The Historical Evolution of the Water Resources Development in the Jordan River Basin in Jordan

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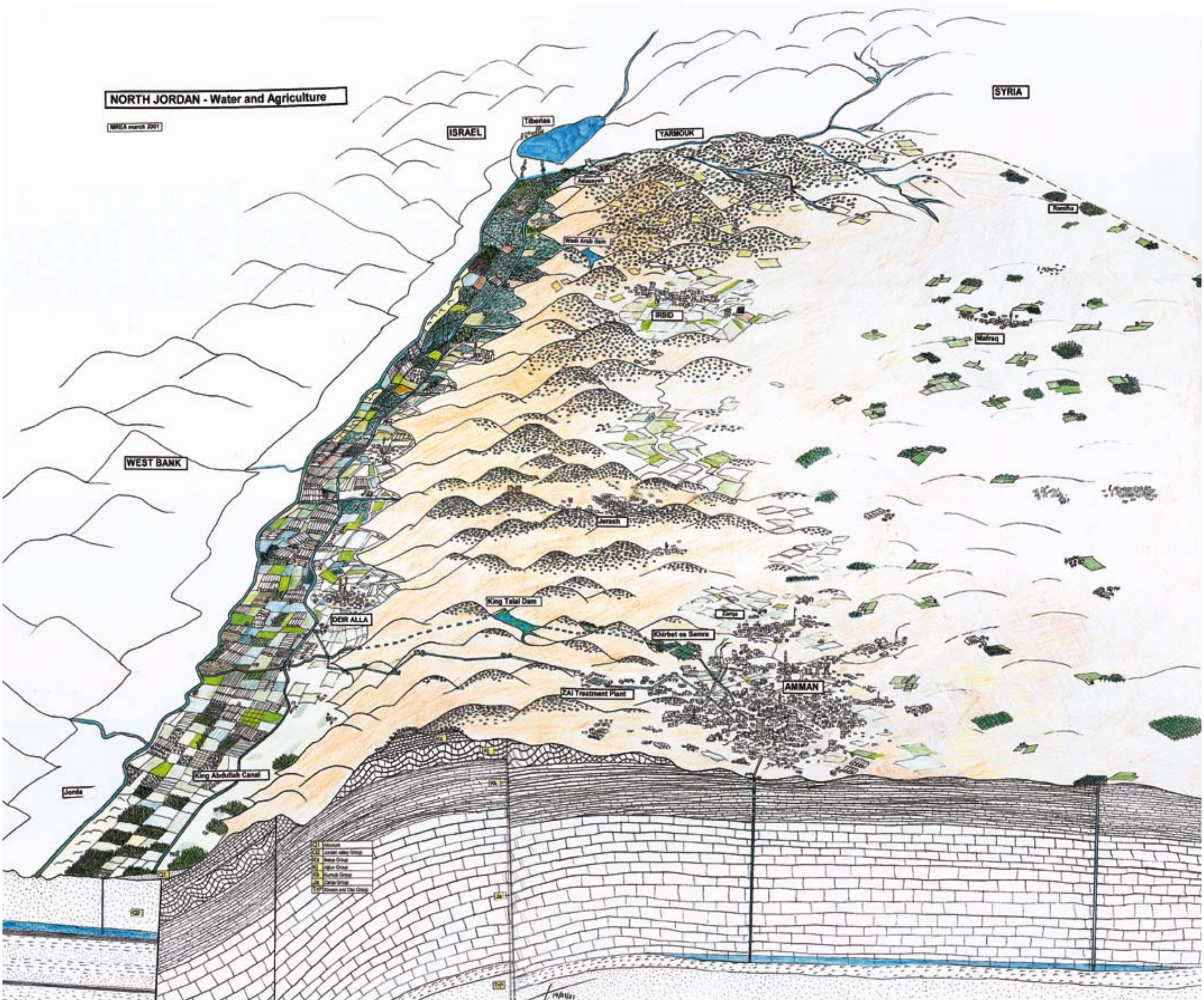

Foreword

This study is being carried out within the scope of the overall River basin comparative study of the historical development of the nine selected River Basins around the World, which is considered as apart of an international research program titled “The Comprehensive Assessment of Water Management in Agriculture”. The research program aim to improve the rural development through agricultural water uses strategies in developing countries. The aim of the River basin comparative study is to derive generic understanding on how societies manage water resources under growing population and basin closure, which problems were forced, and which range of solutions are available for a given physical and social context. It will also focus on both the historical development and the present state of each basin. The study is also expected to provide in-depth basin studies synthesized along the same methodological lines in order to be comparable and to be used as a knowledge base for multidisciplinary researchers. The Jordan River basin was one of the selected basins for the study, which represent the situation of arid and semi arid catchments suffering from sever water shortage. The pressure on water resources in this basin is very high and the competition between water users is tough. Furthermore, this basin lies in a very political tense region where conflict over scarce water resources is internationally recognized.

This study is being carried out by the International Water Management Institute (IWMI) in cooperation with the MREA, the Regional French Mission for Water and Agriculture based in Amman. The French mission’s activities consists mainly the provision of the technical assistance to farmers in order to improve on-farm water management and the water distribution network in the northern Jordan valley and to optimize water use efficiency in agriculture. The French Mission leads the project of Irrigation and Optimization in the Jordan Valley, (IOJOV) in cooperation with the Jordan Valley Authority.

Acknowledgement

I wish to thank the International Water Mangement Institute for giving me the opportunity to contribute in their research program and to extend my sincere gratitude to Francosi Molle for his guideness and being easy to communicate with. The research study was for a short and, indeed, exhausted period but nevertheless fulfilling of professional and personal development.

I would like to express my warm thanks to the French Embassy, the agriculture division (Ambassadede France Régionale Eau et Agriculture, MREA) for receiving me as a guest researcher at their offices, Amman. Special thank is addressed to Mr. REMY COURCIER for being a constructive discussant on my research work and for his valuable comments. I would like to mention also my thankfulness to the MREA staff for their collegial support.

Lastly, but not least, I would like to thank all the engineers from the professional or the academic field whom I interviewed during the conduct of my study for their valuable input, cooperation and positive responsiveness.

Methodology and study approach limitations

The main approach to carry out the study has relied mainly on the intensive review of the existing literatures dealing with several aspects that have contributed to the development process of the basin such as historical, political, socio-economic, water management, agricultural activities and water uses allocation aspects. A complementary approach to accomplish the work has been to arrange interviews with officers in charge or some times researchers that are involved in this subject area. My internship in this study has been to complement and develop the initial work that was done by my colleague Aida Jridi one year ago and to verify figures and data that are documented in the initial report of the study. However, the validation of the figures has been more complicated and the needed effort and time is more than I have thought. Although, data are available, they are most of the time not consistent for different reasons and vary significantly within even the same data source (**Appendix 5**). There are no standardized references for most of the data. In addition, data are available on the national level and extraction the figures that are only related to the basin under study has been not easy. The political context of water resources and related figures contribute to the difficulty of the process of which the answers to inquires about verification of data were most of the times pragmatic. Data analysis and interpretation by comparison with other data sources needs both effort and time, which is restricted by the short duration of the study. However, Data was validated through data source triangulation as shown in tables enclosed in the study. The National Water Master Plan report (1977) and the book that was written by Salameh and Bannayan (1993) are may be the only sources that present an integrated and consistent hydrological data with in the same source, but not within the context of other sources, at least from the literatures that I have read to date.

In brief, I have tried to do the best that I can to produce a good quality report within the time of the study and hopefully I have approached it successfully. Nevertheless, further investigation is to be done if more accurate data is required, especially for the present situation. The National Water Master Plan, which is still under process and will be issued on August, is expected to provide such integrated picture of the present situation of the basin. I would also recommend an interview with Professor Elias Salameh to investigate the relation between the surface waters and groundwater for the basins to avoid the possible double accounting of the groundwater when it also constitute a base flow of some wadis.

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Abstract

The Jordan River is a multinational river flowing southwards through Lebanon, Syria, Israel, Jordan and Palestine. It is totally developed except for the flow of its largest tributary, the Yarmouk River[1] that forms the boundary between Syria and Jordan before joining the Jordan River, downstream of Tiberias Lake, and forms the border between Israel, Palestine and Jordan.

In this report, the historical development of the Jordan River basin in Jordan, the Hashemite Kingdom of Jordan (HKJ), is addressed, highlighting the most significant factors that have played a role in the process to date. Water for irrigation was and still constitutes the lion-share of water use. Thus the focus of the study is mainly on the exploitation of the water resources of the Jordan River basin in Jordan for irrigation purposes. The scope to cover other uses would be complementary.

Artifacts and historical evidences indicate human presence in the basin 400,000 years ago, while cultivation was mastered about 10,000 years ago. Literature also indicates fluctuating periods of prospers, stagnation, and declining. However, the developmental momentum of the Jordan River in Jordan has taken place during the last forty years, when large-scale water development projects were initiated and implemented to harness water resources for irrigation. These projects were viewed as the most attractive solution for: 1) absorbing the unexpected influx of refugees from Palestine resulting from the three wars in the region; 2); engineering social changes by settling former nomadic tribal pastoralists or breaking the power of certain landed groups, 3) boosting the brittle economy of the young country and 4) securing the Jordanian borders from the possible Israeli military attacks and keeping the Jordan valley away from possible occupation attempts. Time, technical and hydro-political constraints, population pressures, rapid and unplanned urbanization, together, accompanied by a main focus on the economic dimension of development, have forced Jordan into easy and quick solutions, leaving it with out much water and resulting in the overexploitation of water resources of the Jordan River basin accompanied by a deteriorated environmental status. The issues of how to mitigate the deterioration of the water resources and to augment the water supply to fill the projected gab of the water deficit pose a great challenge and require, on the same time, huge investments. The envisaged future scenarios to achieve that require cooperation and mutual understanding between planners, politicians and the national community.

[1] A dam is currently under construction

Acronyms and Abbreviations

Above Sea Level…………………………………………………………..	ASL
Amman Zarqa Basin…………………………………………………….	AZB
Below Sea Level………………………………………………………...	BSL
Build Operate Transfer…………………………………………………	BOT
Central Water authority……………………………………………….	CWA
Cubic Meter……………………………………………………………..	m^3
East Ghor Canal………………………………………………………	EGC
Executive Action Team……………………………………………….	Exact
German Technical Cooperation………………………………………	GTZ
Irrigation Advisory Services………………………………………….	IAS
Japanese International Cooperation Agency ………………………	JICA
Jordan Rift Valley…………………………………………………….	JRV
Jordan River Basin……………………………………………………	JRB
Jordan River…………………………………………………………..	JR
Jordan Valley Authority………………………………………………..	JVA
Jordan Valley Commission…………………………………………….	JVC
Jordan Valley……………………………………………………………	JV
Jordan River Basin in Jordan………………………………………...	JJRB
King Abdullah Canal …………………………………………………..	KAC
King Talal Dam …………………………………………………………	KTD
King Talal Reservoir…………………………………………………..	KTR
Lower Jordan River Basin…………………………………………….	LJRB
Million cubic meter……………………………………………………..	MCM
Ministry of Agriculture………………………………………………….	MOA
Ministry of Health……………………………………………………….	MOH
Ministry of Water and Irrigation……………………………………...	MWI
National Water Master Plan……………………………………………	NWMP
North Side Wadis………………………………………………………..	NSW
Participatory Irrigation Management……………………………………	PIM
Saudi Arabia……………………………………………………………..	SA
South Side Wadis………………………………………………………..	SSW
The Hashemite kingdom of Jordan…………………………………...	HKJ
Wastewater Treatment Plant…………………………………………..	WWTP
Water Authority of Jordan………………………………………………	WAJ
Water Authority of Jordan………………………………………………	WAJ
Water Resources Management for Irrigated Agriculture………………..	WMIA
Water Resources Management Master Plan……………………………	WRMMP
Water Treatment Plant…………………………………………………..	WTP
Water User Association……………………………………………….	WUA
Year………………………………………………………………………	yr
Groundwater	GW
Surface water	SW
Treated wastewater	TWW

Currency Equivalents: Jordanian Dinar (JD) = 1.43 US Dollar
Area Measuring Unit:
1 Hectare (ha) = 10 dunums (du)
1 dunum (du) =1000 m^2

Jordan: General context

Jordan covers a land of 90,000 km2 extending from the border with Syria in the north to the tip of the Red Sea in the south and forms the Jordan River border with Israel and the West Bank in the west to the deserts of the east bordering Iraq and Saudi Arabia area. The population is concentrated in the better watered highlands of the northeast, with nomadic herders on the eastern desert boarders. The topographic features of Jordan can be divided into three zones: the Jordan rift valley depression with an average elevation of 300 m below the seal level, the eastern mountains ranging in elevation between zero and 1500 m above sea level and the desert area that covers the eastern and the southern parts of the country. Jordan climate is arid to semi arid. Rainfall ranges between 50 mm in the desert to about 600mm in the eastern mountains adjacent to the Jordan Valley. More than 90% of its total area receives less than 200mm and only 3.2% of the area receives an average annual rainfall greater than 300 mm (**Al-Weshah, 2000**). The total rain fall in Jordan is estimated at 8.5 billion cubic meters of which 85% is lost as evaporation and the remaining fraction flowing into wadis and partially infiltrating into deep aquifers (**Bataineh, Najjar and Malkawi, 2002; Taha and Bataina, 2002**). Irrigated agriculture is constrained by the increasingly limited water availability.

The population of Jordan is estimated to 5 million for the year 2000. The recent growth rate stands at about 3.5% due to natural and non-voluntary migration after the three wars of 1948, 1967, and 1990. More than 78% of the population lives in urban areas concentrated in the northern governorates of Amman, Irbid, Zarqa, Balqa, all of which are substantially elevated from available water resources in the Jordan River Basin. It is also estimated that 38% of the population of Jordan lives in Capital Amman.

Water resources are characterized by scarcity, vulnerability, variability, uncertainty and dependent on the amount of the rainfalls, which vary significantly spatially and temporally. Water resources are very limited-among the scarcest of any country in the world (**The HKJ and the World Bank, 1997**) of which Jordan is one of the poorest seven countries in the world. Available water resources per capita amounts to 249 m3 /cap/yr in 1993 decreased to 163 m3 /cap[2]/yr in 1999 and are projected to only 109 m3 /cap/yr by 2020 (**Taha and Bataineh, 2002**) and 91 m3 /cap/yr by 2025 as a result of the expected population growth (**Bataineh, Najar and Malkawi, 2002**). The expanding population and the climatic and topographical conditions of the country have exerted enormous pressure on the limited water resources and created sever water supply-demand imbalance. Shortage and intermittence of urban supplies is getting severe. Present use already exceeds renewable supply. The available water resources are about 875 MCM/year with a total demand reaching now the 1000 MCM/year. The gap between water demand and water supply was covered by the unsustainable practice of overdrawing in both the renewable highlands and the fossil aquifers. As result, groundwater levels are declining and water quality deteriorating. Jordan has been implementing a rationing program since 1988. During the summer period, the households receive water once or twice per week for 12 to 24 hours. The rationing program has forced the households to invest in water tanks located on house's roofs (**Taha and Bataineh, 2002**).

Water Resources consist primarily of surface water and groundwater resources, with treated wastewater being used on an increasing scale of irrigation, mostly in the Jordan valley. Surface water resources, about 38% of the national water balance, are mainly the Yarmouk River and the other eastern tributaries of the Lower Jordan River (LJR). The Jordan River flow is almost

[2] It is documented that it is estimated to 160 m3 in 1998 (Bataina, Najjar, Malkawi, 2002)

limited because of the complete withdrawal of the upper Jordan water by Israel. The groundwater resources in Jordan are divided in renewable and fossil water reserves. Nowadays, seven out of twelve groundwater basins exceed their pumping extraction safe yields threatening the ecosystem. The main fossil water reserve is the Disi aquifer in the southern desert of Jordan.

Agriculture still has the big share of the national water resources. The agricultural activity consumes about 2/3 of the total water resources in Jordan and is also concentrated in the Jordan River basin. The irrigated area in the Jordan valley is about **30 000** ha and it is about **52 000** ha in the highlands. Most of the irrigated area of the highlands[3], about **35 000** ha is within the Jordan River basin. Out of 52 000 ha of irrigated land in the highland and Badia, **47 800** ha is irrigated mainly from groundwater (**Jabarin, 2001**).

[3] The National highlands crosses the whole country from the north to the south with a width of 30 Km and a length of 300 Km, ranging in elevation between zero and more than 1500 m ASL.

1. The Jordan River Basin Characteristics

1.1 Physical setting

The Jordan River (JR) is a multinational river and, its headwaters tributaries originate from the slopes of Jabel esh-Sheikh (Mount Hermon), in the southern part of Syria and Lebanon and the northern part of Israel, flowing southward through Lebanon, Syria, Israel, Jordan and Palestine for a total length of 228 km along of a longitudinal known as the Valley, or Ghor, before it is discharging into the Dead sea. The historic annual discharge of the Jordan River into the Dead Sea was around **1400** MCM before any of the water development projects of the riparian countries was implemented. The Jordan River system drains a total area of 18 194 Km2 (**NWMP, 1977**). It is principal tributary, the Yarmouk River, forms the borders between Syria and Jordan and divides Israel from Jordan in the Yarmouk triangle.

Figure 1: Jordan River Catchment Area & JRBJ Borders

The lower Jordan River constitutes the borders of the occupied West Bank to the west and Jordan to the east for a distance of about 80 Km. The catchment area of the whole Jordan River can be divided to three sub-basins: the upper Jordan River, the Yarmouk River and the lower Jordan River.

The upper Jordan water resources comes from three major headwaters streams, the Dan in Israel, the Hasbani in Lebanon, and the Banias which was a part from Syria till 1967 and since then it is under Israeli control after the Israeli occupation of the West Bank and the Syrian Golan Heights in 1967. Its catchments include in addition to the three springs, the Huleh valley and the Tiberias Lake and total an area of 2833 km2 (NWMP, 1977). The headwater of the upper Jordan River is fully utilized by Israel, through its National water carrier to its coastal areas and Negev desert. It was estimated by Klein (1998) that the upper Jordan that originates from different water sources contributes to an average of 770 MCM/yr entering into the Lake. He also estimated that water from the basin used by Israel is about 440 MCM/yr in the basin and 350 outside the basin, the Israeli costal areas and the Negev that add up to nearly 800 MCM of which 100 MCM gained from the drainage of the Hula swamps.

The Yarmouk River Sub-basin represents the catchment area of the Yarmouk River, arising in southwestern Syria and flowing for more than 40km km in a southwesterly direction between Jordan and Syria and then joins the Jordan River 10 km downstream of Lake Tiberias. In its lower part, the flow line is the border between Israel and Jordan. Its catchment covers an area of

6974 km2 (**Draft of NWMP Surface Water-main Report, 2003**) of which around 20% (**1426** km2) of this area is within the Jordanian territories. Thus, its riparian countries compromise Syria, Israel, and Jordan of which it lies downstream of both rivers.

The lower Jordan River basin (LJRB) occupies the area downstream the Jordan River between Tiberias Lake and the Dead Sea. The eastern bank of the lower Jordan covers an area of 7163 km2 while the west bank drainages area totals **2344** Km2 (**NWMP, 1977**). The lower JR sub-basin receives water from the side wadis of the Jordan Valley on both sides.

The Jordan River basin in the Hashemite Kingdom of Jordan (HKJ) represents the catchment area of the eastern bank of the lower Jordan River and the Jordan's part of the Yarmouk River basin (**Figure 1**). The JRBJ represents about 40 % of the total Jordan River basin and 7.8 % of the area of Jordan. The Jordan River Basin in Jordan constitutes the wettest area in the HKJ where 83% of the population is concentrated and the potential economic development is the highest. The Basin provides the country with about 80% of its water resources. The agricultural activity consumes about 68% of the total water resource in Jordan and is also concentrated in the JRBJ.

The study here will only focus on this Jordanian side of the whole river basin and more detailed description of the Jordan River basin located in Jordan will follow in other sections of the report. The phrases of the "Jordan River Basin", the "Jordan River Basin in Jordan" and the "basin" will be used alternately to mean the Jordan River in the Jordanian territories.

1.2 Hydrological conditions of the JRBJ

On the worldwide scale of rivers, the only river of significant size in Jordan is the Jordan River. The Jordan River follows an indirect or twisty course from Lake Tiberias in the north until it flows into the Dead Sea in the south, the lowest point on earth, a distance of about 104 to 105 km.

The Yarmouk River is the main tributary of the Jordan River and its water represent the largest and most important surface water resources in Jordan and considered as a vital national resource. The main channel of the river is fed by springs and intermittent streams arising almost entirely in Syria. The annual average discharge of the Yarmouk River in Adasayia, in the north of the HKJ, was **467** MCM[4] in the period between 1927 and 1954, much of it in the form of late winter floods. Khori (1981) documented that the average annual flow[5] of the River was **438** MCM ranging from 240 MCM to 870 MCM a year. Other references indicate that the average annual flow figures are around Salameh's and Khori's figure of **440-470** MCM. Recent measurements of flow showed that the flow of the Yarmouk River has decreased considerably since the late 1980s (**Salameh and Bannayan, 1993**). Its contribution was estimated as 360 MCM/yr around 1993 of which Syria, Jordan and Israel utilized about 160, 100, and 100 MCM/yr respectively (**Al-Jayyousi, 2001; Salameh and Bannayan, 1993**). Over the last ten years the average has dropped to 270 MCM/ yr (**Figure 2**)

4 Million Cubic Meter

5 Khori didn't mention the period

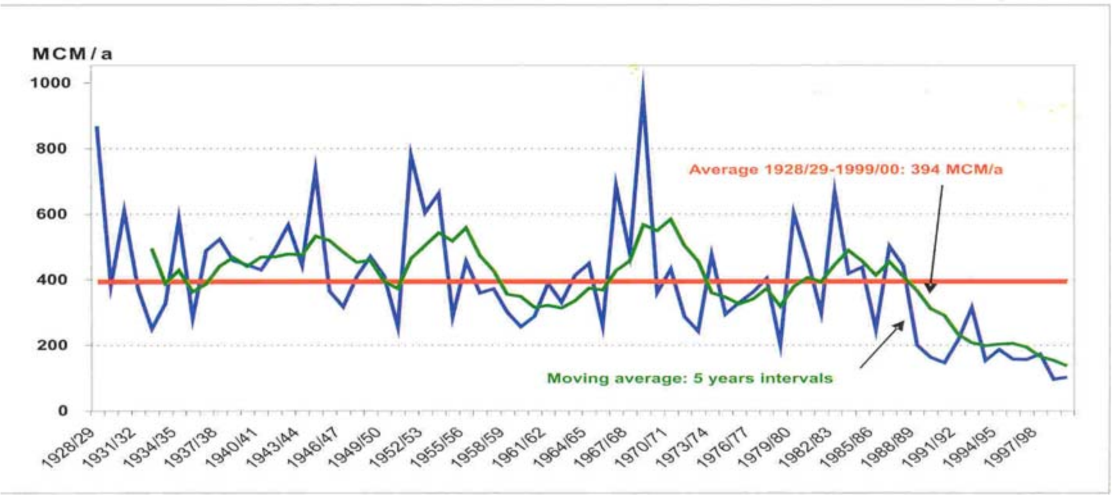

Figure 2: Long term average of the Yarmouk River

The average water flowing from the Yarmouk to Jordan was reduced due to increasing diversion of water through ditches[6] on the Syrian territory and to the drilling of wells in its catchments. Syria uses an average of some **200** MCM per year of the river's natural flow. Israel, at the other hand, pumps **70** MCM of water to irrigate the fertile land bounded by Lake Tiberias and the intersection of the Yarmouk and Jordan River, the Yarmouk Triangle. Jordan, the middle riparian diverts into King Abdullah Canal about 130 MCM of the river's historic average annual flow. Roughly and after all the overall abstraction from the three riparian countries, a round **60** MCM of the river's water flows unused to the unusable and polluted Jordan river and then to the dead sea in the form of uncontrolled winter floods (**Hof, 1998**).

Naturally, and before the headwater development of the Jordan River, the River would discharge around **1400** MCM of water annually to the Dead Sea of which 400 MCM/yr came from the Yarmouk River. The Yarmouk River is not fully developed yet. However, a dam had been planned on the river since the 50s but this dam is still not constructed, due to the political hostility between the riparian countries. Noteworthy is to mention that this dam is under construction at present.

The lower Jordan River forms the borders between Jordan, on the east bank of the river, and Israel and Palestine, on the West Bank of the River. Surface water resources in Jordan mainly come from the Yarmouk River and the Jordan River's eastern tributaries. Jordan cannot use the water of the Jordan River, as its natural fresh water flow has been interrupted, with only the return irrigation flows and saline water remaining. The eastern lower Jordan River catchment lies completely within Jordan and consists, in addition to the Zarqa river, nine smaller wadis and springs. Most of these wadis are currently tapped by dams and diverted to the main irrigation canal in the Jordan valley. The Zarqa River, the second important tributary, has an average natural discharge flow of **85** MCM/yr. The side wadis flow in the valley from the Eastern Hills, combining with the Yarmouk and Zarqa rivers.

Salameh (1993) classifies Groundwater resources in the Jordan River basin in Jordan to include four sub groundwater basins: the aquifer of the Yarmouk River and the northern side wadis, the Jordan valley floor area, southern part of the Jordan valley escarpment, and the Amman Zarqa

[6] In some references (Hof., 1998) it is mentioned that Syria has constructed dams, but officials from the JVA and the National press (Jordantimes) mentioned ditches and not dams.

basins. These basins underline different aquifer systems of which groundwater tables are recharged principally by precipitation. A more detailed description of water resources in the JRBJ will be included in another section of the report.

1.3 Topography

The topographic features of Jordan River Basin can be divided into two zones: 1) the Jordan valley depression (JV), also called Al Ghor, which is the northern part of the Jordan Rift Valley (JRV), up the dead see, with an elevation between 200 m and 400 BSL, and 2) the mountains and the eastern plateau, also called the highlands[7] , crossing the country from north to south, with a width of 30 Km and a length of 300 Km, ranging in elevation between zero and more than 1000 m ASL and bordering the valley all along its course (**Figure 3**).

The Jordan valley, a part of the JRV, was a result of an important geological event that incorporates the rifting along a vertical line (Great African Rift), extending from Ethiopia through the Red Sea in the south to Lake Tiberias in the north, creating a new base level for surrounding surface and groundwater. This event had led to the formation of the Jordan valley along the same line and the highlands on both of its sides. The mountains slope hardly in the western direction towards the JRV depression The Jordan Rift Valley slices through the full length of Jordan for 360 kilometers, from the Yarmouk River in the north to Aqaba in the South, and encompasses three parts: the Jordan valley depression, the Dead Sea and Wadi Araba in the south of the HKJ. The mountains forming the highlands are incised by numerous wadis draining water to the river Jordan.

The Jordan River itself flows in a 30-60 meter-deep gorge, flanked by its narrow flood plain that form a strip, called the Zor in Arabic, along the Jordan River and ranges from 200m to 2km (**Khori, 1981**). During the rainy season, the Jordan River often changes its course, overtops its banks and floods this fertile area. The Katar, an eroded zone of uncultivable land, separates the Zor from the rest of the valley floor (**Khori, 1981**) and consists of impermeable sediments of marine origin (**JVC, 1972**).

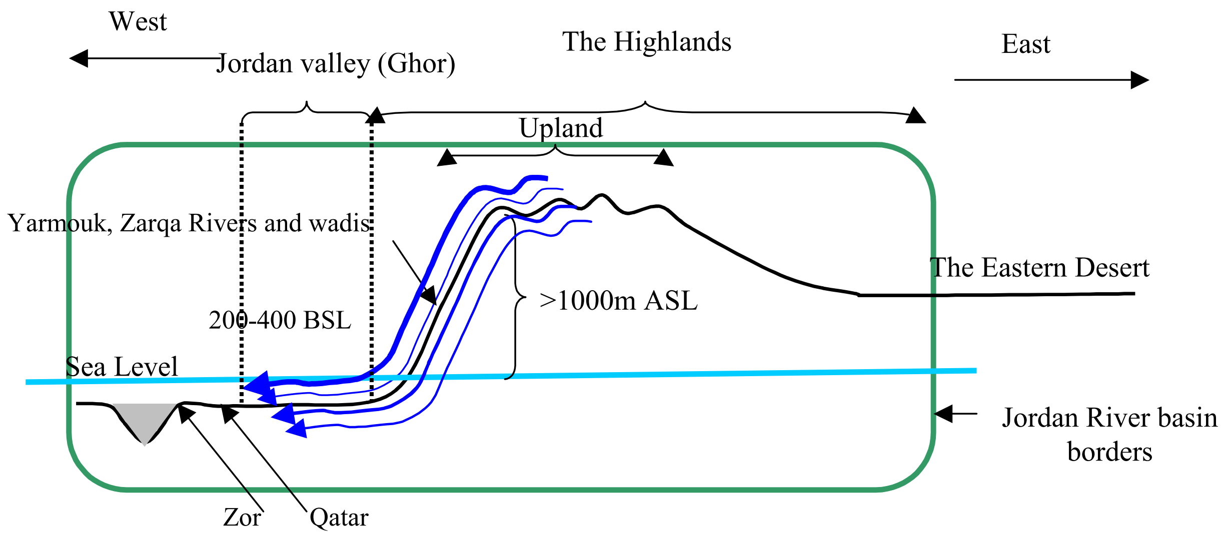

Figure 3: The Jordan River Basin in Jordan: Topographic features

[7] The highlands in this report constitute only the part of the highlands that lies in the JRB

The Jordan valley (JV) is laying in the northern part of the rift valley, upstream of the Dead Sea till south of Lake Tiberias, and bordering the river on a length of **105** km. The Ghor slopes down from the Hills to the Jordan River at a rate of 15 to 25 meters per kilometer (**Khori, 1981**). It is made up of diluvia material washed down from the surrounding hills and deposited over impermeable foundation consisting of marine sediments, which are generally highly saline. The thickness of the deposited sediment is highest at the valley boundary, decreasing towards the Jordan River (**JVC, 1972**). The width of the valley is about 20 Km in the southern part and becomes narrower in its central section with 4 Km width and it regains its 10 km of large in the northern part (**Qaisi, 2001**). The Valley has the advantage of producing winter crops at least two or three months before other parts of the Middle East. It is located between 200 and 400 m below the sea level, acting as a natural hothouse. The irrigated area in the Jordan valley is about **30,000** ha, against about **35000** ha in the highlands.

1.4 The climatic conditions

The JRB catchment's area is characterized by a significant climatic variability from the north to the south and from the east to the west. The analyses of the long-term data (1920's –present) reveal that significant floods occur in a frequency of 2 times per 10 years.

Along the highlands, located on the west of the basin, the weather is usually cold and wet in winter and hot and dry in summer. The mountains receive an average annual rainfall ranging from 600 to 400 mm. The precipitation pick is observed in January and February. Snowfalls are observed once or twice a year in the zones where the altitude exceeds 700 m (**Figure 4**)

Inside the valley, the climate is considered as arid to semi arid. Due to its low level, the temperature in the Jordan valley is higher[8] than in the highlands. During the day the average of temperature in the valley rises between 15° and 22° from November to March and between 30° and 33° in summer. While a temperature of more than 40° is common in summer, it can sometimes drop to the freezing point at winter nights. The amount of precipitation varies from the north to the south of the valley. It is about 380-400 mm in the northern part and it goes to less than 100 mm in the southern areas. The rainy season extends from October to April and the wettest months are between December and March. The average annual rainfall of the areas of our basin ranges between 220mm to 490mm as shown in (**Table 1**).

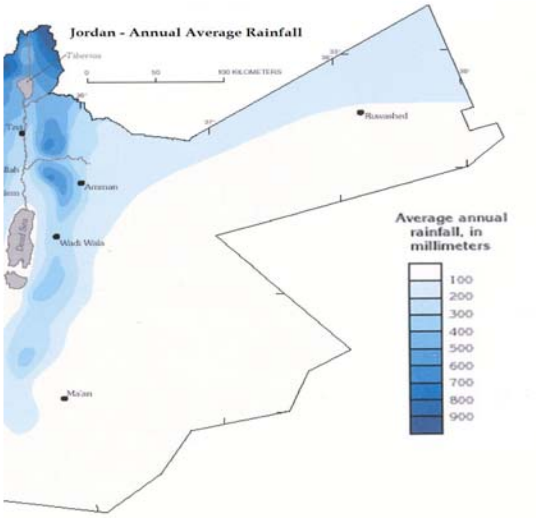

Figure 4: Annual average rain fall distribution

Frost and snow are extremely rare. Relative humidity varies from 64% in the coldest period of the year, to 27% in the hottest summer month. In the northern area, the range is from 70% in winter to 50 % during the summer (**Qaisi, 2001**).

Summer solar radiation accounts for 70% of the annual water evaporation. Potential evaporation in the Jordan Valley is of concern as in some areas the rates are 50 to 80 times the average precipitation and it varies significantly from north to south. Water resources in the JV are scarce and deteriorating (**Qaisi, 2001**). The variations in temperature, humidity, and rainfall produced distinct agro-climatic zones. The variations between northern, central, and southern parts of the JV are clear in terms of water availability, water quality, soil type, and consequently cropping patterns and type of agricultural production.

[8] Temperature in the valley is 6 to 9° more than in the highlands

Basin Name	Basin Code	Catchment Area (Km^2)	Average Annual Rainfall (mm/year)
Yarmouk	AD	1426	280
Amman-Zarqa	AL	3739	220
Jordan valley	AB	780	270
North Side wadis (NSW)	AE,AF,AG, AH,AJ,AK	946	490
South Side wadis (SSW)	AM,AN,AP	736	370
Total		**7,627**[9]	

Table 1: Surface Water Basins in JRBJ (Based on the rainfall for the years 1937/38-2002/03)

Source: The MWI, the draft of the National Water Master Plan, Surface Water-Main Report, 2003.

1.5 Main geological features

The mountains forming the highlands are mainly formed of sedimentary rocks. The valley consists mainly of non-consolidated alluvial sediments of gravel, sand, shale and clay deposits. The salty deposits, clay and shale, were been eroded from the hills bordering the valley and deposed thousands of years ago before the disappearance of the Lake Lisan, which was huge water body linking the Dead Sea to the Tiberias Lake. The valley floor is relatively recent deposition of earth and constitutes a fertile area and an important source for the large agricultural potential in the country today (**Khori, 1981**). Small areas of Basalts are found in different areas of the valley such as Adasiya, Mukheiba, North Shuna in the north and Katar areas in the south.

Most of the groundwater is obtained from Quaternary sand and gravel in the Jordan valley, Cretaceous lime-stone in the Jordan highland and escarpments a long the JV, and basalt in the Jordan highland (**Exact, 1998**).

1.6 Land form and suitability for agriculture

The JV is classified to mainly three different quality of agricultural zones resulted from the interaction of climatic conditions, quality of water used for irrigation and type of soils of which without irrigation, most of the soils in the valley would revert to desert type soils (**Qiasi, 2001**).

The first agriculture zone is a semi arid zone and mainly concentrated in the northern Ghor. The soil of this area is generally deep basaltic soil of low salinity and high permeability. The soil and water quality of this area make it suitable for all kind of vegetables crops, fruit trees and field crops. Farmers in this area prefer to plant fruit trees. In 1998, 55% of the total area was planted with fruit trees. However, the extension of the fruit trees in the north of the valley led to a shortage in water supply in the middle and the southern parts during summer periods.

The central or middle Ghor is characterized by the second type of agriculture zone which is semi arid to arid zone. The deep calcareous-sandy soil of low salinity and high permeability

[9] In the same source (The draft of NWMP Surface Water-Main Report, 2003), table 2.2 includes other figures for the areas. AZB: 3379, NSW:689, SSW:440, and the Total area of the JRBJ is 5934 km^2.

represent only 50% of the total central area. The soil in this area is suitable for vegetables crops and field crops.

In the third agriculture zone, which dominates the southern valley, the soil is shallow with high salinity and low permeability. The zone itself is arid to severely arid area. In addition to the salinity of soils the water quality in this zone is not good enough to have a high productivity. Around 60 to 80% of the total water supply in this zone comes from the King Talal Dam, which reserve mainly reclaimed water. This zone is characterized by the development of banana trees plantations irrigated from KAC and water from Hisban and Kafrein wadis and vegetables that are mainly by private wells with high saline groundwater.

1.7 Water resources in the basin

Surface water in the JRBJ originates from the Yarmouk and Zarqa River and the eastern side wadis. Major springs are primarily located in highlands and escarpments along the JV (**Exact, 1998**). Dams to control the floods tap some of these wadis. Weirs on most wadis divert flows for local irrigation or irrigation uphill from King Abdullah Canal (KAC). Surface water is principally divided between the following sub-basins that drain to Jordan River system:

The Yarmouk River Sub-Basin (AD[10]): The Yarmouk River is the main source of surface water in the country. A detailed characteristic description of this vital source and its hydrological conditions is enclosed in former sections.

The Lower Jordan River Sub-Basin: water flow from the side wadis of the Jordan Valley amounts to about 148 MCM/yr (84 MCM as abase flow and 64 as a flood flow). The main tributaries of the lower Jordan River sub-basin are, the Zerqa River, and the wadis of Al-Arab, Ziglab, Jurum, Yabis, Kufranja, Rajib, Shueib, Kafrein and Hisban (**Table 2 & Table 3**). Most of them are tapped by dams and diverted to the main irrigation canal. Customary, the wadis of wadi Arab, Ziglab, Jurum, Yabis, Rajib and Kufranja are called the North Side Wadis (NSW) and all are located above the Zarq river catchment while the wadis of Shueib, Kaferin and Hisban are called the South Side Wadis (SSW) and all are located below the Zarqa River.

[10] Indicate the given basin code in some literatures such as the National Water Master Plans 1977, 2003.

River or Wadi	Catchment Code	Gauging station	Jordan Catchment Area (Km^2)	Full Catchment Area (Km^2), including the area out side the Jordanian territories
Yarmouk	AD	Adasiya	1426	6,974
Arab	AE	North Shouneh	246	246
Ziglab	AF	Ziglab Dam (upstream)	100	100
Jurum	AG	Entrance (KAC)	23	23
Yabis	AH	Entrance (KAC)	122	122
Kufrinja	AJ	Entrance (KAC)	103	103
Rajib	AK	Entrance (KAC)	95	95
Zarqa	AL	Deir Alla	3,379	4,154
Shueib	AM	South Shouneh	193	193
Kafrein	AN	Ghor Kafrein	159	159
Hisban	AP	Ghor Romeh	88	88
Total			5,934	12,257

Table 2: Rivers and wadis in the Jordan valley and escarpments

Source: (The draft of NWMP Surface Water-Main Report, 2003)

- The Zarqa River (AL)

The Zarqa river is the largest tributary, with annual contribution of 62-65[11] MCM. The River consists of two main branches: wadi Dhuleil, which drains to the eastern part of the catchment area and seel-zerka which drains to the opposite direction and both branches meet at Sukhna to form Zarqa River. Naturally, the eastern part drains only flood flow while the western branch drains flood and base flows. The Zarqa river catchment area is considered as the most densely populated area in Jordan, which comprises around 65% of the country's population and more than 80% of its industry. The area has been characterized by a good climate, proximity to watercourses, and historical settlement of people.
After the 1976, the natural system of the river was changed due to different factors. Theses mainly include the construction of the King Talal Dam which collect fresh and reclaimed water, the over abstraction of groundwater in the catchment area and the industrial and the municipal effluents discharge into the river (**Salameh and Bannayan, 1993**).

- Wadi Arab (AE)

The average discharge of the wadi is a round 28 MCM a year equally distributed to between base and flood flows. The catchment area is agrarian and most population is concentrated in Irbid city (**Salameh and Bannayan, 1993**).

Drilling of wells and pumping of water upstream of the dam has resulted in groundwater table declining and hence the ceasing of groundwater natural discharge. Water extracted is being supplied for drinking water uses for Irbid governorate (**Communication with Eng.Yousef Hassan and Eng Nayef Seder, 2003**).

[11] Other litertures indicate 85 MCM.

- Wadi Ziglab (AF)

Wadi ziglab extends from the Jordan valley to eastwards into the highlands.
Total discharge of various springs along the wadi is 5 MCM as a base flow and to 5 MCM as floodwater. A dam was constructed on the wadi in 1966 to use its water for irrigation the valley. The catchment area is agrarian with natural forests and very little population (**Salameh and Bannayan, 1993**).

- Wadi Shueib (AM)

The wadi lays at elevation ranging from 1200 m above the sea level down to area below the sea level in the Jordan Valley. The average natural flow of the wadi is 1.8 MCM as flood flow and 3.9 MCM as base flow per year. A dam was constructed in 1968 of whose water used for the irrigation in the Jordan valley (**Salameh and Bannayan, 1993**).

- Wadi Kafrain (AN)

The wadi lays at elevation ranging from 1200 m above the sea level down to area below the sea level in the Jordan Valley. The average discharge of wadi Kafrain is 6.4 MCM/year as a total flow consisting of 1.6 MCM as a flood flow and 4.8 MCM/yr as a base flow (**Salameh and Bannayan, 1993**).

- Other wadis discharging into the Jordan valley

These wadis are not dammed and include Yabis (AH), Kufranja (AJ), Jurum (AG), Rajeb (AK), Hisban (AP) and other small catchments. The base flow of these wadis is used for irrigation along their courses and partly at the foothills on the Jordan valley. The figure below (**Figure 5**) shows the drainage basins and the main river catchments of the JRBJ with related codes.

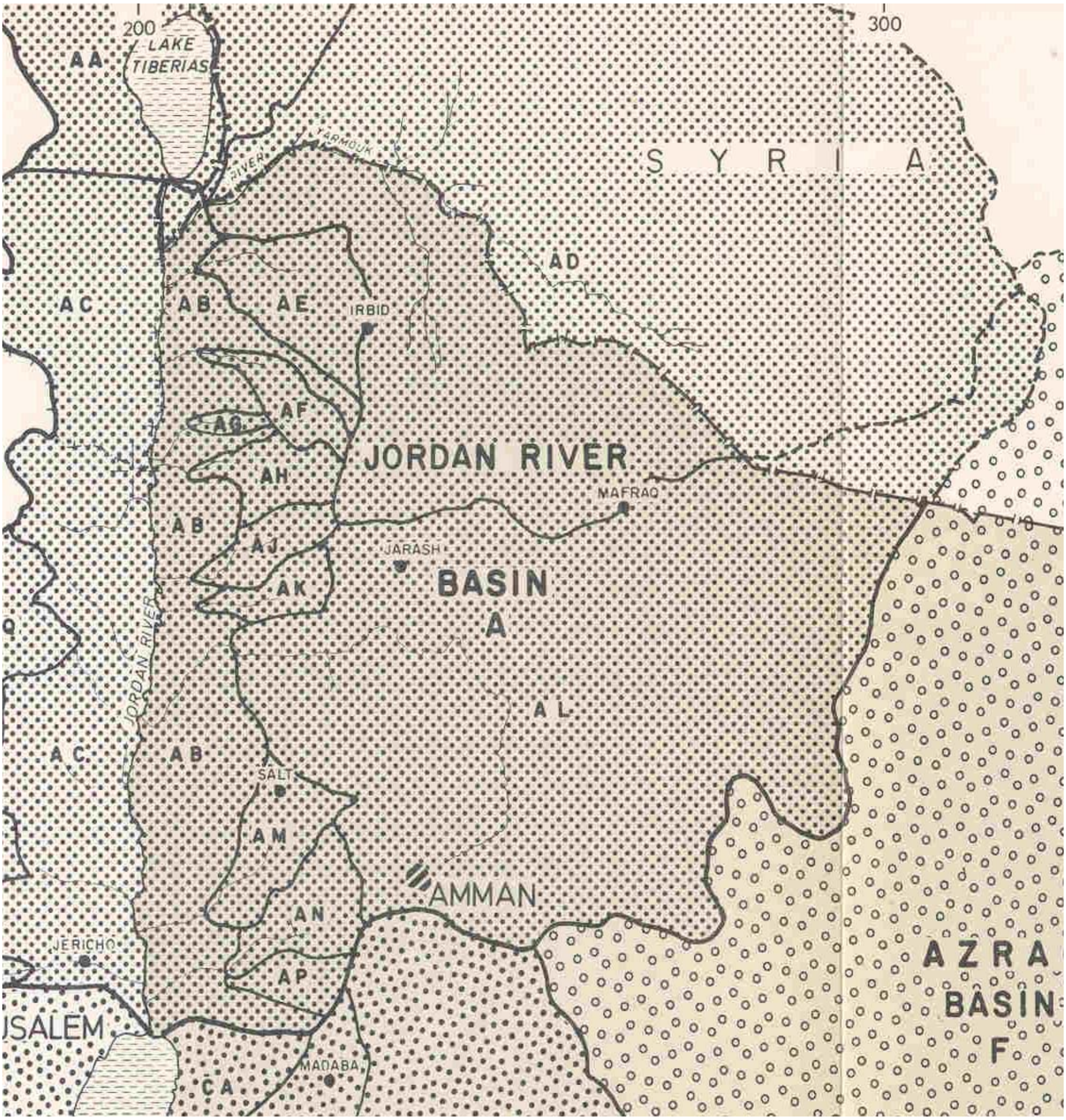

Figure 5: Drainage basins and the main river catchments of the JRBJ.

Source: National Water Master Plan (1977), Drainage basins map.

Sub Basin Code	Located in Sub-Basin	Base flow (1)	Flood flow	Total flow (1)	Base flow (2)	Flood Flow (2)	Total Flow (2)	Base flow (3)	Flood Flow (3)	Total Flow (3)	Base flow (4)	Flood Flow (4)	Total Flow (4)	Total flow (5)
Yarmouk River	Syria	178.2		325.8										
AD	Yarmouk River in Jordan	39.6		74.2	15.0	22.4	37.4							
AE	Wadi Arab catchment	24.9		31.4	18.0	38.7	56.7	1.7	4.0	5.7	14	14	28	1.5-2
AF	wadi Ziglab catchment	8.3		10.5 Total NSW[12]				7.64	0.38	8.02	5	5	10	
AG	wadi Jurm catchment	11.5		11.7 72.5				8.53	0.29	8.82 Total NSW 40.5				4.5
AH	wadi Yabis catchment	6.2		7.8				2.5	1.40	3.9				2.6
AJ	Wadi Kufranja catchment	5.8?		6.8				6.91	1.08	7.99				6.3
AK	Wadi Rajib catchment	3		4.3				4.99	1.12	6.11				4.1
AM	Wadi Shueib catchment	8		9.8 Total SSW[13]	34.8	25.1	59.9	7.92	1.96	9.88 Total SSW 29.77	3.8	1.8	5.7	
AN	Wadi Kafrein catchment	12		13.4 30				12.40	2.80	15.2	4.8	1.6	6.4	
AP	Wadi Hisban catchment	6.3		6.8				3.46	1.23	4.59				
AL	Zarqa River	48.7		90.7	36.5	47.5	84.0	43.0	25.30	68.3	35	~30	64.88	

Table 3: Estimated long term average flows according to volumes of area rainfall

(1) Source: National water master plan, 1977, Potential surface water resources map.
(2) Source: National water master plan, 2003, Surface water resources-Main Report
(3) Source: National water Master plan, 2002 (JICA)
(4) Slameh and Bannayan, 1993
(5) Communication with Nayef Seder

[12] NSW, North Side wadis
[13] SSW South Side wadis

According to Salameh and Bannayan (1993), the groundwater resources involve 4 sub groundwater basins (**Figure 6**)

The ***aquifer of the Yarmouk River and the northern side wadis basins:*** These basins underline one aquifer system of which the recharge of this aquifer takes place at the highlands of Irbid and Ajloun and further to the northeast beyond Jordan's territories. The Mukheiba wells at the slopes of the Yarmouk River and the wadi Arab wells tap the same aquifer and discharge artesian water. The recharge calculated to this aquifer is **127** MCM/ yr with a base flows of **100** MCM a year. This figure includes the groundwater resources of wadi Yabis, wadi Jurum, wadis El-Arab and the Yarmouk River (**El Nasser 1991; Salameh and Bannayan, 1993**). The amount of renewable groundwater, which does not appear as a base flow, was calculated by Salameh (1993) to **23** MCM/yr. The ground water flow is drained to the Jordan valley. The water quality of the Yarmouk River's aquifer is suitable for all uses.

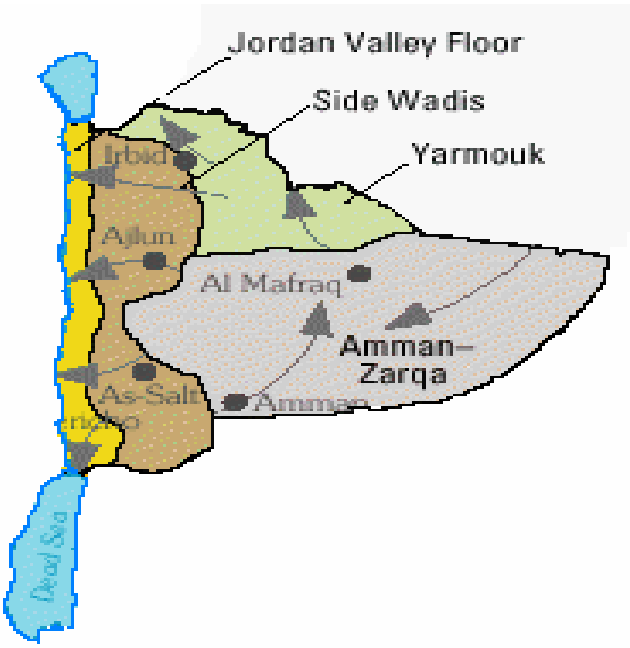

Figure 6: Groundwater sub-basins in JRB

The Jordan valley floor area: this aquifer is lying along the flood plain of the Jordan River. This groundwater table is recharged by precipitations and its flows are coming from the hills bordering the valley. The amount of available water in this aquifer is about **20** MCM/yr. In the northern part of the valley, water quality is good and suitable for agricultural purposes. In the southern part water become brackish because of the saline formation in the area and the infiltration of agriculture return flows. Groundwater salinity is also more relevant in the areas closed to Jordan River. It become less and less important in areas closed to the mountains and the side wadis.

Southern part of the Jordan valley escarpment: the groundwater in this area (south side wadis) is divided in two aquifer systems, the upper cretaceous limestone system and the lower cretaceous limestone system. The groundwater table of the limestone aquifer is not continuous. The aquifer is recharged from the highlands in Amman and Balqa areas and directed towards the Jordan Valley. The amount of renewable groundwater, which does not appear as base flow is estimated as **10** MCM/yr. The good quality of water stored in this aquifer allowed it to be used for many purposes.

Amman Zarqa basin (AZB): The Amman Zarqa Basin covers a total area of **4154** km2 with about **3379** km2 in Jordan and the rest is located in Syria (**The draft of NWMP Surface Water-Main Report, 2003**). It includes the country's largest urban agglomeration, major industrial sites and irrigated areas. The AZB has significant groundwater recharge and represents 32% of the nation's renewable groundwater resources (275MCM/yr) of which half of the pumped water is used for agriculture.

The Amman-Zarqa groundwater basin is divided in two parts, an eastern and a western part. Recharge of the eastern parts comes from Jabal Druze in Syria. Recharge to the western part takes place along the highlands of Amman and surroundings. Groundwater originating in the eastern part flows in a westerly direction whereas water originating in the western hills of Amman flows in an easterly direction. The annual medium recharge of the aquifer estimated at **88**[14] MCM/yr. Its eastern part, extending north to the Syrian border and southwest to the outskirts of Amman constitutes about 80% of the AZB groundwater renewable resources (70MCM). This part also uses 90% of the irrigation use in the AZB. Irrigation activities especially in Dhuleil area located in the eastern parts resulting in irrigation return flows which infiltrate back to the groundwater body underlying the entire area. Industrial and domestic return flows also contribute to the groundwater reservoir.

A recent brochure issued by the Ministry of Water and Irrigation in cooperation with the GTZ indicates the annual safe yield of each groundwater sub-basin. The Amman Zarqa basin safe yield abstraction is about 20 MCM less than it was mentioned in earlier literatures (**Figure 7**)

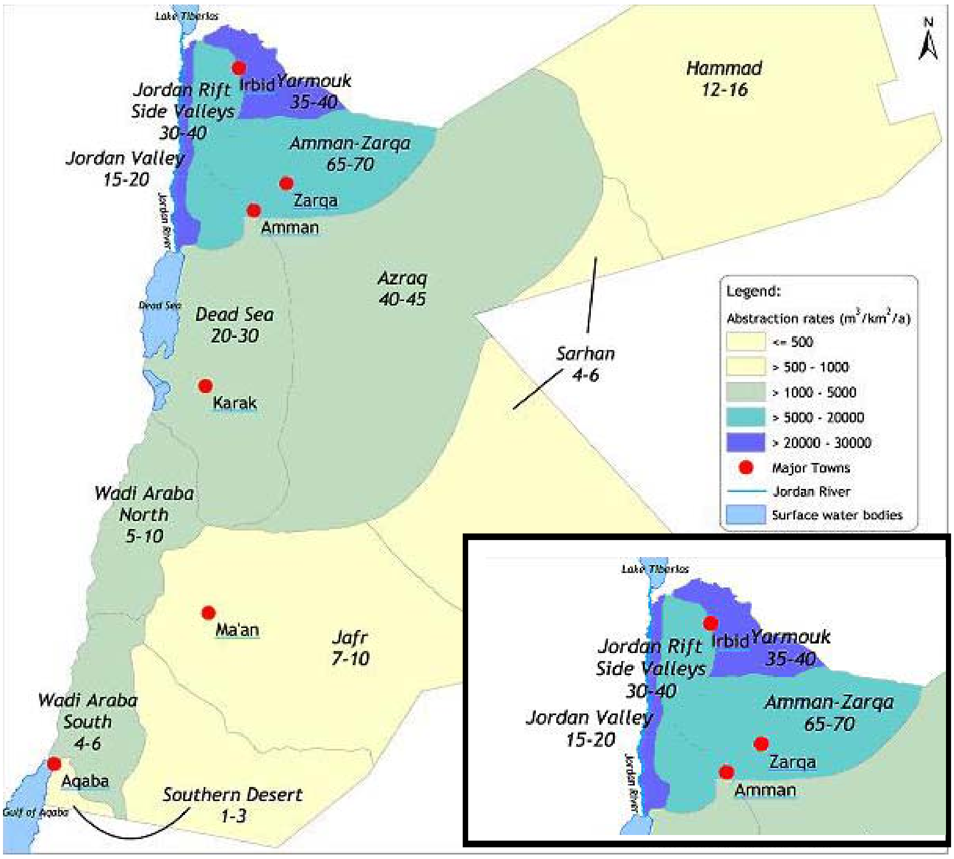

Figure 7: Sustainable annual groundwater abstraction in each basin

Source: The National Water Master Plan Boucher, 2003

[14] Around 35 MCM/yr returns to the surface as base flow along the Zarqa River and the remaining 53 MCM/yr are pumped through wells distributed over the basin (Salameh,E and Bannayan,H.(1993)

1.8 Hydrology scheme and Water Balance (~1900)

The hydrological conditions and water balances of the JRBJ is represented in the following scheme (**Figure 8**). The validity of the represented figures is achieved by data source triangulation as shown in (**Table 4**)

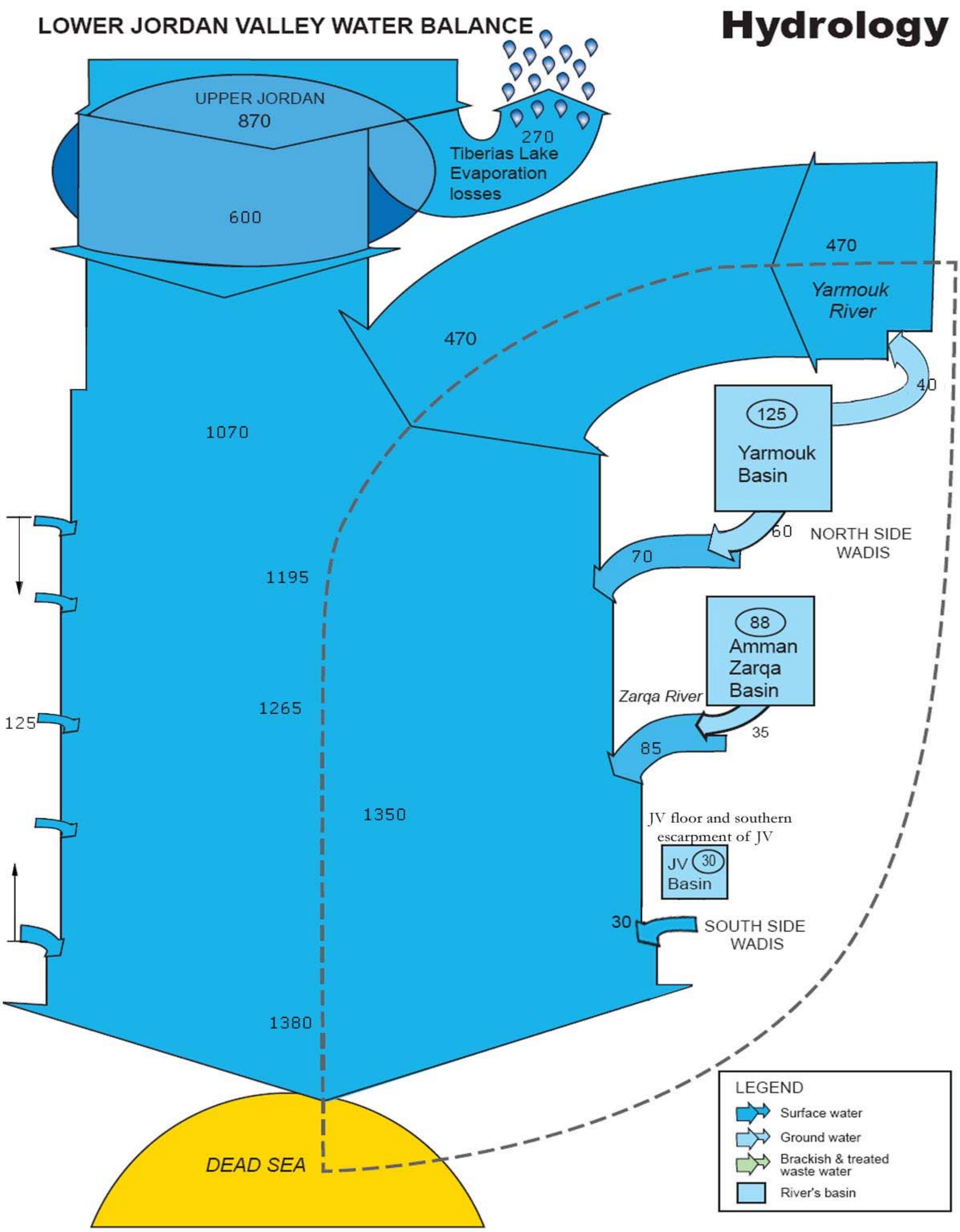

Figure 8: Water balance scheme of the JRBJ (~1900)

Data issue	**Data figure**	**Source/Estimation**
Upper Jordan Natural flow in Tiberias lake (100 is estimated to be used in the Huleh Valley for irrigation, source: http://www.unu.edu/unupress/unupbooks/80858e/80858E06.htm	475 600 520 660 890✓ 870✓	Internet: : http://www.unu.edu/unupress/unupbooks/80858e/80858E06.htm Klein,M (1998)
It is interpretive that the four first figures do not take in account the lake evaporation. It is recognized from other literatures that water pumped through the Israeli NWC is about 440. It is also known that about 100 are used for irrigation in the Huleh valley. Another documented fact is that evaporation from the Lake is estimated as 210-280. One can conclude that marked figures are more precise		
Evaporation from Lake Tiberias	210 283✓ 270✓	GTZ (1998) Klein, M. (1998) Internet: http://www.unu.edu/unupress/unupbooks/80858e/80858E06.htm
Two of the figures are so close 270 and 283 and more frequent. The figure of 270 was considered.		
Historical outflow of Tiberias Lake To the Jordan River	590✓ 600✓ 605✓	Calculated figure from the difference between Data issue 1 and 2. Beaumont, P. (1997) El Naser, 1996?
The average natural flow of the Yarmouk river	455 438 480✓ 300 475✓ 440-170 400 467✓ 470✓	Jayyousi, O. (2001) Khori, R. (1981) Hof, F. C. (1998) Qaisi. K. (2001) Klein, M. (1998) Jayyousi, O. (2001) Internet: http://www.unu.edu/unupress/unupbooks/80858e/80858E06.htm Salameh, E and Bannayan, H.(1993). Internet: http://www.jordanembassyus.org/112298002.htm
As it can be observed, the figure of 470 has the highest frequency in sources. Salameh and Banayan (1993), in his book, give a historical trend for the natural flow during the period from 1920s to 1993 supporting that the Yarmouk flow on the 1920s was about 470. Figures of 300, 170 may be referred to recent measurement on which the flow was affect by the abstraction from the Syrian side or it may be refereed to measurement on drought times or most probably referred to measurement s of the lower Yarmouk River.		
Jordan River natural flow into the Dead Sea In the absence of irrigation	1100-1400 1400✓ 1400✓ 1850 1348✓ 1440✓ 1250-1600	Klein, M. (1998). Al-Weshah, R. (2000). Jaber and Mohesen. (2000). Internet: http://www.unu.edu/unupress/unupbooks/80858e/80858E06.htm El Naser, H (1996) Johnton Plan, 1953-1955 Himmo and Sawalhi, 2003

As it can be seen, the figure of 1400 has the highest frequency in literatures. It also makes sense. If we simply sum up the Historical outflow of Tiberias Lake To the Jordan River (600), the flow of the eastern tributaries of the LJR (150-200) and the flow of the western tributaries of the west bank of the river drained as GW (125) and the natural flow of the Yarmouk river (470), we will end up with a figure about 1400. But please note that this figure is based that there was no irrigation of any scale, which is not completely true.		
The natural flow of the North Side Wadis including base and flood flows, Eastern bank of LJR	72.5✓ 56.7 40.54 50	Calculated from NWMP(1977), Please refer to **Table 3** Draft of NWMP,GTZ (2003) NWMP, JICA (2002) Calculated from Appendix 6 that include data from Nayef Seder (1992-2002)
GTZ, JICA, Nayef seder provide recent measurements and thus can't be considered in this scheme as a mater of the change in the hydrology due to the abstraction of ground water that constitutes the base flow of some wadis. The First figure represent the summation of the calculated total flows for each of wadis: Arab (31.4), Ziglab (10.5), Jurm(11.7), Yabis(7.8), Kufranja(6.8), Rajib(4.3) . Please refer to **Table 3**. Measurements for periods before 1977 (if any) would be even more reliable for drawing the scheme.		
The natural flow of the Zarqa River	90.7✓ 84✓ 68.3 85✓ 65	Calculated from NWMP (1977), Please refer to **Table 3** . Draft of NWMP,GTZ (2003) NWMP, JICA (2002) Khori,1981 Salameh and Bannayan, 1993
The figures are confusing and not easy to analyze. In most of the literatures, the figure is either between 60-68 or 85-90. However if we take into account three things: 1) Khori and the GTZ, 1977, provide measurements before the development of water resources. 2) Salameh (1993) argued that the hydrology of the river didn't change significantly although of the over abstraction due the increase of the recharge (industrial and municipal effluents). 3) Recent measurement of the GTZ, 2003, is 84. Thus the figure seems to be precise is around 85 which is also so close from the NWMP, 1977		
The natural flow of the South Side Wadis including base and flood flows.	30✓ 59.9 29.7✓ 45	Calculated from NWMP (1977), Please refer to **Table 3** Draft of NWMP,GTZ (2003) NWMP, JICA (2002) The JVA, hard copy from Mr. Nayef Sedr (the figure is for the period of 1995-2002)
The total base flow of Side wadis: Shueib (8), Kafrein (12) and Hisban (6.3) constitute about 26. The total flood flow of these wadis is about 4. All the figures are calculated from NWMP (1977), Please refer to **Table 3**. However, the oscillation between the figures of 30 and 60 may be refereed to whether the JV basin Gw is being considered or not. It is worthnotey to indicate that 10 are an existing renewable GW in the southern part of the JV.		
The Water (GW) drained from the eastern aquifer of the West Bank of LJR towards JV	125✓ 100 100-150	Internet: http://www.gci.ch/GreenCrossPrograms/waterres/gcwater/jordan.html Internet: http://law.gonzaga.edu/borders/water.htm Internet: http://www.mena.gov.ps/part3/40_m.htm
Yarmouk River basin of GW	127✓	Salameh and Bannayan, 1993
100 is estimated by Salameh to constitute the base flows of the YR and the NSW. About 40 constitute the base flow of the Yarmouk River (calculated from the NWMP, 1977) and 60 constitute the base flow of the NSW (also calculated from the NWMP, 1977). It is estimated also by Salameh that 23 of this basin doesn't appear as a base flow (Mukheibeh Wells)		
Water drained from the Yarmouk Basin (GW) into the Yarmouk River (SW)	40✓	Calculated from NWMP (1977), Please refer to **Table 3**.
Water drained from the Yarmouk Basin (GW) into the north side	60✓	Calculated from NWMP (1977), Please refer to **Table 3**

wadis (SW)		
Amman Zarqa Basin	88✓	This figure appears in most of the literatures including Salameh and Banayan book.
Water drained from AZB (GW) into Zarqa River (SW)	35✓	Salameh and Banayan (1993). It is stated that about 35 (GW) drained into the Zarqa River (SW)
Jordan valley Basin (JV floor and the southern escarpment)	30✓	Salameh and Banayan (1993). This include the renewable GW in the Jordan valley floor area of 20 and the southern part of the Jordan valley escarpment
Side wadis fresh water including the Zarqa river is estimated to	190✓ 185✓	El Naser, H 1996? Summing up the Zarqa river flow (85) the NSW (70) and the SSW (30) result in 85

Notes :

- Figures related to water are in MCM/year, population in inhabitants and irrigated area in hectares (ha)
- Data figures that are thought to be precise are marked all

Table 4: Validation of figures related to the hydro balance situation of the JRBJ situation for the period 1900

2. Institutional arrangement and water administration

Three main public agencies are vested with primary responsibility of water sector in Jordan: the Jordan Valley Authority (JVA), and the Water Authority of Jordan (WAJ) and the Ministry of Water and Irrigation (MWI)

The Jordan Valley Authority (JVA) is the governmental organization responsible for the social and economic development of the JRV. Originally established in 1972 as the Jordan Valley Commission, it was renamed "Jordan Valley Authority" in 1977, under the Jordan Valley Development Law of the JRV and its evolution as a permanent and structured development planning body for the Jordan Valley was a major new initiative in the evolution of integrated planning concept in Jordan (**Mallat, 2001**). This law was subsequently modified in 1988. The Jordan Valley Development Law (Law 19/88) constitutes a general law aiming at implementing an integrated water and socio-economic project taking into consideration all aspects of relevant to development (**Mallat, 2001**).

The JVA responsibilities are beyond the provision of infrastructure and waterworks and extend to the development of water resources and environmental conditions, protection and conservation of resources, and facilitating conditions for the welfare of the valley (**Daher, 2001**). Although the responsibilities of the JVA are identified by the Jordan Valley development law of 1988, it lacks autonomy and has a conflict of interest and unfair reciprocity relationship with several of the government's institutions, creating confusion with respect to its mission statement. The JVA provides services for other institutions while all sales taxes and revenues accrue to the central governmental treasury (**Daher, 2001**).

The Water Authority of Jordan (WAJ) was created under the law No. 18 of 1988. The WAJ is an autonomous corporate body with financial and administrative independence but its provisions could be partly in contradiction with rules binding official authorities. It has the responsibility to manage all the water and sewerage systems and related projects. The responsibilities and tasks cover areas like survey, development, regulation of water resources and study, design, construction, operation and administration of water and public sewerage project (**Suleiman, 2002**).

The Ministry of Water and Irrigation (MWI) was created under by-law 54 of 1992. The responsibilities of MWI include the formulation of national policies and strategies, planning of water resources development, procuring financial resources, and monitoring water and wastewater projects. The establishment of the MWI was in response to Jordan's recognition for a more integrated approach to effective national water management (**Nemer, 2001; Suleiman, 2001**). The Ministry has taken over the control of the above mentioned both water institutes in order to approach an integrated water resources management.

3. The Jordan River basin trajectory: historical transformation

3.1 Historical overview

Artifacts dating back to 400,000 BC have been found in all parts of the Jordanian desert and hillsides, and even in the foothills of the Jordan valley. Unlike the rest of the country, the valley's archaeological evidence only dates back to 10,000 BC. Two theories were proposed to explain the discrepancy. The first theory assumes the existence of a large water body stretching from the read sea in the south to Tiberias Lake in the north and covering the entire valley. A large inland water body, Lake Lisan, stretched from Lake Tiberias to the Dead Sea BC was formed in 100,000 and lasted until 20,000 BC, when it began to dry and shrink. By 10,000 BC, it was broken up into two inland water bodies: the Lake Tiberias and the Dead Sea and two dry valleys: the Jordan valley and wadi Araba in south Jordan. The second theory assumes that human beings have lived in the valley thousand of years earlier but their remains have been covered by successive earth layers accumulated from eroded soil of the eastern and western hills to form the valley floor that exists today.

Archaeological evidence indicates that the desert of Jordan was wetter than today, with huge lakes expected to be found there until 8000-6000 BC era, when the desert was last occupied, forcing people to move westward into the JV where water was available. Rock Basins and pools as natural water collection with enhanced construction storage were been modified for storage in the Neolithic period (**Lancaster, 1999**). After 6,000 BC, no evidence of human activities is found in the desert. By the late Neolthic and early Chalcolithic periods (4750-3750), Jordan's desert dried out and was emptied of its inhabitants. Only the Jordan Valley and the nearby hills sustained life, with population centers located near watercourses (**Khori, 1981**). The growth and development villages and larger urban centers has taken place for at least 5,000 years and has always been determined by the location of natural water resources.

Archaeological sites in JRB date back to Paleolithic, Neolithic, Chalcolithic, Bronze Age, Iron Age, Roman-Nabataeans, Umayyad, Mamluk and Ottoman Periods. Around 12000 BC, Landscape was domesticated and regional plant repertoire was in place (**Lancaster, 1999**). Evidences of human activities in the Jordan valley dating back to 10,000-6,000 BC era was found across the southern end of the valley, from Al-Jalil (Jericho), in the west bank of the Jordan River, which is considered the world's oldest occupied human settlement, to Rama, wadi Nimrin and Wadi Shu'eib in the East Bank.

The Neolithic period, 6500-4750 BC, witnessed the presence of large and small villages and nomad's styles of life. The economy of this period was mainly pastoral and rainfed farming of wheat, barley and legumes. Evidences of domesticated sheep, goats, cattle and pigs were found in the eastern desert of the country (**Lancaster, 1999**).

In the third century BC, in the early Bronze I-III era, cities associated with a cluster of nearby open villages and nomadic camp started to appear, overlooking the valley floor and located near one of the side wadis leading to the valley from the eastern hills. The JV floor was occupied by a large and sprawl farming communities in the era 2300-1950 BC (**Khori, 1981**). This period was characterized by a life style similar to that of recent Bedouin. Milk was firstly to be produced in this period and crops of olives, dates, figs, grapes, almonds and pomegranate were introduced in the Jordan valley (**Lancaster, 1999**). Research indicates that the area of the Basin flourished during the late Bronze Age (1550-1200 BC) when it traded with Egypt, Greece, Cyprus, Syria and Iraq. Proofs of long distance trade between Jordan and Yemen also exist. The side wadis were the only possible trade communication route that was active in the Bronze Age, connecting the eastern hills, Wadi Araba and the Dead Sea, South Palestine, and south west and the Sinai in Egypt (**Khori, 1981**). Camels are thought to be introduced in this period of time of which they provide significant role in the provision of transportation services for trading and pilgrimage activities afterwards (**Lancaster, 1999**).

The Iron Age I A-C (1200, 918 BC) was a period of strong foreign influence in the valley, and one of the few times in history when it was politically separated from the Hill country in the east. The Philistines had invaded the area about 1150 BC from their territories along the Mediterranean coast and heartland at Gaza and Asqalan and ruled the valley for 150 years. They were then defeated by David, who established a short-lived Israelite Kingdom which was split up into two states in 922 BC, and defeated by the Egyptians, loosening their control over the three native Arab kingdoms, Ammonite, Moabite and Edomite. The period 918 to 332 BC was a flourishing period for the Arabic kingdoms and a peaceful time in the valley as most of the people farmed in the valley floor and only few fortified hill cities are thought to be found. The first small sites of urban settlement were established in this era. The Edomites moved to the west of Wadi Araba and settled in Palestine, allowing for a new tribe, the Nabataeans, to move into southern Jordan from the Arabian Peninsula. Jordan was ruled by Greece from 332 to 63 BC, after they defeated the Persians, except for the south, which remained dominated by the Nabataeans.

In the era of Roman-Nabataeans, (63 BC to 332 AD), Ten Greek cities were joined together into a league of trading centers called Decapolis, after the conquest of Syria and Palestine by the Romans (**Khori, 1981; Abujaber, 1988**). From the middle of the first century and for about 100 years, these cites competed with each other to produce the most modern buildings, monuments and urban complexes, replicating Roman architecture. The Romans built some roads connecting Jordanian cities together and to regional Roman Cities like Bosra in Syria. International route passing through the valley and connecting the Mediterranean port of Haifa with Beisan in north Palestine, northern edge of the valley to southern Syria and Damascus was constructed. Another important route was the southern one passed through Wadi Araba, Ghaza, Petra and Aqaba (**Khori, 1981**). New villages were built at the edge of the desert. Building of village institution, administrative church community, houses and water channels were other signs of the period's prosperity. The economy relied on the flourishing of irrigated agriculture, agriculture industry, trade and Christian pilgrimages (**Lancaster, 1999**).

The Islamic conquest of the seventh century reached Jordan in AD 630-636 and the Ummayads ruled the area from their capital in Damascus for about 100 years. Meanwhile, Jordan continued to prosper being close to the centre of power (**Khori, 1981**). The dominated economy was agricultural, urban trade men and crafts. However, it deteriorated when the Abbasids moved the Islamic Caliphate to Baghdad in AD 750. Jordan reverted to a neglected sidelight to historical events, away from the main power centers and trade routes. Since then, the Abbasid, Fatimid and the Seljuk-Zengid era (AD 750-1174) was a period of general decline. The period was characterized by few stable communities, little productive activity, and insignificant construction.

The evidences indicate that the valley's history, like its twentieth-century experience, includes widely fluctuating periods of prosperity and paucity, war and peace, development and stagnation. It reached its peak in the Mamluk era, in the thirteenth, fourteenth and fifteenth centuries AD, and its lowest point during the Ottoman era, in the sixteenth to the nineteenth centuries.

In 1187, the Ayyubid leader defeated the Crusaders and the unification of Syria and Egypt marked the return of Jordan as a pivotal location in the middle of two great civilizations. The Ayyubid-Mamluk era (1187-1516) was a period of general revival of economic activity in the region that lasted until the Ottomans conquest in 1516. The period was characterized by the increase in urbanization and the institution of the Emirates of Arabs of which the government administration is not necessarily urban but peasants and Bedouin. Under the Mamluks, the Jordan valley reached the peak of its agricultural development, with sugar mills, driven by water, processing sugar cane in many parts of the valley. The area was one among few of the Mediterranean countries that had the potentiality to intensively plant and produce sugar cane on the world market size, which had a high economic value at that time. The population and productivity of the valley increased markedly in these three centuries. The favorable political conditions, population density and markets combined to promote farmers, food processor and traders to achieve optimum productivity during the fourteenth century (**Khori, 1981**). However, the sugarcanes industry declined when sugar industry was developed in Sicily and Spain. One can conclude that the period must have been a characterised by highly developed water resources to irrigate sugar cane plantation and to generate power to many mills.

The prosperity of the Jordan valley started to decline by the Mongul invasion in 1260 AD and after a second invasion in 1401, which left Syria and Jordan, destroyed. Most of the cities were burned including Damascus. A period of decline and disarray had started. The poor administration and the central government of the Mamluk aggravated by natural disasters, the spread of epidemic diseases from Europe, and the infrequency of the rainfall had terminated the valley's "wet phase" (**Khori, 1981**).

When the Ottomans invaded Jordan in 1516, they inherited an already degraded situation and made it worse by imposing high taxes on agriculture, land, commerce, and other forms of income sectors (**Khori, 1981; Lancaster, 1999; Abujabber, 1988**). As a result, the valley collapsed and since the time of 1600, it was almost deserted.

The population of Transjordan in 1596 was estimated at 52,000 people, of whom approximately 31,000 occupied the main towns and villages of the northern parts of Irbid, al Ramtha, Ajlun, Jarash, al- Gour and Al Salt (**Abujaber, 1988**). Mobile groups of Bedouins occupied the uplands located east of these villages. **Appendix 3** shows the significant socio-economic and political remarks of each historical period from the 12000 BC to 1946 AD.

3.2 Agriculture activities

Human beings first mastered cultivated agriculture somewhere near Al-Jalil, near the Zerqa River basin at the wadi Kufrein, 9,000 years ago. At Bab Al Dthraa',in the way to Kerak southward, excavations have turned up carbonized seeds from the world's earliest farming communities. Seeds of wheat, barley, fig, flax, chickpeas, lentils, grapes, dates and olives have been imported into the valley from the nearby hills. Other seeds of peach, almonds and pistachios are believed to be imported from the hills. Surface water was exploited for agriculture purposes around 8000 BC. The post-Pleistocene era witnessed a momentum towards the cultivation of plants and the earliest plant domesticates. In this age, animals were also domesticated. Foodstuff was exported to nearby states 5,000 years ago (**Lancaster, 1999**).

The first farming communities developed between 10,000-5000 BC in the southern part of the valley. Because of lack of technology, farmers relied on the side wadis and springs but not on the Jordan River. This part was much wetter than it today but by that time, it started to dry up. People started moving to the north, setting in motion an historical process of demographic movement and change that persist today.

Irrigation networks were built in the Bronze Age, more than 4,500 years ago. The Nabataeans, in the period 918 to 332 BC constructed extensive water collection and distribution systems in the southern part of the valley (**Khori, 1981**). In the Ummayad Caliphate period, many small farms were scattered through out the valley floor, and used irrigation systems that were first installed In the Roman times. Water reservoirs and channels were common.

Under the Mamluks, irrigation innovations and the world market demand sparked a large-scale sugar industry. Sugar mills were found in many parts of the valley, but were concentrated in the northern area above the Dead Sea. Other sites of sugar mills were found in the south of the Dead Sea. Some of these mills were still being used in the late 1960s. It might the first time throughout history that farmers used the Jordan River water and the side wadis to irrigate sugar plantation that must have approximately covered the entire valley floor. Aqueducts and simple stone canals diverted the water from the side wadis and let it to fall sharply to generate the power needed for the operation of the sugar mills. This was one of rare moments in history of the valley when human and natural resources joined together to achieve the maximum production (**Khori, 1981**).

4. The water resources pre-exploitation phase: 1800-1950

4.1 Socio-economic and political context

4.1.1 The nineteenth century

The Ottomans administration period was characterized by instability and depopulation in both the JV and the high land. Up to 1866, when the Ottomans central government started a land survey, the area was considered as a poor outlying district that did not deserve any attention. Bedouins tribes were the main inhabitants, who moved in and out from the high lands to the JV according to favorable climatic conditions. They were relying on livestock and rain fed crops faming as the main source of income. Pattern of settlements declined but villages and towns remains the center of economic and political activity. Farmers occupied the northern parts of the country around Al Salt and Ajlun of which the village settlement was the norm. The pilgrimage and the interregional trading accompanied the pilgrimage rout was an important factor in the rural economy of Jordan. At the end of the First World War, Transjordan, previously called the "south east Bilad al Sham" area came into existence in 1926 under the temporary British administration. It became fully independent in 1946 as the Hashemite Kingdom of Jordan, HKJ (**Abujaber, 1988**).

The agricultural economy which prevailed in Transjordan towards the 20th century defined three landscapes and greatly dependent on the annual rainfall. The upland relied on producing staple cereals, commercial crops of dried fruits, sheep and goats. The irrigated valleys produced grains and commercial vegetables, while the rain fed plains grew grains and provided commercial services. Cereals were planted around lowland springs while commercial fruits of grapes and figs were grown in the upland. Exchange of products and services took place through pilgrimage seasons (**Lancaster, 1999**).

In the JV, the political climate in the nineteenth century was less turbulent as the valley was a neglected corner for the Ottomans except as a source for tax revenues. The valley developed into regions of barren earth where no water passed. It turned out to wild, hot, inhospitable and dangerous area. The valley was mixed with patches of thick sagebrush-like vegetation near the foothills, wadis and source of groundwater. Settlers were scared by wild animals inhabited the valley and located around the relatively safe places that could be watered by simple canals from the side wadis (**Khori, 1981**).

The JV did not contribute to the development of agriculture in the country during the 19th century and it was only by the end of the 19th century and the beginning of the 20th century (1930s), that the valley's agricultural potential was increasingly recognized (**Abujaber, 1988; Khori, 1981**). Until 1950, the Valley remained only sparsely populated and of minor significance in terms of agricultural production (**Khori, 1981**). Attracted by the warm weather and the availability of the food for animals, nomadic Bedouins traditionally used the valley as a winter home growing wheat, barley, and corn, irrigated with the flow of the Yarmouk River and side wadis and moving back with their herds into the cooler hills in summer season, engaging in trade with city's merchants (**Khori, 1981; Lancaster, 1999**).

In the highlands, water resources only started to be tapped for agricultural purposes in the end of 19th century when agricultural expanded to the highlands areas. The last 25 years of this century witnessed the coming of new immigrants of Circassians, Chechen, and Palestinians from the western mountains, Egyptians, and people from Haurran near Damascus. Having been motivated by the moral responsibility as both a Moslim and a state, the Turkish Empire resettled the outsiders groups of Circassians originally migrated from the Caucasus in 1864, and Chichen during the period 1878 to 1906 who were confronted by difficult situation in the Caucasus and later on in the European regions of the empire as a result of military defeats on both fronts. The Chichen arrived in the years of 1902-5. These populations settled mainly in the highlands within a radius of 25 kilometer from Amman that were close to the running watercourses and became the centers for the newcomers (**Abujaber, 1988**).

The settlement operation was confronted by the original settlers, the Bedouins, who considered the new arrivals as competitors on water and pastoral rights. Later and reinforced by the legal and the militarily support of the Ottoman government, the relation became more normal and friendly. The newcomers were known for their interests in agricultural and pastoral activities and they were able by bringing the new farming techniques to improve the productivity of the agriculture system although they didn't make basic changes in the agriculture system itself (**Abujabber, 1988**)

The gradual growth of population resulting from natural or migration causes, the greater stability brought by the Ottoman administration after 1867, the control gained over the countryside, the increasing interest in farming as an economic venture, all contributed to an increasing demand for agriculture land. It was then that farmers started moving to the eastern districts in the area and around Amman, where much larger areas of land were brought under cultivation (**Abujaber, 1988**) and dense village settlement similar to the Byzantine and early Islamic periods started to be established (**Lancaster 1999**).

The increase demand for agricultural land has lead to the gradual increase of the inherent value of holdings for agricultural cultivation to replace the existing activities of pastures for flocks of sheep, goat and camels. The importance of landownership began to be realized (**Abujaber, 1988**). Practically and before 1880, land purchase and transaction was not existed and customary acquisition to land was based on what is called "tribal division" by agreement or sometimes by force (**Abujaber, 1988**).

Jerash, Ajlun and the slopes used to have intensive tree coverage, including oak, butm, seyal, and sidr. In the late 19th century, the expansion of agriculture, the increase in population, the replacement of local tree products by imported ones, the increase in the Ottoman central government demands for wood for building and their expansion, all contributed to the destruction of the trees. More forest trees were lost to provide firewood, building wood, and charcoal. After the 50s, land was cleared for the expansion of agriculture (**Lancaster, 1999**).

4.1.2 The Twentieth century

The twentieth century has witnessed fast moving political events. During the turbulent decades of Jordan's birth and youth (1926-1956), Jordan was cautiously established on erratic foundation of domestic, regional and international uncertainty and conflict. Its own self-perception as a nation-state had often been clouded by demographic disturbances, inter-Arab ideological rivalries, global strategic competition and a delicate domestic economy chronically kept afloat by injections of foreign aids.

By the early 1930s, a decade after the establishment of the Emirate of Transjordan, the developmental momentum in the young country started by addressing socio-economic aspects of the small, sparsely populated country. Several attempts of national hydrographic surveys and schemes were initiated in the late 1930s but the unruly political climate in the area blew them away.

The clash between the native Palestinians and the hundred of thousands of Jewish immigrants who were pouring into Palestine intending establishment a state on the already inhabited land happened during the 30s. Transjordan with its untapped water and agricultural potentials was envisioned by the international organizations as a destination for either the Jewish immigrants or for the resettling of Palestinians refugees. The Arab-Israeli war of 1947-48 resulted in a sudden influx of Palestinian refugees who settled in the west bank or crossed the Jordan River and gathered in the HKJ and later in the neighboring countries. The total population of Trasjordan in 1939 was estimated to be 325000 whose livelihood is almost exclusively agricultural and pastoral. In 1948, Amman was only a large village of 30,000 people. After the 1948 war, and overnight, Jordan found itself with triple of its former population, which was estimated, to about 1.5 million of people. The West Bank was annexed as an expanded area of the Kingdom. The refugee's factor had to be considered in the Jordan development plans. The need for a strict control of water resources to make living on the land possible was obvious. Many water projects and plans were proposed to tap water for agricultural purposes and to resolve the growing conflict between the riparian countries of the Jordan River. The projects were politically controversial and thus never implemented (**Appendix 4**).

The main planed water projects and changes altered the politics of the Jordan's and Yarmouk's River watershed will be highlighted in the following section.

4.2 The hydro-political context of the Jordan and the Yarmouk Rivers

Plans to develop water resources go back to the 1940s and 1950s, when different riparian countries developed individual programs for water utilization. In the 1950s, different plans were proposed to distribute the Yarmouk's watersheds into its riparian countries but never realized because of political pressures. The first plan came into sense in 1951 by Mills Bunger who envisaged a 480-foot high dam, Maqarin dam[15] , on the River to store 500 MCM for the irrigation of both Syria and the Jordan valley lands. The plan was attractive as it did not rely on the Tebrias Lake as a storage reservoir and could be implemented without the approval of Israel. The Israelis had protested in Washington that Bunger plan was a unilateral development plan of the waters to which it has riparian right. The protest succeeded and the US withdrew its intended finance.

In 1953, Syria and Jordan concluded an agreement to construct the Maqarin dam. Based on this agreement, Syria would use the higher springs of the River for irrigation while the balance of the water would flow downstream into Jordan and generate hydro-electric power for both (**Khori, 1981**). Israel during the period of 1950-1954 focused on the development of its National Water Carrier plan. It has used the Lake as a main storage reservoir and then pumped the Jordan River water outside the basin. The individual plans of water utilization have lead to disparities over water sharing.

The special envoy of the US president, Eric Johnston, devised a plan to placate all the parties to the disputed waters of the Jordan River. The plan was the first to address regional development for the entire Jordan River basin. The Johnston plan allocated annually 45 MCM

[15] Called later after the Jordanian –Syrian agreement the "Unity" Dam or "*Wehda*" in Arabic

to Syria, 774 MCM to Jordan[16], and 394 MCM to Israel. The Arab countries objected the plan as they perceived the water allocation was not fair and insisted that water should be remaining in the catchment area (**Khori, 1981**). The Israeli also objected the plan claiming that their water share was not sufficient and that the Lebanon's Latani River should be included if a regional agreement over water dispute was to be reached. The Israelis insisted on the diversion of the Jordan River to the Negav desert, out side the watersheds, and to use the Litani waters to produce power and to replace the diverted Jordan River water in Lake Tiberias. However, both parties agreed on the principle that all the riparian states have right to use the water of the Jordan River system. The both parties envisaged different allocation and proposed counter projects.

Based on a set of proposals from both parties[17], Johnston revised his plan and came up with the Unified Plan of 1955, which presumed that water would be diverted outside the basin only after in-basin users satisfied their water needs. The plan allocated annually 132 MCM to Syria, 720 MCM to Jordan, 35 MCM to Lebanon with all the rest going to Israel that is depending on the rainfall and run off and estimated of 400 MCM. The Johnston plan (1953-1955) devised that Jordan would be the principal beneficiary of the Yarmouk river. On the basis of this plan, Jordan would be able to use annually 377 MCM out of 492 MCM, the estimated average annual flow of the Yarmouk River at that time. Syria would utilize 90 MCM while Israel would share 25 MCM (**Hof, 1998**).

The plan was technically accepted but not politically approved and thus never realized multilaterally. Israel insisted on receiving 550 MCM and assigning the supervision water-sharing plan to the concerned states. The Arabs wanted the plan to be supervised by a strong international body. In addition, the American linked the financing of the project by resettling of the Palestinian refuges as a part of the project, which was denied by the Arabs. The plan collapsed and the trend to unilateral plans to tap the water resources of the Jordan River basin was initiated.

After the collapse of the Arab-Israeli negotiation, the Jordanian government decided to go a head with the construction of a canal in the eastern side of the Jordan valley initially fed by the diverting the free flow of the Yarmouk River, the East Ghor Canal[18] and explored the implementation process of the 1953 Jordanian-Syrian agreement to exploit the Yarmouk River. Israel, on the other hand, continued the implementation of its National Water Carrier project and since its completion, the water of the upper Jordan River is being utilized by Israel. As a corollary, Jordan and the West Bank have been denied to have their annual water share from the Jordan River.

Several proposals of a construction of diversion schemes were drawn by the Arabs to supply the Jordan valley from the diverted Jordan Headwaters in Lebanon and Syria but were never implemented. In the early 1963, a proposal on diversion of the Lebanese and Syrian headwaters of the Jordan River into the Yarmouk river water was presented by building two dams which were supposedly to be located astride the river on the Jordanian Syrian territory. The project was approved and financed by the Arab states. They started the construction of a small Dam, Khalid Ibn Al Walid in 1966. The project was seen as the first phase of a long term plan to harness the valley's important rivers and side wadis. When 20% of the construction was done in 1967, the six days Arab- Israeli War had resulted in the Israeli

[16] The West Bank was administratively annexed to follow the Hashemite Kingdome of Jordan after the Arab-Israeli war of 1948.
[17] From the Arab side, the proposal was based on Harza appraisal report for irrigation the Jordan valley on both of River's banks.
[18] The construction phase of the canal will be discussed later in the report

occupation of the Syrian Golan heights where the work was proceeding. The dam work was bombed by Israeli aircraft and the whole project was blown away (**Khori, 1981**)

Jordan has concluded separate treaties dealing with the Yarmouk with both of its co-riparians, Syria and Israel. A bilateral agreement was established between Syria and Jordan in 1987. If the treaty has to be completely implemented, Syria would be able to use some 170 MCM leaving about 284 MCM for Jordan and Israel, however; it exploits around 200-220 MCM of the Yarmouk River Water (**Hof, 1998**). The treaty compromise the construction of the Unity dam, Wehdah in Arabic, on the Yarmouk River (**Figure 12**), which would have a gross storage capacity of 225 MCM with effective storage of 195 MCM. Because of the regional political tension and the Israeli reservations over the project, a final settlement was not reached, undermining progress to set up the dam[19] that was agreed upon in the 1987 agreement between the two countries.

Another bilateral agreement over the Jordan River was reached between Israel and Jordan and annexed as article 6 in the peace treaty between them. The treaty enables Israel to capture its customary average of **70** MCM from the Yarmouk (Hof, 1998). Based on the agreement Israel is entitled to pump annually **25** MCM of the Yarmouk River and **20** MCM from the Yarmouk River water in winter but in return has to transfer **20** MCM from the Jordan River to Jordan in summer. This represent a quantity of water that Jordan most likely would miss anyway because of it inefficient diversion and storage capability. Israel is also committed to desalinate 10 MCM/yr out of 20 MCM/yr that already diverted as saline springs to the HKJ. Israel is entitled to provide Jordan with additional 50 MCM/yr of desalinated water with no guarantee that this supply can be achieved.

Deaumont (1997) argues that the treaty with regard to water does seem to confer the major benefits on Israel and fulfils all its ambitions. The idea of "equitable" distribution of water resources forwarded by the Johnston Plan has been ignored and replaced by what has been advocated by the Israeli academics of the importance of international law, rules and regulations in settling the water dispute. It guaranteed a water resources provision that annually totaled of at least 625 MCM, together with an extra 0 to 40 MCM from non-quantified extraction points on the Yarmouk and the Jordan. If only the guaranteed values were considered, it can be seen that Israel is using at least 225 MCM (56%) more water from the Jordan River than the 400 MCM allocated under the Johnston Plan. What is even most important is that, through this treaty, Israel has managed to guarantee that Jordan would not benefit or use other regional water resources from the Litani River in Lebanon or the Nile River in Egypt with out benefiting also Israel. It is worthnoty that Israel has always had ambition to abstract water from the Litani to supply the north of Israel and to abstract the Nile water to supply the Negev Desert.

Since the 1950s and despite the diplomatic approaches to have a good share of the Jordan and the Yarmouk Rivers, Jordan couldn't improve the situation which still leaves it with much less of anticipated water that it should have according to the plans and the treaties (**Hof.,1998**) and (**Deaumont,1997**).

[19] The dam is expected to control, on the average, only 85 MCM of un controlled flood

4.3 Water resources mobilization

The regional political circumstances and the growing population during the last 19th and the beginning of the 20th century initiated the necessity to carry out socio-economic development plans. Such plans have always included the expansion in agricultural land and consequently to the development of irrigation projects. This was accompanied by the increased appreciation of the JV agricultural potentiality. Dozen of plans were proposed to mobilize water resources in the Jordan valley but none of them was materialized. Developing the Jordan valley remained tangential to regional and international affairs. The first hydro-electric power scheme for the Jordan valley was set up in 1910 to build a canal of the same length of the valley in both banks of the Jordan River. The pioneering plan was interrupted by the World War I outbreak when the Ottomans lost the control over the Arab world and the region fall under the British-Franco colonization. The plan of construction a canal along the entire length of the valley was never realized before the early 1960s but with out a power generation and implemented only in the east bank of the river.

The idea of harnessing the valley's water resources for agricultural development was so compelling to the Jordanian central government to break people's historical dependence on the side wadis and springs. However, due to political, financial and technical constraints, minor irrigation schemes were started on the east bank of the valley as far as the early 1940s, generally related to harnessing the waters of the side wadis (**JVC, 1972**). In the Jordan valley, irrigation was needed at all periods and depended on the channeling of water from springs and the flood water in the wadi beds (**Lancaster, 1999**). Weirs and canals were built around the side wadis by packing mud in between stones, tree branches and shrubs, to direct the water into earth channels that led to the planted fields. From the main feeder channel, subsidiary channels are taken off at an angle to flow water in parcels of land (**Lancaster, 1999**). In the southern Ghor, the wadis were tapped by little channels on its left bank, so that the whole Ghor can be turned into a watered meadow (**Lancaster, 1999**). Much of water was evaporated or adsorbed into earth before reaching the cultivated area, which were flooded three or four times a year. Each heavy rain would wash out the irrigation systems, which had to be rebuilt (**Khori, 1981**).

In the period between 1949 and 1956, the irrigation section’s office, established in 1947 by the British colony, built diversion weirs and concrete canals on most important East Bank side wadis to irrigate farms located above the projected East Ghor Canal whose construction had become about to happen in the early 1950's. These were designed to improve the efficiency of the farmers' existing earth channels irrigated networks by reducing water loss and more efficiently diverting side waters to the cereal fields.

In the highlands, people were using some tanks and reservoirs constructed during Roman period to stock the water of wadis and springs and to use it for the irrigation of their small farms. A long wadi zarqa, water was carried in canals for the purpose of irrigation (**Lancaster, 1999**).

4.4 Agriculture activities

During the presence of the Ottomans in the basin, land was collectively owned and periodically distributed (**Lancaster, 1999**). This system, called the ‘mouchaa’, does not encourage people to own lands and to practice farming activities. Farming took place in the areas of Ajlun and al salat, Al- Balqa district (**Abujaber, 1988**). The settlement of the Circassian and Chechen on lands expropriated for tribes in the uplands initiated the land registration transactions in order, for the tribes, to use all their potential agricultural lands (**Lancaster, 1999**). Framers became active community by the end the 19th century. The newly cultivated areas were used for dry farming depending on rainfall and directed towards the production of cereals, barley in general and wheat in particular (**Abujaber, 1988**). Failure of rainfall over one or more than one year meant a hardship on all the living levels (**Abujaber, 1988**). In spite of the abundance of the running water in the wadis, except for the drought seasons, the topography of the land along the wadis did not make easy for the cultivation of more than limited irrigable parcels (**Abujaber, 1988**). Agricultural activity was combined with pasturage as the main resource of income. The upland produced mainly staple cereals, commercial crops of dried fruits such as grapes and figs. The irrigated valleys produced grains and commercial vegetables while the rainfed plains grew grains (**Lancaster, 1999**). The Jordan valley in the late 1930s and 1940s was mostly used to plant wheat, barely and corn.

Technical skills and agricultural services were poor. Most people cultivated their land in the traditional manner they inherited from their fathers. The transition to efficient and marketed agro-business was slow and erratic but it started to take place in the late 1940s (**Khori, 1981**).

Logistics for agriculture produce did not exist in both landscapes. In the high lands, carriages that were brought and modified by the Circassian were used for transport (**Abujaber, 1988**). In the early 1940's, two east-west roads, one in the northern valley and the second in the southern valley, were constructed connecting Trans-Jordan with Palestine that contributed significantly to the gradual transformation of farming to a production for market type (**JVC, 1972**)

4.5 Water management

According to the Islamic law and to the Ottomans code, water can be classified as common water, private and public. Water can be common such as seas, lakes, and unexploited groundwater. Running water can be either public or private depending on whether the bed in which the water flows is owned and where the water flows to un-owned property or owned land. Ownership of waters confers exclusive use and the right to sell water. While water can be sold, what is being sold is the service rendered and the work undertaken to capture the water. Ownership of water is acquired by inheritance, sale or gift of the property that receives the water (**Lancaster, 1999**). In this sense, cisterns, canals and weirs known to have been dug by particular groups or families and constantly maintained by their descendents are owned by them with preferential access.

People were using water flowing from springs and the small wadis. In the highlands, water resources were not yet considerably tapped for agricultural purposes. Water right had been linked with land property on the basis of conventional and traditional practices. Water right and access to irrigation water incorporated three systems. The first system is a common property regime that allows the landowners to access to channeled flooded water based on cropped land size. Representatives from the landowners build the canals and set up the irrigation schedules. The second system distributes water between different sharecroppers decided by the landowner. It is a mixed of common-private property right system. The last system, a private property regime, gives the right to own water found in land from springs or groundwater wells (**Nims, 2001**).

The Ottoman Sultan Abdul Hamid II enacted the first law with regard to water resources management in the region. The law provided the basis for the resolution of disputes over water and land ownership (**Nazzal, 2000**). The first law for managing water resources in the JV and land settlement was enacted in 1933 under the British mandate. The law aimed to demise the musha'[20] land property system leading to dispute and contradiction over land rights. The law registered water rights in the land ownership document (**Nims, 2001**).

Another water right law was enacted in 1946 and considered a turning point in the management of water for irrigation. The law recognized the traditional water rights, which have to be registered with the Department of lands and survey in the water register. Accordingly, the department issues registration bonds to show water share (m3/hour) per unit of land. However the law was also to recognize the joint responsibility of irrigation water management between the state and the landowners addressing only the management of surface water. The law was the first to differentiate between water rights and the right to use water and established a penalty system for violators. It also introduced the concept of payment for water as landowners had to pay for the canals construction and maintenance (**Nims, 2001**).

4.6 Hydrology scheme and Water areas Balance (1950)

The hydrological conditions, water uses and water areas balances of the JRBJ on the 50s is represented in the following scheme (**Figure 9**). The validity of the represented figures is achieved by data source triangulation as shown in (**Table 5**)

[20] A system of tribes land property and rights in Jordan of which each tribe has claimed a boundary for its land.

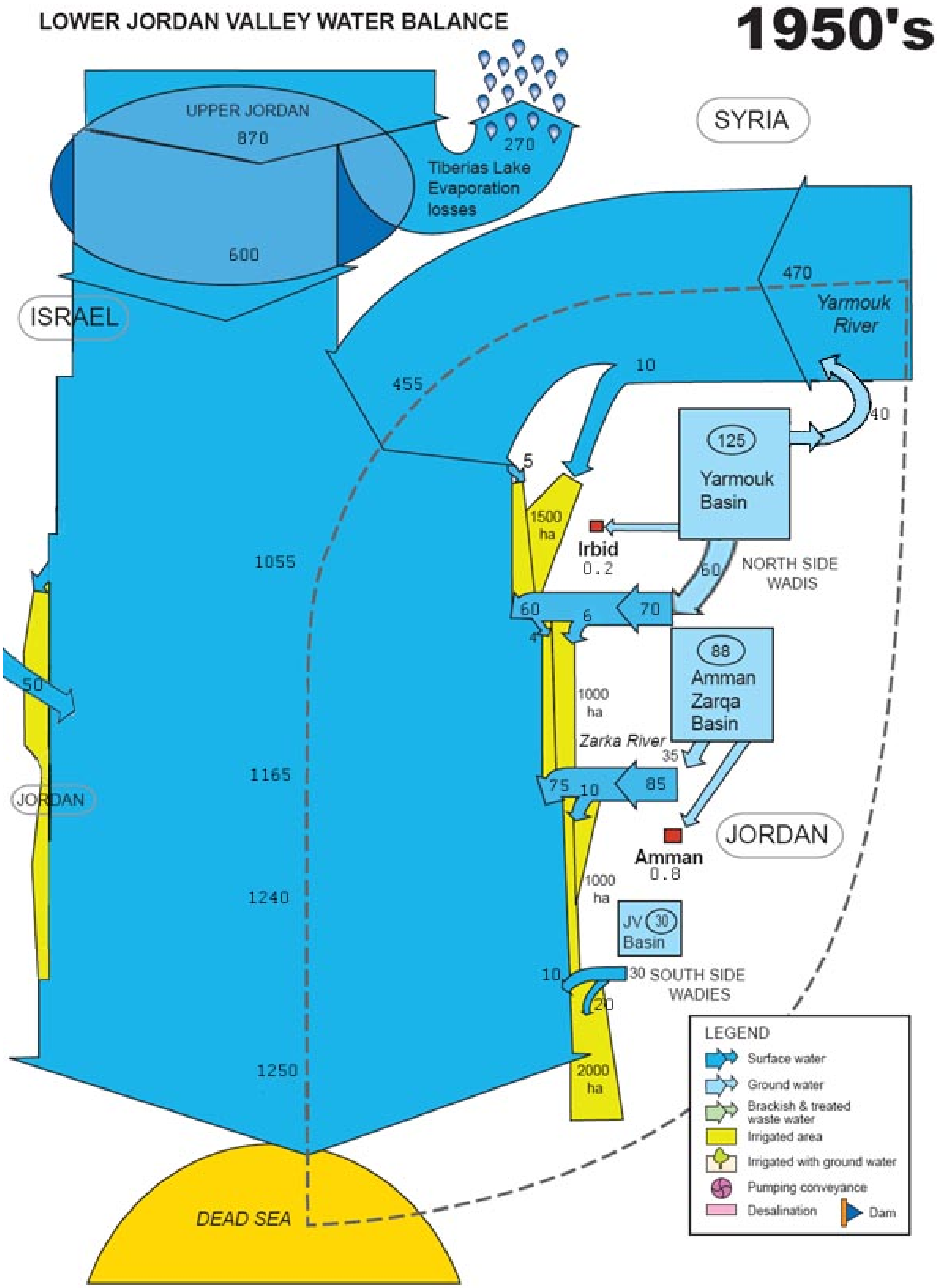

Figure 9: Water balance scheme of the JRBJ (1950)

Data issue	Data Figure	Source/Estimation
1.Upper Jordan Natural flow in Tiberias lake	870	Klein,M (1998). Refer to the hydrological conditions and water budget of the JRBJ (1900)
North (Eastern) Side Wadis flow in the Lower Jordan River	60	70 is the natural flow of the NSW calculated from the NWMP, 1977 and it is estimated that 10 was being used from the wadis for the irrigation of 1000ha
Zarqa River flow in the Lower Jordan River	85	It is estimated that the natural flow in the hydrology scheme is 85 and it is estimated that about 10 from the river is used in irrigation of the 1000ha and thus the rest is 75
South (Eastern) Side Wadis flow in the Lower Jordan River	10	30 is the natural flow of the SSW calculated from the NWMP, 1977 and it is estimated that 20 was being used from the wadis for the irrigation of 2000 in south Ghor. The rest is thus 10
Surface area of the Northern plots irrigated in the JV	1500	Mr. Serpekian estimated the total area that was irrigated in the Jordan Valley (JV) as 55,000 dunums. He said also that the zor land was cultivated at that time. The 55,000 dunums were divided roughly into almost equal areas as shown in the scheme to reflect the indicatively scale of irrigation but in a real geographic figures.
Surface area of the Northern plots irrigated in the JV	1000	
Surface of the Middle plots irrigated in the Jordan Valley	1000	
Surface of the Southern plots in the Jordan Valley from the Southern wadis (East)	2000	
Surface of the irrigated plots in the Jordan Valley from the Wadis (The West Bank of the Jordan River)	~10000	It is estimation. At the moment no literatures is available on this data issue but taking in consideration that agriculture in the West Bank was more practised, one can conclude a figure that is doubled of irrigated land on the East Bank (100000 dunums). Further investigation needed.
Water used to irrigate the Northern plots in the Jordan Valley from the Yarmouk	15	This is estimated based on the acreage of the cultivated area at that time. I assume that 1500ha needs about 15 MCM water based on the fact that in recent times 220MCM was used for irrigation of 24,000ha, although the change in cropping pattern and variation in crop requirements is recognised.
Water used to irrigate the Northern plots in the Jordan Valley from the Northern wadis	10	This is estimated based on the acreage of the cultivated area at that time. I assume that 1000ha needs about 10 MCM water.
Water used to irrigate the Middle plots in the Jordan Valley from the Zarqa River	10	This is estimated based on the acreage of the cultivated area at that time. I assume that 1000ha needs about 10 MCM water.
Water used to irrigate the Southern plots in the Jordan Valley from the Southern wadis (East)	20	This is estimated based on the acreage of the cultivated area at that time. I assume that 2000ha needs about 20 MCM water.
Water used to irrigate the irrigated plots in the Jordan Valley from the Wadis (West Bank)	~ 75	It is an estimation based on the irrigated land. Further investigation needed.
The Water (GW) flows from the eastern aquifer of the West Bank of LJR towards JV (after irrigation use)	~50	By Calculation. If we abstract the estimated irrigation use (75) from the available (125), Refer to the hydrological conditions and water budget of the JRBJ (~1900) we would end up with 50.
Population of Amman	~800,000	Appendix 1 shows that the total population on 1950 was ~1,200,000. One of these sources estimated Irbid's population ~200,000 and Amman's population ~800,000 http://www.library.uu.nl/wesp/populstat/Asia/asia.html
Population of Irbid	~200,000	
The water of Jordan reaching the Dead sea	1250	Calculation the water flows to the Jordan after abstraction the estimated irrigation use. This figure is also based on that no water was used for irrigation at the Syrian side that can't be absolutely true.

Table 5: Validation of figures related to the hydro balance situation of the JRBJ situation for the time of 1950

- Notes: Figures related to waters are in MCM/year, population in inhabitants and irrigated area in hectares (ha)

5. The water resources exploitation phase: 1950-1975

5.1 Socio-economic and political context

In the last 1940s, the Jordanian central government was anxious with the post 1948 war realties of coping with the sudden influx of the Palestinian refugees. In the early 1950s, Jordan was a country of chaotic finance, general unemployment, with no economic activities or infrastructure. Lack of water development prohibited irrigation of any magnitude during the drought years. Farmers practiced rainfall agricultural activities. However, when the rain is deficient, they could not easily overcome the hardened situation. Water and people played decisive factor in the development and stagnation of the Jordan valley, and later, of the young state's brittle economy.

The June 1967 war another historical benchmark, which resulted in another massive influx of Palestinian refugees. People could not stand the four chaotic and frustrating years, which followed the war. The stay in the valley was dangerous and difficult. The Israelis routinely bombed or mined the recently constructed main irrigation canal[21] , EGC, and its substructures and the country was a helpless victim of the regional hostilities. The destruction and human displacement caused by the Arab-Israeli war threatened not only the agriculture productivity of the valley itself, but also the very fabric of the Jordanian economy as a whole. The Valley was emptied of its pre-war 60,000 population who fled to the highlands of Amman, Irbid, Salt and Zarqa (**Khori, 1981**). The internal clashes between Jordanian and Palestinian forces in 1970-1971 had extended the period of chaos in the valley (**Khori, 1981**).

When calm was restored in the late 1971, the development and rehabilitation of what had been destroyed and the integration of Palestinian refugees was vital. The government envisaged the development of the Jordan valley partly as economic project, but also in pursuit of other regional goals. In particular, the area had and still has strategic importance, lying opposite to the West bank and Israel. The political climate implied the sense of fighting and the government has always wished to maintain a large and prosperous population in the area.

A comprehensive and a regionally integrated socio-economic plan was formulated by the Jordan Valley Commission (JVC) from which today's Jordan Valley Authority originated, during the period 1971-1972. The plan "Rehabilitation and Development of the Jordan Valley (East Bank): 1973-1975" was differed significantly from past attempts by the provision not only of agricultural services but also of all village-based and rural society human services such as roads, housing, schools, electricity, and health caring and commercial centers to raise the social and living standards of the inhabitants. The plan was coincided with the three years national plan and introduced the concept of integrated regional development. It included a political dimension-to test the attachment of people to the land in order to prevent any further occupation attempts by the Israelis, to invest in the middle of the war zone, and to inject money in a traditionally erratic sector of the national economy.

When the plan was conceived, 1971 (**Khori, 1981**), there were only 5000 people living in the valley compared to 60,000 before the 1967 war. The plan aimed to attract new residents and to fully exploit the 360,000 dunums of cultivable land. The country conceived the strong agriculture sector as a basis for self-sufficiency and hence the Jordan Rift Valley was considered as the vital core of Jordan's economic aspirations.

[21] The construction started on 1958

Half the estimated budget of the plan was allocated for the development of irrigation works and the rehabilitation of the existing irrigation system. The JVC was established in 1 February 1973, which its main aim was to implement the 1973-75 three years plan. The plan was extended beyond the over ambitious scheduled time implementation due to different reasons and spanned the period from 1975 to 1982 under the crucial demand of social services and settlement infrastructure[22]. This encompass the lake of finance, the complicated requirements of the international financiers, lack of expertise and local government support in addition to the inflationary years of 1974-1976. The control over the full responsibilities of the water works required the development of the JVC to the Jordan valley Authority in May 1977.

In the Highlands before the 1950s, most of the inhabitants were nomadic Bedouin tribes who occupied mainly the area of Mafraq and Zarqa governorates in the AZB and who referred to their region as the Badia. In the early 1940s, the government introduced irrigated agriculture in an attempt to test the dubious Bedouin attachment to land and to assist them in settling down. They shifted from animal husbandry to agriculture activity, in which they had virtually no knowledge or experience (**Jabarin, 2001**). In the 1930, the first wells were dug and water was pumped from Azraq to Mafreq (**Lancaster, 1999**). The shift initiated the exploitation of groundwater resources. However, the large scale exploitation of groundwater in the highlands can be traced back to the 50s and 60s when the diesel motors pumps were heavily introduced.

5.2 Water resources mobilization

The construction of the East Ghor Canal[23] (EGC)

The first appraisal survey giving a precise data on how much water would be needed to irrigate the valley floor was carried out by Harza Engineering co. of Chicago. The appraisal survey was done to include both banks of lower Jordan River. The appraisal report recommended an intensive irrigation project covering 296,000 dunums in the east bank and 165,000 dunums on the west bank. The plan aimed at irrigation of 514,000 dunums of land on both sides of the river, using 760 MCM of water a year, half from the Yarmouk and the balance from the Jordan River, the side wadis and small springs. It was based on the usage of the Lake Tiberias as storage and regulation reservoir for the Yarmouk River, supplementary storage dams would be built on the Yarmouk itself and a gravity canal distribution system would deliver the water to farms throughout the valley (**Khori, 1981**). The report included the first comprehensive soil analysis and land classification ever done for the entire valley, on both sides of the River giving the government an imperative data for any coherent attempt to develop the valley's agricultural potential. The plan targeted at to break the historical pattern of the ever lasting farming and pastoral nomadic by making efficient use of the water resources to maximize productivity and to enhance the living standards of the residents and families income. At the time of the plan's presentation, mid-1955, less than half of the valley's arable land was irrigated and about half went to produce cereals (**Khori, 1981**). The plan could not be materialized because of political dispute around the Jordan River watershed as described in earlier section. However, the canal, the East Ghor Canal, was constructed but to irrigate the East Bank of the river.

Under the department of Public works, the department of Irrigation and Hydro-Electric Power which was emerged from the irrigation section, designed the construction specifications of the first phase of the East Ghor Canal in 1957 (**Khori, 1981**)

[22] People were still living in scattered settlements of mud houses and brick rooms and tent
[23] Later Called the King Abdullah canal- after the first King of Jordan

The implementation of the first water development project was initiated in 1958 when a 69 km long canal started to be constructed. The concrete-lined gravity canal fed by a one km long diversion tunnel running underneath the mountain between the Yarmouk River and the village of Adasiyeh in the north, dropping sharply down from an elevation of -210 to -214 m BSL. Lateral channels branch off the main canal to reach the farmlands. The work was divided into three sections to irrigate a total of 11,700 ha in the northern Jordan valley or Al Ghor. The ambition of the time was to construct a 105 km canal along the whole JV. The canal -the East Ghor Canal (EGC)[24] started to operate in the early 1966. It was a turning point in the modern history of the JV, marking a shift from classical cereals planting to large scale irrigation of high value production of marketable fruits and vegetables. The progress that had been achieved in the few years following the canal operation was dramatic but all was disrupted again by the 1967 war (**Khori, 1981**).

A land distribution scheme was launched in 1962 according to the terms of the East Ghor law, breaking up very large land holdings and allowing more families to live off the rich land. The program aimed to establish a social equity. The redistributed farming land had the right to access irrigation water due to land size and crop type (**Nims, 2001**). Farming licenses were given according to an order of priorities and farmers were not also allowed to sell their licenses except for a family membership. Water irrigation rights were arranged informally between farming communities.

5.3 Agriculture activities

In the period between 1950 and 1960, before the canal operation, farming developed in the valley due to two main reasons: the influx of agriculture-oriented Palestinian refugees and the capitalist impulses of famous landowning Jordanian families. The cultivated area increased and farmers moved from cereals production into the more profitable vegetable production. Cultivated area is estimated by Mr. **Avedis Serpekian**, the former JVA Secretary General, through an interview on October 2003 to 5500 ha. He also said that the Zor land was cultivated at that time. Vegetables farming in the valley spread and reach a momentum (**Khori, 1981**). Fertilizers and chemicals were never used before the 1960s, as the land was deep and rich. Agricultural production had been sold to nearby market cities in Palestine and Trasjordan (**Khori, 1981**). The new constructed roads connecting north with west and another connecting east with west were constructed rendering local markets and the adjacent countries to be more accessible to the production of the JV (**JVC, 1972**).

When the EGC started to operate in the early 1960s, the JV has shifted from classical cereals planting to large scale irrigation of high value marketable fruits and vegetables. In the 1965-66, season vegetables, cereals, fruit tress accounted for 53%, 44%, 3% respectively of the cropped area of the valley (**Khori, 1981**) using surface irrigation by gravity which lasted until 1976. The post canal studies indicated that the EGC substantially increased irrigated farmlands and contributed to a remarkable growth in the agro-business. The land is privately owned and the government didn’t impose a cropping pattern on the farmers. The valley's crop pattern tends to follow free market forces. The maximization of agriculture production was crucial for the Jordan's overall economy. The agricultural area was of a significant scale to fill its trade gap and to increase its productive capacity (**Khori, 1981**). People living in the high lands were attracted to move in the JV and to be involved in farming or other available jobs.

[24] It was later called King Abdullah Canal (KAC) after the first King of Jordan.

The population of the valley reached 66,900 by 1974, compare to less than 5000 post-war 1967 (**Hunaiti, 2002**)

Wadis and springs irrigated fields above the East Canal. Pumps and plastic pipes take water from springs in the wadi bed gravels to new gardens on the slopes high above the springs. Water was pumped into artificial ponds made by excavating a large pit with a bulldozer and lining this with heavy polythene. The ponds were located at the highest point of the garden and the water is gravity fed through plastic pipes to trickle irrigation piping along the crops rows (**Lancaster, 1999**). The development of the southern part of the valley (Karamah area) was mainly based on the usage of the groundwater resources, with more wells drilled and more land irrigated.

The construction of the Esat Ghor Canal resulted in the shifting of the control over water resources to the State. Before any government was involved, farmers had traditional systems for sharing water resources. A complicated, but workable system of water distribution, based on both social connections and financial arrangements had developed over hundred of years. The system became obsolete when the government took over management of JV irrigation in 1977. Since then farmers have to apply for acquiring irrigation water based on their land size and plot according to pre-setup irrigation schedules (**Nims, 2001; GTZ, 2002**).

In the mid 1970, and despite the introduction of the rehabilitation work, cultivation techniques were that same ones that had been used by valley farmers for the past 40 years. Vegetables and fruits were irrigated with inefficient old fashion methods. The use of fertilizes and chemicals were not based on the technical requirements of the farms. Seeds were planted manually and the wastage was high. Three cultivation seasons were applied from: September to January, March-April to June-July and another season falls between the two outer seasons. Products were easily exported by trucks to the Kuwait, Saudia Arabia (SA), and Iraq (**Khori, 1981**)

5.4 Water management

Set of laws was issued during this period to develop the institutions of water management. The Law of 14/1959 allowed establishing the East Ghor Valley Authority when the EGC started to be constructed and the Law 51/1959 to create the Central Water Authority (CWA). The Law of 37/1966 enabled the reforming of CWA into the National Resource Authority (NRA). Law 56/1973 was to create the Drinking Water Corporation (**Mallat, 2001**).

The Municipality law of 29/1955, enacted in 1955, gave the government authorities of Amman and other legally formed municipalities the legal capacity to own and operate water systems and to specify standards for water system construction and to set fees for water use. It also assigned the responsibilities of prevention the pollution of water courses. The law also provided the government the power to construct public sewers and undertake the management and supervision of the sewers (**Nazzal, 2000**).

The Natural Resources Agency was created in 1965 to manage the development and conservation of Jordan's natural resources and was given the powers over mineral and petroleum resources as well as setting policy on water resource development and irrigation (**Nazzal, 2000**).

5.5 Hydrology Scheme and water area balances (1975)

Irrigation water consumption, available water resources, water resources uses of the JRBJ were calculated from the National Water Master Plan for the year 1975 (**NWMP, 1975**). **Table 6** shows the water available (including the imported water from other sub-basins) and water uses in each area of our basin at the time of 1975. **Table 7** shows the population estimates of each catchment area of the JRB. **Figure 10** & **Table 8** shows the location of irrigated lands, the total use of irrigation water and the main source of water used.

Figure 11 illustrates the hydrology scheme based on the collected data from the National Water Master Plan (1977) while **Table 9** shows data extracted from the plan for water available resources and uses on 1975.

Sub-basin	Water resources, uses and the area of irrigated land in the Jordan Basin in Jordan, 1975									
	Water Resources				**Water Consumption (uses)**					**Irrigated land (ha)**
	Total available	SW	Renewable GW	Abstracted GW	Total use	Irrigation	Industrial	Municipal	Others	
YRB	140	125	40	15	7,7	5,4		2,3		531
JV	12		20	12	135,2	134,4		0,8		16159
NSW	87	79,3	20	7,7	11,3	7,8		3,5		2148,5
SSW	44,3	34,3	10	10	26,1	23,6	0,3	2,2		
AZB	135	91	88[25]	44,7	109,8	79,7	5,2	24,9		6574,5
Total	432,3	329,6	178	89,4	290,1	250,9	5,5	33,7		25413

Table 6: Water uses, resources and irrigated land in the JRB's areas in 1975

Source of figures: National Water Master Plan 1977, area balances map

Catchments code	Catchment name	Area (km^2)	Population
AB	Jordan Valley	1,007	99,495
AD	Yarmouk	1,314	172,815
AE	Wadi Arab	267	169,990
AF	Wadi Ziglab	106	20,504
AG	Wadi Jurum	22	1,419
AH	Wadi Yabis	124	14,546
AJ	Wadi Kufranja	111	17,519
AK	Wadi Rajib	85	1,512
AM	Wadi Shueib	178	51,368
AN	Wadi Kafrein	189	24,493
AP	Wadi Hisban	82	2,980
AL (AZB)	Amman-Zarqa- Basin	3,696	1,115,214
Total JRB	Catchment A	7,181	1,691,855
AE,AF,AG,AH,AJ,AK	North Side Wadis (NSW)	715	225,490
AM,AN,AP	South Side Wadis (SSW)	449	78,841
Total (Jordan)		88,698	1,952,000

Table 7: Population records in the JRBJ and in each catchment area of the Basin (1975)

Source: Volume III: "Socio-Economic Aspects", Annex 1, Table 2 and 3, National Water Master Plan (NWMP, 1977)

[25] I do believe that there is double accounting here. 35 MCM of the AZB ground water constitute the base flow of the river. So it should be either calculated as Ground water or surface water but not both as it is the case here.

Irrigated area Code	Located in Sub-Basin	Total irrigated area (dunum), 1 du=0.1ha		Main source of Irrigation	Irrigated water Use MCM/ year		
					Total	GW	SW
AD12	Yarmouk River Basin	5310		SWR and GW	5.4	5.3	0.1
AB12	North Ghour JV, area between Yarmouk River and wadi Yabis	67395		SWR and springs	64.6		64.6
AB13	Middle Ghour JV, area between wadi Yabis and wadi Zaraqa	66960	Total area (JV) 161590	SWR and springs	49.9		49.9
AB14	South Ghour JV, area between wadi Zaraqa and Wadi Shueib	27235		GW and springs	9.3	5.1	4.2
AB15	South Ghour JV, area between wadi Shueib and Dead Sea			GW and springs	10.6	2.3	8.3
AB 22	Catchment between Ziglab and Jurum wadis	75		Springs	0.1		0.1
AB23	Catchment between Jurum and Yabis wadis	50		Springs	0.05		0.05
AB24	Catchment between Yabis and Kufrinja wadis	250		Springs	-	-	-
AB26	Catchment between Wadi Hisban and Dead sea Basin	670	Up hills	Springs	1.3		1.3
AE	Wadi Arab catchment	230	Total area	Springs	0.75		0.75
AF	wadi Ziglab catchment	80	21485	Springs	0.1		0.1
AG	wadi Jurm catchment	100		Springs	0.15		0.15
AH	wadi Yabis catchment	2300		Springs	2.2		2.2
AJ	Wadi Kufranja catchment	2410		Springs	2.1		2.1
AK	Wadi Rajib catchment	1780		Springs	2.8		2.8
AM	Wadi Shueib catchment	2490		GW and Springs	3.5	0.9	2.6
AN	Wadi Kafrein catchment	7875		GW and Springs	11.1	1.5	9.6
AP	Wadi Hisban catchment	3175		GW and Springs	3.6	0.4	3.2
AL73	South east Amman-Zarqa, wadi Dhuleil-Hallabat	29100	Highlands	GW	45.6	45.6	
AL32	Amman-Zarqa, Middle south	9535	Total area	SWR and GW	13.5	10.9	2.6
AL11	Amman-Zarqa, West north	12525	65745	SWR, springs and GW	16.6	9.9	6.7
AL21	Amman-Zarqa, Middle west	1095		Springs and GW	No data		
AL23	Amman-Zarqa, West	2070		Springs and GW	4	2.2	1.8
ALO	Lower catchment between Deir Alla and JV region	5795		SWR	3.9		3.9
		5625		SWR			
		248820			251.15	84.1	167.05

Table 8: Location, acreage, and water source of irrigated land of each Sub-basin of the Jordan River basin in Jordan (1975)

Source: National water master plan, maps of

- Location and acreage of irrigated areas.
- Water for irrigation, average year conditions

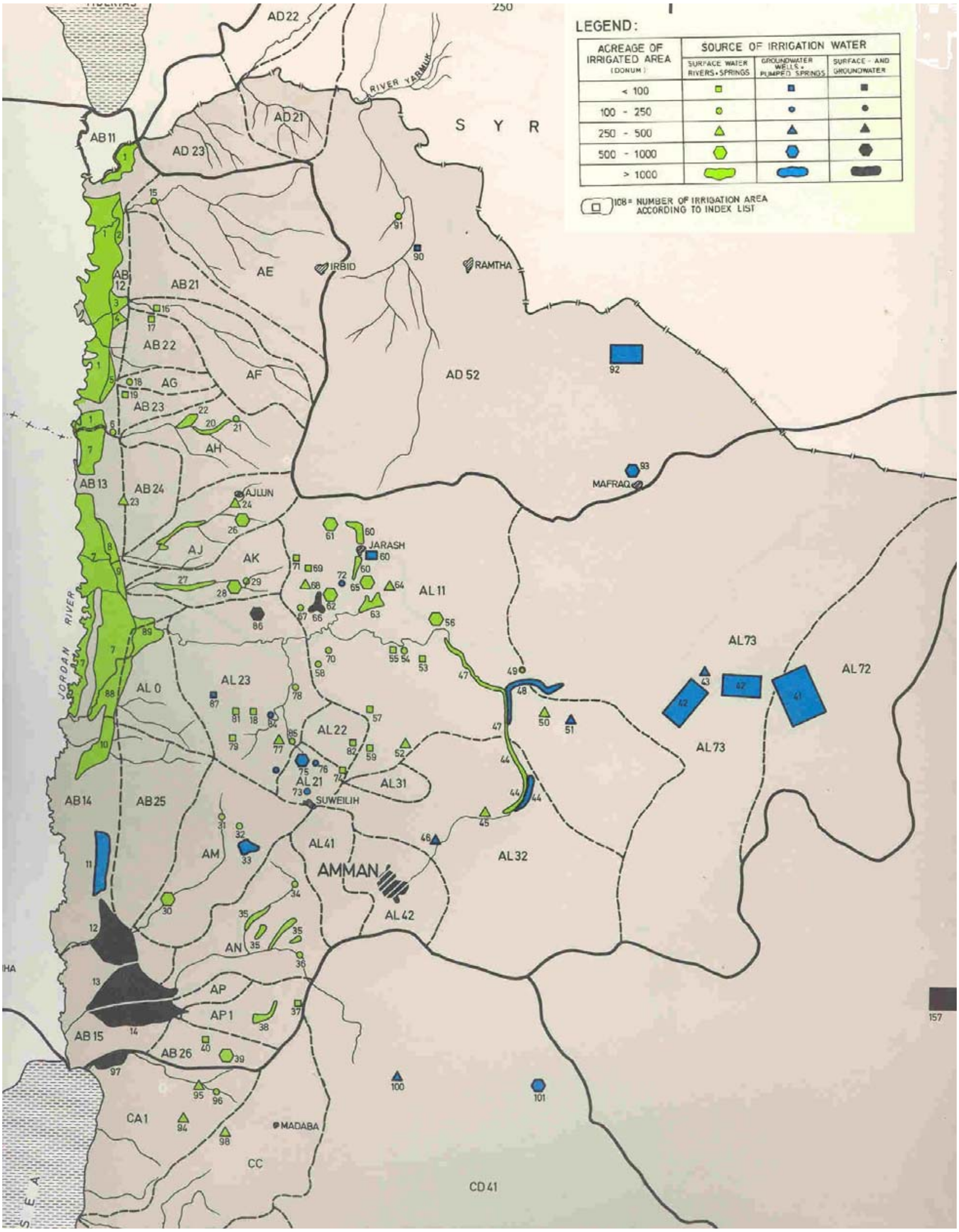

Figure 10: Shows the location of irrigated land in each area of the JRB and identify the source of irrigation water (Surface, ground or mixed)

Source: National Water Master Plan (NWMP, 1975)

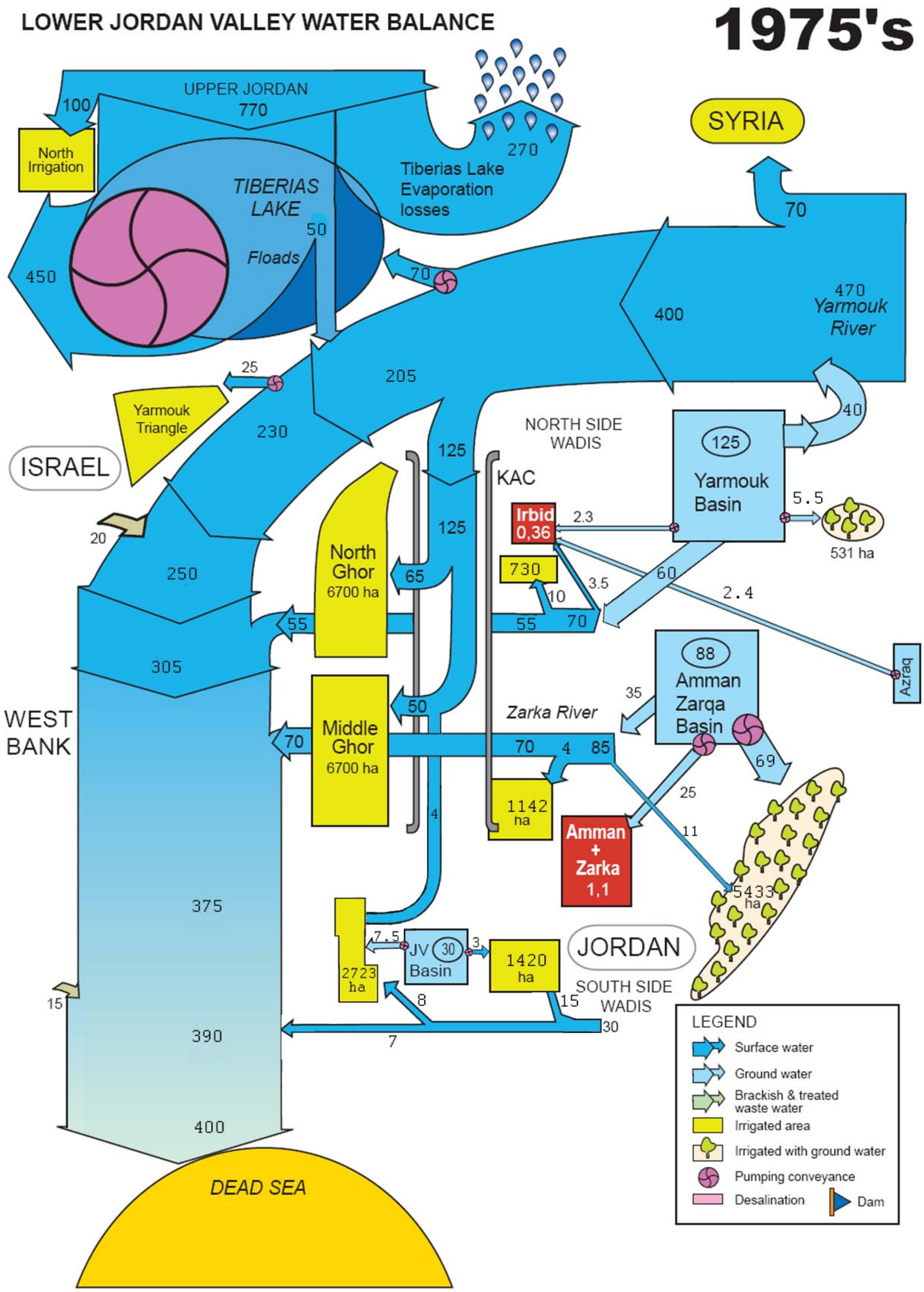

Figure 11: Water balance scheme of the JRBJ (1975)

Data issue	Data figure	Source
Water use for irrigation in Huleh valley in Israel from Upper Jordan	100	http://www.unu.edu/unupress/unupbooks/80858e/80858E06.htm
Natural Outflow of Tiberias Lake as flood	50	Calculated based on water balance of Lake Teberias
The Syrian Water abstraction from Yarmouk	70	The total water volume of Yarmouk basin, NWMP, 1977, the map of potential surface water resources, is calculated as 400. The natural flow of the Yarmouk River is 470 so the difference is believed o be used for irrigation in Syria.
The Israeli water abstraction from Yarmouk for storage+ irrigation of the Yarmouk Triangle + use in Golan settlement	70+25+?✓ 70+not identified volume+6✓ 70-100✓	Hof, F. C. (1998). In his article he didn't mention any use in Glolan settlement El Naser, H 1998, He stated that 70, annual average depending on storage and flood, parts is being used for irrigation the Yarmouk triangle and 6 is used in the Settlements. Inernet: http://www.transboundarywaters.orst.edu/projects/casestudies/jordan_river.html If we sum up 70+25+6 we get about 100 as all sources listed aside indicate
Water pumped from Tiberias Lake to the Israeli National Carrier	420-460 ✓ 405 420-450✓ 450✓ In exess 450✓	Internet: http://www.passia.org/publications/bulletins/water-eng/pages/water04.pdf Klein, M. (1998) Internet: http://www.fsk.ethz.ch/encop/13/en13-ch1.htm#Surface_water_resources Internet: http://www.gefweb.org/Projects/Pipeline/Pipeline_6/Jordan_Water_Quality.pdf Beaumont, P. (1997)
Saline springs diverted by Israel to the Jordan River	20	It is an estimated figure based on the saline springs diverted today (40-50)
Saline springs diverted from the West Bank to the Jordan River	15	It is also estimation.
Water diverted from the Yarmouk River to the JV	125	NWMP, 1977, Water use for irrigation, present situation map
Northern Ghor irrigated Area	6739,5	Calculated from the NWMP, 1977, map of location and acreage of irrigated areas. The area of AB12 (**Table 8**)
Middle Ghor Irrigated Area	6696,0	Calculated from the NWMP, 1977, map of location and acreage of irrigated areas. The area of AB13 (**Table 8**)
Surface of the southern plots in the Jordan Valley covering the area along lower wadi Zarqa, lower Shuieb, to the Dead Sea	2723,5	Calculated from the NWMP, 1977, map of location and acreage of irrigated areas. The area of AB14, AB15 (**Table 8**)
Surface irrigated area along wadis Shueib, Hisban and Kafrein to the Dead Sea	1421,0	Calculated from the NWMP, 1977, map of location and acreage of irrigated areas. The area of AB26, AM, AN, AP (**Table 8**)
Irrigated Area along the Northern Wadis	730	Calculated as the sum of irrigated areas of AE, AF, AG, AH, AJ, AK, AB22, AB23, AB24 from the NWMP, 1977
Irrigated Area between Deir Alla and JV region (lower catchments of zarqa river, proximate to the JV	1142	Calculated from the NWMP, 1977, map of location and acreage of irrigated areas. The area of ALO (**Table 8**)
Irrigated Surface in the Yarmouk basin	531	Calculated from the NWMP, 1977, map of location and acreage of irrigated areas. The area of AD12 (**Table 8**)
Irrigated Surface in the Amman-Zarqa Basin	5433	Calculated from the NWMP, 1977, map of location and acreage of irrigated areas. The sum of areas AL73, 32,11,21, and 23 (**Table 8**)
Water from KAC and springs to Northern Ghor	64.5	´The figure is explicitly identified from the NWMP, 1977, Water use for irrigation, present situation map
Water from KAC and springs to Middle Ghor	49.9	The figure is explicitly identified from the NWMP, 1977, Water use for irrigation, present situation map
Water pumped from Jordan Valley Basin to irrigate the southern plots	7.5	Calculated from NWMP, 1977, Water use for irrigation, present situation map. Refer to **Table 6**, the GW used to irrigate areas AB14 and AB15

Surface water to irrigate southern plots in the Jordan Valley	12	Calculated from NWMP, 1977, Water use for irrigation, present situation map. Around 4 originated from the flood of KAC and 8 from springs.
Water flow of the SSW to the Jordan River	7	The total flow of the SSW is 30 while the total water use is 23. The difference is assumed to flow to the Jordan river
Ground water used to irrigate the area along wadis Shueib, Hisban and Kafrein to the Dead Sea	3.0	Calculated from NWMP, 1977, Water use for irrigation, present situation map. Refer to **Table 8**, the GW used to irrigate areas of AB26, AM, AN, AP (**Table 6**)
Surface water from springs used to irrigate the area along wadis Shueib, Hisban and Kafrein to the Dead Sea	15	Calculated from NWMP, 1977, Water use for irrigation, present situation map. Refer to **Table 6**, the SW used to irrigate areas of AB26, AM, AN, AP (**Table 8**)
Water from Wadis to irrigate areas along the Northern Wadis	8.25 ~ 10	Calculated from NWMP, 1977, Water use for irrigation, present situation map. Refer to **Table 6**, the GW used to irrigate areas of AE, AF, AG, AH, AJ, AK, AB22, AB23, AB24 (**Table 8**)
Surface water use for Irrigated Area between Deir Alla and JV region (lower catchments of zarqa river, proximate to the JV	3.9	Calculated from the NWMP, 1977, Water use for irrigation, present situation map. SW used for the area of ALO (**Table 8**)
Surface water to irrigate areas along the Zarqa river in the Amman-Zarqa Basin	11	Calculated from the NWMP, 1977, Surface water use for irrigation, present situation map. Water use for areas AL73, 32,11,21, and 23 (**Table 8**)
Ground water used to irrigate the areas along the Zarqa river in the Amman-Zarqa Basin	68,6	Calculated from the NWMP, 1977, Ground water use for irrigation, present situation map. Water use for areas AL73, 32,11,21, and 23 (**Table 8**)
Zarqa River flow in the Lower Jordan River	70	Based on calculation: The natural discharge of Zarqa river is 85 and the total use is 15
Municipal and Industrial Use in the NSW area (represented in the scheme by Irbid)	3,5	NWMP, 1977, Area balances present situation.
The NSW water discharge to the JR after the subtract of irrigation and municipal uses	55	By calculation. The natural discharge is 70. The irrigation use was about 10 and the municipal use was 3.5.
Water used for irrigation in the Yarmouk basin (5,3 is from GW)	5.4	NWMP, 1977, Water use for irrigation, present situation map
Municipal and Industrial Use in the Yarmouk basin (represented in the scheme by Ramtha)	2,3	NWMP, 1977, Area balances present situation
Municipal and Industrial Use in the Yarmouk basin (represented in the scheme by Amman)	24.9	NWMP, 1977, Area balances present situation
Water pump from Azraq and AZB for Municipal Use in Irbid	2.4	NWMP, 1977, Area balances present situation
Lower Jordan flow after the KAC diversion and after Israeli pumping	230	Calculation based on previous figures
The water of Jordan reaching the Dead sea	~400	Calculation the water flows to the Jordan after abstraction the water uses.
Population of Amman	1,100,000	NWMP, 1977 (**Table 7**)
Population of Irbid	360,000	NWMP, 1977(**Table 7**)

Table 9: Validation of figures related to the hydro balance situation of the JRBJ for the time of 1975

- Notes: Figures related to waters are in MCM/year, population in inhabitants and irrigated area in hectares (ha)

6. The beginning of the conservation phase: 1975-2000

6.1 Socio-economic and political context

The Jordan valley development plan grew into a series of longer and sizable investment programs to fully exploit the 360,000 dunums of the JRV and to provide the type of rural community social services. The development work expanded $1.5 billion investment and required two decades of execution. In the highlands, groundwater resources exploitation programs were initiated to develop the agro-economic activities, to control the unemployment rates and to raise the welfare of people. Jordan as a whole achieved a rapid growth during 1970-1989, raising dramatically its per capita income[26] but stagnation since then has steadily reduced the per capita income (**Salman, 2001**).

Due to the raising demands for water relative to the limited supplies, the country fell short of water, which constitutes a constraint in any further development. Water resources of each area in the JRB have to be perceived in a national context. Competing demands on water have already emerged. Different water allocation priorities was initiated to satisfy other uses than irrigation and to provide domestic water to Amman-Irbid plateau area.

6.1.1 The Jordan Valley

The valley in the period 1975-1980 passed an unprecedented period of construction and growth in all sectors relying on the international finance agencies and the JV development plans has resulted in desirable social and economic outcomes. The evaluation development projects indicated that the quality of life improved considerably since 1973. The agricultural and the non-agricultural income increased and social services improved dramatically. Income in the Jordan valley increased in the late seventies and eighties. It was estimated to be JD 270 per month in 1978, rising to JD 426 in 1986 and the gab among income groups has decreased (**Hunaiti, 2002**). However, the consequences of the raising water deficient and the growing shrinkage of the agricultural production classical markets without developing new markets have resulted in the flourishing of non-agriculture activities. Educated young people were more attracted to these activities while there was little room to absorb university graduates forcing them to migrate (**Hunaiti, 2002**). The valley's economy had evolved from a uni-sectorial economy based only on agriculture to a multi-sectorial economy based on various-sector such as light industries, tourism and transport (**Daher, 2001**).

The high return in the agricultural investments during the period from the mid of the 70's to the end 80s impacted significantly the population growth of the JV. The annual population growth rate reached 4.5% in 1979 and 5.8% in 1986 of the JV (**Appendix 1**). The annual growth rate for Jordan as a whole was 1-2% less. This difference disappears during 1994-1999 (**Hunaiti, 2002**). The high growth in the population is attributed to the growth of economic activities and the increasing of work opportunities.

In the period during 1994-1999, the annual growth rate decreased and fell down to around 2.5%. The Jordan valley has witnessed outward migration of mainly highly educated and young people leading to shortage in agriculture labor force. This induced an influx of poorly

[26] (From JD 124.6 in 1973 to JD 587.3 in 1982, Salman, 2001)

educated non-Jordanian workers. This also has resulted in increase in the un-employment rate to range indicatively between 11 to 19% (**Salman, 2001; Hunaiti, 2002**).
The household's income also decreased radically of which more than 50 % of the households are so close from the poverty line (**Qaisi, 2001**) as a direct result of the increase in the un-employment rate (**Hunaiti, 2002; Daher, 2001**).

The development programs have had other side outcomes. As previously mentioned when the East Ghor Canal was constructed, irrigation responsibility was transferred to officials from the Jordan Valley Authority who could not develop proper communication channels between officials and the farming community. The farmers felt threatened by the loss of their formerly unchallenged decision making powers. The Jordan Valley Authority (JVA) favoured the biggest tribes at the expense of the smaller families and it did not respect the existing socio-political powers structure (**Khori, 1981**). The consequences of misdistribution of irrigation water, illegal use of water, and inefficiency of water irrigation use are still present to date. Other shortcomings are referred to by **Nims (2001)**, including: the change from subsistence farming to surplus accumulation farming coupled with the shrinkage of export markets and the overlooked growing water scarcity problem, and the overlap between formal and informal water property right systems. **Hunaiti (2002)** has pointed out to another faulty approach of the development plan. He argues that the areas of the Jordan valley differ widely in terms of agriculture resources, however, the development plan tackled all the areas the same by the same policy. The economic rent of a farm unit varies significantly leading to spatial inequity and the creation of poverty “pocket” **(Hunaiti, 2002)**.

6.1.1.1 The emergence of water shortages in the Jordan Valley

According to the JV development program, water was initially allocated to irrigation. In the third consecutive year of drought, in 1978, the National Planning Council was forced to perceive the JV's water resources in a national context. Groundwater and surface water throughout the country were being fast depleted as a consequence of a rising demand relative to limited supplies, and the country fell short of water. The only perceived solution was to construct a conveyance system to divert annually 15, 45 MCM of the Yarmouk surface water to the northern city, Irbid, and to Amman respectively. The Zai water treatment plant was implemented in 1990 to receive the Yarmouk water pumped up from KAC (300 m BSL) to provide Amman (1,350 m ASL) with 45% of its drinking water demand through a 35 km long system of underground steel pipelines. The reduction in the available amount of water for irrigation resulted in the reduction of the irrigated land from the full development of 36,000 ha to 30,000-33,000 ha **(Khori, 1981)**.

6.1.1.2 The reuse of treated wastewater

In the 1980s, the reuse of treated wastewater for agricultural purposes was imposed by the increase in domestic and agricultural water demand. Several wastewater treatment plants were built to treat the sewage of the major big cities in Jordan. Treated wastewater used for irrigation increased significantly and has reached about **60** MCM/yr, mainly irrigating the areas of the middle and southern Ghor. The treated effluents of Amman, Zerqa and Rusayfeh cities are discharged from the As Samarah treatment plant and mixed with the water of the Zerqa River, part of which is used locally and then stored in King Talal Reservoir (KTR) to supply irrigated land in the Zaqa triangle and the Jordan valley.

6.1.2 The High lands

The shift from animal nomadic husbandry to irrigated agriculture during the last four decades in the AZB high lands has resulted in direct improvement of the living standards in the basin and indirect socio-economic benefits to the whole country. Irrigated agriculture represents the main economic activity in terms of population employed and economic return. Currently, the increase of agricultural activity in this basin has led to the establishment of input and output industries that constitute about 85% of the agribusiness firms in the country (**Jabarin, 2001**). It is the most developed watershed in Jordan and the fastest growing region both industrially and in terms of population. The petroleum boom of 1973 in Gulf countries and its economic impact on the region contributed to the overall economic growth. However the overabstraction of water by private and public sectors and the expansion of unplanned irrigated cultivable land are threatening what has been achieved to date. The high share of the livestock production in terms of red meets and dairy products in this basin poses another pressure (**Jabarin, 2001**).

The second Gulf war has significantly impacted the country. On one hand, the beginning of the 1990s was marked by the arrival of more than 300, 000 (**The HKJ and World Bank, 1997**) wealthy Jordanian and Palestinian immigrants from the Gulf countries who mainly settled in the Amman-Zarqa basin increasing the water demand in the basin. On the other hand, agricultural exports have decreased dramatically. The Gulf countries have discontinued importations of agricultural products from Jordan because of its political position and support of Iraq during the war. Saudi Arabia blocked its fruit and vegetables market to the Jordanian products that are irrigated with wastewater. Consequently, the agriculture income has substantially dropped by around 40% from 1994 to 1999.

In terms of population changes, in the latest 1970s, Jordan's population reached about 2.3 million and the greater Amman alone accounted for 1.2 million people (**Khori, 1981**). The Jordan’s population has continued to grow and reach about 3.5 and 4.3 million in the year 1990 and 1995 respectively (**JICA, WRMMP, 2001**). In 1999 the total population of Jordan is about 4.9 million inhabitants of which about 4.3 million inhabited the JRB, 1.86 million live in Amman, 0.77 million in Zarqa, and 1.127 million in the northern governorates of Irbid, Ajloun and Jerash (**JICA, WRMMP, 2001**). **Appendix 1** illustrates the population change in the main areas of the JRBJ.

6.2 Water resources mobilization

6.2.1 In the Jordan valley

The Implementation phase of the socio-economic plan of the Jordan valley moved ahead and other hydraulic investments were realized. The 1975-1980 of the Jordan Valley development plans encompassed projects that irrigate the remaining irrigable land in the JV. The EGC was extended by 18 km to irrigate 3,650 ha and later on by 14.5 km to irrigate about 6,000 ha in the south Ghor. Other dams were constructed and agricultural land expanded.

The most important projects, which were realized in this period, are:

- *The Zerqa River complex*

This project encompasses the construction of The King Talal dam and the 18 km extension of the EGC. The construction started in 1975 and completed in 1978 (Khori). The KTD has a current total storage capacity of 75 MCM. The project aimed to regulate the flow of the Zerqa River and to feed a new irrigation system. Since its construction, the King Talal Dam has received domestic treated effluent. With the except of the flood years, the natural flow of the

Zarqa River cannot reach the King Talal Dam without being mixed with treated wastewater. The EGC was extended by 18 km to receive water discharged from the diversion weir on the Zerqa River and the 2 km long carrier canal to irrigate **36500** dunums of land in the central Ghor that was divided into farm units of 30-40 dunums each.

- *Zerqa Triangular project* including a diversion weir on the Zerqa River and adjacent basin and a network pipe system to irrigate 15,000 dunums
- *The north-east Ghor complex* which includes two separate projects to irrigate 40,000 dunums.

    1. The north east Ghor irrigation project, using the unregulated flow of Wadi Arab and Jurum and the regulated flow of wadi Ziglab to irrigate 27000 dunums. The project started in 1976 and completed in 1979.
    2. The wadi Arab Dam with a total capacity of **20**[27] MCM that regulate the flow of Wadi Arab and irrigate a total land of 1250 ha. The feasibility study was done in 1976, the design in 1980 and completed in 1985.

- *Hisban-kufrein irrigation project* provides sprinkler irrigation for 15,000 dunums. It consist a 4.8 MCM capacity Kufrein dam (built in 1967) to regulate the flood of wadi Hisban into Kufrein reservoir. Work started in 1976 and finished in December in 1980.

- *The 14.5 Km Extension of the EGC*. A main hydraulic investment that was done during this period was the realization of the **14.5** Km extension of the KAC to irrigate 6000 ha of irrigable land in the southern Ghor. It is worth noting that the land allocated along the 14.5 km extension canal is still not distributed as planned and is not being irrigated from the canal due to the declining contribution from the Yarmouk River, except for the rainy seasons in winter. In summer, groundwater from private wells is being used for irrigation.

- *The construction of The Karameh reservoir*. The Karameh reservoir was constructed to hold the access of the Yramouk River and provide water for irrigation in the south but not the water from the KTR, as it has been the case today. Since the dam was completed in 1996, there have been limited opportunities to divert excess water from the Yarmouk. In addition to this hydrological condition, the saline flows of local side wadis and evaporation have resulted in high salinity level of the water reservoir making it impractical to be used for irrigation. However the salinity of the Karama dam is not only attributed to the storage of saline water but it is due to the salinity of the soil itself. This soil was supposed to be washed out for 5 consecutive times to remove the salts out but since there is no sufficient access water from KAC, the soil remained saline and consequently the water kept in the dam (**Communication with Nayef Seder, 2003**)

Figure 12 below shows the main hydro investments (dams) that were constructed to date. It also shows the location of other dams, which are still in the construction and the implementation phase. **Table 10** gives information related to the years of construction, storage capacity and the dam's water resources.

[27] The Dam storage capacity is currently 16.9 MCM due to accumulative sedimentation.

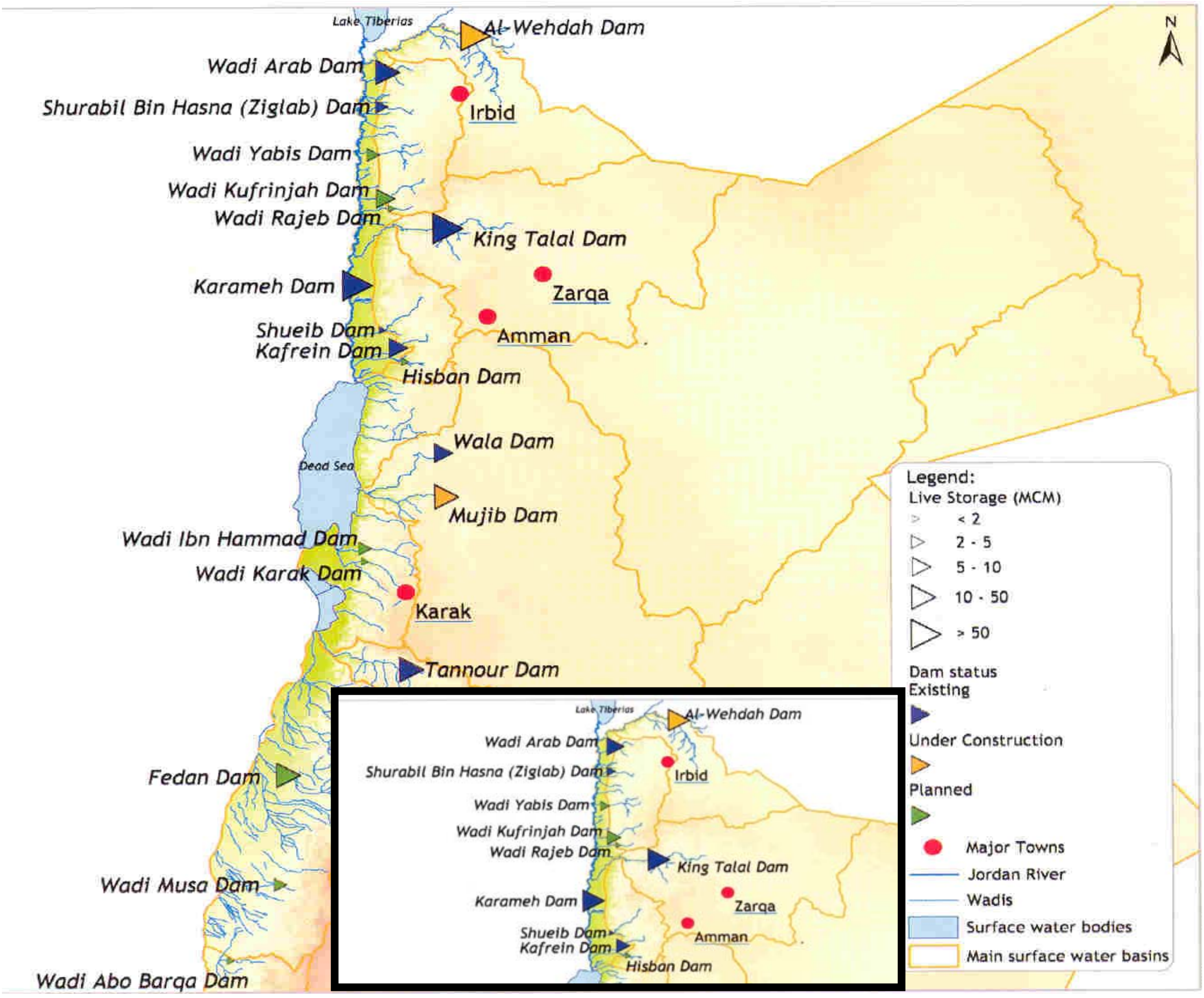

Figure 12: (1) Existing dams, constructed in the last 50 years.
(2) Planned Dams to augment the projected supply

Source: The National Water Master Plan brochure, 2003

Governorate	Name of Dam	Completion Year	Catchment Area (km^2)	Live Storage (MCM)	Purposes	Water Resources
Irbid	Wadi El-Arab	1986	262	16.9	Irrigation of 12,500 dunums in the northern JV, domestic water supply, power generation	From KAC in winter and the floods of Wadi-El-Arab
Irbid	Wadi Ziglab	1967	106	3.9	Irrigation of 12,500 dunums in the northern JV	Flood and base flows of Wadi Ziglab
Jerash	King Talal	1977/1987	3,700	75	Irrigation of 82,000 dunums in the middle JV, power generation	Zarqa River and As-Samra TP wastewater
Balqa	Kafrein	1967/1996	163	8.5	Irrigation of 1,274 dunum and artificial recharge	Flood and base flows of Wadi Kafrein
Balqa	Wadi Shueib	1969	178	2.1	Irrigation of 2,500 dunum and artificial recharge	Flood and base flows of Wadi Shueib
Balqa	Al Karameh	1997	61	55	Irrigation of 40,000 dunum in the southern JV	Surplus water from KAC in winter
Total			**4,470**	**161.4**		

Table 10: Existing large dams in Jordan

Source: Draft of the National Water Master Plan, Surface Water-Main Report, 2003

6.2.2 In the highlands

Ironically, when the JVA started to pay attention to the conservation of water, in the late 1970s and beginning of the 1980s, the government was launching a program aiming at encouraging the development of irrigated agriculture in the highlands. It was granting licenses and soft loans for drilling private wells. It even took further steps. In 1985, the government generously encouraged individuals and private investors to exploit groundwater to expand agriculture into desert land, at the expense of the sustainability of the renewable water resources, and also using non-renewable water basins[28] far away from the population centres (**Hadidi, 2002**). The government intension was to control people's migration to urban centres and to control un-employment rates. Local circumstances have facilitated farming investments. Farm ownership started mainly with Bedouins to enhance stability and welfare. Some of them sold their land proprieties after they got their well licenses as legally, the land is linked by the water rights. Others drilled their wells and sold their farms after they failed to survive the business. As a result, the pattern of farms ownership shifted to private investors. The shift of irrigated agriculture in the highlands to private sector has been also motivated other factors. The cheep land, the accessibility to good quality and quantity of groundwater, the low cost of irrigation water and the convenient climatic conditions to produce and market profitable fruits.

[28] Al-disy and Al-Jarf basins in south of Jordan

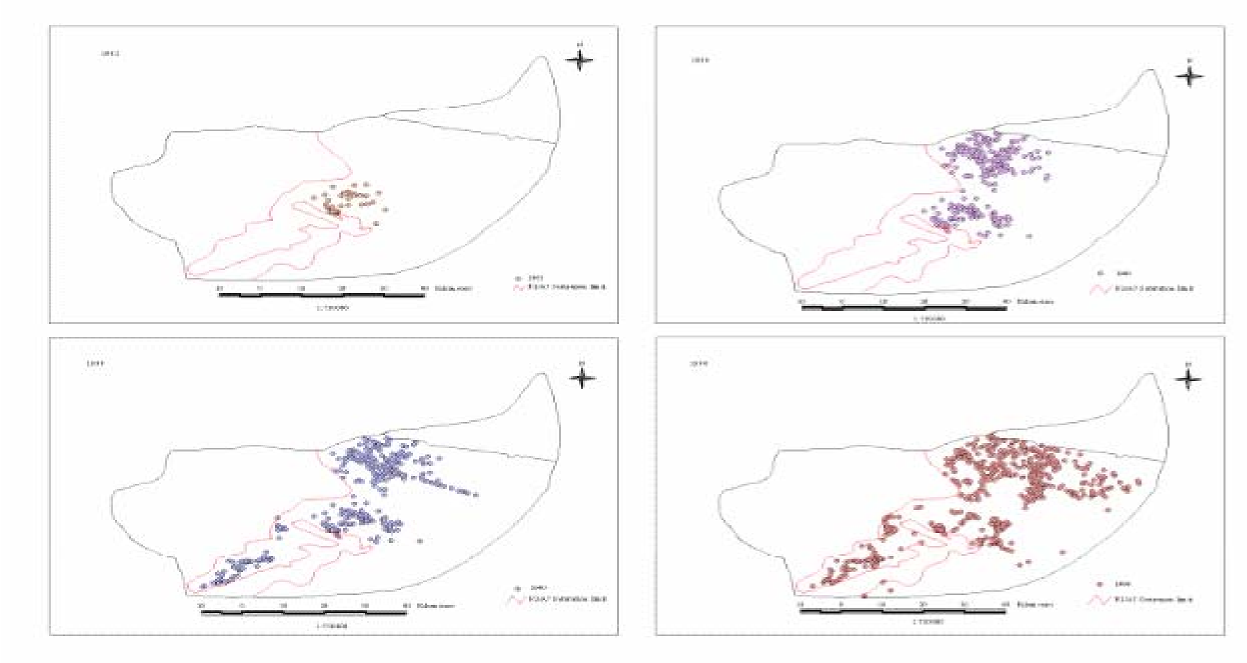

Figure 13: Increase in Groundwater abstraction in the AZB (1956-1998)

Irrigated land in the highlands relies on groundwater from wells where ground water is over abstracted and reaches critical limits. In the 1960, groundwater abstraction was estimated at 8.46 MCM and increased during the 1980s. Pumping expanded to the east, north and northeast (**Figure 13**). Groundwater abstraction in the AZB exceeded the safe yield of 88 MCM by 55% in 1989 and 70 % in 1998. The 1998 extraction rates of groundwater in the AZB were estimated at 150 MCM (**MWI and USAD, 2001**). In 2000, renewable water resources were extracted above the sustainable yield limits by 50 to 43 % respectively. Over-pumping has resulted in significant water level decline, salinity increase, drying up of springs and reduction of water quality and quantity. Should abstraction proceed without control, about 70 % of the wells located in the north-east AZB would be expected to dry up (**MWI and USAID, 2001**).

Currently the total number of wells used for agricultural purposes in the Jordanian highlands is about 1,150 out of a total of 1,648 for the whole Jordan. In 1995, the groundwater abstraction for irrigation in the National uplands was estimated at 190 MCM, accounting for 38% of the total estimated volume of groundwater in Jordan (509 MCM), (**Hagan, 1999**).
In the 1980s, Amman and Zarqa cities began to be supplied with drinking water from basins outside the Azraq[29] aquifer. The Azraq aquifer was in fact seriously exploited for drinking purposes since the late 1970s. The city of Irbid in the northern part of the western highlands was the first to be supplied with drinking water from Azraq (**NWMP, 1977**).

[29] It lies in the eastern side of the country

6.3 Water resources and uses

6.3.1 In the Jordan valley

Agriculture is almost the sole water user in the JV. Surface water from the Yarmouk River, treated wastewater from the King Talal Dam (KTD) that receives treated effluents from Kherbeit Al-Samrah wastewater treatment plant (WWTP) and groundwater has been used for irrigation purposes in the JV. The major water resource in the JV is the Yarmouk River. The Jordan River is highly saline and reaches up to 5000 ppm in the lowest section making it unsuitable for cropping. Only in flood years, once or two a decade, fresh water is released into the lower JV (**Qaisi, 2001**).

In most cases, irrigation water in the Jordan Valley is a mixture of several sources. Thus, its quality is not only a function of the source quality, but also of the proportions obtained from each source which vary significantly according to seasons and rainfall intensity. The various water supplies are generally conveyed through the (KAC), the main water conveyor for irrigation in the Jordan Valley.

The Canal is considered as the artery irrigation water supply system that was built in several stages from 1958-1989 stretching over a total length of 110 km along the Jordan River from the Yarmouk River at Adasiyeh to almost at the shores of the Dead Sea. The KAC distributes water with a progressively reduced downstream flow of 20, 5.71 and 2.27 m3/s. Although, the KAC was originally constructed to convey the fresh water of the Yarmouk River further south, it is now collects intermediate flows from a variety of sources (**Appendix 6 and Appendix 7**). Theses resources irrigate approximately 23700 ha of arable land constituting mainly the north and middle of the JV and 1/3 the southern JV (**Figure 14**). The downstream area is irrigated from water sources of KTD through separate conveying system. There are five retention reservoirs of total capacity of 110 MCM to deliver water to the KAC and to hold the surplus water of the rivers and side wadis to be used in summer. Another intermediate reservoir, the Karameh dam, holds the surplus water from other water resources conveyed by the KAC to be used in summer. The total capacity of all the reservoirs is about 165 MCM (**Nemer; Salman; Davey, 2001**).

KAC conveys fresh water that constitutes a blend of surface water mixed with ground water from the north to the central valley for a distance of 65 km. This quality of water is originated from the Yarmouk River, Tiberias Lake, the Mukheibh wells, Wadi Al Arab Dam and other side wadis, see, **Appendix 6 and Appendix 7** which provided from Mr. Nayef Seder and Yousef hasan. Then a mixture of treated wastewater and fresh water from the Central Valley to the south is conveyed at a distance of 45 km to irrigate the southern parts of the Jordan valley and to supply water to Karameh Dam at the central Ghor. Part of the conveyed water from the north to the central valley is being diverted to Amman for municipal and industrial uses (**Nemer, 2001**).

The average total net water supply for irrigation in the Jordan Valley for the years (1990-99) amounts to 218 MCM. It accounts to about 150 MCM (**Appendix 9**) in the year 2000. Water resources in the Southern area of the JV are mainly from side wadis and saline groundwater. Farmers use some **40** MCM ground waters from a large number of private wells, which irrigate about 30,000 dunum of vegetables and bananas. The water is mainly used for the Hisban-Kafrain area and some parts of the 14.5 km extension area (**Al-Jayyousi, 2001**).

Farmers who use brackish water are aware from their experience of the quality of the water used. It is by experience and experimentation could the farmer recognize the kind of crops that sustain to grow with such type of water (**Hadidi, K, 2002**)

Domestic and industrial uses are supplied from groundwater resources (**Qaisi, 2001**). In 1999, WAJ records show that there are 234 recorded private wells in the Jordan Valley of which 209 are used for agriculture, 24 for domestic, and 1 for industrial purposes (Al-Jayyousi, 2001).

Brackish groundwater is abundantly available in the Jordan valley and not exploited officially at present. Salinity of this type of groundwater reaches 5000 parts per million. As this source of water is not exploited at present, except for the southern areas, by official bodies, the government has permitted the private sector to dig wells in brackish aquifers to extract water.

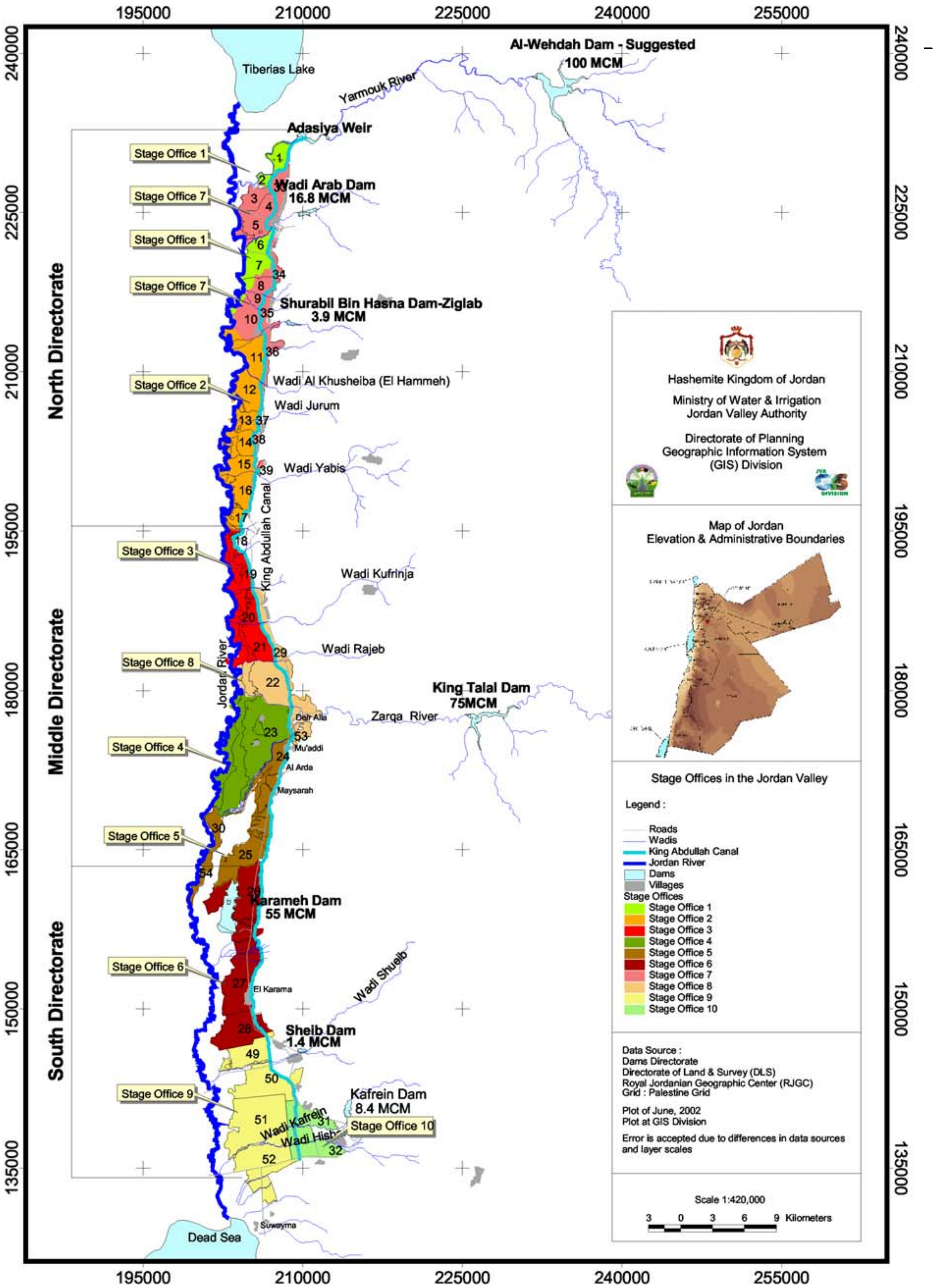

Figure 14: The three divisions of irrigated land in the Jordan valley. North, south and middle

Source: The Jordan Valley Authority

6.3.2 In the Highlands

Available water resources in the highlands encompass mainly groundwater and the Zarqa river surface water. Treated wastewater (TWW) is increasingly used as a non-conventional water resource for irrigation. The increase demand on the water for municipal use has significantly increased during the last decade competing the irrigation water use. The overabstraction of the ground water in the AZB is still significant. While the renewable groundwater is 88 MCM the water abstraction totals not less than **140** MCM. About **80** MCM of this quantity is used to satisfy the municipal and the industrial demand and some about **60** MCM is used for irrigation agriculture (**Communication with Suzan Taha**). Literatures, ARD reports, indicate that irrigation water, eventually, exceed 60 MCM to reach 80 MCM. Please refer to (**Table 11**)

Total quantity of used water for municipal and industrial purposes in the AZB approximate to 140 MCM that constitute 80 MCM of ground water from the AZB basin, 40 MCM of surface water is being pumped from KAC and other 20 MCM imported from other groundwater basins, Azraq and the Dead Sea. **Appendix 11** indicates the abstraction of about 35 MCM as internal resources. Most probably what is meant by internal source is from Amman area but not AZB. The present discharge flow of the Zarqa River is about 65 MCM. The river natural water reservoir of 85-90 MCM has not been changed since the overabstraction during the last 25 years was compensated by the return flows from Amman and Zarqa area. However, and since 35 MCM of the renewable groundwater of AZB that constitute the base flow of the Zarqa River is being extracted as groundwater, the net discharge of the river towards the JV amount to about 65 MCM. Out of this quantity, about 20 MCM is being used upstream the river for irrigated agriculture (**Appendix 10**) and about 45 MCM of water flows downstream to be mixed with the discharged treated wastewater of Al.- Samrah treatment plant in KTD. The discharged water of the TWWP totals about 60 MCM of which 10 MCM is used for irrigated agriculture in the surrounding area and the rest flows to KTD. The mixed water of the zarqa river and the wastewater that annually enter the KTD and flows to the JV for irrigation totals about **100** MCM

6.4 Hydrology scheme and water balance areas (2000)

The water balance scheme of the JRBJ is represented in this section based on the available data to date, which were provided from the different sources and not believed to be so accurate or highly consistent. One clear one is that uses at present don't seem to go consistently with water uses at 1975. The data extracted from the NWMP, 1977, indicate an irrigation use for agriculture in the highlands of about 60MCM of ground water. Ironically, data of present situation indicate almost the same water irrigation use from ground water while the irrigated land expansion is evident. This inconsistency implies further study. These examples are only to show the difficulties that have been faced to reach a reliable and consistent data to be introduced in this study. It is also to indicate that some discrepancies in presented data, on the local level of the basin, are recognized. The final copy of the National Water Master Plan is, hypothetically, expected to present a more integrated data source. However, this study is not issued yet.
Based on the available data, the water balance scheme is represented as follow (**Figure 15**) and data was validated as presented in (**Table 12**)

	Water resources, uses and the area of irrigated land in the Jordan Basin in Jordan, 2000									
Sub-basin	**Water Resources**				**Water Consumption (uses)**					**Irrigated Land (ha)**
	Total available	SW or SW and TWW	Renewable GW	Over/ Abstracted GW	Total use	Irrigation (Sw, Gw, Ww)	Industrial	Municipal (Sw, Gw, Ww)	Others	
YRB[30]	172.5	135 (YR)	40	37,5	37	28.4		8.8		2300???
JV	34		20	34	220	30.1, 145[31], 50	.04,	3.5,		~24000
NSW	70 +28	70	20	28	65	10	0.08,	23,		~730
SSW	40	30	10		7.5	7.5 (upstream use)				~2000
AZB	260	120 (ZR:60, TWW:60)	88	140	236	10, 21, 58,4	6.1	75.7+25 (other basins), 40	2	10300???
Total	~605	355	178	239.5	565.5					476315??? (ARD repot)

Table 11:Water uses, resources and irrigated land in the JRB's areas in 1975

Source of figures: Different references, Susan Taha for the groundwater related figures, literatures, and interpretation of available data.

30 This is a tricky situation. In this report the abstracted GW from the YR is assumed to decresae the NSW wadis flow but not the YRB.

31 The Sw originate from The ZR and used for irrigation in the JV is about 45. It is estimated that 10 MCM is coming from the NSW

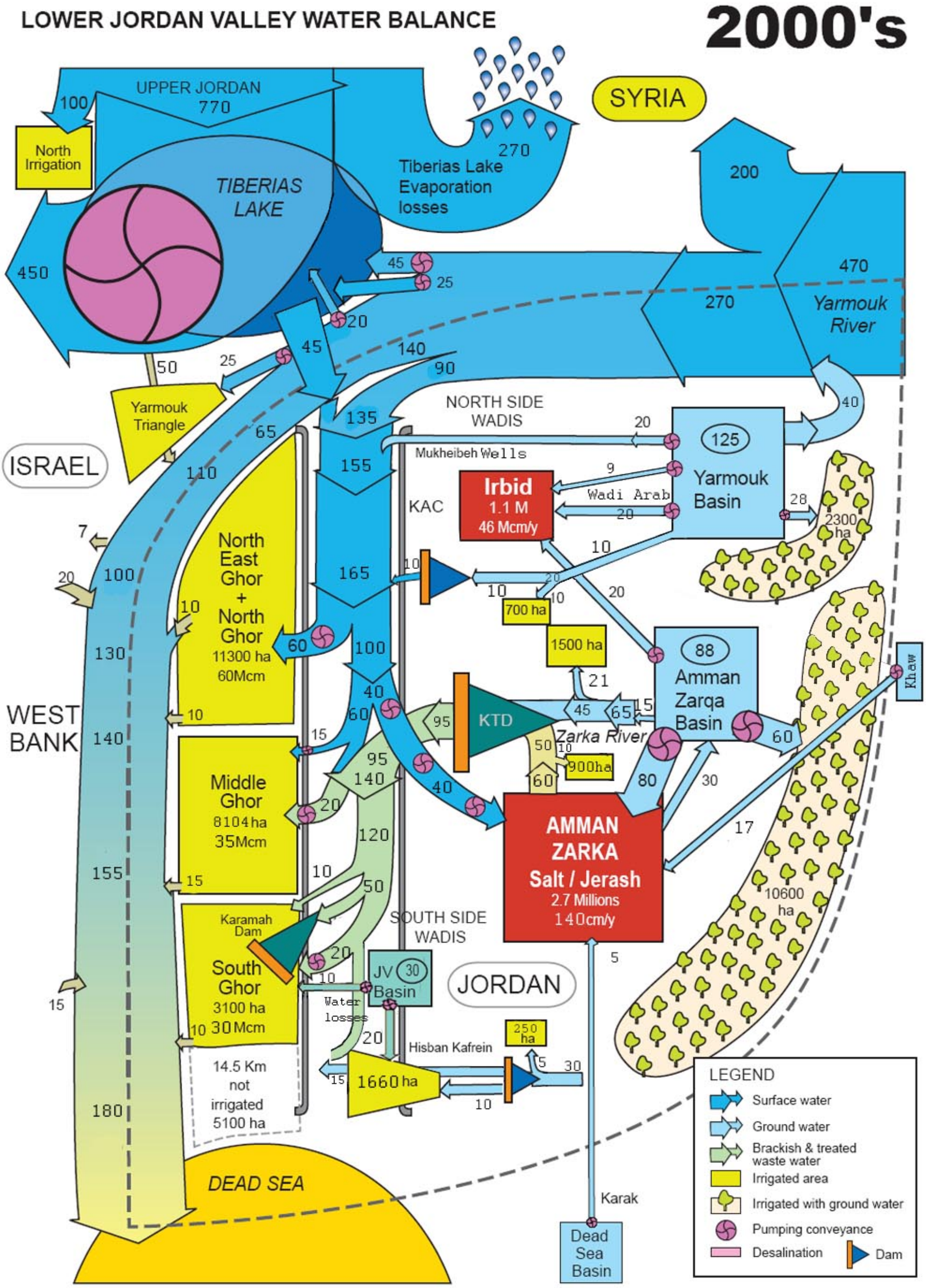

Figure 15: Water balance scheme of the JRBJ (2000)

Data issue	Data figure	Source
The Israeli water abstraction from the Yarmouk River	25✓	Peace Treaty, 1994. This water is to be stored in Tiberias lake and returned back on Summer
Water abstraction concession from the YR during winter	20✓	Peace Treaty, 1994, This quantity to be replaced from the JR water stored in Tiberias lake in summer
Water conveyed to Jordan from Tiberias Lake (average 95-02)	45✓	Communication with Nayef Seder and hard copy delivered from Mr. Nayef, see **Appendix 6**
Water abstracted by Israel from the LYR	70✓ 70✓ 70✓ -100	Hof, F. C. (1998). El Naser, H 1998 Internet: http://www.transboundarywaters.orst.edu/projects/casestudies/jordan_river.html
The unused water flowing from the Yarmouk river to the unusable and polluted Jordan River and finally to the Dead Sea	60✓	Hof, F. C. (1998).
Saline springs diverted by Israel to the Jordan River	40 65 50✓	Internet: http://www.passia.org/publications/bulletins/water-eng/pages/water04.pdf Orthofer, R. (2001). Average of 40 and 60
The Syrian water abstraction from the Yarmouk River	160 180 170 220 130-180 200 ✓ 220	Internet: http://www.passia.org/publications/bulletins/water-eng/pages/water04.pdf ANTEA-BRL. Schema directeur indicatif de gestion des resources en eau du basin du Jourdain Jayyousi, O. (2001) Hof, F. C. (1998) Klein, M. (1998) El Naser, 1996 and communication with the director of Environment Water and tourism Dr Kamal Khdier. Ministry of Planning Internet: http://www.jordanembassyus.org/112298002.htm
Lower Yarmouk River Flow	270✓ 270✓	By calculation: The natural of the YR is 470, Syria abstract about 200 and the rest flow downstream. Internet: http://www.jordanembassyus.org/112298002.htm
The average water of the YR flowing into KAC	90✓	The calculated average flow (1990-2001). See **Appendix 6**
Water diverted from the YR and from Tiberias Lake according to the Peace treaty.	135✓ 135✓	See **Appendix 6 & Appendix 7.** The calculated average of the YR water (90-01) and the calculated average of Tiberias lake water (95-01). The total amounts to 135 http://www.jordanembassyus.org/112298002.htm
The water of Jordan reaching Dead Sea	180 ✓	By calculation the input flows (The water unused and the return flows)
Water diverted from Mokheibih wells to KAC	20✓ 25 ~20✓	Jayyousi, O. (2001). Grawitz, B. Calculated from **Appendix 7**, average data provided from Eng Yousef Hasan (95-02)
Water pumped from the Yarmouk basin to irrigate farms in the Yarmouk Basin	28✓	This figure is provided from Suzan Taha (GW use for irrigation in the YRB). See **Table 11**
Ground water abstracted from the YR basin for municipal	8.8✓	This figure is provided from Suzan Taha (GW use for irrigation in the YRB). See **Table 11**

uses		
Water use for irrigation upstream the NSW	10✓	It is assumed that it is the same water consumption on 1975. This figure also can be extracted from **Appendix 10**, The draft of the NWMP, 2003. The figure constitute the sum of the upstream uses for the NSW
Northern wadis discharge	20✓	Naturally and before significant abstraction, the YRB ground water is estimated as 125. Out of this figure, 60 constitute the base flow of the NSW and 40 as a base flow of the YR. At present, 20 are being abstracted for municipal use in the north (Wadi Arab), 28 is being used for irrigation and 9 are also abstracted for Municipal use. The remaining is about 10 that constitute in addition to the flood flow (10) the total discharge of the NSW. This is based on the assumption that the 40 constituting the base flow of the YR are not affected.
Water flows from the NSW to KAC after abstraction for all the uses	10✓	The difference between the NSW discharge and the water use for irrigation upstream the NSW. This is also supported by data that was given from Mr. Nayef Seder (8.88). See Error! Not a valid result for table.
Storage capacity of the dams at the NSW	20✓	Calculated on approximate basis from **Table 10**
Surface water from the SSW used for irrigation of Wadi Shueib	5✓	See **Appendix 8**
Surface water from the SSW used for irrigation of Hisban –Kafrein	7✓	See **Appendix 8**
The Surface water used for irrigation parts of the southern JV	~15✓	It is the difference between the Total flow of the wadis and the total water use in Shueib and Hisban and kafrein (about 15). See **Appendix 8**
Water pumped from the Yarmouk basin for Municipal and Industrial use in Irbid	20✓	This is based on the fact provided from Eng. Yosef Hasan and Eng. That the wadi Arab water (base flow) as a ground water is being converted for the municipal use in the north
Surface water used for irrigation upstream the Zarqa river	21✓	Se **Appendix 10:** Detailed specification of baseflow monitoring and use per catchment, The draft of the NWMP, 2003.
Waste water use for irrigation in the AZB	10✓	The figure is provided from Suzan Taha (average use of the years 1996-2001)
Surface of irrigated land by surface and waste water	2400✓	(ARD report). In the scheme and for an ease representation it is divided to two areas (1500 +900) proportional to water use from the two sources respectively (1500 is irrigated by surface water and 900 is irrigated by waste water)
Water pumped from the Amman-Zarqa basin for Municipal and Industrial use in Irbid	????	I don't think that water is being pumped from AZB to supply Irbid
Water pumped from Azraq for Municipal Use in Irbid	6???????	According to Amman Water supply diagram prepared by Khadijah , 16 is being extracted but as it shown in the diagram, it is going to Khaw but not mentioning the north
Water pumped from the Amman-Zarqa basin to irrigate farms in the Amman-Zarqa Basin	60 ✓	The data was provided from Suzan Taha. In some literatures of the ARD reports, it is estimated to be about 80
Water pumped in the Amman-Zarqa Basin for Municipal and Industrial use in Amman-Zarqa	82✓	The data was provided from Suzan Taha. 75.7 is used for municipal use and 6.1 for industrial use. However, **Appendix 11**: water resources balances for Amman Governorate (2000), shows that about 35 is abstracted from the basin and 20 is being used from outside the basin, mainly 17 from Khaw and 5 from Madaba
Water pumped from khaw (source of water from Khaldia, Halabat and Mafraq) for Municipal Use in Amman-Zarqa	17✓	According to Amman Water supply diagram prepared by Khadijah , 16 is being extracted but as it shown in the diagram, it is going to Amman but not mentioning the north. See **Appendix 11**
Water pumped from Wala-Hidan/Madaba (Dead sea basin?)	5✓	See **Appendix 11.** The figure is also supported by the Amman Water supply diagram prepared by Khadijah
Water from the Amman-Zarqa Municipality to the Amman-Zarqa Basin (return flow)	30	Salameh, E and Bannayan, H. (1993)
The output of Treated Waste water plant (AZB)	60✓	The figure of 60 as a reclaimed water is motioned in different literatures for the year 2000 (average use of the years 1998-2001)

Retreated waste water flow into the King Talal reservoir	50✓	The figure of 60 as a reclaimed water is motioned in different literatures for the year 2000 (average use of the years 1998-2001). Out of this quantity 10 are being used in the AZB.
The discharge of Zarqa river towards the JV	65✓ 60-65✓	It is argued by Salameh (1993) that the zarqa river discharge hasn't changed from the past. The over abstraction of water in the AZB was compensated by the return flows from the Amman Zarqa municipality. This is also supported by figures listed in Table 3.1: Annual flow volumes in MCM/year for Main Basins, The draft of the NWMP, 2003. Summing up the average flood flow (47.5) and the base flow (36.5) would end up with 85. However the overabstraction of the AZB affect the zarqa river water flow towards the JV. This flow is estimated to 65 (Salameh, E and Bannayan, H. (1993). If the flood flow is approximately 50, the base flow towards the JV is about 15 Communication with Mr. Phillip Magiera, GTZ.
The discharge of Zarqa river into KTD after irrigation	45✓	It is the difference between 65 and 20
Water from the King Talal Dam to the KAC	100✓	Jayyousi, O. (2001). If we sum up the Zarqa river after the abstraction of upstream use (20) and the reclaimed water after abstraction water used (10) the result would be 95, which is close to the figure provided from Jayousi.**.** Error! Not a valid result for table. that constitute data provided by Eng Nayef seder also support this figure
Water pumped from the KAC to Amman for municipal use	40✓	Please referee to data provided from Eng Yousef Hasan, Error! Not a valid result for table. Also it is documented on the diagram of Amman water supply prepared by Khadijah and **Appendix 11**
Water from the KAC to the North-East and Northern Ghor	65✓	The Average water use (1995-2002). Data provided from Eng Yousef Hasan, **Appendix 8**
Water from the KAC to the Middle Ghor and zarqa triangle	35✓	The Average water use (1995-2002). Data provided from Eng Yousef Hasan, **Appendix 8**
Water from the KAC to the south Ghor	31✓	The Average water use (1995-2002). Data provided from Eng Yousef Hasan, **Appendix 8**
Groundwater pumped from the JV Basin to Southern Ghor (irrigation)	30✓	The data was provided from Suzan Taha. See **Table 11**Error! Reference source not found.**.** This water is used mainly to irrigate the Hisban and Kafrein area and part to irrigate the south Ghor. Thus it is divided to 20:10 respectively.
Water from the North and North-East Ghor to the Jordan (return flow from agriculture)	20✓	Orthofer, R (2001) has estimated the return flow of Saline water from Jordan to the Jordan river as 45. In proportional to the area land of the JV, it is estimated to have the return flows as shown.
Water from the Middle Ghor to the Jordan (return flow from agriculture)	15✓	
Water from the Southern Ghor to the Jordan (return flow from agriculture)	10✓	
Saline water abstracted from the JR to the West Bank	7✓	Orthofer, R (2001)
Total Return flows from the West Bank to the Jordan river	35✓	Orthofer, R (2001)
North-east and Northern Ghor irrigated Area	11300✓	Refer to **Appendix 8.** Data provided from Eng Yosef Hasan
Middle Ghor and zarqa triangle Irrigated Area	6620✓	Refer to **Appendix 8.** Data provided from Eng Yosef Hasan
Southern Ghor Irrigated Area including the 14.5 extension (3650+5985)	9635✓	Refer to **Appendix 8.** Data provided from Eng Yosef Hasan
Surface of the southern plots in the Jordan Valley (Hisban Kafrein)	1659✓	Refer to **Appendix 8.** Data provided from Eng Yosef Hasan
Surface irrigated area (Shueib)	250✓	Refer to **Appendix 8.** Data provided from Eng Yosef Hasan
Water flow from KAC and stored in KTD	50✓	It is estimated in reference to the Karameh dam capacity

Irrigated Surface in the Yarmouk basin	2300	This is estimation from Remy based on the knowledge he has.
Irrigated Surface in the Amman-Zarqa Basin	10600	This is estimation from Remy. Literatures say that it about 52000 in the whole national lands and it is 35000 in the JR basin highlands. However and based on research done by Jean Phillip, it is estimated by Remy to be much less than this figure.
Population in Amman Zarqa Municipality	2700000✓	JICA, WRMMP, 2001
Population in Irbid	1100000✓	JICA, WRMMP, 2001
M & I water consumption in Amman-Zarqa	140✓	The ground water used for municipal and industrial uses in AZB is 80 (provided from Suzan Taha) +40 being converted from KAC +17 from Karak and 5 from Madaba
M & I water consumption in Irbid	30	10 from YRB+20 Wadi arab
Loss of released water resources of the JV	18	See **Appendix 9**
Irrigation use for areas having irrigation water rights other than irrigation projects mentioned above	7	See **Appendix 9**
Total Water losses by evaporation	30	Estimation based the difference in water available and water used. See **Figure 15**

Table 12: Validation of figures related to the hydro balance situation of the JRBJ situation for the time of 2000

- Notes: Figures related to water are in MCM/year, population in inhabitants, and irrigated area in hectares

6.5 Agriculture activities

The agriculture sector has witnesses two periods of farming prosperity and decline. The first period started to bring the planned benefits after the impressive hydro- construction projects. In the late 1970s, the technical capacity of farmers started to rise rapidly due to the competition for market shares in the Gulf States and to the competition between farmers themselves after the introduction of new technologies such as drip irrigation, plastic houses, row tunnels and application of mulch[32] systems. The relatively abundance of irrigation water, the developed irrigation networks and the access to new agriculture technologies contributed to the change of from sustenance farming to surplus accumulation practices. This was facilitated by soft loans and tax waivers for the import of agricultural inputs. The agricultural development reached a momentum during the 70s and the early 80s of which the agricultural revenues increased tenfold for vegetables and more than doubled for fruits planting (**Daher, 2001**). This caused inward migration from the cities to the JV. However, the successive socio-political conditions in the Middle East region have led to the shrinkage of the export market of agricultural products, starting a decline in the Agroeconomic business (**Nims, 2001**).

The period of decline in the JV started in the middle of the 1980s. In 1979 at the beginning of the first gulf war, the Iranian-Iraqi war, and at a time when Jordan agricultural productivity was expanding, the changes in regional trade began to alter Jordan‘s position as the main fruit and vegetables supplier of the region. This was also paralleled with the growing water scarcity that was overlooked by the politician's elite. The decline has been aggregated since the second Gulf war for almost the same reasons.

During the early 1990, the government started to be aware that agriculture could not extend any more in both the Jordan valley and in the highlands. Less and less water was allocated to the agricultural activity in the Jordan valley especially after the implementation of Zai project in 1991 to provide Amman city with drinking water. In the Highlands, the development of the irrigated agriculture was limited since 1992 because of the interdiction of well drillings for agricultural purposes in this year.

Currently the agriculture sector is constrained by the limited water allocation for the irrigation, deterioration of soil and water quality, high production costs and poor production practices, weakness of marketing infrastructure and the severely lack of access to developed markets.

6.5.1 The Jordan valley

After the realization of the 18 Km extension of the KAC and the implementation of the Zarqa triangle area, the irrigated area in the Jordan valley expanded significantly from some about 18000 ha in the mid 70s and constitutes about 30000 ha nowadays. Since 1976, farmers were quickly developing drip irrigation under the mulch system and green houses and intensive agriculture was expending. Farmers were practicing the double cropping, which means that the same peace of land was cultivated twice a year. The predominant crops in the Jordan valley are vegetables and fruit trees. The climatic conditions inside the valley allows to farmers to produce winter vegetables crops at least tow months before any other vegetable crops producer in the Middle Eastern market. In addition to the vegetable crops having

[32] The mulch system is a kind of a black plastic sheet covering crops. It was used to suppress the growth of adventives and to minimize the evaporation. The drip irrigation was the most suitable irrigation system to be combined with the mulch.

immediate economic returns, farmers were also developing the plantation of the fruit trees of which mainly were citrus tree. Until the mid of 1970s, Jordan was the major winter fruit and vegetables supplier for its neighboring countries as Syria, Lebanon and Saudi Arabia. The development of the agricultural production was directly related to the implementation of the mulch and the green houses in 1976, the use of new crops varieties, the use of fertilizers, the arrival of the Palestinians with their know-how in the agricultural field, and the implementation of the USAID projects.

The planted crops in the JV constitute mainly vegetables, field crops and citrus trees. The field crops, which include legumes, cereals and fodder such as wheat, lentils, chickpeas, and some summer marginal crops such as corn and sesame are planted in the JV east of the western mountains. These crops can withstand higher rates of salinity and lower water quality.

In the south, Hisban-Kaferin area, dominating agriculture is banana, which is found to be so profitable. Water quantity is not sufficient and most of farmers don't pay water fees. They aren't receptive to the idea of distribution irrigation system and consider it as a failure and they object paying for the provision of meager amount of water as they said (**WMIA, 2001**).

In the middle Ghor, the dominated agriculture is vegetables: tomato, eggplants, potatoes, squashes, cucumbers, peppers, onions, cauliflower, cabbage, and beans of which a considerable part is planted in greenhouses. The degraded water quality of high salinity, impurities and nutrients is considered a critical problem. Water meters don’t and because of the suspended solids don’t perform well (**WMIA, 2001; Salman, 2001**).

In the north Ghor, the main crops are citrus and vegetables and some wheat. The predominate tress are citrus where 84% of the citrus trees are planted in this area (**Salman, 2001**)

Agriculture activities declined since the mid of the 80s and the agricultural export fell down by about 29% during the period from 1983 to 1986 due to two main other factors:

- The importing countries preferred high quality produces. The export market has forbidden the consumption of the wastewater-irrigated produce (**Qaisi, 2001**)
- The entry of Greece and Turkey with lower and subsidized production costs

Arab countries as Syria, Lebanon and Saudi Arabia were developing their own agricultural products and relying less and less on the exportation. The government was then implementing some measures in order to limit the production of certain crops to cope with the market demand. In 1987, the ministry of agriculture has imposed some crops mandates and restrictions.

Other factors have contributed to the declining in agriculture activities. These encompass the mismanagement of farming activities and the conflict between water users, deterioration of the irrigation system and management, and the planting of water demanding crops while the irrigation requirements could not be regularly fulfilled, aggregating the water deficit and have combined the gab between the required and the available water (**Hunaiti, 2002**). Also the prohibition of selling and buying lands units over the years has led, occasionally, to breakdown of the property. Land was inherited by many from the original owners resulting in conflict between heirs and abandoning the land without cropping it. This caused more decrease in land productivity and fragmentation (**Hunaiti, 2002; Nims, 2001**).

6.5.2 The Highlands

In the highlands, and as a result of the official encouragement of the exploitation of groundwater for irrigation, irrigated land expanded from 6,575 ha (**NWMP, 1977**) in 1975 to **35,000** ha today. The main important crops are vegetables crops and fruit trees such as olive, almond, grapes, apricot, apples, plum, peaches, vines and pistachio nuts.

However, the agricultural activity was also assuming the results of the exportation decrease after the Gulf war when Gulf countries have discontinued the importations of the agricultural products from Jordan

6.6 Irrigation and farm management

6.6.1 The Jordan Valley

The seven years development plan 1975-1982, aimed to irrigate land by pressure-pipes systems designed to apply sprinklers irrigation methods through out the valley. However, farmers since 1975 have altered the plan towards extensive use of drip irrigation and plastic hothouses (**Khori, 1981**). The JVA's plans were modified to the wide spread adoption of drip irrigation. The sprinkler irrigation system proposed by the JVA was slowly adapted by farmers as it was thought that the sprinkler irrigation system could lead to the development of fungus and disease problems in tomatoes and cucumber crops. Thus polices had been extended to leave the type of irrigation to the farmers and the ultimate development was to include a combination of surface, drip and sprinkler irrigation systems. This gave the farmers more flexibility to switch from one method to another, from one crop season to the next and even from year to year. Irrigation method in the valley encompasses mainly drip irrigation (60-70%), flood irrigation (10-15%) and sprinkler irrigation (2%). Farmers don't receive water daily. Therefore, they construct small lined reservoirs in their farms to store water when it is delivered by JVA. Surface irrigation is used for citrus and drip irrigation is used for vegetables cropping (**Qaisi, 2001**). The JVA apply two seasonal irrigation practices. In the wet months, water delivers are more generous while in the dry months, delivery of irrigation water is based on a rigid rotation schedules (**Qaisi, 2001**).

About **30000** ha of the total irrigable land in the JV are currently equipped with irrigation distribution network of which **11322** ha (including the EGP) in the North Ghor, **8104** ha (including Zarqa triangular) in the Central Ghor and **9595** ha in the South Ghor. However, the actual irrigated land is around **24,000** ha since it is only **4180** ha from the southern Ghor that is being irrigated from KAC.

Farm management indicate that farmers applying improper cropping practices. Degradation of the quality of irrigation water especially the increase in the water salinity has been remarkable. Some farmers have perceived the usage of chemicals as a compensation technique for the poor quality of water and acquainted to greatly use fertilizers. From such practice, one can conclude that they might be unaware that the treated wastewater is constituted of improperly treated nitrogen and phosphorous. Although farmers do not pay much attention to the destination of the drainage water from percolation and leaching the salt from soil, they reported that they couldn't wash the soil and depend mainly of the rainfall.

The irrigation efficiency was not of a special concern for both, the government or the farmers. This was also because of the fixed water allocation that didn't provide them with any reason to be concerned. The amount of water saved by the introduction of the pressurized irrigation has been slightly significant. Farmers get to use a lot of irrigation water, perhaps more than the real need of the crops, even with a drip irrigation system. Pressurized irrigation and especially the drip irrigation system were conceived to be the most suitable system to be combined with the mulch more than a mean to reduce water consumption.

6.6.1.1 Development of irrigation management in the Jordan Valley

Management of irrigation has proved to be a complicated issue. The rhetoric of water efficiency, scarcity and management revealed that the real problem is the 'illicit stealing', the incapability to control 'illegal irrigation' and the violation of the administrative rules. Simply the problem is not only the water scarcity itself but also the control and relations of power linked to water resource. The GTZ's report (**WMIA, 2002**) provides an integrated image about the complication of the irrigation system and farming obstacles that consider a special reference in this report.

Before any government was involved, farmers have traditional systems of sharing water resources. A complicated, but workable system of water distribution, based on both social connections and financial arrangements was developed over the hundred of years. The systems became obsolete when government took over management of JV irrigation in 1977. Farmers since then realized that they could have their needs from water by cooperating with the government and they started to look at their neighour as a competing rival who provided more that his official share water. At that time, the JVA was a financial and managerial independent entity. In 1988, the JVA came under the MWI, losing it autonomy, with staff brought under the Civil Service Law. Due to the constraints placed upon the JVA by its existing institutional structure, multi-sectoral responsibilities, and limited financial resources, the JVA could not respond properly to the changes and the irrigation infrastructure development has been not always geared to the established sound philosophies of socio-economic climate (**Davey, 2001**).

In the Jordan Valley, farmers have virtually no say in the running of the irrigation system above the farm turnout assemblies (FTA)[33]. The JVA has benevolently provided an irrigation and management infrastructure, which is exclusively top-down. Law 19 of 1988 includes restrictions on users' actions but has no features that empower them. Instead, it has a list of offences and penalties. There are no provisions through which users may manage water above the turnout or vehicles through which they may petition the Government or seek recourse, except as a normal course through the courts (**Mallat, 2001**)

Recently, and after successive individual failures, some farmers came to the conclusion that only a common community based efforts matched their challenges. The number of experiences of farmer's communities, however, was disappointed. Some, frequently the rich and powerful, misused the communal structure for personal benefits. This has discouraged farmers from any kind of cooperative action (**WMIA, 2002**). The experience revealed that farmers of the JV are greatly challenged by many of barriers for agriculture sustainability and water use optimization. Theses are:

- The reduced water allocated for irrigation. In the last tree years farmers were forced to adjust themselves to lower yields or lower quality of crops and fruits. In addition, they lost their incomes in summer seasons where the water shortage is at the maximum.

[33] Along the length of the KAC, there are a number of Turn-Outs, from where water is taken off, either by gravity or via a pumping station, for distribution to the irrigated areas of the JV

Water has been allocated according to the requirements of the licensed crops leaving farmers with little room to decide about quantity of water needed.

- The deterioration of water quality
- Water diversion corruptions by either ditch riders or officials and other illegal activities that are out of control. This effect overall water availability in the valley.
- "Everything's the fault of the farmers"- framers feel they are always to blame for everything". If the water meter is out work, it is never lack of maintenance or impurities of water. While the framers are punished for unauthorized activities, violations of the officials and the ditch riders are never sued.
- Unreliable distribution system leading to inefficiency in the irrigation water usage. Farmers perceive the campaigns currently being conducted of "use water wisely" as an insult to them during times of such scarcity the valley has passed in the last few years. In this sense, increasing water tariff will not motivate farmers to save water. Instead, it could easily put a poor farmer out of business.
- Lack of planning and unreliable seasonal water distribution system- from the farmer's point of view, it is impossible to plan. The JVA does not announce far enough ahead its distribution plan for the season to come and once it comes, it never sticks to plan. As a results, some profit and the majority who act according to plans loose. Steeling has been a normal practice to cope with need in flexible time.
- An aging and badly maintained network that is about to collapse in some area. Ironically to say that the main network has been improved to high level while end lines remained untouched. There is no effective maintenance and rehabilitation program. Emergency repairs take ages often inducing a failure of a season's crop.
- JVA staffing- Irrigation services are still working due to the skills and know how of few highly engaged engineers. Most of them are close to retire while there are no young trained graduates to step in their places.
- Concerns about future development. Farmers are aware of the changes to come in the future that include the increase of the tariffs in agricultural imports, the switch to tourism development and the changes in land purchasing laws. Farmers are extremely worried about their lands, families and livelihood. They might make more money in the tourism sector, but is that what really want for them and their children. Do they really have the choice? Lack of dialogues and consultations with farmers will not achieve a sustainable development.

6.7 Water management

The government has passed many laws to control over water resources by several agencies with different mandates including the JVA, WAJ, Ministry of Agriculture (MOA) and Ministry of Health (MOH) and finally centralized the whole task of allocate and regulate the water resources by the MWI in 1992.

Water resources management in this period has gone through significantly different stages. The Jordan Valley was one step a head compared to the highlands in terms of exploitation of water for irrigation and water conservation management stages. Water scarcity and the water deficit in the supply-demand equation have increased and stressed by the growing demand of the coming Jordanians from the Gulf States after the Iraqi invasion to Kuwait. Water quality, quantity and availability have been severely deteriorated. Consequently, water management polices have to cope and adapt with the natural, social and economical variables.

In the Jordan valley many concepts and mechanisms have been integrated in the water management strategy. In the eighties, market and water productivity mechanisms were introduced. In the 1990s, agricultural adjustment programs were brought in. The concept of food sufficiency had transformed to food security. Currently the concept of Participatory Irrigation Management (PIM) and Water User Association (WUA) is being considered. Other concepts like virtual water and tradable water rights are being debated (**Al-Jayyousi, 2001**). However, these concepts have been issues of discourse between water professionals and not integrated in the real administration of water resources.

The Jordan valley development Law of June 2001 revised JVA's mandate to include mainly water resource management, water distribution, land and tourism development, and environmental protection (**WMIA, 2002**). Laws relating to the subdivision and sale of agricultural land are currently under review in an attempt to limit further subdivision of good cultivatable land (**Qaisi, 2001**). It also laid the groundwork for private sector participation in theses activities.

At the beginning of the 1980s, after 3 years of droughts, the JVA stopped giving authorization for new citrus plantations. However, farmer continued to plant citrus trees in their farms. Irrigation water was delivered based on the land size and the crop type and thus the unlicensed citrus plantations were not receiving the sufficient amount of water. They were receiving the same amount of water allocated to vegetable crops.

Since the early 1990s, other measures were adopted to cope with the rising shortage situation. New banana plantation was prohibited and decisions were taken to reduce the water allocated to agriculture and to allocate water for municipal supply of Amman. The amount of water allocated by the JVA to farms was reduced since 1998. However, the reduction of allocated water was not only attributed to regulations but also to the five consecutive years of drought of 1998 and water scarcity.

In terms of groundwater management aspects, two main related groundwater laws were issued. In 1977, the Groundwater Control regulation was issued to regulate the abstraction licensing of agriculture wells. According to this regulation, water is the property of the state and whoever extracts water, must pay for it. Ground water tariff was imposed on some sectors such as industrial, manufacturing and tourist sectors. This regulation is still in force. The regulation was amended by The Water Authority Act No. 18 of the year 1988. The act emphasizes on the control and the property of the state of the water resources inside the boundaries of the kingdom (**Taha and Bataineh, 2002; Mallat, 2001; Hadidi, K, 2002**). This regulation has imposed tariff on groundwater extracted for agriculture purposes also. The law addresses the limiting of groundwater abstraction and/or cropped areas and opens the way for reallocation and put penalties for unlicensed well drilling. Official licenses of legal water rights are given to the owners of private wells but at the same time, WAJ has the authority to develop these resources without licenses (**Taha and Bataineh, 2002**). The law has also tasked WAJ to regulate the use of water, prevent its waste, and conserve its consumption and recognize the role of private sector in the rehabilitation of aquifers wherever needed.

Water management has undergone a paradigm shift in how water is valued and managed. Application of market mechanisms is widely believed to play a principal role in the water demand management. However the implementation of such mechanisms for water management has been faced by difficulties and not easily applied. Critical social and economic consequences for those people involved in the field are to be expected. Most of the

owners of groundwater wells believe that the water under the ground is their property and the State is not entitled to impose any tariff on or monitor or install any meters on the extracted water. Thus the engagement of the private sector is envisaged from the government side as an approach for imposing the tariff while preserving the interest of the two parties (**Hadidi, K, 2002**).
The groundwater management policy of 2002 stressed that the mining of renewable water resources shall be checked, controlled and reduced to the sustainable abstraction rates.

The government has responded to both the irrigation and urban sectors through a combination of increasingly restrictive regulatory controls and of progressively increasing water use charges. Different measures were implemented to alleviate the supply demand deficit. These are:

- Reduction of irrigation water allocated to the Jordan Valley
- In 1992, drilling agriculture wells was prohibited in all the areas of the country (Hadidi, 2002).
- Control of the abstraction of ground water. In 1994, the Ministry installed water meters on agricultural wells to measure and control the extracted water. Since then decisions were already been taken to strength the control of the groundwater abstraction and to implement water tariffs for the groundwater uses.
- In 1995, the Jordanian authorities adopted a new strategy aiming at the implementation of a water allocation policy. The priority for water allocation was firstly attributed to the urban sector then to the industrial and tourism sector, and finally to the agricultural sector.
- Decisions have been also taken to bring water from Disi aquifer[34] in the south of the country to Amman city.
- The Ministry began to review the water sector and to publish policy paper concerning its strategies to manage water utility, groundwater, surface water and wastewater resources.

Water share for the irrigation in both the highlands and the Jordan Rift Valley use has decreased in the last 5 years according to data provided from the Ministry of Water and Irrigation. Such decrease was attributed, from their point of view, to the decline in groundwater abstraction since the banning of wells drilling in 1992, installation of water meters and the reduction of irrigated areas especially in the valley due to water shortage and droughts. See **Appendix 2**: Irrigation water use development in the both of the highlands and the JRV (1996-2001).

6.7.1 New strategy context

Jordan water policy encountered environmental and political limits due to the raising scarcity of resources and the failure to reach a regional policy resulting in the water sector deterioration. The World Bank has outlined a framework for improving water resources management, based on the treatment of water as an economic good. The MWI has formulate a set of coherent water polices to guide strategic decisions in related to water allocation, water rights, efficiency in services and environmental protection (**Al-Jayyousi, 2001**).

[34] The Disi aquifer is lying in the extreme south of the country. It is a fossil aquifer. It is now used for municipal agricultural and industrial purposes.

The council of ministries approved a water strategy for the country in 1997. It provided the foundation and initiative to formally develop polices addressing the water management of groundwater, irrigation water, water utilities, and wastewater. The strategy aims at securing reliable supplies of adequate quality and quantity, the protection of water resources, enhancement of distribution and allocation efficiency. The strategy also focuses on a more commercial approach to the distribution of available water resources and explores the notion of Water User Association. To bridge the gap between demand and supply of fresh water, the government has taken the initiative to integrate marginal water resources (treated wastewater and brackish water) into the strategy for irrigation. The national water strategy policy (MWI 1997) recognizes the limited opportunities to develop new fresh water resources and to consider that the reclaimed water as a national water resource to be used in the irrigated agriculture and non domestic, including ground water recharge.

Irrigation is still the dominant user of water in Jordan (**Hunaiti, 2002**), and thus a special attention is given to irrigation water management policy. The policy underlines the importance to keep irrigated agriculture and to attain sustainability. It emphasizes resource development and use and stresses the need for technology transfer. It also encompasses control through installing water meters on the groundwater wells and pricing of irrigation water. The National wastewater policy (MWI, 1998) states that reuse for irrigation is given a high priority and reclaimed irrigation water should be delivered at a certain cost while the soil leaching water in the wet seasons would be a free of charge.

The new strategy allowed the involvement of the private sector in the management and operation of the water utilities. In 1999, a management contract was awarded to Lema Water Company which is a consortium including the international French water company Lyonnaise des Eaux[35] and the local company of Montgomery Watson-Arabtech Jardaneh. The government intends to carry out other privatization projects in other governorates in the south and north of the country (**Suleiman, 2002**) and to include also agricultural water distribution projects in the Jordan valley.

6.7.2 Water pricing development for water uses

A water tariff for irrigation water in the Jordan Valley was first introduced in 1961, when the price was set at 1 fils[36] per m3. In 1966, this rate was raised to 2 fils/m3 for users above 1800 m3/month. The JVA allocates water to farmers every month according to the irrigated area and to crops water needs. In 1974 the price was raised to 3 fils/m3 regardless of consumption. Again in 1989, the price was raised to 6 fils/m3. The price of 6 fils/m3 was estimated to cover 12% of the capital costs and 40% of the operation and maintenance cost (**Salameh and Bannayan, 1993**). Today, water charges for irrigation averages about 15 fils/m3. Water metering based on consumption is applied for irrigation water in the Jordan Valley with the exception of farmers in the southern part of the valley where private wells are the source of water.

In the high lands, farmers themselves have to cover all the costs for their water supply, which is generally extracted by pumping from groundwater wells of 200-600m deep or obtained from neighbours within the farm areas. Before 1984, there were no abstraction limits on well irrigation water. Since then, abstraction quotas or upper limits of 50000, 75000, 100000 m3

[35] Called later: Ondeo water service
[36] One US Dollar is equal to 700 fils.

/year are imposed on irrigation well licenses issued by WAJ but have been not enforced. In 1994, water metering on private wells started but still is not enforced successfully yet (**Taha and Bataineh, 2002**). A groundwater tariff about 250 fils/m3 was applied for industrial and touristy uses. A fee of JD 0.25 per m3 of exploited groundwater for drinking purposes was also imposed in the middle of April 2002 (**Hadidi, 2002**).

About 94% of the groundwater wells in AZB have meters installed of which more than 40% of them are not in a working order. Until now, water charges for irrigation averages about 200-250 fils/m3. Recently the Ministry of Water and Irrigation have issued a by-law 2002 to be enforced and have begun to experiment the implementation of a taxation system for agricultural wells.

In Amman and until 1997, the price of domestic water increases with increasing consumption following a block tariff system of water use to which definite progressive prices are assigned. Water for municipal uses was heavily subsidized. Effective in October 1997, and after the water sector review assisted by the World Bank, the entire tariff system was changed to a two part tariffs: volumetric lifeline rate, fixed charges, and water use charges proportional to consumption. The revamped tariff was expected to increase revenues and to attract private sector participation (**Suleiman, 2002**). Municipal water and wastewater tariffs recover only the cost of operation and maintenance but recovery of the capital cost have started as a part of the on-going pricing actions. Taxpayers subsidize the difference of the real cost of water and collected revenues (**Taha and Bataineh, 2002**). Water charges for domestic uses totals about 600-700 fils/m3 but this figure also includes the sewerage services for the same amount of consumed water.

6.8 Water Balance: A critical Situation

Water resources encompass surface, groundwater and treated wastewater being used increasingly for irrigation in unrestricted agriculture, mostly in the Jordan valley and other non-domestic uses, including artificial groundwater recharge. Renewable water resources are estimated at about 780 MCM per year that constitute to 275 MCM of groundwater and 505 MCM of surface water. An additional 100-125 MCM per year is estimated to be available from fossil aquifers. Brackish aquifers are not yet fully explored but at least 50 MCM per year is expected to be accessible for municipal uses after desalination.

Agriculture is the main water user in the JV, with an average consumption of 220 MCM (1990-1999) per year while it consumes about 55% of the abstracted groundwater in the National highlands. Municipal water in Jordan is used by the domestic and commercial sectors, public institutions and small industries that are connected to the public water system. Despite the increase of the municipal water supply (from 218.5 to 237.3 MCM) in the period 1993-1999 due to the increase in population, the per capita consumption of municipal water decreased from 150 liter per day in 1993 to 133[37] liter per day in 1999 and projected to be less. The average share per capita for both domestic and irrigation purposes was 326 liters. The population pressure on the water resources of Jordan has never been intense as today.

The demand for water in Jordan exceeds the available water resources and the gap between both is projected to widen. Competing demands on water have already emerged. The gap between demand and supply for municipal and industrial water services continues to grow. Shortages have become a regular summer experiences and now extend to most of the year.

[37] These figures include the unaccounted for water, UFW, which is estimated to exceed 50% of the overall municipality supply.

The surface water resource has developed to a large extent to be used for irrigation while undeveloped water resources are limited and their exploitation expensive. In 1997, water demand was 950 MCM. Of this, 450 MCM was taken from surface water and the remaining came from renewable and non-renewable groundwater resources. The gap between the national supply and demand, i.e. the shortfall, is being met by over-abstraction from renewable aquifers at a rate of 180-200 MCM per year that corresponds to about 160% of the sustainable yield from the aquifers (**Jaber and Mohesen, 2000**). This overexploitation has led to the depletion of some groundwater basins like Jafer and Dhuleil in the 70s and 80s, while others show a sign of depletion with increase in salinity and declining water level (**Salameh and Bannayan, 1993**). The increase in salinity has initiated the introduction of costly external water sources of less saline from outside the basin to be mixed with the high saline water inside the basin in order to be used and to meet the increasing water demand.

7. Anthropogenic activities vs. environment

In the last three to four decades, The Jordan river basin has witnessed deterioration in its environmental aspects due to overexploitation, industrial effluents, leaching salts from irrigated agricultural lands, overuse of fertilizers and agrochemicals, inefficiency of wastewater treatment plants and seepage from septic tanks and landfill (**Taha and Bataineh, 2002; Nemer, 2001**). The quantity of water has declined and the situation of modest available quantity of water has turned into sever scarcity. Present water use already exceeds the renewable fresh water resources by about 20% and there is no other source to explore. The abrupt level of populations coupled with relaxed controls on drilling operations and the absence of controls on licensed extraction rates has overexploited groundwater aquifers at more than double of their sustainable safe yield in average (**Taha and Bataineh, 2002**)

Until only 50 years ago and before any human intervention, the Jordan River used to discharge around **1400** MCM annually into the Dead Sea before the development of water resources. The river has sustained natural vegetation and wildlife, and it had been in equilibrium with adjacent aquifers. Currently the Jordan River basin is considered as a fully closed and sewer basin. It is receiving brackish water from the saline springs diverted by Israel from Tiberias Lake mixed with industrial, urban wastewater and agricultural return flows. The river discharges only about **200** MCM/yr at its outflow. The water that has been once pure fresh water is now saline and polluted water. The restoration of the River is not socially, economically or politically viable. The partial restoration in the lower Jordan River could not even be a possible target and not an issue that can be resolved locally. The upstream riparians now divert all Jordan River headwaters for other uses outside its catchment rather than flowing through the lower Jordan River to sustain the natural characteristics of the River (**Orthofer, 2001**).

Khori (1981) recognized earlier that the Dead Sea started to shrink and evaporate and the water body is contracted. It is being denied to deliver the 900MCM annual inflow of the Jordan Rivers and the 14 side wadis to maintain its steady state and deprived from the flow of rainwater that is being disturbed by Syria, Israel and Jordan. He also projected that the Sea on the long run would turn into mud flat and finally disappeared. The present state of the Dead Sea proved the correctness of the Khori expectations. The Dead Sea in the shores is proximate to an ecological disaster. Its water level is going down more and more every year. Sinking holes were observed around the Dead Sea. Land is now sinking in this area due to the decrease in the water qanitiy entering the Dead Sea.

The environment of the Jordan valley has been seriously deteriorated. This is evident in the general decline of its environmental status related to water quality, overexploitation[38] of the groundwater and increase in salinity, instability in the hydrological cycles, soil erosion and salinity and fragmentation in agriculture land. Soil degradation has been a direct consequence of land use and ownership polices, groundwater depletion and the excessive use of the fertilizers and irrigation with marginal quality water (**Qaisi, 2001**) and the less available water to leach and wash out the soil. The limited supplies of water resources combined with the poor management of land and water in the JV have created environmental stress factors and constrained agriculture production and its suitability.

[38] In 1993, the total abstraction rate for all uses was about 42 MCM in the Jordan valley Basin while the safe yield for Jordan Valley Basin is only 21 MCM/year (Hussein, A, 2002)

Most of the WWTPs operate beyond the designed capacities, causing contamination of the groundwater wells in their surroundings. This has tuned the water as unsuitable to be used for drinking water. Water sources for drinking water in regarding to some chemical parameters don't comply with the setup Jordanian standards. They are characterized by high salinity, nitrates, and alkalinity content. Thus the government adopted strategy to blend the water sources to bring the chemical parameters to the standards for certain purposes (**Bataineh, Najjar and Malkawi, 2002**).

Although it is being recognized that the reuse and utilization of treated wastewater for unrestricted irrigation is important, the discharge of the treated wastewater to KTR is of a poor quality even in comparison of the set up Jordanian standards. It is widely believed that industrial untreated wastewater is being discharged to Zarqa river although this practice is not allowed by law. The treated wastewater has become an important portion of the Zarqa River flows that is coming mainly from Al Samrah WWTP and discharged to wadi Dhuleil, where it flows downstream to join the Zarqa River and runs for around 32 Km until it reaches KTR and finally conveyed to KAC. The Zarqa River passes through agricultural areas that are proximate to populated areas posing public health risks to residents, workers and farmers in the vicinity and to the consumers of the crops grown in this area (**Nemer, 2001**).

The overcapacity operation of the Al Samrah WWTP in the AZB, the agricultural practices, livestock operations, drainage from animal feeding near the streams and irrigation return flows have all resulted in deterioration of the water quality. Water pollution of the KTR outlet is noticeable. The water is highly turbid and odorous and the presence of solids and wastes are obvious. The negative impacts of poor quality water on agriculture production, soil, public health, and groundwater resources are definite (**Nemer, 2001**).

Fresh water in some watercourses such as Zarqa River, wadi Arab and wadi Shueib was reduced to comply with the water increasing demand of cities and have greatly affected the flow of the springs. The flow was replaced by the effluent of the treatment plants, a process that changed the ecological balance over time (**Bataineh, Najjar and Malkawi, 2002; Salameh and Bannayan, 1993**).

The Azraq aquifer is outside the JRB, however, this basin was extremely exhausted to satisfy the urban demands of Irbid, Amman and Zarqa in our basin and also due to irrigation use. Pumping from Azraq springs began as long as 1963 but significant amounts were not taken from this source until the early 1980s. The pumping of Azraq oasis has destroyed the wetland and its wildlife, incurring a drop in groundwater level of 0.5 to 1 m annually (**Lomas, 2002**). Springs feeding the northern marshes dried out completely in 1987. One of the two springs feeding the southern marshes ceased to flow in 1990 while the second followed in 1992. By the end of 1992, the entire oasis that previously occupies 7,400 ha was almost dry (**The HKJ and World Bank, 1997**).

8. Future Scenarios and prospective

In the past, the major element of the solutions to water supply-demand deficient was to increase supply. Recently, the shift in water planning in Jordan is to more integrated and demand-driven water management. Some solutions have come up with options for reducing demand through a more efficient water technology or through water conservation options. However theses solutions did not succeed to alleviate the water shortage problem and to change the overall system. Future water polices have been proposed and focused on both the demand and supply sides (**Al-Jayyousi, 2001**) and aiming to:

- Enhance increase supply from conventional sources such as the construction of the Unity dam.
- Develop supply from non-conventional sources. These include treated wastewater, artificial groundwater recharge, water harvesting, desalination of brackish groundwater and seawater, and the importation of water across national boundaries.
- Promote greater efficiency and conservation
- Develop an integrated water planning and management framework

Many projects are proposed or designed in order to solve water shortage problem in the few coming years and to approach strategic goals above:

8.1 On the Supply side

1. The construction of the Unity Dam on the Yarmouk river: one of the planned projects is the construction of the Wehdah dam on the Yarmouk River which is supposed to increase the availability of fresh water and to supply Jordan with additional 100[39] MCM/yr of good water quality but under the best Scenarios; the dam will not deliver additional water resources before the year 2010. The project would raise the national storage to capture water resources to the maximum possible utilization (Al-Jayyousi, 2001). The dam may moderately alleviate the water shortage problem if the water supply-demand gap has not been widening by the time of its completion. Also, the government has to carefully scrutinize the planned size of the dam in order to achieve the maximum feasibility of the project as the water of the Yarmouk River entering Jordan's territory has been declining (Salameh and Banayan, 1993)

2. The realization of non-conventional water resources projects:

   Desalination: Two main sources are available to be desalted: the Red Sea at the Gulf of Aqaba, and the brackish water in the south of the JV and the Dead Sea escarpment areas. Desalination of the brackish water in the JV will be explored and identified and is estimated by **JICA (2001)** to provide about[40] 250 to 300 MCM. A study for the construction of a massive desalination plant in the south of the Kingdom is being also carried out.

   The Red-Dead Sea project: A future scenario that calls for regional cooperation in developing marginal and new water resources. During the last Earth summit

[39] It is expected to provide 85 MCM at present.

[40] In another reference (Hussein, 2002) JICA (1995) estimated 20MCM of desalinated water in the Central Jordan valley for the year 2010.

of Johannesburg, Jordan and Israel presented the Red-Dead Sea project aiming the protection of the Dead Sea and the increase of water availability. The regional project is under consideration that is estimated to cost more than one billion dollars. The project envisages pumping of 1500 MCM a year into the Dead Sea to raise its level, to stabilize the aquifers in the region and to mitigate the seepage to the Dead Sea. It offers the possibility of the implementation of a desalination unit using the energy produced by the falling down of water from the Dead Sea to the Red Sea.

The wide use of Treated wastewater in irrigation: Given the facts of the severe water scarcity situation, the future projected water demand, and the deficit in the trade of food commodities, makes every option to increase water availability valuable. Thus the substitution of marginal quality water for fresh water sources is a viable option and makes treated wastewater as valuable water resources for irrigation (**Bataineh, Najjar and Malkawi, 2002; Qaisi, 2001**). The potentiality of exchange groundwater in the highland and the exchange of surface water in the northern Ghor with reclaimed water for irrigation are under study.
Plans are underway to upgrade existing WWTPs to reach high treatment standards and to construct more plants and to expand the sewerage services for the un-served population in rural areas. A project to enlarge the capacity of As-Samra wastewater treatment plant which serves Amman, Zarqa and Rusayfa areas is being implemented. The project will be realized by a private investor according a BOT (Built Operate Transfer) system.

Artificial groundwater recharge: this approach to increase the supply is being investigated by application of different recharge techniques in both of the Jordan valley and the highlands. However studies so far have revealed that such approach for the development of water supply is challenged by the high effluent standards of the pretreated water which require a high economic cost and the withdrawal of public water supplies from the area where it is found to be technically acceptable for recharge making it unsuitable (**MWI, USAID-WRPS, 2001**).

Disi Project: To provide the extending city of Amman with drinking water, the Ministry of water and Irrigation is now planning to transfer water from the Disi fossil aquifer on the border of Saudi Arabia in the south of the country to the city of Amman. This project will provide the Jordanian capital annually with some 100-125 MCM of drinking water for at least 50 years. The project is supposed to construct a 250 Km aqueduct to divert the non-renewable groundwater of the antique fossil aquifer from the south northwards Amman. However, experts are not quite sure about the feasibility of the project. In addition to the high economic cost, which is estimated to be more than $600 million, this project embeds a high risk and uncertainty due to the difficulty of evaluation the environmental cost (). They also fears that by the time of implementation of the project, there will be little water left in the Saudi-Jordanian aquifer reservoir.

International agreement: According to the Peace Treaty signed with Israel in 1994, Jordan expects to be supplied with an additional 50 MCM/yr of fresh water. In order to achieve that, Israel and Jordan shall cooperate in the construction of a de-salting plant. Israel should also provide Jordan with some

10MCM/year after the implementation of the desalination unit of the saline springs feeding now the Jordan River.

8.2 On the Demand side

1. *The study of different scenarios to reduce groundwater abstraction*: In conjunction with the MWI, the USAID funded water resource policy support team proposes different scenarios and management options of groundwater in the Amman-Zarqa highlands. Although it is widely recognized that the reduction of agriculture water use in the high lands is politically difficult and a challenging task, the future scenarios rely on the reduction and control of groundwater abstraction through different approaches. These include the establishment of Irrigation Advisory Services (IAS), wells buy out by the government, the enforcement of abstraction limit, change of groundwater with reclaimed water and municipal and industrial reduction. The preferential of one option over another is based on the socio- economic impact of each scenario (MWI-USAID, May, 2001).

2. *Employment of market mechanisms*: The focus on the commodity dimension of water for paying the full cost of supply is a part of future planning of integrated water management and started to be implemented. The current water management polices which were promoted by the World Bank emphasized the role of private sector participation in water management and what is still questionable is the form of the participation and the organizational set up. Whatever the final form of water management systems, success will always depend on the level of public involvement and participation. The rush into a change might bring about a disaster for the whole country. The International experiences of the privatized water management in the developing countries are not encouraging and the generalization about the management efficiency that can be achieved by private sector is still an issue of argument.

3. *Water Re-allocation polices*: As previously mentioned, since 1994 the allocation policy has prioritized municipal uses over irrigation uses in order to reduce the demand. Currently, works are taking place at Dir Alla in the Jordan valley in order to double the pumping capacity from the KAC to Amman city. The volume pumped from the KAC to Zai treatment plant then to Amman will shift from 45 MCM/yr to 90MCM/year.

9. Critical review and conclusion

The Jordan River Basin in Jordan went through a fluctuating periods of stagnation and prosperity. However, the most dramatic evolution of the basin was quick and took place during the last forty years, leading to the present deterioration of water balance. Regional politics have played the most significant and critical role in that process. In fact, if the Israeli state had not been established on the west bank of the River and if Jordan had not been faced with the sudden flows of refugees during the years 1948, 1967 and 1990, one could imagine a completely different scenario for the basin trajectory, with much less pressure over water resources. The basin was always a victim of the regional hostilities that required the basin to support more than its capacity in a sort lapse of time. This was compounded by faulty policies that exhausted the basin resources to a large extent, while overlooking consequences.

Until the late 1940s, the basin was characterized by abundant water resources in relative to water uses, sparsely and few population who lived mainly on rainfed animal husbandry agriculture and other complementary economic activities, and limited available technology. All of this has been suddenly changed in the beginning of the 1950s. More advanced technology linked to pumps, canals, pipes, dams, and wells drilling was introduced. This was also accompanied by the increase of populations, the oil boom in the Arabian Gulf states and the availability of export markets, the expansion of irrigated agriculture, and the climatic convenience of the basin in both the JV and the highlands to plant various crops at different seasons. These factors have contributed to a rapid growth and development of the whole country but not in a sustainable approach. The development has resulted in overexploitation of water resources and significant deficient in the water supply- demand equation.

Population pressures coupled with financial, technical and time constraints have in the last few decades given the decision makers only limited choices to absorb the unemployed labour force. Jordan, over the last 40 years, was forced into quick and easy solutions to strengthen its brittle economy and viewed the irrigated agriculture as the most attractive business to overcome prevailing conditions.

Water management of groundwater resources in the last 40 years did not examine deliberately the impact of issued acts and legislations on the water reservoir. One of major reasons leading to the water crisis in Jordan was the uncontrolled expansion of the irrigated agriculture especially in the highlands and the lack of groundwater investigation and studies. The first real groundwater study was lunched at the early 1990s. The late prohibition of digging was too belated, although the bad water situation was recognized. The government focused mainly on the mobilization of the economy and how to increase the agricultural exports.

Many factors have lead to the present environmental deteriorated state of the Jordan River basin. The deficient in the water supply-demand situation, the over-extraction of groundwater reservoirs and the depletion of some of them, the degradation of water quality, the pollution of the Jordan River, the soil deterioration, and the dry of springs are all clear implications. The ground water resources that constitute to about one third the Jordan's national resources is over-extracted and depleted. During the last three decades, the development of water resources has been mainly focused on the large scale supply water development plans to increase agriculture production and to satisfy the growing demand that have been never satisfactorily met. Inside the JRB eastern catchment area, the existing water resources are insufficient to cover the demand and water is now carried from outside posing a high cost alternative supply.

The Review of the politics content of the JRBJ indicates the relatively low priority assigned in the past to the water issues by Jordan's political elite. The growing water scarcity problem was overlooked for decades due to the focus on the economic development and the political stability. The current water scarcity status of Jordan is not simply explained by the direct causes of geography and climate but coupled with a complex set of demographic, socio-economic, and political changes of which projects of society were inevitably linked to water programs. What has been important for the stability of the young state is to ensure economic development, secure food, and assimilate the high growth of population. Thus the approaches were seen to intensify the agriculture practices and irrigation schemes and generous allowance for the exploitation of the groundwater resources in the country, valley, upland and even the desert. Yet water may prove to be the most serious challenge ever faced by the country. The demand for water and the ability to control its location, timing, quality and quantity are becoming critical with the growing demand for municipal, industrial and agricultural uses in an arid region. Without more appropriate strategy to the challenge, a shortage of water could be more fatal to Jordan's prospects than all other challenges.

There is a clear communication and mistrust gap between officials and farmers in both of the landscape in the JRB. Farmers were not a part of the decision making process and could not understand the change in polices. For example farmers are convinced that the state has no right to impose tariff for groundwater in their land properties. This may constitute a main reason behind the illegalization practices and breaking of installed water meters. They also believe that government’s intervention is for their benefits, rather than for all people (Hunaitui , 2002). The gap has to be bridged and farmers have to be a part of any decision and they should be encouraged to effectively participate in water management. Without adopting such approach, there will be always a gap between planned strategies and real actual practices.

Although, the Ministry of Water and Irrigation has recognized the need for the integration management approach for water resources, the lack of establishment of coordination mechanisms between parties responsible for strategic planning and parties responsible for implementations is still obvious. Despite the existence of institutions that have plans with ambitious aims and objectives, desired outcomes are not achieved. This is due to many reasons but mainly to: lack of coordination between insinuations, mixed and overlapped responsibilities, absence of action plans and lack of transparency and empowerment of law over all people.

Recommendation: essential issues in any future plans:
The performance of the water sector initiates the change in water planning and institutional arrangement. Reviewing the literatures, reports and the ministry strategies, it seems that many projects and studies were carried out to explore options and alternative for water management. However, the progress seems to be relatively slow. Whatever projects, plans or strategies that are favored by the government, there are some essential blocks for achieving a worthy success and a sustainable water development. At the strategic planning level, a combination of coordinated activities must be undertaken. Setting priorities is of no least importance. In a general context, these should include but not limited to the following:

1. Urgent measures for the protection of water quality and increase or conserve its quantity is of utmost importance and should be dealt with as a first priority.

- Forcing industrial sites to locate treatment plants. These plants should be designed to treat the industrial wastewater to acceptable standards to be discharged to the municipal wastewater. This would improve the quality of treated water and minimize the economic and the technical load on the WWTPs.
- Restrict the excessive use of fertilizers in farming activities.
- Upgrading and ensuring that WWTPs operate according to good standards. Conveyance system of treated sewage water to destinations should be monitored properly to avoid any potential contamination. The KAC and the KTR conveyer system should be also protected from non-point pollution resources mainly from access of nutrients from agriculture.
- Reduction of water losses and the unaccounted for water.
- Conduct of awareness programs and assist farmers in to be acquainted of practices that optimized water efficiency, farm productivity and profitability while minimizing the negative environmental impacts of soil and water courses. This might be done by establishing a technical team of educated and professional team(s) to support farmers with good standards of efficient on farm management practices. The involvement of research centers, the universities, and the community and farmers associations should be planned and motivated.
- It is also important to review the adopted strategy of the mixing of water resources. The importance of this strategy is well recognized under the limited supply situation. The high economic cost of water treatment to acceptable standards and sutability for uses is also not underestimated. However, the mixing strategy has indirectly contributed to the deterioration of water resources. The degradation of each water source should be measured and mitigated by either economic or legislation mechanisms but the way this strategy has handled the polluted water sources gave a wrong perception that things are going well. This has resulted in aggregating the problems on the long term but not providing sustainable solutions. However, a comprehensive feasibility study for separation of water sources has to be carried out.

2. Water institution management set up
   - Review the institutional set up needed to acquire the desired objectives of efficient, integrated and sustainable long term water resources management. None of the economic, social and the environmental desirables should be achieved at the expense of the other two. Such set up should assign one responsibility to the institution without any overlapping while coordination with the others. The balance between the control and the independence has to be recognized and identified. The adopted water institution form should achieve also the balance between the independent management and the political accountability and legitimacy to service that have to meet social and public needs. Action plans and milestone measures should accompany management strategies where deviations from the plans should be justified and irresponsible and non-efficient staff should be dealt with properly.

3. Development the social adaptive and national capacities
   - The water resources management necessitates the need for change in thinking and behavior. Thus, Patience, goodwill and cooperation is needed from the concerned governmental bodies in order to provide support for the development of feasible and sustainable concepts and practices that are crucial to the success of plans and strategies for future water management. The gap of mistrust between the official bodies and people has to be bridged taking in consideration that those social changes take time. Confidence building measures have to be included in any strategy. No

matter the social adaptive capacity level of the Jordanian farmers and citizens, the norm and the attitude of people can be enhanced if they were approached appropriately and transparently. Inefficient of water management aspects can be remedied by only joint forces of all stakeholders. Farmers' and citizens' contribution though legal organized bodies should be encouraged. Without addressing this issue, the success of all other projects and plans will be limited.

- The Jordanian government should develop its national capacity for drawing up the future water strategies and implementation. International cooperation in the term of financial, planning and technical assistance is not in any way underestimated but could be play only a complementary role in the implantation phase. What is important for achieving a sustainable strategy in the water management is the process of implementation and the enforcement mechanisms of what was and is being planned and written on paper. The appropriate polices and strategies, serving the optimized community benefits of present and future generation, need the development of the adaptable and assimilative cultural capacity for implementation. This requires the mobilization of social resources. A decisive factor in water management and plans implementation is how to define and develop on ground a relationship between planners and local community. This is some thing that the international development agencies cannot do too much about it.

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Appendix 1: Population development estimates of the Jordan River Basin in the Hashemite Kingdom of Jordan

Year	Jordan Valley	Amman	Jordan	The Jordan * Basin	Source of estimated figure
1596			52,000	31,000	Abu Jaber
1878					
1905					
1939		30,000	325,000		Khori
1948			1,500,000		Khori
1950			1,200,000 1,237,000		Internet[43] http://www.library.uu.nl/wesp/populstat/Asia/asia.html
1967	60,000				Khori
1971	5,000				Hunaiti
1973	60,000				
1974	66,900				Hunaiti, Dahar
1975	**99495?**		1,952,000	1,691,855	NWMP, 1975
1978	79,900				Dahar, 2001
1979	83,900	1,200,000	2,300,000		Salman,Khori
1986	124,000				Salman
1990		1,450,375	3,468,000	3,165,795	WRMMP, JICA, 2001
1991		1,497,344	3,701,000	3,349,748	WRMMP, JICA, 2001
1992		1,556,954	3,844,000	3,478,954	WRMMP, JICA, 2001
1993		1,627,424	3,993,000	3,611,332	WRMMP, JICA, 2001
1994		1,576,238	4,139,458	4,640,075	WRMMP, JICA, 2001
1995		1,631,000	4,291,000	3,757,800	WRMMP, JICA, 2001
1996	179,000	1,696,300	4,444,000	3,912,600	Salman, WRMMP, JICA, 2001
1997		1751680	4,600,000	4,045,240	WRMMP, JICA, 2001
1998		1809775	4,755,750	4,182,505	WRMMP, JICA, 2001
1999		1864500	4,900,000	4,309,400	WRMMP, JICA, 2001
2000	208000				Qaisi
2002	220000		5,200,000	~ 3,000,000	Aida

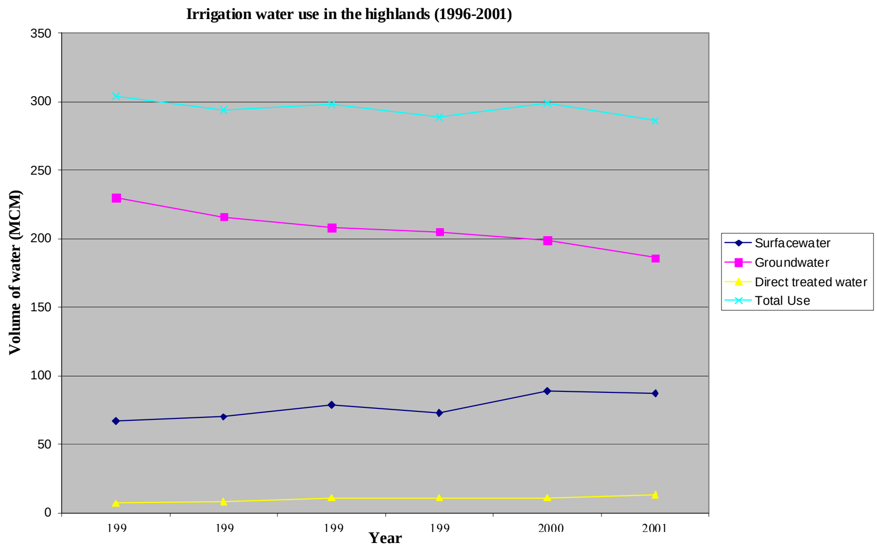
*This includes the population in the governorate of Amman, Zarqa, Mafraq, Irbid, Ajloun, Jerash and Balqa.

[43] http://luna.tau.ac.il/~glowa/eilat/Climate_Change_Water_Resources_Environmental_Conflict-S_Becker.pdf

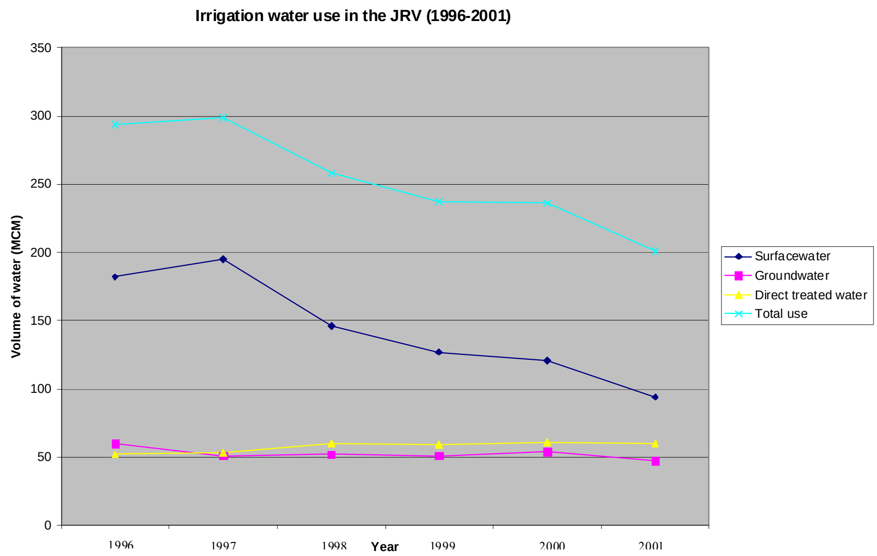
Appendix 2: Irrigation water use development in the both of the highlands and the JRV (1996-2001)

Source: Water information system directorate, 2003

Type of water resources	Irrigation water use in the highlands (1996-2001)					
	For year					
	1996	1997	1998	1999	2000	20001
Surfacewater	67	70	79	73	89	87
Groundwater	230	216	208	205	199	186
Direct treated water	7	8	11	11	11	13
Total Use	304	294	298	289	299	286



Type of water resources	Irrigation water use in the JRV (1996-2001)					
	For year					
	1996	1997	1998	1999	2000	20001
Surfacewater	182	195	146	127	121	94
Groundwater	60	51	52	51	54	47
Direct treated water	52	53	60	59	61	60
Total use	294	299	258	237	236	201



Appendix 3: The Jordan River Basin: Development of the human activities and the socio-economic and political remarks of each historical period (12,000 BC to 1946 AD)

Historical Period	Prevailing Economy	Type of Settlement	Types of Crops and plants	Herding activities	Significant socio-economic or /and political remarks
					Presence of human in the Great Rift Valley, Lebanon
Epipaleolithic			The evolution of Agriculture		Landscape was domesticated. And regional plant repertoire was in place. Plant resources were managed rather than farmed
			Human being first mastered cultivated Agriculture in the JV		Al-Jalil, in the JV is recognized as the world's oldest historical human settlement
					Surface water was exploited for agriculture purposes.
Post –Pleistocene			Emmer, einkorn, and barely associated with Oak woodland	Domestication of animals	A momentum towards the cultivation of plant and earliest plant domesticates
Early Neolithic	Pastoral	-Large and small villages -Presence of mobile groups.	Rain fed farming of wheat, barley and legumes. Wild fruits of pistachio, azarolws, almond, acorn and Sisyphus spina-christa	Domestic sheep	Modification of rock basins and pools as natural water collection with enhanced construction storage. The existing. Of Nomad's style of life.
Late Neolithic	Pastoral, multi-resource nomads in Syria		Woven Cotton is believed to be planted in Jordan	Domestic animals of goats, sheep, cattle, pigs at Azraq	
Early Calcolithic					
Late Calcolithic					
Early Bronze I-III	Trading economy due to the flourish of long distant trading.		Olives, dates, grapes, almond, pomegranate and figs, were planted in the JV ,	Production of milk	Way of life was similar to that of recent Bedouin. The life in the JV might tribally base.
Middle Bronze I-III					
Late Bronze I-III				Camel bones were found	Flourishing economic activities when the area traded with Egypt, Greece, Syria and Iraq.
Iron Age I A-C	Long distance trade between Jordan and Yemen				Strong foreign influence in the valley. It was the first time when the valley was politically separated from the hills.
		Fist small sites of urban settlements			Flourishing and a peaceful period. Arabic kingdom conrol.
					Jordan was ruled by Greece but the south was still dominated by the Nabataeans
Roman-Nabataeans (Byzantine)	The period was characterized by flourishing in the agriculture, agriculture industry, trade and Christian pilgrimages.	Construction of modern buildings and urban complexes. New villages were built at the edge of the deserts.	Rice started to be plant in JV until the 10th century. Old world cotton probably cultivated in the JV in the pre-Islamic period		Building of village institution, administrative church community, houses and water channels. Establishment of a league of trading centers called Decapolis of which most of them were in Jordan

Date	Historical Period	Prevailing Economy	Type of Settlement	Types of Crops and plants	Herding activities	Significant socio-economic or /and political remarks
630-636	Islamic Conquest		Stable communities and insignificant construction			Jordan continued to prosper being close to the center of power.
650-750	Umayyad	Agriculture economy and urban trade men and crafts				
750-1174	Abbasids			Hard wheat and sorghum		General decline
1187-1516	Ayyubid- Mamluk	General revival of economic activities of mainly sugar industry.	Increased in urbanization	Sugarcanes industry was practiced intensively in the JV but it declined when sugar industry was developed in Sicily and Spain. Watermelon was known in this period.		Institute the Emirates of Arabs of which the government administration is not necessarily urban but peasants and Bedouin
1516	Ottoman Empire control	Rainfed crops and livestock was the main source of income. The pilgrim and interregional trade accompanied the pilgrim rout was an important factor in the development of rural economy of south Jordan	Pattern of settlements declined but villages and towns remains the center of economic and political activity. In Ajloun village settlement was the norm.	It was started to plant vegetables: Loubia, onions, aubergine, cauliflowers, cucumber, carrots and asparagus		Until 1866, the Ottoman administration in Jordan was mostly an annual visit by tax collectors.
1878-1906			Dense village settlement similar to Byzantine and early Islamic periods	Plantation of sweet and chilli paper has started. Extention of rainfed cereals. Water resources in the highlands started to be tapped for agriculture purposes.		Migration and Settlement of Circassian, Chechen, and Turkmen from Causcasus
1926						Transjordan came into existence under the temporary British administration.
1946						Jordan become fully independent state and known as the Hashemite Kingdom of Jordan

Appendix 4: The evolution aspects (in brief) of the JRBJ: A recent history (1900-todate)

Development aspects	1990-1950	1950-1975	1975-2000
Population change	Mobile Bedouin tribes in the valley and sparsely populated areas in the highlands. The coming of Palestinian refugees in 1948.	Another migration of Palestinians after the 6days war of 1967. The valley was emptied of its population in 1967 ant until 1971. During the 70s, inward migration from the highlands to the valley.	Demographic boom in the highlands during the 80s. 1n 1990-1991, another influx of retuning Jordanian and Palestinian people from the Gulf countries. Continuous demographic growth at a rate of 3.5% annually.
Political and institutional evolution	Political and communal instability due to the first and the second world wars, the British colonization, the establishment of Israel in 1948, and the brittle economy of the youth state of Jordan after independency. The creation of the irrigation section in 1947, which was, tasked the responsibility for construction and supervision of irrigation works.	The continuation of the political and the communal instability, which embedded the 1967 war. After the 1967 war, the West Bank was annexed administratively to Jordan. The socio-economic plans have to incorporate the Palestinian immigrants.	The creation of water resources management institutes: the JVA, WAJ and the MWI in the 1977, 1988 and 1992 respectively. The signing of the Peace treaty between Israel and Jordan. Water sector review and the emergence of new strategy that include different policies to deal with the water utilities, groundwater, wastewater and irrigation water management aspects. New water reallocation was setup.
Hydraulic investment	Small irrigation canals.	The construction of 69 km canal, the Esat Ghor Canal or KAC	The two projects extension of the EGC and construction of dams and other irrigation projects. The construction of wastewater treatment plants. Intensive exploitation of groundwater resources in the highlands.
Landownership	Bedouin mainly owned Land.	1962: land distribution scheme was launched in the Jordan valley. During the 70s: the shift of landownership in the Highlands from Bedouins to private investors.	The issue of a new law allowing landownership transfere
Agriculture activities and irrigation techniques	Bedouins were growing subsistence agriculture combined with pasturage. The main crops were wheat, barley and corn. Irrigation practices: surface irrigation with a low efficiency	The shifting from subsistence agricultural activity to a productive agriculture for the local and the regional market. The main crops were vegetable crops and fruit trees From 1960 to 1976, surface irrigation technique was used	1976 the development of the mulch combined with drip irrigation and the green houses. The shifts to more efficient irrigation techniques. In the 80s, Agricultural exports decreased
Water management aspects	No water allocation policy.	The policy firstly allocated water for irrigation.	Policy of reduction of the amount of water allocated to the agricultural sector. Municipal uses have to be met first. 45 MCM of EGC water was allocated to drinking uses in Amman. The emergence of new strategy.

Appendix 5: The used figures in the report and the related sources and references

Data Issue	Data Figure	Reference	Period
The upper Jordan Discharge in Tiberias Lake	475 MCM 600 MCM 520 MCM 660 MCM	**Internet:** http://www.passia.org/publications/bulletins/water-eng/pages/water04.pdf **Al-Weshah, R.** (2000). **Jayyousi, O**. (2001). **Internet:** http://www.unu.edu/unupress/unupbooks/80858e/80858E06.htm	2002
Total Input to Lake Tiberias (This, most propabaly, doesn't include water used in Hula valley)	770 MCM 790 MCM	**Klein, M.** (1998). **Internet:** http://www.unu.edu/unupress/unupbooks/80858e/80858E06.htm	
Total water use by Israil from the JR	60% of 1400 (840)	**Mimi and Sawalhi, 2003**	
Historic average output from Tiberias Lake	605 590 600	**El Naser, 1996 ?** **Claculated from Klein, (1998)** **Beaumont, P. (1997)**	
Evaporation from Teberias Lake	210 MCM 283 MCM 270 MCM	**GTZ** (1998). **Klein, M.** (1998). **Internet:** http://www.unu.edu/unupress/unupbooks/80858e/80858E06.htm	
Yarmouk River Average Flow. (*This discrepancy, on the most cases, resulted from different years of measurements between drought and wet years or recent measurement as the flow has declined*)	455 MCM 438 MCM 480 MCM 300 MCM 475 MCM 440-170 MCM 400 MCM 467 MCM 470 MCM	**Jayyousi, O**. (2001). **Khori, R.** (1981). **Hof, F. C**. (1998). **Qaisi. K.** (2001). **Klein, M.** (1998). **Jayyousi, O**. (2001). **Internet:** http://www.unu.edu/unupress/unupbooks/80858e/80858E06.htm **Salameh, E and Bannayan, H.**(1993). Internet: http://www.jordanembassyus.org/112298002.htm	1989-1998
Water pumped from Tiberias Lake to the Israeli National Carrier	420-460 MCM 405 MCM 420-450 450 In exess 450	**Internet:** http://www.passia.org/publications/bulletins/water-eng/pages/water04.pdf **Klein, M.** (1998) **Internet:** http://www.fsk.ethz.ch/encop/13/en13-ch1.htm#Surface_water_resources Internet: http://www.gefweb.org/Projects/Pipeline/Pipeline_6/Jordan_Water_Quality.pdf **Beaumont, P. (1997)**	1978-1992
Saline springs diverted by Israel to the Jordan River	40 MCM 65 MCM	**Internet:** http://www.passia.org/publications/bulletins/water-eng/pages/water04.pdf **Orthofer, R**. (2001).	
Return flow of Saline water from Jordan to the Jordan River	45 MCM	**Orthofer, R**. (2001).	
Lower Yarmouk River Flow	240-280 MCM 270 MCM 325 MCM	**GTZ** (1998). **Internet:** http://www.jordanembassyus.org/112298002.htm **NWMP** .(1977).	

The Syrian water abstraction from the Yarmouk River	160 MCM 180 MCM 170 MCM 220 MCM 130-180 MCM 220 200	**Internet:** http://www.passia.org/publications/bulletins/water-eng/pages/water04.pdf **ANTEA-BRL**. Schema directeur indicatif de gestion des resources en eau du basin du Jourdain **Jayyousi, O**. (2001). **Hof, F. C**. (1998). **Klein, M.** (1998) http ://www.jordanembassyus.org/112298002.htm El Naser, 1996 and communication with Dr. Minstry of Planning	 1995
Diverted water from Israel to Tiberias Lake	65 MCM 100 MCM 70 MCM 136 MCM	**Internet:** http://www.passia.org/publications/bulletins/water-eng/pages/water04.pdf **Jayyousi, O**. (2001). **Hof, F. C**. (1998). **Klein, M.** (1998) http://www.jordanembassyus.org/112298002.htm	
Flood water from the Yarmouk River to the Jordan River	70 MCM 60 MCM	**ANTEA-BRL**. Schema directeur indicatif de gestion des ressources en eau du basin du Jourdain **Hof, F. C**. (1998).	1995
Extracted water share of water from the YR by Israel	70 70 70-100	**Hof, F. C. (1998).** **El Naser, H 1998** **Inernet**: http://www.transboundarywaters.orst.edu/projects/casestudies/jordan_river.html	
Water diverted from the Yarmouk River to the KAC (Jordan Share from the Yarmouk River)	90-110 MCM 100-105 MCM 130 MCM 100-110 MCM 135 MCM	**Internet:** http://www.passia.org/publications/bulletins/water-eng/pages/water04.pdf **Jayyousi, O**. (2001). **Hof, F. C**. (1998). **Qaisi. K.** (2001). **Interview:** with Nayef Seder from JVA	
Zarqa River discharge (without wastewater)	60 MCM 85 MCM	**Salameh, E and Bannayan, H.**(1993), **Jayyousi, O**. (2001). **Khori, R.** (1981).	
Water diverted from Mokheibi wells to KAC	20 MCM 25 MCM	**Jayyousi, O**. (2001). **Grawitz, B**.	
The North Side Wadis flow to KAC	20 MCM	**Jayyousi, O**. (2001).	
The Sorth Side Wadis flow to KAC	40-44 MCM	**Jayyousi, O**. (2001).	
Pumped water from KAC to Amman (Maximum)	45 MCM	**Salameh, E and Bannayan, H.**(1993).	
Water from KAC to irrigate the Northern Ghor	60 MCM	**Jayyousi, O**. (2001).	
Water from KAC to irrigate the Northern Ghor	36 MCM	**Jayyousi, O**. (2001).	
Water from KAC to irrigate the Northern Ghor	41 MCM	**Jayyousi, O**. (2001).	
Water used to irrigate Hisban Kafrein area	5.5 MCM	**Jayyousi, O**. (2001).	
Irrigated area in the northern Ghor	8280 ha 11630 ha	**Salman, A.** (2001). **Al-Weshah, R.** (2000).	 1993
Irrigated land in the Middle Ghor	9110 ha 7770 ha	**Salman, A.** (2001). **Al-Weshah, R.** (2000).	 1993

The 65 km EGC irrigated land	11700 ha		
The 18 km EGC extension irrigated land	3550 ha 3650	**Khori, R.** (1981).	
The 14.5 km EGC extension irrigated land	6000 ha 4180 ha	**Khori, R.** (1981). **Al-Weshah, R.** (2000).	 1993
The Zarqa triangular irrigated land	1500 ha 1650 ha	**Khori, R.** (1981). **Grawitz, B**.	
The NEG irrigated land	3950 ha 4200 ha	**Khori, R.** (1981). **Grawitz, B**.	
Hisban Kafrein irrigated area	1660 ha 1500 ha 1660 ha	**Jayyousi, O**. (2001). **Khori, R.** (1981). **Grawitz, B**.	
Total discharge of the KTD to KAC	100 MCM	**Jayyousi, O**. (2001).	
Treated wastewater used in irrigation in the JV	42 MCM 61 MCM 40 MCM 61 MCM	**Jayyousi, O**. (2001). **Bataineh, F.; Najjar, M and Malkawi. S**. (2002). **Qaisi. K.** (2001). **MWI and USAID**-WRPS. (2001).	1999 2001 2000
Water pumped from karek to the highlands	17 MCM	**Salameh, E and Bannayan, H.**(1993).	1993
Saline water pumped by Israel from the Jordan River	7 MCM	**Orthofer, R**. (2001).	
The natural discharge of the Jordan River into the Dead Sea before the 50s In the absense of irrigation	1100-1400 MCM 1400 MCM 1400 MCM 1850 MCM 1348 1250-1600 1500 1850 1440	**Klein, M.** (1998). **Al-Weshah, R.** (2000). **Jaber and Mohesen** (2000). Internet: http://www.unu.edu/unupress/unupbooks/80858e/80858E06.htm El Naser, H (1996) Mimi and Sawalhi, 2003 **Internet:** http://www.fsk.ethz.ch/encop/13/en13-ch1.htm#Surface_water_resources **Internet:** http://www.gefweb.org/Projects/Pipeline/Pipeline_6/Jordan_Water_Quality.pdf **Johnston plan**	
Recent annual discharge of the Jordan River into the Dead sea	400 MCM 220-250 MCM 100-200 MCM 250-300	**Al-Weshah, R.** (2000). **Klein, M.** (1998). **Orthofer, R**. (2001). **Salameh, E and Bannayan, H.**(1993).	
Total Irrigated land in the JV	24600 ha 30,000 ha	**Orthofer, R**. (2001). **Grawitz, B**.	
Total irrigated land in the JV (actual)	23580 ha	**Al-Weshah, R.** (2000).	1994
Irrigation water demand in the JV	220 MCM 218 MCM 140 MCM	**Grawitz, B**. **Jayyousi, O**. (2001). **Jayyousi, O**. (2001).	 1990-1999 1995-1999
Total Irrigated Land in the Highlands	52000 ha	**Grawitz, B.**, **Jabarin, A.** (2001).	

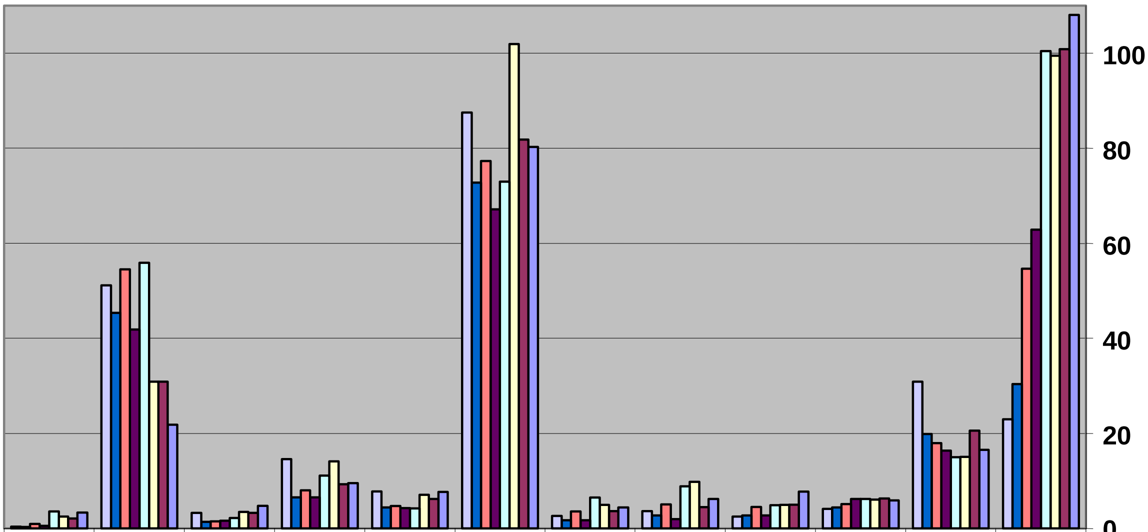
in the whole country			
The lower Jordan flow Base, Flood and total	84,64,148	**Salameh, E and Bannayan, H.** (1993) and **Jayyousi, O**. (2001).	
Israel use from the stream of upper Jordan river	90% of total flow	**Managing water for peace in the middle esat (copy the atrticle)**	
Municipal use for Amman and Irbid	70	**El Naser, H 1996?**	
Side wadis fresh water including the zarqa river is estimated to	190	**El Naser, H 1996?**	

Appendix 6: Sources of water supply in the Jordan Valley (in MCM) during the period of 1990-2002

	Years (1990- 2002)													
Source*	1990	91	92	93	94	95	96	97	98	99	2000	2001	2002	Average
Yarmouk*	98.4	95.5	165	118.5	99.2	108	110.8	99.5	102.3	62.8	54.6	30.4	23	89.85
Wadi Arab	15.2	9.1	30.4	15.5	17.2	17.8	24.5	27.6	23.4	19.6	19.6	18.5	22.8	20.09
Ziglab	6.1	5.6	10.8	9.8	8.5	5.9	6.4	6.1	6.2	6.2	5.1	4.4	4.1	6.55
KTD (including treated waste water)	71.2	92.8	202.2	107.9	112.7	80.2	81.7	101.9	72.9	67.1	77.3	72.8	87.5	94.48
Wadi Zarqa	48.8	68.7	174.9	74	79.1	45.3	45	64.3	29.7	24.8	77.3	72.8	87.5	68.63
Reclaimed water	22.4	24.1	27.3	33.9	33.6	34.9	36.7	37.6	43.2	42.3				33.60
Kufrein dam	8.8	12.8	38.1	26.1	16.4	9.5	9.3	14.1	11.2	6.6	8	6.6	14.6	14.01
NSW	10.7	10.5	14.1	26.9	19.2	6.7	6.5	6.4	7.5	1.1	1.6	1.6	2.6	8.88
Conveyed from Tibrias						21.8	30.8	47.4	55.9	41.9	54.4	45.4	51.1	43.59
SSW						45.6	45.2	45.2	45.2	45.9	44.1	43.7		44.99
Pump from KAC to														
1. wadi Arab dam	13.6	16.7	10	15	15.3	17.2	23.5	26.3	21.9	19.6	16.8	11.7	18.6	17.40
2. Amman	9.6	4.1	28.2	26.5	24.4	39.5	38.1	38.6	37.7	41.4	41.2	39.9	36.7	31.22
Out way water (lost)	0	0	115	14.5	0	0	0.18	0.54	30.9	0				16.11
Total	187.2	205.5	307.4	248.7	233.5	238.8	253.42	282.76	234.1	190.2	206.7	171.8	150.4	223.88

Source of table: The JVA, hard copy from Mr. Nayef Seder.
* Although the Mukheibeh wells should be included but it is not one of the water supply sources. When called with Nayef Seder, he said that it should be included.

Appendix 7: Sources of water supply in the Jordan Valley (in MCM) during the period of 1995 to 2002



	Other Wadis	Tiberias Carrier	Hisban Wadi	Kafrein Wadi	Shueib Wadi	Zarqa Wadi	Rajib Wadi	Kufranjeh Wadi	Jurum Wadi	Ziglab Wadi	Mukheibi Wells	Yarmouk
1995	3,357	21,79	4,817	9,525	7,702	80,223	4,415	6,169	7,761	5,953	16,551	108,015
1996	2,122	30,831	3,264	9,290	6,174	81,791	3,645	4,511	5,000	6,368	20,568	100,818
1997	2,473	30,831	3,449	14,091	7,103	101,928	4,944	9,821	4,942	6,073	15,041	99,497
1998	3,592	55,927	2,194	11,152	4,220	72,972	6,509	8,862	4,878	6,168	15,023	100,417
1999	0,544	41,878	1,663	6,536	4,274	67,143	1,716	1,947	2,733	6,175	16,343	62,854
2000	1,000	54,485	1,498	8,028	4,674	77,287	3,535	5,043	4,518	5,111	17,965	54,616
2001	0,319	45,36	1,375	6,558	4,398	72,774	1,712	2,727	2,771	4,393	19,871	30,414
2002	0,337	51,138	3,296	14,592	7,812	87,514	2,639	3,657	2,502	4,15	30,88	22,953

Appendix 8: The volume of water used for irrigation projects (either released or sold) in the Jordan Valley (1995-2002)

Source: The JVA, Mr. Yusef Hasan

Irrigated projects	Irrigated land (ha)	1995	1996	1997	1998	1999	2000	2001	2002	Average
North Ghor	7309	37.358	41.115	39.350	43.680	35.818	32.357	22.655	27.205	34.942
North East Ghor (NEG) & Wadi Arab	2760 1253	14.639	18.025	19.925	25.165	22.223	20.490	15.029	17.177	19.084
Middle Ghor Zarqa tringular	64540 1650	38.134	36.864	32.482	36.655	29.278	27.920	16.344	21.191	29.948
South Ghor	3650+5985	25.940	26.440	23.087	29.461	24.089	25.097	16.183	18.191	23.561
Wadi Shueib	250	5.212	3.526	5.763	3.240	3.125	3.906	4.269	7.289	4.537
Hisban and Kafrein	1659	9.309	6.344	7.751	5.692	2.806	2.293	1.632	3.761	4.948
Total sold water [44] for irrigation projects		130.592	132.314	128.358	143.893	117.3387	112.062	76.112	94.784	116.932

Irrigated projects	Irrigated land (ha)	1995	1996	1997	1998	1999	2000	2001	2002	Average
North Ghor	7309	49.730	39.232	46.700	50.580	38.580	34.870	25.65	30.336	39.471
North East Ghor (NEG) & Wadi Arab	2760 1253	18.267	20.382	28.330	35.503	28.633	26.006	19.027	19.887	24.504
Middle Ghor Zarqa tringular	6454 1650	36.962	38.087	34.463	41.427	38.084	40.216	25.689	30.114	35.630
South Ghor	3650+5985	33.974	34.250	33.431	38.224	29.469	34.302	20.197	23.588	30.929
Wadi Shueib	250	5.212	3.526	5.763	3.240	3.125	4.779	4.398	7.259	4.663
Hisban and Kafrein	1659	10.012	7.033	10.826	7.347	3.849	4.000	3.551	7.303	6.740
Total water released for irrigation projects		130.592	132.314	128.358	143.893	117.3387	112.062	76.112	94.784	141.938

[44] Plesae note the listed figutres are for sold water but not the actual irrigation water use for each project. It is caluclated from other data provided from the same source that the average water loss (1995-2002) is about 17%

Appendix 9: water resources (into KAC) and irrigation water uses in the JV

Source: The JVA, Mr. Yusef Hasan

MCM/year	1995	1996	1997	1998	1999	2000	2001	2002	Average
Available water from all sources flowing into KAC	276,278	274,382	300,193	291,914	213,806	237,760	192,672	231,470	252,309
Total water released for irrigation projects	154,157	142,602	159,512	176,321	141,740	144,173	98,512	118,487	141,938
Irriglur supply of sold water for irrigation projects	1,122	1,422	1,646	0,754	0,359	0,528	1,954	3,885	1,459
Irrigation water used for areas having water rights outside the irrigation projects	6,319	4,820	3,409	1,862	1,795	2,269	1,607	1,360	2,930
Total water use for irrigation	161,598	148,844	164,567	178,937	143,894	146,970	102,073	123,732	146,327
Total sold water for irrigation projects	130,592	132,314	128,358	143,893	117,339	112,062	76,112	94,784	116,932
Irriglur supply of used irrigation water to areas having irrigation water rights	7,441	6,242	5,055	2,616	2,154	2,797	3,561	5,245	4,389
Total sold and used water for irrigation	138,033	138,556	133,413	146,509	119,493	114,859	79,673	100,029	121,321
The difference between the total released and the total sold and used water	23,565	10,288	31,154	32,428	24,401	32,111	22,400	23,703	25,006
losses %	14,582	6,912	18,931	18,123	16,958	21,849	21,945	19,157	17,307

Appendix 10: Detailed specification of base flow monitoring and use per catchment (Old figures, not yet updated)

Source: The draft of the NWMP Surface Water-Main Report, 2003

Catch-ment Code	**Wadi**	**Reservoir(s)**	**Upstream gauging station**	**Mean baseflow observed at station**	**Use upstream from station**	**Use upstream (basin)**	**Flow in wadis without reservoir**	**Inflow to reservoir**	**Total baseflow**
Code	Name	Name	Code	MCM /yr	MCM /yr	MCM /yr	MCM /yr	MCM /yr	MCM /yr
AE	Arab	Wadi Al Arab	AE0400	dry	0.5	9.0			0.5
AC	At Tayyiba	-	-			NSW			0.0
AF	Ziglab	Ziqlab	AF0003	7.8	0.5			7.8	8.3
AG	Jurum	-	-						0.0
AH	Yabis	-	AH0005	2.5	2.4		2.5		4.9
AJ	Kufrinja	-	AJ0005	7.3	5.1		7.3		12.4
AK	Rajib	-	AK0003	5.1	0.5		5.1		5.6
AL	Zarqa	King Talal Dam	AL0060	31.6	21.0	21		31.6	52.6
AM	Shueib	Shueib	AM0008	7.4	4.0	7.5		7.4	11.4
AN	Al Bahath	Kafrein	AN0006	12.9	1.5	SSW		12.9	14.4
AP	Hisban	(Hisban)	AP0002	1.6	2.0		1.6		3.6
A	**Jordan basin (except Yarmouk)**				**37.5**		**16.5**	**59.7**	**113.8**

Appendix 11: Water recourses balances for Amman Governorate (m3) for the year 2000

Resource input/output	Year 2000												
	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Average
From Zai	2377900	2607692	3289150	3301030	3478340	3171570	3463720	3625600	3489650	3308650	3233000	3219170	3213789,3
Fuheis to Dabouq	0	12600	17500	22330	28525	58256	55621	31777	31777	31910	57580	46688	32880,333
Khaw/Zarqa to Ein Ghazal	1437130	1364590	1443160	1362230	1458270	1422400	1460450	1475260	1375200	1350650	1475510	1520780	1428802,5
Zarqa distribuation to Marka	0	0	4800	4800	4800	4800	4800	4800	4800	4800	4800	4800	4000
Khaw/Zarqa to Marka	104400	104400	111600	43200	43200	43200	44640	44640	43200	44640	43200	44640	59580
Wala-Hidan/Madaba to Muntazah	387326	379382	336889	349201	417508	515054	521263	526284	483433	439365	326375	307725	415817,08
Total external sources	4306756	4468664	5203099	5082791	5430643	5215280	5550494	5708361	5428060	5180015	5140465	5143803	5154869,3
Total External sources/year/MCM													61,858431
Muhajereen well	161696	146711	162897	158068	162479	164322	171648	174982	170933	183387	152395	168803	164860,08
Ras El Ain Spring	0	0	0	162278	243473	199870	178920	160695	146704	160721	134907	250321	136490,75
Taj wells	750797	698500	830229	790155	834366	774960	793535	798026	717370	784847	700945	786772	771708,5
Ruseifa wells	122720	184878	212746	418232	742007	693394	581257	632550	519049	354511	234986	215487	409318,08
Yajouz wells	53137	51220	53387	51925	52564	51746	50982	41541	50836	50604	49714	49958	50634,5
Qastal wells	122133	121245	151903	170256	207139	195190	199658	215294	182165	166490	217838	47215	166377,17
Suwaqa East wells	340052	291156	349654	265035	382906	332882	372575	419957	329573	298829	390281	346301	343266,75
Suwaqa West wells	188334	207695	205097	154682	230812	176025	155886	227833	162130	169856	168152	76635	176928,08
Qatraneh wells	199166	236786	239661	256797	298635	294232	265319	310816	148709	162066	289246	269521	247579,5
Madhona wells	0	0	0	0	0	0	0	0	0	0	0	0	0
Wadi Qattar well	3643	3752	3438	4775	8442	4959	11	4800	2484	2613	3134	2450	3708,4167
Ras El Ain wells	0	0	0	0	0	0	0	0	0	0	0	0	0
Wadi Saqra well	31954	30507	33096	33884	32861	27093	34322	26425	30040	34065	32748	30867	31488,5
Muwaqqar wells	102455	75112	79206	85849	116729	114174	114174	115985	35239	106113	31288	26265	83549,083
Musaitbeh wells	121170	116593	127654	148357	128439	94162	109033	116562	92549	79149	76800	41741	104350,75
Wadi Sir Spring	0	0	0	127920	143862	0	53202	160618	145589	134176	128856	66827	80087,5
Abdoun well	0	0	0	0	0	30484	34349	35415	31687	34614	32718	29757	19085,333
Yadudeh well	0	0	0	0	0	13000	33999	35531	36839	46541	40109	29861	19656,667
Irainbeh well	28129	24494	30910	32359	34110	30775	28888	27971	32416	35228	36250	36186	31476,333
Total internal sources	2225386	2188649	2479878	2860572	3618824	3197268	3177758	3505001	2834312	2803810	2720367	2474967	2840566
Internal resources/year/MCM													34,086792
Zai/Dabouq to Mashara	73912	55888	30508	101901	103220	91334	87752	108769	105698	83805	73806	57653	81187,167
Zai/Dabouq to Yazidieh	21152	63605	70877	29867	98190	123087	129485	64268	33772	9532	96912	99549	70024,667
Zai/Dabouq to Baqaa	45388	47024	65250	68376	72981	78788	83762	80127	83078	88020	80856	79500	72762,5
Zai/Dabouq to Fuheis	39124	14876	0	28756	49252	58256	55621	59045	57498	55103	57580	59525	44553
Zai/Dabouq to Zaatari	12020	10231	10353	28756	17575	20575	21427	22875	19271	15150	14166	12256	17054,583
Zai/Dabouq to Um Joza	36487	19820	19185	28756	42959	39959	51955	55437	46687	38158	30730	26083	36351,333
Aburuseir network to Aburuseir village	5139	3982	3525	28756	5680	3139	3139	2183	2183	1682	1682	2477	5297,25
Thiban Booster to Madaba	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000	45000
Qatrana PS to Qatrana village	14601	14401	15671	28756	19871	21299	24233	24084	18453	17278	14350	12363	18780
1A to Damkhy Village	223	434	1223	28756	985	1217	1217	242	242	0	0	0	2878,25
Total out puts	293046	275261	261592	417680	455713	482654	503591	462030	411882	353728	415082	394406	393888,75
Total output/year/MCM													4,726665
Total water supplied	6239096	6382052	7421385	7525683	8593754	7929894	8224661	8751332	7850490	7630097	7445750	7224364	7601546,5
Average Water Supplied	207970	212735	247380	250856	286458	264330	265312	282301	261683	246132	248192	233044	250532,75
Deir Alla intake	2824593	2890205	3522760	3463580	3663850	3389750	3631800	3744340	3566180	3458750	3469190	3440610	3422134
Deir Alla intake/year/MCM													41,065608