WATER RESOURCES, USE AND MANAGEMENT IN JORDAN - A FOCUS ON GROUNDWATER

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Groundwater governance in the Arab World

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Acronyms

CBJ	Central Bank of Jordan
DOS	Department of Statistics
EU	European Union
GDP	Gross Domestic Product
GO	Gross output
GOJ	Government of Jordan
GVA	Gross Value Added
JD	Jordanian Dinar (1 JD = 1.41 US$)
JRV	Jordan Rift Valley
JV	Jordan Valley
JVA	Jordan Valley Authority
KAC	King Abdulla Canal
KTD	King Talal Dam
MCM	Million Cubic Meter
MJD	Million Jordanian Dinars
MJV	Middle Jordan Valley
MOA	Ministry of Agriculture
MWI	Ministry of Water and Irrigation
MWS	National Water Strategy
NGO	Non-Governmental Organization
NJV	North Jordan Valley
NRW	Non Revenue Water
NVA	Net Value Added
RO	Reverse Osmosis
TVP	Total value of output
UFW	Un-Accounted for Water
USAID	The United States Agency for International Development
WAJ	Water Authority of Jordan
WWTP	Wastewater Treatment Plant

Executive Summary

Water scarcity in Jordan is a significant and well-documented problem that continues to worsen with increasing demand due to high population growth, hosting several fluxes of refugees, economic-development needs, increasing drought events and climate change. Jordan's population has increased from 6.1 million in 2010 to around 9.71 million in mid-2016. The huge increase, despite the lower local growth rate of 2.2%, is attributed to the influx of refugees from other countries, mainly from Iraq and Syria. The expanding population creates enormous pressure for the already scarce and depleted water resources.

The groundwater policy water cannot be appreciated without an understanding of the nature of the Jordanian society. Jordan receives the first wave of refugees in the early of the 19th century who settled on near water resources, Then Jordan became an Emirate on March 1921 and its independence was declared on May 25 1946, The second wave of refugees happened after the formation of the state of Israel in 1948 where thousands of Palestinian forced to leave their homeland. Third waves of displaced people occur during Arab-Israel in 1967, Fourth waves of migrant influx occur during the Kuwait invasion. The fifth waves were during U.S. invasion of Iraq in 2003, and the outbreak of conflict in Syria in 2011. These events resulted in a massive refugee influx into Jordan resulting in a huge pressure on water resources.

Jordan's renewable water resources are limited and insufficient to meet national demand. There are growing signs of apparent over-use in an increasing number of watersheds and aquifers. The fresh-water share per capita per year has fallen from 500 m3 to 140 m3 in the 1975 and 2010, respectively. In 2016, Jordan's annual renewable resources of less than 100 m3/capita are far below the global threshold of severe water scarcity (500 m3/capita). The total groundwater resources was estimated with 600 MCM in 2015, of which 442 MCM stem from renewable resources and 153 MCM from non-renewable resources

Given the water-security threat to Jordan posed by water shortages, water security has become a major domestic issue as population increases rapidly with refugees entering the country because of conflict in neighbouring countries, including a new influx from Syria that is estimated to have 2.72 million people where about 1 million are registered refugees from various countries by the end of December 2015.

Loose water governance in the form of lax enforcement of rules and regulation and lack of equity and transparency has resulted in continuous mining of renewable groundwater resources, with extraction currently 50% over the safe yields, increasing water salinity, declining water table levels and increasing pumping costs. Efficient management of scarce water resources is an existential necessity. It is critical to the livelihoods and well-being of Jordan's people and essential to the country's lasting stability. The driving force for weak by-law enforcement is to ensure political stability, which is the primary objective of water policies in Jordan. In the absence of securing its water assets, Jordan risks near-term economic slowdowns, health hazards, social disruptions, and serious conflicts over water resources.

The water sector has gone through significant phases marked by the various challenges imposed by the tremendous growth of population, as well as the rising living standards and the economic and social development. In spite of that, more than 98% of the Jordanian people are connected to a safe water supply service, while more than 63% are covered by sanitation services. This percentage is expected to increase up to 70% in the coming years through various programs and plans implemented by the Ministry of Water and Irrigation (MWI). Interrupted pumping and non-reliability of water supply services is common over Jordan, Connection rate does not reflect that the fact that many urban and rural communities does not receive piped water for weeks.

However, despite Government efforts to manage the limited water resources and its relentless search for alternative supply, available water resources per capita are falling as a result of population growth. Government's attempts to deal with the scarcity problem focused not only on supply augmentation and supply management, including rationing of water service, but also on demand management measures and the adoption of a public information policy. Despite all measures, the coming scarcity problem will remain a major challenge facing water managers and the country at large.

Despite the institutional reforms that have already taken place, much more remains to be done in terms of both institutional restructuring and capacity building before Jordan's water sector institutions can effectively and efficiently ensure the country's water security. Law enforcement across society plays a major role in accepting the rules and regulation by different water users group.

During the last decade, the weak and lack of real will to enforce the laws and by-laws caused a lack of trust in law enforcement and consequently a feeling of water users and well owner that nothing will happen. Furthermore, the continuous changes in leadership positions within the MWI, JVA, WAJ and water related institutions delay bylaw amendments implementations due to different views of decision makers, and lead to different groundwater policy priorities.

In terms of minimizing aquifer over-draft, groundwater policy emphasizes the need to stop illegal drilling completely by strengthening penalties and punishments, closing existing illegal wells by refilling and capping them after giving a grace period to well owners, and metering all existing water wells. Furthermore, several measures should been implemented to protect aquifers from degradation and over abstraction. These measures include pricing policy, subsidy policy and additional water resource augmentation such as water wellfield delineation, and other institutional measures such as groundwater protection zones, preparation of groundwater vulnerability maps, establishment of a groundwater monitoring system, and further legal amendments to the water law reflecting the necessities linked to groundwater management in Jordan. An incremental discriminating tariff was set in the regulation for water abstracted over and above the permitted annual abstraction rate. The first water quota, with water free of charge, should be reduced.

Farmers in the Highlands opt for different options to cope with recent change in policy and regulations, some of those options coincide with the intended policies such as reduce water abstraction, land fallowing, investment in water saving technologies, changing of cropping pattern, selecting of less water consumptive crops. Other coping measures are selling excess water below the quota to neighbours, manipulation of water meters, claiming incorrect reading of water meters, using personnel relations to reduce meter reading, digging an illegal well near the legal one to irrigate the licensed irrigated area.

Water values based on net profitability have been estimated. The resulting water value is an indication of the economic efficiency of water consumption and a proxy for farmer's ability to pay for water. Results show that cucumber has the highest water value in Mafraq (JD 2.4/m3), with average water values for winter tomatoes at JD 0.94/m3, and for summer tomatoes JD 0.62/m3. Water values for olives are the lowest (JD 0.05/m3) in Mafraq and Zarqa, whereas the water value for olives at national level is (JD 0.26/m3). The water pricing policy should be revised to provide incentives for high value crops and to discourage low water value crops such as olives and clover by eliminating the subsidy on electricity used for water pumping. A decrease of the water quota or an increase in the price of electricity would therefore affect olive cultivation, clovers but will marginally affect vegetables and fruits trees due to the high water values of these crops.

In the light of the challenges faced by groundwater as a result of the ever increasing water demand due to population growth, refugee influxes, and economic growth in addition to groundwater depletion coupled with the negative impacts of climate change, it is necessary to identify and support the design of proactive measures to alleviate the effects of droughts and climate change adaptation measures as well as the promotion of the efficient use of the available groundwater water resources. This situation requires that groundwater resources should be managed optimally and sustained for future generations. A groundwater sustainability policy is highly needed.

1 Historical retrospective on groundwater management and policies in Jordan

1.1 Introduction

Despite the fact that water utilities in Jordan serve 98% of the population, water scarcity remains a major challenge. Moreover, rapid population growth (through natural and refugee influx) is increasing water demand, putting additional pressure on the limited water resources. Annual water consumption is 1,007 million cubic meters (MCM) (MWI, 2016a), of which 50% is used for irrigation. Water demand is met mostly from groundwater (60%), followed by surface water (27.1%) and treated wastewater (13.2%). The demand is met by extracting groundwater aquifers above safe yields.

By providing reasonable volumes of water for municipal and commercial needs, water use in Jordan has exceeded the safe yields for many years. Consequently, these water shortfalls have led to drastic reductions in annual per capita water domestic consumption from renewable sources: dropping from 3,600 m3 in 1946 to 123 m3 in 2013 (MWI, 2016c). The level of 125 m3 classifies Jordan as a country in water poverty, since consumption rates from renewable sources according to the World Health Organization are far under 1,000 m3 per person.

If water supply remains constant, Jordan's per capita consumption from renewable sources is expected to fall to approximately 90 m3 per person per year by 2025. By that same year, assuming current trajectories hold, Jordan's water deficit (i.e., the gap between water availability and demand for water resources) for all uses will grow from about 160 MCM in 2015 to 490 MCM. Jordan's diminishing water assets threaten the country's near-term security. If indeed per capita water consumption drops to 90 m3 per person per year by 2025, Jordan's residents would move from a state of severe to a state of extreme water poverty; economic growth would be constrained; public health possibly threatened; and the potential for large social disruptions heightened.

The fact is that existing sources of water in Jordan are hardly sufficient to cover existing demands from different water consuming sectors - including explicitly water demands for the environment - and will be even less so in the future, requires systematic adjustments of the current situation in water demand management. Main-stream adjustments helped to cope with scarcity situations in the past, but are not likely to provide sustainable overall solutions for the future.

National water resources and the water balance have negative impacts due to higher demand, over-abstraction, and the effects of climate change. There is severe competition among the socioeconomic sectors due to the exponential rise in water demand. The need to have water for domestic use, irrigation, and industrial and environmental protection, coupled with deteriorating water quality and control of water-borne diseases, poses serious water-sustainability challenges (El-Naser et al., 2014). The economic development of the past two decades has created enormous pressure on the quality of the groundwater and surface-water resources. The main challenge for the future is meeting the growing national water demand for the medium to long term. Alternative water-resource management and efficiency strategies are, therefore, needed to optimize the use of this scarce resource.

The national water-sector reallocation policy gives priority to domestic needs, followed by the sectors that provide the highest feasible and economic return per cubic meter of water used. The policy also focuses on adaptive capacity, high resilience, and low complexity in order to address the national water needs. Efforts are underway to address the water security issue by:

(i) improving the efficiency for the distribution and conservation of available resources, (ii) increasing wastewater treatment, and (iii) developing "new water" through rain harvesting and desalination. Given the limited financial resources that are available, the private sector can offer solutions through public/private partnership modalities (MWI, 2016a).

Surface-water supplies[1] contribute approximately 27% of Jordan's total water supply (Table 1). The developed surface water in Jordan was about 265 MCM in 2016 and is projected to increase to no more than 276 MCM by 2020 (Table 2). Groundwater contributes about 60% to the total water supply. However, the unsustainable abstraction of groundwater due to population growth, agriculture expansion, and declining recharge is a major problem today (Al-Omari et al., 2015). It has been exacerbated by the poor enforcement of regulations for private well drilling and the near absence of controls for licensed abstraction rates. As water tables drop, pumping costs and salinity levels increase (Al-Karablieh et al., 2012). Securing additional water can ameliorate water scarcity, ceteris paribus.

Irrigation[2] uses just over half the currently available supply, around 507 MCM, although these figures may underestimate both irrigation use and total water use for various reasons. Domestic use ranks second, around 465 MCM, while industrial use is currently around 37 MCM, which is less than 4% of the total supply but is expected to grow. The Ministry of Water and Irrigation (MWI) updated its strategy to hold agricultural water use at 700 MCM in the future, so a strong challenge will be to generate a great deal more value from utilizing that amount of water (MWI, 2016b).

1.2 Current water resources

Fresh water resources in Jordan consist mainly of groundwater and surface water. Treated wastewater and brackish water desalination are other important non-conventional resources that help bridge part of the gap between supply and demand especially in the municipal and agricultural sector. The different available water resources in Jordan are as follows:

1.2.1 Surface Water

There are fifteen surface water basins in Jordan. The run-off varies significantly from year to year as a result of the variation in the rainfall. The two main surface water sources in Jordan are the Yarmouk River and Zarqa River. The Yarmouk River drains the basaltic plateaus of the Hauran in Syria, an area of fair rainfall and strong runoff. Typical monthly flows of the Yarmouk River at Adasiyia are between 4 and 5 MCM during the dry season and between 17 and 40 MCM during winter. About 110 MCM per year of Yarmouk River, Al-Wehda dam and Mukhieba Wells are diverted to KAC, 70 MCM of which are pumped to the Zai water treatment plant which supplies west Amman. The remaining 40 MCM are used for irrigation in the Jordan valley (MWI, 2013). The Zarqa River is the second largest tributary to Jordan River. The mean rainfall for the watershed is 273 mm, and the median annual stream flow is 70 MCM. In year 2013 the annual discharge was a record of 135 MCM (AFD, 2011).

[1] Excluding treated wastewater which is derived from both ground- and surface water.

[2] Including treated recycled wastewater but excluding green water that is stored in the soil profile and used by rainfed agriculture which is estimated with 100 MCM.

Table 1: National Water Supply and Consumptive Use (MCM) by Sector, 2015

	Source	Domestic	Industrial	Irrigation	Livestock	Total Supply	Share%
Surface Water		**124.2**	**4**	**139**	**7**	**274.2**	**27.2%**
1	**Jordan Valley**	**104**	**4**	**69**	**0**	**177**	**64.6%**
	Jordan Valley(KAC)	66	0	25	0	91	
	Southern Ghors	38	4	44	0	86	
2	**Highlands**	**20.2**	**0**	**70**	**7**	**97.2**	**35.4%**
	a. Springs	19	0	25	0	44	
	b. Base and Flood Flow	1.2	0	45	7	53.2	
3	**Treated wastewater**	**0**	**2.2**	**131.1**	**0**	**133.3**	**13.2%**
	a. Jordan Valley	0	0	90.8	0	90.8	68.1%
	b. Highlands	0	2.2	40.3	0	42.5	31.9%
Groundwater (GW)		**332**	**31**	**237.4**	**0.2**	**600.6**	**59.6%**
	a. Renewable GW	209	21	211.6	0.2	441.8	73.6%
	b. Non Renewable GW	117	10	25.8	0	152.8	25.4%
	c. Desalinated GW	6	0	0	0	6	1.0%
Total Consumption		**456.2**	**37.2**	**507.5**	**7.2**	**1,008.1**	
Share%		45.3%	3.7%	50.3%	0.7%		

Source: Ministry of Water and Irrigation (MWI, 2016a).

Table 2: Development of Resources and Projected Demand (MCM/year)

Year	**2016**	**2017**	**2018**	**2019**	**2020**
Groundwater Safe yield	275	275	275	275	275
Non-renewable groundwater	145	146	147	178	189
Groundwater Over Abstraction	156	152	148	144	140
Surface water	265	267	269	271	276
Treated wastewater	140	175	176.6	176.6	181.6
Additional Resources (Desalination)	11	12	18	19	20
Total Resources	**992**	**1027**	**1034**	**1064**	**1082**

Source: Ministry of Water and Irrigation (MWI, 2016b).

1.2.2 Treated wastewater

Treated wastewater generated in Amman and Zarqa is a main water resource in the Jordan Valley. It is treated at As Samra Wastewater Treatment Plant (WWTP) in Zarqa governorate and discharged to Zarqa River, which ends in KTD. The flow from the As Samra WWTP to Zarqa River increased from about 61 MCM in 2007 to about 106 MCM in 2015 (MWI,2016). Water from KTD is released to KAC where it gets mixed with fresh water there and used for unrestricted irrigation in the Middle and southern Jordan Valley. Treated wastewater reuse for agricultural purposes is becoming one of the technical options to cope with increasing water scarcity. However, the potential adverse effects on soils, land use and crops are a major concern both for farmers and stakeholders, which decreases the willingness to use this unconventional resource and limits the development of this practice. It is frequently cited (Shatanawi and Fayyad, 1996; Al-Zu'bi, 2007; Ammary, 2007 and Carr et al., 2011) that domestic and industrial wastewater exhibits a certain level of microbial pollutant, salinity and heavy metals that farmers do not take into account in the choice of production technology and the management of their cropping systems, which reduces crop yield and may affect the soil, plants and final products in the market.

To compensate for the loss of Yarmouk river water, the Jordan Valley Authority extended the existing Zarqa Carrier II (which conveys water from the Zarqa river downstream of the KTD to the KAC) to the North Ghor irrigation area. The new pipeline, called Zarqa Carrier III, enables another 4000 ha to be irrigated with water from KTD. The transition from using fresh surface water to using treated wastewater for irrigation in North Ghor area comes with considerable problems. The water taken from KTD has a salinity of around 1400-1800 mg/l, which negatively affects yields, especially for citrus, when compared with irrigation from fresh water resources. Also, because of increasing availability of treated wastewater resources, the problems associated with the use of treated wastewater in the northern part of the Jordan Valley should be considered in the near future.

1.2.3 Groundwater

There are twelve groundwater basins in Jordan. Table 3 lists these basins along with their long-term average safe yield. It shows that the total renewable yield of groundwater basins in Jordan is estimated between 231 and 281 MCM with an average of 275 MCM per year. This is an acceptable number for the safe yield of renewable groundwater resources in Jordan. Groundwater resources in Jordan are the main source for domestic water supply. Almost all of Jordan receives water for domestic use from groundwater sources except west Amman which receives water from the King Abdulla Canal. Due to the growing water demand, almost all groundwater resources in Jordan are over exploited which led to the deterioration of their quality. Figure 1 shows the different groundwater basins in Jordan with their safe yields and actual abstractions for the year 2009 given in the white box. Figure 2 shows the spatial distribution of the surface water catchments and their relative position to the groundwater basins. The high water demand is met by over-abstracting the renewable groundwater aquifers. Over abstraction is estimated at about 55% of the safe yield, according to the 2011 water budget.

Additionally, there are also non-renewable groundwater basins that are exploited to meet the growing water demand. Those are the Disi basin and a portion of the Jafer basin with a safe yield ranging from 107-110 MCM as estimated by BGR (2004) or 143 MCM as reported by the annual water budget published by MWI. The Disi fossil water carrier was completed in August 2013 and started to provide additional 107 MCM of fresh water for municipal purpose to Amman and other cities in different governorates. Table 3 shows the abstraction from groundwater basin and their safe yield in 2015. The total abstraction is 625 MCM abstracted from 3,138 known licensed and unlicensed wells. The abstraction rate is 130% of the safe yield of 275 MCM.

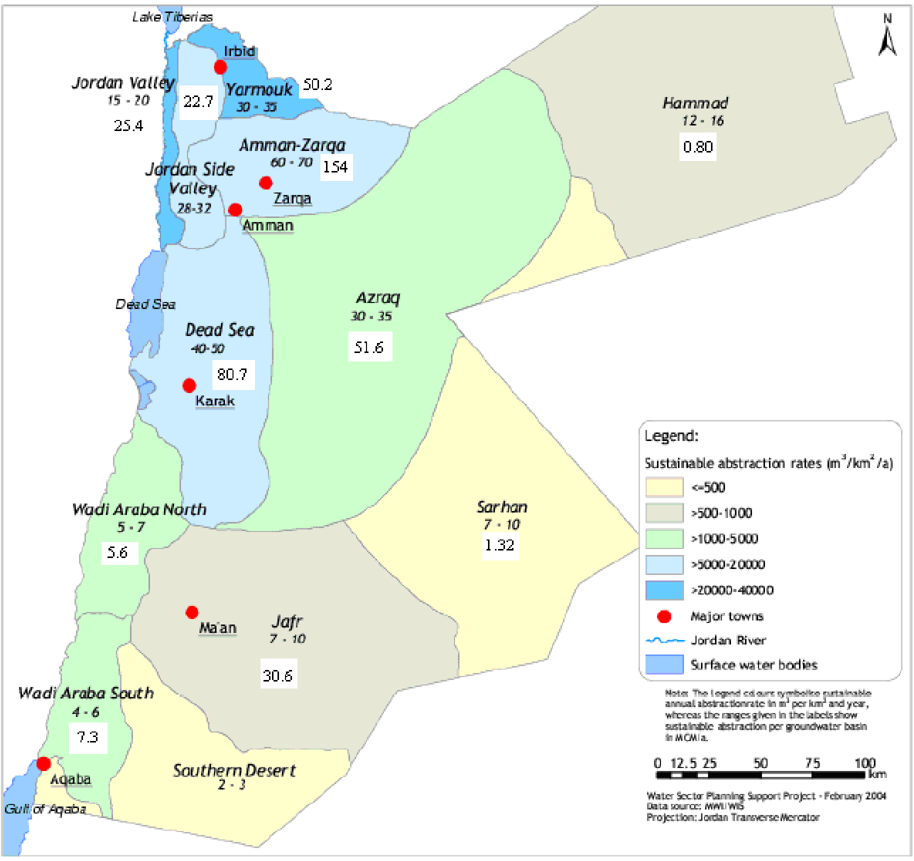
Disi water has been used mainly during (1980-2012) for irrigation purpose (around 50 MCM annually) and to supply Aqaba city with drinking water (around 15 MCM annually). The conveyance of Disi completed in 2013 provides around 107 MCM annually of drinking water to Amman and other middle and northern governorates. This source is considered to be almost the major remaining conventional water source that can be utilized for drinking water. Table 4 shows the historical development of wells in Jordan during the period 2000-2013. The number of agricultural wells (licensed and unlicensed) increased from 1830 wells in 2000 to 2,163 wells in 2015 as shown in Figure 3 despite the banning of the drilling of new agricultural wells since a decision 1992 by the cabinet.

Table 3: Abstraction from Groundwater basins in Jordan and their safe yields in 2015

	Basin	Safe yield MCM	Total uses (MCM)	Balance	No of wells	Percent of Safe yield
1	Yarmouk	30-35	54.16	-14.16	203	135
2	Amman Zarqa	60-70	166.11	-78.61	955	190
3	Jordan Rift Side Wadis	28-32	46.73	-31.73	139	312
4	Jordan Valley	15-20	17.02	3.98	334	81
5	Dead Sea	40-50	89.98	-32.98	469	158
6	Azraq basin	30-35	52.54	-28.54	580	219
7	Hammad basin	12-16	1.87	6.13	15	23
8	Wadi Araba North	5-7	6.33	-2.83	37	181
9	Wadi Araba south	4-6	8.48	-2.98	62	154
10	Sirhan	7-10	1.71	3.29	23	34
11	Jafer non-renewable	7-10	32.85	-21.85	205	343
12	Disi, non-renewable	100	146.96		116	118
	Total	**338-391**	**624.74**		**3138**	**129**

Source: MWI, 2016 open files.

Figure 1: Groundwater basins in Jordan and their estimated safe yields, (BGR, 2004)



Source: NWMP, (2003).

Figure 2: Surface and groundwater basins in Jordan

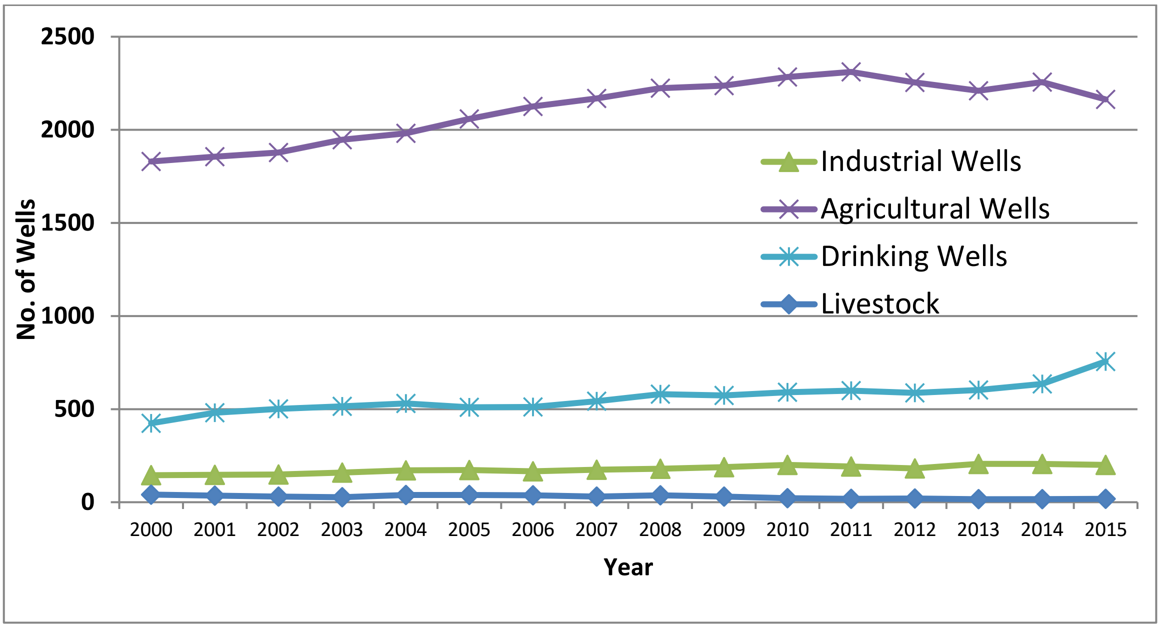
Source: NWMP, (2003).

Table 4: Historical development of operating wells in Jordan

Year	Industrial Wells	Agricultural Wells	Drinking Wells	Livestock	Total
2000	145	1830	424	41	2440
2001	147	1855	480	36	2518
2002	148	1878	501	30	2557
2003	159	1946	515	27	2647
2004	171	1981	531	39	2722
2005	173	2058	509	39	2779
2006	166	2125	511	37	2839
2007	174	2169	543	31	2917
2008	180	2223	581	37	3021
2009	188	2238	573	31	3030
2010	201	2284	591	22	3098
2011	192	2311	599	19	3121
2012	181	2254	588	20	3043
2013	206	2210	602	16	3034
2014	205	2256	636	17	3114
2015	201	2163	756	18	3138

Source: MWI, (2016) open files.

Figure 3: Trends of operating wells by usage in Jordan



Source: MWI, (2016) open files.

1.2.4 Brackish Water

Brackish water for direct use or after desalination appears to offer the highest potential of non-conventional means for augmenting the country's water resources. Several brackish springs have been identified in various parts of the country. Tentative estimates from MWI of stored volumes of brackish groundwater for the major aquifers suggest immense resources, but not all of these quantities will be usable. As such, when referring to statistics about brackish water, the quality, quantity and location of this resource need to be carefully studied in order to assess its potential for utilization.

Modern desalination technologies applied to brackish water offer effective alternatives in a variety of circumstances. In 2015, there were 52 private desalination plants operated by farmers to desalinate brackish water for irrigation purposes and desalinate about 10 MCM annually. Brackish water with salinity between 2,000 and 8,000 ppm is pumped from wells at depths between 100 and 150m. The facilities are generally in operation 24 h/d in summer and 8 h/d in winter. The only energy source used to run the plants is electric power. Desalinated water is mixed with freshwater, whereby the mixed water has salinity of about 650 ppm. Irrigation water applied in particular for bananas as a crop of high market value.

Moreover, there are 44 public desalination plants and an additional 10 under construction that desalinate about 80 MCM annually. All these plants are run or will be run by WAJ to treat saline water for drinking water supply. The units are all of a small size compared to the plants in the Gulf Region.

1.3 Future trends in water resources

Jordan has extensively utilized most of its conventional available water resources. The current groundwater abstraction rates are around 600 MCM in 2015, exceeding the safe yield by around 30%. There are limited options to increase conventional water resources that can be utilized in the future, while the emphasis will be on the development of non-conventional water resources such as desalination. Other projects relying on shallow and deep aquifers will generate additional amounts of 187.5 MCM. The overall amount throughout the time frame of the new strategy will be 422.5 MCM. Wastewater treatment and utilization of marginal water are expected to increase by 94 MCM and 36 MCM, respectively. The total addition to the water budget will be 552.5 MCM. The following is a description of the main future water resources (AFD and CMI 2011, MWI, 2016a).

1.3.1 Red Sea-Dead Sea Water Project Conveyance (RSDSP)

The new water strategy plan to increase the amount of water supply through desalination. The Read Dead Sea Project (RSDSP) constitutes the major part of such increased water supply. The first phase of this strategic project will add 85 MCM to the water budget (Aqaba Supply and Swap in the north through Wadi Arab Water System II and 20 MCM will be for irrigation). The second phase is expected to be implemented between 2020 and 2025 will add about 150 MCM to the water budget. Furthermore, the difference of the water level between the Red and Dead Sea of about 400 m would offer good conditions for hydropower generation. Generated electric power will be used for the desalination process. 141 km of tunnel and closed pipe as well as 39 km of an open channel are required to conduct sea water from the Red Sea to the Dead Sea. A reverse osmosis plant will be located south of the Dead Sea.

1.3.2 Other brackish water desalination

In Jordan, there are two main sources available for desalination: the Aqaba Gulf and the brackish deep groundwater or mineral springs flowing in some basins (Jaber and Mohsen, 2001). Around 250 MCM is the available estimation of the quantity of the brackish deep groundwater (CEC, 2010). Currently, Abu Ezzeghan desalination plant produces around 11-12 MCM annually mixed with KAC water. The most recent large major desalination plant is Zara Ma'in constructed in 2006, which produces around 36 MCM/year. Additionally, there are several small to mid-size water desalination plants operating in Jordan that produce no more than 10 millions of cubic meter per year, these include desalination plants include Karamah Dam with a capacity of 1 MCM/year, Faisal nursery wells with a capacity of 2.3 MCM/year and Bereen wells with a capacity of 1.8 MCM/year.

In the future and in addition to the RDSDWC project, there are plans to expand and construct small to mid-size desalination plants with a potential of increasing annually the desalinated quantity of water by around 15 MCM (MoPIC, 2010, MWI, 2016b).

1.3.3 Treated wastewater

In 2015, around 145 MCM of treated wastewater effluent were reused, of which 125 MCM is being reused primarily in agriculture, mainly in the JV. Such quantity represented around 10% of the total water resources (MWI, 2016a). Jordan's Water Strategy 2016-2025 estimated that the treated wastewater will be around 200 MCM in 2025. As available freshwater resources become increasingly limited, treated wastewater will play an increasingly important. This will increase the contribution of treated wastewater up to 15% of the total water resources. The estimation is based on a set of targets including serving major cities and small towns with adequate collection and treatment facilities, introducing decentralized plants, major industries and mines to have wastewater treatment plants, using grey water in new high-rise buildings, and producing treated wastewater in compliance with international standards to be used as a safe non-potable water source.

1.3.4 *Improve water supply efficiency*

The main objective of water demand management policy is to maximize the utilization of the available water and minimize water losses and conserve water resources, promote effective water use efficiency in order to reduce the gap between supply and demand

The overall Un-Accounted for Water (UFW) of the municipal water sector reached around 180 MCM in 2013, which is equivalent to around 47% of total water supply (MWI, 2013). However, UFW varies among Jordan's governorates, the highest value recorded in Mafraq Governorate and the lowest in Aqaba Governorate with 63.5% and 21% respectively. In the Jordan Valley, the average amount of UFW during the last 10 years is estimated at 34 MCM annually (CEC, 2010). Assuming an ability to reduce this ratio by 75%, then around 25 MCM can be saved annually. Furthermore, there is good potential to save additional water quantities used in the Highlands for irrigation. There are many options to reduce UFW such as ensuring the enforcement of existing laws and regulations to clearly prohibit illegal use of water resources and other appropriate penalties against violators as set forth in the amended Water Authority law. Enforcement of substitution and re-use policy by providing ways and means suitable for storage of treated wastewater until time of use, and thus providing a new water resource which could substitute fresh water and be reused safely in irrigation

1.3.5 *Improve water use efficiency*

The improvement of water use efficiency implies that water users consume less water than they were previously consuming. Thus, the improvement of water use efficiency will not in fact produce new water supply but it allows a reallocation of the saved water to other users. As a national strategy, the Government proposes to target reduction of NRW by 3-6% per year with a targeted reduction to 25% nationally by 2025 and technical losses reduced to below 15%. The strategy thus also includes strengthening the criminalization of water theft and unauthorized wells.

The majority of residential customers are considered to be lower consumers with around 80% of households consuming less than 60 m3 per quarter, which is equivalent to around 110 lpcd assuming a household size of 6 people. The remaining 20% of customers who can be classified as large consumers are consuming around 40% of the water consumed by residents. This amount is estimated to be around 60 MCM per year.

1.3.6 *Efficient use of water in irrigation:*

The limited water resources allocated to agriculture make it necessary to undertake all necessary measures for efficient irrigation systems, taking into account the increase in production and water consumption savings, and also allow the cultivation of larger areas, even in years of water shortages and drought, and this requires the following measures:

1. The introduction of modern water saving technologies and advanced irrigation systems.
2. The adoption of preventive maintenance measures for irrigation systems, which lead to sustain efficient water use and reduce water losses in on-farm, conveyance, and distribution system

1.3.7 *Rainwater harvesting*

The new water strategy (2016-2025) stresses the expansion of water harvesting systems "dams, ponds, excavations" in all regions, especially in the Highlands and desert areas that are suited for it. This water can be used for different purposes and agriculture in particular. A household water harvesting is estimated at 7 MCM and about 15 MCM in the desert and remote areas.

Furthermore the new strategy pointed out that rainwater harvesting systems should be installed for new construction (residential, commercial, industrial, tourism, etc.) where the size of the storage tank depends on average rainfall and the surface area of the building is considered within the construction code. Harvested rain can provide a non-potable water source that can augment existing water supplies. Expanding the use of rainwater harvesting will take time but collecting such quantity can be achieved after 5 years if appropriate incentives and mechanisms are put in place.

1.3.8 Summary of future new water resources

Table 5 summarizes the additional future new water resources. The main source will be desalination and treated wastewater. There is an intention to decrease the groundwater over abstraction from 160 MCM in 2016 to 118 MCM in 2025.

Table 5: Future water resources in Jordan

Year	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*
Groundwater Safe yield	275	275	275	275	275	275
Non-renewable groundwater	189	174	240	241	242	243
Groundwater Over Abstraction	140	136	131	127	122	118
Surface water	276	284	293	306	311	329
Treated wastewater	181.6	191	191	195	195	235
Desalination and SWAP	20	106	107	108	109	260
Total Resources	1082	1165	1237	1251	1253	1459
Total Demand	1,455	1,485	1,493	1,503	1,536	1,548
Deficit in MCM/a	(373)	(320)	(256)	(252)	(283)	(88)

Source: MWI (2016a).

1.4 Future water demand in Jordan

A recent water strategy indicated that the total water use in 2015 amounted to 1,400 MCM, which is probably less than the actual water use due to partially uncontrolled abstraction of groundwater, in particular by agricultural users in the highland areas. Recorded water use by agriculture amounted to 537 MCM in 2009, which equalled about 61% of the total water use. Water for municipal use was the second largest position with about 34% and water for industry and tourism made up for the remaining 5%.

Municipal water use comprises domestic water use at the household level and water for services, such as commerce, health, education, workshop, governmental offices, and communal green spaces. This sector receives water through the public water network which is managed by the WAJ and Jordan's three public utilities. The total municipal water use is expected to increase to about 730 MCM in 2020 according to Jordan's water strategy, and is expected to increase to 778 MCM in 2025.

Industrial water use includes both industries that do not receive water from the public water network and industries with their own water wells. Groundwater represents about 90% of the water use for industry. Industrial water use increased sharply over the last decade up to around 50 MCM in 2015, but annual growth rates differ considerably.

Jordan’s Water Strategy estimated water requirements by oil shales and nuclear power industries to reach about 25 MCM in 2020. The projections by the MWI predicted industrial water use at 70 MCM in 2025.

Table 6: Future Water Demand during the Period 2020-2025

Year	2020	2021	2022	2023	2024	2025
Municipal, Industrial, Tourist demands	730	737	746	755	766	778
Irrigation demand	700	700	700	700	700	700
Oil shale and Nuclear power demand	25	48	48	48	70	70
Total Demand	**1,455**	**1,485**	**1,493**	**1,503**	**1,536**	**1,548**
Deficit in MCM/a	**(373)**	**(320)**	**(256)**	**(252)**	**(283)**	**(88)**

Source: MWI, 2016a.

2 Evolution of groundwater abstraction in the country's main aquifers

2.1 Abstraction, safe yield and overexploitation of groundwater in Jordan

There are twelve groundwater basins in Jordan, and the total renewable yield of groundwater basins in Jordan is estimated between 231 and 281 MCM per year. 275 MCM per year is an acceptable number for the safe yield of renewable groundwater resources in Jordan.

Groundwater resources in Jordan are classified into renewable resources, which are recharged by rainwater, and non-renewable resources (fossil groundwater) like Disi and Jafer aquifers in southern Jordan. Renewable groundwater resources in Jordan suffer from depletion caused by over-pumping over time, particularly for irrigation uses in the Highlands, the safe yield for groundwater pumping is estimated to be about 275 MCM, while the quantities that were pumped in 2014 exceeded the safe yield by about 160 MCM. Recent studies carried out by the MWI using remote sensing techniques revealed that an excess of 225 MCM of groundwater is used annually for agricultural purposes in the Highland areas.

Groundwater resources in Jordan are the main source for domestic water supply. Almost all domestic use in Jordan is based on groundwater except West Amman where the source of water for domestic use is King Abdulla Canal. Due to the growing water demand, almost all groundwater resources in Jordan are over-exploited which leads to the deterioration of groundwater quality. The high water demand was met by over-abstracting the renewable groundwater aquifers. Over abstraction is estimated at about 35% above the safe yield according to the 2015 water budget. Additionally, there are other non-renewable groundwater basins that are exploited to meet the growing water demand. Those are the Disi basin and a portion of the Jafer basin with a safe yield ranging from 107-110 MCM as estimated by NWMP (2003), or 143 MCM as reported by the annual water budget published by MWI. The following aspect will be discussed in more details.

Over-exploitation occurs in ten out of twelve basins and is especially significant in the Amman-Zarqa, Dead Sea, Azraq and Yarmouk basins; the two remaining basins are remotely located thus preventing their over-exploitation. Groundwater over-exploitation leads to declining groundwater levels by an average of about a meter a year in most aquifers, decreasing the base flow and the flow of spring discharge, and drying up springs. This leads to the deterioration of water quality, increase in cost of securing water, and a loss of about a third of Jordan's "strategic reserve" of water by 2030.

By providing reasonable volumes of water for municipal and commercial needs, water use in Jordan has exceeded the safe yields for a number of years and exceeds renewable supply. The GOJ provides high quality and reasonable volumes of water for human and commercial needs which unfortunately has the side effect of depleting the country's groundwater reserves.

Table 7 represents a summary for Table 46, Table 47 and Table 48 in the Annex. It shows that the groundwater use from renewable sources for the municipal sector increased from 179 MCM during the period (1994-2009) to 205 MCM as an average during the period 2010-2013 with an increase of 15%, while it decreased for the industrial and the irrigation sector by 15% and 3%, respectively. For the non-renewable groundwater resources, the uses increased by 133% for the municipal sector and increased by 19% for the industrial sector, while it decreased by 13% for the irrigation sector. Generally, it could be noted that the use of renewable groundwater resources was increased by 3% while in the case of non-renewable groundwater resources the percentage use was increased by 17%. This represents a real threat to non-renewable groundwater resources. It can also be seen that there are still many illegal wells that need to be controlled and prevented from pumping groundwater illegally. Further elaboration of these aspects is presented in the subsequent sections.

Table 7: Historical Groundwater Use as an average for the periods 1994-2009 and for 2010-2015 from Renewable and Non-Renewable Groundwater Resources in MCM

	Period	Municipal	Industry	irrigation	Livestock	Total Uses
Groundwater water use	AVG 1994-2009	192.3	34.0	262.7	3.7	491.7
	AVG 2010-2015	266.8	31.4	244.4	0.3	543.2
	% Change	38.7	-7.6	-6.9	-90.9	10.5
Renewable Groundwater water use	AVG 1994-2009	178.9	26.6	209.8	2.9	418.2
	AVG 2010-2015	205.9	21.8	202.6	0.2	431.0
	% Change	15.1	-18.3	-3.4	-91.5	3.0
Non-Renewable Groundwater water use	AVG 1994-2009	13.4	7.3	52.9	0.8	73.4
	AVG 2010-2015	58.2	9.6	41.9	0.1	109.6
	% Change	334.9	31.5	-20.9	-86.6	49.2

Source: compiled from MWI (1994-2015), Annual report and MWI open files.

Table 8 represents a summary of Table 49, Table 50 and Table 52 in the Annex. It shows the abstraction from groundwater basins in Jordan as a whole and in three selected basins, Azraq, Yarmouk and Amman-Zarqa Basins for the years 1995, 2004 and 2015. It shows that at the national level, the total number of wells has increased from 2,072 in 1995 to 3,138 in 2015. The number of wells has increased in the domestic drinking water wells operated by water utilities under the mandate of WAJ from 296 wells to 620 wells in 2015, which reflects the need to satisfy the increasing demand of the population in Jordan. In addition, the number of wells for irrigation purposes increased from 1,619 wells in 1995 to 2,163 wells in 2015; however the quantity abstracted decreased from 306 MCM in 1995 to 260 MCM in 2015. It can be seen that the total number of wells in Jordan is increasing and the abstraction above the safe yield increased from 23% in 1995 to 49% in 2015.

In the Azraq Basin, the total number of drilled wells (licensed and unlicensed) increased from 484 wells in 1995 to 580 wells in 2015 and the abstraction of groundwater was above the safe yield with 202% in 1995 and increased to 219% in 2015. In the Yarmouk basin, there was a steady still situation regarding the number of wells where the number of wells in 1995 as well as in 2013 was 162, but suddenly increased to 203 wells in 2015, due to Syrian crises, but the abstraction rate decreased from 169% in 1995 to 135% in 2015. This can be attributed to the reduction in groundwater abstraction in the irrigation sector. On the other hand the situation is getting worse in the Amman-Zarqa Basin, where the total number of wells increased from 672 wells in 1995 to 955 wells in 2015, mainly due to the sudden increase in population living in Amman-Zarqa Basin due to refugee influx.

Table 8: Groundwater abstraction and safe yields for Azraq, Yarmouk and Amman-Zarqa Basins and for Jordan as a whole.

Ground water Basin		Azraq			Yarmouk			Amman Zarqa			Jordan		
Year		***1995***	***2004***	***2015***	***1995***	***2004***	***2015***	***1995***	***2004***	***2015***	***1995***	***2004***	***2015***
Safe yield		24	24	24	40	40	40	87	87	87	409	418	419
Domestic, Private	No. Wells		4	10		5	8		32	73		64	136
	MCM		0.2	0.7		0.7	0.18		3.6	5.6		6.8	9.5
Domestic governmental.	No. Wells	26	37	29	32	41	51	114	163	163	296	467	620
	MCM	24	23	18	26	9	12.5	62	75	66.6	1708	208	323
Industrial	No. Wells	2	3	13	1	1	1	49	75	79	89	171	201
	MCM	0.1	0.2	0.6	0	0.2	0.11	6.2	6.9	5.6	21.8	34.1	31.6
Agriculture	No. Wells	435	521	542	127	115	143	509	481	635	1619	1981	2163
	MCM	24	35	33	42	37	41.4	95	60	88	306	251	260.5
Livestock & Remote Areas	No. Wells	21	9	4	2	0	0	0	1	5	68	39	18
	MCM	0.7	0.2	0.02	0.2	0	0	0	0	0.05	7	0.8	0.18
Total water Abstraction		48	59	52.5	68	47	54.1	163	145	166	505	501	624
Balance (MCM)		-24	-35	-28.5	-28	-7	-14.2	-75	-58	-78.6	-95	-173	-206
Total No. of Wells		484	574	580	162	162	203	672	752	955	2072	2722	3138
Percent of Safe yield		202	244	219	169	118	135	186	166	190	123	119.7	149

Source: MWI, (2016) open files.

2.2 Problems in Jordan's aquifers

In Jordan, groundwater basins are suffering from over-exploitation and degradation of water quality, and due to the over pumping and illegal drilling in the Highland areas, especially for irrigation purposes, a drawdown of water tables took place.

2.2.1 Water table drawdown and degradation of water quality

Groundwater is a highly useful and often abundant resource in the past. However, over-use, or overdraft, can cause major problems to human users and to the environment. The most evident problem is a lowering of the water table beyond the reach of existing wells. As a consequence, wells must be drilled deeper to reach the groundwater. Water levels in any aquifer can drop to the point that water can no longer be pumped economically. This drop can occur when the demand (pumping) is greater than the supply, or when extended dry periods happen.

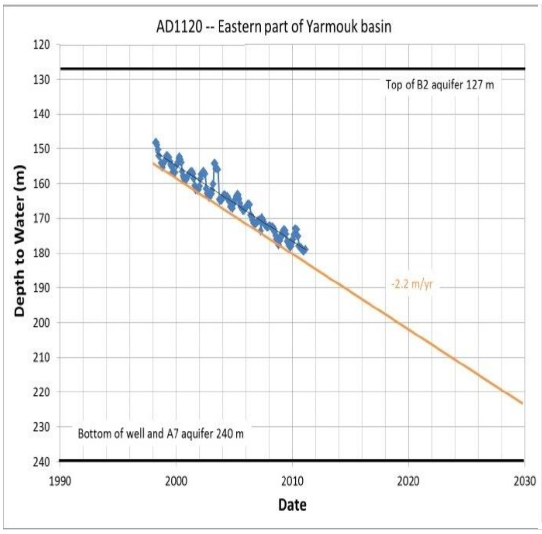
Groundwater is the major water resource in Jordan. However, most of the groundwater basins in Jordan are already exploited beyond their estimated safe yield. Over-exploitation affected ecosystems and many rare birds and plants disappeared totally.

Groundwater over-abstraction is often accompanied by increases in salinity and pollution. These are environmental problems in their own right, and also limit the effective availability of groundwater for many uses. Water quality deterioration in Jordan is, for example, considered to be mainly due to the extensive exploitation of groundwater resources without taking into consideration the safe yield of the aquifers. The hydrographs and water quality trend data for key aquifers in Jordan indicate a strong relationship between water levels and water quality declines (El-Naqa and Al-Shayeb, 2008). As water levels decline, TDS (total dissolved solids) levels increase. In addition to quality problems stemming from groundwater overdraft, point and non-point source contamination from agriculture, industrial and domestic uses are also a major problem in Jordan (El-Naqa and Al-Shayeb, 2008).

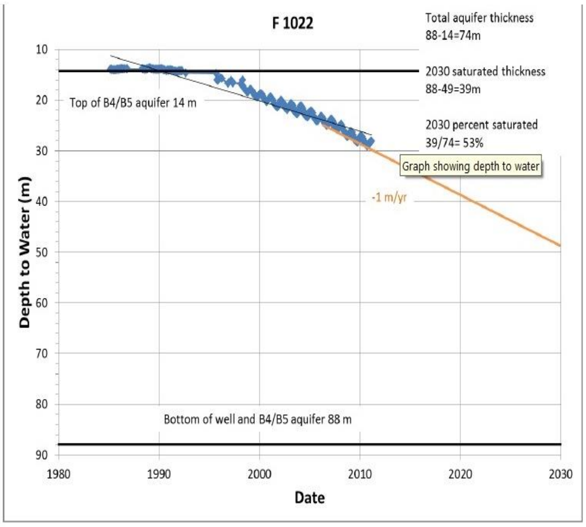
Figure 4 below illustrates a deep well that lowered the water table level and shows a long-term decline over time. Because recharge to the basin was insufficient, this has resulted in a net deficit that results in water-level declines. As a result of overexploitation and water level depletion in the groundwater aquifers, the salinity generally increased over time. Figure 5 below illustrates increased dissolved solids concentrations in the selected basins namely Yarmouk, Zarqa and Azraq Basin, which generally have increased over the years. It illustrates that there is a clear increase in the salinity level in the mentioned groundwater basins.

Figure 4: Groundwater Trends in Yarmouk, Zarqa and Azraq Basin: water level trends and forecasts for selected wells

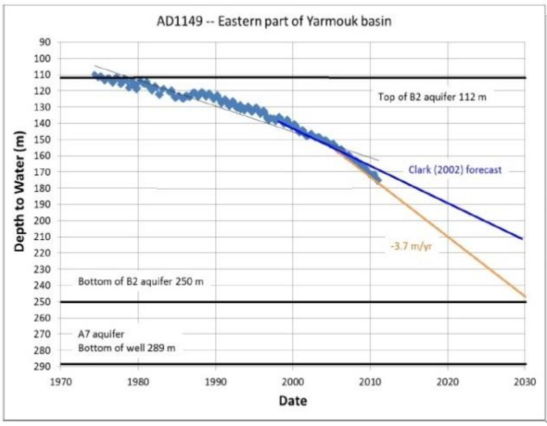
Yarmouk Basin



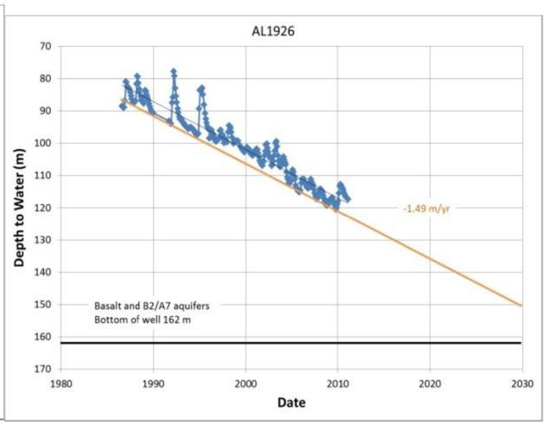
Azraq Basin



Yarmouk Basin



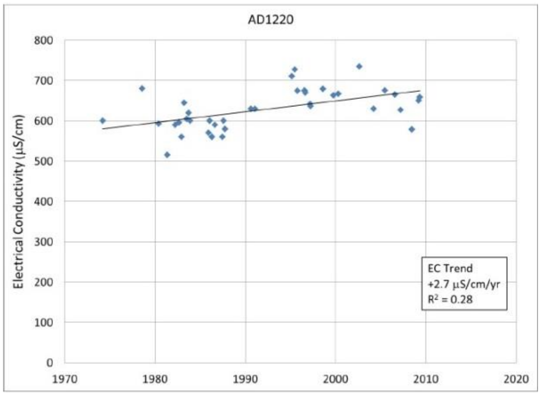
Zarqa Basin



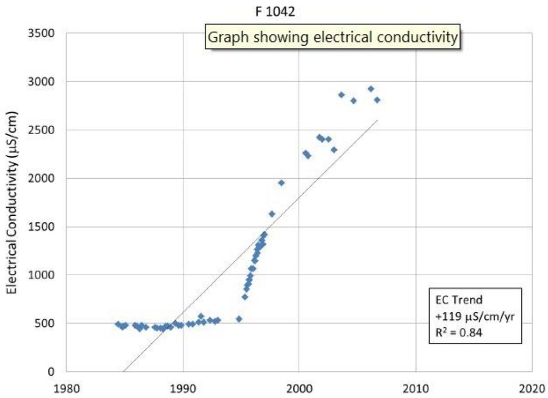
Source: MWI (2015) open files and Goode et al., 2013.

Figure 5: Groundwater Trends in Yarmouk, Zarqa and Azraq Basin: Salinity (electrical Conductivity) Trends for selected wells

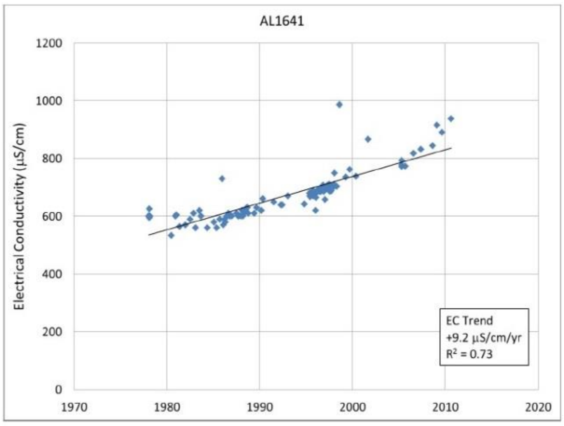
Yarmouk Basin



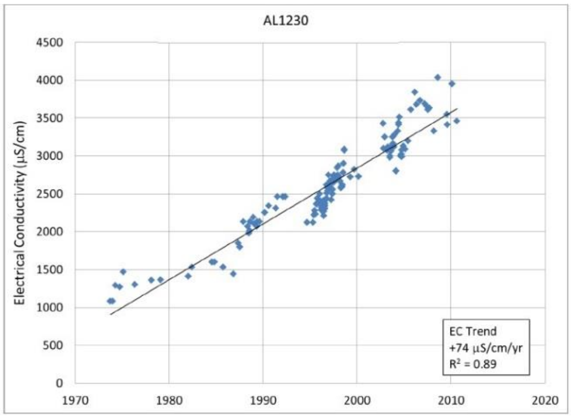
Azraq Basin



Zarqa Basin



Zarqa Basin



Source: MWI (2015) open files and Goode et al., 2013.

2.2.2 Illegal drilling and abstractions

The Ministry of Water and Irrigation took several measures and actions to reduce the over-exploitation and the over-pumping of the groundwater in Jordan. One of these actions is to monitor all groundwater wells in Jordan and the enforcement of different groundwater laws that prohibits the illegal drilling and wells.

In order to protect and preserve groundwater resources in Jordan a National Groundwater Management Policy was issued in 1998 (MWI, 2001). This policy emphasizes the need to protect groundwater resources from over abstraction and related quality degradation, as well as pollution, and give priority in use of the resources to municipal and industrial uses. The Groundwater Management Policy considers also the monitoring of groundwater resources and protection of recharge areas of aquifers as important factors in safeguarding the quality of groundwater resources. In terms of minimizing over-abstraction of aquifers, the policy stresses the need to stop illegal drilling and to meter all water wells (El-Naqa and Al-Shayeb, 2008).

Table 9 shows that more than 1,293 illegal wells have been either backfilled or capped by the Ministry of Water and Irrigation until 2016. In November 2016 the Ministry reported in the media that the total number of closed wells reached to 695 wells between 2014 and 2016 and they captured 38 drilling machines.

Table 9: Number of closed Illegal wells by the MWI until the 2016 in Jordan.

Year	No. of well closed (caped or refilled)	Accumulated No. of Wells closed
before 2007	235	235
2007	26	261
2008	45	306
2009	46	352
2010	57	409
2011	29	438
2012	19	457
2013	141	598
2014	385	983
2015	174	1,157
2016	136	1,293

Source: MWI, (2013). Annual report, and personal communication with MWI staff (2016).

3 Drivers and pressures on groundwater resources

Jordan is facing substantial water shortage problems. All forecast scenarios predict an increase in water demand as a result of many driving forces such as population growth, urbanization, development, economic growth, and sudden influxes of refugees as well as the climate change. The main drivers will be discussed below.

3.1 Population pressure

Population increases produce increasing pressure on water resources both quantitatively and qualitatively. In areas with scarce water resources, the pressure expresses itself in terms of water quality degradation and water resources depletion (over-exploitation of aquifers). Ad hoc water projects to satisfy the needs of sudden increases in the population due to refugee waves may end up causing damages to the environment and may prove to be unsound economically or from a water management point of view. The adopted approach considers that in water scarce areas, the water resources can only cover the needs of a limited number of people. Any depletion and/or degradation are attributed to the number of people exceeding the tolerance of the water resources

Jordan's population comprises 6.5 million people in 2013, with a natural growth rate of 2.6% between 2005 and 2010. In November 2016 the population of Jordan reached 9,852,371 inhabitants (DOS, 2016). Most of the population is urban and only 9.7% live in the rural areas. Jordan has received waves of refugees since World War II (1948, 1967, 1975, 1981, 1990, 2003, 2011) making its social structure complex, and includes about

0.5 million registered Iraqi refugees. More recently another 1,600,000 have fled the civil strife in Syria and are located in cities and border refugee camps.

The trend of urbanization in Jordan is demonstrated by the increase of urban population from 59.9% in 1980 to 78.5% in 2010. The country's biggest city is Amman with 4.0 million inhabitants, which is 42% of the country's total population, followed by Irbid with 1.77 million inhabitants and Zarqa with 1.36 million inhabitants (DOS, 2016).

According to the United Nations, an estimated 2,973,000 international migrants from the Palestinian territories, Iraq or Syria lived in Jordan in 2010 - around 45.9% of the total Jordanian population. Between 2005 and 2010, the average annual net migration amounted to seven migrants per 1,000 people. The civil unrest in Syria since 2011 marked a major challenge for Jordan. Nearly half a million Syrian refugees have crossed into Jordan on top of the 750,000 refugees already there before 2011. As a consequence, Jordan's refugee camps now struggle to absorb all the people (UNHCR, 2015).

3.1.1 Endogenous Population of Jordan (1928-1947)

When the first population census was conducted in 1922, Jordan's population amounted to just 235,000. The main groups from Jordan's population are the Bedouin. As they are known in Arabic, the Bedu, or "desert dwellers," endure the desert and have learned to survive its unforgiving climate. The Circassians are a non-Arab Islamic people originally from the Caucasus region of western Asia. Southward Russian expansion during the 19th century forced the displacement of between 1.25 and two million. A small Druze community lives in Jordan, mainly near the Syrian border. There is also Druze community in Azraq, in the east of the country. Several other minorities complete Jordan's social mosaic. Several thousand Armenians live in Amman and in other parts of the country. The north Jordan Valley hosts a small community of Turkomans and Baha'is, who moved from Iran to Jordan to escape persecution in 1910. Jordan became an Emirate on March 1921 and its independence was declared on May 25 1946, Jordan was declared as a Kingdom with the end of the British mandate under the role of First King Abdullah. Data on population size in Jordan before 1947 is available in the Department of Statistics and covered the period 1922-1947.

3.1.2 First Wave of Refugees- (1947-1952) First Arab-Israeli War

Before the 1948 War, the population of Jordan was 473,000 and growing at an annual rate of about 2.8%. In 1948, the Arab-Israeli war took place and Palestinian Refugees began entering the international borders into Jordan. The period during the years 1947-1952 represents the years of the Palestine crisis and associated military actions (1948 War). A huge number of Palestinians were forced to leave their homeland and move to neighbouring Arab countries, including Jordan between 1947 and 1949. Consequently, Jordan's population rose significantly due to the sharp increase in the population growth rate as a result of net migration, recorded 532,828 in 1949. At that period it was estimated that 57,000 refugees had come to Jordan.

3.1.3 Second Wave of Refugees (1967 Arab-Israeli War)

Jordan's population size in 1967 increased dramatically as a result of the forced migration entered the country from the West Bank during and after the 1967 War. This large size of migration from the West Bank added 245,000 to the total population, which created new pressures on Jordan’s different resources and mainly on the water resources and environment.

The effects of immigration could be seen clearly through the comparison between its population size in 1966 and 1967. Jordan’s population suddenly increased from 1.06 million in 1966 to 1.34 million in 1967, registering a tremendous growth rate of 23.4% between the two mentioned years. The population of Jordan increased significantly during the period 1971-1976 from 1.56 million in 1971 to 1.88 million. But this period was far from the effects of later large immigration waves, when several thousand Lebanese entered the country due to the Civil War in Lebanon in 1975.

3.1.4 Third Wave of Refugees (Second Gulf War- 1990-1992)

Due to the economic crisis in the Gulf States, Jordanian workers started their return to the country. The second Gulf Crisis in 1990 and the following war in 1991 played a significant role in the increase of Jordan’s population in the beginning of the 1990s. Approximately, 300,000 returnees were displaced from the Gulf States, particularly from Kuwait, a large proportion of them were Palestinian refugees with Jordanian nationality. This huge influx of returnees caused a significant increase in population growth rate, which reached 9.8 % between 1989 and 1990.

3.1.5 Fourth Wave of Refugees (Third Gulf War- 2003)

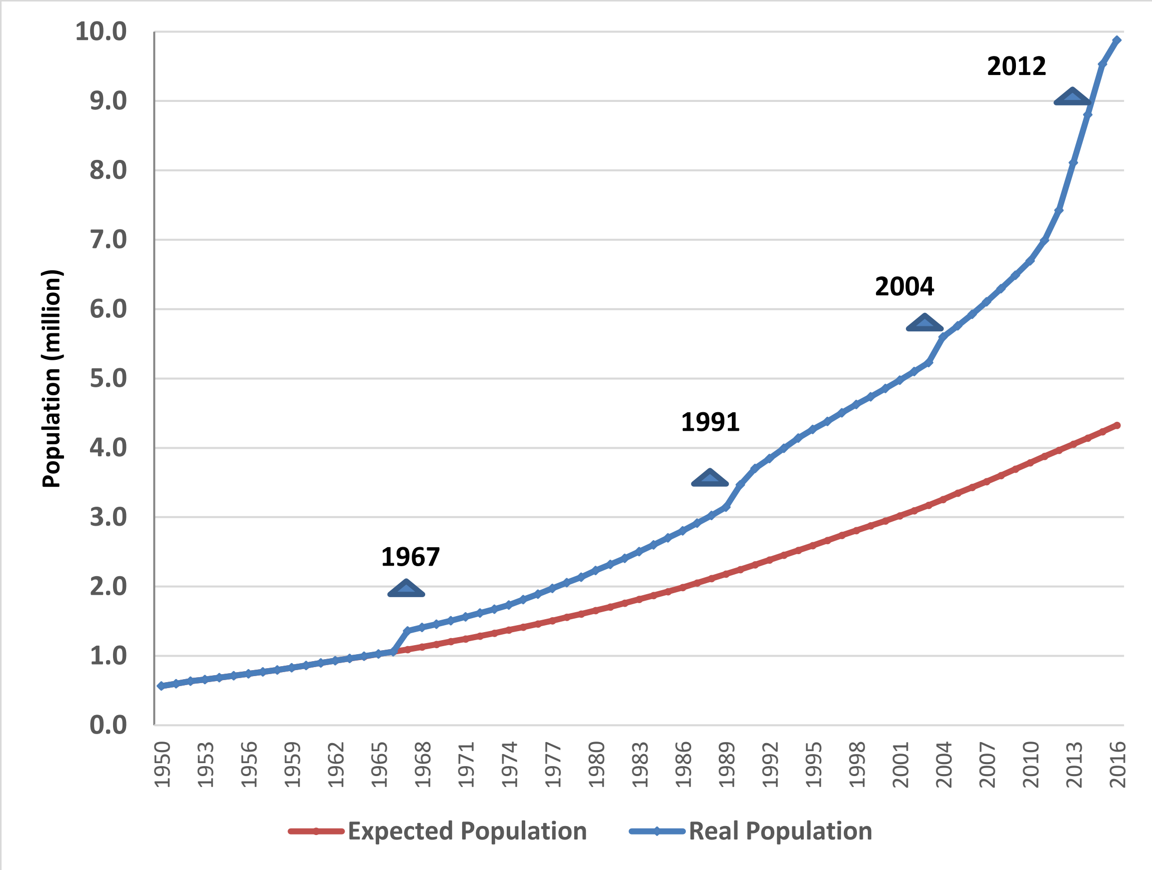
Since the start of the war in Iraq in 2003, increasing numbers of Iraqi nationals have left their homes for different parts of Iraq or have taken residence in neighbouring countries, particularly Jordan and Syria. Iraqi refugees began arriving in Jordan in large numbers in 2003, with about 30,000 currently registered with UNHCR. In recent months, however, Iraqis fleeing the Islamic State have started streaming into Jordan. The UNHCR provides lifesaving services to Iraqi refugees, but these Iraqis generally cannot obtain legal status in Jordan, nor can they return to Iraq safely (UNHCR, 2015b). Their most likely prospect for a long-term solution is resettlement – usually a long and slow process.

3.1.6 Fifth Wave of Refugees (Syrian Crises 2011-open)

The growing Syrian conflict has caused a massive influx of both Syrian immigrants and refugees into Jordan starting from 2010 and accelerating over 2012 and 2013. This dramatic population increase has impacted Jordan’s water and sanitation sectors negatively and heavily strained both the Jordanian economy and resources. Digging new water wells and expansion of water networks had to be carried out to supply new camps with water. In the northern areas of Jordan, the demand of Syrian refugees demand for water services is increasing day by day. Additionally, sanitation services have become an issue of major concern; many cities require the expansion of sanitation capabilities to handle the increase in waste generated.

As of 2015, with about 1.5 million Syrian refugees in Jordan, 621,918 Syrian are legally registered as refugees and only 20 % are living in refugee camps. With the majority of the Syrian refugees spread throughout the country, especially in Amman, Irbid, Al-Mafraq, and Jerash, Syrian refugees were registered in Jordan outside the UNHCR camps. Nearly one third of them live in Amman Governorate (32%), over one quarter in Irbid Governorate (29%), 14% in Mafraq Governorate and 10% in Zarqa Governorate. 45% of all registered non-camp Syrian refugees are from the Dara’a Governorate in Syria. Homs, Rural Damascus and Damascus city are the next most represented governorates of origin (18%, 10% and 9%, respectively) (UNHCR, 2015).

Figure 6: Natural growth versus actual growth of population in Jordan



Source: Authors estimate based on Department of Statistics online data (DOS, 2016a).

3.2 Consequences of population pressure on groundwater

3.2.1 Over-exploitation of aquifers

In 1980, when the amount of extracted groundwater for irrigation reached 138 MCM/yr (World Bank, 1997), the aquifers as a whole were balanced. After that, over-exploitation started and increased gradually to reach 200 MCM/yr in the early nineties and again gradually to more than 250 MCM/yr in 2000. This over-exploitation rate has since then continued. According to the World Bank (1997, 2001), the overdraft from renewable and fossil aquifers in Jafr and Disi was 305 MCM/yr.

If the extracted amount of a groundwater body exceeds its annual natural recharge over a series of years, and if it is practically not expected that under the normal climatic conditions very wet years may compensate for the extracted amounts, the water body is considered to be over-exploited. In this case the groundwater levels or piezometric heads drop monotonously, although with some seasonal or secular fluctuations.

This situation is affecting almost all areas in Jordan; Azraq, Dhuleil, Shoubak, Agib, Qastal, Qatranah, Wadi Arab, Northern Badia, Amman-Zerka and Disi areas. In all these areas water levels are continuously declining, and wells drilled in Dhuleil, Azraq, Disi, Amman-Zerka and partly in other areas have to be deepened and pumps sunk in accordance with continuously dropping water levels.

Dropping water levels result in up-coning of underlying water bodies, which contain generally higher salinities. Hence, their up-coning caused salinization of water bodies under use. In Dhuleil and Badia areas, increasing salinities due to up-coning are affecting the aquifers under exploitation. Salty water is also found at the surface of and underlying playas and certain desert oases. Oases are generally fed by surface and/or groundwater, where the water evaporates and salts accumulate or remain dissolved in the rest of the water.

3.2.2 Requirement of additional water infrastructure

Water resources are scarce for both Syrians and their Jordanian hosts. This increases pressure on Jordan's infrastructure, specifically water supplies, sanitation facilities, housing, and energy. A survey conducted by UNHCR in 2013 found that 84% of visited refugee families found their water quality to be adequate and 87% were found to have adequate sanitation conditions.

Water utilities have not been able to increase the volume of water supply to meet the increasing demand. Residents have even sometimes pressured the water utilities operators and requested more water for their neighbourhoods. Residents feel that the influx of refugees in their communities has intensified the water shortage situation and stresses to the already inadequate infrastructure in many areas. As mentioned before, Jordan received around 622,000 registered Syrian refugees (UNHCR, 2015) residing in the Zaatari camp and living in surrounding communities, especially Mafraq, Ramtha and Irbid (north of Jordan). The residents in Mafraq and Irbid were already water stressed before the arrival of the refugees, and they typically received water deliveries for only six hours every two weeks. Table 10 shows the cost estimate of Syrian refugees on the water sector during the period (2012-2015).

The influx of around 1.6 million Syrian refugees and the low amounts of rainfall in recent years have exerted tremendous pressure on the government of Jordan to respond to the water supply challenges. Due to the presence of Syrian refugees mainly in the northern and central parts of Jordan, water supply in the entire country had to be rearranged. Although water supply from the Disi well field (107 MCM/yr) became operational in July 2013, part of this amount is diverted to the middle and northern governorates. Well fields previously supplying Amman, like Qatrana, Siwaqa, Lajjun, Hidan and Corridor, have now been modified in order to provide water to other cities not able to meet their demand, like Irbid, Zarqa, Kerak and Madaba. A quick solution is needed to cover water supply deficits for the northern and central parts of Jordan in the near future.

Table 10: Cost of Syrian refugee crisis on water sector

Cost Estimate	Unit	2012	2013	2014	2015
No. of Syrian Refugees	person	>400	>600	>800	>800
Total Syrian living in Jordan	person	1,100,000	1,200,000	1,400,000	1,600,000
Daily Water Consumption (@ 70 l/c/d)	m3/day	77,000	84,000	98,000	112,000
Annual Water Consumption	MCM/year	28.105	30.66	35.77	40.88
Annual direct & indirect Cost (430 per/refugees)	Million JD	473	516	602	688

Source: MWI, (2013b) and El-Naser Hazim (2014).

3.2.3 Decrease per-capita share of water

As a result of "rapid population growth," the quantity of drinkable water available on average to the Jordanian population is less than 125 m3 per year, the previous figure before the crisis was 160 m3 per year. The renewable water supply, provided by rainfall, only creates less than 50% "of the total water consumption" so the remainder must be extracted from "aquifers that are already being depleted" (Sullivan, 2014). Water is one resource without the capacity for foreign support, forcing Jordanians to make do with their own resources. Jordan, as a nation, largely depends on foreign aid and its scarce water resources are not renewable (Sharp, 2014). In 2016, Jordan's annual renewable resources of less than 100 m3/capita are far below the global threshold of severe water scarcity (500 m3/capita).

The per capita water supply is estimated with 126 lpd in 2015 based on a total population of 9.53 million inhabitant in 2015. The supply requirement is the demand according to (120 lpd for Amman, 100 lpd for other cities, and 80 lpd for rural areas) in addition to losses in water distribution. The per capita share of consumed water is estimated at 94 lpd. The consumed water is calculated based on the assumption that 50 % of losses are administrate losses and consumed by people illegally (MWI, 2016).

3.2.4 Interrupted pumping

Interrupted pumping of municipal water supply was introduced in Jordan in 1987 by the WAJ, when the water amount from developed sources became insufficient to meet the requirements of keeping the water supply system under pressure, with households receiving water once a week for various durations. The strategies used by households to manage water and overall satisfactions with water supply issues are diverse. The social costs of water rationing and consequent household management are high; the issues of water quality are of central importance to all consumers (Darmame & Potter, 2008).

The interrupted pumping has led to two major impacts: construction of cisterns and roof tanks and damage of the water supply networks. The storage capacity has, at least, to cover the needs for one-week use.

The high-income households had an average water storage capacity of 16.24 m^3, while for the low income consumers storage amounted to 3.12 m^3. On average, the high-income households interviewed consumed 70.24 m^3 of water per quarter, while the low-income households consumed around half this total at 32.68 m^3.

As a result of high UFW, the water supply system of Amman was privatized in 1999. The privatized company LEMA oversaw the reduction in 'unaccounted for' or 'lost' water, the upgrading of the network as well as making improvements in billing and debt collection. In January 2007, the water supply system of Greater Amman was effectively "deprivatized" and placed in the hands of a local company Meyahona ('Our Water'), which is owned by the Water Authority of Jordan, although its remit has remained avowedly commercial (Potter & Darmame, 2010).

3.2.5 Extra rehabilitation of the water supply network

As mentioned above the engagement of the Water Authority of Jordan and the Jordan Valley Authority in the immediate relief water supply and sewerage programs to meet the needs of the different refugees waves, diverted their activities and expenditures totally towards the relief programs. The results of not implementing maintenance and repair, in addition to the "forced" direct pumping to users and not to collective supply reservoirs, caused damage to the water supply networks to a degree that substitution became cheaper than repair. When pumping directly to users without interruption the system will be pressurized and deliver water continuously. This causes continuous expansion and contraction of system components and exposure to corrosion elements.

3.3 Economic policy drivers

Jordan is a heavily urbanized, small, lower to middle-income country with a narrow natural resource base and scarce water resources. Jordan’s score in the Human Development Index for 2011 is 0.698 ranking 95th of 187 countries, down from 0.760 in 2010 (UNDP, 2014).

The major sources of earnings are services (tourism, transport and finance), industry, foreign aid and remittances. For example, the growing industrial sector (e.g. potash, phosphorous, fertilizers, clothing, and pharmaceuticals) collectively generates about 34% of the GDP. The remittances deposited by Jordanians working in foreign countries, especially the Gulf States, represented a very important contribution to the economy ranging from 15 to 25% of GDP between 1995-2009 (US$ 3.5 billion in remittances were received by Jordan in 2009). However, 2011 was a year of challenge to Jordan as a result of the sweeping changes in the Arab region, the global shocks of increasing food and fuel prices, and sharp decline in tourism, remittances and foreign direct investment (-16%, -3% and -32% respectively).

3.3.1 Economic growth, horticultural export

Jordan’s economy has continued to perform well over the last five years. The GDP growth at market prices reached 5.0% in 2015. The main contributing sectors were services, manufacturing, and producers of government services. The percentage share of agriculture in Jordan's GDP has increased to around 3.7%. The agricultural GDP increased from JD 276 million in 2006 to JD 980 million in 2015[3] as shown in Table 11. The per capita GDP has increased from JD 1,801 in 2006 to JD 2,795 in 2015. On the

[3] Central Bank of Jordan (2015). Monthly Statistical Bulletin, Research Department. Volume 50, No. 10, Amman, Jordan.

other hand, inflation, measured by the Consumer Price Index (CPI), witnessed an increase by 5.6% during the year 2013 compared to 4.7% during the year 2012 then decreased to 2.3% in 2015. Furthermore, the unemployment rate during the year of 2015 increased to 14% compared to 13.1% during the year in 2012.

Table 11: Summary Statistics on Jordan's Agricultural Economy, 2006-2013

Jordan Economy	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Agriculture [MJD]	276	307	377	459	561	598	605	714	845	980
GDP at Market Prices [BJD]	10,7	12,1	15,6	16,9	18,7	20,5	21,9	23,8	25.4	26.6
Agricultural share of GDP [%]	2.6	2.5	2.4	2.7	3	2.9	2.75	2.99	3.32	3.68
Per Capita GDP at Current Price [JD]	1,801	1,987	2,478	2,606	2,801	2,928	2,958	2,940	2,889	2,795

Source: CBJ, (2016). Monthly Statistical Bulletin. Retrieved Dec 2016. www.cbj.gov.jo/pages.php.

However, the agricultural sector maintained an increase in monetary value (market price) as reflected in the incremental contribution of agriculture to actual GDP as indicated by the value of the total agricultural gross output (from JD 766 million in 2005 to JD 2,150 million in 2014, crop and animal intermediate consumptions (JD 519 million in 2005 to JD 1,304 million in 2014 and the added value (agricultural gross domestic products) from both crop and livestock products increased from JD 246 million to JD 845 million in 2014) as shown in Table 12.

The increase in the total agriculture gross output is attributed to a steadily increasing market value for livestock products and to the dramatic increase in the contribution of vegetable and fruit tree crops to the total gross crop output (Table 12). In spite of the above increase in absolute monetary terms, the proportionate contribution of agriculture to the national economic growth is very modest, which is reflected in the decline in the sector's share in employment and GDP, despite an increase in water use compared to other fast growing sectors.

The agriculture sector is a major consumer of water, and the returns to water from crop production tend to be low in comparison to other sectors. Table 12 shows that horticulture is becoming the main source of agriculture GDP. The contribution of crops increased from 48% in 2005 to 63% of agricultural GDP in 2011 then decreased to 54% in 2014. The annual growth rate of agricultural GDP was fluctuating during the last decade.

Table 12: Development of Agricultural Activities: Agriculture Gross Outputs, intermediate consumption and Gross Domestic Product (GDP) in million JD.

Indicators	2005	2010	20011	2012	2013	2014
Crop Gross Output	307	710	698	691	857	959
Livestock Gross Output	458	952	976	966	1138	1190
Total Agricultural Gross Output	**766**	**1661**	**1673**	**1658**	**1995**	**2150**
Crop Intermediate Consumption	188	321	320	275	496	499
livestock Intermediate Consumption	319	780	755	778	785	805
Total Intermediate Consumption	**519**	**1100**	**1075**	**1053**	**1281**	**1304**
Crop Value Added,	119	389	378	416	361	460
Livestock Value Added	139	172	220	189	353	385
Total Value Added (A. GDP)	**246**	**561**	**598**	**605**	**714**	**845**
Percent share of crop production	48%	69%	63%	69%	51%	54%

Source: DOS, 2016 open files.

The horticulture sector can be divided into the Highlands and the Jordan Valley. Around 40% of Jordanian agriculture GDP is generated in the Highlands based on groundwater resources. The importance of the agricultural sector in the Highlands stems from the fact that it is the major source of stone fruits and summer vegetables, and also one of the sources of hard currencies originated from exports. One can use a rough estimate of value added of irrigation water by dividing the total value added (agriculture GDP) in each geographical location by water consumed in each location. Table 13 shows that the Highlands yielded the lowest gross water value added with JD 0.3 per cubic meter of groundwater.

Table 13: Contribution of irrigated Highland and Jordan Valley in agriculture Gross Domestic Product (GDP) in 2015 (million JD)

Crop	Jordan	Highland	RJV
Crop Value Added (JD million)			
Field Crops	41	35	7
Vegetables-Winter	172	67	104
Vegetables-Summer	122	91	31
Tree Crops	171	109	62
Total Value Added (JD million)	506	302	204
Percentage Distribution of Value Added			
Field Crops	8%	7%	1%
Vegetables-Winter	34%	13%	21%
Vegetables-Summer	24%	18%	6%
Tree Crops	34%	22%	12%
Distribution of Value Added	100%	60%	40%
Irrigation Water Supplied (MCM)	667	456	211
Water Value Added (JD/m3)	0.758	0.661	0.968

Source: author estimate based on raw data from DOS in 2016.

3.3.2 Urbanization

The distribution of population in urban and rural areas varies significantly among Jordan's governorates. The percentage of urban population to total population for each governorate in 2003 and 2009. In, 2009, Karak and Mafraq have the lowest ratios of urban population (35% and 29.2% respectively), while Zarqa and Amman are the most urbanized governorates with 94.5% and 94% respectively. This obviously illustrated the large variation among governorates; however the change in the percentage in urban population within each governorate during over 6 years (2003-2009) is negligible with maximum variation of ±0.5%.

Urban and rural households have different characteristics and water consumption behaviour. For example, rural areas have more individual type houses (named Dar) while urban areas have more apartment-type houses. Those Dars are normally surrounded by a garden and might have additional facilities such as water pool, small economic activities related to agricultural and animal production. Additionally, the number of family members is also larger in the rural areas derived by the need to have more family members help their families in their agricultural activities. Therefore, water demand and consumption behaviours are expected to vary between the urban and rural areas.

The analysis carried out by Salman et al. (2008) concluded that customers residing in a flat or apartment, which are more common in urban areas, consume less water per household and per capita compared to customers resident in an individual houses, which are common in rural areas. As households in the rural areas have a garden and some agricultural activities inside the house, it is expected that water consumption and supply with be higher in those areas in comparison to the more urbanized areas. Realizing that such water uses are expected to be higher during summer season.

3.3.3 Expansion of Agriculture in the highland areas

The total area of Jordan is about 89.2 million dunums, and this land area can be divided into seven climatic rainfall zones. In general, Jordan is considered as a low rainfall region, since over 86% of its area is a desert and has no economic importance, except for some short-term sporadic grazing at certain times of the year. The level of precipitation decreases from West to East and from North to South and, out of a total cultivable area of about 2.6 million dunums (2.9% of the total land area), 1.5 million dunums (60%) depend entirely on rainfall to sustain any crops, and only about 1.03 million dunums (40%) were irrigated in 2010 (Table 14). The average cultivated area in the 2000-2009 period is about 2.4 million dunums, representing 2.7% of the total Jordanian area and less than 1 dunum per capita. However, the cultivated area varies strongly according to changes in rainfall.

In the last 30 years more and more areas, especially in the highlands and the Badia region, have come under irrigation. The total irrigated area was 253,000 dunums in 1983. The irrigated area constantly increased to reach almost 538,000 dunums in 1990 and 703,000 dunums in 1995 (Table 14). And in 2010, the total irrigated areas reached about 1,035,000 dunums (DOS, 2012). Thus, more than 40% of the total cultivated area is now under irrigation.

Due to variations in rainfall, the increase of irrigated area, the shift to more profitable crops, and major changes in the traditional markets for Jordan's agricultural products, the irrigation pattern has changed. The area of field crops fluctuates sharply from year to year on a decreasing trend. The irrigated field crops increased from 1.7% in 1983 to 8.2% in 1997 and then increased to 13% of total field crops area in 2007. Due to the profitability and comparative advantage of vegetables in Jordan, especially in the Jordan Valley, the cultivated area under irrigation has increased with an annual growth rate of 5% to reach 92% of vegetables area. The drastic change in Jordan occurred in fruit production (olive trees).

The total irrigated area in Jordan during 2015 was estimated at about 1,035 thousand dunums distributed between the Jordan Rift Valley (JRV) with 324,000 dunums and the highlands and the desert areas 711 thousand dunums. There are different factors affecting agricultural water demand that can be grouped into the following factors:

3.3.3.1 Type of irrigation and cultivation technologies

Irrigation technologies commonly used in Jordan include furrow, drip and sprinkler. Open space, greenhouse and plastic tunnels are the most technologies used for cultivation or production. The use of different irrigation and cultivation technologies is influencing irrigation water demand in two ways: 1) irrigation water requirement and; 2) irrigation water use efficiency. Drip and surface irrigation technology are dominant with around 63% and 33% respectively of those technologies are being used for irrigation. The use of sprinkler systems is limited to forage and cereal production and does not exceed 4% (DOS, 2008)

Typical crop water requirements vary depending on the climatic zone where they are planted. However, using different irrigation and cultivation technologies result in changing these typical water requirement. For example, using drip irrigation system will need less water than using sprinkler irrigation system to irrigation same crop.

Table 14: Development of Irrigated areas in Jordan Valley and Highland ('000 du).

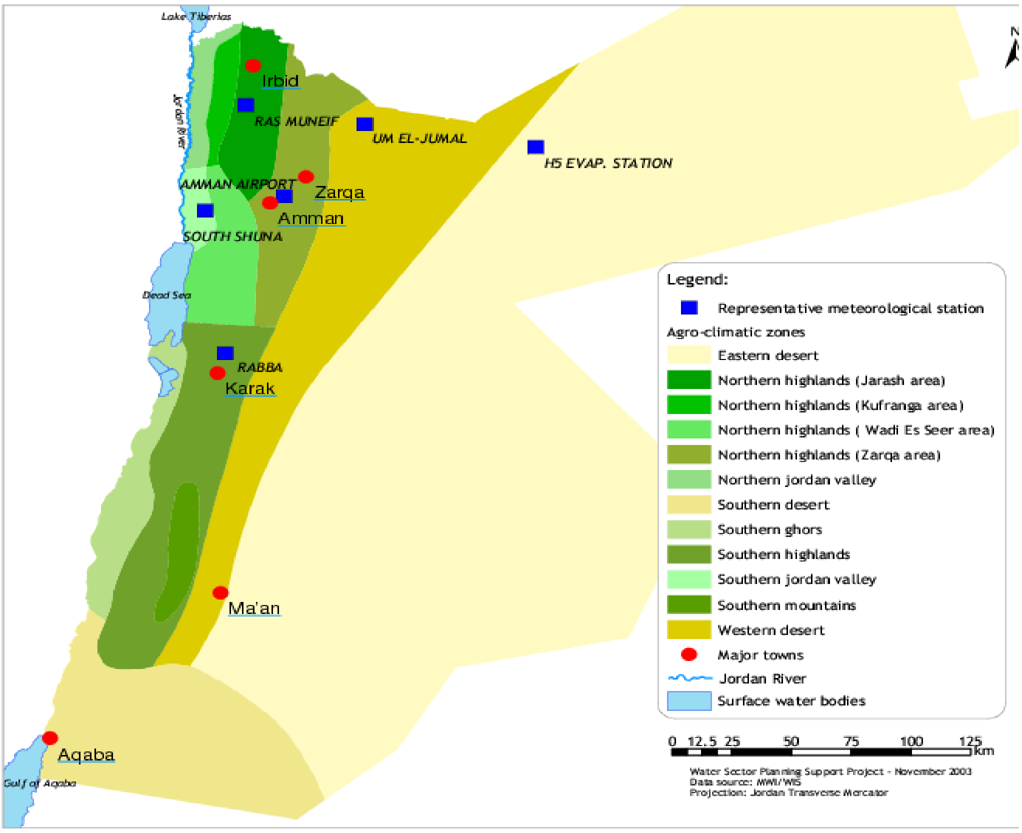
	Jordan Valley				Highland				Jordan			
Year	Tree Crops	Field Crops	Vegetable	Total	Tree Crops	Field Crops	Vegetable	Total	Tree Crops	Field Crops	Vegetable	Total
1995	83	37	143	263	146	45	249	440	228	83	392	703
2000	110	38	172	320	238	43	139	420	348	81	311	740
2005	93	34	156	283	242	52	224	518	335	85	381	800
2010	105	32	197	334	342	97	252	691	447	129	449	1,025
2011	108	20	184	312	362	67	224	653	470	88	407	964
2012	110	29	200	339	362	55	200	617	472	84	400	957
2013	88	26	209	324	363	85	263	711	451	111	472	1,034
2014	90	23	203	316	368	91	275	735	458	114	478	1,050
2015	95	25	199	318	382	72	263	716	477	97	461	1,035

Source: (DOS, 2016). http://web.dos.gov.jo/sectors/economic/agriculture/agriculture-surveys/

3.3.3.2 Cropping patterns and climatic zones

Crops have different water requirements that also vary depending on the climatic zone. Normally crops planted in highlands or cold regions need less water quantity than crops planted in desert, low lands or warm regions. Figure 7 shows the agro-climatic zones in Jordan with three major zones: Jordan Valley, the Highlands, and deserts. Most planted areas are located in the Jordan Valley and the Highlands. The planted part of the deserts is close to the Highlands climatic zone characteristics. Thus, the Highlands and planted deserts are grouped into one category named 'upland'. The typical crop water requirements for field crops, vegetables and fruit trees in uplands and Jordan Valley are presented (AFD, 2011). It can be seen that crops water requirements are higher in the upland area than the JV, where most of vegetable crop are cultivated in summer season and does not benefit from effective rainfall.

Figure 7: Agro-climatic zones in Jordan



Source: GTZ and MWI (2004) National Water Master Plan 2004. Amman, Jordan.

3.3.3.3 Irrigation development in Jordan

Recently, in 2015, the total irrigated area in Jordan reached 1.03 million dunums, of which 318,000 dunums in the Jordan Valley and 716,000 dunums in the upland and the desert as shown in Table 15. Irrigated production is the major subsector of Jordanian agriculture. Large volumes of vegetables are produced in the Jordan Valley and the highland. Table 16 and Table 17 show the cropping patterns at the national level distributed by irrigated and non-irrigated areas in the Jordan Valley and highlands areas. It should be noted here that the majority of non-irrigated area is cultivated by tree crops (mainly olives) and rainfed field crops such as wheat and barley.

In general, the total irrigated areas increased from 666,000 dunums in 1994 to 1,034,000 dunums in 2013. The main increase was in the highlands areas. This expansion resulted in excessive groundwater abstractions from the different aquifers, and has resulted in a decline of groundwater levels and degradation of water quality of some aquifers in the country. Prohibition of well drilling for agriculture in 1992 has been taken as a measure to reduce abstractions from the depleting groundwater resources. In the immediate future, it is expected that other measures and actions undertaken by the MWI will also assist to remedy the groundwater depletion problem.

Table 15: Total Cropped Area by Crop Type and Irrigation System in Jordan, 1994, 2015 (dunums)

Crops	1994			2015		
	Total Area	Irrigated Area	Non-Irrigated Area	Total Area	Irrigated Area	Non-Irrigated Area
Tree Crops	695,924	224,097	471,826	864,171	476,544	387,627
Field Crops	1,177,201	139,269	1,037,932	1,314,065	96,825	1,217,240
Vegetables	313,243	302,665	10,578	487,728	461,433	26,296
Total	**2,186,368**	**666,031**	**1,520,337**	**2,665,965**	**1,034,801**	**1,631,163**

Source: Department of Statistics (2016), Amman, Jordan.

Table 16: Total Cropped Area by Crop Type in the Jordan Valley, 1994 & 2015 (dunums)

Crops	1994			2015		
	Total Area	Irrigated Area	Non-Irrigate d Area	Total Area	Irrigated Area	Non-Irrigated Area
Tree Crops	80,525	80,525	0	95,154	94,958	196
Field Crops	43,550	42,142	1,407	27,242	24,847	2,395
Vegetables	152,552	152,434	118	198,775	198,635	140
Total	**276,627**	**275,101**	**1,525**	**321,170**	**318,439**	**2,731**

Source: Department of Statistics (2016), Amman, Jordan

Table 17: Total Cropped Area by Crop type in the Highlands, 1994 & 2015 (dunums)

Crops	1994			2015		
	Total Area	Irrigated Area	Non-Irrigated Area	Total Area	Irrigated Area	Non-Irrigated Area
Tree Crops	615,399	143,572	471,826	769,017	381,586	387,431
Field Crops	1,133,652	97,127	1,036,525	1,286,824	71,978	1,214,845
Vegetables	160,691	150,231	10,460	288,953	262,798	26,156
Total	**1,909,741**	**390,930**	**1,518,811**	**2,344,794**	**716,362**	**1,628,432**

Source: Department of Statistics (2014), Amman, Jordan.

3.3.3.4 Water availability for irrigation

This is a constraining factor that limits the irrigated lands. Jordan's water strategy addressed that the first priority is for drinking water, which covers domestic and tourist sectors, second priority is for industrial sector and at the lowest priority is for irrigation. Thus, lower water qualities and quantities will be allocated to irrigation under drought periods, which means lower agricultural areas will be planted and so irrigated. In practice, this is mainly applied in JV where JVA puts constraints on the size of the agricultural areas that could be planted when there is not enough water available for irrigation due to drought occurrence or to the increase in domestic demand.

3.3.3.5 Water prices

There are three different types of water sources supply irrigation (surface, groundwater and treated wastewater) with three different pricing structures. These are the irrigation water tariff in Jordan Valley, which is an increasing block water tariff as presented in Table 18, the treated wastewater which is priced at fixed rate of 0.01 JD/m^3, and groundwater tariff presented in (Table 19)

Table 18: Surface Irrigation water tariff structure in Jordan Valley by-Law No. (85) of 2002 and its amendments

Usage Block (m^3 per month)	Irrigation Water Tariff (JD/m^3)
0 - 2,500	0.008
2,501-3,500	0.015
3,501-4,500	0.02
More than 4,500	0.035

Table 19: Groundwater tariff structure in the by-law No. (85) of 2002 and its amendments

No.	Water Quantity (m^3)	Salinity (ppm)	Water Price (JD/m^3)
Licensed agricultural wells			
1	0-150,000		Free
2	151,000-200,000		0.005
3	More than 200,000		0.06
Unlicensed agricultural wells			
1	0-100,000		0.025
2	101,000-150,000		0.03
3	151,000-200,000		0.035
4	More than 200,000		0.07
Agricultural wells in Al Azraq Area with specified quantities			
1	Within specified quantities		Free
2	> specified quantities but less than 100,000		0.02
3	More than 100,000		0.06
Brackish Water Wells			
No.	Water Quantity (m^3)	Salinity (ppm)	Water Price (JD/m^3)
1	0 –150,000		Free
2	More than 150,000	1000 – 1500	0.015
3	More than 150,000	1500 – 2000	0.01
4	More than 150,000	> 2000	0.005
Governmental wells used for irrigation			
	Any quantity		0.025

Source: Underground Water Control By-Law No. (85) of 2002 and its amendments.

3.3.4 Values of irrigation water based on groundwater

Irrigation water is seen as an important rural development factors in Jordan, creating employment opportunities, generating income and enhancing food security. Therefore, huge investments are made in the sector, construction of new irrigation projects, dams and rehabilitating existing irrigation systems. On the other hand, the growing water scarcity causes increasing pressure on farmers to use water more efficiently. Moreover, to formulate a new water policy, water subsidies currently received by farmers shall be gradually removed such as subsidy on the electricity of water pumping. In this context, knowledge about water values can contribute to the objective of improving efficiency through better water allocation.

The rational decision making about water management issues requires reliable estimates of the economic value of water (Hellegers and Perry, 2006). Knowledge of this value is necessary when, for instance, making investment decisions concerning water resources development, policy decisions on sustainable water use and water allocations, or when the socio-economic impacts of water management decisions must be determined (Hussain et al., 2006). Specifically for the agricultural sector, this knowledge is important to design fair, informed and rational pricing systems, providing incentives to irrigators to use water rationally (Perret and Geyser, 2007).

We analyse the water value for groundwater irrigation from farmers' perspective that takes into account the full economic costs of production. The estimation of water value through famers' ability to pay for water in the long run where all fixed costs are variable costs in the long runs vary. The Residual Valuation Approach (RIM) was used based on the enterprise budget for individual crops cultivated in Mafraq and Zarqa basins. The methodology deducts the contribution of non-water production inputs, fixed costs from the gross output and attributes the remaining value to water and producer's surplus for bearing risk (Al-Karablieh et al., 2012; Tabieh et al., 2015).

The water values are based on the net profitability, which is the measure of the surplus or profit accruing from production after deducting all costs (direct and indirect) and thus a proxy for total pre-tax profit income. The resulting water value is an indication of the economic efficiency of water consumption and a proxy for farmer's ability to pay for water.

The gross margins need to be calculated for major crop grown in Zarqa and Mafraq basins in order to analyse the value of water for these crops in the short run and net profitability in the long run. The main components of the gross margin analysis are the total return, which is the field production in kg/du multiplied by the farm gate price JD/kg minus the variable cost and the cost of water in JD/du. The general components of the variable cost are water, The net irrigation water applied by farmers is used to measure the value of irrigation water (which is subtracted later from calculation. The gross margins were calculated without including irrigation water cost in the total variable cost. Farmer's ability to pay in term of water profitability vary from region to region depending on economic activity, climate zones, production season, soils and water qualities, in addition to many other factors. Table 20 shows the average of water value and water profitability values.

The result shows that cucumber has the highest water values in Mafraq (JD 2.4/m3), the percentage of water cost to total cost is 5%. This low percent does not encourage farmers to save water. The average water values based on estimated for different crops, e.g. for winter tomatoes is JD 0.94/m3, and for summer tomatoes is JD 0.62/m3. The field crop of clovers or alfalfa is very low (JD 0.20/m3), for olives at Mafraq and Zarqa is JD 0.05/m3, whereas at the national level it is JD 0.26/m3. The water pricing policy should be revised to provide incentives for high values crops and to discourage low water value crops such as olives and clover. The high value crops have a lower water requirements compared with clover, olive and fruit trees as shown in Table 20. Furthermore, the high value crop have a short growing season compared with other dominant crops A decrease of water quota or increase in the price of electricity would therefore affect cultivation of olives, clover but marginally will affect the vegetables and fruits trees due to high water values in these crops.

In a study conducted by Al-Karablieh (2012) to estimate the economic values for irrigation in Jordan, using the residual imputation method shows that the average value of irrigation water is JD 0.51/m3 at the country level. The observed values of water were in the range of those found in other studies for irrigated vegetables. The aggregate average water value for field crops is 0.44 JD/m3, for the vegetable crops is 1.23 JD/m3 and for fruit trees is 0.23 JD/m3. The aggregate average water value for horticulture was found to be 0.51 JD/m^3.

Table 20: Water Values in selected crops cultivated in highland.

	CRW	Planted Areas (du)			Water Value (JD/m3)		
Location	***Avg.***	***Mafraq***	***Zarqa***	***Jordan***	***Mafraq***	***Zarqa***	***Jordan***
Clover trifoil	1315	26,460	9,255	60,110	0.205	0.202	0.206
Tomatoes, W	453	3,132	50	85,842	0.942	0.919	1.040
Potatoes, W	345	14,321	2,987	51,194	0.729	0.785	0.702
Cauliflower, W	408	3,087	7,629	14,396	0.900	0.870	0.900
Tomatoes, S	605	14,975	770	42,576	0.625	0.584	0.649
Eggplants, S	613	2,355	1,844	11,843	0.341	0.412	0.362
Cucumbers, S	448	3,344		11,668	2.419		2.287
Hot peppers, S	591	5,607	157	7,588	0.495	0.367	0.454
Sweet peppers, S	609	3,855	180	8,759	1.219	0.860	1.012
Lettuce, S	235	2,931	1,470	7,026	1.434	1.290	1.405
Sweet melons, S	580	2,910	420	14,122	0.331	0.293	0.309
Water melons, S	474	6,575	770	25,867	0.370	0.348	0.370
Olives	557	76,302	71,481	262,054	0.057	0.055	0.262
Grapes	669	12,975	7,517	25,940	0.810	0.683	0.890
Peaches	876	12,724	2,170	17,618	0.669	0.401	0.648
Plums, Prunes	859	1,937	151	2,879	0.533	1.233	0.669
Apricots	861	4,144	831	8,625	0.362	0.169	0.304
Apples	875	3,816	376	18,592	0.320	0.593	0.363
Other Fruits	817	8,268	638	999	0.397	0.185	0.252
Other vegetables	322	7,475	20,680	146,970			

Source: calculated by authors.

Table 21: Water Value by Crop type in Jordan

	Planted Areas (du)			Water Value (JD/m3)		
Location	Mafraq	Zarqa	Jordan	Mafraq	Zarqa	Jordan
Field Crops	27,471	14,834	99,715	0.243	0.191	0.218
Vegetable-W	22,412	13,383	193,210	0.776	0.763	0.842
Vegetable-S	45,914	13,550	160,827	0.720	0.613	0.690
Olives	76,302	71,481	262,054	0.057	0.055	0.262
Fruit Trees	121,396	87,609	370,916	0.299	0.163	0.350
Total	293,495	200,857	1,086,721	0.358	0.181	0.438

Source: calculated by authors.

Since, water in not regarded as a private commodity among the Jordanian population, making the question of increasing water tariff is a politically highly sensitive issue. They are many powerful farmers, some of whom are really influential and have very good connections to the top-management.

4 Historical development of water policies in Jordan

4.1 Evolution of water institutions in Jordan

Water institutions in Jordan probably originated with the advent of irrigated agriculture. Their role was to ensure efficient allocation of water in a particular river basin or locality. Those social institutions still exist in many sides Wadi in Jordan, like Wadi Elsir. Farmers group themselves into small groups headed by tribal system.

From an economic point of view many Muslim scholars have divided water resources into three categories (Kadouri et al. 2001). These are private goods, restricted public goods, and public goods. Water which is stored in a container, such as a cistern or reservoir, or in specially constructed infrastructure systems, such as irrigation canals or wells, is regarded as a private good belonging to the owner of the facilities. This owner can do what he wishes with the water, including selling it to another person.

When a water body such as a stream or small lake is situated on lands that are privately owned it is considered to be restricted public goods. In this case the landowner does not "own" the water, but merely enjoys special rights and privileges compared with other users. However, anybody can use the water for drinking purposes and to satisfy basic needs. Agricultural or industrial use of the water cannot take place, however, without the permission of the landowner.

Islam allows water providers to recover their costs. Water itself cannot be sold, because it's considered a social good and owned by the community. But governments, municipalities, and contractors can recover their costs for collecting, storing, treating, and distributing drinking water, and for treating wastewater.

Where water is being sold, Islamic custom decrees that it is the market mechanism that sets the price. In such cases governments are not expected to intervene unless there is evidence of price fixing and manipulation of market conditions by unscrupulous merchants (Kadouri et al., 2001). An important tool in modern water resource management is the management of demand through the use of the pricing mechanism. As this is applied in a modem context its aims are usually to cut down the wastage of water and at the same time to ensure social equity. As such it aims fit in well with Islamic ideals, particularly if it provides the poor with better access to water.

4.2 Land and water rights during Ottoman Period (1516-1916)

The four centuries of Ottoman rule (1516-1916 AD) were a period of general stagnation in Jordan. The Ottomans were primarily interested in Jordan in terms of its importance to the pilgrimage route to Mecca. People during that time relied on private stored rain water or natural spring. Private cisterns were found in almost all the homes. These cisterns covered the basic water needs for domestic hygiene, which was estimated depending on the sources at about 30 litres per person per day.

Land and water tenure cannot be separated. In arid and semi-arid areas, pastoral production needs a carefully structured system of drinking water sources for both humans and animals. In the case of crop production, water access needs to be regulated in line with its scarcity. Access to water, whether from springs or wells, and the way access is organized, have always been central to agricultural production. In the Ottoman era (1516-1916 AD), the use of water was regulated according to Islamic theory and water rights were kept by the district administration in an official register. Legislation for water acquisition and use in the Hashemite Kingdom started in 1938, and due consideration was taken of the prior water rights recognized by the previous Ottoman administration.

According to Islamic theory, wells are divided into those for public use, for private use as personal property, and for private use in pastures, where the owners have priority when they are in the area (Lambton, 1953, p. 210). In some rural areas, well owners are sometimes not the same as the owners of the land. Springs can be natural, in which case the individual who first uses a spring to reclaim the land has the priority; wells are drilled by individuals, who then own them; or bored on private property, in which case they thus belong to the owner of the land (Warriner, 1948).

The 1858 Ottoman Land Code was the legal basis of land and water tenure system in Jordan, Syria, and Iraq until the 1930s. The objective of the code was to provide unified land tenure rules that would define resource access and use. The code defined five categories of lands (Warriner, 1962; Nesheiwat, 1991; Nordblom, 1993; Taimeh et al., 2012):

1. *Mulk* lands are lands held in an absolute freehold, governed by provisions of sacred law and not by those of civil statute law. Two types of rights are involved: ownership of the resource and ownership of use. Under this tenure regime, which is similar to private property in the western sense, the right holder has complete ownership rights because she/he owns the resource and its use

2. *Meeri* lands are lands whose resource is owned by the state, but the use-rights is granted to individuals. This form of 'ownership’ is inheritable and can be sold. Such practice was already introduced during the Abbasid period (762 AD). However, such grants were a transfer of use-rights to the beneficiary while the land remained owned by the state (Nesheiwat 1991; Nordblom 1993). Up to the end of the 18th century, Jordan was part of the Ottoman Empire and only a small part of its lands, which were occupied by customary landholders, was hold under *meeri* rights. These included communities in settled villages practicing semi-communal forms of cultivation. Tribes exercised their customary grazing rights on the areas identified today as the steppe and the *badia* (eastern part of Jordan).

3. *Waqf* (*habou*s) lands are those lands where use-rights were granted to individuals or institutions (mosques, schools, and hospitals) for religious purposes while landowners retain ownership rights. This type of land right was obtained only on *mulk* lands when the owner decided to grant, forever or for a limited period, the ownership of the resource use.

4. *Matruka* lands are reserved for public purposes such as roads, rivers, public buildings, market places, and village threshing floors.

5. *Mawatt* (or *mubah*) lands are dead, unclaimed lands, deserts, and rangelands. All these lands are generally considered as state property. However, anyone can claim them by cultivating it over a fixed period and can eventually acquire *meeri* rights (Neshweiwat, 1991).

A key distinction between *mulk* and *meeri* land rights is that *mulk* rights, which confer absolute ownership, were confined to lands and houses in urban areas and their surroundings. All remaining lands were considered as state property and individuals could only acquire *meeri* rights on their agricultural lands. The ownership of the resource allowed the state to collect taxes and to extract labour from right holders (Warriner, 1962).

Water rights, as endorsed by the Ottoman code and the common codes in view of Islamic hypothesis, turned out to be somewhat confounded after sometime. Water rights were dealt with as individual property.

One of the most important laws found in the Ottoman Era was the *Juridical Provision Journal* for the year 1293 Hijri (1876 AD). The *Journal* didn't have many articles on water related issues except for that related to utilization of potable water. The Journal also highlighted the fact that water was the property of no one, (article 1235); and recognized the right of the river bed and water course which do not harm or damage properties of people, (Articles 1224, 1228, 1229 and 1232) as cited by Marei and Abu-Kishk (2014). The digging of private wells on individual properties was also mentioned in the Articles 1286, 1287 and 1288 of the Journal. Article 1236 pointed out to allowing for the digging a public wells, on the basis that these wells were dug for the benefit of everyone and not monopolized for use by one specific person (Marei and Abu-Kishk, 2014).

4.3 Water policies during the British Mandate period (1917-1946)

The Emirate of the Arab East (1921-1923) and its successor, the Emirate of Transjordan (1923-1946) gradually built a state infrastructure with an Executive Council and later developed an elected Legislative Council. The judiciary branch was independent and run by the courts. The Emirate received financial and technical aid from Britain and was assisted by British civil and military administrators. Legislation in the Emirate consisted of the on-going laws that organized life under the Ottoman Empire, and new laws that were taken from Palestine.

Water administration was focused on municipal water supply, a responsibility assigned inside towns to the municipal councils. The role of the central government was minimal, mainly to facilitate implementation of the projects, legislating for the service, and guaranteeing loans extended to implement the projects. Elsewhere in the Emirate where there were no councils, villagers depended on collection wells in which rainwater was collected, or on springs for their municipal water sources.

Many laws on water were established during this period. An important law was the Law for protecting public water projects and its amendments (1923-1946). This dealt with public water projects, locations, announcements and their maintenance, and prohibited any individual from working in these locations for any reason without direct consent from the authority in charge. It provided the right for people who suffered damage to appeal to the authority of specialization to receive compensation if they could provide proof of damage. The first law related to water was the Law No (818) from 1930 on the water distribution system for Amman[4].

The law clarified the method for acquiring licenses to actualize public water projects. The local legislative leader was specifically in charge of giving licenses. Besides, the law specified the authorizations and disciplines that would be endured by any individual breaking the permit regulations or performing illegal operations in water arrangement areas (Marei and Abu-Kishk, 2014).

[4] The Law of Water Distribution system for Amman No.818 for the year 1930,"Jordan Gazette 280 (16/10/1930): p. 589.

The British Mandate gave more importance to the implementation of water plans benefiting water resources such as the digging of wells for water collection and digging of canals to transport water. The Mandate also determined municipal by-laws, mandating the cleaning of sewages and the digging of toilet facilities away from the municipality areas; explaining that the responsibility for sewage cleaning or drainage was with municipal workers, against fees set out by the municipal council.

4.4 Water policies after Independence (1946-1970)

Jordan earned independence in 1946 and was proclaimed a Kingdom. It had a "Basic Law" that stipulated three branches of government: the Executive, the Legislative, and the Judiciary. The West Bank, the portion of Palestine that was defended and retained by the Jordanian and Iraqi troops during the 1948 war with Israel, united with the Kingdom in 1950.

Between 1946 and 1957, the department in charge of water resources remained to be the Projects Department within the Department of Lands and Surveys under the Minister of Finance. The regulation and control of water resources was to be exercised by the Director of Lands and Surveys aided by the manager of the Projects Department under him. Water rights for irrigation went hand in hand with land ownership rights of those areas to be irrigated. Islamic Sharia was the source of legislation as far as water rights were concerned and the rules issued by the Majallah, the Ottoman Official Gazette, were the major guide in that regard. Ottoman legislation, basically in conformity with Islamic Sharia, had been the "law of the land" for four centuries and its momentum carried through the Kingdom era. As was the case during the mandate period, the local councils of towns and cities remained in charge of the domestic water supplies (Haddadin, 2006).

In 1946, and five months after independence, Jordan issued Water Law No. 38 which dealt mainly with water for irrigation, disputes over water allocation, water settlement and established a water court and water rights for irrigated land to be registered in a Water Table hold by district administrator.[5]

One of the most important laws on water was the 1952 Law for Settlement of Lands and Water No. 40.[6] This law settles all issues and disputes related to the right of ownership, disposal and utilization. It included management of a water registry, providing every piece of land with water resources with the right of ownership of this water, per Article 17. Accordingly, Article 24 stated rights of owners of water wells, caves and river beds in the "announced and settled for" locations in the boundaries of their lands or the neighbouring lands. Consequently, Article 25 included policies of fee collection and revenues for the settlement of lands and water.[7] At this stage of law and by-law development of legislation, groundwater issues were not mentioned. Where digging machines were not available at that time, all of digging activities were done by hand to reach depths not exceeding 20 meters, and the legislation did not differentiate between groundwater wells and rainfall water harvesting collection wells.

[5] The Water Law No.38 for the year 1946,"Jordan Gazette 880 (25/12/1946): p. 508.

[6] This law is still valid and had 17 amendments during (1952-1986), the last amendment is the law no (40) for the year 1986.

[7] The Law for Settlement of Lands and Water No. 40 for the year 1952,"Jordan Gazette 1113 (1952): 279.

A further Legislation issued a year later was the 1953 Law for the Control of Water No. 31. The law defined the management and monitoring of irrigation projects, and the ways of submitting applications to apply for irrigation development plans, determining construction fees, and reasons for cutting water or diminishing its supply. It also addressed the reasons for diminishing the quantity of water used for agricultural lands, defining timetables for water supply and the share of water for each agricultural land, as well as the reasons for amendments, if necessary. Furthermore, it also provided rights to cut water supply in the event that any individual missed a fee payment, providing an article on the utilization of water for household and agricultural purposes such as irrigation and watering animals, or for industrial use[8].

Law No. 51 in 1959 created the Central Water Authority. The new government agency consolidated the multiple departments dealing with water: the Department of Irrigation, the Drilling Department at the Ministry of Public Works, the Department of the Water Resources Development and the Office of Consolidated Services that merged with the Jordan Development Board, and all operational water projects handled by any other department. All of these departments were amalgamated in the Central Water Authority which, following this law, became a new government agency with autonomy responsible for all water matters in the Kingdom including groundwater resources, management and drilling issues.

Law no. 51, issued in 1959, defined the notion of water as: "all the surface and ground water resources including rivers, streams, valleys, lakes, pools, tanks, springs and rain water." This is the first time the law refers to groundwater in Jordanian legislations.

This law was issued to allow the "Central Water Authority" to develop water resources, provide research and study plans, implement them and sign contracts, according to the Law for the Water Utilization on the use of water for household, agricultural, and industrial usage and for producing electricity.

The influx of Palestinian refugees into Jordan created pressures for jobs and means of livelihood. Jordan’s economy was weak and foreign assistance was essential to boost development and create jobs; water was essential for the development process. Because of the urgency, a Department for the Development of Water Resources was established in 1955 and was staffed with American experts and Jordanian employees (Haddadin, 2006).

After the Arab summit conference in 1964, both Central Water Authority and East Ghor Canal Authority were abolished. In 1965, a new entity that included the two aforementioned entities, as well as a department of a Geological Research was established and was named the Natural Resources Authority. Also another organization (Al Rawafid Establishment) was established to use the water of the Jordan River and its tributaries. It adopted the construction of Khalid Dam and the Jordan Valley project in the Jordan Valley. These institutions soon had to face the war in 1967.

This policy and the associated law proved to be very beneficial to the country. It enabled a professional approach to the water sector with particular emphasis on surface water resources, surveys and exploration. The documentation of resources, measurement of

[8] The Law for the Control of Water No. 31 for the year 1953,” Jordan Gazette 1134: 528; “The Law of Water No. 51 for the year 1959,”Jordan Gazette 1465: 4.

flows, measurement of quality parameters, drilling for groundwater investigation, municipal supplies to needy cities, and the like, was initiated.

Therefore, Government management of groundwater resources and related affairs formally started in the late 1950s with the creation of a specialized agency, the Central Water Authority. This was amalgamated in 1965 into a newly founded organization, the Natural Resources Authority, NRA. In 1977, the newly created Jordan Valley Authority, JVA, was authorized by law to carry out groundwater investigation and development over all Jordan. The first By-law issued to regulate groundwater resources was the By-Law No. 14 in 1961. This by-Law, for the first time, regulates well drilling and licensing of drilling activities. This by-law addresses issues such as how one can apply for a licence for drilling, for water abstraction (for what purpose and with which abstraction rate), the necessity to install water meters to measure abstracted volumes, the distance between wells, the dispute between wells owners, and the protection of aquifers.

4.5 Water policies in the 1980s

The Jordan Valley Authority (JVA) was established in 1977 pursuant to the Jordan Valley development Law No. 18 in 1977, later replaced by Law No. 19 in 1988 and then by Law No. (30) Issued in 2001 (MWI, 2012). The JVA was created in order to ensure the social and economic development of the lands of the Jordan Rift Valley through the management of the land and water resources of the region. The JVA was empowered to carry out integrated socioeconomic development of the Jordan Valley area. The mandate area extending from the Northern border of the Hashemite Kingdom of Jordan in the North to the Northern tip of the Dead Sea in the South; the Jordan River to the west and all areas in the Yarmouk and Zarqa basins that lie below the 300m contour line to the East, in addition to any areas the Cabinet considers integral part of JVA. In 1977, an area located between the northern part of the Dead Sea and the northern border of Aqaba with a 500 m above sea level has been added to JVA area upon the Cabinet decision no. (6/59/12/6339). Furthermore, JVA is responsible for earth dams and small reservoirs and ponds in the highland areas. Those small dams and ponds are used mainly for groundwater artificial recharge and livestock watering in remote areas.

In 1983, the Water Authority law was enacted and the Water Authority of Jordan (WAJ) assumed the responsibility of groundwater administration, management and development. The concerned directorate of NRA and that of the JVA were transferred to WAJ in 1984. Both WAJ and JVA came under the umbrella of a newly founded Ministry, the Ministry of Water and Irrigation (MWI) in 1988.

WAJ is responsible for municipal and industrial water supplies and wastewater management. It plans, implements and operates all water supply from surface and groundwater resources in Jordan.

The Minister of Water and Irrigation has overall control, with Secretaries General in the Ministry of Water and Irrigation, Water Authority of Jordan and the Jordan Valley Authority reporting directly to him. According to the Law, the main tasks of the MWI are to formulate water policies, to undertake strategic planning and resource development programmes, to formulate water allocation options, to provide a water resources data base, and to monitor and control water quality.

It is important to realize that many other parts of the government have a role to play in the management of groundwater resources in the Kingdom. The most important is the Council of Ministers that becomes involved with water at the highest level through policy initiation, legislation and finance. Various Ministries have more specific roles. The Ministry of Planning reviews all plans put forward by the MWI and then links with potential funding agencies.

The Ministry of Finance oversees the budget concerning water projects and handles the financial aspects of any loans or international finance for water projects. The Ministry of Health is responsible for drinking water standards and ensuring that wastewater facilities comply with the necessary standards and regulations. It is, however, the Ministry of Agriculture that has the most important secondary role in water policy, as this Ministry has the authority, under the Agriculture Law No. 20 of 1973, to exploit surface water resources through the construction of small dams to provide water for the growth of crops for animal feed. The Ministry can also drill wells to provide water for livestock. The General Corporation for Environmental Protection was established in 1995 in an attempt to bring all issues to do with the environment under one organization. Today, it is responsible for coordinating all environmental policies of the government in the Kingdom.

In 1984 the management of groundwater resources was shifted from the Natural Resources Authority in 1984 to the Jordan Water Authority. The control of abstraction and even drilling was relaxed between 1967 and 1984 due to local political conflicts in Jordan.

4.6 Water policies in the 1990s

The WAJ started to exercise strict control of groundwater regulations in the late 1990s, after many illegally drilled wells and a culture of non-compliance with the regulations had emerged, making control very difficult. Control has improved since this time through the creation of a special surveillance unit for monitoring abstraction and the illegal drilling of wells (Haddadin, 2006).

The first water sector strategy (1998) was associated with policies included groundwater, water utilities, wastewater reuse and management, and irrigational water. An investment program and action plan was developed for the years 1997-2010 and updated in 2002 to extend until 2011. The basic strategy and policies for the water sector in Jordan are compiled and published in Jordan’s Water Strategy and Policies of 1998 (MWI, 1998). The policy statements 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 their sustainable rate.

The depletion of groundwater was singled out by the policy as the major problem facing Jordan’s water sector. This will put the sustainability of irrigation in the Highlands and the desert in great danger. The policy sets specific objectives and principles for groundwater use and management. Particular emphasis was placed on the potential of brackish water desalination for drinking purposes.

The MWI/WAJ receives application for drilling licenses and abstraction permits, and issues such licenses and permits in accordance with the effective groundwater legislation. MWI/WAJ also supervises the drilling, the abstraction, and makes arrangements for the lease of land and use of groundwater for agricultural purposes in remote arid areas. Recently, the MWI has stepped up the activities of groundwater resources studies on a national scale.

By the 1990s groundwater irrigation in the highlands had expanded significantly due to the private investment The groundwater abstraction from largely illegal private wells is estimated to be lowering the groundwater level by about 1 meter per year. Effort made to restrict pumping through higher prices were ineffective, and free water quotas for well were too high. The groundwater decline in the highlands has reached a crisis level and the government is making desperate attempts to limit the pumping, but very powerful farmers typically play a main role in weakening implementation of the legislations.

4.7 Water policies in the 2000s

As groundwater is being exploited at about twice its recharge rate and hundreds of illegal wells exist (MWI, 2009), Jordan must stop its unsustainable extraction of groundwater in order to prevent permanent social, economic and environmental harm and to preserve water for new generation. Jordan's groundwater By-law 85 was created to protect and monitor the country's precious groundwater resources. Under this by-law, responsibility for collecting fees for legal wells has been defined. Before that time, fees from the majority of wells used for agriculture purposes were not collected, in spite of the installation of water meters for most of the wells.

The by-law requires the government should established appropriate pumping reduction plans for aquifers under stress; at that time, 10 out of Jordan's 12 groundwater basins were showing a deficit, the other two were close to their limit, and the situation will only get worse. The MWI established and implemented groundwater management plans in order to slow the dramatic decline in groundwater. The By-law 85/2002 revises the conservation and protection measures of groundwater from illegal use and over extraction.

By the mid-2000s, after over a decade of experience with the WAJ, JVA, and the MWI, a growing recognition began that the combination of the powerful, vertically-integrated water authorities and a MWI unable to grow into the leadership role envisaged for it created a situation of:

- Overlapping institutional responsibilities, particularly with regard to water resources planning, management and project prioritization.
- Conflicts of interest, especially with regard to WAJ and JVA (as WAJ is a bulk water supplier to water utilities and JVA a bulk water suppliers to WUAs in JV), and water utilities distributing water.
- Weak accountability in light of the overlapping responsibilities and conflicts of interest, as well as the non-inclusive, often opaque decision-making processes influenced by shorter term political and economic interests.

The government of Jordan began working with reformers to address these issues by creating municipal water utility companies to assume responsibility for water distribution from WAJ. By the end of 2011, three utility companies had been formed: the Aqaba Water Company (AWC) covering the Aqaba Governorate, Miyahuna covering Amman and Zarqa, and the Yarmouk Water Company covering four governorates in the north. Nonetheless, institutional issues and the lack of reform within the water sector continue to impede Jordan’s ability to achieve international best practice standards.

The water sector is currently under restructuring in a way that essential water-related functions continue to be poorly allocated among WAJ, MWI and JVA leading to institutional overlap. There are several areas in which there is duplication of effort, unclear responsibility for decisions, and poor accountability. First, the legislation creating MWI assigned to it a number of water resource planning and management functions which had previously been assigned to WAJ in an earlier law (USAID, 2011). Second, MWI was established under a WAJ by-law rather than a dedicated law and as such lacks sufficient authority to effectively carry out its water management responsibilities (ibid.).

Article 4 of the By-law No. 5 Administrative Organization of the Ministry of Water & Irrigation for the Year 1992 state that "With due observance to the provisions of each of the Water Authority's Law No. 18 for the year 1988, Jordan Valley Development Law No.19 for 1988 and any other amending or substituting law thereof, the Ministry shall assume full responsibility for water and public sewage in the Kingdom as well as the projects pertaining thereto, formulation and transmission of the water policy to the Council of Ministers for adoption. Also, the Ministry shall assume full responsibility for the economic and social development of the Jordan Valley as well as carry out all the works which are necessary for the realization of this object".

There are significant conflicts of interest between WAJ responsibilities as a bulk water supply and its oversight and management controls over utilities. For example, the MWI is responsible for delineation of groundwater basins, studies of the existing resources, whereas WAJ are responsible for well drilling and water supply. The policy decision-making process is narrowly based and focused almost solely within the Ministry. In addition, MWI has a conflict of interest due to its dual responsibility for both policy decision-making and policy implementation. There is no viable mechanism for monitoring and follow-up in policy implementation. The concern is whether there are clear rules and plausible incentives to make sure that policy directives will be carried out.

The Groundwater Control By-Law No 85 has been passed in 2002. This watershed law (see more details in the following section) regulates groundwater well licensing, drilling, and water abstraction as displayed in the subsequent sections. A tariff was set for water abstracted over and above the permitted annual abstraction rate (WAJ, 2007; El-Naqa and Al-Shayeb, 2009). Furthermore, several measures have been implemented to protect aquifers from degradation and over abstraction. These measures included delineation of groundwater protection zones, preparation of groundwater vulnerability maps, establishment of groundwater monitoring directorate, and issuance of the groundwater by-law in 2002.

In the Water Control By-Law No. 85, Article 25 stipulates that the distance between wells should not be under 1,000 m, and an abstraction license is given without time limit. As indicated by Article 29 , if an area becomes polluted or depleted, the WAJ Board can take measures to stop pollution or depletion including rationalizing extractions or reduce them to the extent that allows to stop pollution or depletion and restore the natural balance to the water layer or underground water basin. For wells for touristic and industrial purposes the permit's holder needs to pay 250 fils for each m3 (~0.37 US$) for each cubic meter pumped. For abstraction from wells for irrigation purposes the permit's holder needs to pay 250 fils for every m3 if the amount abstracted exceeds the maximum allowable amount of 150,000 m3/year (El-Naqa and Al-Shayeb 2009).

The state has to maintain political stability and avoid protest against by-law enforcement and the specified water tariffs for water abstraction in order to maintain agricultural production and farm income to socially acceptable limits, and sometimes turns a blind eye to over-abstraction even if the water level is dropping down.

4.8 Water policies in the 2008-2015

A new Jordan Water Strategy 2008-2022: Water for Life (MWI, 2009) was prepared, specifying drinking water as the main priority in water allocation, followed by industry and agriculture. It includes specific actions and plans with targets to be achieved.

This strategy builds on the previous strategic documents which helped to shape the management of the water sector in Jordan over the past years. The first strategy, "Jordan Water Strategy and Policies", was formulated in 1998. It was followed in 2008 by the, "Water for Life: Jordan's Water Strategy 2008–2022". The National Water Strategy has set the pace for national efforts to manage the water sector and ensure optimal service levels. It is aligned with the MDGs. It looks at all aspects of the water cycle from rainfall to collection, treatment and discharge. The strategy specifies the practical steps and needed actions to be taken include an effective water demand management, an efficient water supply operations and a well-developed institutional reform. In terms of minimizing aquifer over-abstraction, the groundwater policy stresses the need to stop illegal drilling, closing existing illegal wells and metering all existing water wells.

The strategy puts emphasis on two mega projects: the Disi water conveyance and the Red-Dead Canal, the reduction of the Non-Revenue for Water (NWR), having cost reflective tariffs and restructuring the institutions of the water sector.

An institutional problem is the lack of a set of clear policies for correcting the misallocation of scarce water to various uses. Over time such wastage led to conflicts, which in turn threatened social stability and economic coherence. These conflicts also created widespread cynicism and distrust of the entire water sector. For example, there are approximately 3,696 irrigation wells in the Highlands, of which 2,297 are licensed, and 899 are considered "illegal." In other words, approximately 25% of the wells in the Highlands region are operating outside of the law. This fact is well known—and it has persisted for years.

The MWI is assigned responsibility for water resource and strategic planning (including allocation of water) and management of water resources. However, WAJ continues to perform groundwater core management functions such as licensing, permitting and monitoring for groundwater abstraction. Since WAJ is licensing their own wells (for drinking purposes) and private wells, this results in a conflict of interest and contributes to the over abstraction problem.

Under By-law No. 14 of 2014, The Ministry of Water and Irrigation (MWI) is responsible for overall national leadership on policy, strategic direction and planning, in coordination with WAJ and JVA., MWI assumes full responsibility for water and public sewage and all related projects in the Kingdom. MWI aims to upgrade, develop and regulate the water sector and enhance the quality of water services. It has a mandate to develop sectoral policies and strategies; endorse plans and programs related to water resources protection; implement international agreements; develop laws, by-laws, regulations and normative and technical standards; develop private sector partnerships; supervise the implementation of strategic plans and programs; and follow up on the performance of the water companies and utilities.

However, with the amendments to the By-law in 2014, MWI is assuming policy and strategic leadership of the sector. The change will bring greater coherence and harmony to the core tasks (mandates) of all 3 Sector entities – MWI, WAJ and JVA. The MWI will have the added authority for strategic planning, water allocation, permitting/enforcement and data collection and management also a significant role of the MWI is monitoring and evaluation of the action plans of the sector.

4.9 National Water Strategies 2016-2025

The most recent National Water Strategy 2016–2025 (MWI, 2016a) "focuses on building a resilient sector based on a unified approach for a comprehensive social, economic and environmentally viable water sector development". The strategy included provisions for climate change, water-energy-food nexus, and focus on water economics and financing, sustainability of overexploited groundwater resources and the adoption of new technologies and techniques available including decentralized wastewater management

It considers the adopted Sustainable Development Goals (SDGs) based on the achievement of MDGs. The strategy also builds on the new development in the sector, this include the implementation of the approved Action Plan to Reduce Water Sector Losses in 2013, the development in strategic projects (e.g. Nuclear Power plan, Oil-shale and the Red–Dead conveyance), the increased demand resulting from the pressure of Syrian refugees on water resources, increased cost of production specifically the effect of electricity and fuel increased prices, and the fiscal strain affecting the service delivery. It also builds on the recently developed sector polices.

The new National Water Sector Strategy addresses the management of drought and adaptation to climate change through proper policies and regulations. Furthermore, the water reallocation policy calls for launching awareness campaigns addressing the importance of issues such as water harvesting, conserving and protecting resources, while the water substitution and reuse policy proposes the reuse of treated wastewater in irrigation in order to free fresh water to be utilized for municipal uses. It also provides for using the treated wastewater in other economic activities, avoiding negative impacts on water and soil quality.

The new groundwater policy suggests many actions and measures regarding groundwater management, public awareness, legislations, resource investigation and development (MWI, 2016b). Some of these actions and measures drawn from the policy are listed below:

1. Sustainability of irrigated agriculture relying on groundwater is governed by socio-economic considerations that should be delineated into categories whereby a set of policy measures can be designed and applied to these various categories.
2. The agricultural sector's share of ground water resources shall be capped in favour of other sectors that show a higher economic return per cubic meter consumed.
3. Expropriation of use rights arising from legal use of groundwater, or of water rights established on springs from groundwater, reservoirs shall not be made without clear higher priority need, and against fair compensation.
4. Wells shall be closed against compensation for land value or water rights where their designation is zero or negative return.

5. Recharge areas for aquifers shall be protected against pollution caused by whatever means such as solid and liquid waste disposal, mining, landfills, brine disposal, agricultural inputs and the like.
6. Appropriate water tariffs and incentives for groundwater abstraction used in irrigation shall be introduced in order to promote water efficiency in irrigation and higher economic returns for irrigated agricultural products.
7. Legislations pertaining to groundwater management are enforced equally on all well-owners. Strict measures that deter future violations shall be designed and enforced.
8. Laws in effect shall be enforced with due diligence. Periodically update legislation whenever necessary to respond to emerging needs including the needs for improving the acceptance of the water users of the implementation of the laws.
9. A methodology introducing compliance mechanisms for groundwater quality with National Standards shall be adopted.
10. The campaign undertaken by MWI in August 2013, in enforcing bylaw 85(2002) and its amendments, shall be sustained.
11. Prohibition of well licensing for agricultural purposes shall be sustained, and incorporated in pertinent legislation.

5 Legal framework of groundwater management

5.1 Main legal milestones

The Constitution of Jordan provides for equality before the law and equality of rights for all citizens. Water and sanitation are regulated by MWI By-Law No. 14 of 2014; Water Authority of Jordan Law No. 18 of 1988 and its amendments; and Jordan Valley Authority By-Law No. 30 of 2001. Other relevant laws include Public Health Law No. 47 of 2008, Environmental Protection Law No. 85 of 2006, and Groundwater By-law No. 85 of 2002 and its amendments (MWI, 2016a). Groundwater policy is not disconnected from the various water policies and other policies that a country may adopt. "No wonder, then, that water policy gets overhauled, amended or its emphasis shifted in light of political and economic interactions and developments. Water legislation is the tool for implementation of water policy in Jordan" (Haddadin, 2006).

"The hierarchy of legislation in the country has as its peak the Constitution which is adopted through a vote of the elected Lower House of Parliament and by a vote of the appointed Upper House. Next in the hierarchy of legislation come the laws, conforming to the relevant provisions in the Constitution, approved by the Council of Ministers, debated and passed by both houses of Parliament, and issued for enforcement by a Royal Decree. Detailing of the intent of laws is done through regulations/by-laws whose provisions conform to the provisions of the respective law. The by-laws need to be approved by the Council of Ministers only since they are conforming to the law that the representatives of the people (both houses of Parliament) had approved earlier. A Royal Decree is issued to make the by-laws go in effect. Finally, the administrative decisions made by the respective official body form the last link in the "legislative" chain. Those decisions should be conformant with the provisions of the by-laws, the laws and the constitution as the case may be. The Supreme Court has the constitutional authority to look into disputes resulting from non-conformity of administrators of any entity with the legislation in force at the time of the administrative decision" (Haddadin, 2006).

Below, the water legislation and administration required for the implementation of water policy are reviewed, and the inter-links between the water policy and the overall strategy of the country are shown in Table 22.

Table 22: List of policies strategies and laws related to water and groundwater in Jordan

Date	Document Type and Title
	Policy
2008	Water Authority Strategic Plan 2008-2011
2007	National Water Demand Management Policy
2006	Drinking Water Resources Protection Guidelines
2006	Irrigation Equipment and System Design Policy
2006	Irrigation Water Allocation and Use Policy
2004	National Water Master Plan
1998	Irrigation Water Policy
1997	Groundwater Management Policy
1997	Wastewater Management Policy
1997	Water Strategy for Jordan
1997	Water Utility Policy
	Legal
2014	Administrative Organization Regulation for the MWI No. 14
2006	Environmental Protection Law No. 52*
2003	Regulation No. 76: A Regulation in Amendment of the Groundwater Control
2002	Regulator
2002	By-Law No. 85: Groundwater Control By-Law
2002	Provisional Law No. 44: Law of Agriculture*
2001	Temporary Public Health Law No. 54*
1998	Law No. 30: Jordan Valley Development Law
1997	Jordanian Standard No. 287: Drinking Water - Methods of Sampling
1992	Jordanian Standard No. 286: Drinking Water Standards
1991	Administrative Organization Regulation for the MWI No. 54
1988	Jordanian Standard No. 202: Requirements for Discharges of Industrial Effluents
	Law No. 18: The Water Authority Law and Amendments

Policies, strategies, laws, and by-laws, temporary laws for water, groundwater, agriculture, land use, livestock, and rangeland use were interrelated and developed and coordinated by various public ministries as relevant, with valid degrees of performance and effectiveness. Brief descriptions of each are summarized in Table 23.

Table 23: Groundwater Monitoring System By-Laws overtime

Document	Year	Type	Description
Land and Water Law	1952	Law	Define Water allocation, Registered of water right in Water Table
By-Law No. 14 of (1961) Groundwater Monitoring.	1961	By-Law	Regulate drilling of groundwater wells, License of drilling activities
Regulation of Natural Resources Law, No. (12) of 1968	1968	Law	Private Ownership of groundwater
Groundwater Monitoring	1977	By-Law	Prevent wells drilling, distances between wells and the necessity of annual licenses
Jordan Valley Authority, Law No. (18) of 1977	1977	Law	Management of water sources and distribution of irrigation water and land usage, Law No. 18 of 1977
Water Authority Law No 18 of 1988	1988	Law	WAJ is fully responsible for development and management of groundwater resources.
Ministry of Water and Irrigation By-Law No 54 of 1992	1992	By -law	MWI gives the full responsibility for water and public sewage and formulation of water policy
Groundwater Management Policy of 1998	1998	Policy	Development of the resource, its protection, management and measures needed to bring the annual abstractions from the various renewable aquifers to the sustainable rate
Jordan Water Authority Law 18/1998	1998	Law	WAJ authorized to acquire water rights by purchase or acquisition. Survey the different water resources, conserve them, determine ways, means and priorities for their implementation and use, except the use for irrigation
Groundwater Control By-Law No 85 of 2002	2002	By-Law	The by-law describes and entails the different procedures that are needed for controlling groundwater resources in Jordan. It helps explain the utilization and extraction quantity allowed. Moreover, conditions about licenses and their cost for borehole drilling, and water extraction fees are included in this regulation.
Amendment of Groundwater Monitoring Law	2014	By-Law	By-Law regulate groundwater wells operating, increased penalties against the offending drilling, where law is a felony punishable by imprisonment of dissenting drilling. Raising water prices for agricultural wells, backfill wells drilled after the issuance of the by-law.
Amendment of Groundwater Monitoring Law	2015	By-Law	Raising water prices for agricultural wells after well replacement or well deepening, backfill wells drilled after the issuance of the by-law.

Table 24: The policies strategies and laws related to Water, Groundwater in Jordan

Document	Year	Type	Description
Groundwater Management Policy of 1998	1998	Policy	The objective of Groundwater policy is to outline in more detail the statements covered in "Jordan's Water Strategy". The policy statements set out the Government's policy and intentions concerning groundwater management aiming at development of the groundwater resources, its protection, management and measures needed to bring the annual abstractions from the various renewable aquifers to the sustainable safe rate of each aquifer (MWI, 2015a; MWI, 2015b).
Irrigation Water Policy of 1998	1998	Policy	The policy addresses water related issues of resource development: agricultural use, resource management, and the imperative of technology transfer, water quality, efficiency, cost recovery, management and other issues. Linkages with energy and the environment are accorded a separate chapter. The policy is compatible with the Water Strategy and is in conformity with its long-term objectives (MWI, 2015c).
Irrigation Equipment and System Design Policy of 2008	2008	Policy	This policy statement follows from longer-term objectives outlined in the Water Strategy and supplements the Irrigation Water Policy and the Irrigation Water Allocation and Use Policy by establishing a policy on irrigation equipment and system design standards. The policy addresses the following themes: defining and updating equipment standards, raising farmers' awareness of standards, testing and enforcement of standards, training and certifying drip system designers, and institutional responsibilities.
Irrigation Water Allocation and Use Policy of 2008	2008	Policy	This policy statement follows from longer-term objectives outlined in the Water Strategy and elaborates on priorities specified in the Irrigation Water Policy. As such, it comprises an updating and extension of selected elements of the irrigation water policy. In particular it consolidates and elaborates elements of that policy relating to on farm water management, management and administration, water tariffing, and irrigation efficiency. The policy addresses the following themes: defining and updating crop water requirements, water allocation and billing practices, building farmers' water management skills, using reclaimed water, measuring

Document	Year	Type	Description
			deliveries and delivering water to groups.
National Strategy for Agricultural Development: 2002-2010	2002	Strate gy	The strategy discusses the role of the agricultural sector in social and economic development to achieve a sustainable agricultural and rural development taking into consideration the social economic and environmental aspects e.g. protection and conservation of ago-biodiversity of such development. The strategy presents profiles of proposed projects in the five agricultural sub sectors of rainfed agriculture, irrigated agriculture in the Jordan Valley, irrigated agriculture in the highlands, livestock and rangelands and marketing of agricultural produce.
Water Strategy for Jordan of 1997	1997	Strate gy	The document describes Jordan's responsibility towards its water sector by the following themes: resource development, resource management, legislation and institutional, shared water resources, public awareness, performance, health standards, private sector participation, financing and research development.
Jordan's Water Strategy 2008-2022: Water for Life	2009	Strate gy	This strategy specifies that the drinking water as the main priority in water allocation, followed by industry and agriculture. It includes specific actions and plans with targets to be achieved. Furthermore, the strategy emphasis on the two mega projects; the Disi water conveyance and the Red-Dead Canal, the reduction of the Non-Revenue for Water (NWR), on having cost reflective tariffs and restructuring the institutions of the water sector.
National Water Strategy 2016-2025	2016	Strate gy	The most recent National Water Strategy 2016–2025 (MWI, 2016a) focuses on building a resilient sector based on a unified approach for a comprehensive social, economic and environmentally viable water sector development. The strategy included provisions for climate change, water-energy-food nexus, and focus on water economics and financing, sustainability of overexploited groundwater resources and the adoption of the new technologies and techniques available including Decentralized Wastewater management.
Jordan Environmental Law	1995	Law	The Jordanian environmental law was enacted as a temporary legislation in 2003 and was ratified by the Parliament in 2006. This law provided the appropriate legislative umbrella for issuing of the various detailed regulations and instructions regarding the protection of the environment.

Document	Year	Type	Description
Jordan Valley Law	2001	Law	The objective of this law development of the water resources of the Valley and utilizing them for purposes of irrigated farming, domestic and municipal uses, industry, generating hydroelectric power and other beneficial uses; also their protection and conservation and the carrying out of all the works related to the development, utilization, protection and conservation of these resources.
Water Authority Law No 18 of 1988	1988	Law	It established the Water Authority of Jordan (WAJ) established in 1988 as an autonomous corporate body, with financial and administrative independence. The law describes the Mandate of WAJ, in which WAJ is fully responsible for providing municipal water and wastewater services, and development and management of groundwater resources. It also clarifies WAJ's relationship with the Ministry of Water and Irrigation.
Ministry of Water and Irrigation By Law No 54 of 1992	1992	By - law	It established the Ministry of Water and Irrigation, to which it gives the full responsibility for water and public sewage in the Kingdom as well as the projects pertaining thereto, formulation and transmission of the water policy to the Council of Ministers for adoption.
Groundwater Monitoring By-Law No 85 of 2002	2002	By-Law	The by-law describes and entails the different procedures that are needed for controlling groundwater resources in Jordan. It helps explain the utilization and extraction quantity allowed. Moreover, conditions about licenses and their cost for borehole drilling, and water extraction fees are included in this regulation.

Source : compiled from different sources, Sidahmed et al, 2012a; Sidahmed et al, 2012b; MWI, 2015a; MWI,2015b; MWI,2015c, MWI (2016a).

5.2 Evolution of groundwater monitoring by-laws

The first enacted legislation for groundwater was the By-Law No. 14 of 1961 on Groundwater Monitoring derived from Law 51 from 1959. This by-law describes the different requirements and procedures that are needed for water abstraction, drilling and controlling groundwater resources in Jordan. It helps explain the utilization and extraction quantity allowed. Moreover, conditions about licenses and their cost for borehole drilling are stipulated. In this by-law land and water property right are secured by the well owner.

The groundwater monitoring by-law had many amendments through the years as shown in Table 25. A subsequent by-law, No. 85, was issued in 2002, with several amendments until 2015. Usually in the introduction of the by-law there are definitions of the main terms and the abbreviations later used in the articles and paragraph of the by-law. Table 26 shows the appearance of those definitions in the by-laws. This reflects the progress made in understanding of the groundwater system. The groundwater, water abstraction, drilling activities are mentioned at the first time in By-law No. 16 in 1961. Driller and drilling rigs are mentioned in the first time in By-law No.88 in 1966. They distinguish between private well and public well, banned area and spring appear in the by-law No 26 Year 1977. Usually there is a time lag between issuance of the law and real implementation. The lag sometime extends to years, depends on the political situation and the will of decision markers in law enforcement and implementation.

Table 25: The evolution of groundwater monitoring by-laws overtime

Year	By-Law
1961	By-Law No. 14 of (1961) Groundwater Monitoring - not valid
1961	By-Law No.34 (1961) Groundwater Monitoring - Amendment
1966	By-Law No. (88) of (1966) Groundwater Monitoring /issued under article Natural Resources management Act No. 37 of 1966
1973	By- Law No. (12) (1973) An Amendment of By Law No (88) of (1966)
1974	By-Law No. (16) of (1974) Groundwater Monitoring System /issued under article 68 of the Natural Resources management Act No. 12 of 1968
1977	By-Law No. (26) of (1977) Groundwater Monitoring System / issued on the basis of article 68 of the law of management of natural resources (No. 12) of 1968.- not valid
2002	By-Law (85) of (2002) Groundwater Monitoring
2003	By-Law (76) of (2003) Groundwater Monitoring, Amendment
2004	By-Law (68) of (2004) Groundwater Monitoring , Amendment
2007	By-Law (12) of (2007) Groundwater Monitoring, Amendment
2013	By-Law (63) of (2013) Groundwater Monitoring, Amendment
2014	By-Law (36) of (2014) Groundwater Monitoring, Amendment
2014	By-Law (93) of (2014) Groundwater Monitoring, Amendment
2015	By-Law (64) of (2015) Groundwater Monitoring, Amendment

Table 26: The existence of definition for groundwater related abbreviation appeared in the by-laws

Definition	No. 14, Year 1961	No. 88, Year 1966	No 12, Year 1973	No 16, Year 1974	No 26 Year 1977	No. 85 Year 2002	No. 76 Year 2003	No. 86 Year 2004	No. 12 Year 2007	No. 63 Year 2013	No. 36 Year 2014	No 93 , Year 2014	No. 64, Year 2015
Abstraction	E	E	E	E	E	E	E	E	E	E	E	E	E
Well	E	E	E	E	E	E	E	E	E	E	E	E	E
Drilling	E	E	E	E	E	E	E	E	E	E	E	E	E
Groundwater	E	E	E	E	E	E	E	E	E	E	E	E	E
Driller	NE	E	E	E	E	E	E	E	E	E	E	E	E
Drilling Rig	NE	E	E	E	E	E	E	E	E	E	E	E	E
Private Well	NE	NE	NE	NE	E	E	E	E	E	E	E	E	E
Public well	NE	NE	NE	NE	E	E	E	E	E	E	E	E	E
Banned Area	NE	NE	NE	NE	E	E	E	E	E	E	E	E	E
Spring	NE	NE	NE	NE	E	E	E	E	E	E	E	E	E
Water Layer	NE	NE	NE	NE	NE	E	E	E	E	E	E	E	E
Catchment Areas	NE	NE	NE	NE	NE	E	E	E	E	E	E	E	E
Safe Yield	NE	NE	NE	NE	NE	E	E	E	E	E	E	E	E
Depletion	NE	NE	NE	NE	NE	E	E	E	E	E	E	E	E
Surface Water	NE	NE	NE	NE	NE	E	E	E	E	E	E	E	E

Note: E = Existing in the by-law, NE not-existing in the by-law.

6 Groundwater protection policy and tools

Groundwater is a finite resource. It is replenished only when surface water seeps into aquifers. This process of aquifer replenishment is called recharge. Aquifers receive water and release it to springs, wetlands and rivers (baseflow). The safe yield is defined as the level of abstraction considered as acceptable, considering the associated negative impacts. It is therefore in general much less than the recharge itself. The Safe yield is the amount of water that can be withdrawn from an aquifer without significant ecological impacts. In situations where the aquifer has been so much depleted that outflows have been reduced to nothing (e.g. recharge to the Azraq wetland) then the recharge rate can be taken as the amount of water which can be extracted while stabilizing the level of the aquifer.

6.1 Fossil groundwater management in south Jordan

Non-renewable groundwater is water present in aquifers in which the rate of recharge is insignificant within the current water budget of the aquifer. Extraction of water is produced from non-renewable storage. The extraction of water from such non-replenishing groundwater reserves (known as low safe-yield reserves) is known in hydrology as water 'mining'. It is clear that fossil groundwater underlies the entire territories of the country with the exception of the igneous rock stretch north of Aqaba. Non-renewable groundwater is regarded by MWI as a strategic reserve that should be used sparingly and for crucial purposes only, such as drinking water. Dependence on it for long periods of time carries a high risk of depletion and environmental, social and security serious hazards.

In 1983, the government was encouraged by the results of exploration for groundwater in the south (Disi-Mudawwara and Sahl As Suwwan), and pioneered the exploitation of fossil groundwater in that area for agricultural purposes. Soon after the pioneering effort was initiated, it became clear that the government could not continue in the business of agricultural production. The investment in the well fields, electrical transmission from the national grid, and some machinery, had been made already, and there was no way in sight that such investments could be recovered through government farming, nor would the government sustain the wheat production activities.

To recover the investment (or part thereof) and keep the momentum going, the government announced in 1985 its intention to allow private sector companies to exploit the aquifer for wheat cultivation (the country imported 410 thousand ton of wheat, while the domestic production at that time was about 62 thousand tons, which accounted for about 15% of the country needs for bread). Companies were hurriedly formed and rented the state land for nominal rental charges, paid for the assets, and replaced the government in agricultural production. A change was made to the cropping pattern and soon those companies started to produce potatoes and water melon that competed with those produced in the Jordan Valley. The amount of water abstracted annually reached about 85-100 MCM in 2000., but government, motivated by the World Bank through the Agricultural Sector Adjustment Loan 1997, (approved in September 5, 1997 and completed in January 31, 2003) demanded a phased reduction of the amounts abstracted. Little was achieved in reducing the abstracted amounts (World Bank, 2003).

Meanwhile, Law No. 82 in 2002 allowed the Ministry of Water and Irrigation to impose charges on water abstracted in excess of a permitted amount for each well, and that measure upset the owners of the companies. They went to court in 2004 but the verdict of the court was in favour of the Ministry, as the decision was taken in accordance with a new legislation. In the year 2005 a new government was formed and it reversed the policy of charging for the fossil water on the grounds that only the contract signed with the companies regulated their relationship, and that those contracts had no mention of water charges, only land rentals. Legally however, the new government and the companies are right (Haddadin, 2006). The Supreme Court mandate is to rule over management decisions and not on issues of contract disputes so it rightfully ruled that the decision of the Ministry to charge for water is legal and is in line with the regulation that was issued to control groundwater resources according to by-law 2002. The deficiency was in the regulation that ignored acquired rights, a matter to be ruled by a different court, the Court of First Instance. After completion of the Disi carrier in 2013 which conveys fossil groundwater to Amman and the northern governorates, it was agreed with the agricultural companies to reduce water abstraction for perennial crops and to phase out only vegetables from their cropping pattern.

6.2 Development of laws and bylaws according to the existence of abstraction purposes

The purpose and reasons of water abstraction from groundwater are not mentioned in the by-laws before the by-law 26 of the year 1997. This by-law defines the reason of water abstraction for industrial or agricultural purpose.

Table 27 shows the development of laws and by-laws of water abstraction reasons, where in 1966 the minimum area to allow drilling a well was 5 dunums. However, that area was increased to be 50 dunums in the year 1977 and 100 dunums in 2002. One the other hand and due to the increase of water scarcity, laws were started to emerge for most sectors after the year 2002, for instance law No. 85 in 2002 was created for drinking and touristic sectors and since that date those laws/bylaws are still active.

6.3 Groundwater monitoring network

Monitoring of water resources is considered as key to the estimation of surface water and groundwater budgets. It is possible to develop and update water monitoring in all water basins in the kingdom. It is built on current and historical data, programs, and work plans relating to development and management of water resources. Surface water monitoring network includes stations of rainfall, evaporation, floods, springs, basic drainage for valleys, in addition to stations of remote sensing (MWI, 2012).

Groundwater monitoring and the collection of well information started by the introduction of groundwater By-Law No. 14 in 1961. The water authority had the right to collect information about wells. As stated in Article 5: "The competent officials nominated by the Minister or the Secretary General, shall have the right to enter any land for conducting studies or investigation or collection of information related to underground water or for carrying out any measures required by this By-Law." The above statement is still valid in the subsequent by-laws.

Table 27: Appearance of the usage purposes to justify water abstraction over time in the by-laws.

Laws or By-Laws	Irrigation (Min. Irrigated area)	Industrial purposes	Drinking & Municipal purposes	Touristic purposes	University usage purposes	Livestock watering purposes
No. 14, Year 1961	NE	NE	NE	NE	NE	NE
No. 88, Year 1966	5 du	NE	NE	NE	NE	NE
No. 12, Year 1973	5 du	NE	NE	NE	NE	NE
No. 16, Year 1974	5 du	NE	NE	NE	NE	NE
No. 26 Year 1977	50 du	E	NE	NE	NE	NE
No. 85 Year 2002	100 du	E	E	E	E	NE
No. 76 Year 2003	100 du	E	E	E	E	NE
No. 86 Year 2004	100 du	E	E	E	E	NE
No. 12 Year 2007	100 du	E	E	E	E	E
No. 63 Year 2013	100 du	E	E	E	E	E
No. 36 Year 2014	100 du	E	E	E	E	E
No 93 , Year 2014	100 du	E	E	E	E	E
No. 64, Year 2015	100 du	E	E	E	E	E

Note: E = Existing in the by-law, NE not-existing in the by-law.

In 2014, Jordan's groundwater monitoring network includes 116 piezometres to measure groundwater levels. The 12 groundwater basins and the 108 controlling wells are measured manually. Regarding the control of groundwater quality, samples are taken from drinking-supply wells. There are set of controlling wells adjacent to wastewater treatment plants for purposes of groundwater quality control.

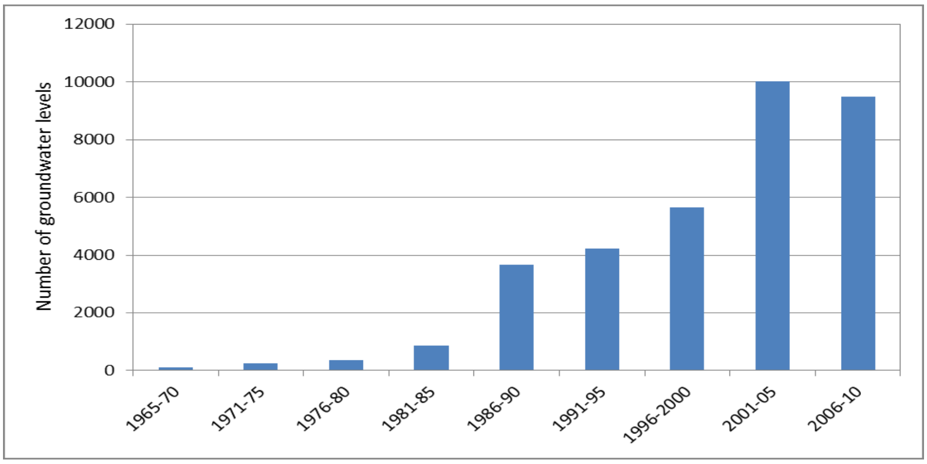
Table 28: Existence of groundwater monitoring terms in the By-laws

Collected Information on	Deep of the well	Diameter of well	Water level	Water drawdown	Static Water Level	Abstraction rate	Meter Installation	Over Abstraction	Water Salinity	Conducting Pumping test
No. 14, Year 1961	E	E	E	E	NE	NE	NE	NE	NE	NE
No. 88, Year 1966	E	E	E	E	E	NE	NE	NE	NE	E
No. 12, Year 1973	E	E	E	E	E	NE	NE	NE	NE	E
No. 16, Year 1974	E	E	E	E	E	NE	NE	NE	NE	E
No. 26 Year 1977	E	E	E	E	E	E	E	E	E	E
No. 85 Year 2002	E	E	E	E	E	E	E	E	E	E
No. 76 Year 2003	E	E	E	E	E	E	E	E	E	E
No. 86 Year 2004	E	E	E	E	E	E	E	E	E	E
No. 12 Year 2007	E	E	E	E	E	E	E	E	E	E
No. 63 Year 2013	E	E	E	E	E	E	E	E	E	E
No. 36 Year 2014	E	E	E	E	E	E	E	E	E	E
No 93 , Year 2014	E	E	E	E	E	E	E	E	E	E
No. 64, Year 2015	E	E	E	E	E	E	E	E	E	E

Note: E = Existing in the by-law, NE not-existing in the by-law.

Groundwater level and electrical-conductivity (EC) data collected by the MWI started in 1960. EC commonly is used as a surrogate for salinity or total dissolved solids. The MWI maintains a database (Water Information System (WIS)) that includes groundwater levels, aquifer-formation depths, and other information for production, monitoring, and unused wells. Over time, the amount of data on water levels in wells has increased substantially (Figure 8), although there has been a small decrease in the number of measurements in the database recently (2006–2010).

Figure 8: Number of groundwater-level measurements for all wells



Source: Goode et al., 2013

Changes in groundwater levels and salinity in six groundwater basins in Jordan were characterized by using well-monitoring data collected from 1960 to early 2011. On the basis of data for 117 wells, groundwater levels in the six basins were declining, on average about -1 meter per year (m/yr), in 2010. The highest average rate of decline, -1.9 m/yr, occurred in the Jordan Side Valleys basin, and on average no decline occurred in the Hammad basin. The highest rate of decline for an individual well was -9 m/yr (Goode et al., 2013).

The salinity in about 58% of the wells in the Amman-Zarqa basin has substantially increased, and the salinity in Hammad basin showed a long-term increasing trend. Salinity increases were not always observed in areas with groundwater-level declines. The highest rates of salinity increase were observed in regional discharge areas near groundwater pumping centers (Goode et al. 2013).

6.4 Zoning and protection areas

The MWI with the cooperation of the German company BGR issued groundwater protection guidelines in 2006 (Margane et al., 2004, 2006). The bylaw 2002 addresses protection of groundwater resources through appropriate land use restrictions. Furthermore, groundwater vulnerability mapping and delineation of groundwater protection zones were implemented since 2005 in Zarqa river basin and Mafraq. Margane et al. (2006) defined a groundwater protection area as an area around a drinking water supply (the size and extent of which is given by the catchment area of a well or spring), which has restrictions on land use and human activities. This definition is independent of the aquifer type (e.g. porous, bedrock, or karst aquifer). In Jordan the following zoning system for groundwater protection areas are proposed to be applied (Table 29).

It is important to legalize the groundwater and surface water protection. By-laws and ordinances have been proposed and are now in the process of acceptance by the Jordanian Government (Table 29). Though their acceptance might take some time, a number of groundwater protection zones have already been delineated and land use restrictions have been proposed.

Table 29: Zoning scheme for groundwater protection zones

Zone	Size	Land use restrictions
Zone I	Springs: 50 m upstream, 15 m lateral, 10 m downstream. Wells: 25 m upstream, 15 m lateral and downstream	Fenced off; access only for personnel of water works and management and control agency (Government purchases property)
Zone II	50-days line; but: maximum of 2 km in upstream and 50-150 m in downstream directions in karst areas: areas classified as highly and very highly vulnerable (groundwater vulnerability map); but: maximum of 2 km in upstream and 50-150 m in downstream directions	Existing settlements and organic agriculture permitted; new development only with permission granted by licensing committee; existing land uses which generate waste and sewage water that may negatively affect the environment have to apply rules of best management practice (BMP), which will be issued by the Government; construction of wastewater collection and treatment systems in this zone will be given priority
Zone III	entire contribution zone	All types of land use are permitted if they are conducted in accordance with the rules of best management practice

Source: El-Naqa and Al-Shayeb (2009).

Zone I. Immediate protection of well/spring against direct pollution sized at about 1 dunum (i.e. 1,000 m2*)* around each water source (spring, well). Within this area no activities will be allowed other than those needed for water abstraction. For public supplies, WAJ will acquire the land and fence it. As for private supplies a similar area should be protected.

Zone II. Protection against bacteriological pollution. This zone is based on a 50-day travel time, or maximum 2 km upstream of a well or spring. Allowed activities within this zone are distinguished according to the development status: On newly developed land; residential use with sewers or acceptable cesspit, and/or organic farming. While allowed activities on already developed land are residential uses provided that they get connected to the sewerage system in addition to organic farming. Other activities have to implement Best Management Practices Activities in Zone II will be intensively monitored.

Zone III. Protection of the entire catchment area. The allowed activities in this zone are still under discussion. For the acceptance of groundwater protection areas, it is necessary that the regulations and restrictions for the protection of groundwater are similar within and outside the groundwater protection areas (MWI, 2009).

6.5 Prevention of groundwater depletion

The Authority has a right to prevent groundwater depletion or groundwater pollution according to article 16 of the by-law 2002 which state:

"If any areas were found to be polluted or depleted, the Board shall take a decision to set the appropriate measures that will put an end to such pollution or depletion including the rationalization or reduction of the extraction rate, to an extent that would allow the halt of pollution or depletion, and the restoration of the natural balance to the aquifer or to the underground water basin."

6.6 Distance between wells

The MWI started to apply by-laws regarding the distance between wells by 25m in 1966 with the By-Law No. 88. Such rule changed to be 1 km in the by-law No 26 in 1977. The distance between new wells and existing springs was introduced in 2002, set at a minimum distance of 3 km and should not harm the spring natural discharge. The distance between wells should be at least 1 km. In the case of replacement well with other well the minimum distance should be 50 m. Table 10 shows the time of distance implementation in the by-Laws, where it shows that distances between wells have not been changed since 2003 in spite of the increased scarcity of groundwater resources in Jordan especially in the irrigated areas.

Table 30: Existence of the term minimum distance between wells in by-laws over time

Laws-By-Law	Distance between Wells	Distance of replacement Well	Distance to Spring
No. 14, Year 1961	existed, but not specified	NE	NE
No. 88, Year 1966	25 meter	NE	NE
No. 12, Year 1973	25 meter	NE	NE
No. 16, Year 1974	25 meter	NE	NE
No. 26 Year 1977	1 km	NE	1 km
No. 85 Year 2002	not harm neighbours	50 meter	3 km
No. 76 Year 2003	not harm neighbours	50 meter	3 km
No. 86 Year 2004	not harm neighbours	50 meter	3 km
No. 12 Year 2007	not harm neighbours	50 meter	3 km
No. 63 Year 2013	not harm neighbours	50 meter	3 km
No. 36 Year 2014	not harm neighbours	50 meter	3 km
No. 93 , Year 2014	not harm neighbours	50 meter	3 km
No. 64, Year 2015	not harm neighbours	50 meter	3 km

Note: NE, not-existing in the by-laws.

6.7 Groundwater vulnerability and delineation maps

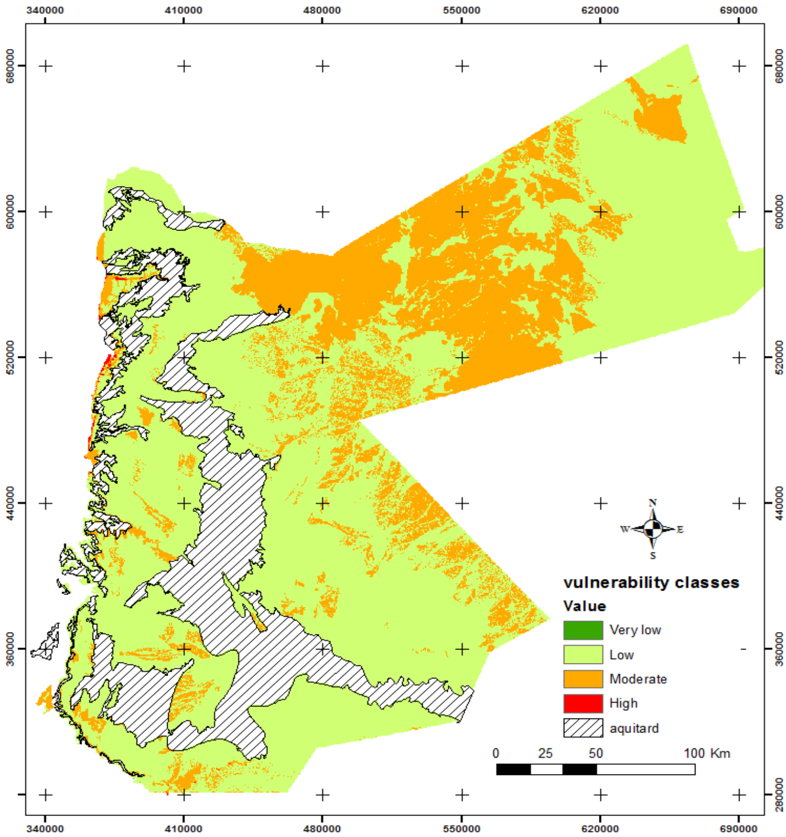
Groundwater vulnerability is an overlay method that is used to determine the ability of pollutants to penetrate to the target aquifer and to harm it. This method helps decision makers by shedding light on pollution areas expected to pollute groundwater aquifers as caused by human activities on the ground surface (Mohammad et al., 2015).

The MWI in conjunction with researchers from Jordanian Universities and BGR prepared vulnerability maps of the shallow aquifers in Jordan using DRASTIC index; this index incorporates the different hydrological factors such as rainfall, depth to the groundwater table, hydraulic conductivity and other factors including topography, recharge ability and amounts, aquifer media and vadose zone effects which naturally participate in protecting aquifers.

These maps are intended to show zones of most potential for groundwater pollution on the premise of hydro- geological conditions and human effects. The greater part of the major geographical and hydro-topographical elements that influence and control groundwater development into the basin. A Geographical Information System (GIS) is utilized to make a groundwater vulnerability map by overlaying the accessible hydro-geological information (Al-Adamat, 2003).

A number of corrective measures have also been proposed for protection zones 2, where the most prominent contamination risks arise from agricultural and cow farming activities. Implementation of these measures should be given high priority. A spreading of cow farming, which is currently mainly concentrated around the village of Ad Dhuleil, towards the Hallabat or Corridor well fields should be avoided under all circumstances and strongly objected by the MWI and WAJ (Figure 2).

Figure 9: Groundwater vulnerability classes for the outcropping aquifers in Jordan

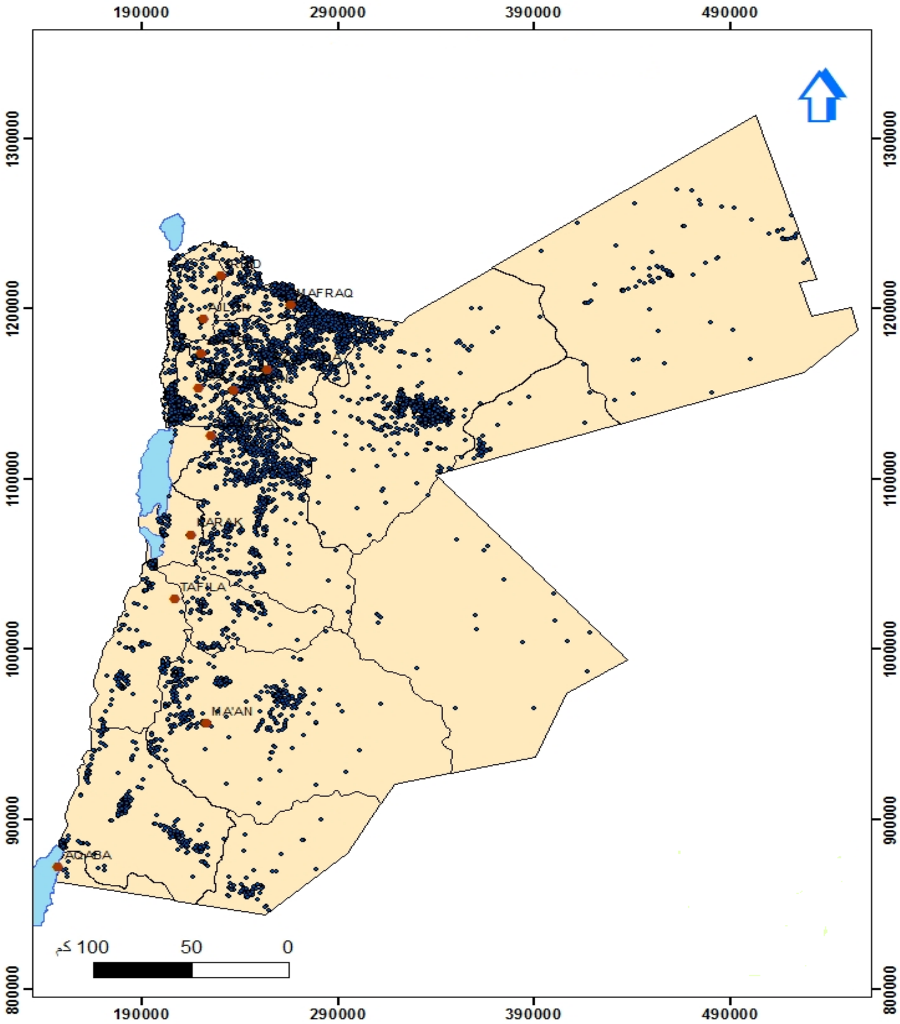


Source: NWMP, 2003.

6.8 Registration of wells

The MWI has carried out the registration of wells all over the country, establishing coordinates and obtain information on depth, water level, year of drilling, water use, etc. As a result, the Ministry established a database during 1992-1995 to register nearly all wells in the country whether they are licensed or illegal. The total number of wells in 2000 was 2,449, of which 1,830 were used for irrigation, 450 for municipal supply and 169 for industrial uses. Furthermore, the total number of working and non-working wells was 6,500 in 2012, of which 3,033 working wells, 800 of them are not licenced. The total unlicensed working and non-working wells was 1,342. There were 2,824 private wells of which 2,435 were working. In 2015 the total number of wells working was 3,138, of which 136 private domestic wells, 620 public domestic wells, 201 industrial wells and 2,163 agricultural wells. In addition to 18 wells in remote areas for livestock watering (MWI, 2016d). The distribution of groundwater wells among aquifers is shown in Figure 10. The distribution of wells and water abstraction for the year 2015 are displayed in the Annex (Table 52).

Figure 10: Distribution of groundwater wells among aquifers in Jordan



Source: MWI, 2014

6.9 The licensing of well drilling and water extraction

The licensing procedure of groundwater abstraction for wells follows the procedure illustrated in Figure 3. The licensing procedure starts with a license of a driller; a person who drills a well should have a license to do that. It is necessary to obtain a separate license for the drilling machine itself. Furthermore, a separate license is required to move the drilling rig from one place to another should. Table 10 shows the changing groundwater licensing activities over time starting from 1961 until 2015.

Table 31: Existence of groundwater licensing activities over time

Groundwater Licensing Activities	No. 14, Year 1961	No. 88, Year 1966	No. 12, Year 1973	No. 16, Year 1974	No. 26 Year 1977	No. 85 Year 2002	No. 76 Year 2003	No. 86 Year 2004	No. 12 Year 2007	No. 63 Year 2013	No. 36 Year 2014	No 93 , Year 2014	No. 64, Year 2015
Drilling	E	E	E	E	E	E	E	E	E	E	E	E	E
Driller	NE	E	E	E	E	E	E	E	E	E	E	E	E
Drilling Rig License	NE	NE	NE	NE	NE	E	E	E	E	E	E	E	E
Driller License	NE	NE	NE	NE	NE	E	E	E	E	E	E	E	E
Use of Drilling Rig	NE	NE	NE	E	E	E	E	E	E	E	E	E	E
Ownership of drilling rig	NE	NE	NE	E	E	E	E	E	E	E	E	E	E
Movement of drilling rig	NE	NE	NE	NE	NE	E	E	E	E	E	E	E	E
Max Volume	E	E	E	E	E	E	E	E	E	E	E	E	E
Purposes	E	E	E	E	E	E	E	E	E	E	E	E	E
Property Right	E	E	E	E	NE	NE	NE	NE	NE	NE	NE	NE	NE
License Cancelation	E	E	E	E	E	E	E	E	E	E	E	E	E
Abstraction test	NE	NE	NE	NE	E	E	E	E	E	E	E	E	E
Licenses Validity	NE	NE	NE	NE	NE	E	E	E	E	E	E	E	E

Note: E = Existing in the by-law, NE not-existing in the by-law.

The following paragraph in the by-law explain the drilling procedures and fees

Article 8 of By-law No. 85, 2002:

Everybody is hereby prohibited to commence drilling a well or extracting underground water, or changing the specifications of an existing well or drilling a substitute well unless a license to this effect in accordance with the provisions of this by-Law has been obtained.

Article 9 of By-law No. 85, 2002:

The licensee to drill a well should carry out under the supervision of the Authority, a pumping test before commencement of the utilization thereof, so that the well production capacity and the water quality may be determined.

Article 11 of By-law No. 85, 2002:

The owner or the possessor of a private well is hereby prohibited to do the following:

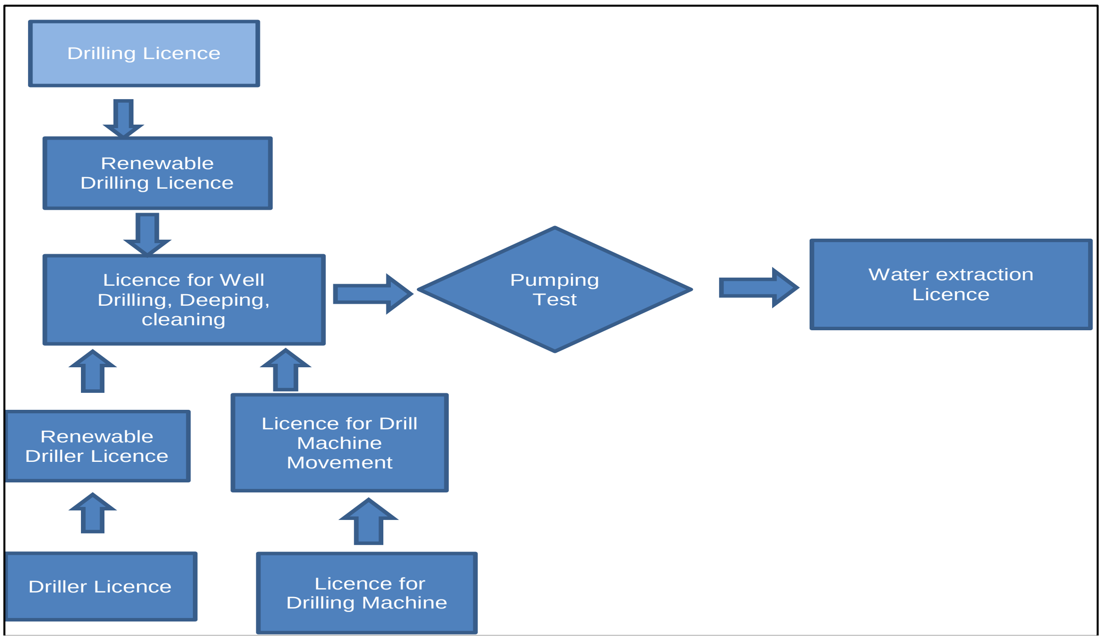
To irrigate any land other than that specified in the water extraction license or to sell this water for irrigation purposes.

To sell the water extracted from the well by water-tankers for drinking purposes or any other purpose without obtaining a prior written approval from the Secretary General, or his delegate, and according to conditions outlined for this purpose. In the By-law No.85 of 2002 there are many licence needs to be involved in groundwater drilling and abstraction, those are: the licensing of wells drilling and water extraction, the licensing of drilling rigs and drillers.

Table 32: The fees shall be levied by the Authority for issuance of licenses in 2002

License type	Price J.D	Price $
Drilling license	1000	1,400
Renewal of drilling license	500	700
Water extraction license	100	141
Renewal of extraction license	50	71
Substitute drilling license	750	1,050
Well Deepening license	500	705
Well maintenance or cleaning license	300	423
Possession or use of a drilling rig license	500	705
Renewal of Possession or use of a drilling rig license	100	141
Driller license	50	71
Renewal of driller license	10	15

Figure 11: Steps for the licensing of groundwater abstractions



6.10 Well drilling prohibition

To regulate water abstraction from groundwater resources after independence in 1946, a well drilling department was created at the Ministry of Public Works. It was clear that the private sector at that time was not prepared to lead in the introduction of drilling technology due to the lack of knowledge, and that the government had to take that role. Later on, the private sector in the early of 1960s took the lead and many drilling activities were conducted. Because of the connections between groundwater and base flow of wadis that farmers were using, it was important for the government to make sure that future well drilling will not harm existing uses of base flows.

The following paragraph in the Water Authority Law No.18 of 1988 stresses that any well should only be drilled after receiving an authorization. There is a direct provision in Article 30-a, item (4) that reads as follows: Article (30):

a) Anyone may be sentenced to not less than six months and not more than two years imprisonment or may be fined not less than JD 1,000 and not more than JD 5,000, or both, if he has committed any of the following deeds:

b) Drilled unlicensed groundwater wells or violated the conditions of the license issued to him.

Paragraph (d) of the same article defines the penalty for violating drilling unlicensed wells or violating the conditions of the license for water abstraction. The penalty, as stated in paragraph (d), will apply, based on a court decision about the violation:

d) If any person is found guilty of committing any of the deeds defined in paragraphs (a) and (b) of this Article, the Court shall convict him and make him pay the total of the damages caused by his violation and compel him to eliminate the damage caused and restore the conditions as they existed before committing such deeds within the period specified by the Court. If he fails to do so, the Authority shall have the right to carry out the necessary works and repairs and charge the convicted person with the total cost plus 50 %.

The By-law from 2002 states that water is public property and under control of the government. Article 8 of the by-law states that everybody is hereby prohibited to commence drilling a well or extracting underground water, or changing the specifications of an existing well or drilling a substitute well unless a license to this effect in accordance with the provisions of this by-Law has been obtained.

In the early 1990s, a decision by the cabinet prohibiting the drilling of new wells in most parts of the country, where aquifers were affected by depletion and quality degradation. The MWI carried out surveys all over the country to register wells, measure coordinates and obtain information on depth, water level, year of drilling, water use, etc. As a result, the Ministry has established a databank to register nearly all wells in the country whether they are licensed or illegal.

6.11 Metering groundwater abstractions

In By-law No. 26 for 1977, articles 19 and 20 specify, for a valid abstraction licence, to install a water meter or apparatus to measure water flows, water abstraction volume. The installation, at the expense of the owner of the well, of a water-meter after it has been approved and stamped by the Authority. This condition should be complied with prior to the issuance of water extraction license. If the authority finds the meter nonoperative or has been manipulated with. In such cases, the water quantities are estimated accordance with rules adopted by the authority board for this purpose.

In 1978, By-law No.21 on the irrigation of the Highlands was issued, with the MWI charging a price for all extracted groundwater for municipal, industrial, and commercial uses, excluding irrigation. The charge was a flat rate at that time of US$ 0.15/m3. All wells were supposed to be metered and fees collected based on the abstraction volume. In 1999, the fees were raised to US$ 0.37/m3 (MWI, 2001).

The MWI also took an important step to install meters on all wells including those used for irrigation, to measure the abstracted volume of water and to limit abstracted quantities according to the license. Farmers refused the installation of meters and some of them even damaged the meters. Farmers found ways to manipulate meter readings, or using personal relation and tribal relation pressure WAJ staff to reduce registered amount. After some time, the enforcement rate of installing water meter was 95%. Farmers were also asked to pay for the amount of water exceeding the limits in the licenses. In 2002, the Cabinet of Ministers approved a new pricing policy on irrigation water—even on amounts already granted in existing licenses—with a block tariff system, where charges increase in relation to the amounts of water extracted (Llamas and Custodio, 2003).

The By-law from 2002 specified again that for a valid abstraction licence the well should be equipped with a water meter installed at the expense of the owner of the well, prior to the issuance of water extraction license. It is necessary to notify the Authority within a period not exceeding 48 hours in case of non-function of the water-meter. The owner of the well shall reimburse the Authority for the fixed maintenance expenses of the water-meter. In such cases, the water quantity shall be calculated in the light of the irrigated area, type of crop, or consumed electricity power and in accordance with rules adopted by the Board for this purpose in coordination with Ministry of Agriculture.

The amendment of the 2002 By-law with the By-law No. 36 of 2014 allowed the Water Authority to determine water consumption in the case of broken meter or any other reasons using electricity consumption, cropping areas and satellite images. Nowadays the MWI is using remote sensing as another method that could be used to verify metering data and to estimate total water abstraction. Satellite image sensitivity to different bands of radiation and resolution of area are increasing and improving the accuracy of this tool as a means to estimate the area of specific crops being grown. In spite of the shortcomings of this method such as depending on the theoretical crop water requirements, but it has been effectively used for monitoring any change in the cropped area over time. On the other hand, remote sensing data analysis is a reliable method for monitoring changes in the cultivated areas. All of the by-laws issued after the Groundwater By-Law No. 85 of 2002 are amendments to this by-law. Table 34 described the context of these amendments. The driving forces for these amendments are the observation of MWI staff in implementation of the by-laws.

Table 33: The existence of metering of groundwater abstraction in by-laws

Metering	No. 14, Year 1961	No. 88, Year 1966	No. 12, Year 1973	No. 16, Year 1974	No. 26 Year 1977	No. 85 Year 2002	No. 76 Year 2003	No. 86 Year 2004	No. 12 Year 2007	No. 63 Year 2013	No. 36 Year 2014	No 93 , Year 2014	No. 64, Year 2015
installation	NE	E	E	E	E	E	E	E	E	E	E	E	E
Monitoring	NE	E	E	E	E	E	E	E	E	E	E	E	E
Meter Sealing	NE	NE	E	E	E	E	E	E	E	E	E	E	E
Meter reading	NE	NE	E	E	E	E	E	E	E	E	E	E	E
Abstraction estimate	NE	NE	NE	NE	NE	E	E	E	E	E	E	E	E

Note: E = Existing in the by-law, NE not-existing in the by-law.

Table 34: Description of the amendments to By-law No.85, 2002.

By-law	Year	Description
Groundwater Control By-Law No. 85	2002	The by-law describes and entails the different procedures that are needed for controlling groundwater resources in Jordan. It helps explain the utilization and extraction quantity allowed. Moreover, conditions about licenses and their cost for borehole drilling, and water extraction fees are included in this regulation.
By-Law No.76, Groundwater Control: An Amendment	2003	Increased license fees, increased volumetric price of abstracted water, curtailing the quantities of water abstracted in Azraq basin to 100,000 m3 per well with 20 fils/m3 and above 100,000 m3 with 60 fils/m3.
By-Law No.68, Groundwater Control: An Amendment	2004	Reduce the volumetric water price to the original By-law No.85 from 2002.
By-Law No.12, Groundwater Control: An Amendment	2007	Define the wells in the remote areas as productive well for livestock water, increase the volumetric price of water for industry, universities and wells owned by public water utilities
By-Law No.63, Groundwater Control: An Amendment	2013	Increase the volumetric price for industry, universities and tourism activities
By-Law No.3, Groundwater Control: An Amendment	2014	The by-law differentiates between public universities and Private Universities
By-Law No.93, Groundwater Monitoring System An Amendment	2014	By-Law regulate groundwater wells operating, increased penalties against the offending drilling, where law is a felony punishable by imprisonment of dissenting drilling. Raising water prices for agricultural wells, backfill wells drilled after the issuance of the by-law.

6.12 Backfilling illegal wells

The MWI takes many actions to close illegal wells that are not registered before 1995. The owners of wells, either working or non-working wells prior to the coming into effect of the By-Law 85 in 2002, whether licensed or unlicensed, must adjust their status within a period not exceeding six months. This means they have to inform the Ministry about their well with full information, date of drilling, depth, abstraction rate, etc. Whoever is denied registration will face legal measures, such as well capping, backfilling of these wells. Unlawful wells drilled after 1995 should be refilled instantly unless if there are financial or social conditions supporting continuation of water extraction out of unlicensed wells. The choice ought to be affirmed by the Council of Ministers, who may sanction the extraction of water from these wells for limited periods.

Article 18 of By-law No.85 from 2002 states that the secretary general may take any of the following measures:

1. Backfill any well drilled without a license in pursuance of the provisions of this By-Law.
2. Backfill any well whose owner did not abide with the conditions of the license granted thereto.

By June 2015, 644 wells had been backfilled, 32 drilling rigs were halted, and 32 excavators stopped. Distribution of notices to the owners of the wells, which requires the decision of the Cabinet, pointing out that he has so far distributed 1,228 notices, with the owners of the wells indicated in the National Gazette. The government is promoting a 'success story' regarding backfilling of wells. However, many wells backfilled were the ones not being used or abandoned, or with very low flow rate, which are therefore not useful for owners anymore.

6.13 Water metering, quotas

Standards and specifications exist for meters, pipes, valves and tubing, however no standards or specifications existed for meter settings. Since situations vary, guidelines for meter settings are established by the water authority. Some considerations include:

- Use of shut-off valves,
- By-pass piping for continuous flow during maintenance or testing, and
- Meter reading options, direct read or remote.

The meter specification adopted by the Water Authority of Jordan (WAJ) is ANSI/AWWA Standard C-701 for cold water meters. Section Four of that standard refers to material requirements for internal and external parts to maintain dimensional stability and operating clearances at an optimum water temperature of 26.6 degrees Celsius[9] (Al–Hadidi, 2012).

As one means to fill gaps in groundwater abstraction data in the program for monitoring meters, electricity consumption data from the National Electricity Company was examined. By calculating the annual abstraction for the wells where pumps are driven by electrical energy, some of the gaps in groundwater abstraction data can be filled. However, estimation of groundwater abstraction using electrical consumption data is only a useful measure to check on specific well whether this well is exceeding the

[9] http://www.acwua.org/sites/default/files/2_khair_al-hadidi.pdf

pumping allowable amount or not. However this measure has its own shortcoming since not all farmers are using electrical pumps.

The following steps are taken by MWI to improve the monitoring of agricultural groundwater use (MWI, 2001):

- Continue the use of well meter readings to obtain actual measurement of applied water, and supplement well meter readings with remote sensing and electricity data.
- Remote sensing is used as a monitoring tool for cropped area and wells buyout, and therefore as a support tool for monitoring the implementation of groundwater management options
- Improve and upgrade the program of well metering. The monitoring process of agricultural groundwater use needs to include:
- Establishment of a meter repair and maintenance system
- Standardization of meters and meters installation
- Strengthening of metering operation
- Data reporting and management
- Water users education and awareness

6.14 Volumetric water pricing system

By-law No. 21 of the year 1978 related to highland irrigated project established a flat rate. The first time volumetric water pricing was introduced in Jordan was in the by-law 85 of 2002. In 2012, the Cabinet of Ministers approved a new pricing policy on irrigation water—even on amounts already granted in existing licenses—with a block tariff system, where charges increase in relation to the amounts of water extracted.

The Ministry instituted this new policy after conducting intensive and difficult negotiations with farmers' representatives. The new pricing system will go into effect after 3 years. Details of the block tariff are: abstractions from one single well of less than 150,000 m3 remain free of charge (in fact, this quantities are sufficient to irrigate 300 dunum of vegetables and about 150 dunum for fruit tress); abstractions of 150,000 to 200,000 m3 will be charged at the rate of US$ 0.036/m3; and abstractions over 200,000 m3 will be charged at US$ 0.09/m3. The introduction of this new pricing policy of irrigation water is expected to reduce greatly the amount of pumping water used for irrigation. The MWI issue a new document related to an action plan to reduce water losses. In this document it was mentioned that in 2017 it is intended to reduce the free abstraction rate from 150,000 m3 annually to 75,000 m3 annually. In 2020 it is intended to increasing groundwater irrigation tariff in the highland and setting a zero amount of free abstraction.[10]

Article 38:

Subject to the conditions of the water license and the quantities specified therein for permitted extraction, the prices levied by the Authority for the water extracted annually are fixed as follows:

[10] MWI, 2013. Structural Benchmark-Action plan to reduce water sector losses. www.mwi.gov.jo/sites/en-us/Hot%20Issues/MWI%20Action%20Plan%20To%20Reduce%20Losses%20in%20Water%20Sector%20(Financial%20Effeciency%20Enhancement).pdf

6.14.1 *Licensed agricultural water wells*

The volumetric price for water abstraction for licensed agricultural wells as originally issued in the By-law No. 85, 2002, is shown in Table 35. One year later (2003) an amendment was passed to the above by-law, the volumetric prices of water abstracted from licensed agricultural well were increased as shown in Table 36. Due to lobbies and farmers pressures on the government, a new amendment was taken in 2004 (by-Law amendment No. 68, 2004). The original volumetric by-Law (85), 2002 are re-applied as shown in Table 37.

Table 35: Volumetric price of water abstracted By-Law (85), 2002- Original

No.	Water quantity (m^3)/a	Water price JD/ (m^3)	Water price US$ /(m^3)
1.	Zero-150 thousand	Free	Free
2.	151-200 thousand	5 Fils/m^3	0.00705
3.	> 200 thousand	60 Fils/m^3	0.085

Table 36: Volumetric price of water abstracted in the by-law amendment (No. 76, 2003) the volumetric prices

No.	Water quantity (m^3)/a	Water price JD/ (m^3)	Water price US$ /(m^3)
1.	Zero-150 thousand	Free	Free
2.	151-200 thousand	25 Fils/m^3	0.03525
3.	> 200 thousand	60 Fils/m^3	0.085

Table 37: Volumetric price of water abstracted in the by-law amendment (No. 68, 2004).

No.	Water quantity (m^3)/a	Water price JD/ (m^3)	Water price US$ /(m^3)
1.	Zero-150 thousand	Free	Free
2.	151-200 thousand	5 Fils/m^3	0.00705
3.	> 200 thousand	60 Fils/m^3	0.085

The following volumetric prices shown in Table 38 will be applied in the year 2016 for only replacement wells or well deepening after licensing these activities according to by-law amendment (No, 64 in 2015).

Table 38: Volumetric prices of water abstracted from replacement wells

No.	Water quantity (m^3)/a	Water price JD/ (m^3)	Water price US$ /(m^3)
1.	Zero-75 thousand	Free	Free
2.	75-200 thousand	10 Fils/m^3	0.0141
3.	> 200 thousand	100 Fils/m^3	0.141

6.14.2 Agricultural wells in Azraq

The original By-law No.85, 2002, stated that the quantities of water extracted in Al-Azraq area from wells licensed with specified quantities shall be free of charge (Table 39). The volumes exceeding this quantity and up to 100,000 m^3 shall be charged (5 Fils - US$ 0.007 per cubic meter). Whatever amount exceeding that volume shall be charged at 60 Fils (US$ 0.085) per cubic meter. Since the original by-law of 2002, volumetric prices have been modified according to by-law amendments (Table 40).

Azraq basin is treated differently from other basins in Jordan due to shallow water table, which encourages water farmers to drill and over-abstract, leading to the intensive exploitation of water from the oasis and the near-total destruction of its ecosystems. The Azraq Oasis is a unique mosaic of wetland ecosystems set in the middle of an arid desert. As the only such source of permanent freshwater within some 12,000 km2, the oasis provides a crucial habitat for a multitude of avifaunal species, and is an indispensable part of the local economy. The water in the shallow aquifer is generally fresh and of excellent quality. It recharges mainly from the northern basin and southern Syria. The recharge volume of the shallow aquifer is about 22 to 24 million m3 per year. The intermediate aquifer consists of limestone, chert, and shale, and is separated from the shallow aquifer by thick aquiclude strata. The recharge volume for the intermediate aquifer ranges from 7-10 MCM per year. The deep aquifer consists of sandstone and has a thickness of about 300 meters. This aquifer has poor quality water due to high salinity (over 20,000 parts per million).

Table 39: Volumetric price of irrigation in Azraq- By-law No.85, 2002

No.	Water quantity (m^3)/a	Water price JD/ (m^3)	Water price US$ /(m^3)
1.	Zero-up to licensed quantity.	Free	Free
2.	Above licensed to 100,000 m3.	5 Fils/m^3	0.00705
3.	More than 100,0000 m3	60 Fils/m^3	0.085

Table 40: Volumetric Price of Irrigation Water in Azraq- By-law amendment No. 68, 2004

No.	Water quantity (m³)/a	Water price JD/ (m³)	Water price US$ /(m³)
1.	Zero-up to licensed quantity.	Free	Free
2.	Above licensed to 100,000 m3.	20 Fils/m³	0.0282
3.	More than 100,0000 m3	60 Fils/m³	0.085

6.14.3 *Unlicensed Agricultural water wells*

The prices of water extracted annually from active unlicensed agricultural wells whose status will be rectified and corrected in the future in pursuance of article (41) as shown in Table 41.

Table 41: Volumetric price of irrigation water abstracted from unlicensed agricultural wells in the in the by-law (2002)

No.	Water quantity (m³)/a	Water price JD/ (m³)	Water price US$ /(m³)
1	Zero – 100 thousand	25 fils/m³	0.035
2	101-150 thousand	30 fils /m³	0.042
3	151-200 thousand	35 fils /m³	0.049
4	> 200 thousand	70 fils /m³	0.098

The By-law amendment in 2014 (No 36) set new volumetric prices for unlicensed agricultural wells (Table 42). These well should be closed or caped until the end of 31/12/2014 unless there are any socioeconomic reasons that justifies the continuity of abstraction.

Table 42: Volumetric Price of Irrigation Water abstracted from unlicensed agricultural wells in the new by-law (2002) amendment in 2014 (No 36)

No.	Water quantity (m³)/a	Water price JD/ (m³)	Water price US$ /(m³)
1	Zero - 10 thousand cubic meters.	150 Fils /m³	0.21
2	10-30 thousand cubic meters.	250 Fils /m³	0.35
3	More than 30 thousand cubic meter.	500 Fils /m³	0.70

6.14.4 *Public wells*

Wells, which belong to government departments, official public institutions, public institutions such as agricultural research institutions and municipalities, or wells established by MWI for agricultural development in remote and desert areas, The price payed by users is shown in Table 43 as mentioned in the By-Law No.85 in 2002.

Table 43: Price of water abstracted from Public Wells (2002)

No.	Purposes of water abstraction	Water price J.D / (m^3)	Water price US$ / (m^3)
1.	Agriculture	25 Fils/m^3	0.035
2.	Drinking or any other purpose.	100 Fils/m^3	0.014
3.	Industrial production, tourism or Universities.	250 Fils/m^3	0.035
4.	The sale of water extracted from wells designated for drinkable water.	250 Fils/m^3	0.035
5.	The sale of water extracted from wells of non-drinkable water.	100 Fils/m^3	0.014

6.14.5 Volumetric price according to water quality

In the original by law of (85) from 2002, discriminate volumetric price of water according to water quality for wells with salinity and utilized for agricultural purposes were set as shown in Table 44.

Table 44: Volumetric price of water according to water quality

Water Quantity (m^3)/a	Salinity	Water price J.D / (m^3)	Water price $ / (m^3)
(0 – 150,000)	Any	free	free
> (150,000)	1350 – 1500 ppm	15 fils/m^3	0.02
	> 1500 – 2000 ppm	10 fils/m^3	0.014
	> 2000 ppm	5 fils/^{m3}	0.07

In the year 2004 By-law No. 86, 2004, the paragraph related to volumetric price by water quality was deleted from the By-law. This means that water tariffs do not discriminate according to water quality anymore, the By-law No.86 for 2004 needs to be revised to take water quality aspects into pricing of groundwater used for irrigation purposes.

The Groundwater By-Law No. 85 of 2002 can be evaluated as a good attempt to limit groundwater abstraction in the highlands that are severely affected by water depletion. However, as the threshold for the introduction of water tariffs was set relatively high at the beginning of the by-law implementation. With the passing of time due to inflations and economic development the water costs is becoming less that 3% of total operational costs. The strong farmer's lobby prevent the adjustment of water tariff; therefore, the effect of the law is questionable in the recent years. As mentioned, water pricing policies in Jordan have never reflected the true value of water. This is partly due to the fact that the "real" costs of water are not defined clearly. This is because the government does not want to burden the customers with such high costs and to sustain food security for Jordanian residents.

7 Water management across sectors

7.1 Domestic water subsidy policies

Municipal water is relatively expensive in Jordan because of the high cost involved in acquiring, treating, transporting and distributing drinking water to urban areas. The average cost of water service in all of Jordan can be estimated to be 0.89 JD/m^3 for billed water (Al-Assa'd et al., 2011). In recent years the government of Jordan has implemented several measures to increase the cost recovery of WAJ and enhance its financial sustainability that include increasing the water and wastewater tariff, reduce water losses and relative improvement of performance, (Van den Berg et al., 2016) even though revenues do not yet cover the full cost of services. They only cover the O&M cost and a small portion of the capital cost. In 2009, the average return per cubic meter received from the water supply billed was JD 0.42 and for billed wastewater was JD 0.16. The overall return including other revenues per cubic meter for billed water was JD 0.6 and for billed wastewater was JD 0.42. This current level of revenues resulted in covering only 65% of the full cost of the service (Al-Assa'd et al, 2011).

7.2 Water Related Policies

7.2.1 Agricultural Marketing policies

Jordanian agricultural production, including what is exported, does not receive any incentives except the price of irrigation water and the cost of water pumping through subsidized electricity for agriculture. Additional production costs and marketing exist however in the form of requirements to use municipal markets, even in the case of exports and even when direct sales to retailers could be made by farmers or farmer organizations.

Current import tariff policy encourages resource allocation to crops that with inefficient water use, in terms of income generated per cubic meter of water used in irrigation (e.g. bananas, apples, and oranges). In the case of apples and oranges at least, it is clear that Jordan does not have a comparative advantage in production as Syria produces oranges and apples of equal or higher quality at a much lower price (Sidahmed et. al., 2012).

7.2.2 Agricultural credit

The Agricultural Credit Corporation or ACC is one of the earliest agricultural loan institutions in the country, established in 1920. Since the ACC law was declared in 1960, the institution has provided JD 501.6 million in loans benefiting 215,000 agricultural projects distributed all over the country (ACC, 2012). The ACC provides soft loans available to farmers and investors in agribusiness. Most of the loans offered by ACC are medium-term loans for financing land reclamation, purchasing farm machinery, planting fruit trees, drilling deep wells, erecting greenhouses and purchasing drip irrigation systems. Around 16% of ACC loans have been for water resource development and wells drilling (ACC, 2012).

7.2.3 Land use policies

There is a continuous decline in previously productive agricultural land relying on rainfed agriculture and an expansion of irrigated areas in marginal lands receiving less than 300mm of rainfall. This is due to the encroachment of urban activities on agricultural lands, and to the absence of a law that regulates land use for different purposes throughout the country. Agricultural land located within municipal boundaries is in danger of being converted to non-agricultural uses. The fragmentation of agricultural land, converting larger parcels into small production units unsuitable for mechanized agriculture, resulted in large areas of land uncultivated every year or to the transformation of agricultural lands to housing and industry complexes. The legislation passed by the government, allowing partitioning of land ownership outside municipal boundaries into smaller areas, has also contributed to the fragmentation of these ownerships and forcing them out of production. On the other hand, Groundwater By-Law No.85 of 2002 specifies that the minimum area for drilling a groundwater well for agriculture should be more than 100 dunums (Sidahmed et. al., 2012).

7.2.4 Rangelands

The poor management of rangelands, the destruction of plant cover, and the allocation of about 10 million du of rangelands known as claimed tribal lands to private owners, without proper plans for their development and management as a natural resource, has weakened the productive capacities of rangelands and affected the livelihoods of the Bedouins living of them. This facilitated the promotion of real-estate business in the rangeland areas and use of large areas for non-agricultural purposes in the Northeast of Jordan. This policy encouraged heads of tribes and influential people to dig illegal wells in the remote areas and planting olive trees to prove their ownership claim of land property (Al-Karablieh and Jabarin, 2010; Al-Karablieh, 2010)

Ineffective or poor compliance with the country's rangeland-related laws and the absence of a national comprehensive and integrated plan for rangeland use and development, and the continued urban encroachment on forest lands resulted in the deterioration of the natural vegetation. At present the vast rangeland areas in Jordan cannot provide animal feed for more than 3 months during the good rainy seasons and less than one month or none at all during drought years.

7.2.5 Agricultural extension policy

The agricultural extension service in Jordan is still not performing efficiently due to a lack of extension officers, training, and appropriate budgets. This reflects negatively on the adoption of technology, and thus on the low productivity and competitiveness of the agricultural sector of Jordan. The first agricultural extension policy was formulated in 1997, aiming at improving efficiency and effectiveness of the agricultural sector in Jordan. Recently, the government applied a new strategy resulting in the amalgamation of public research and extension services under the National Centre for Agricultural Research and Extension (NCARE). The activities of Water Management and Environmental Research Program of NCARE are related to: irrigated agriculture, optimum use of water resources, and management of natural resources in rainfed areas, marginal and desert regions.

7.2.6 Agricultural export policies

Jordan is one of the leading countries in the region in agricultural exports to traditional Arabian Gulf countries and to some EU countries. Total exports amounted to JD 4,750 million whereas agricultural exports amounted to JD 787 million (16.5% of total exports). The total agricultural production in 2012 amounted to 2.2 million tons of which 243,000 tons are field crops, of which 148,000 Clover Trifoil. The vegetable production amounted to 1,568,000 tons of which winter-vegetables amounted to 890,000 tons and summer-vegetables amounted to 677,000 tons, while the production of fruits amounted to 455,000 tons of which one third is olive. In other words, the vegetable exports in 2012 represented 44% of Jordan's production of vegetables, while fruit exports constituted about 24% of the national production of fruits (DOS, 2013).

Therefore, despite its low contribution in the GDP, agricultural exports represent about 14% of Jordan's total domestic exports, as shown in Table 45. Vegetable exports represented about 7.5% of total domestic export. The main destinations of most of these exports are the United Arab Emirates, Kuwait, Bahrain, Syria, Lebanon, Qatar, and Oman. In contrast to the sophisticated markets in the EU, these traditional market destinations do not have high quality and packaging requirements. In the last two years, vegetable and fruit exports have jumped and together they represent almost 70% of total agricultural exports. This indicates that there is a high potential for increasing agricultural exports further. This potential can be realized in the future, depending on tackling major obstacles related to water quantity and quality. Expanding plant exports require the availability of additional water resources of high quality to meet sanitary requirements such as the GlobalGap and SPS regulation (Sidiahmad et al, 2012).

Jordanian agricultural production, including that which is destined for export, does not receive any incentives except the price of irrigation water and the cost of pumping, and the willingness to ban exports temporarily in the face of perceived scarcities on the domestic market. Extra costs on the production and marketing chain are imposed in the form of requirements to use municipal markets, even in the case of exports and even when direct sales to retailers could be made by farmers or farmer organizations.

Table 45: Value of Jordan's Agricultural Exports, 2005-2015 (million JD)

	Vegetables	All Plants	Live animals & animal products	Food and Live Animals	Total Domestic Export	Percent of Vegetable to Total Export
2005	159	196	40	275	2,570	6.17%
2006	162	204	79	322	2,929	5.54%
2007	273	334	14	404	3,183	8.57%
2008	292	377	39	507	4,431	6.58%
2009	280	368	51	513	3,579	7.82%
2010	324	425	72	621	4,216	7.68%
2011	400	585	177	920	4,798	8.3%
2012	457	619	185	967	5,163	8.9%
2013	364	551	193	893	4,805	7.6%
2014	354	527	132	787	4,750	7.5%
2015	356	491	115	730	4,806	7.4%

Source: CBJ (Central Bank of Jordan), (2016). Monthly Statistical Bulletin, Research Department. Volume 51, No. 9, Amman. Jordan.

7.2.7 Energy subsidy policy for agriculture and water pumping

Since the launch of the first Energy Sector Strategy in 2007, Jordan's vision has been to integrate renewables into its energy mix, with targets of 7% and 10% by 2015 and 2020 respectively. Due to the country's dependence on subsidized and low cost natural gas imported from Egypt, Jordan's government had failed, as of 2011, to initiate any meaningful progress in renewable energy and energy efficiency despite the obvious strategic importance of the same in providing energy security and establishing the basis for economic development (Greenpeace, 2013).

Rising concerns about energy resource availability, energy prices, and supply reliability have merged to create numerous opportunities for an aspiring renewable energy sector. Jordan is a non-oil producing country and produces small quantities of gas. Its basic energy requirements are obtained from imported oil and natural gas from different sources. Energy import costs create a financial burden on the national economy as Jordan spends more than 25% of its GDP on the purchase of energy. Domestic natural gas covers only 4% of the Kingdom's energy needs. The Energy Law was modified in 2010 to exploit renewable energy sources and increase the percentage of their contribution to the total energy mix, aiming also to achieve safe supply and promote investment, and improving its efficiency in various sectors (Jordan Law No.13 concerning renewable energy and energy efficiency).

The increasing cost of power generation as reported by the government, (up to 184 fils/kWh, equivalent to USD 0.26/kWh), was due to the disruption of cheap Egyptian gas supplies. Jordan finds itself in a very precarious economic situation given that discounted Egyptian gas supply will not resume at the required quantities and that any resumption is uncertain at best. The cost of power generation for the National Electricity Production Company has steadily increased from a low of approximately 5-7 US$ cents/kWh (for base load gas generation) and a blended cost of generation of 10 USD cents/kWh in 2010, to today's high of 25 US$ cents/kWh. Part of this increase has been passed on to the consumer due to socio-economic pressures Greenpeace (2013).

Jordan had been subsidizing petroleum products for many years, but the system came under pressure beginning in 2003 when it lost preferential fuel supply from Iraq (Greenpeace, 2013). The government then implemented a series of price increases to limit negative budgetary effects. Nevertheless, by 2008, the subsidy bill for energy amounted to about 5% of GDP. Earlier the government had considered raising prices to international levels but had backtracked on an agreement to do so reached with the IMF, because of fears of social unrest such as had happened in 1989 and 1996. In February 2008 the government announced that the fiscal burden from subsidies was no longer sustainable and raised petroleum product prices to international levels by 9% for premium gasoline up to 76% for diesel and kerosene. A plan to remove the subsidy on Liquefied petroleum gas (LPG) used for cooking was abandoned after the intervention of King Abdullah.

The objectives of the subsidy may include supporting the poor and improving equity, achieving energy security, correcting for externalities, and supporting domestic production and associated employment. The type of subsidy is based on a cross-subsidy structure between high-and low volume of consumers with differential blocking tariff system. The government currently subsidizes households that consume 600kW per month and less at a total cost of JD 500 million. In August 2013, the government applied a new tariff system with a 15% increase on all economic sectors, except for agriculture, which was exempted from the hike. Early in 2014, households consuming over 600kW of electricity a month, and whose bill exceeds JD 50, were subject to an increase of up to 15% in electricity prices. The recent agriculture electricity tariff is 60 fils/kWh and for water pumping there is a flat rate price of 87 fils/kWh, whereas household consumer with a block of 601 to 750 kWh pay a tariff of 163 fil/kWh (MEMR, 2013).

The electricity tariff for legal wells has been cross-subsidized by other consumer groups. As a re-alignment of energy subsidies is taking place, energy tariffs are likely to increase significantly. Tariffs increased in 2012 to JD 0.066 per kWh and in 2015 increase to JD 0.087 kWh. Yet, the actual cost recovery based tariff needed to ensure that NEPCO's tariffs do not fall below its buying tariff is likely to be in the range of JD 0.145-0.178 per kWh. Therefore, groundwater is used in irrigated agriculture without a sufficient economic value. Often water is taken without payments from the farmers; their only cost is the energy to pump groundwater.

7.2.8 Public participation in groundwater management

7.2.8.1 <u>The Highland Water Forum</u>

In January 2010, the Highland Water Forum was mandated by Jordan's Prime Ministry with the task of supporting the MWI in developing an Action Plan for sustainable management of the Highlands groundwater basins. As part of its organizational structure, the Forum consists of a Secretariat, an Advisory Board and a Steering Committee. Donors are involved through the development of a financing system that will complement the Forum by supporting the implementation of activities and measures mentioned in the Action Plan. The Highland Water Forum consists of 60 stakeholders from the agricultural water users, government institutions and NGOs and research institutions

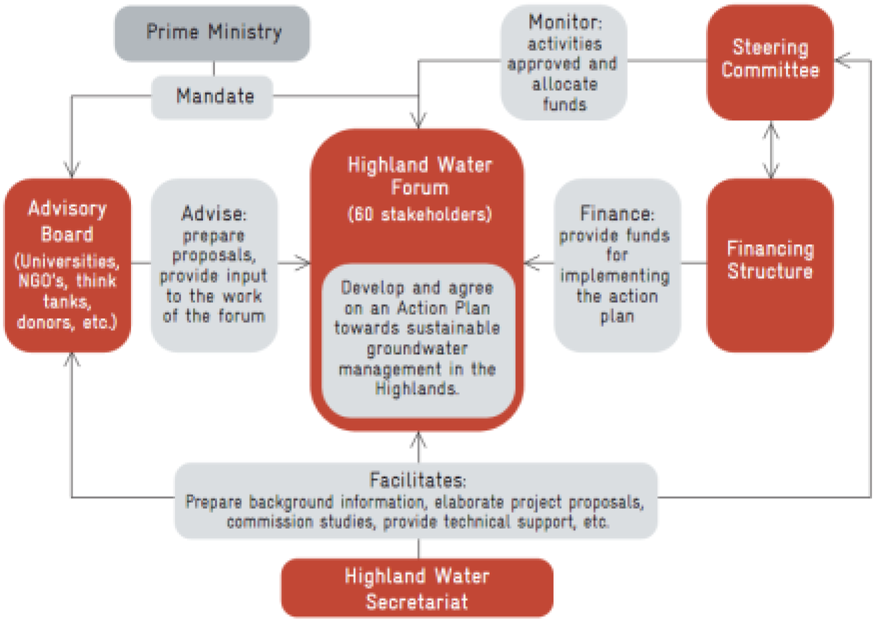
The Highland Water Forum is a multi-stakeholder dialogue that aims to bring the conflicting water users, particularly the water-governing authorities and the agricultural community, to agreement regarding the causes for dwindling groundwater resources, and to collectively think of creative solutions.

The ultimate task of the Forum is to develop an Action Plan towards sustainable management of Groundwater resources, including a clear agenda for implementation. This Action Plan is a contribution to the implementation of the National Water Strategy (2008-2022).

The Highland Water Forum follows a programme approach, which goes beyond disconnected projects and aims to mainstream best-practice techniques into one strategic programme with the overall goal of overcoming groundwater depletion and developing ways of sustainable resource management. Derived from field visits as well as stakeholder and donor consultations, the following fields of intervention have been identified for the Highland Water Forum:

- Improved on-farm efficiency (including optimized irrigation efficiency, better cross-sector data collection, more suitable cropping methods/patterns, etc.)
- Alternative non-water-consuming income sources, to divert new comers to the area from investing in water-intensive activities like agriculture.
- Community development, including measures to raise the region's awareness towards more water-efficient practices.
- Strengthened governmental institutions to better control illegal activities and to effectively enforce laws and regulations.

Figure 12: Highland Water Forum structure



Source: Mesnil and Habjoka, 2012.

7.2.8.2 Ministry of Health

The Ministry of Health's water responsibilities are to monitor the quality of drinking water from different water resources including groundwater resources, and inspect any potential source of pollutants. The Ministry regulates all drinking potable water regardless of its source. It has overall responsibility for examining and permitting any imported or produced potable water including the processes of treatment, transmission, distribution, and storage of potable water to ensure its quality.

7.2.8.3 Ministry of Environment (MoEn)

The Ministry of the Environment was established in 2003, its mandate is to maintain and improve the quality of Jordan's environment by sustaining and conserving Jordan's environmental resources and contributing to sustainable development. Its connection to water policy is less developed, but it has dealt with several cases of poor water quality and over-use of water negatively effecting the environment. The MoEn is involved in the protection of water resources and prohibits any activities that cause pollution or degradation of groundwater resources in Jordan. The ministry is especially working towards the reduction of groundwater abstraction and against the improper disposal of wastewater.

7.2.8.4 Royal Water Commission

The Royal Water Commission was established in 2008 by a royal decree headed by His Royal Highness Prince Feisal. The mandate of the committee is to review and update the national water strategy, suggestion of policies, programs, alternative water projects, such as desalination and treatment to enhance water sources and to review of water legislations, ensure private sector participations, water monitoring.

The Royal Water Commission in 2009 produced a National Water Strategy in consultation with all stakeholders which included the development of a new Water Law, strict caps on future water use for agriculture, and a reduction of groundwater use in the highlands (i.e. increase use of reclaimed water). It is common knowledge that when the new Water Law is passed and restructuring occurs, there will be significant changes. The government still depends on new megaprojects to solve some the water crisis, although it is paying more attention to water demand management (Bakir, 2010)

7.2.8.5 Water & Agricultural Committee in the Jordanian Parliament

Their role is to strengthen the governmental efforts in controlling the water sector on one hand and activate the penalty's system (punishment) for illegal actions on the other hand. Furthermore, the committee discusses ways of enhancing the efficiency of agriculture and water sector performance. The majority of members of the water and agricultural committee are the representative of Jordan Valley and Badia region. Those members are pro-farmers and refused increasing water tariffs.

8 Conclusion

Several measures have been implemented since 1992 to protect aquifers from degradation and overabstraction in Jordan. These measures include banning well drilling, volumetric metering of groundwater abstraction, setting water quota for abstractions, delineation of groundwater protection zones, preparation of groundwater vulnerability maps, groundwater monitoring and attempts to increase the enforcement of water laws. The Groundwater Control By-Law regulates groundwater well licensing, drilling, and water abstraction. A new tariff was set in the regulation for water abstracted over and above the permitted annual abstraction rate. Up to now the application of these laws is still regarded as unsatisfactory, thus suggesting the need for future strengthening of law enforcement through an adequate penalty system. A lack of enforcement, especially of the Groundwater By-Law, is recognized as one of the main challenges for the Jordanian water sector.

Groundwater is being extracted in Jordan at more than double the sustainable extraction rates that allow the recharge of the aquifers. This will lead to severe national insecurity if the problem cannot be addressed quickly. Inexpensive electricity is also encouraging high extraction levels. The groundwater policy is formulated by the MWI but there are many other players participating in formulation this policy, such as the parliament (agriculture and water committee), the cabinet and royal water committee. It is important to realize that many other parts of the government have a role to play in the management of groundwater resources. The most important is the Council of Ministers that becomes involved with water at the highest level through policy initiation, legislation and finance. Various ministries have more specific roles. The Ministry of Planning reviews all plans put forward by the MWI and then links with potential funding agencies.

In terms of minimizing aquifer over-draft, the current groundwater policy emphasizes the need to stop illegal drilling completely by strengthening the penalties and punishments, closing existing illegal wells by refilling and capping the wells, and metering all existing water wells. Furthermore, several measures have been implemented to protect aquifers from degradation and over abstraction. These measures included delineation of groundwater protection zones, preparation of groundwater vulnerability maps, establishment of a groundwater monitoring system. An incremental discriminating tariff was introduced in the regulation for water abstracted above the permitted annual abstraction rate.

In this report, the water values for main crops cultivated in Mafraq and Zarqa basin have been estimated to measure the net profitability of water used. The resulting water value is an indication of the economic efficiency of water in Highland agriculture and can be used as a proxy for farmer's ability to pay for groundwater abstraction. The result shows that cucumber has the highest water value in Mafraq (JD 2.4/m3), the average water value for winter tomatoes is JD 0.94/m3, and for summer tomatoes is JD 0.62/m3. These crops are characterized by a short growing season and moderate crop water requirements. Crop selection in the Highlands should be based on low crop water requirements, land and soil suitability, mainly crops tolerant to soil salinity, and water values as well as water content in final product (measured in m3/kg). The water value in olives is the lowest (JD 0.05/m3) in Mafraq and Zarqa, whereas the water value for olives at the national level is JD 0.26/m3. The water pricing policy should be revised to provide incentives for high values crops and to discourage low water value crops such as olives and clover, eliminating the subsidy on electricity used for water pumping. A decrease of the water quota or increase in the price of electricity would therefore affect the cultivation of olives, clovers and other crops with high crop water requirements, but will marginally affect vegetables and fruits trees due to high water values in these crops. It is also necessary to promote drought and salt tolerant crops with low water requirements such as quinoa and other high value crops.

Convincing farmers to change the cropping pattern to introduce new crops is not an easy task as many farmers do not desire or do not have the ability to change their cropping pattern, even if alternative patterns could result in higher return and less water usage. It would be appropriate to consider water saving technologies, replacement of groundwater with treated wastewater for farms located not far away from the existing or planned wastewater treatment plant.

The most recent National Water Strategy 2016–2025 (MWI, 2016) focuses on building a resilient sector based on a unified approach for a comprehensive social, economic and environmentally viable water sector development. The strategy included provisions for climate change, water-energy-food nexus, and a focus on water economics and financing, sustainability of overexploited groundwater resources and the adoption of new technologies and techniques including decentralized wastewater management. The new groundwater policy suggests many actions and measures regarding groundwater management, public awareness, legislations, resource investigation and development. The water reallocation policy addresses the importance of water harvesting, conserving and protecting resources, while the water substitution and reuse policy proposes the reuse of treated wastewater in irrigation in order to enable the freeing of fresh water for municipal uses.

During the last decade, the weakness or lack of political will to enforce laws and by-laws caused a loss of trust in law enforcement and consequently created a sense of immunity for law violators. Furthermore, continuous changes in leadership positions within the MWI, JVA, WAJ and water related institutions also delayed by-law amendments, and led to different opinion on groundwater policy priorities.

Options for reducing groundwater overabstraction still not in use and to be tried in Jordan are:

- Buyout of wells; especially groundwater wells in the catchment areas with high water demand for urban areas like Madaba and Zarqa.
- Limiting cropped area; through strict by-law enforcement that prevents water selling to neighbors and restrict cultivated areas according to the well drilling license which requires to determine the area to be irrigated before issuing the utilization and drilling licenses.
- Exchange of groundwater with other types of water; this reallocation policy 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 and expand the water network to connect the southern and northern regions. A new conveyance system is planned to convey KTD water to northern Jordan Valley to use treated wastewater for irrigation and free the currently used fresh water to be used for domestic purposes. The Desalination of brackish groundwater shall be given high priority when and where feasible and where safe yields of fresh water is fully achieved (MWI, 2016a).

- Reduced pumping for municipal and industrial sectors from groundwater during wet and normal years to build a groundwater reserve for using groundwater during drought periods and emergency of water shortages in location with plenty of fresh surface water;
- Enforcement of by-laws by prohibiting water sales to neighbors for agricultural purposes; this requires field inspection and monitoring activities. GIS and remote sensing technologies can be very helpful in this regard.
- Curtailing illegal groundwater sale of domestic purposes and from small private desalination plants scattered in the cities. These private water desalination plants purchase groundwater with low TDS from groundwater wells to be desalinated and sold to consumers by the bottle at the price of 1.4 US$ per 20 liters. This practice has been widespread in the last decade as a result of the loss of public trust in taped water quality.
- Support to monitoring groundwater abstractions and implementation of management options using remote sensing and automated warning systems;

Necessary Actions:

- Support the government to enforce current laws to protect water quality and prevent pollution; a continuous public awareness program and outreach needs to be intensified by targeting the relevant stakeholders and beneficiaries.
- Development of incentives to use less water from groundwater in agriculture; this can be done by introducing new irrigation water technologies, computerized irrigation system, hydroponic and buried diffuser technologies.
- Increase disincentives such as tariffs and fines - Adjust legal framework/reform, as required.
- Reviewing the current water volumetric tariff to reflect the recent increase in production costs of other inputs and increase of the agricultural producer price index.
- Develop and implement a plan to phase out the electricity subsidy for agriculture in the Highland areas.
- Develop an action plan for either well buyouts in the Highland or a structured water rights market that would enable agricultural well owners to sell their water use rights for non-agricultural uses.
- Develop transition plans for farmers in the Highland who are growing crops with a low value per cubic meter of water, with provisions for financial assistance to change their cropping patterns and technologies of water use.
- Review subsidies and tariffs for irrigation and water supply, including equity issues related to the fairness of the subsidy and how to target the poor.
- Review cost recovery and other sources of revenues, including subsidies in the energy sector that affect water and potential cross subsidies.
- A new law or amendments to the MWI by-law to establish its preeminence among water agencies in water sector strategic planning and management.

- Amendments to the WAJ law to narrow WAJ responsibilities in ways that reduce overlapping responsibilities with MWI and limit WAJ's responsibilities to a retail water distributor.
- A new law or an amendment to an existing law (e.g. the law governing energy regulation) that creates an independent water regulator or a water regulatory unit within a multi-sectoral regulatory entity.
- Amendment of laws and regulations relevant to the enforcement of protection of water resources including industrial wastewater, bio-solids, and municipal and hazardous waste landfills.

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10 Annex

Table 46: Groundwater water use for 1994-2015 in MCM

Year	Municipal	Industry	irrigation	Livestock	Total Uses
1994	169.79	21.84	305.91	9.32	506.86
1995	199.10	29.62	285.29	6.46	498.47
1996	178.41	33.16	289.69	7.79	509.10
1997	177.56	35.34	266.19	7.12	486.21
1998	182.81	36.30	258.35	7.74	485.20
1999	182.76	35.48	256.36	7.28	481.88
2000	186.08	34.16	256.14	2.56	479.54
2001	192.37	30.75	233.18	1.85	458.15
2002	198.69	34.97	286.34	2.06	522.05
2003	207.45	33.27	277.50	1.84	520.05
2004	214.73	34.10	251.43	0.80	508.10
2005	206.83	33.90	254.65	0.83	496.20
2006	188.87	34.45	245.51	0.81	469.62
2007	202.82	44.89	244.81	0.75	493.27
2008	171.75	36.88	255.16	0.88	464.64
2009	216.53	34.27	236.07	0.56	487.42
2010	222.76	33.90	245.00	0.31	501.97
2011	232.09	32.28	252.43	0.70	516.86
2012	231.41	26.51	250.61	0.60	508.63
2013	257.48	32.48	249.83	0.09	539.89
2014	324.90	32.20	231.20	0.10	591.50
2015	332.00	31.00	237.40	0.20	600.60
AVG 1994-2009	192.3	34.0	262.7	3.7	491.7
AVG 2010-2015	266.8	31.4	244.4	0.3	543.2

Source: MWI, (2016) Open Files.

Table 47: Renewable groundwater water use for 1994-2013 in MCM

Year	Municipal	Industry	irrigation	Livestock	Total Uses
1994	161.92	18.73	256.84	7.92	445.40
1995	168.72	25.87	228.01	5.07	427.67
1996	169.79	29.31	231.95	6.42	437.48
1997	168.68	31.55	207.12	6.00	413.35
1998	173.16	32.03	208.17	6.64	420.00
1999	173.05	30.99	205.44	6.14	415.62
2000	176.36	29.59	204.64	1.41	412.60
2001	182.87	26.30	181.98	0.77	391.92
2002	185.40	30.73	216.28	0.84	433.25
2003	192.74	29.20	210.25	0.64	432.83
2004	192.29	29.11	199.45	0.80	421.68
2005	190.98	24.33	203.18	0.83	419.31
2006	170.19	21.00	200.32	0.81	392.31
2007	185.81	29.59	202.90	0.68	418.98
2008	157.31	18.52	203.47	0.83	380.10
2009	213.14	19.38	196.20	0.52	429.24
2010	203.88	22.02	200.99	0.30	427.19
2011	205.26	19.10	202.40	0.35	427.11
2012	203.88	23.20	200.42	0.45	427.95
2013	205.97	25.98	210.50	0.08	442.53
2014	207.20	19.30	189.40	0.10	419.20
2015	209.00	21.00	211.60	0.20	441.80

Source: MWI, (2016) Open Files.

Table 48: Historical non-renewable groundwater water use for 1994-2013 in MCM

Year	Municipal	Industry	irrigation	Livestock	Total Uses
1994	7.88	3.12	49.07	1.40	61.46
1995	30.39	3.76	57.27	1.38	70.80
1996	8.62	3.85	57.74	1.37	71.63
1997	8.88	3.79	59.07	1.12	72.86
1998	9.65	4.27	50.18	1.10	65.20
1999	9.72	4.48	50.92	1.14	66.26
2000	9.72	4.57	51.49	1.15	66.93
2001	9.50	4.45	51.20	1.08	66.23
2002	13.28	4.24	70.06	1.22	88.80
2003	14.71	4.07	67.25	1.20	87.22
2004	22.44	4.99	51.98	0.00	86.42
2005	15.85	9.57	51.47	0.00	76.89
2006	18.68	13.45	45.19	0.00	77.31
2007	17.01	15.30	41.91	0.06	74.29
2008	14.44	18.36	51.69	0.05	84.54
2009	3.39	14.89	39.86	0.04	58.18
2010	18.88	11.88	44.01	0.01	74.78
2011	26.83	13.18	50.03	0.35	89.75
2012	27.53	3.31	50.19	0.15	80.68
2013	51.51	6.50	39.33	0.01	97.36
2014	107.50	12.90	41.80	0.10	162.10
2015	117.00	10.00	25.80	0.00	152.80

Source: MWI, (2016) Open Files.

Table 49: Abstraction from groundwater basins in Jordan and their safe yields in 1995

		Domestic, Private		Domestic governmental.		Industrial		Agriculture		Livestock Remote Areas					
Groundwater Basin	Safe yield	Wells	Quantities (MCM)	Wells	Quantities (MCM)	Wells	Quantities (MCM)	Wells	Quantities (MCM)	Wells	Quantities (MCM)	Total water Abstraction	Balance (MCM)	Total Wells	Percent of Safe yield
Yarmouk	40			32	25.6	1	0.0	127	41.8	2	0.2	67.6	-27.6	162	169
Amman Zarqa	87.5			114	61.5	49	6.2	509	95.1	0	0.0	162.8	-75.3	672	186
Jordan Rift Side Wadis	15			10	3.2	0	0.0	2	0.3	1	0.8	4.3	10.7	13	29
Jordan Valley	21			15	5.0	1	0.0	167	36.4	0	0.0	41.4	-20.4	183	197
Dead Sea	57			65	34.5	27	8.8	223	44.9	12	1.8	90.0	-33.0	327	158
Azraq basin	24			26	24.1	2	0.1	435	23.5	21	0.7	48.4	-24.4	484	202
Hammad basin	8			2	0.4	0	0.0	0	0.0	8	0.6	0.9	7.1	10	12
Wadi Araba North	3.5			0	0.0	8	3.2	4	0.6	5	0.1	4.0	-0.5	17	114
Wadi Araba south	5.5			9	1.8	0	0.0	33	4.9	2	0.1	6.8	-1.3	44	123
Sirhan	5			0	0.0	0	0.0	0	0.0	2	0.5	0.5	4.5	2	10
Jafer	18			13	5.8	1	0.3	68	9.3	9	1.0	16.5	1.5	91	91
Disi & Mudawara	125			10	7.9	0	3.1	51	49.1	6	1.4	61.5	63.5	67	49
Total Groundwater	**409.5**			**296**	**169.8**	**89**	**21.8**	**1619**	**305.9**	**68**	**7.1**	**504.6**	**-95.1**	**2072**	**123**

Table 50: Abstraction from Groundwater basins in Jordan and their safe yields in 2004

		Domestic, Private		Domestic governmental.		Industrial		Agriculture		Livestock Remote Areas					
Groundwater Basin	Safe yield	Wells	Quantities (MCM)	Wells	Quantities (MCM)	Wells	Quantities (MCM)	Wells	Quantities (MCM)	Wells	Quantities (MCM)	Total water Abstraction	Balance (MCM)	Total Wells	Percent of Safe yield
Yarmouk	40	5	0.7	41	8.9	1	0.2	115	37.4	0	0	47.1	-7.1	162	117.8
Amman Zarqa	87.5	32	3.6	163	75	75	6.9	481	59.8	1	0	145.2	-57.7	752	166
Jordan Rift Side Wadis	15	0	0	28	23.3	0	0	52	2.7	0	0	26.1	-11.1	80	173.7
Jordan Valley	21	0	0	21	7.1	6	1	352	21.7	0	0	29.8	-8.8	379	142
Dead Sea	57	11	1.8	111	49.7	52	11.6	252	27.9	9	0.1	91.2	-34.2	435	159.9
Azraq basin	24	4	0.2	37	23.3	3	0.2	521	34.7	9	0.2	58.7	-34.7	574	244.4
Hammad basin	8	0	0	2	0.6	0	0	0	0	10	0.2	0.8	7.2	12	10.6
Wadi Araba North	3.5	0	0	5	0.7	11	2.8	17	3.4	3	0	6.9	-3.4	36	196.2
Wadi Araba south	5.5	0	0	5	1.2	2	0.4	42	7.5	0	0	9	-3.5	49	164.4
Sirhan	5	0	0	0	0	0	0	12	2.2	4	0.2	2.4	2.6	16	47.8
Jafer	9, 18	5	0.4	33	6.8	21	6.5	79	7.7	3	0.1	21.5	-12.5	141	238.5
Disi & Mudawara	125	7	0	21	11.4	0	4.6	58	46.4	0	0	62.4	62.6	86	49.9
Total Groundwater	**418.5**	**64**	**6.8**	**467**	**208**	**171**	**34.1**	**1981**	**251.5**	**39**	**0.8**	**501.1**	**-172.9**	**2722**	**119.7**

Table 51: Abstraction from Groundwater basins in Jordan and their safe yields in 2013

Groundwater Basin	Safe yield	Domestic, Private		Domestic governmental.		Industrial		Agriculture		Livestock Remote Areas		Total water Abstraction	Balance (MCM)	Total Wells	Percent of Safe yield
		Wells	Quantities (MCM)	Wells	Quantities (MCM)	Wells	Quantities (MCM)	Wells	Quantities (MCM)	Wells	Quantities (MCM)				
Yarmouk	40	3	0.76	32	8.6	2	0.09	129	36.4	0	0	45.85	-5.85	166	115
Amman Zarqa	87.5	31	3.1	183	81.9	81	7.4	590	63.9	0	0	156.3	-68.8	885	179
Jordan Rift Side Wadis	15	1	0.04	42	28	0	0	35	1.1	0	0	29.14	-14.14	78	194
Jordan Valley	21	3	0.49	29	9.6	6	0.18	429	19.1	0	0	29.37	-8.37	467	140
Dead Sea	57	13	2.1	90	40	57	8.8	253	28.1	4	0.004	79.004	-22	417	139
Azraq basin	24	6	0.5	40	20.14	6	0.4	488	37.1	7	0.053	58.193	-34.19	547	242
Hammad basin	8	1	0.012	4	0.9	1	0.004	8	0.13	1	0.01	1.056	6.944	15	13
Wadi Araba North	3.5	0	0	0	0	9	2.6	31	3.9	0	0	6.5	-3	40	186
Wadi Araba south	5.5	0	0	1	0.5	2	0.31	53	6.8	0	0	7.61	-2.11	56	138
Sirhan	5	1	0.11	0	0	0	0	15	1.6	4	0.023	1.733	3.267	20	35
Jafer	9	9	0.63	46	9.5	30	6.2	126	12.5	0	0	28.83	-19.83	211	320
Disi & Mudawara	125	0	0	67	50.6	12	6.5	53	39.2	0	0	96.3	28.7	132	77
Total Groundwater	**418.5**	**68**	**7.742**	**534**	**249.74**	**206**	**32.484**	**2210**	**249.83**	**16**	**0.09**	**539.89**	**-139.4**	**3034**	**129**

Table 52: Abstraction from Groundwater basins in Jordan and their safe yields in 2015

Groundwater Basin	Safe yield	Domestic, Private		Domestic governmental.		Industrial		Agriculture		Livestock Remote Areas		Total water Abstraction	Balance (MCM)	Total Wells	Percent of Safe yield
		Wells	Quantities (MCM)	Wells	Quantities (MCM)	Wells	Quantities (MCM)	Wells	Quantities (MCM)	Wells	Quantities (MCM)				
Yarmouk	40	8	0.18	51	12.50	1	0.11	143	41.37	0	0.00	54.16	-14.16	203	135
Amman Zarqa	87.5	73	5.63	163	66.63	79	5.57	635	88.24	5	0.05	166.11	-78.61	955	190
Jordan Rift Side Wadis	15	7	0.64	79	43.94	4	0.19	49	1.96	0	0.00	46.73	-31.73	139	312
Jordan Valley	21	4	0.18	17	5.52	6	0.29	307	11.03	0	0.00	17.02	3.98	334	81
Dead Sea	57	18	1.43	132	43.24	53	12.17	261	33.04	5	0.09	89.98	-32.98	469	158
Azraq basin	24	10	0.70	29	17.98	13	0.61	524	33.22	4	0.02	52.54	-28.54	580	219
Hammad basin	8	7	0.23	5	1.24	1	0.01	2	0.40	0	0.00	1.87	6.13	15	23
Wadi Araba North	3.5	1	0.09	12	1.89	4	1.53	20	2.83	0	0.00	6.33	-2.83	37	181
Wadi Araba south	5.5	2	0.02	5	0.93	2	0.29	53	7.24	0	0.00	8.48	-2.98	62	154
Sirhan	5	1	0.06	0	0.00	0	0.00	19	1.63	3	0.02	1.71	3.29	23	34
Jafer	27	5	0.33	45	11.70	37	7.12	117	13.71	1	0.00	32.85	-21.85	205	343
Disi & Mudawara	125	0	0.00	82	117.45	1	3.70	33	25.81	0	0.00	146.96		116	118
Total Groundwater	**418.5**	**136**	**9.49**	**620**	**323.01**	**201**	**31.59**	**2163**	**260.47**	**18**	**0.18**	**624.74**		**3138**	

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