Water sector background paper

Project Title: Building resilience to cope with Climate Change in Jordan – Green Climate Fund Project Proposal for Jordan TCP/JOR/3703/C2

16.03.2020

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Summary

The purpose of this report is to provide basic information that may be needed to develop the full proposal of the project entitled "Building resilience to cope with climate change in Jordan through improving water use efficiency in the agriculture sector (BRCCJ)". The aim of this project is to support the objectives of the climate change policy (2013-2020) by building the adaptive capacity of communities and institutions in Jordan, addressing the needs of vulnerable groups, increase the resilience of water management systems as well as agricultural resources to climate change. The project is also aligned with the country's Green Growth Plan (2017) which stresses the importance of building rural resilience by diversifying incomes, ensuring resource availability and reducing environmental impacts.

The project will be implemented in selected Governorates in part of the Dead Sea Basin which includes areas most vulnerable to climate change. The four Governorates where the project will be implemented include Madaba, Karak, Tafilah and Ma'an. The project location was chosen based on a process of consultation and guided by the climate change challenges and related vulnerabilities; the presence of a significant number of poverty pockets, potential for site-specific CCA interventions and complementarity with other projects (e.g. Adaptation Fund in the Jordan River Valley). These Governorates have 152,000 households with a total population of 840,900 and cover an area of 9,839 km^2 which forms 72% of the Dead Sea Basin Area.

This report provides necessary background information related to activities under component 1: Climate Resilient Water Systems. Investing in climate resilient *infrastructure in vulnerable locality to climate change and capacity of local level and community- based water management institutions* will enable households to deal with one of the major risks that emanates from climate change which is reduced access to water. The main outputs under this component include introducing infrastructure to redistribute freshwater over space and time, among these are: i) rooftop water harvesting structures for residential (4000 households) and public buildings (5% of existing schools and worship) and ii) enhancing wastewater treatment reuse systems at four WWTPs (Madaba, Karak, Tafilah and Wadi Mousa). Also, the project will strengthen capacity of local MWI staff and public utilities for improved water governance.

Also this report summarizes the potential sites for the GCF project activities under component 1. Identification of priority areas for mitigation and adaptation is an essential step in preparing a GCF projects. Also, identification of opportunities for interventions in the priority areas is very important at this stage of project preparation. This report has three main parts, the first part focuses on the description of the project area, second part describes the rooftop water harvesting from both residential and public buildings, the third part describes the potential enhancement in wastewater reuse in the project area.

PART I: Context and problem description

1. Baseline assessment: water endowment

1.1. Overview

Water scarcity in Jordan is absolutely a major and critical challenge that continues to jeopardize all aspects of development with limited conventional water resources, increasing demand due to high population growth, hosting several fluxes of refugees, economic development needs, increasing drought events, climate change, geography and the regional geopolitical environment. Currently, the annual precipitation is decreasing at a rate of 1.2 mm per year, while average temperatures are increasing by at least 0.03° degrees per year (WANA, 2016). Jordanian communities have witnessed shift sin rainy seasons as well as destabilization of weather conditions. Sudden and extreme weather events are more common, this likely means longer and drier summers, more severe droughts, harsher winters and an increase in flash flooding and frosts (WANA, 2016).

Consecutive droughts with different severity levels have been witnessed over Jordan which was never announced during the past decade. In the history of modern Jordan, the only time that a state of drought was announced nationwide was in 1998 and 1999 when the country suffered an extreme drought (with a 30% of the annual average rainfall) for two consecutive water years until 2000 (Khordagui 2014; Shatanawi 2013). Moreover, flash flood disasters associated with intermittent heavy rainstorms have become common in drylands and urbanized areas of Jordan where an exceptional high intense rainfall onto dry, steep hillsides and mountains in a short time. This high flow flooded water erodes, transports and deposits large amounts of sediments, ranging in size from microscopic silt particles to enormous rocks. That would lead to an inestimable threat to life and destruction of infrastructure (Farhan, 2016).

1.2. Climate and hydrology baseline

1.2.1. Rainfall statistics

The climate of Dead Sea Basin varies between the Mediterranean in the western and northern basin area and the semi-arid in the eastern and southern basin area. The semi-arid climate is described by dry, hot and dusty summers and cold winters with less than 50 mm per year and the Mediterranean climate is characterized by dry hot summers and rainy-mild winters. The low relative humidity is to be expected with high evaporation rates during the summer months. In the spring and autumn months, the basin is exposed to different dust storms mainly in the southern and eastern areas of the basin. Rain starts in October and lasts until May, but most precipitation falls in January.

Due to the variable topographic features of Jordan, the distribution of rainfall varies considerably with location. Rainfall amounts vary from 192 mm in the Dead Sea Side Wadis basin to less than 131 mm in the Mujib basin. The long term average of rainfall which falls on the Dead Sea Basin is approximately 1911MCM/year. Approximately 92.5% of the rainfall evaporates back to the atmosphere, the rest flows in rivers and wadis as flood flows and recharges groundwater. Groundwater recharge amounts to approximately 5.5% of the total rainfall volume, surface water amounts to approximately 2.% of total rainfall volume (MWI, 2018).

Five rainfall stations were selected to represent the rainfall variation in the project area (Table 4). The daily data for these stations was obtained from the Ministry of Water and Irrigation for the period 1938-2013 for stations except for Shaubak station where the records from year 1963 to year 2013. Monthly and annual rainfall analysis is required for estimating the potential water harvesting from rooftop in the project area. The Madaba, Karak and Tafilah rainfall stations were selected to represent Madaba, Karak and Tafilah governorates, respectively. In the case of Ma'an governorate, two stations were selected to represent potential sites for rooftop water harvesting. These are Shaubak and Wadi Mousa rainfall stations. The monthly mean of Shaubak and Wadi Mousa stations was used to estimate the mean monthly rainfall of Ma'an governorate. Table 1 and Figure 1 show the mean monthly rainfall for these stations. The mean annual rainfall of these stations ranges from 215.9 mm (Ma'an) to 342.6 mm (Karak). Madaba has mean annual rainfall of about 324 mm while for Tafilah was 255.7. These values will be used later in the potential harvested water from rooftop in the project area.

Table 1: Average monthly and annual rainfall (mm) in project area

Month	Madaba	Karak	Tafilah	Wadi Mousa	Shaubak	Ma'an
Januray	75.0	86.5	65.6	44.5	71.6	58.1
Feburary	76.5	73.1	58.9	39.7	57.3	48.5
March	55.8	70.5	50.4	34.1	49.5	41.8
April	21.7	24.3	22.5	18.0	23.4	20.7
May	11.3	8.6	16.1	14.4	10.7	12.5
October	9.1	11.1	8.9	7.6	8.4	8.0
November	39.2	36.9	26.3	17.1	23.3	20.2
December	64.5	71.4	51.9	34.4	53.8	44.1
Annual	324.3	342.6	255.7	166.0	265.7	215.9

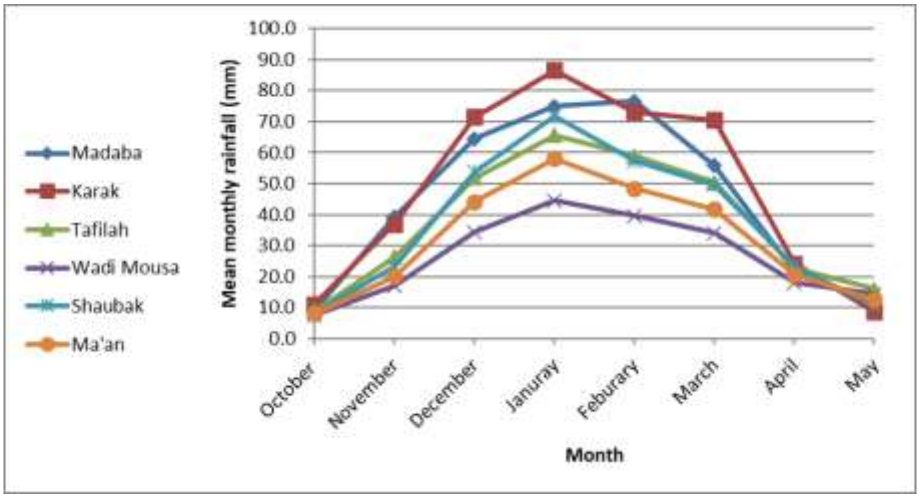


Figure 1: Mean monthly rainfall in project area

1.2.2. Trends in rainfall and temperature

An essential step in climate change impact studies is the analysis of trends in available climatological data records for the selected stations. The trend analysis results for precipitation and temperature that has been conducted by ICARDA for the period 1901-2010 show that annual precipitation has been declining for a long time and that this trend is significant across Jordan. It has been noticed that there is an increase in the maximum annual temperature from 0.3 to 1.8°C and increase in the minimum annual temperature from 0.4 to 2.8°C in all regions. Also, increases in the average number of heat waves and the average number of consecutive dry days are witnessed across the country, specifically in the desert. However, annual rainfall drops 5-20% across the country (ICARDA, 2015).

The period of temperature data that has been used for hydrological modeling for the selected weather station after filling the missing data starts from January 1986 to December 2014, in technical terms, the measurements were carried out at daily time interval. Trend analyses for mean annual minimum and maximum temperatures were conducted for Rabbah Station during the period from 1986 to2014 as shown in Figure 2 and Figure 3. There is a significant increase in the mean annual maximum temperatures of 0.14 0C per year. Moreover, there is also a significant increase in the mean annual minimum temperatures of 0.06 0C per year.

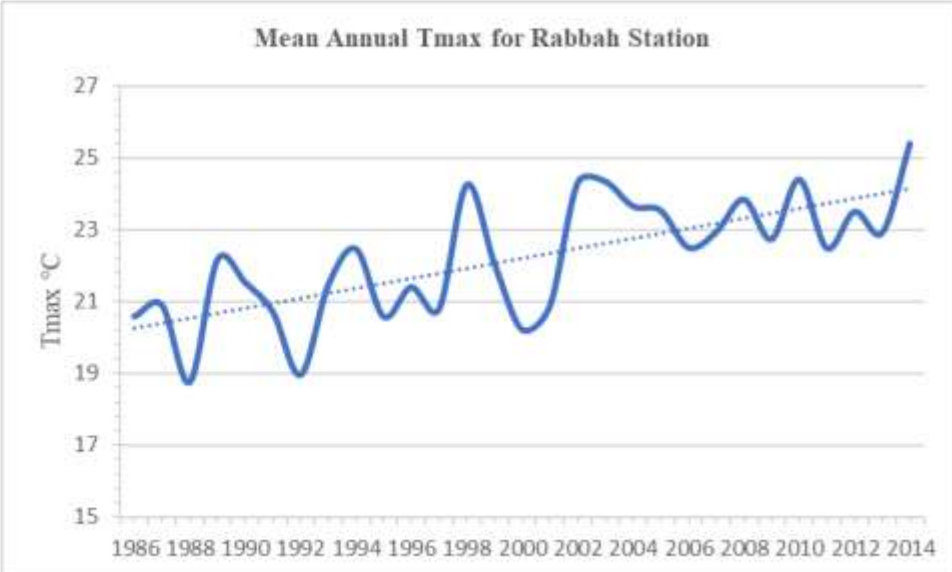


Figure 2: Mean annual maximum temperature for Rabbah Station

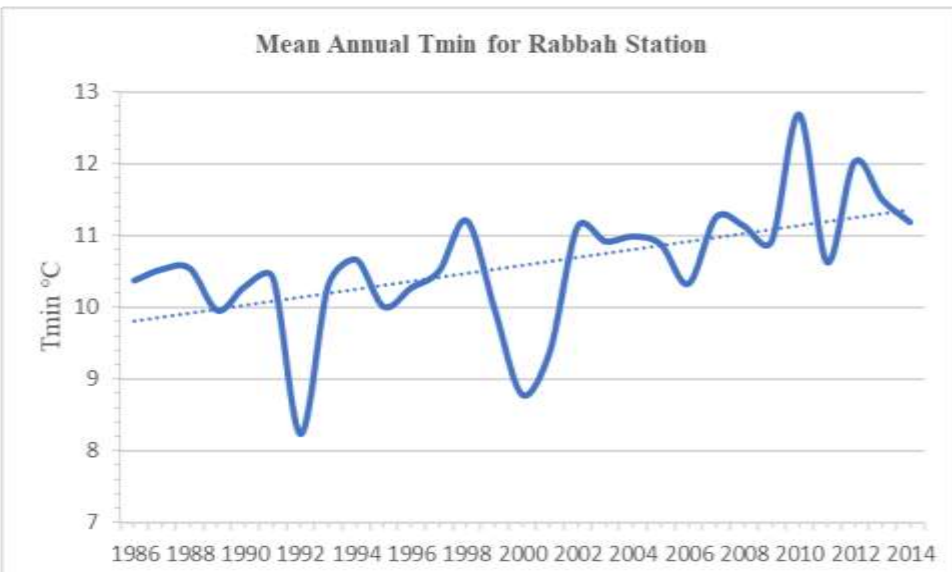


Figure 3: Mean annual minimum temperature for Rabbah Station

The precipitation time series are analyzed for linear trend on annual basis. Figure 4 shows the time series for the annual precipitation for Rabbah station. There is a very slight decreasing trend in the annual precipitation as proposed by the negative slope (-1.43) of the regression line.

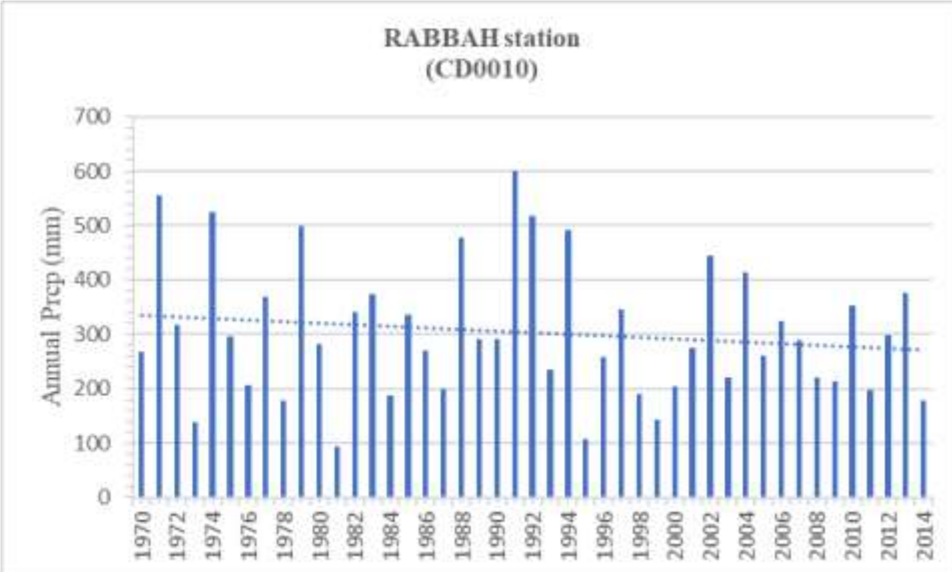


Figure 4:Time series for the annual precipitation for Rabbah station

1.2.3. Surface water availability

Table 5 shows the surface water in the project area. The average annual rainfall is ranging from 131 mm in Mujib basin to 192 mm in the Dead Sea side Wadis. The runoff coefficient is low in the project area and it is ranging between 0.7% in north Wadi Arba Basin to about 4.0% in Mujib basin. The long-term annual volume of water in the Dead Sea Basin is about 1911 MCM. The Mujib basin alone contributes to about 46% of the total volume of rainfall in the Dead Sea Basin.

Table 2 shows the long-term surface water potential in the project area by basin. The total streamflow in the project area is about 147 MCM of which 67% is baseflow and the remaining is flood water.

Table 3 shows the bong-term surface water flow by governorate; Karak governorate has the highest total surface runoff which is about 73.44 MCM, while it is the lowest in Tafilah governorate (7.31 MCM). The total surface runoff in Madaba governorate is about 65 MCM.

Table 2: surface water in project area.

Basin	Catchment area (km^2)	Average Annual Rainfall (mm)	Estimated runoff coefficient (%)	Long-term (1937-1998) Rainfall average (MCM/yr)
Mujib	6727	131	4.0	884
Hasa	2603	128	2.8	334
Dead Sea side Wadis	1508	192	2.5	290
North Wadi Araba	2953	136	0.7	403
				1911

Table 3: Long-term surface water potential in project area (National Master Plan)

Basin	Catchment area (km2)	Average rainfall (MCM/yr)	Baseflow (mCM/yr)	Flood flow (MCM/yr)	Total flow (MCM/yr)
Mujib and Wala	6727	884.0	31.38	33.62	65.0
Hasa	2603	334.0	26.26	5.47	31.73
Dead Sea (southern wadis)	1508	290.0	33.63	6.08	39.71
North Wadi Araba	2593	403.0	8.58	2.55	11.13
Total		1911	99.85	47.72	147.57

Table 4: Long-term surface water flow by governorate

Governorate	River or Wadis	Baseflow (MCM/yr)	Flood flow (MCM/yr)	Total flow (MCM/yr)
Madaba	Wadi wala+wadiMujib	31.38	33.62	**65.0**
Karak	Wadi karak	5.89	1.29	7.18
	Wadi Ibn Hammad&others	10.5	1.84	12.34
	Wadi Hasa	26.26	5.47	31.73
	Wadi khuneizeh	1.43	0.59	2.0
	Wadi Zarqa Ma'in	17.24	2.95	20.19
	Total	61.32	12.12	**73.44**
Ma'an	Wadi Jurdah	0.0	0.22	0.22
	Wadi Fidan	1.64	0.18	1.82
	Qa'aDisi +south Desert	0.0	1.18	1.18
	Jafer	0.0	8.0	8.0
	Sirhan	0.0	7.49	7.49
	Total	1.64	17.07	**18.71**
Tafielah	Wadi Dahel	0.0	0.22	0.22
	Wadi Feifa	3.91	0.39	4.31
	Wadi Mousa	0.0	0.17	0.17
	Wadi Buweirdh	0.8	0.22	1.02
	Wadi Hawwar	0.0	0.28	0.28
	Restricted area	0.8	0.52	1.32
	Total	5.51	1.80	**7.31**

To illustrate the component of the hydrological water budget in the project area, the water balance for year 2017/2018 was considered (MWI, 2018). As can be seen in Table 5, about 92.6% of rainfall is evaporated back to the atmosphere. Groundwater recharge was about 107 MCM (5.5%) while the total runoff is about 40.4 MCM (2%).

Table 5: Water balance for Dead Sea sub-basins for year 2017/2018.

Basin	Area (km2)	rainfall (MCM)	Rainfall (mm)	Evaporation (MCM)	Runoff (MCM)	Recharge (MCM)	% of Evaporation	Runoff Coefficient (%)	% Recharge
Mujib	6608	869.2	132.0	793.1	21.5	54.6	91.3	2.5	6.3
Hasa	2530	332.0	131.2	308.6	3.5	19.9	93.0	1.1	6.0
North Wadi Araba	3011	404.1	138.0	384.3	4.4	15.4	95.1	1.1	3.8
Dead Sea	1692	372.5	240.5	344.4	11.0	17.1	92.5	3.0	4.6
Total/ (average)	13841	1977.8	(146.4)	(1830.4)	40.4	107	(92.58)	(2)	(5.5)

1.2.4. Groundwater resources

Groundwater is being withdrawn at approximately double the natural recharge rates.

Table 6: Groundwater basins, Safe Yield, Abstraction Volumes in 2017 and Deficits

Groundwater Basin	Safe Yield (MCM)	Abstraction (MCM)	Deficit (MCM)
Disi	125	141.58	(16.58)
Amman-Zarqa	87.5	164.98	(77.48)
Yarmouk	40	54.53	(14.53)
Jordan Side Valley	15	45.64	(30.64)
Azraq	24	69.66	(45.66)
Jafer	27	35.53	(8.53)
Jordan Valley	21	27.04	(6.04)
Dead Sea	57	83.85	(26.85)
Araba South	5.5	10.9	(5.40)
Hammad	8	1.59	6.41
Sirhan	5	0	5.00
Araba North	3.5	6.56	(3.06)

Source: Ministry of Water and Irrigation, Jordan Water Sector Facts & Figures -2017

1.2.5. Dams

Dams the best way to store water for usage in municipal and agriculture usage in country such Jordan suffers from water scarcity. In Jordan there are 14 dams among these are 6 in the project area. Table 7lists the dams that are existed in the project area.

Table 7: Dams in the study area.

Dam name	Storage at the end of year (MCM)	Water inflow (MCM)	Water Outflow (MCM)	Dam storage (MCM)
Wala	6.73	13.51	9.21	8.2
Mujib	15.57	32.93	22.75	16.8
Tunner	1.39	8.2	6.81	16.8
Karak	0.086	0.998	0.927	2.0
Zarqa Maein	0.448	2.01	1.565	2.0
Al-Lajoun	0.088	1.49	1.40	1.00

1.2.6. Water supply baseline

Overall picture

Jordan's conventional, or natural, water resources originate in rainfall, ground waters, and surface waters. The country has developed various ways in which to capture, store and distribute these waters, and it has developed some unconventional water resources such as treated wastewater, as well as the utilization of the dam surface water.

Table 8: Water Supply Sources in Jordan in MCM- 2014

Source	Municipal	Industrial	Irrigation	Livestock	Total
Surface Water	**103.8**	**4.8**	**143**	**7**	**258.6**
Jordan Rift Valley	91.4	4.8	83	0	179.4
Springs	12.5	0	20	0	32.5
Base and flood	0	0	40	7	47
Groundwater	**325**	**32.2**	**231.2**	**0.1**	**588.5**
Renewable	207.2	19.3	189.4	0.1	419.2
Non renewable	107.2	12.9	41.8	0	162.1
Abo Zeighan	10.2	0	0	0	10.2
Treated waste water	**0**	**2**	**123.3**	**0**	**125**
Total	**429**	**39**	**497.5**	**7.1**	**972**
Total including additional 225 MCM used for irrigation which were estimated using					**1197**

remote sensing techniques	

Source: Ministry of Water and Irrigation, Water Reallocation Policy, 2016

Reuse of reclaimed water

Due to the overall water shortage in Jordan, the use of renewable unconventional water sources has become increasingly in focus. One of the sources is reclaimed wastewater. The amount of reclaimed wastewater in 2017 was around 165 million cubic meters, from which 90% are reused directly (direct agreements with farmers) or indirectly (mixing with rainwater and surface water in dams). The collected wastewater is clarified in 34 public wastewater treatment plants. In order to obtain optimal and quick treatment of wastewater, in most of the WWTP the mechanical treatment system is used (28 out of 34). (Source: Ministry of Water and Irrigation, Jordan Water Sector Facts & Figures -2017)

Table 9. Development of Influent, Effluent and Operation Capacity for WWT plants in Jordan. Source: Ministry of Water and Irrigation, Water Year Book- Hydrological Year 2016-2017

WWTP	**2015/2016 Influent (m^3/day)**	**2015/2016 Effluent (m^3/day)**	**2015/2016 Operation Ratio %**	**2016/2017 Influent (m^3/day)**	**2016/2017 Effluent (m^3/day)**	**2016/2017 Operation Ratio %**
Tal Mantah	**363.2**	**355.8**	**90.80**	**383**	**377**	**95.8**
Jiza	**773**	**700**	**17.18**	**895**	**868**	**19.9**
Shobak	**95**	**85.5**	**27.14**	**153**	**-**	**-**
Samra	**294862**	**269802**	**81.01**	**344549**	**316832**	**95.7**
South Amman	**5000**	**4500**	**9.62**	**16219**	**15732**	**31.2**
Wadi Shallala	**5912**	**5655.5**	**43.15**	**8421**	**8015**	**61.5**
Mutah-Mazar-Adnaniyyah	**1203**	**1164.4**	**15.83**	**1369**	**1059**	**18**
North Shouna	**777**	**660.7**	**64.75**	**655**	**635**	**54.6**
Za'atari camp	**840**	**780**	**47.73**	**1468**	**-**	**-**
TOTAL	**418 000**	**382 000**	**62.6%**	**482 177**	**449 339**	**64.64%**

The following table gives an overview on applied technologies of existing and planned wastewater treatment plants in Jordan

Treatment Plant	Mechanical Treatment	Treatment Ponds	Biological Treatment	Filtration/ flocculation/ membrane	Disinfection (chlorine, ozone, UV)
As-Samra	Grid		Activated sludge		Chlorine
Aqaba		Stabilization ponds			
Aqaba – MECHANICAL TP					
Salt	Grid		Extended aeration		Chlorine
Jerash	Grid		Extended aeration		
Mafraq			Stabilization ponds		
Baqa'a			Trickling filter		
Karak			Trickling filter		
Abu-Nusir			Activated sludge		
Tafila			Trickling filter		
Ramtha		Stabilization ponds			
Ma'an		Stabilization ponds			
Madaba		Stabilization ponds			
Kufranja			Trickling filter		
Wadi Al Seer		Aerated lagoon			
Fuheis	Grid, Sedimentation		Activated sludge		Chlorine
Wadi Arab			Activated sludge		
Wadi Hassan			Activated sludge		
Wadi Musa			Activated sludge		
Irbid			Activated sludge and trickling filter		
Tel Al-Manteh	Grid, Sedimentation		Activated sludge, trickling filter, polishing ponds		UV

Future Wastewater Treatment Plants (2016-2025) Source: National Water Strategy of Jordan, 2016 – 2025 Ministry of Water and Irrigation | Hashemite Kingdom of Jordan

Project Name	Year	Wastewater Generated	Location
Expansion of Fuhais and Mahes WWTP	2022 - 2025	0.4	Balqa
Expansion of As Salt WWTP: Phase 2	2022 - 2025	0.8	Balqa
Expansion of Ain Al Basha WWTP: Phase 2	2022 - 2025	1.8	Balqa
Expansion of East Jarash WWTP: Phase 1	2016-2017	1.6	Jarash
Expansion of Madaba WWTP & Establishment of Wastewater Network: Phase 1	2017-2020	0.4	Madaba
Expansion of Wadi Al Arab WWTP: Phase 1	2017-2020	1.6	Irbid
Expansion of Central Irbid WWTP: Phase 2	2022 - 2025	0.7	Irbid
Expansion of Ramtha WWTP: Phase 2	2019-2022	2.05	Irbid
Expansion of Wadi Hassan WWTP: Phase 2	2019-2022	1.9	Irbid
Expansion of Wadi Mousa WWTP	2022 - 2025	0.58	Ma'an
Expansion of Aqaba WWTP 2020	2017-2020	5.17	Aqaba
Expansion of Ramtha WWTP Phase I	2019-2020	2	Irbid
Expansion of Kharbit As Samra, Phase II	**2013-2016**	**35**	**Zarqa**
Contribution in the Expansion of Kharbit As Samra for Handling Extra Amount of WW, Phase III	**2020 - 2024**	**35**	**Zarqa**
Jordan Valley Wastewater Project	2017-2019	5	JV
Total		**94**	

The table in Annex II shows details pertaining to the direct use of treated wastewater for irrigation at or near each WWTP. The overall amount of treated effluent produced by WWTPs in the year 2012 was 118

MCM and the overall area irrigated with treated effluent at the WWTPs was 14266 Donum that same year (WAJ, 2012), which represents around 6% of the total land irrigated either directly or indirectly with treated wastewater. Table also shows the number of agreements between farmers and the water authority of Jordan. These agreements specify the conditions according to which treated wastewater is directly used for irrigation near WWTPs.

According to agreements signed with farmers and other official entities, WAJ provides treated water either inside the plant premises or in the vicinities of the plants. The agreements guarantee provision of water in the rate 3m3 a day for each dunum. The total cultivated area is estimated with 14934 dunum. Theoretically, according to the signed agreements, the total amount of water supplied to farmers should not exceed 16.02 MCM per year. In addition to the total quantities of water used in agriculture, around 1.83 MCM per year is currently used by Phosphate Mines Co. for cooling purposes. This amount is coming from Aqaba Plant.

Treated water consumption in premises and vicinities of WWTP

No.	WWTP	Total cultivated areas irrigated with treated water(dunum)	Actual consumption of treated water (MCM/ Year)
1	Assamra	5103	20
2	Aqaba	2080	4.20
3	Ramtha	1206	1.18
4	Mafraq	387	0.60
5	Madaba	862	1.57
6	Ma'an	205	0.22
7	Kufranja	571	0.63
8	Salt	48	0.05
9	Baq'a	447	0.49
10	Karak	589	0.64
11	Tafila	114	0.12
12	Wadi Al-Seer	62	0.07
13	Wadi Hassan	721	0.27
14	Wadi Musa	1069	0.71
15	Al-Akader	994	1.16
Total		**14758 (Dunum)**	**31.91 (MCM/ Year)**

Source: WAJ, 2009.

According to Jordanian laws, reclaimed water is only used for irrigation of non-edible crops such as forage crops and nurseries and trees. Farmers in the Middle and South Jordan Valley receive reclaimed water from the King Talal Reservoir where it was diluted with rain water. The long wadi and the reservoir between the WTTP and the point of use also minimize the contamination of the water. The main concern of the farmers however is the higher salt content of reclaimed water. This problem needs to be addressed at the source of effluents (for As-Samra treatment plant, main polluters are industries and desalination plants)

Farmers mainly use mulch (plastic cover on soil) and drip irrigation in order to avoid excessive evaporation. This practice positively influences microbiological quality of the crops as well. The use of mulch and drip irrigation is considered as very effective barriers for a microbiological contamination.

The irrigation system in Wadi Musa uses pure reclaimed water directly form the WWPT and also applies drip irrigation. In this area, it is only allowed to cultivate forage crops.

No.	WWTP	Crop pattern
1	As-Samra	Forage crops, olive trees
2	Aqaba	Date palm, fruit trees, forage crops, steppe trees.
3	Ramtha	Forage crops
4	Mafraq	Forage crops
5	Madaba	Forage crops
6	Ma'an	Forage crops
7	Kufranja	Forage crops, olive trees, steppe trees
8	Salt	Fruit trees
9	Baq'a	Nurseries, fruit trees, forage crops, olive trees
10	Karak	Forage crops, olive trees, steppe trees
11	Tafila	Forage crops
12	Wadi Al-Seer	Olive trees
13	Wadi Hassan	Fruit trees
14	Wadi Musa	Forage crops, fruit trees
15	Al-Akedar	Forage crops, olive trees

Source: WAJ, 2009.

1.2.7. Water supply and sanitation services

Over the past years, Jordan has achieved high levels of water and sanitation service where 95% of the populations have access to safe drinking water on intermittent basis; and about 63%1 are connected to the public sewer system which collects, transfer and treat the wastewater loads. Current level of service delivered to the population is about 126 liters/capita/day (including 55 liters/capita/day of non-revenue water).(Ministry of Water and Irrigation, the National Water Strategy 2016 – 2025).

On the other hand, coverage of sanitation services is lower than the coverage of water while the wastewater treatment quality needing significant improvement as some wastewater treatment plants are either overloaded or are employing inefficient technologies. The wastewater generated is treated through 33 wastewater treatment plants and is being reused only to irrigate fodder and industrial crops.

Whereas only 63% of the population is connected to public sewer systems, the proportion with safe sanitation exceeds 93%, with one third (1/3) of the population using septic tanks and cesspits. Assuming that infiltration from these is 70%, nearly 50 MCM/year are lost in the ground and threaten the quality of subsurface water. A National Strategic Wastewater Master Plan was prepared in 2014 outlining the status of wastewater treatment in the country and prioritizing needed investments over the coming 20 years. The master plan shows that the investment priorities for MWI will be to increase the sanitation services to cover more than 86% of the population of Jordan by 2035. This will be through focusing future investments in rehabilitation and expansion of current wastewater systems and servicing new localities with population of more than 5000.

For water and sanitation services, the challenge is to sustain the quality services provided to different use at the lowest practicable cost consistent with sustainable operation. This can be achieved through securing additional water supplies to reduce the gap between supply and the increasing demand. This has to be done in parallel with increasing systems' operational efficiency. As for the sanitation services, focus shall be allocated to providing treatment facilities for as much of the wastewater produced in the country as practically possible while maintaining safe hygiene through decentralized systems in households without sewer connections.

2. Baseline assessment: water demand

2.1. Population baseline

The project area is focused on part of the Dead Sea Basin (Figure 1) which compromise four governorates: Karak, Ma'an, Madaba and Tafilah.. Figure 1 shows the location of the four basins over-laid by the districts from different governorates. There are 25 districts are located in the Dead Sea Basin. In 2018, the population of Jordan was approximately 10.3 million. The settlement pattern is heavily influenced by water availability. Jordan is divided into three regions (north, middle, and south). Each region consists of 4 governorates. About 63.5% of the total population lives in the middle region (Amman, Zarqa, Madaba, Balqa governorates), 28.6 % lives in the northern region (Irbid, Mafraq, Jarash, and Ajlun), 7.9% lives in the southern region (Ma'an, Karak,Tafielah, and Aqaba) (DOS, 2018). About 8% of Jordanian population lives in the project area with a total population approximately 824,000 people. More information about population is provided in Annex I.

The project area includes only four governorates (Madaba, Karak, Tafilah and Ma'an), the precent of population of each governorate is shown in Table 1. About 92.6% of Karak governorate lives in the project area. Only 18.2% of Ma'an governorate lives in the project, while 97% and 82% of Tafilah and Madaba governorates live in the project area, respectively. The study area has a population of 630,365 people and has an area of 9839 km2 (Table 1). The population is estimated using Geographic Information System (GIS) tool by overly the district area on the Dead Sea Basin Map. Then the percentage of area of the district located in the DSB was used to estimate the population of the district lives in Basin.

- 92.6% of Karak population lives in the study area,
- 18.2% ofMa'an population lives in the study area
- 82% of Madaba population lives in the study area
- 97% of Tafilah population lives in the study area

	Pop live in Basin	Total pop of the Governorate	% of Gov. population lives in the Dead Sea Basin
Karak	323971	350000	92.6
Ma'an	31953	175200	18.2
Madaba	171493	209200	82.0
Tafilah	103277	106500	97.0
Total	630365		

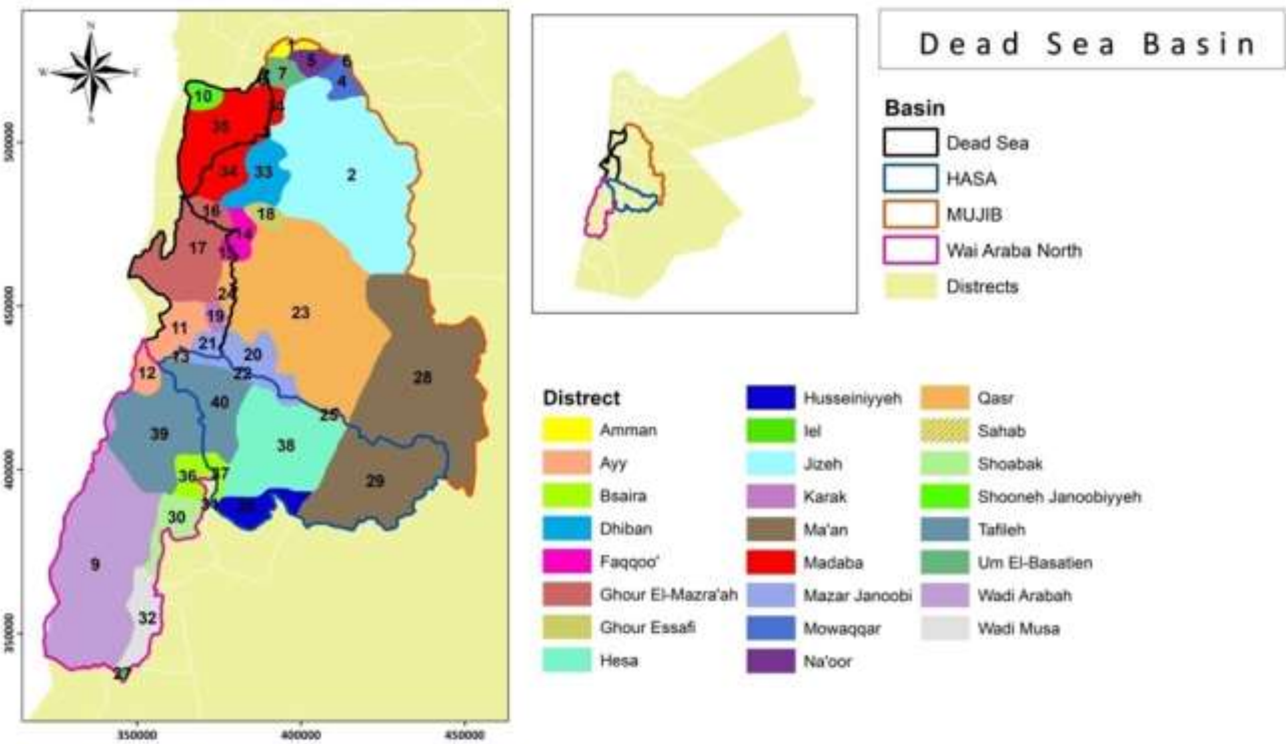


Figure 1: Districts in Dead Sea basin. Source: Author.

There are 17 districts located in the project area with their population (Table 3). All districts of Karak (7 districts) are located in the project, while 5 districts from Ma'an governorate and 3 from tafilahaand two from Madaba.

Table 3: districts located in the project area and their population

Part Number	Governorate	District	total district area sq km	Basin Name	Total population
11	Karak	Ayy	414.6	D.S.R.S.W, N. W. A, HASA	9010
14	Karak	Faqqoo'	122.584	MUJIB, D.S.R.S.W	18580
16	Karak	Ghour El-Mazra'ah	790.216	MUJIB, D.S.R.S.W	23610
18	Karak	GhourEssafi	72.2005	MUJIB	30181
19	Karak	Karak	48.6566	D.S.R.S.W	112060
20	Karak	MazarJanoobi	395.085	MUJIB, D.S.R.S.W, HASA	105150
23	Karak	Qasr	1956.13	MUJIB, D.S.R.S.W,	32510

				HASA	
26	Ma`an	Husseiniyyeh	568.966	HASA	19180
27	Ma`an	Iel	622.16	W. ARABA NORTH	16750
28	Ma`an	Ma'an	30601	MUJIB, HASA	97050
30	Ma`an	Shoabak	428.276	W. ARABA NORTH, HASA	21350
32	Ma`an	Wadi Musa	456.468	W. ARABA NORTH	12961
33	Madaba	Dhiban	255.979	MUJIB	40270
35	Madaba	Madaba	936.929	D.S.R.S.W, MUJIB	168930
36	Tafilah	Bsaira	208.709	W. ARABA NORTH, HASA	27920
38	Tafilah	Hesa	838.487	HASA	11330
39	Tafilah	Tafileh	1122.59	W. ARABA NORTH, HASA	67250

The project area was defined and drawn up expressly to include the most vulnerable districts within the Mujib Basin considering the vulnerability of the people and their agricultural systems. The number of vulnerable households in the project area is estimated at 40000 with a total of about 24,000 rural people living in the 4 targeted governorates. Their vulnerability to climate change is partly a function of their poverty. According to the Ministry of Planning and International Cooperation, there are about 20 regions in Jordan with a poverty rate of more than 25%, which includes 254 communities, with a population of about half a million citizens. The Jordanian government considered them areas of poverty pockets distributed in nine of the twelve governorates in Kingdom, where the governorates of Ma'an included 6 regions. The governorate Karak has 3 pockets of poverty. Then the governorate of Tafeilah has one poor region. The percentage of families whose monthly income is less than 150 dinars in these areas, to 70%, while the proportion of families with income between 150 and 250 dinars to 25%. Jordan has poverty percentage of 15.7. Ma'an has the highest poverty 26.6%.This is high by national standards.

2.2. Water demand

Water resources in Jordan are directed towards four different sectors: agriculture, municipal supplies, industry, and tourism. By far, the largest user of the country’s water resources is the agriculture sector, which uses roughly 60% of the total water supply, while 36% goes to municipal uses, 4% for industry. Agriculture in Jordan is concentrated in two primary regions, the Jordan Valley and the Highlands. While the Jordan Valley is a much smaller area of land, this is where the bulk of the country’s agricultural production occurs and thus, where most of Jordan’s surface water resources are directed. In much of the Highlands, water is acquired from rainfall or wells.

Table 2: Water Uses in 2014 in different Governorates

Governorate	Water Uses								
	Municipal	Non domestic *	Domestic	Refugees	Agriculture (Highland)	Agriculture Jordan Valley	All Agriculture	Industry	All Uses
Ajlun	4.9	0.5	4.4	0.35	4.6	0	4,6	0	9.5
Amman	180	22	158	21.5	43.8	0	43.8	1.72	225.52
Aqaba	16	11	5	0.7	87.4	0	87.4	4.31	107.7
Balqa	35.7	5.7	30	1,7	10.6	100	110.6	0.97	147.3
Irbid	45.2	3.1	42.1	8.6	7.3	57	64.3	0.11	109.6
Jerash	6.7	0.5	6.2	0.3	11.3	0	11.3	0	18.0
Karak	20.5	2.6	17.9	1	17.7	43	60.7	12	93.2
Maan	14.2	3.7	10.3	0.7	110.1	0	110.1	9.59	133.9
Madaba	8.9	0.7	8.2	0.6	6.6	0	6.6	0.97	16.47
Mafraq	24.7	3.4	21.3	8.6	140.2	0	140.2	2.48	167.38
Tafila	5.5	0.6	4.9	0.1	7.1	0	7.1	1.4	14.0
Zarqa	66.6	5.2	61.4	8.3	82.3	0	82.3	5.44	154.4
Jordan	428.9	59	369.9	52.4	529	200	729	39	11.97
Percentage	36%						61%	3%	

Source: Ministry of Water and Irrigation, Water Reallocation Policy, 2016

* Non domestic includes commercial, small industries and tourisms

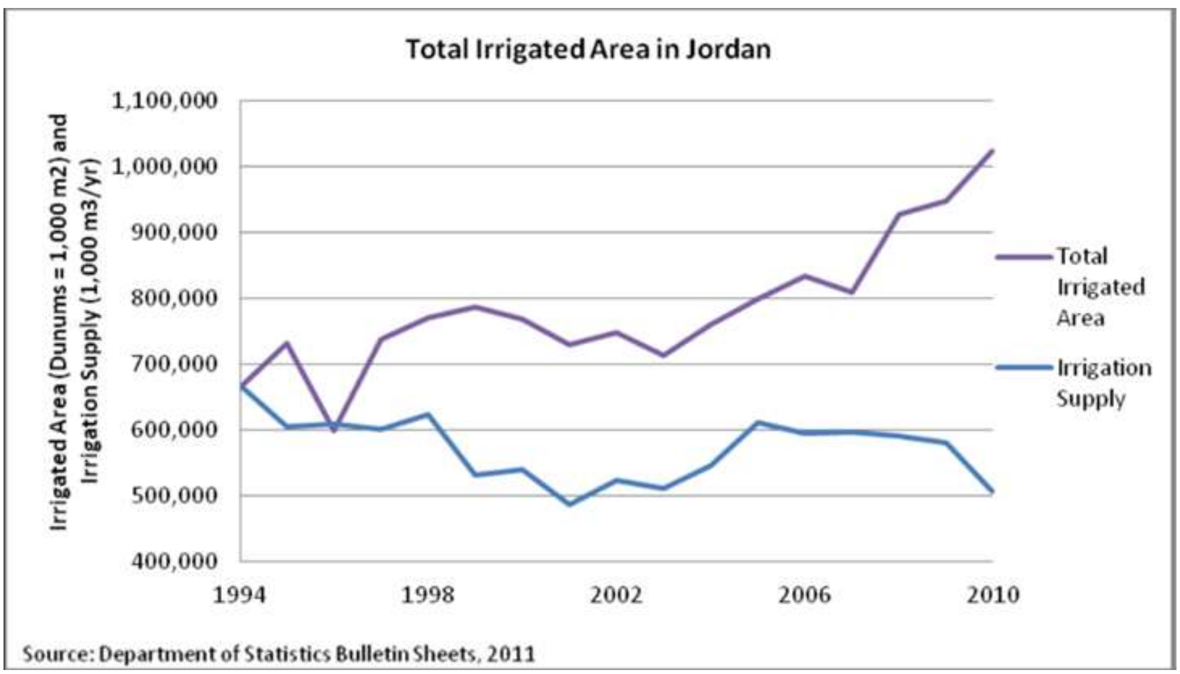
Agriculture comprises a relatively small share of GDP (around 3%), but is important in providing a supply of fresh fruits and vegetables and as a source of export earnings to allow the purchase of staple food grains on international markets. Irrigated agriculture consumes more than 60% (reduced from 75% over the last decade) of the water and has serious socio-economic impacts and high political significance. It provides most of the agricultural production in Jordan and offers the higher percentage of direct agricultural jobs and other jobs in support services. The production of food in semi-arid countries like Jordan is hardly possible without irrigation.

MWI is reinforcing the national priority to address the imbalance of water consumption across Jordan's economic sectors relative to their importance and their contribution towards the country's GDP. Despite the irrigated agriculture significant reduction in the consumption ratio (from 75% to 60%), MWI is aiming for substituting the use of fresh water by treated domestic wastewater and may be other non-conventional resources.

This reallocation approach is intended to serve as a vehicle to set action plans for redistributing the water flexibly between sectors and governorates. It intends to employ a conveyance system for water connecting the southern and northern regions and another conveyance system for treated wastewater in the Jordan Valley to maximize the use of treated wastewater for irrigation and free the expensive useable fresh water for domestic purposes.

A primary challenge in the Jordan Valley is to increase the productivity of water used in irrigated agriculture by both reducing losses and unproductive water use and shifting cropping patterns to include increased production of higher-value crops. A second challenge is to ensure the safety and exportability of produce grown with treated wastewater.

A corollary challenge is to reduce the use of groundwater from highland aquifers to sustainable levels– important both to preserve the resource for urban supply and to preserve the ability of the aquifer as a buffer against drought-induced surface water shortfalls. Enforcement of regulations to this effect is the core of the challenge.

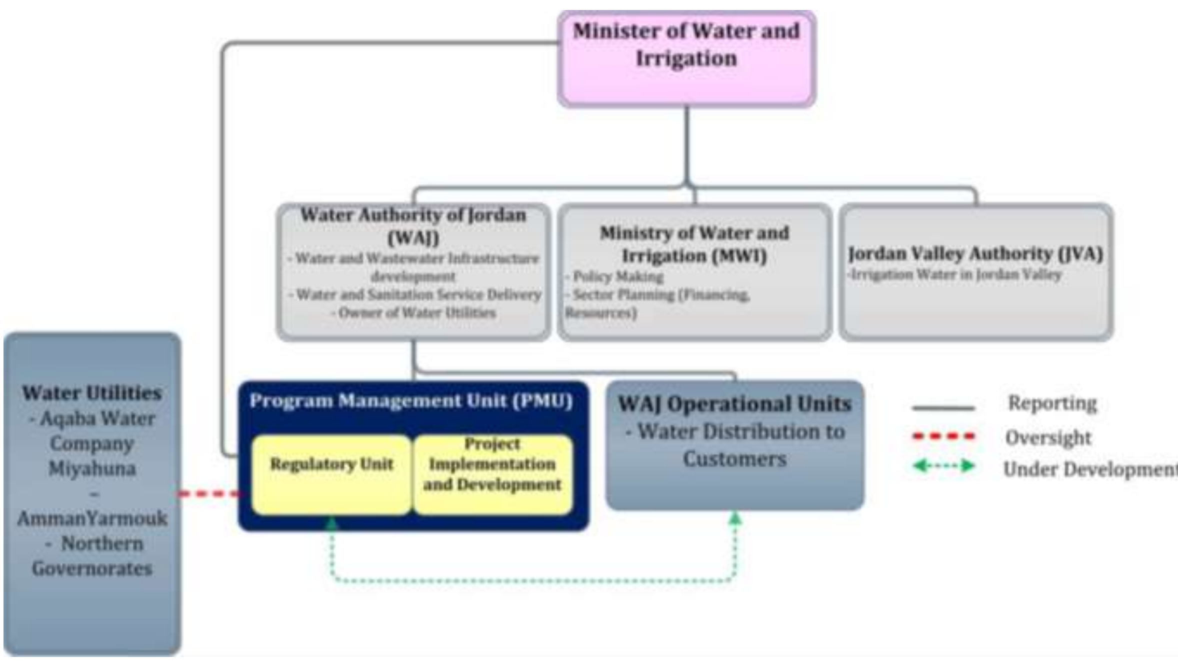


3. Baseline assessment: Policy Landscape

3.1. Water sector architecture

The Ministry of Water and Irrigation (MWI) is responsible for overall strategic direction and planning, in coordination with the Water Authority of Jordan (WAJ) and the Jordan Valley Authority (JVA). WAJ manages bulk water supply and retail distribution in parts of the Kingdom where commercialization of distribution services has not occurred. WAJ is an independent government unit with some degree of autonomy compared to MWI and JVA. JVA is responsible for the socio-economic development of the Jordan Valley, primarily managing bulk water supply for irrigation, domestic, and industrial purposes, as well as promoting land development.

WAJ owns three water companies that manage water and sanitation services in eight governorates. Miyahuna and Aqaba Water Companies are operating as commercial entities to provide water and sanitation services in Amman and Aqaba governorates, respectively. The third one is Yarmouk Water Company, which is responsible to provide water and sanitation services in Irbid, Jerash, Ajloun and Mafraq Governorates. WAJ assigned its responsibilities to the water companies through assignment agreements which are monitored through the Project Management Unit (PMU). The overall sector institutional setup is shown in the figure below.



The above institutional set-up will be changed according to the new law merging Water Authority of Jordan (WAJ) and the Ministry of Water and Irrigation (MWI). On 16th of February/2020 the Jordanian Cabinet approved the draft law to be followed by the necessary constitutional steps for its enactment. According to the draft law, the Ministry of Water and Irrigation will exercise all the functions and powers of the Water Authority and its board of directors as stipulated in the Water Authority Law.

The JVA supported the creation and development of water users' associations (WUAs) in the Jordan Valley and has transferred some operational functions for secondary and tertiary irrigation water delivery to these WUAs.

3.2. Summary of key sector policies

In the last three years, several new conditions and pressures faced the water sector that has already been operating at crisis levels for some time. The Disi water supply was introduced in 2013, operating costs have risen significantly with the rise in electricity prices, and the large number of Syrian refugees in Jordan is placing tremendous pressure on water supply and systems across the country in particular in the north. All of these factors pressured the sector to draft new strategies.

On policies level, MWI issued different policies to further detail the Water Strategy objectives and goals. These include: The Ground Water Policy which set out the Government's policy and intentions concerning groundwater management aiming at development of the resource, its protection, management and measures needed to bring the annual abstractions from the various renewable aquifers to the sustain-able rate of each. Other policies were prepared are: Water reallocation Policy, Surface Water policy. The Energy Efficiency and Renewable Energy Policy was approved by the Cabinet of Government of Jordan GOJ on June 14th, 2015.

Despite the limited natural resources, the narrow economic base and Jordan's location in a conflict-stricken region, the country has made strategic advances towards the achievement of Millennium Development Goals (MDGs). The SDGs reaffirm the need to achieve sustainable development by promoting economic development, social inclusion, environmental sustainability and good governance including peace and security. Jordan committed to these development principles, which is reflected in this National Water Strategy 2016-2025. MWI will coordinate and lead the implementation of the water-related SDGs and targets in Jordan. Achieving the MDGs and the SDGs will lead to optimize the utilization of the resources that are interlinked (water, energy and food security).

The National Climate Change Policy of the Hashemite Kingdom of Jordan 2013-2020

The objective of the Policy (2013-2020) is to build the adaptive capacity of communities and institutions in Jordan, with consideration for gender and addressing the needs of vulnerable groups, to increase the resilience of natural ecosystems and water as well as agricultural resources to climate change, and to optimize mitigation opportunities.

According to this national policy, the main objectives for vulnerability, impact, and adaptation to climate change are:

- Increase the scientific knowledge of climate change vulnerability and impact on water, agriculture/food production, health, biodiversity, desertification and other relevant sectors, with water and agriculture as the key sectors. This will include the link between climate change adaptation and disaster risk;
- Develop national and regional capacity to address climate change risks;
- Develop adaptation strategies in all relevant vulnerable sectors and work towards integrations/filling gaps of climate change aspects into relevant sectors' existing adaptation policies and strategies as well as action plans;
- Strengthen the cross-sector approach to adaptation given the strong thematic relation between the sectors, and strengthen the existing national institutional framework, including the National Committee on Climate Change (NCCC) and its advisory bodies with emphasis on climate change research group; and

- Promote the access to national and international financing for adaptation projects, including mainstreaming climate consideration in the allocation of national budgets.

3.3. Institutional set-up for reuse of reclaimed water

Safety Control and Risk Monitoring

Jordan is one a pioneer among Arab countries in the establishment of a Risk Monitoring System for water reuse. A long-term collaboration between government, research institutions and donors have elaborated many methodologies and tools that benefit the safe reuse of water. Many important elements of a risk monitoring exist today; however, they are not used to the most efficient and effective extent. One obstacle is the communication among the above-mentioned actors and stakeholders. Some tasks are partly duplicated while other relevant issues remain untouched.

Examples for existing elements/ tools:

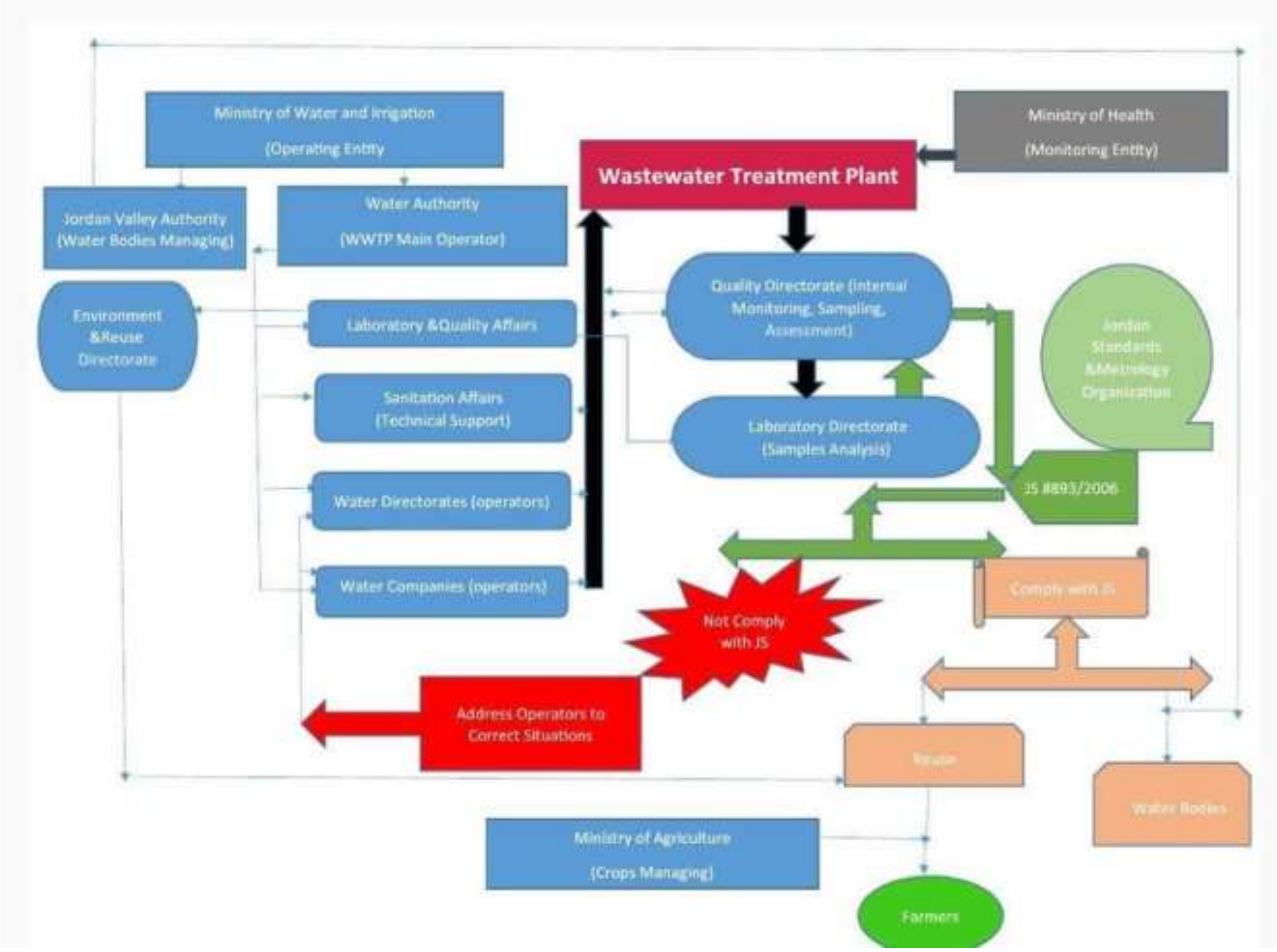
- Frequent monitoring system of effluents from WWTP (WAJ)
- Monitoring of Soil and Groundwater in the Jordan Valley (JVA)
- Advice to farmers on wastewater reuse (JVA and various donor projects)
- Monitoring of Fresh Fruits and Vegetables from the Jordan Valley and Whole Sale Market Amman (JFDA)
- Water Quality Monitoring among Jordan of MoEnv
- Advice to households on greywater reuse for garden irrigation (various NGOs and research institutes within donor funded projects)

The German International Cooperation currently supports the MWI, WAJ and JVA in the establishment of a Safety Control and Risk Management System in the Jordan Valley. This model will be the basis for a general Risk Monitoring concept to be adjusted to other areas in Jordan.

The basis for the currently planned Risk Management Concept for Jordan is the WHO Guidelines on Wastewater and Greywater Reuse (2006). These guidelines will set into standard. A national multidisciplinary working team developed a comprehensive risk monitoring and management system for the use of treated wastewater

This describes the efforts of Jordan towards better management and control of wastewater effluent to increase the available supply of waters of suitable quality on a sustainable basis. The graph below shows the process followed by MWI when it comes to testing of the effluent from wastewater treatment plants and ensuring that standards are followed by farmers.

In the old guidelines, WHO 1989 recommended the implementation of a rather stringent procedure depending mainly on a single barrier approach. This approach requires treating wastewater at a state-of-the-art treatment plant to render treated water of an acceptable quality for reuse purposes. In 2006 WHO-FAO-UNEP issued new guidelines for the use of treated wastewater. The new guidelines encourage the use of multiple barriers approach which is more flexible and less stringent. This approach combines treatment and post-treatment barriers compared to the old approach that relies solely on the treatment plant as the only reliable control measure.



Pre-requisite for the development of risk management plan

Setting a health-based target is a pre-requisite for developing a risk management plan which uses the tolerable risk of a disease as a baseline to identify specific control measures that will reduce the risk of disease to this tolerable level and thus achieving the set health based target. Health-based target can be achieved mainly through following three steps:

- assessing the system
- identifying control measures and methods for monitoring them
- developing a management plan

Unfortunately, the Jordanian standards for wastewater reuse are not being fully implemented. Although there are monitoring programs put in place to ensure the compliance with the regulations in terms of water quality and the type of irrigated crops, farmers do not always conform to these conditions.

Furthermore, and due to the challenges of meeting the growing national water demand and the impact of continued water scarcity; wastewater treatment processes and treated wastewater quality will improve in Jordan and quantities of reclaimed wastewater are likely to grow substantially. Enforcement of laws and regulations currently in use and continuous update and develop laws and legislations to implement the best practices in water use, in line with developments in the water situation in Jordan, is urgently needed to ensure raising of water efficiency, conservation of water resources and the reduction of illegal uses.

Laws and Regulations concerning Wastewater and Water Reuse

Jordan developed its own regulations in 1982 that were very restrictive and prohibited the reuse of the treated wastewater for agriculture. Revisions were made due to the increased awareness of the opportunities of using treated wastewater and due to the progress in technology. The first Jordanian standard for wastewater reuse was issued by the Ministry of Water and Irrigation in 1995 and was updated in 2002 and 2006 for various qualities of water resources. The Jordanian standard is based on WHO guidelines with some modifications to meet the local requirements and conditions (Jordanian standard 893/2006).

The existing standards and laws that directly apply to wastewater reuse are

- the Water Authority of Jordan Law No.18/1988 and its amendments,
- the Jordan Standard No. 202/2007 for Industrial Wastewater Discharges,
- Jordanian Standard 893/2006 for Discharge of Treated Domestic Wastewater, and
- Jordanian Standard No. 1145/2006 regarding the use of sludge.

All of them have monitoring duties and monitoring programmes, which are partly overlapping. However, no regulation exist which defines the cooperation of data exchange and evaluation among these organisations. No institution signs responsible for overall coordination and guidance in case the public health is threatened by bad practices of reclaimed water use.

Ministry of Water and Irrigation, Ministry of Environment and Ministry of Health have monitoring duties and monitoring programmes, which are partly overlapping. **<u>However, no regulation exist which defines the cooperation of data exchange and evaluation among these organizations. No institution signs responsible for overall coordination and guidance in case the public health is threatened by bad practices of reclaimed water use.</u>**

Water Authority Law No 18/1988 amend. 16/1998, 62/2001

This law defines the duties of the management and treatment of domestic and industrial wastewater. The 1998 revision (Water Regulations for Connection to public sewer system) issued according to the by-law No.66 for the year 1994. The rules make it possible for any industry to obtain a connection to the sewer for that portion of their wastewater that meets the quality requirements of the revised discharge standards.

The utilization of recycled water within Jordan has been made possible by the development and evolution of a sound legislative and legal foundation. There are several sets of standards that have paved the way. These include the first law regarding the operation of municipal sewer systems, which was first established in 1955, and the original public health standards first enacted in 1971.

Today there are several sets of standards and guidelines for wastewater, sludge, soil and crops that were derived from the work of the Water Authority of Jordan and the Ministry of Water and Irrigation. However, also other organizations are involved:

- Ministry of Water and Irrigation
- Water Authority of Jordan
- Jordan Valley Authority
- Ministry of Health
- Ministry of Agriculture
- Ministry of Environment
- Jordan Food and Drug Administration

Wastewater Management Policy of 1997

The Wastewater Management Policy of 1997 institutionalizes 62 points regarding the future use and management of wastewater. It shall be considered as a water resource. The following important assertions were made a part of the national wastewater strategy by the policy:

- Wastewater shall not be disposed of; instead, it shall be a part of the water budget,
- There shall be basin-wide planning for wastewater reuse,
- Use of recycled and reclaimed water for industrial use shall be promoted,
- Fees for wastewater treatment may be collected from those who use the water,
- Any crops irrigated with wastewater or blended waters shall be monitored, and
- Ultimately, the role of the government shall be regulatory and supervisory and private operation and maintenance of utilities shall be encouraged.

Jordanian Standards Reclaimed Domestic Wastewater Standard No 893/2006

In 1995, Jordan’s Department for Standards published a comprehensive reuse standard for treated domestic wastewater principally developed by the Water Authority of Jordan and approved by the technical committee for water and wastewater at JISM. This standard was amended in 2002 to widen the reuse activities. **These standards are currently applied to all municipal wastewater treatment systems.** The final version of this standard was issued in year 2006. The standards establish a variable standard for wastewater quality for 7 categories of discharge or direct reuse.

The Reclaimed Domestic Wastewater standard has the following primary components:

- Reclaimed water discharged to streams, wadis or water bodies.
- Reclaimed water for reuse.
- Allowable limit for properties and Criteria for use in artificial recharge for ground water.

The 2006 Standard # 893 includes the following categories of wastewater reuse standards depending on the fate of domestic wastewater after it is released from the wastewater treatment facility:

- Recycling of water for irrigation of vegetables that are normally cooked,
- Recycling of water used for tree crops, forestry and industrial processes,
- Discharges to receiving water such as wadis and catchments areas,
- Use in artificial recharge to aquifers not used for drinking purposes,
- Discharge to public parks or recreational areas,
- Use in irrigation of animal fodder.
- Use of reclaimed water for cut flowers

Industrial Wastewater Standard Specification No 202/2007

This standard defines the quality for final discharge of industrial wastewater to water bodies or irrigation. Standard 202 incorporated the standard no.893/2006 for the reuse of industrial wastewater that included four categories:

- Irrigation
- Recycle inside the industrial establishment.
- Discharge to Wadis, Rivers and Catchments Areas.

The irrigation reuse standard specifies limitations on the direct use of reclaimed water to four categories as indicated in following table:

Table: Criteria for treated wastewater reuse in irrigation and their allowable limits

Parameter	**Unit**	**Jordanian Standards 20061**		
		A	**B**	**C**
BOD	mg/l	30	200	300
COD	mg/l	100	500	500
DO	mg/l	> 2	-	-
TSS	mg/l	50	150	150
TDS	mg/l	1500	1500	1500
PH	UNIT	6 – 9	6 – 9	6 – 9
Turbidity	NTU	10	-	-
Nitrate	mg/l	30	45	45
Total Nitrogen	mg/l	45	70	70

Total PO4-2	mg/l	30	30	30
Escherishia Coli	MPN/100 ml	100	100	Not Applicable
Intestinal Nematodes	Egg/l	< 1	< 1	< 1

Source: Potential of treated wastewater usage for adaptation to climate change: Jordan as a success story, Mohammed A. Salahat*1, Mohammed I. Al-Qinna1, Raed A. Badran2

A represents cooked vegetables, parks, playgrounds and sides of roads within city limits,

B represents fruit trees, sides of roads outside city limits, and landscape, and

C represents field crops, industrial crops and forest trees.

Standard 202 recognized the problem of salt in reclaimed wastewater to be used in agriculture, a limit of 2000 mg/l of total dissolved solids was specified and remain in force for industrial effluents.

Future Perspectives

Jordan faces a high population growth and therefore an increasing demand for water. Considering the limited amounts of renewable freshwater resources in Jordan, these resources have to be protected and saved for drinking water. Therefore, the agricultural sector has to be prepared to depend more and more on marginal water resources such as treated wastewater.

Inadequate tariffs still encourage households, industries and farmers to waste valuable freshwater resources. The low tariffs also hinder the application of reuse technologies as they are financially not attractive to households. In general, Jordanian tariffs do not cover the water production cost and even less the wastewater treatment costs. This leads to a step-by-step deterioration of the existing facilities and hinders the establishment of new treatment facilities.

3.4. Institutional set-up for rainwater harvesting and water demand management

The Government has been making significant efforts since late 1980's to improve water management through policies, regulations, institutional reforms, and technologies. Water demand management (WDM) efforts addressed the agricultural, municipal, and industrial sectors.

Policies & Institutional Reforms

In 1997, the first water strategy was passed along with four supporting policies on municipal and industrial water supply, irrigation, wastewater management, and groundwater management. The strategy had provisions for water use efficiency to manage reduction of water demand.

In 1998, The Ministry of Water and Irrigation established a Non-Revenue Water (NRW) Directorate at the Water Authority for Jordan to reduce physical water losses at the water supply networks and reduce administrative water losses mainly as a result of illegal water use. Since its establishment the Directorate led the design and implementation of several programs such as the rehabilitation of the water distribution and supply networks, development of capacities in the reduction of NRW through training and pilot programs across the kingdom, and introduction of new technologies and equipment to monitor and reduce NRW.

In 2002, The Ministry of Water and Irrigation established a Water Demand Management Unit (WDMU) to institute and promote water demand management and water use efficiency in Jordan. Between 2002 and 2006 WDMU succeeded in introducing water use efficiency technologies and practices for domestic water use and landscaping through educational and social marketing tools. In 2007, the Unit prepared a five year strategic plan to lead the preparation and implementation of the water demand policy, educate the public on water conservation, support the planning and the implementation of water use and reuse efficiency and water harvesting programs, and serve as the national clearinghouse for WDM. WDMU is currently leading water audits and retrofits of government offices and schools, implementing pilot greywater, water harvesting, and water-wise landscaping programs.

In 2006, two agricultural water use efficiency policies were prepared, one on irrigation equipment and system design, and the other on irrigation water allocation and use. An irrigation advisory service was formed and trained to work with farmers and agriculturists to introduce less water intensive/high value crops using fresh, brackish, and recycled wastewater. Plus farmers were assisted on marketing these new crops.

In 2008, a national WDM policy was approved by the Council of Ministers. As its main objective the Water Demand Management Policy is intended to result in maximum utilization and minimum waste of water, and promote effective water use efficiency and water conservation, for social and economic development and environmental protection. Sustained implementation of this water demand management policy will generate water savings that will be an important source of additional water to reduce water deficit and advance economic growth and social development. The Water Demand Management Policy addresses the management of water demands in all sectors of Jordan's economy including municipalities, industry, tourism, agriculture and other activities of national importance. Efforts are currently exerted to develop action plans for governmental entities to implement the WDM policy in Jordan.

In 2009, Jordan prepared a new water strategy under the stewardship of the Water Royal Committee that called for a shift of paradigm, from a supply-oriented approach to an integrated supply-demand management approach. It discussed water demand and supply options, institutional reform, irrigation efficiency, reclaimed water, and alternative water resources. The strategy, recommended actions needed within each goal area. Several recommended actions relate to demand management such as instituting demand management to control groundwater depletions, revising water tariffs, adopting water saving technologies, and promoting awareness about water scarcity and efficient water use.

In 2009-2010, MWI worked with Miyahuna, Aqaba Water, and Yarmouk Water utilities to establish water demand forecast for the next 20 years and develop 5-year water use efficiency plans with specific water conservation programs for each utility.

In 2010, MWI assisted the King Abdullah Center for Excellence (KACE) to integrate water use efficiency in the KACE award criteria. The KACE award is the most prestigious award in the country with more than a hundred public and private institutions competing for it. This is a huge step towards the implementation of water use efficiency measures by all these institutions.

- The Jordanian regulations governing household plumbing are the
- 'Sanitary Wastewater System Code', and
- 'Water Supply Code' (Ministry of Public Works and Housing 1988).

These codes provide guidelines for the design and installation of plumbing systems in domestic properties.

Standards, Code, and Regulations

Developing Water Efficiency Standards. The Ministry of Water and Irrigation is working with the Jordanian Institute for Standards and Metrology (JISM) in developing plumbing standards and technical regulations for efficient water use. So far, standards for lavatory faucets, kitchen faucets, toilets, and showerheads are developed and approved by the plumbing products technical committee.

Updating of the National Water and Sanitation Plumbing Code. **The Ministry of Water and Irrigation is working with the Jordanian Building National Council (JNBC) to modify and update the Jordanian plumbing code to integrate water efficiency standards in the code**. This is being supported by the International Association of Plumbing and Mechanical Officials (IAPMO) in the US.

Establishing a testing lab at RSS. The Ministry supported the Royal Scientific Society (RSS) the establishment of a water testing facility to test local and imported water plumbing products for compliance with technical regulations for water use efficiency. This effort will support the enforcement of the standards and technical regulations to clean the Jordanian market from inefficient plumbing fixtures and appliances.

Enabling Tools & Technologies

- **Water Use Audits and Pilot Programs.** MWI has been implementing water audits since 2002 for large consumers including residential units, Mosques, offices, hotels, and hospitals. Results of these helped in the development of baseline water uses and identify water saving opportunities for these facilities. Pilot programs have been also implemented to assess water use efficiency technology and practices.
- **Best Management Practices.** MWI is developing best management practices (BMPs) guides for efficient water use in high rise and high-density buildings, residential units, hospitals, hotels, offices, and landscape.
- **Water Use Efficiency Tracking Tool.** MWI worked with Miyahuna, Aqaba Water, and Yarmouk Water to customize the water use efficiency (WUE) tracking tool developed recently by the International Alliance for Water Efficiency to assist in the planning of the three utilities water efficiency programs as well as tracking savings from these programs.
- **Water Demand Management Database.** MWI is working the water utilities to finalize the establishment of water use information and database systems to provide the MWI with realistic estimations of water use and water demand forecasting, plus track water demand and water saving for residential, commercial, institutional, and industrial sectors.
- **Financial Mechanisms.** MWI succeeded in establishing the first public-private partnership on promoting water use efficiency in the residential sector. The partnership was formed between HSBC bank and Miyahuna to implement a “let’s save water” initiative as part of Miyahuna 2008 summer water conservation program. MWI is also working with the Water Alliance of Water Economic Forum to work with stakeholders to develop and implement water conservation programs in corporation with the private sector.

4. Climate change risks, impacts and vulnerabilities

4.1. Overview and climate projections

Climate change has exacerbated water scarcity in Jordan due to decreasing trend of precipitation (1.2 mm per year) and increase in temperature (0.03 0C/year) which increases crop water needs and affects plant growth and maturity. Increase in temperature can also intensify the water cycle causing more extreme floods and droughts globally. Annual maximum and minimum temperature have increased by 0.3-1.8°C and 0.4-2.8°C, respectively, since the 1960s. Annual precipitation rates show decreases at most meteorological stations. This has resulted in reduced recharge and less replenishment of surface and groundwater reserves and increase in the incidence of flash floods as was witnessed in 2018. According MWI (2016) the mean and maximum temperature over Jordan will be 2-4 degrees higher, precipitation will be 15-20% lower and potential evapotranspiration about 150 mm higher by 2100.

Climate change projections are not available for the whole project area. However, recently Abdulla and Talafah (2020), developed the climate change projection for Mujib basin which covers an area more than 50% of the project area. So the climate change presented here can be considered a proxy for the climate change projection in the project area.

HadCM3 GCM Projections predict that climate change will have an increasingly serious effect on the hydrology and agriculture of the project area, largely as a result of rising temperatures and changing patterns of precipitation. Rainfall in the basin is projected to decrease, although the amount of decrease exhibits large variability both spatially and temporally. Temperatures in the basin have already increased 0.9 °C over the past three decades and are projected to increase a further 3–5 °C by 2100, 2 above the global average, with a higher rate of increase occurring in the winter months and in mountainous areas that are the source of most surface water.

Table 10 presents the projection of monthly mean precipitation for Rabbah station under A2, B2 scenarios. During the three analyzed periods (2011-2040, 2041-2070, and 2071-2099), A2 and B2 scenario indicates a reduction in mean monthly precipitation from October to March. However, the mean monthly precipitation has been increased in April and May for bothA2 and B2 scenarios which indicate a shifting in the rainy seasons. Table 11 shows the monthly mean precipitation difference for Rabbah station under RCPs.

Table 10:The monthly mean precipitation difference (mm) for Rabbah station under A2 and B2 scenarios

Month	A2a (2011-2040)	A2a (2041-2070)	A2a (2071-2099)	B2a (2011-2040)	B2a (2041-2070)	B2a (2071-2099)
Jan	-10.7	-25.5	-35.8	-14.9	-19.6	-32.0
Feb	-23.9	-30.4	-42.8	-22.5	-28.6	-33.6
Mar	-12.5	-14.8	-23.5	-14.2	-16.8	-20.7
Apr	11.2	7.8	0.8	10.5	10.1	3.8
May	14.6	13.2	8.0	14.2	13.1	10.4
Jun	1.3	0.5	0.1	0.6	0.5	0.2
Jul	0.0	0.0	0.0	0.0	0.0	0.0
Aug	0.0	0.0	0.0	0.0	0.0	0.0
Sep	0.7	0.4	0.2	0.8	0.5	0.3

Oct	-2.4	-2.0	-1.8	-2.3	-2.1	-1.8
Nov	-4.0	-7.5	-13.5	-2.3	-6.5	-10.3
Dec	-10.5	-16.3	-28.3	-9.1	-14.3	-22.1

Table 11: The monthly mean precipitation difference (mm)forRabbah station under the three RCPs scenarios

Month	RCP 24 (2011-2040)	RCP 24 (2041-2070)	RCP 24 (2071-2099)	RCP 45 (2011-2040)	RCP 45 (2041-2070)	RCP 45 (2071-2099)	RCP 85 (2011-2040)	RCP 85 (2041-2070)	RCP 85 (2071-2099)
Jan	-12.0	-10.7	-13.5	-6.1	-12.7	-19.1	-10.7	-19.4	-28
Feb	-20.7	-24.2	-26.4	-23.0	-26.3	-30.2	-22.5	-28.9	-38.8
Mar	-11.2	-12.8	-14.4	-13.1	-15.9	-18.7	-13.7	-16.8	-22
Apr	6.5	4.7	1.6	6.7	1.6	0.5	6.2	1.1	-4.1
May	16.6	14.5	14.4	15.5	13.9	11.5	17.7	13.1	10.2
Jun	0.8	0.5	0.5	0.7	0.5	0.4	0.8	0.3	0.1
Jul	0.1	0.0	0.1	0.1	0.0	0.0	0.1	0	0
Aug	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
Sep	1.9	1.5	1.5	1.9	1.0	0.8	2	0.6	0.1
Oct	-2.1	-2.0	-2.3	-1.9	-2.1	-2.2	-2.1	-2.5	-3.1
Nov	1.0	2.9	1.1	1.7	-2.8	-4.9	1.7	-6	-14.6
Dec	1.8	1.5	2.5	5.8	0.0	-5.6	3.1	-5.2	-17.5

4.2. Impacts of climate change on water resources

Climate change poses new challenges to the management of water resources. The rising variability of rainfall will have a serious impact on multi-dimensional water use and management, including greater increase and uncertainty in extreme events such as droughts and floods. The variability of water resources, especially the variability of rainfall, is a major obstacle to economic growth and rainfed agricultural production in Jordan as well as in the study area. Changes in the precipitation features, including the amount, intensity, frequency and the type of precipitation will also increase the variability of river flow and groundwater recharge and thus affect all sources of water. Analysis of available research data indicates that climate change, manifested through significant temperature increases and uncertain changes in precipitation, will impact the Mujib Basin hydrology and agriculture in numerous ways.

In the medium term (2050), the forecasts for climate change agree that Jordan will get warmer with more frequent heat waves and fewer frost days. In the eastern and southern areas of Badiaa, as well as in the northern and southern areas of the highlands, precipitation can be expected to decrease during the rainy season until 2050, while (TNC, 2014). The country is expected also to become drier with forecast trends suggesting that annual precipitation tends to decrease significantly over time. The rainfall intensity is expected to increase. The runoff is expected to decrease (Jordan INDCs, 2015). In the long term (2100), the results of the CORDEX-RICCAR initiative, based on a wide range of global and regional climate and impact models, show that climate pressure and the effects on the water sector will worsen over time to reach severity in water availability after 2040 (MWI, 2016; RICCAR, 2017). The Third National Communication on Climate Change (2014), using previous RICCAR analysis, suggests that mean and maximum temperatures will be 2 to 4°C higher across Jordan by 2100. The amount of precipitation is 15-20% lower and the potential evapotranspiration is 150 mm higher (TNC, 2014).

Jassim and Alraggad (2009) investigated the impact of climate change on groundwater recharge in the central part of Jordan.; they stated that the decrease in precipitation by 10% to 20% is accompanied by a decrease in groundwater recharge of 24% to 48% while increasing the temperature by 1 - 2°C lowers the groundwater recharge by 11.3% and 23.2%.

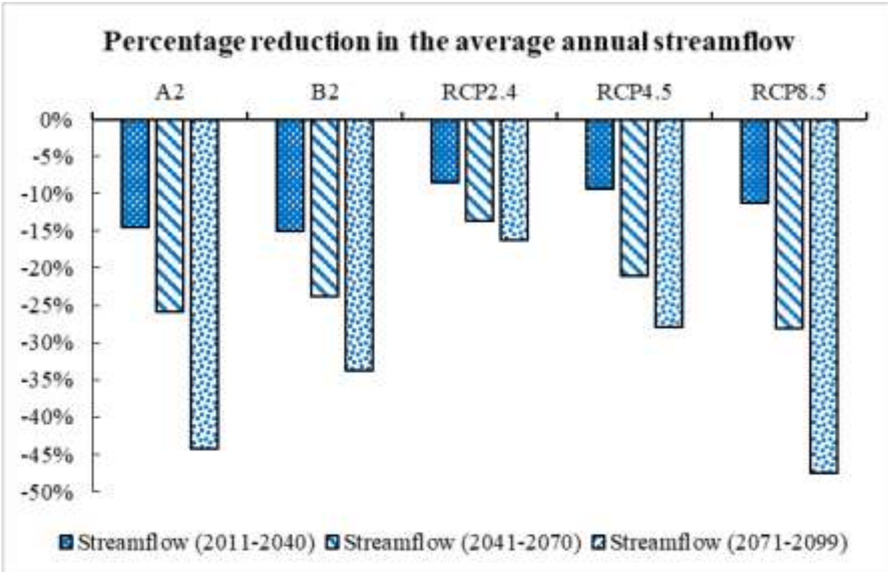
Verner et al. (2013) conducted a study for the World Bank to increase the resilience of the agricultural sector in Jordan and Lebanon to climate change through statistical downscaling techniques. Team members have used SDSM to assess changes in atmospheric conditions at 10 sites. Average daytime temperatures and precipitation from the British Met Office climate model HadCM3 were downscaled under two emission scenarios (SRES A2 and B2) for the period 1961-2099. The results presented a change in average seasonal precipitation and temperatures, confirming the previous studies' results. The average precipitation could be reduced by 10-20%and temperatures could rise by ~ 1.5°C in the 2050s.

Abu-Allaban et al. (2014) investigated the impact of climate change on Mujib's water resources through many incremental climate change scenarios and applied the results to the Hydrological Model of the Soil and Water Analysis Tool (SWAT). They found that the runoff would decrease by more than 30% if the air temperature increased by 2 or 4°C and the precipitation decreased by 10%. Also, the runoff would decrease by more than 50% if the temperature rose by 2 or 4 ° C and the precipitation decreased by 20%.

Abdulla and Talafah (2020) studied the impact of climate change on the water budget components of Wadi Mujib basin. The SWAT model has been to simulate the water budget of this basin. The results revealed that for the period (2011-2040), and under A2 and B2 scenarios, the mean monthly water yield will be reduced from December to April. However, the mean monthly water yield has been increased mainly in May for A2 and B2 scenarios which are a result of the shifting phenomenon in the rainy seasons during the analyzed period. For the period (2041-2070), A2 and B2 scenario indicate a reduction in mean monthly water yield from December to April. However, the mean monthly water yield has been increased mainly in May as well for A2 and B2 scenarios which indicates a shifting in the rainy seasons as well during the analyzed period. For the period (2071-2099), A2 and B2 scenario indicate a reduction in mean monthly precipitation from December to April. However, the mean monthly precipitation has been increased mainly in May for A2 and B2 scenarios which also reflects the shifting in the rainy seasons during the analyzed period.

The percentage changes during the 30 years' intervals 2011-2040, 2041-2070 and 2071-2099 in the average annual simulated streamflow relative to the 18 years' simulated baseline weather scenario (1970–1987) are shown in Figure 6. For A2 and B2 scenarios, the average annual streamflow is projected to decrease during the three analyzed periods with a maximum reduction of 44% under the A2 scenario by the end of 2099.For RCP 2.6, RCP 4.5 and RCP 8.5 scenarios, the average annual streamflow is projected to decrease during the three analyzed periods with a maximum reduction of 47% under the RCP 8.5 scenario by the end of 2099.

Figure 6: The percentage changes during the 30 years' intervals in the average annual simulated streamflow relative to the 18 years' simulated baseline weather scenario (1970–1987)



4.3. Impacts of climate change on the agricultural sector

In Jordan, agriculture is one of the most sensitive sectors to climate change induced impacts. Due to urban expansion in the high rainfall zones, rainfed agriculture had expanded towards the marginal lands of arid and semiarid areas that receive less than 200 mm of annual rainfall. For many years, rainfed agriculture in these areas suffered from droughts and accelerated soil degradation. In these areas, barley is usually cultivated to support the grazing herds whose stocking densities are too high, although in many years grain production is not guaranteed.

According to SNC (2009) Agriculture in Jordan is one of the most vulnerable sectors to climate change because the available water and land resources are limited as most of the country's land is arid and is used as open range. Results of the vulnerability assessment for agricultural sector showed that climate change could have significant impacts, in particular on rainfed agriculture. Livestock sector and the overall food production in the country were identified as most significantly impacted by the adverse impacts of climate change on rainfed cultivation and on the arid and semi-arid rangelands.

The DSSAT had been used to simulate the impact of the different climate change scenarios on barley and wheat. Results showed variations in response between wheat and barley. For both crops, however, it has been found that the reduction of rainfall by 10 to 20 percent had a negative impact on grain yield for both barley and wheat at the different temperature regimes. The maximum predicted losses of yield were 423 Kg/ha and 523 Kg/ha for wheat and barley; respectively. It is anticipated that a 1°C increase in temperature and10% decrease in precipitation will decrease olive yield by5%, while a 2°C increase in temperature and 20% decrease in precipitation will decrease yield by 10% due to lower water availability.

For many vegetable crops, high temperatures may decrease quality parameters, such as size, soluble solids and tenderness. It is anticipated that a 1°C or 2°Cincrease in temperature will decrease vegetables yield by 5 and 10%, respectively. Using the appropriate varieties could help avoid the adverse impacts of temperature increase such as less flower bud induction, higher fruit drop, faster volume growth of fruit, earlier maturation, less total soluble solids and fruit reaches insipid and dry states earlier. Also, planting trees that have high tolerance to higher temperatures such as dates would prevent loss of productivity due to global warming. On the one hand, it is anticipated that a 1°C or 2°Cincrease in temperature will not have a negative impact on an average year if the right varieties or tree types are used.

- The increase in evapotranspiration (ET) rate and decrease in precipitation in drier systems such as the arid and semiarid range lands of Jordan would reduce productivity.
- Potato yields are particularly sensitive to high-temperature stress because tuber induction and development can be directly inhibited by even moderately high temperature. It is anticipated that a 1°C or 2°C increase in temperature will decrease yield by 5 and 10%, respectively (Al-Bakri et al. 2010).

4.4. Impacts of climate change on the rural poor and women

According TNC (2014) Poor in rural areas in Jordan are expected to face the most severe consequences of climate change through disruption of livelihood options that depend on natural resource management. The expected impacts of climate change particularly reduced agricultural productivity and water availability threatens livelihoods and keeps vulnerable people insecure. Poor families and households are the most vulnerable group to the impacts of climate change and deserve the priority the in design of appropriate adaptive measures.

The relation of climate change with gender and poverty is apparent in the following issues:

- Dependence of such vulnerable groups on natural resources that is susceptible to climate change. 20% of the population depends on agriculture for their income. Agriculture vulnerability especially the rain fed and irrigated was also discussed in detail, these discussions lead to the conclusion that this 20% of population which is part of the poorest segment will be most susceptible to climate change impacts;
- Dependence of communities on ecosystem services (water springs, rangelands and natural vegetation in medicine, etc.) that could be affected by climate change;
- A lack of assets which hinders effective adaptation by the poor segments of population;
- Settlements in high-risk areas (i.e. drought prone) in Jordan are known to be of the lower income groups, a fact which magnifies the impact of climate change on poverty of these groups;
- Low levels of education and professional skills that prevent members of poor households for shifting to climate-resilient sources of income.

The role of women in economy of rural areas is known to be substantial. Women in these areas are traditionally responsible for the household economy and are active in field work as well. Any negative impact of climate change will be most sensed by women. Women make crucial contributions in agriculture and rural enterprises in drylands as farmers, animal husbandry, workers and entrepreneurs through their indigenous knowledge.

5. Challenges and opportunities moving forward

5.1. Overarching challenges

Despite the enormous progress in addressing the water challenges for Jordan, some key issues remain that could limit Jordan's ability to ensure a water-secure future.

- Climate change risks not sufficiently taken into account within sectorial policies and investment frameworks.
- Existing climate information, knowledge and tools are not directly relevant for supporting adaptation decisions and actions.
- Weak national capacity to develop sectorial adaptation responses.
- The current institutional setup lacks an appropriate legal framework, clear terms of reference and coordination mechanisms.
- Weak link between information, knowledge, available climate tools and decision-making on adaptation actions at the level of affected sectors.
- National capacity is weak in terms of developing sectorial adaptation measures and measures needed to mitigate the effects of climate change on water scarcity.
- Lack of an integrated view of prioritized supply and demand solutions at the governorate level.
- Lack of alignment of all stakeholders around a common implementation and investment plan with clear timelines and accountabilities.
- Consequences of climate change already present
- New housing areas are not covered by the old water distribution network and require expansion

5.2. Barriers to climate change adaptation and resilience

The following barriers to achieve climate resilience and adaptation option are considered in all the national communication reports to UNFCCC (SNC 2009 and TNC 2014). Those barriers that are relevant to study area are summarized below:

- There is a lack of integration of information and analytical tools on climate, water and agriculture. Responsibilities for hydrologic and climatic information collection, monitoring and communication are spread across different ministries. These include the Ministry of Water and Irrigation, Department of Meteorology (Ministry of Transport) and Ministry of Agriculture. Limited coordination across institutions hampers the effective and efficient management of the country's most critical natural resource.
- The selected study area consists of several parts of different governorates which made it impossible to separate the included villages or towns from other places in the same governorate.
- The data for most of the selected variables are available at the governorate level.
- Some of the variables are not available in the form of time series data, but on interval periods which made it difficult to establish a link between the climate variables and the extrapolated socioeconomic variables.
- Agricultural water use at the farm level has historically been difficult to regulate due to outdated policies, limited integration of water monitoring efforts and subsequent enforcement and lack of information.
- A broader set of policy and institutional issues and weaknesses have further impeded the transition toward climate-resilient agriculture and water management in Jordan.
- Influence on the exploitation of home gardens could be summarized as follows: (1) low rainfall causes low level of water distribution to the households, which leads to a decreasing level of production in home gardens, and (2) the water department in the different municipalities reduced the quantities of water delivered to households during drought years through reducing the frequency of distribution.

- Another barrier is posed by the fact that, at the governorate level, agricultural extension suffers from insufficient numbers of personnel, lack of a proven mechanism to reach the vast number of farmers, and a very low ratio of female agriculture extension staff to support women. In addition, current extension personnel possess an inadequate understanding of climate change threats and responsive practices and technologies that are suitable for local contexts. Extension service providers lack policy-to-practice guidelines and know-how for mainstreaming and disseminating the modest climate change information they have. Nor are they sufficiently aware of or equipped to deal with the effects of climate change on the vulnerable groups of society, who require support specifically tailored to them. Limited mobility of extension staff is also an issue.
- Data availability, consistency and transparency was one of the main identified problems faced during the preparation of climatic scenarios:
    - There are missing data in the daily and monthly climatological time series at the majority of national meteorological stations.
    - There is also a problem in water data availability. The quality of the available data is sometimes inappropriate.
    - The existing climatic and water resources monitoring in the country are facing permanent problems in operation, slow modernization of equipment and reducing of the monitoring network.
- Lack of regional climatic prediction models and downscaling models, thus, Global Circulation Models(GCMs) were used with high spatial distribution. Precipitation modeling using these GCMs models gave poor results.
- Rural households in Jordan rely heavily on climate sensitive resources such as local water supplies and agricultural land, and climate-sensitive activities such as arable farming and livestock husbandry. Climate change can reduce the availability of those local natural resources, limiting the options for rural households that depend on natural resources for consumption or trade
- Some of the interviewed farmers indicated that they do not receive adequate climate information. The majority of those who receive information do not use it. Most of the farmers trust indigenous climate predictions more than contemporary climate forecasts. The reason they gave was that contemporary information is too general and not specific in time and space.
- Lack of financial resources to address needs, conduct research and studies, and implement adaptation measures.
- The main limitations and difficulties for adaptation of agriculture sector would include the lack of national strategies and plans for adaptation. The sector needs more initiative programs to mitigate the adverse impacts of climate change. In addition, agricultural extension and communication systems are among the most important limitations. Currently, scientific research in this area at the country level is insufficient for precise quantification of adverse impacts and vulnerability. The main constraints that need alleviation are technology transfer, availability of data, commitment at society level, adaptation programs at the governmental level, and most important is the lack of financial resources that could strengthen research and adaptation

5.3. Opportunities to solve policy bottlenecks

- Weak enforcement of regulations.
- The construction of buildings across the country has not been coupled with an increase in applying the "simple" rainwater harvesting techniques. The law stipulates that a cistern for storing rainwater must be built as part of any under-construction building, but contractors are not abiding by this and they pay a fine instead of building the cistern.
- Lack of water conservation technologies.
- High water demanding crops.

- Having a positive benefit-cost ratio alone does not automatically increase the utilization of rainwater harvesting. Several other conditions are involved, such as:
    - A team of trained plumbers who can estimate costs and the optimal size of the storage system, and are able to implement projects on site;
    - It is important to monitor and learn from implemented projects;
    - Public awareness is a prerequisite for widespread use of RWH;
    - Government commitment in enforcing the Roof Water Harvesting Code is very important towards achieving successful implementation of this measure;
- Cultural perceptions and religious views regarding the use of water, as well as traditional preferences for its location, taste, smell or colour, are all important and to be taken into consideration; and
- It is important to know the people, to be aware of their concerns, and to encourage their participation at every step of the rainwater harvesting process. It has been shown that the more a community is involved, the greater the potential for a successful project.

5.4. Opportunities to close legislative gaps

- Implementing water harvesting system should be obligatory on Municipal, Tourism and Industrial Sector.
- Inadequate controls on industrial effluent.
- Institutional change in the irrigation agencies to accommodate the new management system is required; Water User Association. This should include the important need to reorient the irrigation agency and plan how to support agency staff to adapt to the new situation and to strengthen WUAs. This re-orientation should be coupled with the establishment of a clear legal status which enables WUAs to have financial autonomy, enforce sanctions and execute their functions of public interest.
- Storage of rain water from roofs shall be enforced. Storage volumes shall be set in building codes depending on roof area and average precipitation
- Wastewater Standards shall be revised and amended to meet direct and indirect water reuse for the production of high value crops.
- Rainwater harvesting systems should be installed for new construction (residential, commercial, industrial, tourism, etc.) where the size of the storage tank that depends on average rainfall and the surface area of the building is considered within the construction code. Harvested rain can provide a nonpotable water source that can augment existing water supplies.
- A mechanism to price (tariff setting) treated wastewater, as well as blended treated wastewater should be developed taking into consideration fairness, cost recovery and economic activities support.

PART II: Technical assessment of proposed interventions

1. Overview

Investing in climate resilient infrastructure in vulnerable locality to climate change and capacity of local level and community- based water management institutions will enable households to deal with one of the major risks that emanates from climate change which is reduced access to water. The main outputs under this component include introducing infrastructure toredistributeof freshwater over space and time, among these are rooftop water harvesting structures (5000 households and 1024 public buildings), and enhancing 4 waste water treatment reuse systems (Madaba, Karak, Tafeilah and Wadi Mousa WWTPs) for 120 farmers.

This component has been designed for enhanced water availability to face adverse climate change impacts. Initially under this component several activities where proposed, but due insufficient information, data and feasibility studies and in other cases unclear connection to climate change impact, these activities reduced to three. These three activities are considered based on different meetings with main stakeholders including Ministries and other stakeholders from the four governorates.,

The first activity under component 1 is the installation of rooftop rainwater harvesting structures and water saving devices for households and public buildings. This activity aims to build climate resilience through improved access to water and efficient water use at the household level and in selected public buildings such as schools, mosques, municipalities for wider dissemination at local community level. The households which benefit from the investment will be expected to contribute part of the costs based on criteria that favours women headed households, those reliant solely on agriculture and identifies roof size as a proxy for determining the share of households. Women will be consulted on designing water outlets as the primary users of domestic water. The investment will be accompanied by awareness and orientation on water conservation at the household level, for municipal staff of public buildings and children and teachers in schools for sustainable behavior change. Households will also be introduced to water conserving devices and gadgets with private sector engagement.

This activity aimed to increase resilience to climate change by conducting holistic sustainability assessments and implementing designs based on standardized criteria that offer affordable, appropriate and cost-effective rain water harvesting (RWH) solutions in the study area. The key objectives of this activity are:

i) Increase resilience to climate change impacts on water availability in the project area;

ii) Improve rural livelihoods;

iii) Increase water availability in selected householdss;

iv) Make affordable, appropriate and innovative RWH systems more available in the study area; and

v) Strengthen human and institutional capacities to implement RWH.

2. Rooftop rainwater harvesting

2.1. Background

The capture and utilization of rainwater is an ancient tradition which dates back to similar techniques used in today's Jordan around 5000 years ago. Rainwater Harvesting (RWH) and storing for domestic uses is an age-old technique used in Jordan. Some of these structures are in good operation conditions such as the Roman pools near Ajlun, Madaba and Mwagger. Building dams to tap stream water, channeled through canals and stored in reservoirs, was practiced by ancient Jordanians about 5,000 years ago to provide drinking water to the old city of Jawa (Abdelkhaleq and Ahmed 2007). The Nabataeans civilization that emerged in the arid region of southern Jordan more than 2,500 years ago; these people built dams to provide their capital city Petra and other settlements with water for drinking and irrigation (Abdelkhaleq and Ahmed 2007; Oleson 1995). Today, rainwater harvesting is gaining popularity again for a variety ofenvironmental and economic reasons. Obviously, technology and techniques havechanged considerably from the days of the early Romans, but the theory remains thesame.

Rainwater harvesting is a technology used for collecting and storing rainwater from rooftops, land surfaces, road surfaces or rock catchments using simple techniques such as pots, tanks and cistern as well as more complex techniques such as underground check dams (Appan 1999; Prinz 1995; Zhu et al. 2004). Harvested rainwater is a renewable source of clean water that is ideal for domestic and landscape uses. Water harvesting systems provide flexible solutions that can effectively meet the needs of new and existing, as well as of small and large sites. The greater attraction of the rainwater harvesting system is the low cost as compared to other water supply systems, accessible and easily maintained at household (Abdulla and Al-Shareef 2009). Harvesting rainwater has a long-term impact on the local water resources by reducing demands for surface and groundwater withdrawals. Also, harvesting rainwater protects the integrity of local water resources by reducing nonpoint source pollution. Including rainwater harvesting in national water supply plans offers an alternative and sustainable water source while protecting the local environment.

Jordan is an arid to semi-arid country with land area of 92000 sq km. It suffered deficits in water resources since 1960s; the country ranks one of the world's 4 most water stressed countries. The total renewable freshwater resources of the country amount to an average of 750 MCM per year. Current water availability in Jordan amounts to about 145 m3 per capita per year, but it is predicted to be lower than 91 m3 per capita per year by the year 2025 (MWI, 2018). Urban development and increasing demand are putting stress on existing water resources. Attention is now focusing on alternatives water sources such as rainwater harvesting systems as supplementary water sources with multi-purpose functions. The increasing pressure on the available resources represent the challenge for scientists, engineers and policy makers because the entire development of the country in the different fields depend on the availability of this vital resource (Abdulla and Al-Shareef 2009)

2.2. Situation in the project area

Rainwater harvesting (RWH) is emerging as popular SCM in Jordan. There is currently a window of opportunity in Jordan with respect to promoting sustainable water management (SWM). Climate change is also expected to generate widespread response to adapt and mitigate the sufferings associated with the extreme events. Societal and cultural responses to prolonged drought include population dislocation, cultural separation, habitation abandonment, and societal collapse. However, climate and culture can interact in numerous ways. We hypothesize that people may resort to modify dwelling environments by adapting new strategies to optimize the utility of available water by harvesting rain rather than migrating to newer areas.

Rainwater harvesting (RWH) is listed among the specific adaptation measures that the water sector in Jordan needs to undertake to cope with future climate change. At present, there is limited application of RWH in the study area (Table 12), despite its high potential for alleviating the impacts of climate change on water security in many areas of Jordan.The total number of existing household water harvesting system in Madaba, Karak and Tafila governorates are 327, 350 and 8, respectively (DOS, 2018). These rooftop water harvesting systems are very small as compared to the existingnumber of households in these governorates (Table 13). Two interrelated reasons explain why people in these governorates do implement rainwater harvesting systems in their households. One reason is attributed to water subsidy which make investment in these systems is not justifiable. The other reason is the cost of investment in these systems which is approximately 2000 US$ (Abdulla, 2019) which is not affordable for most of the people living in this basin where most of them are low income people.

Household water harvesting is one of the priorities declared by MWI in Jordan in its past and updated water policies and strategies. The rooftop rainwater harvesting systems are cost effective and easier technical method of conserving water.Roof rainwater harvesting is a potential source of supply. It is popular as a household option as the water source is close to people, so it is convenient and requires a minimum of energy to collect it. An added advantage is that users own, maintain, and control their system without the need to rely on other members of the community or other stakeholders. The objective is to collect rainwater using appropriate infrastructure (e.g. cisterns) and national expertise to increase the volume of freshwater available for livestock watering and households' gardens irrigation.

Table 14 lists the number of rural single households in the project. Only the number of households that have rooftop ranges from 100-200 m2 will be considered for installation rooftop rainwater harvesting systems. The total number of households under this category is 13885. About 36% of these households will be targeted by the project. Accordingly, the project will benefit 5,000 single households among the most vulnerable in the rural area of the four-targeted governorates. The selected households should have a rooftop area varying between 100 and 200 m2. These households should be located in area where mean annual rainfall is exceeding 200 mm. The direct beneficiaries under this activity will amount to 27,500 persons. In addition, the water harvested through this technology will contribute to the irrigation of 800 dunum (80 ha) of household's gardens and provide drinking water for a total 20,000 animal heads (cattle and small ruminants).

Table 12: Existing rooftop water harvesting systems in the project area (source DOS, 2018)

Governorate	Number of household	Number of people
Madaba	327	1516
Karak	350	1642
Tafila	8	28

Table 13: Distribution of household by Area in Madaba, Karak and Tafila Governorates (DOS, 2018)

	40	75	125	175	250	350	450	600	
	<50 m^2	50-99 m^2	100-149 m^2	150-199 m^2	200-299 m^2	300-399 m^2	400-499 m^2	>500 m^2	Total Area
Madaba									
Apartment	613	4767	10488	7955	2816	200	32	27	972442.5
Single house	126	1017	3728	3636	1293	120	31	40	1586815
Villa	0	0	0	0	130	45	21	36	79300
Total									**2638557.5**
Karak									
Apartment	1036	4534	15570	14249	4632	262	53	72	1534516.25
Single house	592	1928	6692	6874	2922	217	56	70	3081380
Villa	0	0	0	0	41	25	7	14	30550
Total									**4646446.25**
Tafiela									
Apartment	216	1542	7914	3942	596	27	5	2	491322.5
Single house	88	883	3418	1762	426	20	5	1	921695
Villa	0	0	0	0	14	2	0	0	4200
									1417217.5
Ma'an									
Apartment	288	2798	11005	6214	1820	136	38	94	815136.25

Single house	47	451	2382	1266	467	21	1	9	684955
Villa	0	0	0	0	14	4	1	2	6550
Total									**1506641.25**

Table 14: available rural rooftop of single households in the project area (DOS, 2018)

	Roof area of single households (m^2)		
Governorate	100-149	150-199	Houses 100-199
Madaba	1777	1619	3396
Karak	3630	3657	7287
Tafilah	988	461	1449
Ma'an	1245	508	1753
Total	7640	6245	13885

2.3. Advantages of rooftop rainwater harvesting

RRWH technologies are simple to install and operate. Rainwater harvesting is convenient in the sense that it provides water at the point of consumption, and owners (either single-home owner or commercial building owner have full control of their systems, which greatly reduces operation and maintenance problems. Running costs, also, are almost negligible. Water collected from roof catchments usually is of acceptable quality for domestic purposes. In addition, roof top catchments are usually best for satisfactory domestic water requirements because they are close to the dwelling and isolated from many sources of contamination. Rain water may be utilized for drinking and cooking, for which high water quality is required, or for other domestic purposes, such as washing, bathing, toilet flushing, and landscape irrigation after filtration and disinfection. As it is collected using existing structures not specially constructed for the purpose, rainwater harvesting has few negative environmental impacts compared to other water supply project technologies. In summary the main advantages of RRWH are:

- Save water and energy
- Sources of energy are not needed to operate the system.
- Quality of rain water can be used as a primary source for specific uses and so reduce the water bill.
- Does not come into contact with soil and rocks where it dissolves salts and minerals. It is soft and can significantly reduce the quantity of detergents and soaps needed for cleaning.
- Very good for areas that are not served with water.
- Relatively limited technical knowledge is required.
- It uses local construction materials and labor.
- The owner user can easily maintain the system.
- Decrease local erosion and flooding caused by runoff from impervious cover such as pavement and roofs.
- The RRWH is usually found to be socially and environmentally acceptable

2.4. Disadvantages of rooftop rainwater harvesting

Disadvantages of rainwater harvesting technologies are mainly due to the limited supply and uncertainty of rainfall. Adoption of this technology requires “bottom up” approach rather than the more usual “top down” approach emloyed in other water resources development projects. This may make rainwater harvesting less attractive to some governmental agencies tasked with providing water supplies in developing countries, but the mobilization of local government and NGO resources can serve the same basic role in the development of rainwater-based schemes as water resources development agencies in the larger, more traditional public water supply schemes

The main disadvantages are:

- The high initial cost of building the permanent storage facilities, the primary expense is the storage tank.
- The quantity of rain water available depend or rainfall, for long periods of drought it is necessary to store excessively large volume of water.
- The mineral-free water is tactless and could cause nutritional deficiencies people prefer to drink water rich in minerals.

A rainwater harvesting system consists of six basic components (Figure 7): a collection area (roof), a conveyance system, and a cistern or storage tank, filtration, delivery system and treatment. Figure 3shows a schematic of a rooftop catchment system in Jordan

2.5. Technical assessment

2.5.1. Integrated approach to rainwater harvesting

Abdulla (2019) presented an integrated approach regarding rainwater harvesting that includes investigating potential of water savings, optimal tank sizing and cost-benefit analysis at different rainfall zones in Jordan. Water harvesting yields and optimal tank size are calculated for any roof area in different rainfall zones in Jordan. Abdulla (2019) presented basic information about these governorates regarding the existing roof area, annual rainfall (Table 15). The potential saving of water can reach about 7% of the total domestic demand (Table 16).

Table 15. Basic governorate data

Governorate	Total roof area (1000 m^2) (DOS 2015)	Per Capita water use 2015 (L/d/capita) (MWI 2015)	Population (DOS 2015)	Annual Rainfall (mm) (MWI 2015)
Madaba	2638.6	139.5	174,800	325.7
Karak	4646.5	160.2	292,500	355.6
Tafiela	1417.2	132.5	88,900	255.4

Table 16. .potential water harvesting and potential saving in the 12 Jordanian governorates

Governorate	Total domestic demand (10^6 m^3)	Potential water harvesting (10^6 m^3)	Percentage of water saving (%)

Madaba	8.9	0.69	7.72
Karak	17.1	1.32	7.73
Tafiela	4.3	0.29	6.73

This activity has a direct impact as adaptation at the local level. Abdulla (2019) indicated that HRWH system can cover 30% of the domestic demand in typical Jordanian household. All the model systems are also adaptive in the sense that they provide water independently of any problems that might affect the public water supply and/or private tanker water services due to climate-related flooding and/or pollution of surface waters. Locally, risks of storm water run-off, pollution, flooding and erosion have been reduced (Abdulla, 2019). The proposed activities will support communities to access and reliability to water resources. This activity has the ability to cut 30% of water used during the rainy season (about six months). The benefits of rainwater utilization will be increased when a tank is used to store water. Over 30,000 people (5000 households) will be directly benefitted from this activity. This project has the potential to grow in size by increasing the water tank capacity, amount of tanks, or by developing a basement utilization design system.

Existing water supply systems will be improved and rainwater will be harvested for domestic purposes.

Proposed sub-activities are:

- Training and awareness programme on rain water harvesting, climate change adaptation.
- Training to youths and women from the three governorates in a inclusive way.
- The existing drinking water and irrigation supply infrastructure that uses water sources will be improved and upgraded or further expanded.
- Construction of rooftop rainwater collection system in Mujib Basin, every households and school buildings.
- Construction of rainwater collection systems at least of 50 m3 capacity to 100m3 at suitable intervals.
- Construction of recharge ponds and pits for ground water recharge and irrigation.
- Capacity building of Local users committee

Effective Rainwater Harvesting (RWH) techniques have been known and practiced in Jordan for thousands of years. Today there is a rapid increase of interest in rainwater harvesting and storage as a potential water supply to meet part of urban and rural water demand. In this report, rainwater harvesting potential for municipal use in rural and urban areas in four Jordanian governorates (Madaba, Karak, Tafila and Ma'an) has been reviewed. In addition, the feasibility of rainwater harvesting across these governorates has been investigated. The study provides specific recommendations on the most appropriate methods and technologies adapted to Jordan. Tangible figures on quantities of collected water, water quality and its health and environmental impacts, appropriate designs of water harvesting systems, and cost benefit analysis have been provided.

In this report, water harvesting yields are calculated for 5 roof areas for residential buildings ranging from 100 m2 to 200 m2. These roof areas cover only single houses residential buildings. Public buildings such as schools and worship buildings also included. The rainfall data used in this study represents 6 rainfall zones ranging from 50 mm to 350 mm of annual rainfall. The results revealed that potential harvested water that could be obtained from a roof with an area of 100 m2 may range from 8 m3 to 28 m3 for rainfall zones ranging from 100 mm to 350 mm.

This report also provides the optimal tank size for any roof area in these rainfall zones. For example, for a roof area with 100 m2 the water harvesting tank may range from 3.5 m3 to 12.5 m3 for annual rainfall ranging from 50 mm to 350 mm.

Benefit-cost analyses of one roof harvesting systems (concrete tank) have been applied in this report. The unit price that is assigned for the water harvesting plays an important role in deciding whether the proposed system is economically feasible or not. The results revealed that concrete tanks will not be economically feasible in all rainfall zones when a 1.0 JD/m3 is assigned as a cost of harvested water. If 3 JD/m3 is applied (the price of water tanker) the water harvesting systems will be feasible. The construction and installation costs of rooftop rainwater harvesting could cost as little as 800JDfor concrete tank size (less than 8 m3) and might go up to 1500 JD for tank size around 30 m3. In general, the overall system cost typically rises with increasing tank volume, but system cost per m3 of storage falls

By practices and for many years, RWH was highly accepted and adopted practices in many places in Jordan. The latest Population and Housing Census of 2004 (DOS, 2004) indicated that there are about 33200 RWH systems in Jordan. Most of these systems (91.8%) are located in the Northern governorates. This practice of RWH systems is highly related to some cultural values that were gained and transferred from one generation to another. The preliminary cost-benefit analysis suggests that implementing a rainwater collection system is not economically feasible at low water price. But this should not prevent implementing the RWH because there are extra benefits would be added to the system, such as reduced impact on the environment, research opportunity, and better public perception of Jordanian government's goals towards sustainability. The cost of implementing a RWH system would be further reduced by including it in the construction of a new building or during a major renovation of an existing building. For all the reasons discussed above, it is highly recommended that RWH systems should be installed in newly constructed building that has an area greater than 200 m2 and located in zones of mean annual rainfall greater than 300 mm.

2.5.2. System design and components

Catchment area

The catchments area is the surface on which the rain that will be collected falls. The collection area in most cases is the roof of a house or a building; however, catchment areas may include driveways or swales in yards. Rainwater harvested from catchments surfaces along the ground, shall only used for irrigation because the increased risk of contamination. The effective roof area and the material used in constructing the roof influence the efficiency of collection and the water quality. Smoother, cleaner and more impervious roofing materials are preferred; they contribute to better water quality and greater quantity. Tiled roofs or roofs sheeted with corrugated mild steel etc. are preferable since they are the easiest to use and give the cleanest water.

Cement and tiled roofs are the most common roofs used in Jordan (Abdulla 2019). These types of roofs have good durability and provide good quality water. Composite asphalt and some painted roofs are recommended only for non-potable water use because they could leach toxic materials in to rain water as it touches the roof surface. Roofs that have lead materials should be prohibited because acidic rain may cause contamination for collected water from these roofs. Regardless of the roof material, many designers assume about a 20% loss of annual rainfall. These losses are due to roofing material texture, evaporation, losses occurring in gutters and storage tanks, and inefficiencies in the collection process (Abdulla 2019).

Conveyance system

A conveyance system usually consists of gutters or pipes that deliver rainwater falling on the rooftop to cisterns. Gutters or pipes must be properly sized, sloped and installed in order to maximize the quantity of harvested water. The most common materials of gutters are galvanized steel, fiberglass, plastic, stainless copper, cast iron and UPVC. The gutters and down pipes are usually installed in the wall of the building, and sometimes the down pipes are fitted inside the wall during construction. The size of the gutters depend upon the area of the roof and the rainfall amount, the size of the gutters used ranges between 5-10 cm diameter (Alpaslan 1992).The diameter of the gutters can be determined using the Rational Equation ($Q=CIA$). Where Q is the discharge in m^3/sec, C is the runoff coefficient (0.8) and A is the roof area in m^2 and I is the rainfall intensity in mm/hr and can be obtained using the Intensity-Duration-Frequency (IDF) curves. Both drainpipes and roof surfaces should be constructed of chemically inert materials such as wood, plastic, aluminum, or fiberglass, in order to avoid adverse effects on water quality. Leaf screens are important to keep leaves and other debris from entering the system, the gutter should have a continuous leaf screen made of 0.4 mm fine mesh installed along their entire length.

Storage tank

The water ultimately is stored in a storage tank or cistern. For a long time, Jordanians have been building cisterns to collect and store rainfall from roofs of their houses. Concrete tanks are the most common used tanks in Jordan; they can be built above or below ground (Abdulla 2019). They are usually made on site and are durable and long lasting. Above ground tanks are easy to detect cracks and leaks, water can be extracted via gravity and/or pumps, they can also be raised off ground to increase water pressure, they are easy to drain for cleaning, and usually cost less than below ground tanks (Abdulla and Al-Shareef 2009). But they take up space, they are subjected to weather conditions, and require anchoring to the ground for when the tank has lees water. Below ground tanks can save space, but they are more difficult to extract water from - usually need a pump, it is hard to detect leaks or problems, they are difficult to drain for cleaning, there is a risk of contamination from septic tanks or floodwaters, it can be damaged by tree roots, if access point is left uncovered, there's a risk of children, adults and animals drowning or contaminating the water and usually have a large excavation costs. However, they can sometimes crack - especially when they are below ground in clay soil. They're good for preventing algal growth (light can't penetrate) and they keep water cool. The storage tank represents the major cost in the system. The storage tank (cistern) characteristics are:

- A cistern should be durable and watertight.
- Close to the water supply and demand source
- Select maximum height location to avoid pumping cost and extract water by gravity
- Keep away from contaminant source of septic tank at least --- m

- Possibility to add water from other sources such as tanker water in arid seasons (near entrance preferred)
- A smooth clean interior surface is needed.
- Joints must be sealed with non-toxic waterproof material.
- Have a cover to prevent evaporation and mosquito breeding and algae growth fromcontact with sunlight.
- Should not present an excessive danger to users falling in or by the tank failing in a dangerous way
- Should provide water of a quality commensurate with its intended use – water that is used for drinking requires particular care:
- The tank should be covered to prevent entry of light, and sealed against intrusion by mosquitoes and small creatures
- The tank should be ventilated to prevent anaerobic decomposition of any matter that is washed in.

Ideally, it should also:

- Be affordable
- Be easy and cheap to maintain in good condition.
- Have a means by which water can easily enter and easily be withdrawn (into the normal household receptacle used in the area)
- Have some arrangement to satisfactorily handle tank overflow

First Flush

Contaminants washed from a roof are usually concentrated in the first part of the runoff. Such contaminants contain various impurities such as bird droppings and dust. After this initial runoff has washed the roof, the collected water can be considered safe. This process is called the first flush diversion. The purpose of the first flush diversion is to collect and disposal of the first flush of water from a roof, especially where the collected rain water is to be used for human consumption. First-flush devices ensure a certain degree of water quality in harvested rainwater. The first flush volume is assumed to be about 40 liters for each 100 m^2 of roof area. . Many first-flush devices are simply and cleverly designed. Such devices include tipping buckets that dump when water reaches a certain level. The most simple of these systems consists of a stand pipe and gutter downspout located a head of the down spout from the gutter to the cistern, the gutter downspout and top of the pipe are fitted and sealed so water will not flow out the top, once the pipe has filled the rest of the water flows to the downspout connected to the cistern.

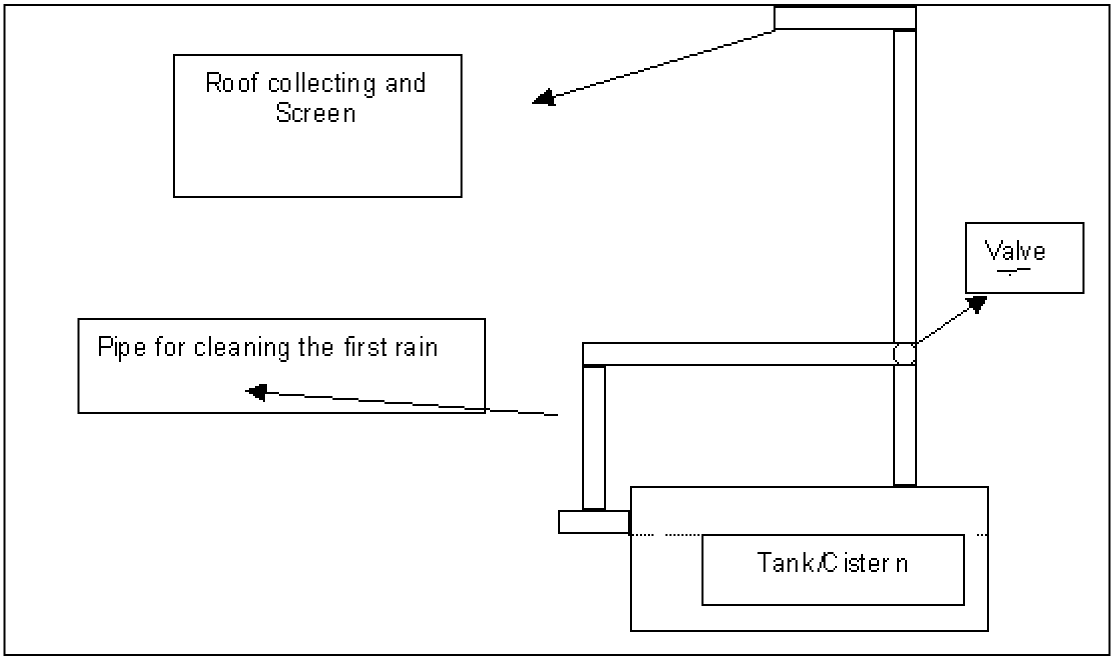


Figure 7: Rainwater harvesting system (source author)

2.5.3. Potential for rooftop rainwater harvesting in households and public buildings

In this report, water harvesting yields are calculated for 5 roof areas ranging from 100 m^2 to 200 m^2. These roof areas cover residential buildings (single houses) (Table 17). In addition, two sizes of public buildings (schools and worship) 500 m2 and 750 m2 (Table 18). Monthly rainfall data were obtained from the Ministry of Water and Irrigation. The rainfall data used in this study represents 6 rainfall zones ranging from 100 mm to 350 mm of annual rainfall. The volume of rainwater that could be harvested from each roof for each rainfall zone was calculated considering the annual rainfall data, the total roof area, and a runoff coefficient (efficiency) of 0.8. Such a runoff coefficient indicates a loss of 20% of the rainwater that is discarded for roof cleaning and evaporation.

Thus, the volume of rainwater that could be harvested from each roof was determined by using Eq. (1).

$$VR = R \times A \times C \qquad (1)$$

Where:

VR = Annual volume of rainwater that could be harvested, (m^3)

R = Average annual rainfall in each rainfall zone (m/y),

A = Roof area in (m^2),

C = Runoffcoefficient (non-dimensional).

Table 17: Potential annual harvested rainwater in m^3 from different roof areas and rainfall amounts in the project area (households)

Roof Area (m^2)	Annual rainfall (mm)					
	100	150	200	250	300	350
100	8	12	16	20	24	28
125	10	15	20	25	30	35
150	12	18	24	30	36	42
175	14	21	28	35	42	49
200	16	24	32	40	48	56

Table 18: Potential annual harvested rainwater in m^3 from different roof areas and rainfall amounts in the project area (Public building)

Roof Area (m^2)	Annual Rainfall (mm)					
	100	150	200	250	300	350
500	40	60	80	100	120	140
750	60	90	120	150	180	210

In addition to single households there is significant number of other buildings such as business establishments (schools, public and commercial buildings) and worship buildings (Table 1). The only information obtained from the Department of Statistics is the number of these buildings. Nothing mentioned about the characteristics of these buildings in term of the size as well as the potential beneficiaries. To calculate the potential water saving the following assumptions were considered:

- Total number of buildings (Business and worship) in the project area as calculated based on the % of governorate population lives in the Dead Sea basin
- Number of targeted buildings: is calculated based on the assumption the project will target 30% of the total number of buildings in the study area
- Mean annual rainfall is calculated for one representative station from each governorate. These stations are Madaba station, Karak station, Tafilah station, and Wadi Musa station
- Roof area is assumed as a minimum of 500 m2
- Runoff coefficient is 0.8 (Abdulla, 2019)
- Water saving (m3) = Runoff coefficient × annual rainfall (mm) × roof area (m)/1000

Usually such buildings have a roof area exceeding 500 m^2 and assuming that the project will target 50% of these buildings.

Gov	Schools	Worship	% of the Governorate population lives in Dead Sea Basin	Number of building	Targeted building 30%	Annual Rainfall (mm)	Roof area (m2)	Runoff Coeff	potential saving (m3)
Madaba	913	200	82	886	266	325.7	500	0.8	34645
karak	1842	300	92.6	2096	629	355.6	500	0.8	89421
tafilah	643	210	97	784	235	255.4	500	0.8	24021
Maan	1296	337	18.2	280	84	270	500	0.8	9069
			Total	4046	1214				157156

2.5.4. Optimal tank size calculation

Usually, the main calculation when designing a RWH system will be to size the water tank correctly to give adequate storage capacity. The storage requirement will be determined by a number of interrelated factors. They include:

- local rainfall data and weather patterns
- roof (or other) collection area
- runoff coefficient
- user numbers and consumption rates

Assuming that rainwater harvesting has been determined to be feasible, two kinds of techniques--statistical and graphical methods--have been developed to aid in determining the size of the storage tanks. These methods are applicable for rooftop catchment systems only.These methods vary in complexity:

- Demand side approach (dry season demand versus supply)
- Supply side approach (graphical methods)

The first method is the simplest method and most widely used. The second method uses statistical indicators of the average rainfall for a given place and it is used in low rainfall areas or areas where the rainfall is of uneven distribution. During some months of the year there may be an excess of water, while at other times there will be a deficit (see Table 4 and Figure 2). If there is sufficient water throughout the year to meet the demand, then sufficient storage will be required to bridge the periods of scarcity. As storage is expensive, this should be done carefully to avoid unnecessary expense. To apply the supply side approach the following steps should be followed

- Plot a bar graph of mean monthly roof runoff for a specific house or building in a specific location. Add a line for demand per month (Figure 8)
- Plot a cumulative roof runoff graph, by summing the monthly runoff (Figure 9)
- Add a line showing cumulative water use

To illustrate the method above consider the following example for a roof area of 200 m^2 and annual rainfall zone of 500 mm

- Roof area: 200 m^2
- Runoff coefficient: 0.8
- Average annual rainfall: 500 mm per year
- Annual available water (assuming all is collected) = 200 x 0.5 x 0.8 = 80 m^3
- Monthly available water = 80/ 12 = 6.66 m^3/ month

So, if we want to supply water all the year to meet the needs of this building, the demand cannot exceed 6.66 m^3/month. Table 19 shows the spreadsheet calculation for sizing the storage tank. It takes into consideration the accumulated inflow and outflow from the tank and the capacity of the tank is calculated as the greatest excess of water over and above consumption. This occurs in March with a storage requirement of 36.9 m^3 (Figure 9). All this water will have to be stored to cover the shortfall during 9the dry period.

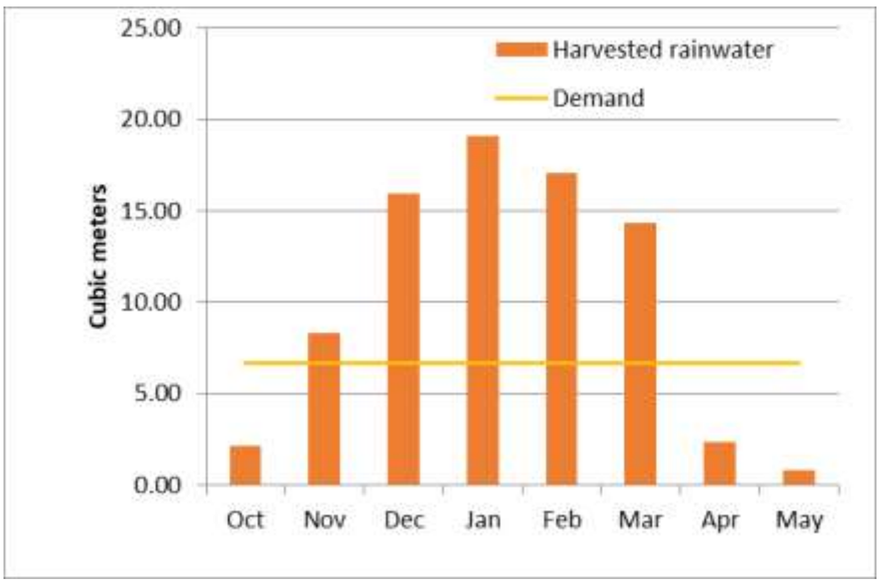


Figure 8: Comparison of the harvested water and demand for each month

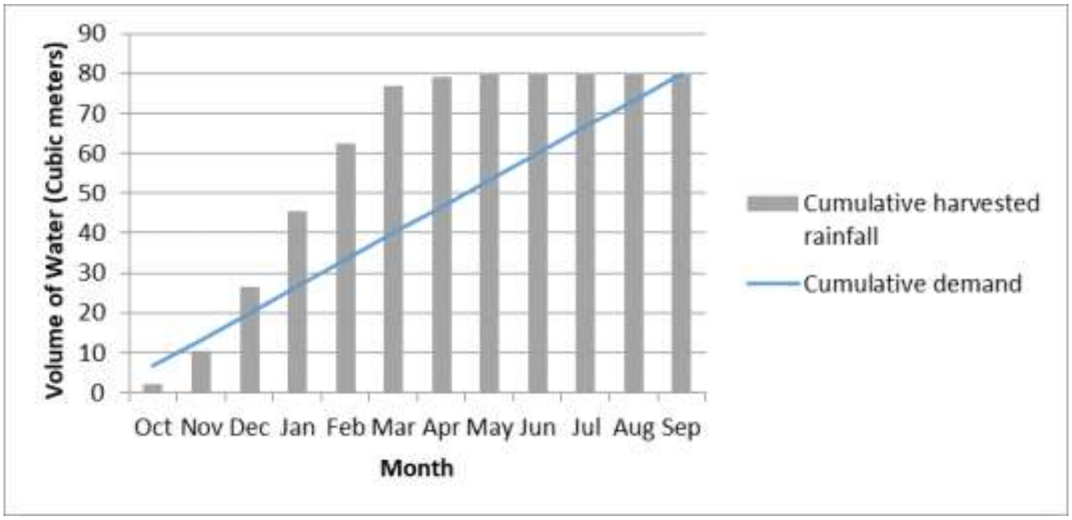


Figure 9: Showing the predicted cumulative inflow and outflow from the tank. The maximum storage requirement occurs in March (36.8 m^3)

Table 19: Example on storage tank calculation

Month	Rainfall (mm)	Rainfall harvested (cubic metres)	Cumulative rainfall harvested (cubic metres)	Demand (based on total utilisation)	Cumulative demand (cubic metres)	Difference between column 4 and 6
Oct	13.39	2.14	2.14	6.67	6.67	-4.52
Nov	51.77	8.28	10.43	6.67	13.33	-2.91
Dec	99.79	15.97	26.39	6.67	20.00	6.39
Jan	119.53	19.12	45.52	6.67	26.67	18.85
Feb	106.48	17.04	62.55	6.67	33.33	29.22
Mar	89.49	14.32	76.87	6.67	40.00	**36.87**
Apr	14.69	2.35	79.22	6.67	46.67	32.56
May	4.86	0.78	80.00	6.67	53.33	26.67
Jun	0.00	0.00	80.00	6.67	60.00	20.00
Jul	0.00	0.00	80.00	6.67	66.67	13.33
Aug	0.00	0.00	80.00	6.67	73.33	6.67
Sep	0.00	0.00	80.00	6.67	80.00	0.00

Based on the above discussion on the optimal tank sizing, the approach applied on the four governorates. Accordingly, Table 20 shows the optimal tank size for single households (100-200 m2) for different roof areas and different rainfall zones (100 mm to 400 mm). Table 20 will be used in selecting the optimal tank size for each roof area in each governorate. Similarly, the optimal tank sizes for roofs 500 m2 and 750 m2 were used to represent the public buildings (Table 20).

Table 20: Optimal water harvesting tank size for different roof areas in the project area (households and public buildings)

Roof Area (m^2)	Annual Rainfall (mm)						
	100	150	200	250	300	350	400
Households							
+100	3.5	5.2	6.95	8.7	10.7	12.5	14
125	4.3	6.5	8.7	10.9	13.3	15.6	17.5
150	5.2	7.8	10.4	13	16	18.7	21
175	6.1	9.1	12.2	15.2	18.7	21.8	24.5
200	7	10.4	13.9	17.4	21.4	24.9	28
Public buildings							
500	17.4	26.1	34.8	43.5	53.4	62.3	70
750	26.1	39.1	52.2	65.2	80.1	93.4	105.1

2.5.5. Cost benefit analysis of roof water harvesting systems

In reality the cost of the tank materials will often govern the choice of tank size. In other cases, such as large RWH programmes, standard sizes of tank are used regardless of consumption patterns, roof size or number of individual users. Cost benefit analysis has been undertaken due to suitable economic information being able to be sourced. The cost of a RWH system is generally easier to evaluate than its benefit. We might get a builder's quotation or we look at similar systems that have recently been built. Generally, system cost is dominated by storage cost and as a rough approximation we can adjust the system cost to allow for a larger size of storage tank according to scale up formula. The operational and maintenance costs of RWH are small compared to the construction costs and therefore only the construction costs have been considered in the cost-benefit calculation. Costs from similar projects have been used to obtain estimates for the construction costs of storage, guttering and water treatment. All these costs relate to the last 3 years and therefore inflation has not been factored in. In this study, cost quotation from recently implemented roof rainwater harvesting projects in Mafraq and Karak governorates. The average cost for underground concrete tank the cost may range from 60-100 JD/m^3 (Figure 7) (Abdulla, 2019).

The above costs are used only to perform the economic feasibility of the proposed tank sizes for different rainfall zones and roof area. Estimating the total cost of concrete tank will involve the consideration of all of the materials involved in the production of the system (steel, concrete, pipes, pumps, steel gate, plastering and isolation), excavation and the required labor for its construction. The system proposed, if feasible, would be in use for many years (close to the life span of the building); hence future costs (and benefits) will have to be discounted before computing total cost. The construction and installation costs of rooftop rainwater harvesting could cost as little as 2000 JD for tank size less than 20 m^3 and might go up to 6000 JD for tank size around 100 m^3 (Figure 10). Figure 8 shows how overall system cost typically rises with increasing tank volume, but system cost per m^3 of storage falls (Figure 11). Table 21 shows a comparison between different type of storage tank. Since the lowest tank size that will be used in this project is 10 m3, it is highly recommended to install concrete tank.

The justification for the selection of constructing underground water storage is shown in the tables (21a &b) below. Additional justification is its cost is reasonable compared to the plastic tanks and it is also permanent structure with life span of about 35 years (Abdulla, 2019). The cost proposed for constructing the concrete tank of 10 m3 and above can be obtained by adopted the proposed cost by Abdulla (2019) and confirmed by site visits and meeting with at least three contractors.

Table 21a: comparison between different water storage

Type	**Advantage**	**Disadvantage**	**Price**	**Source**
Concrete tanks	Cooler water storage Can be customized	High building cost Long building time High maintenance cost Spatial restrictions Building permits	For above and below ground options (the price shown above)	(Abdulla, 2019), also field visits to some contractors confirm the same prices as indicated by (Abdulla, 2019)
Plastic tanks	Easy and quick to install Low cost for small structure Easy maintenance Easy transportation	Risk that beneficiaries sell it Limitation in pipe connections High cost for larger sizes	The price of 1 m^3 tank is 50 US$ For 2 m^3 it cost 110 US$ For 3 m3 it costs 160 US$ After that it will be 150US$. M3 5 m^3 (700 US$) 10 m^3 (1410 US$) 20 m^3 (2820 US$)	(different suppliers)
Metal tanks	Easy transportation Easy/quick installation Modular/variety of sizes Easy maintenance	Tank stability Corrosion	The cost of 1 m3 is about 50US$ For 2 m3 the costs is 125 US% For 7 m^3 with thickness 1.8 mm (325US$) 10 m3 with 1.8 mm thickness	Different suppliers

			(610 US$) 12 m3 with 1.8 mm thickness (750US$)	

Table 21b: Advantages and disadvantages of above and underground water storage tanks (source: Jordan Uniform Plumbing code) (USAID, 2018, Water Management Initiative (WMI))

Storage tank above ground surface	Storage tank underground surface
Advantages Easy to detect leakage	Advantages Required small area
Easy to purchase	not exposed to direct sunlight which usually contributes to the buildup of alage
It can be installed close to demand point which can increase the efficiency of the system	The surrounding temperature is stable
Disadvantages	Disadvantages
Easy to be damaged	Need for a pump to extract water
Required larger area	Difficult to detect leakage
Prone to weather conditions	Contamination from near by sources is possible

Rainwater harvesting's economic feasibility can also be calculated by its synergistic values. Rainwater is soft, which means less detergent is used and released into the environment. Also, utilizing rainwater as opposed to municipal and well water, benefits local streams, lakes, ponds and groundwater sources since less water will be pulled from these sources. Such benefits may not have a direct price, but their value is long lasting and considerable.

Annual benefit of having a RWH system is made up two elements: the annual saving (costs avoided) by having RWH plus the value of any extra water the household uses as a result of having it. This second element – extra water – is very difficult to assess, so it is wisest to base the annual benefit just on the first element, namely the annual saving. For a few households, those who used to pay money for their water to be supplied and brought to the household, the annual saving is fairly easy to work out. The benefits of the RWH system have been quantified in terms of water quantity benefits. The cost of water from tankers during the dry season is 3 JD/ m^3. However due to the water shortages experienced in the dry season, a unit of water obtained during the dry season would be expected to be of higher value than a unit in the wet season. The above cost is the maximum cost that can be paid. Other costs of water were in this study: (0.5 JD/m^3 residential rates at medium to high level of consumption; 1.0 JD/m^3 similar to commercial and industrial rates; 2 JD/m^3). In addition, the following assumptions were used the cost-benefit analysis conducted in this study (Tank useful life= 35 years; Interest rate = 5%)

Figure 12 shows the net present worth benefit (NPWB) for concrete tanks. The price of saved water is assumed to be 0.5 JD/m^3.   The concrete tanks are not economically feasible at this cost.

Similarly, at price of water saving of 1.0 JD/m^3, the concrete tanks are not economically feasible at this cost (Figure 13). At cost of saving of 3 JD/m3, concrete tanks are economically feasible at at this cost (Figure 14).

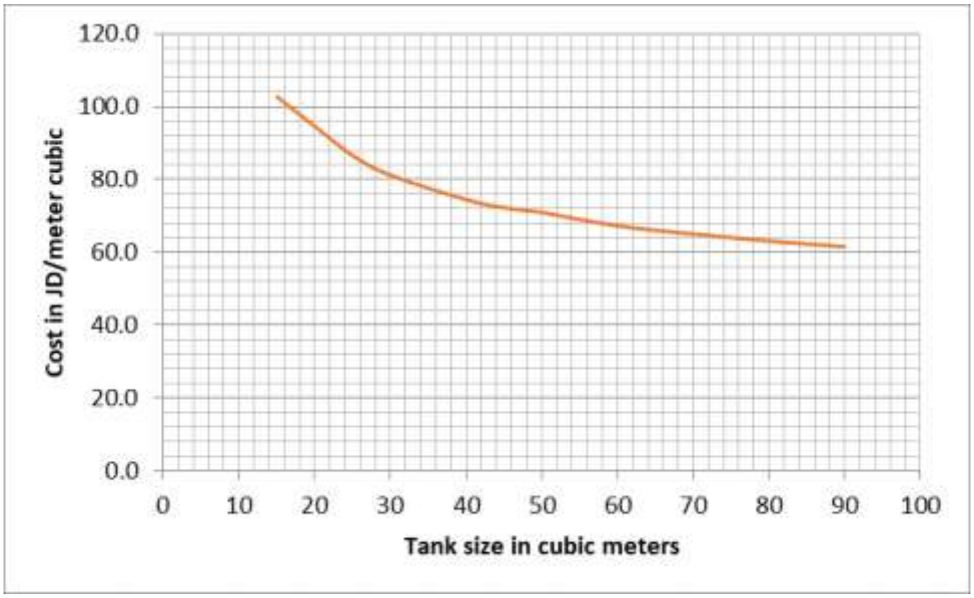


Figure 10: Unit cost variation of RWH storage tank

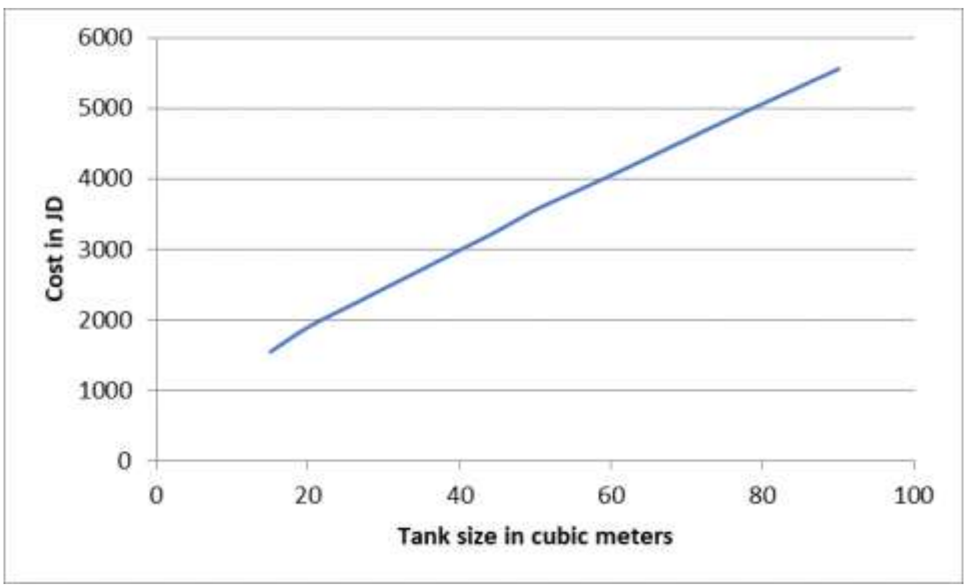


Figure 11: Total cost variation of concrete RWH storage tank

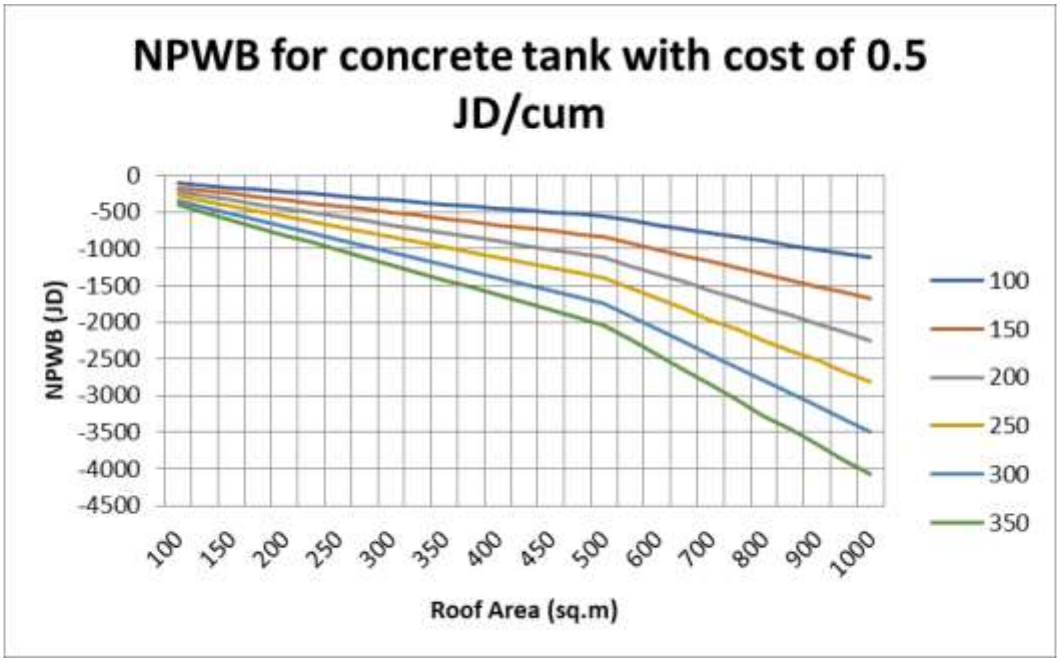


Figure 12: Cost –benefit analysis for concrete tank with water price of 0.5 JD/m^3

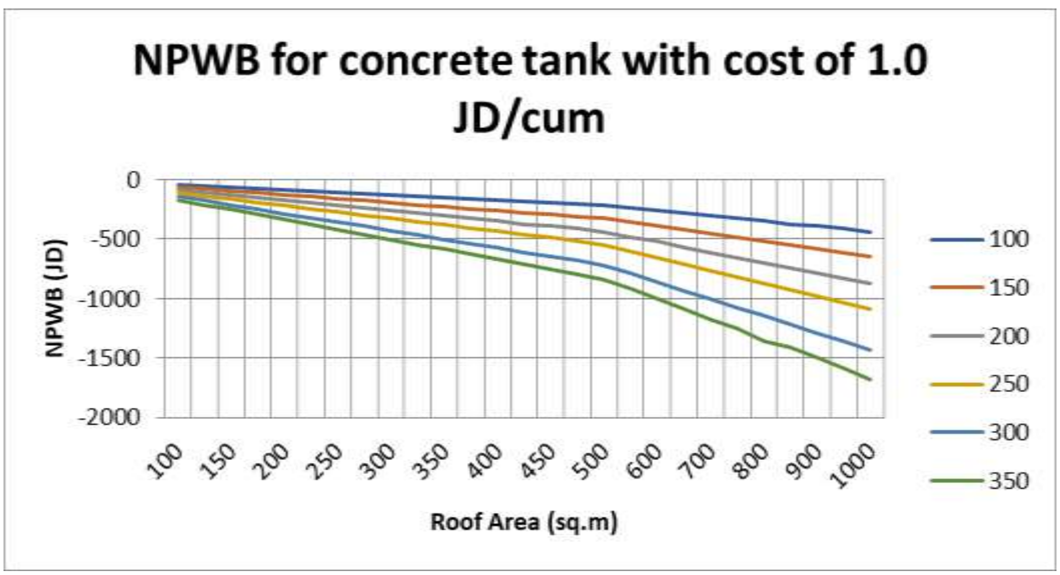


Figure 13: Cost –benefit analysis for concrete tank with water price of 1.0 JD/m^3

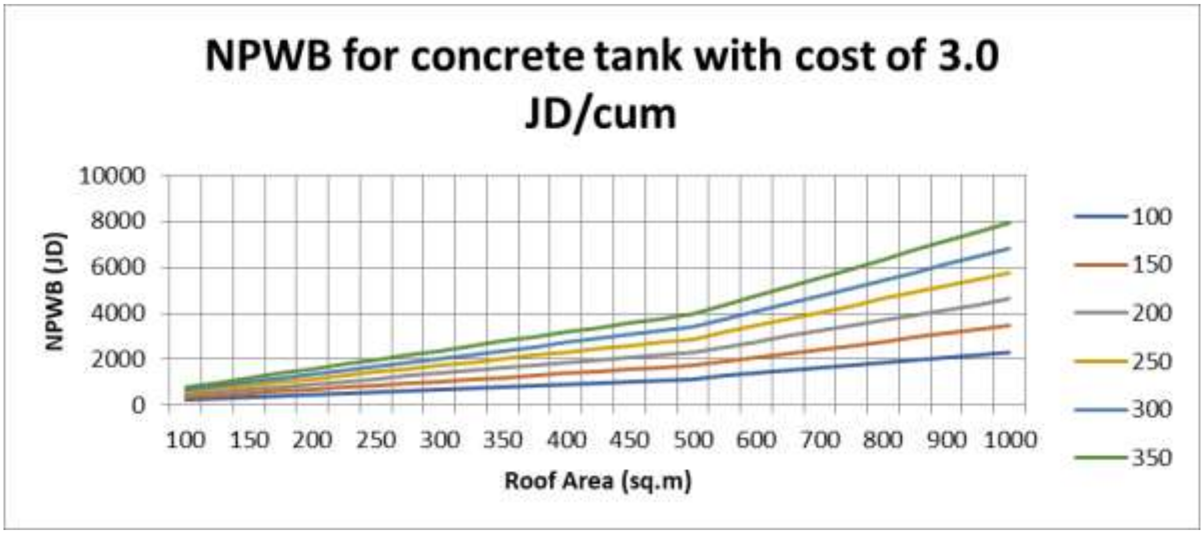


Figure 14: Cost –benefit analysis for concrete tank with water price of 3 JD/m^3

2.5.6. Water quality and its health and environmental impacts

Rainwater itself is of excellent quality; it has very little contamination, even in urban or industrial areas, so it is clear, soft and tastes good. Contaminants can however be introduced into the system after the water has fallen onto a surface. Studies show that rooftop rainwater harvesting, RRWH, yields harvested waters with contaminants in levels acceptable by international drinking water standards (Abdulla and Al-Shareef 2009) and is thus thought to be a superior option when considering domestic water supply, in particular potable water. Among these studies is the one carried by Abdulla and Al-Shareef (2009). Their analysis of samples of harvested rainwater from residential roofs indicated that the measured inorganic compounds generally matched the WHO standards for drinking water. On the other hand, Fecal Coliform, which is an important bacteriological parameter, exceeded the limits of drinking water. However, to be effective, this quality must be both available during collection and maintained until the water is consumed. In the past, this aspect has not been adequately addressed.

Accounts of serious illness linked to rainwater supplies are few, suggesting that rainwater harvesting technologies are effective sources of water supply for many household purposes. It would appear that the potential for slight contamination of roof runoff from occasional bird droppings does not represent a major health risk; nevertheless, placing taps at least 10 cm above the base of the rainwater storage tanks allows any debris entering the tank to settle on the bottom, where it will not affect the quality of the stored water, provided it remains undisturbed. Ideally, storage tanks should be cleaned annually, and sieves should be fitted to the gutters and down-pipes to further minimize particulate contamination. A coarse sieve should be fitted in the gutter where the down-pipe is located. Such sieves are available made of plastic coated steel-wire or plastic, and may be wedged on top and/or inside gutter and near the down-pipe. It is also possible to fit a fine sieve within the down-pipe itself, but this must be removable for cleaning.

2.5.7. System Operation and Maintenance

Operation and maintenance are simple and depend mainly in cleaning the harvesting system annually before the start of the major rainfall season. Maintenance is generally limited to the annual cleaning of the tank and regular inspection of the gutters and down-pipes. Maintenance typically consists of the removal of dirt, leaves and other accumulated materials. Such cleaning should take place annually before the start of the major rainfall season. However, cracks in the storage tanks can create major problems and should be repaired immediately. In the case of ground and rock catchments, additional care is required to avoid damage and contamination by people and animals, and proper fencing is required

It is recommended that a tank be flushed at least once a year to remove all silt accumulation from the previous year, The sediment which builds up on the bottom of tanks should be cleaned when significant buildup occurs; if your tank does not provide a bottom clean-out valve then the tank usually must be drained in order to clean it, all piping system should be flushed and cleaned.

2.5.8. Proposed rooftop rainwater harvesting systems for single households in the project area

The above sections were used to propose the rooftop rainwater harvesting systems to be installed by the project. In Table 22, line 1 lists the targeted governorates. Line 2 shows the proposed rooftop area in each governorate. Two rooftop areas were considered 100-149 m2 (average size 125 m2) and 150-199 m2 (average 175 m2). Line 3, lists the optimal tank size for each rooftop in each governorate. For example, in Madaba governorate, for households that have sizes between 100-149 m2, the recommended optimal tank size is about 15 m3. This size was obtained based on the mean annual rainfall (324 mm) of Madaba station (Table 4) and using Table 20. Line 5 lists, the unit cost per m3 of concrete tank in JD, this information is obtained from Figure 10. Line 6 is the conversion from JD to US$. Line 7 is the cost of the proposed tank. Line 7 is showing the annual potential of water harvesting and is calculated using equation (1) with runoff coefficient of 0.8. Line 8 list the number of households in each governorate for each category of roof top area. Line 9 list of the targeted households meeting the criteria of selection, here we assume only 36% of households will be targeted. The last line shows the total cost of installation. Similarly, Table 23 shows the calculation of public building.

Table 22: Proposed rooftop rainwater harvesting systems for single households in the project area

Governorate	Madaba		Karak		Tafilah		r	
Roof area (m^2)	100-149	150-200	100-149	150-200	100-149	150-200	100-149	150-200
Optimal tank size (m^3)	15	20	15	20	10	15	10	15
Unit price JD/m3	102.8	94.7	102.8	94.7	106.5	102.8	106.5	102.8
Unit Price US$/$m^3$	144.948	133.527	144.948	133.527	150.165	144.948	150.165	144.948
Cost US$ for each tank	2174.22	2670.54	2174.22	2670.54	1501.65	2174.22	1501.65	2174.22
Potential saving (m^3)	32.43	45.4	34.26	47.96	25.57	35.8	21.59	30.2

Total number of rural single households	1777	1619	3630	3657	988	461	1245	508
36% of households install	640	583	1307	1317	356	166	448	178
Total cost	1390892.02	1556497.5	2841270.7	3515819.3	534106.87	360833.55	673039.53	386576.32

Table 23: Proposed rooftop rainwater harvesting systems for public buildings in project area

Governorate	Madaba		Karak		Tafilah		Ma'an	
Roof area (m^2)	500	750	500	750	500	750	500	750
Optimal tank size (m^3)	50	75	60	90	40	65	40	60
Unit price JD/m3	71	64.2	66	61.7	74.6	65	74.6	66
Unit price US$/m3	100	90.52	93.06	87	105.2	91.65	100	93.06
Price of each tank US$	5000	6789	5583.6	7830	4208	5967	4000	5583.6
Potential water saving (m3)	129.7	194.6	137	205.6	102.3	153.4	86.4	129.5
Total Number of schools	913		1842		643		1296	
Total Number of worship	200		300		210		337	
% of schools	45.65		92.1		32.15		64.8	
% of worship	10		15		10.5		16.85	

Total cost of installing tanks in school	228250		514249.56		135287.2		259200	
Total cost of installing worship	50000		83754		44184		67400	
Total cost								

3. Installation of water-saving devices (WSDs)

The government of Jordan realized that conserving and protecting water resources could prove more sustainable and cost-effective. Therefore, the Ministry of Water and Irrigation undertake all the necessary measures leading to the establishment of comprehensive programs for water resources conservation, reduction of water losses, and improvement of water use efficiency in all sectors. A Water Demand Management Unit (WDMU) was established at the Ministry of Water and Irrigation by the end of 2002 to undertake the responsibility of Water Demand Management. The WDMU leads programs of **Water Demand Management at the Municipal Sector** that aim at achieving greater efficiency in residential, municipal and commercial, use of water. Activities include:

A Tariff structure that promotes water conservation: water tariff is used as an economic instrument to set an incentive for water conservation. In this tariff structure, the price per unit of water increases continuously as the total amount of water used. This structure sends a signal to the consumer that increased water use results in an increased water bill. All of households connected to public network are metered for example the number of users metered in Karak is about 47520 while in Ma'an it is bout 22420 (MWI, 2018). The current tariff in Jordan is shown in Figure 15. It is a lump sum for the first 18 m3 of usage, then the price per m3 will increase as the water consumption increased.

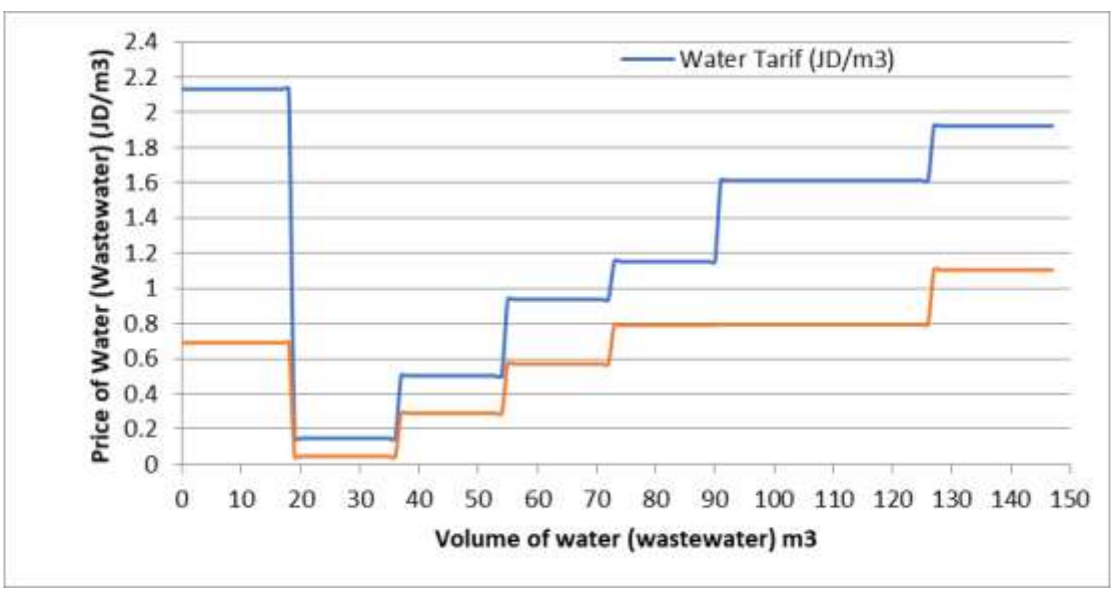


Figure 15: water and wastewater tariff for domestic usage

- Increasing water awareness through water media campaigns: This includes campaigns through T.V. spots, radio and newspapers to explain the water situation and how to participate in efforts in conserving water or using water more efficiently.
- Introducing Water Demand Management concepts at school curriculum: Education at school is used to as a way to increase understanding about water scarcity and learn about more efficient use of water. An interactive CD for Children on Water Demand Management concepts, to support school curriculum concepts has been developed
- Introducing new water laws and regulations that aims at conserving water: For example, the principal code dealing with water consumption, the "National Jordanian Construction Code: Water Supply for building Codes" have been updated to address concepts of water efficiency and thresholds for flow rates in water outlets in buildings. Beautification Codes were also updated to introduce concepts of water savings in outdoor uses of water. Lectures that target design engineers and plumbing technicians to increase awareness of the new codes and their potential water savings are carried out.
- Promoting using technology and water saving devices: Using water saving devices has proved to save 30% of water used in buildings (Abdel Khaleq, 2008). Accordingly, Prime Ministry office in Jordan has issued instructions to all Ministries to install those water saving devices in all governmental buildings. Intensive campaigns through all sorts of media to encourage citizens and large consumers to use those devices were implemented

A major part of those activities were implemented under a five year program known as Water Efficiency and Public Information for Action Program (WEPIA**)**. A second program was started in year 2007 with the title"Instituting Water Demand Management in Jordan"(IDARA). This nationwide program is focusing on instituting sustainable water demand management by helping to establish the required institutional and regulatory framework in the country. The three major objectives under this program are:

1) Building the institutional capacity for water demand management in the involved institutions,

2) Developing and supporting enforcement of laws and regulations for efficient water use, and

3) Demonstrating selected water demand management initiatives to the public.

The installation of water saving devices in the showers and faucets in households and public buildings is a definitive indication of such awareness

There is a potential to conserve water at the households and public buildings level and comprehensive saving programs can achieve significant results. The analysis of water use at the audited office buildings revealed that around 30 percent of the water used could be saved (Abdel Khaleq, 2008).

In Table 24 the potential water saving through installation of water devices in the targeted households in the four governorates. The water saving can reach 0.36 MCM of water per year.

Table 24: Potential water saving in the targeted governorates

	Water saving using WSD					
Gover	Water Consumptions	# of people	Number of Household	Annual consumption	Saving (30% of consumption)	
Madaba	120	5.5	1500	361350	108405	
Karak	120	5.5	1700	409530	122859	
Tafielah	120	5.5	1200	289080	86724	
Ma'an	120	5.5	600	144540	43362	
Total (high consumption scenario, 120 litres/person/day)			5000		361350	m3
Total (low consumption scenario, 75 litres/person/day)	75[1]	5.5	7850[2]	1.2	0.35	MCM

Table 25 shows the estimated cost of installation of water saving devices at a typical household of size 100-200 m2. In estimated the cost of retrofitting these households it is assumed that each household could have 6 faucets and two showers.

Table 25: estimated cost of installation of water saving devices at a typical household in targeted governorates

Type	number	unit price (US$)	total cost (US$)	remarks
Faucet	5	5	25	Source:(MWI, Department of Awareness and Media)

[1] Estimate from Jordan Water Authority: http://www.waj.gov.jo/sites/en-us/Lists/FAQs/AllItems.aspx

[2] Includes number of private and public buildings, where we assume that water consumption per capita in public buildings is lower than in private buildings, but that overall number of users is higher so that overall consumption per building remains the same.

shower head	2	14	28	Source:(MWI, Department of Awareness and Media
Toilet Box	2	90	180	Not recommended due to its high cost
Toilet Bidet	2	7	14	Source:(MWI, Department of Awareness and Media
Total (devices only)			75	Excluding Toilet Box
Total (including price increase to account for uncertainties related to market dynamics and availability)			100	

Examples of efficient technologies that can be installed by the project with their approximate cost These prices are obtained from the Department of Awareness and Media in the Ministry of Water and Irrigation.

- low-flow showerheads (14 US$)
- shower-flow restrictors, (5 US$)
- toilet-tank inserts, (2 US$, it could be plastic bag or bottle)
- faucet aerators, (5US$)
- low- and ultra-low flush toilets (90 US$)
- pressure-reducing valves, (12 US$)

4. Reuse of reclaimed water

4.1. Background

This component has been designed for enhanced water availability to face climate change shocks. In this activity, regulation, storage and distribution hydraulic structures will be built to maximize use of reclaimed water from the Wastewater Treatment Plants in Madaba, Karak, Tafilah and Wadi Mousa (tbc). This will enhance climate resilience at the farm level by providing additional water to grow crops in accordance with Jordan's Water Substitution and Reuse Policy (2016) and will reduce the impacts of wastewater treatment effluents on the ecosystem. In order to demonstrate Government commitment to this investment, it is requested that MWI should produce an official communication addressed to the Green Climate Fund and FAO certifying that it is willing to take-up the operation and maintenance expenditure of the regulation, storage and distribution infrastructure that will be built to maximize the use of the reclaimed water.

There are seven existing WWTPs in the project area. These area Madaba, karak, Tafiela, Wadi Mousa, Ma'an, Mouta, and Lajoun WWTPs. The project will focus only on four of these WWTPs. These are Madaba, Karak, Tafiela, and Wadi Mousa WWTPs. The other three are excluded for different reasons. For example Mouta and Ma'an WWTPs are excluded because the available treated wastewater is totally used by famers nearby the WWTPs and there is no need to introduce any interventions to improve the situation there. For Lajoun WWTP, the wastewater reuse is currently considered by another project. Figure 17 shows the location of WWTPs in the study area. Table 26 shows the coordinates for each WWTP.

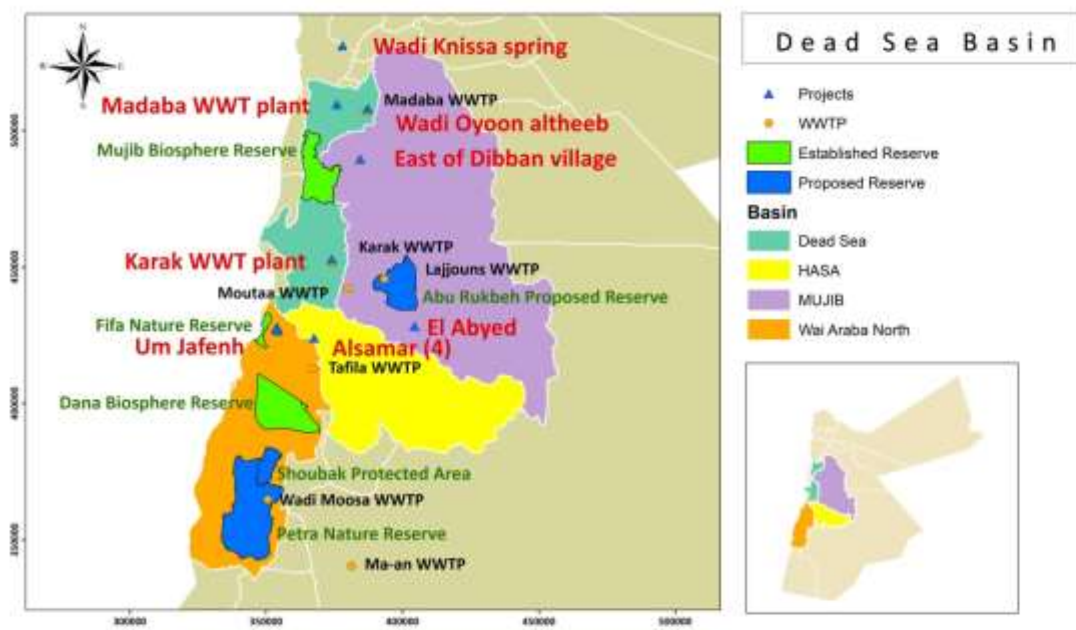


Figure 17: location of WWTPs in the study area

Table 26: Geographical coordinates of the WWTPs in the study area

No.	WWTP Name	Latitude	Longitude
1	Karak WWTP	31°11'49.86"N	35°40'46.69"E
2	Moutaa WWTP	31° 6'22.86"N	35°44'32.14"E
3	Lajjouns WWTP	31° 8'31.32"N	35°52'55.10"E
4	Ma'an WWTP	30°11'38.66"N	35°46'6.24"E
5	Madaba WWTP	31°41'39.44"N	35°48'18.40"E
6	Wadi Moosa WWTP	30°24'10.56"N	35°26'47.47"E
7	Tafila WWTP	30°50'34.32"N	35°36'35.52"E

Table 27 shows the characteristics of the targeted WWTPs in terms of capacity, inlet flow (m^3/day), and adopted treatment technology. The design capacity of the treatment plants ranges from 1600 m3/day (Karak WWTP) to 7600 m3/day (Madaba WWTP). Karak WWTP will be expanded for a capacity that can reach 5500 m3/day; however, timeline for this expansion is unclear. The average inflow to these plants ranges from 1500 m3/day at Karak WWTP to about 7600 m3/day at Madaba WWTP. For Tafila WWTP the current inflow has an average of 1782 m3/day while for Wadi Musa it is about 2857 m3/day. The currently treated wastewater varies among the plants. It ranges from 0.536 MCM in (Karak WWTP) to about 2.53 MCM at Madaba WWTP. The total treated wastewater in these WWTPs can reach to about 4.88 MCM annually. The treatment technology in these treatment plants is not the same. Tafila and Karak WWTPs are using trickling filter technology while the activated sludge treatment is used in both Wadi Musa and Madaba WWTPs.

Table 27 Design capacities, influents and effluents of WWTPs (personal communication, MWI).

WWTP	Design capacity (m^3/d)	Influents		Effluents		BOD (kg/m^3)	Type of treatment
		Avg. flow (m^3/d)	Avg. MCM/y	Avg. flow (m^3/d)	Total Qty. (MCM)*		
Al Tafila	7,500.0	1,781.9	0.65	2,189.9	0.799	0.73	TF
Al Karak	1,600.0 (5500)	1500	0.547	1468	0.536	N/A	TF
Wadi Mousa	3,400.0	2,857.2	1.0	2,780.0	1.015	0.34	AS
Madaba	7,600.0	7,625.5	2.78	6,936.4	2.531	0.7565	AS

Trickling filters (TF), Activated sludge (AS), Extended aeration (EA)

4.2. Reuse of reclaimed water

The effluent from these WWTPs will be used for agricultural purposes inside the premises of WWTP and in their vicinities. The surplus of effluents goes down along wadis where it either dies away owing to evaporation and infiltration or reaches subsequent water bodies like Dead Sea.The reuse of treated wastewater occurs both indirectly, after discharge of the effluent to a river and mixing with freshwater, and directly, e.g. without mixing with freshwater. According to MWI (2019), the total amount treated wastewater produced from the targeted WWTPs for the year 2019 is about 3.28 MCM, where direct use is estimated 2.477 MCM representing 75.55% of the total amount produced (Table 28). Direct **treated** wastewater reuse was achieved through contracting with about 34 farmers to irrigate an area of about 2,437dunums (Table 4). For the year 2019, the Madaba WWTP accounts for 45% of the total direct treated wastewater reuse (1.125 MCM) irrigating about 966 dunums, followed by Wadi Mousa that accounts for 37% (0.9125 MCM), then Karak 17.7% (0.439 MCM) irrigating about 401 dunums. Currently no wastewater reuse at Tafiela WWTP (Table 28).

Table 28: Current used of wastewater treatment plants. (personal communication MWI, 2020)

WWTP	Number of agreements with farmers	Irrigated area (dunums)	Used quantity of treated wastewater (m^3/day)	Annual used of treated wastewater (m^3)	Crop pattern	Potential crop area (dunums)

Madaba	22	966.21	3083.62	1125521.3	Forage crop	1500
Karak	11	401.17	1203.53	439288.45	Forage crops, olive trees, steppe trees	3500
Wadi Mousa	1	1069	2500	912500	Forage crops, fruit trees	
Tafila	N/A	N/A	N/A	N/A	Forage crops	
Total	34	2,437		2,477,310		

Only crop category C will be irrigated (field crops, industrial crops, forest trees). No fruit trees will be grown because the effluent does not meet the standard for category B crops. Types of irrigation systems that are used in these locations are:

- Wadi Mousa WWTP site: drip Irrigation
- Madaba WWTP site: surface irrigation
- Karak WWTP site: surface irrigation and drip irrigation
- Tafiela WWTP site: still wastewater are not used

Drip irrigation is the most suitable for irrigating orchards, fruit and olives trees. Surface irrigation is suitable for field crops but requires land levelling which is costly under the local topographic and soil conditions. Based on field visits, the irrigation water demand is $4m^3$/dunum/d in summer and $2m^3$/dunum/d in winter.

4.3. Water quality issues and standard

The use of treated wastewater for agricultural purposes entails certain restrictions to be developed and applied to ensure public safety and health. Main suggested crops to be grown under treated wastewater include industrial crops and forest trees, parks and playgrounds, cooked vegetables, field crops, or fruit trees. Non-food crops reduce human exposure to reclaimed water, which results in less stringent treatment and water quality requirements than other forms of reuse.

Quality Monitoring

The Wastewater Treatment Plant Owner Party must ensure that the reclaimed water quality complies to the standards and according to its end use. And must carry out the required laboratory tests and document results in official logbooks and present them whenever requested by the governmental monitoring parties (source Jordanian Standard).

The operating party must take composite samples every 2 hr for a period of 24 hrs in accordance with the frequency indicated in the standard. Monitoring parties can collect samples in any way found suitable. **The frequency of collecting samples for both the operating and monitoring parties are determined in the standard.**

Table 31 shows the actual tests of main effluent criteria for the year 2019 with the values higher than Jordanian standards had been shaded. All the four treated wastewater plants have effluent pH within the standard (6 – 9). All the four WWTPs have TSS within limits of B and C (200 mg/l to 300 mg/l).Total dissolved solids (TDS, mg/L) comprise all material dissolved in water including mineral salts and small amounts of organic matter, usually anything less than 2 microns. Values of total dissolved solids for WWTPs are lower than the standards (1500 mg/l). The results in Table 31 show that most of the WWTPs have E-coli higher than the Jordanian standards for categories B and A except for Wadi Mousa WWTP. Thus, the exceeding WWTPs must have higher attention regarding sterilizing and chlorination. Regarding COD, all WWTPs have values within Jordanian standards for categories B and C. BOD concentration for the effluents from these WWTPs is within the Jordanian standard. The parameters that are violating the standard limits are highlighted in yellow.

Table 31: Plant performance with respect to Jordanian Standards for reuse in irrigation

Plant performance with respect to Jordanian Standards for reuse in irrigation										
C - Field Crops, Industrial Crops and Forest Trees										
	pH	BODF	COD ب	TSS ب	TDS	NH4	NO3	PO4	T-N ج	E.coli
Standard	6-9	300	500	300	1500	-	70	30	100	-
Tafilah	7.79	18.02	15.21	34	7.89	68.88	2.26	19.51	80	3979634
Karak	7.81	17.58	27.47	12.53	1015	54.4	14.37	7.11	76.2	721957
Madaba	7.81	22	83.32	21.24	1012	49.16	2.46	5.85	53.97	3937833
Wadi Musa	7.62	2.52	29.58	3.4	882	.69	28	6.29	9.02	6.05
B-Fruit Trees, Sides of Roads outside city limits, and landscape										
	pH	BODF	COD ب	TSS ب	TDS	NH4	NO3	PO4	T-N ج	E.coli
Standard	6-9	200	500	200	1500	-	45	30	70	1000
Tafilah	7.79	18.02	15.21	34	7.89	68.88	2.26	19.51	80	3979634
Karak	7.81	17.58	27.47	12.53	1015	54.4	14.37	7.11	76.2	721957
Madaba	7.81	22	83.32	21.24	1012	49.16	2.46	5.85	53.97	3937833
Wadi Mousa	7.62	2.52	29.58	3.4	882	.69	28	6.29	9.02	6.05

Costs of Wastewater Treatment:

Specific costs for wastewater treatment vary significantly between 3.9 and 680 fils/ m^3influent. The cost strongly is determined by the treatment technology:

- Pond systems or aerated pond systems have specific costs between 3.9 fils/ $m^3$and 100 fils/m^3.
- Activated Sludge systems have average treatment costs of 90 to 180 fils/ m^3.
- More sophisticated systems (e.g. combined technologies and trickling filters) show specific treatment costs from 180 up to 700 fils/ m^3.

Pond sizing for each WWTP

Table 32 shows the analysis of daily rainfall data for four stations in the project area (Karak, Madaba, Tafilah and Wadi Mousa). These stations are selected to represent the rainfall in the four governorates.

The mean number of rainy days varies among these governorates; it ranges from 20 days in Wadi Mousa station to 33 days in Madaba. For example the number of rainy days in Karak stations ranges from 12 days to 49 days per year. On the other hand the number days that have heavy rain are also varying among the governorates. The day heavy rainfall is defined as the day that has a rainfall greater than or equal 22 mm. At this amount of rainfall the land surface becomes saturated and the surface runoff occurs. The assumption of heavy rainfall is obtained by using the method of Soil Conservation Services method (The curve number method). The curve number is estimated to be 70 based on the soil texture and land use in these governorates.

Accordingly, the maximum number of heavy rainfall for the four rainfall stations is ranging from 9 to 12 days. The maximum days of heavy rainfall in Madaba is 12 days while for Karak it is 11 days. The lowest number of maximum heavy rainfall is 6 days for Wadi Musa. The selection of maximum number of heavy days is to be conservative in sizing storage ponds. It is expected that in these days the farmers will not use the treated wastewater to irrigate their fodder crops and trees. In this case it is expected that the treated wastewater will be disposed to the wadis nearby the wastewater treatment plants. So the maximum number of heavy rainfall will be used in sizing in the storage ponds or reservoirs. Accordingly, the size of the ponds or reservoirs is estimated as capacity of each plant multiplied by the maximum number of heavy rainfall days. Table 33 shows the proposed size of the pond for each treatment plant.

Table 32: Statistics of number of daily rainfall (P>0) and heavy rainfall (P > 22 mm)

Governorate	Karak		Madaba		Tafilah		Ma'an	
Rainfall station	Karak		Madaba		Tafilah		Wadi Mousa	
Rainfall	Rainy days	Heavy Rainy days	Rainy days	Heavy Rainy days	Rainy days	Heavy Rainy days	Rainy days	Heavy Rainy days
mean	30.6	4.7	33.3	4.1	26.1	3.1	20.2	1.7
min	12.0	0.0	15.0	0.0	10.0	0.0	9.0	0.0
max	49.0	11.0	54.0	12.0	45.0	9.0	41.0	6.0
median	30.5	5.0	34.0	4.0	25.0	3.0	19.5	2.0

Also, from the field trip it is indicated that the famers used only 1 m3/dunum in the winter months (Dec, Jan, and Feb). That means one third of the WWTP effluent is used by the farmers and 2/3 is spilled. Based on this assumption, estimation for the storage ponds can be estimated using the following equation

Pond storage = 2/3 x Design capacity x 90 days

The pond sizes based on this assumption is very high. So the two approaches give us two estimates for the pond sizes. Selecting any one of them is not appropriate, the first estimate resulted in small pond size which is not conservative and the 2nd estimate can not be economically justified. The average of these sizes could be reasonable.

Table 33 Estimated size of the pond for each WWTP in each governorate

WWTP	Governorate	Design capacity of the WWTP (m^3/day)	Median number of heavy rainfall (days)	Size of the pond (m^3) – METHOD 1	size of the pond (m3) – METHOD 2	Average size
Madaba	Madaba	7600	12	91200	456,000	273600
Karak	Karak	5500	11	60500	330,000	195250
Tafilah	Tafilah	7500	9	67500	450,000	258750
Wadi Mousa	Ma'an	3400	6	20400	204,000	112200

Specification for pond construction (EPA 2019)

- Pond or lagoon must be designed and constructed so that wastewater in the lagoon cannot intersect any underlying seasonal water table.
- Ponds must be designed and constructed so as not to be liable, as far as practicable, to inundation or damage from flood waters.
- Ponds must be designed and constructed to ensure that the contents of the pond do not overflow (unless the overflow has been contemplated in the approved design and normal operation) into waters or onto land in a place from which they are reasonably likely to enter any waters.
- Ponds must be constructed with an appropriate liner which achieves the required permeability criteria and minimizes leakage.
- The prepared sub-grade must be proof-rolled to determine the presence of zones that may require sub-grade improvement. The sub-grade must be smooth and free of stones prior to geosynthetic liner placement.
- Lagoons must be designed and constructed in accordance with appropriate leakage detection requirements.

For lagoons with geosynthetic lining:

- A layer of the geosynthetic liner must be anchored (in accordance with manufacturers' guidelines) to cover the entire floor and all sloping sides of the lagoon.

5. Landscape investment plans

While water-related investments are a key climate priority in Jordan, there is a lack of a clearly articulated investment plans that take into account the specific characteristics of the project area (Ministry of Environment, 2013, pg.25; Jordan's INDC 2015, pg.11). More specifically, landscape water harvesting, groundwater recharge and flash flood mitigation are all priorities expressed in Jordan's key climate policy documents. While the usefulness of these measures to adapt to climate change is clear, there is a lack of understanding of suitable sites for these interventions in the project area. For example., during the field visits, MWI provided a list of water springs and ponds that are seemingly in need of rehabilitation. However, this list lacked clarity on key feasibility aspects, including social and environmental feasibility. After a closer review, it appeared that MWI was not able to justify on technical grounds why certain interventions had been prioritized. By the end of the visit, it became clear that the existing information on water interventions at the landscape level (e.g, flood protection, groundwater recharge, earth dams) was largely insufficient to develop any type of investment proposal, and the need to develop more holistic and integrated investment plans was recognized.

This lack of granularity hinders long-term investment planning, as it prevents donors and governments from having a clear and articulated picture of well-justified and feasible investment projects. To address this key information gap, the project proposes the development of landscape investment plans. This activity emphasizes the 'landscape' dimension of all climate change adaptation actions. This is the key novelty of this activity, which aims to step-up the capacity and information base available to MWI. Thanks to this activity, **<u>MWI will move away from ad-hoc investment decisions towards holistic water planning for adaptation in the Dead Sea Basin.</u>**

The landscape resilience investment plans have the following objectives:

- Set measures and objectives for developing and protecting the water resources of the project area, with a key focus on groundwater recharge;
- Set measures and objectives for protecting the population from the impacts of flash floods;
- Set measures and objectives for harnessing water's potential for agricultural production while protecting the health of aquatic ecosystems.

To achieve the above-mentioned objectives, this activity will employ the following key analysis techniques, following international best practices (ADB 2013):

- Stakeholder consultation and validation;
- Social and economic analysis of the uses of water, and its impacts on agricultural production, social dynamics and inequality;
- Strategic environmental assessment;
- Scenario planning, to assess the role of climate uncertainties in the performance of the proposed investments and identify no-regret measures.

It is envisaged that the landscape resilience investment plans will cover three major themes. First, they will provide a water diagnostic, including an assessment of the status of water resources, their quantity, quality and variability. This theme will also assess existing uses for water. Second, they will discuss disaster risk, with an emphasis on flash floods and droughts, paying particular attention to the potential for groundwater recharge to mitigate both risks. Third, they will examine interventions, assessing their institutional, social, economic and environmental feasibility. This theme is key, as it **<u>provides empirically-grounded and transparent information with which to make the case for investments and guide any future MWI activity in the project area</u>**. These three themes will feed into a landscape resilience plan, which will detail a set of priorities to be validated with stakeholders and chart a path towards financing and implementation.

6. Policy and legislation relevant for implementation

	Activity							
Legislation	**Rooftop rainwater harvesting and water conservation at the household level**	**Rooftop rainwater harvesting in public buildings**	**Reuse of reclaimed water**	**Water user associations**	**Climate Resilient Water Systems**	**Household Capacity to CC**	**Women Agent of Change**	**Scaling up**
Water Authority Law No 18/1988 amend. 16/1998, 62/2001 Water Regulations for Connection to public sewer system	Focus on efficiencies in the use and conservation of water resources	Focus on efficiencies in the use and conservation of water resources	The utilization of recycled water within Jordan has been made possible by the development and evolution of a sound legislative and legal foundation					Technical assistance and training for the Ministry of Water and Irrigation to address and solve identified policy bottlenecks related to climate change adaptation
Revised and updated 'National Water Strategy (2016-2025)	Jordan shall update codes and technical regulations periodically to ensure: The maximum water use in liters / minute or liters / flush for all plumbing fixtures that are installed in newly constructed buildings is specified; Rainwater harvesting systems should be installed for new construction (residential, commercial, industrial, tourism, etc.) where the size of the storage tank that depends on average rainfall and the surface area of the building is considered within the construction code.	Revision of building codes	Harvested rain can provide a no potable water source that can augment existing water supplies.	A national policy dialogue and forum to build awareness and consensus among all stakeholders Community-based water resources management Decentralized governance with oversight and regulation		Implement best practices complying with National Water Strategy, and establishing an integrated irrigation advisory service to advice farmers on efficient irrigation water use in an integrated manner.	The amount of water used for irrigation constitute a large proportion of the annual water budget, therefore programs shall be implemented to increase farmers' awareness and knowledge in the field of water demand management -Water & youth ambassadors, -Knowledge Platform -adaptive capacity to deal with climate change - Enhance private sector participation in public awareness campaigns to implement the	improve agricultural practices and evaluate internal capacities Review legislations for establishing water users associations and other associations and their legitimate role concerning irrigation water in Jordan, including a clear definition of the role of these associations in the irrigation water supply chain, and determine the relationship between water users associations and authorities, decision makers and define the tasks and duties and institutionalization framework.

							policy of water substitution and re-use of treated wastewater in irrigated areas.	
Reclaimed Domestic Wastewater Standard No 893/2006			Specify the quality of treated effluents allowed to be discharged into wadis or destined for reuse in agriculture;					
Wastewater Management Policy of 1997			Wastewater shall not be disposed of; instead, it shall be a part of the water budget Fees for wastewater treatment may be collected from those who use the water Any crops irrigated with wastewater or blended waters shall be monitored					
Water Sector Policy for Drought Management 2018	Ensure adequate supply of water to meet the basic needs of the population to ensure good health and preserve lives	Ensure adequate supply of water to meet the basic needs of the population to ensure good health and preserve lives	Reducing the negative impacts of drought on agriculture			Encourage affected economic sectors and population groups to adopt self-reliance measures that enhance risk management	Encourage affected economic sectors and population groups to adopt self-reliance measures that enhance risk management	
Water Substitution and Reuse Policy, 2016			-Coping with the scarcity situation -Increasing the amounts of treated Wastewater (WW) and considering it as a potential water and revenue source. - Priority for substitution shall be given to irrigated and irrigable lands	The Water Users Associations shall have a role in implementing this policy				
Climate Change Policy for a Resilient Water Sector 2016	new water, water harvesting	new water, water harvesting	wastewater collection/treatment/reuse,		-prioritizing solutions according to a combination of climate specific and other - applying climate proofing steps to		Community engagement on water value/scarcity Educate on value and scarcity of water and on making	

					solutions or investments - water storage, using all options, e.g. dams & reservoirs, ponds, cisterns, aquifer recharge and groundwater storage, soil water storage -		water-efficient project decisions Alternative farmer income schemes	
Surface Water Utilization Policy 2016					-The full potential of surface water shall be tapped to the extent permissible by economic feasibility, and by social and environmental impacts. - Potential shall be tapped and maximum use made of the extensive experience gained within MWI in the design and construction of water harvesting schemes (ponds and desert dams)			

Water Demand Management Policy 2016	Develop a National Standardized Plumbing Code: The MWI through a USAID financed project, IDARA, developed a national standardized plumbing code, which was completed with the exception of the chapters on Grey water and Rainwater Harvesting. Taking into consideration that the UPC is updated every three years, the project should continue to work with the appropriate technical committees to finish the chapter proposed for the new Plumbing Code on Rainwater Harvesting Assist low income consumers to obtain water saving devices for free or at a stimulatory price.	Rainwater harvesting systems should be installed for new construction (residential, commercial, industrial, tourism, etc.) where the size of the storage tank that depends on average rainfall and the surface area of the building is considered within the construction code. Harvested rain can provide a nonpotable water source that can augment existing water supplies.	Expand the use of reclaimed water for industry and agriculture, to the maximum extent possible			Adopt preventive maintenance programs for irrigation systems	The introduction of best technologies and modern and advanced irrigation public awareness campaigns and water education through several means of communication and media focusing on water scarcity and spreading the culture of awareness and responsibility to protect the water sources and its efficient use. Public awareness programs shall be implemented for staff and employee in all sectors (tourism, industrial, commercial, agricultural, etc.), to increase public awareness of importance of water and its efficient use.	The introduction of best technologies and modern and advanced irrigation Applying best management practices of irrigation water use, including water pumping, conveyance, distribution, and storage and management on-farm level. promote the transition of local manufacturing to the production of water efficient products
Water Reallocation Policy 2016	-Water appliances and water saving devices shall be adopted in all housing designs - Storage of rain water from roofs shall be enforced. Storage volumes shall be set in building codes	Storage of rain water from roofs shall be enforced. Storage volumes shall be set in building codes depending on roof area and average precipitation	Wastewater shall be treated and purified for full utilization for industrial, agricultural, cooling and other uses except for drinking purposes.	Close cooperation via a joint committee between Ministries of Water and Irrigation, Environment, Agriculture and other				Planning guidance on sustainable design and construction shall be introduced to the Building Code to ensure that all new homes and apartments shall meet the 120, 100, and 80 l/c/d standard

	depending on roof area and average precipitation			organizations whose activities directly or indirectly involve the performance in the water sector to develop short-, medium- and long-term plans to monitor and control the water quality, use and impacts.				

Annex I: Districts

Table 1 shows more detailed information about the districts located in the Dead Sea Basin. Some of the districts are located in more than one basin. Detailed information about the total district area is shown in Table 2. The population from each district that lived in the Dead Sea Basin is calculated as shown in the last column of Table 1. Accordingly, the total population of the study area is approximately 1,024,662 people. The population for each district was obtained from the Department of Statistics (2019). The area of each district was calculated using Geographic Information System (GIS) software

Table 1: Distrbution of the Dead Sea Basin on the district level. Source: Department of Statistics (2019)

Part Number	Gov.	District	total district area sq km	Basin Name	total basin area sq km	Area of the district (sq km) that is located in the study area	% District Area Percent that is located in each basin	Total population of the district	Population of the district lived in study Area
1	Amman	Amman	231	MUJIB	6584	52	0.79	946340	212274
2	Amman	Jizeh	5233	MUJIB	6584	1777	26.99	130460	44301
3	Amman	Jizeh	5233	D.S.R.S.W	1549	0	0.00	130460	2
4	Amman	Mowaqqar	582	MUJIB	6584	105	1.60	93280	16865
5	Amman	Na'oor	131	MUJIB	6584	85	1.28	143340	92392
6	Amman	Sahab	721	MUJIB	6584	4	0.06	87330	477
7	Amman	Um El-Basatien	163	MUJIB	6584	92	1.40	21580	12174
8	Amman	Um El-Basatien	163	D.S.R.S.W	1549	14	0.90	21580	1852
9	Aqaba	Wadi Arabah	2262	W. ARABA NORTH	2930	1530	52.22	10510	7109
10	Balqa	ShoonehJanoobiyyeh	670	D.S.R.S.W	1549	79	5.09	58280	6850
11	Karak	Ayy	415	D.S.R.S.W	1549	219	14.11	9010	4750
12	Karak	Ayy	415	W. ARABA NORTH	2930	99	3.37	9010	2143
13	Karak	Ayy	415	HASA	2530	12	0.49	9010	269
14	Karak	Faqqoo'	123	MUJIB	6584	100	1.52	18580	15144
15	Karak	Faqqoo'	123	D.S.R.S.W	1549	23	1.46	18580	3436

16	Karak	Ghour El-Mazra'ah	790	MUJIB	6584	81	1.23	23610	2423
17	Karak	Ghour El-Mazra'ah	790	D.S.R.S.W	1549	532	34.37	23610	15905
18	Karak	GhourEssafi	72	MUJIB	6584	72	1.10	30181	30181
19	Karak	Karak	49	D.S.R.S.W	1549	49	3.14	112060	112060
20	Karak	MazarJanoobi	395	MUJIB	6584	229	3.47	105150	60836
21	Karak	MazarJanoobi	395	D.S.R.S.W	1549	69	4.44	105150	18319
22	Karak	MazarJanoobi	395	HASA	2530	98	3.86	105150	25995
23	Karak	Qasr	1956	MUJIB	6584	1867	28.36	32510	31032
24	Karak	Qasr	1956	D.S.R.S.W	1549	69	4.47	32510	1150
25	Karak	Qasr	1956	HASA	2530	20	0.78	32510	328
26	Ma`an	Husseiniyyeh	569	HASA	2530	190	7.52	19180	6414
27	Ma`an	Iel	622	W. ARABA NORTH	2930	10	0.35	16750	278
28	Ma`an	Ma'an	30601	MUJIB	6584	1633	24.80	97050	5178
29	Ma`an	Ma'an	30601	HASA	2530	900	35.58	97050	2854
30	Ma`an	Shoabak	428	W. ARABA NORTH	2930	207	7.06	21350	10307
31	Ma`an	Shoabak	428	HASA	2530	0	0.00	21350	5
32	Ma`an	Wadi Musa	456	W. ARABA NORTH	2930	232	7.92	12961	6589
33	Madaba	Dhiban	256	MUJIB	6584	256	3.89	40270	40270
34	Madaba	Madaba	937	MUJIB	6584	232	3.52	168930	41846
35	Madaba	Madaba	937	D.S.R.S.W	1549	496	32.00	168930	89377
36	Tafilah	Bsaira	209	W. ARABA NORTH	2930	126	4.32	27920	16919
37	Tafilah	Bsaira	209	HASA	2530	58	2.31	27920	7817
38	Tafilah	Hesa	838	HASA	2530	838	33.15	11330	11330
39	Tafilah	Tafileh	1123	W. ARABA NORTH	2930	709	24.21	67250	42491
40	Tafilah	Tafileh	1123	HASA	2530	413	16.31	67250	24720
					150950				1024662

Annex II: Wastewater treatment plants

WWTP	Effluent Quantity (MCM/yr)a	Amount of Reused Effluent (directly and indirectly) (MCM/yr)a	Irrigated Area at or near WWTPs (Dunum)a	Type of Irrigated Crops a	No. of Agreements with Farmers b	%of Direct Reuse of Treated Wastewater b	Destination of Excess Effluent a	%of Direct and Indirect Reuse of Treated Effluent a
As Samra	87	87	3990	Fodder and Olive Trees	34	15	King Talal Dam	100
Al-Fuheis	0.8	0.8	30	Fodder	1	4	Wadi Shu'aib Dam	100
Al-Ramtha	1.4	1.4	1302	Fodder	22	100		100
Madaba	1.8	1.8	1213	Fodder and Olive Trees	27	100	-	100
Al-Baq'a	4.1	4.1	437	Nurseries and a Polo Field	15	13.6	-	100
Kufranja	0.9	0.9	812	Forest Trees	10	100	-	100
Al-Karak	0.7	0.7	609	Fodder and Forest Trees	8	100	-	100
Al-Mafraq	0.6	0.6	660	Fodder	18	100	-	100
Al-Salt	2.2	2.2	100	Olive and Fruit Trees	5	4.4	Wadi Shu'aib Dam	
Ma'an	0.8	0.8	357	Fodder	9	47	Stream	47
Al-Ekeider	1.0	1.0	1069	Olive and Fruit Trees	17	100	-	100

Al-Sharee'ac	0.1	0.96	181	Olive and Fruit Trees	16	100	-	100
Wadi Al-Seer	1.2	1.2	62	Olive Trees	1	4.3	Al-Kafrain Dam	100
Wadi Hassan	0.4	0.4	721	Olive and Fruit Trees	1	100	-	100
Wadi Mousa	0.9	0.9	1069	Fodder and Olive Trees	38	100	-	100
Abu Nuseir	0.9	0.18	75	Ornamentals	1	20	Bereen Stream	22
Al-Aqaba/ Natural Plant	2	2	1580	Palm Trees, Windbreaks, and Green Area	4	100	-	100
Al-Aqaba/ Mechanical Plant	2.6	2.6	-	-	1	100	-	100
Al-Tafileh	0.5	-	-	-	None	-	Ghor Fifa	0
Al-Lajoon	0.3	-	-	-	None	-	Al-Lajoon Stream	0
Wadi Al-Arab	3.7	-	-	-	None	-	Jordan River	0
Al-Talibeyeh	0.1	0.1	-	Forest Trees and Ornamentals	None	100	-	100
Tal Al-	0.1	0	-	Fodder	None	0	-	0

Mantah								
Al-Mi'rad	0.3	0.3	-	-	1	0	King Talal Dam	100
Central Irbid	3	-	-	-	None	0	Jordan River	0
Jarash	1.2	1.2	-	-	None	0	King Talal Dam	100
Wadi Shalala b	0.8b	-	-	-	None	0 b	Jordan Riverb	0b

a Source: WAJ (2012), b Source: (WAJ, 2013) c Desalination Treatment Plant

Annex III: List of funded projects in the study area

Projects funded from the public budget:

This year, 2020: JOD 29,170,000 and you may say this is annual Government capital expenditure for Ministry of Water and Irrigation

Projects funded by international donors with government contribution:

Total cost of the projects as follows: Donors: JOD 738,332,437; Government contribution: JOD 38,172,304

Budget for the year 2020:

Donors: JOD 101,789,000

Government contribution: JOD 6,789,000

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