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Influence of real-time information provided by a mobile phone on the management of rural water supply quality



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Mr Gazi – Amathole District Municipality

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My parents: Brett and Lorraine Wilson-Jones

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Plagiarism Declaration

I know the meaning of plagiarism and declare that all the work in the document, save for that which is properly acknowledged, is my own.

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Abstract

In South Africa, access to safe drinking water is a human right that is explicitly stated in the constitution. Most metro municipalities are meeting the drinking water quality targets, but the smaller rural environments are failing to provide water of acceptable drinking water quality. Reasons contributing to the high incidence of unacceptable water quality are the rural municipalities' inadequate institutional capacity and lack of management and monitoring of drinking water services.

This study investigates the possibilities of supporting rural water service institutions to manage their remote water supply schemes better by addressing the challenge of distance monitoring. Through the creation of real-time information flow between the water service authorities and the water supply caretakers in remote villages, it is to be tested if better information can be received and the status of the rural water supply quality can be monitored. The improvement of information flow is based on introducing a mobile phone application. The hypothesis is that through improving the information flow, decisions on water supply management will be improved.

Case study research was conducted in rural municipalities situated in the Northern Cape Province and Eastern Cape Province of South Africa. Four different municipalities were chosen to reveal the diverse municipal set-up and different challenges facing rural municipalities. Data was gathered through interviews conducted with the municipal managers over a seven month period, as well as through field investigations.

The findings reveal that the mobile reporting system has improved information flow from water supply caretakers to government service providers. The mobile application allowed for distance monitoring of rural water supply schemes. It has helped address the municipalities' institutional capacity problems by improving access to information relevant to decision making. Through the data records displayed on the mobile application, municipal managers were able to track the supply caretakers' performance and subsequently hold them accountable. Through an increase in data availability, water quality failures were easily identified, resulting in improved confidence in the quality of rural water supply.

The access to real-time information has improved the monitoring and communication of rural water quality. Early intervention and the management of non-compliance improved. The mobile technology provided the municipal managers with a tool to monitor their rural water supply

schemes more regularly, but it also became apparent that the management of such schemes only improved if relevant action was taken based on the information received. Greater improvement was seen in municipalities where the tool was used consistently, where time was set aside to follow up on data warnings and protocols existed to follow up on non-compliance issues. Management of the resources did not improve in areas where management staff was severely overstretched and response strategies to problems were non-existent before the implementation of the tool.

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Abbreviations used

ADM	Amathole District Municipality
ANDM	Alfred Nzo District Municipality
AW	Amathole Water
BDS	Blue Drop Score
Bhs	Boreholes
CHDM	Chris Hani District Municipality
CSIR	Council for Scientific and Industrial Research
DM	District Municipality
DMA	District Management Area
DoH	Department of Health
DWA	Department of Water Affairs
DWQF	Drinking Water Quality Framework
E.Coli	Escherichia Coli
EHPs	Environmental Health Practitioners
EU	Ease of Use
GDWQ	Guidelines for Drinking Water Quality
H ₂ S	Hydrogen Sulphide
hh	Households
HLM	Hantam Local Municipality
iComms	Information for Community Orientated Municipal Services
ICTs	Information Communication Technologies
IS	Information Systems
KPA's	Key Performance Areas
LM	Local Municipality
MDGs	Millennium Development Goals

MHD	Municipal Health Director
MHS	Municipal Health Services
NHLS	National Health Laboratory Services
PU	Perceived Usefulness
SANS 241	South African National Standards 241
sms	Short Messaging Service
UCT	University of Cape Town
WCM	Water Care Manager
WHO	World Health Organization
WQM	Water Quality Manager
WQR	Water Quality Reporter
WSA	Water Service Authority
WSI	Water Service Institution
WSP	Water Service Provider
WSPP	Water Safety Planning Process
WTW	Water Treatment Works
WWTW	Waste Water Treatment Works
eWQMS	Electronic Water Quality Management Systems

Chapter One

1. Introduction

1.1 The Importance of Safe Drinking Water

'The combination of safe drinking water and hygienic sanitation facilities is a precondition for health and for success in the fight against poverty, hunger, child deaths and gender inequality' (UNICEF, 2004). The Millennium Development Goals (MDGs) highlight the most important development issues worldwide and have been adopted globally. Target 7C goal is to 'halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation' (UNICEF, 2004). In 2008, 2.6 billion people lacked basic sanitation and 1.1 billion people still had no access to clean potable water (Water and Sanitation Africa, 2008). So far the majority of countries, excluding Sub – Sahara Africa (43% of the population have unimproved access to water), are on track to meeting the MDGs by 2015 (UNICEF, 2004). Through improving the provision of water, other health related MDGs can be achieved (WHO, 2011).

Water related diseases are the single largest cause of disease and death in the world and mainly affect the poor (Lane, 2004). Diarrheal disease causes 2.2 million deaths per year, 1.33 million being children under the age of five (WHO, 2011). In South Africa, 3 million people suffer and 43 000 die annually from diarrheal disease (Mackintosh, et al., 2006). In order to reduce water-borne disease and improve public health, the focus on supplying adequate water quality and sanitation facilities has increased, however a number of challenges still need to be addressed. According to the Department of Water Affairs (DWA) an estimated 30% of consumers are supplied by water services that are not regularly sampled (Rivett, et al., 2009).

To ensure safe drinking water the World Health Organisation (WHO) developed the International Guidelines for Drinking Water Quality (GDWQ). These guidelines are intended to direct the development of drinking water standards worldwide (WHO, 2005). Based on these international guidelines, the Department of Water Affairs (DWA) developed the Drinking Water Quality Framework (DWQF) for South Africa, in December 2005. The intended outcome of the framework was to help effectively manage drinking water quality and protect public health, through a preventative risk management approach, which was encouraged by WHO GDWQ. The DWQF

provides guidelines to all relevant stakeholders and promotes an understanding of the entire supply system from catchment to consumer (Hodgson & Manus, 2006).

Despite frameworks such as the DWQF and drinking water quality standards (SANS 241), current studies reveal that non-metro water service authorities (WSAs) of local governments are struggling to provide safe water to their communities and high incidences of poor water quality are common (Hodgson & Manus, 2006). Reasons for failure and drinking water quality not meeting the national standards include:

- 'A lack of understanding by WSAs regarding the requirements for effective drinking water quality management
- Inadequate management including monitoring of drinking water services
- Inadequate asset management
- Inadequate WSA institutional capacity (staffing, funding, expertise, education)
- Lack of intervention to address poor drinking water quality when detected' (Hodgson & Manus, 2006).

In developing countries, rural water supply schemes are more vulnerable to contamination (WHO, 2011). Rural communities may only have rudimentary water supply facilities and most rely on ground water sources, which are accessed via boreholes and springs. When such water supplies are managed properly, water of high microbiological and chemical quality can be provided. This is due to the underground location of the supply and the protection from surface contamination. But in a study done by Mackintosh and Colvin, it was revealed that ground water supply schemes fail more frequently than surface water supply schemes. Incidences of ground water failure are mainly due to pump breakdown, contamination of the storage reservoir, failure to chlorinate and most common are inadequate management and monitoring practices to identify water quality failures or remediate contamination. When borehole water supply systems are non-functional, users often turn to other non-treated water supplies (Mackintosh & Colvin, 2003). Therefore the management and monitoring of the borehole supply systems and springs are essential in the delivery of safe water.

Rural areas are often more difficult to manage and monitor due to their geographical layout, historical set-up, limited funds and resources. Some rural parts of South Africa have very limited service infrastructure due to their former apartheid homeland status. Dispersed villages and supplies in remote environments, make service delivery costly and monitoring difficult. Monitoring rural water supply schemes such as borehole sources and springs are particularly difficult due to their accessibility. The cost, resources and infrastructure required for routine bacteriological testing of

drinking water quality are often not available in rural environments. Laboratory testing requires trained staff to perform specific techniques, controlled environments and sterilized volume specific equipment (Sobsey & Pfeander, 2002). The lack of available, easily accessible and locally owned accredited laboratories hinders the frequency of monitoring rural water supplies. Inadequate service infrastructure – for example, poor road conditions - further restrict monitoring of rural supply schemes. In order to address this there is currently an international drive towards developing a rapid field detection method for the indication of microbiological water quality (Mackintosh & Colvin, 2003).

1.2 Context of this Study

This study investigated the possibility of supporting rural water service institutions to manage their rural water supply schemes better, by addressing the challenge of distance monitoring. By creating real-time information flow between the water service authorities and the water supply caretakers in remote villages, it was tested if better information could be received and the status of the rural water supply quality could be monitored. The improvement of information flow was based on introducing a mobile phone application. Similar applications have been successfully used as a knowledge transfer tool and have improved communication, monitoring and early intervention warnings in the developing world. The hypothesis is that through improving the information flow, decisions on water supply management will be improved. Aspects such as the usefulness of the mobile application in the process were also assessed. All mobile software was developed by iComms team members. The research presented only assesses the influence that the mobile technology could have on improving information flow to assist rural management.

The research formed one aspect of the University of Cape Town's (UCT) Information for Community Orientated Municipal Services (iComms) project. UCT iComms team was involved from 2007 – 2012 in an international research project, "Aquatest", lead by the University of Bristol. The Aquatest projects aim was to develop a low-cost, sustainable, on-site water quality field test kit in conjunction with a cellphone data transfer tool (Water and Health Research Centre, 2012). The UCT iComms team was responsible for the design and investigation of the use of cellphone technology in improving communication between rural communities and municipalities (iComms, 2012). For more information on iComms and the Aquatest project refer to appendix 1, chapter 12.

Three reporting applications were developed to improve the communication between municipalities and their communities, namely the Water Quality Reporter (WQR), the Water Quality Manger web application (WQM web) and the Water Quality Manger android application (WQM android). The WQR was used in the field by water supply caretakers, also referred to in this document as borehole operators. It allowed on-site personnel to submit their rural water quality results. Data would be received by a central server, which would store and forward the results to the WQM applications. The WQM applications collected, mapped and highlighted the compliance of the real-time data. There was a WQM web application which could be accessed via a PC or a WQM mobile application. All stakeholders involved had access to the WQM web application, so that they could monitor the system. The WQM web application was designed first, but after feedback it was noted that managers are often *on the run* and not office bound. It was realised that a WQM mobile application (WQM android) would be better suited to the lifestyle of many rural managers. The new WQM mobile application, implemented in May 2011, allowed managers to access water quality data wherever they were. Warning smses and colour-coded systems were set up on the phone to help identify problems in the supply.

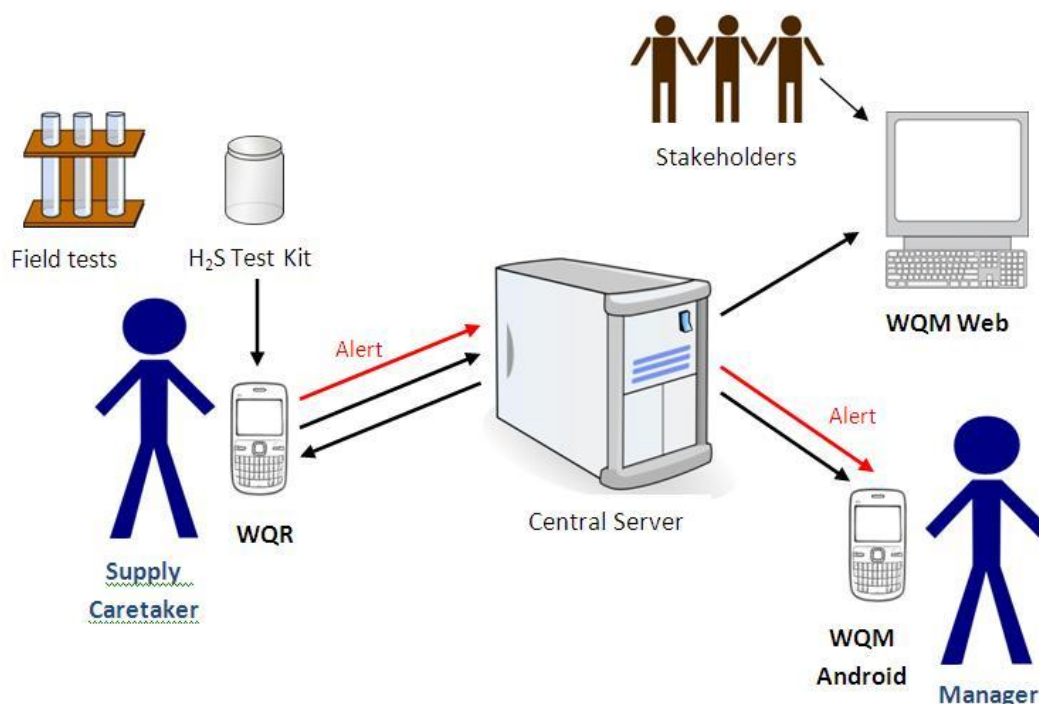


Figure 1: Information flow from on-site Borehole Operator to Government Service Provider, using the iComms reporting system. Red arrows indicate a positive H₂S test result.

The research presented here focused on the impact that an increase in information, being provided through the WQM mobile application, would have on management of the rural water supply

schemes. How real-time information flow would assist municipal managers in making more informed decisions and in having better use over their limited resources. The research only focuses on the influence of improvement in information flow and makes no attempt to evaluate the success or failure of the ICTs project as a whole.

The information systems (IS) were implemented in the research fields with the use of a hydrogen sulphide (H₂S) test kit. The H₂S test kit is a presence/absence (P/A) test for E.coli bacteria and is used on site to determine if there is any microbiological contamination of a rural water supply.

1.3 The Use of ICTs in Developing Countries

The mobile phone has become the choice of information communication technologies (ICTs) in developing countries, the main reason being high consumer demand and easy implementation in vast areas of dispersed population. Initially some development practitioners saw the mobile as a luxury tool of the developed world (Banks & Burge, 2004). But 'the rate at which the cell phone industry has grown, and the extent to which even the poor and rural will go to own one indicates that they are essential tools for daily life and survival' (Shackleton, 2007). Mobile phones have enormous potential in developing regions. They can be used for mass communication, providing information, improving service delivery and social organising (Shackleton, 2007).

'Most target groups ... cannot afford to buy or even access technology used in projects, with the exception of phones. The poor are, moreover, increasingly benefiting from the strategic use of telephone communication... (some projects) clearly demonstrate that telephone technology (land and mobile) can be used effectively to answer communication, information, and business needs of poor people in developing nations' (InfoDev, 2003; Banks & Burge, 2004).

Mobile technologies have a high potential for influencing development in poor regions. They have already been used in a number of sectors to improve societies and individuals lives. Cellphones are easy to use and knowledge can be transferred quickly in a cost-effective manner. There has been sustainable development in the health, education, environmental, farming, business and community service sector with the implementation of mobile phone devices, used for communication and monitoring (Shackleton, 2007). Mobile phones are useful in collecting information in rural areas, where the authority may be situated in a different town. Small amounts of data can be frequently

submitted to professionals, keeping them informed (Blake, 2008). Below are some key examples for the use of ICTs in the developing world.

Telemedicine:

Mobile technology has been used in the health sector to help with communication and observation of patients by health care professionals. Through short message service (SMS), patients can be reminded to take their medicines on time and advice and health care information can also be provided remotely by nurse and doctors. Patient who have no access to hospitals and clinics can report new symptoms and get the required medical advice. This allows for early interventions and the management of symptoms. This communication device can save costs on time and travel and enables people in remote locations to gain access to health care services (Blake, 2008; Banks & Burge, 2004). Examples for such applications are Cell-Life (Kinkade & Verclas, 2008).

Small Businesses and Farmers:

Mobile technology has been used to support rural traders to monitor the demand and supply levels in the market place. Through cellphones they can have direct access to the markets and can determine best prices and appropriate times to sell their produce (Banks & Burge, 2004). Information on job opportunities can also be provided on the mobile, if users have subscribed to such a service (Shackleton, 2007). This type of communication allows the poor to stay informed even if they are living in remote areas. Examples are Monobi's development of Xam Marse (Manobi, 2005).

Financial Sector:

Mobile phone networks can be used for financial transactions in rural areas where there is no access to banks. Through mobile phones customers can 'make person-to-person payments, transfer money, purchase prepaid electricity, and buy airtime for a prepaid mobile subscriber' (Shackleton, 2007). This type of service offers quick, secure and affordable banking services, with users only being charged a fee per transaction. This new innovation addresses the issues of expensive banking charges and the far distances often travelled to banks. Examples are MTN- Banking a joint initiative between MTN and Standard Bank (Shackleton, 2007).

Environment and Services:

Mobile phones are an effective means of communication and are currently helping national reserves in their conservation monitoring (Banks & Burge, 2004). Examples are Push to Talk initiative by the GMS development fund (Kinkade & Verclas, 2008). Mobile on-line information systems are also used in the monitoring of water and wastewater remote facilities. With the use of technology, data can be captured in real time and the information be made available on demand. Mobile remote monitoring is cost-effective, efficient and requires minimum effort. Early warning systems can be set up to alert if measured values exceed process controls (Alex, et al., 2003).

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Chapter Two

2 Research Methodology

This dissertation argues that an increase in real-time information flow will improve the management of the rural water supply schemes, which consist of boreholes and protected springs. To assess if real-time access to information did in fact make a difference to management, literature reviews and field studies were conducted. The effects of information transfer through mobile phone technology in other sectors in developing countries were reviewed to determine expected outcomes for the project. In study sites where the iComms project was implemented, municipal managers were observed over a seven month period to determine how useful they considered the increase in access to on-site information to be.

2.1 Site Participation and Selection

The WQM mobile application was implemented in four rural municipalities, situated in two provinces of South Africa. Hantam Local Municipality (Northern Cape), Chris Hani District Municipality (Eastern Cape), Alfred Nzo District Municipality (Eastern Cape) and Amathole District Municipality (Eastern Cape).



Figure 2: Location of the four case study sites in South Africa, created in Google maps.

Each of the municipalities is a water service authority (WSA) for one or more local municipalities. Sites were selected based on two key factors: 'a reliable electricity supply; and system implementation with government involvement' (Champanis & Rivett, 2012). UCT also received approval from working within each of the municipalities from Provincial Government (Rivett, 2012). Each WSA context differs with regard to management, monitoring and challenges in water service provision. Thus a number of different backgrounds and circumstances of rural water supply were explored through the study. The municipal managers of each municipality were the unit of interest for this study. A qualitative methodology was chosen with in-depth interviews conducted with the municipal managers to highlight the unique management practices and challenges of each of the four selected municipalities.

2.2 Qualitative Analysis

According to Yin (1981) a case study is the most appropriate research method when 'an empirical enquiry must examine a contemporary phenomenon in its real life context' (Yin, 1981). Case study research was well suited to this study since observations were made over a period of time to determine the effects that automated information flow had on the management of the rural water sector. Knowledge gained was used to explore the possibilities of using mobile phones to supporting rural water service institutions. By using multiple case studies a number of experiences could be analysed in order to determine the barriers and enablers of knowledge utilization. Through case study research a number of experiences and practice were documented allowing for qualitative analysis similar to the examples highlighted by Benbassat et al (1987) (Benbassat, et al., 1987).

Qualitative analysis was chosen due to the great depth, detail and focus on context in the study. Due to the number of cases being small, a broad range of experiences were analysed in great depth, for each of the managers. A number of different data collection methods were used to capture *data-rich* findings and ensure validity of the results (Patton, 2002).

Such as:

- Literature from other studies, guidelines and standards.
- Municipality documents and websites
- Direct observation
- Interviews

Direct observation visits to each of the four municipalities were carried out in April/May 2011. Monitoring challenges of poor road conditions and spatially dispersed rural water supply schemes were experienced firsthand, when travelling through the different municipalities. Sampling of water quality was directly observed in Hantam Local Municipality. One of the supply caretakers demonstrated the sampling procedure and explained the importance of each step. The supply caretaker's recording of the water quality results was also studied. Data was recorded on paper, in a logbook at the sample site, and also submitted to the WSA through the WQR cellphone application. In order to evaluate the feasibility and acceptance of the technology by management, observations were carried out on the managers using their WQM application on their android phones, at a meeting in November 2011. The ease with which the managers could navigate their way through the different views on the application, provided insight into the ease of use and usefulness of the tool.

Multiple interviews with the municipal managers, of each study site, were carried out using the standardised open-ended interview structure. This type of format was used for it allows the interview questions to be thought out carefully in advance but it also allowed the respondent to speak in more detail on any particular point. All respondents were asked the same set out questions, which made breadth and depth of information similar from each site, facilitating analysis. Through the open-ended questions, managers were able to express their own thoughts and views freely. This gave insight into understanding their experiences and world views (Patton, 2002).

Face-to-face interviews were carried out with the municipal managers at the site visits in April/May 2011, and at a group meeting held in Cape Town, in November 2011. Throughout the 7 month study period, May –November, ongoing phone call interviews were conducted with the managers, twice monthly.

The aim of the interview with the managers at the site visit, in May 2011, was to establish current practices so that changes in monitoring and management could be determined. These interviews provided background to the study and an understanding of the managers' expectations and attitudes towards an increase in information through the mobile technology. Background interview questions are available in appendix 3.1, chapter 14.1.

The on-going phone call interview questions were conducted to record the managers' adoption of technology and to determine if they were using the information provided by the WQM mobile. Approximately nine questions were asked via unscheduled phone calls every two weeks. Some

questions were repeated over time so that a change in the attitudes of the user could be determined. The ten sets of on-going phone call interview questions conducted can be reviewed in appendix 3.2, chapter 14.2.

At the end of the seven month study period a group meeting was held with all iComms staff and the four municipal managers. Concluding questions were asked to gain insight into how useful the managers thought the system was and what improvements were made. The meeting was also used to provide feedback on the iComms experiences, the challenges that the research team had faced and the lessons learned. Discussions on sustainability and generalization were conducted and suggestions on how to improve the system were encouraged. The benefits of using the tool, sustainability of the system and way forward for each municipality were discussed. Municipal managers sustainability interview questions asked at the group meeting can be found in appendix 3.3, chapter 14.3.

2.3 Data Analysis

In Heeks 2009 paper, *The ICT4D 2.0 Manifesto: Where Next for ICTs and International Development?*, he describes a seven themed design-actuality model that he developed. Heeks uses this model to identify concept-reality gaps, to explain the success and failure of technology implementation in developing countries (for more information on Heek's seven themed design-actuality model refer to chapter 5.2) (Heeks, 2009; Heeks, et al., 1999). In a 2009 iComms Draft Report by Cabral these seven themes were developed further (Cabral, 2009). Cabral incorporates Davis's perceived usefulness and perceived ease of use theory, for technology adoption, demonstrated in his 1989 paper *Perceived Usefulness', Perceived Ease of Use and User Acceptance of Information Technology*, (Davis, 1989) in to Heeks seven themes.

Davis believes that there are two main factors that affect the acceptance or rejection of technology by the user. The factors are on the one side, the perceived usefulness and on the other side, perceived ease of use of the system or tool. The Perceived Usefulness (PU) is defined as 'the degree to which a person believes that using a particular system would enhance his or her job performance' (Davis, 1989). The Perceived Ease of Use (EU) is defined as 'the degree to which a person believes that using a particular system would be free of effort' (Davis, 1989). Each themes questions bear in mind these two key indicators.

The first five themes adapted from Heek's framework focused on changes within the municipality and the benefits that have resulted due to use of information provided by the WQM. The last two themes indicated how the municipal structure, staffing and skills have affected implementation of the iComms reporting project.

The order of the seven themes has been altered to suit the analysis of the study better. Dimensions and indicators were created to reveal to the reader what aspects were addressed under each theme.

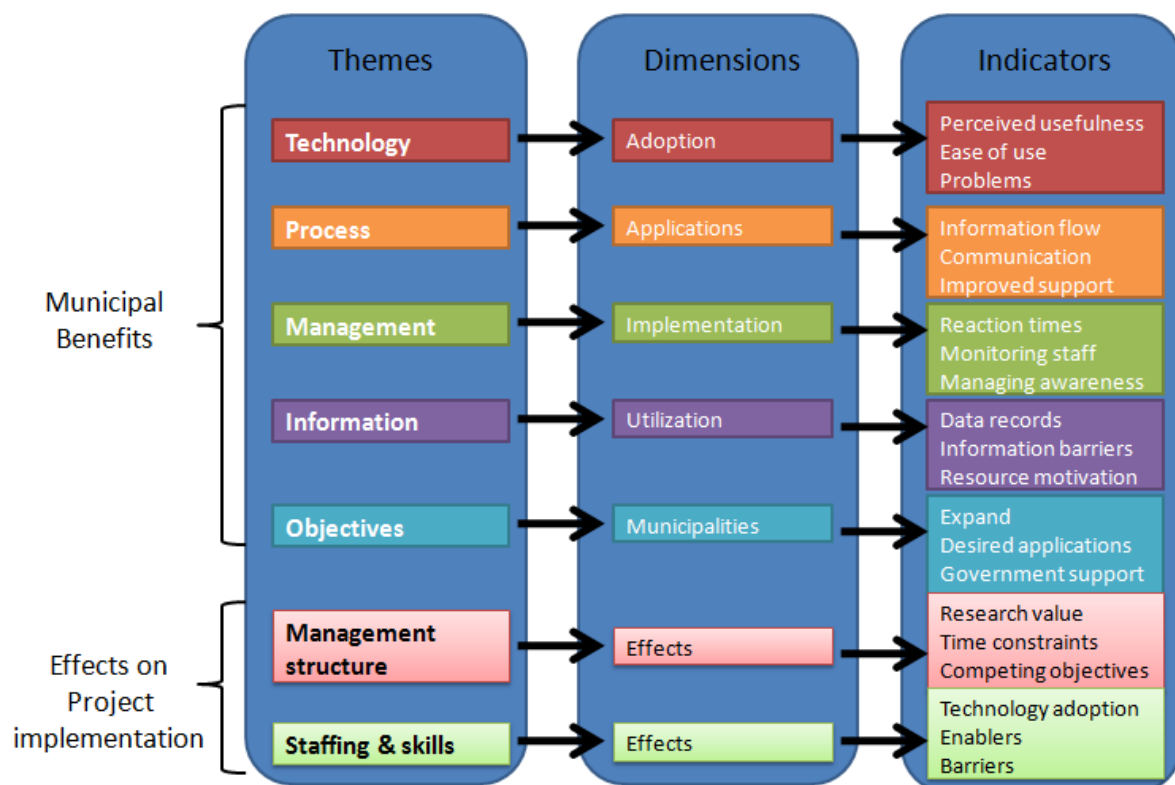


Figure 3: Criteria for analysis, based on a seven themed technology adoption model.

An in-depth description of the municipalities accounts were grouped according to the themes. Changes in processes and management, as well as attitudes were described. An investigation into the findings was conducted to interpret the impact that the information had on the management of the water sector and the significance of the impact. Inconsistencies in the findings were also established and reasons determined.

Chapter Three

3 Water Service Delivery in South Africa

South Africa has a semi-arid climate, with water being a scarce and limited resource. The country's average annual rainfall is 450mm/a, which is only 60% of the world average of 860mm/a (Water and Sanitation Africa, 2008). To worsen this statistic South Africa has very high potential evaporation volumes ranging from 1100mm/a to high 3000mm/a. Conversions of rainfall to run-off are very low, with only 10% (Earle, et al., 2005). Therefore management of water is essential (Department of Water Affairs and Forestry, 1994). There is large water inequality in South Africa directly linked to the historical apartheid structure. People in the rural areas, which were mainly the former homelands, lack basic services. This adds to poverty and under development (Department of Water Affairs and Forestry, 1994). The South African Constitution states that 'Everyone has the right to have access to sufficient food and water' (section 27 (1)b)).

In 1994, 34% of the country lacked access to a formal water supply and 51% of people had no formal sanitation (Earle, et al., 2005). From 1994 onwards, government focused on improving the standard of living of all South African citizens, resulting in an emphasis on service delivery (Earle, et al., 2005). By 2002, an additional 10 million people had been provided with basic water supplies (Department of Water Affairs and Forestry, 2002). Although there have been improvements in quantity (access, scarcity) of water service provision, focus needs to now turn to quality (safety) of the water provided (WHO, 2011).

3.1 Institutional Framework for Drinking Water Quality

Since the 1994 White paper- Water Supply and Sanitation policy, there has been development and implementation of new important policies. The Department of Water Affairs (DWA) no longer has the role of basic service provision for households, as specified in the 1994 White paper, and currently acts as a sector leader and supporter of water services. There is now focus on decentralization of services, with more focus on Local Government (Department of Water Affairs and Forestry, 2002).

The 2002 White Paper - called *Water is Life, Sanitation is Dignity* - recognises the importance of involving all spheres of government in the water sector. It defines the responsibilities of each sector and promotes integrated planning and effective management. Policies include municipal support and capacity building initiatives. It also reviews all previous legislation and water service to ensure a common goal is being reached. DWAFs objectives for water supply, expressed in the white paper are:

- 'All people living within South Africa have access to adequate, safe and affordable water and sanitation services, practice safe sanitation and use water wisely
- Water supply and sanitation services are sustainable and are provided by effective and efficient institutions that are accountable and responsive to those whom they serve
- Water is used wisely, sustainably and efficiently in order to promote economic growth and reduce poverty' (Department of Water Affairs and Forestry, 2002).

3.2 Institutional Roles

All three spheres of government, National, Provincial and Local, are responsible for water services. National Government acts through DWA to ensure water service provision and water resource management. Since the Local Government elections in 2002, service provision has become the responsibility of Local Government. In accordance with the constitution (Act 108 of 1996) Local Government has full operational responsibility for the provision of water and sanitation services (Department of Water Affairs and Forestry, 2002). The constitution also defines the roles of National and Provincial Government as one to support and strengthen the capacity of Local Government and regulate their performance (Earle, et al., 2005).

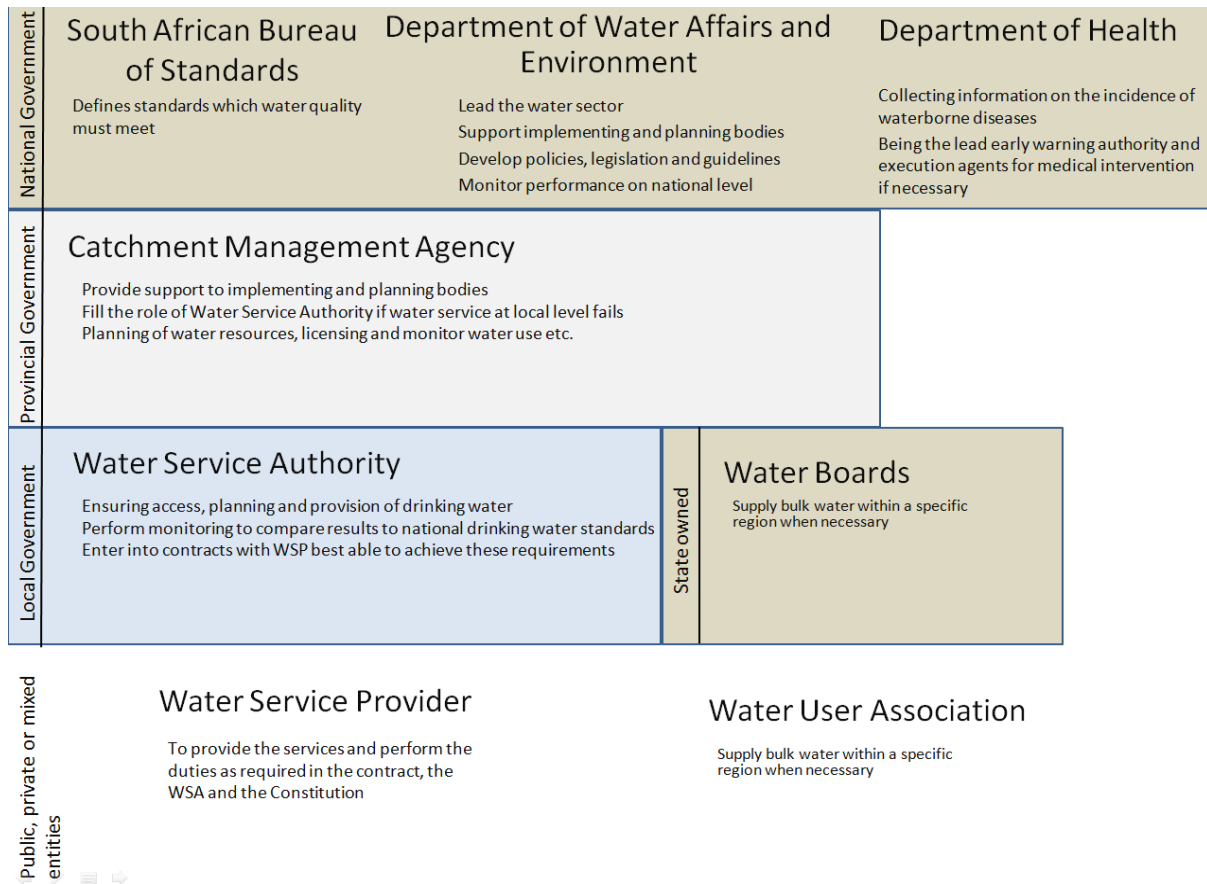


Figure 4: Roles and Responsibilities of water service delivery in South Africa (Linfords, 2011).

3.2.1 Water Service Authorities (WSA)

It is the primary responsibility of Local Government to provide water services to communities within its area of jurisdiction. This is done via the constituted WSA, in terms of the Municipal Structures Act (No. 118 of 1998) (Department of Water Affairs and Forestry, 2005). There are 169 WSA and they range from being metropolitan, district and local municipalities. In terms of section 84 of the Municipal Structures Act, district and metropolitan municipalities have the responsibility for providing water services. However, local municipalities can hold these responsibilities if Provincial and Local Government affairs authorises such an arrangement (Department of Water Affairs and Forestry, 2002).

WSA are to manage the drinking water quality from the catchment areas to the consumer. They must ensure safe drinking water and protection of consumer health through a preventative risk-management approach (Department of Water Affairs and Forestry, 2005). WSA responsibilities include:

- Realization of the right to basic water services, subject to available resources.
- Preparing water service development plans
- Contracting water service providers and regulation of them, to ensure standards are met
- Monitoring of drinking water quality (frequency of sampling and specify sampling points)
- Comparing results to national drinking water standards, SANS241
- Communicating health risks and inform DWA, Department of Health (DoH) and the consumer on: (Department of Water Affairs and Forestry, 2002; Hodgson & Manus, 2006)
 - 'that the quality of water that is supplies poses a health risk
 - of the reason for the health risk
 - of any precautions to be taken by the consumer
 - of the time frame, if any, within which it may be expected that water of a safe quality will be provided' (Department of Water Affairs and Forestry, 2005)

The Water Service Act (No. 108 of 1997) stipulates that there is a need to ensure 'efficient, affordable, and economically sustainable access to water services'. Key changes since the 1994 White Paper are 'Local Government is now the key focus for delivery' and 'more emphasis is being placed on sustainability and the ongoing provision of efficient and reliable services' (Department of Water Affairs and Forestry, 2002).

3.2.2 Water Service Provider (WSP)

A Water Service Provider (WSP) is any institution that has been contracted by the WSA to provide water services to consumers on their behalf. The WSP must carry out its duties in accordance with the constitution, the Water Service Act and within any specific conditions specified by the WSA. WSP are responsible for the operational monitoring (refer to chapter 4.1) of services within their geographically specified area. They must report results to the WSA regularly to help WSA monitor their contractual arrangements. The municipality may be the WSP as well as the WSA, but a clear separation of functions is required. The public must be communicated to in an easily understood

manner and the WSA must be accessible for consumer complaints and suggestions (Department of Water Affairs and Forestry, 2002; Department of Water Affairs and Forestry, 2005).

3.2.3 Department of Water Affairs (DWA)

DWA is the overall leader of the water sector. The department has four main responsibilities with regards to the provision and management of water resources:

1) Policies

DWA formulates, implements and revises national standards and policies. Development strategies to ensure good practice are also prepared.

2) Support

Helps to strengthen and support Local Governments through guideline manuals, technical assistance and capacity building.

3) Regulation

Monitor the sectors performance against national standards (in terms of drinking water quality this would be SANS241). DWA also performs unscheduled audits to ensure Local Governments are successfully performing their water quality management duties.

4) Information

Has the responsibility to manage Local Governments water sector information, so that effective monitoring, support, planning and regulation can be undertaken (Hodgson & Manus, 2006; Department of Water Affairs and Forestry, 2002; Department of Water Affairs and Forestry, 2005)

DWA has the overall responsibility for the management of water resources, policy and regulation of the water sector. Regulation of WSA is vital for it ensures government objectives are being met, systems are sustainable and the consumer is being protected. Support is not only offered to Local Government but also other water institutions and government bodies to help achieve sector targets (Department of Water Affairs and Forestry, 2002).

In terms of drinking water quality, DWA supports and regulates WSAs through:

- ' Developing and maintaining a National Drinking Water Quality Framework
- Managing information, including a sector data base and information sharing system covering key aspects such as tracking WSA monitoring systems and drinking water quality data
- Undertaking periodic regulatory audits of the drinking water quality data and management systems of WSAs

- Developing appropriate, practical and sustainable technical support documents and tools
- Assisting WSAs by reviewing Water Service Development Plans, to ensure that drinking water quality monitoring is included' (Hodgson & Manus, 2006).

3.2.4 Department of Health (DoH)

The Department of Health (DoH) and DWA work closely on water quality standard determination, but the DoH main responsibility is water policy and operational activity. The DoH must ensure health education is carried out simultaneously with the building of infrastructure. DoH work with the Department of Education to help create guidelines and curricula for schools to support health and well being (Department of Water Affairs and Forestry, 2002).

The management of drinking water quality is enhanced by the DoH's support in:

- 'Collecting information on the incidence of water borne diseases (for example, diarrhoea) and the use of this information to facilitate interventions
- Being the lead 'early warning' authority and execution agents for medical intervention under emergency drinking water quality conditions' (Hodgson & Manus, 2006).

The DoH's Environmental Health Practitioners (EHPs) conduct compliance drinking water quality monitoring (refer to chapter 4.2) at metropolitan and district level. Their main concern is microbiological constituents, for these are the parameters that will indicate a potential health risk in the water. EHP function also involves community education on health and hygiene (Hodgson & Manus, 2006).

3.3 An Overview of Drinking Water Quality Frameworks

Drinking water quality frameworks are essential in guiding the development of drinking water quality standards to ensure the supply of safe supply of drinking water (WHO, 2005). The Drinking Water Quality Framework (DWQF) for South Africa is based on the WHO's international Guidelines for Drinking Water Quality (GDWQ), as mentioned in chapter 1.1. The GDWQ highlight the importance of using Water Safety plans as an effective means to ensure safe drinking water quality. The DWQF is the lead policy for drinking water quality in South Africa, it takes a preventative approach to ensure safe supply. The DWQF was developed in reaction to non metro municipalities unacceptably high non compliances to standards and occurring incidences of unsafe water quality (Hodgson & Manus, 2006).

3.3.1 WHO: Guidelines for Drinking Water Quality (GDWQ)

The main aim of the international WHO GDWQ is the protection of public health, through guiding the development of drinking water standards (WHO, 2005) and encouraging a proactive approach to drinking water quality management (Department of Water Affairs, 2011). In developing a country's national drinking water standards, local context must be taken into consideration. The GDWQ are only a base and adaption to environmental, social, cultural and economic conditions must be regarded (WHO, 2004). The World Health Organisation (WHO) Framework for Drinking-Water Quality concept is based on the management of drinking water quality from catchment-to-consumer (Department of Water Affairs, 2011). It outlines 5 key components to ensure drinking water safety (WHO, 2004).

- 1) Health based targets (evaluation of health concerns)
- 2) System assessment (determine whether drinking water supply overall meets health-based targets)
- 3) Operational monitoring (control measures to ensure safety)
- 4) Management and monitoring plans (normal and incidental conditions action plans, including communication)
- 5) A system of independent surveillance (verification and audit system)

The 2004 GDWQ focus on preventative risk management and thus there is high importance on the development of water safety plans (WHO, 2004) .

3.3.2 Water Safety Planning Process (WSPP)

'It is the current international view that the use of a comprehensive risk assessment and also a risk management approach, which includes all steps of the supply chain from catchment to the point of delivery, is the most effective means of consistently ensuring the safety of drinking water supplies' (SABS, 2011).

A Water Safety Plan Process (WSPP) is an assessment of the current risk of hazards within a water catchment area. It consists of three components, which are guided by health based targets and seen as essential in delivering safe water supply:

- 'System assessment and design

- Operational monitoring
- Management plans, documentation and communication' (WHO, 2005).

The system assessment is a description and assessment of the whole water supply chain. It includes upgrade programmes of the existing water delivery system as well as design criteria for new systems. It determines whether health based targets are being met. The WSPP also includes the plans for operational monitoring of identified control measures and verification of these systems. Plans are in place to rapidly detect deviation from operational limits. The management plans within the WSPP should include procedures for normal operation, incident management and emergency situations. The management plans should also include communication plans and give a description of the supporting programmes in place. To ensure the effectiveness of emergency response and incident management protocol plans, reviews should be conducted regularly. Incident plans are designed to give guidance to a number of different types of problems. 'The success of general incident response depends on the experiences, judgement and skills of the personnel operating and managing the drinking-water system'. Emergency plans are the action plans in place. They specify who is responsible for informing the community by issuing boil water alerts and arranging alternate drinking water supplies (WHO, 2004).

A water safety plan determines the likelihood of occurrence and the severity of the situation, if a hazard was to occur (WHO, 2004). The benefits of having water safety plans in place are that the chances of system failures are minimized. When unforeseen hazardous events do occur, there are organised systems in place to react to the failure. Water safety plans also analyse the occurrences of failure throughout the system. It determines whether the existing systems in place are sufficient to achieve health based targets (WHO, 2005). 'Water Safety Plans represent an approach that demonstrates to the public health bodies and regulators that the water supplier is applying best practice to secure water safety' (WHO, 2005).

In the updated WHO GDWQ, there is an increased focus on the development of WSPP. To achieve the goal of the provision of safe drinking water there needs to be a risk assessment on drinking water in all areas of the supply chain from catchment to consumer (Sobsey & Pfeander, 2002).

3.3.3 The Drinking Water Quality Framework (DWQF) for South Africa

The DWQF for South Africa promotes the provision of “safe” drinking water quality through preventative risk management, from catchment to consumer (Hodgson & Manus, 2006). The DWQF recognises the limitations of monitoring only and developed a new approach to understanding the importance of the entire supply system (Department of Water Affairs, 2011). The importance of operational control is recognised as a trigger for short term corrective action and the protection of public health (Hodgson & Manus, 2006).

There are four key issues that the DWQF highlights:

- 1) Commitment to drinking water quality management by all water sector stakeholders
- 2) Effective management through risk assessment and a preventative approach (operational monitoring to identify potential hazards)
- 3) Supporting programs and validation through documentation and reporting (training of staff, community involvement, awareness, transparency and public accountability)
- 4) Review and audits by DWA to assess sector performance (Hodgson & Manus, 2006)

The framework also encourages WSAs to improve drinking water quality through attainment of short term goals and a focus on achievement of minimum legislation (Hodgson & Manus, 2006).

3.4 Regulations

3.4.1 South African National Standards 241 (SANS 241)

The DWQF helps support local governments to comply to the countries drinking water standards. The South African National Standards 241 (SANS 241) is the regulation to ensure that government objectives are being met (Department of Water Affairs and Forestry, 2002). The South African Bureau of Standards is responsible for the development, promotion and maintenance of South African Standards (SABS, 2011; SABS, 2011). All water service institutions and intermediaries must ensure drinking water quality performance against the SANS 241. SANS 241 specifies acceptable drinking water quality at the point of use in terms of microbiological, physical, aesthetic and chemical determinants (SABS, 2011).

SANS 241 – 2011 addresses issues present in the previous SANS 241 – 2006. There are no longer two classes of drinking water quality suitability. All water quality must comply to SANS 241-1:2011

numerical limits, which is water that 'is deemed to present an acceptable health risk for lifetime consumption (this implies an average consumption of 2L of water per day for 70 years by a person that weighs 60kg)' (SABS, 2011; SABS, 2011). The more stringent numerical limits in SANS 241-1 are based on the WHO GDWQ (Department of Water Affairs, 2011). In order to help water service institutions and water service intermediaries achieve this goal, there is a part two to the standard. SANS 241-2: 2011 specifies the application of SANS 241-1:2011 and must be used in conjunction with it.

SANS 241-1:2011 presents the microbiological, physical, aesthetical and chemical determinants. It is an assessment of the suitability and acceptability of the water quality, by comparing results to numerical limits. With the advances in technology, new methods for analysis have been made available. The new SANS 241 recognises the limits of many municipalities and allows for the use of cost effective simple, *test kit* indicators to be used in determining operational compliance. So long as the *test kit* performs to the analysis requirements. 'use any method of analysis, the performance of which with regard to trueness, precision and limit of detection, can offer the necessary limit of quantification in order to comply with the requirements of this part of SANS 241' (SABS, 2011).

SANS 241-2:2011 describes how to implement management action plans and achieve numerical limits stated in part one. Five key elements are identified to establish compliance.

- 1) Water Quality Risk Assessment
 - Assessing water quality risk and documenting hazards from catchment to consumer
- 2) Routine Monitoring
 - Operational and compliance monitoring
- 3) Response Monitoring
 - Implementation of remedial action until water quality is once again compliant.
- 4) Verification of Water Quality
 - Calculating compliance
- 5) A Water Safety Plan
 - Integrated water quality management plans

3.4.2 Blue Drop System

To ensure that regulations are being met audits must be conducted to assess the sectors performance. According to section 62 of the Water Service Act (No. 108 of 1997) it is DWA responsibility to monitor water service institutions. Therefore the DWQF concept of catchment to consumer and proactive management of drinking water quality was developed further, when incentive based regulation of Blue Drop was introduced by DWA, in 2008. The unique South African incentive based regulation is based upon international best practice as well as the South African National Standards, SANS241. It encourages WSA to perform through acknowledging excellence in drinking water quality management. The Blue Drop was intended to turnaround non-compliant WSA's by making water quality information transparent to the public, increasing the accountability of water service institutions (Department of Water Affairs, 2011). Its aim was also to improve the relationship between the WSA and the WSP (Department of Water Affairs and Forestry, 2008).

An incentive based regulation is defined as:

'The conscious use of rewards as well as penalties to encourage performance excellence and continuous improvement, based upon an innovative performance rating system' (Department of Water Affairs, 2011).

Participation in the Blue Drop assessment is mandatory. Withholding information, the provision of false data or the refusal to provide information is illegal according to Section 82 of the Water Service Act (No.108 of 1997) (Department of Water Affairs, 2011). If WSA have serious non-compliance with water quality standards and public health is at risk, DWA will intervene. If there is still failure to improve water quality management and negligence or incompetence is detected then the WSA will be awarded a Red Drop status. This is part of the enforcement protocol and highlights the municipalities' failure to adhere to regulations (Department of Water Affairs and Forestry, 2008).

The Blue Drop certification program assesses water service institutions (WSI) according to key performance areas (KPAs). Previously there were nine KPAs (for years 2009, 2010, 2011), but the 2012 Blue Drop system only has five KPAs. Each year the percentage of contribution of each KPA may vary. There are also bonus as well as penalty points that can be applied which will affect the Blue Drop score (BDS) (Department of Water Affairs, 2011).

Table 1: Weighted requirements of Drinking Water Criteria from 2009 (year 1) to 2011 (year 3) (Department of Water Affairs and Forestry, 2008)

	Criterion	KPA Percentage		
		Year 1	Year 2	Year 3+
1	Water Safety and Security Plan	0	5	10
2	Process controllers	10	10	10
3	Drinking water Quality Monitoring Program	20	15	10
4	Drinking Water Quality sample Analysis	10	5	5
5	Submission of Drinking Water Quality Results	10	5	5
6	Drinking Water Quality Compliance	30	30	30
7	Management of Drinking Water Quality Failures	20	15	15
8	Publication of Drinking Water Quality Performance	0	5	5
9	Drinking Water Asset Management	0	10	10

Table 2: The new Five Drinking Water Criteria, for 2012 (year 4) to 2014 (year 6) (Department of Water Affairs, 2011)

	Key Performance Area	KPA Percentage		
		Year 4	Year 5	Year 6
1	Water safety Planning	30	35	35
2	Drinking Water Quality Process management and Control	15	10	10
3	Drinking Water Quality Compliance	30	30	25
4	Management, Accountability and Local Regulation	10	10	15
5	Asset Management	15	15	15

A breakdown of the requirements of the key performance area and their relative contributions towards the Blue Drop can be viewed in Appendix 2, chapter 13.

The Blue Drop takes a holistic approach to water management and thus a low Blue Drop score (BDS) does not necessarily indicate unsafe water but rather that the management of resources could improve. The Blue Drop certification system aims to create transparency to the public on the management of the water. It is intended to improve public engagement and subsequently aids accountability of the WSA. All WSA are required to publish their results annually so that the public can have access to credible information. This information is currently available on the My Water website by DWA (<http://www.dwa.gov.za/mywater>) (Department of Water Affairs, 2011).

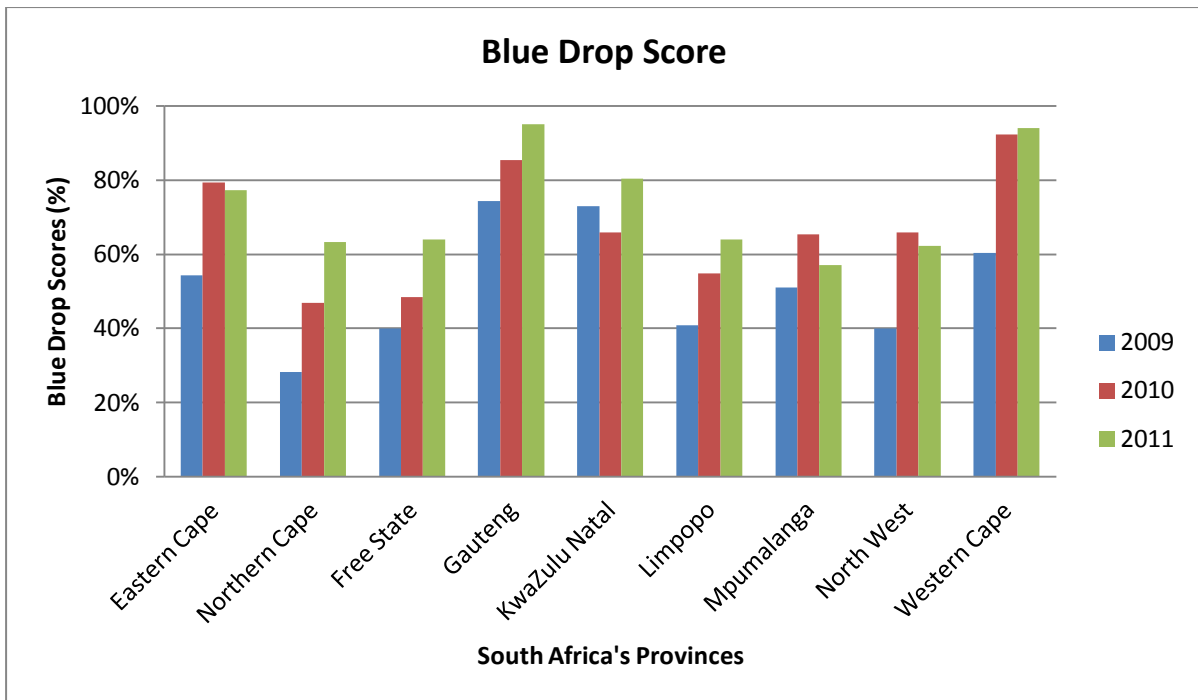


Figure 5: South Africa's Provincial BDS from 2009 -2011 (Department of Water Affairs, 2010; Department of Water Affairs, 2009; Department of Water Affairs, 2010; Department of Water Affairs, 2011)

The graph shows the general trend that the Provincial Blue BDS are increasing, with the exception of the Eastern Cape, Mpumalanga and the North West. These three provinces experienced a decline in BDS from 2010 to 2011.

The average National BDS has been steadily increasing over the last three years. In 2009 the average National BDS was 51.4 %, this increased to 67.2% in 2010 and reached 72.9% in 2011 (Department of Water Affairs, 2010; Department of Water Affairs, 2009; Department of Water Affairs, 2011; Department of Water Affairs, 2010). Microbiological compliance has improved from 93.3% to 97.5% and chemical compliance has increased from 98.9% to 99.5% between 2009 and 2010 (Department of Water Affairs, 2011). The number of drinking water supply schemes being assessed and awarded Blue Drop Certification has also increased over the three year period. In 2009 only 66% of the WSA were assessed. In 2010, 94% of the municipalities were being assessed and in 2011 all 162 municipalities were submitting data. The number of drinking water supply systems managing drinking water with excellence and achieving Blue Drop status has also been rising. In 2009, 23 water supply systems received the Blue Drop status out of the 425 water supply systems that participated. In 2010 this score increased to 38, despite 12 system losing certification and in 2011, 66 drinking water supply schemes got the prestigious award. The figures show overall positive trend in water

quality monitoring and management achievements (Department of Water Affairs, 2011; Department of Water Affairs, 2009; Department of Water Affairs, 2010).

The realisation of the importance of water safety plans in the programme has encouraged WSA to implement a preventative risk-based approach. In 2009 only 9 systems had WSPP in place whilst the 2010 results showed 154 systems included water safety plans into their planning process (Department of Water Affairs, 2011). The Water Safety Plan key performance areas are the only KPA whose percentage contribution to the BDS is increasing annually. In 2013 it will count 35% of the weighted criteria compared to the 0%, in 2009 (Department of Water Affairs and Forestry, 2008; Department of Water Affairs, 2011). Thus more focus has been placed on developing water safety plans, in order for WSA to improve their BDS.

University of Cape Town

Chapter Four

4 Monitoring

It has been established that effective management of drinking water quality requires an understanding of the entire supply system from catchment to point of use. The DWQF for South Africa focuses on a preventative risk management approach and recognises the importance of operational controls. Hazard identification, risk assessment and early warning limits are key to ensure safe reliable water supply. Verification monitoring must also be implemented to ensure protection barriers are working effectively. WSA are required to undertake operational and compliance monitoring as part of their water systems management role. Reliable, up-to-date water quality data can inform decision-making and help effective use of resources. It must be noted that monitoring is only one part of water quality management used to ensure continuous safe supply (Department of Water Affairs and Forestry, 2005).

4.1 Operational Monitoring

Operational monitoring is the measuring of parameters that will be used to predict and control output quality of drinking water being provided (Hodgson & Manus, 2006). The objectives are to ensure health based targets are being met through effective systems management. Each control measure identified should be monitored in a timely manner to ensure compliance or provide an opportunity for remedial action (WHO, 2004; Hodgson & Manus, 2006). Key parameters are monitored against numerical limits that are more stringent than the SANS 241 specification. This is done so that when warning limits are exceeded, short term corrective actions can be implemented. Process control can be regained before standard limits are exceeded. This preventative monitoring approach ensures safe, reliable drinking water is being provided (Hodgson & Manus, 2006).

Wherever possible, operational monitoring should be continuously undertaken using on-line testing devices of key parameters (Hodgson & Manus, 2006). This will allow output quality to be assessed on an ongoing basis and problems in the supply can be picked up immediately. Planning and documentation of preventative and corrective procedures must also be undertaken, as part of the operational monitoring process (Department of Water Affairs and Forestry, 2005). The five top key parameters of potable water quality, according to the Quality of Domestic Water Supplies are faecal

coliforms, electrical conductivity, ph, turbidity and residual chlorine from treating the water (Department of Water Affairs and Forestry, Department of Health, Water Research Commission, 2001; Department of Water Affairs and Forestry, 2001).

4.2 Compliance Monitoring

Compliance monitoring is a verification system and indicates the overall performance of the supply system. It should be implemented at all points in the supply system. Water at the treatment schemes must be monitored as well as in the distribution network and at the consumer supply points. Compliance monitoring assesses if all the barriers that are in place to purify water and prevent contamination, are working effectively and that public health is being protected (Hodgson & Manus, 2006). A limitation of compliance monitoring is that 'it promotes reactive management, rather than proactive preventative management, as corrective actions are initiated only after drinking water quality monitoring indicates that guideline values have been exceeded' (Department of Water Affairs and Forestry, 2005).

Table 3: Compliance Monitoring Frequencies for E.coli (or faecal coliforms) in distribution system (SABS, 2011).

1	2
Population served	Total number of samples per month ^a Minimum
< 5 000	2
5 000 to 100 000	1 per 5 000 head of population
100 000 to 500 000	1 per 10 000 head of population
≥ 500 000	1 per 20 000 head of population
^a During the rainy season, sampling should be carried out more frequently to ensure that all spatial and temporal risks are apparent.	

Sampling frequencies are based on the population served, volume of water supplied and incidence of failure. The frequency of sampling to obtain more data and information about the supply depends on the comparative cost/benefits. Microbiological contamination is directly linked to disease and is a health concern. Microbial monitoring should be conducted more frequently than chemical monitoring, as health-based risks are normally only associated with short term exposure compared to the long term exposure associated with chemical contamination. 'Sampling frequencies for water leaving treatment depends on the quality of the water source and the type of treatment' (WHO, 2004).

Compliance monitoring assesses the water quality data against the numerical limits specified in SANS 241-1. A full SANS 241 analysis should be conducted at least annually on all schemes (Department of Water Affairs, 2011). The more frequently the water is tested the more reliable the data, for concentrations of substances fluctuate (SABS, 2006). Average quality is based on the data collected over a one year period (Department of Water Affairs and Forestry, 2001).

Table 4: Microbiological determinants (SABS, 2011).

1	2	3	4
Determinand	Risk	Unit	Standard limits
<i>E. coli</i> ^a or faecal coliforms ^b	Acute health – 1	Count per 100 mL	Not detected
Cytopathogenic viruses ^c	Acute health – 2	Count per 10 L	Not detected
Protozoan parasites ^d <i>Cryptosporidium</i> species <i>Giardia</i> species	Acute health – 2 Acute health – 2	Count per 10 L Count per 10 L	Not detected Not detected
Total coliforms ^e	Operational	Count per 100 mL	≤ 10
Heterotrophic plate count ^f	Operational	Count per mL	≤ 1 000
Somatic coliphages ^{c,g}	Operational	Count per 10 mL	Not detected

^a Definitive, preferred indicator of faecal pollution.

^b Indicator of unacceptable microbial water quality, could be tested instead of *E. coli*, but is not the preferred indicator of faecal pollution. Also provides information on treatment efficiency and aftergrowth in distribution networks.

^c Confirms a risk of human infection and faecal pollution, and also provides information on treatment efficiency. The detection of selected viruses confirms faecal pollution of human origin.

^d Confirms a risk of infection and faecal pollution, and also provides information on treatment efficiency. The detection of selected protozoan parasites confirms a human health risk.

^e Indicates potential faecal pollution and provides information on treatment efficiency and aftergrowth.

^f Process indicator that provides information on treatment efficiency, aftergrowth in distribution networks and adequacy of disinfectant residuals.

^g Process indicator that provides information on treatment efficiency.

The Water must comply with the numerical limits given in the table above. If the microbiological test results exceed that of the numerical limits given in column 4, an unacceptable risk to health is implied. 'As the microbiological value increases, an increasing risk to health is implied' (SABS, 2011). *Escherichia coli*, faecal coliforms and total coliforms give an indication of the microbial quality of the water and its potential risk to human health.

If the alert levels of the bacteria are exceeded, immediate remedial action is required and non-routine follow up testing must be done until acceptable levels are once again reached (SABS, 2006). People particularly sensitive to infection due to the presence of faecal coliforms and total coliforms

within their drinking water, are HIV positive infected people, children under the age of 2 and individuals on immune-suppressive medication. In high concentrations 10 – 100 faecal coliform count per 100mls, clinical infections are common in all users and over 100 counts/100ml serious health effects in all users (Department of Water Affairs and Forestry, 2001).

Compliance monitoring should also take consumer complaints into account when assessing the satisfactory quality of the water. Consumer complaints must be logged, recorded and evaluated. Consumers are valuable information providers and can highlight potential problems in the water supply system (Hodgson & Manus, 2006).

4.3 Ground Water Supply

All four study sites rural water supply schemes are supplied by boreholes and a few springs. Ground water sources that are at sufficient depth and within confined aquifers normally provide good quality water. Shallow, unconfined aquifers are susceptible to contamination through sewage seepages and storm water flows.

Deep boreholes are microbiologically safe and chemically stable provided direct contamination has not occurred. Therefore the protection of ground water sources is vital to ensure safe water provision to the surrounding communities. By introducing control measures, the ground water sources can be protected from contamination. Control measures include a catchment management plan, which protects the ground surface and ground water sources from pollution. This is done through the control of waste and effluent, land use planning, diversion of storm water, intercepting and diverting run-off and introducing security to protect the boreholes. Control measures also include community awareness and education on the impact of their actions on the water quality.

All boreholes should be sealed and encased to a sufficient depth to ensure that contamination does not occur through surface run-off or shallow ground water seepage. 'The greater the protection of the water source, the less the reliance on treatment or disinfection'. Chlorine treatment is the most common disinfection process and is effective in killing bacteria and removing most viruses. Most supply systems require an adequate level of disinfection to ensure *safe* drinking water that is free of microbiological risk. Yearly sampling frequencies may be sufficient for stable groundwater sources where substances which occur naturally, have slow variation over time (WHO, 2004).

4.4 Field Test Kits

‘Water quality and surveillance in most developing countries is inadequate to test all drinking water sources regularly, this is largely due to poor laboratory facilities, widely spread water sources and resource crunch’ (Tambekar, et al., 2007).

‘Frequent examination by a simple method is more valuable than less frequent examination by complex tests or series of tests’ (WHO, 2004). In water supply systems where the majority of sample results indicate negative microbiological contamination, presence/absence (P/A) field test kits can be used. These tests allow more frequent testing of the supply due to their simple, fast, cost-effective method. P/A test allow for maximum detection of contamination within the supply, but are not as accurate as laboratory methods (WHO, 2004).

4.4.1 Hydrogen Sulphide (H₂S) Test Kit

The hydrogen sulphide (H₂S) test was used in the study sites to detect on-site faecal contamination of the borehole water supply schemes. The H₂S test was first developed in 1982 by K.S Manja and since then various modifications to improve the test have been carried out (Tambekar, et al., 2007). The microbiological field test produces hydrogen sulphide by bacteria linked with faecal contamination. A positive result of possible faecal contamination will be indicated through the medium of the test producing a black precipitate, as a result of the reaction of the H₂S with iron. This indication of colour change means that there is the possible presence of either total coliforms, faecal coliforms or specific faecal bacteria (E.coli) (Sobsey & Pfeander, 2002). The H₂S P/A test has a greater sensitivity than other faecal contamination tests (most probable number technique MPN and membrane filter technique MFT) and therefore a false positive may arise due to non-pathogenic bacteria creating hydrogen sulphide. For example sulphides can be reassessed from proteins and amino acids, therefore a number of sources can result in a possible positive H₂S test result (Sobsey & Pfeander, 2002).

The H₂S test kit is cost effective, easy to use and requires no need for technical staff. Its use is recommended for routine monitoring in small community supplies and villages, due to the limited skills, manpower and laboratory facilities in these environments (Tambekar, et al., 2007). ‘The H₂S strip test that permits the evaluation of the sanitary quality of water for small community water supplies has been tested and supported in a previous year by the Water Research Commission

(Report number 961/1/99)' (Genthe & Jagals, 2003). The H₂S test can be carried out at room temperature and is suitable in warm climate countries that have ambient temperatures between 25° - 44° (Tambekar, et al., 2007). The H₂S strip test has > 85% agreement when compared to faecal coliform tests normally used to assess water quality (Genthe & Jagals, 2003).

Although the H₂S test is simple to use and a fraction of the cost of standard laboratory test it is not recognised as a suitable test for detecting faecal contamination of drinking water. The sensitivity and uncertainties associated with the test are too great and false positives may arise due to sulphide produced by non-faecal bacteria or the presence of them in natural geological sources (Sobsey & Pfeander, 2002).

It has been recommended to use the H₂S test, for the detection of contamination, in areas where other regular water quality testing is not possible. The test does give a good indication of water quality but must be used with caution (Sobsey & Pfeander, 2002). It can be used to detect potential problems that may exist in the supply network, as well as indicate potential health risks. The early warning device can prompt investigation and remedial action, limiting the spread of contamination (Genthe & Jagals, 2003).

Chapter Five

5 Information Communication Technologies

It is believed that support can be provided to government through the application of Information Communication Technologies (ICTs). Through an increase in information flow, there can be more effective management and an improvement in service delivery. Information technology can be used to 'stimulate economic growth, increase productivity, create jobs and improve the quality of life' (Gichoya, 2005).

In the 1990s significant development changes took place. The internet was born as well as a formalization of the Millennium Development Goals (MDGs) in 2000. The potential of ICTs to help reduce poverty, improve health, education and gender inequality was realized (Heeks, 2009). Although technologies have been recognised as a tool to help achieve the MDG, there is still the challenge of the *digital divide* between developed and developing countries. The *digital divide* with regard to ICTs is the difference 'between those people with access to technologies and the ability to use them effectively, and those without' (Walsham & Sahay, 2005).

Odedra (1993) in Gichoya's paper: Factors Affecting the Successful Implementation of ICT Projects in Government, argues that most ICTs, with the exception of the mobile phone, are more easily implemented in Western countries where there are adequate resources, skills and infrastructure. It is believed that ICTs can be developed to increase economic growth and improve quality of life (Gichoya, 2005). Infrastructure and internet connectivity in poor communities often remains inadequate, adding to the technological gap. Not only is the network coverage important as well as roads and electricity supply, but the level of education and capabilities of the community play a large role in the sustainability of ICTs projects. 'Solutions of technological problems thus need to be seen in conjunction with other physical constraints, and of course with human capabilities' (Walsham & Sahay, 2005). Governments thus need to focus on reliable service delivery, otherwise the disadvantaged will suffer further through a widening of the divide (Kleine & Unwin, 2009).

5.1 Review of ICTs in Developing Countries

ICT projects often fail in developing countries due to the *Global North* replicating successful Europe and North America projects in developing regions (Heeks, 2009). Pre-existing *blueprint* designs are often implemented and the poor are expected to adapt to them. Invention-down approaches fail due to there being no understanding of the local context and existing technologies. Failure of invention-down projects also occurs because designers focus on what they believe are the needs of the community rather than determining what the people's needs and desires are. The systems implemented may work technically, but fail to make a development contribution due to the gap in understanding the developing countries resources, capabilities and demands of the poor (Heeks, 2009).

'Universal solutions are unlikely to be successful in multiple locations spanning different social, political, institutional and strategic contexts. There is a need for a pragmatic balance between global standards and local needs' (Walsham & Sahay, 2005).

Success of ICT projects is based on local stakeholders and beneficiaries participating in the design of the project, which must match local development goals (Heeks, 2009). The ICTs design must also be based on lessons learnt from previous projects. There must be flexibility and an on-going improvement to meet local needs. Local capacities and capabilities must also be taken into consideration as well as the competency of the leadership. An appropriate technology must be chosen that suits the local realities. All risks must be identified as well as financial and social sustainability evaluated. To ensure sustainability it is important for projects to be locally owned (Heeks, 2009).

From the beginning of a project, sustainability issues must be addressed. Therefore a new emphasis has been on longitudinal implementation and design rather than the off-the-shelf quick fix solutions (Heeks, 2009). The operation and maintenance costs of the project must also be at a rate affordable to the beneficiaries, particularly when dealing with poor communities (Kleine & Unwin, 2009).

Scaling ICTs projects and ensuring sustainability is very difficult. Failure of trying to turn a pilot project into development stages often results, due to: financial constraints; operation and maintenance issues; shortages of skills or high staff turnover. In order to design for sustainability,

members of the Technology and Infrastructure for Emerging Regions (TIER) suggest three important aspects must be considered: 'optimisation of an existing system, financial self-sufficiency, and operational self-sufficiency' (Surana, et al., 2008).

Building onto and improving existing systems helps buy-in from community members into using the new system. The importance of current systems is often understood by locals and optimising them reduces the chance of neglect and failure. All systems must also have financial self-sufficiency. Start-up cost can be subsidised, but the operation and maintenance cost must be recovered, in order for systems to be sustainable. All systems operation and maintenance must also be able to be carried out by the local community. Hardware must be durable enough to resist the local conditions and software must be easily managed. There must also be a tool for experts, removed from the situation, to manage and support remote systems (Surana, et al., 2008).

5.2 Design - Actuality Model

High failure rates of IS projects are believed to result due to a lack of understanding between the IS designer and the current realities. Evidence suggests that failure rates in developing countries are higher than those in industrialized countries. Reasons for this are the resource constraints, lack of infrastructure, technology and human capacity (Heeks, 2002).

Heeks categorises IS system outcomes, in developing countries, into three groups indicating the degree of success or failure of a system.

- 1) **Total failure** of a system never implemented or in which a new system was implemented but immediately abandoned
- 2) **Partial failure** of an initiative, in which major goals are unattained or in which there are significant undesirable outcomes. Associated with partial failure is the **Sustainability failure** of an initiative that first succeeds but is then abandoned after a year or so.
- 3) **Success** of an initiative, in which most stakeholder groups attain their major goals and do not experience undesirable outcomes' (Heeks, 2002).

There are high opportunity costs associated with failure. Heeks suggests that developing countries will suffer greatly if failure occurs due to their limited capital, skills and resources. Based on his assessment, a widening of the digital divide gap and an increase in global inequality with regards to technology could be a possible outcome (Heeks, 2002).

Heeks suggests that in order to address the failure of IS projects the design–actuality gap must be minimized. ‘The greater the change gap between current realities and the design concept (i.e. requirements and assumptions), the greater the risk of failure’ (Heeks, et al., 1999). According to Heeks there are two types of design-actuality gaps that affect IS adoption. There is the gap in understanding the countries local context and the hard-soft gaps between technology and behavioural actualities (Heeks, 2002).

Problems arise according to Heeks when the IS designer is not locally based. When IS designers from industrialised countries are trying to create for developing regions, the remoteness of the designer makes it difficult to understand the physical, cultural and economic situation that they are designing for. Often assumptions are made about the users in terms of their skills and objectives. This frequently results in design-actuality gaps. ‘The greater the degree of change, the greater the risk of failure’ (Heeks, 2002).

Local improvisation and end user development are suggested as one way to ensure small design-actuality gaps and improve success rates. By using participative approaches and involving the end user in the IS design and implementation, local capabilities can be realised. The information needs, objectives and values of the benefiter can be highlighted and designed for (Heeks, et al., 1999; Gichoya, 2005). ‘An ICT project implementation can only be perceived to have succeeded if the perceived benefits are realised’ (Gichoya, 2005).

Design – actuality gaps between *hard* technological systems and *soft* organisational context may result in failure. IS are considered *hard* models, for they are designed according to logic, rationality, formality and objectivity. They often do not take into account the *soft* behaviour actualities. *Soft* realities are social objectives, human limitations and politics of organisations. Customised IS is important, for it is designed to the individuals unique requirements and takes the *soft* realities into account. It also involves end-user input which has already been highlighted as an instrument for success (Heeks, 2002; Heeks, et al., 1999). Technology must be seen as a *tool* and as part of a multi-dimensional process in helping achieve development objectives (Heeks, et al., 1999).

Heeks created a seven themed model to help identify the design-actuality gap in Health Care Information Systems (HCIS) (Heeks, et al., 1999). Through assessing each step and rating the mismatch between design concepts and on the ground realities the likelihood of failure can be assessed

(Heeks, 2002). According to Heeks the seven themed model can be equally applied to other fields besides health, in developing countries (Heeks, 2002). The model was used in this dissertation to assess the impact of information flow, provided by a mobile phone, on the management of rural water supply quality. An assessment of each of the following seven themes took place.

- Information
- Technology
- Process
- Objectives and values
- Staffing and skills
- Management and structure
- Other resources: money and time

Figure 6: The seven themes of the Design- Actuality Model

A detailed description of the seven themes and how they were used to analyse the study data will follow in chapter 0.

5.3 Mobile Technology in Developing Countries

Taking into account the hard gaps in the technology and soft realities on the ground, mobile phones were chosen as the communication device for this study. Initially acceptance and utilization of ICTs in developing countries was slow (Banks & Burge, 2004). This mainly subscribed to technological costs, lack of infrastructure, lack of finance and logistic problems. The introduction of the mobile phone has been seen as a tool that can really benefit the poor and have sustainable use in developing countries. This is due to its relatively cheap costs, high demand, ease of network expansion and willingness of companies to invest (Banks & Burge, 2004). 'In 2006, the mobile became the first communication technology to have more users in developing countries than in developed ones' (Shackleton, 2007). In the developing world more than 800 million mobile phones were purchased between 2004 and 2007 (Shackleton, 2007). The mobile has helped *leapfrog* the digital divide. Due to their ease of implementation in developing countries, the mobile has helped people in rural settings have access to communication devices (Banks & Burge, 2004). Mobile phones are a technology accepted by most age groups. Little skills are required to navigate through the applications and previous projects have shown the ease of adoption. Research show that the

older generation, less familiar with technology may be limited in using cellphones, but there is a greater chance of use of mobile phones than the internet (Blake, 2008). One of the benefits of the mobile is distance monitoring. 'Mobile phones are widely accessible and appear to be an efficient method of communication' (Blake, 2008).

In 2004, the estimated number of mobile users globally was 1.325 billion. In Africa the number of subscribers increased from 625,000 to over 67 million in the ten years between 1995 and 2005 (Banks & Burge, 2004).

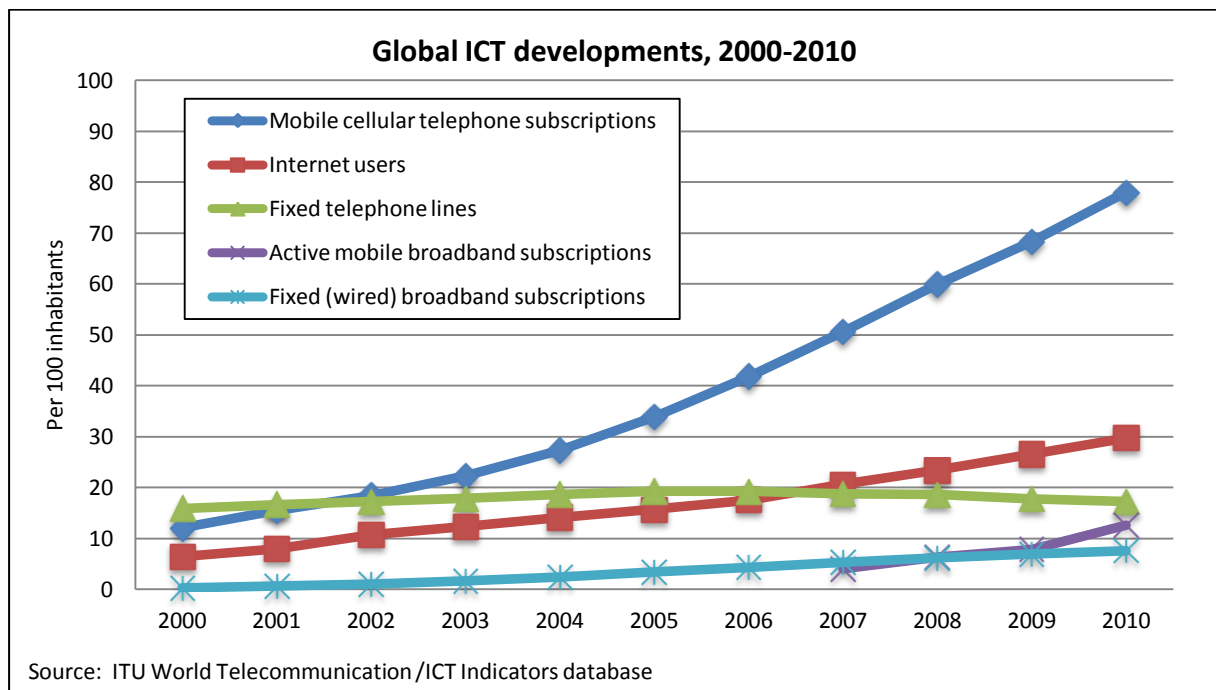


Figure 7: Global trend in ICTs between 2000 and 2010

The figure above shows that mobile technology is the fastest growing ICT throughout the globe.

The cellular growth rate in Africa was reported to be higher than any other region in 2004, as it has been since 1999. In 2004 there were 76 million mobile users compared to only 24 million fixed line users (World Summit on Information Society, 2005). The large number of mobile subscribers in Africa is due to a number of factors. African culture is enriched with oral story-telling and values communication. There are also cheap pay-as-you-go sim cards and recyclable handsets available, which allow poor members of society to be connected (Banks & Burge, 2004).

In South Africa there are three dominant service providers, Cell C, Vodacom and MTN. The government ensures cell coverage throughout the nation by requiring the cell providers to extend networks in rural locations and provide public phone booths (Banks & Burge, 2004). As a result 90% of the country has relatively cheap cellphone coverage and 96% of the population lives within areas of mobile signal (Shackleton, 2007). Due to the wide wireless coverage in South Africa, mobiles are a good option for rural development. Mobile phones also have the advantage of being supplied in different languages, for example Cell C provides customers with services in the 11 official languages in South Africa (Banks & Burge, 2004). In 2007, there were 30 million cellphone subscribers in South Africa (Shackleton, 2007).

5.3.1 The Mobile Phone as an Application for Information Flow

In order to improve information flow, to assist with distance monitoring and the management of the rural water supply schemes, an appropriate ICTs technology had to be chosen as the communication device. The countries physical constraints and available infrastructure as well as the culture and human capabilities in the study sites were taken into consideration (Walsham & Sahay, 2005). The mobile phones high demand and ease of implementation, due to most of South Africa having mobile coverage (Shackleton, 2007), made it the technology of choice to facilitate information transfer in the iComms Reporting project. Mobile phones are also suited to the study environments due to their relatively durable hardware and low operational costs (Heeks, 2009; Kleine & Unwin, 2009). These sustainability factors facilitated implementation and adoption of technology, which impacted on automated information flow.

It was important to ensure that the information being provided by the mobile phone was relevant and useful to the beneficiaries (Heeks, 2009), which were the municipal managers in the different study sites. Therefore the municipalities participated in the designing of the iComms reporting tools. Flexible and unique questions were developed for each study site to ensure that the information being provided addressed the management issues raised by each of the municipalities (Heeks, et al., 1999; Heeks, 2002). It was important that the UCT iComms IS designers were indigenous to South Africa and therefore had a good understanding of the local context in which they were working (Heeks, et al., 1999).

Chapter Six

6 iComms Reporting System

A social-technical approach as well as an iterative and incremental process was used in the designing of the ICTs software. The iComms team believed that ‘those who will be affected by a system should to some extent be able to guide its development’ (iComms, 2011; Mumford, 1995). Therefore stakeholder analysis was conducted. Municipalities’ expectations as well as the iComms team intent were discussed at the outset of the project. The main problems established were not ones relating to water quality but rather to accountability and support. All interviewees stated that they had difficulty tracking what was happening on-site, identifying problems and supporting the supply caretakers (also referred to as borehole operators).

The discussion confirmed that a tool was needed to help improve information flow between supply caretakers in remote locations and the responsible WSA. The iComms team developed three reporting tools, the WQR, WQM web and WQM mobile, to assist with:

- ‘Improving communication between borehole operators based in communities and the responsible WSA
- Supporting borehole operators so that they are able to carry out operational monitoring procedures
- Collect reliable and up-to-date information about the water quality supplied to consumers’ (iComms, 2011)

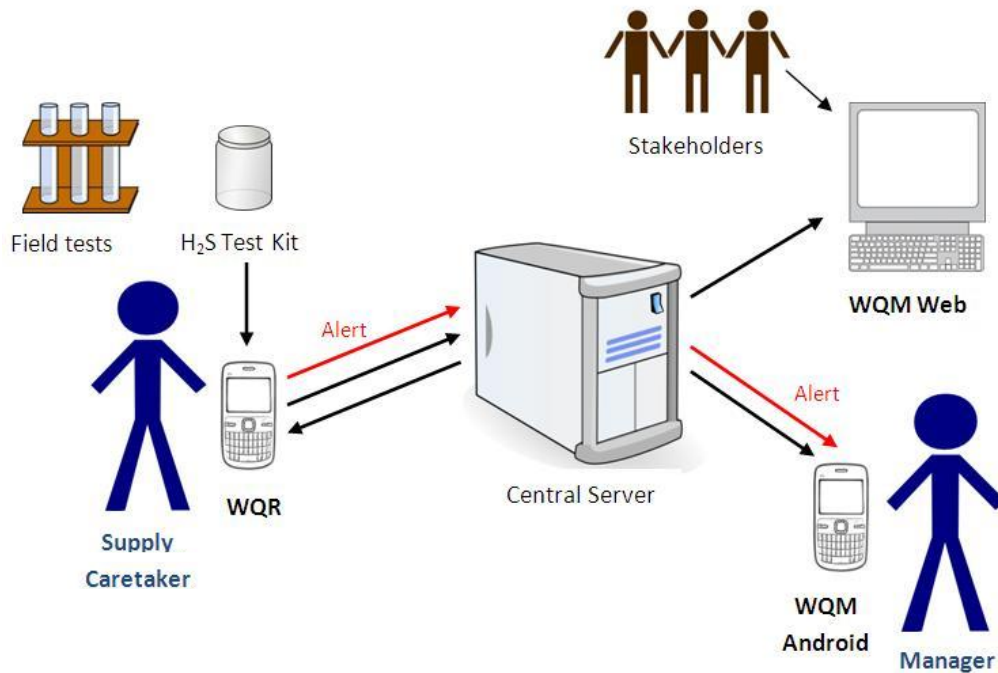


Figure 8: The Reporting system flow overview, red arrows indicate non-compliance

On site supply caretakers are equipped with basic cellphones containing the WQR application (described in chapter 6.1). This allows them to record and transfer water quality results to management. Weekly the supply caretakers would check the rural water supply schemes for microbiological contamination, with the use of an H₂S field test kit. The H₂S test results along with any other operational parameters being tested would be recorded onto the WQR application. Forms would then be submitted to a central server, hosted by UCT. Here results would be verified, checked against regulatory values and stored. Supply caretakers would then receive a conformation sms back to inform them that their data transfer had been successful. This is important for it facilitated reporting and an increase in information flow, for it assured them that their work is important.

Data stored on the UCT server was accessible through the WQM applications (described in chapters 1.2 and 6.3). The municipal managers are able to receive real-time information, via the WQM application, and create feedback loops on what action is to be taken. The WQM web-base system allows stakeholders involved to access and monitor the systems progress. The WQM android was designed to give municipal managers an overview of the rural water quality data collected. It enables the municipal mangers to access their rural water quality results on a 24hour basis wherever they are.

The black arrows in the reporting system flow overview (figure 8) illustrate the flow of information when results were within the compliance standards, whilst the red arrows illustrate information flow

when there is non-compliance, results falling outside of acceptable limits. The same process is followed for failures, but an extra alert sms will be received by management when an H₂S test fails, to inform them that there are problems onsite that they must immediately attend to.

Each reporting tool was developed using an iterative user-centred design methodology. 'Iterations over several cycles of development make it easier to define and redefine requirements, which users are often initially not able to articulate in a way that software engineers will understand' (iComms, 2011; Brooks, 1987). Two to three design iterations were implemented over time, each reviewing the software and making changes to meet the needs of the user. The long implementation time allowed for longitudinal observations and a relationship of trust was established between the iComms research team and the municipalities (iComms, 2011).

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6.1 Water Quality Reporter (WQR)

The WQR was designed to be used in a rural setting by on-site borehole operators, also referred to as supply caretakers. It is a mobile phone application that allows water quality data collected in the field to be loaded and transmitted to the WSA. The WQR was designed to build onto existing practice in the municipalities where operational monitoring was already being conducted. Here the borehole operators were recording water quality test results into log-sheets located at the supply sites. In these municipalities, the need to record and report data was clearly understood by on-site personal, which facilitated reporting and information transfer. Operational parameters normally tested onsite include ph, turbidity, electrical conductivity, free available chlorine and in this case H₂S. WQR forms may require information on each of these aspects to be filled out as well as other customised questions can be answered for instance, *is the water running*. Data is then transmitted to a central server via GPRS. All water quality data submitted to the server can be accessed through the WQM applications (iComms, 2012).

‘A typical WQR user session proceeds as follows:

- Select sample point/site to collect data for using navigator keys and menus (figure 9)
- Select form to be filled in using navigator keys and menus (figure 10)
- Answer form questions as prompted, using the keypads (figure 11)
- Confirm form inputs and submit to WQM (or save it to sender later if there is no network coverage) (figure 12)’ (Champanis & Rivett, 2012)



Figure 9: Form Select + Menu

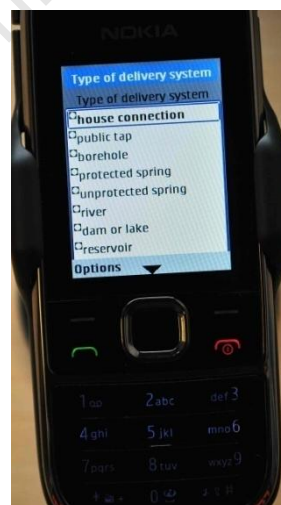


Figure 10: Sample Point Collection

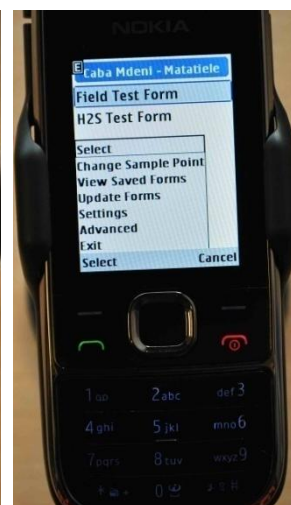


Figure 11: Questions

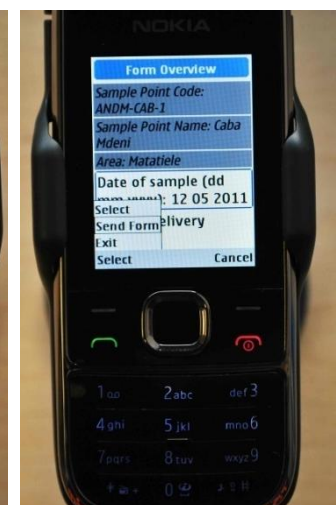


Figure 12: Sending Forms (iComms, 2011)

6.2 Water Quality Manager Web (WQM Web)

The WQM web application was designed so that all relevant stakeholders and authorities could access the water quality results and stay informed. It was also intended to be used by the municipal managers to organise and manage their site information. Reports on data collected, results per operator or results per site are set up on the WQM. There is also a Google Maps feature that gives an overview of all sample points and a pop up feature showing their compliance (Google maps is familiar to most web users and was therefore chosen to support this feature). Data is constantly updated with each submission of the on-site operators' reports.

WQM | Water Quality Manager

Demo domain (sample data) **Map View** [Search Reporters](#) [Admin](#) logged in as guest [Change Domain](#) [Logo](#)

Demo point 5 / Demo area 1
 Reporter: Michael
 Latest test result: (2011-03-14)

Point Type	H2S
ground	pass

Compliance:
 Insufficient data

Result summary:

Turbidity			Electrical conductivity			pH			Free chlorine		
min	max	avg	min	max	avg	min	max	avg	min	max	avg
0.30	71.10	10.93	0.20	7.49	2.19	2.43	8.10	7.41	0.00	0.40	0.21

2011-08-01 to

Demo area 1

- [Demo Point 1](#)
- [Demo Point 2](#) (no coords)
- [Demo Point 3](#)
- [Demo Point 4](#)
- [Demo Point 5](#)

Demo area 2

- [Demo Point 6](#)
- [Demo Point 7](#)
- [Demo Point 8](#) (no data)
- [Demo Point 9](#)
- [Demo Point 10](#)

[Select All](#) / [Select None](#)

Report Type:

- Full Report
- Site test counts
- Reporter test counts

2011-08-01 to

Sample point has data Sample point has no data Sample point not selected for reporting

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Figure 13: WQM Map View (iComms, 2011).

6.3 Water Quality Manager Android (WQM Android)

Municipal managers spend large amounts of time out of the office and on the road. Through feedback sessions it was discovered that a potable reporting tool would be better suited to the life style of the rural municipal manager. In May 2011 the WQM mobile android application was implemented in all study sites. This is a read only application which gives an overview of all water quality data available on the WQM web application (iComms, 2011). The HTC Desire mobile phone was chosen to host the WQM application. Other smart phone and tablets can also host the WQM mobile application (iComms, 2011). Through the WQM mobile, managers are able to view their rural water quality results whilst being *on-the-run*. There are many data views available on the phone to help manage the results.



Figure 14: Choosing Area

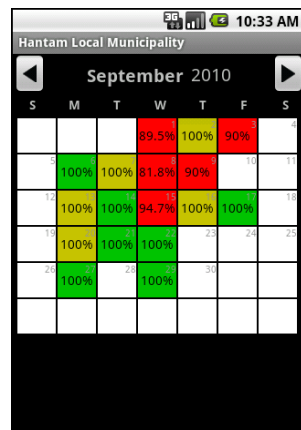


Figure 15: Calendar View

Hantam Local Municipality: 2010-09-15			
Compliance: 94.74%			
Sampling Point	Town	Parameter	Value
Brandvlei Water Treatment	Brandvlei	h2s	negative
Calvinia Storage	Calvinia	chlorine	0.48
Calvinia Storage	Calvinia	ph	7.52
Calvinia Storage	Calvinia	turbidity	0.56
Calvinia Storage	Calvinia	conductivity	0.18
Calvinia Storage	Calvinia	h2s	negative
Calvinia Water Treatment Works, Final	Calvinia	chlorine	0.5
Calvinia Water			

Figure 16: Day Detailed View



Figure 17: Map View (iComms, 2011)

A calendar view, figure 15, gives a summary of each town per month. Through this application the previous months results can be viewed and patterns identified. Further drill-down to each day provides a view on the individual parameters recorded and their compliance. A Google maps view on the phone provides locations of all sample points and colour codes their compliance (based on a 30 day rolling window) (iComms, 2011; Champanis & Rivett, 2012). The different colours on figure 15 serve as a traffic light system with green being a pass, yellow being data in acceptable ranges and red being failures of the allowable ranges (Champanis & Rivett, 2012).

6.4 Obtaining the Software

The system was designed to facilitate information transfer in order to help rural municipalities monitor and manage their rural water quality and increase communication. In these environments resources as well as budget are limited, so cost effective solutions are vital. 'Governments are becoming reluctant to use software that they cannot modify internally or where they are required to pay annual licence fees. To ensure sustainability and a successful handover of our software to government it was important to provide open-sourced solutions' (iComms, 2011). The WQR, WQM web and WQM android software is all available for free online under various open-sourced licenses. To attain the software refer to appendix 1 (chapter 12.3) for the download links.

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Chapter Seven

7 Description of the Four Study Sites



Figure 18: A Map of South Africa's Provinces (Theodora's Map Store, 2006)

There is an estimated 49 991 300 people residing in the nine provinces of South Africa. The largest province in the country geographically, is the Northern Cape Province followed by the Eastern Cape Province. It was in these two provinces that the four studies sites for this dissertation were located. Hantam Local Municipality is located in the Northern Cape Province, whilst Chris Hani, Alfred Nzo and Amathole District Municipalities are located in the Eastern Cape Province.

7.1 Hantam Local Municipality (HLM), Northern Cape

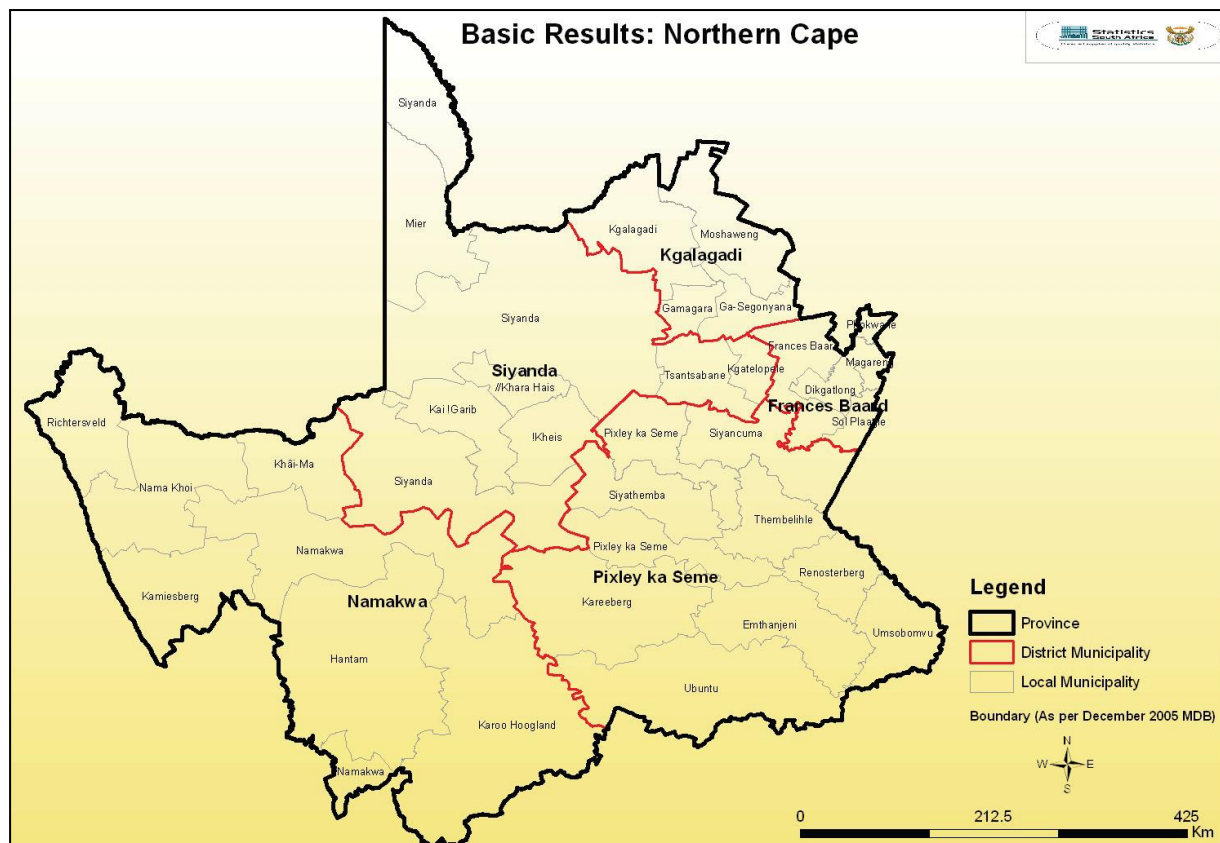


Figure 19: A map of the Northern Cape showing district and local municipalities (Statssa, 2007).

The Northern Cape consists of 5 district municipalities and 31 local municipalities and district management areas. Hantam Local Municipality, which was our study area, is located in the Namakwa District in the Northern Cape (Statssa, 2004).

The 362 000 km² of the Northern Cape is home to 1 100 000 people, which is only 2.2% of the South African population (Statssa, 2010). In 2001 it was recorded that 83% of the population lived in urban areas in the Northern Cape and in the Namakwa District, which is higher than the national average of 56.3%. The province is made up of predominantly coloured people, 52% of the population, and Afrikaans is the language most spoken. Literacy levels for the province are the third lowest in South Africa at 83%. In the Northern Cape 16.5% of the population have a matric certificate and 6.1% have a higher level of education (Statssa, 2004). In 2010 it was reported that the unemployment rate was 24.3% for the Northern Cape (Statssa, 2011).

Urban area definition: An area that has been legally proclaimed as being urban. It includes a town, city or metropolitan area

Population group: Statistics South Africa (Stats SA) continues to classify people by population group, in order to monitor progress in moving away from apartheid based discrimination of the past. However membership of a population group is now based on self-perception and self classification, not a legal definition. In 2001, five options were provided based on the questionnaire. Black African, Coloured, Indian or Asian, White or Other (Statistics South Africa, 2001).



Figure 20: Hantam Local Municipality within the Namakwa District (Statssa, 2012).

Hantam Local Municipality (HLM) consists of five small towns: Brandvlei, Loeriesfontein, Nieuwoudtville, Middlepos and Calvinia. All towns are dispersed due to the historical farming structure. Calvinia is the main town and has a population of 15 000 people. Population densities in Hantam LM are extremely low with 1 person/km², which is lower than the provincial average of 3 people/km² and well below the national average of 40 people/km². There is a total population of 21 000 people residing in 26 000km² of the LM (Statssa, 2007).

The main economic income in Hantam LM is generated through agriculture and the farming of sheep, ostrich and cattle (iComms, 2011). In 2009 the HIV prevalence amongst antenatal clinic attendees, women aged 15-49, was 17.2% in the Northern Cape and 0% in the Namakwa District. Therefore the HIV prevalence amongst antenatal women in Hantam Local Municipality can be reported as 0% (Department of Health, 2010).

Education Statistics source from Population Census 2001. Education attainment for persons aged 20 years or older by province, S.A, 2004.

Unemployment rate: The unemployed are those people within the economically active population who:

- 1) Did not work during the seven days prior to the interview;
- 2) Wanted to work and were available to work within a week of the interview; and
- 3) Have taken active steps to look for work or start some form of self employment in four weeks prior to the interview (Statssa, 2006).

Economically active: Employed or unemployed persons (15 to 65 years of age) (Statssa, 2006)

HIV Statistics: Source HIV amongst 15 – 49 year old women attending public antenatal clinics. Confidence interval 95% (95% CI)



Figure 21: Hantam LM

Hantam Local Municipality is the WSA and WSP for its five towns. In the municipality it is the responsibility of the Department of Health to ensure safe water supply to the surrounding communities. Hantam's Department of Health is situated in Calvinia and is managed by the Water Service Manger, who was the contact person for this study. Due to Hantam being a small local municipality, the Water Service Manger has multiple responsibilities. He is head of the Social Department, runs the Department of Traffic, Sanitation and Library and is involved in environmental health. Water quality monitoring is only part of his many responsibilities and accounts for 7% of his time.

Hantam LM has a semi-arid climate due to its Karoo location (Property 24, 2012). Most of the precipitation in Hantam is received in winter. The annual average rainfall for the region is 146mm (Saexplorer, 2011) which is substantially below the 450mm/annum average rainfall of South Africa (CSIR, 2009). In Hantam Local Municipality water is a scarce resource with rivers running dry through most of the year

'The Challenge is to give enough water to the people and to maintain your boreholes'

Water Service Manager

and most of the water being provided is supplied from ground water sources. Calvinia is the only town that has a water treatment works (WTW), which according the Water Service Manger is currently not meeting the South African standards. All other towns are supplied by borehole water that is pumped into a reservoir and disinfected through chlorination. Boreholes are protected by fencing and microbiological contamination is rare. The problems experienced are the drying up of boreholes in summer, so management of the supply is vital.

7.1.1 Monitoring History

Prior to 2009 there was no monitoring plan implemented on the water supply systems. Ad hoc compliance monitoring was conducted approximately every 6 months and chemical samples were taken on an annual basis. In 2009, Hantam LM received instruments from DWA so that operational monitoring of pH, chlorine, turbidity and electrical conductivity could be undertaken on the water supply systems. In addition to this the municipality started compliance monitoring all their water supply systems monthly.

Due to the dispersed nature of the different towns and far travel distances from the main town Calvinia, operational monitoring is conducted by onsite supply caretakers. The supply caretakers of each town conduct the operational monitoring daily and record the results

Loeriesfontein 150km,
Middlepos 90km
Brandvlei 150km
Water Service Manager

in a logbook, located at the supply site. Every month the Water Service Manager visits each of the supply sites to carry out the compliance monitoring procedure. During this time the supply caretakers observe the procedures and report any problems experienced throughout the previous month. Communication through the different levels of management is good, with daily communication and monthly meetings. Despite this, supply logbooks and operational data deviations from SANS 241 numerical limits will only be recognised by management in the monthly site visits. Supply caretakers located at the sites have thus been trained to read and compare chlorine results to the SANS 241 specification of <0.5 mg/l (SABS, 2006), so that dosing can be adjusted accordingly to ensure adequate disinfection and safe supply.

Compliance monitoring procedures are conducted monthly in accordance SANS 241 frequencies, minimum of 1 drinking water quality sampler per 10 000 people served. A full SANS 241 analysis is conducted on all water supply schemes annually. A current challenge with compliance monitoring is the distance to the closest accredited laboratory which is 400km away in Cape Town. Bacterial water samples and blood samples from the local clinic are transported together by the Department of Transport to the National Health Laboratory Services (NHLS) in Cape Town. Chemical compliance samples are taken by the Water Service Manager to the Council for Scientific and Industrial Research (CSIR) in Stellenbosch. All samples are collected, cooled and transported to the relevant laboratory within 24 hrs, to ensure preservation of samples. Receiving feedback on compliance monitoring results can take up to ten days. Since compliance monitoring can only be done monthly, operational monitoring of water sources is vital in order to have a well functioning early warning system in place.

In 2009 UCT iComms team introduced the H₂S on-site-test kit and the WQR to the municipality. The municipality incorporated the tools into their existing operational monitoring practices. Daily, the supply caretakers would test the chlorine, ph, electrical conductivity and turbidity of the supply. Weekly, they would add the H₂S tests to their routine, to test for E.coli contamination. With the implementation of the WQR, the operational data results were recorded using the cellphone application as well as writing it in the site logbooks. The additional step of writing the results was done based on the requirements of the municipality to have written record, since the project was a research study. Although some additional work resulted due to the extra recording step, the workflows of the supply caretakers stayed the same. The only new concept that was introduced was the speed with which information provided by a supply caretaker could be accessed remotely in Calvinia.



Figure 22: Supply caretakers learning how to use the WQR on their cellphones (photographer Alayne Semler)

7.1.2 Drinking Water Quality Failure

When an H₂S test failed, the following protocol was adopted: An H₂S resample was taken to ensure the positive result was not a consequence of the incorrect sampling procedure (for instance dirty hands). If the H₂S turned black a second time both the Water Department and the Infrastructure Department were requested to investigate the cause of contamination. As an immediate step supply caretakers carried out the flushing of the taps and pipes to remove the contaminated water. Chlorine levels were then adjusted to ensure adequate disinfection and a H₂S resample was conducted. If there was still non-compliance a water quality laboratory sample was taken and sent

to the NHLS in Cape Town. The protocol adopted for the H₂S test did not vary substantially from the procedures generally adopted when water contamination occurs. If a contaminant cannot be immediately rectified the community is informed and *boil water* alerts are issued to the consumers. The specific area is informed through pamphlets and the local fire-brigade issues voice notices through its loudspeakers. If contamination occurs within the main town of Calvinia, the radio is also used to broadcast boil water instructions. It was reported that there are no resource deficiencies limiting the WSA from following through on remedial action, when it is required. Normally water quality is compliant again within 24hrs of identifying the contamination.

All reservoirs are chlorinated with hypo-chloride liquid, which is constantly delivered through a pumping system. If water quality failure occurs due to pump breakage, the 24hr maintenance team would be contacted. Each pump station has a standby pump that can be substituted when repair or maintenance needs to be conducted on the main pump. This ensures operation and compliance to drinking water quality standards are once again met in a timely manner.

7.1.3 Communication of Drinking Water Quality

Monthly drinking water quality compliance is communicated to the public through the DWA 'My Water' website, www.dwa.gov.za/mywater. Since only 6.1% of the households in the HLM have access to the internet other means of communication have also been established. The Water Service Manger stated that monthly adverts are placed in the local news paper stating the quality of the water being provided. Also the town of Calvinia has a notice board that reports the town's drinking water results for each month. Despite these efforts the municipality management indicated that it assumes the majority of the consumers to be unaware of the details of drinking water quality but that the overall perception of water quality by the population is *good*. All drinking water quality results are recorded and submitted by the Water Service Manager directly to DWA through the Blue Drop certification program.

7.2 Chris Hani District Municipality (CHDM), Eastern Cape

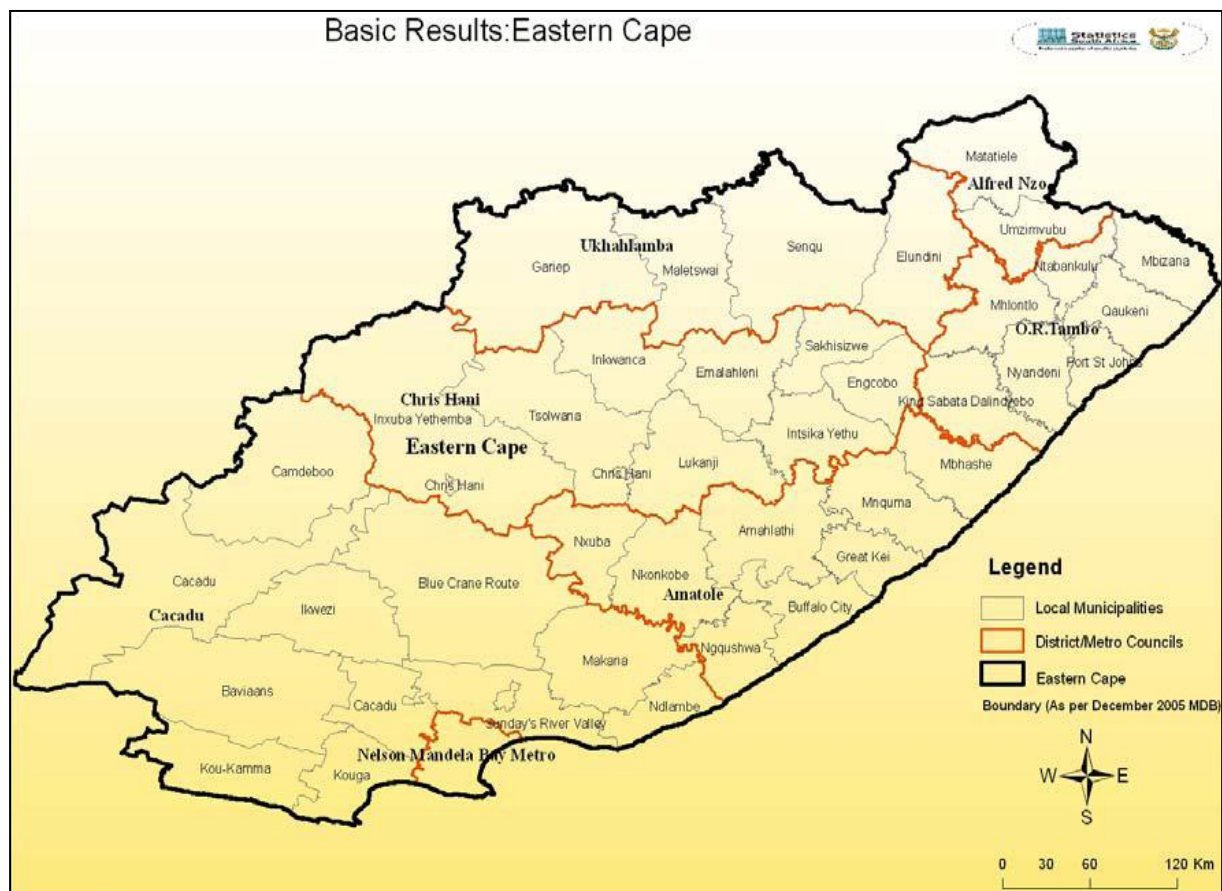


Figure 23: A map of the Eastern Cape showing District and Local Municipalities (Statssa, 2007).

The Eastern Cape Province comprises of one metropolitan municipality, Nelson Mandela Metro, 39 local municipalities and six district municipalities (Statssa, 2007). The province has a land area of 17 000km² and is home to 14.4% of South Africa's population, which is 6 500 000 people. The population is predominantly Black African, 86%, and isiXhosa is the predominant language (Statssa, 2006). Literacy rates in the province are 60.1%, which is significantly lower than the national average of 88.2%. Only 14.1% of the population has a grade 12 school certificate and only 6.3% have a higher education degree. Unemployment rate in the province is at 29.6% which is also higher than the national average of 26.2% (Statssa, 2006). HIV prevalence in the province has been increasing with 27.6% of antenatal women being infected in 2008 and 28.1% being infected in 2009 (Department of Health, 2010).

Population group

Statistics South Africa (Stats SA) continues to classify people by population group, in order to monitor progress in moving away from apartheid based discrimination of the past. However membership of a population group is now based on self-perception and self classification, not a legal definition. In 2001, five options were provided based on the questionnaire. Black African, Coloured, Indian or Asian, White or Other (Statistics South Africa, 2001).

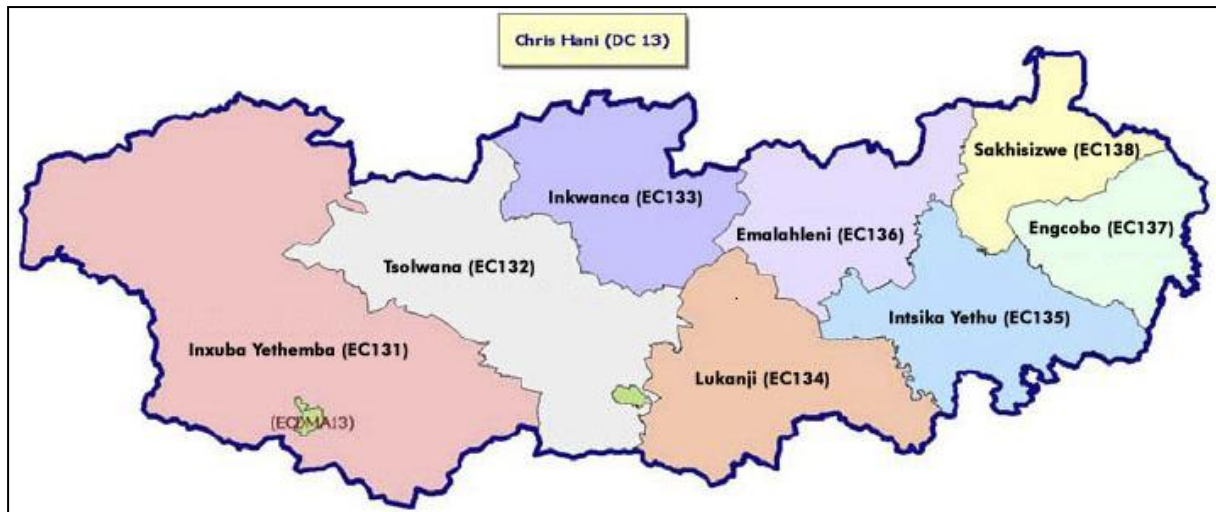


Figure 24: Map of Chris Hani District Municipality and its Local Municipalities (Tsolwana Municipality, 2009).

Chris Hani District Municipality covers an area of 37 000km² and has a population of 800 000 people (Chris Hani District Municipality, 2009/10). There are eight local municipalities Inxuba Yethemba, Tsolwana, Inkwanca, Lukanji, Intsika Yethu, Emalahleni, Engcobo, Sakhisizwe and one district management area (DMA), Mount Zebra National Park, within the CHDM borders (Chris Hani District Municipality, 2009/10). The historical setup of apartheid homelands resulted in a high number of population living in rural villages (Steele, 2009). Today 71% of the population of Chris Hani District reside in rural villages. CHDM landscape comprises of rural towns, Queenstown, Cradock, Middelburg, Elliot and Engcobo (former homelands) surrounded by commercial farms (Chris Hani District Municipality, 2009/10; Steele, 2009).

Unemployment rate: The unemployed are those people within the economically active population who:

- 1) *Did not work during the seven days prior to the interview:*
- 2) *Wanted to work and were available to work within a week of the interview; and*
- 3) *Have taken active steps to look for work or start some form of self employment in four weeks prior to the interview (Statssa, 2006).*

Economically active: Employed or unemployed persons (15 to 65 years of age) (Statssa, 2006)

HIV Statistics: Source HIV amongst 15 – 49 year old women attending public antenatal clinics. Confidence interval 95% (95% CI (Department of Health, 2010))

The Chris Hani District experiences vast temperature ranges between the seasons. Summer temperatures can reach 40°C, whilst minus temperatures are expected in winter. CHDM is situated on the watershed of 4 major rivers: the Great Fish River; the Kei River; the Mbashe River and the Orange River. The District receives a good annual average rainfall of 400mm, but droughts and dry spells can occur. CHDM makes use of both its surface water and ground water sources for supplying its communities (Chris Hani District Municipality, 2009/10). Approximate 73% of the Districts population has access to water services at minimum RDP standards (Steele, 2009). The service delivery backlogs are however still high due to historical structure of the communities and the limited capital funding (Chris Hani District Municipality, 2009/10; Steele, 2009).



Figure 25: Chris Hani DM (photographer: Alayne Semler)

Chris Hani District Municipality is the WSA for the entire District whilst the local municipalities are the WSP for their individual areas. The District Municipality is responsible for the compliance monitoring, whilst the local municipalities have the legal obligation of conducting operational monitoring on the water supply schemes. The Municipal Health Services (MHS) Department of Chris Hani Municipality is responsible for auditing the water quality. The Municipal Health Director (MHD) – who this study engaged with – has the responsibility of managing water quality in the District, but his responsibilities also include environmental health, HIV/AIDS management, fire services, disaster management and primary health care. 40% of his time is dedicated to water related issues.

RDP defined as basic water supply. 25 litres of potable water per person per day (or 6000 litres per household per month) within 200 meters of a household, which is not interrupted for more than seven days in any year; and with a minimum flow of 10 litres per minute in the case of communal water points (Department of Water Affairs and Forestry, 2002).

7.2.1 Monitoring History

The water quality compliance monitoring procedures are carried out by EHPs. Currently the District has 19 EHPs, with water quality testing only being one of their many responsibilities. They are also responsible for auditing air pollution, abattoir and meat safety, food, disposal of the dead and chemical safety. It has been reported that 60% of their time is dedicated to water quality monitoring. It was observed that EHPs similar to the managers have been assigned many tasks, which can result in other aspects of their work taking higher priority than water quality management and monitoring.

Compliance monitoring is complicated in CHDM due to the dispersion of the supply systems and the long travel distances to laboratories, which makes monitoring difficult and expensive. Prior to 2009 the closest accredited laboratory was in Port Elizabeth, which is 500km away from Chris Hani's Municipal head office in Queenstown. Sample turn-around-time was lengthy and could take up to five weeks before results were received. In 2009 a laboratory was established in Queenstown, which allows all water quality compliance monitoring samples to be analysed locally. Prior to the establishment of Chris Hani's laboratory, compliance monitoring was conducted on an ad hoc basis approximately once every quarter. Today the municipality takes an average of 200 samples per month. Despite the large amount of samples taken, it is estimated that 800 boreholes in rural areas have never been tested (iComms, 2011).

Local municipalities conduct operational monitoring on the WTW located in their main towns but not on the rural untreated borehole water. In the District about 80% of the water supply schemes are untreated according to an EHP. The rural water supply schemes that are treated are chlorinated manually with chlorine tablets or HTC floaters. The negative effects of this type of chlorination is that overdosing can easily occur which leads to the water having a bad taste and smell, which leads to the communities using alternative open water sources, such as rivers which may be contaminated. The EHPs test for chlorine when they conduct their monthly compliance monitoring.

In 2009 UCT iComms team became involved in CHDM. One of the reasons why the Government of the Eastern Cape identified CHDM as a pilot site for the iComms project was the fact that only 25% of the water sources within the District were being monitored (iComms, 2011). At the start of the project all relevant departments and the CHDM council were informed on the intent of the research

initiative. Presentations were given and all role players were involved with the development and implementation of the H₂S test kits and WQR within the District.

The H₂S tests were carried out on the borehole schemes, where the water had been pumped into a reservoir and chlorinated. At the time of the study, the borehole operators at the supply sites were employed by the local municipality. They had the responsibility of dosing the water and carrying out the H₂S test weekly. They were provided with cellphones containing the WQR, so that H₂S test results could be transferred to the WSA. Previously no water quality results were recorded at the borehole schemes due to their being no testing of on-site parameters.



Figure 26: EHP of Chris Hani taking a water sample (photographer Alayne Semler)

7.2.2 Drinking Water Quality Failure

After the implementation of the H₂S test, the following procedures were adapted in case of a failure. The supply caretaker was asked to inform the EHP of the failure. The EHPs would then visit the site and take a laboratory sample. The sample was analysed and results returned within 24 hours. The majority of failures usually occur due to insufficient chlorination. If the laboratory sample showed contamination, the Area Manager was informed to determine the cause of the problem. The EHPs would also inform the Ward Councillor and would conduct health and hygiene awareness in the affected community. All water quality failures were rectified within 24 hours. Prior to the implementation of the H₂S, WQR and WQM, there was no contact between the WSA and the supply

caretakers. Water Quality failures would only be identified through an increase in diarrheal cases at the local clinics or ad hoc compliance monitoring.

7.2.3 Communication of Drinking Water Quality

One of the challenges of the CHDM is that water quality failure is not formally reported to the community within 24 hours as legislation requires. If major failures occur over vast areas, warnings may be sent out over the radio. In the majority cases, water quality concerns are communicated verbally with ward councillors, community and traditional leaders contacting the relevant stakeholders. Communities usually meet with EHPs to discuss immediate measures such as disinfection of the water. The supply caretakers are also used to inform the communities and issue boil water alerts. Although the District has no formal lines of communication, strong community bonds are used to manage the risk.

Communication of water quality results between the WSA and the WSP are very good according to the MHD. Each month the WSA submits all its compliance and operational records to the Area Manager within the local municipality. The WSA compiles full reports of the Districts water quality and presents them to council and the standing committees on a quarterly basis. Water quality results are loaded onto the Blue Drop system monthly and published on an annual basis. The District realises that its reporting of monthly water quality compliance to the public is insufficient. The MHD indicated that the municipality is trying to make provision for the publication of water quality reports in the quarterly Chris Hani news letter and on its webpage.

7.3 Alfred Nzo District Municipality (ANDM), Eastern Cape

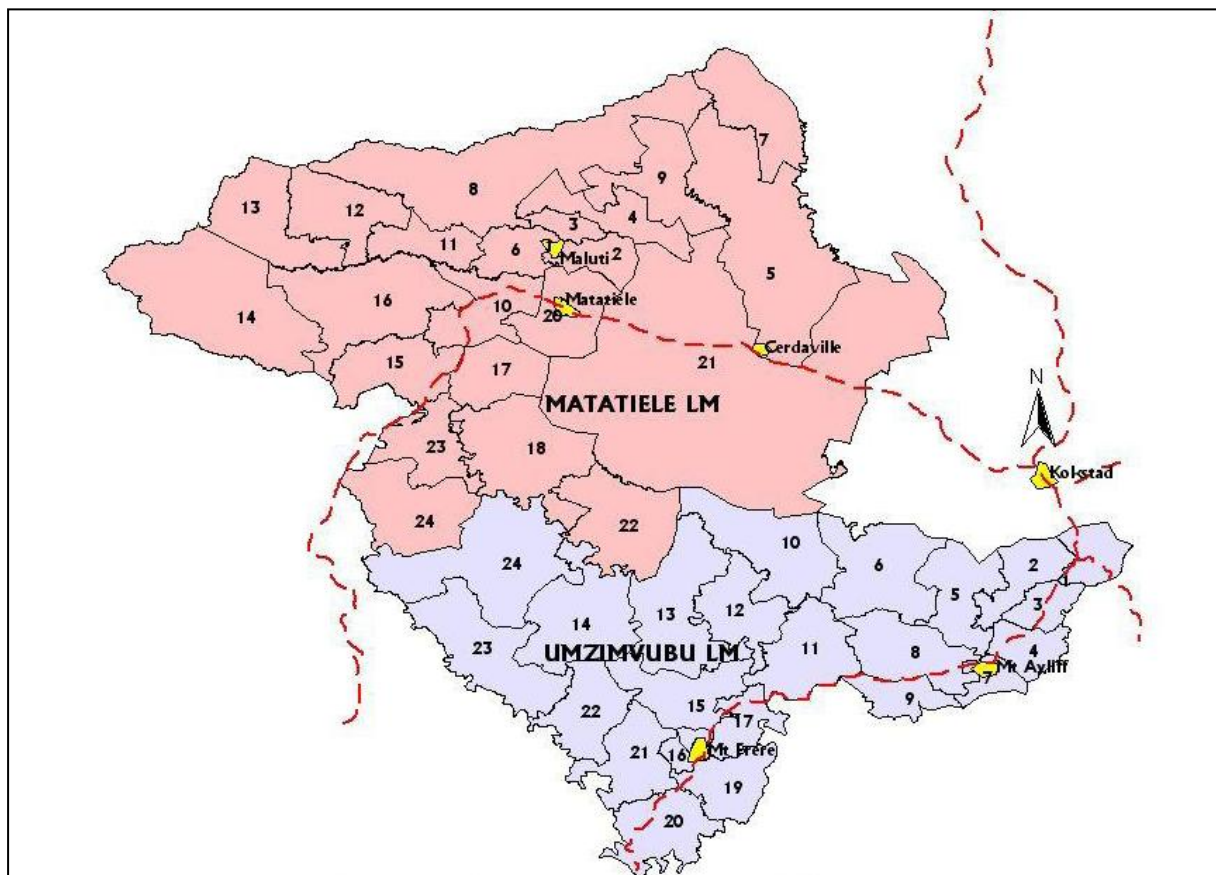


Figure 27: Alfred Nzo District and Local Municipalities (Alfred Nzo District Municipality, 2007-11).

Alfred Nzo District Municipality (ANDM) has a mountainous terrain with an area covering 7 000 km². It encompasses two local municipalities, Umzimvubu and Matatiele (Statssa, 2007). ANDM has high population densities of 60 people/km² (national average is 40 people/km²) and is home to 480 000 people (Alfred Nzo District Municipality, 2007-11).

This remote municipality has limited infrastructure and services due to it being a former apartheid homeland, the Transkei (De La Harpe, 2003). ANDM has no major urban areas and 94% of the population live in rural communities (Alfred Nzo District Municipality, 2007-11). The population structure reflects the history of apartheid, with the workforce migrating to mines and metropolitan areas, leaving the children with the elderly to care for them (iComms, 2011).



Figure 28: ANDM.

ANDM is the WSA and WSP for both its local municipalities. The iComms study implemented the H₂S and reporting system in Matatiele Local Municipality. The Assistant Director of Water Services was the iComms personal contact within the District but he left the position half way through the study and was not replaced before the study was finalized. His responsibilities were water and waste water service provision as well as water quality management, operation, maintenance and refurbishment of WTW and waste water treatment works (WWTW). The Assistant Director was a trained civil engineer and indicated that 70% of his time was dedicated to drinking water related matters.

Matatiele has an Area Manager, who is a Water Service Technician. She is responsible for managing the rural supply caretakers situated at the borehole schemes. Compliance monitoring of drinking water quality is the responsibility of the Department of Health. In Matatiele there is one EHP responsible for conducting the compliance monitoring on all boreholes and WTW. Both the Water Service Technician and the EHP have the duty to respond to rural water quality failures and implement remedial action. They work in close collaboration and used to report to their manager the former Assistant Director of Water Services.

Alfred Nzo District has an abundance of water supply within its borders, the entire District falls within the UMzimvubu river basin. There are four main rivers within the municipal area, the Tina River, Kinira River, UMzimvubu River and the Mzintlava River (Alfred Nzo District Municipality, 2007-11). Therefore the District is well resourced in terms of water supply. The area also receives a good average rainfall of 790mm/annum. Climate temperatures are milder than Chris Hani's and range from 7-10° in winter to 18-24° in summer (Alfred Nzo District Municipality, 2007-11).

Natural disasters are prone to the area, floods, hail and thunderstorms can be experienced in summer whilst velt fires are common in the winter months. Tornadoes and extreme erosion can also occur due to the adverse climate (Alfred Nzo District Municipality, 2007-11). The District suffers challenges in terms of water service provision, with only 58% of the District having access to water within RDP standards (Alfred Nzo District Municipality, 2007-11). The former Assistant Director reported that 40% of the population travel an average of 2 hours per trip to their water sources. Development of service delivery in the District is hindered by skill shortages, lack of financial resources and topographical layout.

7.3.1 Monitoring History

Most of the communities receive water from ground water sources. Spring and borehole water is pumped into reservoirs where disinfection takes place. All springs and boreholes are protected, with the pumps secured in pump houses, to prevent vandalism and limit contamination. Borehole operators located onsite use chlorine floaters and chlorine tablets to disinfect the rural water supply. Problems with this type of dosing is that the amount of chlorination depends on the level of water within the reservoir. There are no automated dosing systems in place and chlorine concentrations cannot be controlled.

Compliance monitoring used to be conducted monthly on all WTW and boreholes schemes. The EHP would take samples and send them to Mthatha laboratory, which is not accredited for SANS241 water samples. The analysis of the sample was at no cost to the municipality, due to the laboratory being government owned and the results would be received within a few days. Contamination of the borehole schemes would only be detected through the monthly test result since no operational monitoring occurred. When the Blue Drop system was implemented, the Districts focus turned to the WTW and the use of Mthatha's unaccredited laboratory became a problematic since it resulted in the District Municipality loosing points for using an unaccredited laboratory. Today all compliance monitoring samples are taken to the accredited Umgeni Water laboratory in Durban for analysis. Due to the increase in cost of sending samples away and use of a private laboratory, the District can now only compliance monitors its WTW. Umgeni Water tests for E.coli and total coliforms, neither chemical parameters are being analysed nor is a full SANS 241 analysis being conducted.

At the WTW operational monitoring is conducted daily. During the time of the study the H₂S test was the only operational monitoring procedure being conducted on selected borehole schemes. At these sites contamination of the rural water supply was checked weekly and H₂S test results were reported through the WQR application on the borehole operators' phones. The study started in 2009 in ANDM which was the same year the Blue Drop initiative took place and when compliance monitoring of rural sites stopped. During the time of the study microbiological alerts were identified through the use of the H₂S on-site test kit.



Figure 29: Supply caretaker of ANDM taking a water sample (photographer Alayne Semler)

7.3.2 Drinking Water Quality Failure

Rural supply systems experience fluctuations in turbidity. High turbidity can shield bacteria from disinfection and can cause contamination of the water. Contaminated water can sometimes be identified through the local clinics, when diarrheal cases increase. If an increase in diarrheal cases was reported or when an H₂S test failed during the study period, the following procedures were adopted. The failure was reported through the WQR and the Assistant Director was informed through the alerts on the WQM mobile application. The Assistant Director of Water Services would contact the Water Service Technician and EHPs to investigate the cause of contamination. The chlorine levels would be checked and increased if necessary. If there was a noticeable source of contamination, for instance a deceased animal in the proximity of the water source, then the pipes

would be flushed and the reservoir cleaned. The following day an H₂S test would be used to confirm if the remedial steps taken were effective. If a positive H₂S test indicating contamination results, the EHP would take a laboratory sample.

7.3.3 Communication of Drinking Water Quality

There is no regular reporting of water quality results to the consumers. Occasionally an article is posted in the local newspaper indicating the Districts drinking water compliance of the conventional schemes. The former Assistant Director believed that the lack of communication to the public reflected negatively on the Blue Drop system. Water quality failures are also not formally communicated to the public. If water quality failures occur, the ward committee, an elected body which represents community interests, will be informed by the Area Manager or EHP and they have the responsibility of distributing the warning. Chlorination of selected rural water supply schemes has only recently taken place, therefore the Assistant Director believes that the communities are not alarmed when warnings of poor water quality are distributed and only become concerned when there is an outbreak of disease.

The communities sometimes complain about the taste of the water, in cases where chlorine levels are too concentrated (which can happen because there is no automated chlorine dosing) or where the community is

'Sometimes they say there is too much chlorine and their tea does not taste nice'

Assistant Director of Water Services

not yet accustomed to the taste of the chlorinated water. When these problems arise the Water Service Technician will check the chlorine levels and adjust the dosing accordingly. The EHP will also conduct health and hygiene talks in the area, to educate the community on why their water needs to be disinfected. Otherwise, education is only given through presentations by the Area Manager and EHP when the municipality conducts its Integrated Development Planning programmes.

The District reports to government through the Blue Drop system only. The main challenge that the former Assistant Director identified in the reporting to Blue Drop, was administrative capacity. Maintenance and remedial action steps have never been recorded and there is often no proof as such that remedial steps were taken. The District also has no water safety plans in place which not only restricts their BDS but also limits the capacity to manage water

contamination. The limited human capacity and skills shortage required each municipal personnel to have multiple responsibilities which often resulted in priorities changing daily. The former Assistant Director felt that it was inappropriate for ANDM to be judged using the same criteria and standards that are used in well-resourced cities, where dedicated teams are responsible for water quality management.

University of Cape Town

7.4 Amathole District Municipality (ADM), Eastern Cape



Figure 30: Map of Amathole District Municipality (Amathole District Municipality, 2010/2011), Source: Urban-Econ Eastern Cape, 2009.

There are 1 670 000 people residing within the 23 600km² of the Amathole District. Population densities are stable at 69 people/km² (Amathole District Municipality, 2010/2011). Amathole District Municipality (ADM) is split into eight local municipalities: Mbhashe; Mnquma; Great Kei; Amahlathi; Buffalo City; Ngqushwa; Nkonkobe and Nxuba. The District is predominantly rural and is comprised of the former apartheid homeland areas of the Ciskei and the Transkei. ADM has large inequalities and little development has taken place outside of the main cities due to its historical structuring (Amathole District Municipality, 2010/2011).

ADM has a naturally diverse environment. Coastal temperatures range from 14 - 23° with more extreme conditions inland, 5 - 35° and winter snow being experienced on the northern mountains (ADM, 2009). Precipitation in the District ranges, the dry valleys receive 500mm/annum and the escarpments get an annual rainfall of 1000mm (Essential Amathole, 2012). The District has four main drainage regions within its borders: the Great Fish River Catchment; Amathole Catchment; Great Kei

River Basin; Mbashe River Basin. Although ADM is seemingly well resourced in terms of water supply, recurring drought conditions are common (ADM, 2009).



Figure 31: Amathole DM (Photographer Alayne Semler)

ADM is the WSA and WSP for seven out of its eight Local Municipalities. Buffalo City Local Municipality is its own WSA and has the responsibility of providing water to the City of East London. Due to the vast area that Amathole District covers, management of the District is split into

Eastern Region: Mbashe & Mquma LM
 Central Region: Amahlathi LM
 Western Region: Ngqushwa, Nkonkobe & Nxuba LM
 Water Care Manager

three regions. The WSA division allocates the responsibility of compliance monitoring to Amathole's Department of Health, whilst its WSP sector is responsible for the operational monitoring of WTW and WWTW. The management person that the iComms team dealt with in the municipality was the head of the Water Care Unit for the Eastern and Central regions within the municipality. The Water Care Unit falls under the Operation and Maintenance Division within the WSP sector. Thus the Water Care Manager (WCM) has the responsibility of ensuring that all the WTW and WWTW comply with SANS 241 operational parameters. He also is responsible for the rural water supply.

Amathole District has many challenges, especially in terms of service delivery. Although 89.95 % of ADM population have access to water at RDP standards, the delivery of water service infrastructure has been problematic. Most of the WTW and WWTW are dilapidated and have reached their design life. The poor road conditions and a high percentage of non-revenue water make refurbishment and upgrades a challenge (Amathole District Municipality, 2010/2011).

7.4.1 Monitoring History

In 2005/2006 it was widely recognised that the local municipalities were not coping with their responsibilities of water service provision. Thus, the WSP role was removed from the LM and handed over to the District municipality. As a result the Districts focus on water quality monitoring shifted to upgrading and refurbishment of the conventional schemes. The Water Care Manager indicated that 70% of his time is dedicated to the water treatment works and the other 30% to waste water.

There are two supervisors in the District who are responsible for the 34 WTW and 260 boreholes. In 2008, Amathole Water (AW) was contracted to be the Water Board. All the conventional schemes are compliance monitored monthly by Municipal Health Services (MHS). Compliance samples are analysed at the accredited Amathole Water laboratory, located in East London. As of June 2011, AW was contracted as the WSP for all the conventional schemes. Each WTW has process controllers stationed on site, who are responsible for the daily testing of ph, turbidity, electrical conductivity and residual chlorine. It is the Water Care Managers responsibility to certify the compliance of the operational parameters through his monthly site visits.

When the District became the WSP, it also inherited the local municipalities' borehole schemes. Water from protected springs and boreholes are used for rural water supply, although some community members are still using untreated open sources. All boreholes and their pump stations are protected through fencing and are equipped with steel doors to avoid vandalism.

Prior to 2008 no data was collected on the quality of water in the rural areas. MHS started compliance monitoring all borehole schemes twice yearly in 2008. Although workflows for the boreholes had not been established, EHPs collected samples from boreholes approximately every 6 months. All samples were sent to AW laboratory where a full SANS 241 analysis was conducted annually. The number and dispersion of rural supply systems have made monitoring difficult with some of the farthest borehole being an estimated 300km away from AW Laboratory.

Through the ad hoc compliance monitoring, contaminated sources were identified. In sources where failures were frequently identified, chlorine meters were installed. According to the Water Care Manager, only a quarter of the boreholes within the District are chlorinated. In these chlorinated sites, borehole operators are employed to monitor the chlorine levels twice daily. Results are recorded in logbooks on site and are reviewed every third month by supervisors. Operators are able

to adjust the electronic dosing to respond to chlorine levels that are below the municipalities acceptable 0.2mg/l.

In 2009 the H₂S test Kit and iComms WQR were introduced to the municipality. The system was implemented in six sites, where borehole schemes were being disinfected and compliance monitored monthly. Chlorinated borehole schemes were selected so that the residual chlorine and H₂S test results could be reported simultaneously through the WQR. By sending both results, failures due to inadequate chlorine dosing could be identified. The iComms reporting system allowed the municipality to identify failures in a timely manner. Previously there was no communication with the supply caretakers and adjustments in dosing were left up to them.



Figure 32: Standpipe (photographer Alayne Semler)

7.4.2 Drinking Water Quality Failure

Prior to iComms involvement, rural water quality failures would only be identified through the ad hoc compliance monitoring. After the implementation of the H₂S test, water quality was being monitored on a weekly basis in certain areas. If an H₂S failure occurred, the following procedures were followed. The water supply caretaker would inform his supervisor and check the chlorine levels. Normally failure was due to inadequate disinfection and water quality would be compliant again within 24 hrs. The following day if the H₂S resample failed again, MHS would be contacted to take a compliance monitoring sample. It would take approximately 5 days to generate and review the compliance sample results. During this time the operation and maintenance team would

investigate and implement the required interventions. Normally this would involve flushing the system and cleaning the reservoir. If results came back positive, a further lab sample would be taken to determine if the remedial action was successful. Only 10 days after the initial detection of contamination would a boil water alert be issued, if the second laboratory results were positive.

7.4.3 Communication of Drinking Water Quality Results

The water quality failure identification process mentioned above includes the step of informing the community when contamination occurs. Formal workflows have not been designed to issue *boil water alerts* to consumers. The municipality is also not using any formal media to inform the community of their monthly drinking water compliance results. The Districts council is informed through Local Water Forums, held on a quarterly basis. All rate payers and community members are encouraged to join as this is the only opportunity they have to learn more about the water quality of the District. Reports on the quality of water and waste water throughout the District are prepared and presented by the Water Care Unit and MHS at the quarterly forums. ADM report their water quality to government through the Blue Drop system and eWQMS (refer to appendix 2.2, paragraph 13.1). Both systems are in place since it is on the one hand a legislative requirement to report to the Blue Drop system, but on the other hand the local Council prefers eWQMS reporting layout. Only in 2011 did ADM start reporting compliance monitoring on the Blue Drop system, for some of its boreholes schemes.

'Currently we are not communicating the failures to the community'

Water Care Manager

Municipal Health Services are responsible for conducting community education and awareness of safe practice and handling of water. Each month the EHP visits an area and gives education on health and hygiene. In many areas communities prefer water that is not chlorinated due to the taste and smell that chlorine results in. Here HMS informs the community of the importance of disinfection and assures them of the safety of the water. The challenge of the large District and spread of communities is that education is once off and many of the villages have not yet been informed on safe water practices. Another reason for communities to continue using untreated water sources are travel distances to safe water supply.

7.5 Service Delivery and Access to Technology in the Study Sites

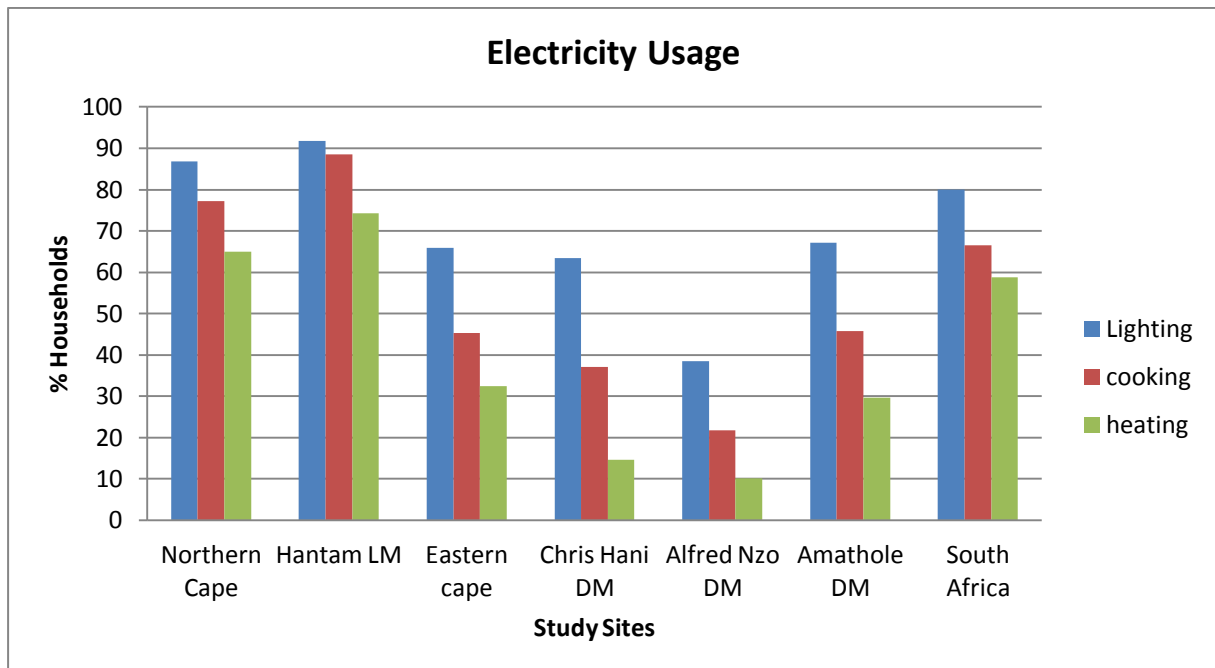


Figure 33: Household (hh) electricity usage for lighting, cooking and heating in the study sites, their provinces and South Africa (Statssa, 2007).

Electricity usage in the Northern Cape is higher than the national average, whilst in the Eastern Cape it is below national average. The graph shows that the general trend of electricity usage is the same for all sites, with lighting being the most common, followed by cooking and then heating. The large distribution of services and infrastructure throughout the Northern Cape is due to its historical farming set-up and lack of homelands. In Hantam, 91.8% of households have electricity for lighting, 11.8% more than the national average. The low electricity usage for lighting, cooking and heating in the Eastern Cape is due to its historical structure. The apartheid setup left the homeland areas without any formal infrastructure and as a result service delivery in these areas are lacking. The visuals highlight that ANDM is the least resourced in terms of electrical infrastructure, with only 38.5% of households using electricity for lighting compared to the national figure of 80%. CHDM and ADM household electricity usage for lighting is 63.4% and 67.1% respectively. Both are also below the average electricity usage for the country but are on a par with the provincial household usage of 65.9%.

Table 5: Access to piped water in the study sites, their provinces and South Africa (Statssa, 2007).

% HH having access to piped Water, CS 2007				
Area	Total Access	Inside dwelling/yard	Community Standpipes	No access
Northern Cape	94.4	80.3	14.1	5.6
Hantam LM	93.9	92.9	1	6.1
Eastern Cape	70.9	43.8	27.1	29.1
Chris Hani DM	75.5	39	36.5	24.5
Alfred Nzo DM	67	16.7	50.3	43
Amathole DM	76.3	43	33.3	23.7
South Africa	88.6	69.5	19.1	11.4

The difference in service delivery between the Northern Cape and the Eastern Cape is again highlighted in the table above. The Northern Cape Province has a higher amount of households with access to water than the South African national average. Hantam Local Municipality provides a remarkable 92.9% of its households (hh) with water inside of their property. Only 1% of households have access to water via community standpipes, which is 18.1% less than the national average. In the Eastern Cape household access to water is below the national figure of 88.6%. Again the figures reveal the effects of the historical apartheid error and its impact on the level of service delivery in the homeland areas. The Eastern Cape Province has only provided 70.9% of its households with access to water services, this means 29.1% of households have no access to water. Figures for CHDM and ADM are similar with 24.5% and 23.7% of households having no access to water, whilst the situation in ANDM is dramatically worse. Here 43% of households are without water, 50.3% are using communal standpipes and only 16.7% have access to water services within their properties.

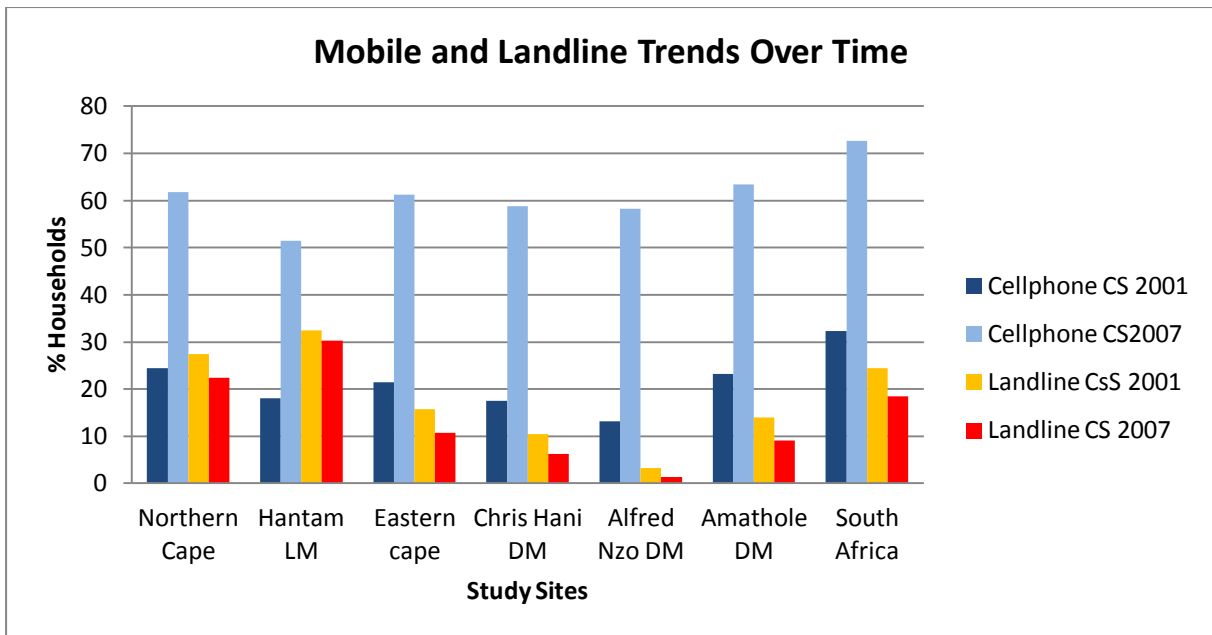


Figure 34: Percentage of households that owned a cellphone or landline in 2001 and 2007. Source CS 2007 (Statssa, 2007; Statssa, 2007).

The graph shows that throughout South Africa the number of mobile subscribers is increasing at a rapid pace, whilst the number of fixed line users is declining. The number of cellphones owned by South African households has increased from 32.3%, in 2001, to 72.7% in 2007. There has been a 39.7% increase in cellphone ownership in the Eastern Cape households, this is just below the national growth rate of 40.4%. The Northern Cape Province and Hantam LM have also experienced increases of 37.3% and 33.5% respectively in mobile subscription. Whilst there has been a serious increase in cellphone subscription, the number of landline users has declined. The average decline in fixed line users has been 5.9%. The graph shows that a slightly greater percentage of households in the Eastern Cape study sites own a cellphone compared to that of Hantam LM, Northern Cape. There is a rapid move towards the ownership of mobiles, making them the communication technology of choice, in South Africa.

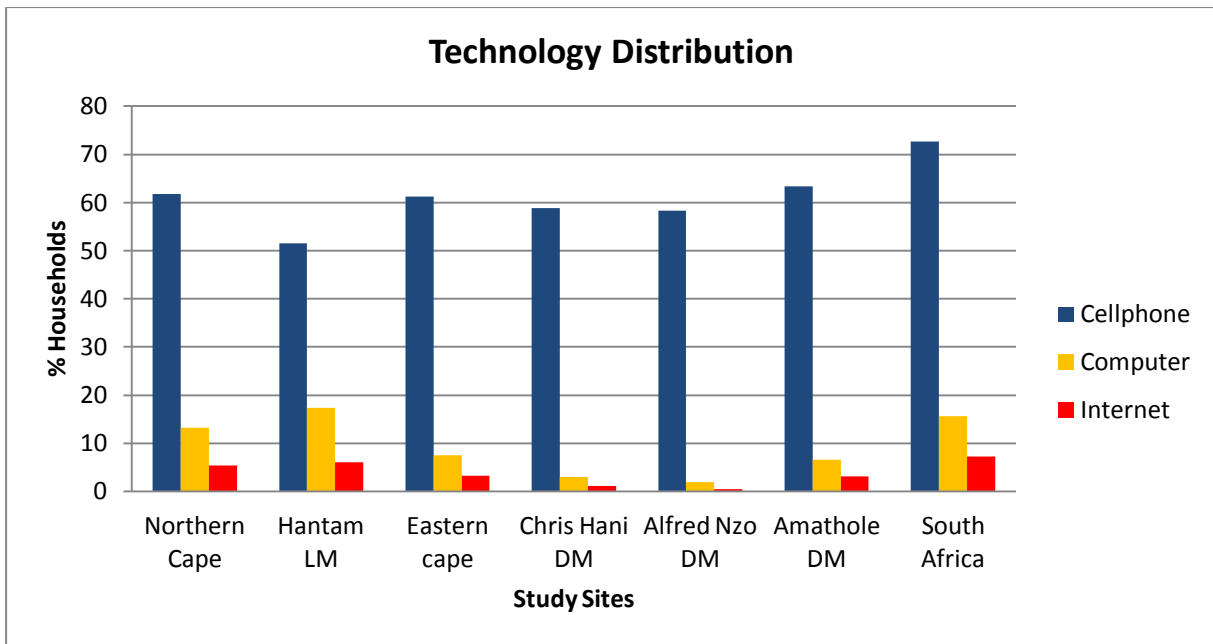


Figure 35: Percentage of households that have access to a cellphone, computer and the internet in the study sites, their provinces and South Africa. Source SC 2007 (Statssa, 2007; Statssa, 2007).

The graph clearly indicates that more households have access to cellphone technology than other communication devices. Cellphone ownership per household is particularly high in South Africa due to the high network coverage, with 95 % of the population living in areas of cellular signal (Shackleton, 2007). Computer and internet access figures are similar for the Northern Cape areas and the countries statistics, whilst the Eastern Cape Province and its study sites have slightly lower access than the national average. The graph corresponds to the mobile vs. landline graph (figure 34) and confirms that mobile phones are the most widely distributed means of communication throughout South Africa.

7.6 Blue Drop Score of Study Sites

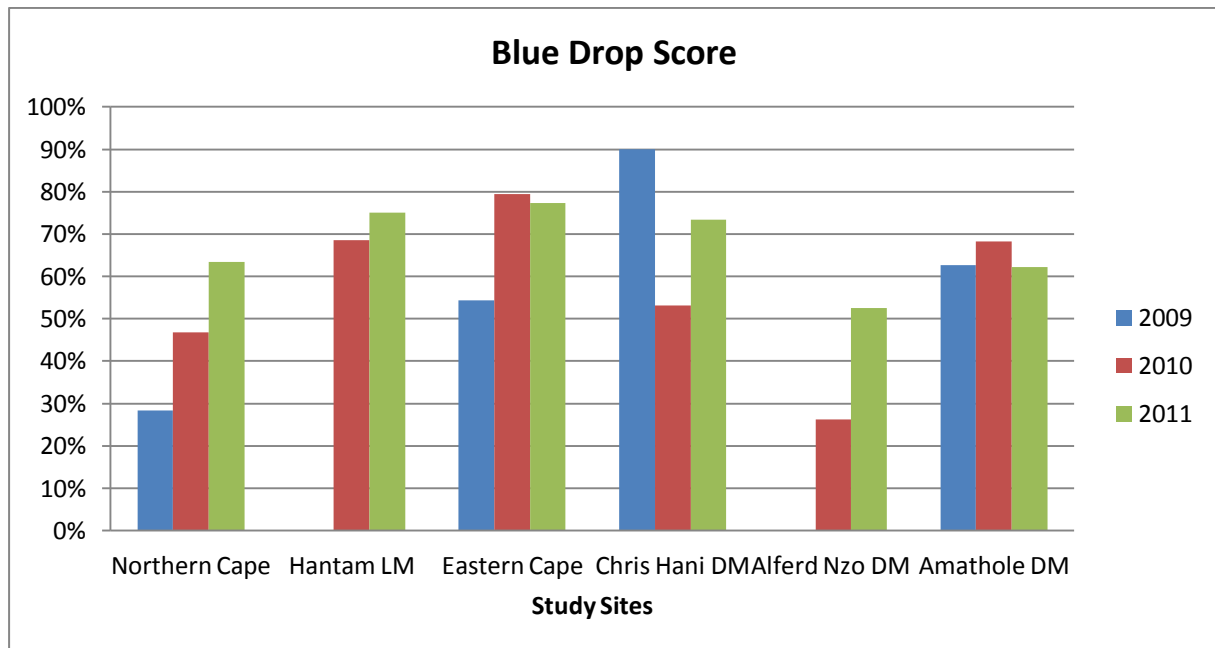


Figure 36: BDS for the study sites and their provinces for 2009, 2010 and 2011 (Department of Water Affairs, 2010; Department of Water Affairs, 2011; Department of Water Affairs, 2009).

The 2009 BDS values do not give a good representation of the water quality within the districts. In 2009, Hantam LM and Alfred Nzo DM failed to supply the required information to the Blue Drop system and as a result achieved a zero score. Also in 2009, only one out of the 11 water supply schemes in CHDM was assessed. Therefore its 90% BDS does not represent the overall compliance of the District. The graph shows that there has been a definite increase in the BDS for the Northern Cape Province and Hantam WSA throughout the last three years. Hantam WSA has improved dramatically gaining 68.5% BDS and 75.1% BDS in 2010 and 2011 respectively. This score of 60% - 80% represents *good drinking water quality management*, according to DWAF. The Eastern Cape Province experienced a slight decline in BDS from 79.4% to 77.3% between 2010 and 2011. A similar trend was observed for ADM with a 6% drop in 2011 to a BDS of 62.2%. But ANDM and CHDM experienced satisfactory increases in BDS between 2010 and 2010. With ANDM almost doubling its BDS in 2011 and Chris Hani DM having a 20.4% increase in BDS between 2010 and 2011.

60% - 80%: *There is sufficient proof that the municipality/ institution has adequate processes in place to ensure safe water supply. However, there is room for improvement towards Blue Drop certification, since portions of the requirements are not complied with as yet.* (Department of Water Affairs, 2011).

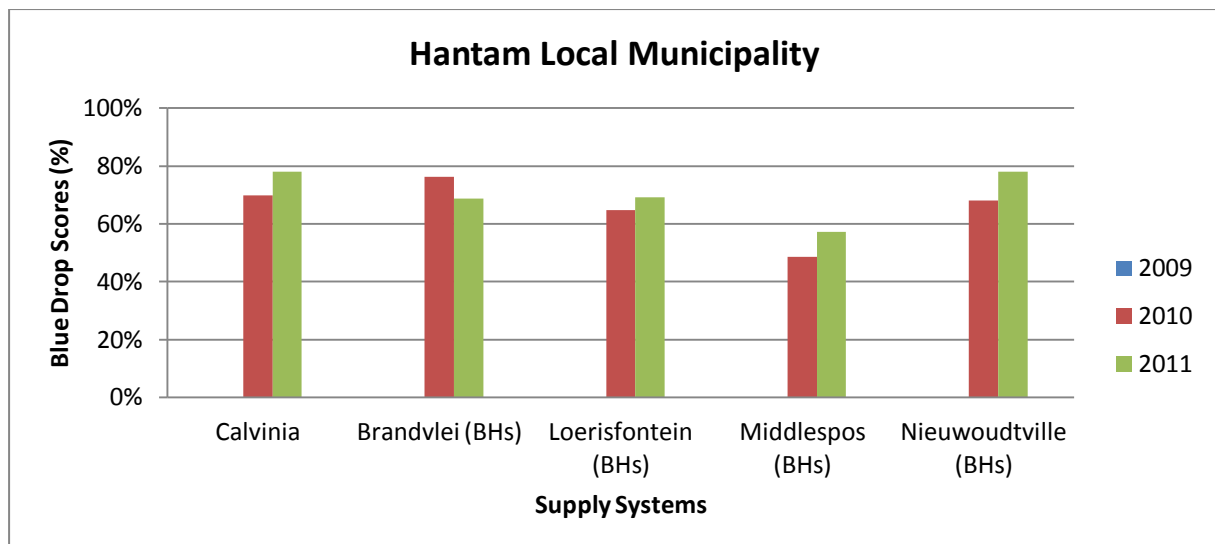


Figure 37: Breakdown of the BDS for the last three years for the various towns within Hantam LM (Department of Water Affairs, 2010; Department of Water Affairs, 2011).

The graph shows a zero score for 2009, due to failure of the WSA to submit the required data to the Blue Drop systems, resulting in no assessment being conducted. The results for 2010 and 2011 show that all the towns' water supply systems achieved a *good drinking water quality management* rating, besides for Middlepos. Middlepos's 2011 result of 57.2% imply that there is *Reasonable (satisfactory) drinking water quality management* of the supply system. The Blue Drop results for 2010 and 2011 show that there has been an average increase of 7.8% in four out of the five areas and a decrease of 7.6% in Brandvlei's supply system.

60% - 80%: There is sufficient proof that the municipality/ institution has adequate processes in place to ensure safe water supply. However, there is room for improvement towards Blue Drop certification, since portions of the requirements are not complied with as yet. (Department of Water Affairs, 2011).

50% - 60%: The municipality/ institution has an average level of ability and understanding to manage drinking water quality according to most of the regulatory criteria. However, this is not sufficient to ensure full confidence from DWA in the ability of the systems and those responsible for drinking water quality management in this specific water supply system (Department of Water Affairs, 2011).

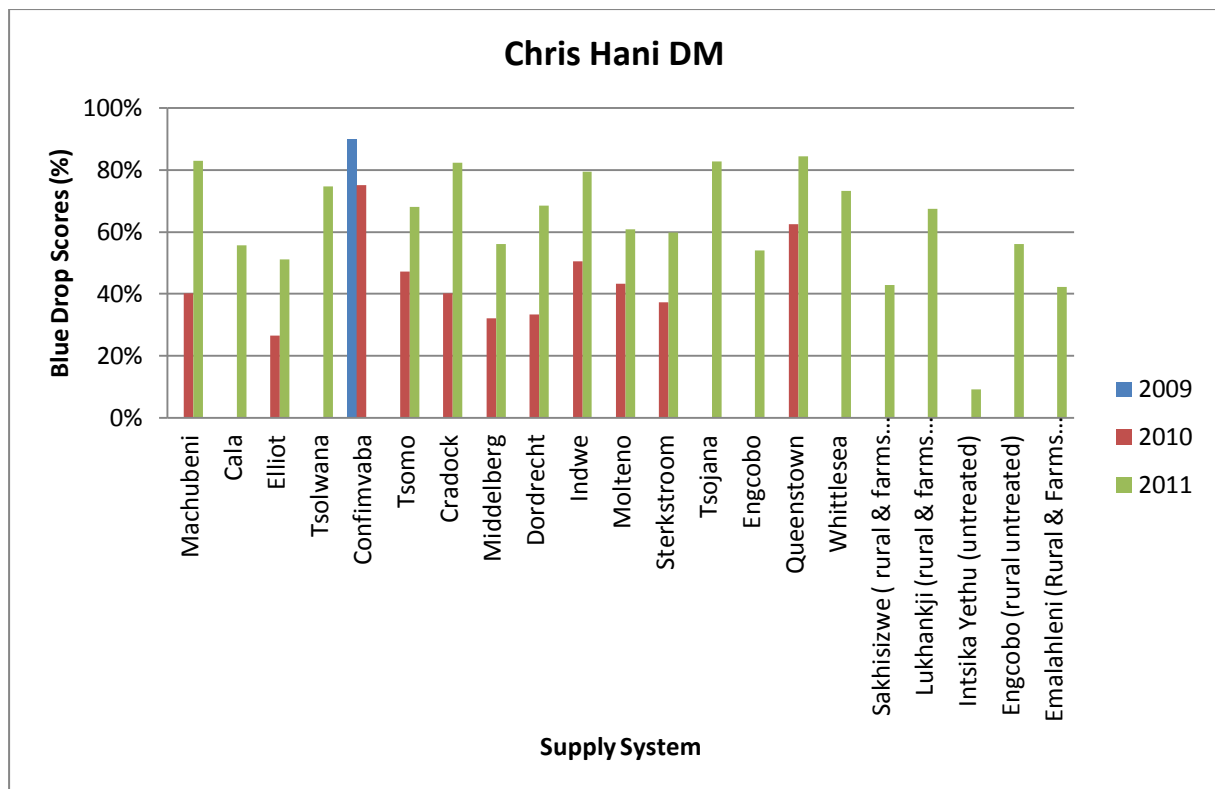


Figure 38: Breakdown of the BDS for the last three years for the various local municipalities within Chris Hani DM (Department of Water Affairs, 2010; Department of Water Affairs, 2011).

The number of water supply schemes being monitored on the Blue Drop 2011 has almost doubled since the previous year. Currently 20 supply schemes are being reported on and some rural untreated areas have been included in the 2011 Blue Drop report. This shows a positive trend that the municipality is starting to focus on untreated rural sources as well as its treated supply systems. For the areas that were reported on in both years, there has been a clear increase in BDS from 2010 to 2011.

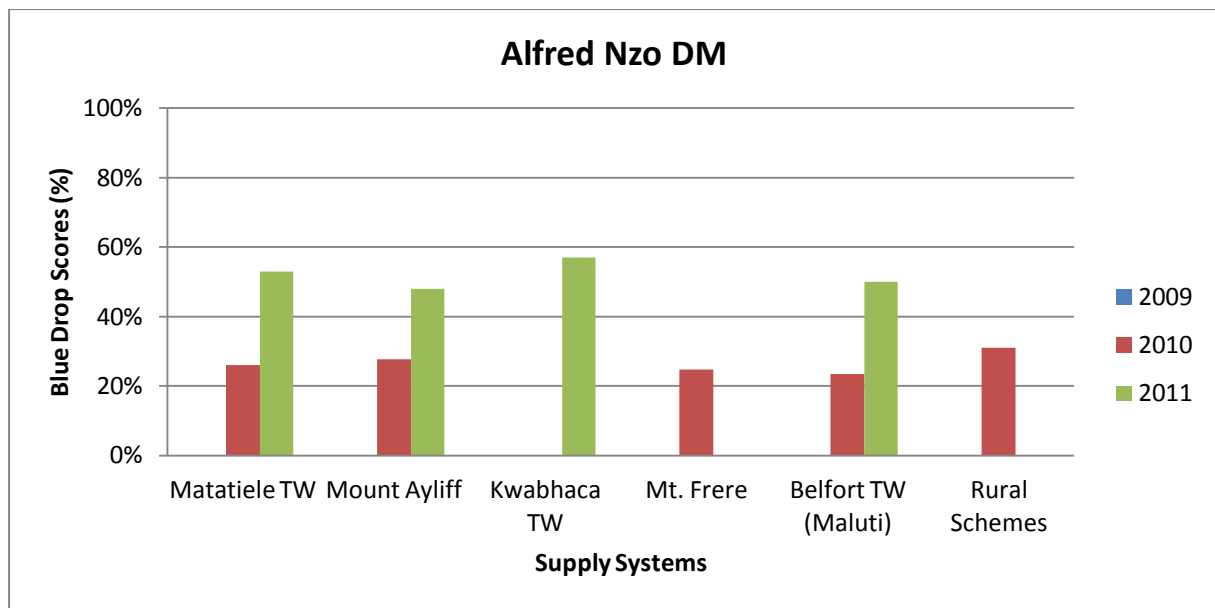


Figure 39: Breakdown of the BDS for the last three years for the various towns within Alfred Nzo DM (Department of Water Affairs, 2010; Department of Water Affairs, 2011).

The graph shows that there has been a large increase in the BDS for those schemes monitored from 2010 to 2011. But No rural water supply schemes have been reported on for 2011. So the increase of 26.3% of the Districts BDS does not give a true representation of the improvement in monitoring throughout the municipality, for no untreated water sources were included. This graph highlights the problems associated with the Blue Drop, that only the supply systems loaded onto the Blue Drop are being assessed, therefore the BDS is a representation of only the supply systems reported on and not of the Districts entire drinking water supply.

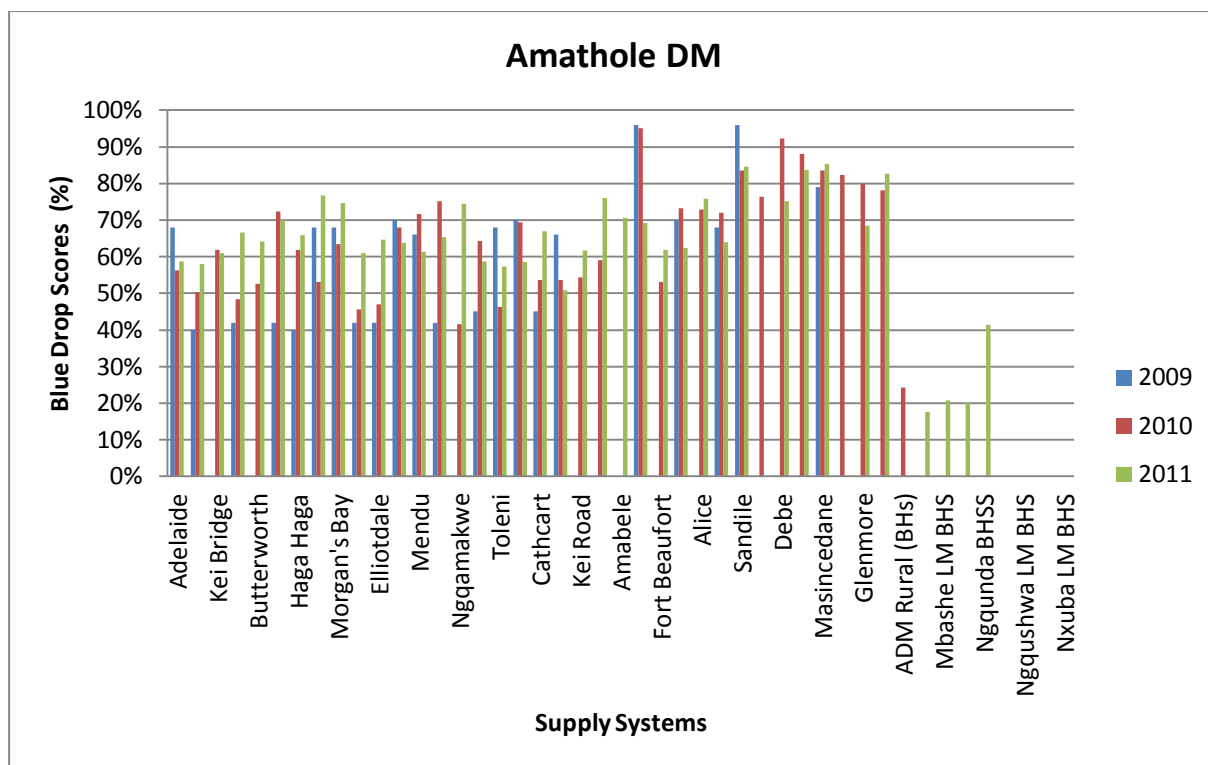


Figure 40: Breakdown of the BDS for the last three years for the various towns within Amathole DM (Department of Water Affairs, 2010; Department of Water Affairs, 2011).

ADM BDS of 62.2% in 2011 has remained fairly constant over the last three years. The graph highlights the biggest improvement in the latest 2011 Blue Drop report, with an increase in the number of supply schemes being monitored. There has also been an inclusion of rural borehole schemes into the Blue Drop report. Although not all have been reported on, their inclusion shows that the municipality has currently extended their focus to rural water supplies and borehole schemes. With the inclusion of untreated sources it is hoped that future BDS will give a more realistic representation of the municipalities overall performance.

Chapter Eight

8 Findings and Analysis

The description of the four study sites gives background into each individual municipalities monitoring, management and communication practices. In this chapter, the findings of the study as well as the analysis of the increase in information provided by the WQM mobile application and its effects are presented using the seven themes below.

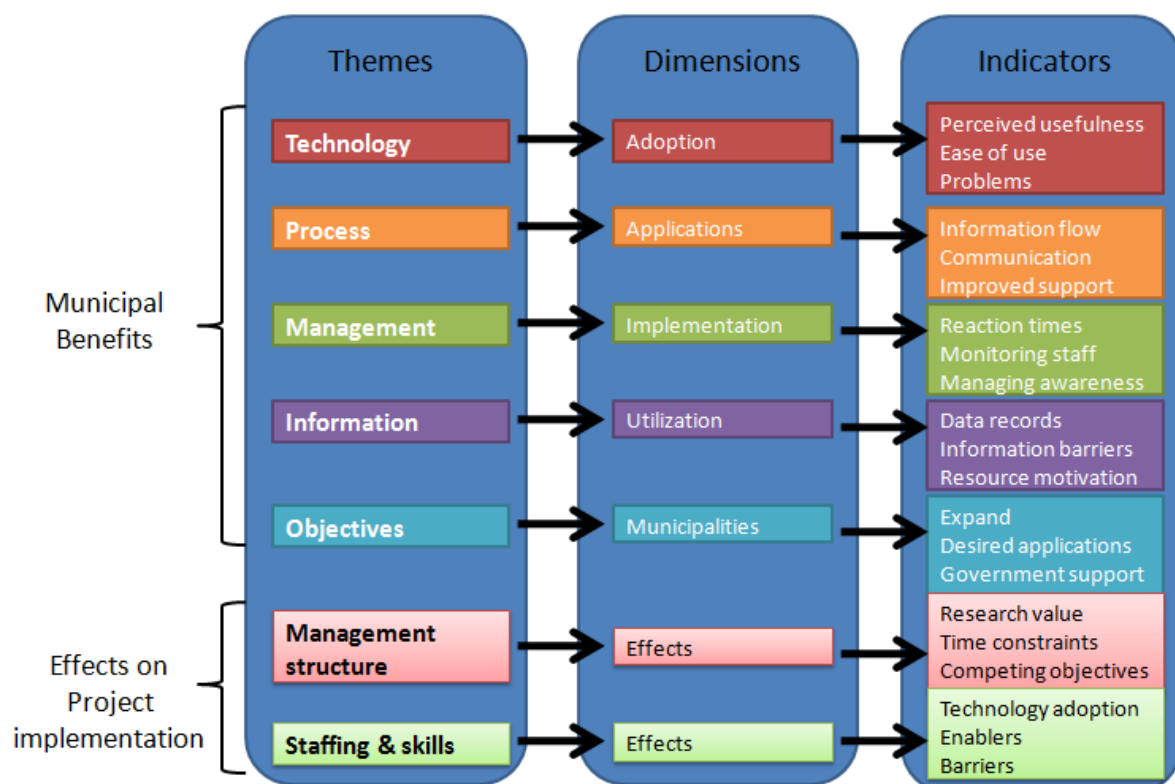


Figure 41: Criteria for analysis, based on a seven themed technology adoption model.

The first five themes of the above model discuss and analyse the changes within the municipality and the benefits that have resulted due to the use of the information provided by the WQM.

Technology:

The adoption of technology by the municipal managers was measured using three indicators. The first, “perceived usefulness”, indicated the degree to which the manager believed that the WQM tool would increase his job performance. The second, “ease of use”, indicated how much effort it would take to use the system and the last dimension, problems, revealed the problems experienced with the WQM by the municipal managers.

Process:

The application of the WQM and the effect it had on the municipalities processes were determined by assessing the change in: information flow between borehole operators and the municipal authority; communication between the different levels of management; and the amount of support provided to the borehole operators.

Management:

Implementation of the WQM and its effects on the management of the rural water supply schemes were discussed and analysed according to the change in: reaction times to water quality failures; monitoring staff performance; and managing awareness in terms of communication of drinking water quality results and failures.

Information:

This theme looked at how the information provided by the WQM had been used by the municipal managers. The indicators revealed: how the amount of information recorded had changed and the impact it had on future planning; the limitations of the information provided by the WQM; and the usefulness of information to influence decision making and resource allocation.

Objectives

After use of the WQM application for a period of time, the municipal managers recognised further opportunities for the application. The indicators revealed the intention of the municipality to: expand implementation of the iComms reporting system; develop further applications on the WQM to increase its usefulness; and to involve National Government in approving the use of the system for external reporting.

The last two themes indicated how the municipalities' structure, available staff and level of skills affected implementation of the iComms reporting project.

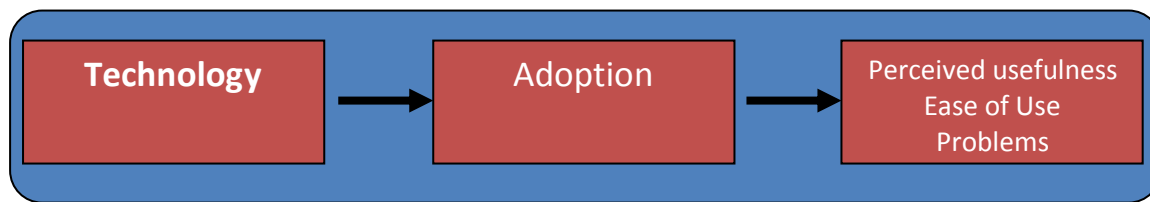
Management Structure

The management structure of the municipality affected the adoption and implementation of the iComms reporting project. Successful implementation was influenced by: the municipal managers perceived importance of being involved in university research; the time constraints of the municipal staff; and the competing functions within the rural municipality.

Staffing and Skills

The municipal staff's technical ability and level of performance affected the implementation of the iComms reporting project. The amount of information provided to the WQM was depending on the amount of information reported through the WQR by the supply caretakers. Therefore, the indicators provided insight to the adoption of technology, as well as enablers and barriers of reporting the water quality results through the WQR.

It must be noted that limited information was gathered on the use of the WQM in Alfred Nzo District Municipality. Only the base interview questions and four out of the ten sets of ongoing phone call interview questions were conducted. As of the 10th of August 2011, the team was unable to make contact with the Assistant Director of Water Services. Later it was reported that he had left Alfred Nzo District and relocated to Chris Hani District Municipality. The iComms team was not informed of the move and subsequently discontinued the project since the position of the Assistant Director of Water Services was not fulfilled before the project ended. Since the abandonment of the iComms reporting project there has been no management and monitoring of the borehole schemes, however, borehole operators continued submitting their H₂S test results.



8.1 Technology

8.1.1 Perceived Usefulness

At the outset of the study, most of the managers had high expectations of the influence of the WQM mobile application. Managers believed that an improvement of information flow would be the key aspect in improving their monitoring and management practices. The WQM application was designed using feedback and input from the managers. All municipalities WQM application forms were customised to the municipal managers' requirements, to ensure the individual needs of each area were addressed. Most of the managers had the perception and expectation that the mobile system would make it easier for them to manage their rural water supply schemes. They believed that a constant stream of information would improve their monitoring, reporting and communication of rural water quality and also allow them to monitor the borehole operators' performance. They looked forward to knowing what was happening on site at all times, as well as obtaining the rural water quality results more regularly and to be able to make decisions on follow-ups faster. At the end of the study it was revealed that an improvement of information flow was only one of many aspects needed to improve management. Despite this, most of the managers still perceived the tool as being useful for it allowed them to monitor their rural water supply schemes, identify water quality failures and assess operators' performance.

'Every time we had an interview with someone and we made a comment on something it was changed or updated and I think that is really important – there is not one size fits all.'

Municipal Health Director – CHDM

8.1.2 Ease of Use

All the municipal managers found the WQM mobile application user-friendly and easy to navigate, as they were accustomed to technology and different communication systems. They were also co-designers of the WQM mobile application, which resulted in the sequence of the application to be intuitive to their established workflow. The mobile application was reported to be more convenient

than the WQM web application. Even when the managers were in the office, they found it quicker and more suitable to access their rural water quality results through the mobile phone. Only one of the manager reported using the WQM web application, whilst another manager stated that he did not know how to access the results through the web.

'Before I wasn't expecting that there was a system that helped and was so user-friendly and just anytime, anywhere you can just go ... and check the water in your area.'

Water Care Manager – ADM

Initial adoption of the technology by management went smoothly, but novelty of the tool wore off within the first two months. All managers were initially interacting with the WQM several times a week. One manager was even checking the application three to four times a day. Over the seven month period, these interactions

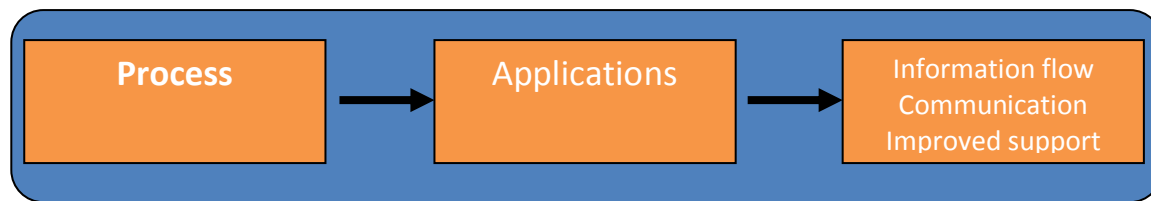
'It is very useful, I think especially when you are not in the office and you are going to conferences or meetings. Don't have to drag your laptop and all you accessories with you.'

Water Service Manger – HLM

decreased in most cases to once a week. One manager reported that once he was comfortable with using the system, he only considered weekly check-ups as necessary, unless alert smses were received. Decreased use of the application was therefore identified to be based on the novelty of new technology wearing off, the familiarity with the application increasing and the decision of the managers to reduce reviews to weekly checkups. Even with reduced interaction, having the technology continuously present was seen as a requirement by management so that alerts to water quality failures could still be received.

8.1.3 Problems with the Technological Application

During the study period, two of the municipal managers had technical problems with their HTC android phones. Both of the managers could not update the latest rural water quality results for approximately two weeks. The iComms team was not notified about the problems prior to them being identified through the phone interviews. The problems were easily rectified and the managers assured the iComms team that the benefits of the WQM exceeded the temporary technical setback.



8.2 Process

8.2.1 Information Flow

Before the implementation of the WQR and WQM, operational parameters were not being regularly reported to the municipal authority in all municipalities. Two of the four municipalities, Hantam Local Municipality and Amathole District Municipality, had existing monitoring practices in place. Borehole operators would test for operational parameters and adjust chlorine levels when necessary. All results were recorded daily in logbooks located on site and reviewed periodically, not more than once per month. With the introduction of the H₂S test and WQR application, a new parameter and reporting step had to be included in the operators' workflows. Building onto existing workflows facilitated implementation, for the borehole operators already had procedures in place and understood the importance of testing, recording and reporting water quality results. In one of the municipalities, the extra step of recording the results on the WQR resulted in a decrease of recording operational parameters. Daily chlorine reports loaded on to the WQR slowly decreased, until only H₂S test results were being reported on the WQR weekly. With the municipality no longer getting feedback on chlorine levels, a positive H₂S test could no longer be correlated to low chlorine levels. This illustrated how the introduction of new systems could disrupt existing processes. Regardless, it was reported that in all municipalities, information flow had increased from borehole operators to the municipal managers, due to use of the iComms reporting system.

Despite some municipalities conducting operational monitoring procedures on their rural schemes, most of them conducted no regular microbiological tests. Contamination of the rural water supplies would only be detected through ad hoc compliance monitoring or through the local clinics. With the introduction of the

weekly H₂S tests and the mobile information transfer system, contaminated water was quickly identified and the authorities were notified. It was reported that all water quality failures identified by H₂S tests, were normally rectified within 24hrs of detection.

8.2.2 Communication Changes

'Previously we didn't have really a system in place...there was no real system of tracing failures and what was the intervention done.'

Municipal Health Director – CHDM

In order for the water quality information to be effective, workflows had to be established to incorporate the data into. Good communication lines between the different levels of management and on-site personnel facilitate good practice and improve management. In two of the municipalities, the amount of communication between managers, supervisors and the borehole operators increased due to the implementation. In the one municipality, there was already regular communication between the different levels of management. The manager reported that collection of information through the WQM mobile application allowed an increase in communication without having to travel long distances to receive the data. There was more telephonic communication to question data gaps or exceeded limits, but face-to-face communication did not change. In the other municipality, the borehole supervisors communicated twice monthly with borehole operators, as well as when a positive H₂S was reported. New workflows and communication lines were set up in one of the municipalities, where previously there was no contact with the borehole operators. In two municipalities communication between the managers or supervisors and the borehole operators was unaffected, although there was more data being reported.

8.2.3 Improved Support

'Immediately when there is a positive result we go quickly, go and check what is happening there. In certain areas you find that the guys run out of chlorine tablets, they didn't even inform us that there is no chlorine.'

Water Care Manager – ADM

In all the municipalities it was reported that rural water quality failures are normally due to inadequate chlorine dosing. In municipalities where the chlorine results were submitted along with the H₂S test reports, it was easy to see if contamination was related to the amount of disinfectant. Positive H₂S test results were often due to the operators running out of chlorine tablets/ floaters, or if there was a blockage in the chlorine pump. Previously, the municipal authorities were not always informed when water supply sites ran

out of disinfectant. With the implementation of the alert smses on the WQM, municipal managers were informed of rural water quality failures and could determine if such failures were linked to chlorine levels being too low. The increase in knowledge allowed the municipal authority to support the borehole operators in fulfilling their duties by providing them with the necessary requirements to disinfect the water.

A lack of data, or large data gaps, were also used to identify problems on site. Non-reporting was analysed back to borehole operators experiencing technical problems with their phones, or having run out of airtime, leaving them unable to contact the municipality for support. In one municipality, the manager reported that data gaps were also a result of all the H₂S test kits being used up. The WQM mobile application highlighted failures and revealed data gaps. Through the system, managers were able to identify the needs of the operators, so that support could be provided to them, to help them carry out their operational monitoring procedures.

University of Cape Town



8.3 Management

All four municipal managers stated that the most useful aspects of the WQM mobile application, was being alerted to water quality failures wherever they were, and being able to monitor staff performance. The WQM mobile application improved management of the borehole schemes and allowed for failures to be detected and attended to in a more timely manner.

8.3.1 Reaction Times

All managers expressed that their confidence in the borehole water quality had increased, as they knew what quality of drinking water was being supplied to the consumer. The WQM mobile was referred to as a 'live system', as real-time information on the borehole schemes was being received. Reports were generated frequently and according to the managers, sample turn-around time and failure identification was dramatically reduced, from the conventional laboratory sample analysis. Managers reported that overall their workload

'It helps me manage the quality of water in the rural schemes. As before I didn't know if there is a failure in the particular scheme.'

Assistant Director of Water Services – ANDM

'I would say it assists me ... to intervene as soon as possible when there are non-compliances.'

Water Care Manager – ADM

had not increased, but the time spent on the rural water sector had. Alert smses informed managers of water quality failures, which managers had to react to. More time was spent by management communicating with the EHPs and determining the problems on site and remediation steps taken. This led to an increased focus on the borehole schemes in all municipalities.

8.3.2 Monitoring Staff

The WQM mobile application stored all data being submitted and allowed for revision of results. Managers could view the frequency and amount of data submitted by individuals. Staff performance could be monitored and individuals held accountable for their actions. The WQM mobile was used in some cases as an educational tool when discussing borehole operators' performance. Managers showed proof of reporting record to individuals and questioned the evident data gaps. In one municipality, the manager reported that the WQM mobile application made it easy for him to see who was reporting and who was not, but due to time constraints he had not been able to follow up on why results were not reported as frequently as required. The WQM system enabled managers to monitor staff performance, but management of staff was unaffected if no actions were implemented. The 'usefulness' of the WQM mobile as a management tool was limited by the municipalities own structure, time and resources.

'I have picked up that there are certain areas that are not taking samples, but there is nothing as a department that we have done about it so far.'

Water Care Manager – ADM

In all four municipalities it was reported that the EHPs and borehole operators were more motivated to perform their duties. Some managers believed that the EHPs and operators were more committed because they understood the importance of the data and the impact it could have on decision-making. The increased performance of the staff improved the data availability and allowed for an increase in the monitoring and management of the borehole schemes. In one municipality, the manager believed that the borehole operators felt less pressured, for they knew the quality of the water.

<p>'I wouldn't say its pressure but for the operators I think they have shown more dedication to it and I think the importance of understanding why we are doing it.'</p> <p>EHP – CHDM</p>	<p>'The guys (borehole operators) have more energy.'</p> <p>Water Service Manager – HLM</p>	<p>'I can see sort of an improvement and also that willingness.'</p> <p>Water Care Manager – ADM</p>	<p>'The people (Borehole operators) that are doing it, are very enthusiastic about it.'</p> <p>Assistant Director of Water Services – ANDM</p>
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8.3.3 Managing Awareness

It was thought that an increase in availability of information from the WQM would lead to an increase in distribution of the results. This was not the case, for the frequency of reporting water quality results to the consumers did not change in any of the municipalities, but the increase in failure identification led to more communication of failures to the consumers. There was, however, no change in the way the municipalities reported the failures.

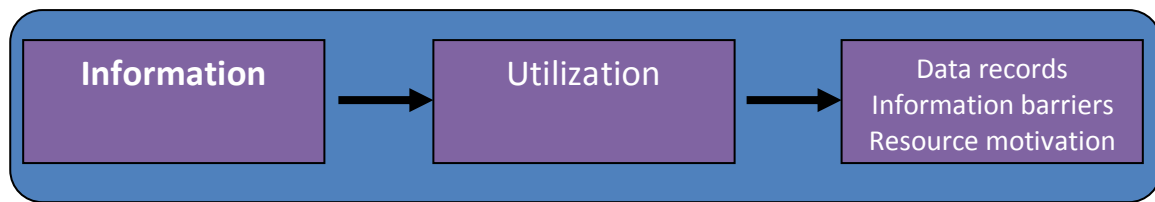
When the iComms reporting project was first implemented in 2009, it was reported to the public in two of the study sites. The municipalities informed consumers through the local newspapers and awareness was created by the ward councillors and borehole operators. In these two municipalities most of the community perceived the use of the system as an improvement in water service delivery, as they were aware that their water was being monitored regularly. In a third municipality, a few of the consumers were made aware of the system due to enthusiastic borehole operators proudly showing their iComms phones and clear H₂S tests, stating that their water was safe. Municipalities that created awareness of the system received positive feedback from community members and acknowledgment of the improvement in monitoring.

'Now they feel they know the quality of the water. Their water is being checked on , they are confident that they are drinking good quality water. Someone is doing something about the water.'

Municipal Health Director – CHDM

'It's much better communication and awareness around water quality within the District.'

Municipal Health Director – CHDM



8.4 Information

8.4.1 Data Records

‘At least now we know what we are giving to the consumer community out there, because before we are not even knowing the quality of our boreholes.’

Water Care Manager – ADM

As mentioned earlier, in most municipalities, there was no regular collection of rural water quality data, due to the municipalities’ limited staff capacity, resources and funding. Most borehole schemes are situated far from municipal offices and are hard to reach due to poor road

conditions. The municipal managers reported that previously they were unaware of the quality of the water that they were providing to their consumers in the rural areas. Through the WQM application, managers had access to water quality results that they would not normally receive. The H₂S and WQM reports allowed for early detection of contamination, which restricted the spread of disease and limited health implications.

‘The position to know where the hot-spot are and what needs to be done in terms of planning in the future.’

Water Care Manger – ADM

The information from the WQM was also used by the municipal managers to identify patterns in the data. The WQM application stored a record of information and through the calendar view, previous months and their

compliance could be recalled. Through the use of the application, hot-spot areas could be identified where failures had re-occurred and it was possible to make provisions in order to avoid further failure. The records of information were also used to identify trends over time and to assess where there were overall improvements in the water quality. The managers felt that they were able to supervise on site performance more readily and better plan for the areas that were monitored with the WQM.

8.4.2 Information Barriers

In all municipalities, the municipal managers found that additional information could be provided through the WQM mobile. The municipalities that were only reporting H₂S test results expressed a desire to start testing and reporting other operational parameters. They found the data transfer system effective and believed that the greater the amount of information received, the easier it would be to monitor the rural schemes. The other municipalities that were reporting all operational parameters through the WQM mobile, found the amount of data submitted insufficient. Operators were not reporting all parameters as frequently as required, data gaps resulted, which restricted monitoring and decision-making. Managers viewed these information limits as a municipal problem that would have to be addressed through better staff management.

8.4.3 Resource Motivation

‘(WQM) gives us more information for decision-making and focus on various departments requesting funding.’

Municipal Health Director – CHDM

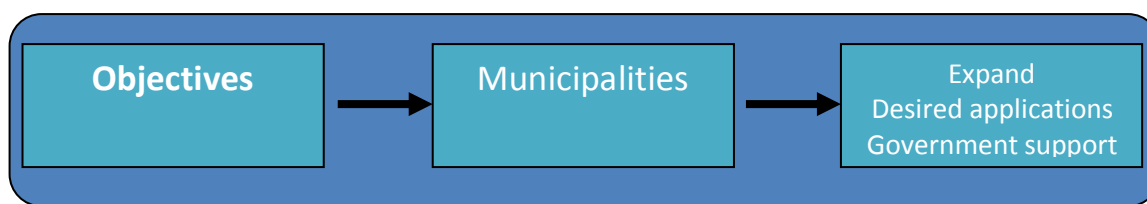
Due to the municipalities’ involvement in the iComms project and the legislative requirements of the Blue Drop system, additional work was required of each of the municipalities. The two systems resulted in more data being captured and recorded on both the boreholes and the conventional schemes. The increase in responsibilities and data availability was used by two of the municipalities to motivate to their council for additional funding, resources and skilled personnel. In one of the municipalities, a six million rand budget was allocated to water quality monitoring. Three million rand was allocated towards the employment of staff and the balance for the provision of additional resources, such as, special water quality vehicles.

‘Our motivation was based also that there is also this project we are doing with UCT, monitoring of the boreholes... and also there are requirements by DWA, the Blue Drop.’

Water Care Manager – ADM

‘We are getting 4 new bakkies, 5 EHPs, just dealing with water quality. I think the council saw the need in terms of the information that we submitting to them on a monthly basis.’

Municipal Health Director – CHDM



8.5 Objectives

8.5.1 Expand Implementation

Only one of the municipalities had all its borehole supply schemes included in the iComms project. The other three municipalities all expressed the desire to implement the H₂S and reporting system throughout their districts. In these three municipalities, only a few of the borehole schemes in the districts are chlorinated. If the system was expanded to include all rural supply schemes, critical areas that experience regular contamination could be identified and disinfected. This would allow the municipalities to make better use of their limited resources.

<p>‘With this system we can identify hot-spots and focus on that. Shows you where your critical areas are and you can put more resources and effort to that area, to address backlogs in that area.’</p> <p>Municipal Health Director – CHDM</p>	<p>‘We are thinking of expanding to other schemes as well.’</p> <p>Assistant Director of Water Services – ANDM</p>	<p>‘I would be able to see more and if we can include almost all of our boreholes to the android phone, that would make my life much more easier.’</p> <p>Water Care Manager – ADM</p>
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8.5.2 Desired Applications

All municipalities reported that they lacked proof of intervention steps taken when water quality failures occur. For the municipalities that had rural supply schemes loaded onto the Blue Drop, this was currently costing them points with regards to achieving Blue Drop Status. One of the municipal managers suggested that it would be useful to include an intervention form into the WQM application. EHPs or responsible personnel conducting the remedial action could then fill out an application, indicating what steps were taken to rectify the situation. This would increase reporting and communication between the managers and

‘I report the failure, then I must immediately report what was my intervention.’

Municipal Health Director – CHDM

EHPs. This extra intervention report would also assist in providing proof and details to Blue Drop if any of the rural schemes were incorporated.

8.5.3 Government Support

The municipalities who took part in the study gave positive feedback on the usefulness of the iComms project, but there was a strong desire to get National Government involved. All municipalities suggested that they would like DWA to approve the H₂S and reporting system and allow its incorporation into the Blue Drop program as part of operational monitoring of rural water supply schemes. Some municipalities reported that they would like DWA to approve the H₂S test as an appropriate operational monitoring tool, before they implemented it throughout their district.

'If we do this we can still get good quality data we can react on.' 'Now it starts making economical sense, starts making management sense.'

Municipal Health Director – CHDM

'I think it is going to be optimised when you have communities that take responsibility of their water quality and they assist Local Government in decision making.'

Municipal Health Director - CHDM

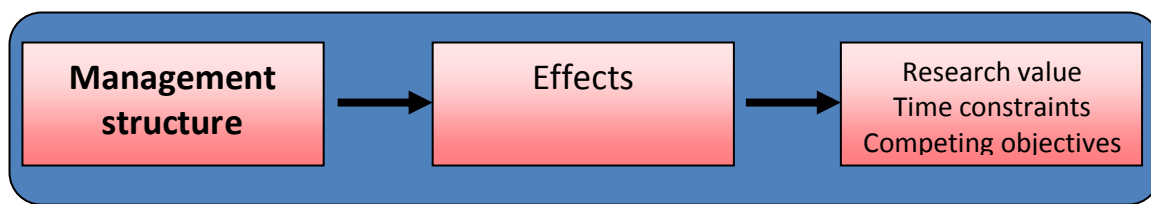
One of the district municipalities involved is only the WSA for its area and has responsibility for overall supply quality. The manager stated that he would like the H₂S and reporting system to form part of the compliance monitoring procedures. Currently, only 25% of the District is compliance monitored, despite sample analysis taking place in the internal laboratory. The municipal manager

'If we implement this now we can start using village health workers, community members, borehole operators to start getting your data in. So the EHP is going to be an overall manager of that area, but the community is going to monitor their water quality.'

Municipal Health Director – CHDM

believed that the only way to cover large areas was to get community members involved in water quality monitoring. His suggestion was for communities to be provided with H₂S test kits and WQR phones so that they could take ownership of their supply. The EHPs would only be used as co-ordinators to deal with problems and manage the system. This way, the manager believed, good quality data could be received throughout the district at an affordable cost.

Effects on project implementation



8.6 Management Structure

8.6.1 Research Value

‘The things that we want to get changed in our communities through research, we must feed the universities the right information, so to develop systems that can help us get into a goal.’

Municipal Health Director - CHDM

‘But on the other side a university institution is independent, they are not like consultants.’

Municipal Health Director - CHDM

‘It’s easier for people like universities to come and make a recommendation, than for us in our own organisations.’

Municipal Health Director - CHDM

The amount of skilled staff, time and effort that is allocated to a project is determined by the value management places on the project. Some managers believed that it was vital for the municipality to get involved in research projects, so that their views could be communicated and positive change could take place. It was felt that municipalities must correctly inform the researcher, so that systems could be designed to meet the municipalities unique needs and goals and not just the pre-conceived ideas of the researcher. One of the managers reported that their municipality thought it was particularly important to be involved in university research. In South Africa, there is a perception that academic research is ‘for the people’ and ‘against’

existing structures (iComms, 2011). It has also been recognised that universities research aims and view-points are different to consultant groups. Universities are interested in the research itself and do not mind the success or failure of a project, as long as learning was achieved. Consultants, on the other hand, develop systems in order to increase profitability. The manager stated that the municipal council, who is responsible for deciding what projects are adopted, are also more inclined to trust universities research and recommendations.

The involvement of outsiders in municipality-run projects can have positive and negative effects. All the municipal personnel involved in the project were more eager to perform due to the University’s involvement. A negative of having the University involved, was that in some cases the researchers

became a municipal resource. In one municipality, there was a communication gap between management personnel and the borehole operators. By gathering research through phone interviews with borehole operators, the iComms members developed trust, addressed the borehole operators' complaints and partially filled this communication gap. The municipal manager reported that being involved in the iComms project highlighted the existing communication gaps within the municipality, and that unless they were internally addressed the project would fail if the University was not involved. In this instance the University was performing a management role by monitoring and supporting the borehole operators. My twice-monthly phone interviews with the municipal managers may also have had an effect on the amount of interaction they had with the WQM mobile. Managers knew that outside monitoring was taking place and this may have increased their interaction with the WQM and focus on the borehole schemes. Therefore, it is important to manage the impact that the researcher has on the project implementation. In some instances in this project, the researcher became a valued resource for the municipality. Problems associated with this, was that when the research ended and no more contact was made, the project outcome could change.

'She was also assisting us because trying to bridge the gap between the management, internal management and our process controllers.'

Water Care Manager - ADM

management personnel and the borehole operators. By gathering research through phone interviews with borehole operators, the iComms members developed trust, addressed the borehole operators' complaints and partially filled this communication gap. The municipal

manager reported that being involved in the iComms project highlighted the existing communication gaps within the municipality, and that unless they were internally addressed the project would fail if the University was not involved. In this instance the University was performing a management role by monitoring and supporting the borehole operators. My twice-monthly phone interviews with the municipal managers may also have had an effect on the amount of interaction they had with the WQM mobile. Managers knew that outside monitoring was taking place and this may have increased their interaction with the WQM and focus on the borehole schemes. Therefore, it is important to manage the impact that the researcher has on the project implementation. In some instances in this project, the researcher became a valued resource for the municipality. Problems associated with this, was that when the research ended and no more contact was made, the project outcome could change.

'We are also seeing in terms of our, our operators, you know that eagerness now. It was before the guys there was nothing that was driving them to work. But now you can see because even when you speak to them they will say no they are talking to, we phones Cape Town.'

Water Care Manger - ADM

8.6.2 Time Constraints

'I think sometimes your management is so held up in other stuff and that is really because of under resourcing in terms of management structures. That you sometimes put these things on the side for now until there is a real issue.'

Municipal Heath Director - CHDM

'I should just send a supervisor to check what is happening now, there is that gap because there is not that interlink, although there is Philip (Water Quality Technician)'

Water Care Manger - ADM

Some of the managers reported that they were not always able to conduct follow-ups on the data received through the WQM mobile, due to time limits and a number of other pressing priorities. The limited time available to the managers to conduct interviews became evident when I was unable to contact one of the managers for eight weeks, from 25 July to 13 September 2011. During this time it was reported that he was on site, at a workshop or too busy to take my calls. When contact was made, the manager was in the financial

department and not his own office. This revealed that the high workload has a profound effect on the ability of staff to manage additional information. The manager was aware of on-site conditions – which was clear from the comments he made during interviews - but his time limits, lack of existing workflows and shortages of staff restricted him from utilizing the information and conducting follow-ups to problems identified. The municipal manager identified a gap in middle management, for there were only two supervisors responsible for all water supply schemes within the District. Therefore,

‘If we can address the shortage of staff issues, then at least we will be able to see the improvements.’

Water Care Manager - ADM

there was no capacity to follow up on the problems experienced at the rural schemes. Buy-in to the project from management was seen, but the limited municipality capacity restricted full utilization of the iComms reporting system.

8.6.3 Competing Objectives

There are many competing functions within a rural municipality that are performed by the same personnel. As a result, the limited staff, managers’ time and a constant change in priority often resulted in neglecting systems that do not require immediate attention. The Managers reported that sometimes they were only able to react when water quality failures occurred.

‘There is no way we can sample, there is just snow all over the place.’

Assistant Director of Water Services - ANDM

‘Most of the teams out there in the field, assisting with the disaster because peoples offices are now flooded and we had to move people from their houses, clearing roads and all of those things.’

Municipal Health Director - CHDM

In late July of 2011, the Eastern Cape experienced extreme weather conditions. Flooding and large amounts of snowfall took place throughout the study site districts. As a result, the municipal offices were closed and the roads shut, preventing monitoring of the water supply schemes. Over the next few days all municipal personnel were stationed in the field to assist with disaster management. Offices and homes were flooded and roads had to be cleared of snow. This

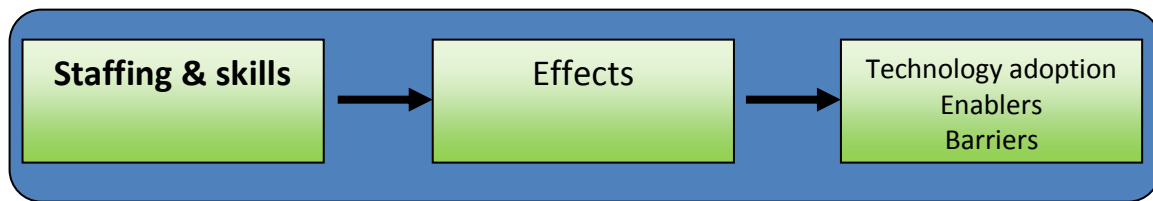
revealed the uniqueness of rural municipalities in that the change of priorities affects all municipal staff independent of their core function, since everyone has to contribute in a crisis.

Another example of prioritisation was the focus on developing water safety plans in one of the district municipalities. The manager spent months on site with external consultants, learning how to develop water safety plans for their entire District, so that their BDS could increase. As a result,

limited time was spent by management on monitoring the rural water quality and attending to problems identified by the WQM.

<p>'There is something else that we are doing, we are developing Water Safety Plans for the entire District.'</p> <p>Water Care Manger - ADM</p>	<p>'We want to be a part of it, so we can be able also to do water safety plans for the rest of our WTW.'</p> <p>Water Care Manger - ADM</p>
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University of Cape Town



8.7 Staffing and Skills

8.7.1 Technology Adoption

Despite some technical challenges with both the managers and operators phones, the municipalities reported that they were in control of the reporting system. In the managers' opinion, no additional training was required for either themselves or the borehole operators and they were able to manage the system, as long as the iComms team could be relied on for support if technical problems arose. Technical problems experienced by the borehole operators that were common to the project, included:

- Running out of airtime
- Deleting the WQR application by mistake
- Downloading other applications onto the phone

The downloading of games, music and ringtones used up airtime and took up memory space on the phone, often to the extent that the WQR application was deleted, or no longer had enough memory capacity to run. Although this negatively affected the implementation of the iComms project and limited the amount of data received by the WQM, it showed peoples ease of adoption of mobile phones.

'I've been using the application for quite some time now and I don't think I will be having any problems, the results are coming now.'

Water Care Manger - ADM

'No, no, no problems with the application. The operators seem to be doing what they are supposed to be doing, I'm getting results.'

Assistant Director of Water Service - ANDM

'Yes, I think they can cope with the system.'

Water Service Manger – HLM

'Most people here are coping and they can continue with this project.'

Municipal Health Director - CHDM

8.7.2 Enablers of Implementation

The amount of information the municipal managers had to base their decision-making on was directly influenced by the amount of information reported by the supply caretakers through the WQR application. Not only did the ease of adoption of the mobile technology by the borehole operators facilitate data transfer, but there was prestigious perception and enhancement of one's social status associated with the use of technology. The operators that took part in the project desired some acknowledgement for using the system, so the iComms team held a ceremony and issued them with certificates and participation t-shirts. In order to acknowledge their performance on a daily basis, confirmation smses were received on their phones whenever data was submitted through the WQR application. This was important since it provided the important feedback to operators that their results were being received. The importance the operators felt from using the system aided data transfer, for it encouraged reporting and allowed more informed management of the rural water supply schemes.

8.7.3 Barriers of Implementation

Municipal managers required frequent reporting to base their decision-making on. In many municipalities, the choice of who to employ to dose and care for the rural water supply schemes was not up to the managers. Normally supply caretakers are old, trusted community members, selected by the consumers in the village. Older generation personnel are less familiar with technology and this hinders their adoption of new technical systems. Although most of the operators managed reporting through the WQR, the municipal managers reported that in future, employment of staff would be based on their literacy levels and their ability to be trained. Another municipal manager considered education for the borehole operators as being critical. In his opinion, the operators must be informed that their work influences municipal decision-making and is important to ensure the delivery of safe supply.

'If you are looking for a borehole operator, we are just taking anybody for that position, if it is an old person who can't even write. But today it is an eye-opener that you need to have personal that is going to understand the importance of supplying that water to his community.'

Water Care Manager - ADM

'Operators are from communities, so from each community we ask them to provide us with someone who will be responsible for the water.'

Assistant Director of Water Services - ANDM

'They must know why they are monitoring, why the data is important because at the end of the day the data that they are submitting assists us in making decisions.'

Municipal Health Director - CHDM

One of the managers believed that a barrier to implementation of the iComms project was that the system was run by the university. He believed that if the reporting system was fully adopted by the municipality, the frequency of reporting water quality data would increase. His perception was that the operators were viewing the reporting system as a temporary one, belonging to and benefiting the university. In this same municipality, one of the borehole operators had never reported his results through the WQR on his cellphone. The manager believed that there was no buy-in to the project from this employee. This revealed that all participants had to realise the benefits and had to have a strong desire to be involved in the project, otherwise data gaps would result and the system would not be effective.

'They know that this is not the actual system of the municipality, it is a system for you, UCT.'

Water Service Manger – HLM

'It's now to get this guy jacked up and buy into this system.'

Water Service Manger – HLM

University of Cape Town

Chapter Nine

9 Discussion and Conclusion

This dissertation has shown that improved real-time access to water quality information could result in better management of the borehole water supply schemes. It is often difficult for rural municipal managers to gain access to their rural water quality data, since municipal offices are situated in urban environments away from borehole schemes. The WQM mobile application allowed for distance monitoring of the rural water supply schemes. Managers had access to rural water quality test results on a daily basis in any location.

The WQM mobile application successfully addressed the iComms goals established in the outset of the project:

1) Collect reliable up to date information on the rural water quality

Through the use of the iComms reporting tools, WQR and WQM, municipal managers had direct access to their on-site water quality test results. In all municipalities, there has been an improvement of information flow from borehole operators to government service providers. This has helped address the municipalities' institutional capacity problems, as site visits to collect data were replaced by real-time data transfer. Through the increase in data collection, reliable records could be established to base decision-making on.

2) Identify water quality failures

Through the WQM mobile alert smses, water quality contamination was easier reported and managed. Managers reported that the improvement in early intervention has resulted in water quality normally being compliant again within 24 hours. The ability to track water quality failures has resulted in managers being more confident about the quality of the rural water supply.

3) Monitor what is happening on site at the borehole schemes

Through the WQM, managers were able to regularly view the water quality compliance results for their individual study sites, as well as monitor the borehole operators' performance. The data records on the mobile phone showed the frequency of reporting the

different operational parameters. The documented proof enabled managers to hold their staff accountable for their actions.

4) Support the borehole operators in performing their operational duties

Municipal support could be provided to the borehole operators, as the WQM mobile identified their resource needs and technical problems experienced on site. A lack of chlorine supply may have been the cause of a positive H₂S test, or a lack of data could have been due to the operator experiencing technical problems with their phones. Increased support was important, for it reassured the borehole operators that their work was significant and motivated them to perform.

5) Improve communication between borehole operators and the municipal managers

Through improved information flow and the identification of problems on site, communication between the WSA and the borehole operators had the potential to increase. If good communication lines and workflows were in place, problems could be addressed through an increase in communication. The implementation of the WQM had no effect on face-to-face communication.

The WQM mobile application improved distance monitoring, accessing and observation of test results, increased communication, and support provided to individuals, early intervention and the managing of non-compliance. These results have been supported by Blake in his study of Mobile phone technology in chronic disease management (Blake, 2008) and in Cell-Life's *Aftercare* program (Kinkade & Verclas, 2008). Mobile phone usage in the *Push to Talk* and *Xam Marse* initiatives have also seen some of the benefits mentioned above (Kinkade & Verclas, 2008; Manobi, 2005).

Mobile technology allows the monitoring on-site information, but management can only improve if action is taken based on the results received. The mobile technology only provided municipal managers with access to real-time water quality information. Improved management of the borehole schemes relied on the capacity of the municipality and the perceived importance of the information system.

The research showed that management would improve if the following four factors were evident:

1) High perceived usefulness

If managers believed that the project was important and would benefit the municipality, they would fully engage with the system, provide valuable feedback and motivate their staff to perform and become involved.

2) Managers Time

Interaction with the WQM mobile application was quick and convenient and was designed to allow busy managers to monitor their rural water quality results. Managers still had to have enough time to communicate with the responsible personnel to go and investigate data non-compliances and follow-up on remediation steps.

3) Workflows

In order for the information being received through the WQM mobile application to have had an impact, there needed to be workflows in place to integrate the data into. The municipality needed to have clear guidelines and steps to follow, so that when situations arose, they could be dealt with accordingly.

4) Capacity

Lastly, the municipality had to have enough available staff and resources to attend to problems on site. Improved management of the borehole schemes could only take place if there were personnel following up on data concerns. There also needed to be available resources, such as, bakkies and chlorine, to attend to problems.

Without these four factors, management and therefore improvement of water quality might be unaffected even if the monitoring of the source was done well. Greater improvement was seen in municipalities where the tool was used consistently, where time was set aside to follow up on data warnings and protocols existed to follow up on non-compliance issues. Management of the resources did not improve in areas where management staff was severely overstretched and response strategies to problems were non-existent.

Table 6: Project outcome in the different study sites

Study Site	Factors Affecting the Use of Information				Improved Monitoring of BHs	Improved Management of BHs	Project Outcome
	Perceived Usefulness	Managers Time	Workflows	Capacity (staff & resources)			
Hantam LM	✓	✓	✓	✓	✓	✓	Success
Chris Hani DM	✓	✓	✓	✓	✓	✓	Success
Amathole DM	✓	✗	✗	✗	✓	✗	Partial Failure
Alfred Nzo DM	✓	Project Abandoned					Total Failure

In Hantam Local Municipality and Chris Hani District Municipality, all the design goals were achieved and management of the borehole supply schemes improved. These municipalities saw a benefit in keeping the system, but long term sustainability can only be determined once the project has been fully handed over to the municipalities at the end of 2012. In Amathole District Municipality, there was partial success of the initiate, as monitoring of the rural supply schemes improved and some of the municipality's goals were met. Management of the supply schemes in this municipality was, however, unaffected due to there being restraints on the manager's time, a shortage of staff and no workflows in place for the borehole schemes. In Alfred Nzo District Municipality, the project experienced total failure, due to the system being implemented but abandoned three months after with the Assistant Director leaving.

The research supports the hypothesis that management of rural water supply quality will improve with the use of mobile technology. It is conditional that the municipality has the capacity to act on research data and the willingness to fully engage with the information systems.

Whilst the research revealed the positive effects that an improvement of information flow could have on the management of the rural water sector, the results also exposed a number of aspects that must be considered in order for management to improve. Assessing the success and failure of the ICT project on the municipality as a whole was beyond the scope of research.

Chapter Ten

10 Recommendations

One of the aspects that was not addressed by municipalities was the importance and legal requirement to engage with communities. None of the municipalities were providing feedback through an appropriate medium, to the communities, on the compliance of their rural water quality. It is recommended that further studies be conducted on using the information provided by the WQM mobile application, to report to the consumers. If the consumer's knowledge of their water quality improved, there may be an increased perception in service delivery.

It is also recommended that further studies are done to see how the increase in information and records of data stored on the phone, could be used to influence risk assessment. The records of water quality incidences over time, allow one to map the risk associated with each scheme. This could influence the development of water safety plans for the borehole schemes. If the H₂S and iComms reporting system were expanded over a greater area, sources that are regularly contaminated could be identified and chlorination systems set-up. A study on how the H₂S and iComms reporting tools have affected disease out-breaks and the number of diarrheal cases could also be done, to assess the impact that the system has on the management of disease.

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12 Appendix 1

12.1 Aquatest Project

The Aquatest project's aim is to develop a low cost water testing device for microbial contamination, to help identify unsafe water supplies and improve access to safe water. The Aquatest project is an international project led by the University of Bristol. Other organisations involved include:

- WHO
- Aquaya Institute, USA
- Health Protection Agency (HPA), USA
- PATH, USA
- University of California- Berkeley, USA
- University of Cape Town, South Africa
- University of North Carolina, USA
- University of Southampton, UK
- University of Surrey, UK

The funding for the project was awarded by the Bill and Melinda Gates Foundation's Global Development Fund, which granted the University of Bristol US \$13 million, to develop the Aquatest project. This will be done in collaboration with a number of international multidisciplinary organisations. Early preparatory studies started in October 2007 and the project is intended to conclude in September 2012.

The Aquatest device is designed to support professionals in meeting their water quality requirements. It is based on meeting most national water quality guidelines. It is intended for use by: water quality management professionals and specialists; community based water managers (especially in the rural setting) (Water and Health Research Centre, 2012).

12.1.1 The Aquatest tools

The Aquatest project consists of an on-site testing device accompanied by an incubator, UV torch and a cellphone reporting system. The University of Cape Town's iComms team was responsible for the design and implementation of the cellphone technology in building an information-management system. Each tool is briefly described below:

The Aquatest device is a single plastic testing unit that can be used in the field. It tests water quality samples for the presence of E.coli (indicator of faecal contamination). This quantitative analysis has an accuracy to detect one E.coli per 100mls, which is enough for the supply to be considered unsafe (according to SANS241). The test works by releasing a growth medium and separating the sample into chambers. The sample is then incubated for 24hrs and the results read by use of a UV light. The number of chambers that are florescent indicates the amount of contamination. Once results have been captured, a turning of the device will release a disinfectant, allowing safe disposal of the device.



Figure 42: Image of the Aquatests device (Water and Health Research Centre, 2012).

The incubator is designed to be used in developing regions where there may not always be an electricity supply. The incubator works by using boiling water to melt a phase change material that will store the heat for the required 24hrs. A constant temperature of approximately 37° will be reached, allowing adequate E.coli growth in the sample.

A UV torch is used to indicate the presence of E.coli by fluorescence in chambers. A most probable number (MPN) technique is used to estimate the amount of contamination (MPN table are provided with the device).

A WQR cellphone application allows on-site personnel to store and report the water quality test results to authorities responsible for supply. The data transfer system is low cost and easy to use. It is specifically designed to be used in rural environments where supply schemes are dispersed and reporting is difficult (Water and Health Research Centre, 2012).

12.2 UCTs iComms Involvement

iComms 'aim is to develop mobile infrastructure to monitor the delivery of basic services, such as safe drinking water, to rural communities' (iComms, 2012). The iComms team has been involved in a number of projects that use appropriate technologies to help the development of the healthcare, environment and now water quality departments. They focus on using low cost technologies to improve service delivery to poor communities. All projects are designed using open-source software this is to encourage use and enable systems to be altered to fit the unique requirements of beneficiaries.

As part of the Aquatest project, the iComms team had the responsibility for developing a water quality data transmitting device in order to communicate the Aquatests results to water quality professionals. The iComms team was further responsible for:

- 'Integration of water quality results into existing information systems using open-source software
- Development of a feedback loop between communities and supporting authorities, e.g. information regarding status of water quality, routine water quality information, targeted requests' (iComms, 2012)

The iComms team has created various software tools to help efficiently manage information flow in the government sector. The Aquatest reporting system consists of a Water Quality Reporter (WQR); Water Quality Manager, web application (WQM web) and a Water Quality Manager android application (WQM android). Testing of the information technology system was carried out in a cross-section of developing countries. Early adopters were Cambodia, Vietnam, Mozambique and South Africa.

12.3 Obtaining the iComms Reporting Software

The WQR, WQM web and WQM android software is all available for free online under various open-sourced licenses. For specific installation requirements and guidelines, please see the following website pages (iComms, 2011):

- Water Quality Reporter
<http://bitbucket.org/icomms/wqreporter/overview>
- Water Quality Manger (Web)
<http://github.com/icomms/wqmanager>
- Water Quality Manager (Android)
<http://github.com/icomms/wqmandroid>

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13 Appendix 2

Table 7: A breakdown of the requirements of the Key Performance Areas and Indicators and their relative contributions towards the Blue Drop Score for Years 4 to 6 (Department of Water Affairs, 2011).

	Key Performance Area	KPA Percentage			Key performance indicator		KPI Percentage		
		Year 4	Year 5	Year 6			Year 4	Year 5	Year 6
1	Water safety Planning	30	35	35	1.1	Water Safety planning process	10	10	5
	1.2				Risk Assessment and review of control measures	30	30	35	
	1.3				Risk based monitoring programs	25	25	25	
	1.4				Credibility and Submission of Drinking water Quality Data	20	15	15	
	1.5				Incident management	15	20	20	
2	Drinking Water Quality Process management and Control	15	10	10	2.1	Compliance with Regulations - Works Classification	15	10	10
	2.2				Compliance with Regulation - process Controller Registration	50	50	40	
	2.3				Availability of signed WTP logbook	35	40	50	
3	Drinking Water Quality Compliance	30	30	25	3.1	Compliance per Determinant (according to monitoring programme)	60	60	60
	3.2				Risk Assessment defined Health Index	20	20	20	
	3.3				Operational Efficiency Index	20	20	20	
4	Management, Accountability and Local Regulation	10	10	15	4.1	Management Commitment	40	40	40
	4.2				Publication of performance	30	30	30	
	4.3				Service level agreements / Performance Agreements	30	30	30	
5	Asset Management	15	15	15	5.1	Annual Process audit	20	20	20
	5.2				Asset Register	15	15	15	
	5.3				Availability and Competence of maintenance Team	15	15	15	
	5.4				Operations and Maintenance Manual	15	15	15	
	5.5				Maintenance and Operations Budget and expenditure	20	20	20	
	5.6				Design Capacity versus Operational Capacity	15	15	15	

13.1 Appendix 2.2 – Emanti’s Water Quality Management System (eWQMS)

Emanti Management (Pty) Ltd developed a Water Quality Management System (eWQMS) to help water service institutions track, analyse and interpret data, to help improve the quality of water provided. The system also highlights areas of concern that require intervention, along with corrective suggestions. The eWQMS system is accessed via the internet and has been proven to successfully assist WSA meet the National Drinking Water Management Framework Requirements. The eWQMS management tool is used for:

- ‘Regulatory compliance by WSAs
- The timeous supportive intervention in water quality failures (chronic and acute)
- Infrastructure improvement
- Capacity development of municipal staff’ (DWAF, accessed October 2010)

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14 Appendix 3

14.1 Appendix 3.1 - Historical Interview Questions

For the Municipal Managers - April 2011

GENERAL INFORMATION

1. Please state your job title and how long you have been doing it?
2. What does your job entail (what other sectors besides water do you manage?) and what is your main priority within your sector?
3. What are the main challengers in your job?
 - Do you have enough time and resources?
4. What are the main challengers with water provision?

INFORMATION

5. How do you think better information can improve decision making? So far has the system help you improve your decision making?, do you make more informed decisions now?
6. Do you receive information from a greater/ more areas than you did before?
7. Has the H₂S affected the compliance monitoring frequency or areas where its carried out? (hot spots identified)

IMPLEMENTATION

(before UCT gave you the android phone)

8. Do you have a work and personal phone or use the same one for both?
9. Have you looked at the latest water quality excel report on your cellphone or on the computer? (specify) And was it easy to access and analyze?
10. Have you used the data received in the monthly report and where have there been improvements?

- Reporting
 - Making a decision
 - Implementing remedial action
 - Notifying authorities
 - Informing the community
11. Do you feel the system on your phone, getting smses of water quality data, (before Android – old system) is helping you manage water quality and do you feel it is compatible with the other monitoring and management systems already in place?
 12. How have you experienced the implementation of the H₂S and the reporting system? (Does it fit in well with how you like to work)- do you like using it?

Challenges

13. What were the challengers and how did you receive and collecting water quality data before cellphones were used by the borehole operators? And how often was data collected? And how often is it collected now?
14. Do you still meet your borehole operators as often as before implementation?
15. When the H₂S turns black does the borehole operator report that directly - sms?
16. When you get informed that contamination is detected, what do you do? And is anything preventing you from following through on remedial action?

OBJECTIVES and VALUES

17. Do you feel that you are serving your community? And that they know the quality of the water they are consuming ? If they suspect pollution would they contact you?
18. Are the community members aware of the H₂S and Reporting system and has it increased the amount of communication to consumers? (now you have more information to communicate)

ORGANIZATIONAL PROCESS

Reporting and General

19. What areas do you serve?
20. Is the municipality the WSA and WSP for all areas within its jurisdiction? If not, then who is?
21. Please explain what you do in terms of drinking water quality management?
22. Who do you work with and what do they do? (e.g. Mayor, EHP, etc)
23. What are your responsibilities to government authorities – DWA and DoH?
24. How do you report drinking water quality data to government and the consumer? (Blue Drop or eWQMS) and how often do you report this?, what are the benefits?
25. What can government do to help deliver water services?

TECHNOLOGY

Cellphone

26. What do you expect from the new cellphone application?

Blue Drop

27. Do you think there is a benefit in reporting your results to Blue Drop? And is there a benefit in knowing other peoples status? (what other municipalities do you look at) How important is it to achieve Blue Drop status?
28. What aspect of the Blue Drop scoring do you need to improve?, and do you think that the new HTC phones and WQR system will help you achieve a greater score on the Blue Drop?

14.2 Appendix 3.2 – Ongoing Phone Call Interview Questions

10 weeks worth of questions asked approximately every 2-3 week, between June and October 2011

TECHNOLOGY

1. Have you used the Water Quality Manager (WQM) on the cellphone? (Yes/ No)
 - If No: why not?
2. Have you experienced any technical difficulties? (breakages or malfunctioning)
 - Are there any application errors?
 - What were you doing when the application stopped working? (what step were you on)
 - For how long has the application not been working?
 - Why have you not contacted us?
 - Do you know how to reload the application?
3. Do you find the application easy to use?
4. Does it do what you want it to?
5. Have you looked at the web (WQM) application? (Yes/No)
 - if No: Why not?
 - if Yes: What do you think about it?
6. Are any borehole operators not reporting their results?
 - What do you think is the reason for this?

IMPLEMENTATION

1. Is the cellphone system fitting in well with your monitoring and management program?(Yes/No)
2. How would you normally get this information feedback without the phone?
3. Who would give it to you/ how would you get it?
4. Are you happy with the current management structure?
5. Has your work load increased due to the new system (Yes/No)
 - if Yes: In what way?
6. How much time a week are you using the phone for water related activities?
7. What other activities are you using the mobile phone for? (personal, municipal)
8. Were you surprised by any information received by using the system?

9. What actions have been taken this week based on the information gained from the cellphone?
10. Are you experiencing any challenges with the application?
11. Do you feel additional training is required for yourself or the borehole operators?

INFORMATION

1. Have you looked at the water quality manager on your cellphone this week?
2. Has the cellphone made a difference? (Yes/No)
 - In what way?
3. What limitations in management and monitoring can the cellphone not address?
4. How has the quality (reliability/ timeliness) of the information changed?
5. Do you find the cellphone tool aids you in your job?
 - How and why?
6. Has the uncertainty and speed in decision making changed?
7. Has your confidence in the quality of the water in the boreholes changed?
8. When the data shows a failure, are any factors preventing you from follow through on remedial action?
9. How much use has it been to have the water quality information mobile, so you can access it wherever you are?
 - Please explain
10. Do you mind my phone calls?

OBJECTIVES and VALUES

1. How do you report to consumers?
2. Has there been an change in the frequency of reporting to consumers, since the use of the android phones? (more information to report or more informed about failures)
3. Do you hold your staff more accountable, because of what you see from the data? (gone back to them and said why did you not test here, or dose with chlorine on this date etc.)
4. Do you think you are better serving your community?
5. Does the community know you are now monitoring their water supply?
6. Do they know about the cellphone system?
7. What do you think is the community's perception on water service delivery?

8. What factors are limiting the system from working effectively? (skills, training, staff – facilitating conditions and external barriers)
9. Do you think the application had any effect on the productivity or performance of the staff involved? (including yourself)

Android phone and taking over the system (INFORMATION)

1. Are you looking at the monthly excel reports on the web or are you just using your android phone?
2. Do you know if the android phone and H₂S test system has had an impact on your resource use and requirements? (i.e. need more staff, but less time and money for travel) Can I email you and get some figures?
3. Do you find it easier to manage the areas loaded on the android system compared to those that are not? (i.e. monitoring chlorine levels?)
4. Do you think the system is beneficial enough that you would set money aside in your municipal budget to fund the upkeep and running of it?
5. If the system was handed over what would you do about airtime allowance, how would you monitor and manage it?
6. Also we have found that the operators upload music onto the phones and this takes up space and often as a result the WQR application is deleted. If you were to take over the system how would you deal with this constant arising issue?
7. If you took over the system how would you address the issue of stolen and lost phones, would you replace them?
8. Has there been any change in the communication gap between the district and the local municipalities, since the use of the system?

Extra questions for ADM and CHDM

- If we handed over the system would the DM still run it or would they give it to the LM to manage?
- Will you offer support in anyway if the local municipalities were to take over the system?
- Do the local municipalities get the data results of our system, do they have username and password to web address?

Extra questions for Hantam LM

- Why do you think the system would run more smoothly if the municipality took over the system and did all the maintenance on the system?
- Are all the operators testing everyday as you would like?, have you checked this on your android phone?
- Please can I ask you to collect all the operators IMEI numbers, they are located on the back of the phone behind the battery. Can you please email me all of them, need them to open a case and block the phones encase they get lost or stolen.

Blue Drop, Our Sites and LM (INFORMATION)

1. What are the main challengers and resource limitations you have, when it comes to the borehole (BH) schemes?
2. How many BH schemes do you have?
3. How many are registered on the Blue Drop and are active?
4. Please can we get a list of our sites and indicate which are registered and active on the Blue Drop?
5. What data are you using to report operational monitoring on the Blue Drop for the BHs?
6. In reporting to Blue Drop who loads the lab results onto the system, the DM or does the lab do that directly?
7. How many LM are there within the DM?
8. Are the borehole operators involved in the project employed by the DM or LM?
9. If employed by LM - does this cause any problems?

Extra questions CHDM

- Is the DM the WSA and WSP, why is the LM not the WSP?
- Does the LM do any additional operational monitoring?

Extra questions ADM

- Do you compliance monitor Amathole Water?, who's results get sent to the Blue Drop?
- You were reporting to Blue Drop and eWQMS, has there been any changes with the new financial year?
- Have you managed to compile a Blue Drop report that council approves of, that resembles something similar to that of eWQMS reporting?
- Have you now grouped your BHs as planned per LM and are they now compliance monitoring the biggest one in each group?, is this BH loaded onto the Blue Drop and active?

Extra Questions Hantam LM

- Why do you have the WSA role and not the DM (for Hantam instead – ignore all LM questions)
- Does Hantam do the compliance monitoring as well? Does the DM do any?

Boreholes and Chlorinating (PROCESS)

1. Do you compliance monitor all your BHs monthly? (How frequently and how many?)
2. Are you chlorinating all your BHs and reservoirs they feed into, within your DM?
3. How do you dose your reservoirs with chlorine? (chlorine pumps or tablets)
4. What are the negative effects of this type of dosing (pump breakages or operators not dosing)
5. Are you checking the chlorine levels? And how frequently do you do this?
6. How were the chlorine levels recorded before UCTs cellphone system? Does anyone receive the results, how frequently (and how, through what medium?)
7. When did you start dosing with chlorine and testing the chlorine levels?
8. Do any of your BH schemes have water safety plans?

Extra Question CHDM

- Before UCTs system, you said compliance monitoring, of boreholes etc., were done on a ad hoc basis, is this still the case? (want to know if they are now taking monthly samples of their borehole water)

Community and Failures (PROCESS, OBJECTIVES and VALUES) + Interdepartmental Communication

1. If there is a failure please run through the process. Is a lab sample taken or just on-site test kits used?
2. How long before the results are generated and the community is informed? (is a resample taken?)
3. What media and methods do you use to inform the community if there is non-compliance?
4. How would the community contact you if the suspected pollution? How often does this happen?
5. Do the people ever complain about the taste of the water due to the chlorine and go to the river instead?
6. How often is health and hygiene awareness done? who conducts this?
7. What percentage of the community use rain tanks?, do you test their water or supply them with chlorine?
8. Are the people aware that their water needs to be chlorinated before they can drink it?

Extra Questions CHDM

- Are you currently reporting the water quality results in the quarterly Chris Hani news letter? Since when have you been doing this? Is it done on a continuous basis?
- What percentage of the community receives this news letter? How do you report water quality to the other percentage?

Extra Questions ADM and CHDM

- Do the people ever complain about the taste of the water due to the chlorine and go to the river instead?

Extra Questions Hantam LM

- Since you first put an article in the newspaper about the H₂S system, when it was implemented, has anything more been communicated to the community about the system?

System Information (PROCESS, OBJECTIVES and VALUES)

1. How have you used the data?, where have there been improvements?
2. What aspects of failure identification have improved due to use of the system, have any patterns been identified? (timeliness, reason for failure, no longer wait to be informed by the clinics?)
3. Has the time spent on travel, by the EHPs changed at all, with regards to monitoring the Borehole water?
4. When the system is not working properly, how does that add to your workload?
5. In your opinion, does the time and energy it takes to rectify the systems problem outweigh the benefits of the tool?
6. How can we make it easier so the system is not an extra burden on your days work, or the work of the EHPs?
7. Does the system help identify resource needs of the operators, for instance chlorine supply?
8. How often are your EHPs communicating with your operators?, how do they do this?

Extra Questions CHDM

- In an earlier interview, you said you were establishing another two labs in Middelburg and Intsikayethu, has this been done? when will they be up and running?
- What was the reason for establishing another two laboratories?

Extra Questions ADM

- Does Philip visit every BH scheme monthly or only those conducting H₂S tests/ chlorinating?
- Clarify: you said you have 9 (.....) people just focusing on the BH schemes, employed to assist

STAFFING and SKILLS

1. How much time do you spend on the water sector?
2. Has the Android phone affected this at all?
3. Do you focus more on conventional schemes or BH water now? Which takes up more time and resources?
4. How often are your EHPs communicating with your operators?, how do they do this?
5. Are you happy with your current management and monitoring structure? Has there been any recent changes involved with the system and for what reason?
6. Do you and your staff feel more pressurised to perform because of the Android system?
7. Is there any staff development and training for the operators?, how frequently is this done?
8. Do you think it makes a difference for outside people to get involved? Does it make a difference with regards to the people's perception, how much work is done?
9. Do you think the operators are now coping with the system and will carry on doing so in the future?

Extra Questions CHDM

- Have you given your EHPs, Vuyeka and Zukile, the username and password to the website so that they can monitor as well?

Extra Questions ADM

- Have you given your EHP, Philip, the username and password to the website so that he can monitor as well?
- Do you still feel there is a shortage of staff capacity at supervisor level?, have any more staff been employed since may?
- You informed me that you sent qualified process controllers on a training course at collage, has this been completed?

14.3 Appendix 3.3 – Sustainability Questions

Managers Meeting November 2011

1. Has the android phone measured up to your initial expectations of it?
2. Do you have any suggestions on how to improve the android application?
3. What was the most surprising thing you learned?
4. Do you think communities and municipalities needs were addressed and designed for from the beginning and during the project?
5. Do you think that we had an appropriate understanding of the local context in which we were working?
6. Do you think the project built onto and improved existing practices in water quality monitoring and reporting? How?
7. Do you feel the system would improve if the EHP also had Android phones, how and why?
8. Do you think implementation of the project could be improved in any ways?
9. How do you think the system would run effectively without UCTs involvement?