ESCWA

ACWUA
Arab Countries Water Utilities Association

Climate Change Impacts and Adaptation to the Human Settlements Sector Using Integrated Water Resource Management (IWRM) Tools

Contents

Chapter 1: Introduction

Climate change presents various challenges for human settlements and their growing populations. Level of urbanization has been high across all Arab countries due to the economic and social opportunity that urban centers provide compared with rural areas.

The field of integrated water resources management (IWRM) provides a set of tools and measures that can help cities and urban centers adapt to impacts caused by climate change.

RICCAR has resulted in a set of outputs that mainly imply lower precipitation rates, higher temperature degrees as well as more frequent and extended extreme events (sand storms, heat spills and flash rainfall storms) across the Arab region.

Like other parts of the developing world, Arab states strive to provide improved access to water and sanitation services and to meet sustainable development goals (SDGs). However; challenges introduced by climate change will add more constraints to achieving such access. Climate change is expected to produce extreme climate events such as increases in the intensity and frequency of heavy precipitation, floods and droughts. Sanitation services and storm water drainage systems, in particular, will be vulnerable to these extreme events across urban areas of the Arab countries. Water supply systems including water storage facilities, pipe networks as well as pressure regulating elevated tanks can also be affected by climate change extreme events. Research is therefore needed to provide insights and advice to human settlements as to how to cope with and adapt to such extremes while pursuing plans to reach a universal coverage of water supply and sanitation access to inhabitants of the human settlements in the Arab countries.

In this module, a set of IWRM tools will be outlined and discussed to help achieve better adaptive capacity of Arab human settlements to extreme climate events focusing on water supply and sanitation services in particular.

There are lots of physical risks associated with climate change that Arab urban settlements will have to confront and adapt to. Such risks include:

- Sea-level rise
- Heavy precipitation events and Flooding
- Landslides
- Tropical cyclones
- Extreme heat events
- Sand storms
- Drought

Such extreme climate events induced by future changes in climate will certainly alter various livelihood aspects in a city life. These impacts can be categorized into the following titles:

1. IMPACTS UPON PHYSICAL INFRASTRUCTURE

- Damage of residential and commercial buildings due to flooding, for example
- Disruption of transportation systems and damage of vehicles
- Energy systems: both energy demand and supply will be affected
- Damage and disruption of water supply and sanitation systems

2. ECONOMIC IMPACTS

The expected climate extreme events will increase the vulnerability of the urban economic assets and businesses. Climate change and extreme events will have both direct and indirect impacts on the city life in sectoral activities such as:

- Industry and commerce
- Tourism and recreation
- Insurance: extreme climate events like storms and flooding could result in increasing demand for insurance while reducing insurability.
- Impacts on livelihood as well as ecosystem services

3. PUBLIC HEALTH IMPACTS

Climate change will increase the global and regional disease burden. At the city level, intense rainfall events and consequent flooding can include public health concerns associated with flooded sewage collection and treatment infrastructure. The higher temperature can result in accelerated occurrence of algal blooms in water reservoirs and re-growth of pathogens within potable water pipe networks.

4. SOCIAL IMPACTS

Slums and marginal communities are common in some Arab cities and these will unsurprisingly be the most vulnerable to impacts by climate change. In addressing the social impacts in human settlements, there issues that need to be investigated and these include:

- Poverty and unemployment
- Gender issues
- Age groups like children and the elderly
- Ethnic and other minorities

5. DISPLACEMENT AND FORCED MIGRATION

“Climate refugees” has been an expected outcome that even the international film industry realized and produced few movies on. Many parts of the Arab region has for long been suffering from the problem of refugees due to reasons other than climate. However; refugee populations who live in camps are much more vulnerable to extreme climate events now and in the future.

1.1 Tools To Identify/Indicate Cities Vulnerability

Actual vulnerability of a city or an urban center will be shaped by the degree of resilience and preparedness of that city to climate change impacts. The following indicators can be used to assess vulnerability:

- Urbanization rate
  The Arab region is one of the highly urbanized regions of the World. Urbanization rate reaches as high as 90 percent in some Arab countries especially in the Gulf and in some North African countries[1]

- Economic development

[1] UNDP, 2010, Arab climate resilience initiative, Arabian Gulf University

- Physical exposure: How much of a city population and economic assets are located in high-risk areas like flood plains
- Urban governance and planning
- Disaster preparedness
- Robustness of infrastructure systems
- Flexibility and responsiveness of urban management schemes

The Arab region has about 34,000 km of coastal lines with many urban centers and large cities loacted in coastal areas. For exmaple, countries in North Africa have most of their urban areas at the coastal lines (Figure 1). Among other impacts, sea level rise will affect groundwater resources that many human settlements rely on for water supply across the Arab countries. In fact, sea level rise will be crucial to many Arab cities especially in the GCC countries like Bahrain and Dubai (artificial coastal land) but data is not yet available (due to vertical resolution of related models) to elaborate on this concern.

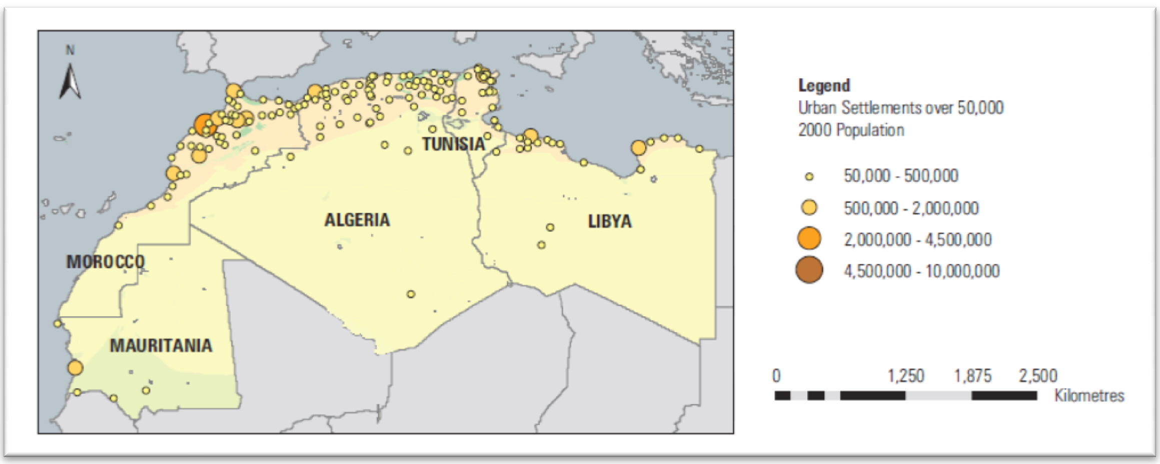

Figure 1: Urban settlement in Arab countries in Norh Africa[2]

Studies indicate that climate change is already underway. Early in the twentieth century, there were already concerns that the climate was changing and that such changes were occurring because of the effect ofhuman activity on the Earth's climate. However, these concerns remained unverified until the advent ofpowerful computer models in the 1970s that could represent complex interactions that influence the Earth'ssystems. Improved research, assessment and monitoring of natural phenomena also increased scientificunderstanding of the contribution of human activities to the climate and climate variability.

By the end of the century, it became evident that global temperatures had increased over the last 150 years, and that this increase was dynamically changing climate patterns and the sustainability of land, marineand freshwater systems. While understanding the causes of these changes is an integral part of the global scientific and political debate, the urgent challenge facing the Arab region is to assess and adapt to these changes within the context of specificities, conditions and constraints that characterize the Arab region.

[2] UN-DESA, 2009, World Urbanization Prospects: The 2009 revision population database.

The Arab region currently faces major water challenges related to sustainable management of water resources and the delivery of water services for domestic, agricultural and industrial use. Climate change and climate variability can increase the risks and the costs of water resources management, impact the quantity and quality of water resources, and generate secondary effects that influence socio-economic vulnerability and environmental sustainability. A clear understanding of these risks and impacts is necessary to inform policy formulation and decision-making in support of efforts to achieve sustainable development in the Arab region.

RICCAR adopted an integrated assessment methodology that is based upon simulating climate change scenarios using various modeling and assessment tools (see Figure 2), including: (a) GCMs, (b) RCMs, (c) RHMs, (d) socio-economic vulnerability assessment (VA), and (e) integrated mapping (IM)[3]

The following are anticipated **outputs** of step d:

- Consensus on the relevant socio-economic parameters and indicators that comprise and structurethe vulnerability assessment and the identification of vulnerability hotspots;
- Standardized geospatial data sets of computed parameters and indicators of socio-economic vulnerability, associated with specific RCMs and RCM projections.

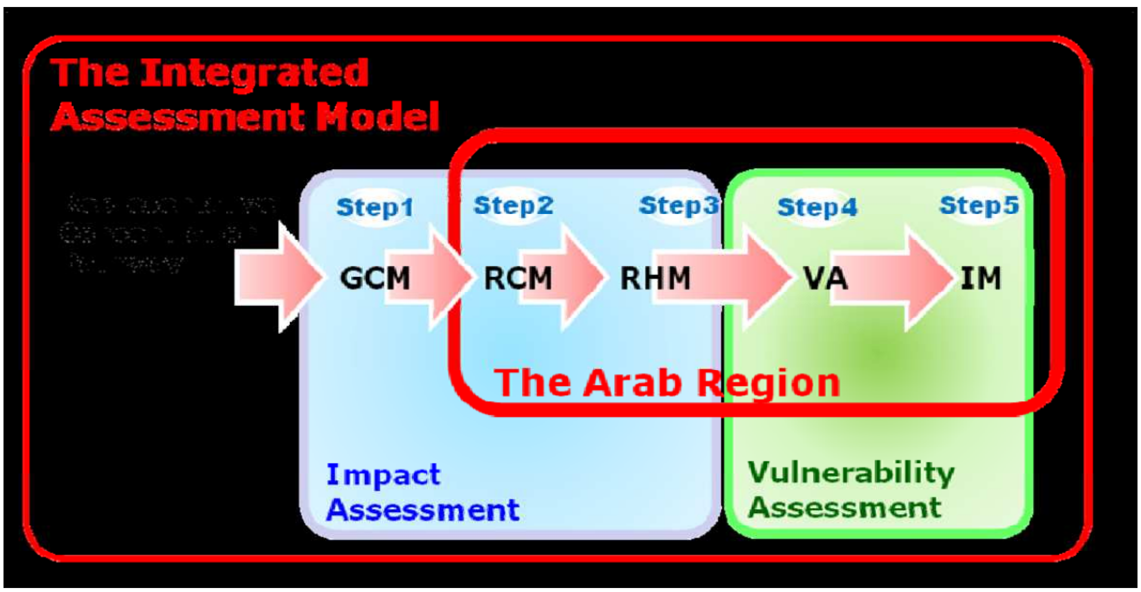

Figure 2: The 5-step integrated assessment model envisioned and used by RICCAR

RICCAR has resulted in certain climate change implications that will affect human settlements of the Arab states in various ways. Higher temperatures and heat waves will imply more pressure on available water resources that are already among the poorest in the World. Intensive rainfall events in less durations will translate into flooding of storm drainage networks and wastewater collection systems. As for the coastal urban areas, expected seal level rise will impact human settlements through salt water intrusion into their ground water reserves as well as direct flooding.

[3]RICCAR, 2015, Training manual on the integrated vulnerability assessment methodology

Arab cities even without the risks associated with climate change already face many problems such as stretched/intermittent water supply, improper sanitation services, weak institutional frameworks, weak coordination between stakeholders as well as poor governance in general. Factors like high NRW (Non-Revenue Water) and ineffective sanitation infrastructure do characterize the water and sanitation aspects of many Arabian cities.

Poverty, unemployment, high urbanization rate and high population growth rate are also features of many Arab urban centres

It is useful to look at the Arab world as sub regions (as will be seen later in this Module) to realistically characterize Arab cities according to clear differences in wealth and development amongst various regions of the Arab world. It is true that RICCAR and for the first time has been successful in providing CC scenarios, impacts as well as vulnerability assessments for the Arab region as one climatic domain (Arab Domain); analysis of CC impacts on the human settlements level cannot and should not ignore basic differences between those urban centres regarding quality of infrastructure, level of institutional strengths and goodness of governance – all adding to sensitivity of a human settlement to exposures induced by CC. Exposure and sensitivity will shape the expected CC impacts and then help identify the level of vulnerability each city will reasonably face.

Over 56 % of the Arab population at present lives in urban areas (large cities and small towns), while in some countries the percentage of people living in urban areas is as high as 87% of the total population; The urban population is growing at an accelerated speed of the overall growth in population, while the overall population growth rate is also amongst the highest in the world; Arab urban areas are a major source of economic and human development for the opportunities they provide in the form of employment, education, health, communication facilities, trade and tourism.

This Human Settlement Module is designed to train stakeholders on using IWRM tools and measures that can help Arab human settlements adapt to impacts of climate change.

1.2 Training objectives and methodology

This Module aims to provide hands on training on how Arabian human settlements can adapt to future climate change impacts using identified tools of integrated water resources management (IWRM). RICCAR outputs indicate that the Arab region will suffer serious impacts of climate change most notably lower rainfall and elevated temperatures. There are many tools within the domain of IWRM that local governments and various stakeholders including the general public can make use of within Arabian urban settlements that can help adapt human settlements of the Region to cope up with climate change induced impacts.

Secondary Objectives: The Module is one of a total of 5 module-training package that includes the sectors of agriculture, human health, economics and environment in addition to human settlements. It is hoped that by adopting a TOT (training of trainers) approach, the 5-module training manual will help stakeholders across the Arab countries respond to future challenges of CC impacts and the use of IWRM tools as means of adaptation and reducing vulnerability.

Methodology of the training will adopt the following scheme:

1) Introductory PowerPoint presentation and question/answer session on basics of climate change science and expected trends using RICCAR outputs

2) A total of 3 (three) Group Exercises using focus groups and reporting of group results on a flip chart

GE # 1: **Factors for adaptive capacity in human settlements: Ranking exercise for the 4 (four) Arab sub regions**

GE # 2: **Selection criteria for best IWRM tools → Screening/Ranking of best adaptationmeasures**

GE # 3: **Water supply and Sanitation in Za'atari Refugee Camp in Jordan → Dealing with emergency situation!**

3) Sector-based Impact assessment Case studies. A total of 6 (six) case studies will be considered whereby trainees read and then report in groups on each case and its contribution to adaptation. Details of the six case studies are outlined in the Appendix and the titles of these cases are noted below:

CS #1: **Grey Water Reuse in Oman**
CS #2: **Water Reuse in KSA**
CS #3:**Using AutoCAD Civil-3D, SewerCAD and SSA Software to Adapt Storm and SewerNetwork Design for Climate Change Impacts**
CS #4: **NRW reduction in Jordan>> Are we doing any better?**

CS #5: **Managed aquifer recharge as an integrated water resource management approach for preventing seawater intrusion in Hazmieh, Beirut area, Lebanon (ACCWaM Pilot Project)**

CS # 6:**Appropriate Water Abstraction through Bank Filtration to improve Drinking Water Supply in Upper Egypt**

1.3 Targeted stakeholders

- Water utilities' professionals and water planners in government
- Civil society and to a lesser extent local community representatives

Chapter 2: Framing Sectoral problems

Water supply in Arab human settlements continues to face economic and governance challenges in addition to the scarcity of the resource itself

While RICCAR outputs are helpful in dealing with the Arab states as one climatic Arab Domain, there exit distinct differences in the level of development, wealth, education, human resources development as well as robustness of infrastructure between various regions in the Arab World. Therefore; it would be more realistic when talking about urban areas and human settlements to segregate the Arab states into four sub-regions (Figure 3):

a) Mashreq: Egypt, Iraq, Jordan, Lebanon, Palestine, and Syria

b) Maghreb: Algeria, Libya, Morocco, Tunisia, Mauritania

c) GCC (Gulf Cooperation Council) countries: Bahrain, Kuwait, Oman, Qatar, KSA, UAE

d) STC (Southern Tier Countries): The Comoros, Djibouti, Somalia, Sudan and Yemen

The first exercise in this Module will be a ranking exercise whereby trainees cooperate in groups to understand the main general factors that outline adaptive capacity of a human settlement. Ranking will be exercised on the sub-region level to give insights about general vulnerability of human settlements in each. Factors that affect adaptive capacity include good governance, strong institutions, quality of infrastructure, the level of education and public awareness, the socio-economic status and the level of scarcity of water resources (measured as WPC: water per capita). Table 1 below depicts this ranking (scale 1 to 10)

Table 1: Ranking of Arab sub regions along factors for adaptive capacity

Factors for Adaptive Capacity	**Sub-regions of the Arab World**			
	a	**b**	**c**	**d**
Strong institutions and good governance				
Quality of infrastructure				
Education and public awareness				
Socio-economic status				
IWRM programs in place				
Average WPC region-wide (projected at				

2025)				

Moreover; several Arab countries have been in political and security turmoil since 2011. Wars have resulted in massive destruction of urban infrastructure as is the case in Syria, Iraq and Yemen, for instance. This has also resulted in massive waves of migrants especially from Syria and Iraq which will form increased challenges to the water supply and sanitation services in the receiving urban areas like those in Lebanon and Jordan, in particular. Another exercise will focus on water and sanitation in the Za'atari Syrian refugee camp in North Jordan so that trainees can gain experience on the use of IWRM tools under emergency scenarios which will only exacerbate impacts of climate change

Figure 3: Arab sub-regions[4]

Mashreq	Maghreb	Gulf Cooperation Council	Southern Tier Countries
Egypt	Algeria	Bahrain	The Comoros
Iraq	Libya	Kuwait	Djibouti
Jordan	Morocco	Oman	Somalia
Lebanon	Tunisia	Qatar	Sudan[1]
Palestine	Mauritania	Saudi Arabia	Yemen
Syrian Arab Republic		United Arab Emirates	

[4] The state of Arab cities 2012/2013: Challenges of urban transition, UN-HABITAT

While it is going to be difficult to think of an Arab urban centre or city that would be representative of all Arab states, we will focus on the IWRM tools that can help Arab human settlements adapt to climate change, in general. However; we will keep in mind the sub-regions introduced and justified above in our analysis throughout this Module.

Grouping of the Arab States into the four clusters above is conceived useful as this Module proceeds to case studies from various Arab countries. The success of adaptation interventions will depend on many variables that include level of governance, economic ease and level of education among local population. Clustering the Arab States above will help think of interventions that better suit the local mosaic of economy, governance and socio economic status in each sub region.

2.1 General features of IWRM and Its Tools in Arab Human Settlements

The Arab region is classified as arid to semi-arid region and it is indeed the poorest in fresh water resources worldwide. Figure 4 below shows population projections and renewable fresh water availability for certain Arab countries from all sub-regions. While population will continue to increase in high rates in all Arab states, a significant decline is projected in available fresh water resources per capita in all these countries.

According to the Figure, all reported Arab countries with exception of Lebanon will have WPI (Water Poverty Index) of less than 1000 cubic meter per capita per year which is the poverty line adopted by UN. In fact, many Arab countries are already below this poverty line in 2015 and some countries suffer an absolute poverty in fresh water resources whose WPI stands at 120 cubic meters per capita[5].

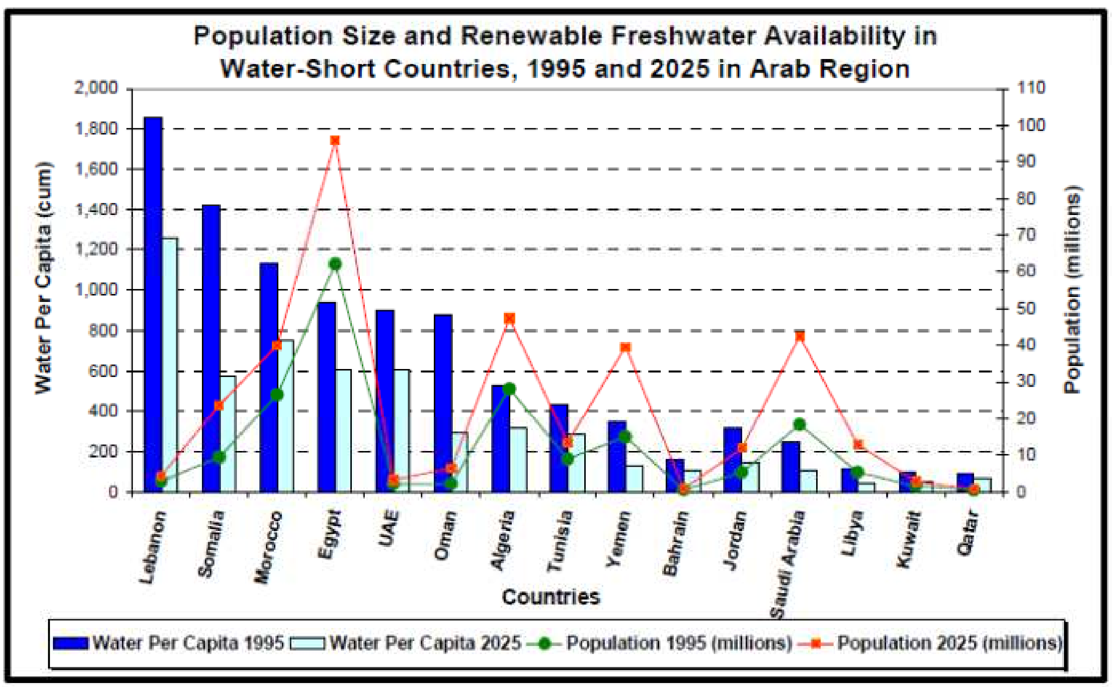

Figure 4: Population projections and renewable fresh water resources availability in Arab states from all 4 sub-regions[6]

[5]Grey Water: Potential Non-Conventional Resources for Water Demand, Rifaat Abdel Wahaab, Oman, June 2012

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If we take Egypt as an important example, Figure 5 shows the rapid growth rate of population in the period between the year 1800 to 2025 and it is associated with a clear decline of the per capita share of fresh water resources. Since the year 1998, this share has been already below the poverty line of 1000 cubic meters per capita.

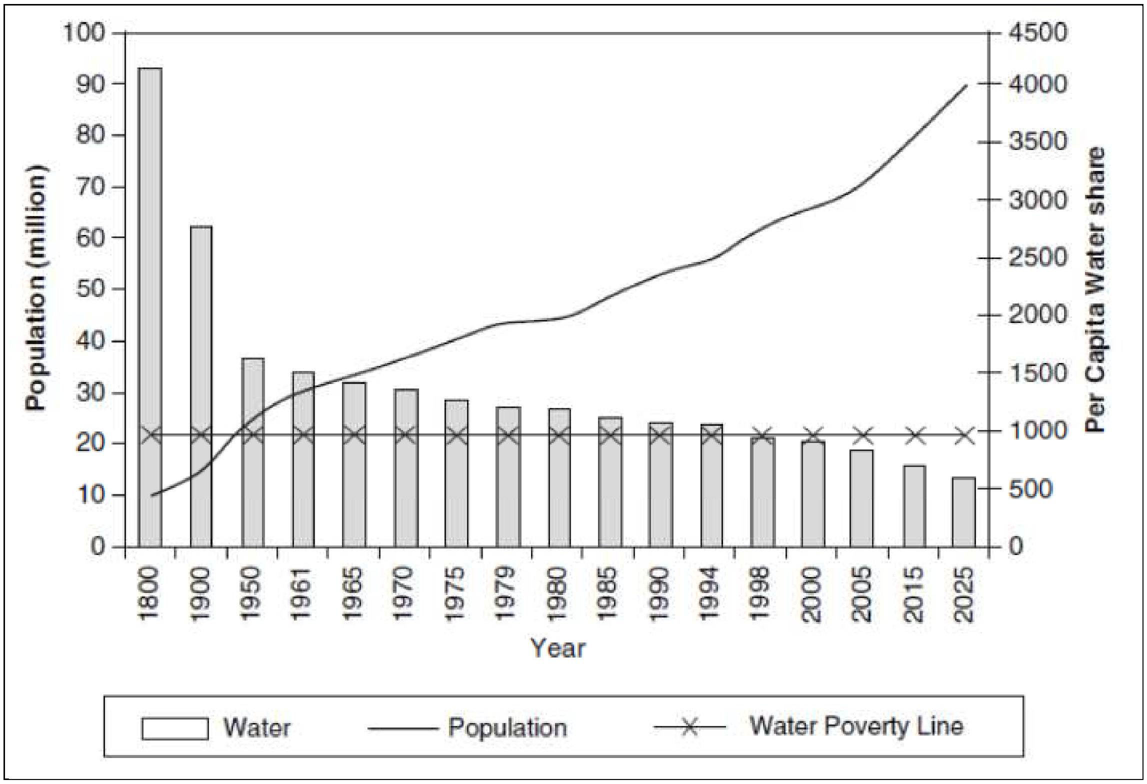

Figure 5 :Population growth and per capita share of water in Egypt[7]

The water sector in the Arab region suffers from chronic problems and faces many challenges in terms of water supply and sanitation services. These challenges are common in most of the Arab countries and are summarized below:

- Limited water resources; which lead to a large gap between available resources and increasing demand for water due to the high rate of population growth, rapid urbanization and economic development.

- The impact of political instability in the Arab region (Arab Spring); which lead to internal and external migration in several Arab countries, has dramatically increased the demand for water in the host countries and damaged the infrastructure in the countries of the Arab Spring

- Most water utilities operate under centralized management; especially in the field of planning anddetermining tariffs, regulations and laws that regulates the work of water utilities (salary scales, andemployment regulations)

[7] Grey Water: Potential Non-Conventional Resources for Water Demand, Rifaat Abdel Wahaab, Oman, June 2012

- Brain drain from the public sector to the private sector within the same country or from one country to another

- Limited financial allocations in many facilities in the area of training and capacity building, technology transfer and limited financial resources for the implementation of mega projects in water supply and sewage treatment plants

- Many Arab countries have reached lending ceiling, thus cannot take any more loans to implement water projects

- Very limited initiatives from the national private sector to finance strategic projects

2.2 Intermittent supply

In many Arab states such as Jordan, Lebanon, Yemen and Palestine water distribution systems and pipe networks serving human settlements are not flowing with water continuously and that is because of water scarcity and also due to energy shortages. This results in inconsistent and higher pressures on pipe joints and valves resulting in more water losses as unaccounted for water

Many urban areas in the Arab region deal with water scarcity by rationing/scheduling through intermittent supply, and this implies the following:

- The need for water storage at the household level which incurs financial burden on the households due to:

- Cost of underground cisterns
- Cost of pumps
- Cost of roof water cisterns
- Extra cost for maintenance of the storage cisterns, pipes and pumps

- Reliance on water tankers
- Water quality problems associated with storage
- Water quality problems associated with unknown sources of tanker water (illegal GW wells, for example)

Therefore; intermittent supply puts household water security at issue in many Arab cities like Sana'a and Amman.

Cross contamination is another consequence of intermittent supply. This results of the Zero-pressure status when pipes are empty and exposed to inflow of polluted water through pipe cracks and bad joints. This problem can be worsen during events of intense rainfall caused by climate change.

Elevated temperatures expected by RICCAR will also raise real concerns about chemical as well as microbiological quality of potable water supplies both in storage reservoirs, elevated tanks and pipes. Algal growth should be expected in reservoirs under higher temperature scenarios. In water supply pipes, re-growth phenomena might be exacerbated and oxidation-reduction water chemistry can be altered.

2.3 Enhancing water efficiency at the city level

A. Improving infrastructure

B. Better management

In the decades to come, climate change may make hundreds of millions of urban residents – and in particular the poorest andmost marginalized – increasingly vulnerable to floods, landslides, extreme weather events and other natural disasters. Citydwellers may also face reduced access to fresh water as a result of drought or the encroachment of saltwater on drinking watersupplies. These are the forecasts, based on the best available science. Yet none of these scenarios needs to occur, provided we act now with determination and solidarity.

The stakeholders in the water sector in theArab region should go beyond the traditional management. Most of the water utilities are being operated basedon centralization with reference to absolute laws and regulations. Thus it is now emergently crucial for utilities anddecision-makers to adopt the effective solutions and the find proper environment to face all these ongoing challenges.
Here arises the role of the Arab Countries Water Utilities Association (ACWUA) and other community-basedorganizations, in raising awareness at all levels within utilities, especially at the top and middle management levelsthat have the direct influence over decision makers, in emphasizing the need for development of new policies,and the amendment of existing legislations that would encourage the reform processes in water utilities.

While it is widely believed that urban centers are a major contributor to CC phenomenon, it is impossible to make accurate statements about the scale of urban emissions, asthere is no globally accepted method for determining their magnitude. In addition, the vast majority of the world's urbancenters have not attempted to conduct GHG emission inventories.

With increasing urbanization, understanding the impacts of climate change on the urban environment will become even more important. Evidence is mounting that climate change presents unique challenges forurban areas and their growing populations. These impacts are a result of the following climatic changes:

- Warmer and more frequent hot days and nights over most land areas;
- Fewer cold days and nights in many parts of the world;
- Frequency increases in warm spells/heat waves over most land areas;
- Increased frequency of heavy precipitation events over most areas;
- Increase in areas affected by drought;
- Increases in intense tropical cyclone activity in some parts of the world; and
- Increased incidence of extreme high sea levels in some parts of the world.

Mediterranean and Middle East countries to predict the percent change in rainfall with respect to mean monthly values:

- The results show that in the dry season (April to September), by the year 2050, northern Africa and some parts of Egypt, Saudi Arabia, Iran, Syria, Jordan and Israel are expected to have reduced rainfall amounts of up to 20% to 25% less than the present mean values.12
- This decrease in rainfall is accompanied by temperature rises in those areas of between 2 °C and 2.75 °C.
- For the same period, the temperature in the coastal areas of the southern Mediterranean and Middle East countries will rise by about 1.5 °C. In winter, rainfall will decrease by about 10%–15%. Winter temperatures in the coastal areas will also increase, but by only 1.5 °C on average, while inside the region it will increase by 1.75 °C to 2.5 °C.

Ragab and Prudhomme (2000) claim that, given the above-mentioned predictions, in order to meet the water demands in the next century, more dams and water infrastructure will have to be built in southern Mediterranean and Middle East countries and, by rethinking water use with the aim of making it more productive, a new paradigm will have to be adopted. They argue that two approaches will be needed:

- Increasing the efficiency with which current needs are met and increasing the efficiency with which water is allocated among different uses.
- In addition, non-conventional sources of water supply, such as reclaimed or recycled water and desalinated brackish water or seawater, are expected to play an important role.

Table 2. Physical characteristics of Arab countries[8] (Source: FAO 2013; UNDESA 2011; UNDP 2013).

Country	Area,2011 (thousand square kilometers)	Length of coast, 2005 (kilometers)	Rainfall , 2002 (millimeters per year)	Total actual renewable water sources, 2011 (10^9cubic meters per year)
Algeria	2,381.74	998	257	11.67
Bahrain	0.76	161	-	0.12
Comoros	1.86	340	2,448	1.2
Djibouti	23.2	314	107[a]	0.3
Egypt	1,001.45	2,450	107	57.3
Iraq	435.24	58	225[b]	89.86
Jordan	89.32	26	179	0.94
Kuwait	17.82	499	36	0.02
Lebanon	10.45	225	656	4.5
Libya	1,759.54	1,770	131	0.7
Mauritania	1,030.70	754	199	11.4
Morocco	446.55	1,835	340	29
Oman	309.5	2,092	29	1.4
Palestine	6.02	40	-	0.84
Qatar	11.61	563	36[b]	0.06
Saudi Arabia	2,149.69	2,640	151	2.4
Somalia	637.66	3,025	408[a]	14.7
Sudan	1,879.36	853	741[c]	64.50[c]

[8] FAO, 2013

Syria	185.18	193	366	16.8
Tunisia	163.61	1,148	355	4.6
UAE	8.36	1,318	52	0.15
Yemen	527.97	1,906	231	2.1

a. *Data are for 1999.*
b. *Data are for 1998*
c. *Available only for Sudan former –currently Sudan (Arab state) and South Sudan (non-Arab state).*

Table 3 below shows the available renewable water resources for each Arab country both surface and ground water resources

Table 3: Conventional water resources availability in Arab countries, 2011 (billion cubic meters per year[9]), FAO, 2013

Country	Surface water: total renewable		Groundwater: total renewable		Water dependency ratio
	Actual	Natural	Actual	Natural	
Algeria	10.2	10.2	1.5	1.5	3.6
Bahrain	0.0	0.0	0.1	0.1	96.6
Comoros	0.2	0.2	1.0	1.0	0.0
Djibouti	0.3	0.3	0.0	0.0	0.0
Egypt	56.0	84.5	1.3	1.3	96.9
Iraq	88.6	95.3	3.3	3.3	60.8
Jordan	0.7	1.2	0.5	0.7	27.2
Kuwait	0.0	0.0	0.0	0.0	100.0
Lebanon	3.8	4.1	3.2	3.2	0.8
Libya	0.2	0.2	0.6	0.6	0.0
Mauritania	11.1	11.1	0.3	0.3	96.5
Morocco	22.0	22.0	10.0	10.0	0.0
Oman	1.1	1.1	1.3	1.3	0.0
Palestine	0.1	0.1	0.8	0.8	3.0
Qatar	0.0	0.0	0.1	0.1	3.5
Saudi Arabia	2.2	2.2	2.2	2.2	0.0
Somalia	14.4	14.4	3.3	3.3	59.2
Sudan	62.5	147.0	7.0	7.0	76.9
Syria	12.6	41.8	6.2	16.0	72.4
Tunisia	3.4	3.4	1.6	1.6	8.7
UAE	0.2	0.2	0.1	0.1	0.0
Yemen	2.0	2.0	1.5	1.5	0.0

Available water resources consist of conventional resources (surface and ground water) and non-conventional resources (desalinated water and treated wastewater. Table 4 below shows amounts of wastewater produced and reused per year in each Arab country

[9] FAO, 2013

Table 4. Total water withdrawal, raw wastewater and treated wastewater in the different Arab countries in $10^9 m^3$/year.

Country	Total wastewater produced ($10^9 m^3$/year)	Total water withdrawal ($10^9 m^3$/year)	Volume of Treated Wastewater ($10^9 m^3$/year)	Volume of Treated Water reused ($10^9 m^3$/year)
Algeria	6.07	0.82	0.7**	0.051
Bahrain	0.3574	0.0449	0.076	0.0163
Comoros	0.3574	-	-	-
Djibouti	0.019	-	-	-
Egypt	68.3	3.76	2.971**	0.700
Iraq	66	0.575	0.098**	0.0055
Jordan	0.941	0.117	0.111**	0.102
Kuwait	0.913	0.25	0.239*	0.078
Lebanon	1.31	0.31	0.004***	0.002
Libya	4.326	0.546	0.04***	0.04
Mauritania	1.7	-	0.0007***	0.00035
Morocco	12.6	0.700	0.177**	0.080
Oman	1.321	0.098	0.037*	0.0023
Qatar	0.55	0.444	0.066*	0.043
Saudi Arabia	23.67	0.73	0.652*	0.166
Somalia	3.298	-	0	-
Sudan	37.32	-	-	-
Syria	16.7	1.37	0.550***	0.550
Tunisia	2.85	0.461	0.240**	0.068
UAE	3.998	0.5	0.454*	0.248
West Bank & Gaza	0.418	0.05	0.03***	0.00544
Yemen	3.4	0.074	0.046***	0.006
TOTAL	256.303	10.85	6.492	2.164

*GCC water statistics book, 2010, ** Dubai Expert meeting, ***FAO-AQUASTAT 2009

More data for non-conventional water resources mainly desalinated water and treated wastewater reuse are provided in table 5 below.

Tables 2 to 5 provide trainees with basic set of data on water resources availability in each Arab country so that a basic knowledge on conventional and non-conventional resources can be gained and some of these data can be use during the training exercises and case study elaborations

Table 5. Non-conventional water resources availability in Arab countries, various years ($10^9 m^3$/year) (Source: FAO 2013)

Country	Desalinated water produced	Treated wastewater (municipal)			
		Produced municipal wastewater	Collected municipal wastewater	Treated municipal wastewater	Direct use of treated municipal wastewater
Algeria	0.017 (2002)	0.73 (2010)	0.150 (2010)	0.15 (2010)	-
Bahrain	0.102 (2003)	0.08 (1997)	0.073 (1997)	0.06 (2005)	0.016 (2005)
Djibouti	0.0001 (2000)	-	-	-	0.0001 (2000)
Egypt	0.100 (2002)	8.50 (2011)	6.500 (2011)	4.80 (2011)	0.700 (2011)
Iraq	0.007 (2000)	-	0.579 (2009)	-	-
Jordan	0.100 (2005)	0.18 (2008)	0.118 (2010)	0.11 (2010)	0.084 (2005)
Kuwait	0.420 (2002)	0.25 (2008)	-	0.25 (2005)	0.078 (2002)
Lebanon	0.473 (2006)	0.31 (2011)	0.103 (2009)	0.004 (2006)	0.002 (1991)
Libya	0.018 (2000)	0.55 (1999)	0.167 (2009)	0.04 (2009)	0.040 (1999)
Mauritania	0.002 (2000)	-	-	0.0007 (1998)	0.0007 (1998)
Morocco	0.007 (2000)	0.70 (2010)		0.12 (2010)	0.070 (2008)
Oman	0.109 (2006)	0.09 (2000)	0.073 (2009)	0.04 (2006)	0.037 (2006)
Palestine	-	-	-	-	0.010 (1998)
Qatar	0.180 (2005)	0.06 (2005)	0.073 (2009)	0.06 (2006)	0.043 (2005)
Saudi Arabia	1.033 (2006)	0.73 (2000)	-	0.67 (2003)	0.217 (2006)
Somalia	0.0001 (2000)	-		0.0 (2003)	-
Sudan and South Sudan	0.0004 (2000)	-	-	-	-
Syria	-	1.36 (2002)	0.302 (2009)	0.55 (2002)	0.550 (2002)
Tunisia	0.013 (2001)	0.25 (2010)	0.240 (2003)	0.19 (2008)	0.068 (2010)
UAE	0.950 (2005)	0.50 (1995)	-	0.29 (2006)	0.248 (2005)
Yemen	0.025 (2006)	0.07 (2000)	0.136 (2009)	0.0 (1999)	0.006 (2000)

** Note: Insufficient data for Comoros*

2.4 Status of storm and wastewater infrastructure in Arab cities:

The status of management and effectiveness of water and sanitation infrastructure across the Arab region is not satisfactory. Many Arab state governments still wholly rely on foreign aid and loans to implement and maintain such crucial infrastructure like Jordan , Yemen, Egypt, Lebanon and Morocco. GCC countries benefiting from the oil wealth have been able to build impressive infrastructure as is common to most urban areas of the Arabian gulf. However; even in rich cities like Jeddah we have seen real challenges to storm water drainage infrastructure among others.

With RICCAR outputs of more intense rainfall storms expected across the Arab domain, urban areas and human settlements should be prepared to build resilience to cope up with expected flood events like Cyclone Guno that hit the Sultanate of Oman in 2007.

Of particular significance is the urban planning policies that has to be reviewed and updated to enact measures such as:

1. Avoiding flood plains in locating institutional and economic enterprises such as emergency administration buildings and hospitals
2. Upgrading of existent storm water drainage and sewage collection networks to handle expected surges in flow
3. Capacity building and training technical staff to consider climate change scenarios in the design process in water and sanitation infrastructure
4. Building awareness especially among middle and high level decision makers on the seriousness of expected impacts by climate change on the city infrastructure

Figure 6 below shows a recently flooded sanitary water manhole in the city of Irbid in Jordan

Figure 6 : flooded manhole in a sewage line in Irbid, Jordan, July 2015

Figures 7 to 10 below shows pictures of recent floods in Oman, Morocco and Jordan respectively.

Figure 7: Flooding by Cyclone Guno in Oman, 2007

Figure 8: Street damage in the aftermath of cyclone Gonu in Oman, 2007

Figure 9: 2015 flooding in Morocco

Figure 10 : 2014 flooding in Amman, Jordan

Chapter 3: Impact and vulnerability assessment of the Sector based on RICCAR outputs

Human settlements and cities in the Arab countries should build adaptive capacity for extreme events of climate change

3.1 RICCAR indicators and outputs that feed into the identification of adaptation measures

RICCAR outputs mainly outline a temperature rise and a reduction in the total rainfall amounts across the Arab region in the coming decades. For example, figure 11 below depicts expected temperature and precipitation changes for the Atlas mountains region in Morocco. Of course, various scenarios of expected radiative forcing were utilized in these predictions as shown in figure 12 where RCP8.5 represents the worst case scenario if no mitigation policies were developed and enacted while the scenario RCP 4.5 (CO_2 emission and radiative forcing) represents a more realistic and optimistic scenario if mitigation measures were realized and executed.

Massive sand storms, intense rainfall events, extended high/low temperature periods are examples of RICCAR outputs that human settlements should deal with in their efforts to build more capacity of adaptation to climate change.

Extreme weather events will mostly impact water and wastewater infrastructure within urban areas. In many Arab cities, flooding of sewer manholes is not uncommon due to several factors including inefficient management, lack of funds to expand sewage network in a rate that is close to the urbanization rate.

A basket of tools within the field of IWRM are available and should be used to help human settlements adapt and reduce vulnerability to extreme events under various scenarios of climate change. Such IWRM tools are detailed later in this Module.

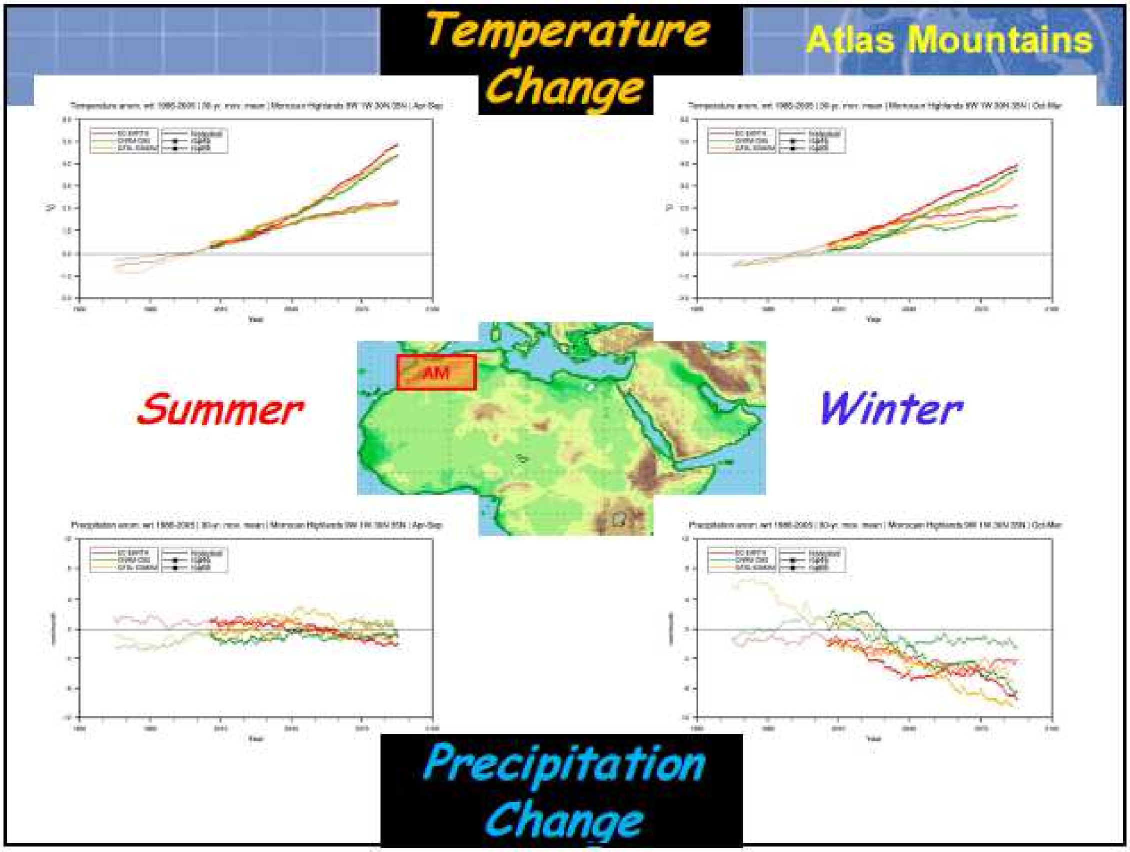

Figure 11: Expected temperature and precipitation change for Atlas mountains by RICCAR

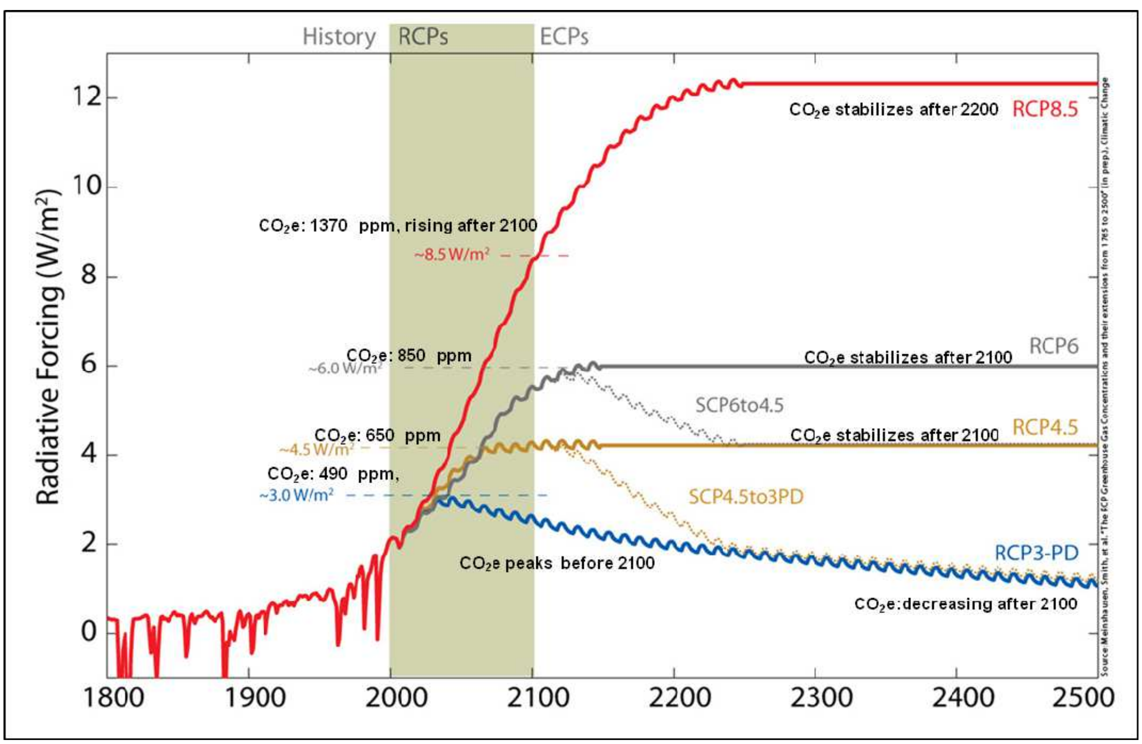

Figure 12: Modeled scenarios of radiative forcing including those for mitigation action/no action policy situations, RICCAR

RCP8.5 shows the constant increase of radiative forcing, rising to more than 8.5 W/m2 by 2100 and continuing to rise for some time thereafter. This concentration pathway represents the extreme case that applies in the case of little or no mitigation measures;

RCP4.5 shows a stabilization in radiative forcing after a peak of 4.5 W/m2 towards the middle and up to the end of twenty-first century. An alternative pathway for RCP4.5 peaks at 4.5 W/m2 before 2100 and then declines after 2100 to follow the path of RCP3-PD. This shows the possibility of a delayed climate response to mitigation measures, reflecting the effect of delayed policy action and climate momentum;

3.2 Other impact and assessment tools available at the sector level

Adaptation of human settlements will basically depend on enhancing resilience and reducing vulnerability of urban activities to extreme events of climate change. The Arab city already faces many challenges that will only be exacerbated by climate change. Robust infrastructure and abundance of resources can and will enhance adaptive capacity like it is the case in the GCC countries. Awareness about climate change and expected associated impacts remains an important adaption venue for all Arab cities including those within GCC countries. Governance, likewise, needs to be enhanced and relieved from beaurocracy

Being a region of scarce water resources, the Arab countries have been investing in many IWRM tools for decades to cope with scarcity. Extreme events will impact almost all aspects of the city life most notably transportation systems, telecommunications, public health, water and wastewater infrastructure as well as tourism among many other urban aspects.

3.2.1 Storm and Sanitary Drainage networks and their performance under assumed climate scenarios (RCP 4.5 and RCP 8.5) – Case from Jordan:

As the name implies, Strom drainage network is responsible of the drainage of storm rainfall runoff in a safe way in order to prevent any undesirable implications; such as floods, that may affect other physical components (e.g. roadways) or even endanger lives of inhabitants in a specific area.

Sanitary network on the other hand, is responsible of the safe drainage of wastewater discharges into the desired endpoint (e.g. a treatment plant). Since that wastewater is composed mainly of organic material, and sometimes toxic material, its effects grade from aesthetic implications such as bad odours to serious health threats (e.g. Cholera epidemic, London 1854)[10].

There are two types of sewer networks (see Figure 13 below):

1. <u>Combined network</u>: a network system that collects both sewage discharge and surface runoff into one pipe.
2. <u>Separate network</u>: a network system that collects sewage and runoff in two different pipes. The separate network type is the network type that is recommended for water scarce regions like the Arab states.

[10] A severe outbreak of cholera that occurred near Broad Street in the Soho district of London, England in 1854 due to the large influx of people and a lack of proper sanitary services. (http://en.wikipedia.org/wiki/1854_Broad_Street_cholera_outbreak)

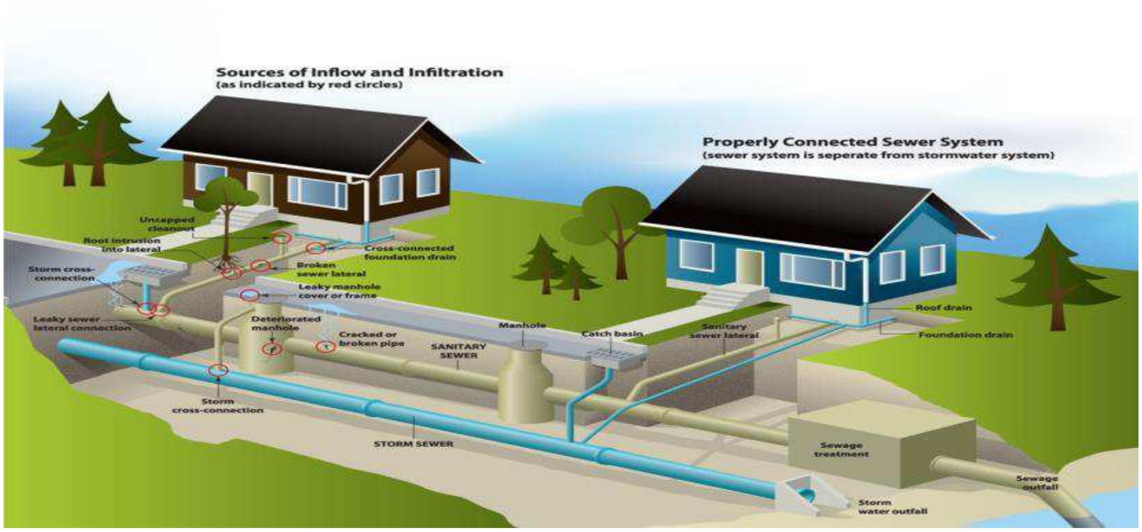

Figure 13: Separate sewer networks (http://www.utilitieskingston.com/wastewater/Overflows.aspx)

- The preliminary layouts of the two networks using AutoCad civil 3d considered the existing ground as the reference for the rim elevation of manholes while in the real situation the reference is the paved finished surface because we are simulating already existing drainage networks , so while designing and adjusting pipes slopes; minimum cover constraint was violated, i.e. the rim elevation exceeded the top of the existing ground but this was not considered an issue because, as mentioned, the reference we are constrained by is not the actual reference which would be higher due to the thickness of the different layers of the pavement.

- To attain the minimum velocity for the sanitary pipes, the slopes constraints were defined between (6-12%), because when choosing a wider range of slopes, SewerCad “redistributes” the slopes of the pipes within the defined range, and that caused problems when double checking the network in SSA, because pipes with small slopes were surcharged, which can be explained because of the slow discharge of the wastewater inflow through the pipe due the low slope and when the inflow increases the pipe will be surcharged, and that’s why SSA was used to double check the designed network via SewerCad

- The diameters of the storm drainage network are increasing with the increase of the drainage area which is considered rational.

- Although the designed networks gave rational results the chance of getting something wrong still exists, because the design relied entirely on computer softwares which depend entirely on the data inputted and the experience of the person using them.

3.2.2 Incorporating Climate Change Scenarios in the Calculations and Assumptions for Design of urban Storm drainage networks

The main input parameters for the design of storm sewer pipe networks in urban cities are:

1. The area of the drainage basin

2. The runoff coefficient

3. The rainfall intensity

Runoff coefficient depends on the imperviousness of the drainage basin and therefore is a direct function of the level of urbanization in the city, the higher the area is urbanized the higher will be the value of the runoff coefficient whose value falls between 0 and 1

Intensity-Duration-Frequency (IDF) curves for the catchment area is a basic tool of the design of the storm drainage basin and is the one that is strongly reflect future climate change scenario through the expected increased density (i) of the design storm.

Therefore the design procedure will proceed as usual in the engineering practice paying attention to the two design inputs outlined above

The purpose of this study was to examine the performance of the designed storm and sanitary drainage networks when subjected to certain changes governed by climate scenarios predicted for Jordan, to determine wither these scenarios have a visible impact on the two networks or not, and if there's an impact; do the two networks maintain their capability to drain inflows, or failures in the networks are to be expected. These analyses were performed using SSA and SewerCAD software as will be explained in the upcoming sections.

3.2.3 Climate Scenarios

- Projection of different climate scenarios are obtained from Global Circulation models (GCM's) and Regional Climate models (RCM's) which simulate the response of the climate system under consideration when exposed to different green house gases (GHG) scenarios.
- Climate scenarios can be described as a possible image of the future, thus these scenarios are considered "highly uncertain" and that's why many projected climate scenarios can be found globally and regionally. This implies for Jordan as well; so in this study the scenarios chosen were based on Jordan's TNC report because, one, it is considered the most recent official report representing the climatic conditions projected for Jordan and two, it adopts major changes concerning "emission and concentration scenarios of GHG".
- Choosing the scenarios depended on two parameters of concern, precipitation as the main parameter and temperature as the secondary parameter. The predicted values provided in TNC for these two parameters are *per year*.
- The chosen GHG scenarios were:
    i. RCP4.5 (Moderate scenario) and the year of interest is year 2035 because it predicts both negative and positive values in terms of precipitation.
    ii. RCP8.5 (Extreme Scenario) and the year of interest is year 2085 because it predicts the highest values, in terms of precipitation and maximum temperature.

The Rational Method, shown in the box below is the chosen hydrological method to calculate peak flow (Q_{peak}) in the network; this method is one of the frequently used methods for designing storm networks for small watersheds. A watershed is defined "small" has an area up to 80 hectares (0.8 km^2), hence our study area (0.56 km^2) can be classified as a small watershed and the rational method is applicable.

$$Q_{peak} = 0.278\ CIA$$

Q: flow (m^3/s) ‖ C: runoff coefficient ‖ I: storm intensity (mm/hr) ‖ A: drainage area (km^2)

- The runoff coefficient was assumed to be (0.5) for the entire sub-basins in the network.

- Assumptions used in the Rational Method[11]:
    1. The peak flow occurs when the entire catchment (sub-catchment) is contributing to the flow.
    2. The rainfall intensity is the same over the entire catchment area.
    3. The sub-catchments should be rectangular in shape or nearly rectangular, and if not should be converted to a rectangular equivalent.
    4. In order to calculate (Q_{peak}), storm intensity (I) is measured from IDF curve of the design storm by assuming that storm duration (D) is equal to the time of concentration (t_c), which is defined as *"the time required for water to flow from the hydraulically most distant point in the drainage area to the discharge point"*. Time of concentration was calculated depending on "Kirpich" formula shown in (equation 6).

$$t_c = \frac{0.00032 * L^{0.77}}{S^{0.385}}$$

tc: time of concentration ‖ L: Hydraulically most distant point (m) ‖ S: slope

- Design Storm was assumed to be a storm with 15 years return period.
- The conventional design method of pipes' diameters consists of:
    1. Dividing the catchment area into smaller sub-catchments.
    2. Calculating peak flow using the rational method equation (equation 2.4).
    3. Using manning's equation (equation 2.3, section 2.2.1/D) to calculate the diameters.

The method for designing the storm network depended on the conventional method, i.e. the sub-catchments were determined as was shown in section 2.2.2/B; the rational method was selected in SSA software as the hydrology method and (t_c) was calculated using "Kirpich's" equation.

But after that the design process took an iterative form by inserting the required data for analysis (IDF curves[12], shown in figure 21, and defining the design storm chosen for design) then analyzing the preliminary network (which had a 300mm pipe diameter, the minimum diameter allowable in storm networks[13]). Any pipe diameter that failed in the analysis was enlarged by the next commercially available diameter (e.g. 400mm replaced with 450mm…etc), taking into consideration changing connected downstream pipes as well, and the analysis was re-run until getting suitable pipe diameters with no failures.

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[11] Ch14, Urban Storm water Management Manual, Malaysia.

[12] The IDF curves were created based on data from Consulting Engineering Center (CEC), IDF relation manual, 1.0 edition / 15 years storm values are not available and were interpolated.

[13] مدن، المؤسسة العامة للتعليم الفني والتدريب المهني، السعودية

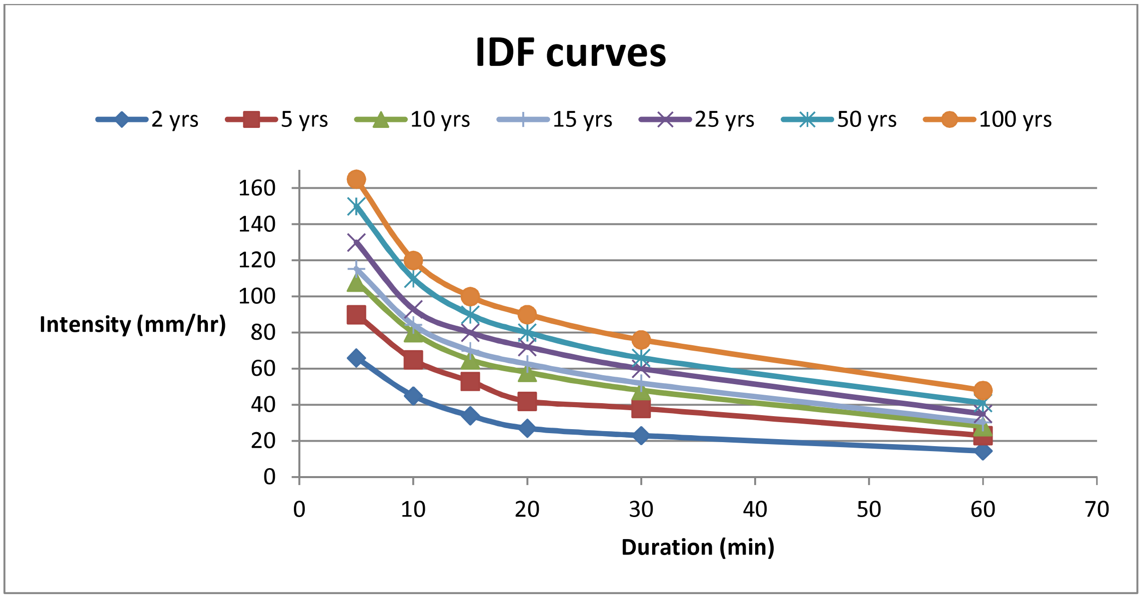

Figure 14 : IDF curves for The city of Irbid

3.2.4 Performance analysis of sanitary network under assumed scenarios

The effect of climate change on sanitary network is not direct, i.e. the effect of increase or decrease in precipitation or temperature will affect the DWF (daily consumption rate, specifically) and infiltration flow, mentioned in section 2.2.1/D, which in turn may affect the performance of the sanitary network. The accurate data of how daily consumption and infiltration rates will be affected could not be found, so to approach the effect of climate change mentioned earlier, two scenarios based on precipitation and temperature data were **assumed** and examined:

1. Increase in water availability (precipitation increase), and increase in temperature will increase people's daily consumption, while infiltration rate will increase due increase in precipitation. The assumed increase value was 50%.
2. The share per capita and infiltration will decrease due to decrease in precipitation. The assumed value of decrease was 50%.

The adjusted flows related to the first assumed scenario were inserted into SSA using "External inflows" tab mentioned earlier in section 2.2.1/D, in order to check if the pipes or manholes capacities will be exceeded, and the flows related to the second assumed scenario were inserted into SewerCad to check if a violation to minimum velocity (0.6m/s) will occur.

3.2.5 Performance analysis of storm network under assumed scenarios

- Unlike the sanitary network, the impact of climate change scenarios on storm network is direct, the parameter of concern used for analyzing storm network was "precipitation", to simulate its effect it was **assumed** that increase or decrease in precipitation is in the intensity of the design storm (I) and to simulate the assumed impacts, the IDF curves inserted into SSA at the design phase were adjusted with respect to each scenario using “IDF curves” tab in SSA, figure 15.

- Two extreme cases were taken for each GHG scenario (RCP4.5 and 8.5), i.e. minimum and maximum projected precipitation values in the year of concern of each case were examined, resulting four cases in total, highlighted in table 5[14].

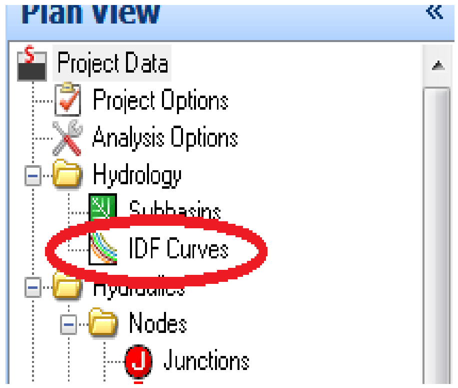

Figure 15: IDF curves tab menu in SSA

Table 6: GHG scenarios and the projected effect on precipitation and temperature per year on country level

	RCP 4.5					RCP 8.5				
	Year	Minimum	Medium	Maximum	Reference	Year	Minimum	Medium	Maximum	Reference
Precipitation (mm)	2035	-15.9	-8.2	9.2	-3.0	2035	-20.4	-12.9	-0.5	-12.9
	2055	-24.2	-15.4	0.7	-15.4	2055	-26.5	-15.0	-7.0	-12.9
	2085	-22.5	-13.6	-5.7	-12.0	2085	-38.0	-21.9	-10.9	-14.8
Mean Temperature	2035	0.9	1.2	1.8	1.2	2035	1.3	1.6	2.2	1.6
	2055	1.6	1.7	2.5	1.8	2055	2.1	2.6	3.4	2.6
	2085	1.8	2.1	2.8	2.5	2085	3.8	4.0	5.1	4.0
Maximum Temperature	2035	1.0	1.1	1.8	1.1	2035	1.3	1.5	2.3	1.5
	2055	1.6	1.7	2.5	1.7	2055	2.2	2.6	3.5	2.5
	2085	1.7	2.1	2.8	2.5	2085	3.8	4.1	5.0	3.9
Minimum Temperature	2035	0.9	1.1	1.7	1.3	2035	1.2	1.6	2.1	1.7
	2055	1.5	1.7	2.4	1.8	2055	2.0	2.5	3.3	2.7
	2085	1.7	2.0	2.8	2.5	2085	3.7	4.0	5.1	4.0

Designed sanitary network (via SSA softare) and storm drainage network are respectively shown in Figures 16 and 17 below.

[14] Table 4.10, page 121, TNC

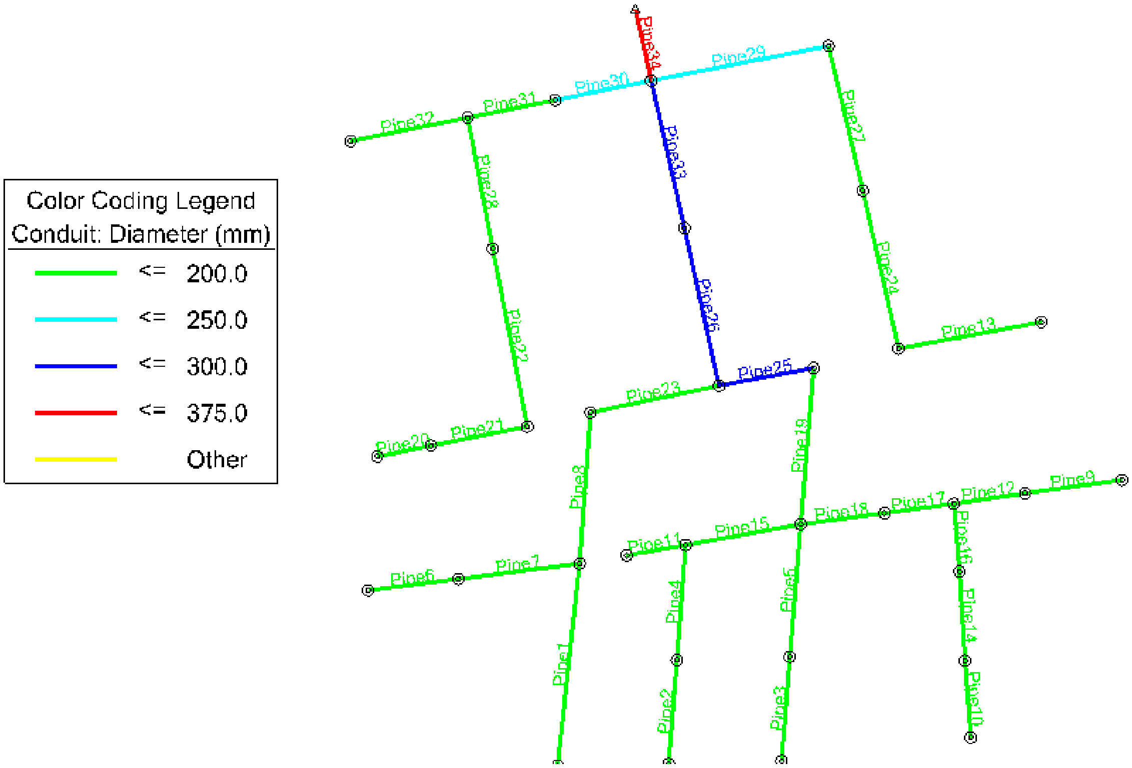

Figure 16: Designed sanitary network

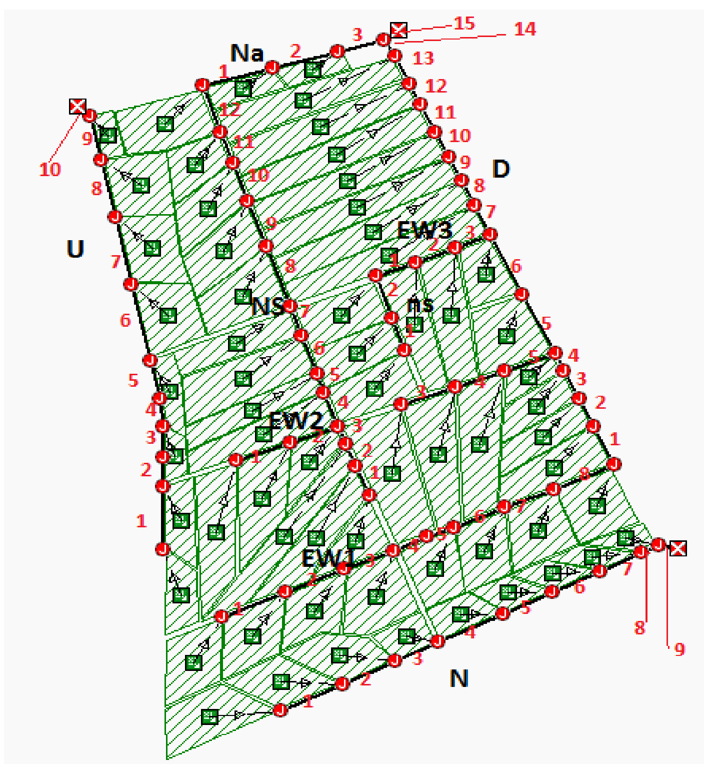

Figure 17 : Storm network

3.2.6 Storm and Sanitary networks performance under assumed climate Scenarios

I. Sanitary Network:

Scenario 1 simulation using SSA

After increasing DWF values and infiltration rate value by 50%, the network failed in some lines as shown in figure 18 , the blue dots indicate flooding in manholes and red lines indicate pipes surcharged. Flooded volume in each manhole in mm per hectare area (ha-mm) is shown in table 7 below.

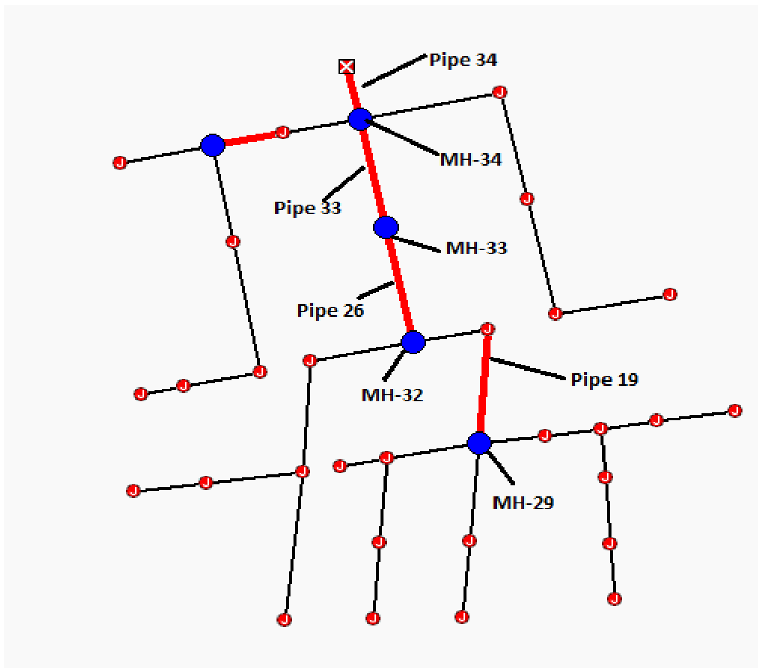

Figure 18: failure in Sanitary network due scenario 1

Table 7: Total flooded Volume

Manhole	Flooded Volume (ha-mm)
MH-29	85.15
MH-33	226.44
MH-34	398.34

II. Storm network

The analysis of the network under assumed scenarios didn't show any predicted failures in the designed network, neither when the IDF curves' intensity values were increased, nor when they were decreased.

- The designed networks can't be considered a perfect representation of the already existing networks, because the design aimed to get safe and functional networks, and a network on paper differs from a network on field, and for that reason the designed storm drainage network was safe under all the different scenarios which may not be the case for a real existing storm drainage network.

- The scenarios assumed are based on small knowledge of what was found and understood concerning climate change, a science that's considered "highly uncertain". Also, the assumed scenarios are based on present methods of design and analysis while recent studies show that in order to simulate real effects of climate change; new methods should be adopted, e.g. the approach to create new downscaled IDF curves[15], i.e. The results obtained can't be considered conclusive of what will really happen, they only give an image of what could happen if the assumed scenarios were to happen under the assumed circumstances.

- The softwares used for analysis are based on present-day methods of design and analysis, while scientists are aiming towards developing new softwares that take into consideration the variability of climate change.[16]

  One important factor of the design of storm water drainage networks is the land use features of the human settlements. Accelerating urbanization rates in Arab cities have resulted in flooded systems even without impacts of climate change. Figure 19 below shows a flooded road tunnel in Amman, Jordan in winter 2014 where invesitigations revealed the cause to be lack of maintinance of the pumping system ahead of the rainy season as well as design difficiency!

Figure 19 : Street tunnel flooded with storm water in West Amman, winter 2014

[15]Development of Probability Based Intensity-Duration-Frequency Curves under Climate Change, Tarana A. Solaiman and Slobodan P. Simonovic, THE UNIVERSITY OF WESTERN ONTARIO
[16]SDSM software, developed by Canadian Climate Data and Scenarios

Figures 20 and 21 below show two parts of Amman, Jordan with distinct difference of the level of urbanization which directly relates to the runoff coefficient critical for the design of storm water drainage systems

Figure 20: Land use features dictate value of the Runoff coefficient for storm sewer design, AlMadeena Tunnel, Amman Jordan

Figure 21: More intense urbanization and higher run off coefficients, AlWaha, Amman Jordan

Chapter 4: Identification of adaptation measures and options (IWRM tools) for the Sector based on the impact and vulnerability assessment results

In urban areas, Useful tools of IWRM include rain water harvesting, water reuse and water demand management

4.1 Stocktaking of available adaptation measures

4.1.1 Water Harvesting

Water harvesting is recognized as an efficient and practical IWRM tool that meets adaptation to climate change. Rain water harvesting (RWH) is/can be implemented at the ecosystem level, watershed level and at the urban and household levels. Benefits of RWH at the various levels include but not limited to groundwater recharge, soil erosion control, flood control and improving water supply in the Arab region where water scarcity has been a challenge for development. The total average amount of rainfall region-wide is estimated at 2,238 billion m3 while only 200 billion m3 is shown in the renewable surface and groundwater reserves across the Arab World. The numbers speak of a great potential for rain water harvesting at all levels in the Arab states.

The present water supply and stormwater problems in most cities of the Arab region will mount in future. The concept of 'Integrated Urban Water Management' (IUWM) seems to be most appropriate; it includes:

(a) Water Supply Management: Rainwater harvesting on urban buildings or

other sealed surfaces, offers new chances to cover the ever growing urban water demand.

(b) Water Demand Management can be achieved through a combination of behavioural changes and technological fixes such as water saving devices (WSDs).

(c) Excess Water Management deals with stormwater and floodplain management.

In case study #1 (see annex), an exercise will be done on the feasibility of rainfall water harvesting at household level including the calculation of harvested water volume and necessary storage requirements

Harvesting may also be practiced at small catchment level and at basin level as will

4.1.2 Water demand management and water ration

- Public awareness Campaigns
- Installing water saving devices (WSDs)
- Programs for water recycle/reuse for large water consumers like hotels

4.1.3 Reuse of Grey water

Greywater is wastewater from showers, bathroom, washing machines, dishwashers, and kitchen (any source at home other than toilets).

Expanding grey water use in the Arab world can help address the region's acute water shortage and improve the water equation. The private sector can invest in the treatment and reuse of grey wateras an alternative source of water, highlighting that although Arab countries have made strides in wastewater reuse over the past two decades, the level of wastewater services still has room for improvement.

Grey water can be recycled using individual treatment units within the homes that produce it, with no need to channel it to large treatment plants, and it can be easily treated and reused in households for irrigation and other purposes. Countries should consider grey water as a source of water that can bridge the gap between supply and demand.

The advantage of recycling greywater is that it is a large source with a low organiccontent. To illustrate, greywater represents up to 70% of total consumed water butcontains only 30% of the organic fraction and from 9 to 20% of the nutrients. Moreover, in an individual household, it has been established that greywater couldsupport the amount of water needed for toilet flushing and outdoor uses such as car washing and garden watering. For example in the UK, on average, toilet flushing and outdoor use represent 41% of total domestic water usage whereas greywater from shower, bath, hand basin, laundry and dishwasher correspond to 44%.However, at larger scale, other applications such as irrigation of parks, school yards,cemeteries and golf courses, andfire protection have beenconsidered.

Treatment technologies for grey water recycling

Concerns over dwindling groundwater reserves and overloaded or costly sewage treatment plants have generated interest in the reuse or recycling of grey water, also called "sullage", both domestically and for large-scale irrigation.

However, concerns over potential health and environmental risks mean that many municipalities require intensive treatment systems for legal reuse of grey water, making it expensive for both commercial and residential use. But, there exist simple and low-cost treatment systems for grey water treatment at the household level. See Case study # 1 (Appendix) on grey water treatment in Oman

Grey water differs from water from toilets, which is designated as sewage or black water to indicate it contains human waste. Grey water makes up 70-90 per cent of residential wastewater, according to web sources.

Table 8: Distribution of household domestic water use

Toilet flushing	35%
Wash basin	8%
Shower	5%
Bath	15%
Laundry	12%
Dishwasher	4%
Outside use	6%
Kitchen sink	15%

Table 9. Suggested distribution of grey water application/reuse split

Applications	
Toilet flushing	54 %
Irrigation and Garden watering	36 %
Outdoor use and cleaning	5 %
Laundry	2.5 %
Infiltration	2.5 %

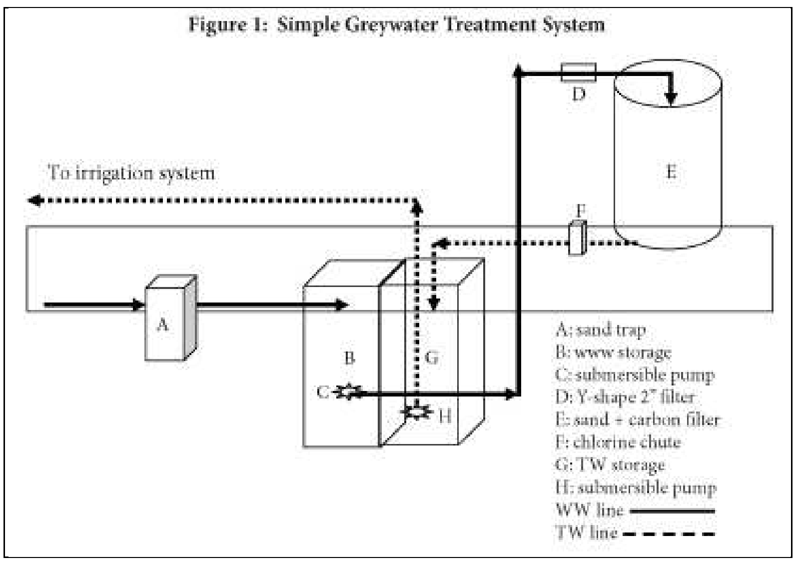

Figure 22: Simple treatment line for grey water reuse at small scale

4.1.4 Water Foot Prints tool

The concept and methodology of water footprint assessments can assist water managers, government officials, scientists and the private sector to understand the quantities and types (blue, green, grey) of water involved in producing specific products and in assessing the impact of products or whole production sectors on the actual water demand and water resources available. This may in turn contribute to improving the product's, or the sector's overall water efficiency.

Public awareness is crucial in helping various sectors of human settlements understand challenges associated with climate change especially large water-consuming institutions such as hotels and factories. Concepts of water reuse and recycling within factories and hotels should be emphasized.

It is strongly advised to propagate the culture of virtual water within all stakeholders in human settlements. Establishments, institutions, urban farms, hotels and others should be introduced to the significance of preparing reports of the WFP of their activities. With water tariffs used as an effective tool for water demand management, WFP for institutions become both relevant and feasible.

4.1.5 MDGs and SDGs after 2015

Many Arab states failed to meet the MDGs relevant to water supply and sanitation. In deed, as many other developing countries instead of contextualizing MDGs in initial conditions and national priorities and development plans, the thinking was focused on the international donor agencies and international responsibly. But the MDGs were meant to be collective targets for the world as a whole which did not have to be reached by every country. This has led to a disproportionate emphasis on the importance of external financing in the pursuit of MDGs. But success or failure in the pursuit of MDGs depends largely upon what happens within countries, where governments are both responsible and accountable for outcomes.

Generalized MDGs or contextualized MDGs**?**

Generalized MDGs and contextualized MDGs should not be presented as an either-or choice. Indeed, posing them as alternatives creates a false dilemma. Generalized MDGs were objectives for the world as a whole. And these global goals were meant to be modified in the context of initial conditions and national priorities. In other words, the MDGs constituted a set of norms and provided a framework for national governments to formulate their objectives with reference to specificities in time and in space. Given these norms, country-oriented MDGs could have reflected differences in priorities and objectives. Therefore, generalized MDGs and contextualized MDGs are complements rather than substitutes. Of course, it is important to strike a balance because global goals should allow space for differences in initial conditions and in national priorities. This space cannot be too much and should not be too little.

External finance is a complement to, but cannot be a substitute for domestic resources. The role of the State remains critical in the process of development. International donors could help countries adopt policies and strategies, suitable for and appropriate in their respective national contexts, that are conducive to the pursuit of development objectives embedded in the MDGs.

Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation

GOALS AND TARGETS (FROM THE MILLENNIUM DECLARATION)

GOAL 7: ENSURE ENVIRONMENTAL SUSTAINABILITY**, Target 10**

INDICATORS FOR MONITORING PROGRESS

30. Proportion of population with sustainable access to an improved water source, urban and rural

31. Proportion of urban and rural population with access to improved sanitation

4.1.6 Cutting on the Non-revenue water (NRW)

NRW (non revenue water) means: is water that has been produced and is "lost" before it reaches the customer. Losses can be real losses (through leaks, sometimes also referred to as physical losses) or apparent losses (for example through theft or metering inaccuracies). High levels of NRW are detrimental to the financial viability of water utilities

NRW is still higher in Arab cities when compared with other parts of the World. Many Arab cities have adopted PPPs to transform water utilities from governmental administration to private sector commercially-based management. One main promise of this transformation has been to cut on the unaccounted for water

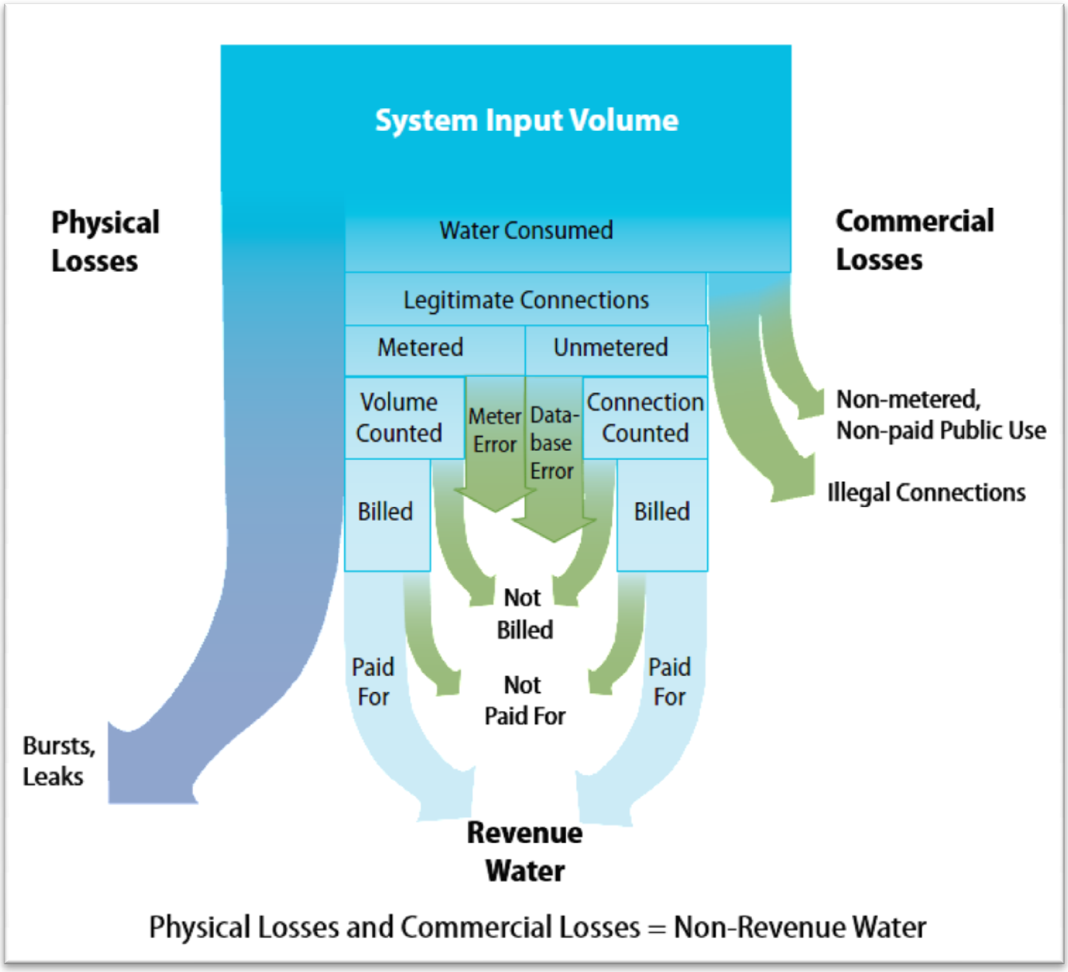

Figure 23: Components of Non-revenue water

Under climate change scenarios, water utilities should continue a good work of trying to reduce NRW which typically entails:

- Reducing physical losses
- Using advanced and innovative Sensors (acoustic and water borne) to detect leaks
- Investing in better governance with a goal of minimizing response time
- Administrative non-leak losses should also be investigated and resolved

Table 10. Water losses in the water supply distribution system in selected Arab countries, 2005 (Source: FAO 2013)

Country	% of loss
Bahrain	15
Egypt	50
Iraq	50
Jordan	50
Kuwait	8-10
Lebanon	50
Oman	23
Palestine	40
Saudi Arabia	25-40
Syria	48
Yemen	30

New advancement in leak detection technology and sensors can be and should be used in order to reduce the NRW in all Arab urban areas especially in the GCC region where water supply relies on desalination to cover at least 50 % of the demand

4.1.7 Wastewater Reuse/Recycle

Reuse of treated wastewater is indispensible tool for enhancing adaptive capacity to climate change impact. Reuse has been a practice in most major Arab cities before CC concerns and it has perceived for long as an important factor of the wise water management whereby treated effluents are used in restricted irrigation schemes and leaving the scarce resources of fresh water available for domestic supply.

Table 11 shows amounts of wastewater produced, treated and re-used in selected Arab countries

Table 11. Total water withdrawal, raw wastewater and treated wastewater in the selected Arab countries in $10^9 m^3$/year.

Country	Total wastewater produced ($10^9 m^3$/year)	Total water withdrawal ($10^9 m^3$/year)	Volume of Treated Wastewater ($10^9 m^3$/year)	Volume of Treated Water reused ($10^9 m^3$/year)
Algeria	6.07	0.82	0.7**	0.051
Bahrain	0.3574	0.0449	0.076	0.0163
Comoros	0.3574	-	-	-
Djibouti	0.019	-	-	-
Egypt	68.3	3.76	2.971**	0.700
Iraq	66	0.575	0.098**	0.0055
Jordan	0.941	0.117	0.111**	0.102
Kuwait	0.913	0.25	0.239*	0.078
Lebanon	1.31	0.31	0.004***	0.002
Libya	4.326	0.546	0.04***	0.04
Mauritania	1.7	-	0.0007***	0.00035
Morocco	12.6	0.700	0.177**	0.080
Oman	1.321	0.098	0.037*	0.0023
Qatar	0.55	0.444	0.066*	0.043
Saudi Arabia	23.67	0.73	0.652*	0.166
Somalia	3.298	-	0	-
Sudan	37.32	-	-	-
Syria	16.7	1.37	0.550***	0.550
Tunisia	2.85	0.461	0.240**	0.068
UAE	3.998	0.5	0.454*	0.248
West Bank & Gaza	0.418	0.05	0.03***	0.00544
Yemen	3.4	0.074	0.046***	0.006
TOTAL	256.303	10.85	6.492	2.164

*GCC water statistics book, 2010, ** Dubai Expert meeting, ***FAO-AQUASTAT 2009

For detailed aspects and issues related to wastewater reuse in urban areas of the Arab region, see Case Study # 3 on KSA.

A summary of select guidelines and mandatory standards for reclaimed water use in a variety of U.S. states and other countries and regions is presented in Table 12 below. Some minor differences are apparent; for example, some measure FC, while others measure total coliforms. The use of total coliforms is more restrictive than using FC alone, without necessarily being a more expensive testing method. Most also measure other indicators of sufficient treatment, such as filtering or otherwise removing suspended particles that could serve as bacteria substrates: BOD5 and turbidity or TSS. It is also useful to measure chlorine residuals as evidence of disinfection.

Table 12: International and Arab countries standards for reuse of wastewater.

International Examples of Reuse Standards

Country/Region	Fecal Coliforms (CFU/100ml)	Total Coliforms (CFU/100ml)	Helminth eggs (#/L)	BOD_5 (ppm)	Turbidity (NTU)	TSS (ppm)	DO (%of Saturation)	pH	Chlorine residual (ppm)
Australia (New South Wales)	<1	<2150	—	>20	<2	—	—	—	—
California (USA)	—	2.2	—	—	2	—	—	—	—
Cyprus	50	—	—	10	—	10	—	—	—
France	<1,000	—	<1	—	—	—	—	—	—
Germany (g)	100 (g)	500 (g)	—	20 (g)	1-2 (m)	30	80-120	6-9	—
Israel	—	2.2 (50%) 12 (80%)	—	15	—	15	0.5	—	0.5
Kuwait (Crops not eaten raw)	—	10,000	—	10	—	10	—	—	1
Kuwait (Crops eaten raw)		100		10		10			1
Oman 11A [a]	<200	—	—	15	—	15	—	6-9	—
Oman 11B [a]	<1,000			20		30		6-9	
South Africa	0(g)	—	—	—	—	—	—	—	—
Tunisia	—	—	<1	30		30	7	6.5-8.5	—
UAE	—	<100	—	<10	—	<10	—	—	—
USEPA(g)	14 for any sample, 0 for 90%	—	—	10	2	—	—	6-9	1
WHO (lawn irrigation)	200 (g) 1,000 (m)	—	—	—	—	—	—	—	—

Note: (g) signifies that the standard is a guideline and (m) signifies that the standard is a mandatory regulation
[a] Two categories of reuse rules are in place in Oman, based on application limitations common in many countries.
Source: Adapted from USEPA, 2004

Obstacles to wastewater reuse implementation in Arab countries cab be summarized:

1. Technology and infrastructure availability
2. Water Resource Management frameworks
3. Regulations and Recycled Water Quality
4. Socio-Cultural Beliefs and Religious Practices
5. Public Perceptions and Terminology

Branding Recycled water! NEWater?

Social acceptance of reclaimed wastewater is still an issue in the Arab region that can be overcome via public awareness and carefully designed media messages and careful selection of vocabulary

4.1.8 Water Tariffs

Pricing policy is one of the main driving factors for water reuse or lack thereof. Water tariffs are set based on a number of formal criteria defined by law, as well as informal criteria. Formal criteria typically include one or more of the following:

• Financial criteria (cost recovery)
• Economic criteria (efficiency pricing based on marginal cost)
• Environmental criteria (incentives for water conservation)

Social and political considerations often are also important in setting tariffs. Tariff structures and levels are influenced in some cases by the desire to avoid an overly harsh burden on poor users or by other political considerations. Water tariffs should be easy to understand for consumers. This is not always the case for the more complex types of tariffs, such as increasing-block tariffs and tariffs that differentiate between different categories of users.

4.1.9 Managed GW Recharge-Aquifer Recharge and Recovery

A variety of different types of water are stored or treated in managed aquifer systems, including:

• Reclaimed water
• Potable water (including desalinated water)
• Surface water (treated to varying degrees)
• Storm water
• Raw groundwater (inter-aquifer systems)

Managed aquifer recharge (MAR) was defined by Dillon (2005) as the *intentional banking and treatment of waters in aquifers*. The term *managed aquifer recharge* was introduced as an alternative to *artificial recharge*, which has the connotation that such use of the water was, in some way, unnatural (Dillon, 2005). MAR can be either a storage technology, treatment technology, or both. With respect to reclaimed water, MAR can be used to store seasonally available excess water (intra-annual supply management), to strategically store currently available excess water for future use, or to serve as a treatment (polishing) step in a multiple-barrier approach to reclaimed water reuse.

Other similar terms have been introduced for MAR techniques. The term *aquifer recharge and recovery* (ARR) refers to the artificial recharge of water into an aquifer and its later recovery for subsequent use with a primary goal of water treatment. ARR of reclaimed water can be very cost-effective wastewater treatment technology. The term *managed underground storage* (MUS) was introduced by the U.S. National Research Council (2008) to denote "the purposeful recharge of water into an aquifer system for intended recovery and use as an element of long-term water resource management."

MAR includes a variety of techniques, some of which are applicable to effluent storage and treatment. Aquifer storage and recovery (ASR) is an important MAR technique, which was defined by Pyne (1995) as: *The storage of water in a suitable aquifer through a well during times when water is available, and the recovery of the water from the same well during times when it is needed*

ASR systems offer the following advantages for reclaimed water storage:

• Much lower costs than surface storage options
• Very large storage capacities that are typically available at no cost
• Much lower land requirements than surface reservoirs
• No water losses due to evapotranspiration
• Less severe environmental impacts due to small system size
• Potential improvement in water quality through the natural attenuation of concentrations of pathogens and chemical contaminants

• Minimal adverse aesthetic (e.g., visual, odor) impacts

The main disadvantages or limitations of ASR systems include the following:

• Unfavorable hydrogeological conditions potentially resulting in low recoverability of stored water
• Adverse changes in water quality potentially occurring due to fluid-rock interactions (e.g., metals leaching)
• Adverse public and regulatory perceptions, particularly if indirect potable reuse is Involved

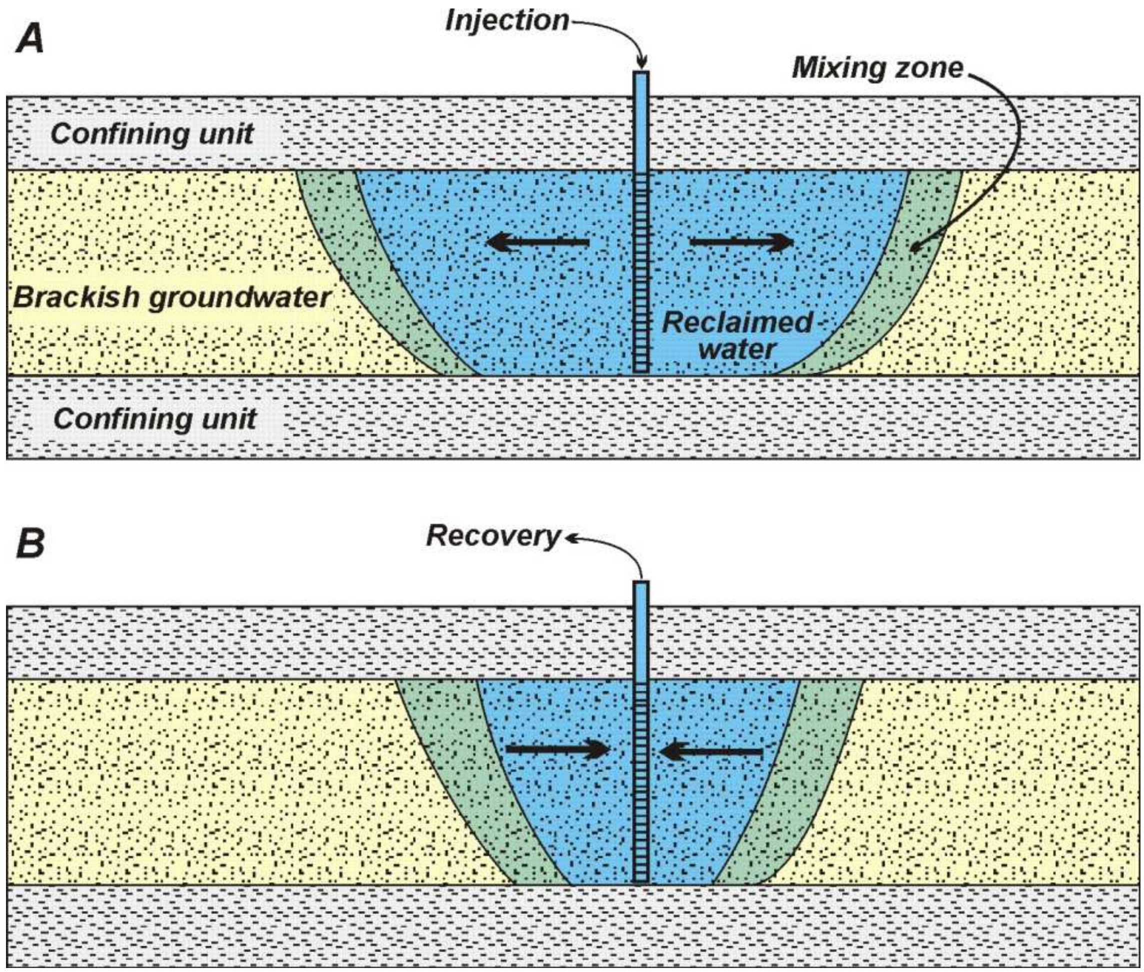

Figure 24: Conceptual Diagram of ASR Using Brackish Storage Zone
Note: A) Injection of freshwater displaces native brackish groundwater. Freshwater and brackish are separated by a mixing zone. B) During recovery, freshwater is drawn back toward the ASR well.

It is recognized that neither the balloon nor the bubble metaphor is accurate for the reservoir used to store freshwater (e.g., Vacher et al., 2006; Maliva et al., 2006). The distribution of injected freshwater is controlled by aquifer heterogeneity: injected water preferentially enters the most permeable beds within the storage zone. The freshwater reservoir may also become asymmetrical in response to natural and anthropogenically influenced hydraulic gradients and density stratification.

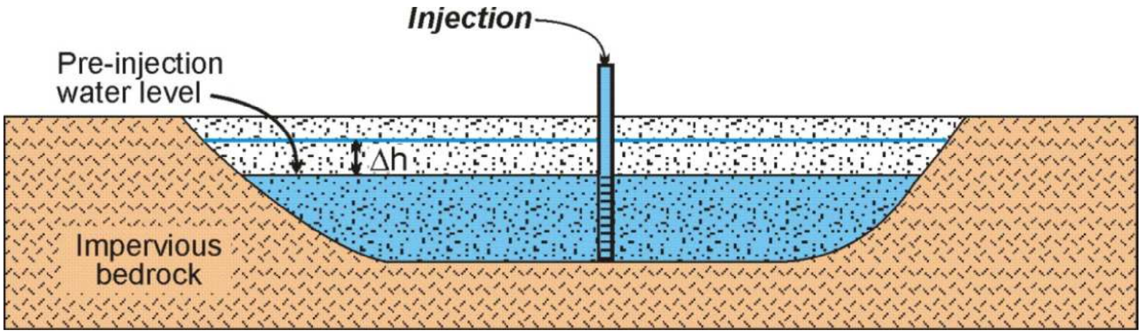

Figure **25:** Conceptual Diagram of Physical Storage ASR System

Note: The increase in the volume of stored water is the product of the increased water level or head (Δh) abovepre-injection levels, aquifer area, and storativity.

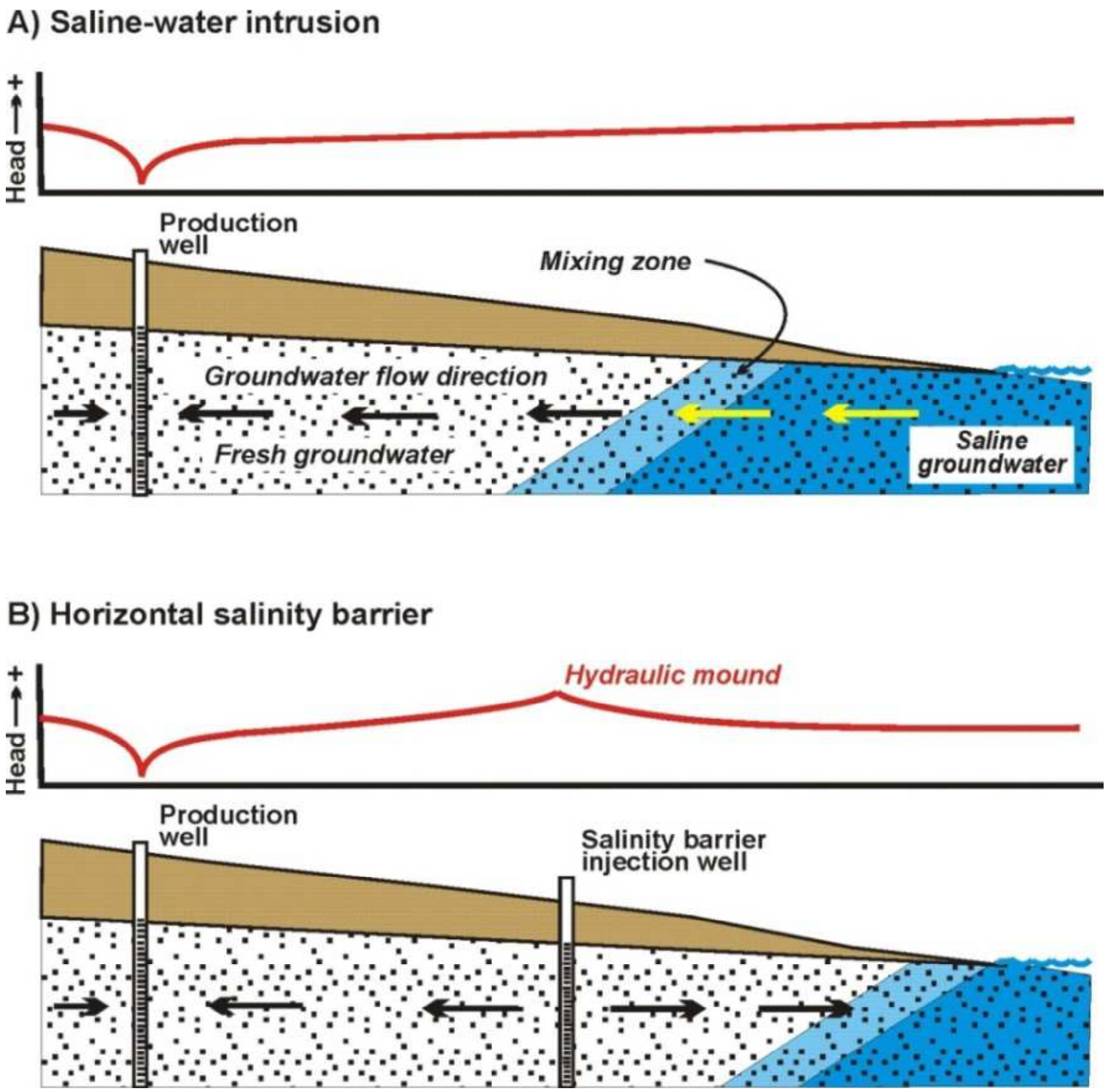

Figure 26:Conceptual Diagram of Salinity Barrier System
Note:

A) Saline-water intrusion occurs when groundwater pumping induces a landward hydraulic gradient at the saline-water interface
B) A salinity barrier restores a seawards gradient for forming a hydraulic mound between production wells and the saline-water interface

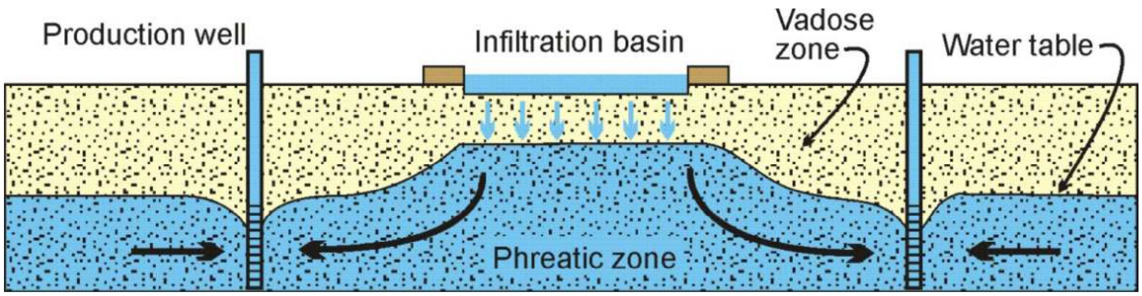

Figure 27:Conceptual Diagram of SAT System
Note: Reclaimed water is recharged using infiltration basins. The quality of the water is improved by natural attenuation processes as it flows to production wells first through the vadose zone and then the phreatic zone

Table 13 below can help identify acceptable and optimal features of GW quantity and quality for potential exploitation of these water reserves. In certain cases, GW reserves might be available but not ready to use by urban centers because of contamination, high salinity levels or prohibitive pumping costs.

Table 13: Hydraulic and water quality acceptability ranges of ground water reserves.

	Parameter	Fatal Flaw	Unfavorable	Acceptable	Optimal
1	Aquifer water quality TDS (mg/L)		> 10,000 mg/L or ≤ 1,500 mg/L	5,000 ≤ x < 10,000	1,500 < x 5,000
2	Aquifer transmissivity (m^2/d)	< 50	50 ≤ x <200 < 2,000	200 ≤ x <500 1,000 ≤ x ≤ 2,000	500 to 1,000
3	Aquifer storage capacity	Minimal capacity	Inadequate capacity	Adequate for anticipated MAR applications	No restrictions
4	Aquifer depth (m)	> 1,500	400 ≤ x < 1,500	100 < x < 400	≤ 100
5	Aquifer heterogeneity and porosity type	-	Karst-dominated flow	Moderate heterogeneity	Intergranular (matrix-dominated flow)
6	Storage zone confinement	-	Poor	Moderate	Highly effective
7	Aquifer hydraulic gradient	-	< 1:1,000	1:5,000 ≤ x < 1:1,000	≤ 1:5000 or gradient is beneficial (ASTR)
8	Adverse fluid-rock interaction potential	-	Common reactive minerals and evaporites	Not expected to be a significant problem	High-stability mineralogy (e.g., quartz sands)
9	Aquifer potable reuse	Indirect potable reuse cannot be avoided	Widespread use of aquifer for potable supply (domestic)	Potable reuse could be avoided through system siting.	Aquifer not used for potable supply
10	Proximity to site of RQTSE supply or	-	Long dedicated conveyance would	Some additional	MAR could be sited near WWTP

Most of the Arab region is faced with acute water shortages that put tremendous pressure on utilities to develop and sustain adequate water supplies to be able to meet existing and future demand. Climate change, population growth and economic development are at the heart of the ever-increasing gap between water demand and available supplies. Developing additional water supplies from non-traditional water resources such as desalination adds financial burdens on the utilities which subsequently become in need of government support and subsidies. As a means to confront all those challenges, many utilities see the need for performance and efficiency improvements-particularly related to improved services, financial sustainability, and customer satisfaction; for developing water infrastructure responsive to current and emerging needs; and for providing services within an environment conducive to good performance and satisfied customers.

Scarcity of water resources translate into difficulties in providing services to customers continuously in many countries in the region. This is reflected by intermittent water supply (Jordan, Yemen, Palestine, Lebanon, Iraq…), and results in stressful O&M conditions that impact the quantity and quality of water supplied, the level of services provided and consequently customer satisfaction, and also the WSS infrastructure integrity. These stressful O&M conditions and difficulties entail a high level of expenditure the utilities need to undertake, related to capital investment projects for the rehabilitation and replacement of the assets that deteriorate rapidly due to intermittent supply.

In those cases where governments choose to develop new water resources- conventional and nonconventional, this comes at a very high price that needs to be paid for either by the governments that choose to, such as the oil rich countries in the GCC investing heavily and currently at the forefront of users of the very highly energy intensive desalination technologies, or by private investors who aim at recouping their investments in due course, or by the customers paying for the service.

The dominant social paradigm that water is not an economic good, rather a public good that needs to be provided to all for free. This does not make provisions for the cost of developing water resources, or the infrastructure constructed, operated and maintained to distribute this water to its end users. Subsequently, and especially nowadays with the Arab Spring and the political volatility in the region, governments are not ready to remove any subsidies they are paying to the cost of services. However, these subsidies are yet another burden that not all countries are able to support, thus leading the utilities into the vicious cycle of deterioration of assets.

In the decades to come, climate change may make tens of millions of Arab urban residents – and in particular the poorest and most marginalized – increasingly vulnerable to floods, landslides, extreme weather events and other natural disasters. City dwellers may also face reduced access to fresh water as a result of drought.

In the next section of this Module, a set of tools available through the IWRM field will be identified and screened as measures for helping urban centers adapt with extreme climate change events.

4.2 Screening criteria

Selection criteria for IWRM Tools of adaptation potential for Arab human settlements will be discussed, and input by trainees will be sought, organized and listed. This will be implemented through exercise # 1 mentioned above and in the Appendix. Based on sub-regions of the Arab World, selection of the most appropriate tools and the ranking therein might be a little different. For example; cities in the GCC sub-region consume much higher amounts of water per capita as compared to the other 2 sub-regions, yet high cost desalination is the main source of water supply within the GCC countries. Tools of water ration, public awareness as well as water tariffs might be more relevant/efficient to this sub-region than the others who suffer lower income as well as scarcity of water.

In general, the following suggested criteria can be the basis of training dialogue on screening options and tools of IWRM at the human settlement level:

1.Technical feasibility of applying the tool within the urban context

2. Cost

3. Social acceptance

4. Addition to adaptive capacity of the human settlement

5. Indirect positive value

6. Previous experience and local capacity for implementation

7. Technology transfer of IWRM between Arab countries

4.3 Screening of adaptation measures

Table 13 below depicts a listing of the IWRM tools outlined in this Module. These tools are of clear value for enhancing CC adaptation across human settlements in the Arab countries. However; these tools would be screened and ranked during the training based on the criteria discussed above.

Chapter 5: Adaptation measures implementation matrix

Tools of IWRM provide opportunity for human settlements in Arab countries to better adapt to climate change

Table 14: Matrix of IWRM Tools for adaptation in human settlements in the Arab countries.

	Technical feasibility	**Cost**	**Social acceptance**	**Adaptive capacity**	**Indirect positive value**
HH Harvesting					
Grey water reuse					
NRW Reduction					
WW Reuse/Recycle					
WDM					
Public Awareness					
Virtual water and WFP					
Sewage Networks					
WDS and storage facilities					
GW Recharge					

Chapter 6: Areas for Action: Suggestions for Follow-up

6.1 National Policy Level

Adaptation to CC needs to be incorporated in all relevant policies of infrastructure maintenance/development as well as water security issues at the human settlement level.

Where localgovernments areweak or ineffective,household andcommunity-based strategies becomemore important forreducing climatechange risks andimpacts in urban areas. However; the primary responsibility for developing national policies and programs on CC adaptation remains with national governments.

There are basic questions to inform the process of adaptation planning and these are:

• What is the need and motivation / justification for adapting (while recognising uncertainty)?

• What are the options for change / innovation?

• How can one prioritise and select between the options?

• What roles are undertaken by whom, including who pays for what?

• How and when is it to be evaluated?

Adaptation policies should follow an integrated form of assessment which has the following benefits at the national level:

- Engages a cross-sector of stakeholders ranging from Government to civil society.
- Integrates scientific methodologies, traditions and standards into interdisciplinary analysis tobridge the gap between science and policy making.
- Links impact assessment to vulnerability assessment.
- Conducts analysis and assessment across relevant geographic scales and time scales.
- Recognizes and takes into account regional specificities.
- Accounts for scientific uncertainty, and seeks to reduce it through objective methods.

Figure 28 below shows a suggested framework of logical sequence of how adaptation measure/projects/retrofits might be approached and evaluated

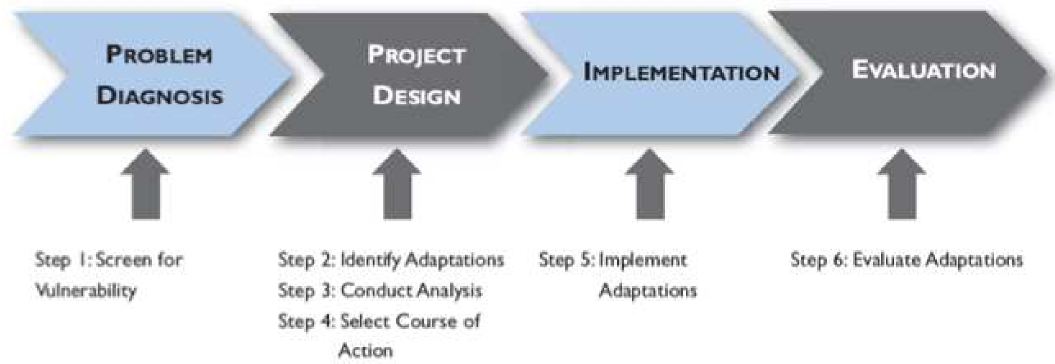

Figure 28: Process of adaptation measure implementation at the Human Settlement level.

6.2 Global Policy Level

Adaptation decision-making can be informed by various tools, methods and approaches. These include participatory as well as expert-based approaches. The use of a (computerized) decision support system (DSS) is a means to compare different possible interventions.

An important principle is that there is no one method/approach/tool that suits all circumstances of adaptation decision-making. Adaptation methods, in other words, have conditions of applicability likethe preferences of stakeholders affected by the decision which might be overlooked in practice. The specification of the problem and the available 'inputs' to the decision process should inform the choice of policy.

A second important principle is that there is much uncertainty in adaptation decision-making. This challenges the identification of good options and the creation of shared understanding about possible outcomes.

Thinking of policy advice, however, it is useful to consider certain measurable indicators of the socio-economic vulnerability of human settlements, these can be:

Social factors

- Population density
- Percentage built area in floodplains
- Individual income
- Individual education
- Percentage child malnutrition and infant mortality;

Economic factors

- Energy prices
- Household access to water and sanitation

- Food imports
- Market access

Specific national policies factors

which contribute internal vulnerability factors and could be represented by complex indicators such as:

- The level of application of integrated water resources management
- The effectiveness of water demand management,
- Actual water storage capacity

Again, the identification of vulnerability indicators should be reached through consultative processes in view of responding to the interests and priorities of policy-makers and other stakeholders.

Assessment of human settlements vulnerability and adaptation to CC can follow (1) an Indicator based approach or (2) a sector-based modelling approaches (water supply, sanitation, health, transportation systems, tourism, etc...)

For example, water-related climate change hazards, such as floods, rainfall events, droughts, and water-borne epidemics can be represented by variables measuring their expected intensity, duration and frequency based on projected impacts. The positive or negative effects of those hazards on those indicators then enable the identification of regions, communities, groups and ecosystems that are more or less vulnerable to water-related hazards arising from climate change.

In the following table, a list of factors/indicators (with suggested method of measurement for each indicator) are listed along sectors that shape livelihoods in human settlements. These include water management, food supply, economy and demography.

Table15: Selected Demographic, Economic and Water related Indicators for the Arab Region

Category	Factor	Measure
Water resource planning and management	Application of IWRM	Level of application
	Efficiency of water demand management	Cost recovered from water fees (%)
	Water network losses	Water network losses (%)
	Water storage capacity	Water storage to total water resources (%)
	Status of strategic water reserves	Abstraction to total strategic water resources (%)
Economy	General state of the economy	Gross national income (GNI)
		Gross domestic product (GDP)
		Gross savings (% of GNI)
		Total reserves (% of total external debt)
		Total debt services (% of GNI)
		Lending interest rate (%)
	Population relative wealth	GNI per capita
		GDP per capita
		Unemployment (% of total workforce)
	Poverty	Population earning less than US$1.25 per day (%)
	Economic diversification	Value added – industry (% of GDP)
		Value added – services (% of GDP)
	Energy consumption	Electric power consumption (kWh per capita)
	Energy cost	Diesel fuel price
Demography and income	Population size	Total population
	Population growth	Population growth
	Population-female	Number of women to total population (%)
	Population density	Population per km^2
	High concentration of people in urban areas	Population in the largest city (% of total population)
		Population in urban agglomerations of more than 1 million (% of total population)
	Economically dependent population	Number of young and old to working-age population (%)
Agriculture	Dependency on agriculture	Agricultural land to total (%)
		Workforce in agriculture (%)
		Rural population (% of total population)
	Dependency on rain-fed agriculture	Rain-fed land (% of total)
	Level of land degradation	Degraded land (% of total)
Food security	Reliance on single or few crops	Top three strategic crops (% of total products)
	Reliance on locally produced food	Food produced locally (%)
	Food productivity	Cereal yield per hectare (kg)

Chapter 7: Cost of water adaptation measures

While this module deals with adaptation of human settlements to climate change and the role of IWRM tools available, it must be emphasized that in most Arab countries its agricultural sector that has the lion share of the national water budget. There is a lot to do in reconsidering the huge subsidies given to the agricultural sector where many Arab countries provide irrigation water at a minimal or no cost to farmers while domestic water supply has a service charge that is considerably higher when compared with irrigation water. Despite of the complex social and cultural issues associated with the high subsidies for irrigation water, a slight policy change in this regard might control overconsumption in the irrigation sector, thus by helping human settlements cope with climate change increased pressures on water supply for human settlements across the Arab countries.

Adaptation tools and measure can be too many and at the end the cost of implementation should be the driving factor to select the most appropriate tool or measure. In a World Bank study on the cost per cubic meter of water saved or delivered for nine adaption options (Table 16 below), the cost ranged from a low US $ 0.02 by improving agricultural practices to a high of US $ 2.00 per cubic meter of cutting domestic demand[17]. The World Bank study estimates the supply/demand deficit to be 200 km^3 in 2045 and that it will cost US$ 104 billion per year for the Arab region as a whole. This cost is equivalent to US$ 0.52 per m3 but with high variability between Arab countries from US$ 0.02 in Algeria to US$ 0.98 in the UAE.

The growing gap between supply and demand across the Arab region and the projected impacts of climate change on the quantity and quality of available water for human settlements strongly support an urgent need to reconsider water allocation and service charges and management practices within each water using sector and on the national as well as regional levels.

Table 16: Cost of one cubic meter of water saved/produced under shown adaptation measure, World Bank, 2012

Adaptation measure	**Cost (US$/$m^3$ water)**
Improve agriculture practice	0.02
Expand reservoir capacity (small scale)	0.03
Reuse domestic and industrial wastewater	0.03
Reuse irrigation water	0.04
Expand reservoir capacity (large scale)	0.05
Reduce irrigated areas	0.10
Desalination by renewable energy	1.30
Desalination by conventional energy	1.85
Reduce domestic and industrial demand	2.00

[17] The World Bank, 2012, MENA development report: Adaptation to climate change in the Arab countries

References and further reading

1. References:

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6. UN-DESA, 2009, World Urbanization Prospects: The 2009 revision population database.
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[1]SDSM software, developed by Canadian Climate Data and Scenarios

2. Additional Readings (Suggested):

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2. The World Bank, 2012, MENA development report: Adaptation to climate change in the Arab countries

Appendix

A. Exercises and Case Studies

I. Group Exercises: Using focus groups method and flip chart reporting in training sessions:

Group Exercise # 1

Factors for adaptive capacity in human settlements: Ranking exercise for the 4 (four) Arab sub-regions

Group Exercise # 2

Selection criteria for best IWRM tools → Screening/Ranking of best Climate Change Adaptation measures

Group Exercise # 3

Water/Sanitation in Za'atari Refugee Camp in Jordan → Dealing with emergency situation!

II. Sector-based Adaptation Case studies

Case study #1. Grey Water Reuse in Oman

Oman is an arid country where the pressure on freshwater reserves is as severe as that of any other arid or semi-arid country in the world. Increasing water availability by treating and reusing wastewater, particularly for irrigation, is a government policy in Oman. Identification of alternative sources of water and development of appropriate technology to harness them in order to reduce pressure on freshwater reserves and production capacity in Oman is a priority.

Experience from overseas, and in particular from arid and semi-arid countries, indicates that greywater can be a cost-effective alternative source of water. Greywater is washing water; water coming from baths, showers, washing machines, and bathroom sinks. Some sanitary experts define greywater as water that is lower quality than potable water (drinking water), but of higher quality than black water. Studies have shown that 80% of water used in Omani households is greywater.

Greywater can be used to further sustainable development and resource conservation without compromising public health and environmental quality. Under most conditions, it would be possible to reuse greywater with minimum treatment. Water for domestic use is produced at a very high cost. Domestic wastewater (combined greywater and black water) is also treated at high cost and then used for limited irrigation. If greywater is separated from black water, likely benefits will include water savings, reduction in wastewater treatment costs, and reduction in groundwater pollution, and will have positive environmental and economic benefits.

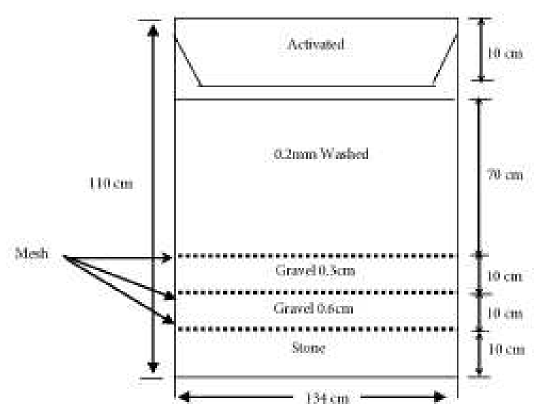
A research project was completed at Sultan Qaboos University in Oman with the objectives to quantify greywater production in urban Omani households and mosques, characterize important water quality parameters, and design simple treatment systems. Results show a high degree of variability of greywater production and its quality from individual households and mosques. Experimental data show that a simple treatment system combining aeration, sand filtration, and chlorination will be able to meet the existing Omani reuse standards.

Studies have shown that 80% of water used in Omani households is greywater.

Commercially available greywater systems are too expensive for individual households and small mosques. Therefore, a low-cost low-maintenance treatment system was designed (Figure 1), constructed, and operated at a mosque (Al Hail, See photo above).

The ablution water was sent through a sand trap (A), to allow settlement of soil particles. Since the sand trap was shallow, periodic cleaning of this trap was easy. Subsequently, the ablution water was conveyed by gravity to the ablution water storage tank (B), and the water dropped from near soil surface to the water level, aerating on its way. The ablution water storage tank has a storage capacity of 3.82 m3 per day if necessary, but it was noted that maximum ablution water produced in a day was only 1.94 m3. Therefore, the storage tank will be adequate to store more water, in the event that the number of worshippers increased in the future. A submersible pump (C) of 0.4 horsepower was installed in the ablution water storage tank, which was controlled by a float. The pump operated whenever approximately 0.68 m3 was added to the storage tank. Thus, untreated water was not held in the storage tank for prolonged periods. Water lifted by the pump was sent through an irrigation filter (D). This prevented floating matter proceeding further. Subsequently, water entered a filter unit (E), which consisted of an activated carbon tray (10 cm deep), 0.2 mm washed beach sand (70 cm deep), gravel 1/8 mm (10 cm deep), gravel ¼ mm (10 cm deep), and stones (10 cm deep) (Figure 2).

Figure 2: Design of sand and activated carbon filter (drawing not to scale)



Following filtration, the water passed through a chlorination chute (F), packed with chlorine tablets. These tablets contain 90% chlorine as Trichloroisocyanyric acid with solubility of 1.2g/100g of water at 30o C (its commercial name is NEO-CHLORO). Filtered water mixed with chlorine was then dropped into the treated water storage tank, being aerated on its passage. The treated water storage tank could store up to 3.825 m3 per day if necessary.

A commercial system was installed at Sultan Qaboos University mosque which is much larger and produces a lot more greywater. This system also performed well and produced water satisfying the existing Omani standards for reuse. A commercial system was also installed in a household in Al Hail and its performance was also excellent.

The financial analysis showed that the internal rate of return (IRR) for the locally manufactured (Al Hail mosque system) and the commercial systems (SQU mosque) for the mosques were 14.9% and 19.06%, respectively. This shows that such systems will be cost effective. IRR for the commercial system at a private house indicated that such systems will not be cost effective. Costs of the systems and the amount of greywater treated were the main factors affecting the outcome of the financial analysis.

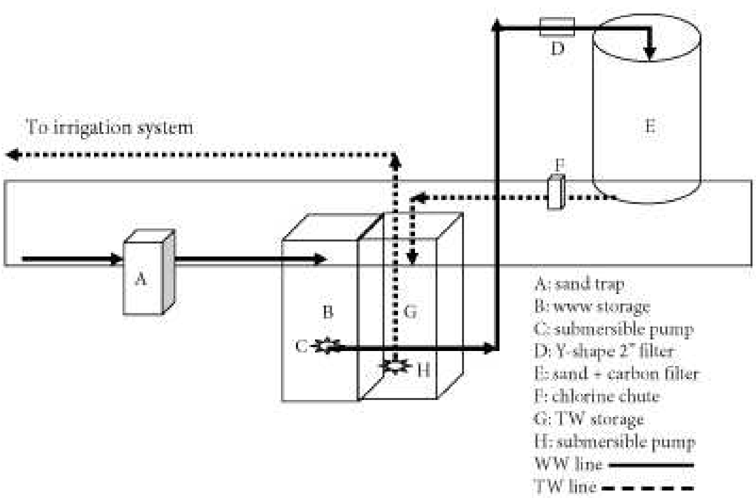
It is worth mentioning here that such systems are not restricted for treatment of greywater only. It is possible to use this system for improving the quality of low-quality surface water. A similar system was installed in the Al Jabal Al Akhdar area of Oman (see photo below). The government completed the building of 24 retention dams for storing surface water in this mountainous area. Most of these reservoirs are eutrophic because of the fecal matter of goats and donkeys that gets washed into the reservoir via surface run-off. These waters are also contaminated with unacceptable levels of coliform bacteria and some also had pathogenic *Escherichia coli*.

The treatment unit significantly improved the quality of water with regards to COD, TSS, and a few other water quality parameters. Coliform and *E. coli* were completely eliminated. Treated water met the Omani standards for reuse for irrigation. A survey among the adult male population of the village overwhelmingly showed their eagerness to adopt this system and use the treated reservoir water for uses other than agriculture. Such change in water use patterns will definitely have an impact on groundwater extraction, as household requirements for groundwater are likely to decrease.

A mosque lawn irrigated with treated greywater

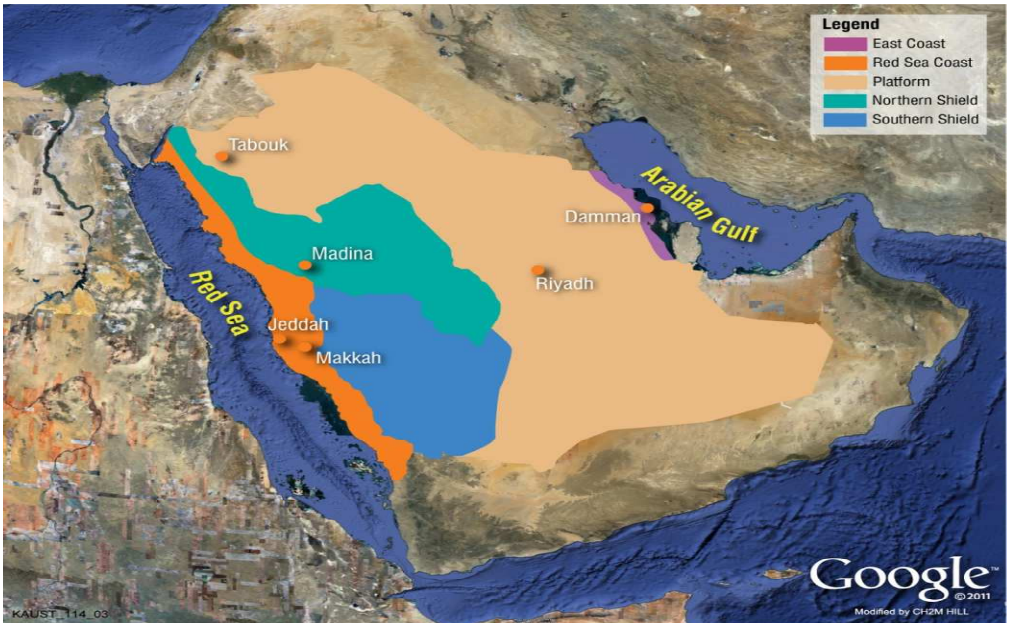
The constructed treatment system in Al Jabal Al Akhdar, Oman

Figure 1: Simple Greywater Treatment System



Study #2: Water Reuse in KSA

KSA has a number of goals for providing water, wastewater, and reuse infrastructure in cities with populations greater than 5,000 people. In general, it is planned that the coverage for water supply and sewage collection will be nearly 100 percent in these cities by the year 2025. It is also planned, in general, that all of the sewage collection systems will be connected to WWTPs by the Year 2025. With many WWTPs currently under construction, the existing sewage treatment capacity in KSA will more than double when operational. Further, it is planned that all effluents will be beneficially reused.

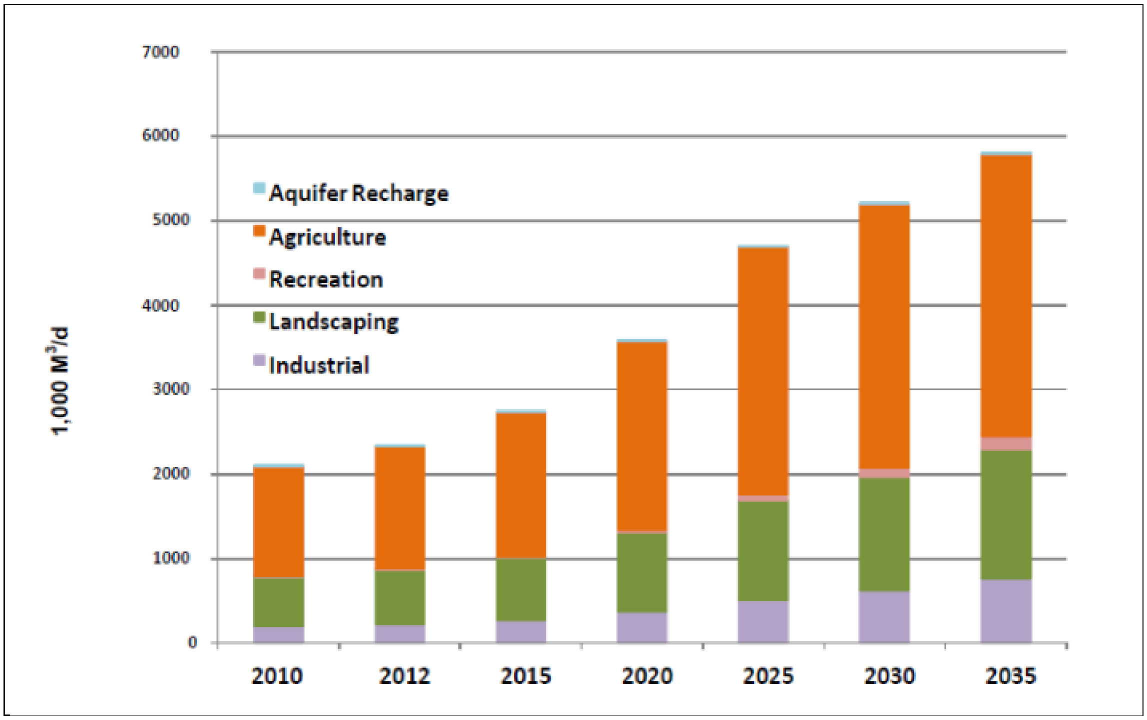


Water Province	Water Resources
East Coast	Primary source is desalinated seawater; also non-renewable groundwater resources
Red Sea Coast	Desalinated seawater and renewable water resources
Platform	Non-renewable groundwater resources only; desalinated water is supplied from the East Coast water province
Northern Shield	Renewable water resources, although rainfall is much lower than in the Southern Shield
Southern Shield	Renewable water resources due to significant rainfall amounts (up to 500 millimeters (mm)/year)

Current water supplies consist of desalinated water, which is expensive to produce, and groundwater, which is a non-renewable or slowly renewable resource. The growth in population in KSA will significantly increase both water demands and wastewater flows. The increase in coverage by water distribution systems and sanitary sewer systems will add to these increases. The significant amount of additional effluent expected to be generated provides an important opportunity for reuse to offset water demands for non-potable uses. The use of reclaimed water for cooling by industries or commercial enterprises, and possibly by public buildings, could increase due to the high expense and environmental costs of using desalinated water or groundwater for such purposes.

A large supply of effluent water that is currently discharged from WWTPs is unused. Current reuse of wastewater in the six largest cities ranges from none in Makkah to 3 percent in Dammam and to nearly 100 percent in Al Madinah. In Riyadh, wastewater reuse is approximately 66 percent and in Jeddah it is 17 percent. This resource is probably not being used for a number of reasons, including lack of distribution infrastructure, lack of public awareness and acceptance, and lack of financial incentives.

Biosolids are another renewable resource that can be recycled but which are currently being disposed of by landfilling or disposal at designated locations. There is little indication that biosolids are beneficially reused. Requirements for the use of biosolids in agriculture exist, but there appears to be generally little awareness among farmers of the benefits of using sludge in agriculture. Therefore, along with the significant infrastructure capital investment planned to meet the service goals for 2025, an investment in better informing the public of the value of these resources is needed.



The obstacles for the advancement of water reuse can be summarized as follows:

• The existing infrastructure is lacking in wastewater treatment capacity.
• Sewer systems are leaking and the overall infrastructure network lacks sufficient connectivity and advanced treatment plants to increase recycled water availability at higher quality.
• Aging WWTPs are producing recycled water of inadequate quality.
• There is no network to distribute high-quality recycled water to end users.
• Generally, the public has often been unclear about the difference between municipal wastewater, grey water, and recycled water. However, the public is aware of being adversely affected by the pollution caused by the lack of wastewater collection or when the existing municipal WWTPs dump poor quality effluent into the environment. Additionally, there is a lack of credible information about (1) the types of treatment processes available and the capability of WWTPs to produce recycled water meeting government standards and (2) the quality of recycled water that is recommended for various applications. The result is fear of using the recycled water due to beliefs that such use would result in health problems
• In order to meet the stated reuse objectives and build public trust, KSA must make prioritized investments in wastewater collection, treatment, and distribution and share relevant information about appropriate treatment processes to ensure the protection of public health.

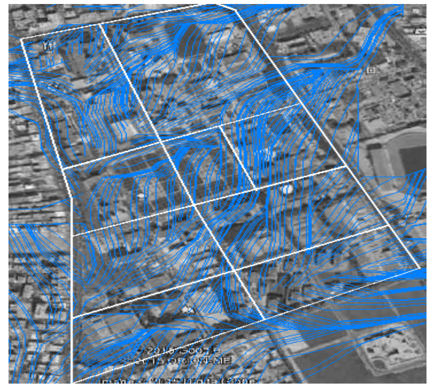
Case Study # 3: Using AutoCAD Civil-3D, SewerCAD and SSA Software to Adapt Storm and Sewer Network Design for Climate Change Impacts: Irbid, Jordan

Irbid city is located north of Jordan and it has sanitary as well as storm water drainage networks. Expected impacts of climate change include more intense rainfall events that will affect existing drainage infrastructure.

Part of the city network is analyzed to examine capacity of existing network to handle an extreme rain event, then it is re-dsigned for a hypothetical rainfall storm of higher inensity and less duration than the original design storm.

AutoCad Civil 3D software is used to simulate the water flow in the network and provide visual represenation including videos of the progression of flooding inside the pipe network and service manholes.

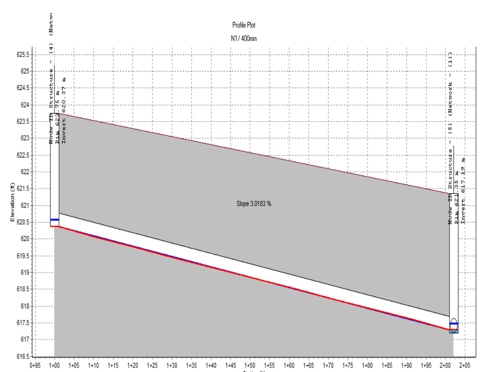
Steps used in case study



Catchment area used in case study

RICAAR scenarios used in case study

	RCP 4.5					RCP 8.5				
	Year	Minimum	Medium	Maximum	Reference	Year	Minimum	Medium	Maximum	Reference
Precipitation (mm)	2035	-15.9	-8.2	9.2	-3.0	2035	-20.4	-12.9	-0.5	-12.9
	2055	-24.2	-15.4	0.7	-15.4	2055	-26.5	-15.0	-7.0	-12.9
	2085	-22.5	-13.6	-5.7	-12.0	2085	-38.0	-21.9	-10.9	-14.8
Mean Temperature	2035	0.9	1.2	1.8	1.2	2035	1.3	1.6	2.2	1.6
	2055	1.6	1.7	2.5	1.8	2055	2.1	2.6	3.4	2.6
	2085	1.8	2.1	2.8	2.5	2085	3.8	4.0	5.1	4.0
Maximum Temperature	2035	1.0	1.1	1.8	1.1	2035	1.3	1.5	2.3	1.5
	2055	1.6	1.7	2.5	1.7	2055	2.2	2.6	3.5	2.5
	2085	1.7	2.1	2.8	2.5	2085	3.8	4.1	5.0	3.9
Minimum Temperature	2035	0.9	1.1	1.7	1.3	2035	1.2	1.6	2.1	1.7
	2055	1.5	1.7	2.4	1.8	2055	2.0	2.5	3.3	2.7
	2085	1.7	2.0	2.8	2.5	2085	3.7	4.0	5.1	4.0



Flood progression in network

Case Study # 4: NRW reduction in Jordan>> Are we doing any better?

Jordan has moved into privatization of water supply and sanitation services since 1999 when the first management contract (PPP) was enacted for the capital city of Amman. Other governorates followed such as Aqaba and Irbid where private sector companies manage these services. One main challenge that seems to persist is the real reduction of non-revenue water.

With visual aids like the figures and table below, the case study will use a guided discussion that focuses on both the physical losses in the supply system and the administrative component of the NRW as well. Effectiveness of PPP contracts in dealing with the NRW problem will be discussed and analyzed during the exercise

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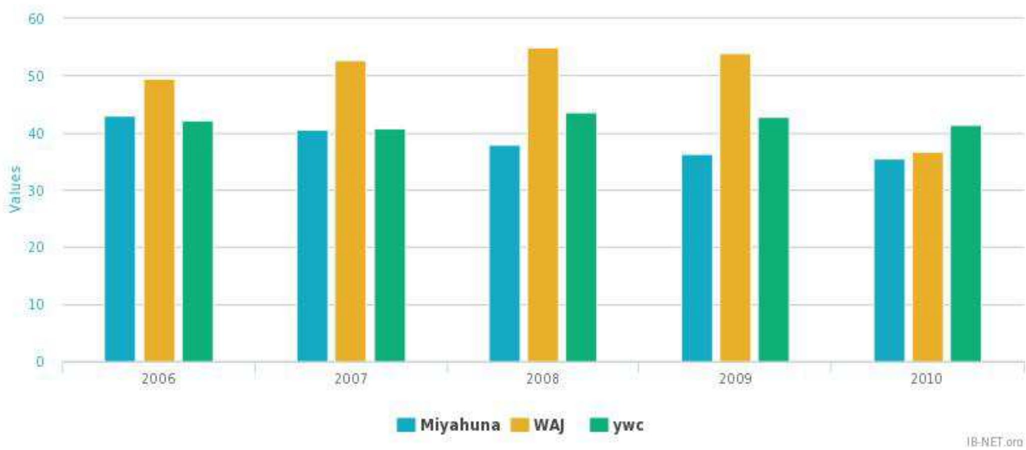
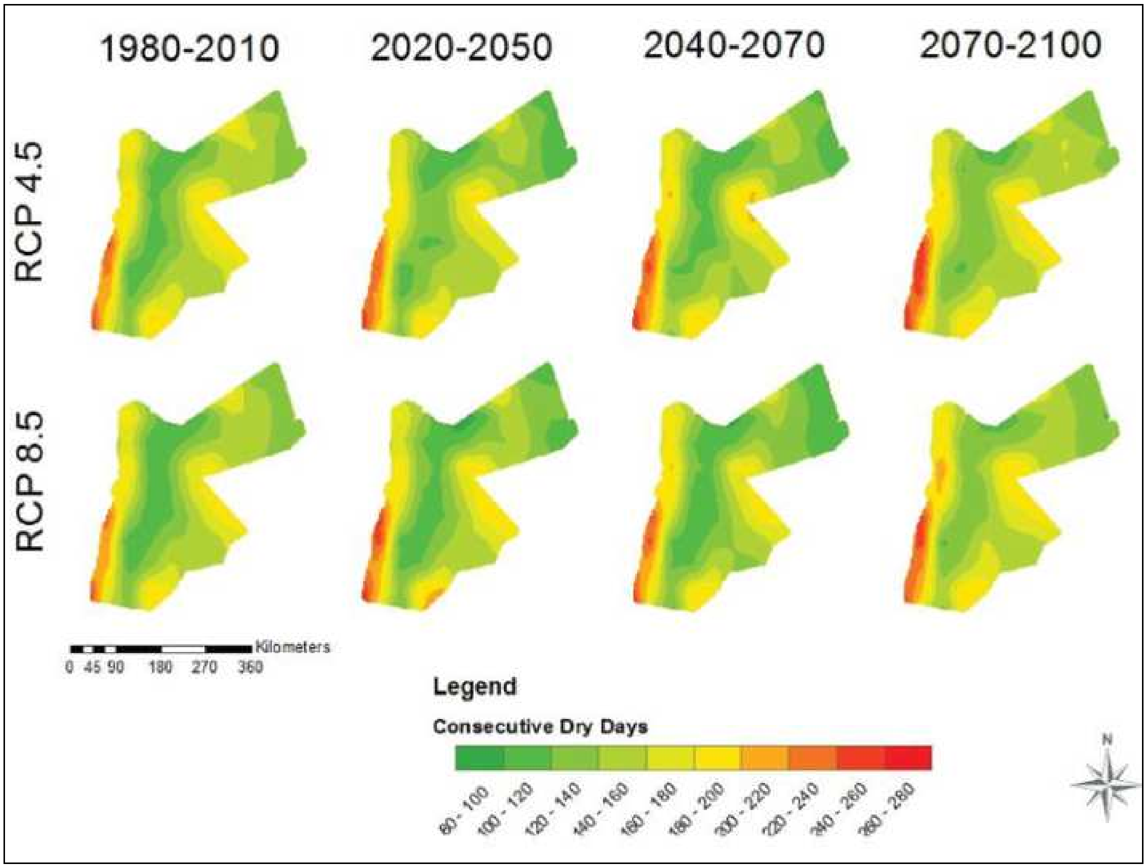


Drinking Water Supply and Non Revenue Water (2000-2013) (Million M³)

Year	NRW	Drinking Water Supply MCM
2000	52.00%	239
2001	48.65%	246
2002	48.00%	249
2003	49.39%	262
2004	46.48%	281
2005	45.48%	291
2006	43.47%	291
2007	43.34%	294
2008	43.88%	315
2009	44.00%	326
2010	42.90%	352
2011	42.00%	347
2012	47.00%	354
2013	48.00%	381



Case Study # 5: Managed aquifer recharge as an integrated water resource management approach for preventing seawater intrusion in Hazmieh, Beirut area, Lebanon (ACCWaM Pilot Project)

german cooperation
DEUTSCHE ZUSAMMENARBEIT

Implemented by:
giz

Most coastal areas in MENA countries are affected by population growth, urbanization and the impacts of climate change. Hence many coastal aquifers suffer from overexploitation, seawater intrusion and hence deteriorating water quality.

The area around **Beirut, Lebanon**, is no exception from the rule: (1) a steadily growing water demand, (2) a shrinking of the natural groundwater recharge in the watershed area and (3) an increase in surface runoff.

To explore the potential of **artificial aquifer recharge** using an appropriate IWRM approach, a Feasibility Study was commissioned by the GIZ program **ACCWaM** in 2013. (GIZ = German Agency for International Cooperation; ACCWaM = Adapting to climate change in the water sector in the MENA region). **ACSAD** is taking a share in the project. **First findings** indicate, (a) that in Lebanon presently about 740 MCM/year of water are flowing unused to the

Hazmieh, a steadily expanding

Mediterranean Sea, a good share of it enters the sea around Beirut, (b) that seawater intrusion has progressed further inland than expected, (c) that the emptying of the coastal aquifers are not only due to overextraction, but to reduced recharge in the mountainous parts of the watershed (caused by decline in precipitation, reduction of snow cover, more settlements, deforestation, etc.) as well as in urban areas (sealing of the ground by buildings, parking lots etc.), (d) that solutions to the problem have to include supply side (e.g. groundwater recharge, rainwater harvesting) and demand side measures(awareness campaigns, water metering, etc.).
The implementation of a remediation project will depend on a close cooperation of State organs, NGOs and the public; the high costs involved will ask for the involvement of an international donor.

Contact: Dr. M. Bartels (matthias.bartels@giz.de) or Dr. G. Lichtenthaeler (gerhard.lichtenthaeler@giz.de), ACCWaM-Program, Cairo
Link: http://www.accwam.com/IAP/3/Lebanon.html

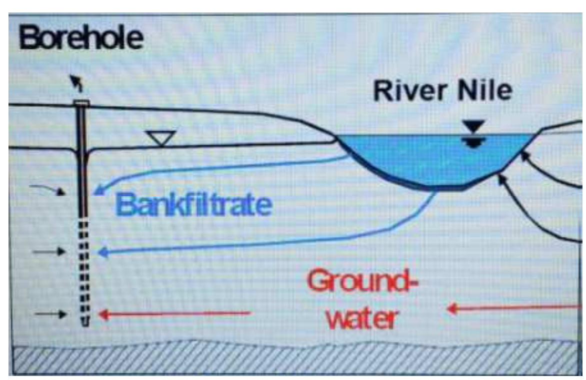
Case Study # 6: Appropriate Water Abstraction Through Bank Filtration to Improve Drinking Water Supply in Upper Egypt

Throughout the Egyptian water sector reform process, the responsibilities of governorate-owned and run enterprises have been increasingly transferred to the newly established utilities for water supply and wastewater disposal. These new enterprises have been consolidated gradually, but there are still deficits in carrying out these services economically and efficiently.

The objective of the GIZ program dealing with drinking water supply in Upper Egypt is therefore to improve water and wastewater management services in that area.

Investigations revealed that the use of riverbank filtrates was an interesting option to secure water supply to a number of cities along the river Nile, which use presently surface water for their domestic water supply. Surveys in recent years indicated a significantly higher water quality of bank filtrates when compared to water abstracted directly from the river. The utilization of bank filtrates within the GIZ program is still in its early stages, but it became evident, that concerted efforts are required to put into practice the full potential of bank filtration in Egypt and to understand the processes involved.

Contact: Mr. Ernst Doering, Programme Coordinator, Water Supply and Wastewater Management Programme (WWMP), GIZ, Cairo, Egypt;: ernst.doering@giz.de; www.giz.de



Source: HTW Dresden, Germany

B. Training evaluation form (To be prepared later)

Key challenges in Arab HS that are relevant to CC

- Water Resource Challenge
- The Institutional challenge
- The awareness gap
- High UFW/NRW in most Arab cities
- Low rate of rainfall water harvesting at the HH level
- Low rate of rainfall water harvesting at the basin level
- City landscape irrigation by reclaimed water
- Two water pipe networks one for drinking and one for landscape
  Success story: City of Abu Dhabi
- Urbanization: planned vs unplanned
  Success example from Kuwait vs Amman
- Solar Energy-driven Desalination water supply
- Virtual water and water footprints
- Cold spell: Freezing pipes
- Hot spell
- Sand storms especially in GCC cities
- Moving sand dunes especially in GCC cities

C. Suggested Key Messages:

- The outcome of Successful adaptation is resilience

- The lack of adaptive capacity to deal with problems caused by climate variability and climate change is … related to the scale of … the adaptation deficit

- Where local governments are weak or ineffective, household and community strategies become more important for reducing climate
  change risks and impacts in urban areas

- Supporting local responses should be one aspect of an overall adaptation strategy for urban areas
- In practice, the development of infrastructure which reduces climate change impacts is often beyond the capabilities of even the best organized and most representative community organizations
- Community-based adaptation and pro-poor adaptation are intrinsically linked