their water supplies. This involves the use of Indigenous Technical Knowledge (ITK) as it relates to water supply design (Howes and Chambers, 2009).

The field research indicated that the ITK had embraced some of the more practical elements and construction techniques of the supplies. Advanced construction concepts, such as the use of steel reinforced concrete lining, were not well understood in the ITK systems, and were therefore less common. A significant proportion of the traditionally built unimproved sources used some form of 'slab' intended to prevent the source from collapsing due to erosion at the lip. This ‘slab’ was normally a rubber car tire, though there was the occasional sighting of a concrete slab (Figure 78).

Figure 78: Locally built unlined 'traditional source' of drinking water - Makonilina

Several of the water points were also protected with manhole covers. These were built by local wielders and were occasionally observed to be lockable. The majority of the traditionally built sources were without any form of headwall. Many of the sources are built without an observable appreciation or understanding of the benefits, or the potential dangers, of aspects such as groundwater aquifer flow, flood prevention, surface runoff reduction or source protection from local contaminants.

The experiences in Tonkolili suggest that the rural communities are still some way from understanding the' intended function' of their water supplies through the use of 'design' alone. It was found that the locally built solutions were not built to mimic the advanced NGO constructed systems. Instead they can be seen as a response to the communities own understanding of their water supply problems. The traditionally built sources also indicated that the socio-technical system does not have the capacity to provide local solutions to the problems of water lifting. This is not a safety concern in itself but there were no observed examples of locally engineered solutions to reduce the burdens on water collection at the source.

The concept of 'technological choice' is continually referred to in rural water supply literature. It is considered an essential component for providing sustainability of the sources (for example: Brikké and Bredero, 2003; Harold and Stef, 2011; Harvey and Reed, 2004). Out of 50 villages questioned only two were given any choice in their hand-pump technology, but not in alternative approaches to collection. The lack of technological choice is further confirmed by the low range of technological diversity in the approaches to water.

The choices presented to communities concerning their water supplies did not offer households flexibility in how they approached, collected or used their water.

The surveys in the 150 villages found no case studies or examples of household treatment solutions such as bio-sand or ceramic household filters (Lantagne et al., 2006). Many households had heard of post-collection treatment options such as boiling water (88%) but only a minority actually boiled water before drinking (8%). The households that did boil water had usually received this information from MCHPs due to the NGO health campaigns for pregnant mothers. There were no households that continuously treated all their water. The main reasons given were that there was no time for this practice (44%), no money (15.3%) or it was not a household practice (11.3%). This contradicts the responses of people who determined safe water as being 'treated' and yet they did not treat their water either at the source (see Chapter 4: Part 2) or in the household. It suggests that the interviewed households are providing an expected response concerning safe water – rather than their actual understanding of the description.

The omissions in technical options partly suggest that the NGOs do not believe that communities can make informed decisions about their water supplies, and require the decisions to be made on their behalf. Though most communities were found to have accepted the relationships between NGOs (as service providers) and communities (as mostly passive receivers of assistance) there was one notable exception. An informal meeting with youth in Kumrabai Junction, carried out during a post-survey evaluation during the cholera epidemic, had one young mother express a radically different viewpoint. She expressed a previously unheard sentiment: *"why did you never teach our fathers, uncles and brothers to build the wells?"* This, perhaps rebellious statement, did not register with shock among the gathered youth. There were no chiefs or elders present during this discussion which was ultimately no more than a grouping of ten young people between the ages of 18-25 years. The complicity through their silence indicated that this may be a privately held viewpoint by the youth. It appeared as almost a counter-cultural attitude to the dependency norms unintentionally created by NGOs. This sentiment was never expressed during any of the formal FGDs which involved a mixture of age groups. This suggests that the committees and older village members have accepted the conditions of the relationships between themselves and their service providing organisations, but that this may not be a unanimous decision.

Since the conception of the appropriate technology movement 'technological choice' has been seen as an ideal. There is a counter-ideological theory by those who support the opposite: a reduction in technical choices available to the communities (Skinner, 1996). There has been vocal support for standardising the water supply technology design in Sub-Saharan Africa. For example the report to the World Bank, using the same Stat-Wash database used in this research, emphasised:

> *"Unless there are specific local or technical reasons, future construction should give preference to India Mark II type handpumps. These are already the most popular model, constituting 64% of all handpumps, and further standardization of models will allow the sector to economize on spare part supplies and training of mechanics"* (Hirn, 2012).

The rationale is that; by simplifying the required private sector response then standardisation could potentially increase the sustainability of the water supplies. If this rationale were sound, and it could be shown to create sustainability, then it would indicate that the communities do not need to participate in their water source design aspects. It would allow the engineers to make decisions on behalf of their communities - without the villages' needing direct involvement in the technical aspects. This concept can be contradicted by the same findings used to promote standardisation. The STAT-Wash Database only provides a conservative estimate of functionality (See Chapter 4: Part 1) but it does provide sufficient detail to suggest that this theory is incorrect. The data indicates that there are an estimated 12,000 hand-pumps in Sierra Leone (Hirn, 2012). The most popular technology found in this survey, for both hand-dug wells and boreholes, is the India MK II - a conventional lever action hand-pump. There are an estimated 7,679 of these hand-pumps. Furthermore it is also regarded as the bestselling hand-pump in the world (Wood, 1994)

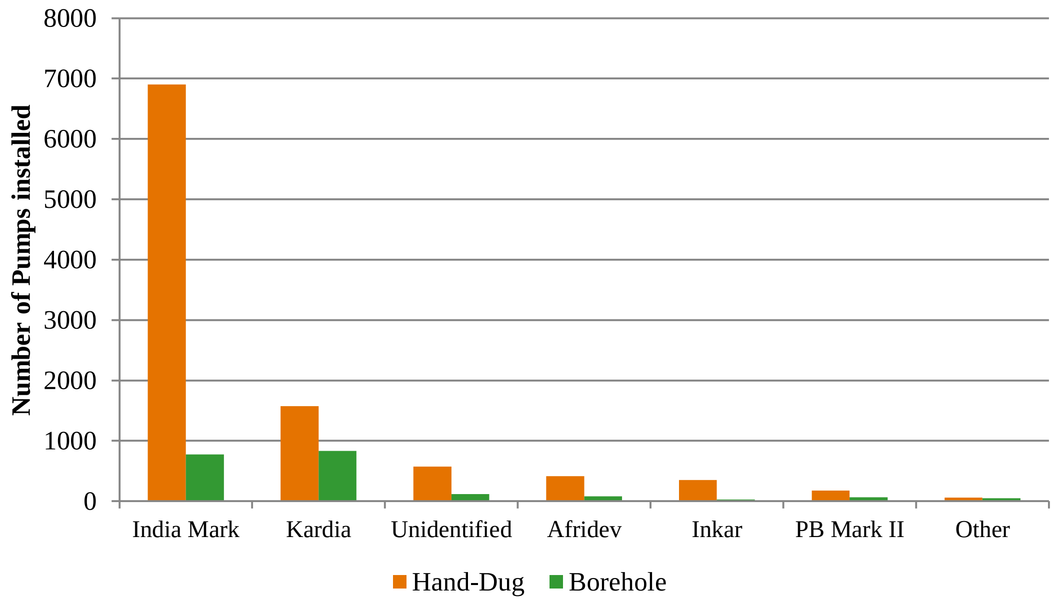


Figure 79: Hand-pump technologies in Sierra Leone (source: STAT-Wash database)

The India MKII has grown in popularity with NGOs and has been provided in increasingly larger quantities since the end of the conflict period (see Figure 80). The widespread use of this technology has had an impact on the private sector responses. Every supplier that stocked spare parts sold India MKII components (see Table 8).

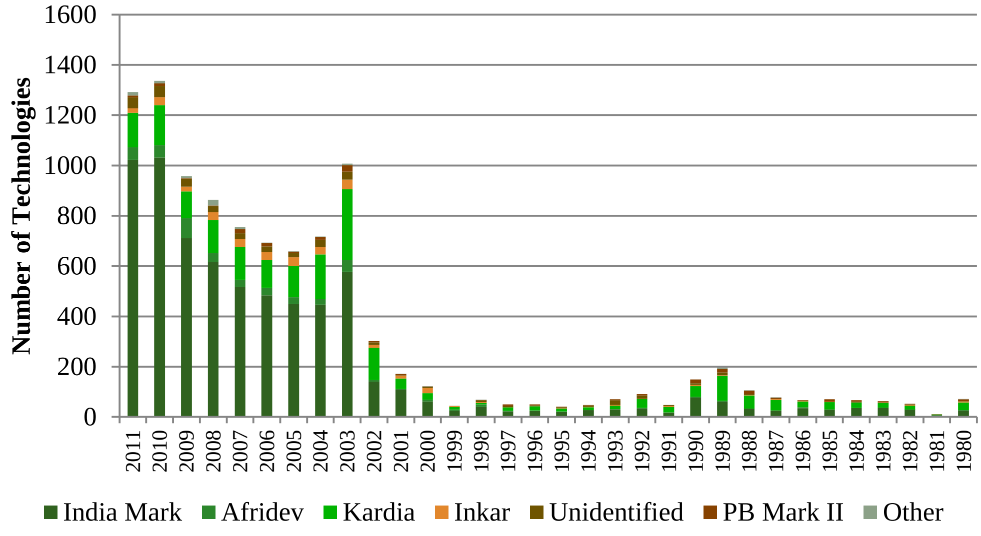


Figure 80: Hand-pump technologies implemented (source: STAT-Wash database)

Therefore it the argument for standardisation was correct then the India MK II wells would have to indicate higher rates of functionality that other technologies to recommend standardisation as a viable option (Figure 81).

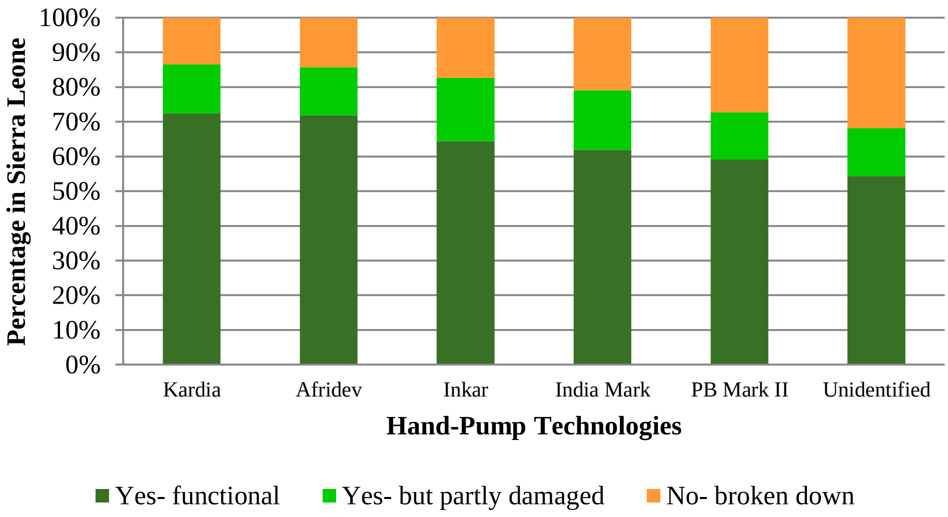


Figure 81: Technology failure by hand-pump type (Source: STAT-Wash database)

The STAT-Wash database has shown that the India Mark II was more likely to require repairs than the alternative technological choices such as the Kardia, Afridev and Inkar handpumps (Hirn, 2012). Therefore artificially reducing the choices available to the communities would not provide an automatic advantage with regards to the sustainability of the systems. The success of the mobile phone, which has succeeded in rural Tonkolili despite the prolific range of phones brands, adaptors, models and battery types indicates that standardisation is not required if the users can understand the use of the technology.

The abilities of the communities in Tonkolili to infer by design the properties of their artefacts are extremely limited. There are three aspects that have been concluded by the research into understanding technologies by design:

- It is theoretically possible for the communities to provide solutions by constructing their own responses to water supplies. Given the current output of technologies in Sierra Leone - waiting for communities to infer by design and ITK alone would require several decades, if not more, for them to incorporate safe water design features into their local construction.
- The potential for introducing more complex technologies have stalled as they would require more participation from the households – and the NGOs have struggled to provide a technology as simple as the hand-pump well.
- The suggestion that limiting the choices of the communities will enhance the sustainability of the resources is not a credible solution. Technical choice remains a fundamental element in water supplies in Sierra Leone.

4.3.6 Summary of the Condition of the Socio-Technical Systems

This chapter has stressed that the water supply technologies, provided by NGOs to the rural populations in Tonkolili, are not currently known through inductive or deductive reasoning by the households. The rural communities are also not presently capable of learning the properties and merits of safe water through designing solutions for themselves. There are basic elements of authority that are used, both direct and indirect, which have allowed a small measure of success in the short term. As evident from the condition of the current socio-technical systems; depending on authoritative reasoning alone can be shown to be unsustainable in the long term. It was found that depending on this sensitisation has resulted in a declining impact over time.

The assessment of the properties of the artefacts indicates that there is an ‘indirect’ rejection of the technologies by the socio-technical systems in Tonkolili. This is neither dramatic, nor violent, as would be the case in circumstances leading to the outright and direct rejection of the technologies. Instead the water supplies are shown to have a subtler technical decline caused by the intentional mismanagement of the sources. The causation is due to the inability of the communities to independently determine the sociological properties of their technological artefacts.

The concept of ‘participation’ in development projects has been continually referred to as a development orthodoxy (Duraiappah et al., 2005). Community participation is designed to be a consultative empowerment process. Through information sharing, consultation and devolution of decision making powers it is supposed to establish communities as effective decision-making entities and, as stated by Harvey and Reed:

> *" community participation remains indispensable for sustainable rural water provision in Africa"* (Harvey and Reed, 2006a).

This chapter has shown that current development practice provides only a limited, and occasionally token, element of participation from the communities in their water supply ‘solutions’. This form of participation has not provided the sustainability for the technologies that has been anticipated in the supporting literature.

The field study suggested that the communities have not been involved in the foundation of their projects - in that they do not participate in the ‘problem’. This explanation appears to be paradoxical, because the communities are obviously the people who suffer the consequences of drinking contaminated water, and therefore, by default, participate in the problem. However the NGOs have based their models of sustainability on solving what was assumed to be a shared concept. This extends further than the conclusion that the communities are not being simply 'motivated' to address the sustainability of their water supplies (Carter et al., 1999). Providing 'motivation' precludes an empowerment through sensitisation approach. Instead the findings suggest that it is a lack of knowledge that is missing. This necessitates some form of ‘education’ and a learning process for the households to understand the true nature of their 'problems'.

The actions of the communities appear irrational to an outside observer that understands the concepts of 'germ theory'. This is particularly acute when watching a mother giving her child water from an unimproved source when improved water points are available. Sierra

Leoneans are not consciously harming their children - as this would contradict countless observed examples of care and attention given to their families. Prior to a paradigm shift in scientific thinking every nation has had similar attitudes towards their water (Kuhn, 1970). The practices observed in Tonkolili are therefore consistent with human behaviour. Due to their lack of deductive reasoning they are operating in a subjectively rational manner towards their technologies.

4.3.7 Discussion on the Socio-Technical Systems with Engineers

As has been discussed in the previous chapters the responses to sharing these results depended on the prior opinions of the engineers,. Those that were dismissive of exploring the social context of the technologies were uninterested in this particular interpretation of the findings. Posing questions on comparative studies between the success of the mobile phone technologies and the problems of the water supplies were explained using alternative explanations. One possible suggestion was that mobile phones had better marketing and that if water supplies were to be as successful then *"widespread advertisements and publicity campaigns were all that would be required".* Though mobile phones adverts are common in urban areas they are much more infrequent in the rural areas. The uptake of mobile phones in the rural areas has been successful regardless of the awareness raising campaigns. That is not to suggest that advertising has not, or would not, be successful in a rural environment. Mobile phone advertisements raise awareness of new payment tariffs and new mobile phones suited to the markets - but these also depend on the users being aware of the inductive and deductive qualities of the product being sold.

Without acknowledging a fundamental missing link in the knowledge of the communities many engineers another proposed alternative was to refer to the communal nature of the water supply systems over the individual's use of a phone. As a shared resource the water supplies are dependent on a number of complex sociological factors to work successfully in order to be maintained. Problems evolve and culminate when each member in the community assumes that another household will contribute. Without sufficient members actually making payments then any water supply scheme would naturally fail. As discussed in the previous chapter - this process can be shown to have happened in Tonkolili. In this sense a comparative study with mobile phone technologies is redundant. However, these complex community interactions are undoubtedly significant but they do not explain why the communities do not prioritise water as being communally important. As discussed before this does not indicate why other communal properties such as school constructions, warehouses, farmlands and other village facilities can be maintained without experiencing the same issues. Therefore it is more likely that it is individuals perceptions that, when taken separately, are not fully significant but as a whole will change the outcome of the socio-technical system. Stating that the reason they fail is because they are communal property, without a requisite and complete understanding of context, would be to ignore normal human behaviour when presented with problems of this type.

What this research suggests is that there may be fundamental human reasons for the causation of failure. Looking at the history of engineering, and in particular to that of germ theory, suggests that element of human psychology has been known for centuries. It should be noted that the engineers that stressed the importance of sustainability in the discussions were much more open to understanding how NGOs interacted with this socio-technical systems. These engineers were usually from the technical backgrounds that emphasised the importance of 'appropriate technology'. Even as an important element in the discussion of water supplies the socio-technical system represents only one component of a much larger socio-cultural system. To explore this relationship further would be to understand the importance of the technologies with regards to a much larger system.

CHAPTER 4: RESULTS AND DISCUSSIONS

Part 4: The Socio-Cultural Systems

4.4.1 Introduction

4.4.1.1 Sustainability and the Socio-Cultural Systems

This research investigates the practices of engineers that are not from within the socio-cultural Sierra Leonean background and do not have an inherent knowledge of the country. As this can often cross the rich-poor divide the differences between socio-cultural systems could be regarded as being the opposite of a homophilous relationship:

> *"the degree to which pairs of individuals who interact are similar in certain attributes, such as beliefs, education, social status, and the like"* (Rogers, 2003).

Therefore this relationship could be regarded as being largely heterophilous. For an innovation to be diffused a certain degree of heterophily is required otherwise no transfer would be necessary because no new information would be exchanged between the social systems. For a successful diffusion of an innovation:

> *"an ideal situation would involve two individuals who are homophilous in every way, except in knowledge of the innovation"* (Rogers, 2003).

As a crucial element in the engineering practices observed in Sierra Leone, the heterophilous nature of the technology transfer, caused by the differences between the two socio-cultural systems of the implementing organisations and the beneficiaries, requires investigation.

Determining the structure or behaviour of the entire socio-cultural systems in Sierra Leone is difficult. This is partly due to the lack of locally written material which details aspects such as customary observances, local laws, societal organisations and language. As with any socio-cultural system many parts of its identity consists of elements that can be explicitly stated. However there are also aspects that consist entirely of information that is tacit and therefore cannot be explained, rationalised, or perhaps even experienced, by individuals external to this system. In Tonkolili this 'indigenous knowledge' is found in many aspects of community living such as laws, proverbs, songs and stories. The information can also be disseminated locally through practices such as art, dances, religious observances and rituals. Certain, though not all, indigenous knowledge aspects in Sierra Leone are linked to the secret societies. It is clear that these societies have custodianship over many elements of communal living in the villages (Fanthorpe, 2007). Even without these solidities the communities have their own local knowledge that may be found regionally, communally or at the household level (Dorjahn, 1977). Information from the indigenous knowledge systems, whether originating from the secret societies or from local observances, can be used to distinguish one community from another and provides a crucial element of identity for each of the villages. The variation of different knowledge types, as well as levels of sophistication, introduces difficulties in determining the exact nature of the socio-cultural systems interaction with the water supplies.

Water supply projects, which have been brought from outside the indigenous socio-cultural knowledge systems, are intended to operate successfully within this environment. The rhetoric of NGOs supposes that the water supplies have been fully integrated into the socio-cultural systems. The ideals of the development sector, particularly with regards to emphasised programming language such as *'participation', 'sustainability', 'ownership'* and *'cultural acceptance'* were not matched by what was observed at village level. Furthermore, this lack of integration of technologies, and the consequences of the socio-technical failures, has meant that other multi-sector approaches have missed opportunities that could have brought poverty alleviation to the rural communities. This chapter will evaluate three of the most noteworthy aspects observed during the research placements. These are as follows:

1. ***Indigenous Practices:*** This highlights elements of ITK were found to have already existed within the socio-cultural system, prior to NGO interventions, and that could have been developed or encouraged. These should have been used to influence normal development practice in engineering.
2. ***Immediate Socio-Cultural Transformation:*** As the introduction of new technologies can alter a socio-cultural system it is possible to have the actions of the communities altered by the technological intervention. These can vary between transformational and liberating - or dominant and oppressive. Monitoring the small and indirect impacts of the interventions can provide an understanding of the extent, type and success of any transformations that have taken place.
3. ***Broad Socio-Cultural Transformation:*** For many NGOs adopting a SATT model for development, the water supplies were not built only to address the problems with communities' lack of access to improved sources. The process of its construction, and the sustainability mechanisms that are put in place, are intended to have wider implications and affect broader goals in the socio-cultural systems

This chapter will explore these three elements in detail to determine the impact that the technology transfer had on the socio-cultural systems of Sierra Leone.

4.4.2 Indigenous Practices

The analysis of water supplies in rural Sierra Leone primarily investigated hand-dug well and borehole systems. This was because there were few other technical interventions found in the project areas. The Indigenous Technical Knowledge (ITK), as has been discussed in the previous chapter, was not capable of providing hand-dug sources that were fully protected and safe for human consumption. This does not mean that there are no household decisions that have been made, using only indigenous knowledge, which could have acted as the foundation for achieving national water supply targets. The most notable was the household's use of rainwater collection for drinking water purposes. The water quantity surveys indicated that the majority of households (97.8%) collected rainwater as a source of drinking water. This was estimated to have averaged over 30% of the total water that entered the household during the wet season (Figure 82).

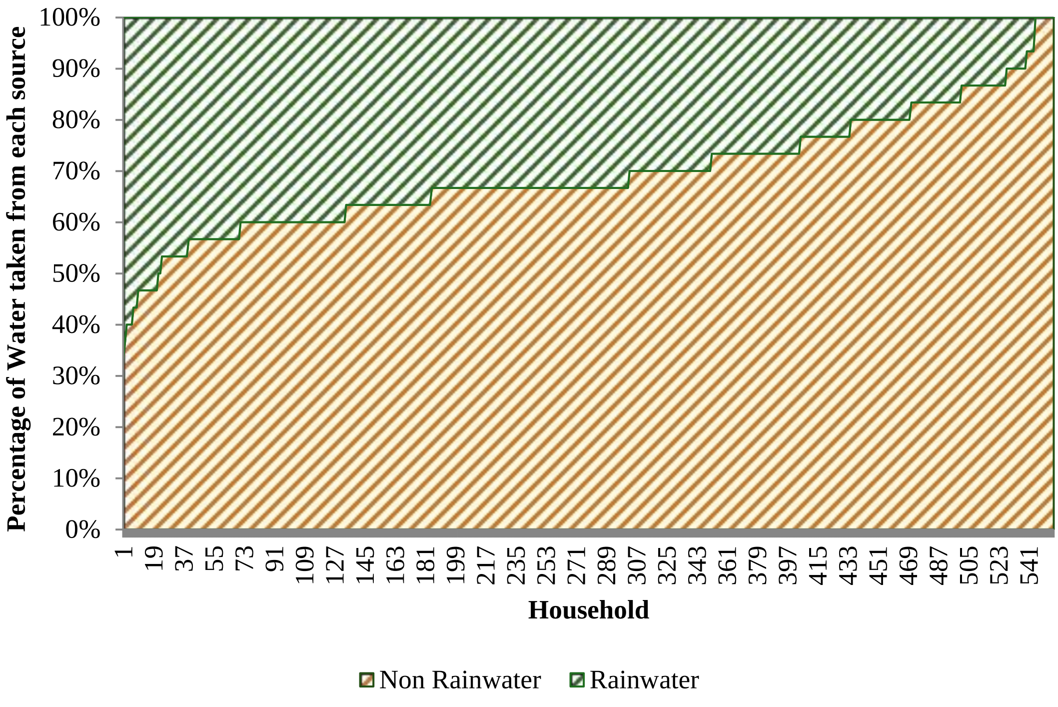


Figure 82: Use of rainwater in 565 households in Tonkolili

The methods of collection varied with each household: for example - some simply placed containers outside in the rain, others diverted water from their roof into a container while other households used communal buildings, such as mosques and schools, to collect the rainwater. Certain households had thatch roofs, which were unsuited to gathering water, but there were several examples of households sharing access of their corrugated-iron roofs with their neighbours. Most of the containers used were temporary (*i.e.* used for other purposes and not designed solely to store rainwater). There were several examples of permanent water storage that were used exclusively for rainwater collection (Figure 83). These were small containers that were located at the foundation of the households. According to community discussions these were built and supplied by one of the large international organisations. The NGO had later abandoned the practice and the coverage of these water storage containers became limited.

Figure 83: Example of permanent rainwater collection container - Robis

Permanent rainwater storage containers were noted to be popular at mosques. In the socio-cultural system in Tonkolili there appears to be a link between the Islamic culture and the use of rainwater. The location near the mosques was mainly to provide water for the Islamic practice known as Wudu. This is a sacred washing of hands, mouth, throat, nose, ears, arms up to the elbow and feet that symbolises spiritual cleansing and purity in readiness for coming before God. The use of water from certain sources is restricted for this practice - but the use of rainwater is considered to be an acceptable "pure" source. Given the scale of the Islamic population in Tonkolili the popularity of using rainwater can at least be partially attributable to the influence of the religion on the socio-cultural system. The ability for the communities to actively use rainwater presents both an engineering solution and technical transfer opportunity. As a disclaimer for the following discussion: though this opportunity exists it would be technically naive to suggest that this could be a mainstream approach to resolving water supply issues in Sierra Leone - but it could offer new method for interacting with the communities to achieve water supply targets.

The most important problem with the current systems is the build quality of the rainwater collection methods which usually source water from unclean roof structures. It is highly probable that the results of water quality testing from current collection methods would be very poor. Many of the observed households had guttering to collect the rainwater but they did not incorporate any form of filtration methods or first-flush systems to prevent contaminated runoff from entering the source. There were no observable examples of locally built down-pipes. The collected water usually free-fell from the guttering into the storage container. A typical example of rainwater collection can be shown in (Figure 84). Note the guttering on the roof structure and the condition of the containers.

Figure 84: Example of household rainwater harvesting

There were no filters on the guttering, or on the containers, that would have prevented sediment from entering the storage. Households using expensive water protection solutions, such as retention or volume filters, would be unlikely given the rural environment; however there were no indications of locally built filtration methods that could be constructed using local resources. Examples of these include sand-basin filters or using mosquito mesh as a macro-filter (Worm and Hattum, 2006).

The storage containers that were used for rainwater collection were usually very small and could only store water for a day or less. There were some examples of larger containers, but these were uncommon and they lacked downpipes –meaning that they became large open sources. Both the large and small rainwater collection containers were never observed to be covered or protected from contamination. Open sources would increase the exposure of the household to water vectors such as mosquitoes as well for larger animals such as rats (DFID, 1998). The open exposure would also allow sunlight to enter, increasing bacteria growth, as well as allowing foreign contaminants and airborne particle to enter into these systems (Gould and Nissen-Petersen, 1999; Worm and Hattum, 2006). This suggests that the water they store would have a high chance of being unsafe for human consumption. There were no examples of locally built sources that were "*functional and watertight with a secure cover*" (Gould and Nissen-Petersen, 1999). As these solutions are potentially unsafe and inefficient the ITK the process is limited to being classified as 'water collection' rather than a fully functional 'Rainwater Harvesting' system.

Regardless of the quality of the household's rainwater collection methods, this practice is indigenous to the socio-cultural system in Tonkolili. As there is no behavioural change required to get people to use this source, as the information is already within the communities, it would be rational to expect that there would be many projects that had worked in partnership with this existing indigenous knowledge. The STAT-Wash database estimated that only 0.08% of the total water supplies were fully constructed rainwater harvesting systems. Some of these projects were found in Tonkolili (Figure 85). These had been built using capital intensive methods and could be considered a LTT approach to hardware provision. These systems were not replicated in neighbouring villages. Therefore these could only be considered as a pilot scheme that was not successful in bringing the approach to scale.

Figure 85: Example of a permanent rainwater harvesting systems - Bongay

The collection of rainwater currently forms part of the indigenous knowledge of the socio-cultural system in Tonkolili. However the corresponding information about long term storage does not. The majority of households interviewed did not store drinking water for more than 3 days (58%) and the remainder drank their water within the same day that it was collected. Just less than a quarter of the households (24%) used the same container for collection of water for drinking purposes. Though there is beneficial indigenous knowledge in one aspect of RWH – the local use of rainwater, but the technology transfer would still require local behavioural change with regards to storage. Therefore the interactions of the socio-cultural system in Sierra Leone could result in both untapped potential but they also offer corresponding problems. There are evident problems when depending on RWH as the main source of drinking water, particularly in the dry season, but most NGOs have not engaged with or strengthened the local cultural practices to accommodate larger water storage. This approach would have increased the technological choices available to the communities.

4.4.2.1 The impact of Indigenous Knowledge on Water Supply Projects

The purpose of demonstrating the RWH aspects is to indicate that there are parts of rural communal living that have not been addressed in the water supply sector. Rainwater

Harvesting offers a potential solution but could not be considered as a panacea for achieving rural water supply targets. The RWH solutions that were observed in Sierra Leone have only indicated that, should current attention be focused on this technology, then the approach is likely to result in LTT model. The pilot schemes did not indicate a progression of the socio-cultural system and instead has resulted in linear provided non-scalable solutions. They were demonstrably, and perhaps ostentatiously, an engineering solution that had been designed independent to the context of the socio-cultural system. The introduction of alternative choices to the water supply sector is commendable but it is the method of delivery and design that requires an introspective analysis. Suggesting that there are benefits in alternative technological approaches, such as RWH, does not mean that the weakness of the current socio-technical systems could be bypassed by providing a 'silver bullet solution'. For example a RWH system would still requires some form of education and management for their cleaning and maintenance. Therefore they are still culpable for failure due to the lack of deductive knowledge within the households.

Finally, the lack of water storage at household level should be a concern regardless of what option is suggested for water supplies. Household storage should be regarded as the foundation for water supply projects – and yet water collection mechanisms have been prioritised. The lack of attention given to a socio-cultural element that is so definitively missing –household water storage, as well as an element that has been ignored in mainstream engineering practices – such as RWH, suggests that many of the engineers have designed these solutions with pre-conceived ideas about the solutions that are 'appropriate' for the needs of the households.

4.4.2.2 Local Innovation and Technologies

A measure of success in water supplies should be measured on how the socio-cultural system is responding, in its own unique way, to its rural water supply problems. Much of this has already been addressed in the previous chapters concerning the private sector performance and the current limitations in learning by design. As implementation of the technologies is within the context of a system the artefacts can have either a negative or positive impact on both individual and unrelated parts of the system. The extent of this influence, and the willingness to extend the boundaries of the culture to accommodate the success of the technology, can be noted in the emergent practices of individuals within this system. The mobile phone technologies offer a comparative example of technological immersion of an artefact into an external socio-cultural system. The phone has transformed the way in which Sierra Leoneans communicate with each other, but it has also introduced new and emergent practices to the socio-cultural systems, which by themselves would be meaningless without the artefacts. The nature of these activities has not been determined by outside influences and is instead an indigenous response which has increased the success of the artefact.

There are various examples of such local responses to phones but the most commonly observed practice was the use of house wall or windows as a contact list for phone numbers. This practice was regularly observed in the villages (Figure 86).

Figure 86: Examples of household walls and windows - Makabie

This is an indigenous response that has formed due to a number of local conditions. Due to the lack of energy grids in rural areas continual charging of mobile phones in a rural location is not always possible. It was also noted that many of the phones had multiple Subscriber Identity Module (SIM) cards. This allowed users to benefit from multiple tariffs schemes. As contact numbers would be shared over multiple SIM cards a visible record of phone numbers would be more practical. Using the walls of houses for artistic purposes is not an uncommon sight in Tonkolili. There are many markings and drawings that use either charcoal or chalk. The phone-numbers are not displayed artistically but were usually scrawled in various media by different people. The majority of the numbers were used as a basic contact directory list, or as a number to contact the homeowner, but other more subtle uses of writing on the household walls have emerged. Certain houses have started using their wall spaces as advertising that can be used for selling products or services (Figure 87).

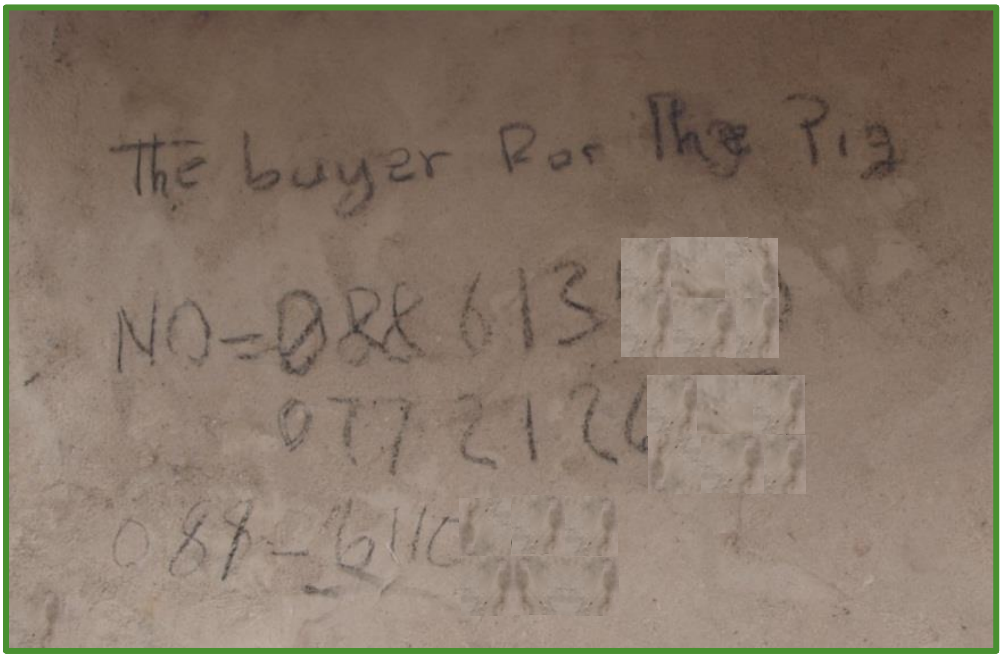


Figure 87: Seller information - Masuba

The purpose of highlighting this case study is not to draw a direct comparison between phones and water supply technologies, which have no need for information to be spread on walls, but instead to show the extent that the mobile phone technologies have been immersed within the socio-cultural system. The phones have progressively altered the practices of the communities, with new approaches being developed that have accommodated the functionality of the phone. They have actively increased the compatibility of phones into rural village living to better suit the households needs. This practice has increased the 'observability' of the technology:

> *"an innovation that is more visible will drive communication among the individual's peers and personal networks and will in turn create more positive or negative reactions"* (Rogers, 2003).

Many homeowners, though not all, were found to be content having their personal spaces altered to suit these technologies. Their pride in displaying their mobile phone was not matched by their approaches to their water supplies. Where the Sierra Leonean socio-cultural systems have embraced the mobile phone, and in turn have allowed the system to be transformed by the innovation, the water supplies – which are more essential to survival, have not been given the value that they deserve.

A further indication of the integration of the mobile phones into the socio-cultural systems in the communities is the development of locally built technologies that are designed to sustain their use and compatibility in the rural areas. Given the ‘high technology’ definition of a mobile phone it would appear unlikely that there could be local contributions from poorly equipped and technically untrained populations of Tonkolili towards their continued operation. The site visits indicated that this was not the case and that there were some innovations that were constructed using only local knowledge and resources. These solutions were designed to accommodate the weaknesses in energy supply in rural communities. The lack of reliable electricity in Sierra Leone's rural areas necessitates the use of a power generator. As these are expensive to own and run, as they use petrol or diesel, they are not regularly found in every village. This means that certain households are without the ability to regularly charge the lithium-ion batteries of their phones. Certain households have responded to this issue by developing locally made solutions to this problem. Their solutions involve cheap local batteries, wires and a wooden base and have been adapted from locally built torch solutions (Figure 88). These are combined to give a small charge to a phone.

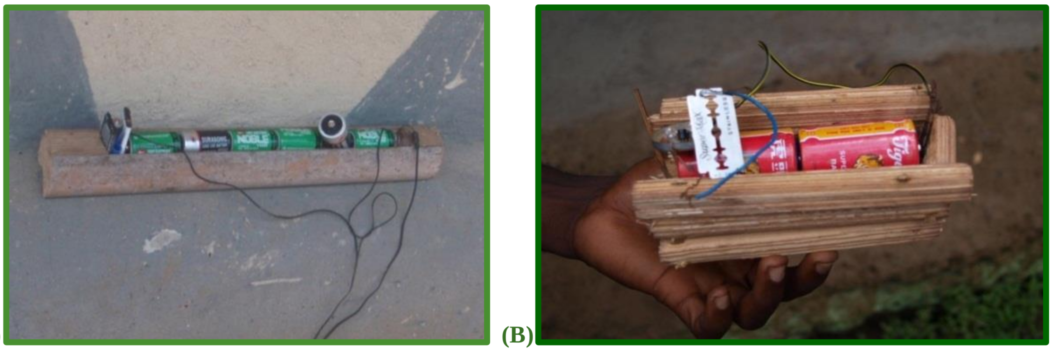


Figure 88: (A) Example of locally built phone charger (B) modelled on local torches

These solutions are not capable of quickly or efficiently charging the mobile batteries – and do not fully charge the phones, but they were suggested to be capable of providing the phone with enough power for a call. It is not known how common such locally built solutions are within the villages – as searching for these was not the purpose of the research visits. The frequency of observations of these local solutions indicated that this was not an unusual practice. When compared to the lack of innovation on water supplies – which is not limited only to the design of the water lifting devices, but also includes access, storage, collection process and water point protection – it further suggests that the socio-cultural system does not regard improved water as being worthy of local innovation. There was one exception – an aspect as important as any other witnessed in the field visits. It was noted that certain children attempted to build local solutions to assist them with their tasks of carrying of water. Though rudimentary, and not a fully efficient solution, it did indicate that at some stage of development within the socio-cultural system, there was an inclination for focusing ITK onto the problems of water supplies (Figure 89). There were no examples of these systems being brought to scale, or advanced in complication, and therefore their design was limited to the practices of children.

Figure 89: Locally built water collection method - Masuba

The involvement of local artisans in water supply projects is limited by the engineering approaches to providing water supplies. Given the standard engineering practices by most NGOs to their projects - the ability for an artisan to influence the technical elements is severely restricted. The only area of construction that is required of the communities, which do not include maintenance aspects of the NGO built components, are the fences. Though 96.4% of the fences did not provide suitable protection to the water sources there were still some examples of well-built locally constructed fencing. These few villages showcased their capacities of the communities to protect their sources using locally available materials (Figure 90).

Figure 90: Example of a locally built fence - Nyriko

The FGDs with the WUCs suggested that the fencing represents more than a protection for the source, but a statement of communal duties towards the water supplies. Several of the FGDs and communal discussion claimed that the community by-laws had been abandoned because the fencing around the well was no longer present. For example in Kumrabai Junction, even though there water points fencing was estimated by the chairpersons to take less than a week to fix, the committee insisted that they have been too busy with *'brushing'* (*i.e.* clearing the bush areas) for the last four months to spare this time. Without their fence they indicated that there were no boundaries to the well area and none of the by-laws are addressed in this time. The relationship between the by-laws and the fences should realistically not be important as the fences can be constructed using only local labour and materials. If many of the villages are not repairing their fences, while also making parallels between this aspect of technical failure and the non-adherence to their stated responsibilities, then they are purposely allowing their regulations at the source to lapse. Therefore the role that the fencing plays can symbolically represent more than the failure of duties in one technical area. The quality of the fencing can instead be seen as a measurable indicator of the socio-cultural response of the village towards their water supplies. There is a correlation between the condition of fencing and the final grading for the wells (Chapter 4: Part 2). This analysis compared the final grades to the condition of fencing at each source. As the condition of the fencing is considered a maximum of a 'Grade D' issue then the results are without circular referencing (Table 11).

Table 11: Fencing and maximum grading of the water point

	Total Percentage and number of Graded Wells	Percentage of each grade with properly constructed fencing
Grade A	27% (80)	8% (6)
Grade B	33% (97)	26% (25)
Grade C	36% (106)	31% (33)
Grade D	4% (6)	50% (6)
Grade E	1% (3)	100% (3)

The results indicated that the probability of finding a problem with a well is directly proportional to the condition of the fence. Though a fence can only be considered as a minor component in the construction of a well, it provides a barometer for measuring each community's cultural support for their water supplies. Of the 295 evaluated wells 193 wells had no fence and 27 wells had extremely porous fencing due to poor construction. This suggests that the socio-cultural system is not embracing the water supply solutions and purposely allowing their responsibilities, which are agreed at the projects inception, to lapse.

4.4.3 Well Type and the Immediate Socio-Cultural Transformation

The failures to achieve technical immersion into the socio-cultural systems and the socio-technical system are best understood through an evaluation of the three different well location types most commonly found in Sierra Leone. These are:

1. The community wells – which are normally based in central location in villages
2. School wells – those based at primary or secondary schools
3. Health clinic wells – those based beside PHU, MCHPs and CHCs

Each of these source types often has their own water management committees. Health clinic wells usually have the health staff, usually nurses or PHU technicians, as part of their committee. The school wells are linked to their school's Parent-Teacher Associations (PTAs). Whereas the communal wells, which can be more than one water point, have a village Water User Committee (WUC) that is part of the Village Development Committees (VDCs). As they are differently organised there is a different socio-cultural response to each water point. Community wells have been the main focus of the previous chapters, and their condition has been shown to vary with each village.

The health clinic water points were found to have had a disproportionate success rate in comparison to the communal systems. The majority of health clinics had their hand-pumps in working order. This was regardless of the condition of other water points within the communities. The best examples of hand-pumps, those with the lowest grading of failure, were usually those that were located beside the health clinics. Site visits to the few health clinics which did have non-working hand-pump wells usually involved urgent requests from the local nurses to resolve the outstanding technical issues. This was one of the few occasions where a beneficiary had identified the need for repair, rather than for the provision of new sources, as being of more concern. More importantly the nurses fully articulated their need for this water point as primarily being a health issue. They offered examples of situations where their lack of 'safe' water had almost caused fatalities – such as during child birthing, cholera outbreaks, or while addressing emergency medical procedures. The lack of access to an improved source usually meant that they had to manually collect water from an unimproved source and to treat it themselves before using it for medical purposes. The nurses' articulation of "safe water" in these instances was scientifically accurate and included scientific terminology such as "bacteria", "pathogens" and "germs" in the correct context. Additionally it was noted that several of the water supplies situated beside the health clinics were undergoing repairs – a process that was rarely noted during the visits to the community sources.

There is more than a single reason which could be offered to explain why health clinic water sources were found to be in a more functional state than their communal counterparts. These reasons could include: a higher proportional investment in health clinics over village supplies by international donors, the continued involvement in the health units by local government bodies (such as the District Health Management Teams), as well as the high number of expatriate health NGO staff visiting the health clinic locations on specific visits. Regardless of these advantages the ability and willingness of the nurses to advocate for their needs in an informed manner, and the fact that they are capable of having their sources maintained locally, suggest that there is a direct correlation between knowing that a source is improved and having the rational and safe practices towards the artefact. Unfortunately there were no measurable differences between the condition of the water supplies of communal wells with villages that had an operational health clinic and those that had none. This suggests there are problems with the diffusion of health information, which can be shown to have been known by the nurses, into the health clinics host communities.

The water points at schools provided the exact opposite example of the success observed at the health clinics. Almost all the rural schools evaluated were primary schools or institutions that did not have a science department. Schools, unlike the health clinics, are not usually built within the normal boundaries of the villages. The reasons for a village making such a decision are obvious - the noise emanating from these locations during school hours is exceptionally loud and obtrusive. As traditionally built households do not have any sound-proofing there is a clear preference to not be located next to the educational infrastructure. Therefore the schools water points are located further than the more centralised communal sources which are commonly used by the households. The rationale for providing sources of water at the school level is also logical. Without a local source children would be without an improved source of water during their school hours – both for drinking water purposes but also for sanitation activities. The travel into the village to collect water could disrupt their educational activities. Therefore the rationale behind such an intervention is credible - but it has fundamentally underestimated the nature of the socio-cultural system. As established in the previous chapter, households favour convenience over the concept of 'safety' that comes from outside their socio-cultural system. As households do not perceive the health benefits of wells in their own village, then water points that are further outside the communal groupings are even less likely to be appreciated. The result is that the socio-cultural system will respond accordingly. This would have implications for acquiring tariff charges for maintenance as there is less fidelity to these sources. The field research indicated that school wells were found to have disproportionate levels of failure in comparison to the communal wells. The most noted feature was not that the hand-pumps wells were damaged, which was more of a problem with the communal wells, but that the entire lifting mechanisms (including all pipes, cylinders, bolts, chains and the entire hand-pump systems) were usually missing (Figure 91).

Figure 91: Compilation of various primary school wells in Tonkolili District

There are three stated reasons from within the socio-cultural systems that were used to explain the regularity of this technical problem:

1. Salvaged to restore existing hand-pumps: In the first instance, salvaging the water points is not of the greatest concern, as it would be a reprioritisation of water supplies of the communities to suit their needs. However this socio-cultural response has clearly not been anticipated by the implementing agencies. The lack of maintenance carried out on water points in the villages suggests that this practice is ineffective (see Chapter 4: Part 1).

2. Intentional dismantlement: Perhaps of more concern than the use of salvaging the technologies was the explanation, given by a community spokesperson in the Chiefdom of Kholifa Mabang, who provided a detailed account of how, when and where hand-pump spare parts could be sold on the black market. This involved transporting hand-pumps parts to markets in Conakry, the capital of Guinea, rather than Freetown. The prices in Conakry were apparently better and there was a willingness to buy. The main buyers of these 'spare parts' were alleged to be private citizens engaged in house building in the city – though these claims could not be substantiated. The level of detail involved in this account suggested that this information could be credible. It also suggested that the use of the black market in this way is widely known. As these claims could not be corroborated with evidence it is difficult to determine the extent of truth, if any, in these events. Regardless if they are stolen, or sold by the communities themselves, there is clearly a market for these assets that is available. This is not only for thieves, but also for communities that do not understand the value of their water points, but are willing to profit from the intervention. As the evidence which details this misuse is anecdotal it does not prove that any wrongdoing actually took place - but the implications are severe.

3. Lifting systems were stolen: The interviews with many of the schools spokespersons indicated that the hand-pumps had been 'stolen'. Given the historical background of conflict, looting and violence in Sierra Leone this eventuality should not be considered as improbable (Ferme, 2001). Villages do have the ability to safeguard against theft if they so choose. Encasing the lifting system in concrete is a local 'bush-job' that can be used to protect the sources. This option is not advised, as it restricts maintenance activities, but there were no noted examples of security protection given to the school systems. This was found to be true within villages that had secured village pumps, but stolen hand-pumps at the schools (Figure 92).


(A) (B)

Figure 92: Two water points in Kumrabai Station (A) Village Well and (B) School Well

The NGOs that have provided water supplies, and yet have not understood how the socio-cultural system will react to the water-points are liable to repeat the same mistakes again (Figure 93).

Figure 93: Missing school well hand-pumps - Mathinka Bana

The examples of both the health clinic and school water points indicates that there is currently not enough information known about how the socio-cultural system will actually respond to their technologies. The differences between the health clinic interactions, which are valued for their safe water, and the school wells, which are under-prioritised, have only further reinforced the concept established in the previous chapter that their needs to be a conceptualisation of the 'problem' of unsafe water within the socio-cultural system. This is necessary otherwise the villagers can react dangerously, irrationally and even illegally towards their technical artefact.

4.4.4 Broad Socio-Cultural Transformation

The lack of access that rural dwellers have to their improved sources of drinking water is only one aspect among many that are faced by populations in Sierra Leone (Chambers, 1983). The rural communities play an important role in the continuation of both positive and negative social and cultural attitudes and practices. Although the years of conflict are over there are a number of human rights issues that remain outstanding in Sierra Leone (HRW, 2011). The responsibility for addressing these issues remains with the people of Sierra Leone and its democratically elected government (World Bank, 2009). Their invitation to the international community to assist them in the realisation of these rights has allowed for a greater emphasis on the entire spectrum of issues that affect individuals (Campese, 2009; Kirkemann and Martin, 2007).

The progress in the realisation of human rights in development practice is of paramount importance to many of the activities of the international NGOs and their donors. The provision of water has long been regarded as a fundamental right. This realisation has been the basis for the implementation of many projects (El Hadji Guissé, 2005; "The human rights-based approach to development: the right to water," 2005). Increasing access to water in Sierra Leone remains as only one of the many interdependent and indivisible human right issues that the international community has sought to promote and address. This is because individuals have an entire range of civil, political, economic, social and cultural rights. These rights, of themselves, are regarded as being both universal and egalitarian and are inclusive of both an individual's natural and legal rights (Eyben and Ferguson, 2000). The relationships that human rights have with each other were confirmed by the 1993 Vienna Declaration and Programme of Action:

> *"All human rights are universal, indivisible and interdependent and related. The international community must treat human rights globally in a fair and equal manner, on the same footing, and with the same emphasis* (UNHCR, 1993).

The realisation that projects activities are not neutral, and that the associated actions, or inactions during implementation can have a simultaneous effect on other rights issues, is central to the understanding of the Rights Based Approach (RBA) to international development (Byars et al., 2009; Kirkemann and Martin, 2007; "The human rights-based approach to development: the right to water," 2005).

Given the number of construction, maintenance and management opportunities involved in producing technical artefact then the engineering process has the capacity to further the realisation of the human rights beyond a projects functional objective. The opposite is also true; that through malpractice, or ignorance of the non-neutral nature of the implemented artefact, engineering also has the capacity to actively suppress or ignore the rights of the individual. The NGOs that implement water supply projects are usually acutely aware than they are attempting to achieve more than the provision of safe water - and have actively sought to broaden the objectives of these programmes (Harvey and Reed, 2003).

To be consistent with the preservation of human rights and collective identities there are certain aspects within the socio-cultural systems that should be left unaltered and untouched by any development activities. Examples of these include the communities' cultural structure, their cultural and artistic expression, their religious belief structures and their traditional (and non-harmful) cultural practices. There are other aspects of Sierra Leone's socio-cultural systems that NGOs have deemed as harmful, such as Female Genital Mutilation (FGM), and have been specifically targeted for change (Bjälkander et al., 2012). These are aspects of the socio-cultural systems that are considered to be detrimental to the continued wellbeing of each individual within the communities. The arguments for attempting to alter these issues, which are so detrimental to health, are a case of antagonism between social anthropologists and human rights activists in developing countries (Messer, 1993). Additionally these changes may not be desired by all elements within the communities - particularly from those who hold power and can gain from the oppression of others. Therefore many development projects actively seek to change certain aspects of the nature of socio-cultural systems. They attempt to target a range of practices that are inconsistent with the rights of the individual, such as the use of child labour, abuse of judicial authority, enslavement and sexual exploitation. Though some of these practices can have their roots in the indigenous belief systems, and could be argued to be traditional practices, they are not considered beneficial for the stability of the socio-cultural systems in its entirety. This is not only recognised by external observers but also by those within Sierra Leone itself (USSD, 2008). However, attempting to influence change in the socio-cultural system is apparently a contradiction in approaches as social, cultural and political rights can be argued to be given less precedence than other more universally recognised human rights. This is a matter for rights law and outside the scope of this thesis to discuss in more depth. As the ethics of this thesis considers that an engineering intervention is a moral necessity, then it is intended that interventions should be done is such a way that minimises damage to the positive aspects of the socio-cultural system, while also targeting the negatives that are within the boundaries of the engineering intervention to effect.

Large development agencies recognise the complexities in interacting with interlinked rights issues but instead of confronting these issues directly, which is usually the role adopted by advocacy groups and human rights activists; they normally use their implementing procedures to subtly and gently influence change. The actions of the NGOs in service delivery are used as a method of achieving multiple rights objectives simultaneously. This does increase complexity in approaches as even simple projects can require detailed explanations of how indirect rights issues, that are unrelated to the primary project objectives, can be influenced, or transgressed, during a technical intervention (Byars et al., 2009). Although in the provision of water supplies the objective of 'providing access to an improved source of drinking water' is the prime directive that is being addressed, certain indirect rights issues, such as increasing women's participatory roles in society, protecting children from labour, increasing accountability of local governments, can all be influenced by the activities of the programme. Ideally this would allow a project to achieve multiple purposes in a single intervention. Therefore engineering has the capacity to impact projects both positively, by indirectly addressing negative social and cultural elements that are unsustainable, or negatively, by imposing ideals that are not beneficial for the stability of the socio-cultural systems

4.4.4.1 Gender and Water Supply - A Case Study in a Socio-Cultural Systems

There are an entire range of negative socio-cultural human rights issues in Sierra Leone, such as tribal antagonisms or abusive patronage systems, which are not explicitly addressed by development agencies. Many organisations have broad mandates they rarely make explicit reference to altering the socio-cultural systems as a specific objective. One of the most noteworthy exceptions, due to the widespread scale of the problems, is in addressing the inequalities that exist between genders. This is not only a development focused problem but is applicable in all nations. Gender inequalities affect all parts of civil life in every society, culture and nation in the world. Addressing these inequalities has the support of international law and is enshrined in the rights of the women. The Convention on the Elimination of All Forms of Discrimination against Women (CEDAW) was adopted in 1979 by the UN General Assembly. The Convention defines discrimination against women as

> *"...any distinction, exclusion or restriction made on the basis of sex which has the effect or purpose of impairing or nullifying the recognition, enjoyment or exercise by women, irrespective of their marital status, on a basis of equality of men and women, of human rights and fundamental freedoms in the political, economic, social, cultural, civil or any other field*" (UN, 1989b).

In development practice gender issues are usually classified as 'mainstreaming' issues in that they affect all programming activities over all their operational sectors. Therefore the water supply programmes of NGOs generally include a provision for determining how the activities will alter, assist or affect gender roles. As gender issues are explicitly targeted by NGOs, and visible efforts were made with regards to dealing equality and empowerment issues in Tonkolili, then it was included as part of the field research into water supplies in Sierra Leone.

One of the most noted relationships between poverty and the populations of developing countries is the predominantly large percentage of women who live in extreme poverty. The exact values and ratios are unclear. A UN Conference in 1995 suggested that woman embody of as much as 70% of the world's poor (UN, 1995). Their lack of gender-specific data for substantiating these claims makes the exact figures difficult to calculate (Chant, 2008). However there is sufficient evidence to suggest that women suffer higher incidences of poverty, in greater depth, in more persistent means and face more barriers to overcoming the traps of poverty than men (Chant, 2003; Painter, 2004). The reasons for these inequalities are significant and are determined by a range of factors which are found within many nations in both the developed and developing world. These include, but are not limited to, land tenure rights, enrolment in educational institutes, pay inequalities, male-female differences in household responsibilities, access to financial assistance and the segregation of economic activity. To achieve true equality and empowerment there is no single issue that can be addressed. Though certain advocacy campaigns target specific activities, such as Gender Based Violence (GBV), the majority of campaigners are aware that real changes can only be made when there is an alteration of traditional practices and attitudes towards women.

Sierra Leone's recent conflict history, the countries adherence to traditional practices, and the nations male dominated social hierarchies, exemplifies many case studies in violations of the rights of the women. There are too many individual gender equality aspects to raise, and not all are concerned with water supplies. Five elements were noted to be of particular importance to the success of water supply projects:

A. Women's roles and authority in household water supplies
B. Women and the Selection of Sources
C. Education and women in household water supplies
D. Gender Authority in the Support Mechanisms
E. Women and Alternative Approaches to Water Supplies in Tonkolili

These will be discussed in more detail to provide an understanding of the impact of water supplies and their indirect capacity to transfer negative aspects of the socio-cultural system:

(A) Women's roles and authority in household water supplies

The KAP surveys in Tonkolili explored the relationship between women and their water supplies. The collection of water would be an arduous task even when sources are relatively close to the households. Labour intensive collection methods normally involve carrying water on the head, a typical approach to heavy lifting for all manner of resources in Sub-Saharan Africa. Using labour reducing methods, such as wheel barrows, carts or domesticated animals for collection are exceptionally uncommon occurrences in Tonkolili.

The role of water collection in the 150 surveyed households indicates that it is mainly regarded as a gender specific role. These households were asked for their water quantities using the token distribution method. Many of the replies indicated that households had different members collect the water but that this differed between certain genders and age groups. Men were reported to collect water in 14% of the households. The majority (83%) of homeowners claimed that it was the women collected from the sources. There were several examples of the tasks being shared between genders. Water collection was also regarded as a child's role (a child was classed as those under the age of fourteen). In 85% of the households it was reported that the girls collected water. It was also reported that 67% that their boys fetched the households water.

Though there appears to be a degree of equality at a younger age, and that there are some households that share the duties, the quantities of water collected by the age and gender groups clarifies the extents of inequalities. The average amount collected, by the 14% of men that collected water, averaged only 18.7% of the total household water. There were no cases where the water collection was entirely reliant on the men. Though the boys collected water, in 67% of the households, this amount averaged was no more than 22% of the total fetched. Girls of the same age collected water in the largest percentage of the cases (83%) but also in the highest quantities, with over 54% of the total water brought to the household from girls within this category (Figure 94). Adult women who collected water averaged 44% of the total water supplied to the households.

Figure 94: A typical sight of girls collecting water in Tonkolili - Mamuri

Comparing both of these results indicates the scale of the inequalities concerning gender and the fetching of water for household purposes (Figure 95)

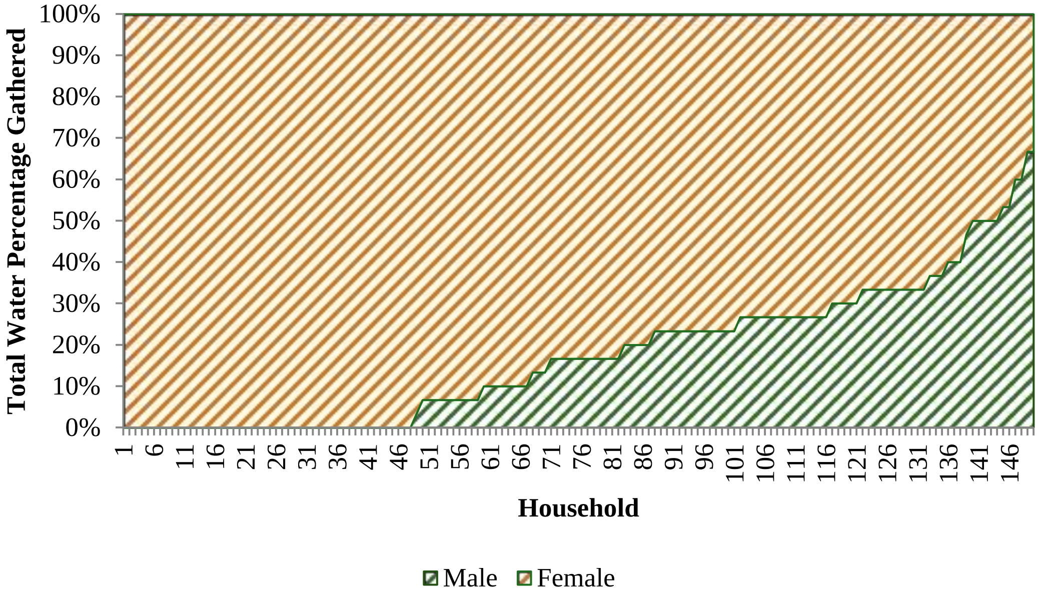


Figure 95: Source of water collected sorted by gender

The results indicate that the collection of water sources are specifically a role that women provide to the household. The role appears to be established at a young age, with boys only providing water in exceptional cases, rather than being demonstrated as being their main responsibility in the households. In their later years the men are unlikely to collect water. In the few cases where men do collect water the households are usually male dominated. All but one of the households, which had the men bring back more than 50% of the household's water, had a majority of males living in the houses.

Though 68.7% of the interviewees were female the majority of KAP surveys showed that it was the male who was regarded as the head of the household (86.7%). Female only households, or those that had an absent senior male figure - through divorce, death or geographical separation, were found to be headed by females. Given the dominance of this gender in the household decision making the surveys indicated that in almost all decisions regarding water supply, including the use, treatment and storage of water, women were regarded as the main decisions makers (Table 12).

Table 12: Gender decisions on water supplies

	Selection of water source	Quantity of collection	Water shortage Strategy	Household water usage	Water storage	Purchase household items
Female	89.3%	95.3%	88.7%	96.7%	95.3%	48.7%
Male	7.3%	4.7%	1.3%	3.3%	3.3%	17.3%
Joint	3.3%	0.0%	10.0%	0.0%	1.3%	34.0%

The only component of water supplies that men were more heavily involved in was the purchasing of household items such as buckets and storage containers. This aspect has an important socio-cultural impact as the procurement of new resources offers important power dynamics in the households. These decisions are comparable with the gender roles on the procurement of mobile phone technologies (Table 13).

Table 13: Gender decisions on mobile phones

	Buying phone credit	Buy upgrades or phone items	Buying new phones	Paying for Repairing phones
Female	12.7%	9.3%	8.7%	7.3%
Male	60.7%	64.0%	59.3%	64.0%
Joint	8.0%	6.7%	13.3%	9.3%
No Decisions made	18.7%	20.0%	18.7%	19.3%

With regards to mobile phone choices the decisions for procurement are heavily male dominated. These results indicated that water supplies are one of the few areas where technical decisions are actually more gender balanced, though the use of household financial resources is still heavily male dominated.

(B) Women and the Selection of Sources

Given that the majority of the household's decisions about water are made by females then the choice of sources can be sensitive to their preferences of collection. The KAP survey raised questions which were directed at those that were responsible for the highest percentage of water collection in the household. The replies were aggregated by the gender of the interviewee. These questions sought to understand what the water collectors liked most, and least, about their collection process. These were qualitative responses which prevented the results from being influenced by interviewer bias. The responses were usually confined to certain categories and themes (Table 14).

Table 14: Reasons for liking the sources used – group by category of response

	Percentage of Total households	
	Female	**Male**
Social reasons (*i.e.* meeting with friends)	32.2%	5.4%
Displaying new containers	12.1%	2.7%
Hand-pump technology	11.4%	0.0%
No reasons for liking their sources	8.7%	4.0%
Fulfilling Responsibility	8.7%	0.0%
Drinking or using the water	4.0%	0.0%
Allows space to play	2.0%	2.7%
Allows freedom from other chores	2.0%	0.0%
Enjoys as part of the cooking	2.0%	0.0%
Likes the distance	1.3%	0.0%
Is rewarded for using the source	0.0%	0.7%

The results indicate that social patterns have formed to coincide with the labour intensive task of water collection (Table 14). These practices can be highly influential in the decisions to use or to abandon sources. The males, usually boys, suggested that they were social reasons for liking the collection process. Their responses indicated that it offered them the chance to play before collecting the water. This appears to be less time dependent than the women's and girl's explanations suggesting that the boy's activities are only occasional. Observing patterns of communal living in the villages, and the gender distribution in the villages during the day, suggests that the women are mostly concentrated a very small geographical area whereas the men are more often found outside the communities (in farms or in towns). The concentration of women to the centre of the village can be restrictive to an individual's freedom of movement. The greatest benefit that was associated with using a source of water was continually linked being able to talk socially, and in privacy, during the walk to and from the sources. Therefore certain social patterns can have formed that have allowed women to periodically leave their village. This can explain why the close proximity of a source to the household is not the only rational reason for the selection of a water point. Providing a centralised solution, though rational, may be intentionally ignored by beneficiaries because it restricts the traditional practices of the socio-cultural systems.

Many of the older interviewed women only valued what they felt were their duties and responsibilities towards their families. The socio-cultural system has clearly established that water collection is a task that is central to a women's role within the community. It is clear that the tasks are difficult, particularly from disabled, pregnant or elderly women, but there was still a source of pride and communal belonging displayed in the performing of this duty. This could also be considered as an expression of inclusion into a social system.

There were more variations in responses from what was disliked most about the collection process. These too have been summarised under specific categories (Table 15).

Table 15: Reasons for disliking the sources used– group by category of response

	Percentage of Total households		Percentage by Gender	
	Female	Male	Female	Male
Distance travelled to the source	19.5%	3.4%	23.4%	20.0%
Queues at the source	13.4%	1.3%	16.1%	8.0%
Collection method (*i.e.* difficulties using pulley wells)	10.7%	0.7%	12.9%	4.0%
Weight of containers	8.7%	6.0%	10.5%	36.0%
No Answer – not willing to explain	8.7%	4.0%	10.5%	24.0%
Time taken collecting water	6.0%	0.0%	7.3%	0.0%
Condition of the container	5.4%	0.0%	6.5%	0.0%
Hazards during collection	3.4%	0.7%	4.0%	4.0%
Loneliness (*i.e.* without friends)	2.7%	0.0%	3.2%	0.0%
Water condition	1.3%	0.7%	1.6%	4.0%
Locating Water Source	1.3%	0.0%	1.6%	0.0%
Bureaucracy at the water point	0.7%	0.0%	0.8%	0.0%
Energy taken to collect water	0.7%	0.0%	0.8%	0.0%
Wastage that occurs at source	0.7%	0.0%	0.8%	0.0%

The distance to the sources was often a reason for disliking the water collection methods. This was not only limited to the total distance walked but also to the local topography – such as having to travel through hills, through densely forested areas or into swamplands. The queues at the sources were also a major source of discontent. This was not only because of the time taken but also due to arguments and quarrels that could break out at the sources. The by-laws for wells could specifically target women if fighting occurred (see Chapter 4: Part 2). The male and female FGDs both indicated that women were the most heavily fined during quarrels. Much of these responses, including distances and queues, are similar to what has been discussed before with regards to preferences of sources; but there are four aspects that have not been covered before:

1. ***The weight of the containers:*** the weight of the containers was either referenced on its own or with respect to the distance. This was often regarded as a problem, however there were very few designed methods by the adults to improve the water collection process – such as creating an innovative water carrying mechanisms or communal water storage to

maximise efficiency of collection. The socio-cultural system was observed to accept the difficulty of water collection without challenge.

2. The condition of the containers: Again the issues of containers were raised as a social status issue. Many of the water collection devices were used until they were irreparable. Complaints about the containers was not noted to be an issue with the males but was primarily a concern for the women who used the sources. Given the number of times women visited their water point and the visible nature of walking to the sources it can be understood why this was a problem. It was also noted during the FGDs that the threat of withholding a container for the violation of by-laws at the sources was sufficient enough to enforce behavioural practices.

3. Hazards: Very few people said they selected their source to avoid hazards but there were five respondents who suggested that this was one of the reasons they disliked the source that they used. The main problem was for those that had to cross roads to reach their supplies. Given the weight of the collected water and the associated lack of mobility that these would provide, combined with the lack of traffic policing on rural roads, this is a rational fear. The case study in Kumrabai junction, which is separated by a main road, indicated that crossing the road could be a sufficient enough deterrent to stop people using sources. The only other hazard mentioned was a fear of snakes.

4. Isolation: The inverse of the preferential social aspect of sources was also true, that people could dislike the isolation of having to fetch water on their own without their normal social gathering. It is an emotive response which again highlights the social causations for the selection of water sources. A scheme that is too far removed from the village may not be utilised not because of the condition of the water, or ease of use, but because of the social implications that such a distance necessitates.

The KAP surveys indicated that social reasons for the selection of a source provide a significant role in the household decisions. As indicated before the selection of water points is mainly considered as a women's prerogative and is therefore sensitive to the existing social practices of the women. The previous chapter has explored the notion of selecting a 'convenient' source is more important than the selection of an alien concept of the 'safety' of water. The responses suggest that there have been social patterns which will remain in existence regardless of where the water points are located. Therefore providing a source of water in a pre-determined location could potentially severely disrupt the social fabric of a community. Having a centralised source is a rational solution, as it offers the highest access to all, but it may invite incremental pressures resulting in the source being abandoned. This appears to be a no-win situation in the SATTs approach.

(C) Education and women in household water supplies

There are many parallels between providing women with education and the health of the household (DFID, 2005; McFerson, 2011). The recent cholera outbreak highlighted the importance of women in household water, but also their vulnerability to water related diseases which can be caused by a lack of education (Rancourt, 2013). As the previous chapter explored, the linkages between 'safe' water and its usage have not been established at the household level. Given the women's role in household decisions about water the entire model of service delivery is dependent on this aspect. Therefore the education of women is of paramount importance. Only 0.8% of the 1,410 women covered in the KAP survey had some form of secondary education. There was a noted inequality between the genders in secondary school education, but it was not dramatically much larger (2.8% of 1,385 men). With the women's role in the household this omission in education is regarded as a more critical problem.

Formal institutions are not the only source of information that can determine household practices. Certain accounts have mentioned that there are practices that can be dictated by the women's secret society which can influence their choices of water sources:

> *"Final cleansing rituals following rites of passage through Poro and Sande, and the walk from the water- side back to the village afterwards as an accredited member of the society are highly significant. Indeed the social and spiritual aspects of interacting with others during such communal water use are usually seen as much more important than intangible parameters such as water quality, and the idea of using wells purely from a water-quality perspective is sometimes viewed with scepticism"* (Akiwumi, 2003).

Akiwumi's account in Sierra Leone was with the Mende tribe, as opposed to the Temne of this research, but it was within the same secret societal grouping that most women in the rural communities are members. Therefore there is the suggestion that other traditional socio-cultural practices can heavily influence women's choices for their sources of water. Given the protective and secret nature of the secret societies (see Chapter 2: Part 3) it could not be expected that these results could be explicitly stated by those that were surveyed. The irrational use of water supplies, even when they are conveniently close, would mean that this area should be considered as a relatively unexplored component of the selection of sources (Denney and Ibrahim, 2012).

(D) Gender Authority in the Support Mechanisms

As most NGOs have mandates to address gender inequalities that exist with the socio-cultural systems their responses can be analysed. The organisations have attempted to use the social support mechanisms as a method of achieving gender equality. The most notable was the inclusion of women within the Water User Committees (WUC). The purpose of their inclusion was to have more women stakeholders within the decision making bodies. The results of the 100 gender surveyed villages suggested that women consist of 44% of the total numbers involved in the formation of the WUC. The results indicate that there is a varying degree of balance, which supposedly offers gender equality, in these posts (Table 16).

Table 16: Gender equality of the water user committee's formation

Gender balance	Number of villages
Less than 50%	49
More than 50%	32
Equal	12
No committee	7

The distribution of gender is relatively balanced in the formation of these Water User Committees. The actual success of these committees has already been established (see Chapter 4: Part 2). Even if they were successful in their core functionalities, which they are not, it is difficult to suggest how the number of women provides contributes successfully to dealing with gender inequalities. The participation of women in these groups appears to be a token representation rather than offering any real executive powers (Harvey and Reed, 2004; Harvey et al., 2001). The water point's executive authorities are intended to be within the decision making bodies of the WUC. However both the village and communal surveys indicated that the water points remained within the control of the chiefs and elders (Table 17). There are sometimes women present in the classification of 'elders' however the Temne tribe normally has dominant male leadership roles at community level.

Table 17: Decision making of water points

	Household Survey Results	Village Survey Results
Chief/Elders	81.3%	66.7%
Individual	4.7%	15.3%
Committee	0.0%	14.7%
Community	10.0%	1.3%
Other	3.3%	0.0%

The gender roles, as determined by the WUCs, does very little to enforce equality. Instead it may actually establish further bias towards women with what could be perceived as international approval. The summary of the FGDs on each genders responsibility correspond directly to the tasks that a woman is expected to fulfil in the household (Table 18).

Table 18: Roles of women and men in the water user committees

Women	Men
Sweeping	Fencing
Weeding	Gathering bush poles
Monitoring by-laws	Collecting money from tariff
Providing food	Making drainages
Cleaning (scrubbing) the water points	Chlorination
Enforce by-laws (collect money)	Maintenance tasks

As stated in Mamilligbla *"Each* [person] *performs their own gender roles. Men assemble and repair the fence, while women clean the well area"* [MAM/M/7]. The WUCs are central to dictating what a genders role should be with regards to water. The most important aspect of this is the authority that the tasks provide. In all cases men felt that their duties and responsibilities were harder than those of the women – regardless of the total labour hours worked per month. The roles of the men are only required periodically - as opposed to the weekly, or even daily, requirements for the cleaning duties of the women. A properly constructed fence would not require substantial repairs for several years. When the focus groups were asked about their equality of tasks there were almost continual references to the roles of men being 'harder' because they were supposed to collect the bush-poles for the fencing. The only exception was in Mathinkabana where the men had reportedly abandoned their duties leaving it to the women.

An important aspect for discussing the socio-cultural considerations is that the WUCs, even if they were successful, would not provide any increase in the realisation of gender equalities. They would also not progressively eliminate the discrimination against women that already exists in Tonkolili. They give women representation on powerless committees and their participation in these groups only established, and perhaps even institutionalised, existing discriminatory roles.

The gender inequalities that existed within the WUCs are minor in comparison to the role of women within the recruitment and practices of the water supply technicians. In total nineteen local technicians were interviewed during the FGDs. Of these, fifteen were male, four were female. There were a substantial number of gender issues with the technicians that were interviewed. Though the FGD requests for interviews in the villages were explicit in requiring the presence of all those that had been trained, none of the female's originally attended and additional effort had to be made to ensure that they were invited.

Criticism in the villages of the female technicians was common. The male technicians in Malagbla insisted that *"women do not have the muscles to fix the wells"*. The female technicians were accused of *"not having the intelligence to fix the well"* in Matotuka and *"not having the strength"* to fix the wells in Mathinkabana. In Mathinkabana the women thought that the men knew more about the wells than they did. In both Matotuka 2 and Mathinkabana it was thought that having sufficient physical strength to repair the wells was the most important determining factor for recruiting technicians. In all the cases of female technicians the women were given roles in cleaning and managing the well, but the tasks of repairing the sources was left to the men. Realistically this negates the women being defined as 'technicians' as none of the interviewed women were practicing their technical skills. The group discussion indicated that the socio-cultural system was not prepared to host female technicians.

(E) Women and Alternative Approaches to Water Supplies in Tonkolili

The communal and household surveys both indicated that the water supply technologies have not been adapted and designed to support the rights of the women. The decision making processes about the location of water points, even if they were gender inclusive, have been too dependent on explicit knowledge – what the women know, rather than appreciation of their tacit approach to water supplies. There reasons for using alternative sources are consistent with their traditional and cultural rights. Though NGOs have attempted to be more inclusive in their approach to gender inequalities in Tonkolili their actions may only have entrenched and supported existing inequalities.

The research addressed water supplies by investigating hand-dug and borehole well technologies. These were the subject of the research because they were the most predominant technical approach to providing safe drinking water to households. As an engineering solution there are other technological alternatives that could have been better utilised to suit the practices of the women - such as the household treatment of unimproved water through various methods of filtration and chemical treatment (Lantagne et al., 2006; Rosa and Clasen, 2010). The 150 household surveys questioned the use of alternative technologies in water supplies at the household level (Table 19).

Table 19: Use of water treatment technologies in 150 surveyed households

	Cloth Filter		SODIS		Chlorination (Household)		Ceramic Filtration		BioSand Filtration	
	Known	Used	Known	Used	Known	Used	Known	Used	Known	Used
Yes	13%	2%	11%	1%	31%	4%	5%	0%	3%	0%
No	87%	11%	88%	11%	69%	96%	95%	5%	97%	3%

Some of the technologies were known at household level but it was rare to find examples of alternative treatment being used. During the entire field research of the 150 villages, excluding chlorination, there were no examples of water treatment technologies that had been introduced at the village level. This was confirmed by the household results. Chlorination, which was mainly tablet form and available in some local shops, and cloth filters, which involve placing a cloth sheet over the water inflow to act as a macro-filter, were only observed in exceptionally rare cases (Table 19). For the households that did practice some form of treatment had mixed responses as to where the knowledge about the treatment originated. Family relations, development agencies and health centres were all referenced as the source of information. Traditional leaders, such as chiefs and headmen, were never identified as the main source of information in the advertisement of water treatment options.

4.4.4.2 Broad Transformational Socio-Cultural Issues

As stated before, gender equality is only a single human rights issue, in a plethora of multi-dimensional and interconnected problems, which need to be addressed in Sierra Leone. One of the most urgent is the growing number of uneducated and unemployed youths, who are mostly male, that have congregated around urban and peri-urban areas. These young men are not considered in the same bracket of 'victims' of poverty as other higher prioritised groups such as; pregnant women, mothers, young children, the elderly, people with disabilities or those who are in need of medical attention and support. The young men are usually healthy and capable of labour, but opportunities for work and capacity building are rare in the rural areas. The rights issues of the vulnerable are certainly important – but ignoring the young male demographic could undermine all progress in all other areas. There is an historical precedent for this in Sierra Leone. As Richards explained; the RUF heavily recruited from within these numbers, capitalising on their marginalisation, frustrations and their lack of education to form the militant force which inflicted innumerable atrocities upon the rural communities (Richards, 2005). Since the end of the conflict the social dynamic within Sierra

Leone's has not radically changed. There still remains the potential for a disruptive individual or faction to recruit within these numbers, which are arguably larger now than at the conception of the RUF, and to violently manipulate the situation for political, economic or social gains. In the case of youth development - this oversight may have serious consequences for the stability of Sierra Leone in the future.

4.4.5 Summary of the Impacts on the Socio-Cultural Systems

The socio-cultural systems are impacted by the role that the technologies play in the communities. The three issues raised above are only a small cross-section of the entire spectrum of socio-cultural activity. Even within the discussions about these three components the conclusions have only briefly touched on such complex and intertwined topics.

The provision of water supplies could have had the ability to transform the socio-cultural systems in Sierra Leone. The study period indicated that many of the rural socio-cultural systems have not been positively affected by current actions in providing water supplies. Opportunities, such as utilising existing indigenous knowledge, enhancing gender equality or facilitating local development of technologies, have been missed. It is also possible to see that the impact that certain water supply projects have had on their socio-cultural systems may actually have had a negative influence in the systems developmental progress. The issues of gender equalities and youth development are only two aspects that could be furthered by engineering interventions. Current socio-cultural transformation in development engineering, which can be shown to have happened if a technology can be understood from within the socio-technical system, has been limited.

4.4.6 Discussion on Socio-Cultural Systems with Engineers

Once again there were found to be polarities in opinions regarding the engineers participation in addressing the socio-cultural issues associated with engineering interventions. For example when discussing the issue with the technical head of a major organisation his answer was straightforward. In his opinion he found that engineering activities of NGOs showed that there was *"rarely"* any long term social and cultural understanding of the impacts that a technical interventions may cause.

Other engineers took the opposite viewpoint and appeared indifferent to the impact or the potential of engaging with the socio-technical systems - beyond that of reaching purely technical goals. Certain engineers focused specifically on elements of working in development engineering that had affected their progress. As one engineering co-ordinator in Sierra Leone stated about the socio-cultural system within the country:

> *"We are asked to address 'corruption' within the system. What people from outside do not understand is that here corruption cannot be removed from the system. Corruption is the system."*

Broader arguments were also raised - for example the suggestion that the problems were more to do with the concept of development as a whole:

> *"I do not think these [socio-cultural issues] are a genuinely significant issue as there are structural problems related to development that undermine the introduction of new technologies and that are related to the idea of development as it has evolved."*

This followed similar discussions patterns to discussing the results of previous chapters. The further from traditional engineering topic matter that the conversations developed the more disparate the opinions of each engineer became. As mentioned before, in the discussion regarding the technical success of the water supply interventions, this would involve raising topics which affect both engineering but also introduced broader development issues (See Chapter 4: Part 1). Through these conversations it becomes apparent the range, scope and depth of issues affecting what appears to be even simple technology transfers in engineering projects. This affects more than just water supply - as one engineer explained:

> *"[the] impacts of access to clean water, or rural electrification are often culturally far reaching, regardless of the technology used"*

A host of cultural issues such as; the impact of local governance, the effects of corruption, the suitability of NGOs in their roles, grassroots perceptions of aid and the erosion of civil society were just some of the topics discussed - alongside all the socio-cultural interactions described in this chapter. Prioritising which needs were thought to be the most important depended on the previous experience and the individual philosophy of each engineer. Given the broad spectrum of topics that could be discussed most engineers responded with one of two very different reactions:

1. To effectively shut down in communication beyond problems that had a purely technical scope. Many engineers with this philosophy saw making either immediate or broad socio-cultural alterations as being outside the scope of what should be expected of engineering interventions.

2. To expand topics of conversation and invite further discussions on the impact that an engineer can provide over and above that of their technical assistance. In this instance the immediate and broad socio-cultural considerations were taken as fundamental components of working within developing nations.

Regardless of which standpoint was taken it was clear that engineering was being affected by the context of the developing countries in which it operates. As the engineering co-ordinator of what was, at the time, the largest development infrastructure provider in Sierra Leone stated:

> *"The first rule you must have when working here as an engineer: forget everything you know about engineering"*

CHAPTER 5: CONCLUSION

The Role of the Engineer in International Development

The aim of this thesis was to understand and progress the role of the engineer in international development. What became apparent throughout the exploration of each of the chapters is that there is a polarity that exists within the different philosophies and approaches of the engineers operating in international development.

This polarisation could perhaps be traced to the historical foundation of the profession. It was found that the concept of what it is to be an 'engineer' is not a straightforward exploration in itself. There was found to be no standard definition that can be used to fully explain, or classify exactly, the nature of the profession. The combination of the two rationalisations of the *'broad'* and *'narrow'* definitions can be used to most readily explain the true nature of the profession (Chapter 2: Part 1). The functional core of the profession will always be most readily explained within the boundaries of the 'narrow' definition. In the 18th and 19th centuries, as the profession of engineering was originally evolving from this solely 'narrow' definition, it was capable of contributing to achieving functional goals - but without the requisite understanding of the moral obligations of the profession to society (Chapter 2: Part 1).

In more recent times, particularly after the post-industrial era, the profession has developed a broader realisation of its role within society. This 'broad' definition was not divorced from its functional core but had evolved gradually over generations. The progression of engineering into development practice is not the only indicator of such ethical developments. Other areas within the profession benefited from such a change - such as the introduction of environmental engineering or the emergence of health and safety practices (Chapter 2: Part 1). In such instances the socio-cultural systems influenced the role that the engineer would take within society - through the expectations and needs of their environments. However, it could be argued, that even within this spectrum engineers gravitate towards different ideologies - for example some engineers are more concerned about the impact on the global environment whereas others focus more on the technical challenges of large scale construction.

Development engineering has exhibited this same spectrum of behaviour (see Chapter 2: Part 2). The 'linear' interpretation of addressing development needs is akin to the engineers who feel that their role is to engage primarily with the functional roles of the profession. This has resulted in certain organisations who operate a Linear Technology Transfer (LTT) approach. Likewise engineers that engage in a 'broad' approach, and are more inclusive in their engagement with other cultures, tend towards the Appropriate Technology Transfer (ATT) approach (see Chapter 2: Part 2). Large organisations were shown to have a need for the entire spectrum and therefore combine both approaches into a Synergetic Approach to Technology Transfer (SATT). The discussions with engineers throughout the research have indicated that many of them do not see their approaches as being an exact combination of both approaches. Instead they have shown tendencies towards each of the poles of the 'linear' and 'appropriate' categories. In many ways this could be argued to be an expression of the individuals understanding of engineering and where their interest gravitates. Expecting the profession to fulfil the 'narrow' obligations could result in projects being more linear in scope whereas introducing appropriate technology concepts could indicate a 'broad' expectation from the profession.

To understand the effectiveness of this combination of the two approaches a case study was required. It was found that Sierra Leone provided an important example of how engineering practices are influenced by such philosophies. Looking holistically at the findings presented in this study offers some important realisations about working in international development. It found that working in Sierra Leone was:

- ***Contextual*:** Reviewing the water supply projects in Sierra Leone indicated that understanding the local context is critical to the success of a project. This is apparent in the presentation of the brief overview of the history of the country (see Chapter 2: Part 3). It can also be shown that this nation, like many others throughout the developing world, had a relationship with engineers that existed prior to that of 'development engineering' (see Chapter 2: Part 1). The more recent history of the country, in particular the Mano River War, has not resulted in a less challenging environment to operate within (see Chapter 2: Part 3). However, the most significant element regarding context is in the understanding that the communities exhibits properties that cannot be fully understood by those from outside the socio-cultural systems. The secret societies are the most prominent example but there are countless more examples of practices and opinions that can only be understood within the context of Sierra Leone (see Chapter 2: Part 3).

- ***Complex:*** Sierra Leoneans within the villages exhibited constant networking capabilities that, as an outsider, were difficult to understand. Their cultural hierarchies, tribal structures, clan organisations, religious beliefs, societal rules and political movements combined to give a rich, vibrant but ultimately complex system (see Chapter 2: Part 3). This was noted throughout the field research in the communities (Chapter 4). The reasoning for many decisions about water supplies were based on a logic formulated from within a complex system. The causations behind many practices cannot be understood through linear interpretations alone (see Chapter 4: Part 3).

- ***Adaptive:*** One of the most important realisations was that the communities were adapting to suit engineering interventions. The communities were fully capable of adjusting their practices to suit what they perceived as their needs. In the case of mobile phone technologies this resulted in adapting the culture to suit a new technical intervention (see Chapter 4: Part 3 and 4). In the case of the more development orientated interventions this adaptability worked in a different way. Without a full understanding of the need of water supplies (see Chapter 4: Part 3) communities were shown to adapt to the presence of the NGOs by allowing them to build and maintain their technologies on their behalf without regards for their own responsibilities (see Chapter 4: Part 2).

Looking at the empirical evidence presented in the grading of both technical criteria and the social support criteria indicated the success of current interventions strategies in Sierra Leone.. Almost 60% of the 295 water points surveyed were described as having serious technical problems. Over 33% of the water points exhibited 'significant failure' - a criteria that could technically be corrected by the communities. It was found that only 4% of the water points had very minor problems that could be corrected without outside assistance (see Chapter 4: Part 1). The most logical conclusion from seeing these results is that there is a problem with construction. In certain cases, particularly for the pulley well systems, this would be correct (see Chapter 4: Part 1). If this was the case for all water supplies then this study would suggest that the engineers engaged in development had perhaps broadened their approaches to technology transfer too far. Then the conclusion should be on focusing on the technical quality of works over the more *'software'* elements of construction.

The counter argument is just as persuasive and it is in this regard that an understanding of the concept of local 'context' becomes important. The study of the social support mechanisms had shown that in many cases the water supply systems had been allowed to fail (see Chapter 4: Part 2). Many of the basic indicators for functional Water User Committees, successful spare part supply chains and technical maintenance were found to be missing or not achieving their aim (see Chapter 4: Part 2). The following studies into the socio-technical and socio-cultural systems found that there are a host of social issues that undermine the success of a water supply intervention. In this regard the opposite conclusion could be reached from that stated above: that engineers are not engaging successfully with the social systems and that a 'narrow' expectation on the profession has been limiting the overall sustainability of the systems.

A more balanced opinion would be to state that there are issues with both approaches. As development agencies adopt what could be described as a SATT approach to engineering while (as described in Chapter 2: Part 1) only usually utilising a single engineer then the model is inherently biased to the philosophies of this professional. An engineer only intending to adopt a technical focus would struggle with the contextual nature of countries such as Sierra Leone. Those approaching the field with solely 'software' orientated skill sets were likely to result in poor quality technical interventions. What was apparent from the case studies was that a balance is required - a combination of both technical and non-technical skills within a single programme.

Perhaps the most important finding from sharing and discussing the field results with all parties, both engineers and non-engineers, was the continual emphasis on what can only be described as a *'shadow profession'*. This *'shadow professional'* was an individual that was an amalgamation of a social anthropologist, water supply specialist, an educational technologist and more besides. This individual was supposedly the middle ground between the practical engineering activities, the context of Sierra Leone and in ensuring that the social mechanisms set in place actually work. The reasons for referring to it as being a *'shadow'* is that an individual trained in such methods were never encountered in all the years of research in the field. It was found that engineers would direct their frustrations towards management for not fulfilling the roles that they needed from such an individual. Similarly the senior programme managers would also be frustrated as they expected the engineers to be fulfilling this role within the communities in which they work.

What is clear from the research period in Sierra Leone is that such a *'shadow professional'* needs to exist. In doing so they would be the bridge between the polarities of current approaches. It is within this finding that a redefining of the role of the engineer is possible. Again this depends on the choices of the profession of which two have become prominent:

Choice 1: Consolidation of existing technical skills: The role of the engineer could be defined as isolating technical problems from their context but working in partnership with what is currently only a *'shadow profession'*. This would depend on this *'shadow'* role developing as an actual support to the technical role. This profession would operate without a traditional engineering element (*i.e.*, not solely construction focused) in partnership with the engineers. In doing so the profession would revert to the 'narrow' scope of engineering and deal only with the technical elements of construction leaving the 'broader' scope of interventions to these individuals. This would limit the need for engineers to appreciate a full understanding context as instead they would perform only limited and controlled technical interventions. For this to be a mainstream approach to development the engineering profession would relinquish much of its position and responsibilities, as well as its role, in the field.

Choice 2:. Expansion of the engineers 'broad' skills: The alternative to consolidation is that this *'shadow'* role should develop from within the existing structure of the engineering profession. From military to civil, from civil to mechanical, and onwards throughout history the engineering profession has continually redefined its roles to suit emergent needs (see Chapter 2: Part 1). In international development the need to combine the 'non-technical' elements of practices to that of the social sciences suggests that there is a 'broader' realisation to the role that could be redefined in future. For this to be incorporated within the profession of engineering then an engineer would be expected to have a balance of fundamental technical skills combined with in-depth appreciation and understanding of the cultures within which they work.

This research has indicated that the engineering profession is approaching a cross-roads in how it is defined in international development. One case study is not sufficient to determine which path the profession should take. Given the complexities of development, as indicated in the wide range of issues affecting engineering practice, it is no more of a correct moral choice to adopt a *'narrowing'* on the scope of engineering interventions. In doing so the profession would be admitting that it needs more rigorous support from other sectors. Likewise it is not more morally agreeable to emphasise the opposite scenario: that engineers could *'broaden'* the scope offered by the profession and fully accept the challenges offered by poverty within the context of engineering. Ultimately this choice will be determined by the countless numbers of engineers already working in development and those that will participate over the coming decades. What can be concluded from this research is that the current status quo has resulted in poor standard of engineering in the world's poorest nations. As the case study in Sierra Leone suggests the current realisation of the engineer does not, as yet, give a true account of the assistance that the profession could provide in international development. The current state of affairs should not be acceptable to what Davis described as *"the most important technical profession of them all"* (Davis, 1998)

CHAPTER 6: FURTHER WORK

Alternative Approaches to Development Engineering

6.1.1 The Challenge of an Alternative Approach to Development Engineering

The role of the engineer in international development has been, and will continue to be, determined by the service of delivery model of the NGO. The most commonly used model (the SATT approach) has shown to have a number of technical, social, socio-technical and socio-cultural limitations in how it approaches technology transfer in rural communities. Should the NGO community withdraw from Sierra Leone, the rural water supply systems would most likely rapidly decline into a state of non-functionality (Hirn, 2012). In many ways the failures outlined in this research, given the stated aims and objectives of development agencies, are perhaps an inevitable feature given the scale of the challenges.

The expected standard and measure for successfully introducing a technology are perhaps impossibly high. Water supply technologies are expected to offer an improved source of water that should be available to all community members for an indefinite period of time. While providing sufficient yield they must also be capable of having a solution that can be understood by the communities, have multiple options available ensuring technical choice and even be desirable for the communities for their own financial investment. The technologies must also be sustainable, be maintained indefinitely and inspire local private sector involvement. To achieve 'appropriateness' they must also be adapted to suit the local context and never be harmful to the local social, cultural and environmental systems over their anticipated life cycle.

This technology has to achieve all these standards, and more besides, within the context of a developing country. Nations such as Sierra Leone have complex barriers to development including fragile instructional structures, particularly the inadequate secondary and tertiary education support, that cannot be relied upon. Private sector response in many developing nations cannot be relied upon given the lack of financial investment. These institution are more acutely weak in the rural areas. Technologies are supposed to achieve success regardless of the educational constraints of the host populations, their priorities, their cultural and indigenous knowledge boundaries and their low technical capacities. Additional barriers exist for rural development including the remoteness of communities and the associated difficulties involved in market development in these areas.

Finally, the implementing organisations have similar restrictions. These include any technical intervention conforming to the ethical standards set from within the agencies. This includes all aspects of participation, ownership and due socio-cultural considerations. The development agencies actively seek to address large populations over wide spatial geographies. The NGOs have limited budgets, low technical support and are unable to provide 'high end' technical solutions that could shortcut development. The development organisations also have to be accountable and the projects transferrable to local governments and authorities.

6.1.2 Possibility Alternative Approach to Development Engineering

Regardless of these challenges the issues documented in this study with the current ATT, LTT and SATT approaches suggests that a new paradigm in engineering practice needs to be sought. The empirical data gathered for this research was primarily gathered to assess the implications of utilising current development approaches. Conceptualising, operating and testing an alternative approach would have been outside the scope of this research. Though the data gathered for this research was intended for critical evaluation there was constant suggestions, both tacit and explicit, for future research opportunities and for the potential development for a new paradigm in development engineering.

There were several potential opportunities raised in the research that suggest such a paradigm could exist. The emphasis for a new paradigm should be on emphasising the strengths of the communities. As this research has shown communities are both complex and adaptive. Their complexity arises due to the combination of indigenous knowledge systems, intricate internal politics and their own perceptions on need. They can adapt to suit interventions shaping their culture around artefacts they determine as being important (such as the mobile phone) or tacitly reject technologies that are undesirable (such as many of the observed water supply systems).

The following three observations were made during the research placement. Each warrants further research that could eventually lead to a change in perception of the role that engineering could provide in alleviating poverty:

1. A Systems Approach to Poverty

Much has already been said about the need to develop 'systems' that can be used to address global poverty issues (Jowitt, 2003). A new method of understanding the host communities is to understand, and perhaps even model, their culture as a knowledge network. Instead of using current approaches that are geared towards producing the goal orientated 'artefacts' the overall objective would be to have this 'knowledge network' respond to the technologies. This would require setting theoretical boundaries of where information is being transferred between different smaller communities. This would correspond to the existing linkages that can be observed in communities throughout the rural areas.

As Sierra Leone continually demonstrated - almost all aspects of the socio-cultural system are interlinked and, at some level, interconnected. The survival of each of the communities would not be possible if they were incapable of communication outside the boundaries of their villages (see Chapter 2: Part 3). The entire tribal structure depends on inclusive alliances, socially constructive behaviour and village partnerships (Richards et al., 2004). Each of the communities that were visited was essentially different in key characteristics and behaviour, and therefore there was nothing standard about their formation. They did however constantly, though unconsciously; exhibit their connections to their neighbouring communities. For example, walking to the unimproved sources around the villages highlighted the myriad of footpaths and back-roads connecting each of the villages to each other. These linked even the most disparate community to a much larger network. Therefore the fundamental architecture of the rural networks already exists.

An example of a potential knowledge network model was created for Kholifa Mabang (Figure 97). These potential linkages were determined by the proximity of each village, the main road access and the local topography. These linkages are only theoretical as the actual design would depend on regional cohesion between neighbouring villages. It is used here to indicate an example of the layout of such a network (Figure 97).

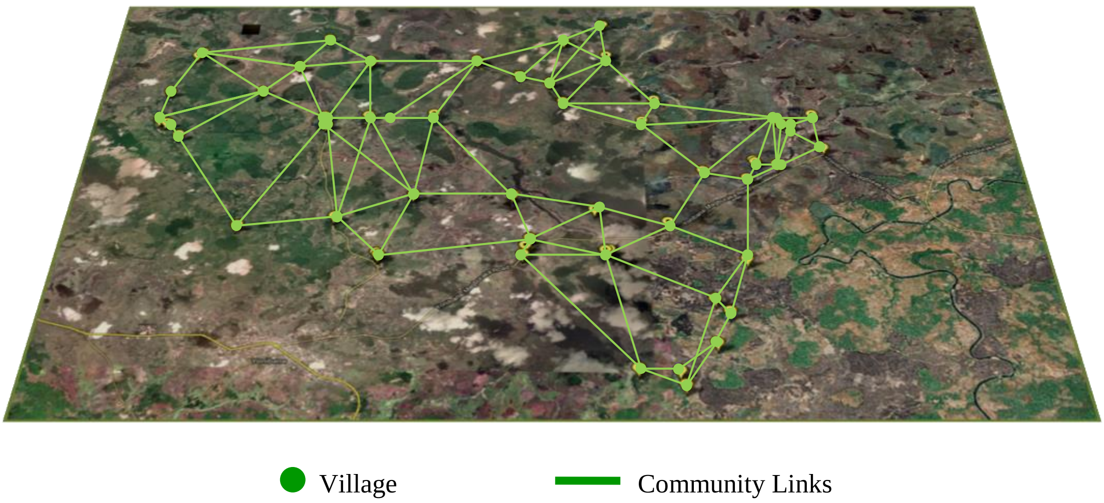
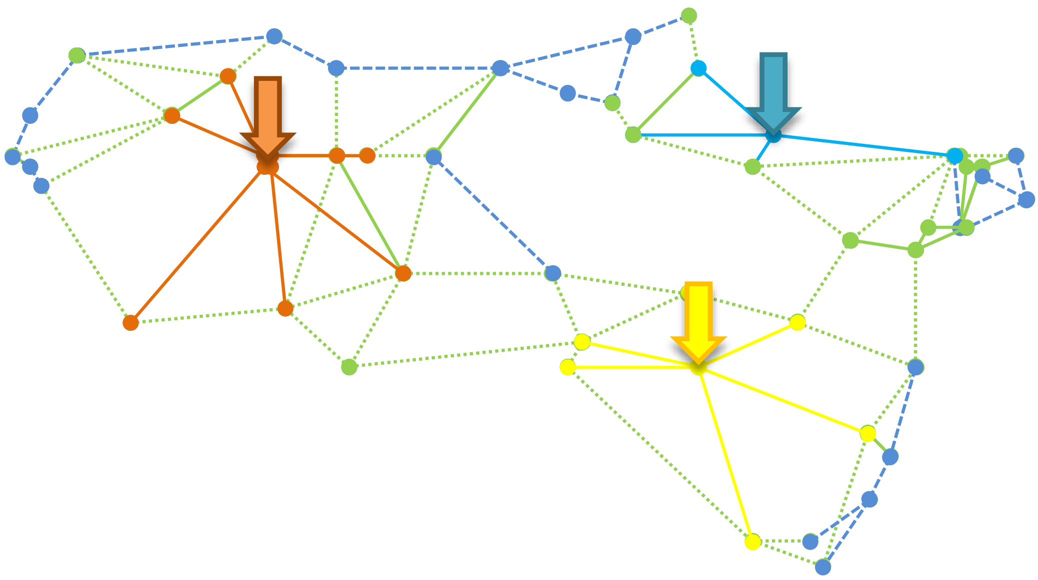


Figure 96: Example of a knowledge network - Kholifa Mabang chiefdom



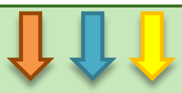
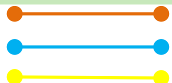
Item	Name	Description
	Technical Intervention	These capacity building technical interventions are located in regions that have the capacity to manufacture and produce technical solutions or services
	Primary Linkages	These are the linkages for villages that can immediately benefit from the technical intervention through proximity to the solutions
	Secondary Linkages	The secondary links are between villages that have immediate access to the intervention and those that have none.
	Tertiary Linkages	These are usually the linkages between the most remote villages. As they are part of the knowledge network they would still have equal access to the interventions, but would require an intermediary.

Figure 97: Example of intervention strategy in Kholifa Mabang

The concept of the distributed network is based on the socio-cultural understanding of the formation of communal living in Sierra Leone. Historically there has been less interest in how the communities organise themselves and respond to their own survival. It is possible that this overlooked aspect has held the key for a rural-focused solution to solving technical problems

Suggesting a systems approach, in particular this 'distributed network', would require an unprecedented level of monitoring. The engineering input would be focused on the cores - but would crucially involve more than the profession participating in such a scheme. To develop and monitor such a system would require sophisticated planning and participation of communities on a large scale. Such an approach would not have the issues of 'scaling up' that normally hinder development engineering as its planning would have to be envisioned as a complete system. Individual interventions would not provide enough information on how the socio-cultural and socio-technical systems are responding. The scale of designing and developing such an intervention would be outside the scope of this research but further work could model a smaller system to see if the approach could offer an alternative to the SATT approach to development engineering.

2. Increasing the Scientific Capacities of the Socio-Technical System

The second element concerns the interactions with the existing knowledge networks themselves - with or without the development of the 'distributed network' outlined above. The field research in rural Sierra Leone indicated that one of the primary problems with water supplies is the lack of scientific education within the communities. The communities require information that will allow them to understand the nature of their water supply problems. This includes the transmission routes of diseases and illness through their water contamination. There is a real need for the communities to understand how their technical solutions are capable of providing safer alternatives than their unimproved sources.

The foremost challenge of the knowledge networks is to disseminate scientific information at the rural levels. The current limitations of the socio-technical systems are important. The lack of secondary education and literacy mean that disseminating written information would be ineffective. Classroom style teaching practices, particularly those that replicate didactic approaches in many secondary schools in Sierra Leone, would not be capable of producing the behaviour change required (Freire, 1970). Many NGOs have understood the current limitations of the education systems in Sierra Leone and have opted for sensitisation projects. As discussed in Chapter 4: Part 4, this pedagogy is an ineffective alternative that has not increased the sustainability of the water supplies. This is not the only approach that could be taken as there are other unexplored methods of teaching which can be suited to the local context in Sierra Leone.

The starting point of the educational activities is not to attempt to recount the entirety of scientific knowledge regarding safe water. For example, providing the full scientific explanation of germ theory, combined with scientifically exact terminology, would be a meaningless endeavour. At the rural level this information would be confusing and detrimental to the success of the interventions. There is however a baseline of information which needs to be understood by as many community members as possible. Additionally applying only didactic teaching methods would be ineffective when the terminology is beyond the grasp of the audience (Freire, 1970). There are alternative approaches that could be utilised for teaching scientific principles which instead depend on a method of experimental learning pedagogy (Byars and Antizar-Ladislao, 2011). The exact nature of the education would be dependent on the types of technical interventions that are intended to be available to the knowledge network. This experimental learning depends on observation and active participation in the learning process. It can be rationally implemented using only the resources that are available at the rural level. Therefore the teaching can be as inclusive as possible – without sacrificing the scientific integrity of what is being taught. The theory of this 'intermediate education' is found in Appendix N.

The FGDs indicated that there are many willing participants, at both an individual and a collective level, who are willing to receive more information about their water supplies. Furthermore there is no requirement for every member within the social groupings to have the required knowledge about safe water. Instead what is sought is a quorum number of participants that can understand the concepts and respond on behalf of their communities. This creates redundancies at the village level as the process is not dependent on every member understanding or accepting all aspects of the knowledge in order to produce a socio-cultural transformation.

The educational aspects of the knowledge network could act as the foundation for the engineering solutions that are to follow. There is perhaps no explicit role for the engineer in the creation or of the knowledge network or in many of its educational aspects. Much of this should be the remit of educational technologists, local scientific teachers or community mobolisers. For this reason the development of such educational resources and teaching plans remains outside the scope of this study. However, without this framework then all the engineering practices that follow could become inconsequential. Further research could allow for the creation of such material and for feasibility studies in linking such an educational response to engineering projects in future.

3. Increasing the Technical Capacities of the Socio-Technical System

The third and final area of further research is with regards to the technical education required of the socio-technical system. This education is one that allows a community to participate effectively in the provision of a technical solution or build their own artefact without continuous external support. There are already countless training manuals and guides on every type of technical interventions that are available. Many of these have been tried and tested in a development context , such as BioSand filters and Ceramic filtration (Hansen et al., 2012; Lea, 2008; Skinner, 2003), but as yet have never been integrated into mainstream development practice. Instead this education is focused increasing on community resilience and building the technical capacity - without a specific technical artefact being provided. This is the use of technical information that will allow beneficiaries to become service providers capable of responding to their own needs.

This form of education is similar to Sutton's examples of 'self-supply' teaching used in ATT approaches (RWSN, 2006; Sutton, 2009). It should be possible for sufficiently innovative villages to provide solutions, using the educational building blocks of their technical lessons, which have been designed, or simply modified, at the local level. They are already capable of achieving this with mobile phone technologies (Chapter 4: Part 4). Furthermore this creation of local solutions was also noted in hundreds of site visits from the most unlikely of sources. It was observed that the children, using only their natural abilities, local resources and innovation, had created their own toys (see **Error! Reference source not found.** & Figure 99). This presents an indication of what could be the foundation of technical education. The natural ability of children to 'engineer' local solutions to their problems is undoubtedly the most overlooked element of the socio-cultural system in engineering in Sierra Leone. It is from this indigenous engineering ethos that the concept of a local engineer could be formed. At some level this process is similar to the conception, formalisation and institutionalisation of engineering in the industrial nations (see Chapter 2: part 1).

Figure 98: Examples of toy makers found in Tonkolili

Figure 99: Examples of locally made toys found in Tonkolili

Kamal Kar’s concept of CLTS highlighted the importance of children as ‘agents of change’ (Kar, 2003). A new paradigm in development thinking could similarly benefit from the existing willingness, curiosity and innovation of the children, such as was displayed in Tonkolili. For example this technical education could be introduced as games and challenges that seek to provide technical solutions to local problems. Like the scientific teachings such development of teaching resources would require the input of additional professions in order to be successful.

It is possible that unique water supply innovations could be conceived entirely within the socio-technical systems. This could use indigenous knowledge to conceive entirely new methods and artefacts for providing safe drinking water to the households. As long as certain elements of an artefacts design remain tightly regulated, such as the water being ‘assumed safe’, then the process of local adaption to suit the local context could be actively encouraged. This could create an actual 'appropriate technology' in water supply in rural Sierra Leone - a distinction in the definition of 'appropriate' that has not yet been fully realised in the literature. It is impossible to hypothesis what artefacts could result from such an innovation - but the rainwater harvesting offers a reasonable indication of locally available solutions that could combine scientific knowledge to ensure safety, technical design to produce efficiency, and local knowledge to provide the element that is 'appropriate' for local needs.

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Appendix A: Water Point Mapping Data

The following are a description of the two sources of secondary data used in this research:

Water Point Mapping (Inter Aide): This surveyed three rural districts in Sierra Leone (Bo, Koinadugu and Tonkolili). It was carried out in 2010 by Inter Aide - a French NGO operating within the water supply sector in Sierra Leone. Their datasets cover a total of 2,859 villages in the three areas and provided details of villages that do not have access to water supplies. Their information included a basic 'working/not working' summary of water points. They also provided seasonal information about certain sources. The water points were not GPS monitored therefore only the village, section and chiefdom names can be used to verify results. The information was provided to the Sierra Leone WASH committees, specifically for the International NGOs operating in Sierra Leone. It is unclear if the datasets were published in any formal proceedings, but the results have informed programming practices by development agencies operating in the rural areas. This dataset has been used in this study as a comparative source used for defining the functionality of the water supply systems. The information that supports the definitions of the condition of the water points is limited. It was also noted that there were inaccuracies in the spelling of village names – which can make the results difficult to verify.

STAT-Wash Database: This was a comprehensive mapping exercise carried out in Sierra Leone in 2012. The research was led by the Ministry of Energy and Water Resources (MoEWR). It was supported by the World Bank's Water and Sanitation Program (WSP), UNICEF and DFID. The report on results is written by Hirn and will be the point of reference for the database of information (Hirn, 2012). This mapping exercise plots over 28,000 water points in Sierra Leone but did not include information on villages that did not have access to water supplies. The data includes preliminary data on breakdowns and partial damage to water points. All of the water points are mapped using GPS co-ordinates and are therefore comparable to the technical analysis of this research. The scale of this mapping exercise is extensive but the reliance on non-technical staff and the quantity of information has resulted in limited descriptions of the water points and their conditions.

The STAT-Wash information used to calculate information in this thesis has two omissions. Firstly, water points that were built in 2012 have not been included, as many are still under construction during data collection period (including: 620 hand-dug wells, 215 protected sources and 62 boreholes). This does also not include of new projects which were awaiting the end of the wet season, in 2012, before construction can start. Secondly there are a large number of water points that have unknown dates of construction (1648 protected sources, 668 hand-dug wells and 183 boreholes). It is possible that there may be differing reasons for the dates of these sources being unknown. The ‘unknown’ dates of more recent interventions types, such as hand-dug wells and boreholes, could potentially relate to the widespread movement of people, both as Internally Displaced Persons (IDPs) or refugees in Ghana, Liberia, Guinea and Côte d'Ivoire, during the war and post-war phases. This tumultuous period would have resulted in verifiable village information being lost and can account for the differences in pre-war estimates being lower than the reported 35%. These numbers could potential be distributed over the trends of current water supply numbers, but the inaccuracies would be considerable.

Appendix B: Villages Surveyed

Village	Village Name	Latitude	Longitude	Number of households	Estimated Number of people	Total Number of Wells
1	Barayrin	8.65935	-11.58643	17	200	1
2	Bombeh	8.6341667	-11.44472	32	350	3
3	Bongay	8.5118167	-12.1638	45	400	2
4	Boynbowl Nene	8.4917167	-12.16155	32	366	1
5	Bukbuka	8.82315	-11.85812	10	100	1
6	Fothaneh	8.5911333	-11.38248	40	500	4
7	Fothaneh Junction	8.5733333	-11.53355	40	280	3
8	Fothaneh Thana	8.4817333	-12.17475	34	700	1
9	Gaindema	8.54385	-12.09127	69	1242	1
10	Komrabai Mamila	8.57795	-11.35328	19	255	2
11	Konta Thama	8.7269167	-11.95627	45	600	1
12	Kump America	8.5281333	-12.0877	47	700	4
13	Kumrabai Junction	8.539	-12.09797	27	286	2
14	Kumrabai Station	8.5421333	-12.25162	18	150	5
15	Mabai	8.6851667	-11.89923	70	950	2
16	Mabai	8.7037667	-11.82832	34	535	3
17	Mabamp	8.56615	-12.17275	46	400	1
18	Mabang	8.45125	-12.12658	85	1250	7
19	Mabarewa	8.5600333	-11.81472	13	200	1
20	Mabarr Line	8.6440833	-11.50292	30	700	1
21	Mabathof	8.6516333	-11.39622	30	600	1
22	Mabineh 1 & 2	8.6053	-11.89343	60	700	2
23	Maboboh	8.62255	-11.41395	26	500	3
24	Mabokoh	8.6693833	-11.97405	80	950	4
25	Mabom St	8.6515833	-11.97995	35	570	2
26	Mabome	8.66465	-11.51953	80	1500	4
27	Machain	8.5411333	-11.87138	35	350	1
28	Maconteh	8.6264333	-11.55015	38	500	2
29	Madina	8.6369833	-11.51393	25	255	2
30	Mafabaneh	8.47545	-12.34998	8	110	1
31	Mafalatha	8.7673333	-11.87675	24	355	1
32	Mafam	8.4771167	-12.1189	52	500	3
33	Mafang	8.6861833	-11.93198	15	200	1
34	Mafanta	8.6371	-11.83107	27	398	3
35	Mafaray	8.4552333	-12.12762	22	300	1
36	Mafokoya	8.59585	-11.40563	11	102	1
37	Magbafeth	8.5212	-12.119	35	500	1
38	Magbakai	8.68805	-11.95595	12	150	1
39	Magbakrr	8.4634833	-12.11942	22	300	3
40	Magbala	8.7186833	-11.41668	10	150	1
41	Magbanto Bana	8.6203167	-11.51643	45	500	1
42	Magbasia	8.7025667	-11.9691	16	300	1
43	Magbeseh 2	8.7862	-11.8712	35	550	3
44	Magbonho	8.5522833	-12.13008	50	400	3
45	Magbunto	8.58545	-11.99452	50	517	2
46	Makabie	8.59655	-11.51852	25	250	1
47	Makalfah	8.6180833	-11.8689	45	630	1
48	Makeni Koray	8.6274667	-11.55808	54	500	2
49	Makeni Lol	8.6023333	-11.49103	3	16	1
50	Makinali Bana	8.59335	-11.9074	30	400	1

51	Makinth	8.6299333	-11.98182	50	600	3
52	Makombor	8.7417667	-11.89693	17	230	2
53	Makonday	8.9452	-11.81017	9	100	1
54	Makonday	8.6539	-11.95027	70	700	6
55	Makone Yambie	8.62725	-11.83913	14	200	2
56	Makonie	8.6379	-11.57543	44	450	3
57	Makonilina	8.5573167	-11.81508	98	1800	5
58	Makonkonie	8.5795167	-11.81543	53	600	3
59	Makonkoro	8.55555	-11.39225	32	450	1
60	Makonteh Thoma	8.6098833	-11.61177	60	850	3
61	Makumbu	8.6734667	-11.90317	29	200	1
62	Makump	8.6710167	-11.965	18	575	1
63	Makump Kapath	8.66315	-11.94417	30	350	3
64	Makundu	8.69315	-11.4583	12	300	2
65	Makwma	8.73425	-11.876	30	500	1
66	Malongba	8.5404167	-12.13273	45	750	1
67	Mamaila Gbla	8.5154	-12.2851	26	400	3
68	Mamaka	8.6942333	-11.9835	80	1000	5
69	Mamankmoi	8.5648167	-12.01842	15	300	1
70	Mamanor	8.4922167	-12.14185	32	500	4
71	Mamanso Kafah	8.6024167	-11.4253	32	535	4
72	Mamantya	8.48475	-12.28545	18	155	1
73	Mamorka	8.63435	-12.0177	30	300	1
74	Mamunta	8.6420167	-11.71817	75	950	4
75	Mamuri	8.5812167	-11.95442	50	375	2
76	Mangay Bana	8.6453667	-11.84552	60	700	3
77	Mangayloo Road	8.7019167	-11.90607	48	550	1
78	Mange	8.7887333	-11.9098	26	355	2
79	Mapaki	8.63135	-11.87897	58	800	5
80	Mapakie	8.63	-11.38322	46	500	2
81	Mapolie	8.4900333	-12.11048	72	800	2
82	Marokie Bana	8.7416333	-11.42907	9	102	1
83	Masagbay	8.5549667	-12.04298	44	450	1
84	Masang	8.5560167	-12.03617	80	806	5
85	Masang Junction	8.5588667	-11.8861	8	60	1
86	Masann	8.6897	-11.81492	10	150	1
87	Masara Komeh	8.5916833	-11.93758	45	500	1
88	Masara Tholly	8.55265	-12.24988	40	500	1
89	Masereku	8.5074333	-12.14477	18	255	1
90	Masheriffu	8.597	-11.46593	17	247	1
91	Masiaka	8.5834333	-11.81403	87	700	1
92	Masimara	8.4975667	-12.1597	24	300	1
93	Masimoh	8.5327	-12.05113	18	443	2
94	Masobintha	8.5431167	-12.03305	32	120	2
95	Masokoh	8.5988167	-11.3862	64	260	6
96	Masokoray	8.6535833	-11.96155	25	350	1
97	Masoria	8.6959	-11.9212	14	200	1
98	Massabe	8.5595833	-12.03243	25	500	2
99	Masuba	8.7006333	-11.93882	21	175	2
100	Matali	8.5483	-11.80305	36	600	3
101	Mathimbo	8.54735	-12.15305	60	600	3
102	Mathinka Bana	8.7155833	-11.90182	57	700	4
103	Mathinkay	8.5846667	-11.42837	33	550	3
104	Matholley	8.62535	-11.59645	50	600	1
105	Mathonkara	8.7352667	-11.90363	25	300	2
106	Mathora	8.5851667	-11.4279	60	900	2
107	Matufulie	8.5250167	-12.10653	76	754	1
108	Matuku	8.5211167	-12.10393	31	600	2

109	Matuku 2	8.4915667	-12.19397	45	550	3
110	Maworro	8.62215	-11.6268	45	763	5
111	Mayami	8.6578333	-11.89173	19	300	1
112	Mayan	8.6254167	-11.96437	50	500	1
113	Mayatha	8.65745	-11.82595	48	550	4
114	Mayeto	8.5949833	-11.88518	21	310	1
115	Mayinka	8.6500167	-11.96322	30	300	2
116	Mayinkoko	8.69725	-11.88465	17	160	2
117	Maymbaray	8.5558833	-11.45067	20	450	2
118	Mayola	8.5874	-11.98188	27	300	1
119	Mayossoh	8.6000833	-11.99025	96	450	6
120	Mayossoh Line	8.6117167	-11.55203	26	260	1
121	Patefutain	8.6266167	-11.5395	22	350	2
122	Patifu	8.5896667	-11.8272	40	572	4
123	Petifu Limba	8.5169833	-11.8545	30	350	2
124	Petifu Mayorpor	8.5696	-11.50458	60	1300	6
125	Robassa	8.6097333	-11.97453	22	480	1
126	Robinkie	8.6360167	-11.86625	65	444	5
127	Robis	8.51735	-12.06533	20	350	1
128	Robis	8.6895333	-11.91575	68	500	5
129	Robol	8.50255	-12.12825	27	500	2
130	Rochain Kawanda	8.65565	-12.04017	12	98	1
131	Rochan	8.7252	-11.9601	66	800	3
132	Rogberay	8.5873	-11.93935	14	300	1
133	Rogberka	8.7738667	-11.85215	36	850	3
134	Rogbesseh	8.5689833	-12.24445	56	1000	1
135	Rokankrr	8.75735	-11.88625	52	650	2
136	Romankro	8.6477167	-11.93378	19	300	2
137	Romolah	8.5736167	-11.41187	26	500	1
138	Ronetor	8.6892833	-11.83835	30	355	1
139	Ropolo	8.5206	-12.28892	60	600	2
140	Ropothaka	8.5729333	-11.92773	54	756	1
141	Rosengbeh	8.6224167	-11.8901	70	800	1
142	Rosint	8.7085	-11.91263	48	500	4
143	Rothuke	8.5351333	-12.24585	20	350	2
144	Rotobel	8.7289333	-11.918	22	500	1
145	Rowalla 3	8.7279167	-11.92192	7	100	1
146	Rowallah	8.5481	-11.87943	20	300	2
147	Royema	8.57315	-11.45098	18	234	1
148	Sarr Ben Thy	8.6010333	-11.38882	15	300	1
149	Two house	8.7028833	-11.87035	35	400	1
150	Upper Mayatha	8.65935	-11.58643	15	158	1

Appendix C: KAP Survey Form

Household Water Supply KAP Study

1. District:	**2. Chiefdom:**	**3. Section:**	**4. Village:**
5. Date of visit:	**6. Int. Start Time:**	**7. Int. End Time:**	**8. Visit:**
9. Longitude :	**10. Latitude:**	**11. Gender of Interviewee:** M ☐ F ☐	

1. Household Information

1.01 ***(Observe)*** **House type:**
Traditional Mud Brick and Thatch Roof ☐ Traditional Mud Brick and CI Sheet Roof ☐ Cement and CI Sheet Roof ☐

1.02 How many people are in the household:

1.03 Please indicate the number of males / females in each age group in the h/h:

Age	Male	Female
0 – 5 yrs		
6 – 15 yrs		
16 – 30 yrs		
31 – 45 yrs		
> 45 yrs		

1.04 What is the main sources of income *(those not in full time education)*:

Farming & Agricultural labour	☐
Non- agricultural labour	☐
Small trading	☐
Government job	☐
Private sector job	☐
Other *(please specify)*	☐

1.05 Combined total monthly household income *(average):*
<50,000le ☐ 50,000 – 100,000 le ☐ 100,000 – 300,000le ☐ 300,000 – 500,000 le ☐ >500,000 le ☐

FOR HEAD OF HOUSEHOLD ONLY

1.06 Gender of the head of the h/h: Male ☐ Female ☐

1.07 Age of the head of the h/h: 0-15 yrs ☐ 16 – 25yrs ☐ 26 – 35 yrs ☐ 36 – 45 yrs ☐ >46 yrs ☐

1.08 Religion :	**1.09 Ethnicity :**

1.10 Indicate the maximum level of schooling completed by the head of h/h :
Primary 1-3 ☐ Primary 3-6 ☐ Junior Secondary 6-9 ☐ Senior Secondary 9-12 ☐ Tertiary ☐ No schooling ☐ Islam ☐

2. Water Supply

2.01 Token Meaning: Total water collected in the household in one month. Use **ALL** tokens.
****30 tokens to be used****
Question: Where do you get most of your water from? A) In the wet season & B) in the dry season?

Source:	**Open Wells**	**Well with Pump**	**Borehole**	**Public Tap Stands**	**Private House tap**	**Rainwater**	**River**	**Spring**
Token Number (Wet):								
Token Number (Dry):								

2.02 What is the main (most used) source:

Open Wells	Well with Pump	Borehole	Public Tap Stands	Private House tap	Rainwater	River	Spring
☐	☐	☐	☐	☐	☐	☐	☐

2.03 Are their multiple sources used of these types of wells?
Open Wells: Well with Pump: Borehole: Public Tap Stands:

2.04 Why do you use the water sources that you do, provide answers for your main, second and third sources of water? (*ask and wait for the response)*

Reason	Main Source (Wet)	2nd Source (Wet)	3rd Source (Wet)	Main Source (Dry)	2nd Source (Dry)	3rd Source (Dry)
Source Type:						
No cost	☐	☐	☐	☐	☐	☐
Low cost	☐	☐	☐	☐	☐	☐
Most reliable (works most of the time)	☐	☐	☐	☐	☐	☐
Closest to household	☐	☐	☐	☐	☐	☐
Good quality water	☐	☐	☐	☐	☐	☐
Only source	☐	☐	☐	☐	☐	☐
No one stops me from using source	☐	☐	☐	☐	☐	☐
Least busy	☐	☐	☐	☐	☐	☐
They suit my needs (disability etc)	☐	☐	☐	☐	☐	☐
Low risks	☐	☐	☐	☐	☐	☐
Other *(please specify)*	☐	☐	☐	☐	☐	☐

2.05 For the main water source:

Question	Time (mins)
How long does it take to reach this source?	
How long does it take to queue at this source?	
How long does it take to return from this source?	

2.06 How many times a day is water collected from the source? *(Number of times)*

2.07 What months of the year are you most likely to have water shortages?

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

2.08 When your household has a shortage of water for drinking, what actions do you take?

Actions taken for shortages	Yes	No
Reduce the amount of water used in household	☐	☐
Compliment main source with another source *(still draw some from your main, but also from other sources)*	☐	☐
IF YES	Which source is used	
Use an entirely different source *(stop using the main, change to another source)*	☐	☐
IF YES	Which source is used	
Buy water *(Grafton, plastic water)*	☐	☐
Other *(please specify)*		

2.09 Please indicate in your household who is the person who makes the decision for the following?

Task	Male	Female	Joint
Which source of water to use	☐	☐	☐
How much to collect at the water source	☐	☐	☐
How to cope during water shortage in dry seasons	☐	☐	☐
How much water to use in the household	☐	☐	☐
Who makes decisions on water storage	☐	☐	☐
Buy new household items (buckets, filters)	☐	☐	☐

2.10 How would you describe safe water?

2.11 Any Comments to be made about household water supply:

3. Ownership

3.01 Please ask the following about the main source of drinking water?

	Individual	Household	Community	Chief /Elders	Local Government	NGOs	Other
Who controls the well?	☐	☐	☐	☐	☐	☐	☐
Whose property is the well?	☐	☐	☐	☐	☐	☐	☐
Whose responsibility is it to make decisions about the well?	☐	☐	☐	☐	☐	☐	☐
Whose responsibility is it to fix the well?	☐	☐	☐	☐	☐	☐	☐
Who should provide new wells?	☐	☐	☐	☐	☐	☐	☐
Who has the capacity to provide new wells?	☐	☐	☐	☐	☐	☐	☐

Please specify other

1.02 Any comments on ownership:

4. Water Supply Choice

4.01 What do you *(or did you)* think of the well?

Reason	**Yes**	**No**
Strong flow of water *(good flow rate)*	☐	☐
Well had plenty of water *(not much shortages)*	☐	☐
Ease of effort to get to water *(ease of pumping)*	☐	☐
Short queues *(at the source)*	☐	☐
Good tasting water *(fresh and clear)*	☐	☐
Other *(please specify)*	☐	☐

4.02 Any comments on thoughts on water supply choices:

5. Water Collection Mechanism

5.01 Is a rope and bucket ever used to collect water at the source? All the time ☐ Sometimes ☐ Never ☐

5.02 Does the household own a rope and bucket for collection? Yes ☐ No ☐

5.03 Does the household ever share rope and bucket with others? All the time ☐ Sometimes ☐ Never ☐

IF YES	**5.04 *(Observe)* Condition of the rope and bucket?** Dirty ☐ Worn ☐ Damaged ☐
IF YES	**5.05 *(Observe)* What is the material of the rope:** Rubber ☐ Reinforced strap ☐Traditional Material ☐

	Other ☐
IF YES	**5.06 Quantity of water capable of being lifted in a single raise:** (litres)

5.07 Token Meaning: Total water collected in the household in one month. Use **ALL** tokens.
****30 tokens to be used****
Question: Of all the water collected in one month who carries what amount of it?

Carrier:	**Man**	**Woman**	**Girl Child**	**Boy Child**	**Water Vendor**
Token Number:					

5.08 To the person responsible for the collection of water – What do you like most about the task of fetching water?

Proxy Response: Yes ☐ No ☐
Gender of the person who answers: Male ☐ Female ☐

5.09 To the person responsible for the collection of water – What do you like least about the task of fetching water?

Proxy Response: Yes ☐ No ☐
Gender of the person who answers: Male ☐ Female ☐

5.10 Any comments on water collection mechanisms:

6. Water Storage

6.01 Is water stored for household usage? Yes ☐ No ☐

IF NO	**6.02 Why not?**

6.03 What is the longest is water stored for: 1 day ☐ 1-3 days ☐ 3-7 days ☐ 1-2 weeks ☐ > 2 weeks ☐

6.04 Is drinking water stored separately? Yes ☐ No ☐

6.05 Is the water stored in the same mechanism used to draw water? Yes ☐ No ☐

6.06 *(Observe)* For the most used containers used to carry water from the source:

Container Type	**Quantity**	**Approximate Volume of One**	**Clean**		**Lid**	
(i.e bucket, 5 Gallon drum)	*Number*	*(In gallons)*	*Yes*	*No*	*Yes*	*No*
			☐	☐	☐	☐
			☐	☐	☐	☐
			☐	☐	☐	☐

IF YES

6.07 *(OBSERVE)* What container does the family use to store drinking water?

Household Water Storage	**Quantity**	**Approximate Volume of One**	**Clean**		**Covered**		**Used for Rainwater Storage**	
	Number	*(In gallons)*	*Yes*	*No*	*Yes*	*No*	*Yes*	*No*
5 Gallon Can *(Jerry Can)*			☐	☐	☐	☐	☐	☐
Traditional ceramic pot			☐	☐	☐	☐	☐	☐
Plastic receptacle *(large tub)*			☐	☐	☐	☐	☐	☐
Saucepan / pot			☐	☐	☐	☐	☐	☐
Plastic water tank			☐	☐	☐	☐	☐	☐
Bucket			☐	☐	☐	☐	☐	☐
Plastic Bottles			☐	☐	☐	☐	☐	☐
Other *(please specify)*			☐	☐	☐	☐	☐	☐

7. Water Treatment

7.01 Do you leave water to stand before drinking? Yes ☐ No ☐

IF YES — **7.02 How long do you let the water stand for?**
<10 mins ☐ 10-30 mins ☐ 30 mins – 1 hr ☐ 1 hr – 6hrs ☐ 6 hrs – 1 day ☐ >1 day ☐

7.03 Do you boil water before drinking? All the time ☐ Some of the time ☐ Infrequently ☐ Never ☐

IF NO — **7.04 Why do you not boil water:**

Reasons for not boiling water	Answer
I was not aware of this	☐
I do not have the money for this	☐
I do not see the use of boiling water	☐
It is not in my habits	☐
I do not have time for boiling water	☐
Other *(please specify)*	

7.05 Has the household ever heard of these treatment systems: *(please read all)*

Treatment	Known about		Where did they learn about the system	Used		Condition of system	
	Yes	*No*		*Yes*	*No*	*Working*	*Not working*
Cloth Filter	☐	☐		☐	☐	N/A	N/A
Chlorination	☐	☐		☐	☐	N/A	N/A
SODIS	☐	☐		☐	☐	☐	☐
Ceramic Filter	☐	☐		☐	☐	☐	☐
Sand Filter	☐	☐		☐	☐	☐	☐
Other *(please specify)*	☐	☐		☐	☐	☐	☐

7.06 *(If known about but not used)* **Why do you not treat your drinking water?**

Household water treatment systems	Answer
I do not know enough about the system *(education incomplete)*	☐
It is too costly, I cannot afford	☐
Not necessary as water is clean and safe	☐
Do not like to change taste of water	☐
Need to discuss with partner	☐
Other *(please specify)*	

8. Rainwater Harvesting

8.01 Does the household collect rainwater for drinking? Yes ☐ No ☐

IF NO — **8.02 Why does the household not collect for drinking rainwater?**

Reason	Answer
Thatch roof	☐
Household owner does not allow for rainwater collection	☐
Rainwater is unclean	☐
No storage for water	☐
Do not understand rainwater harvesting	☐
Other *(please specify)*	

IF YES — **8.03 Where did they receive information on collecting rainwater for drinking?**

IF YES — **8.04 Where is rainwater stored**: *(mixed – mixed with other water, permanent – purpose built container)*
Mixed Temporary Container ☐ Stand Alone Temporary Container ☐
Mixed Permanent Container ☐ Stand Alone Permanent Container ☐

9. Participation

9.01 Did the household participate in the building of the water supply system? Yes ☐ No ☐

IF YES	**9.02 How did the household participate?**

Task	Yes	No
Providing materials	☐	☐
Providing labour	☐	☐
Providing access	☐	☐
Providing land use	☐	☐
Financial contribution for the system	☐	☐
Financial contribution to upkeep	☐	☐
Design of the system	☐	☐
Other *(please specify)*		

9.03 Would the household have liked to contribute more in the well projects? Yes ☐ No ☐

IF NO	**9.04 Why not?**
IF YES	**9.05 Why?**
IF YES	**9.06 In what way?**

9.07 Do you think that the village could provide a well system without outside help? Yes ☐ No ☐

IF NO	**9.08 What support is needed?**

10. Technology

10.01 Does the household own a phone? Yes ☐ No ☐

IF NO	**10.02 Do you share a phone with others**? Yes ☐ No ☐
IF YES	**10.03 How many phones?** quantity

10.04 Did you buy the phones or were they given or rented? Bought ☐ Given ☐ Rented ☐

IF GIVEN	**10.05 Who gave the phone?**
IF RENTED	**10.06 How much is rent** (Leones/month)

10.07 How much did the phones cost (minimum and maximum prices)? min: max:

10.08 What is the condition of the phone(s)? Excellent ☐ Scratched ☐ Badly Worn ☐ Severely Damaged ☐

10.09 What is the average household expenditure (phone credit) bought each month?

10.10 What would you do if your phone partially broke? Save to get it fixed ☐ Get it fixed immediately ☐ Replace it ☐ Do nothing ☐

10.11 Have you ever had your phone fixed before? Yes ☐ No ☐

IF YES	**10.12 How much did it cost to fix?** le

10.13 What would you do if the phone broke completely? Save for a new phone ☐ Buy a new phone immediately ☐ Not replace it ☐

10.14 Where would you buy a new phone?

10.15 Have you ever replaced a phone before? Yes ☐ No ☐

10.16 Have you ever bought any of these items for the phone?

Items	Bought	
	Yes	*No*
Charger	☐	☐
Adaptor (for plug)	☐	☐
Battery	☐	☐
Case	☐	☐
Ringtones	☐	☐
Other *(please specify)*	☐	☐

10.17 Are they available at local market? Yes ☐ No ☐

10.18 Are they available from traders who come to the village? Yes ☐ No ☐

10.19 Who makes the decisions regarding household spending on phones?

Task	Male	Female	Joint
Buying credit	☐	☐	☐
Buying upgrades	☐	☐	☐
Buying a new phone	☐	☐	☐
Spending money on repair phones	☐	☐	☐

10.20 Any comments on alternative or appropriate technologies:

11. Scientific and Technical Capacity

11.01 Please answer the following:

Statement	True	False	Don't Know
Sand can be used to clean dirty water	☐	☐	☐
The 'flange cog screw' is part of a pump system	☐	☐	☐
The 'mechanised toner' is part of a pump system	☐	☐	☐
The 'rising main' is part of a pump system	☐	☐	☐
Sierra Leone is capable of manufacturing its own pump	☐	☐	☐

11.02 How many people in the household have taken Science course in school:

	Male	Female
Science Class		

11.03 Please answer the following:

Statement	True	False	Don't Know
Rainfall is made of new water	☐	☐	☐
Rainwater is dangerous to drink after a storm	☐	☐	☐
Clear and tasteless water is safe to drink	☐	☐	☐
All bacteria is dangerous	☐	☐	☐
Water cannot be stored for 1 month without treating it with chemicals	☐	☐	☐
Safe water can be stored for 3 months in a sealed container and is still safe	☐	☐	☐

11.04 What is the most important resource in Sierra Leone?

12. Health and Hygiene

12.01 How often do you wash your hands? Every time I work with my hands ☐ At intervals ☐ Irregularly ☐ Seldom ☐

12.02 Do you always use soap? Every time I wash ☐ Occasionally, when available ☐ Seldom ☐ Never ☐

12.03 ***(Ask to see the soap if they do not produce it in one minute, mark it as not present)***
Present ☐ Not present ☐

12.04 Do they use alternatives to soap: Ash ☐ Sand ☐ Gel ☐ Other ☐ *(please specify)*

12.05 ***(Observe)*** **Is there a designated hand washing site** Yes ☐ No ☐

12.06 ***(Observe)*** **Do they have separate water for hand washing- if so what do they use?**

System	Answer
No separate system	☐
Tippy Tap	☐
Plastic Tea-Pot	☐
Plastic Basin	☐
Plastic Bottle	☐
Other *(please specify)*	

12.09 How much is spent on medical treatment per month ***(average)?***
Wet Season : <5000le ☐ 5000 – 10000 le ☐ 10000 – 35000le ☐ 35000 – 50000 le ☐ >50000 le ☐
Dry Season : <5000le ☐ 5000 – 10000 le ☐ 10000 – 35000le ☐ 35000 – 50000 le ☐ >50000 le ☐

13. Other Comments

Any other comments on Water Supply:

Appendix D: Community Survey Form

Community Survey Form

1. Village:	**2. Date:**	**3. N:**	**4. W:**
5. Number of Houses in Village:		**6. No. of People in Village:**	**7. No. HH surveys:**
8. Number of Improved Wells Working: Not working:		**9. Number of boreholes Working: Not working:**	**10. Number of unimproved sources:**

11. Who controls the wells: Individual ☐ | Household ☐ | Community ☐ | Chief/Elders ☐ | Committee ☐ | NGOs ☐ | Other	
12. Whose property is the well: Individual ☐ | Household ☐ | Community ☐ | Chief/Elders ☐ | Local Government ☐ | NGOs ☐ | Other	
13. Who has the ability to modify or upgrade the well: Individual ☐ | Household ☐ | Community ☐ | Chief/Elders ☐ | Local Government ☐ | NGOs ☐ | Other	
14. Does the village have storage to spare parts? Yes ☐ | No ☐	
If yes	**15. Are the spares in good condition** Yes ☐ | No ☐ **Are they stored in a dry/safe place** Yes ☐ | No ☐
If no	**16. Where can you buy spares** Don't Know ☐
If no	**17. Why have you not bought spares**
18. Does the village have storage of tools Yes ☐ | No ☐	
If yes	**19. Are the tools in good condition:** Yes ☐ | No ☐ **Are they stored in a dry/safe place:** Yes ☐ | No ☐ **Is the tool set complete:** Yes ☐ | No ☐
If no	**20. Where can you buy tools** Don't Know ☐
If no	**21. Why have you not bought tools**
22. Does the village have a trained technician: Yes ☐ | No ☐	
If yes	**23. Are they capable of taking apart and replacing the handpump** Yes ☐ | No ☐
If no	**24. Does the village have an outside technician that they can contact** Yes ☐ | No ☐
25. Are the wells treated with chlorine: Yes ☐ | No	
If yes	**26. Who treats the well:**
If yes	**27. How often:** When the well was built ☐ Weekly ☐ | Monthly ☐ | 1 – 3 months ☐ | 3 – 6 months ☐ | 6 months – 1 year ☐ | over 1 year ☐
If yes	**28. What dosages are used:** 1 tbsp ☐ | 2 tbsp ☐ | 3 tbsp ☐ | Depends on water ☐ | Don't know ☐
29. Is there a water user committee Yes ☐ | No ☐	
If yes	**30. How often do they meet to discuss the wells:** Never ☐ Weekly ☐ | Monthly ☐ | 1-3 months ☐ | 3-6 months ☐ | 6mths- 1 year ☐ | when there is a well issue ☐
If yes	**31. How many men and women are on the committee: (men), (women)**

32. Who is not allowed to use the well:

	Not allowed	Allowed
Small Children (<5)	☐	☐
Old people	☐	☐
Blind people	☐	☐
Sick people	☐	☐
Those with known cases of HIV/AIDS	☐	☐
Practising society members	☐	☐
Other (please state):		

33. Does the village collect a tariff? Yes ☐ | No ☐	
If yes	**34. How much is collected per household per month:**
If yes	**35. How often is it collected:** Monthly ☐ | Occasionally ☐ | Irregularly *(or not from everyone)* ☐ | Not currently collected ☐
If no	**36. Does the community wait until the well is broken before collecting money?** Yes ☐ | No ☐

Appendix E: Hand pump Well Observation Form

Hand pump Well Observation Form

1. Well Ref No:	2. Date:	3. Village:	4. N:	5. :
6. Well provider:	**7.Date built:**	**8.Water level (m):**	**9. Depth (m)**	**10. Diameter (m)**

11. Well type: Handpump Well ☐ | Other ☐
Rope and bucket currently used *(regardless of well type):* Yes ☐ | No ☐

12. Well currently in use: Yes ☐ | No ☐ **13. If No – Date last used:**

14. Is there any reason why the well is not currently used (apart from the well not functioning)?
Bad water ☐ | Social reasons (i.e. body or animal in well) ☐ | Water extraction mechanism not favoured ☐
Well system unwanted ☐
Other (please specify)

15. Handpump: Handpump present: Yes ☐ | No ☐
If present, what type of handpump: India MK II ☐| Kardia ☐ | Afridev ☐ | Inka ☐ | Other ☐
Other (please state):
No Handpump: No handpump ever installed ☐ | Was installed, but stolen ☐ Was installed, but missing ☐

16. Handpump Function: No handpump ☐
Rusted/Severely Damaged Handpump ☐ | Single Rusted components of handpump ☐
Damaged, or missing, fast-moving replaceable parts ☐
Un-greased hand pump ☐ | Handpump make excessive noise in operation ☐ | Handpump satisfactory ☐

17. Handpump Security: No handpump ☐
None or missing security cover ☐ | Concrete security cover (handpump sealed in place) ☐ | Metal Security cover ☐

18. Well Cap:
No cap ☐ | Severe ponding ☐ | Moderate ponding ☐ | Slight ponding ☐ | Dirty Cap ☐ | Exposed Rebar ☐
Finger width (or larger) cracks ☐ Hairline cracks ☐ | Sagging of the cap ☐ | Cap satisfactory ☐

19. Well Wall:
Complete Collapse ☐ | Sizable failure affecting formwork ☐ | Finger width fissures in wall ☐ | Joints exposed ☐ Hairline cracks ☐ | Dirty well wall ☐ | Well wall satisfactory ☐

20. Well Area:
No well area ☐ | Well area smaller than 2m x 2m ☐ | Sagging well area ☐ | Erosion ☐
Severe Ponding ☐ | Mild ponding ☐ | Dirty well area ☐ | Well area used for other purposes ☐
Area satisfactory ☐

21. Apron
No apron ☐ | Damaged apron ☐ | Dirty apron ☐ | Apron satisfactory ☐

22. Fence
No fence ☐ | Porous fencing (that allows in goats) ☐ | Porous fencing (that allows in ducks) ☐ | Missing gate ☐
Fence satisfactory ☐

23. Spillway:
No Spillway ☐ | Damaged Spillway ☐ | Inadequate spillway (missing ball stones, ponding) ☐ | Blocked spillway ☐
Spillway satisfactory ☐

24. Manhole
No manhole cover ☐ | Damaged or rusted manhole ☐ | Missing hinges on manhole cover ☐
Inadequate manhole (cover does not fit hole) ☐ | Sealed Manhole ☐ | Manhole satisfactory ☐

25. Lining (Casing) type:

Concrete lined	☐
Clay/mud lined	☐
Aggregate/concrete lined	☐
Stone (Brick) lined	☐
Other	☐
Other (please state):	

26. Casing: Casing cannot be seen ☐
No casing ☐ | Collapsed Casing ☐ | Inadequate, damaged or missing casing(s) ☐
Finger width damage to any casing ☐ Hairline cracks on any casing ☐ | Dirty casing ☐ |
Casing satisfactory ☐

27. Pipes Pipes cannot be seen ☐
Missing pipes ☐ | Cracked pipes ☐ | Superficial rusting ☐ | Rusted or severely damaged pipes ☐ | Missing riser ☐ | Unclean pipes ☐ | Damaged Valves ☐ | Missing or damaged Seal ☐ | Pipes satisfactory ☐

28. Location
Well beside: School ☐ | Health Clinic (or MHC etc) ☐ | Community well ☐ | Other ☐
Other (please state):
Distance to permanent structure (latrine, main road, livestock shed etc) : less that 30m ☐ | more than 30m ☐
Distance to temporary structure (latrine, rubbish pits etc): less that 30m ☐ | more than 30m ☐
Does the well flood: Yes ☐ | No ☐

29. Seasonal availability: When does the well go dry? Never ☐
Jan ☐ | Feb ☐ | Mar ☐ | Apr ☐ | May ☐ | Jun ☐ | Jul ☐ | Aug ☐ | Sept ☐ | Oct ☐ | Nov ☐ | Dec ☐

30. What is the condition of the water: No Water ☐ | Clean and Clear ☐ |
Oily ☐ | Particles ☐ | Poor Taste ☐ | Metallic Taste ☐ | Cloudy (turbid) ☐ | Colour ☐ | Salty ☐ |
Other (please state):

31. Any other information:

Appendix F: Borehole Observation Form

Borehole Observation Form

1. Borehole Ref No:	2. Date:	3. Village:	4. N:	5. W:
6. Borehole provider:	**7.Date built:**	**8.Water level (m):**	**9. Drilled Depth (m)**	**10. Diameter (m)**

11. Borehole currently in use: Yes ☐ | No ☐	**12. If No – Date last used:**

13. Is there any reason why the borehole is not currently used (apart from the borehole not functioning)?
Bad water ☐ | | Water extraction mechanism not favoured ☐ | Borehole system unwanted ☐
Other (please specify)

14. Handpump: Handpump present: Yes ☐ | No ☐
If present, what type of handpump: India MK II ☐| Kardia ☐ | Afridev ☐ | Inka ☐ | Other ☐
Other (please state):
No Handpump: No handpump ever installed ☐ | Was installed, but stolen ☐ Was installed, but missing ☐

15. Handpump Function: No handpump ☐
Rusted/Severely Damaged Handpump ☐ | Single Rusted components of handpump ☐
Damaged, or missing, fast-moving replaceable parts ☐
Un-greased hand pump ☐ | Handpump make excessive noise in operation ☐ | Handpump satisfactory ☐

16. Handpump Security: No handpump ☐
None or missing security cover ☐ | Concrete security cover (handpump sealed in place) ☐ | Metal Security cover ☐

17. Borehole Cap:
No cap ☐ | Severe ponding ☐ | Moderate ponding ☐ | Slight ponding ☐ | Dirty Cap ☐ | Exposed Rebar ☐
Finger width (or larger) cracks ☐ Hairline cracks ☐ | Sagging of the cap ☐ | Cap satisfactory ☐

18. Apron
No apron ☐ | Damaged apron ☐ | Dirty apron ☐ | Apron satisfactory ☐

19. Fence
No fence ☐ | Porous fencing (that allows in goats) ☐ | Porous fencing (that allows in ducks) ☐ | Missing gate ☐
Fence satisfactory ☐

20. Spillway:
No Spillway ☐ | Damaged Spillway ☐ | Inadequate spillway (missing ball stones, ponding) ☐ | Blocked spillway ☐
Spillway satisfactory ☐

22. Lining:
Collapsed Lining ☐ | Inadequate, damaged or missing lining ☐ | Lining satisfactory ☐

23. Pipes
Superficial rusting ☐ | Rusted or severely damaged pipes ☐ | Pipes satisfactory ☐

24. Location
Borehole beside: School ☐ | Health Clinic (or MHC etc) ☐ | Community Borehole ☐ | Other ☐
Other (please state):

Distance to permanent structure (latrine, main road, livestock shed etc) : less that 30m ☐ | more than 30m ☐ Distance to temporary structure (latrine, rubbish pits etc): less that 30m ☐ | more than 30m ☐ Does the Borehole flood: Yes ☐ | No ☐
25. Seasonal availability: When does the Borehole go dry? Never ☐ Jan ☐ | Feb ☐ | Mar ☐ | Apr ☐ | May ☐ | Jun ☐ | Jul ☐ | Aug ☐ | Sept ☐ | Oct ☐ | Nov ☐ | Dec ☐
26. What is the condition of the water: No Water ☐ | Clean and Clear ☐ | Oily ☐ | Particles ☐ | Poor Taste ☐ | Metallic (rust) Taste ☐ | Cloudy (turbid) ☐ | Colour ☐ | Salty ☐ | Other (please state):
27. Any other information:

Appendix G: Index for Focus Group Discussions

ID Number	ID Code	Date	Village	FGD Type	Total Members	Gender	Participant Ages
1	[FER/M/1]	15/3/12	Ferry Junction	WUC	3 Members	Male	35, 36, 42
2	[KUM/M/2]	8/3/12	Kumbrabai Junction	WUC	4 Members	Male	37, 29, 29, 36
3	[KST/M/3]	12/3/12	Kumbrabai Station	WUC	4 Members	Male	38, 38, 37, 37
4	[MAG/M/4]	7/3/12	Magbontho	WUC	4 Members	Male	45, 43, 47, 50
5	[MTB/M/5]	14/3/12	Mathinkabana	WUC	10 Members	Male	25, 50, 41, 42, 45, 22, 29, 68, 39, 37
6	[MTU/M/6]	6/3/12	Matatuku 2	WUC	12 Members	Male	32, 19, 25, 31, 43, 23, 50, 60, 26, 31, 27, 40
7	[MAM/M/7]	13/3/12	Mamillagbla	WUC	6 Members	Male	78, 35, 32, 33, 38, 29
8	[FER/F/8]	15/3/12	Ferry Junction	WUC	3 Members	Female	33, 65, 48
9	[KUM/F/9]	8/3/12	Kumbrabai Junction	WUC	4 Members	Female	55, 28, 26, 36
10	[KST/F/10]	12/3/12	Kumbrabai Station	WUC	4 Members	Female	35, 30, 70, 20
11	[MAG/F/11]	7/3/12	Magbontho	WUC	4 Members	Female	50, 70, 60, 35
12	[MTB/F/12]	14/3/12	Mathinkabana	WUC	10 Members	Female	27, 38, 34, 36, 32, 46, 38, 35, 26, 31
13	[MTU/F/13]	6/3/12	Matatuku 2	WUC	7 Members	Female	40, 70, 25, 25, 50, 70, 80
14	[MAM/F/14]	13/3/12	Mamillagbla	WUC	6 Members	Female	50, 35, 45, 20, 25, 50
15	[MTU/T/15]	6/3/12	Matotuka 1	Tech	4 Members	3M/1F	-
16	[MAG/T/16]	7/3/12	Magbontho	Tech	2 Members	Male	-
17	[KUM/T/17]	8/3/12	Kumbrabai Junction	Tech	3 Members	Male	-
18	[KST/T/18]	12/3/12	Kumbrabai Station	Tech	2 Members	Male	-
19	[MAM/T/19]	13/3/12	Mamillagbla	Tech	2 Members	Male	-
20	[MTB/T/20]	14/3/12	Mathinkabana	Tech	6 Members	3M/3F	-
21	[KUM/UF/21]	8/3/12	Kumbrabai Junction	VWU	5 Members	Female	70, 58, 65, 78, 70
22	[KST/UF/22]	12/3/12	Kumbrabai Station	VWU	5 Members	Female	20, 70, 20, 35, 38
23	[MAG/UF/23]	7/3/12	Magbontho	VWU	5 Members	Female	35, 50, 65, 40, 37
24	[MAMUF/24]	13/3/12	Mamillagbla	VWU	5 Members	Female	45, 60, 54, 57, 55
25	[MTU/UF/25]	6/3/12	Matatuku 2	VWU	5 Members	Female	45, 26, 55, 30, 40
26	[KUM/UM/26]	8/3/12	Kumbrabai Junction	VWU	5 Members	Male	55, 40, 46, 50, 40
27	[KST/UM/27]	12/3/12	Kumbrabai Station	VWU	5 Members	Male	25, 30, 36, 40, 45
28	[MAG/UM/28]	7/3/12	Magbontho	VWU	5 Members	Male	41, 45, 40, 43, 38
29	[MAM/UM/29]	13/3/12	Mamillagbla	VWU	5 Members	Male	27, 25, 28, 70, 29
30	[MTU/UM/30]	6/3/12	Matatuku 2	VWU	5 Members	Male	42, 51, 52, 50, 35
31	[FER/UX/31]	15/3/12	Ferry Junction	VWU	10 Members	Mixed	65, 30, 55, 25, 70, 72, 55, 40, 38, 45
32	[MTB/UX/32]	14/3/12	Mathinkabana	VWU	10 Members	Mixed	60, 40, 25, 50, 45, 65, 45, 40, 48, 43

Appendix H: Water User Committees Results

a) Theme: Safe Drinking Water

- [FER/M/1] Clean, no different taste, free from debris, no particles
- [KUM/M/2] Colourless, water has no germs, odourless, tasteless, impurities (particles)
- [KST/M/3] Colourless, tasteless water, no particles, no smell (odourless)
- [MAG/M/4] Clean, no odour, clear, tasteless, colourless, free from germs.
- [MTB/M/5] Clean, clear, no debris, odourless, no *(Temne)* 'nictoro' no particles, no faeces
- [MTU/M/6] Colourless, tasteless, clean, taste, germs (60 year old man answered this)
- [MAM/M/7] Clear, clean and odourless, with no particles, should not be black or contain debris. It has to be cold.
- [FER/F/8] From a well with a pump. Water from local wells needs to be boiled and cooled before storing, then filtered. Water with no colour and taste does not make you sick.
- [KUM/F/9] Boiled and put in a container. Members no longer boil water as it is too costly, however each member uses alum (local treatment).
- [KST/F/10] Clear. Water that is taken care of by taking care of container where water is stored. Use clean cups for drinking. Clean and maintain well area and protect from animals so that water is safe. Pure water does not have colour and is free from bacteria, germs and has no taste.
- [MAG/F/11] Boiled water. Water without minerals and particles. Protect bathing source from laundering because it will contaminate water used for bathing.
- [MTB/F/12] When you take care of the container used to fetch water. Drinking water is boiled. All committee members note that they boil their water, one member also applies alum. Pure water has not been contaminated by flies.
- MTU/F/13] When water is fetched, it is boiled before drinking and all of the bacteria are killed. Only people with knowledge boil water, but the committee is training on this. When people fetch water in streams, they fetch water and use the same bucket for washing and laundry, this results in contamination. Water with no bacteria is pure.
- [MAM/F/14] Good taste, clean, without fly, covered water

b) Theme: The WUC Formation and Purpose

i. Theme: Missing Member

- All present: [FER/M/1], [KUM/M/2], [MAG/M/4], [MTU/M/6], [MAM/M/7], [KUM/F/9], [KST/F/10],[MAG/F/11] & [MAM/F/14]
- [KST/M/3] The entire committee was replaced in 2009. They original members left to do gold mining.
- [MTB/M/5] There are a total of 40 members in the committee. Only 10 of them are present because of the maximum size of the surveys.

ii. Theme: WUC selections and appointment

- [FER/M/1] Elected by the community. Elected for life, unless they die or leave.
- [KUM/M/2] Appointed, no changes since their appointment. Appointed for life. Community selects the user committee.
- [KST/M/3] User committee changes every five years. They will be changed. The first committee was appointed in 2004 and replaced in 2009.
- [MAG/M/4] Elected by the community, never re-elected the positions. They are there until they move to another village.
- [MTB/M/5] Depends on how hard you work. Elected for life - voted by community.
- [MTU/M/6] Well committee chosen by those in the immediate vicinity of the well. Elected. Still have the same committee. Selected from an appointment of community. Have the position for life.
- [MAM/M/7] Committee is selected through community election. Members think they were selected because they are clever and efficient.
- [KUM/F/9] Selected through a community meeting where potential members are introduced and a vote is cast. If you work well with the committee, your term can be indefinite.
- [KST/F/10] When committee loses a member, they are replaced by the committee chair calling on whole community to select a new member.
- [KST/F/10] User committee is selected through a community general meeting. A group of people are selected to be part of the committee. Each person is presented and votes are cast, depending on how desirable they are as a member. No term limit.
- [MAG/F/11] A member is elected by selecting a group of best suited people, voted by community members. Members serve term for life, unless a committee member is not performing duties, then they are asked to leave.

- [MTU/F/13] People are appointed by a committee vote, through election. Members are elected based on their cooperativeness in the community and how many community meetings they attend as well as their community engagement. Participants have sat on the committee for 1, 2, 4 and 5 years. They note that there are elections every year, however, it seems that terms are indefinite.
- [MAM/F/14] Elected by the community. No specific time, elected for life

iii. Theme: Replacement of Members

- Community voting: [MAG/M/4], [MTB/M/5], [KST/M/3], [MAG/F/11], [KUM/F/9] [FER/M/1] Elected by the youth leader, they will replace them. Everyone is happy with their positions.
- Other Information: [KUM/M/2] The person leaving will be responsible for appointment of their replacement. [MTU/M/6] Person can be voted out. No one has been voted out yet. [MTU/F/13] A member is replaced through election. The selection criteria of a nominee is that they regularly and punctually attend community meetings and how active they are in the community. They think of a community member that is clean and responsible. If it is a woman, they approach the husband first. [MAM/F/14] Call for a meeting, will occupy vacancy, if you are not doing duties you will be asked to leave.
- Never replaced a member: [FER/M/1], [MAG/M/4], [MTB/M/5], [MTU/M/6], [MAM/M/7], [FER/F/8], [KUM/F/9], [KST/F/10] & [MTB/F/12]
- Other Information: [MTU/F/13] One female member has passed away. In the process of replacing her. [MAM/F/14] Replaced and old, sick person. [KST/M/3] The four previous committee members. Thing were good during that committees direction, but since then two of their pumps have been stolen. One of the wells was replaced.

iv. Theme: Responsibilities of the WUC

- [FER/M/1] Fencing, keeping the area clean, cutting grass, wash the well area, stopping children using the well.
- [KUM/M/2] Rehabilitation of the well. Well spoiled- tell the community. Discuss the options. Meet with the technicians when there is failure. Tell people that they should do the fencing. There is currently no fence: the chairpersons say that it would take a week to fix. However the committee insist that they have been busy with

brushing for the last 4 months. Without the fence none of the by-laws are addressed. They also admitted that the lack of fence does not impress the NGO.

- [KST/M/3] Cleaning well, creating and implementing by-laws, fencing. There are currently no fences. Multiple excuses were given. Due to rainy season (which finished in November), they live in a savannah and therefore there are no sticks. ‘Bamboo is not there’. * *There is clear indication that sticks and bamboo have been found for other purposes**. The committee report that trying to get the community to do the fencing is hard.
- [MAG/M/4] Cleaning the well surrounding, if the well gets spoiled repair. Levy fines for the by-laws. Inform people that they should apply medicine. Chlorinating the well. December 2011 was the last time they chlorinated. NGO chlorinated last. chlorinate once per year (2 tsp). Don’t know the cost of chlorine.
- [MTB/M/5] Taking care of wells, wells have a problem ask for financial help, find a technician. They contributed money. Collected in march 60,000le and at another time 70,000le. Responsible for collecting bush-poles. Fence got spoiled and they never repaired it. August 2011 when the fence got spoiled.
- [MTU/M/6] Responsibilities: Making fence, making drainage, looking after the well (so that the children don’t spoil it), cleaning drainage, clean area, making by-laws, Chlorination of the well.
- [MAM/M/7] Committee if for delegating responsibilities at the household level (chairman does this). Committee enforces cleaning and maintaining the well area. There is fine for not doing tasks – 5000le. Some have violated, been fined and paid.
- [FER/F/8] Committee if for telling community about safe drinking water and cleaning and fencing well area.
- [KUM/F/9] Responsibilities include determining what repairs and needed and costs. Collecting money from the community and committee members for repairs. Previously, collected 4000le from upper section and 4000le from lower section weekly. These amounts are no longer collected.
- [KST/F/10] Major responsibility is serving as a guide for the protection of the well. Responsible for maintaining well and make sure it is always clean.
- [MAG/F/11] Committee is for supervising community members in water usage. Formed as a protective measure to mitigate misuse of water supply systems. They were happy to form the committee in 2005 because water knowledge has not been good in the past. Responsibilities include washing the pipe that is being repaired by technicians. Control users, especially children. Clean well area, it is currently

unclean because they have had too much to do protecting their plantations. They only clean the well the works. (Researcher note: Demonstrated cleaning the well area and pump. Took shoes off before entering well area).

- [MTB/F/12] There is a chairlady and chairman. The committee is for cleaning and maintaining the wells. Committee calls on entire community to give tariff of 1000le per household for repairs. The last time this was collected was 2 weeks ago. Technicians has been called to fix the well. Sometimes they take a collection just among the members for repairs – about 25,000le.
- [MTU/F/13] To protect wells by seeing that they are clean. Committee gives training to community on maintaining well area and keeping water clean. Make sure the water is well is not misused by community members, especially children. Major responsibility is to make sure well area is clean. Serve as a protector for the well, for better of community. They relay information to local technicians regarding problems with the wells. Responsible for payment of technician and preparing food for them when they are working on wells. They interact with NGO (who provided wells) by discussing community targets. When NGO provided the well, they gathered the community, provided them with education. Meet twice a month.
- [MAM/F/14] Clean well, impose the laws (fine) 1000le. Cleaned regularly, sweep every morning.

v. Theme: WUC Training

- [FER/M/1] Not trained therefore offers no training. Will make by-laws announcements.
- [KUM/M/2] Training on household water usage. NGO provided the training.
- [KST/M/3] The first committee offered training. The new group has not been trained and therefore has no training to give.
- [MAG/M/4] They received no training and therefore give no training given.
- [MTB/M/5] Not trained themselves. Only the technicians are trained.
- Committee does no training, but does do chlorination publicly and therefore anyone can learn.
- [MAM/M/7] Training is done for technicians, none for the committee. NGO trained technicians and the technicians briefed the community and showed them how to assemble the pump.

- [FER/F/8] Training is on keeping well area clean and limiting contamination in water storage containers. Storing water on a table. Training was done by NGO for 3 days.
- [KUM/F/9] Committee is formed and trained by NGO. Training was on cleaning and taking care of the well. It is formed to protect the well. . For the well that is not used because of disrepair, they relayed the problem to the engineers who said he would fix it, but hasn't yet. Committee feels bad about this promise not being fulfilled, but feel that there is nothing that they can do. They still clean the well and treat it with chlorine even though it is broken and not in use. When well worked, water was used for bathing and laundering (drinking is not mentioned).
- [KST/F/10] Training done by NGO for 3 days. Informed how to maintain and clean well, must fence well area.
- [MAG/F/11] Training done by NGO consists of well maintenance and advise to community about well use and maintenance. Training exercises are done on cleaning the well early in the morning, removing the grass and debris from well area. *More training is needed – the more you learn, the more you get experience.*
- [MTB/F/12] Training was done by NGO. Included well maintenance and how to identify problems at the well. Training include information on germs. When questioned on germs, response was "not allowing defecation around well and no cockroaches".
- [MTU/F/13] Training is done on well maintenance and keeping water clean – this training is shared with the community. NGO provided them with well knowledge and reporting mechanisms for problems with wells. In more detail, the training consisted of the following. Do not let children fetch water at the well. Do not allow animals to sleep at wells at night. Elevate water that is fetched by putting container on a table to prevent against contamination. This leads to information on maintenance of home, cleanliness and hygiene. Maintain pump with grease. NGO stopped providing grease, so community stopped using it and are having trouble with the pump. Why don't you buy your own grease? It's very expensive. How much? Not sure. Researcher encouraged committee members to identify the cost and take a household collection. Water treatment systems, such as chlorine, provided by NGO in the past. The community's relationship with NGO is coming to an end.
- [MAM/F/14] They give training. Facilitators taking care of well, by law training.

c) Theme: Thoughts about current well condition

- [FER/M/1] Only use the fence for the well that is for the borehole (drinking well). Care wells not used for drinking. Rope and buckets at all the Care wells.
- [KUM/M/2] Rust in the pipes and in the water. The water is of poor quality. There are germs, colour and animals in the well area (nictoro – larvae). Germs are small – like worms (about 1cm big). *Used beads of grass to show their size*. Germs can be see with you own eyes.
- [KST/M/3] Only one of the wells (out of five) are currently working. All the wells have a taste and smell (metallic tasting).
- [MAG/M/4] *Wells have poor fences and bad drainage*
- [MTB/M/5] Two of the wells are working, two are currently not working.
- [MTU/M/6] Neglect the well so that repairs will happen. This will appeal to the NGOs. No reporting channel no support. Decision made as a group to neglect the well. Bush poles not brought for the fencing. Repairs have been made since by NGOs. Bush-poles have not been collected for the fencing of the well. The pipes are broken and therefore the pumps are broken.
- [MAM/M/7] Wells are in bad shape. They can drink the water, but use a rope and bucket as the pump doesn't work because there are holes in the well pipes.
- [FER/F/8] Conditions of well is ok, but water table is low, so it takes awhile to fetch water at borehole well. There are long ques. The water tastes good from this source. Other wells are used for domestic purposes.
- [KUM/F/9] The condition of the wells is not good. The use of the pumps is non-existent. Rope and bucket used proves to be difficult and increases contamination.
- [KST/F/10] Condition of the wells is not good because pumps aren't working and water is not good, they require treatment.
- [MAG/F/11] Condition of wells is not good. Water quality is not good and there are water shortages. Community only uses one well, but water table is down.
- [MTB/F/12] Condition of wells is not good because wells are not fenced. Contamination from animals is highly possible. Well doesn't function properly because pipes give the problems.
- [MTU/F/13] One major problem with the well is that it has not been fixed and the water is very dirty and dark in colour. The well is therefore not good. A report was made in December 2011 to NGO and the community was promised that the well would be fixed, it has not been. They plan on calling a meeting with the committee to call a technician to fix the pump.

- [MAM/F/14] The current conditions are bad. Rope and buckets used. Wells are currently dried up. Not happy with no fence. Goats, dogs and animals are entering. Males are responsible for the fence. Report to the men about fence, made promises but did nothing. This was four months ago. No reason given for not fixing the fence.

d) Theme: Gender Equality

vi. Theme: Sharing of Responsibilities

- [FER/M/1] Chairperson passes the message to the community about work that needs to be done.
- [KUM/M/2] Chairman gives responsibilities for repair. Sue people that doesn’t help. Take people to court that don’t pay.
- [KST/M/3] They are shared equally between men and women.
- [MAG/M/4] Nominate the person for responsibilities such as for fencing or collecting the money from the community.
- [MTB/M/5] Chairperson identifies the tasks and delegates. He also finds community members to assist. Contributions are taken by the chairman at household level.
- [MTU/M/6] Chairperson makes the decisions. Decisions and tasks identified by chairman. Dealt with by the chief if something is not going well.
- [FER/F/8] Responsibilities identified and shared through committee discussion. Men fence and repair, while women clean and levy fines.
- [KST/F/10] Starts from the beginning, when wells are first built. Responsibilities are shared based on strengths of men (labour and repairs) and domestic tasks for women (cooking and cleaning). This separation exists because power is not the same between men and women, men work harder than women.
- [MAG/F/11] Men’s tasks are based on building and strength, while women’s tasks are domestic.
- [MTU/F/13] The committee is split between men and women’s responsibilities with a female head and a male head. Sharing responsibilities is based on cooperativeness among members. Example: If there is a problem with pipe spillage, members take a collection and chose active female and male members to source parts and relay information to the technicians.
- [MAM/F/14] In times of cleaning, pass on responsibility. Town crier will announce to the village. They will supervise the cleaning. Other people will help from the community.

vii. **Theme: Male/Female Responsibilities**

- [FER/M/1] Women: Sweeping, weeding, monitoring violators of by-laws. Men: fencing, bush poles, cleaning and weeding.
- [KUM/M/2] Women: Sweeping, weeding, and providing food for workers. Men: labour- fencing and weeding.
- [KST/M/3] Women: cleaning the well area, by-laws. Men: Fencing and by-laws (the chairman polices the by-laws).
- [MAG/M/4] Men: bush poles for fencing, collecting money, making drainages (drainages and fencing has not been done).
- [MTB/M/5] Women: Cleaning and clearing the well area, enforcing the by-laws. Men: fencing, finding money.
- [MTU/M/6] Men: Chlorinate the well. Tax the entire community (2000le) per household. Control measures determining the type of people that can use the pump. Make fence. By-laws and caretakers. Women: Sweeping, weeding, washing and cleaning well area, stop animals entering the well area, block gates, In times of shortages make sure that people queue. By-laws and caretakers.
- [MAM/M/7] Men's responsibilities include fencing and collecting a monthly contribution from households – 1000le per household. Stop collecting this because five houses were burned in a fire – money had to go towards fixing houses. Women's responsibilities are cleaning the well area.
- [KUM/F/9] Men present issues to technician and help with repairs. They build fencing around well areas. Since well stopped working, they removed the fence. They also clean the pipes. Women give instructions to the community on cleaning the well area. They collect money for repairs and prepare food for the technicians doing the repairs. Clean well area. Men and women members contribute 50,000le for training of local technicians (NGO facilitated). NGO determines the responsibilities and tasks for women and men.
- [KST/F/10] Men: fence well area. Fence not erected at the moment because well isn't working. Women: enforce bylaws of women tying hair and wearing shoes and clean well area. "Imparting knowledge on community as a whole".
- [MAG/F/11] Responsibilities are identified and shared through a general meeting and discussion with committee. With problems with the well, they are discussed and a decision is made on what to do. Each member contributes 500le to repair costs.

- [MTB/F/12] Men: fencing and repairing well. Women: cleaning the well area. Fence has not been assembled because there have been ceremonial activities in the community for the past month. Will fence well now. Responsibilities are identified and shared by discussion and division of labour and at stages of repair.
- [MTU/F/13] Women: levy fines against members who break well rules. Fine is 1000le. Women are in charge of cleaning the well – sweeping and scrubbing. Women cook food for labourers and technicians. Tasks for men are to fence the well. Men: provide labour for well construction and repairs. Men apply treatment to the well.
- [MAM/F/14] Women: Cleaning, by-laws for the well. Men: fence and fixing the wells (includes the technicians)

viii. Theme: Equality of Tasks

- Shared: [FER/F/8], [KUM/F/9], [MAG/F/11] Specific mention of Gender Roles: [KST/M/3] The work is shared equally. They carry out their ***'gender roles'*** equally. [MAM/M/7] Women and men do 50/50 on the committee**.** *"Each performs their own gender roles".* Men assemble and repair the fence, while women clean the well area.
- Men's responsibilities are harder: [FER/M/1] Men do all the labour intensive work. Women are vigilant on monitoring the by-laws. [KUM/M/2] Men's work is harder. Woman can't bring the bush-poles. [MAG/M/4] The men do more than the women (tasks are 'more' than women). Bringing bush-poles can only be done by the men. Women only clean once in a while. [MTB/M/5] Chairman has more takes because the women cannot feed them as men. [KST/F/10] Women and men do not do 50/50 on committee. [MTU/F/13] Men do more work than women because of the construction of the fence. [MAM/F/14] No the male has more responsibility. The men work harder. Women continued to work. [KUM/M/2] Women make the decisions. Women come together. Men decide to do something then regress because they have 'more to do'.
- Women's responsibilities are harder: [MTB/F/12] One participant argues that there is 50/50 because they take part in male activities. If men collect the sticks for the fence, women carry them out of the bush. All members contribute the same amount of money. Another participant argues that men have the power to collect sticks, but women are busy cooking and do not help. Men do more labour, so they do more work and it is not 50/50.

ix. Theme: Equality on the Committee

- [FER/M/1] Chairman makes the decisions. However chairman and chair women have equal decision making powers.
- [MAG/M/4] There are fairness – there are gender roles to play. Cleanliness women – other tasks are male.
- [MTB/M/5] Chairman makes the most decisions. Between men and women 'the voice of men is stronger'. Has more influence because their 'voice is heavier'.
- [MTU/M/6] There is equality because each do their gender roles: for example during the time of making a fence women cook the food for the men.
- [MAM/M/7] Men have more power than women because its from God. Men are above women. Due to physique, they are stronger than women, so men take the lead. They live by the example of their forefathers, whose wives were under them, roles are inherited.
- [FER/F/8] There is equality on the committee, however women have more power than men because women make community function and take care of the well every day. *If women have more power than men, how is there equality on the committee?* Because takes are 50/50 and there is a chairman and chairlady.
- [KUM/F/9] Men have more power on the committee than women because power and equality are based on the Creation story. *"Men have more strength and suffer more so women should not strain them"*
- [KST/F/10] There isn't equality on committee because tasks aren't the same. Men and women don't have the same amount of power because women don't have the capacity to perform what men do – repairs and building.
- [MAG/F/11] There is fairness between women and men on the committee because they contribute the same amount of money.
- [MTU/F/13] There is fairness between women and men. Work that men do such as fencing the well, cannot be done by women. They have their appropriate and designated tasks, which is fair.
- [MAM/F/14] Yes, power is shared. Tasks are shared. Decisions are a combined effort.
- [MTU/M/6] There is fairness because each and everybody has a part to play in the by-laws. They have confidence in their technicians because 'they can assemble the entire pump'
- [KUM/M/2] Chairman makes the decisions. Men make more decisions. The 'strength of men is more'. Strength is required for the decisions.

x. Theme: Individuals with the most responsibility

- Chairman: [FER/M/1], [KST/F/10], [MAG/F/11], [MAM/M/7]
- Chairwoman: [FER/F/8] Assistant chairlady has more responsibility because the committee tasks are her sole job. She, along with the other members, derives an income from the fines.
- Men (General): [MTB/M/5], [MAG/M/4] Men have heavy responsibility, women don't decide. Men make the decisions. Chairman is the youngest of the males. Chairman makes important decisions. Sometimes the woman is not there. Women goes out often, leaves the village regularly. Main decisions are made by man.
- Both Chair Persons: [MTB/F/12], [MTU/M/6] & [KUM/F/9] More responsibility is held by a male member who is the chairman. There is also a chairlady who holds more power than some of the men because she chairs the committee in the chairman's absence
- Other information: [MTU/F/13] The male chief has more responsibility in the committee because he is the head of committee, the eldest and the chief. He therefore commands respect in the community. He does some work on his own like communication with guests.

xi. Theme: Communicate with the chief

- Chairman: [FER/M/1], [KUM/M/2], [MAG/M/4], [MTB/M/5], [KUM/F/9], [KST/F/10] & [MTB/F/12] Chairlady/Both: [MTU/M/6] [MAM/F/14]

e) Theme: Government Participation

- No participation: [KUM/M/2], [FER/M/1] [KST/M/3] [MTB/M/5], [MAM/M/7], [FER/F/8], [MAG/F/11] & [MTU/F/13]
  Government Promises: [MTU/M/6] The chair people have met with the local government. The promised 20 wells to the community, but has shown nothing. There was no paperwork to confirm these promises. The VDC passes every day. [KUM/F/9] Local government has made promises about building a school, provision of seedlings and livestock. None done anything yet. [MTB/F/12] Local government has promised to make a road linking them to the main junction and promised to replace damaged well pipes. [MAM/F/14] Had a meeting, when NGO leaves the local government said they will offer help. However they also said that they make no promises.

- Government Action: [KST/F/10] Local government (Tonkolili District Council) fixed one of the wells in 2010. Promised to fix another broken well, but haven't thus far.

f) Theme: Community Finances

xii. Theme: Community Bylaws

- [FER/M/1] Women to tie hair, no shoes, same rules for men, no sweat, small "pekin" not allowed in the well area, clean area, buckets used, no quarrelling, (all 1000le fine) shortages require proper queues (2000le and the bucket is taken for violating). Community comes up with the bylaws.
- [KUM/M/2] Not working on the fence (5000le). No laws without the fencing. Hair must be tied, no children in well area, no shoes (all 5000le). Weeding around the well (not being done).
- [KST/M/3] Women not tying their hair, shoes in well area, small children, children bringing rubbish into the well area, no children fighting. (all 1000le)
- [MAG/M/4] Untied hair (500le), Using well after 8pm (1000le and take container), Small child 0-5yrs (1000le and take container), fighting (1000le), wearing shoes (1000le), spitting (l000le)There have been no violations therefore no fines.
- [MTB/M/5] Tie hair, no shoes in well. Water locked at 8pm.**At this point in the discussion 3 members of the community came in sight of the user committee members in the meeting. All three of them were women with untied hair and no shoes. This was met with general embarrassment.** With no fence they do not actually keep the by-laws. By law fines are 1000le
- [MTU/M/6] By-laws: Women have hair tied (1000le), Shoes in well area (1000le), dirty rubber (1000le) 30000le has been collected in fines (given to the treasurer)
- [MAM/M/7] Bylaws exist. They were written down but the document was destroyed in the fire. Example: No collection of water past 9PM. Example: No shoes worn in well area. Example: Hair must be tied for women. Example: No children fetching water. Example: Not allowed to fetch water with a dirty container. NGO didn't suggest bylaws, community selected them.
- [FER/F/8] Bylaws exist, they are written down (researcher saw them). Example: If a person doesn't tie their hair or wears shoes, they are fined 1000le. The last time a fine was given was 2 weeks ago. Note: They don't have local technicians because there was no technician training by an engineer when well was first put in.

- [KUM/F/9] Bylaws exist, but are not written down: If you are absent from a meeting, you are fined 5000le, Inform community of fines, Must not wear shoes in well area, Must tie hair in well area, Do not send kids to fetch the water, If you climb onto the well area near the manhole, you are fined 5000le, Discussion: If no on returns to fix the wells (NGO or government), they will continue to use their open wells. Wells put in by NGO will stay broken.
- [KST/F/10] Bylaw exist, 5 in total. Not written down. Example: Do not enter well area with shoes. Example: Do not allow lactating mothers to carry their baby because if you are using rope and bucket, baby might fall or spit/vomit into well. Fines given are not paid because people refuse to pay them. The original amount was 2000le per fine. The current chief does not have control of the community to enforce the payment of fines.
- [MAG/F/11] Bylaws exist. Example: If a committee member is not present at a meeting, you are fined 1000le. There are five bylaws in total.
- [MTB/F/12] Bylaws exist, written down. 7 in total. Example: Fine of 5000le if committee member does not complete a task. Example: If you don't contribute to repairs, you are fined 1000le, if you refuse, you are taken to the chief.
- [MAM/F/14] No shoes, untie hair (1000le), people should not rush at pumping, queuing rules, no fighting, no collecting water after 8pm (all 2000le except hair). Money documented. The chairlady collects money. 40,000 le collected for repairs.

xiii. Theme: Current Tariff Scheme

- [FER/M/1] No tariff system in place. They thought that they could get money from the by-laws. Total collected from by-laws since the well was built – 2000le.
- [KUM/M/2] Used to contribute (500le) per household. Collected a total of 60,000le. Gave the technicians the money who fixed a hole in the pipe.
- [KST/M/3] There was an original tariff of 300le paid for three years then it stopped. The previous chairman/treasurer disappeared with the money. Since then money has not been gathered.
- [MAG/M/4] There was a tariff system (500le per household). Not operating currently. Collected 30000le. No record of collection. Last collected August 201
- [MTB/M/5] Tariff system started in 2004, worked for three months (500le) per household. Contributed up to 25,000le before stopping. Changed to a break and pay system. People are afraid of corruption, worried about someone 'eating' the money. There is little trust. Cannot undo the damage currently caused to the wells because

they are too much money. 150,000le. Never actually asked for the prices except for the pipes. Contributions take time people. People will not contribute immediately. Fully dependent on the NGOs coming to help them.

- [MTU/M/6] There is a tariff system in place, 500 le per month. It is only paid by those in local vicinity to the well. Open wells are used by those too far away. Worked for a while charging everyone, then it failed (no time given).
- [MAM/M/7] Monthly contribution of 1000le per household. No longer collect. NGO doesn't implement the tariff system, they come up with it themselves.
- [FER/F/8] No tariff system because they don't have problems with their wells.
- [KUM/F/9] Tariff system of 500le per week per household. No longer exists. One person used to look after the money.
- [KST/F/10] Tariff system does not exist because previous chief who commands respect is no longer in the community and therefore it is difficult to collect tariffs.
- [MAG/F/11] The community tariff system is not set, however it exists, amount depends on the problem with the well.
- [MTB/F/12] Monthly contribution of 1000le per household. Controlled by chairman. Tariff system should be increased, but people will refuse to pay increase.
- [MTU/F/13] A tariff system does not exist. A fine system exists for well violations. A female member of the committee controls the money for this, which is contributed to repairs. 100,000le repair was paid for by a relative from Freetown in addition to the fines collected.
- [MAM/F/14] No Tariff

xiv. Theme: Thoughts on Current Tariff Scheme

- [FER/M/1] No tariff system.
- [KUM/M/2] No records of any money collected are available. In 2006 someone collected 60,000le and left with the money.
- [KST/M/3] They have no intention of using a tariff system.
- [MTB/M/5] No tariff system. Technicians admonished them for their lack of contributions to the well system.
- [MTU/M/6] The money was given to the technicians recently. They bought plastic pipes for the well, but they were too short, therefore people lost confidence in the system. They refused to pay when the technicians asked for more money. Currently won't pay the tariff.

- [KUM/F/9] Tariff system should have been increased, but the community did not agree.
- [MAM/F/14] Not collected any money.

xv. Theme: Record and Control of Money

- No records of collection: [FER/M/1], [MAG/M/4], [MTB/M/5]
- Chairlady controls money: [KUM/M/2], [KUM/F/9]
- Chairman controls money: [MAG/F/11]
- Youth leader controls the money: [FER/M/1]
- Other information: [MTU/M/6] 40,000le was collected by the community for the replacement of a chain when it was broken. Money was given to the treasurer. User committee makes decisions, auditor (external to the committee) approves, then the treasurer releases the money.

g) Theme: WUC Harmony

- No disputes. [FER/M/1], [KST/M/3], [MAM/M/7], [FER/F/8], [KUM/F/9], [KST/F/10], [MTU/F/13] & [MAM/F/14]. Other non-dispute information: [KUM/M/2] When decisions are made and are disputed at a household level they are taken to court. (Samos) [MTB/F/12] No disputes. Fine system encourages each member to contribute equally.
- Disputes: [MAG/M/4] Chairlady complained about the lack of fencing. The men promised that they would do the fencing. In December 2011 she complained about the fencing (still not done). [MTU/M/6] The disputes are mostly among the women. There are by-law quarrels. The Chair person will levy a fine on the quarrel. There is a fine of 4000le for fighting at the well. Children that fight will lose their container. Committee debated that the money for fines is to be 2000le and it was approved. [MAG/F/11] There have been disputes over work and labour and money not distributed properly amongst the members. Members derive a small income irregularly.

h) Theme: Community Response to water Shortages

- [FER/M/1] Borehole shortages. Queuing initiated (first come, first served). Revert to open wells and river.
- [KUM/M/2] There is bureaucracy between the wells. Wells appear to be appointed to groups. There is no changing of wells due to shortages.
- [MTU/M/6] The committee will ‘add depth’ to well. They used to lock the well, but the lock spoiled. They revert to a rope and bucket system. More than 3 containers are not

allowed. Timings are given for large containers. Drinking and bathing water is only taken in the mornings. This allows the well to recharge.

- [KUM/F/9] Shortages dealt with by asking men to renew local wells.
- [MAG/M/4] Both wells dry up in March and April. They recommend that people use the local wells.
- [MAG/F/11] They deal with shortages by digging new and well protected sources, such as open wells. Protect with palms.
- [MTU/F/13] When dealing with shortages, the committee has a meeting about alternative water sources.

i) Theme: Rainwater and the WUC

- Not encouraged: [FER/M/1] & [MAM/F/14] [KUM/M/2] Committee does not encourage people to use rainwater. "Rainwater is bad for drinking". "Rainwater is contaminated". [MAG/F/11] They don’t encourage rainwater usage because it is a contaminated water source – contains dust and particles.
- Encouraged: [MTU/M/6] Committee allows people to drink rainwater. Rainwater is not allowed to be stored on the ground. It is used for drinking but there are by laws that govern rainwater. Committees powers extend beyond the well. [KUM/F/9] Advise people to use rainwater, except for those with a thatch roof as it contaminates water.
- Not required: [KST/F/10] No because people already have this knowledge. [MTU/F/13]. They don’t encourage the community to drink rainwater as everyone possess this knowledge already.

j) Theme: People Prevented from Using the Well

- [FER/M/1] Children, mad people, blind people, the aged, livestock, HIV/AIDS, epilepsy, performing bundu or poro society members.
- [KUM/M/2] People that refuse to carry out tasks. People with diarrhoea, TB, HIV (if they know they have it), old women, blind people, children. None of these people can enter if they wish. Sowee can enter. By-laws say that people with HIV cannot enter. The by-laws are not written down.
- [KST/M/3] Old people, sick people, those with HIV/AIDS, blind people, epilepsy. Poro and Bundu members are allowed by not while practising.

- [MTB/M/5] Those with diarrhoea, the blind, old people, those with HIV/AIDS, epilepsy, small children *again a small boy is noticed to be using the well during this discussion. No mention is made that he is too small*
- [MAG/M/4] Children (0-5years), Diarrhoea, leper, HIV/AIDS if they know they will not allow. Blind people, the aged and those too old. *On HIV: “people with HIV cough and spit on the floor and are therefore dangerous and can give people HIV” * Poro/Bundu society members are OK.
- [MTU/M/6] Small children, old women, 'Lepord' – 'Sowee' not allowed. People with HIV/AIDS would not be allowed, Diarrhoea not allowed. People with shoes not allowed. Epilepsy not allowed 'Poro' society- 'mircles', 'sokos' not allowed to drink. 'Sowes' not allowed to drink. 'Sowes' and 'Sokos' are known by name.
- [MAM/M/7] Small children don’t allow people with epilepsy or diarrhoea. HIV positive person not allowed to collect water, if they talk at the well, they will transmit to the water.
- [FER/F/8] They don’t know about undesirables and didn’t list any potential undesirables.
- [KUM/F/9] People with sores on their feet and legs cannot use the wells.
- [KST/F/10] Man in community with epilepsy is not allowed to use because he might spit in the well (Researcher note: community FGD mentioned that he still uses the well).
- [MAG/F/11] Undesirables are considered to be those with leprosy, TB, HIV/AIDS. Communicable disease will contaminate the well If someone with TB coughs or spits into the well, people drawing water from this source will get sick.
- [MTB/F/12] No, but wouldn’t allow sick people.
- [MTU/F/13] Only children are undesirables.
- [MAM/F/14] Children, those with diarrhoea, blind, epilepsy, HIV/AIDS people

k) Theme: Changes to the committee

- [FER/M/1] Fundraising, charging per bucket so that they can make repairs Farming – produce will be sold and put in a bank and they can replace the well system.
- [KUM/M/2] Committee are happy. Chairperson would appoint messenger that violates law. Contribute at household level to pay for repairs. Develop community trust issues while the wells is working.
- [KST/M/3] The wells need to be fixed as soon as possible.
- [MTB/M/5] Fencing should be done. Money should be collected by a labour gang.

- [MTU/M/6] Pave the water area. Train a carpenter, self supply water for the well. Create a system for farming (speaking on his own behalf – lots of people were critical of this suggestion). Increase the amount of fines levied. Household tariff system increased.
- [MAM/M/7] Since wells were constructed, they have only applied chlorine once, this needs to be changed to more applications. Technicians don't treat the wells because they are not supplied with treatment. Committee has decided to go to town to inquire about chemicals (Researcher note: why wasn't this done before the FGD – lack of urgency). They would like the well pipes changed from metal to plastic. If they no longer have NGO help, they will re-implement tariff system. They will increase the tariff system from 1000le to 2000le. They were discouraged from re-implementing tariff system due to the fire outbreak that damaged 5 houses. Will continue to consult with NGO for help.
- [KST/F/10] They think that the committee functions properly. The lack of fine and tariff system is not good because they need money for repairs, but have none. This isn't the fault of the committee, it is the chief's duty to enforce payment of fines and tariffs.
- [FER/F/8] Implement a tariff system so that they could be ready if there are problems with the wells. Might do this in the future.
- [KUM/F/9] Chairlady serves as an advisor to the committee, which she introduced as it was not done in the past. She oversees issues on the committee.
- [MAG/F/11] Would have a different tariff system so that well is fixed and working. Fence has wide openings. Chair woman finds the fence unsuitable and committee has made plans to fence the openings. Animals knock the fence down.
- [MTB/F/12] They would like to treat the water every 3 months, but this has not been done for awhile. NGO was previously treating every 3 months.
- [MTU/F/13] Would like to have a tariff system for each household. Would not like responsibility than men because they don't participate in male tasks like fence building, well digging and plastering.
- [MAM/F/14] Tariff system not required. A contribution is desired for the wells. Pay other people (not the user committee) to replace the fence.

Appendix I: Technician Results

l) Theme: Formation (Gender and Technicians)

- [MTU/T/15] Woman was trained but has been forced out: "She can't fix the well" she was also accused of not having the 'IQ' for fixing the well. She was dropped from the meeting for this reason. She has been told to focus on cleaning and sweeping (not what she was trained to do as a technician)
- [MTU/T/15] Women's training was different from men. She was only trained on cleaning the well area, which is what she was already trained on for the water committee. She thinks she is trained differently from men because their powers are not the same, their physical strengths are not the same, therefore she is not able to repair things. She would like to have the same training as men and has voiced her opinion in the community about this unfairness, specifically to the chief. Chief on the technicians to note unfairness, but nothing has changed. Her husband thinks she is capable of the same training as men.
- [MAG/T/16] Community elected – chosen by the community, and they volunteered, No women volunteered for the position of technician, No message was received that they were looking for a woman was an option. Selected 2 women
- [KUM/T/17] Appointed by the community.
- [KST/T/18] When invited for the training they said that they only needed men
- [MAM/T/19] Community elected – chosen by the community. Women are not able to fix the well as they lack the muscle to fix it.
- [MTB/T/20] Six technicians trained by NGO. Three technicians originally showed, though three women were also trained. The women were later were invited to join. The women had problems with the labour intensive tools and were therefore reduced to clearing the well areas. Strength was the main requirement for fixing wells. The women agree on this. When asking who has the most knowledge about the wells there was a dispute. It was agreed by both the men and the women that men have the most knowledge about wells. The community has no confidence whatsoever in the local technicians. The technicians cannot perform their jobs. They only have 2 days training.

xvi. Theme: Training

- [MTU/T/15] Trained in 2004 by NGO. Received multiple trainings from 2004 to 2007 (as high as one a month)Trained to: fix wells, application of chlorine, cleaning of wells, fencing for wells, regulations for fetching water at wells and well usage procedures. No training on casting concrete (which the wanted to learn). Learned a bit about it when NGO were working with them.

- [MAG/T/16] Training at Mabang. Three days training. Did not learn about the parts of a well. Learned about community's contribution for wells. To clean rust with wire brush. Loosen pipers and take them apart. Wants more skills and training- to build a well
- [KUM/T/17] Three days training- two days theory one day practical."The two days training was not enough." Trained in Kumrabai Junction. Trained to: loosen pump, sort out blockages, about fencing and clearing the area, checking the bolts and knots. All the technicians currently drink water from the unimproved sources
- [KST/T/18] The length of the training is two days. Learned to assemble pump by loosening the cylinder head. Learned how to chlorinate
- [MAM/T/19] Trained on loosening the head and taking apart the pump. One days training. Learned about greasing the well, but have not done so since last year.
- [MTB/T/20] The technicians cannot perform their jobs. They only have 2 days training.

xvii. Theme: Well Repairs

- [MTU/T/15] Three wells – two are working. One has failed. Pipe has failed – and possible for the technicians to fix. Technicians do not know the prices for fixing any of the well components. Engineers never told them the prices for the parts of the well. Would have to travel to Freetown for the spare parts. The technicians used unskilled members to assist with the wells Technicians get the community to contribute to the wells. 1 year since the well was broken. They estimate that it will cost 200,000le to fix the pipes. Even small amounts cause problems. Larger amounts are impossible to fix. Grease: lubricate the chain. Have fixed minor repairs before: when the pipes burst, when the cylinder is dirty and when the pipes need cleaning.
- [MAG/T/16] Haven't put grease in the handpump since Jan 2011. Pipe is spoiled ('cut'). When the well is not working they turn to the NGO. Will use the rope and bucket. Will not afford the pipes. Never turn to government only to NGO. Councillor never helps them and has no plans to. 60,000le is the maximum the village has ever given for well repairs.
- [KUM/T/17] Wells are not working because they have rusted. No tools or spare parts to fix the well. The technicians can't get people to listen about their ideas for

repairs. One of the technicians had an idea for a well wall made from local bricks that were made in the village. The technicians also can't get people to assist them in fixing the wells. They have no authority over the committees. The technicians ideas for well repairs: Make contributions of 10,000 le per month & the parts for repair are too expensive to repair with only 500le. One of the wells was badly made. And has seepage from the road. People won't pay for the systems and revert back to the old systems. Community abandoned any upkeep of the wells because they are not working (no fences or clearing of wells). The technicians never greased the well

- [KST/T/18] Four of the wells are not working. Pipes are rusted, the threads are battered. "Water can't pass". The one pump that has been fixed was from a technician from the ministry of water and energy. The technicians are confident that they could fix all the wells. But want more training on pumps. Two of the pump heads (at the school and at the station) have been stolen since they were installed.
- [MAM/T/19] Three of their wells are not working, one has parts missing, none have been repaired.
- [MTB/T/20] No tools to fix the wells. Were dependent on a tool bank for tools. Have fixed the well before for a cost of 40,000le. A technician came from Mabang to fix the wells. He has skills because he moves from place to place to fix the wells. The tools were left with Mabang. Mabang refuses to share the tools and therefore there is a monopoly on what repairs get done in other villages. Greased the well bearings last week. Very low knowledge on greasing.

xviii. Theme: Chlorination

- [MTU/T/15] Constant contradiction on times chlorinated and dosages between the three technicians, No understanding about the timings of when they add chlorine, Last time they chlorinated was Feb 2011 (one said it was August 2011)
- [MAG/T/16] One dose per year (depends on the volume). 2 tsps per year. This caused a fight between the technicians as one said it needs to be done every month. His reasoning is that the well is used often and there is a change of water. Last time they chlorinated was Feb 2012 with 1 tsp. They said that the chlorine is spoiled and therefore it cannot be seen.
- [KUM/T/17] Last chlorinated in September 2011. The amount of Chlorine depends on the depth of the well. According to their training they are supposed to chlorinate every two months.

- [KST/T/18] The amount of chlorine depends they add depends on the amount of water in the well. Chlorine got spoiled and the stopped chlorinating it a year ago. No money to buy chlorine. Because the well got spoiled they stopped using it. Saw no reason to waste the chlorine. Chlorine kills germs. Germs are Nictoro – you can see germs with your eyes. They are yellow because they give yellow fever.
- [MAM/T/19] Trained on chlorination, but decided it wasn't a technicians job. Not Chlorinated since last year
- [MTB/T/20] Chlorine is added by checking the water depth. Chlorine not added to the wells for over a year. They know that they need to chlorinate every three months. They are waiting for the NGO (NGO) to bring more chlorine.

m) Theme: Tools and Spare Parts

- [MTU/T/15] Spare parts are promised but they are never provided by the community, Inadequate tools for repairs, There used to be a tool station at Kumrabai Station. They were controlled by a nurse called Francis who died. NGO provided the toolbank
- [MAG/T/16] Tool bank missing – no tools at community level. No store for spare parts close to village. NGO always comes to repair well when they ask – therefore they have never been forced to ask or look for spares.
- [KUM/T/17] No tools or spare parts to fix the well. Tools were at a tool bank in Kumrabai Station. The tools were reported to be stolen. The tool banks places too much trust and dependability in one place.
- [KST/T/18] Used to grease but they can't loosen because they have no tools. Toolbank was established in Kumrabia Station. Toolbank was taken or stolen. There was a book to say that someone received the tools. A mistake was made between transporting the tools between the villages and the tools went missing.

n) Theme: Financial Costs

- [MAG/T/16] Prices on estimates dependent on visitors to the village that never know the prices of the pumps. Cost of new well (Don't know) Cost of spare parts (Don't know) Costs of tools (Don't know)
- [KUM/T/17] Only know the price for the entire well. Do not know the prices for spare parts. Chain costs 75,000le
- [KST/T/18] Estimate that a well costs 17,000,000 le. Have no idea about the costs of spare parts for the well

- [MAM/T/19] Cost of new well (Don’t know). Cost of spare parts (Don’t know). Estimate that it will cost 2.5 million le to fix one of the wells that are currently broken. Very rough estimate based on tools, work and pipes. Costs of tools (Don’t know)
- [MTB/T/20] Cost of new well (7,000,000le). Cost of spare parts (Don’t know). Cost of tools (Don’t know) Will contribute when something breaks. Last time when something happened it costs 80,000le

Appendix J: Village Water Users Results

o) Theme: Safe Drinking Water

- [KUM/UF/21] Safe drinking water is clean. It must be boiled and sifted through a special cloth (Researcher note: H/H survey responses to water treatment were that they never treated their water because it was too costly or not in their habits, however FGD responses are different, possible group effect). Pure water does not have a taste or a smell.
- [KST/UF/22] Safe drinking water is water without taste, colour and is clean. For water to be clean, the water source must be taken care of. Community has local well water, doesn't have colour or taste.
- [MAG/UF/23] Safe drinking water needs to be fetched with a clean container it must be covered to store.
- [MAMUF/24] Safe drinking water is clear and clean, usually covered so that particles cannot enter. It is cold and tasteless.
- [KUM/UM/26] No colour, clean, cold, no particles, germs. *germs are small, very red and can be seen with your own eyes*
- [KST/UM/27] Without rust, odourless, no nictoro, clear, no particles
- [MAG/UM/28] Safe drinking water is from a hand pump well that works. Clean water is odourless with no colour. Safe drinking water should be stored in a clean container – placed on a high table.
- [MAM/UM/29] Safe drinking water has no particles, it is clean and clear, cold and does not have a taste.
- [MTU/UM/30] Healthy life is water. (No consensus – lots of pauses). Open wells are OK to drink because the water is cold. Only God knows bad water (lots of laughing). You feel fresh after drinking from an unimproved well.
- [FER/UX/31] Safe drinking water is clean and cold. It is in categories – water can be clean and clear, but is still dirty. Any water that is exposed, can look clean but might not be safe. Covered water is safe. Water through a pump coming from the ground is safe. Germs are nictoro, which can and cannot be seen with the naked eye. They are small animals. They defecate in water. If you drink water, you will have diarrhoea and vomiting. If you reuse container without cleaning, nictoro will enter. Found in open well. Chlorine removes nictoro.
- [MTB/UX/32] Safe drinking water should not have colour, taste or germs and should be clean. Germs are from dirt and particles. If someone has long nails and puts them

in food, germs will get into the food. Local small germs ‘nictoro’. Germs can be black or white. Sometimes they can see them and sometimes they can’t.

p) Theme: Normal Interaction With WUC

- [KUM/UF/21] A participant responded that she interacts with the water user committee by being involved with cleaning. She reports on breach of bylaws at the well and takes the offender to the town chief. She puts pressure on committee to perform their functions properly. They feel that the committee performs their functions. (She was originally on committee, but was replaced because she had poor health).
- [KST/UF/22] Interact with water user committee by helping with cleaning the well area. *'They are useful and important'.*
- [MAG/UF/23] Interact with committee through general cleaning at the well. Give committee money that is requested. Report problems with wells to the committee.
- [MTU/UF/25] They relay problems with the wells to the committee. They are not sure if the committee can fix the problem. They assist committee members and technicians in erecting the well. They committee requests financial contributions from them.
- [KUM/UM/26] Water tasted rusty from the start and therefore not used for drinking. Lodge complaints to the user committee. They passed it on to the NGO. The NGO changed the pipe and brought in medicine (chlorine). Still not good for drinking
- [KST/UM/27] They work together to clean and clear the wells. This current committee (as opposed to the original) is the best. The previous committee ‘chopped’ the money. The current committee is more honest.
- [MAG/UM/28] Interact with committee in community meetings if there is a problem with the well with the aim of sorting out the issues. Combine forces to reinforce payment of fines when there is non-payment.
- [MAM/UM/29] Interact with water user committee by guarding the wells and helping to monitor them. Give committee money for repairs. No longer give tariff because wells are broken and have dried up. If NGO no longer helps them they will plan a way forward through a meeting. Committee is useful because decisions are made clear to the community.
- [MTU/UM/30] They have no issues with the committees. They had input in the creating of by-laws. They do not disagree with the by-laws. The committees ask for input and exchange ideas. The user committee is useful as it offers control over the

wells. The committees work until the well no longer works. Then they will revert back to the previous systems. They have no support from their families that visit from outside (in Freetown) as they are scared of witchcraft. Their Freetown relatives bring plastic water with them when they visit (bottled water).

- [FER/UX/31] Interact by committee showing them benefits of well for the health and information on well sanitation. Contribution of money to help with repairs. They used to charge 100le per bucket – only lasted for 5 months. Money collected totalled 42,000le, it was not recorded. Not sure where money is now. Committee useful because it is effective in caring for the well.
- [MTB/UX/32] Interact with water user committee with tasks for well – assembling the fence and repairing the well. Contribute money for repairs with well. As women keep kids away from well, help to clean and help monitor well bylaws. The committee is useful because it performs tasks that they are supposed to.

q) Theme: Normal Interaction With Technicians

- [KUM/UF/21] Interact with the technicians through communication about well repairs. Technicians tell the community about problems with wells. If technicians are repairing the well, the committee supplies them with food. Technicians are capable even though wells aren't working. The technicians can fix the wells that are currently broken because they don't have the well parts and they need Concern to go into the well to fix it. "Locals technicians can only fix external problems, no internal problems".
- [KST/UF/22] Learn new knowledge on taking care of water. Teach rope and bucket cleanliness (don't leave on the ground). Learn about water treatment. Aren't treated anymore because wells are working properly. Well pump not working, but well is used for drinking with the rope and bucket, even though it is not treated. (Researcher note: based on understanding of water safe drinking water is, listed above, community assumes that water is clean).
- [MAMUF/24] Interact with technicians by contributing to pup repairs – 40,000le for the whole community. Each household paid 2000le. Capable and useful because they have made wells because repairs were done in the past.
- [KUM/UM/26] Yes they are useful (very adamant about this point). They are not blamed for the problems. They have the ability to dismantle wells.
- [KST/UM/27] The technicians know their job. They have fixed the wells before (the one at the school). They are confident that they know what they are doing.

- [MAG/UM/28] Interact with technicians when there is a problem with the well. Work together by providing labour. They think that the technicians are capable. With currently broken, the problem is with the pipe and beyond the capacity of the technicians. Also, the water table is too low for water, even if it is fixed it can't be used (Researcher note: the water table rises and falls, therefore it would work if the well was fixed properly).
- [MTU/UM/30] Seen the technicians in action and they trust them. For the local repairs they worked together with the technicians to solve problems with holes until a repair can be made.

r) Theme: Lessons taught by WUC for the community

- [KUM/UF/21] They learn about keeping the well and well area clean. They are taught that children should not fetch water. Tie hair when fetching water. A functioning well should have a fence. They were taught about boiling water and water storage systems and containers.
- [MAG/UF/23] Learn how to clean and take care of the well. Taught them how to take care of health and how to reduce flies around well. Committee taught them that when fly defecates it leads to malaria.
- [MAMUF/24] Interact with water user committee by knowledge. Committee passes message and knowledge to them about what to do with the well, information on fines and refusal of fine payment. They interact in decision making with bylaws. They are useful in taking care of wells.
- [MAMUF/24] They learned new knowledge about taking care and cleanliness of well. Taught you to queue properly at the well.
- [MTU/UF/25] They learned about not wearing footwear in the well area and always wearing hair up and covered. They learned about cleaning water storage containers and storing them on tables. Covering drinking water.
- [KST/UM/27] No the committee does not teach them anything.
- [MAG/UM/28] They learnt about water treatment.

s) Theme: Usefulness of WUC

- [KUM/UF/21] The committee is useful because they impart knowledge on the community. They think they could still have wells without the user committee, but they would only be local wells.

- [MAG/UF/23] Committee is useful because they clean the well area and communicate with community about well issues.
- [MTU/UF/25] The committee is useful because they teach new things that the community didn't know about before. They also inform the community of problems and repairs for the well.
- [KST/UM/27] Prefer to work with the committee. They see to anything and get the community to be involved in water.

t) Theme: Usefulness of Technicians

- [KUM/UF/21] Yes because they can fix minor problems with wells.
- [KST/UF/22] Interact with technicians by assisting/observing how to repair the pumps. Technicians have fixed one well in the past. Current repairs needed are above the ability of the community technicians. Outside technicians are not called because there isn't any money to pay them. Asked if they would contribute to the repair, they said yes. (Researcher notes: possible group effect or lack of communication between them and committee).
- [MAG/UF/23] Interact with technicians regarding problems with the wells. Appeal to technicians to fix wells. Initially, when they reported a problem, technicians fixed the well, but it broke shortly after. Currently, technicians are unable to fix it. Despite this, they think that the technicians are capable.
- [MAM/UM/29] Interact with technicians by observing them assembling the pump. Techs taught community how to apply treatment. They were not taught the measurements for applications (Researcher note: knowledge transfer is often partial, with token efforts). Technicians were the people who applied the treatment.
- [FER/UX/31] Don't have technicians. Would rather interact with a local technician than an outside technician. Will go about getting these by selecting technicians and getting training for them
- [MTB/UX/32] Don't interact with technicians because they don't perform their functions. Technicians can't repair wells. When there is a problem with the well, they have to bring technicians into the village to repair.

u) Theme: Aspects that require attention of the WUC

- [KUM/UF/21] Participant was on the committee but was asked to leave because he health wasn't good and she wasn't able to complete the tasks. She would appear to donor agencies to repair wells or create new water sources for community, if she were on the committee again. She would push for security at the well. Report issues to chair and ask to go down to local government to seek their provision of better water sources. Appeal to chairman to find outside technicians to repair wells.

- [KST/UF/22] One participant noted that she would insist that people to contribute money by approaching people peacefully, rather than forcefully…"water is life, if you have the money, contribute so that we can have water". All of the participants would like to be on the committee.
- [MAG/UF/23] Participant offered that they would work harder than committee members presently do. Work would include cleaning area more sufficiently.
- [MAMUF/24] If they were on the committee, they would strengthen bylaws and would improve chemical treatment in wells.
- [MTU/UF/25] Teaching more and new knowledge would provide more well protected wells. Making better fences around the wells and keeping the well area cleaners.
- [KUM/UM/26] If the wells were working they would pay a small amount weekly for the wells. They would be happy to do so.
- [KST/UM/27] They have ideas on making contributions for the wells. A monthly contribution of (500le) per household is proposed.
- [MAG/UM/28] If they were on the committee, they would find a lock for the pump at night and would visit the water source every hour. They would also add better drainage and spillage.
- [MAM/UM/29] They would maintain a tariff system to put towards well repairs.
- [MTU/UM/30] Fencing, repair pumps, encourage household contributions. Money should be collected for food, not for repairs. The youth should do the work.
- [FER/UX/31]If they were on the committee, participant would train members in the community to know more about the well. Would fundraise so they could have funds for potential repairs.
- [MTB/UX/32] If they were on the committee, they would stop people from laundering near the wells. Would enforce bylaws more effectively, as they are broken often. Would keep well area more clean and would increase fines.

v) Theme: Restricted Access to the Well

- [KUM/UF/21] Not currently. If participants were sick, they wouldn't' use the well because of contamination at the open man hole.

- [KST/UF/22] Man with epilepsy is an undesirable and uses the well. Committee doesn't stop him, which is their responsibility.
- [MAG/UF/23] Children are undesirables. They perceive undesirables as sick people with TB and HIVAIDS. Do not know of anyone in community with these diseases.
- [MAMUF/24] Only small children. Undesirables are small children and people with TB, leprosy, scabies, HIV/AIDS and malaria.
- [KUM/UM/26] Small children, old women, people with epilepsy, lepers, people with HIV and blind people. *Concern said not to share water sources with people that have HIV as this is a transmission route for the disease. Not to share water from people that have used the same source.*
- [KST/UM/27] Small children, coughing people, people who spit, women with untied hair, people with diarrhoea – HIV/AIDS/ blind / epilepsy / leper / boils / swollen parts
- [MAG/UM/28] Undesirable using the well is one male who has leprosy and will contaminate the well source. If water drops on his feet, the illness will stay in the well area and enter their containers and the well.
- [MAM/UM/29] Undesirables that use the well are children and people who do not tie their hair and wear shoes when fetching water. Undesirables are naked women, people with epilepsy, leprosy, blind people, HIV/AIDS, injured and elderly. Participants wouldn't share a cup with an HIV positive person.
- [MTU/UM/30] People that are blind, people with wounds, children below 6 years, Other NGOs

w) Theme: Gender Equality in the Community

- [KUM/UF/21] There is gender equality in the community. Female chiefs not allowed due to customs. However, this is balanced out because men are not allowed into their secret societies.
- [KST/UF/22] Gender equality doesn't exist in community because when programming is introduced in community, it is communicated to the men first then the women. When asked whether Sheku and Alannah were equal, participants said yes because we have the same rights. When asked whether a participant and Sheku were equal, participants said yes because they come from the same ancestors, live in the same country and have equal rights. In general, women and men are not equal when they are married, men must exert more control.

- [MAG/UF/23] There is gender fairness in the community. According to social custom, chiefs cannot be female. Men are more powerful, they control women because it is the word of God and men are the breadwinners. Although there isn't equality in the village, husband passes a little money to the women, so it is fair.
- [MAMUF/24] Gender equality does not exist because men are stronger than women. However there is fairness because they pay the same amount in taxes.
- [MTU/UF/25] Yes, there is gender fairness in the community . Men don't help in secret society production, therefore equality exists.
- [KUM/UM/26] Yes there is gender equality. They gave examples of genders being equal "the males also cook". There are gender problems with land tenure and rights of inheritance.
- [KST/UM/27] There is no gender equality. Male is in charge. Male takes charge of female. Male pays dowry therefore he is responsible.
- Male is responsible for feeding and clothing. If there is a problem with the parents then the male is responsible.
- [MAG/UM/28] Women have 99% fairness, men have 100%. Men have 1% more because they are husbands and control their wives. In society, not everyone can be equal, men should have more power than women because they carry the responsibility of paying the bride price.
- [MAM/UM/29] No, men are more powerful than women. They have more responsibility than women because they provide for the home.
- [MTU/UM/30] They claim to have gender equality in the community.
- [FER/UX/31] Gender equality exists because there are equal opportunities and rights in the community.
- [MTB/UX/32] No, there isn't because men are supposed to be in front because they are the breadwinners (female response). Men agree because of land tenure, which is solely male. If men and women do equal labour on farm, men are still considered higher because it is the custom.

Appendix K: Information on Technical Grading

Table Notation

For estimated costing:*

- *$$$$$$ = multiple wells required (minimum of $10,000)*
- *$$$$$ = cost exceeds that of a single well (around $5000)*
- *$$$$ = cost of repair not exceeding a new well ($5000)*
- *$$$ = Tariff gathered resources (costs not exceeding $500)*
- *$$ = minor costs for repairs (not exceeding $100)*
- *$ = Only consider small cost for materials (costs not exceeding $25)*

*For technical expertise **:*

- *Eng - Engineer, can be national, but normally international for NGOs in Sierra Leone*
- *H Tec - Highly trained technician, normally national technical staff f working for the NGO*
- *L Tec - Locally trained technician, normally local to the village and trained by the NGO*
- *Car - Pump Caretaker, can be more than one individual and is normally the responsibility of the committee*

No.	Description	Mode of Failure	Common Causation of Failure	Possible Repair Required	Estimated Costing*	Technical Expertise**
1.1	The purpose of the lining is to ensure that the well retains its excavated shape, allowing access to the water in the aquifer, while at the same time helping to prevent contamination of the aquifer.	[A] Collapse or lining [B] Inadequate, damaged or missing lining (or cassion) [C] Finger-width (or larger) damage to lining [D] Hairline cracks on lining [E] Dirty lining	[A] Collapse caused by poor construction techniques, no lining poor design choice [B] Damage caused to cassion may result in exposed risk to communities, risk decreases with lower linings [C] Poor mixing of concrete on a single, or stone lining, on a single section of the well [D] Fracturing most likely caused be poor concrete mixing or engineering procedure in the placement of linings [E] Unclean well - possibly caused by damaged pipes, or using the manhole for access	[A] Complete Reconstruction of the water point [B] Removal of damaged casings and relining of the source [C] Can be repaired but damage, particularly in the first few meters from the ground surface, should be sealed to prevent ingress of contaminated water from the surface [D] Minor fractures can be repaired with a mortar mix, however an inspection is required to address if it is not significant failure that has occurred [E] Cleaning rotation schedule to be provided locally	[A] $$$$$ [B] $$$$ [C] $$$ [D] $$ [E] $	[A] (Eng) [B] (H Tec) [C] (H Tec) [D] (L Tec) [E] (Car)

(Abbott, 2001; Collins, 2000; OXFAM, 2008; Watt and Wood, 1979)						
1.2	The well wall (or headwall) is designed to prevent contamination entering the water point. They also safe guard the source by preventing accidents to children and animals. The well wall should extend at least 50 cm off the base of the apron. Additionally the join between apron and the lining should be secured and sealed.	[A] Complete collapse of parapet [B] No well wall or sizable failure affecting formwork [C] Finger-width (or larger) fissures in wall [C+] Significant gap between the headwall and cover [D] Hairline fissures or cracks [E] Dirty Well Wall	[A] Poor construction design, complete collapse would result in damage to the apron and lining [B] Inadequate design of water point, wall failure would have to be significant [C] Poor construction quality or damage caused by erosion [C+] Damage to mortar attaching the well cover to the wall [D] Fractures caused by poor, but not significantly poor loading design [E] Dirt building up because of little or no cleaning procedures	[A] Complete reconstruction of the well wall and linings, complicated because of the damaged caused by this failure on other aspects of the source [B] Headwall to be redesigned and constructed, depends on the damage to the formwork [C] & [C+] Involves large amounts of concrete and potentially rebar maintenance, trained and skilled technician required to provide technical repairs [D] Should only require minor maintenance and basic information on mortar mixing to resolve [E] Cleaning rotation schedule to be provided locally	[A] $$$$$ [B] $$$$ [C] $$$ [C+] $$$ [D] $$ [E] 0	[A] (Eng) [B] (Eng) [C] (H Tec) [C+] (H Tec) [D] (L Tec) [E] (Car)
(Boschi, 1982; Brikké and Bredero, 2003; Collins, 2000; UNICEF, 2009a)						
1.3	A well cover reduces direct contamination by reducing foreign objects entering the water. As the cover should be designed to take loading it should be made with reinforced concrete. The cover should allow access to the water source, through either a manhole or hand-pump.	[B] Missing or severely damaged cover [B+] Sagging (or hogging) of the cover [C] Finger-width or larger cracks [C+] Severe Ponding on Cover [D] Hairline cracks [D+] Mild ponding on Cover [E] Exposed Rebar [E+} Dirty Cap	[B] Poor design of water point, Unsealed cap resulting in damage, Poor casting of cover [B+] Poor design of steel reinforcement [C] Poor casting of cover and load design [C+] Erosion caused over time, incomplete maintenance schedule [D] Fractures caused by stress loading [D+] Erosion caused by extensive well usage [E] Poor finishing on water point [E+] Dirt building up because of little or no cleaning procedures	[B] Design of well cover to suit the conditions of the well, casting and construction of the design. Would require understanding of design of reinforced concrete [B+] Redesign of reinforcement, recasting of the cover [C] Survey required to address whether the loading was likely to lead to collapse, otherwise repair requiring	[B] $$$$ [B+] $$$$ [C] $$ [C+] $$ [D] $ [E] 0	[B] (Eng) [B+] (Eng) [C] (H Tec) [C+] (H Tec) [D] (L Tec) [E] (Car)

				mortar mixes and design of reinforced steel [C+] Layering of screed required to address significant erosion [D] Should only require minor maintenance and basic information on mortar mixing to resolve [D+] Simple mortar screed required to address [E] Rebar required to be filed to reduce hazards [E+] Cleaning rotation schedule to be provided locally		
(Brikké and Bredero, 2003; Collins, 2000; USAID, 2010)						
1.4	An apron should be about 2m wide and sloping outwards away from the headwall. A slope of at least 1 in 50 (2%) is recommended. It should have allow spilt water to reach the drainage and spillway and divert it from the well site. The apron is designed to stop the earth around the water point being churned up, creating stagnant pools of water and an unhygienic surrounding to the well. Serious pooling normally occurs at the base of the apron. This can cause erosion and potentially affect the well lining.	[B] No well apron [B+] Sagging Apron [C] Severely limited or damaged apron [C+] Severe Ponding [C++] Severe Erosion [D] Minor cracks [D+] Mild Ponding [D++] Mild Erosion [E] Dirty apron [E+] Mild Ponding	[B] Poor design of the water point [B+] Poor design of steel reinforcement also caused by differential settlement in the underlying soil [C] Poor design of water point, poorly constructed block work or concrete [C+] Poor concrete screeding, inadequate slope design, aggravated by ponding water [C++] Significant amounts of water ponding around the water point - undercutting the apron, long-term erosion caused by extensive well usage [D] Fractures caused by stress loading [D+] Poor concrete screeding allowing water to pool, inadequate sloping to draining [D++] Small pools of water ponding around the well, poor drainage design [E] Dirt building up because of little or no cleaning procedures [E++] Small	[B] Redesign the water point to include apron slab surrounding the water point [B++] Remove existing slab and replace with redesigned slab [C] Adjust design and construct slab to include adequate drainage, adjust block work to suit well issues [C+] Resurface apron, including steel reinforcement where necessary [C++] Resurface apron, particularly extending the perimeter of the slab ensuring water cannot pool [D] Minor repairs using basic mortar mixes for fractures [D+] Minor screed resurfacing of water supply [D++] Ensure that water	[B] $$$$ [B+] $$$$ [C] $$$ [C+] $$ [C++] $$$ [D] $$ [D+] $$ [D++] $$ [E] 0 [E+] $	[B] (Eng) [B+] (Eng) [C] (H Tec) [C+] (H Tec) [C++] (H Tec) [D] (L Tec) [D+](L Tec) [D++] (L Tec) [E] (Car) [E+] (Car)

			areas of inadequate screed allowing water to pool	cannot pool under the slab by building adequate embankments [E] Cleaning rotation schedule to be provided locally [E] Small areas of screed to be addressed		
(Brikké and Bredero, 2003; Collins, 2000; Skinner, 2012; UNICEF, 2009b; USAID, 2010; Wagner and Lanoix, 1961)						
1.5	Spillways and soakways are important for draining wastewater from the well site. The 'soak ways' are either stone-filled pits or 'French drains' (shallow stone-filled trenches) these allow the water to dissipate into the soil.	[C] No spillway or soak way [D] Damaged Spillway or Inadequate spillway or soak-way [E] Blocked or dirty Spillway or soak-way	[C] Inadequate design of water point [D] Poorly constructed design, or missing maintenance over a longer period [E] Incomplete maintenance scheduling	[C] Redesigned to include spillway - minor construction required [D] Minor repair required to drainage, to stop pooling [E] Completion of spillway- provide ball stone where necessary. Maintenance schedule to be provided.	[C] $$ [D] $$ [E] $	[C] (H ec) [D](L Tec) [E] (Car)
(Skinner, 2012)						
1.6	The drainage area is linked to the edges of the apron, and should run into the spillway or soakways to decrease ponding.	[C] No drainage area [D] Damaged drainage [E] Dirty Drainage	[C] Inadequate design of water point [D] Damaged caused by volume of people using the source and standing on the drainage area, poor construction quality of finished work or poor maintenance schedule[E] Incomplete maintenance scheduling	[C] Redesign and construct drainage area, should not involve complex tasks to construct [D] Correct minor construction issues, create a maintenance schedule in order to resolve [E] Cleaning rotation schedule to be provided locally	[C] $$$ [D] $ [E] 0	[C] (H Tec) [D] (L Tec) [E] (Car)
(Brikké and Bredero, 2003; UNICEF, 1999; USAID, 2010)						

1.7	A manhole cover allows for the internal components of the well to be inspected and maintained easier. It also offers some support should the hand-pump fail and, as a temporary measure, the well can be used as an open system. The manhole cover should be made in such a way as to allow easy access, when necessary, but to also discourage frequent unnecessary opening. Sealed manhole covers limit the application of ease of access.	[C] Missing manhole cover or Sealed Manhole [D] Damaged/rusted manhole cover	[C] Extensive wear and tear, inadequate designs, poor security measures on water supplies [D] Normal wear and tear on manholes	[C] Replace the manhole cover with an operable, and lockable, cover [D] Treat any minor rust aspects using grease and file	[C] $$$ [D] $	[C] (H Tec) [D] (L Tec)
(Collins, 2000; Smet and Wijk, 2002)						
1.8	The primary purpose of the fencing is to protect the sources from contamination by animals. It also clearly defines the boundaries of the water point.	[D] No Fence [E] Porous fence or missing gate	[D] Poor community contributions or service delivery expectations of communities [E] Incomplete advice on safeguarding water supplies	[D] Construct fence using locally available labour, may include some small technical tasks including hinges and binding of structures [E] construct missing components of fence and ensure that the fencing is non-porous, create maintenance schedule	[D] $ [E] 0	[D] (Car) [E] (Car)
(Brikké and Bredero, 2003; Collins, 2000; Smet and Wijk, 2002)						

2.1	The hand-pump consists of many components which vary depending on the technology. Common components include: handle, head assembly, stand assembly water tank and flange. Additionally there are a list of fast moving parts which include replaceable components such as nuts, bolts, washers and the connecting chain. Hand-pump components should be greased with machine oil every two weeks. Pulley systems are open wells that operated without handpumps and require the functionality of their lifting to be assesed.	[B] Failed pulley system [C] Missing hand-pump (in their entirety) [C+] Rusted or Severely Damaged Components [C++] Permanent Concrete Security [D] Damaged or missing fast-moving replaceable parts [D+] Missing Security Cover [E] Noise pollution [E+] Ungreased Pump	[B] Failed pulley systems due to community negligence and flawed concept of success of a water point [C] Hand-pumps that have been stolen or have been taken apart to replace but never completed. Also includes incomplete projects. [C+] Usually caused by low pH and acidic groundwater, also caused by not replacing components which have common wear and tear over several years [C++] Concrete casting to secure hand-pump in place, this leads to damage when the system needs to be repaired [D] Standard wear and tear on basic components [D+] Missing cover to secure hand-pump components to stop them being stolen or vandalised [E] Noise caused by rusted or damaged pump components [E+] Ungreased or untreated mechanical parts, this is only noted if the components have not had any recent treatment	[B] Redesign of the well to include hand-pump components. May require multiple adjustments to revert changes to hand-pump systems [C] Provide new hand-pump including security cover [C+] Replace damaged components, set up maintenance schedule [C++] Chip away at the concrete and replace with security cover- involves only unskilled labour [D] Replace removable components [D+] Replace security cover [E] Address noise causing components by including locally available dampeners [E+] Grease hand-pump components, set up maintenance schedule	[B] $$$$ [C] $$$$ [C+] $$$ [C++] $$ [D] $$ [D+] $$ [E] $ [E+] $	[B] (Eng) [C] (L Tec) [C+] (L Tec) [C++] (L Tec) [D] (L Tec) [D+] (L Tec) [E] (L Tec) [E+] (L Tec)
(Brikké and Bredero, 2003; Collins, 2000; Mishra, 1993; RWSN, 2008; Skinner, 2003)						
2.2	The lifting systems are the components that are usually submerged in water and internal to the well system. They include all the non-hand-pump components such as the connecting rod, riser pipes, plunger rod and the cylinder assembly.	[B] Missing/No lifting system or extensively rusted/damaged pipes [C] Damaged Single Component (i.e. cylinder) [D] Superficial damage (pipes), or unclean pipes	[B] Poor construction, long-term wear and tear damage on lifting components, low pH groundwater that is acidic resulting in the corrosion of any submerged iron based components, such as galvanized iron riser pipes and rods used for handpumps. [C] Damaged by either normal wear and tear, corrosion or fracturing [D] Localised damage such as fracturing of pipes	[B] Replace entire lifting system, replace all damaged pipes and provide measures to reduce the impact of treatment in the water supplies, [C] Replace component, set up maintenance schedule for other components [D] Use labour intensive methods to repair any damage caused to	[B] $$$$ [C] $$$ [D] $	[B] (H Tec) [C] (L Tec) [D] (L Tec)

			that can be addressed by replacement of single components, can be caused be wear and tear, corrosion or fracturing	pipes, should only include the cost of repairs, not replacement		
(Brikké and Bredero, 2003; Harvey and Reed, 2004; Richard Luff, 2001)						
3.1	Contamination caused be the direct aquifer pathway from a latrine or nearby structure. The standard used suggests that significant risk is caused by less than 25 day travel time.	[A]Proximity to permanent or immovable structure high risk (expensive) [B] Proximity to permanent high risk structure (less expensive than the well) [D] Proximity to temporary high risk structure	[A], [B] & [D] Can be caused by the implementing organisation not planning their implementation activities correctly and ignoring safety protocols, can also be caused by communities that construct building post well construction.	[A] Dismantle existing well that causes risk to the community and construct new water point [B] Move the existing structure to another location or dismantle the threat causing construction and clean and disinfect the well [D] Move temporary structure and clean and disinfect the well	[A] $$$$$, [B] $$$$ [D] $	[A] (Eng) [B] (Eng) [D] (H Tec)
(Skinner, 2012; USAID, 2010)						
3.2	Assessment of the flooding of a well. Water points should not be located in any other area liable to seasonal flooding	[A] Well dramatically below floodplain [B] Well just below floodplain	[A] No topographical survey carried out prior to construction [B] Topographical survey not investigating peak flooding, changes in the local topography due to unforseen actions (such as construction or mining)	[A] Dismantle flooded well that causes risk to the community and construct new water point [B In areas where seasonal floods may occasionally submerge the well the entire operating platform and apron slab may have to be raised above ground by the required height for the predicted depth of the flood (perhaps a metre or more) to keep the pump and the upper section of the borehole casing above flood water level	[A] $$$$$, [B] $$$$$	[A](Eng) [B] (Eng)

(Skinner, 2012; USAID, 2010)						
4.1	Seasonal variation occurs when the water table rises or lowers affecting the availability and recharge of the water supply	[A] No water all year [B] Water available for only 6 months or less [C] Water available for only nine months [D] Water shortages during peak season [E] Slight water shortages	[A] Lack of water could be caused by other modes of failure, could also be caused by digging when the water table is at its highest resulting in little or no water all year [B] Common with wells that have been dug in the wet season when the water table is high, this will result in less than 6 months of available groundwater [C] The water table may fluctuate leaving a well without water at the peak of the dry season [D] Water shortages either caused by minor fluctuations in the water table during some parts of the year [E] Water availability causing minor inconvenience to household water supplies during peak dry periods	[A] Water points that are completely dry may not be worth extending depth as there may not be water below, consider dismantling existing water point and reconstructing a new point [B] Excessive deepening of the water point required including multiple linings and cassions [C] Slight extension in depth of the well required [D] Options to create community water shortage procedures to cope with key periods in peak dry seasons [E] Minor considerations required to address inequities that may happen during some days or weeks in the year	[A]$$$$$ [B] $$$$ [C] $$$ [D] $$$ [E] 0	[A](Eng) [B] (Eng) [C] (H Tec) [D] (L Tec) [E] (Car)
(DFID, 1998)						
4.2	The technical operation evaluates the intended continual usage of the water point	[B] Pump required to be in operation more than 10hrs [C] Pump required to be in operation more than 6hrs [D] Pump required to be in operation more than 4hrs	[B] [C] & [D] Depends on the type of pump utilised and the availability of water resources. Queuing also considered as a factor of the number people using the water point.	[B] [C] & [D] Consider replacing the pump with a higher yielding model for delivery - otherwise refer to other modes of failure that may address these problems	[B] $$$ [C] $$ [D] 0	[B] (Eng) [C] (L Tec) [D] (L Tec)
(Skinner, 2012)						

4.3	The yield per person is an internationally recognised human right. This is calculated as a factor of the number of people dependent on the water point.	[A] 0/l/p/d [B] less than 7/l/p/d [C] between 7/l/p/d and 40/l/p/d	[A], [B] & [C] Caused by the number of people exceeding the capacities of the water point. The more excessive failures happen when more people are reliant on a single water point	[A] Construct multiple new water points in the community [B] construct another water point in the community [C] Consider extending the depth of the well to increase yield	[A] $$$$$$ [B] $$$$$ [C] $$$	[A] (Eng) [B] (Eng) [C] (Eng)
(Sphere, 2011)						
5.1	The quality of water addresses how close with regards the 'safe' water that the well can produce. The overarching standards are those by WHO on drinking water guidelines. Though much of the water supply problems can be linked to other failures that have occurred, some of the conditions are found in the groundwater, and are not a factor of any other mode of failure.	[A] Highly contaminated water source on one or more dangerous contaminants [B] Fail indicators monitored by Sphere Standards for water quality [C] Fail commonly monitored WHO indicators for water quality [D] Fail WHO Standards for water quality [E] Higher than intended values in WHO standards for any parameter	[A] [B] [C] [D] & [E] - Contaminants can be in the groundwater, in the nearby surface water or introduced into the system by humans or animals. They can vary in impact, risk and magnitude and depend on a number of indicators to address.	[A] [B] [C] [D] & [E] – Each response depend on the type of contaminant and the type of response required. Extreme variations include dismantling the well and reconstructing in a new location [A] to building an on-site treatment such as for the removal or iron and manganese [C] or chlorinating the source [E]	[A] $$$$$$ [B] $$$$$ [C] $$$$ [D] $$$ [E] $$	[A] (Eng) [B] (Eng) [C] (H Tec) [D] (L Tec) [E] (C Tec)
(Gorchev and Ozolins, 1984; Sphere, 2011)						

Appendix L: Pulley Well Statistics

		Casing	Spillway	Well Wall	Cap	Well Area	Apron	Manhole	Fence	Pulley	Security	Pipes	Location	Seasonal	Water	Flood
Total Grading	Grade A	53	0	5	9	0	0	0	0	0	0	0	4	10	0	0
	Grade B	16	0	6	8	7	0	0	0	67	0	67	0	26	0	3
	Grade C	3	37	9	1	33	14	21	0	15	75	15	0	17	55	0
	Grade D	0	25	21	11	1	18	53	81	0	8	0	0	10	0	0
	Grade E	3	20	12	30	33	23	0	2	0	0	0	0	4	0	0
	No Failure	8	1	30	24	9	28	9	0	1	0	1	79	16	28	80
Percentage of Grade	Grade A	63.9%	0.0%	6.0%	10.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.8%	12.0%	0.0%	0.0%
	Grade B	19.3%	0.0%	7.2%	9.6%	8.4%	0.0%	0.0%	0.0%	80.7%	0.0%	80.7%	0.0%	31.3%	0.0%	3.6%
	Grade C	3.6%	44.6%	10.8%	1.2%	39.8%	16.9%	25.3%	0.0%	18.1%	90.4%	18.1%	0.0%	20.5%	66.3%	0.0%
	Grade D	0.0%	30.1%	25.3%	13.3%	1.2%	21.7%	63.9%	97.6%	0.0%	9.6%	0.0%	0.0%	12.0%	0.0%	0.0%
	Grade E	3.6%	24.1%	14.5%	36.1%	39.8%	27.7%	0.0%	2.4%	0.0%	0.0%	0.0%	0.0%	4.8%	0.0%	0.0%
	No Failure	9.6%	1.2%	36.1%	28.9%	10.8%	33.7%	10.8%	0.0%	1.2%	0.0%	1.2%	95.2%	19.3%	33.7%	96.4%
Percentage of Category	Grade A	58.2%	0.0%	5.5%	9.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.4%	11.0%	0.0%	0.0%
	Grade B	7.1%	0.0%	2.7%	3.5%	3.1%	0.0%	0.0%	0.0%	29.6%	0.0%	29.6%	0.0%	11.5%	0.0%	1.3%
	Grade C	1.0%	11.9%	2.9%	0.3%	10.6%	4.5%	6.7%	0.0%	4.8%	24.0%	4.8%	0.0%	5.4%	17.6%	0.0%
	Grade D	0.0%	10.5%	8.8%	4.6%	0.4%	7.6%	22.3%	34.0%	0.0%	3.4%	0.0%	0.0%	4.2%	0.0%	0.0%
	Grade E	2.3%	15.3%	9.2%	22.9%	25.2%	17.6%	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	3.1%	0.0%	0.0%
	No Failure	2.4%	0.3%	9.1%	7.3%	2.7%	8.5%	2.7%	0.0%	0.3%	0.0%	0.3%	23.9%	4.8%	8.5%	24.2%

** Note: these calculations are based on a number of independent checks highlighting the maximum grading*

Appendix M: Hand-pump Well Statistics

		Casing	Spillway	Well Wall	Cap	Well Area	Apron	Manhole	Fence	Pulley	Security	Pipes	Location	Seasonal	Water	Flood
Total Grading	Grade A	9	0	0	6	0	0	0	0	0	0	0	9	2	3	0
	Grade B	26	0	11	10	0	0	0	0	0	0	29	0	11	0	8
	Grade C	19	86	24	16	58	16	31	0	53	48	30	0	82	69	0
	Grade D	4	41	47	14	4	43	88	141	19	151	18	0	18	0	0
	Grade E	12	60	54	63	95	45	0	51	9	0	0	0	11	0	0
	No Failure	141	24	75	102	54	107	92	19	130	12	134	202	87	139	203
Percentage of Grade	Grade A	4.3%	0.0%	0.0%	2.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.3%	0.9%	1.4%	0.0%
	Grade B	12.3%	0.0%	5.2%	4.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	13.7%	0.0%	5.2%	0.0%	3.8%
	Grade C	9.0%	40.8%	11.4%	7.6%	27.5%	7.6%	14.7%	0.0%	25.1%	22.7%	14.2%	0.0%	38.9%	32.7%	0.0%
	Grade D	1.9%	19.4%	22.3%	6.6%	1.9%	20.4%	41.7%	66.8%	9.0%	71.6%	8.5%	0.0%	8.5%	0.0%	0.0%
	Grade E	5.7%	28.4%	25.6%	29.9%	45.0%	21.3%	0.0%	24.2%	4.3%	0.0%	0.0%	0.0%	5.2%	0.0%	0.0%
	No Failure	66.8%	11.4%	35.5%	48.3%	25.6%	50.7%	43.6%	9.0%	61.6%	5.7%	63.5%	95.7%	41.2%	65.9%	96.2%
Percentage of Category	Grade A	29.0%	0.0%	0.0%	19.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	29.0%	6.5%	9.7%	0.0%
	Grade B	24.5%	0.0%	10.4%	9.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	27.4%	0.0%	10.4%	0.0%	7.5%
	Grade C	3.1%	14.0%	3.9%	2.6%	9.4%	2.6%	5.0%	0.0%	8.6%	7.8%	4.9%	0.0%	13.4%	11.2%	0.0%
	Grade D	0.7%	6.8%	7.8%	2.3%	0.7%	7.1%	14.5%	23.3%	3.1%	24.9%	3.0%	0.0%	3.0%	0.0%	0.0%
	Grade E	2.9%	14.6%	13.1%	15.3%	23.1%	10.9%	0.0%	12.4%	2.2%	0.0%	0.0%	0.0%	2.7%	0.0%	0.0%
	No Failure	8.8%	1.5%	4.7%	6.3%	3.4%	6.7%	5.7%	1.2%	8.1%	0.7%	8.3%	12.6%	5.4%	8.6%	12.6%

Note: these calculations are based on a number of independent checks highlighting the maximum grading

Appendix N: Intermediate Education in Sub-Saharan Africa

Water treatment and supply: intermediate education in Sub-Saharan Africa

P. Byars and B. Antizar-Ladislao

ABSTRACT

In 1973 the economist E.F Schumacher wrote 'Small is Beautiful'. In this he created the vision of a concept known as 'intermediate technology'. Directly from this grew the popular 'appropriate technology' movement. An appropriate technology, in the ideal sense, is designed with special consideration of the environmental, ethical, cultural, social, political, and economical aspects of the community it is intended for. The term 'appropriate technology' is continually used when referring to water supply and treatment technologies in international development. The widespread provision of hand-pumps in Africa by Non-Governmental Organisations (NGOs) fully characterises the approach and remains the most prominent display of technologies, transferred on a charitable basis, between the developed and developing countries. However, after years of NGOs working with hand-pumps in Africa the first signs are showing that there are widespread problems with the current approach. In many cases the nature of 'appropriateness' is determined from the perspective of an external technical expert and not by the communities themselves. The lack of appropriateness is leading to severely unsustainable projects. This paper explores the linkage that has not been clearly mapped in technology transfer, i.e., the use of scientific and technical education. The focus of the transfer is on developing the knowledge and skills necessary to evaluate 'appropriateness' from the perspective of the end user. It explores the concept of 'Intermediate Education' – a method of using experimental learning to address a systemic weakness in safe water provision in development.

Key words | appropriate, education, intermediate, international development, technology

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INTRODUCTION

A recent global estimate of water supply in the developing world suggests that 884 million people still require access to safe drinking water (WHO & UNICEF 2008). Optimistically this indicates that 1.6 billion people have now been granted access to safe drinking water since the 1990s. Some of these solutions have been large, centralised and capital intensive projects like piped water systems and dams. However in Sub-Saharan Africa, where generally speaking these large scale solutions for a myriad of reasons are unavailable, the situation remains unresolved. Many of the inhabitants of Sub-Saharan Africa are now classed globally as the 'bottom billion' (Collier 2007). Due to the rural nature of much of the poverty, safe water supply is generally dependant on small scale, labour-intensive and 'low' technologies. Recently, due to large international pushes, improvements have been reported in water supply provision. However the rate of progress, as reported by certain UN agencies, makes the assumption that those that have been provided with an improved source have continued to use them in a sustainable fashion (WHO & UNICEF 2008). This is contrary to independent studies which suggest that this is not the case. In a selected range of countries in Sub-Saharan Africa it is estimated that between 30–60% of pumps fail and that at any given

doi: 10.2166/ws.2011.100

time only two out of three pumps are working (Hazelton 2000; DWD 2002; Sutton 2005; Harvey 2007). One of the few relatively recent surveys, carried out in Tanzania and looking historically at water supply systems, suggests that over a 25 year period there is a 90% failure rate of water supply projects (Haysom 2006). As the problems facing rural water supply are wide-ranging there is no single mitigation or remedial action available.

Engineering in international development

Much of the engineering carried out in developing countries is identical to that of a developed country in that it is primarily capital intensive. However, to suit the needs of the poorest, the engineering carried out by Non-Governmental Organisations (NGOs) has begun to differ from traditional engineering approaches, and is defined as development engineering. Development engineering is more focused on village level and labour-intensive approaches. It has been argued that development engineering requires continual local participation in order to be successful (Skinner 2003). The technologies adopted are often considered 'low' technologies, i.e., ones that do not require specific specialisations to manufacture and use. These technologies include examples such as hand-pump wells, water filters, smokeless stoves, ventilated improved pit latrines and rainwater harvesting systems. The Millennium Development Goals state that, by 2015 the global community will reduce, by half, the proportion of people without sustainable access to safe drinking water (UN 2000). The primary response by the developed countries to this goal has been to supply hand-pumps to resolve water supply issues. However, as discussed before, sustainability is a key issue in these development projects. It has been suggested that at a fundamental level sustainability depends on the relationship between the technology, the engineer and the communities themselves (Carter *et al.* 1999). The widespread failure in sustainability points to a systemic problem regarding how the technologies are transferred, and the capacities of the communities to receive these ideas. This paper is concerned with an issue that Schumacher expressed as the '*missing link in the whole enterprise*' – the use of education (Schumacher 1973).

PREPARING SOCIO-TECHNICAL SYSTEMS

This paper explores three arguments which promote the need for developing the socio-technical systems in international development: (i) technology acceptance in development, (ii) indigenous and scientific knowledge, and (iii) participation in development.

Technology acceptance in development

Successful technology integration is most clearly observed in the widespread adoption and use of mobile phone technologies throughout Sub-Saharan Africa (Smith 2009). It is possible to travel throughout Africa, to some of the poorest and most remote areas within its interior, and find villages with no water supply or functioning sanitation systems, but an abundance of mobile phones. It is even possible to find local phone repairmen, as well as all the associated luxury items and paraphernalia which accompany these phones. These markets are thriving with mobile related wares, a private sector response that has developed without, or possibly despite, NGO involvement (Smith 2009). This can be juxtaposed against the private sector involvement in water supply technologies. Much of the failures of water supply projects are attributed to the lack of, or weak, private sector involvement. So why are mobile phone technologies succeeding where water supply technologies are so clearly failing? The response essentially draws on one of the most fundamental market philosophies – supply is entirely dependent on demand. Mobile phone technologies ultimately address a perceived need. This need creates the demand, and that demand creates a market thus ensuring private sector involvement. It would be condescending to suggest that those in developing countries do not demonstrate a clear understanding of the importance of drinking water. Neither do these people willingly accept a water supply that may look as though it can cause harm. However, there is widespread acceptance of sources that would not suffice, even on a temporary basis, for those in a developed country. This poses an important question: can those in poverty simply be told that a source of water is unacceptable, and will this suffice for them to change their interpretation of their needs?

Developed countries can often overlook the social factors that allowed their health systems to develop. For instance, the history of the United Kingdom has many examples of scientific breakthroughs being rejected when its own society was not prepared to hear, or to understand, what was being suggested. There is no better example than that of the 1854 cholera epidemic in the water supply in Soho, London (Johnson 2006). Dr John Snow famously used this outbreak to contradict the miasma theory (that cholera was caused by 'bad air'). He traced the Soho outbreak to a single public hand-pump well. This well had been dug less than three feet from a cess-pit. After using statistics to prove the connection to the illnesses the pump handle was removed. As the pathogenic theory of medicine (or germ theory) had not yet been discovered Dr Snow had no way of articulating how the mechanisms of the disease worked. This may appear to be a triumph in effectively sensitising local residents, without imparting the full scientific facts, when dealing with water supply issues. The final part of the story suggests otherwise. After the cholera outbreak had subsided the government, still uncomfortable with the idea of a faecal-oral transmission route, reinstalled the handle of the hand-pump. It was not until the widespread acceptance of germ theory in the late 19th century that the transmission routes of cholera were understood. The Soho cholera outbreak offers parity to the current actions in the developing world. Simply sensitising communities might work in the immediate context of an emergency, but is severely flawed as a sustainable intervention. In international development, community water systems are allowed to fall into decay. It has also been noted that when a system stops working the users return to their previous sources of water. This indicates that there is very little development of the scientific understanding of their problems. Therefore to suggest that a community aspires to 'safe' drinking water precludes that there is some recognition of a scientific understanding of what this entails. Without ensuring clarity on some of the fundamental aspects of science there exists no basis upon which to build a suitable appreciation of either the problems or solutions that are available.

Indigenous and scientific knowledge

Introducing scientific understanding to effectively deal with global water issues is crucial for sustainability. Scientific knowledge is not, however, a silver bullet. Overemphasising the importance of science can result in it being mislabelled as 'truth'. Science offers only one of the many ways of understanding the natural world. Therefore scientific knowledge requires its own scrutiny in relation to sustainable development.

Scientific knowledge is a body of reliable knowledge that can be logically and rationally explained; it can be repeatedly tested and verified through experimentation, and is used to make empirical sense of the natural world (Aristotle, 4th century BCE 1989). It is acquired through long periods of inquiry and investigation, and in the ideal sense, a combination of complete human learning which is collated, compiled, analysed and sourced from a wide range of social and cultural backgrounds as well as historical periods. This is comparable to indigenous (or traditional) knowledge, which generally refers to the long-standing traditions and practices of certain regional, indigenous, or local communities. In many cases, traditional knowledge has been orally passed down for generations from person to person. Many forms of indigenous knowledge are expressed through stories, legends, folklore, rituals, songs, and laws. This knowledge generally evolves to better understand local conditions and issues. It is regarded as the basis for local-level decision making in issues such as agriculture, education, natural resource management and a host of other activities (Warren 1991). There are similarities with scientific and indigenous knowledge; both seek a way of understanding the natural world, both use a method of experimentation to generate proof and both are used to govern knowledge, attitudes and practices. Developed societies have their own forms of indigenous knowledge; those with little scientific merit become 'urban legends' or 'old wives tales', those with merit become incorporated into normal living practices. There are many examples of this type of knowledge evident in the developed world's culture. They also exhibit the ability to discredit harmful myths by using their scientific understanding of the natural world to do so. However, even in the developed world, the success of this 'debunking' process generally depends on the scientific abilities of those involved.

Engineering can, at least partially, be described as an applied science: the application of scientific knowledge transferred into a physical environment. As such, engineering inherits both the strengths and weaknesses of scientific knowledge. It uses the current understandings of scientific facts as a firm basis upon which to create internationally recognised standards. These are then used to govern engineering practice. Rejection of this core principle of engineering would be counterproductive. It is argued that knowledge of scientific principles, the 'laws of nature', of materials and of methods are in a sense, absolute (McRobie 1981).

This paper suggest, that for all the opportunities that science offers, it is this 'absoluteness' that creates the systemic problems when dealing directly with communities with little or no scientific background. The most disruptive aspect of scientific knowledge is its sheer dominance over 'traditional' or 'indigenous' knowledge. 'Modern scientific knowledge is centralised and associated with the machinery of the state; those who are its bearers believe in its superiority. Indigenous technical knowledge, in contrast, is scattered and associated with low-prestige rural life; even those who are its bearers may believe it to be inferior' (Chamber 1980). It could be argued that engineering in international development, exemplifying the core philosophy of this scientific dominance, follows exactly in the same vein. The justification for this domination is that 'indigenous' knowledge has no scientific basis and therefore should be omitted from engineering practice. In doing so, the rejection of indigenous knowledge omits the single most defining aspect of appropriateness, and hence the sustainability of a technology: the context upon which the technology relies – the very part that makes it 'appropriate'.

Participation in development

The lack of context in technological interventions in developing countries is observed in more than one area of engineering practice. Because water supply projects, particularly hand-pump wells, produce such positive short term results with regards to the reduction of water related infections, the social and cultural implications of a technical solution can often go unnoticed and unchecked. The cultural practices of a community have to change, sometimes dramatically, in order to openly receive a water supply technology. In exploring the concept of intermediate technology E.F. Schumacher called for '... a gentle approach, a non-violent spirit, and small is beautiful' (Schumacher 1973). One of the key attributes of 'gentleness' is a willingness to accept terms upon which a project could be rejected, or perhaps more crucially, redesigned in line with the environmental, ethical, cultural, social, political, and economical needs of the communities. The redesign of a project solution is reliant on the technical capacity of a community. Some practical alterations are not suggested because of the 'locked in' aspect of technology transfer. The community does not have the ability to suggest reasonable alterations to a technology because of their limited technical and scientific grasp of what they are being provided with.

The increase in 'participation' within development projects; over a number of development sectors has been shown to increase both the ownership and long term sustainability of a project. Ideally speaking, community participation is a consultative empowerment process which is designed to establish communities as effective decision-making entities (Harvey & Reed 2007). For the community to be involved in a water supply project there must be information sharing, consultation, decision-making, and initiating action (Guijit & Shah 1998). Due to the lack of technical teachings generally found within local communities, participation remains severely limited. This vacuum allows the engineer or 'technical expert' to dominate (Botes & van Rensburg 2000) and this unintentionally leads to the use of manipulation where '... participation is undertaken in a manner contrived by those who hold power to convince the public that a predefined project or program is best' (Duraiappah *et al.* 2005). This reduces the communities' ability to problem-solve technical issues for themselves and in doing so creates a culture of dependency. Water supply projects must be capable of being maintained at the village level and this requires the users to be completely comfortable with all parts of the technology. Participation has to extend to more than just permission for land use, identification of site locations and labour provision. If a community, without basic scientific and technical knowledge, is unable to make a reasonable input into the design aspects of a water supply and treatment project, then this should be regarded as one of the root causes of lack of ownership and sustainability.

DISCUSSION

Science and technology education in the developing world

The dialogue, between those with indigenous and those with scientific knowledge, needs to be created. This link is crucial for three reasons: first, to develop a market for water supply and treatment projects; second, to be linked with indigenous knowledge to create a 'context' for the technologies; and lastly, to provide a dialogue which allows communities to engage with the engineers, thereby presenting a gentler way of technologies being adapted and accepted into community life. Therefore the importance of scientific teaching in a development context cannot be understated. The most obvious place to look for these teachings is within the education systems of the developing countries themselves. In the developed world it is these institutions that are initially responsible for sharing scientific knowledge. A basic overview of science and technology education in Sub-Saharan Africa is not altogether positive:

- Similar to the schooling systems of the developed world, science classes such as physics, biology and chemistry are most commonly found in a secondary school teaching curricula. However Sub-Saharan Africa suffers from a massive underinvestment in secondary schools. Over 70 million of the region's secondary school-age children are not enrolled in secondary schools (Lewin 2007).
- As discussed before, many of the poorest people in development are typically found in rural areas. Due to the lack of financial support secondary schools are generally found in urban and peri-urban environments in developing countries. In lower secondary education, for example, the average gross enrolment ratio is 66.5% in urban areas, but only 22.2% in rural areas. The pattern of coverage does vary over countries (Mingat & Ndem 2008). Overall people in rural areas are less likely to receive a science or technical lesson.
- Within the secondary schools that are available, whether rurally located or not, there is a common lack of materials and teaching resources. Crucially, this limitation ensures that science and technical education is taught didactically. This severely limits the effectiveness of the teachings and could potentially alienate students from the subject matter. This is taught counter to best pedagogical practices (Freire 1970).
- Finally, the education of science and technology is fashioned directly on the curricula used by the developed nations. The academic irrelevances and alien concepts make them less suited to their role within a developing country (Harrison 1979). This in turn can enhance human flight capital – the brain drain.

The ideal situation would be to have secondary education widely available, with science classes taught in the most effective manner, with all available resources to ensure that there is the capacity to do so, while also providing a curriculum that is both useful and relevant for a Sub-Saharan African. Due to financial requirements, this remains outside the capacity of development agencies to provide. The provision of secondary schools should remain a long term goal of development; however, simply ignoring the importance of scientific and technical education is severely affecting both the short, medium and long term effectiveness of water supply and treatment projects.

NGOs currently engage in a form of community education. They do this by using sensitisation: limited teaching practices that are dependent on the community accepting what the NGO teaches, without the opportunity of exploring the nature of the lessons in more detail. This practice is similar to Dr Snow's efforts in Soho – though he was not at the time withholding information, but was unaware of the full situation himself. The ultimate ambition of sensitisation is not to encourage scientific growth but to mobilise a community to effectively deal with their health issues. For example in sanitation awareness 'health and hygiene promotion' has already provided a very important role in mobilising communities to understand their health situation. Kamal Kar's Community Led Total Sanitation (CLTS) has already been pivotal in demonstrating the seismic shift that happens when a community fully grasps the immediacy of their situation (Kar 2005). The triggering method adopted by Kar does not fully include a scientific understanding of the problems, instead uses disgust and embarrassment to alter community practices. This use of sensitisation cannot be faulted in itself, as it has very successfully contributed to a widespread adoption of 'defecation free zones' and safer sanitary practices. However, Kar admits that one of the most limiting factors is getting communities to aspire to climb a 'sanitation ladder' (Kar 2003). This again relates to the importance of scientific and technical education.

Intermediate education

The economist Schumacher fully understood the importance of intellectual support. He claimed that the gift of useful knowledge was the best aid that could be given (Schumacher 1973). What this study suggests is providing a form of intermediate education as the basis for this educational support. This would be intermediate between scientific and indigenous knowledge, between full scale education systems and sensitisation and between the cultures of the developed and the developing worlds.

Richard Feynman, the Noble laureate in Physics, argued that the test of all knowledge was to experiment – the sole judge of scientific proof. Experiments produce, he maintained, the laws that give us hints about our world. Allied with our imaginations they develop to become the 'great generalisation' allowing us to see the great patterns beneath the laws, only to experiment again to see if the correct guesses were made (Feynman 1964). Experimentation is, in short, a crucial aspect of scientific learning. The term 'intermediate education' refers to a form of capacity building of the host community which primarily builds their scientific and technical understanding by exploring, through experimentation, issues which affect them, and the solutions that are available. The defining attributes of the Intermediate Education concept are:

- *Promotion of scientific and technical growth:* The primary function of the intermediate education concept is to ensure that there is an increase in scientific and technical growth in the host communities. This should not be confused with capacity building, which focuses on teaching related to the construction, operation or maintenance of a water supply and treatment project. Capacity building is a vital aspect of water projects, but is specifically geared towards community participation external to the technology itself, not in the community understanding of the sciences used to create, develop and design the technology. Similarly, intermediate education is not intended as an exercise in health and hygiene promotion; instead it is intended to show the scientific nature of both the health problems, as well as the solutions. Though both capacity building and health promotion would be complimented by the intermediate education concept, it remains independent and has its own unique focus and contribution to a water project.
- *Experimental learning:* Intermediate Education uses a form of teaching which depends almost entirely on experimental learning. This hands-on experiment-based learning allows for full participatory interaction by students. It can also be conceived as providing empowerment, as certain experiments can unlock the problem solving potential of those being educated.
- *Technology catalyst:* Though this paper challenges the usage of the term 'appropriate' it is not intended to diminish the importance or necessity of a technical intervention. The opportunity to provide intermediate education would not exist without a technological intervention. Intermediate education is intended to fulfil a role linked directly to the 'technology transfer' of a water treatment and supply solution. For this reason it uses the technology which is presented to the community, such as a BioSand filter, or Rainwater Harvesting Systems, as a catalyst for engaging with the host community. The experiments are directly associated with this catalyst and not intended to be independent.
- *Material Resources:* The experiments themselves must be capable of being sourced and created locally using only sustainable and renewable resources. Recycled materials are ideally suited for this purpose. The experiments however cannot misrepresent the scientific integrity of the concept being explained. School equipment which requires high capital investment, such as Bunsen burners and microscopes, should be avoided where possible. Experiments that depend on metaphoric interpretations, such as using humans to 'represent' micro-particles, should be also be avoided unless deemed vitally necessary.
- *Open Access:* The experiments have to be developed in a way that ensures that they are inclusive to all members within the community. Though the experiments would

most comfortably compliment a school curriculum, it should also be suitable for those outside the education system through peer-to-peer groups and existing community social networks. The material should also be developed in such a way that purposely ensures the participation of women and children. Providing technical support for both these groups is specifically mentioned in the charter of human rights (Byars *et al.* 2009).

This type of education could comfortably fit within current water resource projects. It would involve only a fraction of the total project costs. Health and hygiene promotion has already indicated that educational components can be considered important contributors to engineering projects in development. The intermediate education concept would also give ample opportunities for developing world technicians to work with local education authorities. This would allow more end-user feedback for the technologies, which has been conspicuously lacking in development engineering programming. It would also allow the capacities and skills of the technicians to be further developed that are appropriate for the local needs of the communities. Like the CLTS concept, skilled facilitation is key to making this approach work.

Though the intermediate education concept may develop demand and thus create a market system, or assist in making technologies more appropriate, or simply support an education system, the results will not be dramatic in the short term.

CONCLUSION

The intermediate education concept is purposely aimed at achieving long term growth in the developing world. Engineering in development should not only be about applying a technical solution to a systemic problem; instead it should also be about developing the capacity of a socio-technical system to adapt its own version of 'appropriate'. The concept of intermediate education seeks not to dominate but to bridge the gaps between disparate worlds. It seeks to more fully involve communities in the designs that affect their lives. It should allow a community to participate more fully in a project, consistent with their cultural beliefs, without sacrificing the scientific integrity and the health benefits of safe drinking water. It should also offer a form of engineering empowerment, allowing those facing scientific problems to not only understand the nature of their problems, but to know where to look for solutions, be that the private sector, their local civil society groups or perhaps themselves. And finally the intermediate education should work directly with those who need the tools to effectively form their own future – the children of the developing world. Therefore this concept would directly fulfil Schumacher's true spirit of appropriateness – a gentle approach, a non-violent spirit, and small is beautiful.

ACKNOWLEDGEMENTS

This research was funded by the Engineering and Physical Sciences Research Council (EPSRC). The authors acknowledge the comments of Prof. James Smith. Special thanks to Ruan Roux, Jonathan Choksey and Miriam Hansen and Engineers Without Borders, Edinburgh, for their continued contribution to developing both the Intermediate Education concept and the associated experimental materials.

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First received 6 June 2011; accepted in revised form 7 September 2011