Partnering for solutions:

ICTs in Smart Water Management

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Additional information and materials relating to this report can be found at: www.itu.int/itu-t/climatechange. If you would like to provide any additional information, please contact Cristina Bueti at tsbsg5@itu.int.

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Executive Summary

Today, information and communication technologies (ICTs) have become pivotal in everyday life. Though there are many initiatives designed to enhance water sustainability, efficiency and accessibility via ICTs to address the water crisis, there is still a need for standardization and proper ICT governance. Provision of this ensures that there is proper management of these technologies, avoiding the possible increase in consumption or environmental damage from electronic waste. Smart water management (SWM) therefore is a key policy issue on the global stage.

As part of their mandate to secure a sustainable future, both ITU and UNESCO, have set out to raise awareness on ICTs and SWM. The International Telecommunication Union (ITU), the United Nation's specialized agency for ICTs, develops internationally recognized standards which act as defining elements in the global infrastructure of ICTs. ITU, the very heart of the ICT sector, recognizes the positive influence that ICTs can play in the distribution, management, and allocation of our water resources. Consequently, ITU's Focus Group on Smart Water Management (FG-SWM) provides a peer forum to tackle the gaps in "ICTs and SWM" so that countries can overcome the global water challenges collectively.

The United Nations Education, Science and Cultural Organization (UNESCO), on the other hand has been a leader in building the scientific knowledge base to help countries manage their water resources sustainably. Through the International Hydrological Programme, the UN-wide World Water Development Report, the UNESCO-IHE Institute for Water Education, as well as affiliations with countless research centres and water-related Chairs on water around the world, UNESCO is strengthening global water security.

Though economic growth, climate change and rising populations highly influence the availability of global water resources, strategic incorporation of ICTs in SWM can mitigate some of these challenges. Such achievements, however, are unattainable without proper stakeholder involvement and buy-in. The principal intention of this report is to go further and emphasize how ICTs can overcome some of the challenges faced in the water sector when there is proper stakeholder involvement.

The first section of this report seeks to showcase the significant roles stakeholders can play in the area of ICTs and SWM, while the second section highlights a few SWM initiatives and their accomplishments on a national, regional and international scale. Case studies selected were chosen to highlight how ICTs can be incorporated to address some issues related to the current global water crisis such as water security, water accessibility, climate change, aging infrastructure and management.

The intention is to provide an overview of ICTs as a strategic instrument in SWM. It is also envisioned to act as a catalyst for further discussion and future successful implementation of SWM initiatives worldwide.

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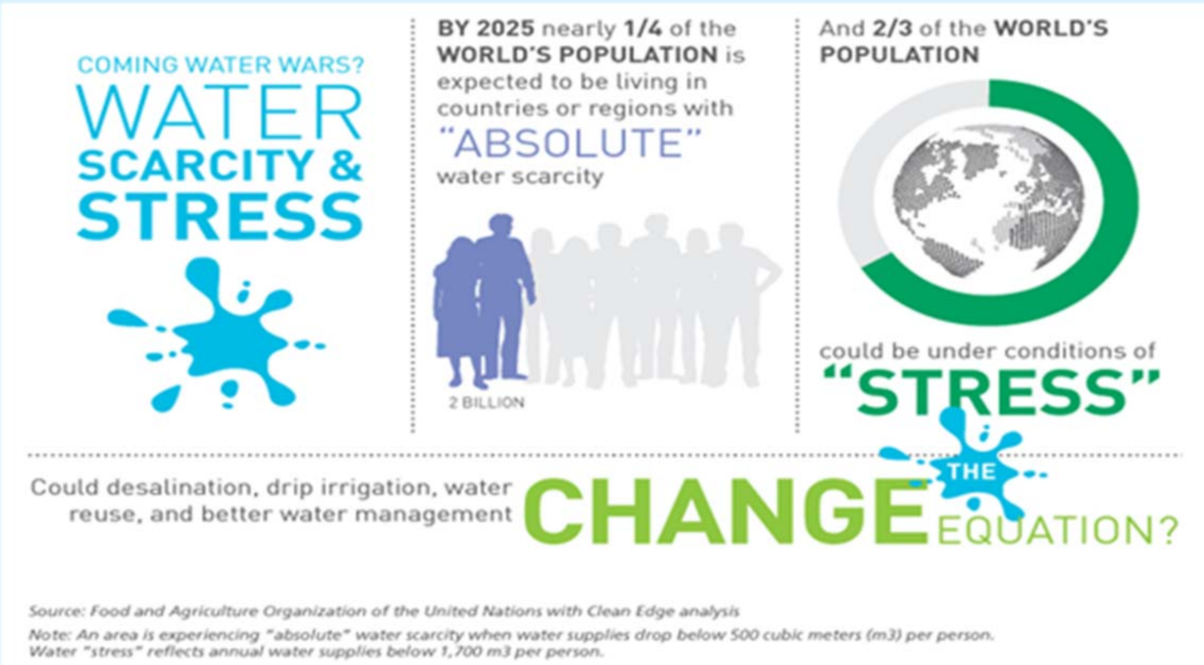
1 Introduction

1.1 Background

Safe and adequate fresh water resources are essential to the economy and political stability of a country, but more importantly they are necessary to the sustenance of basic livelihoods. Access to basic water services, including clean drinking water and sanitation, is still unavailable to a large fraction of the world's population. According to UN estimates, 85% of the world's population live in the most arid regions of the planet; 783 million people do not have access to clean water; almost 2.5 billion do not have access to adequate sanitation; and six to eight million people die annually from the consequences of water-related disasters and diseases (CIMUN, 2013).

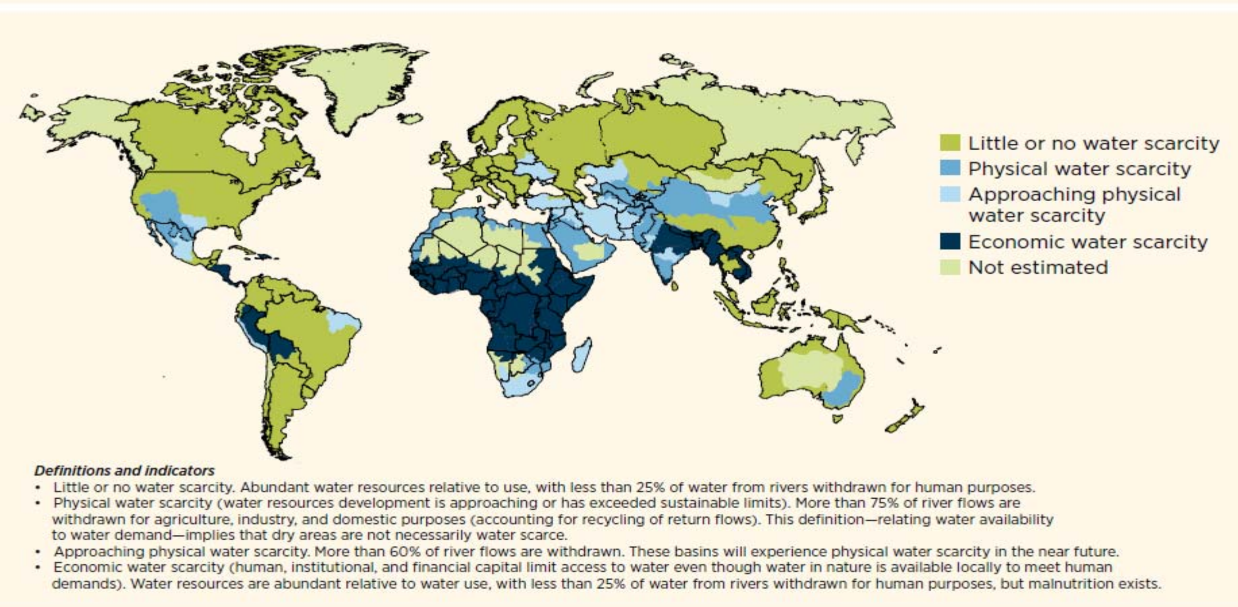
Figure 1 – Water scarcity and water stress issues poses a threat to the global population



Water scarcity and water stress have also become crucial global issues (Figure 1). "Around 1.2 billion people, or almost one-fifth of the world's population, live in areas of physical scarcity, and 500 million people are approaching this situation. Another 1.6 billion people, or almost one quarter of the world's population, face economic water shortage (where countries lack the necessary infrastructure to take water from rivers and aquifers)" (UN 2013). In addition, climate change threatens to further affect the supply and demand of our water resources as adverse climatic conditions, in consequence, will undoubtedly influence the reliability and quality of the world's water supply, hydroelectric generation, and food security.

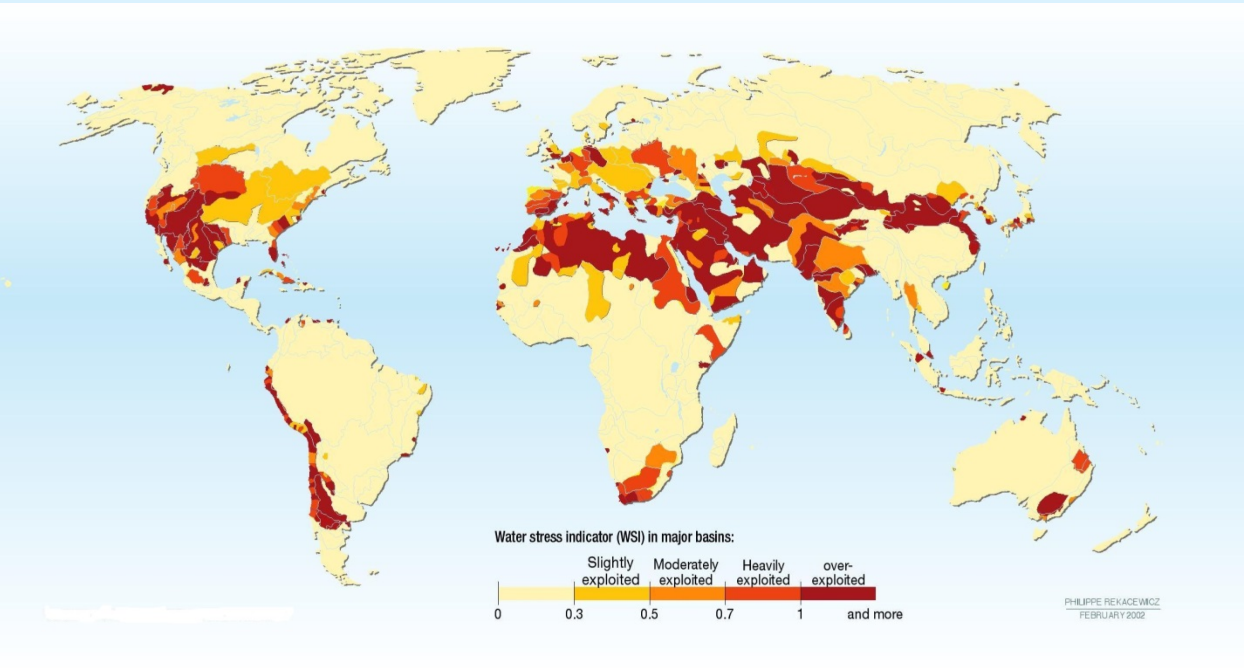
Globally, water management practices have also been placed under scrutiny, since in some cases these procedures have only further exacerbated the current water crisis. In many counties, though there are enough fresh water resources for its population, management of these resources is less than optimal. Poor water management is a huge problem faced by many developing countries as well as emerging nations, as they seek to find the right balance between supply and demand. Therefore, important sectors in a country are unable to obtain a reliable clean supply of water thus causing economic water scarcity to be a major issue in some countries (Figure 2). Over-exploitation of water resources (Figure 3) is also a major cause of physical water scarcity in many countries (Figure 2) as some countries push for economic development; unfortunately in most cases their water resources usually pay the price.

Figure 2 – Global physical and economic water scarcity



Source: Comprehensive Assessment of Water Management in Agriculture (2007, map 2.1, p. 63, © IWMI, http://www.iwmi.cgiar.org/).

Figure 3 – Global water stress indicator (WSI) in major basins



Source: http://www.grida.no/graphicslib/detail/water-scarcity-index_14f3

Consequently, reliable access by citizens to a safe water supply and proper sanitation is another major challenge facing both the developed and developing countries, as they endeavour to obtain sustainable development. Recognizing this, the United Nation's (UN) Millennium Goal 7 calls to halve the proportion of the population without sustainable access to safe drinking water and basic sanitation by 2015. UN Millennium Goal 7 like all Millennium Development Goals is a blueprint that was agreed to by all the countries of the world and all the world's leading development institutions. In 2010, the UN also declared that access to clean water and sanitation is a basic human right since water is vital to preserve human dignity. Water, though a prerequisite for the realization of human rights and development also plays a vital function within the environment.

Realizing the importance of safeguarding water resources as well as the environment for future generations, the UN Millennium Goal 7 also calls to integrate the principles of sustainable development in the policies and programmes of countries and to reverse the loss of environmental resources and reduce biodiversity loss. Sustainable water management is therefore as critical as the health and biodiversity of the water resource systems.

Comprehending that safe, fresh and clean water is both fragile and finite as well as by striving to attain the Millennium development goals, globally, countries have been working towards addressing their water issues either collectively or single-handedly. The European Union's Water Framework Directive (EU WFD) stipulates that all states of the EU must aim to achieve good ecological status in all water bodies (rivers, lakes and groundwater) by 2015. This has led to the evolution of environmental assessments; most notable, the Environmental Flows concept, defined as the quantity, timing and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems (Brisbane Declaration, 2007). However, implementation and assessment of such concepts within the management of water bodies have been extremely challenging.

While in the USA, dispersed authorities, multiple agencies, diverse jurisdictions, and competing demands make coordination among water managers difficult though the challenges of water management which often require collective action and decision making across intersecting issues, space and time (Scarlett, 2012). The Great Lakes and St Lawrence Cities Initiative however is one example of a successful cross-jurisdictional initiative that has been effective in increasing water efficiency and reducing demand across the North American region (UNEP 2012). Despite similar initiatives, freshwater issues such as droughts and floods, eutrophication, dams and river fragmentation, saltwater intrusion, non-point source pollution and urban run-off still remain a challenge in some parts of the North America.

Unlike the EU and North America, African countries have struggled with effective water governance. Weak policy, legalisation and enforcement prevent water from being managed and allocated efficiently and sustainably across the all sectors and remain as some of the main reasons why water access is still high on the agenda for African countries. Though financing has been mobilized to an extent to improve access and sanitation in some countries, these have been project-based and often lacked sustainability. With monitoring and evaluation systems across the African continent recognized as in the early stage of development and corrupt practices endemic to most water supply and sanitation institutions, progression from the current situation is a challenge (AfDB WPP, 2010). Additionally, development in the managerial and technical capacities of local authorities as well as systematic coordination is also necessary to instil change in African countries.

Though the availability of clean water in sufficient quantities and of sufficient quality was declared a human right by UN Decision 64/292 and is recognized in the constitutions of some Latin American and Caribbean (LAC) countries (UNEP, 2012), proper water governance also remains a challenge in the region. Consequently, the protection and appropriate management of water resources and sanitation has been included as a high priority agenda item at the Latin American and Caribbean Initiative for Sustainable Development (LACI); despite these efforts to foster integrated water policies, LAC still report significant challenges in co-ordinating water policy action across ministries and between levels of governments (Akhmouch, 2012). Water governance therefore should be addressed to in order to tackle further issues related to the sector such as policies, funding and accountability.

"Water-related problems are particularly acute in Asia; although Asia is home to more than half of the world's population, it has less freshwater—3 920 cubic meters per person per year—than any continent other than Antarctica" (Leadership Group on Water Security in Asia, 2009). Asia's drive for economic development has unfortunately led to overexploitation and degradation of its natural resources in some cases. Moreover Asian Water Development Outlook (AWDO) has noted that although water governance has improved in Asia, there is still room for further development since major fundamental changes are still needed in nearly all the countries in the region (AWDO 2009, 2013). Some of these areas include access to water supply and sanitation, pollution, transbounday water management, investment and stakeholder involvement.

Consequently, environmental flow science, water governance and sustainable water management have remained as significant global issues within the water sector. Though sustainable water management policies have been high on the agenda of most governments, the link between information and communication technologies (ICTs) and sustainable water management has not been made. Thus the opportunities of using ICTs in sustainable water management have not been fully grasped, even though "the number of mobile subscriptions is twice the number of individual piped water connections in India" and "in Africa, the number of people within range of a GSM signal has already overtaken the number with an improved water supply" (Hope & Thomas 2012).

Information and communication technologies (ICTs) have a high capacity to improve the current water resource management of many countries. Satellite remote sensing, cloud computing, semantic sensor web and geographical information systems are just few examples of technologies currently available which can be used innovatively, to obtain real-time water use information in order to track, forecast as well as identify new sources of fresh water. Precise and reliable information that is easy accessible is crucial for proper decision-making within a watershed.

Reliance on historical hydrologic weather patterns to predict future variables are no longer practicable due to the high weather variability associated with climate change. Smart metering technologies, a now growing industry, can provide individuals, businesses and water companies with information about water usage and demand as well as aid in management. ICTs (e.g. web-enabled sensors and communication networks) provide a unique opportunity for water stakeholders to obtain reliable and relevant information easily, which can be used for proper decision-making as well as an instigator for behavioural change.

1.2 Smart water management

The world, as it was known, 30 years ago is not what it is today; neither will it be the same 30 years from now. Such a dramatic change in such a short period of time is mainly attributed to the development of ICTs. Modern ICTs have provided today's society with a vast array of innovative communication capabilities and have transformed the world into a global village. ICTs have been influential in the world's collective economic, social and cultural development. Harnessing this technology within the water sector creates a more intelligent means to manage and protect the planet's water resources.

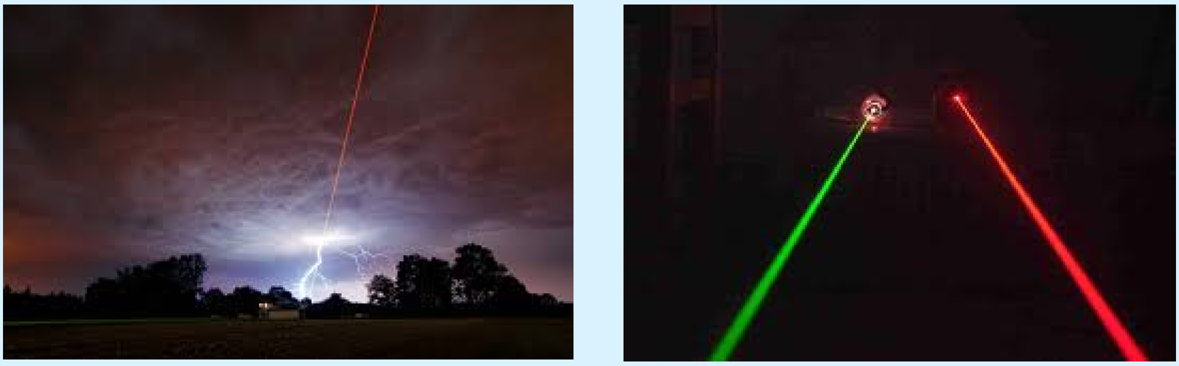
Managing the world's fresh water resources has become an ever growing challenge in the face of development and climate change. Proper management of such a fragile resource is crucial as the world's water consumption increases to satisfy the earth's growing population and development in the agricultural and industrial sectors. Institutional constraints, aging infrastructure, information, communication and technology gap, poverty, lack of investment, poor data and lack of quality of services are just some key challenges that the water sector faces. In order to ensure that the world's water resources are present for future generations, proper management now is critical.

Smart water management (SWM) seeks to alleviate challenges in the water sector by promoting the coordinated development and management of water, through the integration of ICT products, solutions and systems in order to maximize economic and social welfare without compromising the sustainability of water as a resource or the environment; in other words, adopting a sustainable approach to water management and consumption through the use of ICTs. Incorporation of such technologies in SWM can be adapted to continuously monitor and diagnose problems, prioritize and manage maintenance issues and use data to optimize all aspects of the water distribution network.

SWM tools fall into these main categories; data acquisition and integration (E.g. sensor networks, smart pipes, smart meters, etc.), modelling and analytics (e.g. MikeURBAN, etc.), data dissemination (e.g. radio transmitters, WIFI, Internet etc.), data processing and storage; (e.g. cloud computing.), management and control; (e.g. SCADA, optimization tools), and visualization and decision support (e.g. web-based communication tools). However, it should be noted that the examples provided are not confined only to the areas represented but may overlap within these categories.

The possibilities of ICT incorporation in SWM are vast. ICT tools have made it possible for high resolution of digital geographical data through remote sensing or alternatives (e.g. LIDAR survey). In addition, ICT tools are able to capture geographical information in digital format at higher resolution and with more accuracy. Advanced ICT techniques using laser tools (Figure 4) are able to easily apprehend stream flow data from one end of a river without the use of a stream gauge. Digital geographical data can be used to create digital topography models, while digital photography and videography have made it possible to store and retrieve large volumes of ground information, both of which are of equal importance to decision-makers.

Figure 4 – Laser devices



Source: http://web367.login-102.hoststar.ch/hene_laser.htm

By making enhancements in data acquisition and integration, ICTs have the capability of providing reliable real-time information needed for the monitoring, measuring, modelling and managing of water resources. Reliable data leads to better decision making since due to climate change, historic data may no longer be as dependable and therefore cannot be used alone. Consequently, clearer projections can be made to mitigate water stress and scarcity areas as well as population growth by providing information necessary to help improve access. Improvements to management and control, demonstrate that ICTs can be used to enhance water allocation by ensuring it is done in a more fair and equitable manner. Sensor networks, smart pipes and smart meters can also help to identify leaks and aid in the reduction of non-revenue water due to aging infrastructure.

Smart water metering systems refer to systems that measure water consumption as well as abstraction and automatically communicate the information for monitoring and billing purposes; this differs "from conventional meters in that they measure consumption in greater detail and transmit that information back to the service provider without the need for manual readings" (Hope & Thomas, 2012). Technological advances in smart metering have evolved data transport, acquisition and storage in this area (Figure 5).

Figure 5 – Components of intelligent remote data collection for smart metering

Source: http://www.moxa.com/solutions/AMI/index.htm

By combining smart water metering and mobile banking, a reliable, transparent and secure flow of funds and information between the consumer and the water service provider can be achieved, reducing water payment transaction costs as well as administrative costs thereby increasing revenues in the water utilities. These technologies help to reduce the use of water, aid in the improvement of water infrastructure, as well as enhance the access and delivery of data acquisition to maximize the return on investments through reliability and transparency.

SWM produces tangible benefits such as the reduction of non-revenue water, energy, arrears, customer costs, as well as improvements in inventory savings, cash flow, communication, and the optimization of expenses and increase in revenue (Sheikh, 2011). Some intangible benefits also include improvements and enhancement in process, planning and decision-making, staff management and efficiency, safety, and enhanced information quality (Sheikh, 2011).

Consequently, ICTs have the capacity to be a strategic enabler to drive SWM policies and assessments. SWM therefore if implemented properly can used to mitigate many challenges associated with the global issues of today. However there must be collaboration between the different sectors to ensure its success.

1.3 Key stakeholders involved in ICTs and smart water management

The water sector virtually impacts all other sectors of a country. The expansion of scientific knowledge and technological applications is currently changing the way water is used, cleaned and reused to meet human, economic and environmental needs. However, for SWM to effectively tackle global water issues, stakeholder engagement is imperative. The type of ICTs used in a SWM plan or project, is as effective and efficient, as the understanding of the roles and responsibilities played by the stakeholder group in question. SWM stakeholders fall into diverse groups according to their roles (advising, producing solutions, making decisions, etc.), perspectives and/or influence.

A stakeholder in this report is defined as any individual, group, or institution that has a vested interest in SWM by being potentially directly or indirectly affected by its projects, activities, policies, and/or has the ability to influence SWM's outcomes. Whereas stakeholder engagement is seen as a more inclusive continuous process; reflecting social responsibility, transparency and good stakeholder relations for the ultimate goal of successful completion of a project. Thereby ensuring that there is no waste of resources, and/or overlapping responsibilities when addressing critical water issues through the regulation and management of key players within the smart water framework which is of critical importance.

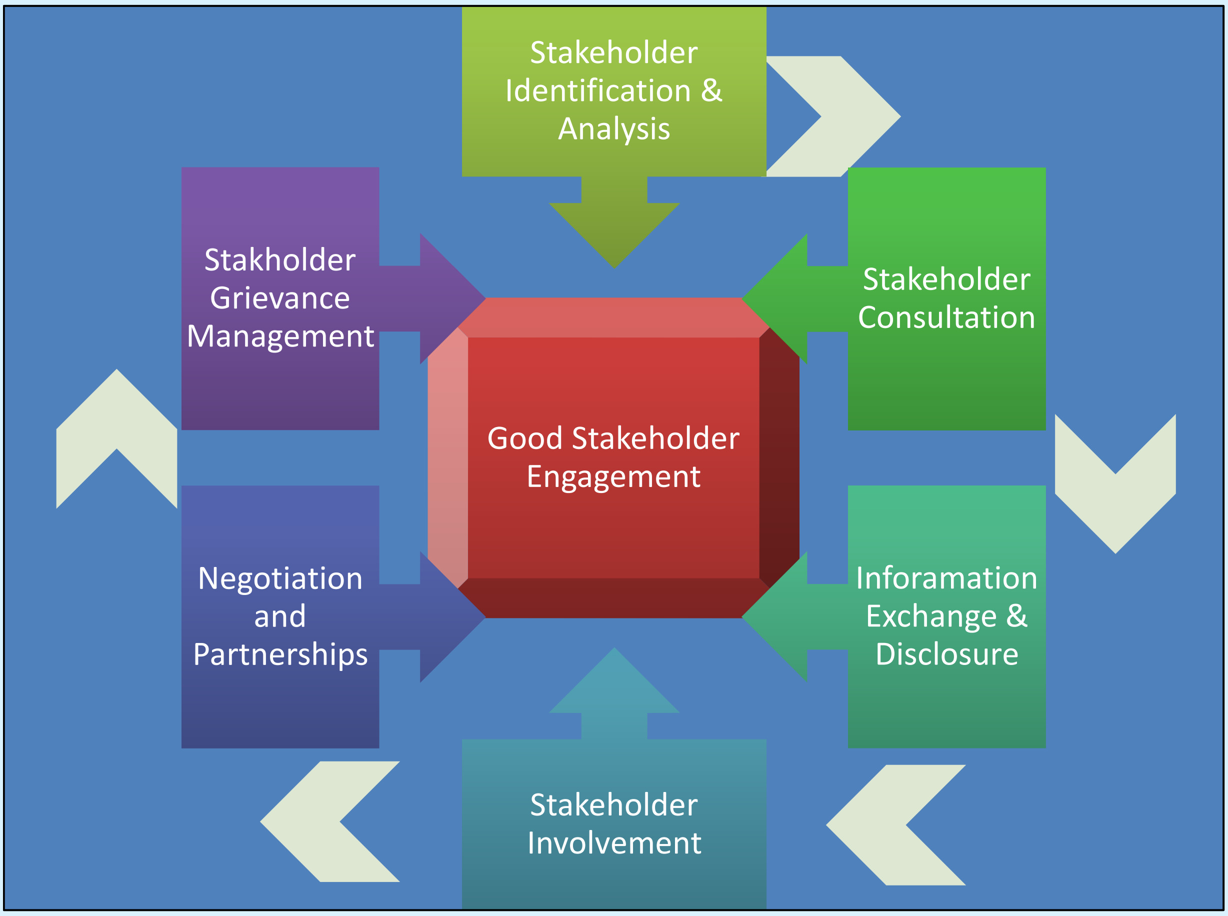
Stakeholder engagement typically involves the main areas represented in Figure 6 where in this report;

- ***Stakeholder identification and analysis*** refers to the determination of stakeholders, identification of where their vested interests lay, identification of how directly or indirectly they can be affected, as well as the identification of their ability to influence SWM outcomes.
- ***Stakeholder consultation*** refers to the identification of stakeholder's interests and concerns, and refers to the initiation and the sustentation of constructive external relationships over time.
- ***Information exchange and disclosure*** refers to the provision of information to allow stakeholders to act or participate in an informed manner, ensuring transparency while properly managing sensitive issues.
- ***Stakeholder involvement*** refers to the full inclusion of stakeholders in project development and/or monitoring in order to address their interests and concerns.
- ***Negotiation and partnerships*** refers to the proper management of stakeholders to ensure that agreements on specific issues can be reached by

promoting good faith negotiations which satisfy the interests of all parties. Remembering that not all stakeholders necessarily share the same concerns or have unified opinions or priorities related to SWM.

- ***Stakeholder grievance management*** makes provision of a medium for stakeholders to complain and have their complaints be heard to enhance the overall outcome of SWM initiatives.

Figure 6 – Good Stakeholder Engagement



Source: Adapted from IFC 2007
http://www.ifc.org/wps/wcm/connect/938f1a0048855805beacfe6a6515bb18/IFC_StakeholderEngagement.pdf?MOD=AJPERES

For successful integration and implementation of SWM within countries, stakeholder involvement is necessary and should not be conducted in a parallel but rather as an iterative process strategically woven throughout to strengthen the end result. "Inclusive processes increase awareness and understanding of issues and challenges, generate more data, help determine priorities, increase support for remediation programs, and generally enhance the likelihood of success" (EPA, 2013).

Once properly engaged, stakeholders will increase the credibility of efforts and soothe the transition of SWM initiatives. However, it should be mentioned that in this report, the focus here, is placed on identifying and highlighting the key stakeholders in SWM. Such identification can ensure that the relevant bodies and/or institutions are enabled to lead proper stakeholder engagement in SWM projects.

Three stakeholders groups were identified in this report; those affected by the global water issue or those whose activities strongly affect the issue; those who possess information, resources and expertise needed for strategy formulation and implementation of SWM; and those who control the implementation of the various responses.

Each stakeholder group is unique, due its goals, makeup, operation and the driving forces of their effort within SWM.

Further distinctions of the main types of stakeholders involved are described below:

- **Stakeholders who have influenced "ICTs and smart water management"**

This group is leading the way in the development of SWM solutions, products and tools and comprises ICT corporations and organizations, scientists/academia and research groups, as well collaborations with businesses, the industry, corporate entities and non-governmental organizations (NGOs).

- **Stakeholders who have a direct impact on "ICTs and smart water management"**

This group directly affects or is affected by policies related to the water sector and therefore have a major part to play in the implementation of SWM programmes within countries. This includes international governmental organizations, governments, municipalities, water authorities and water managers, as well as regulators on water issues and the environment in local, regional, national and international levels.

- **Stakeholders who have an indirect impact on "ICTs and smart water management"**

This group affects the overall water supply in countries regarding both quantity and quality. It consists of citizens, agriculture, the industry, as well as all other users of the waterways (fisheries, etc.). Notably in this report, focus will be placed on the first two main categories, as the third will be focused in successive reports.

The past has shown that without proper collaboration, many initiatives, plans and proposals fail to address issues related to the water sector. Global water issues must therefore be addressed concurrently in a collective holistic manner through partnerships. Hence, collaboration is necessary to ensure that the right information regarding these issues is known in order to solve them effectively; thus ensuring the success and sustainability of any initiative. Collaboration occurs only when there is proper stakeholder involvement and therefore cannot occur if stakeholders are not identified. As mentioned earlier, one main objective of this report was to highlight the significant stakeholders related to SWM and this will be further elaborated consecutively.

2 Stakeholders who have influenced “ICTs and smart water management”

2.1 ICT corporations and organizations

Since both small and large ICT companies have a significant global reach, the ICT sector has been increasingly addressing human rights issues and other challenges faced by society through the use of technology in terms of development of their products, services and technologies. By extension, there has also been a steady growth in the development of technologies for SWM by ICT corporations. ICTs, therefore, are increasingly becoming a key enabling tool for data acquisition, early evaluation, communication or automated management in the water sector.

ICT companies have developed devices tailored to key activities within the water sector upon the realization of the effect that information and communication technology can have on the sector as well as how easily these devices could be implemented in different aspects of the hydrological cycle.

This has led to the improvement of water allocation, consumption and usage, in the mitigation of natural hazards and in the protection of the natural environment, all of which are needed in the water sector. Some of these devices comprise water quality sensors, smart metering, rain water harvesting, early warning systems and public access to monitoring websites. These key activities primarily involve investigation/survey, monitoring, designing and operation (Table 1).

More and more ICT companies and organizations are fostering new flow measurement technologies to reduce costs and gain revenue in the water sector, through the introduction of advanced meter reading, data acquisition, demand response, and distribution automation technologies. This means the development of a new and growing market. The predicted cumulative market opportunity in smart water metering is expected to reach EUR 7.8 billion by 2020 for meter manufacturers, installers and data and network management companies (Cutler, 2013).

By partnering with other stakeholders such as governments, academia, water utilities and industry, ICT companies can provide solutions to problems faced by each sector, thus promoting innovation. This ensures that the right technology is delivered to the right stakeholder. Tailored innovative ICT solutions by the ICT professionals cannot be developed if other stakeholders do not identify the major challenges/gaps faced in the water domain; a rapport with ICT co-operations, organizations and professionals would ensure that the identified gaps are filled if not solved.

Table 1 – Some areas where ICT companies are developing products and software in smart water management

Area	Products/Software	Outcomes
Weather forecasting	• Remote sensing from satellites • Wireless sensor networks • Geographical information systems • Sensor networks and Internet	• Improvement in weather forecasting
Mapping of water resources, water supply and distribution	• Geographical information systems (GIS) • Buried asset identification and electronic tagging • Smart pipes, smart hand pumps, smart river meters and smart metering • Real-time risk assessment; • water portal systems • Supervisory control and data acquisition (SCADA).	• Improving the management of water distribution networks; • Reducing losses of water by active leakage control; • Reducing network damage and deterioration; • Reducing the risk of infection in the water system; • Increase in revenue; • Improvements in customer relations.
Water demand forecasting	• Geographical information systems (GIS); • Ground penetrating radars; • Optical and pressure sensors; • Clouding computing; • Supervisory control and data acquisition (SCADA).	• Rain/storm water harvesting; • Managed aquifer recharge; • Process knowledge systems; • Improvements in water resource management.
Early warning systems	• Geographical information systems (GIS); • Sensor networks; • Early warning websites; • Mobiles and mobile network; • Digital Delta.	• Reservoir management flood and flood mapping; • Quick data acquisition, data processing and analysis; • Quick and easy data dissemination to warn the public.
Irrigation in agriculture	• Sensor networks; • Geographical information systems (GIS); • Mobiles and mobile network; • Subsidiary communications authorization (SCA) and radio data systems (RDS).	• Reduction of water consumption • Improvements in enterprise and resource planning.

2.2 Academia and research institutes

There has been a steady increase in water resources research worldwide as countries and funding agencies turn to academia and experts to develop new technologies for the management of the dwindling fresh water supply. Water issues addressed by research programmes have been in close coordination and collaboration with several universities and institutes, under governments, to support the decision-making of existing water resource problems in many countries.

Mainly research has focused largely on providing safe drinking water and proper sanitation in order to combat the Millennium Development Goals, water to secure livelihoods and increase development in relation to food and energy, water governance and management to improve policies and project management as well as water-related hazards (e.g. flooding). In all these cases research has included climate change and its possible effect on these aforementioned areas.

However with the age of information technology, research on information and knowledge systems have catapulted and their applicability to water systems have developed. Academia and research institutes who focus either is related to ICTs or water management therefore have been creating innovative tools, programmes and technologies for water management systems to decrease vulnerability to water shortages, more intense storms, and other potential impacts of climate change and increase sustainability of the resource in retrieval, distribution, management as well as in use for agriculture.

With regard to the SWM, investments have led to the development of new and cost-effective technologies. As a result, there are a growing number of leading experts and groups from academia and research institutes working on a number of projects related to ICTs and SWM worldwide.

Out of the various examples of regional, international and global academic SWM initiatives is the HydroNet project. This project comprises several European universities and aims to develop a new technological platform for the improvement of monitoring water bodies using intelligence infrastructure. Deltares on the other hand is an example of an independent institute for applied research in the field of water, subsurface and infrastructure and has developed Delft-FEWS, a hydrological forecasting and warning system.

With the need for an innovative research agenda, academia and research institutes are helping to increase ICTs' application to the areas of data collection, decision support and communication networks to formulate more adaptive strategies which can alleviate water challenges faced on a regional, national and global level.

2.3 Non-governmental and community-based organizations

Non-governmental organizations (NGOs) and community-based organizations (CBOs) assist countries and communities in the sustainable management of their scarce water resource as well as make provisions for the attainment of a fresh clean water supply to areas most in need. This is normally done through projects which supply necessary equipment, training to improve capacity, as well as support from experts.

More NGOs and CBOs are increasing their role in the development of ICTs in SWM. One way is through the funding of research programmes. Another way is via awareness by mobilizing the involvement of local communities through the various outreach programmes that involve ICTs in SWM.

NGOs and CBOs which are internationally recognized have been able to couple creativity and innovation within the field of research and testing through their investments and numerous projects. They have in the past helped to develop drinking water standards and regulations and will ultimately have some influence in the development and communication of policies related to this field in the future.

Box 1: The Green Cross has developed "Smart Water for Green Schools", an initiative which "smarts" rainwater harvesting to provide safe drinking water to over 52 000 people in Ghana, the Ivory Coast, Argentina, Bolivia and China. American Water has also been working with various companies to develop and test new cost-effective acoustic leak detectors which use a two-way communication system that automatically collects and transmits consumption data from meters to a computer network.

2.4 Corporate entities, businesses and the industry

A clean reliable source of water is necessary for economic growth; industries will only thrive if there is such access. More importantly, there is a crucial need for businesses as well as for industries to develop water management plans especially if they use significant quantities of water in order to maintain resource sustainability. It is also very important for this sector to consider the impact their products have on the water environment.

Over the years, corporate entities have been recognizing their role in water-related issues. More importantly, they have also noticed how water scarcity can affect their businesses and how the toll of climate change can impact their water supplies. In an Ethical Corporation report on 'Unlocking the Profit in Water Savings' 99% of respondents believe that water will become more of a priority for businesses in the next five to ten years, while 52% of sustainability managers ranked "water stewardship" within the top five most important issues. Companies, therefore, realizing the prospects of return in investments, are investing in and developing more innovative water initiatives.

Corporate entities, businesses and industries around the world have been strategically investing in technologies for water-use efficiency and wastewater treatment. These efforts are reducing their operational costs and increasing their return benefits. Coca-Cola, Diageo and SABMiller are just a few big names in business that have dived into the agenda on water sustainability. The World Business Council for Sustainable Development (WBCSD) has even developed a global water tool (GWT) which is a free and easy-to-use tool for companies and organizations to map their water use and assess risks relative to their global operations and supply chains.

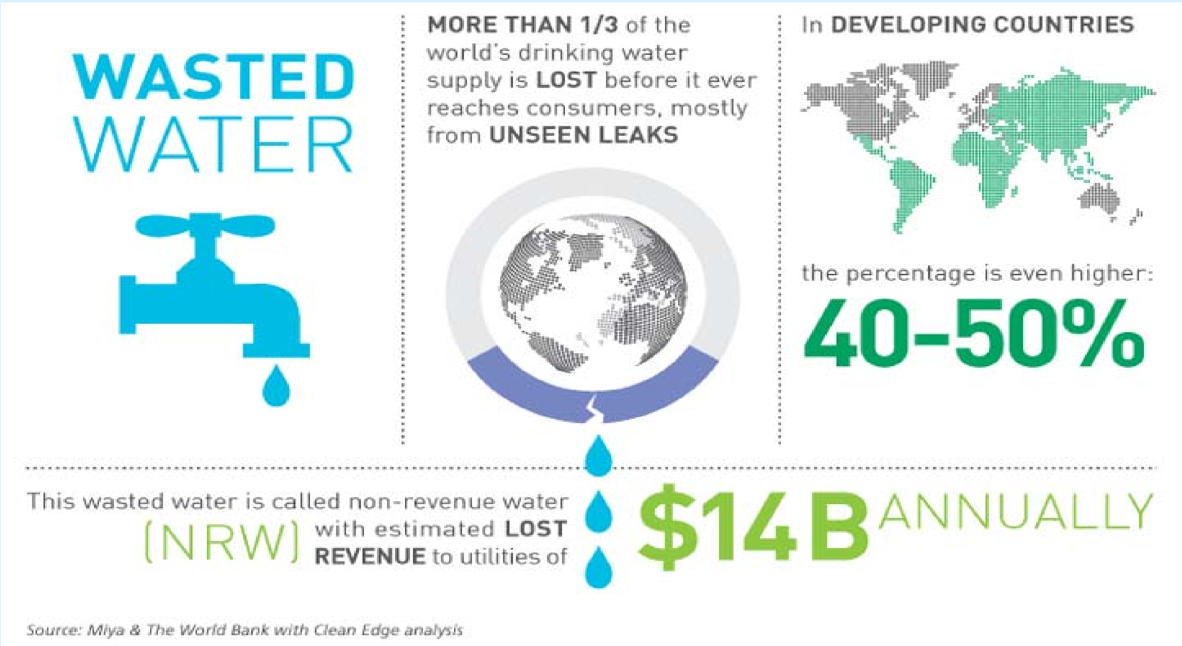
The use of ICTs in SWM of businesses, corporate entities and industries can reduce operational costs and risks and additionally loosen some of the constraints that have been placed on water resources by climate change, thus ensuring the sustainability of a multi-billion dollar sector worldwide.

3 Stakeholders who have a direct impact on "ICTs and smart water management"

3.1 *Water industries and utilities*

Water leakage is a major problem for utilities (Figure 7). It is estimated that 40% of clean water is lost yearly in leaks (Sensus, 2013). Many water industries and utilities have identified the need for smarter infrastructure and technological investments as well as a smarter means to measure performance, since aging infrastructure and increases in energy prices continue to plague this sector. It is estimated that "over three-quarters of the required spending, globally, on water supply, from 2005-2015, should be for operating, maintaining and replacing existing facilities" (WSP, 2013). Therefore, intelligent technologically advanced management systems, which can improve the efficiency of water dissemination, have become high on the agenda for water industries and utilities.

Figure 7 – Water leakage is a challenge in water utilities



Incorporation of ICTs in SWM of this sector allows utilities to improve efficiency, reduce costs while at the same time enhance customer service, thereby creating better customer engagement. This can be done by improving the water industries' infrastructure through ICT solutions such as smart meters, communication systems, software and services. According to Sensus (2012), utilities can save between USD 7.1 and USD 12.5 billion each year by implementing smart water solutions.

Many water suppliers and utilities have incorporated geographical information systems (GISs) and other intelligent technologies to assist in asset management by improved data storage and acquisition, planning and analysis through vulnerability intelligence, field mobility using geospatial technology, operational awareness with web-based applications and viewers as well as through stakeholder engagement by allowing customers access companies via Twitter, Facebook, etc.

By implementing and further developing new technologies in SWM, it is becoming possible for private and state owned companies in water industries and utilities to experience real-time monitoring and control, to reduce the peak-period of water and energy distribution loads, and moreover to improve rapport with consumers, ultimately creating an efficient self-sufficient system that is sustainable.

Box 2: Marshfield Utilities of the United States implemented an advanced metering infrastructure (AMI) technology which uses a remote two-way wireless communication to retrieve customer energy usage information for the improvement of utility's efficiency in customer service and billing activities, emergency response, and load management as well as to enable active consumer participation in managing energy usage and costs through energy efficiency and demand response to shift peak loads. Marshfield Utilities recognizes that the implementation of information and communication technology is cost-effective and enhances utility infrastructure.

3.2 Municipalities, governments, and international governmental organizations (IGOs)

Water governance is about the processes through which water resources are managed and governed (Teisman & Hermans 2011). Decision-making and implementation are therefore major processes in water governance. Municipalities, governments and international governmental organizations are players in water governance and are significant stakeholders in "ICTs in SWM".

SWM is not feasible if there are no laws and policies governing it. Regulation spurs the development of environmental technology which tackles water availability and water quality, making municipalities, governments and international governmental organization very important to the overall process. Regulations vary in scope; however, this group tends to set standards for their country. Moreover, rewards and incentives to leverage smart water technologies are necessary to ensure the implementation.

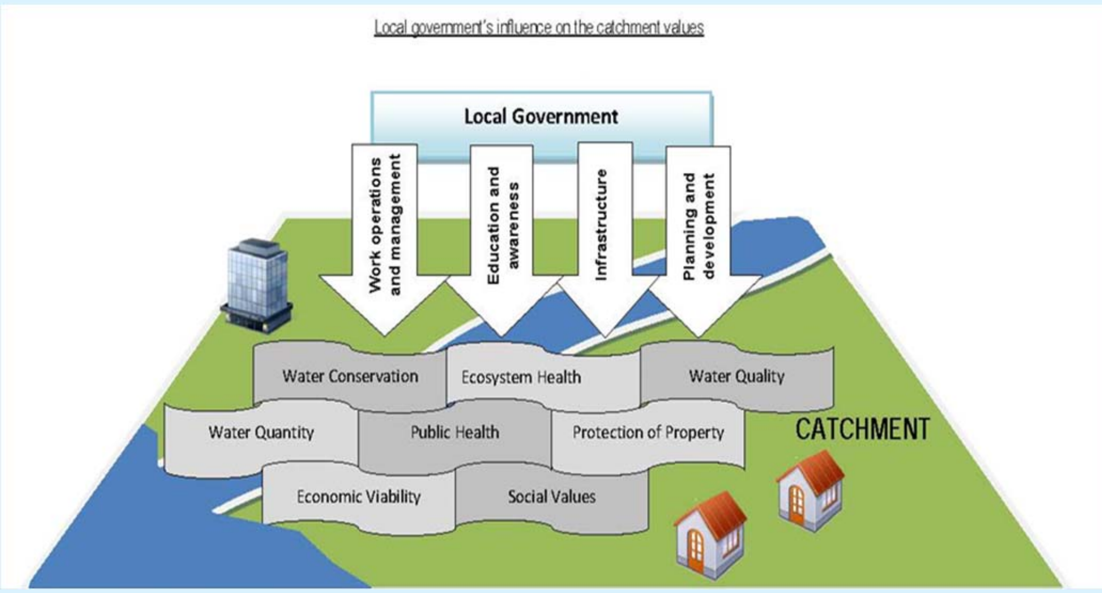
Municipalities, governments and international governmental organizations therefore play an important role in overseeing and implementing SWM systems since they have both a direct and an indirect responsibility for the water security of their country or region.

3.2.1 Municipalities

"Countries are confronted with significant challenges to securing financially sustainable water and sanitation services in their cities" (OCED 2013). Municipalities, administrative divisions within a country, usually have powers of self-governance within certain jurisdiction. Governance at a municipality level therefore affects many layers within the water resource management of a catchment as seen in Figure 8.

Since municipalities also sometimes function as water service authorities and water service providers, proper management and protection of their water resources is important for the planning, development and maintenance of their services. Today with the development of "Smart sustainable cities", municipalities are exploring the use of technology to aid in water management through this concept.

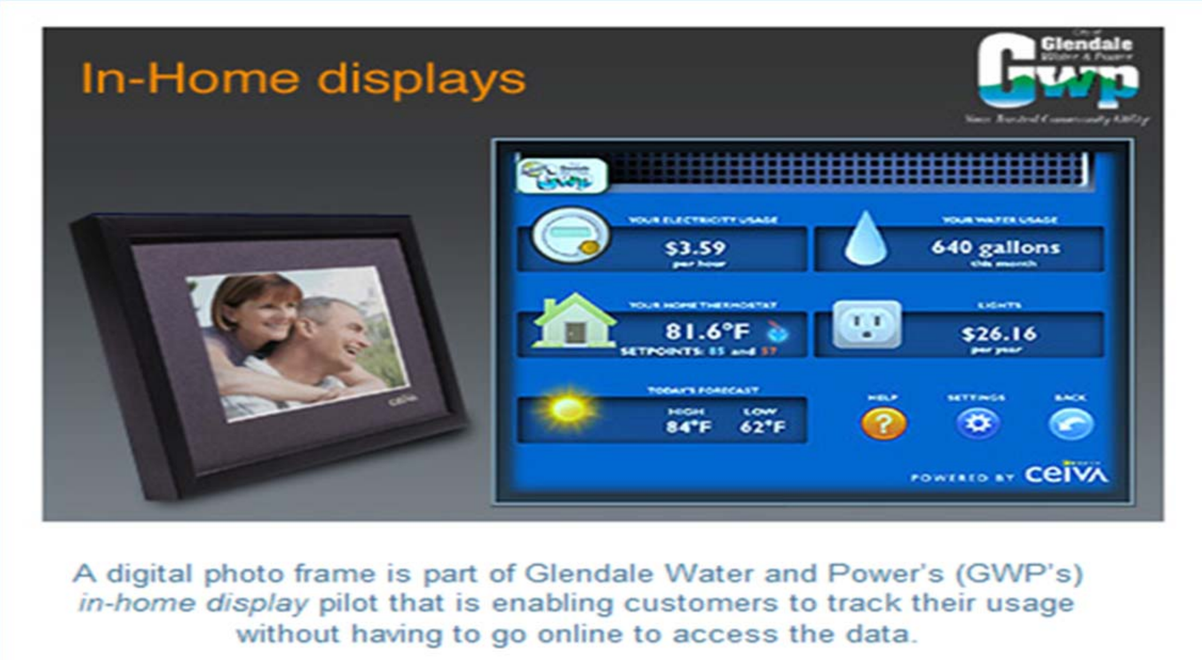
Figure 8 – Municipalities' influence in the water sector



Source: http://www.peel-harvey.org.au/wp-content/uploads/Local-Government-diagram1.jpg

Many municipalities are now installing municipal wireless networks, implementing e-government initiatives to turn cities into the networked bodies of the future. Such implementation has seen new opportunities as well as fostered co-operation between local governments and their residents, enabling better service provision by municipalities by increasing efficiency and responsiveness while at the same time reducing costs (Figure 9).

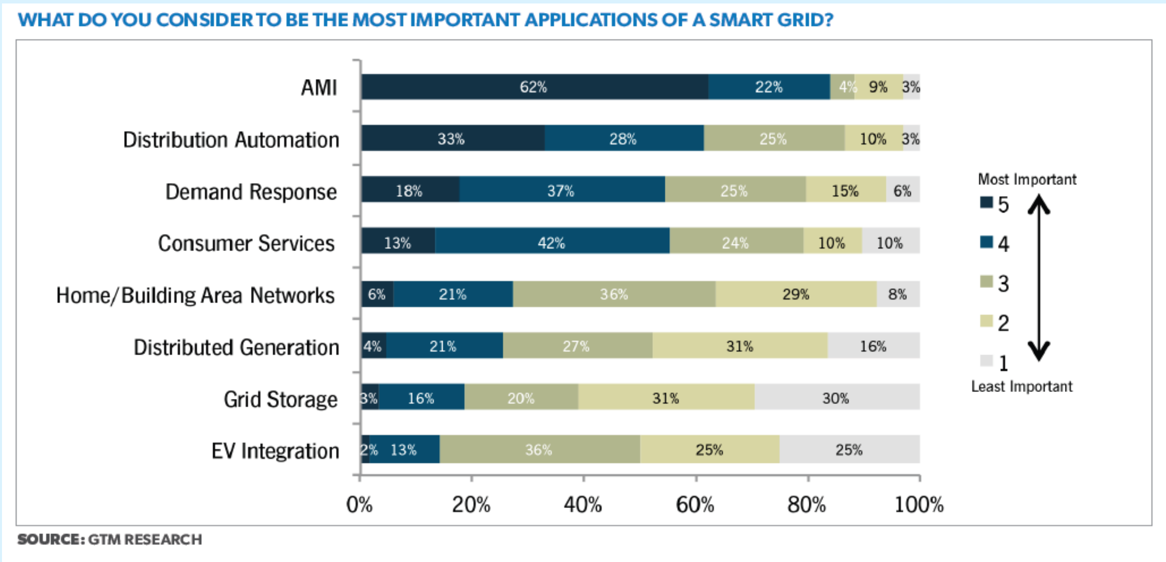
Figure 9 – Technology provides new ways for customers to track their water usage



Source: http://www.smartgrid.gov/case_study/news/glendale_california_municipal_invests_smart_grid_enhance_customer_services_and_impro

From a GTM Research survey, in collaboration with the Municipal Smart Grid Summit (MSGS), where key decision-makers from a diverse group of American municipal utilities were polled on the most important application smart grid technologies (Figure 10) advanced metering infrastructure (AMI), distribution automation, demand response and consumer services were considered to be the most important.

Figure 10 – GTM Research survey



Through the implementation of smart city initiatives, municipalities are also employing SWM, through the use of smart water metering. This has given way to new possibilities within the reporting of leaks, faulty water pipes and general conditions of water canals and other infrastructure by citizens. Complaints now can include a simple photo and answers to questions about the faulty water canal or pipe which is then uploaded in real time to a central database. An example of this is IBM's Smarter Cities Water Management Solution. Municipalities are also seeing the benefits and opportunities ICTs are playing in the management of their water resources through the use of SWM.

Box 3: The British Columbia's Government of Canada has initiated a Living Water Smart programme for sustainable water stewardship. The Living Water Smart is a provincial plan and delivery that involves eleven ministries and a range of stakeholders, and the vision will be achieved through actions and targets one of which includes smart spending on smart infrastructure. Technology is used to harness information on consumption and to improve water use efficiency.

Source: http://livingwatersmart.ca/

3.2.2 Governments

Governments are increasingly facing more challenges (water scarcity, pollution, flooding, etc.) as they seek to secure safe water supplies in an economically and environmentally viable manner. By using innovative solutions provided by ICTs, governments can respond to these challenges in a cost-effective manner.

Over the past few years, developed countries have been encouraging research by the private sector through subsidies and tax incentives for specific types of research in environmental research and development. This has fuelled innovation in the field of ICTs and water management. "Water Point Mapping can help governments allocate support where it is needed most. In Liberia, 150 data collectors equipped with phones using FLOW software mapped more than 7,500 water points" (WSP, 2013).

Research and extension programmes using ICTs in SWM within sectors with high water consumption have been found to have extremely high internal economic rates of return. However, proper regulation of this sector is of equal importance to ensure that technological choices are appropriate and have no negative impacts on the environment.

Although opportunities created by ICTs in the field of water management are notable, many governments are unaware of their benefits. Even though some governments are aware of such benefits, they are not implementing the proper tools to drive the continued growth of this sector. Governments have a variety of tools at hand which can influence growth in this sector. Two major tools commonly used to influence the behaviour of their citizenry and lead to the proper implementation and regulation of smart water initiatives are: economic instruments (e.g. charges, fees, taxes, etc.) and regulatory instruments (e.g. by-laws). Such instruments can facilitate the incorporation of ICTs in SWM through the implementation of water-use efficiency measures by stakeholders.

Box 4: Smart water management in Israel

Israel, one of the most water scarce countries of the world, has in recent years experienced drought and is currently combating other pressures to its water supplies. In 2006, Israel established the Novel Efficiency Water Technologies (NEWTech) programme which was effectively implemented in 26 government funded water projects. The NEWTech in Israel is a national programme supporting the Israeli water technology sector. The system is built upon Israel's experience in coping with water scarcity problems and through the incorporation of separate industrial elements to enhance the water sector. The NEWTech method helps to reimburse 70% of the installation costs.

In addition, companies such as TaKaDu and Whitewater have shined as a result of this form of policy support. The TaKaDu helps to manage and detect leakages, whereas Whitewater supports real-time warning systems. TaKaDu in Israel provides water infrastructure monitoring as a service and acts as the "online eyes and ears" of the network. The company's software allows water utilities to minimize water loss and to improve operational productivity without any network changes and or capital expenditures. The system is based on the mathematical and statistical algorithms that use readings from water metering equipment which includes the flow, pressure, quality and turbidity.

3.2.3 International governmental organizations

International governmental organizations (IGOs), which are composed primarily of sovereign states, play an important role in global water governance by providing a neutral forum for debate or negotiation to resolve water disputes. They also set benchmarks through their advocacy for efficient, equitable and ecologically sustainable water policies and practices for its member states. IGOs can affect the role, positioning and function of national governments in their approach to sustainable water management. Knowledge sharing between memberships is normally embedded in IGOs and facilitates proper sustainable management for all.

The fusion of technology and water resource management on a global scale requires discourse and awareness. Many IGOs concede that ICTs can, once tapped productively, help alleviate some fundamental problems associated with poor water resources in many countries. Some IGOs are currently driving research initiatives by collaborating with leading experts and critical stakeholders in ICTs in SWM which many countries may not have or cannot afford. This provides an outlet or platform, and through the provision of relevant accurate data and information by IGOs allows for better decision-making.

Other possibilities can see the coordinated implementation of SWM on a large scale within transboundary river basins. IGOs can possibly in this context provide such an essential forum. This is very important because the world's water resources are normally shared between countries and regions. A total of 145 nations include territory within international basins, and 21 countries lie entirely within international basins (Water for Life 2013).

Therefore, the rapport between countries is extremely important to ensure positive cooperation, commitment and management in shared water resources since the delineation of water basins does not conform to political boundary lines. ICTs in SWM could possibly ensure the economic and environmental sustainability in all countries instead of a favoured few, possibly reducing international water disputes. This is envisioned by ITU's Focus Group on Smart Water Management (FG-SWM).

FG-SWM was established by the ITU-T TSAG meeting in Geneva, 4-7 June 2013, since ITU recognizes the positive influence that ICTs can play in the distribution, management, and allocation of our water resources. FG-SWM acts as an open platform for SWM stakeholders (i.e. academia and research institutes, municipalities, non-governmental organizations, ICT organizations, industries, etc.).

The FG-SWM mandate is as follows:

- Collect and document information on national, regional and international SWM initiatives; reporting on current activities and technical specifications.
- Specify the roles to be played by ICTs in SWM.
- Develop a list mapping key stakeholders involved in the area of ICTs and SWM.
- Develop key performance indicators (KPIs) to assess the impact achieved through the use of ICTs in water management systems.
- Develop a set of methodologies for estimating the impact of ICTs on water conservation.
- Identify water-management ICT applications and services with the potential to ensure interoperability and the benefits of economies of scale.
- Draft technical reports that address standardization gaps and identify new standardization work items to be taken up by its parent group, ITU-T Study Group 5 (Environment and climate change).

Through collaboration with stakeholders, FG-SWM encourages continued progress in ICTs and SWM, by fuelling discourse, partnerships, and cooperation through meetings and conferences.

Notwithstanding, the United Nations has always placed substantial focus on water to safeguard the poor through the creation of the Millennium Development Goals, and to encourage the world to take action on global water challenges, by providing a blueprint sanctioned by all the world's countries and leading development institutions. Through its UN-Water inter-agency, it has also helped to bring water and water-related issues to the top of the global political agenda.

UN-Water is the United Nations coordination mechanism for all water-related issues, promoting coherence in, and coordination of the UN system actions. UN-Water has also been advancing the implementation of the complex agenda of ICTs in SWM, through research, collaboration and relevant initiatives to allow for collective responsibility on a global stage, promoting comprehensive efforts on different aspects of SWM.

Therefore, the role the international governmental organizations (IGOs) play in SWM cannot be neglected; provision of such forums is imperative to highlight best practices and instigate change on a global scale.

Box 5: The EU's @qua Project is an ongoing programme which is a clear example of how governments can trigger research and adoption of ICTs in smart water management. The European Commission launched this thematic network under its CIP-ICT PSP Programme which, in summary, aims to leverage innovation ICTs in response to growing societal demands on water in Europe. Its objective seeks to promote the uptake of ICT solutions in order to address the fundamental problems of efficiency, faced by public and private services of the water management domain in providing information related to implementation and uses of ICT solutions.

The @qua approach in the first step identifies gaps and problems experienced in the European water sector by professionals. In the next step it uses ICT professionals to create innovative ICT solutions to alleviate these problems. The third step seeks to develop a "level of sharing" to refine solutions created in the 2nd step and roadmap a way for implementation. Hence, the final step will produce guidelines, standards and specifications for more efficient water management.

4 Highlights of global smart water management initiatives

The impending global water crisis means that action should be taken now to ensure livelihoods of the future. SWM may be a solution to this global problem only if there is proper stakeholder involvement employed.

The global water crisis will not be alleviated if we act in isolation. These far reaching consequences affect basic livelihoods and threaten our future, the environment and the world as we know it. Everyone has to part to play in order to build solutions to this issue. By partnering our knowledge and ideas through collaboration, effective responses can be made to help ease if not alleviate these issues.

The key aforementioned stakeholders who have influenced "ICTs and SWM" have developed tools, products and systems. However these innovations cannot be effective if not properly implemented through policies and regulations that are defined by governments. Despite its possible complexity, collaboration between these different stakeholders is necessary in order to take a holistic approach to manage our water resources and drive SWM solutions.

Though global water issues have been categorized under broader headings for simplicity, one should not forget how complex these issues are; every situation, either national or regionally, is unique and case specific due to climate, size, culture, revenue, infrastructure, etc. But again one must reiterate that ICTs are strategic instruments in SWM; nevertheless their possibilities will not be realized if we do not partner for solutions.

Consequently, the focus of this section seeks to illustrate key SWM initiatives where such collaboration between stakeholders has been effective in creating tangible results. These cases are not meant to act as best practises but to highlight some accomplishments of SWM initiatives that have come about only through careful collaboration.

Currently there are various initiatives worldwide on these issues; different stakeholders aware of SWM opportunities are driving initiatives and creating solutions on different scales. Hence the examples put forward here are intended as only as a mere snapshot. Featured initiatives are on national, regional and international scales which address crucial global water challenges such as water accessibility, water security, climate change, aging infrastructure and water supply management.

4.1 SWM and Water Accessibility

4.1.1 Sarvajal on a mission to bring "water for all" in India

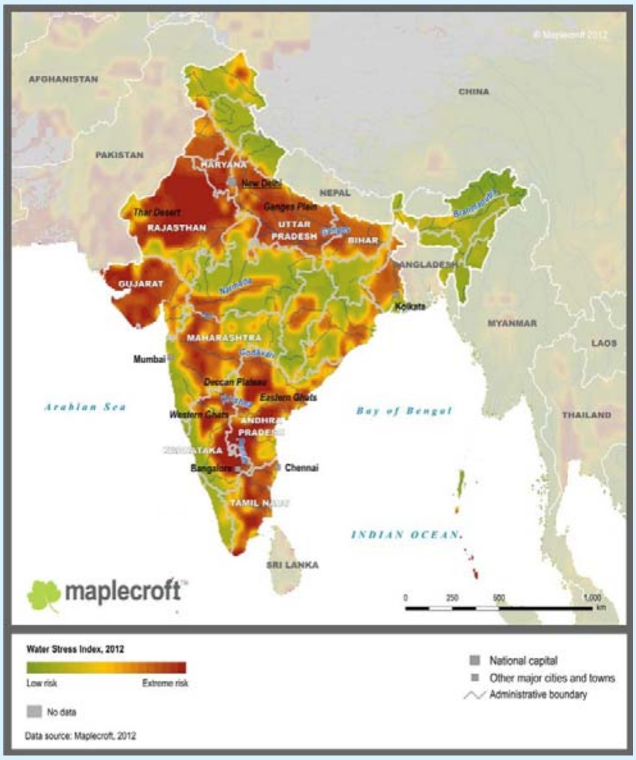
India is facing chronic water problems; high water stress (Figure 11) coupled with high population densities, high water demand by all sectors (agriculture, industry, etc), poor water quality and lack of infrastructure due to delayed investment in water facilities have created an inadequacy in supply for those who depend on it the most. 150 million people lack access to clean water in India with twenty-one states are unable to provide access to clean drinking water to its rural inhabitants (Sevea, 2013).

Furthermore by depleting its groundwater reserves at a rate far greater than natural cycles can replenish in some states as well as fluoride contamination (Figure 12) have both further crippled the provision of safe drinking water in India especially since over 21% of transmissible diseases are related to unsafe water (Sevea, 2013).

However Sarvajal ("water for all" in Sanskrit), is on a mission to make safe drinking water accessible and affordable in India. For instance in the town of Churu, Rajasthan, Sarvajal brought the price of private drinking water down to less than USD one cent per litre (Kalwani, 2012). Founded in 2008 by Piramal Water Private Limited, Sarvajal is a for-profit social enterprise that has won several awards in area of technology and water.

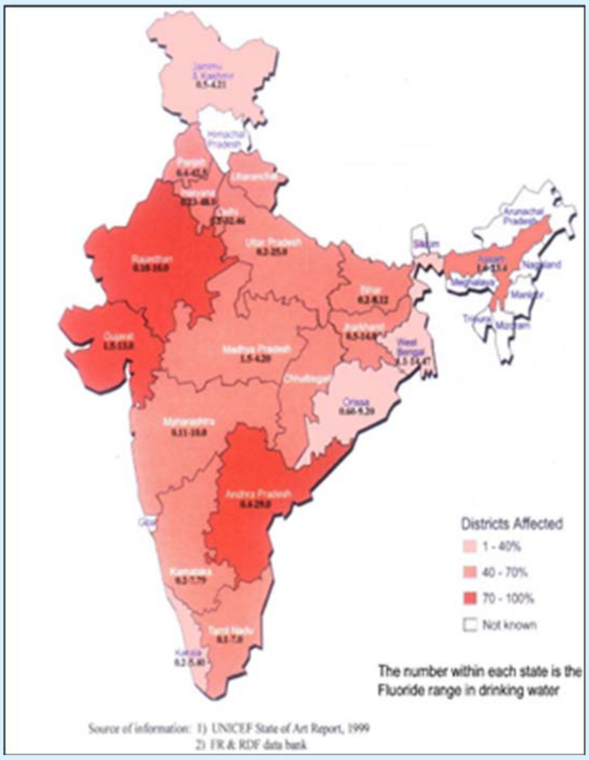
Using three distinct technologies, Soochak (small water treatment plants), water ATMs and SEMS, Sarvajal is providing a wide network of decentralized safe drinking water treatment and distribution technologies in rural areas and urban slums. Sarvajal is improving water access in India by the use of cloud computing and mobile technology which reduces costs, and along with sensors allow for improved monitoring in remote areas.

Figures 11 – Water Stress in India



Source: [*http://reliefweb.int/sites/reliefweb.int/files/resources/map_2137.pdf*](http://reliefweb.int/sites/reliefweb.int/files/resources/map_2137.pdf)

Figure 12 – Fluorosis Prevalent States in India



Source: [*http://www.schools.indiawaterportal.org/node/820*](http://www.schools.indiawaterportal.org/node/820)

Deployed in different areas, Soochaks are filtration centres using reverse osmosis and ultrafiltration units that are equipped with sensors and cloud-based remote monitoring systems to provide real-time intelligence, quality management, at reduced operational costs (Figure 13). Sarvajal's water ATMs, which allow customers to buy safe clean water, are solar-powered and cloud-managed, allowing access 24/7 (Figure 14). Utilizing a combination of sensors and modems, Sarvajal collects data that is transmittable over mobile networks. Integrated within Soochak and the Water ATM, SEMS is a customized ERP system that manages service, maintenance, and supply chain operations from source to consumption, providing quality control through its centralized network.

Figure 13 – Sarvajal's water filtration system, Soochak

Source: [*http://gigaom2.files.wordpress.com/2013/09/sarvajal-water-filtration-sys.jpg*](http://gigaom2.files.wordpress.com/2013/09/sarvajal-water-filtration-sys.jpg)

Figure 14 – Women use Sarvajal's water ATM

Source: http://assets.inhabitat.com/wp-content/blogs.dir/1/files/2011/10/Sarvajal-Water-ATMs-1-537x368.jpg

Sarvajal however entrusts their solutions to local franchisees, people who act as water stewards for their community and operate these equipment in their villages. At a fee to local franchisees, Sarvajal assembles Soochak and Water ATMs, monitor and control water production remotely through its centralized network while local franchisees distribute the supply either by operating out of a store with a larger filtration unit or by managing water ATMs, reclaiming revenue through the customers who use these services. There are roughly 127 rural franchises serving almost 70 000 people where families pay around USD 3 per month for clean water (Meinhold, 2011).

In the case of the water ATM system, local franchisees supply clean drinking water into the ATMs while community members/customers either get their pre-pay water balances from the franchisee or pay using coins or pre-pay cards, which they can recharge easily via cell phones. Since these water ATMs are connected to a cell phone network, Sarvajal is informed immediately when there are leaks, allowing for quick repairs. In remote areas where clean water is scarce, Sarvajal's water-dispensing ATMs provide a cheap solution (Schwartz, 2013) and since water ATMs miniaturize the point of sale; Sarvajal can now serve many different groups in highly segregated areas of the country, ensuring that more people have access to water (Kalwani, 2012).

Sarvajal's story shows how by partnering with businesses, ICT companies and communities, ICTs can bring solutions in water scarce areas while at the same time creating new business models.

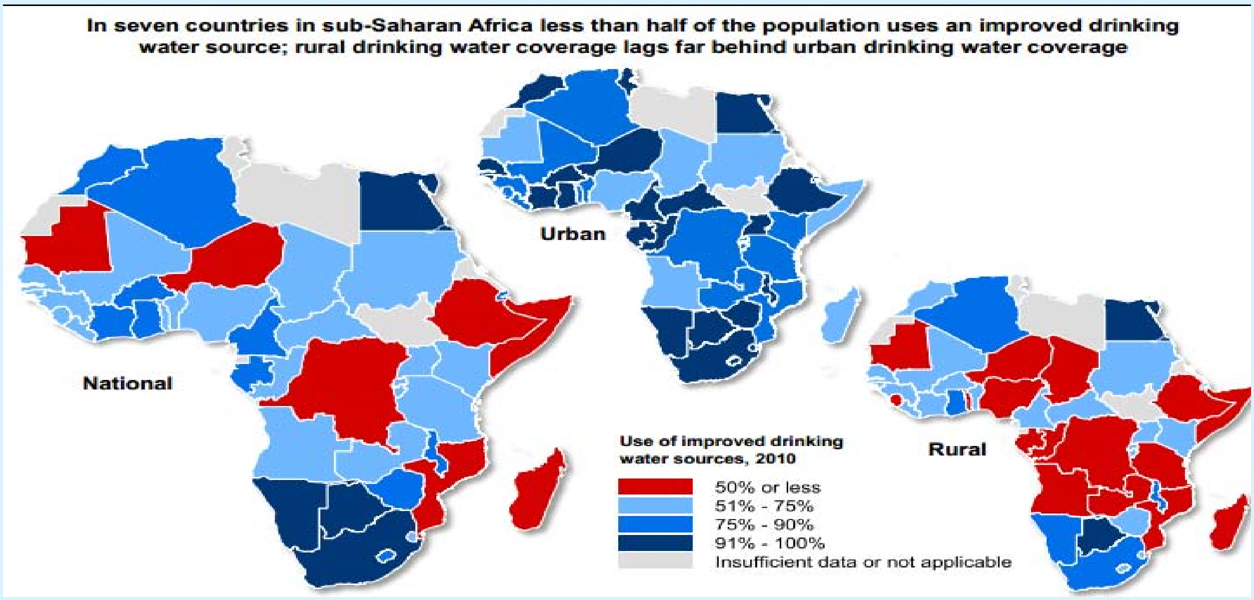
4.1.2 Smart hand pumps improves access in Africa

As mentioned before water issues in Africa have been challenging. Despite an increase in drinking water coverage from 56% to 66% from 1990 to 2010, there has been an increase in the number of people relying on unimproved drinking water, from 279 million in 1990, to 344 million in 2010, with 115 million people having to directly draw on surface water to meet their drinking water needs (AMCOW 2012). The situation becomes even more serious in rural Africa where a lack of reliable access to clean water is an enduring problem (Figure 15).

Millions of people across rural Africa are dependent on hand pumps for their water supplies however many of these pumps are broken or non-functional in remote areas. Therefore a Research for Development project funded by UK Department for International Development (DFID) undertaken by the Oxford University is hoping to improve water access to rural communities through the use of smart pumps.

The pilot project which is set in the Kyuso District of Kenya, aims to establish a broad case for smart water systems in developing countries. These smart water systems primarily harness innovations in mobile communication and are designed to capture, transmit and process data to improve water security and reduce poverty.

Figure 15 – Urban and rural drinking water coverage in Africa



Source: http://www.wssinfo.org/fileadmin/user_upload/resources/Africa-AMCOW-Snapshot-2012-English-Final.pdf

In Kyuso district, located in the eastern part of the horn of Africa, 95% of its population live in rural areas, of which 60% fall below the USD 1 per day poverty threshold and here more than one-sixth of hand pumps found are non-functional over a period of weeks to even months (Hope & Thomas 2012). Most households in the area depend on an irregular water supply and may take more than 30 minutes to fetch water due to these problems. By incorporating robust water-point data transmitters (WDT) into the handle of the hand pump, in 70 villages across the Kyuso District it is envisioned that these challenges can be overcome using mobile technology (Figure 16).

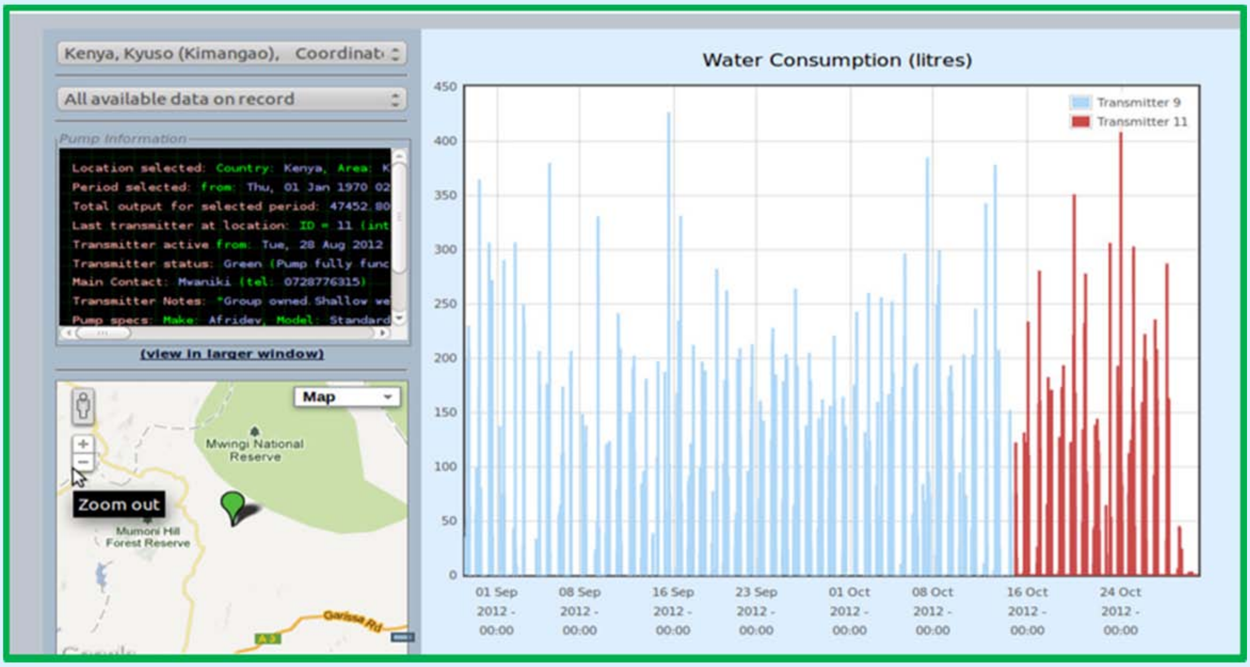
Figure 16 – Installation of a smart pump

Source: http://r4d.dfid.gov.uk/pdf/outputs/water/SmartWaterSystems_ProgressReport_Nov2012.pdf

WDTs are used to estimate the water flow from the hand pump by automatically registering the movement of the handle. It measures hourly usage and transmits using SMS (short messaging service), the amount of water used from the hand pumps to the central district office and that of national managers. This system therefore provides real time monitoring as well as alerts the system when the hand pump is broken; allowing for quick maintenance and repair to be completed in a timelier manner, ensuring more reliable water access to rural communities.

The technology also employs a modified database to summarize data from all the hand pumps and a user interface to properly and easily display the data obtained. The SMS messages are therefore routed directly through a modem into Frontline SMS, a free open source software package, and then into a structured query language /hypertext pre-processor (SQL/PHP) database. Consequently, the user interface is equipped to transform the data into pump usage; the processed information is then displayed in a graphical format together with the location of the pump as in Figure 17, creating an immediate status imagery of individual pumps.

Figure 17 – Automatically-generated mobile data from a smart hand pump



Source: http://r4d.dfid.gov.uk/pdf/outputs/water/SmartWaterSystems_ProgressReport_Nov2012.pdf

Thus by partnering with academia and governmental agencies to exploit new and low cost ICTs, the performance and accountability of institutions that manage water resources can be increased to ensure that water is accessible to those who need it the most.

4.1.3 GRIDMAP set to increase water reserves in the drought stricken parts of Africa

In the horn of Africa, erratic rainfall patterns, and arid climates, have also contributed to the reduction in access to clean drinking water. Water scarcity in this region is further exacerbated by the lack of understanding of groundwater as a resource, since data is incomplete, fragmented and outdated; inhibiting scientists in region to improve the water situation.

However the Groundwater Resources Investigation for Drought Mitigation in Africa Programme (GRIDMAP) hopes to combat climate change in water-scarce areas of Africa in order to mitigate long-term drought and famine (Figure 18). GRIDMAP, a groundwater mapping project, formulated in 2012, is a scientific consortium of regional partners working together to assess the groundwater potential in the horn of Africa and build drought management capacities (UNESCO, 2012). The project is in collaboration with UNESCO, the Government of Japan, the Flemish Government, the United States Geological Survey, Radar Technologies International as well as the regional water ministries and scientists.

Figure 18 – Excerpts from the GRIPMAP project

Source: http://www.unesco.org/new/fileadmin/MULTIMEDIA/FIELD/Nairobi/pdf/GRIDMAP%20Flyer.pdf

The project uses WATEX©, an advanced satellite exploration technology which combines remote sensing, seismic and conventional groundwater information to explore and map groundwater occurrence over large areas in short periods of time. WATEX© was used in the past to locate water for Sudanese refugees in Chad in 2005 (Nakweya 2012). Conversely GRIDMAP aims to identify and map regional groundwater resources for emergency situations and long-term development (Figure 19), develop groundwater management tools to combat drought and build skills and capacities for managing groundwater for drought and conflict mitigation.

Specifically in drought-stricken northern Kenya, the project has recently seen some success in 2013 by identifying reserves of water in Turkana County in the form of the Lotikipi and Lodwar Basin Aquifers (Figure 20). Currently of Kenya's 41 million population, 17 million lack access to safe water, and 28 million do not have adequate sanitation (UNESCOPRESS, 2013).

The Lotikipi Basin Aquifer, located west of Lake Turkana, could potentially increase Kenya's water resources while the smaller Lodwar Basin Aquifer could serve as a strategic reserve for the development of Lodwar, the capital of Turkana County, provided the reserve is confirmed (UNESCOPRESS, 2013). This find could possibly sustain the country's water needs for over 70 years (Okutoyi, 2013).

Figure 19 – GRIPMAP experts trace groundwater sources in arid regions. Kenya, December 2012

Source: http://unesdoc.unesco.org/images/0022/002204/220416e.pdf

By harnessing the power of ICTS, and through careful partnerships between consortiums of scientists, ICT companies, water ministries, governments, and IGOs, water accessibility in developing countries can be attained, just as it is on its way to being increased in Africa.

Figure 20 – Water gushing out of a Napuu area borehole

Source: http://www.unesco.org/new/en/media-services/single-view/news/strategic_groundwater_reserves_found_in_northern_kenya/#.UwDN7mJdXmt

4.2 SWM and Climate Change

4.2.1 Mobile weather service in Uganda

The World Meteorological Organization (WMO), with support from the Norwegian Government and the World Bank, has partnered with other key organizations and stakeholders in Uganda, to provide necessary weather and climate information, through its WMO mobile weather alerts in two pilot projects. The WMO mobile weather alert pilot projects launched in Uganda, take advantage of the widespread availability of mobile phones and targets fishermen on Lake Victoria and farmers in the Kasese District. With an important goal of establishing and maintaining an interchange between the pilot communities and service providers for feedback, the projects seek to ensure possible long term sustainability of the service.

Lake Victoria, the largest lake in Africa, divided between Kenya, Tanzania and Uganda, supports over 3.5 million people as Africa's largest inland fishery, and produces over 800 000 tons of fish annually, currently worth about USD 600 000 000 (WMO, 2012). Large enough to create its own micro climate, conditions on Lake Victoria can change suddenly; strong winds, and high waves have been estimated to cause the death of some 5 000 fishermen every year on Lake Victoria (WMO, 2012). Therefore to help protect these fishermen and to secure their livelihoods, the project combines mobile technology, weather forecasting and local knowledge, to provide an areal weather alert service to fishing villages on Lake Victoria (Figure 21).

Joining forces with the Ugandan Department of Meteorology (UDoM), Mobile Telephone Network Group (MTN), Ericsson, the National Lake Rescue Institute (NLRI) and the Kalangala Fishing community, WMO have formed a unique partnership to create this necessary mobile alert.

The alert system uses colour-coded weather warnings and includes a 4 km resolution forecast model over Lake Victoria to help capture more accurate information on local weather conditions. Tailored local weather forecasts are sent free of charge to registered fishermen every day by SMS in the local language, giving fishermen the opportunity to plan ahead and take appropriate action if conditions change. In addition to gaining continuous feedback on the usability of the service, two surveys were also conducted to acquire information on how the service could be improved in the future. Since its inception in 2011, over 1 000 fishermen from various communities in the Ssese Islands have registered for the service.

Figure 21 – Fishermen on Lake Victoria

Source: http://i.dailymail.co.uk/i/pix/2010/08/01/article-1299403-0A95C4E8000005DC-41_634x421.jpg

This unique weather information service enables fishermen and traders to make informed decisions on when and where to fish in Lake Victoria, thus helping to save lives and preserve livelihoods. According to one survey conducted on the mobile phone service by the Grameen Foundation AppLab Uganda, which targeted 200 fishermen using the mobile weather alert service, 96% reported that the device was very useful and helped to safeguard their lives (WMO, 2012).

Conversely the meaning of these mobile alerts is a bit different for the famers of the second project in the Kasese District. Realizing the need for Ugandan farmers to access necessary weather information and use it in decision-making, the objective of the second project was a bit different since 90% of Uganda's rural population survives on subsistence farming, which is mostly rain fed (WMO 2012). The aim of this pilot was therefore to increase farmers' resilience to the changing climatic conditions and improve their livelihoods

In the Kasese district, rain usually starts falling in late February until early March, and farmers have historically planned their ploughing and sowing activities using this long-standing temporal pattern of precipitation. However due to changing climate variations, the rainfall period has gradually changed.

Thus, the project seeks to enhance the end-to end process in agro-meteorological services and to deliver agricultural advisories more directly to farmers in the Kasese District using a with 10-day, monthly and seasonal forecasts (WMO, 2012). Also the project distributed plastic rain gauges within the community and held training workshops (Figure 22) with community knowledge workers on how to use the gauges to record daily precipitation and transmit the information to the UDoM using their cell phones. The data collected is used to improve the quality of the weather and climate information alerts.

Therefore it can be seen that stakeholder involvement can improve livelihoods which depend on water resources as a source of income by incorporating simple ICTs to combat climate change.

Figure 22 – A Mobile Weather Alert workshop

Source: http://www.wmo.int/pages/publications/bulletin_en/archive/61_1_en/documents/bulletin_en.pdf

4.2.2 Early warning systems in Latin America and the Caribbean (LAC)

Over the years, mainly attributable to international cooperation and assistance, the development of early warning systems (EWS) has flourished as key disaster preparedness and mitigation strategies in the Latin America and the Caribbean (LAC). Two notable EWS in the region, include the Central American Flash Flood Guidance System (CAFFG) and the Aburrá Valley's natural hazard early warning system, Sistema de Alerta Temprana (SIATA) in Columbia.

The CAFFG is a fully automated EWS that was developed and designed to be a regional flash flood guidance system (FFG) for Central America with a 100-300 km2 spatial resolution and 1-12 hour temporal resolution.

The need was identified after the devastating effects of Hurricane Mitch in 1998. The project was funded in collaboration with US NOAA National Weather Service, US NOAA Office of Global Programs, USAID, an U.S. Government agency that works to end extreme global poverty and enable resilient in democratic societies as well as the Hydrologic Research Center (HRC), a non-profit research corporation, in partnership with national Central American meteorological and hydrological centres.

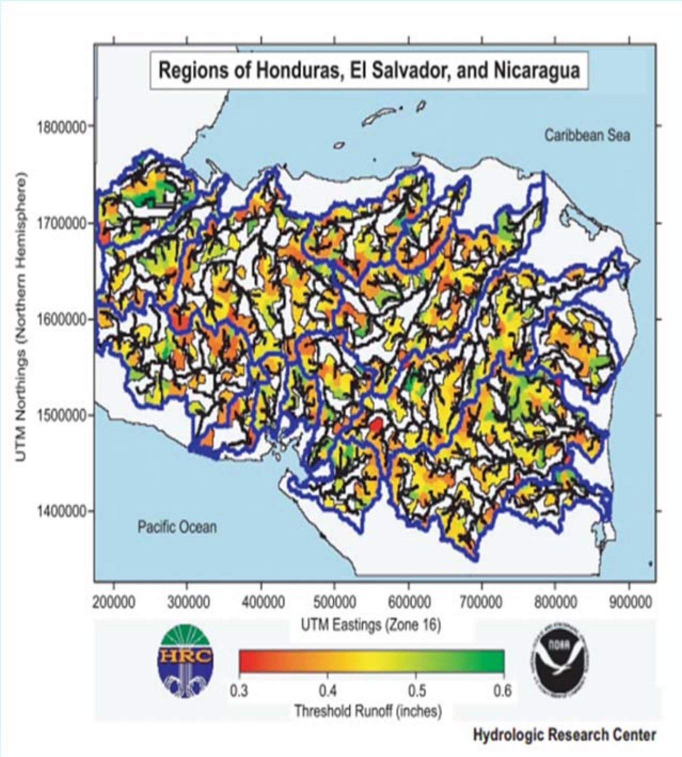
CAFFG became operational in 2004 and covers all the Central American countries. Designed to accommodate existing global digital spatial databases for Central America as well as the real time remotely-sensed and on-site precipitation and temperature databases, data is obtained from:

- satellites (NESDIS-NOAA) to get rainfall estimates;
- rain gauges, radar, digital elevation data (from the United States Geological Survey's GTOPO30 database);
- land cover datasets (from the University of Maryland's Global Land Cover Facility);
- and a digital database of soils and terrain properties (from the FAO).

The data is then inputted into system models (Figure 23) for the computation of FFG (the determined expected volume of rainfall accumulated over a given small watershed for a given time period that is just enough to cause bankfull flow which would lead to possible flood alert).

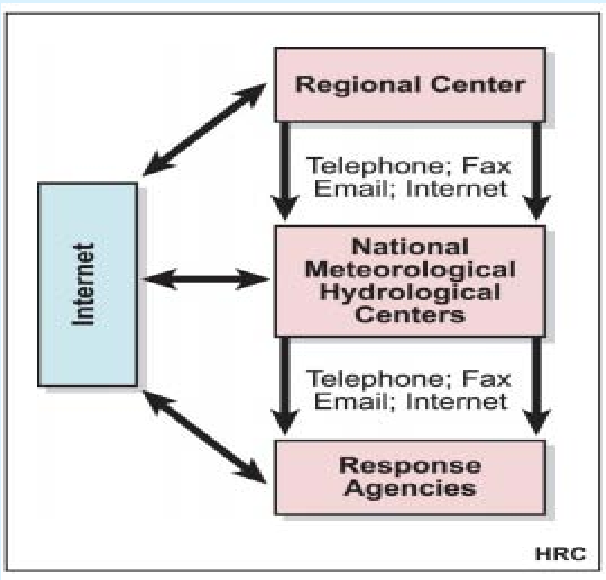
The FFG values are then made available to national meteorological and hydrological agencies as well as disaster preparedness response agencies within the Central America region to support of their flood warning and response missions. The dissemination pathway is shown in Figure 24 and is updated hourly or every 6 hours. In the end system provides timely centralized guidance for the issuance of effective flash flood warnings for small river basins in each country's area of responsibility.

Figure 23 – Elevation data, streams, and watershed Figure 23 – Boundaries used in the CAFFG



Source:http://www.meted.ucar.edu/communities/hazwarnsys/ffewsrg/FF_EWS.Chap.8.pdf

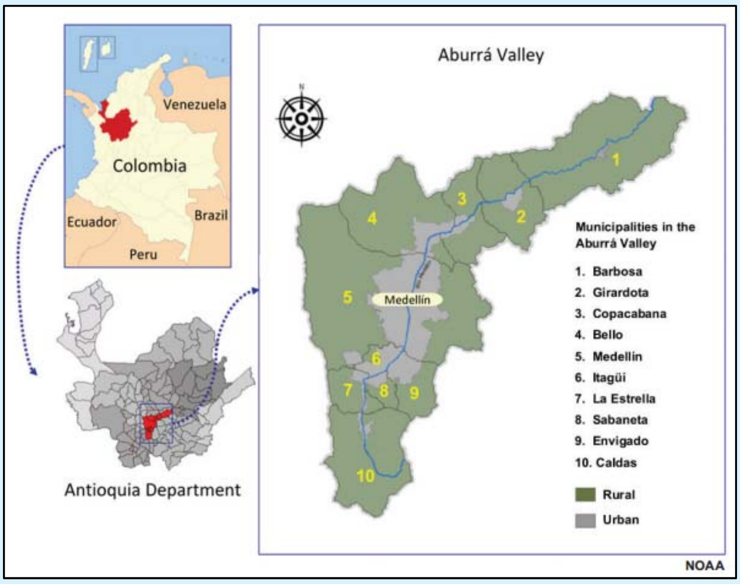
Figure 24 – CAFFG dissemination pathway



Source: http://www.meted.ucar.edu/communities/hazwarnsys/ffewsrg/FF_EWS.Chap.8.pdf

Another EWS innovation is found in the Aburrá Valley, Colombia The Aburrá Valley, the natural basin of the Medellín River, is one of the most populous valleys of Colombia's Andean Region with an urban agglomeration of roughly 3 million inhabitants (Figure 25).

Figure 25 – Location of the Aburra Valley, Colombia



Source: http://www.meted.ucar.edu/communities/hazwarnsys/ffewsrg/FF_EWS.pdf

High slopes make the area highly prone to landslides and storm water erosion. To mitigate the risks the Sistema de Alerta Temprana – Early Warning System (SIATA) in Aburrá Valley was developed to provide real time monitoring of hydrological and meteorological occurrences within the Aburrá Valley region; generating vital information for environmental management and risk.

SIATA is a project which partners with the Aburrá Valley Metropolitan Area, the Mayor of Medellin, the Administrative Department of Risk Management (DAGRED), Columbia's Water, Energy and Gas Public Utility (EPM) and its power generation company, (ISAGEN). SIATA was consolidated as an important prevention strategy for the Municipal System for the Prevention and Attention of Disasters SIMPAD with the main objective of alerting the community in a timely manner on the probability of extreme hydro- meteorological events. By improving response through timely warning the reduction of the impacts of such phenomena was envisioned.

Significant investment in recent years has been extended to promote the creation, maintenance, development and technical strengthening of the system. The Aburrá Valley Metropolitan Area signed in December 2011 a Framework Agreement with public enterprises of Medellin and ISAGEN combining technical, logistical and financial efforts for the implementation, operation and maintenance of the EWS of the Aburrá Valley in order to promote actions aimed at better understanding of risk management.

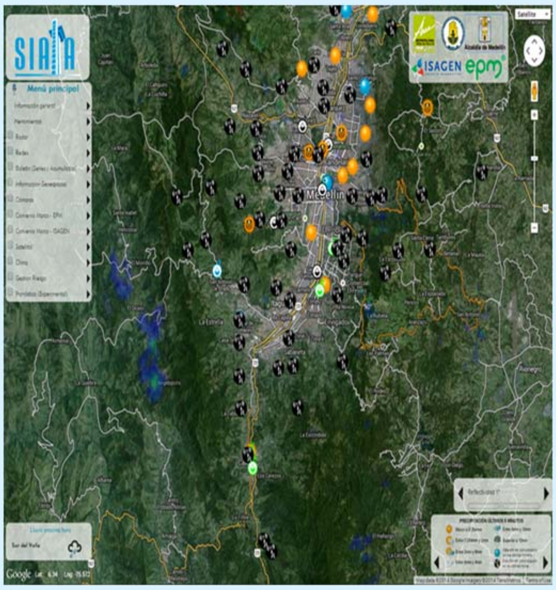
For proper functioning of the EWS, constant and reliable data is obtained from the monitoring of atmospheric variables, watersheds and slopes of the region through the rainfall measuring network weather nets, level sensors, soil moisture sensor networks, and the hydro-meteorological radar. After all the necessary information is integrated into the system, accurate community warnings are issued.

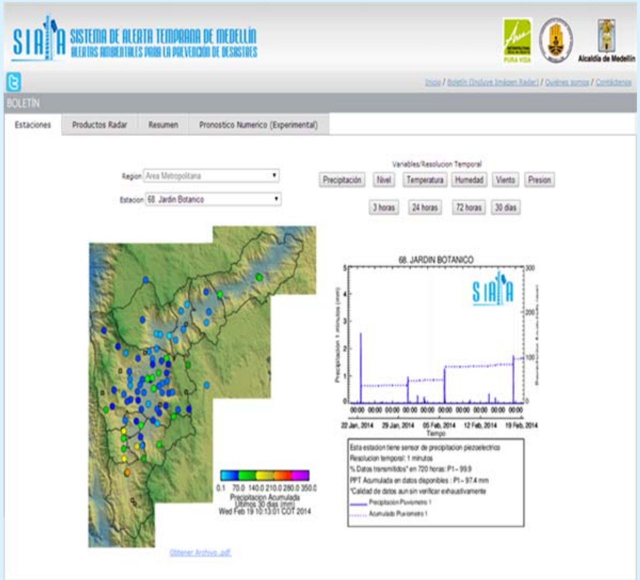
Stations which support the EWS are distributed throughout the Aburrá Valley and operate under strict calibration as well as corrective and preventive maintenance. By ensuring the reliability of the data (such as rainfall, temperature, relative humidity, the wind speed and direction, the level of streams and the saturation level of the soil etc.), improvements in the reliability of the community alerts can be made.

Incorporation of a real-time communication type GPRS ensures that there is constant flow of information between stations and the main server. The information is continuously updated and displayed to the community through the SIATA web platform (Figures 26 and 27) as well as other ICT tools that have been designed to disseminate information (e.g. SMS).

These examples show that through governmental, regional and international partnerships, effective EWS using careful ICT integration can be developed within LAC.

Figures 26 and 27 – Different aspects of the SIATA web platform





Source: *http://www.siata.gov.co/newpage/index.php*

4.3 SWM solutions for aging infrastructure

4.3.1 WaterWiSe improving operational efficiency of Singapore's water supply system

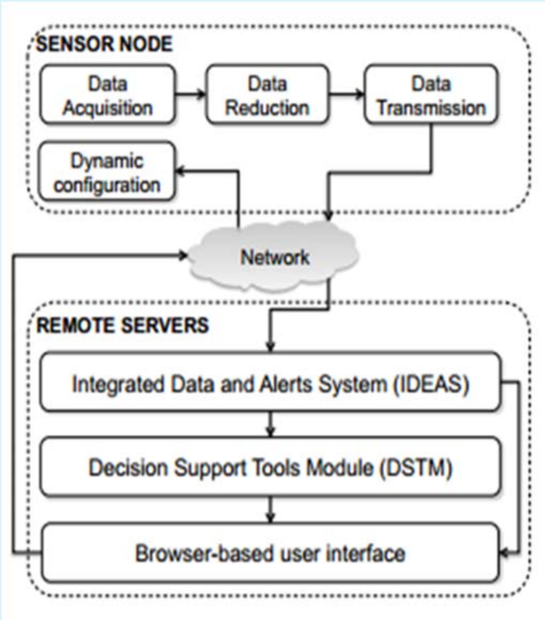
Aging infrastructure is a major challenge for water utilities and one of the main reasons for leakages within the water distribution system. If not undetected burst pipes and mains can account for significant water loss within a water distribution system. Therefore to help improve operational efficiency of the water supply in Singapore (Figure 28) and combat issues related to aging infrastructure, the Wireless Water Sentinel (WaterWiSe) project was initiated in 2008.

Figure 28 – Snapshot of Singapore

Source: *http://blog.wearespaces.com/wp-content/uploads/2013/06/sgskyline1.jpg*

The project which was supported by Singapore's National Research Foundation (NRF) was established through the careful collaboration between Singapore's Public Utilities Board (PUB), Singapore's Center for Environmental Sensing and Modeling (CENSAM), part of the Singapore-MIT Alliance for Research and Technology (SMART), the Intelligent Systems Centre (IntelliSys) and the School of Computer Engineering (SCE) of the Nanyang Technological University (NTU).

Figure 29 – WaterWiSe's layers



Source: http://cee.mit.edu/system/files/SHMII-v6.pdf

WaterWiSe, currently being marketed by Visenti Pte Ltd, is a cloud based platform which provides real-time water distribution monitoring. The system can operate self-contained by using its own analysis and management interfaces, or can be integrated into a water utility's existing infrastructure such as its GIS platform.

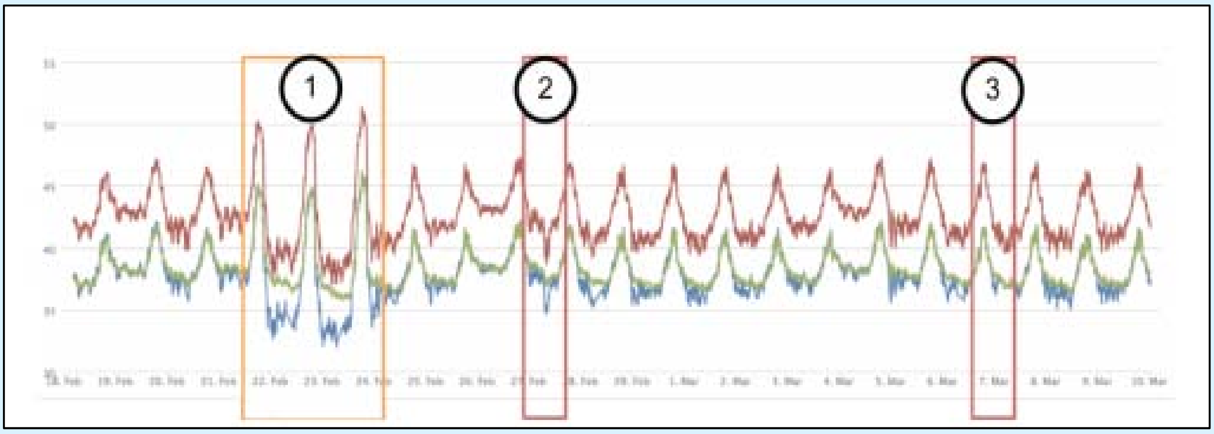
The main components of WaterWiSe are displayed in Figure 29. Data collection is obtained in part from integrated wireless sensing multi-probes which are deployed within the water distribution network, enabling sampling and transmittance of relevant data such as hydraulics (pressure, flow), acoustics (hydrophone) and water quality (pH, ORP and conductivity) in real-time (Figure 30).

Figure 30 – WaterWiSe multi parameter sensor attached to a gate valve

Source: http://cee.mit.edu/system/files/SHMII-v6.pdf

The integrated data and electronic alerts system (IDEAS), and the decision support tools module (DSTM) are both very important areas of the WaterWiSe system. IDEAS is responsible for data stream management, analytics and alerts while DSTM uses the data aggregated by IDEAS to provide decision support tools on a demand-zone basis. Though IDEAS performs analytics to detect and localize abnormal events (e.g. leaks and bursts), or longer-term trend changes as seen in Figure 31, the basis of DSTM is a "real-time" hydraulic model set to calibrate the water utilities' network model every 15 minutes, using recently collected sensor data.

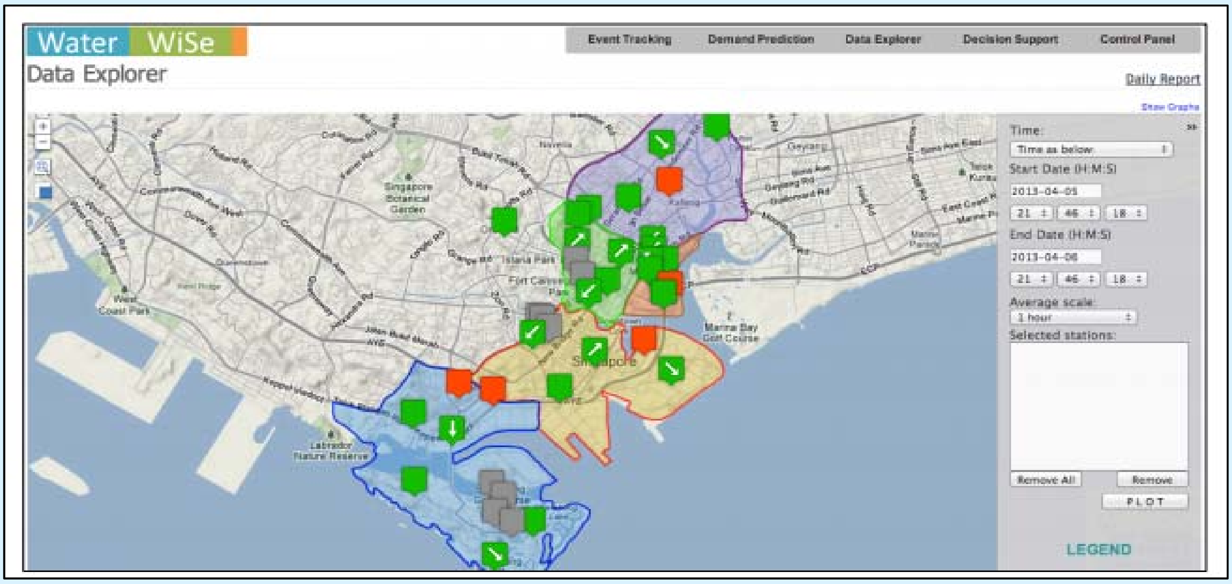
Figure 31 – An example of a WaterWiSe post analysis, where (1) shows an unusual operation, (2) shows a suspected break event and (3) shows the first reports of leakage.



Source : http://www.visenti.com/res/pubcasestudy-visenti.pdf

In Singapore, the WaterWiSe project consisted of three phases; Phase 1, a basic system with a selected number of sensor nodes was installed to demonstrate the viability of long term monitoring and data collection; Phase 2, which saw an expansion to 26 wireless network sensor nodes, enabling online monitoring of hydraulics and water quality within the distribution system in the Fort Canning-Pearl's Hill (FCPH) zone of central Singapore; and Phase 3 which focused on developing and evaluating a new generation of multiprobes that have enhanced sensing functionality (PUB, 2013). The platform was integrated into PUB's SCADA system to exchange sensor data and operated remotely with a stand-alone browser-based interface (Figure 32).

Figure 32 – The WaterWiSe user interface showing station locations overlaid on a map



Source: http://cee.mit.edu/system/files/SHMII-v6.pdf

Over the course of the WaterWiSe project a proof-of-concept 8-node network of integrated multi-probes collecting only pressure data was scaled to a 50 node network covering several supply zones with an area of 80 km^2 (PUB, 2013). Since 2009 WaterWise has been successful in aiding in event detection such as leaks and bursts, system analysis (such as post event analysis), real time monitoring and operations as well as decision support.

The WaterWiSe case in Singapore has exhibited that low cost wireless sensor networks can be applied to water distribution networks to produce data necessary for the real time on-line monitoring of hydraulic and water quality parameters within a large urban setting; improving remote detection of leaks and pipe burst through real-time monitoring and hydraulic modelling**.**

By partnering with water utilities, academia and ICT institutes, the WaterWiSe project was able to improve the day-to-day operations of the water distribution system in Singapore.

4.4 SWM and Water Security

4.4.1 The U.S. EPA Water Security Initiative

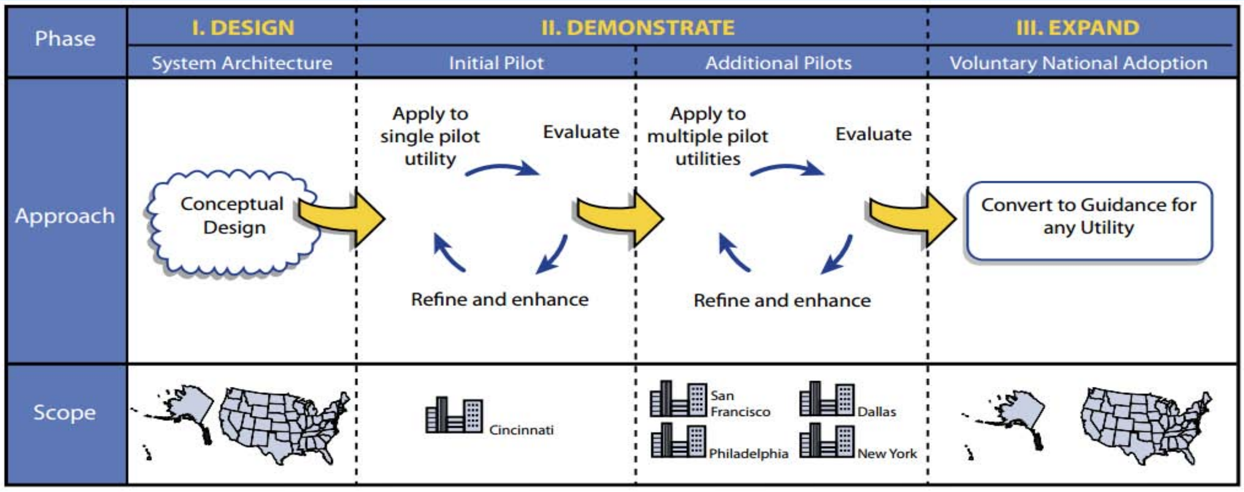
Though water security seeks to ensure both the reliability and availability of water in terms of quantity and quality for health, livelihoods and production, security also means protecting the water supply system from contamination which may come in the form of pollution, accidents, and terrorist attacks. Ensuring the safety and security of water resources of a country has been increasingly a concern for utility managers.

The United States Environmental Protection Agency is an U.S. federal agency entrusted to protect human health and the environment through creating and enforcing regulations. Its water security (WS) initiative is a program developed to address contamination risks of drinking water distribution systems within the U.S.A. The initiative was established in response to Homeland Security Presidential Directive 9, under which the Agency must "develop robust, comprehensive, and fully coordinated surveillance and monitoring systems, including international information, for… water quality that provides early detection and awareness of disease, pest, or poisonous agents" (EPA Office of Water, 2010). Components of WS include online water quality monitoring, consumer complaint surveillance, public health surveillance, routine sampling and analysis and enhanced security monitoring.

The WS initiative consists of three phases as seen in the Figure 33 where Phase I consisted of the development of the conceptual design for a contamination warning system for timely detection and appropriate response to drinking water contamination incidents to mitigate public health and economic impacts; Phase II the testing and validation stage, used the contamination warning systems through pilots at drinking water utilities and municipalities in order to make refinements to the design as needed based upon pilot results; and where Phase III which is still ongoing will develop practical guidance and outreach to promote voluntary national adoption of effective and sustainable drinking water contamination warning systems within the U.S.A.

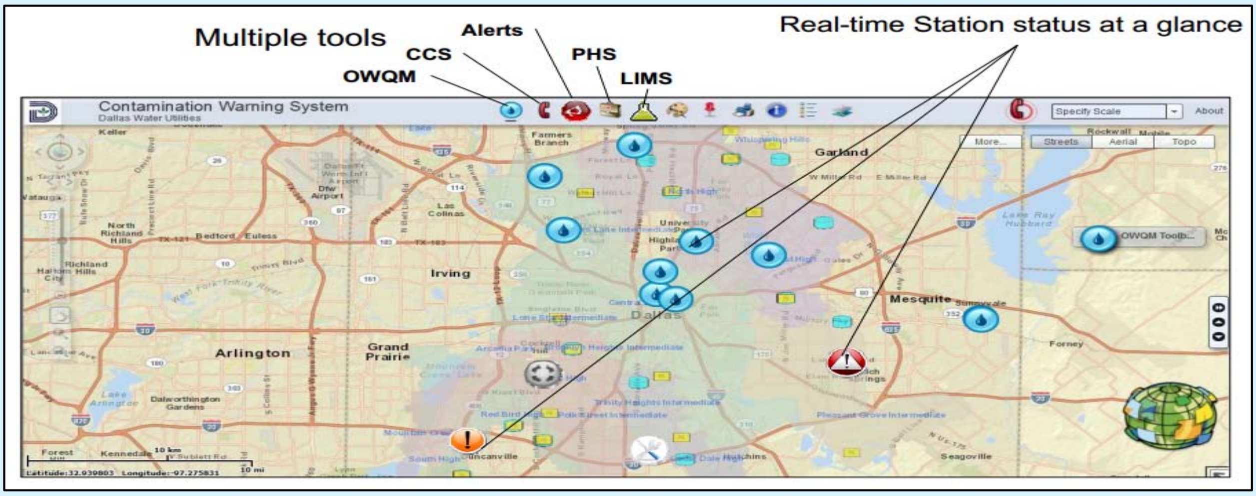
Online water quality monitoring development in the Phase I led to a proposed systematic assimilation of ICTs (sensor technology, models, event detection software, GIS etc.) to create a comprehensive drinking water contamination warning system (CWS) as seen in Figure 34. The CWS consists of array of technologies for information acquisition and management in order for data to be captured, managed, analyzed, and interpreted in time to recognize potential contamination incidents and mitigate such impacts. Part of this included the installation of online water quality monitoring (OWQM) stations throughout the water distribution service area to detect security concerns and to improve distribution system operations.

Figure 33 – Phases of the U.S. E.P.A.'s W.S. initiative



Source: http://water.epa.gov/infrastructure/watersecurity/lawsregs/upload/100917_WSI-Fact-sheet_9059.pdf

Figure 34 – Snapshot of the U.S. E.P.A.'s CWS



Source: http://ipsc.jrc.ec.europa.eu/fileadmin/repository/sta/cinet/docs/erncip/downloads/operators/Real-Time-Technologies-for-Early-Contamination-Warning.pdf

Installation locations for the OWQM stations were selected using EPA's threat ensemble vulnerability assessment—sensor placement and optimization tool (TEVA-SPOT), an analytical tool built upon a distribution system hydraulic model that uses probabilistic analysis and optimization to conduct a vulnerability assessment and determine optimized sensor placement (PWD and CH2M HILL 2013). Another important component refers to event detection systems (EDS) which are designed to monitor water quality data in real time and produce an alert if water quality is deemed anomalous (EPA, 2013).

By proper ICT assimilation the provision of an integrated information stream was made possible which can independently provide timely initial detection of potential contamination incidents as well as improve the credibility of incidence evaluation faster and more reliable, than if an individual information stream was used alone. By proper collaboration and dialogue with U.S. water utilities in Phases II and III, validation of the tools and software that were developed in Phase I, was properly evaluated and will facilitate nationwide implementation once finalized; ensuring an effective contamination warning system within the entire of U.S.A.

4.5 SWM and Decision Support

4.5.1 Improving Decision Support systems for water resource management in Europe

For water managers, policy makers and governments to make the right decision on water related issues, sufficient and relevant information is essential to encourage the right decisions to be made. Recognizing the need for improved information accessibility based on EU WFD and other water related policies, the EU (Figure 35) launched the WISE-RTD Water Knowledge Portal to guide specific user groups to find appropriate information related to water research, technology and development. This web-based portal can be used to locate considerable policy information as well as research and industry resources that support the WFD in Europe.

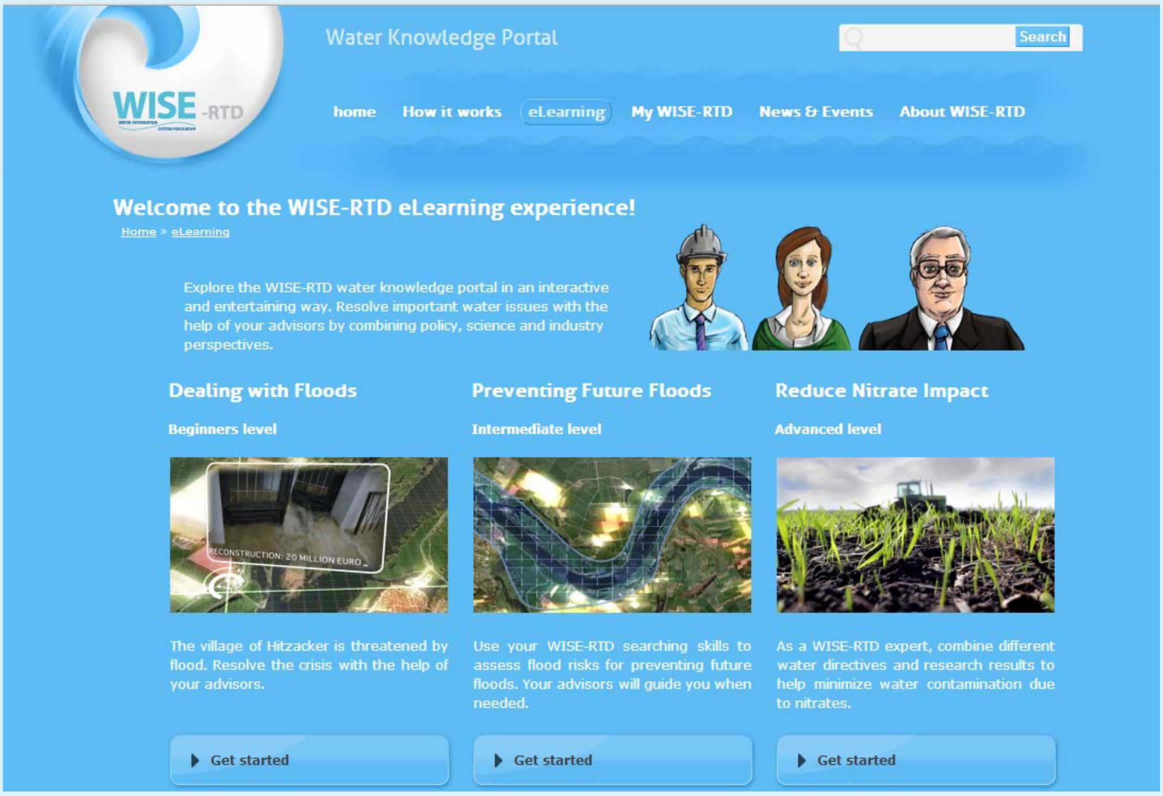
Figure 35 – The EU member states

Source: http://thumbs.dreamstime.com/z/european-union-map-13463478.jpg

WISE-RTD database incorporates information based on policy, data, modelling and projects based research. By intelligent keyword linking algorithms, the system permits quick and easy retrieval of policy, science and technology related information as well as interlinks the relationships between them. The portal also provides websites which contain guidance documents, synthesis reports, reviews, experiences of projects on implementation, selections of ICT tools, methodologies and results of national and EU funded research projects. Information is gathered from a European, national and regional level and is currently available in the main languages of the EU (eventually the site will be covered in all EU official languages).

Users such as water managers can therefore find current scientific information and/or software as well as experience to help them make better decisions in their respective cases. The My WISE-RTD community allows users to publish their own research or technological development related information, track easily the latest information in tailored area(s) (interests specified by the user) and interact with other members, to share knowledge and experiences. The portal also has extensive eLearning modules to help users grasp the full functionality of the website as seen in Figure 36.

Figure 36 – Snapshot of the eLearning module (WISE-RTD water knowledge portal)



Source: http://www.wise-rtd.info/en/bleu-page/welcome-wise-rtd-elearning-experience

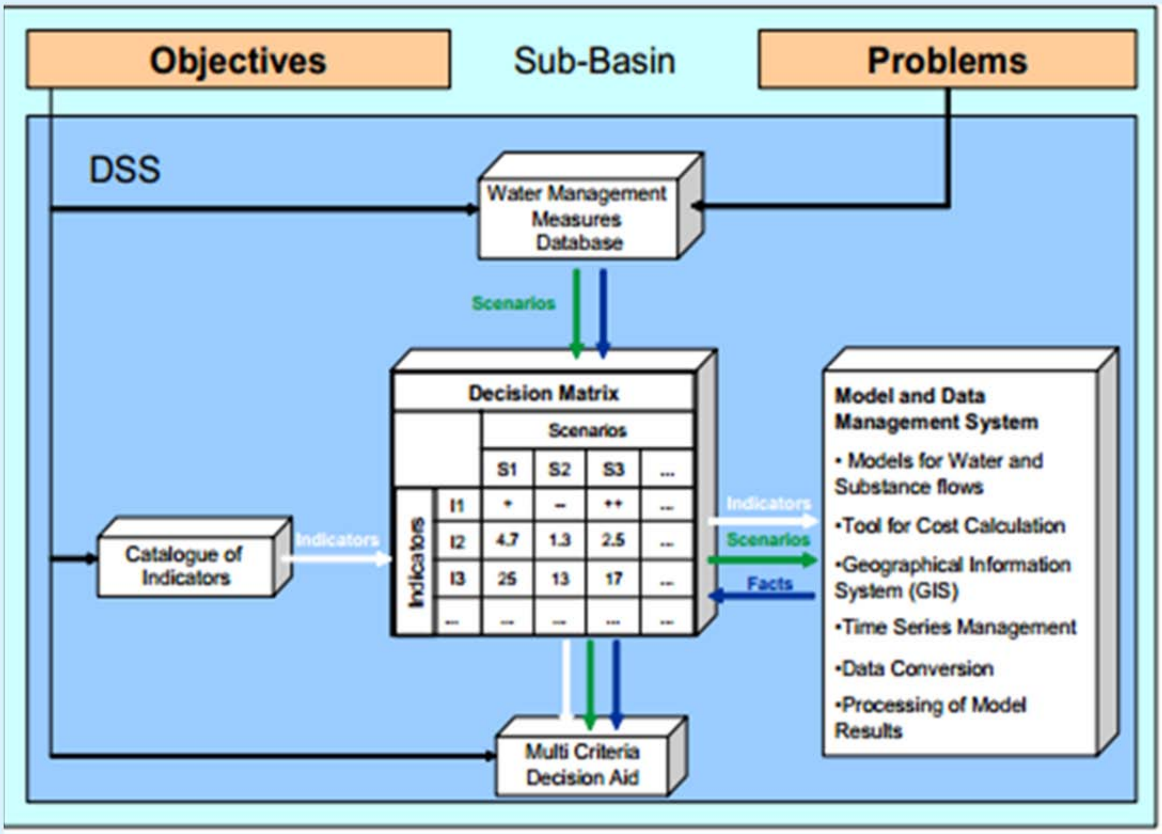
In addition, the WISE-RTD water knowledge portal will be used to evaluate if policy questions have been answered by the research and technological development (RTD) outcomes and whether stakeholders' needs identified are covered by policy issues. The information will be derived using gap-analysis to provide recommendations for the future developments.

Other tools which assist with decision support include models and integrated software. Effectively managing small intensively used watersheds for mitigation planning measures have become increasingly complex. Therefore decision support systems enable key stakeholders to carefully evaluate situations based on the reliable information. Moreover Europe has been implementing web-based decision support systems within their territories to manage river catchment issues as well as to inform the public about water related issues within their catchment (e.g. flooding). Most of these have been done through careful collaborations within regions, and key stakeholders to ensure proper dissemination of information. The case below seeks to give some further insights on decision support systems as a tool for SWM.

The WSM300 project was developed to provide an appropriate decision support system for small watersheds. Supported by the Deutsche Bundesstiftung Umwelt (DBU) – German Foundation for the Environment, the main objective of the WSM300 project was to develop a methodology which guides and supports an improved water resources management on the level of small watersheds (Sieker et. al 2006) in some sub-basins in Germany. This project was undertaken in collaboration with Ingenieurgesellschaft Prof. Dr. Sieker, Darmstadt University of Technology, SYDRO CONSULT, Saxonian State Institute of Agriculture and the Berlin University of Technology. The project sought to mitigate the pressures and impacts on water resources in small watersheds resulting from anthropogenic activities and took in consideration the EU WFD as well as the objectives of integrated river basins management (IRBM).

It should be emphasized that WSM300-DSS is not a monolithic software application but rather a methodology for IRBM in small watersheds supported by suitable software tools (Sieker et. al 2006). WSM300-DSS structure incorporates a web based decision matrix which works on both a consultative level and engineering level; a database of measures which is an amalgamation of relevant data (such as preconditions, costs, literature etc.); an information system which allows for proper visualization of scenario development through the use of GIS; a catalogue of indicators defined for assessment; and multicriteria assessment tool to ensure that a more holistic evaluation of the data (Figure 37). If desired, multi-criteria decision aid methods can further help find the optimal scenario and mediate between stakeholders (Sieker et. al 2006).

Figure 37 – Structure of WSM300 DSS



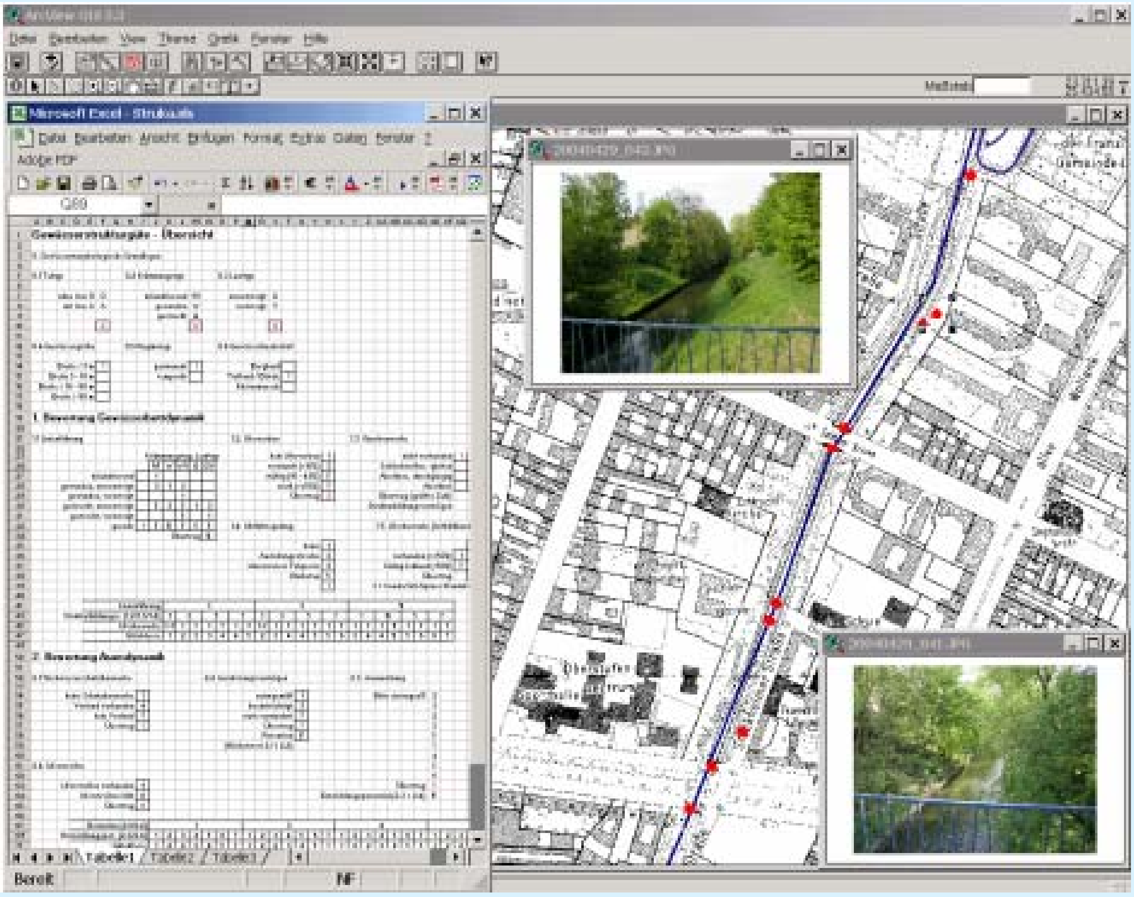
Source: http://www.iwaponline.com/wpt/001/0004/0010004.pdf

GIS tools enable data-storage, data presentation and handling as well as provide tools necessary for multi-criteria assessments. Incorporation of both concept and tools within of existing software components and supports the processing of model-outputs to indicator-values, allows a comparison of the scenarios and provides a good basis for a decision (Figure 38). The system was built to be controlled by experts and has been successfully applied in a wide spectrum of different sub-basins; varying from a heavily urban sub-basin, an urban and agricultural sub-basin as well as an agricultural and forestry based catchment area used for a drinking water dam. A demonstration version is available at www.wsm300.de.

Notably the WSM300-DSS project during the case studies stage took a "stakeholder involvement approach" to bridge communication between different stakeholder groups within the different catchment cases. This led to the further development of river committees which aid the development of objectives and scenarios needed for the proper assessment using the DSS for their respective cases.

Another product of WSM300-DSS project was the development of a web-based "River-Information-System" established to inform the public about the newest developments within their catchment. The WSM300-DSS project illustrates that by partnering with different stakeholders within a catchment area using an integrate water management approach as well ICT tools, proper decisions can be made for overall sustainable water management.

Figure 38 – Information system for the Panke river catchment, Germany



Source: http://www.iwaponline.com/wpt/001/0004/0010004.pdf

5 Opportunities and challenges

The impending global water crisis means that action should be taken now to ensure livelihoods of the future. SWM may be solution to this global problem only if there is proper stakeholder involvement employed. The previous section revealed that with proper coordination, involvement and information sharing between stakeholders, SWM tools, products and systems can be developed and implemented; creating a vast amount of opportunities. However though the opportunities are notable, on a global level, challenges still exist. Overcoming these challenges will therefore ensure that global water issues are tackled effectively.

5.1 Opportunities

ICT use in SWM has a wide application and a clear set of benefits, which, in general, increases water use efficiency and therefore decreases consumption. Some major areas where improvement is evident are listed below:

- **Real-time monitoring**

Technologies such as smart metering, SCADA, GIS, telecommunication sensors and decision support systems allow for the provision of real-time reliable data. This means that water utilities have the opportunity to make improvements in demand response and distribution. Similarly, water losses in the water distribution system can therefore be reduced. Customers and companies are now able to better track and monitor water usage. By extension, this creates transparency within the water management system, allowing for more equitable allocation and distribution of water resources by managers.

- **Improvement in water access**

Technologies such as water point mapping can aid in access improvement in water supply, by allocating resources to deliver basic services where they are needed the most, and by extension these technologies can measure progress and performance. Smart technology has also been incorporated into standpipe management models to improve standpipe performance monitoring and regulation, ensuring that the unconnected poor are able to enjoy reliable access to a fresh clean supply of water.

- **Reduction in water consumption**

Since water managers, industries, businesses and consumers are better able to monitor their water usage, ICTs provide the tools needed to create advanced water use efficiency in all sectors. Incorporation of sensors in agricultural sectors ensures that crops are watered when needed, reducing large volumes of water normally lost due to wastage.

- **Reduction in operational costs**

"Water utilities can save up to 20% of water leakage levels and reduce energy consumption by 30% through smart water infrastructure" (Cutler 2013). Improvements in operational efficiencies mean that administration costs can be reduced as well as costs incurred from non-revenue water, creating an optimization of expenses. Thus immediate and long-term impacts of smart water metering and smart water grids, in a business case, represent significant savings.

- **Integration of smart water management in smart sustainable cities (SSC)**

SSC essentially are efficient cites; efficiency here mainly focuses on the use of intelligent technology and a more active involvement by its citizens. SWM is highly incorporable into SSC and it safeguards economic growth and sustains a higher quality of life as well as it maintains ecological and environmental resources for future generations. Consequently, ICTs will ensure that the cities of tomorrow are more water efficient.

- **Environmental flow integration**

Though the benefit of ICTs in environmental flow assessments of water resources management has not been comprehensively detailed here, there is a clear potential. The use of ICT products, solutions and systems (e.g. sensors networks, GIS, etc.) in the proper monitoring and assessment of environment flow can lead to better decision-making in sustainable management of this resource.

- **Greater public involvement**

Customers are able to report leaks more efficiently by providing real-time data to water utilities. Improvement in communication between water utilities and the public can lead to an enhancement in public awareness with regard to consumption and water usage.

5.2 Challenges

Though there are substantial opportunities of ICT use in SWM, global developments in this area are currently insufficient and are mainly due to the areas listed below:

- **Lack of standardization**

Though ITU has developed ICT standards in ubiquitous sensor networks (USNs) and the Internet of things (IoT), which are also relevant to this sector, there is still need for further standardization. Standardization and development of best practices in this area ensures that incentives are done in an efficient, equitable, and ecologically sustainable manner. Current development is being accomplished in an ad hoc manner which in the end cannot be sustainable. Standardization maintains integrity, and adherence ensures that there is compatibility, interoperability, and a certain level of quality, therefore reduction of risks.

- **Lack of policies**

Policies can make or break smart water markets by either encouraging or hindering the development and deployment of SWM systems. Policies therefore need to be properly coordinated and developed out of clear research and careful examination of the water sector within a given country. Coherent cross-sector policies and a multi stakeholder formulated water resources management strategy are essential to the success and sustainability of these tools.

Policy development should not be taken lightly since the current trend in policy development of most countries is fragmented and sector specific. Generally, in most countries there is no coherent multi-sector and/or multi-stakeholder coordinated policy on water management and/or conservation. Therefore policies and other regulatory based enforcements in addition to carefully developed economic incentives for sharing water consumption information, and reducing water consumption will have a positive effect on the development of the smart water ecosystem, once implemented properly.

Accordingly, an integrated policy formulation approach that integrates different governmental sectors, NGOs, CBOs, academia, and the private sector is necessary for the success and adoption of water resource management policies on the national and regional levels.

- **Proper ICT governance**

Lack of ICT governance impacts investment as well prevents stable coordinated and comprehensive planning to address future requirements and proper integration. Proper governance in this sector creates certain safeguards that encourage efficiency and effectiveness.

- **Lack of incentives/funding**

Governments and the banking sector need to provide more incentives for funding and research. Adequate subsidies and tax incentives can facilitate changes in behaviour within the water sector as well as the citizenry. Banks can also play an important role through loans and investments. It has been observed that many small ICT companies are unable to thrive since some banks may deem such projects as high risk due to their unfamiliarity with such investments.

- **Lack of awareness**

Proper dissemination is needed for this approach to get the buy-in required. Furthermore, awareness, proper education as well as dissemination are essential for proper management of any resource. Many countries, though aware that technology can drive economies, are not necessarily conscious of the role ICTs can play in water management or of its usefulness. Nonetheless, many countries have access to technology but not many are harnessing this technology for the use of water management. More emphasis has been placed on the development of smart cities but not on how ICTs can act as an enabler of SWM on a larger scale.

On the other hand, most ICT systems procured by businesses and governments have been implemented with minimum and sometimes no integration with other systems preventing further benefits to be harnessed. If customers are better informed about their supply options, they will be able to make better decisions on usage and the manner in which they consume water.

6 The path forward

SWM is a viable option for sustainable water resource management in the face of water scarcity, climate change as well the other constraints endured in the water sector. These advantages which can be gained by ICT incorporation in water management could possibly see the attainment of the UN Millennium development goals for water and sanitation, if properly implemented. However, focus needs to be placed on this subject to allow for stakeholder buy-in and proper collaboration by the relevant sectors especially those that have a direct impact as they set the pace for implementation.

Notwithstanding, communication between stakeholders in ICTs and SWM is also necessary. Proper integration and stakeholder involvement prevents fragmented and uncoordinated approaches to water management issues, and therefore leads to a smarter way of water management. Appropriate intelligence adoption in SWM can only be achieved if there is a focus on partnering the right technologies with the right stakeholders. Discourse must be bridged to ensure that information from utilities, municipalities, regulators, investors industries, technology providers and academia can be properly harnessed. This allows for the development of innovative partnerships, creating the right solutions for all.

Development of standards, policies and ICT governance is imperative to ensure that there is integrity in the process as we try to manage our water resources in the 21st century. Therefore, guidelines, strategies and best practices in SWM must be developed in a collaborated effort with key stakeholders. They should be properly tailored through protocols to promote efficiency, accountability and non-discrimination.

Moreover, development of a global portal on ICTs contribution to SWM is needed to provide a secure interface for the easy dissemination of technological advances and best practices on SWM, as well as to encourage and create a global system-wide, coordinated action. Furthermore, the development of clear methodologies to evaluate the social and economic impacts of ICTs in SWM is essential to appropriately measure ICTs' influence.

ITU's realm as an international standards organization as well as through its main objectives will seek to stipulate integrity, compatibility and interoperability within ICTs in SWM. Through the provision of an international platform for the development and procurement of SWM standards, ITU's commitment to standardization in the ICT sector will pave the way forward for ICTs in SWM mainly in these key areas:

- Targeted, integrated and coordinated research in ICTs in SWM, to facilitate the provision of best practices in this sector.
- Development and specification of SWM standards particularly in water information transfer, storage, access and update that allow relationships between geographic and time-dependent characteristics such as smart metering.
- Lead in facilitating implementation and development relating to ICTs in SWM infrastructure development in countries.
- Set the precedence in information and training sessions to assist countries in the implementation of ITC methodologies concerning SWM, thereby improving capacity development in those countries.
- Maximize the impact and awareness in ICTs in SWM through a streamline delivery in various networks.

ITU's Focus Group on Smart Water Management (FG-SWM) is therefore working to achieve these goals so that there is 'Smarter Sustainable Water for all'.

Glossary

AfDB WPP	African Development Bank Water Partnership Programme
AMCOW	African Ministers' Council on Water
AMI	Advanced Metering Infrastructure
ATM	Automated Teller Machine
AWDO	Asian Water Development Outlook
CAFFG	Central American Flash Flood Guidance System
CBO	Community Based Organizations
CCP	Console Command Processor
CENSAM	Singapore's Center for Environmental Sensing and Modeling
CIMUN	The Cathedral International Model United Nations
CT	Computed omography
CWS	Contamination Warning System
DAGRED	Administrative Department of Risk Management
DBU	Deutsche Bundesstiftung Umwelt – German Foundation for the Environment
DFID	The United Kingdom Department for International Development
DSTM	Decision Support Tools Module
EPM	Columbia's Water, Energy and Gas Public Utility
ERP	Enterprise Resource Planning
EU	European Union
EU WFD	The European Union's Water Framework Directive
EWS	Early Warning Systems
FCPH	Fort Canning-Pearl Hill, Singapore
FFG	Flash Flood Guidance System
FG-SWM	Focus Group Smart Water Management
FP	Framework Programme
GIS	Geographical information system
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GPRS	General Packet Radio Service
GRIDMAP	The Groundwater Resources Investigation for Drought Mitigation in Africa Programme
GSM	Global System for Mobile Communications
GWT	The WBCSD Global Water Tool©
IBM	The International Business Machines Corporation
IC	Integrated Circuit
ICT	Information and communications technology
IDEAS	Integrated Data and Electronic Alerts System

IGO	International governmental organization
IntelliSys	The Intelligent Systems Centre
IoT	Internet of Things
ISAGEN	Columbia's Power Generation Company
IT	Information Technology
ITU	The International Telecommunication Union
ITU-T	Telecommunication Standardization Sector
JMP	Joint Monitoring Programme
LAC	Latin America and the Caribbean
LACI	The Latin American and Caribbean Initiative for Sustainable Development
LAN	Local Area Network
MSGS	Municipal Smart Grid Summit
MTN	Mobile Telephone Networks Group
MWI	Ministry of Water and Irrigation
NewTech	The Novel Efficiency Water Technologies
NGO	Non-governmental Organization
NRF	The Singapore's National Research Foundation
NRLI	The National Lake Rescue Institute
NTU	The Nanyang Technological University, Singapore
OECD	The Organisation for Economic Co-operation and Development
ORP	Oxygen Reduction Potential
OWQM	Online Water Quality Monitoring
PHP	Hypertext Pre-processor
PLC	Programmable Logic Controller
PUB	Singapore's Public Utilities Board
RDS	Radio data systems
RTC	Real-time Clock
RTD	Research and Technological Development
RTP	Real-time Transport Protocol
RTU	Remote Terminal Unit
SCA	Subsidiary Communication Authorization
SCADA	Supervisory Control and Data Acquisition
SCE	The School of Computer Engineering of the Nanyang Technological University
SEMS	Sarvajal Enterprise Management System
SIATA	Sistema de Alerta Temprana- Early Warning System
SIMPAD	Municipal System for the Prevention and Attention of Disasters
SMART	Singapore-MIT Alliance for Research and Technology

SMS	Short Message Service
SQL	Special-purpose Programming Language
TEVA-SPOT	Threat Ensemble Vulnerability Assessment—Sensor Placement and Optimization Tool
TOU	Transmission Operating Unit
TSAG	Telecommunication Standardization Advisory Group
UDOM	The Ugandan Department of Meteorology
UN	The United Nations
UNEP	The United Nations Environment Program
UNESCO	The United Nations Educational, Scientific and Cultural Organization
UNICEF	The United Nations International Emergency Children's Fund
US	The United States
USA	The United States of America
USAID	The United States Agency for International Development
US EPA	The United States Environmental Protection Agency
USN	Ubiquitous Sensor Networks
US NOAA	The United States National Oceanic and Atmospheric Administration
WBCSD	World Business Council for Sustainable Development
WSP	Water and Sanitation Program

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