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**WATER RESOURCES MANAGEMENT**

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**1.0 INTRODUCTION**

Water is essential to all forms of life. It is the key driver of social and economic development and is essential in maintaining the integrity of the natural environment. In spite of this, water resources are unequally distributed. Furthermore, population growth, rising water pollution and the impacts of climate change will result in increasing competition between different water users over water resources. As the traditional sectoral and fragmented management approach often results in the unsustainable management and use of water resources, Integrated Water Resources Management has become internationally accepted as the most promising approach for achieving efficient and equitable management of water resources and sustainable development.

Although the South African water governance provides the legal framework basis for sustainable social, economic and environmental development, concerns over water quantity and quality are becoming stronger. Therefore, an integrated approach of water management is becoming more important. The United Nations General Assembly has recognized safe freshwater and sanitation as both a fundamental need and universal human right (UN 2010). Water is necessary to all forms of human, animal and plant life. It is essential for overall human well-being and supports all aspects of human livelihoods. Furthermore, water plays an essential role in supporting productive human activities such as agricultural, energy and industrial production, sanitation, transportation services, fishing and tourism (UNEP 2009, Kundzewicz et al. 2007, and Xie 2006).

According to Global Water Partnership (2009:6) water issues touch all segments of society and all economic sectors. But water resources are not only for social and economic benefits, they must also be recognized as fragile and limited natural resources that are an integral component of ecosystems, thus providing essential ecosystem services1 for the human beings. The access to water is often used as a key indicator for development (Orasecom, 2012). A lack of access to safe and sufficient drinking water is widely recognized as a poverty indicator (Koppen et al. 2002). In combination, water scarcity and poor governance impede the achievement of water security. Target 7a of the Millennium Development Goals (MDGs) pursue the objective to “half the proportion of the population without sustainable access to safe drinking water and sanitation by 2015” (UN 2012). In the coming decades, the global water demand will primarily grow due to population and economic growth, rapid urbanisation and the increasing demand for food and energy (GWP 2009).



While the global demand for water resources continues to increase, in many parts of the world the quantity and quality of water resources are diminishing (Vörösmarty et al. 2005). Competition for water use and conflicts are likely to increase as societies face a number of social, economic and political challenges on how to govern water wisely, especially in respect to climate change (Taylor 2001). But asides from physical water scarcity, a lack of access to safe water can be traced back to technical issues such inefficient water use or a lack of adequate involvement of local communities. Inadequate governance structures, uneven power relations, poverty, inequality within societies and isolated, fragmented planning without cooperation between different water user sectors and stakeholders lead to inefficient use of water resources. Apart from population and economic growth which often leads to excessive water extraction, erosion of river catchments, increased industrial pollution and municipal waste is considered to further degrade water quality and hence reduce the quantity of usable waters.

Furthermore, climate change is thought to have overall negative impacts on water resources such as changes in the hydrological cycle, creating increased rainfall variability, more frequent and intense floods and droughts and further degradation of water bodies (GWP 2012). Alongside other human activities, it is presumed to be one of the major factors that puts pressures on the world’s freshwater resources, thus increasing the vulnerability of human beings and ecosystems (Kundzewicz et al. 2007). As climate change is expected to increase global water stress in terms of surface and groundwater supplies, many countries will face new challenges in the water sector (Alavian et al. 2009). In spite of this, current water management practices are estimated to be inadequate to meet the demands of the growing population, or to reduce the negative impacts of climate change (Kundzewicz et. al 2007).

Therefore, sustainable management of freshwater resources is a key development priority to meet the growing demand of the world’s population for water and to achieve a secure and sustainable water future. Water security forms the foundation of food and energy production and of overall long-term social and economic development (Bigas 2012). The concept of Integrated Water Resource Management has emerged in response to the global `water crisis´ and is nowadays the most accepted approach in achieving sustainable water management and therefore, water security. It is widely recognized, that improved water resource management is a major step toward achieving a more equitable, prosperous world (BMU 2001). Cooperation across sectors represents one of the most important issues for successful Integrated Water Resource Management (IWRM) implementation.

Also, investments in research and development in water technologies, systems, treatment, use and productivity, all support sustainable water management. Sustainable management of water resources8 requires the participation of all members of society and requires important changes to policy, legal and institutional structures. It is recognised that connecting different water users promotes the wiser uses of water resources so as to achieve long-term sustainability by promoting fairer water sharing among competing users (GWP 2012). Successful IWRM implementation results in economic efficiency and social equity without compromising ecological sustainability. Its takes climate change into account, and considers the (competing) interests of different sectors and water users to achieve overall water security und sustainable development (GWP 2013, UNDP 2006).

Water is a key factor in achieving the Millennium Development Goals. Water plays a key role for food security, poverty reduction, economic growth, energy production and the human well-being, thus highlighting the multiple linkages between water, poverty and development. Without adequate adaptation measures, climate change is considered severely affect economic, social objectives and ecological aspects. Effectively managing freshwater resources is imperative for the health of our environment, economy, and societal wellbeing. Historically, the reliable delivery and treatment of water supplies were considered best practice for the management of water resources. As such, tremendous amounts of infrastructure were created to deliver these goals (Ansar et al. 2014). Several creative and practical management practices, optimization methods, and modelling frameworks have been proposed to provide solutions for water scarcity. First, appropriate water management practices are key to effectively managing water resources.

Several water management practices include water conservation, efficient water markets, green infrastructure, and alternative transfer methods. Supply infrastructure improvements, agricultural irrigation technology upgrades, indoor urban water conservation (e.g. efficient toilet renovations), and outdoor urban water conservation represent the opportunities available to municipal and agricultural agents when planning for water supplies. The framework enables the exploration of technologies to alleviate critical tipping points through institutional controls, new supplies, and water-conserving technology. The framework for integrated water resources management include effective and efficient control, protection, use, management, conservation and monitoring to ensure sustainable development of the assets. This requires active involvement and participation of all stakeholders such as government departments, non-government departments and community.



This paper will explore a clear distinction between climate change, water conservation, water security and integrated water resources management. The paper is divided into eight major sections. Section eleven explores the water resource management at a global level. Section seven examines the challenges of the global water situation. Section eight elaborates the concept of water stress and its driving factors. This factors include climate variability, water resources, climate change and water resources, water shortages, scarcity and stress. Section nine explores the factors that contribute to water scarcity. This factors are divided into four phases. The factors explores from physical reasons, economics reasons, environmental and social reasons. Section ten explains the challenges of integrated water resources management. Some challenges pertains water availability (hydrological balance modelling), water demand (operations, economic measures, behaviour patterns, and legal institutional measures). Whereas other factors are extended to water supply systems, environmental flows, water quality, water quantity and water balance.

Section eleven explore the factors affecting water demand and distribution. This factors involve population, household occupancy rate, level of service of water supply for each household, tarrif services, willingness and ability to pay for the services. Cultural values, traditional and religious beliefs, climate change, water quality education, local knowledge and indigenous practice. Section thirteen examines the principles of water resources management. This principles include municipal wastewater treatment works, available renewable water for internal use, water supply shortage index, water supply requirements, full water service cost and environmental water stress. Section fourteen explores the concept of water security. Section seventeen elaborates the legislative framework for water resource management. This regulations are the guiding instruments that seeks to ensure water conservation, protection, monitoring, usage, management and effective control. Section eighteen explores the water conservation and demand management practices and solutions.

Section twenty examines the role players responsible for integrated water resources management. Some important role players are government institutions, political structures, women and community. Section twenty-five examines the concept of water sustainability. Section twenty-six explores the aspect of education to improve community and the next generation to take responsibility for integrated water resources management. This include knowledge and awareness, the role of community in ensuring safe water supply, training and capacity building, public awareness, partnerships and collaboration, community empowerment. The last two sections are general discussion and conclusion.



**2.0 OVERVIEW DEFINITIONS OF VULNERABILITY, CLIMATE CHANGE, CAPACITY BUILDING, SOCIAL EQUITY AND SUSTAINABLE DEVELOPMENT**

Integrated Water Resource Management (IWRM) is considered to be the adequate response in order to achieve water security (Orasecom 2013). A water secure world reduces poverty and increases living standards, especially for the most vulnerable. According to GWP (2013), sustainable development can only be achieved with a water secure world. Climate change have a great impact on the water resources. Climate change have a positive and negative impact of the water resources because water availability and non-availability. IWRM highlights the human dimension to achieve sustainability. The following are definitions of vulnerability, climate change, capacity building, social equity and sustainable development:

* OECD (2013) defines Vulnerability as a measure of the extent to which a community, structure, service or geographical area is likely to be damaged or disrupted, on account of its nature or location, by the impact of a particular disaster hazard.
* Climate Change is a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods (UNFCCC 2013).
* Capacity, is the sum of skills, abilities and qualifications of people.
* Capacity Building is a process which improves existing skills, strengthens problem solving abilities and creates knowledge.
* Social Equity refers to the basic right of people to have equitable access to safe and sufficient water (CAP-NET 2008).
* Sustainable Development is defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (UN 1987).



**3.0 OVERVIEW DEFINITIONS OF WATER CONSERVATION, WDM, WATER FOOTPRINT, WATER RESOURCE, WATER COURSE AND WATER VARIABILITY**

Water conservation is the minimisation of loss or waste, care and protection of water resources and the efficient and effective use of water.

* Rabe et al. (2012) define “Water Conservation as the minimisation of loss or waste of water, which includes preservation, care and protection of water resources plus the efficient and effective use of water.
* Rabe *et al.* (2012) define Water Demand Management as the adaptation and implementation of a strategy such as policies and initiatives by a water institution or consumer.
* Water Demand Management is defined as the use of strategies by water institutions to influence water demand in order to meet diverse objectives (Ali, 2010: 150) and focuses on reducing water consumption to reconcile water supply with demand.
* Water Footprint” is defined as the total quantity of freshwater used to produce the products and services consumed within a country (Hoekstra, 2003).
* According to Förch and Thiemann (2004), Water Resource is not only a basic need, but is also a centre-piece of sustainable development and a crucial part of poverty alleviation.
* Water Course means any river, stream, channel, canal or other visible topographic feature, whether natural or constructed, in which water flows regularly or intermittently including any associated storage and/or storm-water attenuation dams, natural veils or wetland areas.
* Climate Variability refers to short term changes in climate variables such as temperature, solar radiation, evapotranspiration, and rainfall and has a serious impact on population health, it threatens food security, water resources, biodiversity conservation, and affects the socio-economic aspect of a community (Xu *et al.* 2017).

**4.0** **OVERVIEW DEFINITIONS OF FRESH WATER, WATER SECURITY, ENVIRONMENTAL SUSTAINABILTY AND INTEGRATED WATER RESOURCE MANAGEMENT (IWRM)**

IWRM represents a process with no fixed beginning or end, but rather as a long-term approach that seeks to shift unsustainable forms towards sustainable water management systems (GWP 2009). Water security and environmental management are good examples of integrated water resources management. The following definitions have an impact on integrated water resources management.

* Fresh Water is a finite and vulnerable resource, essential to sustain life, development and the environment.
* The GWP (2012) defines Water Security as a world where every person has enough safe, affordable water to lead a clean, healthy and productive life.
* Environmental Sustainability is about protecting and managing the water resources and ecosystems in a way that does not undermine the life-support system thereby compromising use by future generations of the same resource (Cap-Net 2008:9).
* Integrated Water Resources Management (IWRM) is a systems approach to water management, recognising the need to manage the entire water cycle and its interconnectivity.
* The GWP (2009) defines IWRM as a process that promotes the co-ordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.
* Pollard (2002) defines IWRM as simultaneously a philosophy, a process and an implementation strategy to achieve equitable access to and sustainable use of water resources by all stakeholders at catchment, regional and international levels, while maintaining the characteristics and integrity of water resources at the catchment scale within agreed limits.

**5.0 WATER RESOURCE MANAGEMENT AT THE GLOBAL SCALE**

Freshwater resources around the world have been over used, polluted, fought over and squandered, with little regard for the human and ecological consequences” (Glieck, 1998: ix). Unsustainable use of water is the order of the day throughout the globe. Conflicts over scarce water are mounting. Dramatic drops in the water table as well as the seasonal drying up of large rivers before reaching the sea are signs of the unsustainable use creating havoc for millions of people. Glieck (1998: 574) defines the sustainable use of water as the use of water that supports the ability of human society to endure and flourish into the indefinite future without undermining the integrity of the hydrological cycle or the ecological system that depends on it.

However, the layers of complexity that underpin that definition can be found in the diversity of human society, which is divided by political, social, cultural and economic boundaries. According to the United Nations Water Conference (1977:127) “all peoples, whatever their stage of development and their social and economic conditions, have the right to have access to drinking water in quantities and of a quality equal to their basic needs” (UN,1977 cited in Gordon et al., 1994: 127). It is also recognized that human excreta and sewage are important causes of the deterioration of water quality in developing countries, and the introduction of available technologies, including appropriate technologies, and the construction of sewage treatment facilities could bring significant improvement (McGranahan and Satterthwaite, 2004). During the past few years there has been an increasing realisation of the importance of water management in the continuing well-being and development of the developing countries, especially those located in the arid and semi-arid regions (UN, 2001).

Furthermore planners and decision-makers have started to realize the critical importance of efficient water management for the sustainable development of their countries. While water covers some 70% of the planet’s surface, less than 3% of this is freshwater (Samson and Charrier, 1997). Much of the world’s freshwater resources are frozen in the polar ice caps or deep underground (Biswas, 1991). Surprisingly, in most parts of the world availability and quality of freshwater is taken for granted. “Without being overly alarmist, figures and trends appear to indicate otherwise; serious questions relating to global freshwater quantity and quality are rapidly emerging-apparently unknown to the general public and authorities in general (Falkenmark, 1994:16). New sources of water are becoming scarce, more expensive to develop, and requiring more expertise and technological knowhow for planning, design and implementation (Anderson, 1998). Accordingly, water can no longer be considered a cheap resource, which can be used, abused, or squandered without much consequence for mankind’s future.



Currently, water is considered a critical resource for the survival of the arid and semi-arid countries. Political tension between neighbouring countries over the use of international rivers may escalate to the point of war during the early part of the Twenty-First Century (Biswas, 1991). Especially in areas where water supplies are already scarce and conflicts of sharing the international water supplies already exist (example, The Jordan Valley, the Nile, the Tigris and the Euphrates), there is also a danger of conflict over water which may lead to future wars to control the water in the region (Global Water Partnership, 2000; Giordano and Wolf, 2003; Clausen, 2004; Cai, Ringler and Rosegrant, 2006).The world’s population is increasing steadily.

Consequently, water requirements for domestic, agriculture and industrial purpose and for hydroelectric generation are also increasing. This of course is not a new trend. For example, current estimates indicate that the total global water consumption during the first 80 years of the 20th Century (1900-2000) saw a 200 percent increase in the world’s average per capita water use, which accounted for a remarkable 566% increase in withdrawals from the world’s freshwater resources (Jackson, et al., 2001). This massive increase in water extraction coincides with another debt on the water ledger: a significant portion of these resources have now become unusable due to industrial and agricultural pollution (Baris and Karadag, 2007). Since all life depends on water, present trends of waste water and pollution threaten the earth’s basic life support systems (Pottinger and Horta, 1999; Jackson, et al., 2001). The general trend is likely to continue well into the coming decades because of the steady increase in the world’s population. Present estimates indicate that the current world population is likely to reach 10 billion by the Year 2050.

Of these the less developed countries will contribute nearly 80 percent or 8 billion (Jackson, et al., 2001). Biswas (1991) correctly declares that while there is no direct relationship between population and water requirements; it is clear that with a substantial increase in world population, the total water requirement will increase as well. Early in the Twenty-First Century, more than half of the world’s population will be living in urban areas. By the Year 2025, that proportion will have risen to 60%, comprising some 5 billion people. Rapid urban population growth and industrialization are putting severe strains on the water resources and environmental protection capabilities of many cities” (Gordon et al., 1994: 97). According to The United Nations 80 percent of all sickness and death among children in developing countries is related to unsafe drinking water that is due to water pollution problems.

 “Chief among point sources of water pollution is municipal sewer systems, industry, and power plants” (Marsh, 2005: 283). Scarcity of freshwater resources and the escalating costs of developing new sources have a considerable impact on all forms of national development and economic growth (industrial, agricultural and human settlement). Better management of urban water resources, including the elimination of unsustainable consumption patterns, can make a substantial contribution to the alleviation of poverty and the improvement of health and quality of life of the urban and rural poor (Falkenmark, 1995). As human activities increase, more and more waste products are contaminating available sources of water. Among the major contaminants are untreated sewage, agricultural chemicals, and industrial effluents. These contaminants are seriously affecting the quality of water.

Since comprehensive water quality monitoring programmes in nearly all developing countries are either in their infancy or even non-existent, a clear picture of the status of water pollution and the extent to which water quality has been impaired for different potential uses is simply not available at present (Biswas, 1992: 4). Freshwater is a finite and vulnerable resource essential to sustain life, development and the environment. Its sustainable management demands a holistic approach, linking social and economic development with the protection of natural ecosystems, close links should be maintained between land and water uses across the whole of a river basin or a groundwater aquifer (Marsh, 2005).

5.1 Water Resources in Africa

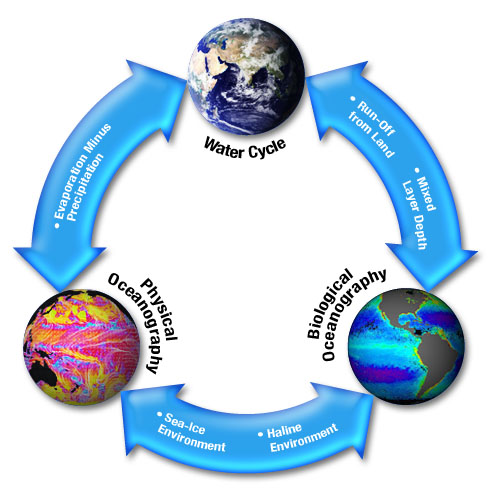
While Africa is among the most endowed continents in terms of freshwater resources, its people have the lowest access to clean water for drinking and sanitation; the lowest per capita food production; and the lowest access to the water-dependent services such as electricity (hydropower). More than 40% of Africa’s population has inadequate access to water as opposed to 15% in Latin America and 20% in Asia (World Bank Council and Global Water Partnership, 2001). Africa has over 50 significant water basins spanning nearly all countries. For 14 of these, practically their entire national territories fall within shared river basins. There are also large inland water bodies such as lakes Victoria, Chad and Kariba. In Sub-Saharan Africa (SSA), international river basins constitute the principal source of water resources. About one-third of the world’s international river basins are found in SSA. Thirty five countries in the region share the 17 major river basins. Furthermore, international rivers also include 11 river basins between 30000 and 100000 sq. km. (Yilma, et al., 1997). These international rivers have implications for long-term management of water resources.

The distribution of water in major parts of Africa is characterized by complex patterns and striking paradoxes which exhibit an abundance of rainfall over the equatorial zone contrasted by extensive and extreme aridity of the Sahara desert in the north and the Kalahari desert in the South. About 50 percent of the total surface water resources of the continent are in one single river basin (i.e.) the Congo basin and 75 percent of total water resources are concentrated in eight major river basins (i.e.) the Congo, Niger, Ogoague (Gabon), Zambezi, Nile, Sanga, Chari-Logone and Volta (Yilma, et al., 1997). In Africa, only a minimal amount can currently be used as viable fresh water. Besides, several rivers and lakes have undergone a marked reduction in flow rates and surface area (UNESCO, 2005). Groundwater wells are also threatened by desertification.

According to Yilma et al. (1997) in the past 20 years, available freshwater resources in Africa have greatly declined due to severe and prolonged drought. Water pollution resulting from industrial effluent, urban run-off, sewerage and agro-chemicals are on the increase and continue to deteriorate freshwater quality and affect its quantity. “The sharp decline in availability of freshwater supply due to hydrologic, climatic and environmental change is visible even in the Congo-Zaire basin” (Yilma, et al., 1997:35). The meteorological and hydrological services in the African region are not efficient due to government budgets. As a consequence, there is insufficient data to support water development projects and the development of national plans for water resources management. Rivers are the main sources of freshwater in the region. However, several of the rivers and lakes in Africa are undergoing a marked reduction in flow rates with Lake Chad facing the most serious problems (World Bank, 2004b).

With regard to water use and management, the major water-consumptive uses in Africa are for agriculture activities and human settlements (Beekman and Pieterson, 2007). However, there has been an increasing use of water in the industrial sectors which is affecting water quality. It is predicted that by the Year 2025 several African countries will experience water scarcity. As it stands now, 11 countries are experiencing water stress and are countries undergo water scarcity conditions (World Bank, 2004b). Rapid population growth, expansion of irrigation areas and industrialization has put pressure on the available water resources. For the developing countries of Africa, a major portion of the needed increase in safe drinking water and sanitation facilities is expected to come from existing fresh water rivers through sustainable use of water resource management. In Sub-Sahara Africa, urbanisation heightens the relationship between available water quantity and water quality. Cities are faced with mounting costs of water shortages, water treatment, well deepening and development of new sources (ECA, 1995).

Most fresh water resources in Sub-Sahara-Africa are located in trans-boundary watercourse systems and shared river basins. “Management and protection of these shared basins is required through a strong commitment to regional collaboration, for example, within sub regions the Southern African Development Community (SADC). Similarly, “the environmental initiatives of the New Partnership for Africa’s Development (NEPAD) framework is a key initiative for improving water resource management for social, economic, and environmental security in Africa” (DEAT, 2007:166). A high proportion of big industries are located along river banks and coastal zones of West Africa. Such an arrangement leads to pollution from municipal and industrial discharges, which, combined with overexploitation of available water resources threatens the river catchment environment as well as the supply of freshwater resources (World Bank, 2004b). More than 50% of the lake basin of East Africa’s population do not have access to piped water (WHO and UNICEF, 2004).



They depend on natural sources like springs, streams and rivers. Such sources should be protected from any form of degradation. Unfortunately, urban centres along the shores of the lake and river throw their industrial and domestic waste into the river and other water bodies. Government departments that are supposed to control pollution or degradation of water resources are still not decentralized in their operations. They lack finance and human resources to effectively carry out their mandates. Water Resource Management (IWRM) seeks to address in an integrated, coordinated and balanced way, the needs of upstream and downstream users, current and future beneficiaries, different water uses (such as environmental, agricultural, pastoral and industrial uses), supply and demand factors, social and economic benefits, and other aspects of water management (Mc Granahan and Satterthwaite, 2004). WRM is based on the Dublin principles, of which subsidy and participation of water users in management are important elements. The principles agreed at the International conference on Water and Environment, held in Dublin in 1992, are as follow:

* Freshwater is a finite and vulnerable resource, essential to sustain life, development, and the environment.
* Water development and management should be based on a participatory approach, involving users, planners and policy makers at all levels.
* Women play a central part in the provision, management and safeguarding of water.
* Water has an economic value in all its competing uses and should be recognized as an economic good.

The use of the hydrological basin and catchment units for planning purposes rather than administrative units, and improved coordination between different sectors and government department are significant. Pollution from untreated municipal and industrial wastes is causing health-threatening conditions in surface water resources. At the same time, over-abstraction and contamination are depleting groundwater resources. At present in many developing countries, it is estimated that about 85% of available water resources are used for agriculture, 10% for industry, and 5% for domestic supplies; this distribution of water resources will need to be re-evaluated, especially where water resources are scarce (Gordon et al., 1994:114).

Providing potable water supply to communities’ costs money. Some communities can afford to pay, while others cannot. All urban dwellers pay for the potable water they consume (United Nations-World Water Assessment Programme (UN-WWAP), 2006). The principle that advocates the “user must pay” for potable water has to consider the willingness and affordability of the communities that get the water services and at the same time the cost of the water schemes. Therefore, charging consumers for water should be done carefully because if prices are set too low, revenues may not be sufficient to cover the full costs of supplying water. If, on the other hand, they are set too high, households may not be able to afford consuming the water, and again revenues will not be sufficient to cover the full cost. In summary, the quality of freshwater is declining in Africa and in many parts of the world due to human induced land degradation, salinization, and pollution by toxic compounds and domestic, industrial and agricultural contaminants, including farmyard manure (Yilma, et al., 1997).

Therefore, water resource management should cover the utilization and development of water resources in an efficient, environmentally sound, equitable and reasonable manner in order to satisfy society’s demand for water. The following section presents the main aim and objectives of this research thereby illustrating the motivation of the study of water resource management in the urban areas of is essential.

**6.0 OVERVIEW CONCEPT OF INTEGRATED WATER RESOURCES MANAGEMENT (IWRM)**

Integrated water resources management (IWRM) is a systems approach to water management, recognising the need to manage the entire water cycle and its interconnectivity. During the preparatory conferences for the UN Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992, the concepts underlying Integrated Water Resources Management were for the first time widely debated (Savenije and Van der Zaag, 2008). Important steps in the process towards more coordination have been the formation of the Global Water Partnership (GWP) and the World Water Council (WWC), which both have the aim to coordinate the implementation of IWRM principles and practices worldwide. The WWC concentrates on raising awareness at political levels, whereas GWP aims at the implementation of IWRM concepts at the operational level. The Dublin Principles state that IWRM implies (ICWE, 1992) an inter-sectoral approach, representation of all stakeholders, consideration of all physical aspects of the water resources, considerations of sustainability and the environment.

Accordingly, approaches to IWRM do not regard the ecosystem as a “user” of water in competition with other users, but as the base from which the resource is derived and upon which development is planned (Jewitt, 2002). Water is one of the most important natural resources because it is viewed as key to prosperity and wealth (Arbue’s *et al*., 2003). According to the Department of Water Affairs (DWAF) Strategic Overview of the Water Sector in South Africa (2013), South Africa is ranked as the 30th driest country in the world. The country is semi-arid with rainfall varying from less than 100 mm per annum in the west to over 1500 mm per annum in the east. Average rainfall is 450 mm per annum which is well below the world average of 860 mm per annum. Climate change predictions are for a drier western half of the country and for far more variability with more extreme events to the east (Department of Water Affairs National Water Resource Strategy 2nd, 2013). A large percentage of the population in South Africa has inadequate domestic water supplies and experience critical water shortages.

The inadequacy of the service is in terms of the volume of water delivered, inappropriateness of water distribution facilities, excessive walking distance, and long queues at water points, poor maintenance and inadequate bulk water development. Effective and efficient water management in the South African context is crucial for future development, poverty alleviation, job creation and addressing inequalities in society. Water scarcity could be a limiting factor to growth and development. In South Africa, the freshwater resources are being over-exploited, thus water could be a major constraint on the implementation of the National Development Plan 2030, which emphasises the need for accelerated economic growth, transformation and investment (Hedden & Cilliers, 2014: 1a). According to Hedden and Cilliers (2014: 2b), water crises are emerging worldwide at various different levels due to a scarcity of water and high demand by people, farmers and industries.

This demand requires alternative approaches to water provision and demand management solutions. These crises occur nationally and across different regions worldwide. The nature of crisis differs from country to country, depending on the severity of the water scarcity and constrained supply. According to the World Economic Forum (WEF) Global Risks Report released in 2017, water scarcity ranks as the third most concerning top five (5) global risks in terms of impact (World Economic Forum Global Risk, 2017). As noted by the National Planning Commission (NPC) (2012), South Africa is a water scarce country. Food, fuel and water are interconnected, particularly in the context of climate change. Their impact on one another, together with water scarcity, could derail the elimination of poverty and the envisaged reduction of inequalities by 2030. Furthermore, according to the National Water Resource Strategy 2nd (2013), South Africa is a water-stressed country and it is facing a number of water challenges and concerns, including security of supply, environmental degradation and resource pollution.

The nature of South Africa’s water scarcity requires urgent intervention as the country has limited water resources. Consequently, the limited water resources require careful management to enable the provision of basic water services to every citizen. It is estimated that the sustainability of the country's fresh water resources has reached a critical point and its associated management is now at a crossroads, unless urgent steps are taken to preserve existing water resources and introduce water conservation and water demand management initiatives (National Water Resource Strategy 2nd, 2013). In this regard, security of water supply is crucial for investments to take place as well as protection of existing industrial investments and possible business expansion. It is common knowledge that water supply is not only limited to industries, but is required for domestic use as well.

This is particularly important in South Africa where historically, under the apartheid system of government, the majority of black South Africans did not have access to water. As a result, the water services sector is still characterised by skewed water distribution patterns emanating from the apartheid era, albeit the picture is changing gradually (Department of Water Affairs and Forestry Water Conservation and Water Demand Management Strategy for the Water Services Sector, 2004). According to the Department of Water Affairs (2004), the water services providers are expected to initiate and implement interventions and measures aimed at efficiency of water use. In this regard, the Water Services Act (No 108 of 1997) and the National Water Act (No. 36 of 1998)4 provide the basis for the legislative framework within which water supply, sanitation services, water resource management and water use need to take place.

According to the Department of Water Affairs (DWAF) Strategic Overview of the Water Sector in South Africa (2013), South Africa is ranked as the 30th driest country in the world. Climate change predictions are for a drier western half of the country and for far more variability with more extreme events to the east (Department of Water Affairs National Water Resource Strategy 2nd, 2013). In this regard, a Water Demand Management Strategy (WDMS) should involve a wide range of demand management measures for it to be effective. These measures include *inter alia,* cost reflective pricing for the project; customer metering to determine consumption levels;reticulation leakage detection, repair programmes and pressure reduction to reduce water losses; community education campaigns to build social capital and awareness; retrofitting of water efficient equipment to minimise equipment deficiencies; reduction of water use through rationalisation to restrict over consumption and introduce restrictions; and regulation of efficiency of water use, especially in new buildings by introducing solutions such as rainwater harvesting and grey-water reuse.

**7.0 CHALLENGES OF THE GLOBAL WATER SITUATION**

Fundamental change and rapid development of human society during the last two centuries has put immense pressure and competition, be it in quantitative or qualitative regard, on the natural freshwater resources in numerous regions of the world. Future water security is one of the major challenges addressed by the Millennium Development Goals, not only in terms of safe drinking water supply and sanitation, but also in its inherent relation to food and health security, economic development and environmental conservation. Typically, even though not exclusively, countries affected by the most obvious and dramatic negative effects are among the world’s poorest.

Their water stress usually caused by limited natural freshwater availability or by the lack of adequate infrastructure to utilize available resources - or most often even both. The United Nations define “water stress” to occur where the volume of freshwater available for supply to agricultural, industrial, environmental and domestic purposes lies below 1700 m³ per year and person, and “water scarcity” occurs when annual water supplies drop below 1000 m³ per person (Falkenmark, 1989). Many regions in the World experience even much more critical scarcity, providing less than 500 m³ per person and year, which is then considered as “absolute water scarcity”. Global studies estimate that today approximately one billion people are already experiencing water stress or water scarcity due to deficient resources (UNDP, 2006). Additionally, 500 million more live in regions threatened by water stress in the near future, due to their natural surface water resources being exploited beyond sustainable limits (CAWMA, 2007).

Physical resource scarcity appears to be most acute in countries of the Middle East and Northern Africa, but also in parts of Northern China, India, Australia and the United States. And besides physical scarcity, another 1.6 billion people face shortage of clean freshwater even in countries with abundant resources, due to the lack of appropriate supply and treatment infrastructures and insufficient capacities to develop such (CAWMA, 2007). Nearly a quarter of Sub-Saharan Africa’s population is estimated to live under such conditions of economic water scarcity (UNDP, 2006). Beyond given natural hydrologic conditions, lacking infrastructure and the high population pressure, another major reason for the degradation of freshwater resources often lies in mismanagement. Notwithstanding the rising global awareness for sustainability, the rapid development of urbanisation, industrialisation and economic growth has ever outpaced society’s adaptive reactions to the complex demands of future water security.

Thus, inefficiently targeted investment, insufficient human capacity, ineffective institutions and poor governance have resulted in continuous misuse and overexploitation of the resources over the past decades. On the other hand extensive policy and market failures have received only limited corrections from concerned institutions (Biswas et al., 2009). Unfortunately the countries that are facing the most urgent need for institutional reform and large investments are again the world’s poorest in terms of per capita income. Grey and Sadoff (2007) see these countries in a low-level equilibrium trap, having never been able to make the investments needed to achieve water security, because such investments can only be resourced from the growth that water insecurity itself constrains. From a slightly more pessimistic perspective, this situation does not only pose an equilibrium trap but an actual downward spiral, since the driving factors that are denying improvements are also likely to induce negative feedback on the actual water situation, as it is the case for example with the human influence on the process of desertification or the salinization of groundwater due to continuous over pumping. Once more, the consequences are persistent in limited development opportunities, environmental degradation, declining groundwater tables and increasing conflict over water allocations. The highest social and political complexity in water management matters arises where competition over water resources becomes trans-boundary. As today almost half of the world’s population lives in internationally shared river basins, bi- or multilateral collaboration over water resources truly is an issue of global significance. History has revealed that interaction on trans-boundary freshwater resources bears as much, or actually even more, incentives for cooperation and political stability, as it holds potential for conflict if neglected (Hamner & Wolf, 1998).

However, many challenges remain to be addressed in order to extend and stabilize sustainable and just water sharing between riparian actors, particularly with regard to an expected future of worldwide intensifying freshwater competition. Despite the international efforts, the envisioned MDG for water security appear unlikely to be met in 2015. On the contrary, several trends are likely to aggravate the situation over the coming years in fast pace. Many of the already water-stressed countries are facing continuous high population growth rates. In addition, the per capita water use has been growing even faster than the population during the last century, while water use patterns changed. And simultaneously, pollution and decline of natural freshwater bodies show upward trends. These considerations lead to the prognosis that the pressure on water resources will constantly increase with rising demands from agricultural, municipal, industrial and environmental usages. By 2025 it is estimated that 1.8 billion people will be living in regions with severe water scarcity, and two-thirds of the world population could be under conditions of water stress.

Climate change scenarios expect changes in rainfall patterns and amplification of extreme events and additionally undermine the urgent need for a more coordinated and integrated approach to the present water resources. In the effort to cope with these challenges, the Integrated Water Resources Management approach has been the most prominent strategic water management concept in the international discourse during the last decade. But its implementation appears an intricate challenge in itself. In this respect, a uniform tenor across disciplines is heard, which consistently emphasises the necessity to enhance the communication and understanding between scientific domains, as well as between scientists, policy makers and the public society, in order to ensure a best-possible response to the upcoming water resources challenges. The importance as well as the challenges of achieving future water security has already rooted in the global awareness nowadays.



**8.0 WATER STRESS CONCEPT AND ITS DRIVING FACTORS**

Water stress occurs when continuous abstraction is greater than the amount of renewable water, affecting the availability of water resources. This causes water quantity to continuously reduce until it becomes difficult to meet human and ecological water needs (Shiao & Stockholm 2013; Barbara *et al.* 2014). Water stress is married to climate variability that leads to aridity and drought, such that it is important to understand both conditions and their relation to water stress.

8.1 Climate Variability

Climate variability refers to short term changes in climate variables such as temperature, solar radiation, evapotranspiration, and rainfall. It has a serious impact on population health, it threatens food security, water resources, biodiversity conservation, and affects the socio-economic aspect of a community (Xu *et al.* 2017). Change in climate is more gradual over a longer period, however, on a multi-seasonal time scale, climate experience short fluctuations (IPCC 2007). Yet, even though this shows differences in climate events, yet, it may not affect the long-term average. These short-term changes in climate play a very important role that cannot be ignored. Different researchers have established that mortality rates, disease outbreaks, fish population and fishery activities, and respiratory diseases of infants are strongly linked to climate variability (Gubler *et al.* 2001).

The variability of climate is responsible for the increase in sea surface temperature and severity of extreme weather events such as flooding and droughts (Luber & Prudent 2009; Guimarães *et al.* 2017). Amongst other aspects of climate variability, drought is one of the major driving factors behind land degradation, streamflow reduction, food security and diseases. Drought is regarded as a period of lower rainfall relative to a long-term average (Wilhite & Glantz 1985; Maliva & Missimer 2012). Despite all the understanding around drought, it is difficult to precisely define at what point drought starts. This is due to the fact that drought occurs over an extensive period of time (Wilhite & Glantz 1985). When drought occurs continuously within a region, it affects water resources due to less rainwater supply (Maliva & Missimer 2012; Klemas & Pieterse 2015). Drought occurs in both high and low rainfall regions. Therefore, depending on the amount of moisture, a region’s climate condition could be determined as either humid or arid. A region is arid if it experiences lower rainfall more often or has a low amount of moisture.

Even though humid regions can experience drought, arid regions are more vulnerable to drought, because of their dry conditions (Wilhite & Glantz 1985). A population living in dry conditions that frequently experiences drought spells will likely over-exploit water resources in the attempt to respond to drought impacts. This continuous exploitation of water resources will then result in water stress (Barbara *et al.* 2014). Different researchers have used Geographic Information Systems (GIS) and Remote Sensing (RS) in water management studies. It is recommended by various researchers to use GIS and RS as analytical tools to monitor the impact of climate variability on water resources in order to implement adaptive and responsive measures (Govender *et al.* 2009; Ghosh *et al.* 2013; Van Loon & Van Lanen 2013).

8.2 Water Resources

Water resources are dwindling and a water crisis is imminent in many regions of the world. This has profound implications for food security, people's health and the functioning of aquatic ecosystems. The availability of water is influenced by factors such as climate change and pollution, which affect both the quantity and quality of surface water and groundwater. Climate change causes increased global temperatures, which may increase precipitation in certain regions. However, the accompanying increase in potential evapotranspiration could lead to reduced runoff and a decline in renewable water supplies (Jury and Vaux, 2007: 42). Polluted rivers and streams affect agricultural production and negatively affect people's health. Child mortality from exposure to polluted water, for example, has become a big threat with five times more children dying of diarrhoea than of HIV/AIDS worldwide1 (World Economic Forum, 2011: 132). Pollution of water bodies also adversely affects social welfare, as it reduces the value of water as a recreational and environmental good.

Pressures from the supply- and demand-side have resulted in *physical water scarcity*, and almost all water resources have been allocated. *Economic water scarcity*, in contrast, occurs as a result of the "lack of capital investment or appropriate institutions to support the use of that capital. This causes many poor households to remain without access to water and basic sanitation, even in areas where water is available. The problem of pollution is exacerbated by economic water scarcity, as urbanisation and expanding urban informal settlements contribute to increased urban runoff. Institutional inefficiencies have contributed to the lack of access to safe water for consumption and food production, the degradation of water resources and the destruction of wetlands (Cosgrove and Rijsberman, 2000). Attempts to deal with water scarcity have focused primarily on addressing supply shortages, including options such as building or enlarging dams, drilling wells and building water transfer facilities (e.g. pump stations and pipelines) between various water catchment areas. Although new technologies allow for the development of new water sources and these measures are relatively costly. Desalination in particular has adverse side-effects, since it contributes to the emission of greenhouse gases. Less attention has been given to institutional mechanisms that influence water management, such as pricing water at full economic cost or taking account of the value of ecosystem functioning. More recently, water managers have come to realise that water as an economic, social and environmental good requires careful management and as such a more integrated approach. Water resource management encompasses a number of issues and relies on a variety of role players to extract, produce, allocate and distribute water to various sectors and to ensure its preservation as an environmental resource.

Therefore, if water resources are to be managed to ensure sustainable use of resources, the behaviour and perceptions of these water users must be incorporated into the decision-making process. Water demand management policies are therefore essential components of an integrated approach towards water resource management. In South Africa water resource management has also received much attention in recent years, given that the country is approaching a situation of physical water scarcity. South Africa is a dry country with an average annual rainfall of 450 mm per year, about half of the world average (Department of Environmental Affairs, 2006: 145). Rainfall is seasonal and unevenly distributed across the country. In combination with high temperatures and high rates of evaporation, this implies low rates of groundwater recharge. On the other hand, population growth together with rapid urbanisation and industrialisation has led to an increasing demand for water.

An economic water scarcity, as many poor households in South Africa do not yet have access to safe drinking water or basic sanitation facilities. More recently, water managers have come to realise that water as an economic, social and environmental good requires careful management and as such a more integrated approach. Water resource management encompasses a number of issues and relies on a variety of role players to extract, produce, allocate and distribute water to various sectors and to ensure its preservation as an environmental resource. The water resources are to be managed to ensure sustainable use of resources, the behaviour and perceptions of these water users must be incorporated into the decision-making process. Water demand management policies are therefore essential components of an integrated approach towards water resource management. Water demand management is defined as the use of strategies by water institutions to influence water demand in order to meet diverse objectives and focuses on reducing water consumption to reconcile water supply with demand.

Conventional theory argues that household demand for water depends on the price of water, on income and on a range of other factors such as household size and climatic conditions. Water managers can therefore, in principle, achieve a reduction in water consumption by using water pricing as demand management strategy. Water pricing has received much attention in recent years and there are many empirical studies, particularly in developed countries, which estimate the impact of water price changes on the consumption of water. One of the arguments in favour of using water pricing as demand management tool is that relatively high prices will discourage large-volume users. However, the price elasticity of demand may differ between different categories of households, for example between poor and rich households. Varying consumption patterns between households depend on different lifestyles and habits, which vary with income (Ayadi, Krishnakumar and Matoussi, 2002).

If demand for water is price inelastic, substantial increases in price would be required to bring about large reductions in water consumption. Water pricing as demand management tool has therefore not been a popular option, given the belief that its effect as conservation tool is minimal. Reducing water consumption and improving affordability to the poor through the tariff structure are not the only considerations in an integrated water management approach. Water resources serve urban communities in various other ways. Lakes, rivers and streams are used for recreational purposes and there is an environmental value to conserve water bodies, since they contribute to the effective functioning of ecosystems. On the other hand, polluted rivers, streams and lakes pose health risks to individuals and decrease the potential value of these water bodies as recreational and environmental sites, particularly in urban communities.

The value that people attach to water bodies and the impact of pollution on their welfare must therefore also be considered in an integrated management approach. In South Africa water resource management has also received much attention in recent years, given that the country is approaching a situation of physical water scarcity. South Africa is a dry country with an average annual rainfall of 450 mm per year, about half of the world average (Department of Environmental Affairs, 2006: 145). Rainfall is seasonal and unevenly distributed across the country. In combination with high temperatures and high rates of evaporation, this implies low rates of groundwater recharge (Ashton and Haasbroek, 2002). On the other hand, population growth together with rapid urbanisation and industrialisation has led to an increasing demand for water. A related problem is economic water scarcity, as many poor households in South Africa do not yet have access to safe drinking water or basic sanitation facilities.



Given the current state of water resources in South Africa, sustainable water management is therefore crucial. Water policy and legislation have been developed and enacted which make water demand management an essential part of water management policy. Water pricing is a key element of South Africa's water demand management strategy. Setting the appropriate water pricing structure, though, is a complex task, since it has to comply with multiple objectives and legislation set at national level. Municipalities in South Africa generally make use of the IBT structure. However, even though water pricing is considered an important tool to reduce consumption, economic principles seldom form an integral part of the tariff-setting process. Hosking (2011: 49) investigated the tariff setting process of fourteen municipalities in South Africa and found that none of them used marginal cost pricing principles as a guide for setting tariffs.

Water pricing has therefore not received adequate recognition for its economic role in achieving water conservation. Furthermore, information on how households respond to prices (i.e. the price elasticity of demand) does not form part of the tariff adjustment process, as water managers usually do not possess this information. Surface water bodies (composed of dams and rivers), ground water occurrences, and wetlands constitute the water capacity of RSA. However, despite the presence of all these water resources, water availability is not proportionally distributed across the country. This disproportion varies greatly even within the different catchments (DEA 2014). National Water Resources Strategy 2nd focuses on equitable and sustainable access and use of water by all South Africans while sustaining the water resource. Equity and redistribution can be achieved through the authorisation process and other mechanisms and programmes such as water allocation reform, financial support to emerging farmers and support to urban and rural local economic development initiatives (Department of Water and Sanitation, National Water Resource Strategy 2nd, 2013).

Water resources management involves development, control, protection, regulation, and beneficial use of surface (rivers and reservoirs) and groundwater resources. Computer models play an important role in almost all aspects of water resources management including in the overall water resources management decision-making process (Wurbs, 1994). Computer-based Decision Support Systems (DSS) are useful tools for this because they allow the user to forecast and evaluate the impacts of different possible future trends and management strategies before implementing them (Mugatsia, 2010). In the following sections, several models commonly used for analysing the water balance of river basins and used as decision support tools in water resources planning and management are briefly discussed.

Surface water in South Africa are the main sources of water supply, which constitutes about 77% of water resources. They are essentially comprised of rivers and dams across the country. These water bodies are mainly affected by low occurrences of rainfall that reduces the total runoff (Binns *et al.* 2001; DEA 2014; DWA 2011). On average, the total runoff in RSA is about 49 000 million m3/annum (DEA 2014). Despite this, the majority of this water comes from catchment areas situated in mountains and is usually affected by the spatial and climate variability (Binns *et al.* 2001; DEA 2014). In prior studies, water stress was monitored in specific fields including soil moisture, vegetation, surface, groundwater, and rainfall deficiency (Hughes & Saunders 2002; Ghosh *et al.* 2013; Vaghefi *et al.* 2013; Chari 2016). To prove the occurrence of water stress, a study should consider monitoring influencing factors of water resource reduction.

The majority of the research on water stress was done using the argument that factors such as drought, abstraction or even aridity are the main drivers of water stress. They concluded that climate variations, particularly drought are the main factor causing water stress heedless of the field of study (Mukheibir & Sparks 2003; Collins *et al.* 2009; Maliva & Missimer 2012; Barbara *et al.* 2014). It is difficult to single out an aspect of climate change and definitively say, it is the true definition of water stress (Shiao & Stockholm 2013). Both ground water resources and surface water resources are useful for all human needs. This does not exclude the fact that rainfall is also useful for human needs. Therefore, a reduction in rainfall could also be referred to as water stress (IPCC 2007; Adams & Peck 2008; Raneesh 2014). Water stress is a two-word concept, water and stress. To confidently say there is water stress, there has to be water and a factor causing it to reduce in quantity. The process of causing water to reduce is referred to as water demand.

In this light, some researchers have identified evapotranspiration as a stressing factor to both rain water and surface water resources (IPCC 2007). In this case, it could be said that water stress has occurred. In other cases, abstraction and climate variability have played a contributing role to the depletion of water resources (Adams & Peck 2008; Van Loon & Van Lanen, 2013). In this case also, it could be said that there is water stress. Therefore, water stress is not limited to the reduction of surface water resources such that it becomes difficult to meet human needs. Rather, it extends to any stressing factor that prevents the entire ecosystem to be water-satisfied. In the case of this study, water stressed is viewed from the perspective of surface water reducing, due to climate and population water demand. This process is more pronounced in arid regions where drought is more frequent (Maliva & Missimer 2012).



8.3 Climate Change and Water Resources

Climate change presents a significant concern for the availability, access and quality of water resources, particularly in Africa (Ziervogel et al., 2010). South Africa on the continent is generally a semi-arid to arid country which experiences a highly variable climate and limited freshwater resources (Adewumi, 2010). With such limitation water resources are vulnerable to the occurrence of extreme weather conditions, often caused by climate variability and change. Droughts are an example of such extreme events weather conditions, which the potential result in to the significant adverse socio-economic impacts. South Africa is vulnerable to the occurrence of drought as the results of its location, topography and generally low rainfall (national annual rainfall average of approximately 500mm) (LeComte, 2016).

Local groundwater governance is being neglected by local administrations in some region. Lack of appropriate implementation plans for local groundwater governance to monitor and maintain adequate water resources at a household level is evident in most cases. Furthermore, in most of the villages, users are unaware of local groundwater good governance which manages the rural water demand and use supplied to them from water source/point. Under drought conditions, the abstraction (demand) of water tends to be overlooked, especial to rural unmetered area. Hence, it is essential to assess rural domestic water demand and use in order to design appropriate implementation plan for local groundwater good governance to those rural communities in drought-prone with unmetered. Climate change is another contributing factor to increasing water scarcity. Callan (2010: 287) defines climate change as "a major alteration in a climate measure such as temperature, wind, and precipitation that is prolonged, i.e. lasts decades or longer."

One of the contributing factors to climate change is the excessive production of greenhouse gases caused by human activities, such as the burning of fossil fuels (Callan, 2010). The higher temperatures can affect human health and lead to changing weather conditions, such as rising sea levels (due to melting glaciers) and increased storm intensity, both of which will adversely affect coastal towns (Tietenberg and Lewis, 2009). The impact of climate change on water resources depends on the effect of changing weather patterns on the supply of water, as well as on changes in the demand for water as a result thereof. Water availability is affected when there are impacts on the hydrological cycle, and changing temperatures and variability in precipitation patterns affect the water supply (IPCC, 2007). Increased temperatures result in more water evaporation; however, increased precipitation may offset these losses.

The net effect on water availability also depends on how climate change affects the demand for water. Climate change affects the demand for irrigation water. Warmer and drier weather conditions can make it more profitable for farmers to apply irrigation instead of dry land farming. In regions with available and affordable water, more farmland will be irrigated and increase the water amount applied per acre (Frederick, 1997: 6). However, the impact on global water requirements for irrigation depends on how regions are affected by climate change. According to the IPCC (2001), irrigation-use water models predict lower requirements in regions such as the Middle East and Africa (due to increased precipitation), whereas India will require more water for irrigation. It should be kept in mind, though, that other factors such as pricing and population growth also play a role in determining demand (IPCC, 2001).

The impact of climate change on domestic water use depends on what the water is used for (IPCC, 2001). Outdoor water use can be affected if increases in temperature increase the demand for water. The quality of water can also be affected by increased temperatures, which are a consequence of climate change. Higher water temperatures and variability in precipitation affects water quality, since increased temperatures reduce the dissolved oxygen levels in the water and this affects aquatic life (IPCC, 2007). Moreover, increased rainfall can increase sedimentation and pollution due to higher levels of runoff and flooding. This affects water quality, since excessive amounts of pollutants enter water resources as a result of higher volumes of water. Water resources are further polluted by sources such as farming, urban runoff and industrial activities.

8.4 Water Shortages, Scarcity and Stress

As governments struggle to provide basic water services while global water scarcity increases, tough decisions about water allocations and infrastructure development will have to be made. Most countries are poorly equipped to anticipate and adapt to the economic consequences of increasing water scarcity because they lack sufficient information about water use and resources (Lange & Hassan, 2006). Water is a valuable global resource and everyone should help look after it by using it carefully and wasting less. Some countries have high rainfall and large stores of water in the form of rivers and lakes. Others have few water stores, or irregular rainfall, and in hot climates water suppliers dry up quickly (Hunter, 2010). A sufficient quantity of clean water is the prerequisite to good health and without it humans become susceptible to a surprisingly wide range of diseases and health-related problems.



Access to adequate and safe drinking water should be a basic human right, yet today there are people globally who do not have access to sufficient safe drinking water. Many of these are managing on as little as five litres a day for all their drinking, washing and cooking needs (Watkins, 2006). According to Hunter (2010) most plants and animals are composed mainly of water and no living thing can survive without it. Since water is essential to life, it should be a basic human right. However, despite many international agreements over human rights, the rights to fresh water have largely been ignored, perhaps because the scale of the problem is so enormous. Drinking water quality, especially in terms of pathogens (that can produce disease or illness), cannot be isolated from sanitation, specifically the lack of adequate sanitation facilities. Various health problems created by the lack of access to clean drinking water and proper sanitation have a daily impact on 50 per cent of the population of development countries.

The minimum requirement for water has been estimated as 502 litres for drinking, 20 litres for sanitation, 15 litres for bathing and 10 litres for food preparation (Gray, 2008). Water scarcity is becoming one of the most critical risks threatening social and economic development throughout the world. South Africa is currently classified as a ‘water stressed’ country. This is largely due to climatic conditions in combination with human settlement patterns. South Africa is characterised by relatively low annual average rainfall combined with high evaporation rates (Watkins, 2006). Stress is an imbalance between available supplies within various regions on the one hand, and demands on those supplies by multiple users on the other hand. Most commonly linked to population growth, extreme drought and inadequately maintained or deteriorating infrastructure, the causes of stress include a combination of demographics, climate and economics. Understanding stress is vitally important for discerning the localised pressure of climate change, mass migration and agricultural production (Feldman, 2012).

Scarcity of water is widely perceived as the key feature undermining water security. Water security has been defined as “the reliable availability of an acceptable quantity and quality of water for health, livelihoods and production, coupled with an acceptable level of water-related risks” (Grey & Sadoff, 2007). However, the notion of scarcity is both a skewed and limited view of water security and mostly passes as water scarcity, are policy-induced consequences of mismanagement, while it is limited because physical availability is only one dimension of water security. One arena where water stress is most vivid is in so-called “megacities’’ which are urban areas composed of tens of millions of people. Cities are likely to see more conflict over fresh water supplies in the future.

They are also touchstones for innovations in conservation, waste water re-use and recycling and desalination (Feldman, 2012). Desalination can be considered as an alternative for solving a given set of fresh water demand problems. It becomes a real alternative when fresh water is an expensive local commodity due to the cost of making it available or due to market competition when it is scarce. Other water sources that are also capital intensive include long water transfers, the reclamation of sewage water and even deep aquifer development in extreme situations (Custodio, 2006). Access to water is imperative to a successful development strategy, because access to clean water is one of the most significant resources for reducing poverty and disease, improving the life of the poor through rural development and for increasing food security (Reid & Vogel 2006). One of the major concerns in achieving this goal has been the slow delivery of water access to poor and remotely located people. This issue has often been confused with the notion of water scarcity. Water scarcity can be defined in various ways.

Rijsberman (2006: 6) refers to a person as water insecure' if that person does not have access to water that is safe and affordable, such that consumption needs can be fulfilled. If this occurs for a sizeable area and for a number of people in the area, the area can be referred to as 'water scarce. However, Rijsberman (2006: 6) points out that it is not easy to define water scarcity, as a number of factors play a role in determining whether an area can be classified as water scarce. These may include the way the needs of people are defined, whether the requirements of the environment have been accounted for, the percentage of the water resource made available for these needs, and the temporal and spatial scales used in defining scarcity. A measurement of the scarcity of water is usually based on some relationship between the water resources available and the human population that depends on these resources, i.e. water availability per person per year.

One measure developed to indicate the level of water stress is the Falkenmark Water Stress Index. According to Gleick (2002), Falkenmark used population and water availability to develop a measure that indicates how many people can be supported by a country's natural water resources. The Falkenmark Water Stress Index sets the water availability per capita per year threshold at 1700 cubic metres, given estimates of sectoral and environmental requirements (Rijsberman, 2006). Another measure used to express water scarcity is the Water Resources Vulnerability Index, which represents the total annual water withdrawals as a percentage of the water resources available, where the withdrawals refer to the water extracted from the ground, streams and rivers to meet the needs of people (Rijsberman, 2006: 8). Water is considered extremely scarce if annual water withdrawals exceed more than 40% of the annual supply.

An alternative definition of water scarcity draws a distinction between physical and economic water scarcity (Comprehensive Assessment of Water Management in Agriculture, 2007). Physical water scarcity refers to having inadequate resources to meet the demand for water. Sandford (2009: 25) defines it as a state where water use approaches sustainable limits of supply. It is especially the arid regions which experience physical water scarcity. Economic water scarcity, in contrast, is the result of insufficient investment in water infrastructure to cater for the increasing demand for water, or of institutional constraints which make it difficult to ensure the equitable distribution of water, especially where people are too poor to obtain access to water services. According to Van Koppen (2003), this type of water scarcity often prevails in Africa, as some countries do not have the economic resources to develop their water resources.

One of the exceptions is South Africa, where the physically available water has already been developed (Van Koppen, 2003: 1048). Around the world countries have begun to experience increasing scarcity of freshwater relative to growing demand. Rijsberman (2006: 9) states that no matter how water scarcity is analysed, the general conclusion is that almost two-thirds of the world population will be affected by water scarcity. A study by the International Water Management Institute as cited in Seckler, Barker and Amarasinghe (1999: 29), estimated that approximately 1.4 billion people reside in regions where severe water scarcity will occur early in the 21st century. In addition, by 2025 absolute water scarcity will become a reality for more than 1 billion people in arid regions. Physical water scarcity is the result of an increasing demand for water due to high population growth, changing lifestyles brought about by economic growth, and climate change. The simple definition of water scarcity is a shortage in the supply of water in relation to the corresponding demand (Chatterton et al, 2010).

Thus it can be defined as insufficient water to meet the normal needs of population within a country. Utilisateur (2006:23) attributes different meanings to the water scarcity as: an imbalance between supply and needs; demand exceeding water availability; and increasing consumption of water above the available supply. Furthermore, scarcity is the result of limited natural supply relative to population need. Therefore, dealing with water scarcity depends on understanding the causes of the scarcity (Utilisateur 2006:24). However, Orr et al. (2009) argue that despite the many attempts to understand the issue of water scarcity, it is still difficult to find specific conclusions that show if water is scarce around the world or if it is just unevenly distributed and is therefore a matter of management. Elhance (1999) defines water scarcity as human life and civilization depends on continuously available fresh water of the highest quality for numerous uses (e.g. drinking, cooking, washing the body and washing clothes).



Water is not allocated equitably across regions and within countries. Thus, it is logical to describe the water problem as one of allocation rather of water shortage. Yang and Zehnder (2002) summarise this by stating that the net water capacity of the world is arguably enough to meet global demand, but that water is not evenly apportioned; some regions have over-abundance of water, while others are arid and drought-stricken, and the general availability and quality of potable water is in decline. According to this argument, limited water resources are a result of the lack of management, an effective planning system and cooperation between those requiring water and those with surplus capacity. Water Scarcity Indicators (WSI) one of the simplest indicators of water scarcity, the ‘Water Stress Index’ is proposed by Falkenmark et al. (1989).

The authors argue that ‘Water Stress’ is experienced when levels fall below 1700m3/capita/year of renewable water: this includes use in different sectors, such as household, industrial, agricultural and environmental. When the level falls below 1000m3/capita/year then countries are considered to have ‘Water Scarcity’ and any country that has less than 500m3/capita/year is considered as ‘Absolute Scarcity. Water scarcity should not only be considered in volumetric terms (limited as it is by the natural availability of surface and groundwater), but there is also the need to link water scarcity with socio-political and institutional processes and management. Water scarcity often results in high levels of emigration and may lead to local or national conflicts and wars (Homer-Dixon, 1994 cited in Mehta, 2007).

1. **FACTORS THAT CONTRIBUTE TO WATER SCARCITY**

The scarcity of water resources in South Africa is an increasing concern as the country is situated in a semi-arid region; its annual precipitation is below the world average and it experiences high evaporation rates (Department of Water Affairs and Forestry, 2004). Furthermore, the rate at which the water quality is declining is a related concern; pollution of rivers and streams and underground water resources is a major problem in South Africa. De Villiers and Thiart (2007: 343) investigated the nutrient status of the 20 largest river catchments in South Africa and found that only one catchment did not exceed the recommended water quality guidelines. Some of the more likely reasons for the level of pollution were found to be runoff from sewerage plants and human settlements. In addition to the physical supply constraints, the demand for water is increasing as the country experiences growth in population and urbanisation. The causes of water scarcity are diverse; some natural causes, while others occur as a result of human activity. The predominant debates currently site the causes of water scarcity as largely deterministic, in that scarcity is a result of identified cause and effect.

However, if water scarcity is the point at which water stress occurs (the point at which various conflicts arise, harvests fail and the like), then there are also less definable sociological and political causes. Many of the causes are inter-related and are not easily distinguished. Some of the main causes are listed below. The list is not in order of priority although some causes have greater impact than others *(Len, 2001)*. Water scarcity is caused by a number of factors, natural and socio-economic: physical; economic; environmental; and social and political. These reasons are discussed in the following sections. A measurement of the scarcity of water is usually based on some relationship between the water resources available and the human population that depends on these resources, i.e. water availability per person per year (Rijsberman, 2006: 7). One measure developed to indicate the level of water stress is the Falkenmark Water Stress Index.

According to Gleick (2002), Falkenmark used population and water availability to develop a measure that indicates how many people can be supported by a country's natural water resources. The Falkenmark Water Stress Index sets the water availability per capita per year threshold at 1700 cubic metres, given estimates of sectoral and environmental requirements (Rijsberman, 2006). Countries with a reading of between 1 000 and 1 700 cubic metres per capita per year are considered water stressed. If the water supply falls below 1 000 cubic metres, a region is considered water scarce, and if it falls below 500 cubic metres this indicates absolute water scarcity. Another measure used to express water scarcity is the Water Resources Vulnerability Index, which represents the total annual water withdrawals as a percentage of the water resources available, where the withdrawals refer to the water extracted from the ground, streams and rivers to meet the needs of people (Rijsberman, 2006: 8).

Water is considered extremely scarce if annual water withdrawals exceed more than 40% of the annual supply. An alternative definition of water scarcity draws a distinction between physical and economic water scarcity (Comprehensive Assessment of Water Management in Agriculture, 2007). Physical water scarcity refers to having inadequate resources to meet the demand for water. Sandford (2009: 25) defines it as a state where water use approaches sustainable limits of supply. It is especially the arid regions which experience physical water scarcity. Economic water scarcity, in contrast, is the result of insufficient investment in water infrastructure to cater for the increasing demand for water, or of institutional constraints which make it difficult to ensure the equitable distribution of water, especially where people are too poor to obtain access to water services. According to Van Koppen (2003), this type of water scarcity often prevails in Africa, as some countries do not have the economic resources to develop their water resources.

One of the exceptions is South Africa, where the physically available water has already been developed (Van Koppen, 2003: 1048). Water scarcity is caused by a number of factors, natural and socio-economic: physical; economic; environmental; and social and political. These reasons are discussed in the following sections.

**9.1 Physical Reasons**

The physical reasons for water scarcity refer to a natural limitation on water resources within a country (quantity shortage). The International Water Management Institution (IWMI) has categorised countries depending on their capability to meet their estimated water demand. Thus any country that could not meet its demand for water due to a natural shortage is considered to be in physical water scarcity. This kind of scarcity takes place in arid and semi-arid regions such as Central and West Asia and North Africa (IWMI, 2007).

9.1.1 Food Production

SADC countries continue to have problems related to food security. In the mix of the drought of 1990s all the countries in the region had to import food in various forms, from greens to cereals. With the increased population it has become more imperative for countries to devise better water management policies so as to be self – sufficient and provide food for the citizenry. The case of Botswana is a good example: through its policy of ensuring food security through economic growth following its recognition of water scarcity. The rewards from good economic policies are used to import food in time of need. South Africa finds it’s self in unique position as it has to make internal transfer of food when there are shortages in other regions of the country and then import food in time of shortages nationally (FAO 2009).

9.1.2 Land use

Land management and particularly usage play a big role in the availability and supply of water. A decrease in vegetation cover could lead to water run - off and consequently diminish the volume of ground water infiltration as the storage capacity of dams and lakes are also reduced through siltation. A region’s climatic change may also be affected by the extent of drainage on wetlands and level of deforestation. The need for proper farming methods and land management can’t therefore be under - estimated as anything to the contrary will have devastating consequences.

A related land usage issue is the plantation of ‘thirsty’ crops in mountainous areas. Planting such crops may have some economic benefits but it also comes with negative spill overs in the form of water availability. Such situations may lead to reduced water run off for such vegetation resulting in the considerably reduced level reduced level of water availability for downstream users *(Len, 2001)*. There are aspects of climate, soil type and geography which affect vulnerability. For example, steep hillsides will influence what type of farming practices are used, and increase the likelihood of landslides. Human activity is constantly degrading the natural environment, making it more fragile and less able to resist extreme weather

**9.2 Economic Reasons**

However, water scarcity may not arise just because of physical water shortage but because of economic reasons such as a lack of sufficient financial resources or poor service delivery. This type of shortage is more apparent in poor countries such as Sudan and Egypt. It occurs as a result of lack investment in water infrastructure and effective technology (Rijsberman, F. 2006).

9.2.1 Population Growth

An increase in population growth is a main cause of water scarcity. Population growth comes with two direct elements of water demands: the direct consumption by the people; and more importantly water for the developmental needs of the growing population. According to UN – HABITAT (2009), country, city and town planners and policy makers are continuously facing increased challenge of providing water services for their ever growing population and the expansion of economic activities to meet the demands of the growing population. Whereas the population of the more industrialized countries is either decreasing or constant, the developing countries’ population is constantly increasing at a rapid rate, yet the water resource availability remains constant and is continually polluted by the growing population. There SADC region, whose population growth rate is between 2.2% - 3.8% (cite) faces an even bigger problem with the need to grow enough food to feed the population. Demographic change has major implications for the demand for water. According to the United Nations (2009), the projected world population is estimated at approximately 11 billion people in 2050 (based on a constant-fertility variant scenario), of whom 87% will reside in less developed regions. The increased growth causes a higher demand for water to fulfil consumptive needs, but it also leads to a greater demand for food. This implies even more pressure on resources to produce goods and services.

At the same time, urbanisation has increased in most parts of the world. In 1970, approximately 67% of the world's population resided in rural areas (UNESCO, 2006). Over the past decades this proportion has declined significantly as people move to cities and towns in search of better living and working opportunities. It is projected that by 2020 only 44% of the world population will be living in rural areas. This trend has implications for water management as more people will require access to basic water and sanitation. The runoff generated from urban settlements will also influence the quality of water resources, especially if adequate water and sanitation facilities lag behind the growth in urbanisation. This is especially the case in many less developed counties.

9.2.2 Climate Change

Climate change is another contributing factor to increasing water scarcity. Callan (2010: 287) defines climate change as "a major alteration in a climate measure such as temperature, wind, and precipitation that is prolonged, i.e. lasts decades or longer." One of the contributing factors to climate change is the excessive production of greenhouse gases caused by human activities, such as the burning of fossil fuels (Callan, 2010). The higher temperatures can affect human health and lead to changing weather conditions, such as rising sea levels (due to melting glaciers) and increased storm intensity, both of which will adversely affect coastal towns (Tietenberg and Lewis, 2009). The impact of climate change on water resources depends on the effect of changing weather patterns on the supply of water, as well as on changes in the demand for water as a result thereof. Water availability is affected when there are impacts on the hydrological cycle, and changing temperatures and variability in precipitation patterns affect the water supply (IPCC, 2007).

Increased temperatures result in more water evaporation; however, increased precipitation may offset these losses. The net effect on water availability also depends on how climate change affects the demand for water. Climate change affects the demand for irrigation water. Warmer and drier weather conditions can make it more profitable for farmers to apply irrigation instead of dry land farming. In regions with available and affordable water, more farmland will be irrigated and increase the water amount applied per acre (Frederick, 1997: 6). However, the impact on global water requirements for irrigation depends on how regions are affected by climate change. According to the IPCC (2001), irrigation-use water models predict lower requirements in regions such as the Middle East and Africa (due to increased precipitation), whereas India will require more water for irrigation.



It should be kept in mind, though, that other factors such as pricing and population growth also play a role in determining demand (IPCC, 2001). The impact of climate change on domestic water use depends on what the water is used for (IPCC, 2001). Outdoor water use can be affected if increases in temperature increase the demand for water. The quality of water can also be affected by increased temperatures, which are a consequence of climate change. Higher water temperatures and variability in precipitation affects water quality, since increased temperatures reduce the dissolved oxygen levels in the water and this affects aquatic life (IPCC, 2007). Moreover, increased rainfall can increase sedimentation and pollution due to higher levels of runoff and flooding. This affects water quality, since excessive amounts of pollutants enter water resources as a result of higher volumes of water. Water resources are further polluted by sources such as farming, urban runoff and industrial activities.

9.2.3 Poverty and Economic Policy

Poverty is one factor that can expose one to extreme water scarcity in the face of any level of drought. People in poor communities can hardly finance alternatives to traditional sources of water such as boreholes. Therefore, in times of drought, the poor are forced to buy water at high prices from those who can afford to store in big reservoirs or acquire it from boreholes. Poor communities can thus hardly meet the prices demanded for water. Any given situation of drought or water shortage would have dire consequences for a poor community than a middle income community. It is for this reason that the macroeconomic policy of a country, and its effectiveness in addressing poverty, will have an important role in determining what constitutes conditions of water stress. Similar climatic conditions in two countries will cause famine in the poorer country and a temporary, limited economic depression in the wealthier country’ (Len, 2001).

9.2.4 Legislation and Water Resource Management

The lack of adequate legislations can impact negatively on an already bad effect of water scarcity. There are water laws that give exclusive rights to some specific users, of which an example may be found in the agricultural sector. Where these are good security measures for such investments, it might also have some adverse effects, such as putting other communities into jeopardy in times of water scarcity. Water Laws in South Africa (present and future) would provide everyone guarantees or rights to basic minimum supplies of water.

These laws should be balanced and equitable so as not to negatively affect the development of other sectors of the community or society. The effects of the Riparian Doctrine in the current Water Act are a case in point *(Len, 2001)*.

9.2.5 Sectorial Resources and Institutional Capacity

Due to the precarious nature of the economic situation of countries around South Africa, it becomes extremely difficult to design and implement measures that would minimize, if not avert, water scarcity. Institutions to handle water issues tend to be weak and are characterized by unnecessary bureaucracy and inefficiencies. Despite South Africa being in a far better financial position compared to neighbouring SADC countries, not much has been done in the design and implementation of disaster management policies. It is a matter of lack of will as against lack of resources, and this leads to water scarcity, a situation that could have been averted quite easily (Kayaga, 2011). National government has to make decisions on spending priorities, for example health and agricultural services may be underfunded if more spending is directed towards defence or debt repayment. Also, the prices of internationally traded commodities such as coffee, sugar or cotton will influence the price farmers receive for their cash crops.

* 1. **Environmental Reasons**

This kind of water scarcity means water is abundant within a country but the population are not able to access it due to environmental problems such as pollution by pesticides or contamination by salt water (Rijsberman, 2006). Increased populations are leading to the depletion of existing water resources, which in turn make them unusable or high costly to treat. This can be clearly seen in the Arab region in Asia where irrigated farming is expanding which in turn increases use of chemical fertilizer and pesticides and therefore raises the levels of contamination (UN, 2003).

9.3.1 Water Pollution

Pollution of water resources reduces the supply of clean water. Water quality is worsened by the increasing degradation of the resource through the pollution of rivers and lakes, as well as of groundwater resources. Freshwater resources such as rivers, streams and lakes are environmental receptors for pollution discharge resulting from a variety of human activities. Industrial and agricultural effluents are some of the major causes of water pollution as the water resources do not have the capacity to absorb excessive pollution flows (UN Water, 2007). According to Rosegrant (1997: 5), some of the main contaminants found in water resources are detergents, pesticides, toxic metals, fertilizers, and disease-causing agents responsible for illnesses such as cholera. In addition, surface waters are affected by pollutants through precipitation. Acid rain is the result of atmospheric pollutants affecting surface waters through contaminants in the precipitation (Callan, 2010). The consequence of water pollution is a decline in the quality of the resource and therefore a decrease in the availability of water. If a water resource is contaminated, there is less water available for competing uses. Water quality problems have adverse consequences for human activities since consumption and production activities are affected. In the case of the former, not only is there less water for drinking purposes, but recreational activities are also adversely affected.

People cannot swim, surf or fish in contaminated water as this can lead to health problems. The pollution of surface and groundwater adversely affects the amount of water available for use. According to the SADC (2008), the quality of water in Southern Africa is primarily influenced by human activities such as deforestation, irrigation, and industrial and urban pollution. One of the key reasons for increased urban pollution is population growth and increased urbanisation. The latter has placed immense pressure on existing infrastructure and many cities in Southern Africa (such as Lusaka and Johannesburg) are experiencing urban expansion that exceeds the capacity of existing water and sanitation infrastructure systems. This results in urban runoff that is uncontrolled and leads to the pollution of rivers and streams (SADC, 2008). Another major contributor to water pollution in South Africa stems from mining activities, primarily in the northern regions of the country. According to Oelofse (2008: 2), mining impacts on the environment through the release of chemicals.

This degrades water resources, which in turn has health and safety implications for surrounding communities. Recently the acid mine drainage in Johannesburg has received a great deal of attention. Acid mine water is created when old mineshafts fill up and mixes with the sulphide mineral iron pyrite and the acidic water then starts to drain in the environment ("Johannesburg on acidic water time bomb", 2010). If no remedial action is taken, the acid mine drainage not only threatens water ecosystems, it will also affect the water supply and agricultural activities. In addition, it has detrimental implications for the poorer communities of Gauteng, who live close to contaminated areas (Johannesburg on acidic water time bomb, 2010). A comparison of the cost of augmenting water supply with alternative sources such as desalination has shown it to be relatively expensive. An analysis of augmenting options for the Western Cape revealed that desalination of seawater was the most expensive option, costing approximately R12 per cubic metre (Van Rooyen et al. 2011).

However, even though desalination is currently relatively more expensive than other augmenting options, it is inevitable that the greater Cape Town area will become dependent on desalination for its water supplies by approximately 2030. Another supply augmenting option is reusing of waste water, which is already applied in South Africa and plays a significant role in matching demand and supply of water. An analysis of the marginal cost of reusing water, however, showed that it is relatively more expensive than using surface water or groundwater. The estimated marginal cost of reusing water (for the Western Cape) was estimated at double the cost of expanding surface water or groundwater resources (Van Rooyen, 2011: 17).

9.3.2 Water Quality

Polluted water reduces the volume of water available for use, especially in times of water scarcity. During periods of water sufficiency, the volume of polluted water is reduced because rivers would have more dilution factors to contain toxic elements. The reverse is the case in times of scarcity where rivers are hardly able to cope with toxic elements; they are thus sensitive to pollution just as the people who depend on it. Causes of water pollution or contamination include agricultural return inflows, industry and domestic uses. Both surface and groundwater can be affected by pollution (UN – HABITAT, 2009).

9.3.3 Water Supply

Environmental impacts of water includes animals and plants depend on water and when drought occurs their food supply is diminished and habitats are thereby damaged. Following are some examples like destruction of wildlife habitat, food and drinking water for wild animals is unavailable leading to migrations, disease increase in wildlife as food and water supplies are reduced. Water levels in reservoirs, rivers, lakes and underground reservoirs reduce. Loss wetlands and increased wild fires. Deterioration in soil quality and wind and water erosion of soils become more prevalent.

**9.4** **Social and Political Reasons**

Social and political reasons for water scarcity occur in places where there may be an abundance of water. However, people are not able to access the water as a result of political issues or socio-cultural reasons or poor water management and policy. This can be clearly seen where the water is abundant but the scale of development projects presents major challenges its management pointed out that water scarcity is partly a social construct which is determined by water availability and consumption patterns.

Therefore, it may be more beneficial to define water scarcity as a particular mix of availability and demand at which water stress occurs. Water scarcity is also associated with population increases. This increasing of the world’s population leads to increased food demand which is resulting in increased pressure on water resources. Water use has increased as the average income has increased, affecting patterns of consumption, and thus creating water scarcity. Consumption patterns contribute to drawing the picture of future resources use. Chatterton et al (2010) pointed out that the source of water use is important to judge if the meat production affects the environment. Raising awareness of water scarcity should play a vital role in sustainable water management. Thus, Allan (2002) argues that although politicians and environmental researchers are aware of water scarcity, it is noticeable that the public discourse is still weak around water issues.

However, authors such as El-Naser (2005) claims that in some circumstances raising public awareness is not the only way to help in improving water management. Therefore, he argues that, if other solutions such as improving water productivity are applied along with raising public awareness, it would be more effective in developing water management in some regions. Challenges with water resource management in South Africa are attributed to low rainfall events, political breakdowns, racial groups, limited physical resources, rapid population growth and a stagnant economy (Molobela & Sinha 2011). The lack of a definite definition of water stress discussed above highlights that there are various causes that in turn have various effects on water resources. The causes include, but are not limited to primarily aridity, drought resulting from climate variability, and abstraction and secondarily population growth, policy implementation for management of water resources (Seppala 2002; Shiao & Stockholm 2013; Klemas & Pieterse 2015; Pradhan *et al.* 2017).

Each of these factors has a role that it plays in the ecosystem, as each influence water resources in different ways. It is important to investigate how each of these factors affects water resources in order to be able to design possible solutions to water stress. The natural changes in climate are expected to lead to more frequent drought in some areas, and floods in other areas. This will also cause acidification of lands by reducing soil moisture content, the amount of expected rainfall, and severe agricultural drought (Adams & Peck 2008; Raneesh 2014; Ettera *et al.* 2017; Xing-Guo *et al.* 2017). This evidence shows that drought and aridity are climatic components that will affect water resources. The national government may provide resources to a particular district or withhold them, often for political reasons (for example the voting preferences of that district’s population). A government’s motivation for action is often a desire to retain power at the next level.



**10.0 CHALLENGES OF WRM**

10.1 Water Availability

The availability of water significantly influences the actual volume of water used as opposed to the water demand. Water used is in numerous instances considerably lower than the demand due to water shortages. This occurs particularly in areas which are ravaged by prolonged droughts. The availability of water is a function of the mean annual precipitation, ground water potential, borehole success rate, the presence of regional schemes with adequate capacity, the presence of well-structured maintenance programmes and the availability of funds for development of water resources and water supply infrastructure. Access to available water supplies is mainly a function of the type of water supply system installed, number of water abstraction points developed and the population density.

Several water supply system types are in common use and include fully reticulated systems with water borne sewage, yard tap systems, street tap systems, wind pumps, hand pumps and direct abstraction from springs, streams and shallow wells. The water use at home is limited by the ease with which the water is obtained from the water supply system. In the case of a rudimentary water supply system where water is scooped from streams, springs and shallow wells, it is required that the water user carry the water over long distances, and in addition, the water is quite often not readily available at the collection point. In such cases, water use activities such as washing of laundry, and to a limited extent, bathing, tends to be transferred from the house to the source.

The volume of water used in such cases is therefore relatively low. Hand pump, wind pump systems and particularly street tap systems require considerably less effort to draw the water, but access may be impeded by long walking distances. Improving access to available water by providing yard tap systems or house connection systems results in a considerable increase in water use. Water is readily available for high water use activities such as bathing, sanitation and garden water use. As a hydrological model is necessary for the analysis of water availability in the workflow (to achieve a spatially and temporal distributed water balance and to assess future conditions) for the analysis of water availability.

10.1.1 Hydrological Balance Modelling

The components of a hydrological water balance are precipitation (P), runoff (R), evapotranspiration (ET) and change in water storage (ds): Under specific hydrogeological conditions, in particular in karstic areas, natural underground inflow and outflow (I) must also be taken into account.

10.1.2 Hydrological Model

The model implements a conceptual process-oriented approach and has been developed especially to suit conditions in mountainous environments with their highly variable environmental and climatic conditions, including a snow and glacier module. To effectively evaluate this model, following data are required for the hydrological model include a digital elevation model (DEM), a land use map, a soil map, precipitation and temperature data, river discharge data for calibration of the model. In order to calculate evapotranspiration according to Penman-Monteith (Monteith, 1975), extensive meteorological input (relative humidity or water vapour pressure, global radiation, wind speed and sunshine duration) data at high temporal resolution are required. This is however not a limitation since more simple evapotranspiration formulae are also available in the model and allow for application in regions where meteorological observations are scarce. PREVAH contains a number of tuneable parameters which are used to adjust the model to the conditions prevailing in a specific catchment. In practice, this means that the agreement between observed and simulated hydrographs has to be maximised by selecting a suitable set of such parameters. This is referred to as model calibration and is a key process in the application of hydrological models.

Calibration is particularly difficult due to inherent limitations and uncertainties (input data, model structure, basin characteristics, process understanding and scaling issues), as a consequence of which a number of local optima exists rather than a global optimum. Model calibration is therefore a complex task and has received considerable attention over the years (Viviroli et al., 2009). Different climatological stations can be used for the model, in order to represent precipitation and temperature elevation-dependent gradients which are typical for mountainous regions. At high altitudes rain tends to accumulate, which is known as the orographic effect. Temperature decreases with increasing altitudes. Climatological measuring stations at higher altitudes are however underrepresented (as in almost any station network in mountains). Therefore it is advisable to include as many measurements from stations at high altitudes as are available. Therefore daily time series on relative humidity, wind speed, global radiation and sunshine duration were acquired from the ZAMG. Snow accumulation and snow melt are addressed according to (Hock, 2003).



10.2 Water Demand

The importance of several of the factors and parameters assumed to have an influence on the water demand, are not applicable in the South African context and therefore made direct application of the methods doubtful. Factors which influence water demand are as follows in the water demand estimation model, water demand is the dependent variable and the factors which are thought to influence water use include socioeconomic parameters, access to water, water availability and inhibitors and are used as independent variables. The water demand model is thus based on the theory that water demand is a function of the various factors which define consumer behaviour and that variations in domestic water demand can be accounted for by differences in population density, household size, family structure, housing type, gardening activity, electricity use, income, business activity, education, expenditure pattern, motor vehicle and other fixed asset ownership, agricultural activity, water supply system type, sanitation facilities, water tariff, water quality, people per abstraction point and water user type.

Most working definitions of water demand management consist of the following components: reducing the quality or quantity of water required to accomplish a specific task; adjusting the nature of task so it can be accomplished with less water or lower quality water; reducing losses in movement from source through use to disposal; shifting time of use to off – peak periods and increasing the ability of the system to operate during drought seasons (David, 2005). Water Demand Management is further defined as the ways of developing and implication of strategies, policies, measures or other initiatives aimed at influencing demand, to achieve efficiency and sustainable use of the scarce water resource. In order to achieve effective WDM, water authorities or service provider should commit to the using of human, physical and material resources in the process of improving the efficiency in water use both within the water supply system and on the customer’s side (Savenije and Van Der Zaag 2002). Water Demand Management measures is about the purpose of this research is to see how government structures at the municipal level engage with the community in building the capacity of WDM through knowledge and information sharing. A number of water demand management measures exist, as discussed below:

10.2.1 Structural and Operation Measures

This could be used at the utility level to reduce water losses by organizing the process of water distribution networks to carry out the active role of water leakage management or to install pressure reduction in some zones identified as having unnecessarily high pressures. This can also be introduced to end – user’s premises by placing fixtures and appliances with devices that use water in more efficient ways (White et al, 2001).

10.2.2 Economic Measures

This involves proper use of market - based signals to attract interested types of decision – making. They either give financial rewards for good behavior or impose costs for undesirable behavior (Cantin et al 2005).

10.2.3 Behaviour Modification

WDM programs should be designed from an analysis of the ways that motivate to take actions and change their ways of thinking and responding to this challenges. Awareness raising and public education programs for modifying the behavior of water consumers may be used hand in hand with other WDM measures for more effective strategies (Texas, 2004).

10.2.4 Legal and Institutional Measures

There is always variety of regulatory tools that can be developed to ensure WDM options. There is a need that this law must be conducive towards the effective legal and institutional functioning. To ensure that water service providers carry out a comprehensive water resource planning to cover resource management, production management, distribution management, and customer side management. The demand for water includes the requirement for water services in agriculture, industry, domestic and other purposes while distribution is the delivery of water to consumers with appropriate quality, quantity and pressure. The distribution system is used to describe collectively the facilities used to supply water from its source to the point of use. Burchi and Andreas (2003) define water distribution as the function of assigning water from a given source to given uses. The spatial demand and distribution of water resources vary depending on a number of factors such as willingness to pay, infrastructural capacity, modern technology, distribution systems and components. Warwick (1997) emphasized the need for an economic efficiency operational criteria requiring the distribution of stream flows until the net marginal utility in per capita water consumption is achieved. The relation between the quantity of water used and the price is illustrated by the demand curve. The main variables that determine water demand is discussed with particular attention to water price, household income, weather variables, household size and composition, time for fetching water, education, village population and water accessibility.



* Water Price

Demand theory states that as the price of a good increases, the demand for that good decreases (Froukh, 2001). Therefore, it is expected that price will negatively influence the quantity of water use from purchased sources. When a price of water exists, then it is quite easy to compute a per unit price for each household and each source. The price of non-piped water has been considered exogenous in all studies except in David and Inocencio (1988). These authors argue that the price of vended water is endogenous because price is determined by demand and supply factors. Due to the fragmented nature of the water vending market, household decisions of water demand are likely to influence its price. Even if free of charge, the collection of water from non- piped sources usually involves costs for hauling water from distant sources.

* Household Size and Composition

Arouna (2009) analysed households’ water use behaviour as a function of water availability by explicitly estimating domestic water use for both rainy and dry seasons when water is respectively in surplus and scarce. Domestic water consumption will likely increase with household size, following Keshavarzi et al., (2006) and Froukh (2001), both household size and composition affect water use, and more over household size has been found to be the most important factor affecting water consumption. In the analysis, household size and composition involve the ratio of children to adults and gender of the household head respectively.

* Time for Fetching Water

Time used for fetching water and efforts required to carry heavy water buckets has an opportunity cost. This implies that the further away a source is located from the house and the longer one must queue, the less water from the source will be used (Gazzinelli et al., 1998). Sandiford et al., (1990) thus hypothesized that the time for fetching water (that is walking time plus waiting time) will be negatively related to the quantity of water use.

* Village Population

In some areas, people mainly rely on public water sources, either free or purchased. It is expected that per capita water use will decrease as the population increases (UN-CSD, 1994). In some areas, people can only collect fixed quantities of water in order to allow everybody to have at least a small quantity for basic use only. In a larger population, a household member has to queue several times before obtaining the desired quantity.



* Weather Variables

The change in weather variables poses risks to water security through altered drought frequency and intensity thus changing water demand. These potentially affect water availability for abstraction, storage and supply (Joanne, 2012). Maidmat and Miaou (1986) suggested that rainfall has a dynamic effect on water demand. It reduces water demand initially, but the effect diminishes over time. Sometimes water users appear to respond to the mere occurrence of rainfall than its amount, therefore, the number of rainy days should be a better explanatory variable than the amount of rainfall in a given period (Martinez-Espineira, 2002b).

* Water Accessibility

It is expected that as with other economic goods, better accessibility will positively affect the quantity of water consumption. Accessibility of water supply points principally supplying adequate and quality water for the wellbeing of human health. Sustainable access to improved and safe drinking water is one of the MDGs goals. USAID (2006) Ethiopian report estimates percentage coverage of water supply at 40% while NGOs and WHO report the coverage as 22 %.

10.3 Water Supply System

Water supplies in semiarid regions vary significantly on an annual basis. To account for the uncertainty in water supplies municipalities often purchase water according to a firm yield ratio. The firm yield ratio corresponds with the expected amount of water a water user may receive during a given year. Water availability is ensured by its reservoir; however, the distribution is a problem since water demands have increased over time while the supply system has lost its automatic function which has resulted in an on-request system. In most cases, water users have no fixed time schedules for water supply and therefore, experience shortages especially in times of high demands. According to Renate (2007), problems in distribution of water are caused by timing and scheduling and not by too small infrastructure capacities as the water users’ claim. The deficiencies of the system lead to unclear, unequal and stressed water distribution. The basic of a modern distribution network is intended to meet the actual water demand, self-cleaning velocities of 0.4 m/s regularly in the network and the unidirectional flow. The main characteristics of a modern distribution network are a branched system with pipes with a relatively small diameter. In the design process, several steps can be recognized such as to determine the water demand, arrange sections, compose main structure, design sections, check pressure drops and fit in flows. The supply point is the ‘end’ of the distribution network as far as the water company is concerned.



The water meter is the last part of the connection and in unmetered situations; the stopcock is the last part of the connection. Then the actual house installation starts and that is where the water is consumed. For calculation reasons, the pressure at the actual supply point should be at least 200 kPa as the minimum acceptable pressure (Chin, 2000) when no water is abstracted from the installation. Reason behind this is that the pressure at the highest tap point is enough to overcome the hydraulic resistance of the house installation and the tap point itself.

10.4 Environmental Flows (EF)

IWRM do not regard the ecosystem as a “user” of water in competition with other users, but as the base from which the resource is derived and upon which development is planned (Jewitt, 2002). Therefore, in order to evaluate the available water resources, environmental flows (EF) have to be defined. The notion of environmental flow needed to maintain environmental functions in a river ecosystem is an attempt to find a compromise between productive uses and some protection threshold. Hydrological EF methodologies are by far the most common used, as they are the simplest methodologies. They rely primarily on the use of hydrological data, usually in the form of naturalized, historical monthly or daily flow records. They are often referred to as fixed-percentage or look-up, where a set proportion of flow, often termed the minimum flow, represents the environmental flow requirements intended to maintain the freshwater fishery, other highlighted ecological features, or river health at some acceptable level, usually on an annual, seasonal or monthly basis.

Holistic methodologies address the flow requirements of the entire riverine ecosystem, based on explicit links between changes in flow regime and the consequences for the biophysical environment. Recent advancements include the consideration of ecosystem-dependent livelihoods. According to EFs should mimic natural patterns of flow variability in a river. All components of the natural hydrological regime have a certain ecological significance. Maintaining the full spectrum of naturally occurring flows in a river is, however, hardly possible on account of water resources development (Smakhtin, 2007). Magnitude, frequency and duration of some or all flow components is modified and the suite of acceptable flow limits for such modifications can ensure a flow regime capable of sustaining some target set of aquatic habitats and ecosystem processes. EFs can therefore be seen as a compromise between river basin development on the one hand and maintenance of river ecology on the other. The Swiss Water Protection Act establishes specific flow values for different average flow rates, which must be maintained or increased in certain cases, depending on geographic and ecological factors.



10.5 Water Quantity

The water quantity map presents all water demand stakeholders and available water resources (groundwater, springs and surface water). The map can be generated for any time step. By means of this map, it is possible to visualise water flows from water resources to water demand stakeholders (e.g. springs to water supply undertaking, surface water from streams to reservoirs for technical snowmaking.

10.6 Water Balance

The conceptual balancing approach was straightforward in defining different compartments and their inflows and outflows. It is inevitable that certain flow paths or storage components stay highly uncertain. Elements without the availability of measurement data or directly related studies, and which also cannot be properly balanced from other components, have to be estimated from the experience of experts or the international literature. In the case of the Wadi Shueib water balance this primarily concerns several components of the groundwater flow, and here especially the sewer leakages and the resultant unintentional recharge, as well as potential lateral groundwater flows. Furthermore, the irrigation related evapotranspiration and return flows, as well as the amount of private water imports. Nonetheless, the international literature provides a multitude of examples where even highly uncertain water balancing approaches have been usefully applied in the water resources studies at catchment scales (e.g. Fleischbein et al., 2006; McCartney, 2000).

**11.0 FACTORS AFFECTING THE RATE OF WATER DEMAND AND DISTRIBUTION**

Many water supply schemes in rural areas are fairly basic; however, the patterns of demand and distribution are more complicated and tend to be dependent on many factors (Wallingford, 2003). Such factors include:

11.1 Population

The growing population increases the demand of water for domestic use, food security and industrial development. The population growth trend has resulted in reduction of per capita water availability (UN-WATER, 2006). Water demand and use are directly related to the population.

However, in rural areas, it is often difficult to estimate the population levels accurately due to lack of accurate and up-to-date census data; lack of up-to-date aerial photography or remote sensing data from which to estimate the number of settlements in an area and migratory labour with the male members of households often working in urban areas for long periods of time (Wallingford, 2003). Population growth and economic development have placed stress on water resources (Varma, 2010) which has resulted in a decrease of per capita water availability. The international water management group (UNFPA,2007) asserts that urbanization and industrialization which commonly had high population densities has caused an adverse variability in quantity and quality of water resources therefore retards the demand and distribution of water (WRI, 2007).

11.2 Household Occupancy Rate

Household occupancy rates and level of service affect water demand and distribution. Studies have shown that low rate occupancy households generally use more water per head than higher rate occupancy ones. The level of service can be defined in terms of water supply based on quantity and quality of water available within a given distance, sanitation in terms of whether there is a pit latrine, pour-flush latrine or piped sewerage and a stipulated measure of reliability.

11.3 Level of Service of Water supply for Each Household

Water is often viewed as primarily a social good. Many countries’ constitutions enshrine the basic right of every citizen to a safe supply of water; however, water can also be viewed as an economic good. In many circumstances, rural domestic water users have to pay a tariff towards the cost of their water supply. In some cases, consumers are able to choose the level of service for which they are willing to pay. Demand functions and curves can be produced that are related to the following: quantity of water demanded; price or tariff level of the water; price of other related goods or services; household income and other socio-economic factors. The above variables are often known as determinants of demand. Many researchers agree that different levels of supply and different levels of service will display different functions regarding demand. However, as a rule, water use will generally increase as the level of service increases and decrease as tariff levels increase.

11.4 Tariff Levels

Drought is a recurring phenomenon and its impact on water resources is usually devastating (Mati, 2005).

Floods lead to disasters particularly in low-lying areas. Occasionally floods have caused devastating impact on the sector. Both climate variability and environmental degradation have resulted into catchment degradation, drying up of rivers, receding of lake levels, heavy siltation in dams and pans meant for both hydropower generation and water supplies and deterioration of water quality (UNWATER, 2006). Crop failures occur in the same areas prone to seasonal flooding. Floods also ravage many areas particularly Lake Victoria region, Tana River, Garissa, Taita Taveta and Nairobi (Bancy, 2012). Having to pay for water significantly reduces the water demand and consequently the volume of water used by households. It is generally agreed that pricing mechanisms are an effective means of conserving water (Kreutzwiser et al, 1989). A policy decision has recently been made by the Department of Water and Sanitation to recover at least the operating and maintenance costs of delivering water.

The purpose of charging for water is therefore two fold viz, to discourage waste, irresponsible water use, limit water losses and to promote an awareness of the scarcity of water. Secondly, charging for water delivered is required in order to generate income so as to ensure the sustainability of the water supply facilities. Two basic tariff systems are in general use and include the flat rate fee whereby households are required to pay a fixed monthly fee regardless of the volume of water used and the other is based on charging for water in relation to the volume of water used. Quite often, the latter tariff systems is combined with a sliding scale which makes provision to charge higher rates for use above certain cut-off levels. This tariff system is particularly effective in terms of curbing wasteful and irresponsible water use practices.

Charging for water significantly reduces the water demand. The degree of reduction varies in accordance with the tariff type as well as the level of living or in other words, the water demand level. Water users which have a relatively low level of living, and therefore have a modest water demand, display a small reduction in water demand should water be charged in relation to the actual volume of water used. The reduction is marginally less should the flat rate system be applied. On the other end of the scale, communities which have a high level of living and therefore have a high water demand, experience a reduction of 30% or more, should the sliding tariff system be applied. The reduction is only about 10 to 15% should the flat rate fee be applied.

11.5 Willingness and Ability to Pay

The development and implementation of water use management strategies are aimed at influencing water demand and distribution in order to achieve adequate level of water consumption and maximum utilization of the finite resource (National Water Policy, 2006).

11.6 Local Knowledge and Indigenous Practices

The price signals provide the information needed to allocate and distribute water more effectively. The water pricing is a major instrument that can be used to resolve inevitable trade-offs (Winpenny, 1994). It forms part of the broad effort that strengthens water use governance and value long-term ecosystem services. Water pricing ensures efficient utilization of water resources in order to achieve a high level of cost recovery. Water conservation measures can be promoted by structuring the system rates and charges to reflect the seasonal variation of water use, the cost of production and distribution during peak hours (American Water Works Association, 2007).

* Metering

Water use metering is an essential element for efficiency and conservation management of water resources (Kenny, 2005). Water metering is required for water loss control, accounting and rate making (Perret, 2009). Inaccurate reading leads to inaccurate information about water use and leak detections. Metering is a means of achieving a diurnal demand management in terms of water waste control and detection exercise. The aim is to manage water losses in the network within the economically acceptable levels thereby making better use of the limited resource. Where a water supply is fully metered, the consumption patterns of various categories of consumers can be determined by monitoring the meter readings over a period of time (CMWSP, 1997). All water supplies experience water losses through leakage in the transmission systems, illegal connections, faulty meters and wastage. In general, this is estimated at 20% of the total supply but poorly managed systems may experience losses even greater than 50%.

* Restrictions and Prohibitions

Water use restrictions and prohibitions are part of command and control tools. Water regulatory agencies and water service providers establish restrictions and bans in water use during droughts for non-essential purposes such as washing cars and watering flowers.

Mandatory restrictions are shown to be an effective tool for drought coping as saving measured in expected use per capita range from 18-56% cent compared to 4-12% saving during periods of voluntary restrictions. Mandatory restrictions are effective in reducing water consumption.

* Public Information Initiatives

The customer should understand the water bill which clearly identifies use rates, charges and other pertinent water use information such as home water conservation measures. The water bill provides contacts and phone numbers to report leaks and waste and also proposes initiatives.

* Water Reuse and Recycling

Gray water (waste water) from certain uses is treated and filtered to remove solids are reused for specific purposes such as toilet flush or redistributed for irrigation, helps to reduce water use requirements through efficiency and conservation strategies, a core element of sustainable resource management.

11.7 Cultural Values, Traditions and Religious Beliefs

Water is an important life sustaining resource necessary for economic development and general wellbeing of the society. It is, therefore, in the best interests of every member of the community that it be used efficiently to serve the interests of all indiscriminately. It is for this reason that the study sought to establish the strategies currently being employed by the community in the study area to manage important resource.

11.8 Climate Change

Extreme events related to climate change such as heat waves, droughts and increased precipitation can lead to an increasing water scarcity and water quality degradation within the sub-catchment posing a significant seasonal water demand variability of 4.82% between the dry and wet seasons. Development and Population growth alongside climate and land use changes have posed the risk of water shortage. The rate of water demand is increasing which is a reflection of an increasing population, land use activities and climate change. The results reveal that despite the availability of adequate water resources, water shortage remains a great challenge to water sector demands.

Demographic, land use and climate change which is not reversed to some degree by policy intervention may be difficult to adjust to a manageable level in future. Policies and programmes to reduce water demand and wastage depend on efficient water use systems and conservation strategies. The right of the people to access adequate quality water from improved water sources for their livelihood is a priority concern in the basin however this is limited by lack of regulatory framework to measure water sector performance by the water service providers. Water strategic plans and policies towards improving access to household water demand and distribution are affected by political differences, limited funding by the government and dilapidated infrastructure. Climate change presents a significant concern for the availability, access and quality of water resources, particularly in Africa (Ziervogel et al., 2010).

South Africa on the continent is generally a semi-arid to arid country which experiences a highly variable climate and limited freshwater resources (Adewumi, 2010). With such limitation water resources are vulnerable to the occurrence of extreme weather conditions, often caused by climate variability and change. Droughts are an example of such extreme events weather conditions, which the potential result in to the significant adverse socio-economic impacts. South Africa is vulnerable to the occurrence of drought as the results of its location, topography and generally low rainfall (national annual rainfall average of approximately 500mm) (LeComte, 2016). During 2015-2016 the country has been severely affected by the El Nino drought, the adverse effects of which are still being experienced (LeComte, 2016). Long-term rainfall records collected by the South Africa weather services (SAWS) indicates that the annual total rainfall for south Africa for the period January-December 2015 (403mm), has been the lowest since 1904.

This current study argued that water resource has been significant pressured by the occurrence drought for supply and use, especially in rural areas. South Africa drought is unique phenomenon that is not merely affecting activity on agriculture however also on rural domestic water demand and use contributing society. Drought can be describes as a sustained and extensive occurrence of below average natural water availability, and can thus be characterized as a deviation from normal conditions of variables such as precipitation, soil moisture, groundwater and stream flow (Loukas & Vasiliades, 2004). Groundwater resource in alternated source and require protection and monitoring for sustainable use, at household local level in unmetered rural areas by putting appropriate plans in places that manage the abstraction (demand) and use (consumption).



11.9 Water Quality

Water quality has a limiting influence on the water usage per person. The impact of water quality on water use is related to the distance between the source and the home as well as the particular use of that water. Excessively high salinity, measured as total dissolved solids (TDS) or electrical conductivity (EC), in domestic water would significantly reduce the actual water use. In areas where TDS exceeds 1 500mg/l residents would prefer to purchase water for cooking and drinking from a water seller and use the salty water for other purposes. In many cases the hardness of the water is a problem and water for clothes washing is obtained at high cost from other sources in view of the difficulties of forming a suitable lather with salty water. High nitrates, which cause methaemoglobinaemia (blue babies) in young children, is seldom recognised by communities as a problem and therefore does not affect water use. Similarly high fluorides, which cause staining of teeth and crumbling of bone, is seldom recognised by communities as a problem and therefore does not affect water use.

11.10 Education

Education is considered to be an indicator of the potential to generate income. Without education, it is generally only possible to obtain unskilled positions. With higher levels of education, better employment opportunities are presented and consequently higher levels of income may be achieved. It is also considered that education may be a good indicator of the value orientation of the communities. With increased levels of education, expectations and the desire for improved living conditions is thought to increase. Information regarding education is available for the communities in each of the villages in KwaNdebele. A plot of education (% of the economically active community which has no education) versus average monthly household income shows a wide degree of scatter (refer to Figure 3). This is due to the fact that various other mediating variables play a role, e.g. age, experience and political influences. The small data set is considered insufficient to validate the statements made. A general trend is however discernable from the available information.

**12.0 WRM PERFORMANCE INDICATORS**

In order to compare and evaluate the planning alternatives within the scenario simulations a set of suitable indicators has to be selected. Recommended frameworks for selection or development of sustainability and IWRM indicator. Although valuable as starting point, it appears that the majority of general environmental indicator frameworks primarily concentrate on the development of simplified conceptual models and causal chains or networks. The purpose is hereby usually to narrow down very encompassing objectives, like “sustainable development” or “WRM”, to receive a structured set of categories and subjects of interest (e.g. Bossel, 1996). Consequently the number of proposed IWRM indicator sets comes close to the number of undertaken practical WRM studies in total. At the same time related studies point out that the quality of the indicator selections relies primarily on how precise objectives and decision questions can be defined (e.g. Besleme & Mullin, 1997; Bossel, 1999; Niemeijer & de Groot, 2008). Vague or overly broad problem formulations (e.g. “loss in biodiversity”) are of little use in selecting indicators (Segnestam, 2002). Ergo, the mentioned indicator frameworks mostly apply themselves to identify and order critical factors from the wide spectrum of theoretically possible things to assess in complex systems.

Readily available indicator sets on the other hand are either rather general or if specific usually hardly fit to the objectives of an explicit planning and decision situation. The actual selection of indicators was therefore organised in direct reference to the stated objectives and the catchment model and discussed during several sessions with project partners and stakeholders. Despite the well elaborated objectives, the selection was still not trivial and was guided by a range of quality. Naturally, the leading consideration has to be that of the actual purpose of the indicator, be it e.g. monitoring of current system states or trends, comparative developments on larger scales or specific performance of planned and undertaken actions in relation to goals and targets.

12.1 Goal Relevance

As the ultimate goal of strategic scenario planning is to support the decision making process, it is of primary importance that the selected indicators can be directly used as decision criteria for the objectives addressed.

12.2 Decision Maker Relevance

The usual range of different perspectives from scientist over practitioners to policy makers holds the risk for indicators missing the decision relevant information.

12.3 Clarity

It is important that indicators are unambiguously defined and offer clarity in their interpretation. For the decision maker this means a solid scientific basis as well as transparency of its underlying assumptions and meaning. This often means to find a balance between a complexity that fully covers a system element and ease of understanding.

12.4 Computability/Measurability

Naturally an indicator has to practically assessable and quantifiable (at least normatively) with appropriate means. In the Wadi Shueib use case this basically meant that the indicators should provide the possibility for simulation with the available model capabilities.

12.5 Number of Indicators

A very important criterion for decision making indicators that appears often neglected is the extent of proposed indicators sets. It is not unusual for indicator sets in the environmental assessment domain to comprise more than 50 or even above 100 recommended measures. There are perhaps two main reasons for this tendency on the one hand scientists understand indicators as a possibility to communicate their system understanding and modelling capabilities to the public and to policy makers. On the other hand, it is the attempt to thoroughly cover all aspects of a natural system and to minimize uncertainties, which almost unavoidably leads to an ever growing number of suitable measures. It is obvious, that in the case of real planning and decision situations an overly large set of indicators necessary to cover the intended objectives, consequently means a large set of decision criteria, which then may rather hamper the decision process. This perhaps also contributes to the common IWRM critique of over integration and being idealistic and non-achievable (e.g. (Biswas, 2004).

12.6 Non-Redundancy

Especially when intended as decision criteria it appears sensible, that the indicator set avoids redundancy in relation to the objectives in order to avoid a weight bias. Interrelations between indicators on the other are of no concern. The indicator set eventually selected for this study has to be understood as a minimum set with the purpose to directly and efficiently assess the objectives of the water strategy.

**13.0 PRINCIPLES OF IWRM**

13.1 Municipal Waste Water Treatment / Recharge Ratio

According to the stated objective of increasing the volume of captured and treated waste water this indicator comprises the assumed volume of total waste water produced with the amount of municipal waste water treated in centralised and decentralised treatment facilities, also including the volumes pumped from the septic tanks and cesspits in urban and rural areas.

13.2 Available Renewable Water for Internal Use

The annual per capita total renewable water resources volume is frequently used (in slightly different forms) as a direct measure for the resource pressure within a given area (Falkenmark, 1986; Gleick, 2003; UNEP/GRID-Arendal, 2008). Most of these indicators are assessed on a national or basin-wide scale and are often used for inter-basin comparisons regarding actual and future water stress and potential for conflict (Yoffe et al., 2003). Perhaps most often cited in this respect is Falkenmark’s Water Stress Index (Falkenmark, 1989) which divides a countries total available water resources in the form of net precipitation and water imports by its population and relates the resultant per capita availability to an estimated gross per capita water requirement (including household, agricultural, industrial and environmental needs). One of the main criticisms on the Water Stress Index is that it does not take the true availability for use, with respect to infrastructure, of the water resources into account, nor does it account for a countries ability to adapt and to find alternative water sources (Rijsberman, 2006).

These, however, are crucial points for water management planning studies. Accounting only readily developed (available for use) renewable resources gives a better image of the true resources development in an area which is desirable for assessing the strategic objective of maximising the availability. Thus, for this study the available resources were considered as the total sum of water volumes produced from renewable sources, including surface runoff, groundwater, reclaimed water and harvested rainwater. With regard to the sources and consequently the quality types the indicator comprises sub-indicators for groundwater, stored runoff and reclaimed water.

13.3 Water Supply Shortage Index

To assess the unmet demand of water supply it is important to consider quantity as well as frequency of supply shortages. The water supply shortage index was originally developed for dam operations to assess annual shortages over multiyear periods (Srdjevic, 1987). It is also convenient for to assess monthly shortages of any other supply framework as it acts as an indicator of both frequency and quantity of shortages.

13.4 Water Supply Requirement

In the light of Jordan’s current situation, where water demand exceeds available renewable resources, the establishment of adequate demand management measures appears vital for any future development. The stated objective of demand management might be misleading, as the essential goal is actually to reduce the amount of required supply. This may involve the reduction of “actual water demand” through various approaches (e.g. enhancing water awareness, water saving incentives and improved efficiency of domestic, irrigation and production technologies), as well as the decrease of required supply by internal reuse, water harvesting and the reduction of distribution losses and avoidable water wastages (Twort et al., 2000). In scarce environments, the actual water consumption is of course mostly dependant on the offered supply. Thus, in order to assess a supply requirement it is necessary to preliminary set a target volume for the actual use, in other words the water demand, e.g. the anticipated volume of per capita available water for domestic consumption or the volume necessary per agricultural area or production unit. Water efficiency enhancements or public water awareness programmes aim at directly reducing the water demand, whereas reuse and loss reduction efforts attempt to reduce required supply.

13.5 Full Water Service Cost

A basic economic measure to assess the cost effectiveness (also: least cost analysis) of alternative investment options in the water sector is the unit cost of supply and sanitation. It can be appropriately applied in cases with pre-set objectives, as e.g. with the anticipated water supply and sanitation goals in strategy planning. As “Full Service Cost” per supplied cubic meter at the demand site the unit cost has to include all capital, operation and maintenance costs for production, distribution, return flow collection and treatment. By accounting the unit cost at the demand side, distribution and return flow losses are merged into the cost figures.

Capital costs are typically annualized over the expected life span of an investment and combined with yearly operation and maintenance costs to account for the time value of money. The full service costs can easily be split into sub-indicators for water supply and sanitation costs by accounting only the particular infrastructures. It is important to note that the proposed cost indicator can only be understood as a relative metric for reflecting the influence of investment decisions on the direct water service costs within the boundaries of an autarkic system. In order to achieve a full economic cost assessment as well as an understanding of the economic value of the water resources it would be furthermore necessary to include the opportunity costs of alternative supply options as well as eventual economic and environmental externalities (Rogers et al., 1998).

13.6 Environmental Water Stress (with return flows)

Accounting for the environmental response to short or long-term water scarcity or water stress situations is difficult due to the multiplicity of involved factors as well as the natural adaption ability. An accepted concept in ecology is that the preservation of aquatic ecosystems should be considered according to their natural flow regime variability (Hughes & Hannart, 2003). Based on this assumption, Smakhtin et al. (2004) proposed a relatively pragmatic approach for defining the environmental water stress of a river basin by setting the actual runoff in relation to the natural high and low flow volumes. For that purpose they defined the environmental water requirement (EWR).

**14.0 WATER SECURITY**

The magnitude of the global freshwater problem and the issues related to it have been significantly underestimated. Around one billion people on our planet have unreliable water supplies; in addition, more than two billion people lack access to basic sanitation (Bigas, et al. 2012). In the historical perspective, national security in many countries was understood to mean military security but now this understanding has been developed to add the water element to the human security equation. This is because water can play a vital role in either international or national conflicts. As long as the underlying institutions and capacity are in place for such cooperation to happen, water tensions can also offer the chance for cooperation between countries (Prud’homme, 2011). Water security is essential for social and economic development in general and it is closely linked to food security. While water has an essential role in enhancing health, well-being and economic progress, particularly in developing countries, the most developed countries in the world face uneven water supply and quality problems that are also threatening their security (Bigas, et al. 2012). For instance, water availability in the USA is already considered as one of the inputs in the national security equation, where there is concern about the availability of sufficient water to meet the country’s water, food and energy needs. Furthermore, the problem has become more complicated as a result of water stress, which is expanding at the international level and particularly in mid-latitude countries that are already considered to be water scarce (Frank, 2006). This circumstance combined with increasing numbers of environmental migrants moving within and beyond national boundaries threatens and hinders important development progress in those countries. All cumulative and compounding water problems, affecting either quantity or quality, and their environmental impacts will eventually converge internationally. These impacts are exacerbated by increasing population growth, which causes competition for limited water resources.

In light of all of these problems, particularly water contamination, high standards of treatment with intensive and comprehensive monitoring are required (Dinar, 2004). Due to legislative congestion (Solomon 2010), along with rapid increase of population which have led to increase demand on the water, the world still faces a growing global water problem and this inactivity in the face of water crisis cannot be ignored. Therefore, to fill the gap in international water leadership, considerable urgency in creating new forms of hydro-diplomacy are required to address the root causes of the global water crisis and to address the lack of political will and effective governance (Solomon 2010). The magnitude of the global freshwater problem and the issues related to it have been significantly underestimated. Around one billion people on our planet have unreliable water supplies; in addition, more than two billion people lack access to basic sanitation (Bigas, et al. 2012).

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**15.0 ACCESS TO WATER**

Access to the water is one of the main limiting factors which inhibits the domestic water user from obtaining the full water requirement. In most villages and settlements throughout South Africa domestic unit water use is low and in many cases, this may be ascribed to poor access. Access to water is a function of source of water, systems type, queuing time at the water point, and is a function of the number of water points and population, walking distance.

15.1 Water Source

The sources of water from which domestic water may be obtained include streams, rivers, dams, springs, shallow wells, boreholes and rainwater harvested from roofs. In many villages and settlements, residents have access to more than one water source and in such cases, the water drawn from the various sources is used for specific purposes.

Spring water, would in such cases for example be used for cooking and drinking, whilst river water would be used for personal hygiene and clothes washing. Dams have in many instances been constructed on rivers to improve the reliability and extent of water supply. Dams provide storage which improves the reliability of water supply during periods of low flow or zero flow. Water drawn from dams is usually treated before being conveyed and distributed to the domestic water user. Access to such water is usually good.

15.2 Water Distribution System

A wide range of water distribution types are in common use. Access to the water from the various systems improves with the sophistication and level of distribution coverage, ie as the number of taps or abstraction points on the reticulation increases, so access improves and water use increases. In general, the water supply systems used include scooping directly from the water source where essentially no steps have been taken to provide abstraction facilities, through to the most sophisticated water supply systems where houses are fully reticulated with multiple taps provided in the kitchen, bathroom and garden.

15.3 Walking Distance

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| Walking distance may significantly increase the effort of drawing water for domestic purposes in terms of time taken to fetch water and energy expended in conveying the water. Evidence of excessive walking distance include washing being done at the source rather than at home and the extensive use of wheelbarrows which is aimed at reducing the burden of fetching water. It also needs to be borne in mind that a walking distance of less than 100 m may be classed as excessive should the gradient exceed 1: 8 to 1: 12. The walking distance is primarily a function of the water distribution system. Undeveloped springs, streams and wells are usually located relatively far from the villages and therefore systems where water is scooped directly from the source usually involves walking distances in excess of 500 m. Walking distances on street tap reticulation systems vary from less than 100 m in developments were extensive street taps have been installed to more than 500 m in cases where only a limited number of street taps were commissioned. In the latter cases, the number of people served by the street taps is also excessive and further restricts water use. The principle of Dublin statement stressed the importance of a water sustainable development plan in 1992, and put different countries in the world on a task to words the goal of working together to deal with water challenge within different stakeholders in the community to manage water crisis.  Therefore the example of Uganda’s approach to the community involvement and India’s on water supply management will be highlight in the discussion bellow. According to Mugisha (2004), there are not many variations in water supply systems; the raw water supply must be extracted, treated in some cases distributed and the system must be financed and managed by responsible sectors. Having a focused governmental sector is crucial for reform champions (Mugisha & Berg, 2008).  **16.0 INTEGRATED WATER RESOURCES MANAGEMENT PERSPECTIVE**  Integrated water resource management promotes the management of water at the catchment level by combining different management scales and the inclusion of multiple stakeholder (Blomquist, Dinar, & Kemper, 2005). IWRM can be used as a tool towards the achievement of sustainable development. IWRM is a concept which has developed over many years and many documents have attempted to define it. However, there still appears to be no unanimous, internationally accepted definition of IWRM. The most commonly used and well accepted definition however, can be found in the Global Water Partnership (GWP) Toolbox.199 The GWP defines Integrated Water Resources Management (IWRM) as a process which promotes the coordinated development and management of water, land and related resources in order to maximise economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems and the environment.  16.1 Objectives of IWRM  The main objective of IWRM is the management of water resources in a sustainable manner so as not to affect the functions of the ecological, social or economic systems that utilise the resource (Odendaal, 2002). The aim in formulating national water resources management strategy is to provide measures to manage the resources in accordance with adopted goals and policies. This development objectives involves the water resources assessment, policy and strategic framework, implementation plan, actions of implementation, monitoring and evaluation to meet the national development goals.    Integrated Water Resources Management (IWRM) | International Decade for  Action 'Water for Life' 2005-2015  The World Bank (1994) indicated that the final goals of national strategy do not need to identify specific investment projects, although it may outline or provide broad directions for an investment program. In addition, the water resources management strategy should emphasize such aspects of water development as the necessary institutional and human resources framework, and should address the medium- to long-term (5-30 years) issue of building or enhancing a country's water management capacity. Such a strategy should incorporate the views of water resources stakeholders by including them in the formulation process.  16.2 Elements of IWRM  The operational aspect of IWRM is integration. Integration itself is a complicated exercise (Anderson et al, 2008; Rahaman & Olli, 2005) because there are four dimensions involved: sectoral (and sub-sectoral) integration; geographical integration; economic, social and environmental integration; and administrative integration (water resource planning and management responsibilities). It therefore requires certain conditions to make it feasible. Implementing IWRM is then seen as a question of getting the “three pillars” right. That means moving toward an enabling environment of appropriate policies, strategies and legislation for sustainable water resources development and management; putting in place the organizational framework through which the policies, strategies and legislation can be implemented; and setting up the management instruments required by these institutions to function.    But practically getting the three pillars right may be a daunting task. These three pillars of IWRM are sometimes referred to as the scope of IWRM (GWP, 2004:38; Boutkan and Stikker, 2004:151). The first element, organisational roles, consists of: Creating a framework through which implementation is carried out from trans-boundary to basin level, and from regulatory bodies, to local authorities, civil society organisations and partnerships; developing human resources; upgrading the skills and understanding of decision-makers. The second, enabling environment encompasses three issues:    Figure **Error! No text of specified style in document.**.1 The “three pillars” of Integrated Water Resources Management (Jønch-Clausen, 2004).   * Policies   Developing appropriate policies, strategies, and legislation for sustainable water resources development and management.   * Legislation   Covering ownership of water, permits to use (or pollute) it, the transferability of those permits, and customary entitlements.   * Financing and incentive structures   Allocating financial resources to meet water needs (JonchClausen, 2004).  These pillars are seen as the broad elements of IWRM (GWP, 2004; Jonch-Clausen, 2004, Biswas, 1990). There are many crucial elements of IWRM which can be outlined which are:   * IWRM involves a regional, basin based approach to the management of fresh water resources. * IWRM involves the management of river basins through river basin organisations based on partnerships with municipalities and the provincial government. * IWRM links environmental, economic and social policy. * IWRM integrates all facets of water management while taking into account socioeconomic and environmental objectives. * IWRM incorporates environmental considerations and public participation in planning in a systematic manner. * IWRM requires co-ordination between all bodies responsible for development of freshwater resources. * IWRM is strongly related to the concept of sustainable development in that they both seek the integration of social, economic and environmental factors into planning, implementation and decision making. * IWRM provides for a holistic approach to the management of freshwater resources. * IWRM states that water should be recognised and managed as an economic good. * IWRM links land and water uses across the whole of a catchment area or groundwater aquifer. * IWRM integrates surface water, groundwater and the ecosystems through which they flow. * IWRM provides for increased co-operation in the management of entire river basins. * IWRM requires integration of sectoral water plans and programmes within the framework of national economic and social policy.   16.3 Principles and Theories in the IWRM  Integrated Water Resources Management (IWRM) has become a critical issue because both population and economy are growing, bringing an increasing demand for freshwater along with an increase in pollution due to human activities. Whereas the amount of available water in the hydrological cycle remains constant, this increasing demand for freshwater resources results in increased competition for the limited water resources. The role of water as a social, economic, and life-sustaining good should be reflected in demand management mechanisms and implemented through water conservation and reuse, resource assessment, and financial instruments. The concept of IWRM is linked to the principles adopted by the Dublin Conference on Water and the Environment (ICWE 1992) and (UNCED 1992).  This is however contested. It is argued that the United Nations Conference, held in Mar del Plata in 1977, which was endorsed by all member governments, had more to say on IWRM than the Dublin Conference, which did not even have any governmental approval (Biswas, 2004). The Dublin principles are presented below:   * Water is a finite, vulnerable and essential resource which should be managed in an integrated manner. * Water resources development and management should be based on a participatory approach, involving all relevant stakeholders. * Women play a central role in the provision, management and safeguarding of water. * Water has an economic value and should be recognized as an economic good, taking into account affordability and equity criteria.   16.4 Dimensions of IWRM  Van der Zaag (2001) said "Integrated water resources management seeks to manage the water resources in a comprehensive and holistic way. Hence, engineering, economic, social, ecological and legal aspects need to be considered, as well as quantitative and qualitative aspects, and supply and demand. Moreover, also the management cycle such as planning, monitoring, operation & maintenance, needs to be consistent". It, therefore, has to consider the water resources from a number of different dimensions. Due to the nature of water, integrated water resources management has to take into account of the following four dimensions and illustrated in figure (2.3) and as stated in Savenije (2000):   * The water resources, taking the entire hydrological cycle into account. * The water users, all sectoral interests and stakeholders. * The spatial scale, which includes the spatial distribution of water resources , uses and the various spatial scales at which water is being managed, as the individual user, user groups, watershed, catchments, international basin; and the institutional arrangements that exist at these various scales. * The temporal scale: taking into account the temporal variation in availability of and demand for water resources, but also the physical structures that have been built to even out fluctuations and to better match the supply with demand.   1. Integrated Water Resources Management Characteristics      * + 1. IWRM is a balancing process among other things; it coordinates the development and management of water and other related resources, with the objective of attaining water security and sustainability. (GWP, 2002). IWRM is an iterative method, in which implementing one policy or management tool may result in the need to modify others. It requires vision and political will to introduce, but with careful consultation and preparation can bring rich rewards. Because water is pervasive throughout the economy, almost all-national economic and social policies could have major impacts on water use. (GWP, 2002).     2. IWRM is a process of change from unsustainable to sustainable resource management.     3. IWRM promotes a holistic view, where it looks at the entire hydrological cycle and the interaction of water with other natural and socio-economic systems. The same water can serve many different purposes, in different places. However, the planning and operation of water systems is usually fragmented, causing a lack of co-ordination, waste and conflict. Moreover, water is frequently neglected when decisions are made about crop patterns, trade and energy policies, and urban design and planning, all of which are critical determinants of water demand. The sustainable use of the resource calls for the creation of institutions and systems that can transcend these traditional boundaries.     4. Integration: IWRM is based on perception of water as an integral part of the ecosystem, a natural resource and a social and economic good, whose quantity and quality determine the nature of its utilization. The integration approach has to incorporate policy options that recognize these element, develop national water polices and to base the demand for the allocation of water resources on equity and efficient use (Al Radif, 1999).     5. Economic Value: The concept of water as an economic good is distinguished clearly between the value of water, the allocation processes, and pricing, which are a part of the cost recovery issue. The economic value of water is highlighted within the IWRM through a greater stress on demand management rather than supply-side actions, a recognition (and estimation where possible) of the economic value of water in different uses, acceptance of the notion of opportunity cost (what is lost to other uses from taking it for a particular purpose) and attention to cost recovery, though with concern for affordability and securing access for the poor. (GWP, 2000b).   16.6 Integrated Water Resources Management Components  IWRM deals with water resources in the broadest possible manner. It has to look at water resources in the context of the entire economic-, social- and eco-systems of the nation or region. Operationally this means that policies and programs in other resource areas have to be carefully analysed to see how they will influence demands placed upon the water sector. The following are components of IWRM:  16.6.1 Economic Efficiency  Economic instruments – using value and prices for efficiency and equity. This holds a set of economic tools involving cost effectiveness and cost benefit for water resources to meet appropriate demand for water users. In addition to the use of different prices and other market-based measures to provide incentives to consumers and to all water users to use water carefully, efficiently and avoid pollution.  16.6.2 Equity  16.6.3 Environmental Sustainability  16.6.4 Management Instruments  The practical management tools required will vary from situation to situation. One of the central IWRM challenges is to find the right mix of management tools. Such tools range from water resources assessment, demand management, social change instruments, conflict management, regulatory instruments, economic instruments and information and communication instruments. This calls for capacity building to nurture, enhance and utilize the skills and capabilities of human resources and institutions at all levels so that they can function effectively and contribute significantly to the attainment of the goal set out for IWRM. Water resources assessment – understanding resources and needs. Assessment starts with the collection of hydrological, physiographic, demographic and socio-economic data, and setting up systems for routine data assembly and reporting.  Water resources assessment – understanding resources and needs. Assessment starts with the collection of hydrological, physiographic, demographic and socio-economic data, and setting up systems for routine data assembly and reporting. Plans for IWRM – combining development options, resource use and human interaction. The planning should recognize the need for parallel action plans for development of the management structures. Demand management – using water more efficiently. Demand management involves a set of tools for balancing supply and demand focusing on the better use of existing water withdrawals or reducing excessive use rather than developing new supplies.  Social change instruments – encouraging a water-oriented civil society. Information is a powerful tool for changing behaviour in the water world, through school curricula, university watercourses and professional and mid-career training. Transparency and product labelling are other key aspects. Conflict resolution – managing disputes, ensuring sharing of water. Conflict management has a separate compartment here since conflict is endemic in the management of water in many countries and several resolution models are described. Regulatory instruments – allocation and water use limits. A set of tools on regulation is included covering water quality, service provision, land use and water resource protection. Regulations are key for implementing plans and policies and can fruitfully be combined with economic instruments. Information management and exchange– improving knowledge for better water management. Data sharing methods and technologies increase stakeholder access to information stored in public domain data banks and effectively complement more traditional methods of public information (GWP, 1999).  16.6.5 Enabling Environment  The enabling environment comprises national, provincial and local policies and legislation. These constitute the ‘rules of the game’, which enable all stakeholders to play their respective roles. Polices – Setting goals for water use, protection and conservation. Policy development gives an opportunity for setting national objectives for managing water resources and water service delivery within a framework of overall development objectives. Legislative framework – the rules to follow to achieve policies and goals. This includes tools for use in the development of water law. Water law covers the ownership of water, the permits to use (or pollute) it, the transferability of those permits, and customary entitlements and underpin regulatory norms for as conservation, protection, and priorities. Financing and incentive structures – allocating financial resources to meet water needs. The financing needs of the water sector are huge, water projects tend to be indivisible and capital intensive, and many countries have major backlogs in developing water infrastructure.  16.6.6 Institutional Framework  Regarding governing and institutional roles, clear delineation of responsibilities between actors, separation of regulation from service provision functions, adequate coordination mechanisms, filling jurisdictional gaps, eliminating overlaps and matching responsibilities both to authority and to capacities for action are all parts of institutional development.  Creating an organizational framework – forms and functions. Starting from the concept of reform of institutions for better water governance, to the needed organizations and institutions, from trans-boundary organizations and agreements, basin organizations, regulatory bodies, to local authorities, civil society organizations and partnerships. Institutional capacity building – developing human resources. This includes tools for upgrading the skills and understanding of public decision- makers, water managers and professionals, for regulatory bodies and capacity building for empowerment of civil society groups. (GWP, 2003).  16.6.7 IWRM Model  The IWRM model includes a distributed hydrological model, land surface process (LSP) model, groundwater model, water quality model, sediment transportation model, food chain model, crop growth model, reservoir operational model, socio-economic model. This model is integrated because they are closely associated with water cycle model. The model incorporates natural activities, human made activities, social and economic activities. This model can be used in various systems like water resources management system, water planning system, water risk management system, climate change, water network management system, agricultural management system and wastewater management system.  image1    **17.0 LEGISLATIVE FRAMEWORK FOR IWRM**  17.1 Constitution of the Republic of South Africa (Act 108 of 1996)  According to Rabe *et al.* (2012: 3), the world’s freshwater supply faces challenges relating to quality, quantity and potential conflict over shared international water resources. Potential water related conflicts are fuelled by shared water resources among different countries, such as the existing Nile River conflicts. Again, increasing population growth, together with accelerated economic development, urbanisation and industrialisation are resulting not only in increased water demand, but an upsurge in return flows, pollution loads and solid waste. This places ever increasing pressure on limited freshwater resources (Rabe *et al.,* 2012). In light of this challenge, the South African Government introduced a number of legislative and policy frameworks aimed at responsible management of freshwater as a scare resource.  The right to water found in the constitution has been substantiated by two main acts called the Water Service Act (WSA) and the National Water Act (NWA) (Gowlland-Gualtieri, 2007). The constitution assigns the responsibility of management of water resources to the national government while local governments (municipalities) are responsible for the management of water and sanitation services. Accordingly, the NWA creates a comprehensive legal framework for the management of water resources, these being rivers, streams, dams and groundwater, which are the responsibility of the national government (Gowlland-Gualtieri, 2007). Section 24 of the Constitution states that all citizens of South Africa have the right to an environment which is not harmful to their health and well-being, an environment which is protected and sustained by reasonable legislative criteria (RSA, 1996). These reasonable legislative criteria include measures that prevent pollution and ecological degradation, promote conservation and secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.  The Constitution of the Republic of South Africa, 1996 Chapter two of the Constitution of South Africa 1996 contains the bill of rights that is the foundation of social equality in South Africa. Section 7(2) of this constitution clearly articulate that; it is the government’s duty and obligation to obey these this right through the realization of its objective in the bill of rights (Thompson et al., 2001). This constitution also preserves equal right. Section 9 of this constitution also protects a person from unfair discrimination irrespective of, ethnic group or social origin thus, everyone is equal before the law.  Furthermore, section ten of this constitution protects the right to human dignity (Thompson et al., 2001) and this constitution also preserves the right to health care, food, water and social security. According to Scanlon et al. (2004). Subsection two of this section articulates that the government is obliged to ensure that all these rights are fully and effectively realised. Section 74 (2) (c) of the Municipal Systems Act, 32 of 2000, as amended, entails that the municipality must deliver basic services over a variety of steps. For example, the Free Basic Water Policy was adopted by South Africa in 2000 in order to provide sufficient water for all its citizens. In terms of the policy, the mandatory water quantity per month is six thousand litres per person which makes the quantity of 25 litres for everyone each day within the family of eight and the least possible distance is 200 meters (Hall, Leatt and Monson 2006:58). This establishment is directed to the underprivileged people. The Municipalities govern this provision by having an indigent policy in place for people who qualify to fill the necessary form for them to get a rebate (Msangi et al., 2007).  In order to meet the aforementioned water management challenges South Africa has an extensive body of environmental law and policy which has an influence on the management of freshwater resources. These include, inter alia, the Constitution of South Africa, the National Environmental Management Act (NEMA), the National Water Act, the Water Services Act, conservation legislation, land use planning laws, mining legislation and relevant regulations and policy documents. Together these documents provide for the management of South Africa’s freshwater resources. An analysis of this legislation and policy, and a comparison with the concept of IWRM as discussed above will enable an assessment of the extent to which South Africa includes the concept of IWRM into its water management regime as it appears on paper. The Constitution is the supreme law of South Africa. It contains fundamental rights which have an impact on water management and contributes to South Africa’s inclusion of IWRM into its law and policy.  One of the main objectives of IWRM, as stated above, is to satisfy the freshwater needs of all people. Similarly the Constitution provides for the right to access to sufficient water and that the state must take measures within its means to achieve the progressive realisation of this right. This is a remarkably similar objective to the overall objective of IWRM as stated in Agenda 21. This Constitutional provision further provides that the state is under a duty to take reasonable measures to achieve access to sufficient water; accordingly, there is a duty on the state to take reasonable measures to achieve one of the primary goals of IWRM.    Section 24(b) is of most importance to IWRM; it essentially states that the state is under a duty to protect the environment through reasonable measures that prevent pollution and ecological degradation, promote conservation and secure ecologically sustainable development of natural resources while promoting justifiable economic and social development. This section provides for protection of the environment and sustainable development, and as seen above these are integral aspects of IWRM. IWRM inter alia requires the freshwater resources be developed and maximised, taking into account socioeconomic factors while protecting the environment. This is essentially the sustainable development of freshwater resources.  The inclusion of some of the most crucial elements of IWRM in the South Africa’s environmental right is a positive sign for the inclusion of IWRM in South African water law. Importantly these Constitutional provisions relate to the protection of the environment as a whole; every aspect of the environment should be protected and managed in a sustainable manner. Thus if land, water and other resources were all managed accordingly then land based pollution and effects on freshwater resources would be taken into account when deciding how to develop land. In this way the Constitutional provisions above indirectly provide for linkages between land and water based management, a strong element of IWRM.  17.2 National Water Act (Act 36 of 1998)  The Act brought about a major shift in water resources management in South Africa, by recognising that water is a natural resource that belongs equally to all people in South Africa. Therefore, it highlights the important role of stakeholder participation in water management by promoting the equal involvement, participation and decision-making of all stakeholders at different levels. It fosters water management at the lowest possible level through decentralised decision-making by established catchment management agencies (CMAs) to reach previously disadvantaged communities and to address race and gender inequities (DWAF 2008, KOPPEN ET AL. 2002). Hence, the NWRS is about putting the policy and laws of the national water governance of the DWAF into practice, by addressing social equity and economic growth, without compromising environmental sustainability (see DWAF 2012). To control water use and pollution in the country, the NWRS includes the economic tool of Water Licensing, which covers all aspects of licensing and permits related to water abstraction in South Africa. It is a legal tool to control water abstraction between different water users from low water users with a minimal risk to impacting water resources, to middle water users until high-volume water users such as in agriculture andindustry which have a very high risk of impacting water resources. It aims to obviate water over use, which may have negative impacts on catchments and other water users. Water licensing aims to create fairer water allocation between different users, thus promoting more efficient water use and hence, ensuring the sustainable management of water resources (DWAF 2008). It is compulsory for every new water user (small water users such as subsistence farmers) or covered by a general authorization, to apply for a license. Priority areas represent stressed catchments, where water demand exceeds water supply, such as the Orange-Senqu river basin (DWAF 2008). The National Water Act also includes the Free Basic Water Policy, which was introduced in 2000. This social tool addresses the basic human water needs of poor people in South Africa, who cannot afford to pay for water.  It aims to contribute towards the government’s fight to eradicate poverty. The government guarantees 25 litres per person, per day of domestic water provision, or respectively 6000 litres per month of free water per household. Water use exceeding 6000 litres per household, are then charged according to stepped tariffs. This policy formally ensures that everyone can have access to sufficient and clean water, but the implementation is the responsibility of the local governments. Besides providing a basis amount of free water per household, the government has committed itself to provide appropriate infrastructure to bring water to an adequate distance from poor people’s homes, so as to achieve a minimum state of welfare (KOPPEN ET AL. 2002). Only with adequate infrastructure can the implementation of the NWA be guaranteed (FAO 2001). In light of this challenge, the South African Government introduced a number of legislative and policy frameworks aimed at responsible management of freshwater as a scare resource.  South Africa's National Water Actof 1998, provides the legal national framework for the effective and sustainable management of South Africa’s ground and surface water resources; in terms of their protection, use, development, conservation and control, in an integrated manner (DWAF 2004, DWAF 2008). As historically, water resources were unequally distributed during the apartheid in South Africa, the policy of the new government tried to address those inequalities by ensuring the unprejudiced water allocation throughout the Republic, to satisfy the basic needs for all inhabitants (FAO 2001, KOPPEN ET AL. 2002). The new National Water Act was formulated during and immediately after the apartheid era and completely replaced the previous Water Act from 1956. National Water Act (NWA). The NWA of 1998 is the principal legal instrument related to water resources management in South Africa (DWAF, 2004). Under the auspices of the Department of Water Affairs and Forestry (DWAF), it was drafted based on a thorough review process, including research of water management in other countries and inputs from public participation forums (Waalewijn et al., 2005). The National Water Act highlights the essential role that water plays for social and environmental justice and promotes the overall goal to achieve sustainable economic, social and environmental development through integrated water management approaches (FAO 2001, KOPPEN ET AL. 2002). In order to put the National Water Act into practice and to ensure efficient and sustainable water management, the first National Water Resource Strategy(NWRS) was published in 2004. According to MUNNIK (2011), the National Water Act requires the Minister to establish a NWRS, which must provide information about how water resources will be managed and about the establishment, function and power of the institutions that will manage water resources within the country. It presents the instruments by which to plan, develop and manage water resources in an integrated and sustainable manner, across all sectors, so as to achieve national development objectives (DWAF 2012, FAO 2001). |

It changed and modernized the legal and institutional framework for water management in South Africa by replacing the 1956 Water Act. In line with the general objectives of water policy reform in South Africa, the Act also seeked to redress imbalances of the past. The three major principles for water management are underscored in the National Water Act: equity, sustainability and efficient and beneficial use for the society. Following specific key elements of the National Water Act, which will guide water management in South Africa in the coming years, are identified. First, the status of the nation’s water resources as an indivisible national asset was confirmed and formalized: all water resources belong to the nation and the national government is entrusted to act as the custodian of the nation’s water resources (Oosthuizen, 2002; Mukheibir and Sparks, 2003; Waalewijn et al., 2005).

A second important innovation in the NWA was that environmental water demands and demands for basic human needs are guaranteed as a right. They should be protected within an allocated volume known as the Reserve (Waalewijn et al., 2005). Thirdly a new system of allocation was conceived. The system will use water pricing, limited term allocations and other administrative mechanisms to bring supply and demand into balance in a manner which is beneficial to the public interest (Oosthuizen, 2002). In this context, the riparian system of allocation, in which the right to use water was tied to the ownership of land along rivers, was abolished and replaced by a system of limited-period and conditional authorizations to use water (Nieuwoudt, 2002). The Act furthermore contains provisions to enable the transfer or trade of these water use rights between users.

To promote the efficient use of water and to achieve cost recovery, users will be charged the full financial costs of providing access to water, including infrastructure development and catchment management activities (Oosthuizen, 2002; Perret and Geyser, 2007). The new legislation has also changed the institutional context of water management. The aim of establishing new institutions was to delegate water resources management to regional and localised levels, to involve stakeholders in water resources management and thereby give effect to integrated water resources management (Karodia and Weston, 2000). These objectives are in line with two cornerstones in South African constitution: first the principle that people should be able to participate in the decision-making process as and when it affects them and second the subsidiary principle, whereby functions that can be more efficiently and effectively carried out by lower levels of government should be delegated to the lowest appropriate level (Mac Kay, 2003). Catchment Management Agency (CMS) possess management authority in its specific water management area.

For this area they are expected to progressively develop a CMS to secure the protection, use, development, conservation, management and control of water resources. These strategies have to be in alignment with the National Water Resource Strategy. The CMAs, which are placed directly under the Minister of Water Affairs and Forestry, will be governed by a Board and have the role of seeking agreement on water related matters among various stakeholders. This Act is implemented by the Department of Water Affairs (DWA) and gives a legislative framework to the way in which water resources are developed, managed, used, protected, conserved and controlled. Along with these aspects, there are other important factors such as geo-hydrological activities of identifying, surveying and mapping (demarcating) the nature and extent of a specific water resource, that need to be considered even before the water resource can be protected, used, developed, conserved, managed and controlled (Nealer & Raga, 2008b).

The aim of the NWA has been to introduce integrated water resource management to South Africa through a process that focuses on the meeting of basic human needs, equity in access, facilitating social and economic development, protection of the aquatic and associated ecosystem, reducing and preventing pollution and degradation and meeting international obligations (RSA, 1998b). The National Water Act (NWA) is South Africa’s primary legislation dealing with the management of freshwater resources. The preamble of the Act recognises that South Africa is a water scarce country with many water management challenges. It recognises that the ultimate aim of freshwater resources management ‘is to achieve the sustainable use of water for the benefit of all users’, it recognises the need to protect the quality of water resources to ensure 

sustainability, and the need for ‘integrated management of all aspects of water resources’ and lastly, it recognises the need for regional management of water resources on a catchment level. Although these provisions are contained in the preamble of the Act and are thus not enforceable, they do point out the objectives of the Act all of which greatly resemble the principles of IWRM. The NWA’s purposes are to ‘ensure that the nation’s water resources are protected, used, developed, conserved, managed, and controlled in ways which take into account amongst other factors. These factors for consideration bear a similar resemblance to many of the core principles of IWRM. The NWA here provides for a list of considerations which need to be taken into account in every aspect of freshwater resources management.

The list itself is extensive, containing a variety of considerations however; this is not a closed list indicating that all other relevant considerations should be taken into account in the management of freshwater resources. This approach is reminiscent of sustainable development in terms of NEMA and IWRM’s holistic approach to the management of freshwater resources. Although not specifically mentioned, it is clear from the application and content of these considerations that the NWA seeks to achieve an integrated approach to freshwater resources management. NWA provides for the establishment of water management strategies. Firstly, the Act provides for the establishment of the National Water Resources Strategy (NWRS), which provides for guidance on the management of freshwater resources across the country as a whole. It also serves as a framework for regional, or catchment level management of freshwater resources.

The NWRS deals with very similar content to the NWA; however it gives effect to and expands on its provisions. The NWA also provides for the establishment of catchment management strategies (CMSs); these strategies are to be developed for the management of freshwater resources on a regional or catchment level. CMSs must be in harmony with the NWRS, one of the main objectives of the development of CMSs is to seek co-operation and agreement on water-related matters from various stakeholders and interested persons. Not only are these strategies themselves inclusions of IWRM principles, but one can also see that the integrated approach in the aforementioned legislation must be passed down to regional policy.

17.3 Water Services Act (Act 108 of 1997)

This Act defines the role of water service authorities (municipalities, water service institutions, water boards) and minimum standards for basic water and sanitation services – giving expression to the principle of equity. One of the main objectives of the Act is to provide the right of access to basic sanitation and water supply along with an environment that is not harmful to human health or well-being. When taking this objective into consideration, it is important for authorities to ensure the quality of water provided to the community is of such a nature that it is not harmful to an individual’s health and well-being. This is to be taken into account in the management of the water for Aliwal North community with regard to water scarcity. The Water Services Act, 108 of 1997 stipulates that all spheres of government must provide water supply services in an efficient, equitable and sustainable manner. The Act also requires municipalities that have been given water services provider status to provide measures to promote water conservation and demand management.

Such activity should be included in the municipalities WC and WDM Strategy and Business Plan as well as the Water Services Development Plan (WSDP). The water services Act 108, of 1997 is responsible for the rights of access to basic water and sanitation. Furthermore, this Act also ensures the establishment of Weatherboards and water services committees. The rights of access to basic water supply and basic sanitation that will guarantee the atmosphere that is not detrimental to society necessitate a responsibility to be recognized and realized. In terms of section 3(1) of the Water Services Act, 1997, every single individual has the right of accesses to basic water supply and sanitation. Subsections 2, 3 of this section stipulate that water services institution must ensure the successful achievement of this wright. Every water authority must in its water services development strategize and be responsible for the means to accomplish this right. Water provision must be non- discriminatory and justifiable the provision of water must be fair and equitable to the beneficiaries.

Section 4 (1) (2) of the Water Services Act 108, of 1997, makes it clear that water services must be provided in accordance with terms and conditions set by the water services provider. These environments need to be available to the community. Subsection (2) (C) provides for the conditions for payment, tariffs and the circumstances under which water services may be limited or discontinued must be made public to the citizens. The water panels and the water services authorities, as well as their jurisdictions, are clear in the stated in the above Act. The Water Services Act 108, of 1997, states, "every water services authority has a duty to all consumers" to provide water which is free from contamination. The water services experts include; the national, provincial and the local government. Conversely, about the Water Services Act, 108 of 1997, the obligation is with the local government to make water available to the people inside its region. Everyone has a right to access to clean water Republic of South Africa 1996 Act 108 of 1996.

In consequence, DWAF by means of guiding principle introduced the water supply and sanitation programme in 1994 with an intention to realize this constitutionally enshrine the right of access to sufficient water and healthy environment for all with the focus on the rural area. Moreover, the Free Water Policy was put into place in July 2001 and in 2004 approximately 155 of the 170 water service experts appealed to be providing Free Basic water. The objective aimed at in 2004 remained at 70% of the populace even though the concrete measurement of the entire population attended was 65% this reveals a slight underperformance (Burger, 2008). In 1998, the legislation approved the National Water Act of 1998. The Act intentions are to regulate and the use of water resources as well as safeguard them from pollution, obstruction, and exploitation. Moreover, to guarantee that every person has equitable access to them, to incorporate the administration of surface water and groundwater (Burger, 2008).

The implication of these guiding principles and Water Acts is to guarantee that the water service excess that occurred when the different constitutionally nominated government emanated to control is pointed out and that water provision must be a worldwide right and not for the special few as it was the case in the apartheid regime. The serious implication of these policy frameworks is to address the inequalities of the past with respect to delivery of water resource to all citizens. The Water Services Act of 1997, provides the regulatory framework and rights for the provision of basic water and sanitation services by the municipalities, water service authorities and providers to households and other municipal water users at local level (DWAF 2012, UNESCO 2010). The Act also contains rules for municipalities, about how they should provide water supply and sanitation services and provides norms and standards for tariffs (DWAF 2008). Both, the National Water Act from the national level and the Water Services Act from the local level provide legal instruments and the legal framework with which to manage water resources and water services sustainably (DWAF 2012).

The water services Act 108, of 1997 provides for the rights of access to basic water and sanitation. The establishment of Water boards and water services committees are also provided for in this Act. The rights to access to basic water supply and basic sanitation that will ensure the environment that is not harmful to society must be realized. In terms of section 3(1) of the Water Services Act, 1997, everyone has the right to accesses to basic water supply and sanitation. Subsections 2, 3 of this section maintain that very water services institution must take reasonable measures to realize these rights. Every water authority must in its water services development plan, provide for measures to realize this right. The provision of water must be fair and equitable to the members of the public. Section 4 (1) (2) of the Water Services Act 108, of 1997, provides that water services must be provided in line with terms and conditions set by the water services provider. These conditions must be accessible to the public. It provides for the conditions for payment, tariffs and the circumstances under which water services may be limited or discontinued must be made public to the citizens. The water boards and the water services authorities as well as their jurisdictions are well explained in the above Act. The Water Services Act 108, of 1997, states that “every water services authority has a duty to all consumers” to provide water which is free from contamination. These water services authorities include; the national, provincial and the local government. However, according to the Water Services Act, 108 of 1997, the onus is with the local government to provide water to the communities within its jurisdiction (Louw 2003:107). The Water Services Act (WSA) essentially gives effect to the right to access to water in the Constitution.

It has its objects in, inter alia, providing for the right to access to a basic water supply and the right to basic sanitation and for an environment that is not harmful to human health and wellbeing. The Water Services Act, 108 of 1997 stipulates that all spheres of government must provide water supply services in an efficient, equitable and sustainable manner. The Act also requires municipalities that have been given water services provider status to provide measures to promote water conservation and demand management. Such activity should be included in the municipalities WC and WDM Strategy and Business Plan as well as the Water Services Development Plan (WSDP). The water services regulations emanating from the Water Services Act, 108 of 1997 reiterate the importance of water conservation and water demand management by stipulating the following:

17.3.1 National Water Resource Strategy 2nd (NWRS2)

National Water Resource Strategy 2nd (2013) sets out how the country will achieve the core objectives of water that supports development and elimination of poverty and inequality; water that contributes to the economy and job creation; and water that is protected, used, developed, conserved, managed and controlled sustainably and equitably. The major focus of the NWRS2 is equitable and sustainable access to and use of water by all South Africans while sustaining our water resource. Equity and redistribution will be achieved through the authorisation process and other mechanisms and programmes such as water allocation reform, financial support to emerging farmers and support to urban and rural local economic development initiatives. The NWRS states that with growing population, and focus on economic growth and development, there is a need to ensure water security and healthy water ecosystems able to support national imperatives.

Apart from the water demands of the economic sectors – energy, mining and agriculture, increasing urbanisation and industrialisation put enormous pressure on scarce water resources in terms of management and allocation (National Water Resource Strategy 2nd, 2013). Despite well-developed water resources infrastructure with more than 4,395 registered dams, South Africa is rapidly approaching full utilisation of available surface water yields (National Water Resource Strategy 2nd, 2013). There is a need to find new ways of reducing water demand and increasing availability, and such innovative measures will have to move beyond traditional engineering solutions of infrastructure development (National Water Resource Strategy 2nd, 2013). As a consequence, future water resource planning. The management and investment require prioritisation of key interventions such as greater focus on WC and WDM initiatives where every drop counts and waste of water is reduced.

Increased research, investment and utilisation of ground water; prioritisation of wastewater reuse and investment in more storage systems such as dams, where opportunity exists. It deals with the investment in desalination of seawater as an alternative source of water and this can include small scale plants; treatment of mine water, especially in former and current mining areas; and prioritisation of catchment rehabilitation, clearing of invasive alien plants and rainwater harvesting. The Climate Change Response Strategy, which is part of the NWRS, is the national response to climate change for the water sector. The White Paper on the National Climate Change Response provides an integrated framework to minimise the impact of climate change and to maximise any beneficial impact. According to DWAF (2012), South Africa is both a contributor to, and potential victim of global climate change and is highly vulnerable to climate variability and change. Therefore, coping strategies will not only require mitigation measures, but also adaptations to current and future climate change impacts.

The Climate Change Strategy considers the vulnerability of people, the ecosystems and the economy and integrates them into both short- and medium-term water sector planning approaches (DWAF 2012). The three key objectives of the climate change strategy are therefore to address climate change in short- medium- and long-term water planning processes, to implement IWRM so as to maximise water security and resource protection under changing climatic conditions, and to reduce the vulnerability and enhance resilience to water-related impacts of climate change amongst communities and sectors at greatest risk (see DWAF 2012). NWA provides for the establishment of the NWRS, which seeks to achieve three fundamental objectives; equitable access to water and the benefits of the use of water; the sustainable use of water by striking a balance between water requirements and the need to protect water resources; and efficient, effective water use for maximum socio-economic development.

The NWA also provides that the NWRS must, inter alia, ‘promote the management of catchments within a water management area in a holistic and integrated manner. These objectives are all characteristics of IWRM and it is clear that South Africa seeks to manage its water in a manner consistent with many of the principles of IWRM. Importantly the NWRS informs all aspects of freshwater resources management throughout the country thus its principles should be widely applied. NWRS provides for resource-directed measures and source directed measures. It also briefly provides for the protection of groundwater resources and wetlands. The protection of freshwater resources is an important aspect of IWRM; not only does IWRM require a balance to be struck between environmental protection and socio-economic development, it also states that freshwater resources need to be protected for their sustainable use into the future. Control of water use to protect the environment here is done through the authorisation of water use, this may include general authorisations (for which no licence is required) or authorisations by way of water use licence, which may have a range of conditions attached to it.

Water use in terms of the NWA is broadly defined and includes almost any activity in relation to water, thus these strategies are important in controlling how, and how much water is used in South Africa and will accordingly be important in ensuring that South Africa’s water is in fact used in a sustainable manner as IWRM requires. These are essentially resource-based measures for the protection of freshwater resources. These strategies are based on the following principles; water institutions should seek to provide water efficiently and effectively, minimising losses; water users should strive for efficient water use; and water demand and conservation management should be an integral part of planning for water resources management. These strategies also provide for water conservation and water demand management strategies for various sectors which have a notable effect on freshwater resources, these include; agriculture, mining, industry power generation and education. In addition to providing for the protection of freshwater resources which has been mentioned often, these strategies also provide for the integration of water considerations into different sectors which affect the management of water.

17.4 The White Paper on Water Supply and Sanitation Policy

According to Muller (2012), Prof Kader Asmal announced this White Paper, MP Minister of Water Affairs and Forestry in the Republic of South Africa, This White Paper was made known to the public since water and sanitation were because they were essential to the RDP development. Over 12 million people lacked access to basic water and sanitation. On July 1, 1994, a new department called the Department of Water Affairs and Forestry imaged.



South Africa remained separated into eleven various homelands, six self-governing regions, and the main RSA region, administered by the tri-cameral parliament. In addition, all this took place just before the Department of Water Affairs and Forestry came into being. Water supply matter was to be addressed instantaneously after jobs and housing. The Republic of South Africa regrettably was experiencing inequality in water supply and consequently, the introduction of the White Paper on Water Supply and Sanitation was taking place. Towards the end of the nineteenth century, people were still experiencing severe inequality in terms of water supply services in South Africa. According to Machethe (2011), piped water supply, for instance, was between 95.4 and 100% for the Indians, whites and coloured. Only 43.3% of the black community had piped water to their households.

The maximum quantity of water in South Africa for that period was catered for white commercial agriculture, on the other hand, Section C of the of the Water and Sanitation Policy indicates that basic services together with the provision of water are a human right. In terms of the constitution of South Africa, 1996 everyone regardless of colour, race, and gender are the same before the law. For that reason, everybody is eligible to free basic water supply (Affairs and Forestry, 1994). In relation to the White Paper on Water Supply and Sanitation Policy (1994:14-15), the free basic water supply is well defined as 25 litres per person per day. This measures the least possible prerequisite for direct use, for the preparation of food and for personal hygiene. The least possible distance is 200 meters. The accessibility of water from the channel must not be less than 10 litres per minute (Msangi et al., 2007). The consumer of the water services must pay for this service. The South African government also embark on funding the underprivileged people that could not afford required payments.

The misunderstanding that may perhaps come out about the government support may be that everyone irrespective of the poor or rich, people might all want to benefit from the government. These may possibly turn out to be a problem for the department (NWA, 1998). The white paper is also responsible for the role of water panels as; acting of managers or representatives of DWAF at the provincial level (DWAF, 1998). The roles assigned to the water boards are the improvement of water supply and sanitation facilities at the regional level. The local water committees play a supportive role to the local democracy (Affairs and Forestry, 1994). The role of the national government is to make sure that, what is taking place at the grassroots level meets the average. Therefore, the role of central government is monitoring, performance auditing and regulating functions.

Furthermore, it is vital to associate women in all constitutional organizations, in the water segment as well as local water committees. It is in this white paper that the controlling of drought and other disasters is underlined. The white paper control irrigation boards because the historically, the South African water development was focused on irrigation and massive public assets were assigned to the development of water resources for the possessors of appropriate agricultural land. The owners of land started a very small amount of the population (Affairs and Forestry, 1994). In conclusion, this white paper inspires development that is demand driven and community-based. Monitoring and auditing are still within the authority of the central government (Affairs and Forestry, 1994). Provincial government improves and advances local government and local government implements. The water boards may also be responsible for services straight to the users in the nonexistence of local government.

To accomplish the objectives of this white paper, a united common undertaking of government, the private sector, NGOs and the communities is stimulated (Affairs and Forestry, 1994). According to Gleick (1998), section 27 of the constitution of the Republic of South Africa offers a right to health care, food and social security. Likewise, Gleick (1998), supports the statement on the South African Constitution (Act 108 of 1996) in Chapter 2 of the bill of rights and Section 24 that enshrines the right of everyone to have an environment that is safe to their health or wellbeing. Section 27 emphasizes the significant right that everyone has the right to have access to sufficient food and water and Social security, including appropriate social assistance. On the other hand, an unreserved commitment of the government responsibility or an obligation to make available health care, food and water service delivery are in demand.

The right to water condition point towards the states obligation to provide basic services merely to individual's components of the population deprived of the resources to guarantee the right to have health care, food, water and social security (Gleick, 1998). However, those who have resources by now indeed do have access to health care, food, water and social security, as they can manage to pay for them, and therefore are not entitled to these services from the state. Section 27(2) stipulates that the government needs to proceed with law-making and supplementary procedures, contained by the constitution to accomplish the progressive realisation of these rights. The constitution ensures accountability for instantly recognizable regulation as to the implication of adequate water. More significantly, to the concept of the quantity and quality of water for each of the single individual entitled to access and the significance is thus far to measure by a South African court of law (Gleick, 1998).

According to Bond and Dugard (2008), despite legitimate rights South African poor people are not fortunate to enjoy the equal rights on access to water as rich people. The authors argue that the rights have to consider that they are not far-reaching, and an argument relating to the restriction of such rights is consequently justified. The policy automatically discriminates against large poor households in which only the rich people must enjoy adequate access to water provision (Bond and Dugard, 2008). Likewise, the South African government employed the free basic water (FBW) policy in July 2001 to ensure that all South Africans had access to a basic amount of safe water by 2004 (Conteh, 2008). However, the FBW provision does not ensure the fundamental water supplies and special water necessities of most low-income households (Conteh, 2008). Low-income families need additional kilolitres than the 6-kb portion and are therefore expected to pay the full price for their water service.

According to the affordability crisis has not been addressed as tariff structures and cross-subsidization mechanisms remain inadequate. Bond and Dugard’ (2008) study shows the negative relationship with the existing systems within the country of South Africa, which is not the kind of market-friendly rights relationship or system that preserve poor people in water poverty. Furthermore, based on the confirmation of Bond and Dugard (2004) there is a need for an alternative approach and thorough examination to the existing policies that constitutionally-guaranteed human rights and look at the South African Constitution as the enhancement of human dignity and the realization of equal opportunity on access to free basic services. This helps to achieve the objectives of the study to describe the causes of water shortages and answers the question on the main challenges of water provisioning in the study. Moreover, it answers the question over the possible solution to ensure adequate water provision.

This also corresponds with the ideas postulated in the background of this study that although policies are in place and as good as, they are, people's right to a reliable water supply is not yet realized. The administrative system fails to implement, develop and manage water resource to ensure that this constitutionally enshrine right is observed. The argument below highlights the challenges facing urban and rural development and the supply of basic services such as water and sanitation in developing countries in general and South Africa. This is regardless of policy, law-making and institutional restructuring that has taken place since 1994. The current underperformances in the delivery of basic services enquire the root of policy origination and carrying out.



The consequential complications approximating the short supply of basic services such as water, sanitation, and the rapidly increasing of informal settlements in urban centres are often testified to poor policy implementation. These obstacles question the natural surroundings of relationships water and sanitation policies. The degree of incorporation and management in the implementation of such policies thus come to be open to discussion. This study is, therefore, an attempt to examine the challenges and its causes in the provisioning of water as the basis of the study.

17.5 The National Environmental Management Act(NEMA) (Act 107 of 1998)

NEMA provides South Africa’s environmental governance framework that secures the protection of the environment e.g. though addressing environmental pollution. The Act acknowledges that all elements of the environment are linked and interrelated, and takes into account the effects of decisions on all aspects of the environment and all people in the environment by pursuing the selection of the best practicable environmental option (DWAF 1999:12). The Department of Environmental Affairs and Tourism (DEAT) regulates this Act along with relevant provincial Departments of the Environment. The Act lays down basic environmental principles and makes room for cooperative environmental governance through the establishment of principles for public decision-making on matters affecting the environment. Principles such as Duty of Care, Polluter Pays and Sustainability are promoted (Annon, 2009a). In both the National Water Act (Act 36 of 1998) and the NEMA (Act 107 of 1998) pollution is defined as implying a human-induced change in environment that has an adverse effect on human health or well-being.

In both these Acts, it is evident that pollution must be prevented as far as possible and in instances where it does occur, all possible measures must be taken to prevent such pollution from continuing or returning. The National Environmental Management Act (NEMA) gives effect to section 24 of the Constitution. It seeks to achieve ‘co-operative environmental governance’ and to provide a framework for integrated environmental management in all decisions and development in South Africa. Sustainable development is a strong feature of NEMA, where it is described as the ‘integration of social, economic and environmental factors in the planning, implementation and evaluation of decisions to ensure that development serves present and future generations. Again one can see the similarities in the principles of IWRM and the provision for sustainable development in both NEMA and the Constitution. NEMA, being South Africa’s framework legislation for environmental management, contains many provisions relevant to the management of freshwater and in turn IWRM.

Firstly, NEMA provides for a set of Environmental Management Principles, which are important considerations to take into account in all environmental decisions. The application of these principles is extensive; they apply throughout the republic to all actions of all organs of state that may significantly affect the environment; serve as a framework upon which environmental management and implementation plans must be based on; they serve to guide the exercise of any function when making decisions in terms of NEMA; and lastly they serve to guide the interpretation, administration and implementation of any laws concerned with the protection of the environment. The NEMA principles are extensive in content and contain many provisions which are relevant to the management of freshwater resources and in particular IWRM. The NEMA principles state that environmental management ‘must place people and their needs at the forefront of its concern’ while serving their ‘physical, psychological, developmental, cultural and social interests equitably.

This provision speaks of many elements of IWRM; as seen above the overall objective of IWRM was to provide sustainable water to people, this would be placing people’s needs at the forefront of its concern. This principle also alludes to a holistic approach to environmental management, taking into account and balancing all contributing factors, another core principle of IWRM. The NEMA principles, like the Constitution, provide for sustainable development. However, the principles expand the concept of sustainable development by stating that it is a concept which requires consideration of all relevant factors. In particular the principles state that sustainable development requires that where there are negative impacts on the environment these should be avoided and where they cannot be avoided, they are minimised and remedied. The principles further state that the development or use on renewable resources should not exceed the level which would put them at jeopardy.

As mentioned above there are great similarities between the concepts of IWRM and sustainable development. The manner in which it is included in the NEMA principles not only reinforces this factor, but also adds to the understanding of the extent of considerations that need taken in achieving sustainable development. Another NEMA principle which deals with a core element of IWRM inter alia, states that ‘environmental management must be integrated, acknowledging that all elements of the environment are linked and interrelated. One of the defining elements of IWRM is that there must be recognition and links between the management of water, land and other resources, which NEMA provides for explicitly. This is a particularly important principle in the context of freshwater resources management as it is well accepted that water cannot be manage in isolation from the environment in which it exists and the people that interact with it.



There are many other NEMA principles which relate directly to the concept of IWRM including public and stakeholder participation in environmental governance; ‘intergovernmental co-ordination and harmonisation of policies, legislation and actions relating to the environment; the polluter pays principle; and the need to specifically protect sensitive, vulnerable, highly dynamic or stressed ecosystems. The NEMA principles accordingly introduce many aspects of IWRM into South African environmental law and management which will obviously also relate to the management of freshwater resources, thus South Africa’s water legislation and management must be guided by these principles. The importance of these principles lies in the extent to which they apply and in the value of their content. One of the goals of IWRM is to overcome the fragmented management of freshwater resources. This is also one of NEMA’s primary objectives in respect of environmental management generally. In order to deal with fragmentation NEMA provides for co-operative governance.

In addition to the aforementioned NEMA provisions relating to co-operative governance NEMA contains a chapter dealing with ‘Procedures for Co-operative Governance. Section 11 of NEMA essentially provides that certain government departments must prepare environmental implementation plans and further, that certain departments must prepare a consolidated environmental implementation plan. These plans should be made with the view of achieving consistency among plans. One can see that the purpose of these provisions is to, inter alia, ‘co-ordinate and harmonise the environmental policies, plans, programmes and decisions of the various national departments that may affect the environment. IWRM seeks to achieve co-ordinated development and planning; plans such as these (if implemented) will undoubtedly help to achieve a truly integrated environmental and water management.

Lastly, NEMA also has its purposes in achieving integrated environmental management. It does so by the inclusion of a chapter on this topic, the purpose of this chapter is to promote the application of appropriate environmental management tools in order to ensure the integrated environmental management (IEM) of activities. It further states that the objective of IEM is to promote the integration of the NEMA principles in all decision making that may significantly affect the environment; to identify, predict and evaluate the actual and potential impacts of the environment, socio-economic conditions and cultural heritage so that these impacts can be minimised while the benefits are maximised; to ensure that the effects of activities having an effect on the environment receive adequate consideration before such actions are taken; to ensure public participation; and to identify the best environmental management for a particular activity, in accordance with the NEMA principles. These goals have many similarities with the above outlined elements of IWRM. One can see that both IEM in (terms of NEMA) and IWRM both seek to achieve a holistic management model. NEMA seeks to achieve IEM through environmental authorisations. In this regard NEMA states that the ‘potential consequences for impacts on the environment of listed activities or specified activities must be considered, investigated, assessed and reported to the competent authority. Thus, where a person wishes to conduct a listed or specified activity they must apply for an environmental authorisation, the applicant must follow the procedure outlined in the 2010 Environmental Impact Assessment Regulations. It prohibits a person from commencing a listed or specified activity without the requisite authorisation. This process ensures that at least in respect of listed or specified activities environmental concerns will be taken into account if the process is followed in a suitable manner.

Section 24 previously stated that any activity that may significantly affect the environment should be subject to environmental authorisation. This is perhaps more appropriate if one looks at the requirements and application of the NEMA principles, it would also ensure greater protection of the environment and in turn water. NEMA has clearly introduced some of the core characteristics of IWRM into South African environmental law and management which will in turn have a direct influence on the water management policy of South Africa. The fact that NEMA applies to the environment as a whole is also important in the context of IWRM as IWRM seeks to integrate the management of all resources so that water can be effectively protected, thus by having one overreaching piece of legislation that guides all other environmental legislation is already a step towards achieving IWRM in South Africa. However, in order to completely assess South Africa’s inclusion of IWRM we must assess the relevant sectoral legislation.

17.6 Municipal Structures Act (Act 117 of 1998)

Chapter 5 of the Act provides a clear definition of the roles and functions of a specific municipality. The Act provides for a Category C (district) municipality to have the power and functions to administer the bulk supply of water that affects municipalities in the district (potable water supply systems, waste water and sewage disposal systems and solid waste disposal), whereas a Category B (local) municipality is only responsible for storm water management systems in its own jurisdiction area. The Minister for Cooperative Governance and Traditional Affairs after consultation with the Minister of Water Affairs and the members of the Executive Council responsible for the local government in a specific province could authorise a Category B municipality to exercise power with regard to their potable water supply systems (Nealer & Van Eeden, 2010). Looking at the important explanations given above, a paradox seems to exist in the legislation and its implementation, specifically with regard to water services management in the local government sphere of South Africa. Currently, in most cases, the Category B municipalities have been taking responsibility for their own bulk water supply in terms of potable water and the management of their grey water in their jurisdiction areas. These municipalities are directly connected to the water end users at a grass-roots level, but the Structures Act delegates the authority for water services management away from the Category B municipality and gives the authority to the Category C municipality in whose municipal management area the Category B municipality falls. The responsible Category C municipalities are often located very far away and do not have the capacity, skills or experience to manage the water services in order to be in line with the Integrated Development Plan of their respective Category B municipalities. This leads to confusion and grey areas where the respective municipal responsibilities are concerned, which in turn results in poor municipal management of the water services (Nealer & Van Eeden, 2010).

17.7 Municipal Systems Act (Act 32 of 2000)

In combination with the Municipal Structures Amendment Act (33/2000b) and Local Government, the Municipal Planning and Performance Regulations No. 7146 (2001), the Municipal Systems Act identifies a number of obligations for environmental management and sustainable development by local government that must be accommodated and reflected in the institutional framework and policies of a municipality (Pretorius, 2009). This Act defines the main principles, processes and mechanisms that are necessary to enable municipalities to progressively move towards social and economic upliftment of their respective communities. In this Act, the integrated development plan of a municipality is defined (Joubert, 2008).

**18.0 WATER CONSERVATION AND WATER DEMAND MANAGEMENT PRACTICES AND SOLUTIONS**

Cook *et al.* (2009) (cited in Fry, 2015) described water demand management (WDM) as a process or use of technology to promote the efficient and sustainable use of water. Cook (2009) argues that WDM is the most cost effective method of making more water available while reducing the growth rate of water demand. This could play a crucial role in decreasing the need for large scale investments in the future. As clearly explained in the Water Conservation and Water Demand Management Strategy (2004), water remains a precious resource needing to be utilised efficiently and sustainably before any consideration of new water resource development. The opportunities to increase water use efficiency are available across all water use sectors and require strong will and leadership. Accordingly, the following are some of the key interventions that can be considered as part of water conservation and demand management solutions:

18.1 Water Pressure Management

According to McKenzie (2014: 9), water pressure management remains one of the most important WDM interventions needing to be considered when attempting to drive down water losses and improve the success of WDM interventions. Notwithstanding this minimum level of pressure, leakages in the system are still caused by pressure. In this regard, the higher the pressure, the higher the possibility of leakages and the lower the pressure the lower the possibility of leakages. When pressure is systematically reduced, water leakages from the system are correspondingly reduced. It is imperative, therefore, to maintain an acceptable level of pressure in order to protect the system from leakages as a result of pressure. To this end, reducing water pressure can be achieved in a number of ways, such as those listed below:

*Fixed outlet pressure control*- involving the use of a device – a pressure reducing valve (PRV) – to control the maximum pressure entering a zone (McKenzie, 2014: 146).

*Time modulated pressure control*- this device can provide a further reduction in pressure during off-peak periods. This form of pressure control is useful in areas where water pressures build up during the off-peak periods (McKenzie, 2014: 146).

*Flow modulated pressure control*- provides flexibility and addresses any concerns regarding firefighting flow requirements because the controller will open up pressure if required to maintain the necessary system pressure to support increased flow (McKenzie, 2014: 146).

*Closed loop and hybrid control* **-** provides a pressure sensor at the critical point used to monitor water pressure. This provides some form of feedback to the controller at pre-defined intervals.

In some instances, it will record a full day of pressure information before transmitting the data to the controller, who will then adjust the pressure profile for the following day (McKenzie, 2014: 146).

18.2 Water Conservation

According to the National Water Resource Strategy 2nd (2013), water conservation is the minimisation of loss or waste, care and protection of water resources and the efficient and effective use of water, whereas WDM is the adaptation and implementation of a strategy by a water institution or consumer to influence the water demand and usage of water. Consequently, water conservation initiatives should aim to reduce usage of water and recycling of wastewater for different purposes, like domestic usage, agriculture, industries and businesses. According to the United Nations Environmental Programme (2009), the main goals of water conservation include the following:

*Habitat Conservation:*the aim of habitat conservation is to minimise human water use by helping to preserve freshwater habitats as well as reducing the need to build new dams and other water infrastructure.

*Energy Conservation:*the aim of energy conservation is to reduce the high demand for energy that is devoted to water management in terms of water pumping, delivery, and wastewater treatment facilities.

*Sustainability:*the sustainability approach aims to ensure availability of water for future generations by ensuring that the withdrawal of fresh water from an ecosystem should not exceed its natural replacement rate.

**19.0 THE CONCEPT OF THE ECONOMIC VALUE OF WATER**

Water resources are natural assets, the value of which resides in their ability to create flows of goods and services that are valued by society (Agudelo, 2001; Turner et al., 2004). Although not all authors use exactly the same classification, two broad categories of economic values derived from water can be distinguished, use values and non-use values (Agudelo, 2001; Turner et al., 2004; Comprehensive Assessment of Water Management in Agriculture, 2007). Use values are also known as extrinsic values or direct use values. They arise from direct interaction with water resources. As use has a number of dimensions (quantity, quality, timing and location), the values can be classified along these dimensions, specifying the water use under several different categories. There are three options are considered: by sub tractability, by location, and by economic role (Agudelo, 2001). First, according to their sub tractability water use values can be subdivided into consumptive and non-consumptive values. After consumptive use, water or some of its characteristics are not available anymore for use by others.

Because every water use has both quality requirements and quality effects, it is not just the reduction in the amount of water, which determines whether a use is consumptive or not. A reduction in any quality characteristics of that water, which otherwise could be beneficially used elsewhere, also makes a particular use consumptive. Non-consumptive use values include the benefits received by those who leave the water and its properties essentially intact for others to use. Examples of consumptive uses of water are: municipal and industrial use, agricultural use, wastewater transport and assimilation. Non-consumptive uses include: hydropower, fishing, most water based recreation, navigation. Another breakdown of uses is by location. The water uses that are occurring in a watercourse and that are dependent on its flow characteristics are called in stream uses (e.g. navigation, hydroelectric power generation, recreation and waste dilution).

Uses where the water is removed from the watercourse are called off-stream uses (e.g. municipal, agricultural and industrial water demand). Thirdly, in economic terms, according to its role in the production chain, water can be classified or defined as either an intermediate or a final good. An example of water as an intermediate good is the water use in the production of other goods or services, such as irrigation of crops or driving of turbines to make electricity. Alternatively, water can also be used as a final good by the final consumer in households or for recreational activities like swimming. The value of water used as an intermediate good depends on the ultimate value of the resultant goods or services, while the consumer’s uses of water provide direct utility and value. Non-use values constitute the second main category of water values. They are sometimes called intrinsic values, passive use values, or existence values. Non-use values are values placed on the existence of a resource and its physical, biological or cultural characteristics. They are not associated with any specific use.

Non-use values include benefits received from knowing that a good exists, even though an individual may not even directly experience it. Some authors like Turner et al. (2004) also include the bequest value and the option value within the non-use values. The fourth Dublin principle that water has an economic value in all its competing uses has been accepted by the advocates of IWRM as a pivotal principle (ICWE, 1992; GWP, 2000; Smith, 2004; Rahaman & Varis, 2005). Based on this economic good principle water is to be treated like any other natural resource, such as fisheries or minerals (Rogers et al, 2002:1; Jonch-Clausen, 2004). Generally, the argument is that the owner (the government, community or private party) should charge satisfactory fees for water use (Sewell and Biswas, 1986) and the price of the services provided by its development should reflect their costs. The interpretation of this principle generates considerable controversy (Berck, 1996; Shiva, 2002; Barlow and Clarke, 2002; McDonald and Ruiters, 2005; Savenije, 2002; Savenije and Van der Zaag, 2002).

There are two different interpretations given to this principle. First, economists argue that water should be allocated among competing users or uses on the basis of the economic value derived, that is, the value of the use (Savenije and Van der Zaag, 2002; Smith, 2004: 2) and the market is expected to ensure that water is allocated to its highest value use (Briscoe, 1996; Rogers et al, 1998). Thus price policy can bring about allocation efficiency (GWP, 2005; Placht, 2007) and help maintain the sustainability of the resource (Rogers et al., 2002:2). In the management of water resources in an integrated manner where the economics, legal and environmental aspects complement each other three things supposedly occur: increased prices improve equity, efficiency and sustainability of the resource (Rogers et al, 2002; Jonker, 2002; Placht, 2007).

There must, however, be appropriate use of management instruments to achieve economic efficiency in water usage (Rogers et al, 1998) and this must be done in an enabling environment through legislation and policies to address equity issues (Jonch-Clausen, 2004). The World Water Commission endorses the argument for the need for full-cost pricing of water: “Commission members agreed that the single most immediate and important measure that we can recommend is the systematic adoption of full-cost pricing of water services” (World Water Commission, 2000: 33). This position calls for the construction of appropriate tariff structures to meet different social, political and economic goals in different situations. Treating water as a commodity has been noted to produce some transformative effects of the focus on exchange value becomes the driving force for water production instead of a social rationale. Consequently the making of profits takes precedence over public good ethics and professional values; a rationalization of service delivery along industrial lines” i.e. the division of tasks into smaller and smaller components, separated from other water activities and analyzed for efficiency improvements” (Smith, 2005: 169).

This neo-liberal principle shifts the emphasis on the supply of services based on the need to supply according to the ability to pay. “Using price mechanisms to redirect water to high-value uses is proving complex (IWMI, 2007) and these complexities make the application of IWRM very difficult. The second interpretation of water as an economic good is the “process of integrated decision making on the allocation of scarce resources, which does not necessarily involve financial transactions”. This implies that on the basis of all the costs and benefits of alternative options (using the marginal utility of water) the most appropriate choices should be made about the allocation and uses of water resources (IWMI, 1998). Second, that IWRM is superior to sectoral approaches because it recognises water as a social and economic good and gives room for exploring ways of achieving equitable access to water resources and obtaining maximum economic and social welfare out of it.



It seeks to the coordinated development and usage of water resources, which is able to promote sustainable utilisation of the resource. The bequest value is derived from the knowledge that a feature of a water resource will be passed on to future generations so that they will have the opportunity to enjoy it. The option value is the satisfaction that an individual derives from the ensuring that a resource is available for the future given that the future availability of the resource is uncertain. It can be regarded as insurance for possible future demand for the resource (Turner et al., 2004).

19.1 Economic Water Scarcity in South Africa

In addition to physical water scarcity there is also a lack of adequate water infrastructure in South Africa, which results in an unequal distribution of water resources. Many communities, particularly in rural areas, lack the appropriate water infrastructure and the financial or institutional capability to deliver basic water and sanitation services. An investigation into the state of municipal infrastructure in South Africa revealed that, even though some municipalities had put in place good practices in terms of infrastructure maintenance, few of them had adequate plans for the provision of renewal infrastructure. Institutional and financial capacity also differed considerably between municipalities. A lack of technical staff, the inability to plan and allocate funds prudently, as well as a reliance on the national government to provide financial support, were some of the underlying reasons for the wide disparities in the delivery of services (CSIR, 2006).

These findings are confirmed and expanded in the report State of Local Government in South Africa. The report makes specific references to the challenges facing rural and urban municipalities. Rural municipalities face severe infrastructure backlogs, which require a substantial improvement of financial and institutional capacity (COGTA, 2009: 45). Urban municipalities, in contrast, are faced with increasing population growth particularly an increase in informal settlements, and they must improve their spatial and infrastructure planning (COGTA, 2009: 45). The water scarcity problem in South Africa therefore has two dimensions: there is both physical and economic water scarcity. The subsequent discussion focuses on the extent of economic water scarcity, the inadequate provision of basic water and sanitation services.

19.2 Estimation of Water Value

Neoclassical economic theory predicts that, in a competitive market, the economic value of a good corresponds to its market price, which reflects individuals’ willingness to pay for that good. For water however, due to the limited role played by markets, valuation techniques must be used (Young, 1996; Agudelo, 2001). Several methods for estimating the value of water have been developed. They can be grouped according to whether they rely on observed market behaviour and data to infer economic value (indirect techniques), or alternatively use survey methods to obtain valuation information directly. Examples of indirect techniques used for valuing irrigation water can be found in following studies: Kulshreshtha and Tewari (1991) used derived demand functions. Faux and Perry (1999) and later Latinopoulos et al. (2004) used a hedonic pricing approach and several authors, among whom Lange (2007), Agudelo and Hoekstra (2001) and McGregor et al. (2000), used residual imputation approaches to estimate water values. Other indirect techniques such as the averting behaviour method, travel cost method, income multiplier approach and replacement cost/cost savings methods are less relevant for irrigation water valuing.

Direct valuation techniques seek to elicit preferences of individuals through questioning them on their willingness to pay for a good or a service. These techniques include the contingent valuation method, contingent ranking and conjoint analysis. Hassan and Farolfi (2005) for example used the contingent valuation method to estimate water demand functions of different users in South Africa and Salman and Al-Karablieh (2004) determined farmers’ willingness to pay for groundwater in the highland areas of Jordan. A detailed discussion of water valuation methods can be found in Young (1996) and more recently in Lange and Hassan (2007). In general, the most scientifically accepted methods are those based on actual market behaviour and information (Hussain et al., 2007). In the case of South Africa, there are currently no water markets from which values for irrigation water can be derived.

Furthermore since subsistence farmers in the study area are not paying for water, it is impossible to establish a relationship between price and demand from actual behaviour to generate demand functions. Moreover, because water is still provided by the government for free, strategic biases or simply the belief among smallholders that water is a free gift (Abu- Zeid, 2001), could probably lead to erroneous estimations of water values when using direct methods such as contingent valuation (Wasike and Hanley, 1998). Although this method clearly has its shortcomings, which are discussed in a next section, it was considered the most suitable technique to estimate water values for the studied small irrigation schemes.

19.2.1 Residual Imputation Method (RIM)

The RIM determines the incremental contribution of each input in a production process. If appropriate prices can be assigned to all inputs but one, the remainder of total value of product is attributed to the remaining or residual input, which in this specific case is water (Young, 1996; Agudelo, 2001; Lange and Hassan, 2007). Residual valuation thus assumes that if all markets are competitive, except the one for water, the total value of production (TVP) equals exactly the opportunity costs of all the inputs (Agudelo, 2001). Where:

*TVP*= total value of the commodity produced

*VMPi* = value of marginal product of input i

*Qi* = quantity of input i used in production, w for water.

It is assumed that the opportunity costs of non-water inputs are given by their market prices (or their estimated shadow prices). Therefore the shadow price of water can be calculated as the difference (the residual) between the total value of production (TVP) and the costs of all non-water inputs to production. The residual, obtained by subtracting the non-water input costs from total annual crop revenue equals the gross margin (GM) and can be interpreted as the maximum amount the farmer could pay for water and still cover costs of production. The RIM determines the incremental contribution of each input in a production process. If appropriate prices can be assigned to all inputs but one, the remainder of total value of product is attributed to the remaining or residual input, which in this specific case is water (Young, 1996; Agudelo, 2001; Lange and Hassan, 2007). The technique is based on two principal axioms (Young, 1996). The prices of all resources should equal returns at the margin.

This is a well-known condition for competitive equilibrium, i.e. as would occur if perfectly competitive markets were to exist for all agricultural inputs. The total value of production can be divided into shares, in such a way that each resource is paid according to its marginal productivity and the total product is completely exhausted. This is satisfied when the total value function is a linear homogeneous production function. Euler's theorem shows that this is the case when a production function involves constant returns to scale. Residual valuation thus assumes that if all markets are competitive, except the one for water, the total value of production (TVP) equals exactly the opportunity costs of all the inputs (Agudelo, 2001):

TVP = ∑VMPi Qi + VMPwQwi

TVP= total value of the commodity produced

VMPi = value of marginal product of input i

Qi= quantity of input i used in production, w for water.

It is assumed that the opportunity costs of non-water inputs are given by their market prices (or their estimated shadow prices). Therefore the shadow price of water can be calculated as the difference (the residual) between the total value of production (TVP) and the costs of all non-water inputs to production. The residual, obtained by subtracting the non-water input costs from total annual crop revenue equals the gross margin (GM) and can be interpreted as the maximum amount the farmer could pay for water and still cover costs of production.

19.3 Valuation of Natural Resources

Economic valuation of environmental and natural resources entails assessing the preferences of society with regards to an environmental resource or public good. It is a method used for assigning monetary value to the outcomes of choices about policies, projects and programmes (Bateman et al., 2002). Valuation of natural and environmental goods has grown importance in recent years. This has been mainly due to efforts by governments to increase resource allocation efficiency and sustainability in the face of increased human pressures. Moreover, natural resources are also resources such as labour and capital; therefore, it is important that they are appropriately and sustainably managed.

According to Pearce (1993), important conservational and sustainable strategies for natural resources and public projects are rightfully addressed when economic values are identified. Most natural resources and public goods are provided freely and thus have missing markets. In light of missing markets, resources are mismanaged and inefficiently allocated due values of goods and services being not revealed (Kadekodi, 2001). At times where markets exist, inefficiencies may still occur due to improper regulated markets. Water generally is one good which is under-priced due to its public good characteristics. According to Whittington et al. (1991), such kinds of environmental or public goods are the main causes of externalities. Consequently, markets cannot efficiently allocate such goods with pervasive externalities, or for which property rights are not clearly defined (Haab and McConnell, 2002).



Therefore, in solving for externalities, it is important that economic values are attached to such public goods. Valuation of natural resources like water therefore, reveals the economic value or benefits individuals derive from their services for proper management (Whittington, 1998). There are quite a number of economic methods used in valuing public or environmental goods and they specifically belong to two categories. In the first category are those which depend on observed human behaviours and thus derive inferences about preferences and economic values from such behaviours. The second category is those which rely on stated or revealed preferences by individuals. The main valuation techniques between these categories are hedonic and travel cost methods for the first category and while the second category consist of choice modelling and contingent valuation methods (Haab and McConnell, 2002). According to Tietenberg and Lewis (2012), the first category represents those involving observed behaviour and the second category as one involving hypothetical behaviour. Revealed preference method includes Hedonic Price Method (HPM) and Travel Cost Method (TCM) while stated preference includes the Contingent Valuation Method (CVM) and Choice Modelling (CM).

19.4 Economic Value and Allocation of Water

A sense of the economic value of water implies the attachment of different values to different uses of water. These values will vary from setting to setting as decided by the community, although it is invariably the case that survival and public health uses will be high-value uses; whereas recreational uses will be comparatively lower-value (Easter et al., 1997). For instance, “the physical features of the country of Ethiopia are composed of highlands, plateaus and lowlands; the highlands are mostly associated with high rainfall, several springs, lakes, streams and rivers” (MWR, 2003: 36). Because there is plenty of water in the highlands, people do not value water very much. In the lowland areas, where water is scarce; people give more value to water. According to Easter et al., (1997), where water is becoming scarce, it is desirable to discourage low-value uses.

Where users have entrenched rights to water supply, reallocation is only possible if they can be encouraged to sell some of their water to others presumably for higher-value purposes (Winpenny, 1994). The possibility of reallocating water to high-value purposes should be investigated as an alternative to, or in parallel with, developing new sources of supply; in this context the use of water markets can be appropriate. Others however, argue that the introduction of water marketing and pricing would violate human rights (Bakker, 2001). Bakker (2001:154) further points out that “Rather than being driven by social equity goals which focus on the payment capacity of the population, the market reflects economic equity criteria. Because of the cost, poor users will be discouraged from using water for necessary basic needs; what Narsiah (2010:15) terms “the market becomes the regulator of human rights. The recognition of human rights is thus determined by the ability to pay (i.e.) human rights are determined in economic terms”. Despite the fact that the “allocation of values to water uses helps in the following areas: balancing scarce resources with increasing demand; the reduction of wastage and loss, conservation of the resource, and shifts in consumption towards higher value uses (Water Guide EU, 1998:49). In order to have sound management of water resources there is a need to embody the concept of equity and give priority to the satisfaction of basic needs. It is imperative that existing facilities be utilised and maintained to the optimum, so that water losses are minimised and available supply capacities are fully used (World Bank, 2000). In this regard, it is essential to carry out integrated water resources management.

The water policy issued by the Ethiopian Government in 1999, when fully implemented, creates an enabling environment for water resources development and allocation among competing demands. In meeting this policy’s clear stipulation that water has to be considered both as an economic and social good, pricing of water has to be geared in order to promote economic efficiency, social equity and ecological sustainability (World Bank, 2000). In this regard, the proper pricing of water is one way of resolving a number of problems in the sector. The proper pricing of water will result to more efficient allocation of water; encourage conservation of water; and greater efforts in the part of suppliers to reduce nonrevenue water (Water Guide EU, 1998). Pricing water, if implemented and enforced fairly and equitably, would generate revenues that could be used for sector improvement.

The most important role of water valuation relates to demand management and better allocation of water among the various uses. The value of water depends on its quantity, quality, location, access reliability and time of availability. Valuing water is linking the concern that water uses must be able to meet different social, economic and environmental functions. Water resource development and management strategies can be viewed in terms of economic and non-economic measures. Pricing policy and allocation of property rights over the use of water is considered economic measures in demand-oriented approach. Whereas the use of regulations to control water demand, promotion of public awareness about the importance of water, reduction of reticulation and other losses of water production, and the use of water efficiently in a sustainable manner are included in non-economic measures. Economic measures have been applied in Ethiopia in order to promote the allocative efficiency of the use of water. For example, pricing policy has been applied to a smaller extent in urban areas.

The Ethiopian government developed a comprehensive National Water Management Development (2000) strategy that shows more commitment to the use of non-economic measures of water demand management than the previous supply-oriented plan. It suggests that the use of water tariffs to reduce water demand must be complemented by educational campaigns on water conservation and the use of water saving technologies (MWR, 1999). The fundamental aim of an economic approach to fresh water management is the efficient use of the available water resources at a given time and under given environmental conditions (Figueres et al., 2003). The economic management of catchment water resources can best take place at a basin-wide, sub-basin or regional level. Recent reviews of the basin-wide approach designed primarily on hydro-geological rather than administrative boundaries, could provide the basis for pursuing an integrated approach to water resource management and for solving regional and sectoral conflicts (Easter, 1999). This economic approach could spark the beginning of new institutional arrangements that provide water users incentives to manage their catchment water resources.

This presupposes water resources must be treated as an economic and social good between the upper and downstream water users. Under the neoliberal umbrella, the Cold War period, Hirshleifer et al. (1969: 2) underscored the appropriation of water as a commodity and, just like other goods, societies need it in order to satisfy the needs of their members. The basis for the economic argument is that water has an economic value and therefore is a commodity that must be bought and sold as any other commodity. It is further asserted that full cost recovery and business principles became the guiding principles of service delivery. “This is indicative of the organisational and institutional restructuring under a neoliberal regime” (Narsiah, 2010:17). The proponents of water economics explain that water scarcity could easily be solved with market instruments because it is a renewable and reusable resource. They explain that there is more than enough water worldwide. According to them, the challenge is a question of spatial and temporal distribution. Overcoming this challenge depends largely on the willingness of the people (especially the state and other actors) to use water resources economically.

19.5 Economic Use of Water

The economic management of water is possible within the catchment of the river system of Addis Ababa. One way of water management is that of recycling, using markets for water quantity allocation or quality renewal. Until recently, water utilization and management in the Ethiopia River basin has been far from a basin-wide approach.

Water development strategies were not coordinated. However, Integrated Water Resources Management (IWRM) is emphasized in the policy document and thus the policy recognizes the hydrologic boundary or basin as the fundamental planning unit and water resources management domain. Increasingly, the river basin is emerging as a unit of management of land, water and other natural resources in an integrated fashion. Besides, since 1999 due attention has been given to alleviate the problem of access to safe water supply and achieve rapid socioeconomic development through better health care and productivity by formulating a water resources management policy. The acceleration in the competition of the main water uses: domestic, industrial and agricultural, calls for effective and sustainable water resources management. Hence, the need for a holistic approach to water resources management. The government of Ethiopia has developed a comprehensive National Water Strategy, and goes a long way to meeting the criteria of rational decision-making based on the principles of Integrated Water Resource Management as discussed at the Dublin conference.

Among others, the strategy emphasises strategic issues under general water resource management, and a detailed elaboration of issues relating to water supply and sanitation, hydropower development, and irrigation development within the context of integrated water resource management from a basin perspective (MWR, 2001a). Most of the established projects have been sector oriented and as a result there is a conflict of interest between the different water users. Projects are often plagued by the lack of a cohesive approach. For example, The Koka dam, Tis Abay Dam and Melka-Wakena Dam were originally planned and designed for a single purpose that is to generate power to meet the increasing need for electricity. However, these dams have become useful to regulate the high flood season and supply water for the downstream irrigated land and water supply for downstream towns and villages after they generate electricity. There is growing recognition that planning considerations extend far beyond the interest of single purpose projects.

The government of Ethiopia has increasingly been recognized that water resources management viewed from basin-wide perspective. From the state water development policy point of view, it seems that the integrated river basin approach is being accentuated to a significant degree (Arsano, 2007). Effective river basin management is essential for sustainable growth and poverty reduction; to protect loss of ecosystem and biodiversity; to reduce loss of life from floods; and to provide improved drinking water services for local communities (UN-WWAP, 2006). This results in creating strong inter- sectoral allocation of water that enable sufficient supplies for irrigation, hydro-electric, municipal water supply and ecosystem maintenance. This is evidence of integrating water resource development and management in the context of the economic use of water 

resources in a regional context. They need to be viewed at the river basin level. Hence, they are multipurpose development in nature, providing many benefits associated with human well-being such as a secure water supply, irrigation for food production, hydroelectric generation, flood control and watershed management. The hydropower potential of these reservoir sites is the most significant aspects of water resource development in Ethiopia, since per-capita energy consumption and access to safe water supply in Africa is among the lowest in the world (The Reporter, 2009). Recent advances in integrated water resource management are appreciated from a basin perspective, especially for the economic use of water.

**20.0 WATER DEMAND MANAGEMENT (WDM)**

According to Utilisateur (2006:34) ‘The term “water demand” is defined as the volume of water requested by users to satisfy their needs’. Water demand management refers to the implementation of policies or measures which serve to control or influence the amount of water used (Utilisateur, 2006). It focuses on reducing demand for water by means such as raising awareness and shifting consumption patterns to lower water requirement products. The traditional approach to meeting the rising demand was by increasing the use of existing water resources. This has created serious problems of unbalanced water resources in terms of water availability and withdrawal, water shortages, and the degradation of water quality (Chapagain and Hoekstra (2007). Until the recent past, for most developing countries in particular, water resource management was oriented towards supply-driven approaches which involved looking for solutions through new water supply projects. Shifting towards water demand management has become indispensable for the sustainability of water resources, the environment, economic efficiency and social development (Hoekstra, 2007).

WDM can be achieved by the control of several types of factor, which are: technical, economic, administrative, financial and social measures to regulate the use of water with the aim of amount, manner and price in which water is accessed, used and disposed, with the ultimate goal of easing pressure on freshwater resources supplies (Brooks et al., 2003). In the simple way, the International Development Research Centre (IDRC) defines the water demand management as “To get the most from the water we have” (Abu Qdais, 2003). According to Fang et al. (2007) water demand management refers to that supplying water is only one side of the supply-and-demand paradigm of water utilisation, and many initiatives have been undertaken to reduce demand by improving behaviour and technologies to utilise water more efficiently. The management of water demand uses different methods to control demand such as licensing, penalties and water pricing, which have improved water use by up to 95% in the US, Israel and Cyprus (Plaut, 2000). A further method is improving crop productivity efficiency by using the water efficiently in agriculture. Importing water-intensive goods instead of producing them locally is referred to as importing ‘virtual water. This expression is used to describe the amount of water which has already been used to produce crops in the exporting country. It reduces demand in the importing country as the crops are produced abroad, thus freeing up supply (Allen, 1999). On the demand side, according to FAO (2000), several meetings about water management and environmental issues, such as the Global Water Partnership (GWP) and the World Water Council (WWC), have emphasised the important role of water users in improving water management. The FAO (2000) states that while water strategy was traditionally dominated by policy makers and water suppliers (and other industries where appropriate), modern approaches attempt to involve all stakeholders in water strategy, including end users.

Overall, water demand management seeks to find an acceptable equilibrium between limited water resources and competing, usually increasing, demands for water, using policy and technical means. Many societies face the problem of water scarcity as they have an inadequate supply of water to fulfil the needs of their growing populations. Expected demographic changes in developing countries such as population growth and urbanisation will ensure a growing demand for water. As discussed previously, it is estimated that the proportion of the urban population of developing countries will rise to over 60% by the year 2050 in less developed regions, which will affect the quantity of water required. It will also influence waste water management, since the quality of water is also an important aspect of water management. Water demand management aims to reduce the amount of water required by consumers, as well as to bring about a more efficient water distribution system without leakages.

Water demand management is "about the governance and tools that motivate people and their activities to regulate the amount and manner in which they access, use and dispose of water. Arntzen (2003), water demand management is undertaken for both environmental and economic reasons. The former refers to the increasing water scarcity faced by many countries, and implies managing the demand on the environment. Economic reasons include ensuring that water is distributed to users in the most cost-effective manner, since water demand management can reduce water losses and costs (Arntzen, 2003: 11). In some countries, physical water scarcity is not a concern and water demand management is mainly applied for economic reasons. In countries such as South Africa, however, both environmental and economic reasons apply (Arntzen, 2003).



Water demand management is typically presented as part of an integrated approach to water resources management and corrects an historic tendency to overemphasise supply side investment. Dziegielewski (2003: 30) indicates that water demand management should receive explicit consideration within an integrated water resource management framework, since it broadens the options available in a holistic management approach. A thorough knowledge and management of the demand side will assist water professionals to manage the available resources within a complex and dynamic system. A distinction is made between demand management and demand-side management (Stiles (1996), as cited in Brooks (2006: 523). Demand management refers to a broad range of methods and processes applicable to the requirements of water consumers, as opposed to the supply needs of water providers.

In contrast, demand-side management refers to activities that are adopted specifically by water utilities to balance supply augmentation and demand reduction. In his quest to provide an operational definition of water management in the broader sense. Brooks (2006) emphasises the importance of not viewing water demand management as yet another technology. Rather, it should be seen as policy that operates within a larger framework, i.e. it is a governance concept. For this purpose Brooks (2006: 524) provides an operational definition which focuses on both the quantity and the quality of water. The efficacy of conveying water, given different levels of demand, and the need to ensure resilience in water systems when dealing with shortages. According to Meyer (2007: 23), demand management refers to strategies applied by water institutions in an attempt to influence the demand for water, taking into account various objectives such as efficiency, social development and equity, and the sustainability of water supply and services.

It is therefore important to keep in mind that the design of policies must meet various criteria and cannot only address the efficient use of the resource. This view is supported by Savenije and Van der Zaag (2002: 99), who state that not only should policy achieve an efficient and sustainable use of the resource, it should also encourage equity and environmental integrity. Water demand management policies differ from supply management options in that the behaviour of consumers must be considered. According to Borisova, Rawls and Adams (2009), demand management is related to the choices made by consumers and requires their active participation through behavioural changes. It is therefore imperative that water managers are aware of the preferences of water consumers, since this is vital for water conservation (Dupont, 2005). Knowledge of water use on the demand side can be used to design alternative water demand management options.



One example is the community based educational programmes suggested by Mathipa and Le Roux (2009). They analysed the water-use patterns of two rural communities in South Africa and designed a framework to develop community-based educational programmes. One aspect of their design entails the establishment of water committees for each community and the official recognition of such bodies by local authorities.

20.1 Water Demand Management Measures

The purpose of this study is to see the importance of engagement between government and the community in building the capacity of WDM through knowledge and information sharing. A number of water demand management measures exist.

20.1.1 Structural and Operation Measures

This could be used at the utility level to reduce water losses by organizing the process of water distribution networks to carry out the active role of water leakage management or to install pressure reduction in some zones identified as having unnecessarily high pressures. This can also be introduced to end – user’s premises by placing fixtures and appliances with devices that use water in more efficient ways (White et al, 2001).

20.1.2 Economic Measures

This involves proper use of market - based signals to attract interested types of decision – making. They either give financial rewards for good behavior or impose costs for undesirable behavior (Cantin et al 2005).

20.1.3 Behaviour Modification

WDM programs should be designed from an analysis of the ways that motivate to take actions and change their ways of thinking and responding to this challenges. Awareness raising and public education programs for modifying the behavior of water consumers may be used hand in hand with other WDM measures for more effective strategies (Texas Water Development Board, 2004).



20.1.4 Legal and Institutional Measures

There is always variety of regulatory tools that can be developed to ensure WDM options. There is a need that this law must be conducive towards the effective legal and institutional functioning. To ensure that water service providers carry out a comprehensive water resource planning to cover resource management, production management.

20.2 Actions for Water Demand Management

Addressing WDM requires different types of actions which are listed down in various ways according to Louw & Kassier (2002). Giving out different types on incentives, whether through legal obligations, economic incentives, or motivated through public information/ education programs. Some kind of tools used structural for example network improvement or retrofitting water devices in the end users’ properties, or structures such as pricing or education, which leads to infrastructural improvements. By location of water supply system, whether at the water treatment plant, storage tanks conveyance and distribution network, or in end users’ properties. The entity bound to carry out the measure for example the local authority, service provider or end users. Final by sectors in which measures are applied, such as urban use, industrial use or agricultural use. Actions can either be positive or negative depending on the planning, organising, implementation and controlling the process.

**21.0 INTEGRATED WATER RESOURCE MANAGEMENT (IWRM)**

The failure of water supply to keep up with demand has resulted in IWRM being adopted to balance water supply management and water demand management against a background of population growth (Frank, 2006). The aim is to produce sustainable development in water management UN (2003). As a response to the world’s fresh water resources coming under increasing pressure due to growth in population and increased economic activity leading to increased competition for and conflicts over the limited freshwater resources, IWRM, using a participatory process World Bank (2006), focuses on working out solutions that are acceptable to all stakeholders, taking account of differing interests, particularly among the various sectors.

This approach is concerned with the decentralisation of water management by involving all the stakeholders concerned in keeping with the principle of subsidiary. The subsidiarity principle, which states that management decisions should be taken at the lowest appropriate level, with central government retaining regulatory and support roles, implies all aspects of life, such as education curriculum of children and international agencies and post-graduation studies, support water management (WBI, 2006). In other words, it promotes all levels of societies to participate in managing water resources. Bouchouata et al (2012) pointed out that environmental education in general, and water education in particular, provide a means to address the challenges of water management in water-scarce regions. This is emphasised by Jardiouia et al (2015) as they also pointed out that, as it is difficult to train people how to be aware of the need to improve water management and thus be able to manage water rationally, the role of education is crucial indeed.

Okpala (2009) pointed out that the necessity for a broad and comprehensive approach supports international cooperation and postgraduate and continuing professional education targeted to ensuring the adoption of best practices. Integrated water resources management (IWRM) is a systems approach to water management, recognising the need to manage the entire water cycle and its interconnectivity. The importance as well as the challenges of achieving future water security has already rooted in the global awareness nowadays. The right way forward, however, remains item of research and dispute and for some part even belief. Integrated Water Resources Management (IWRM) approach has been the most prominent strategic water management concept in the international discourse during the last decade. The intellectual evolution of the IWRM idea has to be understood in different facets and steps. Although it appears difficult to define the exact origin of the term IWRM itself, the United Nations Water Conference in 1977 in Mar del Plata is often seen as fundamental benchmark in the development of a global water awareness (Biswas, 2004).

The contemporary rising international recognition, however, certainly started in accordance with the general strengthening of sustainable development ideas and international integrated resources management thinking. However, coordinated efforts towards integrated management in the form of comprehensive and strategic planning practices have already been undertaken for a considerably longer period. The basic moving spirit hereto was the transition from the historical approach of sectoral separated towards a holistic planning and implementation strategy of water issues and related resources. This transition originated in the wish for an improved coordination and development between competing uses (e.g. flood and pollution control, water supply and conservation) under increasing usage pressures resulting from population growth, intensified irrigation and industrialization. This progress already started at least during the first half of the 20th century with the multiple purpose river development practices. Besides this sectoral coordination, it has especially been the spatial integration that received early attention in the domain of water resources management. There are approximately 261 international river basins today (Wolf et al., 1999) and good water relations have always been a factor of political stability between co-riparian administrations. Whereas historical trans-boundary cooperation mostly concerned issues of navigation, borders and single purpose rights, it has developed in accordance with the water sector to nowadays serve multi-purpose basin strategies. Global Water Partnership (GWP), who has also long been a major advocate of the IWRM concept. It explicitly states the need to jointly address water, land use and other resources issues, thus requesting a very holistic management approach reaching beyond the water sector alone. In this point the cited World Bank definition agrees but at the same time it puts more weight on the aspect of IWRM as participatory process with a need for stakeholder involvement.

Participation appears also the leading aspect in the USAID understanding, the latter also giving the sole definition directly demanding an integration of scientific views and approaches. The aspect of economic, social and environmental consideration in the water management process, appears to be inherent in all discussed definitions, however, it is most emphasized in the wording of the GWP and the USAID. On the other hand, the World Bank definition and to a lesser extent the USACE, appear to shift from the archetypical goal of sustainability to rather promote a “balanced and acceptable” (or in other words: less un-sustainable) utilization of the resources. It is furthermore interesting to note, that GWP, USAID and USACE understand IWRM essentially as a process, not a state or a concept, thus implicating continuity. The World Bank definition takes an exceptional position here as well, describing IWRM as a coordinative framework to be established as a platform for balanced water management processes.

Moreover, defining IWRM within one or two sentences appears to advocate the approach as fully sensible and pragmatic procedure, and consequently as the rationally favourable path towards sound and responsible water management. IWRM paradigm has at least succeeded in bringing water professionals together, inter-sectoral and trans-boundary, in a community that goes far beyond questions of legitimation. Especially in an environment as conflict-prone as the Middle East, this already has to be perceived as an invaluable success. IWRM modelswere therefore developed to provide an integrative platform to address the different subsystems of the IWRM domain. In most cases they emerged as river basin simulation models from a hydrological basis with a focus on water allocation and water balancing.

Typical application objectives are to manage river basins operation and development, address conflicts in water uses or evaluate socio-economic and environmental impacts of alternative management strategies. A classical distinction is made between simulation and optimization models, although state-of-the-art models often contain elements of both (Wurbs, 2005). The general approach is to simulate the movement of water through a system of river reaches and nodes that represent reservoirs, diversions and abstractions, demand sites and other network elements, in order to simulate and optimize different allocation scenarios.

21.1 Sustainability and IWRM

Sustainable water management aims to reduce vulnerability and enhance resilience so to achieve its overall goal: water security and therefore sustainable development for people and ecosystems. IWRM aims at achieving sustainable water management through economic efficiency, social equity and environmental sustainability (GWP 2013). One of the major principles that drives IWRM is the involvement of *all* stakeholders in water management, especially women who are traditionally often disadvantaged. The involvement of local communities is considered to enhance their resilience, for example to deal with the impacts of climate change. To promote participation, decentralisation and capacity building play a vital role in order to adequately involve local communities (CAP-NET 2009, GWP 2012). Local community involvement is a key component to achieving sustainable development and the implementation of IWRM.

According to UFZ (2011), capacity building is a process which improves existing skills, strengthens problem solving abilities and creates knowledge. Capacity, is the sum of skills, abilities and qualifications of people. There is an urgent need for additional skills in the management of water resources, institutional reforms, conflict resolution, social and communication skills in the existing and new water managers. Thus, the implementation of capacity building is becoming more important, as it highly contributes to sustainability in the water sector. Inadequate capacity has been identified as a recurring issue preventing the achievement of many national and international sustainability goals, such as poverty reduction or improved access to safe water supply and sanitation. In order to meet the demands of population growth, changes in consumer behavior, increasing pollution of water bodies and the impacts and prediction uncertainties of climate change, sustainable water management is key to achieving sustainable development in the 21st Century. According to GWP (2013), sustainable development can only be achieved with a water secure world.

A water secure world reduces poverty and increases living standards, especially for the most vulnerable. The GWP (2012) defines water security as a world where every person has enough safe, affordable water to lead a clean, healthy and productive life. It reduces poverty, advances education, and increases living standards. It is a world where there is an improved quality of life for all, especially for the most vulnerable who benefit most from good water governance. To achieve water security, an integrated approach is important. The idea of ´Integration´ was developed to replace the traditional, fragmented and uncoordinated use, development and management of water resources (GWP 2013). There is a general consensus that competition for water resources will increase. Hence, the consideration of the needs and demands of all stakeholders is essential to avoid conflicts and to ensure equitable decision-making over water resources (GWP 2012, CAP-NET 2009, TAYLOR 2001).

Integration´ implies horizontal and vertical cooperation. Horizontal refers to cooperation between different sectors within a country (agriculture, energy, industry, finance, education and health), while vertical refers to cooperation between levels (international, national, regional and local) (VARIS ET AL. 2008). Beside the biophysical dimensions of water management, IWRM highlights the human dimension to achieve sustainability. It considers the interdependency (Nexus) between different water users, sectors and groups, and recognizes that the unsustainable and unregulated use of water resources of one sector might have impacts on another sector (GWP 2012). As a lack of cross-sectoral cooperation results in unsustainable management and use of water resources. IWRM means a shift from the traditional top-down to the more sustainable bottom-up approach (GWP 2012). While the top-down management approach is characterized by decision-making at high levels and without adequate consultancy of local needs and interests, the bottom-up approach is characterized by participatory decision-making on lower levels.

However, it is important to consider that IWRM represents a ´process´ with no fixed beginning or end, but rather as a long-term approach that seeks to shift unsustainable forms towards sustainable water management systems (GWP 2009). According to Cap-Net (2008:7), IWRM promotes the following aspects to achieve sustainable development and water security. According to UNEP (2012), improved water management leads to positive environmental impacts, resulting in improved water quality (e.g. due to improved waste-water treatment). Sustainable water management looks at the hydrological cycle in the basin, takes the needs and conflicting interests of multiple water users into account, and addresses the role of water within the context of social and economic development and environmental sustainability (CAP-NET 2008:7). IWRM emphasises economic and financial sustainability, water resources should be managed as an economic good so as to achieve efficient and equitable use, while also conserving and protecting water resources at the same time (XIE 2006).

**22.0 ROLE PLAYERS RESPONSIBLE FOR WRM**

22.1 Political Framework for WRM

As the global water crisis is rarely viewed as a problem of physical water scarcity alone, but rather as a problem of governance, the successful implementation of WRM is highly dependent upon a country's water resources governance framework. The following section explores the role of water governance and then focuses on the particular case of water governance in South Africa.

22.2 The Role of Water Governance

The following quote highlights the interconnectedness of water governance and WRM: "The governance dimension is strongly associated with the WRM concept. It can be assumed that the specific design of a governance system affects the decision-making and implementation of WRM (UFZ 2011:14). Water Governance (WG) is defined as the political, social, economic and administrative systems that are in place, and which directly or indirectly affect the use, development and management of water resources and the delivery of water services at different levels of society (UNDP 2013). According to UNDP (2013), water governance has social, economic, political and environmental dimensions.

The social dimension of water governance refers to the equitable use of water resources, because it is often unevenly distributed in time and space, between rich and poor or rural and urban settlements. Water related services and water allocation have direct impacts on people’s livelihood opportunities and their health. The economic dimension draws attention to the role of water in economic growth and the efficient use of water resources within economic activities. Economic growth highly depends on water and other natural resources and effective governance can contribute to positive effects on per capita income in many countries around the world. The political dimension of water governance refers to water stakeholders at international, national and local levels, including marginalised citizens such as indigenous people, women or slum dwellers, and their ability to influence and monitor political processes and outcomes and to be active participants in decision-making. The environmental dimension indicates the sustainable use of water resources and ecosystem integrity, resulting from improved water governance. It includes parameters such as quality and quantity of water resources and acknowledges its importance for maintaining ecosystem services. As water quality is declining in many parts of the world due to intensive agricultural use, poor people's livelihood opportunities often depend directly upon sustained access to natural resources such as water, particularly those in areas prone to pollution, droughts and floods (UNDP 2013). As water governance provides the legal framework for all actions in the water sector, it determines the (sustainable) development of water resources and thus has profound impacts on people’s livelihoods. The key role of governance is to create an institutional and administrative framework, where people with different interests can peacefully cooperate and coordinate their actions (GWP 2003).

The ability of local governments to successfully apply WRM principles depends highly upon the water governance framework and the awareness of existing governance structures to plan and implement WRM. Local governments are usually not involved in the development of legislations and national policies. Rather they have the role of carrying out mandates in water management. Furthermore they are responsible for involving allmembers of its community and particularly for promoting participatory decision-making and involvement of disadvantaged groups, thus contributing to sustainable bottom up approaches (PHILIPP ET AL. 2008). The Republic of South Africa is a constitutional democracy and consists of three structures of government, namely: national, provincial and local governments. The Constitution represents the supreme law of South Africa and forms the basis for any water governance there. South Africa's constitution ensures human rights and is internationally considered to be one of the most progressive constitutions in the world (DWAF 2009). Act 106 confirms that everyone has the right to have access to sufficient food and water and to an environment that is not harmful to their health or well-being.

The Act claims that the environment must be protected for the benefit of all people living now and in future, by preventing pollution and ecological degradation, promoting conservation and securing ecologically sustainable development and through use of natural resources which promotes justifiable economic and social development. It declares the national government as the custodian of all ground and surface water resources and puts local government in charge of municipal water services (Bill of Rights, Section 24, DWAF 2008). The Constitution furthermore separates the powers between the national, provincial and local government and emphasizes the cooperation between all levels. According to the Act, the overall management of water resources is allocated to the national government, while the management of water and sanitation services for all citizens is allocated to the municipalities. As the successful implementation of the WRM principles is highly dependent on having an enabling environment to do so, which is subject to the water governance framework of a country (PHILIP ET AL. 2008), interview partners were asked about the role of South Africa’s government in water management. The actual implementation however, is the responsibility of the municipalities who also have to monitor compliance with laws within the municipality population and local industries. The government should raise awareness of water-related issues through campaign. Water licensing is identified as the main political ´tool´ to control water use and pollution, especially in the industrial sector. The National Water Act (NWA) is a key part of water governance in South Africa and includes the free basic water policy which provides a certain amount of free water so as to cover the basics needs of poor households. When asked about the role of government in climate change, the South African White Paper on Climate Change was identified to be the main tool on managing water resources under climate change. To promote decentralisation, catchment management agencies (CMAs) were founded to ensure decentralized decision-making from the basin level.

22.3 The role of Women

WRM highlights the important link between gender and sustainable water management. Only if women are adequately involved in using, managing and developing water resources from the household level to higher levels, will water management succeed and be sustainable (GWP 2013, LEWIS 2006). Therefore, all interview partners were questioned specifically about the role of women. The interview partners assessed the involvement of women in managing and developing water resources as being very low, especially in traditional rural areas. In urban areas gender imbalances are much lower and certain improvements are already noticeable, as for example some women occupy key positions in ministries. Inequalities within society can be traced back to traditional ´thinking´ and other cultural aspects, a lack of self-confidence of women towards themselves and a lack of support for each other.

22.4 The role of the community in ensuring safe water supplies

According to UNDP (1990) the global water conference endorsed community management as the guiding principle in water management. This was part of the reaction to the continuous failures in upkeep and maintaining of community participation schemes of the 1980s. Paradigm championed by Chambers et al. (1980) that communities should not just be involved in system inception, but should accept sole responsibility for and ownership of the whole life cycle of the system entrusted to the community. Other supporting principles on community management was adopted from The New Delhi Statement (1992) - promotes an integrated approach in addressing different challenges of developing nations, that involves changes in procedures, attitudes and behavior and integrate full participation of women at all levels in sector institutions. It further encourages the use of appropriate sound financial practices, where community management should play a significant role in promoting their communities. This principle was further stressed in the Dublin Statement on water sustainable development in 1992 (ICWE 1992), which agreed that water development and management should be based on a participatory approach involving users, planners and policy makers at all levels. They emphasized that women play a central part in provision, management and safeguarding of water because the adverse impacts of water affects them most during water crisis times. It is against this background that this study will seek to investigate the level of involvement of the community of by way of examining the knowledge and information sharing in water demand management. Activities linked to community management:

* Encouragement of water development and management based on a participatory approach involving users, planners and policy makers at all levels.
* Application of the principal that decisions are to be taken at the lowest appropriate level with public consultation and involvement of users in the planning and implementation of IWRM activities and projects.
* Support and assistance to communities in managing their own system on sustainable basis.
* Encouragement of local population especially women, youth, indigenous people and local communities in water management.
* Linkages between national plans and community management of water.
* Integration of community management within the context of overall planning.

**23.0 WATER MANAGEMENT**

The scale of the water problem means that it must now be treated as a global concern and not just a national concern. The imbalance in the supply and use of water is related, most importantly, to food security, which often cause or exacerbate different kinds of conflict Hoekstra and Chapagin (2007). It is useful to review the current approaches of water management across the world, which mostly focuses on water supply management, such as finding additional water supplies.

Improving water efficiency could be made on three levels of water use for local; national; and global. The aim of water management should be using less water to gain the same output. Therefore, systematic and integrated decision-making is required to achieve sustainability in water resources management, recognising the relationship between decision-makers on all three levels (Gallopin & Rijsberman, 2000). At each level – local, national and global water resource management has to focus on the two sides of the equation: supply and demand. While water supply management focuses on increasing quantity, water demand management focuses on reducing water demand (Savenije, 2000).

23.1 Water Supply Management

The rapid increase in population experienced since the beginning of 20th century has imposed additional pressures on water resources in order to meet increased demand. The extra population has resulted in increases in domestic, agricultural and industrial use, impacting on both quantity and quality, and resulting in attempts to improve supply (Al Radif, 1999). The response of water resource management to increasing demand for water (due to the essential increase of population relative to available water capacity and infrastructure as well as aspiration lifestyles) has generally been met by channelling water from legacy sources (e.g. reservoirs) toward new settlement areas, as part of general urban planning rather than a comprehensive water strategy (Figure 2.2) (Al Radif, 1999). Water supply management focuses on managing the existing water resources more efficiently as well as searching for additional supplies. This includes, in Libya, for example, the widespread construction of dams in high-water areas, with the contents used in short periods of drought and transferred to where it is needed.

However, this solution is only effective where runoff is high and there is a strong systemic enforcement of regulations. Developing countries, particularly those in arid or semi-arid areas such as Saudi Arabia, have a noticeable weakness in the enforcement of regulations that has led to ineffective water resource management (Postel, 1992; UNEP, 2002). Furthermore, there is a lack of awareness among both people and decision-makers about the need to conserve supplies. In countries, such as China, water transfer from high-water areas to the population centres has been successful as a part of the solution to water shortages. However, in countries such as Yemen no alternative solutions are available, which has resulted in increased pressure on local water resources and has led to depletion of its water resources (Chapagain and Hoekstra (2007).

23.2 Water Demand Management (WDM)

According to Utilisateur (2006:34) ‘The term “water demand” is defined as the volume of water requested by users to satisfy their needs’. Water demand management refers to the implementation of policies or measures which serve to control or influence the amount of water used (Utilisateur, 2006). It focuses on reducing demand for water by means such as raising awareness and shifting consumption patterns to lower water requirement products. The traditional approach to meeting the rising demand was by increasing the use of existing water resources. This has created serious problems of unbalanced water resources in terms of water availability and withdrawal, water shortages, and the degradation of water quality (Chapagain and Hoekstra (2007). Until the recent past, for most developing countries in particular, water resource management was oriented towards supply-driven approaches which involved looking for solutions through new water supply projects. Shifting towards water demand management has become indispensable for the sustainability of water resources, the environment, economic efficiency and social development (Hoekstra, 2007).

WDM can be achieved by the control of several types of factor, which are: technical, economic, administrative, financial and social measures to regulate the use of water with the aim of amount, manner and price in which water is accessed, used and disposed, with the ultimate goal of easing pressure on freshwater resources supplies (Brooks et al., 2003). In the simple way, the International Development Research Centre (IDRC) defines the water demand management as “To get the most from the water we have” (Abu Qdais, 2003). According to Fang et al. (2007) water demand management refers to that supplying water is only one side of the supply-and-demand paradigm of water utilisation, and many initiatives have been undertaken to reduce demand by improving behaviour and technologies to utilise water more efficiently. The management of water demand uses different methods to control demand such as licensing, penalties and water pricing, which have improved water use by up to 95% in the US, Israel and Cyprus (Plaut, 2000).

A further method is improving crop productivity efficiency by using the water efficiently in agriculture. Importing water-intensive goods instead of producing them locally is referred to as importing ‘virtual water’. This expression is used to describe the amount of water which has already been used to produce crops in the exporting country. It reduces demand in the importing country as the crops are produced abroad, thus freeing up supply (Allen, 1999). According to FAO (2000), several meetings about water management and environmental issues, such as the Global Water Partnership (GWP) and the World Water Council (WWC), have emphasised the important role of water users in improving water management. The FAO (2000) states that while water strategy was traditionally dominated by policy makers and water suppliers (and other industries where appropriate), modern approaches attempt to involve all stakeholders in water strategy, including end users. Overall, water demand management seeks to find an acceptable equilibrium between limited water resources and competing, usually increasing, demands for water, using policy and technical means. Water demand management aims to reduce the amount of water required by consumers, as well as to bring about a more efficient water distribution system without leakages. Water demand management is about the governance and tools that motivate people and their activities to regulate the amount and manner in which they access, use and dispose of water (Baroudy, 2005: 1). According to Arntzen (2003), water demand management is undertaken for both environmental and economic reasons. The former refers to the increasing water scarcity faced by many countries, and implies managing the demand on the environment (Green, 2003: 239).

Economic reasons include ensuring that water is distributed to users in the most cost-effective manner, since water demand management can reduce water losses and costs (Arntzen, 2003: 11). In some countries, physical water scarcity is not a concern and water demand management is mainly applied for economic reasons. In countries such as South Africa, however, both environmental and economic reasons apply (Arntzen, 2003). Water demand management is typically presented as part of an integrated approach to water resources management and corrects an historic tendency to overemphasise supply-side investment. Dziegielewski (2003: 30) indicates that water demand management should receive explicit consideration within an integrated water resource management framework, since it broadens the options available in a holistic management approach.

A thorough knowledge and management of the demand side will assist water professionals to manage the available resources within a complex and dynamic system. A distinction is made between demand management and demand-side management (Stiles (1996), as cited in Brooks (2006: 523)). Demand management refers to a broad range of methods and processes applicable to the requirements of water consumers, as opposed to the supply needs of water providers. In contrast, demand-side management refers to activities that are adopted specifically by water utilities to balance supply augmentation and demand reduction. In his quest to provide an operational definition of water management in the broader sense, Brooks (2006) emphasises the importance of not viewing water demand management as yet another technology. Rather, it should be seen as policy that operates within a larger framework, i.e. it is a governance concept. For this purpose Brooks (2006: 524) provides an operational definition which focuses on both the quantity and the quality of water, the efficacy of conveying water, given different levels of demand, and the need to ensure resilience in water systems when dealing with shortages. According to Borisova, Rawls and Adams (2009), demand management is related to the choices made by consumers and requires their active participation through behavioural changes. It is therefore imperative that water managers are aware of the preferences of water consumers, since this is vital for water conservation (Dupont, 2005). Knowledge of water use on the demand side can be used to design alternative water demand management options. One example is the community-based educational programmes suggested by Mathipa and Le Roux (2009). They analysed the water-use patterns of two rural communities in South Africa and designed a framework to develop community-based educational programmes. One aspect of their design entails the establishment of water committees for each community and the official recognition of such bodies by local authorities. The government or water managers can apply direct intervention to reduce water consumption (Brooks, 1997); this may require the installation of water-saving devices.

Water-saving technologies include measures such as double-action cisterns and low volume showers, which may be viewed as more long-term water conservation measures (Stephenson, 1999: 115). Other instruments include efficient garden irrigation systems and tank displacement devices. Water demand measures, Renwick and Green (2000) evaluated the demand management policies of eight water agencies. The price of water is one of the key determinants of the demand for water and is an important tool for reducing demand (Griffin, 2006: 243). This is based on the economic principle that water is an economic good and should be priced according to its opportunity cost. Griffin (2001: 1335) states that the increased cost of supplying water can be attributed to increasing water scarcity, higher infrastructure costs and stricter environmental and health regulations.

Water was recognised as an economic good long before the Dublin Water Principles proclaimed it as such in 1992. An important aspect of this classification is its impact on the management of water. One consideration that favours the use of demand-side management tools, particularly water pricing strategies, is that they are usually less costly to implement than supply augmentation (which may entail building more dams). The premise behind this is that water demand is not fixed and can be adjusted. Renzetti (2005: 22) argues, however, that in practice there has been little emphasis on using the price of water to signal the opportunity cost of consumption. In fact, water pricing rarely achieves efficient levels of consumption (Tyler, 2007). In addition, water pricing does not take account of variations in use in relation to distance from source or the time or season of use.



This has led to water being consumed at more than the optimal social level. Water resource management involves a great variety of actors interacting in numerous ways and at diverse levels. According to the World Bank (1995) policy paper, “Water resource management that follows the principles of comprehensive analysis, opportunity cost pricing, decentralization, stakeholder participation, and environmental protection and investments across sectors, promote conservation, and improve the efficiency of water allocation (World Bank, 1995:27). Integrated Water Resources Management (IWRM) is concerned with the management of water resources, demand and supply (Global Water Partnership (GWP), 2000). In this regard, it is possible to achieve sustainable water resource use through a holistic multi-disciplinary approach. “The need for IWRM arises from regular interactions, uses and interests of interdependent groups that converge around a uniform whole” (GWP, 2000:17).

Integration ensures respect and consideration of the needs and interests of each stakeholder. The challenge is to regulate water resources use to ensure sustainable and equitable use among various groups. The general objective of IWRM is to promote in an environmentally sound, equitable and sustainable manner the utilization and development of water resources. At the international Conference on Water and Environment held in Dublin January (UN, 1992b) also recognized the importance of IWRM and proposed that direct attention should be paid to the following six areas. These were namely the following:

* Integrated water resources development and management
* Water resources assessment, and protection of water resources
* Water quality and aquatic ecosystems
* Drinking water supply and sanitation
* Water and sustainable urban development, and
* Water for sustainable food production and rural development.

In the absence of the proper management of water, conflicts within countries often arise from competing water uses, and from overlapping and competing jurisdictional mandates of agencies dealing with water issues (Yilma and Donkor, 1997). An integrated approach has therefore important institutional dimensions that would help to avoid conflicts related to water management. Continuing water scarcity that is experienced in most sub-Saharan countries necessitates the adoption of IWRM approaches (UNFPA, 1999). In these premises the integrated approach to dealing with them is critical.

Integrated Water Resource Management (IWRM) is attempting to meet all interests of various stakeholders and to coordinate them. Department of Water Affairs and Forestry (DWAF) (1996: 18) stated that the conceptual basis of integrated catchment management relies on recognition that the different components of the hydrological cycle are intimately linked to one another and each component is affected by changes in every other component. Therefore, they cannot be managed effectively as separate or disconnected units. DWAF (1996) further states that the sustainable management of the water resources of a catchment becomes increasingly difficult if there is a fragmentation of institutional, political and administrative boundaries within the catchment. Therefore, the integrated nature of social and environmental systems calls for an integrated approach to management of these systems (Berkes and Folke, 1998).

Given that Ethiopia is a developing country it is useful to review the important case study of Indian experiences regarding water resource management. Watershed management approach came into prominence in India during 1980s and 1990s as a result of the recognition of the link between environmental degradation and poverty. There is recognition in India that ‘Water knows no boundary’ and watersheds have no social or political boundaries. The water resources planners of a region must ignore the political boundary to harness and explore the resources in an integrated manner, making sure that it strikes a balance between the drinking, agricultural, fisheries, navigational and environmental needs, not only for the nation, but most optimally for the region (Ahmad, 2003:181). Therefore, water resources in the watershed should be managed in a holistic manner. Projects in watershed management now have ultimately been linked to the sustainable development framework of local level focus.

The guidelines issued the Indian government under the Ministry of Rural Areas and Employment (MRAE) in 1994 cover four government watershed management programmes and outline the procedure for implementation by changing the water sector planning from a top-down technocratic approach to a bottom-up grassroots approach. The goal is to establish a participatory water management environment with establishment of institutional structures at all levels to monitor the functions of the programmes. The guidelines emphasises local participation in the design and implementation of the programmes (Baumann, 1998). The holistic and participatory approach to catchment management developed in India is important and very relevant to the Ethiopian water resource management context. Given that decentralization is an important issue in the management of Ethiopian water resources, cognizance needs to be taken of the Indian approach.

In this regard, there is a need for the establishment and maintenance of appropriate institutional structures for the management of resources. It is argued that water resource management entails not only an understanding of issues pertaining directly to standing and flowing water, but also an understanding of issues pertaining to the management of the entire catchment. Therefore, the IWRM approach argues that there is a fragmentary approach to water resources management and is one of the challenges hindering water resource development in Ethiopia. For this issue the best solution is a holistic approach to integrated water resources management.

23.3 Integrated Water Resource Management (IWRM)

The failure of water supply to keep up with demand has resulted in IWRM being adopted to balance water supply management and water demand management against a background of population growth (Frank, 2006). The aim is to produce sustainable development in water management UN (2003). As a response to the world’s fresh water resources coming under increasing pressure due to growth in population and increased economic activity leading to increased competition for and conflicts over the limited freshwater resources, IWRM, using a participatory process World Bank (2006), focuses on working out solutions that are acceptable to all stakeholders, taking account of differing interests, particularly among the various sectors. This approach is concerned with the decentralisation of water management by involving all the stakeholders concerned in keeping with the principle of subsidiary. The subsidiarity principle, which states that management decisions should be taken at the lowest appropriate level, with central government retaining regulatory and support roles, implies all aspects of life, such as education curriculum of children and international agencies and post-graduation studies, support water management (WBI, 2006).

In other words, it promotes all levels of societies to participate in managing water resources. Bouchouata et al (2012) pointed out that environmental education in general, and water education in particular, provide a means to address the challenges of water management in water-scarce regions. This is emphasised by Jardiouia et al (2015) as they also pointed out that, as it is difficult to train people to be aware of the need to improve water management and thus be able to manage water rationally, the role of education is crucial indeed. Okpala (2009) pointed out that the necessity for a broad and comprehensive approach supports international cooperation and postgraduate and continuing professional education targeted to ensuring the adoption of best practices.

**24.0 THE CONCEPT OF WATER FOOTPRINT**

Traditionally, national water use was based on the volume of water extraction in the country. While this is useful, it does not reflect the actual water needs of the population in terms of agriculture (the focus of this thesis) because some of those needs are fulfilled through imported virtual water. Hoekstra (2003), cited in Chapagain (2006), developed a measure of water withdrawal that includes the virtual water in imported goods which are consumed within a country. Consequently, this measure shows both direct and indirect water use in a country. Chapagain (2006) pointed out that the prevailing method of calculating the withdrawal from the source relative to demand at the destination does not reflect the whole lifecycle implications of products’ water footprints. The water footprint is defined by Hoekstra (2003) as an indicator of freshwater use that looks not only at direct water use of a consumer or producer, but also at the indirect water use. The water footprint of a nation breaks down into two main components: the internal water footprint and the external water footprint (Hoekstra, 2008).

The internal water footprint refers to the domestic fresh water used to produce the goods and services consumed inside the country by the inhabitants of a particular area. The external water footprint refers to the freshwater used out of the area to produce goods and services and then imported for consumption inside the particular area. It is closely related to the virtual water concept discussed above. Distinguishing between internal and external water footprints is essential when analysing the footprint of a delineated area, such as a country. Before the concept of the water footprint was introduced, there was only limited awareness among policy makers about the characteristics of the agricultural production and supply chain, which have strong influences on the volume of water consumption and pollution. The concept of water footprint develops our understanding of the total water use from the perspective of consumption. It is analogous with the concept of ecological footprint and creates awareness of how and where this precious resource is used. The water footprint is an accurate indicator of water use that shows both the direct and indirect usage of a consumer or a producer Hoekstra et al. (2011).

A water footprint can be estimated for an individual, a family, a village, a city, a province or a nation. It not only includes the volume of water used but where this water is used. Developing this understanding can assist in forming a basis for a better management of the globe`s freshwater resources (Hoekstra & Hung, 2005). The water footprint of a country is normally different from the actual domestic use of domestic water either because the country is importing and/or exporting water in virtual form.

24.1 The Components of Water Footprint

Hoekstra and Chapagain (2008) point out that the two elements internal and external of the water footprint include three components: green water, blue water and grey water. They are defined more clearly by Hastings and Pegram (2012) as among the subtypes of water footprint, the green footprint is particularly concerned with rainwater temporarily stored close to the point of precipitation (i.e. before it enters the soil and general water table system); once water recharges groundwater and it is used in production it is known as blue water; and grey water footprint is concerned with freshwater used to assimilate or dilute pollutants in relation to conventional expectations and standards of quality. For the purposes of this thesis, the terms green, blue and grey water are used as defined by Hoekstra and Chapagain (2008) as follows: The blue water footprint is the volume of freshwater that evaporated from the global blue water resources (surface water and ground water) to produce the goods and services consumed by the individual or community. The green water footprint is the volume of water evaporated from the global green water resources (rainwater stored in the soil as soil moisture). The grey water footprint is the volume of polluted water that associates with the production of all goods and services for the individual or community.

24.2 The Importance of the Water Footprint

The importance of water footprint is that it introduces a new clear and accurate indicator of water consumption within a country by adding the volume of water in the form of virtual water to the volume of water used inside the country from domestic sources. This indicator is able to contribute to developing water management methods and help decision-makers draw up a suitable water strategy in the face of growing demand. Hoekstra and Chapagain (2007) point out that analysis of water footprints gives new data and perspectives that provide a more optimistic viewpoint about the threat of a water shortage. Because of the new knowledge, traditional water and food security concepts are likely to change in the minds of most policy-makers. In conclusion, policy and infrastructure planning should consider water footprint for its intrinsic worth, and it is also a useful tool to increase public awareness and promote collaborative efforts that bring stakeholders together.

24.3 Major Determinants of a Water Footprint

According to Hoekstra and Chapagain (2008) to determine the water footprint of a country, there are four factors that contribute. These are: consumption volume; consumption pattern; climate; and agricultural practice.



24.3.1 Consumption Volume

This is generally related to the national income of a country. It partially explains the high-water footprints of nations such as the USA (2,480 m3 /year per Capita). In Europe, two south European countries Italy (2,300 m3 /year per Capita), Spain (2,400 m 3 /year per Capita) have high water footprints, despite not being wealthy compared to other European nations (Smil, 2008). In rich countries, where the income of people is high, consumption of goods is more than others which immediately increases water footprint. Therefore, it explains the large water footprint of countries such as the USA and Canada as a result of high meat consumption, where 1 kg of beef require 15,000 litres of water (15m3 /water) to 30,000 litres (30m3 /water). However, soybeans (for protein) and corn require an average of between about 500 and 1,900 litres (0.5 – 1.9m3 / of water per kilogram of harvested grain (Smil, 2008).

24.3.2 Consumption Pattern

Hoekstra and Chapagain (2008) point out that consuming large volumes of meat significantly increases the water footprint. This is one of the factors that contribute to the large water footprints of different nations such as the USA, Canada, France and Spain. For instance, the consumption rate of meat in the USA is up to 124 kg/Capita/year, which is more than three times the world average consumption rate of meat (38kg/Capita/year) (Speedy, 2003).

24.3.3 Climate, Evaporation Demand at Place of Production

Areas with a high evaporative demand will have a larger water requirement per unit of crop production than areas with low evaporative demand because more water is lost to evaporation. This contributes to the large water footprint of nations such as Iran, where its water footprint is relatively high (1,624 m 3 /Cap/year) as a result of low yields of crops (Hoekstra and Chapagain, 2008).

24.3.4 Agricultural Practice: Water Use Efficiency

This refers to the efficiency with which water is used in crop production. It includes poor agricultural practice such as using inefficient technology for irrigation systems and water pricing.

The awareness of farmers and decision-makers about water use efficiency has a significant effect on the water footprint of a nation. Hoekstra and Chapagain (2007) argue that this is an acceptable explanation for the high-water footprints of nations such as Thailand, Sudan, and Nigeria. For example, although the global productivity average of rice yields is 3.9 tonne/ha in the period 1997–2001, Thailand, where water efficiency is low, has rice productivity of 2.5 tonne/ha in the same period (Hoekstra and Chapagain, 2007).

**25.0 THE CONCEPT OF WATER SUSTAINABILITY**

Maintaining water sustainability in sub-Saharan Africa is a goal for reducing poverty and hunger. Africa holds about one-third of the world’s major international water basins (United Nations Environment Programme [UNEP], 2010), and has an abundance of water resources, including large rivers, lakes, and widespread ground water resources. Yet, despite this abundant water supply, more than 300 of the 800 million people in sub-Saharan Africa live in water scarce environments (New Partnership for Africa’s Development (NPAD, 2006). Furthermore, Africa faces several socio-economic challenges that call for action in order to counteract current poverty and underdevelopment trends. The role of water to accomplish needed socio-economic development goals is becoming increasingly apparent. The vast majority of Africa’s water basins are international and water resource management is difficult without partnership and cooperation between countries (United Nations Water/Africa Agency, 2009). Conflicts between countries have expanded and could intensify as water scarcity increases (Schreiner & Hassan, 2011). While laws exist to deal with water conflicts at the national and local levels. Current international laws are inadequate to address conflicts between countries (United Nations Water/Africa Agency, 2009).

25.1 The role of Climate change

Climate change is one of the factors influencing water resources. Precipitation, temperature and evapotranspiration are the major climate change drivers that affect water resources (IPCC 2007). According to the global assessment of water resources, water resources will be subjected to stress by climate change, and population growth scenarios around the world (Raneesh 2014). According to the Global Climate Model (GCM), within the next 100 years, temperatures will rise, causing rainfall to decrease in some areas and increase in other areas (IPCC 2007). This change in climate will also affect seasonal precipitation such that winter rain will increase and yet, this increase might not occur in times when it is most needed. The increase in temperature and decrease in precipitation will eventually affect the balance between water demand and supply.



**26.0 THE ASPECT OF EDUCATION TO IMPROVE COMMUNITY SO THAT THE NEXT GENERATION HAS THE TOOLS AND MINDSET TO TAKE RESPONSIBLE ACTIONS FOR INTEGRATED WATER RESOURCES MANAGEMENT (IWRM)**

Many human behaviours, including social, political, and economic actions, have an impact on the natural environment, and are responsible for causing many of the current environmental challenges and issues. This raises the importance of education, particularly Integrated Water Resources Management Education (IWRME), as a necessary tool to equip people to address environmental issues and move towards environmental sustainability. Educators widely accept that a focused Integrated Water Resources Management Education (IWRME), program should teach problem solving, decision making, and citizenship action skills in addition to basic ecosystem, water supply, water management, water conservation principles (UNESCO 1978, Hart 1981). In developing IWRM Action Plan, it will be necessary to address the national targets for species and habitants. Education is useful in such a way that it raises awareness of the need for biodiversity thereby gaining wider public commitment. Education and awareness campaigns help to provide a basis for monitoring progress in biodiversity conservation, water conservation, IWRM at both local and national level. Education is very important and it creates a room for awareness to the community.

Education plays a vital role is transforming the community to learn, encourage and strengthen the morale, attitude, behaviour and knowledge of the members. International Integrated Water Resources Management Education (IIWRME) declarations such as the Tbilisi Declaration have highlighted that investigating peoples’ environmental awareness, attitudes, and behaviour towards environmental issues could inform educational approaches geared towards a more sustainable future. These objectives are important in this study as they illustrate the importance of water conservation, protection, management, control and use and control for the awareness, attitudes, and participation (behaviour). Although education in and about the environment aim to enhance awareness and understanding, education for the environment goes beyond awareness to students developing a sense of responsibility to be actively involved in the resolution of the environmental issues. It adopts a holistic approach to the study of environmental problems, and is global and interdisciplinary. Education for the environment therefore acknowledges the socio-political dimensions of environmental issues (Jickling & Spork, 1998; Tilbury, 1995) and includes critical education objectives and an issue-based pedagogy. Principles of environmental education towards improving the knowledge and commitment of the community:

26.1 Knowledge and Awareness

Environmental problems such as global warming, acid rain, fresh water scarcity, deforestation, desertification, loss of biodiversity, soil depletion and many others, have become a major concern (Iran Politik, 2015). Air and water pollution have reached such levels that they have already resulted in serious health problems, as well as negative impacts on the environment (Hassanshahian et al., 2013). From an environmental point of view, lack of environmental, water conservation and preservation awareness and knowledge among people, especially students who are the future leaders and policymakers, will mean that environmental problems continue unresolved. Traditional IWRMEE used a scientific approach and was mostly concerned with knowledge of the effects of environmental problems. The community gets to know about the effects of environmental issues without necessarily gaining understanding about the root causes of these issues or how these might be addressed. Indeed, as some researchers have indicated, such knowledge can create a great sense of worry, weakening commitment, and disempowering students by overwhelming them with too much information about the issues, without helping them to actively try to solve the issues.

The main goal of environmental education is the development of the student’s and communities ability to act and effect change, it follows that associated knowledge and insight should in essence be action oriented. Decisions and behaviours about integrated water resources management, water conservation are influenced by environmental awareness and attitudes (Kollmuss & Agyeman, 2002). Environmental and water conservation is a responsibility of everyone in the community. It is with the community to have the right attitudes, skills, and awareness and be willing to participate to issues affecting the environment. A good working relations helping to achieve commitment from key organisations. With the guidance of legislations which serves as a guiding instrument to guide the key stakeholders about their roles and responsibilities. Development of plans which offers many opportunities for assisting with the delivery of biodiversity targets and are often crucial in this respect.

Partnerships are also encouraged to be developed in such a way to ensure that programmes for biodiversity conservation are maintained in the long-term. Effective partnerships in terms of raising awareness of the importance of biodiversity and to ensure that opportunities for conservation and enhancement of the whole biodiversity resources are fully considered. To provide a basis for monitoring progress in biodiversity conservation from the key stakeholders.



26.2 The role of the Community in Ensuring Safe Water Supplies

According to UNDP (1990) the global water conference endorsed community management as the guiding principle in water management. This was part of the reaction to the continuous failures in upkeep and maintaining of community participation schemes of the 1980s. Paradigm championed by Chambers et al. (1980) that communities should not just be involved in system inception, but should accept sole responsibility for and ownership of the whole life cycle of the system entrusted to the community. Other supporting principles on community management was adopted from The New Delhi Statement (1992) promotes an integrated approach in addressing different challenges of developing nations, that involves changes in procedures, attitudes and behavior and integrate full participation of women at all levels in sector institutions. It further encourages the use of appropriate sound financial practices, where community management should play a significant role in promoting their communities (Schouten & Moriarty, 2003’).

This principle was further stressed in the Dublin Statement on water sustainable development in 1992 (ICWE 1992), which agreed that water development and management should be based on a participatory approach involving users, planners and policy makers at all levels. They emphasized that women play a central part in provision, management and safeguarding of water because the adverse impacts of water affects them most during water crisis times. It is against this background that this study will seek to investigate the level of involvement of the community of Aliwal North by way of examining the knowledge and information sharing in water demand management. Activities linked to community management encouragement of water development and management based on a participatory approach, involving users, planners, and policy makers at all levels. Application of the principal that decisions are to be taken at the lowest appropriate level, with public consultation and involvement of users in the planning and implementation of water projects. Support and assistance to communities in managing their own system on sustainable basis.

Encouragement of local population, especially women, youth, indigenous people and local communities in water management. Linkages between national plans and community management of waters and integration of community management within the context of overall planning. A positive outcome for the new team which was formed was that it was stipulated that management and the staff had to have the knowledge of the crisis situation and how to address it. The new appointed managing director devised the solution of working with every community member to deal with an ongoing crisis. In a way of responding to a growing concern of water challenge and limited resources at its disposal and the building capacity and strengthening operations in various innovative approaches which included; effective change management, emerging managerial tools and principals, water loss management, water resource protection and stakeholder coordination, timely water production capacity building. Water resource protection and stakeholder coordination faced many external difficulties which affected service delivery that came as a result of climatic change, and involved the quantity and quality of raw water in most areas of the country. A continuum approach was developed to respond to the water challenges. One of these approaches was to emphasis on compliance with abstraction permit conditions, among others, the need for utility restriction of war water abstracted within the acceptable limits. The NSWC management increased the watch on surveillance of the source and condition with the environment protection authorities and communities where measures were undertaken to protect the source and reduce any adverse impacts.

Timely water protection and capacity building; A major investment was put in place prior to 1998 resulted in extensive Idle plant capacity for most infrastructure systems. The excessive idle plant capacity gave rise to economical depreciation costs, which brought operation cost up due to the oversize system. These massive investment activities also meant the funds were focused to that project and there were no enough funds left to carry out network expansion programs. However, coming from a new connection policy, expansion of customer base and improvement in service delivery improved that utilization capacity of the system to 75% in 2007. Though new water supplies will continue to be developed and new water systems installed, particularly in the developing world, neither the MDG nor the secularly growing demands for food will be met from actions on the supply.

26.3 Training and Capacity Building

Water sector capacity building supports the process of transformation for the implementation of integrated water resources management, including water policies and legislation, institutional development and human resources development“ (CAP-NET 2002:4). The two interviewed experts in capacity building for water management consider capacity building to be essential for successful IWRM implementation and to enhance resilience to climate change impacts. Capacity building aims to make expertise available, to support decentralization processes for decision-making and empowers people on the local level to develop skills.



As capacity building supports the ability, to manage water resources effectively and to maintain local water infrastructure, it ultimately contributes to people’s resilience at local level. WDM as a major component of integrated water resources management is still at a preliminary stage of development. What is clear is that, whatever the path of development, training and capacity building will be essential. What is not clear is the level and type of training and capacity building that this project should include, particularly given the possibility for adjustment among tasks, as suggested elsewhere. For example, prior to decisions about how to approach guidelines, it is premature to suggest appropriate training. Decisions are still further complicated by the fact that, as emphasized above, considerable capacity is being built through the project itself. Analysts are beginning to see WDM as a promising field for research and the officials are recognizing the need to introduce WDM into programming; and new tools and techniques are being introduced and tried.

Still another problem in making choices lies in the fact that differences between training and capacity building are not clear in the proposal. In my use of the terms, capacity is built to serve a panoply of activities that will occur over the longer term; training is arranged for a specific task that needs to be accomplished in the near term. Capacity building contributes to raising awareness for water-related issues, including the impacts of climate change. Awareness is important to support integrated approaches and sustainable water management (IP12, UNESCO 2009). Interview partners considered awareness building and environmental education from school level as important, to promote water harvesting, to improve water supply in the basin and to achieve an overall sustainable use of water resources (IP1, IP3; IP8; IP11). Awareness can start from basic education where culture can be built so that people coming-out of institutions understand the importance of the water sector and how water resources should be managed (IP11Q9).

Furthermore UNEP (2009) stresses the importance, to raise public awareness about the water effects of climate change, reminding users of the necessity and limitations of water resources for human existence. Awareness contributes to developing climate change adaptation strategies (UNEP 2009 Capacity building programs across sectors and levels of large proportion of suggestions made refer to capacity building on all levels and sectors to support the implementation of IWRM (IP1; IP6; IP7; IP10; IP11). According to CAP-NET (2011:1), capacity building for institutions and individuals is essential to manage, develop and use water resources sustainably, and to adapt to increasing climate variability and climate change within a context that addresses gender equity and sustainable livelihoods”.

It is believed that capacity building prevents conflicts in the basin, helps to control illegal use of water resources, leads to better financial management, helps to maintain infrastructure and supports the implementation of IWRM e.g. through effective planning, increased inter-sectoral interaction and stronger involvement of disadvantaged groups (IP1; IP6; IP11). Furthermore, people on the ground develop skills that directly contribute to improving livelihoods: people should be empowered in a sense that they need to develop portable skills that they can also use for other projects or in their own, if they develop an own business” (IP7Q2). Upgrade of Infrastructure, according to UNEP (2009), the physical infrastructure is generally more advanced in countries that have adopted integrated approaches. As water infrastructure is the base to ensure access to water, investments in infrastructure to ensure access to water as well as capacity building are important to enable people to value the water infrastructure and to adequately and sustainably maintain it.

Involvement of disadvantaged people, empower women and decentralise decision-making is important. Without the involvement of local communities and their interests and needs, implementation of IWRM is not possible (DUNGUMARO & MADULU 2002). Interview partners identified the rural poor, including subsistence farmers and women as the most disadvantaged groups in participation of decision-making. As competition over water resources is particularly high in the water stressed and the protection of poor people’s rights to water for productive purposes is of high importance. Suggestions referred to increasing the involvement of disadvantaged people to provide equal decision-making across sectors and levels. Greater involvement can be achieved through effective communication between planners and water managers with the rural poor and through the provision of access to information, whenever water governance decisions are taken (KOPPEN ET AL. 2002). Interview partners also highlighted the important role of women in water-related issues and advocate for their greater involvement in water management to contribute to sustainability (IP1; IP3).

Beside traditional gender inequities, women themselves also need to develop more self-confidence and support each other. Furthermore, awareness building and cooperatives at local levels also contribute to the empowerment of women. Involving disadvantaged people also implied further decentralisation and decentralized decision-making on the basin level (IP3; IP4; IP7), highlighting that “[…] decision-making should be decentralized to the community as much as possible” (IP7Q2).

26.4 Public Awareness

An overall drought preparedness and management programme must proactively incorporate risk assessment and planning for various sectors and population groups, to reduce the risk of identifying and adopting appropriate mitigation measures (Wilhite, 2000 cited in Low, 2005). According to Low (2005) monitoring, prediction and early (regular updated) warning are considered to be the foundation for appropriate responses and recovery measures, which require the development of an organisation framework and institutional capacity. Capacity building needs in Africa for education, training and awareness include the development or the improvement of national programmes for formal or non-formal education, as well as raising awareness on climate issues in academic and research institutions and amount the public at large (Low, 2005). George Municipality implemented a Public Awareness Campaign in 2009 to 2011, including the following general measures (Basson & Mooiman, 2010). Banners on main access roads, lamp post posters for certain areas in George, billboard signage at main entrances to various areas, posters at public places: municipal offices, libraries, clinics, etc.

Information on digital screen in accounts payment offices and plasma screens in municipal offices and other areas in town. Creating public awareness about water scarcity Continue public awareness campaigns and water education through several means of communication and media focusing on water scarcity and spreading the culture of awareness and responsibility to protect the water sources and its efficient use. Public awareness programs should be implemented for staff and employee in all sectors (tourism, industrial, commercial, agricultural, etc.), to increase public awareness of importance of water and its efficient use in the community. Capacitate and empower community members Developing the capacity of water sector institutions and capacity-building of human resources must be given priorities, through organizing training and continuous education programs (whether internal or external training), in particular for those concerned in the implementation of water demand management policy, and provide them with the needed experience and communication through close interaction with relevant parties with experience and knowledge in the field.

Training operating and maintenance technicians in all water and water facilities, to raise their skills and enable them to perform various tasks with professionalism and in accordance with best practices for operations, maintenance, planning and management. drought mitigation measures Finally, drought mitigation measures should be made available to the people, since it has been proven that, in drought prone areas, it should be clearly indicated to the community members that drought is a natural phenomenon and may occur from time to time.



It should be made clear that water scarcity has a negative impact on all sectors, especially irrigated agriculture sector, and therefore it is necessary to develop strategy and action plans to manage the drought crisis, including early warning systems for drought preparedness in the event of an occurrence. It is widely recognized, that without a change in the way consumers and industries use water, sustainable water resources management is not possible. Awareness around the value and scarcity of the resource is therefore extremely important to achieve sustainable water management (SCHAAP & STEENBERGEN 2001). When questioned about their awareness of water-related issues in the basin, interview partners identified a general lack of awareness of water scarcity or the value of water and also the consequences of water pollution. According to stakeholder's experiences, a lack of knowledge (capacities) within the population was identified as a possible reason. Furthermore it seems that the government does not do enough to raise awareness about water-related issues or climate change within the country. However, experts did note some improvements of awareness within the population during the last few years.

26.5 Partnerships and Collaboration

Partnerships with other agencies and organizations working on water issues in SADC are critical to full development of the WDM project. In particular, plans for joint work on regional water policies and on awareness and communications been worked out with the SADC Water Sector Coordinating Unit (WSCU). Both teams deserve credit for persevering to the point where now they appear to be working in a collaborative mode. Joint activities currently focus around two areas of work: one on regional water policies (few of which currently refer to WDM) andthe other on increasing awareness of WDM. In addition, SADC’s Water Resources Technical Committee was helpful in the initial stages of establishing a base for the Country Studies.

Increase cooperation and communication across levels and sectors about IWRM is about cooperation and communication between different stakeholders from different sectors and levels (GWP 2013). To achieve integrated water management, IP8 highlights that people from the water sector have to work hand in hand with people working in agriculture and other sectors, this would mean an integrated way (IP8Q11). Suggestions for governments refer to better cooperation with lower levels: “The government should work more with the local level and small farmers and other stakeholders (IP9Q3). IP13 concludes: “I think IWRM needs to create a good link between local communities and marginalized groups and link them with local and national government” (IP13Q7).



26.6 Compliance of Water Licensing

To prevent tensions between different water users, the water license presents a tool to control allocation in the water scarce Orange-Senqu river basin. As non-compliance of water licensing by high volume users was identified as an impedement to sustainable water management, interview partners demanded compliance from high-volume water users and for the municipalities to improve their monitoring systems (IP3; IP7; IP8). Integrate climate change to water management plans about water resources will be increasingly affected by climate change terms of quantity and quality. Water management must respond to new risks through climate change and develop adequate adaptation responses (see UNSECO 2009). However, primarily the most vulnerable groups to climate change impacts have to be identified to develop adaptation measures, measures to mitigate and adapt to the impacts of climate change cannot be identified without first assessing the vulnerability of existing water management and water functions“ UNEP (2009:11).

In terms of agriculture, interview partners suggested that more efficient water use and the diversification of crops would be possible ways to adapt to dry conditions in the basin. Awareness building is important to draw attention to climate change impacts, to strengthen capacities within the government and to develop adequate adaptation measure, thus enhancing capacities and resilience to climate change (IP5; IP10). To plan for climate change also requires an understanding of the drivers that impact the hydrological cycle and awareness around the interconnections between water and climate change. Providing access to information in terms of what the impacts of climate change are, is seen as a key element to all subsequent adaptation measures (IP2; IP13). Better modelling and prediction would furthermore support climate change adaptation in the water sector, thus demanding for more involvement of scientific knowledge in certain decision processes.

26.7 Water Demand Management Strategy

According to the Human (2013a) to meet the challenge of growing demand on raw water resources, and to ensure that growth and development remains sustainable in the George municipal area, the George Municipality committed itself, as far as practically possible, to uphold and continually impose the water demand management (WDM) measures currently in place, and to impose new measures where water demand management could be further improved. The water demand management measures by the government include, Water Master Plan, pipe replacement and maintenance program, complaints system, standby teams for immediate repair of burst pipes, pressure management, promoting use of water efficient fittings, zone metering, telemetry system, installation of bulk meters in existing areas for monitoring, accurate records of water use and losses, promote rain water harvesting, promote indigenous gardens and water restriction. WDM strategy refers to measures that community can use to reduce water wastage and inefficient use, and includes measures to effectively manage and sustain efficiency targets. Installation of systems that measure and identify certain key parameters, such as minimum night flows, and systems to enable detailed and regular water audits and water balances.

26.8 Community Involvement

Community involvement can be a good strategy to report and inform government about water wastes, water leaks, pipe bursts. This can improve service delivery and customer relations; it has improved on the flow of water and reduced losses incurred. Community provides unskilled labour and locally available materials in the integration of community water resource management. Community involvement regarding water management.According to UN (2012b), water scarcity is not solely a natural phenomenon, is also a human phenomenon, a numerous of human activities such as untimely water use, pollution, insufficient or poorly maintained, infrastructure or inadequate management systems can result in or exacerbate water scarcity.

As noted by the United Nations, there are adequate water resources to meet our needs, but water is distributed unevenly and too much of it is wasted, polluted and unsustainably managed. A community’s vulnerability to climate change will depend upon the magnitude of the impact and the community’s sensitivity and adaptive capacity, According to Kenneth et (1999) the Socioeconomic impacts of floods, droughts, and climate and non-climate factors affecting the supply and demand for water will depend in large part on how society adapts. The poor and those living in developing countries are the most vulnerable because they have fewer social, technological, and financial resources to enable them to adapt.

* Sensitization on effective use of water

Workshops in schools and churches by water officials are the major means of public education being used in the study area. Such sensitization events are also done by water supply staff at market places in their respective areas of operation.

Among the topics covered in the public education forums are water use management practices like reporting leaking taps, burst water pipes, water recycling and control of free flow of water from taps. Additional measures such as public showers and taps at beaches disconnected, public taps disconnected on municipal property e.g. at graveyards, campaigns to ensure each public toilet had a brick/hippo bag, and residents installed flow reducing devices on private showers and taps and indigents encouraged to report leaks in their homes these were repaired at no cost. Marketing or advertising could occur on a quarterly or bi-annually basis and on social media, local radio, billboards and in the local newspaper, as a friendly reminder to respect water, its consumption and conservation.

* Building community of practice for water sensitive strategy

According to Carden (2015: 5), developing a strategy in terms of water sensitivity is core to the future sustainability of water resources because water is a fundamental enabler of all life and primary catalyst for human development. Increasing urbanisation and extension of services to underserviced areas provide an opportunity to plan and manage water differently. In this regard, a water sensitive strategy should be linked to WSUD as it integrates water cycle management with the present built environment through urban planning, urban design and urban management. This provides multiple benefits and opportunities to overcome the challenges of water management. WSUD can help with the following:

* Building flexibility and adaptability into city water sources as well as water supply catchments
* Building flexibility and adaptability into sanitation ensuring healthy cities
* Blue-green infrastructure with cities providing ecosystem services
* Building social and institutional capital in cities supporting water educated communities (Carden, 2015: 6).

Carden (2015: 6) emphasised that better urban water management provides the core for multi-value, multifunctional urban spaces fit to cope with future challenges, and that building a community of practice aims to create strategic learning alliances so that stakeholders can engage in collective sense-making and vision-building, while placing strong emphasis on community participation and the creation of social capital and human development. Carden (2015: 17) explained that the development and management of a Water Sensitive Design Community of Practice programme aims to strengthen the researcher/stakeholder and the implementer interface. This would assist in leveraging partnerships and facilitate, manage and document technology, thus transferring opportunities from the planning and design phases through to the piloting  (adapting) and implementation phases. The author proposed the following strategies for community of practice. Enabling environment through social learning by empowering communities and community based solutions. Shared interest, joint activities and discussion in order to create understanding and social capital for better community involvement. Enhanced generation of knowledge through collaborative learning processes, knowledge management and exchange. Adaptive management embedded in social learning processes by creating an environment that supports adaptation and systematic learning and growth.

26.9 Community Empowerment

The results show that, for the community members to be effective, they have to be empowered and ensure their involvement in water governance. In this regard, the local community members have to be assisted to participate fully in the process, which will make them manage the limited, and scarce water resources effectively use them equitably and in a sustainable manner. Furthermore, if water infrastructure such as community water tanks and Jojo tanks can be made available through government support to the community rainwater could be stored, it could be used during the dry seasons of droughts allowing for more water available to the community. In order to take care of the issue of water shortage, as women are the defenceless people, their inclusion in basic leadership is exceptionally required. Training women on their rights with the goal that they know how to fight against any injustice and for their rights will help them to go far towards enabling them and their community members later on. Community knowledge is imperative.

There is in this manner the need to manage shameful acts of injustice that socially, financially and substantially minimized females through regulations, which aim to diminish imbalance and enhance prosperity. It was demonstrated from the findings that sexual orientation is performed in terms of water it thus makes sense that there is a need for change in how young men and young women are raised so they can all participate in gender-neutral activities. The results show that, for the community members to be effective, they have to be empowered and ensure their involvement in water governance. In this regard, the local community members have to be assisted to participate fully in the process, which will make them manage the limited, and scarce water resources effectively use them equitably and in a sustainable manner. Furthermore, if water infrastructure such as community water tanks and Jojo tanks can be made available through government support to the community rainwater could be stored, it could be used during the dry seasons of droughts allowing for more water available to the community. This information is important in the study because it provides the researcher with possible solutions to be implemented to mitigate the water problem. Although faced with limited physical, financial and ecological resources to potential water supplies, countries try their best to set the right institutional foundation of their water sector. These efforts are reflected in terms of legal and policy reforms and water user organization establishments. Ethiopia has begun to recognize since 1993 the functional distinction between centralized mechanisms needed for coordination and enforcement and decentralized mechanisms needed for user participation and decision-making. The recent example of this ongoing decentralization is utility agencies in the urban water sector. The importance of user’s participation for effective decision making at the lowest practical level has also been realized. Water supplies services in most towns and cities in Ethiopia are organized as Urban Water Supply Services established by Government proclamation in many of the big cities and towns found in Regions.

They are autonomous and plan, develop and operate, within the legal and policy provisions that they are required to do. Recurrent droughts, inadequate clean water supply and the poor state of water resource management in the country have prompted professionals and practitioners to get organized into civil groups and help water development efforts. The Ethiopian Rainwater Harvesting Association was formed in 2000. This Association has been engaged in grassroots level research and dissemination of relevant knowledge to water users both in the rural and urban areas. According to the EWRMP, in order to enhance readiness to pay and ensure transparency in the financial management and fair and balanced services, users and communities are required to participate in the management of the systems. The full participation of users is very important for effective decision making at the lowest practical level.

But, in view of the social and economic complexities prevailing in the urban centres, the decision making process could be through elected representatives in Government and associations organized to meet and support certain social and economic demands of respective urban communities. Rahmato (1999) indicated that the formation of civil groups in the water sector is a new phenomenon in Ethiopia, which is hoped to fill the gap left due to the institutional instability in the water sector. These societies are already gathering large pools of membership with diverse expertise and experience. Increased public participation in the water sector will greatly help expand the knowledge about the water sector and will serve as a public watchdog on governmental and business handling of the country’s water resources. The necessity of community participation in decision-making processes, incorporating gender issues in water resource management policies.



26.10 Public Participation

The water problem is a collective issue that requires a collective solution to the problem. Thus, shared reasoning that will train individuals about the significance of water conservation, raising awareness enlightening community, agriculturists and businesses regarding the hugeness of water saving condition and sheltering them from contamination is recommended. This could assemble a superior associated and engaged society, which empowers straightforwardness and trust in the quest for collective objectives. The growing populace and a new way of life increment more interest in water provisions and more resources to deliver. This implies that if the nation is not taking care of this in future this will require more water assets. Thus, it is recommended that public organizations, common society, and local gatherings must meet up and work in tandem with each other.

26.11 Environmental Change

It is recommended that people should maintain natural resources for living and future generations. Industries should use less water and recycle in order to maintain groundwater levels.

**27.0 CONCLUSION**

In view of the discussions above, I am strongly convinced to conclude that water is essential to all living things. It forms part of our lives and is deeply embedded in our traditions and cultural backgrounds. The quantity and quality of water is an essential component in socio-economic development as well as poverty reduction. Significantly numerous factors have an impact on both water resources and the integrated, sustainable and equitable management of water. Water resources such as lakes, rivers and coastlines attract people for a number of reasons. Clean water is crucial for domestic purposes (bathing, washing, irrigation, drinking), industrial uses (cooling purposes), transportation, recreation (e.g. swimming, fishing, skipping, diving as well as tourism), hunting, biodiversity support (ecological needs) as well as aesthetic enjoyment. Historically, water has been used to dispose of and dilute contaminants. The chapter presented results of the data analysis based on the focus group discussions of questionnaires, observations and key informant interviews carried out.

The section discussed the socio demographic characteristics of respondents, water sources, social impacts of water scarcity and environmental preparedness, mitigation measures of the community regarding water scarcity issues. The main reasons for lack of awareness or information of water scarcity were discussed. Most households relied on assistance from NGOs and government to cope while their major strength to adapt to the impact of scarcity. This thesis identified the disparity between South Africa’s water governance framework, which provides the legal framework for IWRM and the implementation of IWRM on the ground. The National Water Act is widely recognized as one of the most comprehensive water laws in the world. The Department of Water and Sanitation, summarizes, that although paradoxically South Africa has a fairly well developed water management and infrastructure framework which has resulted in a perceived sense of water security (urban and growth areas), IWRM faces many challenges.

This thesis furthermore highlights the importance of participatory decision-making for sustainable water management. However, despite the decentralisation policies (Catchment Management Agencies) of South Africa’s government to promote decentralized decision-making and to increase the involvement of local communities, interview partners assessed involvement and participation in the basin to be unequal. The local (rural) poor, people in informal settlements and women were identified to be the most disadvantaged and marginalised in decision-making and the most vulnerable groups to climate change. As the involvement of all stakeholders is estimated to be highly significant to the implementation of IWRM, a proper `bottom-up´ approach is obviously lacking so far, thus affecting successful IWRM implementation in some communities. Capacity building is important in order to reduce vulnerabilities of people to the impacts of climate change and to enhances their resilience to climate change impacts, although some challenges such as high costs or a lack of willingness to cooperate present major obstacles for capacity building to succeed. Recommendations refer to national, provincial/basin and local levels and tackle a range of aspects such as capacities building, awareness building, further decentralisation processes needed to involve local communities and women, a need for stronger focus on social and environmental aspects especially from political and municipal sides and an improved monitoring of compliance with regulations were all demanded. Investments in water infrastructure would for example raise access to water, thus enabling people to improve livelihoods and build resilience against climate change impacts.

As certain groups are highly disadvantaged in participation opportunities, capacity building is facing challenges to support sustainable water management and the impacts of climate change are likely to worsen water scarcity in the basin, projections of future development poses many questions. These include improved access to water and sanitation services, particularly in rural areas in the last two decades, and higher awareness around water-related issues within the country. Nevertheless, IWRM is a slow process and it will still take several years to achieve water security and the overall goal of sustainable development within the basin. It is important for the government departments to start monitoring and evaluating the demand of water versus water supply and water conservation practices to conserve, protect, use, manage, control and develop water resources.

However, the experts gave several recommendations in order to tackle those problems and to support sustainable water management. First and foremost, the experts called for capacity building on national, municipal and local level. Capacity building plays a huge role in the support of IWRM implementation through which people can develop awareness of water related issues and the impacts of climate change, thus enhancing the resilience of the population. Environmental education was also suggested to raise awareness for environmental issues, beginning from school age so as to achieve more acceptance and acknowledgement of the importance of sustainable water management. Awareness campaigns within the population were seen as potential ways to tackle pollutions issues and to reinstate the economic value of scarce water resources in the basin. As IWRM stands for equal participation in decision-making over water resources between different users, the involvement of marginalized groups such as local communities should form a primary focus.

Furthermore, as these groups are considered to be highly vulnerable to climate change impacts, access to information on adaptation measures would help to build resilience. South Africa’s water governance is considered to be one of the most advanced in the world, providing the theoretical framework for IWRM. Although the interviewed experts identified several obstacles for successful IWRM implementation, most of them seemed generally optimistic for the future of IWRM. Thirdly, the discussion in chapter 6 is worthy to discuss. As IWRM is a highly complex concept, it was very hard to focus on both what makes IWRM work, while at the same time evaluating the whole of process of IWRM implementation, the role of climate change and it's constrains to succeed sustainable water management at the same time. Although many hypotheses were developed during the coding process itself, only three were presented and further discussed in detail. Furthermore, as the third hypothesis tried to analyse the importance to include climate change into water management strategies, it was not possible to properly focus on adaptation strategies that are important to reduce vulnerabilities to climate change.

Rather it tried to highlight the importance to integrate the impacts of climate variability and change into water management to achieve water security and sustainable development. Although the author attempted to discuss as much given information as possible from the results (in chapter 5) but even reducing this to only 3 hypothesis, it was very challenging to focus in detail. As, for this thesis only experts from national and provincial levels were interviewed, another suggestions for future research refers to the choice of interview partners. IWRM promotes a participatory decision-making approach involving of all different users. Therefore, further investigation of and interviews with marginalized groups such as the rural local population and people of informal settlements is recommended, particularly to evaluate perceptions and awareness of water related issues, the impacts of climate change and their views towards participation opportunities in decision-making processes.

In consideration of the various national laws, acts and processes in the water sector, it would be also quite interesting to have a closer look at South Africa’s water governance and the legal framework for IWRM. Regarding the assumption that the water crisis is a crisis of governance, a future area of research could focus on South Africa´s water governance more in detail. In terms of climate change, adaptation strategies to climate change despite prediction uncertainties would also form an interesting focus. Furthermore, to return to the basin in a few years so as to access progresses made in IWRM implementation, would also be an interesting extension to this master's thesis. As water scarcity and therefore competition between users is likely to become more aggressive in the basin in future, another study of the progress of IWRM implementation would be interesting.



The factors that contribute to IWRM, water security, environmental management, adequate water supply and distribution, water quantity and water balance are important factors to be taken into account to ensure equitable provision of potable water to the community. Alternative water sources such as boreholes, springs, and wetlands should be looked at in order to ensure that the supply meets the demand at all times. Management instruments are needed to be in place to mainstream the cost of water supply. IWRM is a balancing process and change from unsustainable to sustainable management. It promotes holistic approach to integration, water demand management, economic value and economic use of water.

**28.0 BIBLIOGRAPHY**

ADAM, A. (1999) Water Supply up grading projects-their potential impacts. Integrated Development for water supply and sanitation, 25th WEDC Conference, Addis Ababa, Ethiopia, 1999.

AGRAWAL, A. & GIBSON, C. (1999) Enchantment and disenchantment: The role of community in natural resource conservation. World Development 25 (4), 629-649.

Ajami, N. K., Duan, Q., and Sorooshian, S. (2007). “An integrated hydrologic Bayesian multimodel combination framework: Confronting input, parameter, and model structural uncertainty in hydrologic prediction.” Water Resources Research, 43(1), 1–19.

ALAVIAN, V., H.M. QADDUMI, E. DICKSON, S.M. DIEZ, A.V. DANILENKO, R. F. HIRJI, G. PUZ, C. PIZARRO, M. JACOBSEN, B. BANKESPOOR (2009): Water and Climate Change: Understanding the risks and making Climate-smart investment decisions: The World Bank.

Anderson, R. L., Steinitz, C., Arias Rojo, H. M., & Bassett, S. (2003). Alternative futures for changing landscapes: the Upper San Pedro River Basin in Arizona and Sonora. Washington; London: Island Press.

Ansar, A., Flyvbjerg, B., Budzier, A., and Lunn, D. (2014). “Should we build more large dams? The actual costs of hydropower megaproject development.” Energy Policy, Elsevier, 69, 43–56.

Bdour, A. M. (2012). Perspectives on a Strategic Jordanian Water Project: The Red Sea to Dead Sea Water Conveyance Construction. Journal of Emerging Trends in Eng. & App. Sciences, 3(1).

Becker, A., & Hattermann, F. (2005). Model-supported Participatory Planning for Integrated River Basin Management (Deliverable No. D3/11-13) Deliverables. H.-C. W. 3: Harmoni-CA-Project.

Becker, K. (2000). Hydrological and Hydrogeological Investigations along Wadi Shueib, Jordan. Unpublished Diploma-Thesis, University of Karlsruhe, Karlsruhe.

Ben Hussein, M. (2010). Fuheis residents demand relocation of cement factory. Jordan Times, April 18th 2010.

Bender, F. (1974). Geology of Jordan. Berlin: Gebrüder Borntraeger.

BERGER, R. (2008): Using Software in Qualitative Research: A Step-by-Step Guide. Forum Qualitative Sozialforschung/Forum: Qualitative Social Research, 10(1), Art. 23. Available at: http://nbn-resolving.de/urn:nbn:de:0114-fqs0901235 (02.01.2013).

Berners-Lee, T., Hendler, J., & Lassila, O. (2001). The Semantic Web - A new form of Web content that is meaningful to computers will unleash a revolution of new possibilities. Scientific American, 284(5), 34.

BGR, & MWI. (2010). Delineation of Groundwater Protection Zones for the Springs in Wadi Shuayb Groundwater Resources Management: Federal Ministry for Economic Cooperation and Development.

BIGAS, H. (2012): The Global Water Crisis: Addressing an Urgent Security Issue. Papers for the Inter Action Council, 2011-2012. Hamilton, Canada: UNU-INWEH.

Black, E., Hoskins, B., Slingo, J., & Brayshaw, D. (2011). The Present Day Climate in the Middle East. In S. Mithen & E. Black (Eds.), Water, Life and Civilisation: Climate, Environment and Society in the Jordan Valley. Cambridge: Cambridge University Press.

Blaney, H. F., & Criddle, W. D. (1950). Determining water requirements in irrigated areas from climatological and irrigation data. Washington, D.C.: U.S. Soil Conservation Service.

BMU - BUNDESMINISTERIUM FÜR UMWELT, NATURSCHUTZ UND REAKTORSICHERHEIT (2001): Ministerial Declaration. The Bonn Keys. Bonns Recommendations for Action.

Borgstedt, A., & Subah, A. (2008). Groundwater Protection and Sanitation - Practical experiences in Jordan. Paper presented at the International Symposium on Coupling Sustainable Sanitation & Groundwater Protection.

Bossel, H. (1999). Indicators for sustainable development: theory, method, applications: a report to the Balaton Group. Winnipeg: IISD International Institute for Sustainable Development.

Brachman, R. J. (1985). On the Epistemological Status of Semantic Networks. In R. J. Brachman & H. Berlin Heidelberg: Springer Müller, F., & Wiggering, H. (2004). Erfahrungen und Entwicklungs potential von Ziel- und Indicator systemic.

J. Levesque (Eds.), Readings in Knowledge Representation (pp. 191-215). Los Altos, CA: Kaufmann.

California Department of Water Resources. (2010). 20x2020 Water Conservation Plan.

CAP-NET-INTERNATIONAL NETWORK FOR CAPACITY BUILDING IN INTEGRATED WATER RESOURCES MANAGEMENT (2008): Conflict Resolution and Negotiation Skills for Integrated Water Resources Management.

CAWMA. (2007). Water for food water for life: a comprehensive assessment of water management in agriculture. London: Earthscan.

Cazier, D. J., & Hawkins, R. H. (1984). Regional application of the curve number method. Proceedings of the Water Today and Tomorrow: Irrigation and Drainage Division Special Conference, New York.

Ceccaroni, L., Cortés, U., & Sànchez-Marrè, M. (2004). OntoWEDSS: augmenting environmental decision-support systems with ontologies. Environmental Modelling & Software, 19(9), 785-797.

Chermack, T. J., Lynham, S. A., & Ruona, W. E. A. (2001). A review of scenario planning literature. Futures Research Quarterly 17(2), 25.

Clerc, V., de Vries, A. E., & Lago, A. P. (2010). Using wikis to support architectural knowledge management in global software development. Proceedings of the 2010 ICSE Workshop on Sharing and Reusing Architectural Knowledge, Cape Town, South Africa.

Darari, F., & Manurung, R. (2011). Linked Lab: A Linked Data platform for Research Communities. Paper presented at the International Conference on Advanced Computer Science and Information System (ICACSIS).

Dingman, S. L. (2008). Physical Hydrology (2nd ed. Ed.). Long Grove, Ill.: Waveland.

DoS. (1994). Jordan National Population and Housing Census. Amman: Department of Statistics of the Hashemite Kingdom of Jordan.

DoS. (2004). Jordan National Population and Housing Census. Amman: Department of Statistics of the Hashemite Kingdom of Jordan.

EEA. (2005). EEA core set of indicators Technical report. European Environmental Agency. Luxembourg: European Environmental Agency. Ekins, S., Hupcey, M. A. Z., & Williams, A. J. (2011). Collaborative computational technologies for biomedical research. Hoboken, N.J.: Wiley.

Esty, D. C., Levy, M., Srebotnjak, T., & de Sherbinin, A. (2005). Environmental sustainability index: benchmarking national environmental stewardship. New Haven: Yale Center for Environmental Law and Policy.

EXACT. (1998). Overview of Middle East Water Resources. US Geological Survey.

Fahey, L., & Prusak, L. (1998). The eleven deadliest sins of knowledge management. California Management Review, 40(3), 265-+ Fahey, L., & Randall, R. M. (1998). Learning from the future: competitive foresight scenarios. New York: Wiley.

Falkenmark, M. (1986). Fresh-Water - Time for a Modified Approach. Ambio, 15(4), 192-200.

FAO. (2016). “AQUASTAT database.

Fedra, K., Weigkricht, E., & Winkelbauer, L. (1992). Decision Support and Information Systems for Regional Development Planning Problems of Economic Transition: Regional Development in Central and Eastern Europe. T. Vasko. Avebury, Aldershot, UK.

Fischhendler, I., & Heikkila, T. (2010). Does Integrated Water Resources Management Support Institutional Change? The Case of Water Policy Reform in Israel. Ecology and Society, 15(1).

Flexer, A., Guttman, J., Haddad, M., Hötzl, H., & Rosenthal, E. (2009). The Water of the Jordan Valley: Scarcity and Deterioration of Groundwater and Its Impact on the Regional Development. In H. Hötzl, P. Möller & E. Rosenthal (Eds.). Berlin, Heidelberg: Springer.

Galaz, V. (2007). Water governance, resilience and global environmental change - a reassessment of integrated water resources management. Water Science and Technology, 56(4), 1-9.

Genesereth, M. R., & Nilsson, N. J. (1988). Logical foundations of artificial intelligence (Reprint. with corr. ed.). Palo Alto: Kaufmann.

Giupponi, C., & Sgobbi, A. (2008). Models and Decisions Support Systems for Participatory Decision Making in Integrated Water Resource Management. In P. Koundouri (Ed.), Coping with Water Deficiency (Vol. 48, pp. 165-186): Springer Netherlands.

Goovaerts, P. (1997). Geostatistics for natural resources evaluation. New York: Oxford Univ. Press.

Gregory, K. J., & Walling, D. E. (1976). Drainage basin form and process: a geomorphological approach (repr ed.). London: Arnold.

Grimmeisen, F., Zemann, M., Sawarieh, A., Wolf, L., & Goldscheider, N. (2012). Grundwasserschutz in urban geprägten Karstgebieten mit semi-aridem Klima - Fallstudie Hazzir-Quelle, Wadi Shueib, Jordanien. - Poster presented at the FH-DGG Tagung 2012, Dresden 2012.

GTZ, WAJ, Dorsch Consult, & ConsulAqua Hamburg. (2009). Assessment of pump efficiency, pump operation and energy saving potential Improvement of Energy Efficiency. G.-J.-G. W. Program. Amman: GTZ/WAJ.

Gupta, J. N. D., & Harris, T. M. (1989). Decision support systems for small business. J. SYST. MANAGE., 40(2), 5.

Guttman, J. (2009). Hydrogeology. In H. Hötzl, P. Möller & E. Rosenthal (Eds.), The Water of the Jordan Valley: Scarcity and Deterioration of Groundwater and Its Impact on the Regional Development. Berlin, Heidelberg: Springer.

GWP. (2000). Integrated Water Resources Management (Background Paper No. 4) TAC Background Papers. Global Water Partnership-Technical Advisory Committee. Stockholm: Global Water Partnership.

GWP - GLOBAL WATER PARTNERSHIP (2009): A handbook for Integrated Water Resources Management in Basins.

Haddadin, M. J. (2002). Diplomacy on the Jordan: international conflict and negotiated resolution. Boston: Kluwer Academic Publishers.

Haddadin, M. J. (Ed.). (2006). Water Resources in Jordan: Resources for the Future. Washington: RFF Press. Haddadin, P. M. J. (2006). Water Resources in Jordan: Evolving Policies for Development, the Environment, and Conflict Resolution: RFF Press.

Hahne, K., Margane, A., & Borgstedt, A. (2008). Geological and Tectonic Setting of the Upper Wadi Shuayb Catchment Area, Jordan Technical Cooperation Project: Groundwater Resources Management: Special Report. B. MWI. Amman; Hannover.

Hamner, J. H., & Wolf, A. T. (1998). Patterns in International Water Resource Treaties: The Trans boundary Freshwater Dispute Database. Colorado Journal of International Environmental Law and Policy, 9 (1997 Year Book), 20.

Hareuveni, E., & Stein, Y. (2011). Dispossession and Exploitation: Israel’s Policy in the Jordan Valley and Northern Dead Sea B'Tselem Information Sheet. B'Tselem. Jerusalem: B'Tselem.

Hargreaves, G. H., & Samani, Z. A. (1985). Reference Crop Evapotranspiration from Temperature. Applied Engineering in Agriculture, 1(2), 4.

Helming, K., Pérez-Soba, M., & Tabbush, P. (2008). Sustainability Impact Assessment of Land Use Changes.

Himpsl, K. (2007). Wikis im Blended Learning: ein Werkstattbericht. Boizenburg: vwh.

Hoff, H., Bonzi, C., Joyce, B., & Tielbörger, K. (2011). A Water Resources Planning Tool for the Jordan River Basin. Water, 3(3), 718-736.

Holzner, B., & Marx, J. H. (1979). Knowledge application: the knowledge system in society. Boston: Allyn and Bacon.

Horowitz, A., & Flexer, K. (2001). The Jordan Rift Valley. Lisse: Balkema.

House, W. C. (1983). Decision Support Systems: a data-based, model-oriented, user-developed discipline. New York: Petrocelli.

HPC. (2009). The Demographic Opportunity in Jordan - A Policy Document. T. H. P. C. o. Jordan. Amman, Jordan: The Higher Population Council of Jordan.

Humpal, D., El-Naser, H., Irani, K., Sitton, J., Renshaw, K., et al. (2012). A Review of Water Policies in Jordan and Recommendations for Strategic Priorities Jordan Water Sector Assessment. USAID. Amman: USAID.

IPCC. (2007). Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva: IPCC.

Jägerskog, A. (2003). Why states cooperate over shared water: the water negotiations in the Jordan River Basin. PhD Thesis, Linköpings universitet, Linköping.

Jasper, R., & Uschold, M. (1999). A Framework for Understanding and Classifying Ontology Applications. Paper presented at the IJCAI-99 Workshop on Ontologies and Problem-Solving Methods (KRR5).

JICA. (1995). The Study of Brackish Groundwater Desalination in Jordan. Japan International Cooperation Agency: Japan International Cooperation Agency.

Jiries, A., Ta’any, R., Abbassi, B., & Oroud, I. (2010). Agriculture Water Use Efficiency in Wadi Shu'eib Area, Jordan. Pol. J. Environ. Stud., 19(2), 5.

Kaempgen, B., Riepl, D., Vrandecic, D., & Hermann, B. (in preparation). D203 - Definition of exchange format protocols for the connection of Dropedia with SMART-DB SMART-Deliverables. Karlsruhe: SMART Project.

KOPPEN, B., V. NITISH JHA & D. J. MERREY (2002): Redressing Racial Inequities through Water Law in South Africa: Interaction and Contest among Legal Frameworks.

Krabina, B. (2010). A Semantic Wiki on Cooperation in Public Administration in Europe. Journal of Systemics, Cybernetics and Informatics, 8(3).

Kristensen, P. (2004). The DPSIR Framework. Paper presented at the Workshop on a comprehensive assessment of the vulnerability of water resources to environmental change in Africa using river basin approach.

Krötzsch, M., Vrandečić, D., & Völkel, M. (2006, November 5-9, 2006.). Semantic MediaWiki. Proceedings of the Semantic Web - ISWC 2006, Athens, GA, USA.

Kugler, S. (2010). Non–Revenue-Water (NRW) Reduction – Key to improve economic performance of water and wastewater utilities. Proceedings of the Arab Water Week, Amman.

Kühn, O., & Abecker, A. (1997). Corporate Memories for Knowledge Management in Industrial Practice: Prospects and Challenges. Journal of Universal Computer Science, 3(8), 25.

Kunz, D. (2003). Soils in the Wadi Shueib catchment area and their protective potential for the groundwater - Salt area/Hashemite Kingdom of Jordan. Unpublished Diploma-Thesis, University of Karlsruhe, Karlsruhe.

Labadie, J. (2005). MODSIM: River basin management decision support system. In V. Singh & D. Frevert (Eds.), Watershed Models. Boca Raton, Florida: CRC Press.

Lafarge Cement Jordan. (2010). Annual Report and Financial Statements. L. C. Jordan. Amman: Lafarge Cement Jordan.

Lange, C. (2011). Enabling collaboration on semiformal mathematical knowledge by semantic web integration. Heidelberg and Amsterdam: AKA Verlag and IOS Press.

Lankford, B. A., Merrey, D. J., Cour, J., & Hepworth, N. (2007). From Integrated to Expedient: An Adaptive Framework for River Basin Management in Developing Countries (Vol. 110). Colombo, Sri Lanka: International Water Management Institute.

Lein, Y., Hashhash, M. A., & H.A., H. (2001). Not Even a Drop: Water Crisis in Palestinian Villages. B'Tselem Information Sheet. B'Tselem. Jerusalem: B'Tselem.



Lenz, S. (1999). Hydrological Investigations along the Wadi al Kafrein and the Kafrein Reservoir, Jordan. Unpublished Diploma Thesis, Universität Karlsruhe, Karlsruhe.

Leuf, B., & Cunningham, W. (2008). The Wiki way: quick collaboration on the web ([Nachdr.] ed.). Boston [u.a.]: Addison-Wesley.

Liebowitz, J., & Wilcox, L. C. (1997). Knowledge management and its integrative elements. Boca Raton, Florida: CRC Press.

Linstone, H. A., Turoff, M., & Helmer, O. (1975). The Delphi method: techniques and applications. Reading, Mass.; London: Addison-Wesley.

Loucks, D. P., Beek, E. v., & Stedinger, J. R. (2005). Water resources systems planning and management: an introduction to methods, models and applications. Paris: UNESCO.

Luijendijk, J., & Lincklaen Arriëns, W. T. (2007). Bridging the knowledge gap: the value of knowledge networks. Proceedings of the International Symposium Water for a Changing World - Developing Local Knowledge and Capacity, Delft, The Netherlands.

MacDonald, S. M., Hunting Technical Services Ltd., & Sultat al-Miyah al Markaziyah. (1965). East Bank Jordan water resources (Vol. 6). London, Amman: Central Water Authority of Jordan.

Marakas, G. M. (2003). Decision support systems in the 21st century (2nd Ed.). Upper Saddle River, NJ: Prentice Hall.

Margane, A., Rohstoffe, B. f. G. u., & BGR. (2002). Contributions to the hydrogeology of Northern and Central Jordan: with 11 tables. Stuttgart: Schweizerbart.

Masri, M. (1963). The geology of the Amman-Zerqa area, Jordan. Amman: Central Water Authority.

McIlwaine, S. (2009). Managing Jordan's Water Budget: Providing for Past, Present and Future Needs. In C. Lipchin, D. Sandler & E. Cushman (Eds.), The Jordan River and Dead Sea Basin (pp. 61-73): Springer Netherlands.

Medema, W. (2008). Integrated Water Resources Management and Adaptive Management: Shaping Science and Practice. PhD Thesis, Cranfield University, Cranfield.

Menzel, L., Teichert, E., & Weiss, M. (2007). Climate change impact on the water resources of the semi-arid Jordan region. Proceedings of the 3rd International Conference on Climate and Water, Helsinki.

Mietzner, D., & Reger, G. (2005). Advantages and disadvantages of scenario approaches for strategic foresight. International Journal of Technology Intelligence and Planning, 1(2), 220-239.

Mikbel, S. H., & Zacher, W. (1981). The Wadi Shueib Structure in Jordan. Neues Jahrb. Geol. Palaeontol., Monatshefte, 5.

Mittra, S. S. (1986). Decision support systems: tools and techniques. New York: Wiley.

Molle, F. (2008). Nirvana Concepts, Narratives and Policy Models: Insights from the Water Sector. Water Alternatives, 1(1), 25.

Monteith, J. L. (1973). Principles of environmental physics. London: Arnold. Moreda, F. (1999). Conceptual rainfall - runoff models for different time steps with special consideration for semi-arid and arid catchments. PhD-Thesis, Vrieje Universities Brussel, Brussel.

Moriasi, D. N., Arnold, J. G., Van Liew, M. W., Bingner, R. L., Harmel, R. D., et al. (2007).

Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. Transactions of the Asabe, 50(3), 16 Motik, B., Patel-Schneider, P. F., Parsia, B., Bock, C., Fokoue, A., et al. (2009).

Mukhtarov, F. G. (2008). Intellectual history and current status of Integrated Water Resources Management: A global perspective. In C. Pahl-Wostl, P. Kabat & J. Möltgen (Eds.), Adaptive and integrated water management: coping with complexity and uncertainty (pp. 167-185).

Müller, M. Huch & H. Geldmacher (Eds.), Umweltziele und Indikatoren (pp. 221-234): Springer Berlin Heidelberg.

Müller, R. A., Cardona, J., Subah, A., Abbassi, B., & van Afferden, M. (2011, August 21-27). Implementation research for decentralized wastewater concepts in Jordan. Proceedings of the World Water Week, Stockholm.

Murakami, M. (1998). Alternative strategies in the inter-state regional development of the Jordan Rift Valley. In I. Kobori & M. H. Glantz (Eds.), Central Eursian Water Crisis: Caspian, Aral, and Dead Seas: United Nations University Press.

MWI. (1997). Water Strategy of Jordan. Amman: Ministry for Water and Irrigation.

MWI. (2004). National Water Master Plan for Jordan. MWI. Amman: Ministry for Water and Irrigation.

MWI. (2009). The Hashemite Kingdom of Jordan: Jordan's second national communication to the United Nations Framework Convention on Climate Change. National Communications to the United Nations Framework Convention on Climate Change. M. o. W. a. Irrigation. Amman: MWI.

MWI. (2010). Annual Report. Ministry of Water and Irrigation. Amman.

Nakicenovic, N., Alcamo, J., Davis, G., de Vries, B., Fenhann, J., et al. (2000). Special Report on Emissions Scenarios: a special report of Working Group III of the Intergovernmental Panel on Climate Change. New York, NY: Cambridge University Press.

Newman, B. D., & Conrad, K. W. (2000, 30-31 Oct. 2000). A Framework for Characterizing Knowledge Management Methods, Practices, and Technologies. Proceedings of the Third Int. Conf. on Practical Aspects of Knowledge Management (PAKM2000), Basel, Switzerland.

Nonaka, I., & Takeuchi, H. (1995). The knowledge creating company: how Japanese companies create the dynamics of innovation. New York, NY: Oxford Univ. Press.

OECD. (1993). OECD core set of indicators for environmental performance reviews Environment Monographs. OECD. Paris: Organization for Economic Co-Operation and Development.

OECD. (2006). Applying Strategic Environmental Assessment. Good Practice Guidance for Development Co-Operation DAC Guidelines and Reference Series. OECD: Organisation for Economic Co-Operation and Development.

OECD-ORGANISATION FOR ECONOMIC DEVELOPMENT AND COOPERATION (2013): Vulnerability.

Oki, T., Valeo, C., & Heal, K. (2006). Hydrology 2020: an integrating science to meet world water challenges. Wallingford: IAHS Press.

Oren, E., Völkel, M., Breslin, J., & Decker, S. (2006). Semantic Wikis for Personal Knowledge Management Database and Expert Systems Applications. In S. Bressan, J. Küng & R. Wagner (Eds.), (Vol. 4080, pp. 509-518): Springer Berlin / Heidelberg.

Pahl-Wostl, C., Downing, T., Kabat, P., Magnuszewski, P., Meigh, J., et al. (2005). Transition to adaptive water management: The NE Water project NE Water Working Paper: New approaches to adaptive water management under uncertainty. I. o. E. S. Research. Osnabruck: University of Osnabruck.

Parker, D. H. (1970). Investigations of the Sandstone Aquifers of East Jordan: The Hydrogeology of the Mesozoic-cainozoic Aquifers of the Western Highlands and Plateau of East Jordan: F.A.O. Documentation Centre.

Parker, K. R., & Chao, J. T. (2007). Wiki as a Teaching Tool. Interdisciplinary Journal of Knowledge and Learning Objects, 3, 15.

Phillips, D. J. H., Attili, S., McCaffrey, S., & Murray, J. S. (2004). Factors Relating to the Equitable Distribution of Water in Israel and Palestine. In H. I. Shuval & H. Dwiek (Eds.), Water resources in the Middle East: the Israeli-Palestinian water issues: from conflict to cooperation: Springer.

Quennell, A. M. (1951). The geology and mineral resources of (former) TransJordan (Vol. 2): Colonial Geology and Mineral Resources.

Rahaman, M. M., & Varis, O. (2005). Integrated water resources management: evolution, prospects and future challenges. Sustainability: Science, Practice, & Policy, 1(1), 6.

Rapport, D. J., & Friend, A. M. (1979). Towards a Comprehensive Framework for Environmental Statistics: A Stress-Response Approach. Statistics Canada, Occasional Papers, 90.

RCW, & MWI. (2009). Water for Life: Jordan's Water Strategy 2008-2022. Amman: Ministry for Water and Irrigation.

Riepl, D., Kaempgen. B, & Wolf, L. (2011). Making informed decisions - a collaborative and knowledge based IWRM planning exercise in Wadi Shueib, Jordan. Proceedings of the IWRM2011, Dresden.

Rogers, P., Bhatia, R., & Huber-Lee, A. (1998). Water as a Social and Economic Good: How to Put the Principle into Practice TAC Background Papers. G. W. Partnership. Stockholm: Global Water Partnership.

Rothenberger, D. (2009). Improving Water Utility Performance through Local Private Sector Participation - Discussion Paper Series of the German Jordanian Programme: Management of Water Resources. Amman: GTZ.

Roux, D. J., Rogers, K. H., Biggs, H. C., Ashton, P. J., & Sergeant, A. (2006).

Roy, B. (1996). Multicriteria methodology for decision aiding. Dordrecht; London: Kluwer.

Sahawneh, J. (2011). Structural Control of Hydrology, Hydrogeology and Hydrochemistry along the Eastern Escarpment of the Jordan Rift Valley, JORDAN. PhD-Thesis, Karlsruhe Institute for Technology, Karlsruhe.

Saidam, M. Y., & Ibrahim, M. N. (2006). Institution and Policy Framework - Analysis of the Water Sector in Jordan Co-ordination Action for Autonomous Desalination Units based on Renewable Energy Systems. R. S. Society. Amman: Royal Scientific Society.

Salameh, E. (2008). State of Water Strategy and Policy. In H. Hötzl, P. Möller & E. Rosenthal (Eds.), The Water of the Jordan Valley. Berlin Heidelberg: Springer-Verlag.

Salameh, E., & Udluft, P. (1985). The hydrodynamic pattern of the central part of Jordan (Vol. c38). Hannover.

Schaffert, S., Gruber, A., & Westenthaler, R. (2005, November, 23-25, 2005). A Semantic WIKI for Collaborative Knowledge Formation. Proceedings of the SEMANTICS 2005, Vienna, Austria.

Scheffer, J. (2002). Dealing with Missing Data. Res. Lett. Inf. Math. Sci., 3, 7.

Schoemaker, P. J. H. (1995). Scenario Planning: A Tool for Strategic Thinking. Sloan Management Review, 36(2), 15.

Schumm, S. A. (1977). Drainage basin morphology. Stroudsburg, Penns. Dowden.

Schwartz, P. (1991). The art of the long view (1st ed.). New York, NY: Currency Doubleday.

Scott, D. A. (Ed.). (1995). A directory of wetlands in the Middle East. Gland, Switzerland: IUCN, The World Conservation Union; Slimbridge: International Waterfowl and Wetlands Research Bureau.

Segnestam, L. (2002). Indicators of Environment and Sustainable Development - Theories and Practical Experience ENVIRONMENTAL ECONOMICS SERIES. The World Bank. Washington, D.C.: The World Bank.

Segura, F. S., Pardo-Pascual, J. E., Rossello, V. M., Fornos, J. J., & Gelabert, B. (2007). Morphometric indices as indicators of tectonic, fluvial and karst processes in calcareous drainage basins, South Menorca Island, Spain.

Shepard, D. (1968). A two-dimensional interpolation function for irregularly spaced data. Paper presented at the Proceedings of the 1968 23rd ACM national conference.

Simon, H. A. (1960). The new science of management decision. New York: Harper & Row.

Smeets, E., & Weterings, R. (1999). Environmental indicators: typology and overview Technical Report. Copenhagen: European Environment Agency.

Smith, C. G. (1966). The Disputed Waters of the Jordan. Transactions of the Institute of British Geographers (40), 111-128.

Solis, C., Ali, N., & Babar, M. A. (2009, 19-19 May 2009). A Spatial Hypertext Wiki for Architectural Knowledge Management. Proceedings of the Wikis for Software Engineering, 2009. WIKIS4SE '09. Sommaripa, L. (2011). Water Public Expenditure Perspective Working Paper Jordan Fiscal Reform II Project. USAID. Amman: USAID.

Sprague, R. H., & Carlson, E. D. (1982). Building effective decision support systems. Englewood Cliffs, N.J.: Prentice-Hall.

Sprague, R. H., & Watson, H. J. (1986). Decision Support Systems: Putting theory into practice. Englewood Cliffs, N. J.: Prentice-Hall.

Tchobanoglous, G., Burton, F. L., Stensel, H. D., Metcalf, & Eddy. (2003). Wastewater Engineering: Treatment and Reuse: McGraw-Hill.

Trappe, J. (2007). Delineation of Groundwater Protection Zones for Baqqouria Spring According to Jordanian Guidelines. MSc thesis, FH Koeln, Cologne.

Tuomi, I. (1999). Data is more than knowledge: Implications of the reversed knowledge hierarchy for knowledge management and organizational memory. Journal of Management Information Systems, 16(3), 103-117.

UNFCCC - United Nations Framework Convention on Climate Change (2013): Article 1. Definitions.

Available at: http://unfccc.int/essential\_background/convention/background/items/2536.php (26.07.2013).

UN - UNITED NATIONS (2012): The Millennium Development Goals. Available at: http://www.un.org/millenniumgoals/ (27.11.2012).

UN - UNITED NATIONS (2010): General Assembly Adopts Resolution recognizing Access to Clean Water, Sanitation.

UNEP - UNITED NATIONS ENVIRONMENTAL PROGRAMME (2012): The UN-Water Status Report on the Application of Integrated Approaches to Water Resources Management.

VÖRÖSMARTY, C.J., C. LEVEQUE, C.C. REVENGA (2005): Fresh Water. Chapter 7. Millennium Ecosystem Assessment Board.

XIE, M. (2006): Integrated Water Resources Management (IWRM). Introduction to Principles and Practices. World Bank Institute (WBI).

R.T. PEREZ (2007): Perspectives on climate change and sustainability. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 811-841.

Zeleny, M. (1987). Management support systems: Towards integrated knowledge management. Human systems management. 7(1), 59-70.

Zemann, M., Wolf, L., Hötzl, H., Sawarieh, A., Seder, N., et al. (2012). Pharmaceuticals as long term reacers of intentional and unintentional wastewater reuse in the Lower Jordan Valley. - Poster presented at the IWRM 2012, Karlsruhe, and November 21-22 2012.

Zwicky, F. (1969). Discovery, invention, research: through the morphological approach (1. American ed.). Toronto: Macmillan.

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