MINISTRY OF WATER AND IRRIGATION

Water Resource Policy Support

Irrigated crops in the Jordan Valley

WATER REUSE OPTIONS IN THE JORDAN VALLEY

WATER REUSE COMPONENT

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TABLE OF CONTENTS

ABBREVIATIONS

ARD	Associates in Rural Development
AZB	Amman-Zarqa Basin
BMP	Best Management Practices
BOD_5	Biochemical Oxygen Demand, Five Day
COD	Chemical Oxygen Demand
DA	Development Area
DO	Dissolved Oxygen
ECC	Economic Consultative Council
FCC	Fecal Coliform Count
GAP	Good Agricultural Practices
GIS	Geographic Information System
GPS	Global Positioning System
GTZ	German Technical Cooperation
HL	Highlands
HRZ	Hashemite-Rusefieh-Zarqa area
IAS	Irrigation Advisory Service
IRG	International Resources Group
JICA	Japanese International Cooperation Agency
JV	Jordan Valley
JVA	Jordan Valley Authority
Km^2	Square Kilometers
KTR	King Talal Reservoir
LEMA	Lyonaise des Eaux Management-Amman
LIMS	Laboratory Information Management System
m^3	Cubic meter
M&I	Municipal and Industrial
MCM	Million cubic meters
MOA	Ministry of Agriculture
MOH	Ministry of Health
MWI	Ministry of Water and Irrigation
NCARTT	National Center for Agriculture Research and Technology Transfer
NIR	Net Irrigation Requirements
NPW	Net Present Worth
NRA	Natural Resources Authority
RA	Rapid Appraisal
RS	Remote Sensing
SO	Stage Office
SS	Suspended Solids
TDS	Total Dissolved Solids

TO	Task Order
UFW	Unaccounted for Water
USAID	United States Agency for International Development
WAJ	Water Authority of Jordan
WRPS	Water Resources Policy Support
WSP	Waste Stabilization Ponds
WWTP	Wastewater Treatment Plant

ACKNOWLEDGMENTS

This report was written by Peter G. McCornick, Nisreen Haddadin and Ramzi Sabella.

The Jordan Valley is a fascinating and complex water system, with a long history. Many people have patiently provided their insights into this system, and voiced their concerns with respect to water use and water reuse in the valley. The farmers deserve special mention. Faced with the challenges of irrigation management under water short conditions and poor water quality, they took time to relate their experiences and concerns.

We would like to specifically acknowledge the valuable contributions of Engs. Suzan Taha, Edward Qonqor, Yasser Nazzal and Rasha Sharkawi of the Ministry of Water and Irrigation. Also Engs Ilham Abu Aisha, Qais Awais, Yousef Al-Sakran, Yaseen Abu Znaineh, Taiseer Masalha, Shafeik Al-Habish, Taiseer Al-Gazawi, Mahmoud Menwer, Naeif Seder, Laith Al-Wakid and Husam Al-Deen Elaide of the Jordan Valley Authority.

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EXECUTIVE SUMMARY

This report presents the identification and pre-feasibility level investigation of options for using increased supplies of recycled water in the Jordan Valley from the wastewater treatment plants in the Amman-Zarqa basin. The identified options are the potential demands that will be considered in the possible scenarios for managing recycled water fromin the Amman-Zarqa basin.

Irrigation with recycled water from the Amman-Zarqa basin is technically feasible and can sustainably produce a wide variety of crops. The restrictions on crops, primarily due to the salt and chloride levels, will require good management to be productive and prevent salinization of the soils. Other constituents are of concern, particularly the microbiological contamination and, at certain times of the year, nitrogen. With the upgrades planned for As Samra, the nitrogen issue, unlike the salts, will be addressed. Microbiological contamination will also be addressed, but contamination of water in the wadi from sources other than treated effluent, remains a concern. Other constituents are, as yet, not constraints to irrigated agriculture.

Irrigation water management in the Jordan Valley, despite considerable efforts in recent years, has much room for improvement, although it should be realized that improved management will more than likely not result in conservation of water, but in improved productivity. Also, maximizing returns from irrigated crops will be limited by the lack of storage on the KAC water supply. Much of that water supply is only available in the wet, winter season and, other than leaching of the soils, is not at the time when the crops can use it.

Although there is a possibility that new fresh water sources may become available for irrigated agriculture in the Jordan Valley, this is not likely, especially considering the chronic National water deficit and the Government's policy to exchange effluent for fresh water resources. The analysis assumes that, as a best-case scenario, fresh water resources will remain as they are now.

For using increased volumes of recycled water in the Jordan Valley, the basic options are:

- Karameh Directorate - intensification of irrigated agriculture,
- Middle Directorate - intensification of irrigated agriculture
- Northern Directorate – replace KAC canal water in the event it is transferred to domestic use.

The option of exchanging for some fresh water in the Kufrein area (stage office 10 in the Karameh Directorate) was examined, but, after further investigation, discounted because the water within the Kufrein reservoir is considered not suitable for domestic use.

The Northern Directorate was included because if recycled water is allocated elsewhere it will remove the opportunity of replacing any short-fall in fresh water resources in the Northern Directorate should water be reallocated to domestic use.

In the case of the Karameh directorate, the total irrigation water demands, including those lands presently irrigated, would be 76 M-m^3. Of that, 63.6 M-m^3 would come from KTR and/or Karameh dam, and the remainder, as fresh water, from KAC and/or Kufrein. The total additional water requirements from KTR would be 39.6 M-m^3. The cost for implementing this, exclusive of on-farm costs, is JD 2,200,000, which is the conveyor from KAC to Kufrein (stage office 10). The major benefits would be an increase of 38,000 dunums receiving reliable water supplies and general intensification because of more reliable water supply. Details are provided in Table 1. The major negative would be the potential increase in groundwater contamination.

Table 1. Summary of results from analysis of options

	(A)		(B)		C	(C/A)	(C/B)	OPERATING
OPTION	AREA **	VOLUME OF WATER		FRESH	CAPITAL COST			COST
	dunum	Total	KTR*	REPLACED	Total	JD/Dn	JD/CUM	JD/CUM
Karameh	38,000	39,600,000	39,600,000	0	2,200,000	58	0.056	0.074
Middle	6,000	6,000,000	6,000,000	0	0	0	0.000	0.000
Northern	69,000	72,000,000	58,000,000	58,000,000	87,000,000	1,261	1.500	0.015

* Where blending, assumes20 percent freshwater
** Either increased area through intensification or replacement of area presently using freshwater

In the middle directorate, the costs of intensification are nominal as the infrastructure is already in place. However, the volume of water involved (6 M-m^3) is small. In practice, this intensification in the middle directorate is likely to happen with no intervention. The reason it is not presently functioning at this intensity is the constraints on water supply. Details are provided in Table 1. There would be some risk of increased groundwater contamination, although the anticipated improvement in effluent quality should have an overall positive effect compared to the present situation.

The cost of developing a conveyor to the Northern Directorate is high, even without considering the loss of yields caused by the lower quality water, and the need for further on-farm developments, such as filters. The volume of water required to meet the needs of a water-short northern directorate is high (58 M-m^3). Further details are presented in Table 1. The major negatives would be the reduction in overall production in the directorate requiring major changes in cropping patterns, and the potential increase in groundwater contamination. On the other hand, this option could become economic depending on the value of the freshwater saved and the extent of the agricultural losses which would be incurred with the removal of existing freshwater supplies.

Micro-biological contamination of the KTR water reaching the Jordan Valley, which is only partly due to effluent from wastewater treatment plants, poses a significant health risk, primarily in the winter months. The prevalence of drip irrigation and the use of plastic mulches reduces the risk of the water coming in contact with the part of the crop that is likely to be eaten raw. However, the present levels of contamination are unacceptable, with fecal coliform counts in excess of the Jordanian Standards reaching the Jordan Valley one month out of four. Restricting cropping patterns in the Jordan Valley to comply with the

Jordanian Standards is not realistic. Further disinfection of the water supply once it reaches the valley should be considered. In the short term, minimizing the water supplied from KTR during the wet winter months when microbiological contamination from the highlands is high, would alleviate the problem.

It cannot be emphasized enough that any further elevation of salts in the KTR could be catastrophic to irrigated agriculture in the Jordan Valley. In addition, there remain a number of issues that need to be addressed to improve the overall productivity and sustainability of irrigated agriculture in the Jordan Valley, especially if the volume of recycled water is to be increased. Those relating to the management of quantity of water supply are well documented and known, and pre-requisites for improved agricultural productivity. Others, that specifically relate to water reuse, include:

- Clogging agents in both the KTR and KAC water create a large maintenance problem. Further efforts in developing and introducing on-farm filter methodologies suitable for the Jordan Valley are needed, and the overall concept of a more centralized filter system needs to be re-evaluated. The use of drip systems with larger emitters (bubblers) may be appropriate for some crops.
- There is considerable confusion with regards to the quality of the KTR water, especially amongst the smaller farmers who do not have access to this type of information. Dissemination of the quality information, which is already available (MWI/ARD, 2000c), will alleviate this situation
- Pathogens, as discussed above, pose a threat to the health of the field-workers and the general public. In addition to the wastewater treatment plants in the basin, contamination from the upper Zarqa urban centers, illegal dumping of septage, and intensive livestock operations contribute to this situation. The available data on microbiological contamination in the wadi are insufficient to determine the relative contribution of each source type, but a comprehensive investigation is required. Also, re-introducing disinfection at As Samra needs to be seriously considered.

I. INTRODUCTION

BACKGROUND

This report presents the pre-feasibility level study for the use of increased supplies of recycled water in the Jordan Valley. These developments may utilize some of the increases in effluent to be generated from the Kherbit As Samra wastewater treatment plant and other existing and planned wastewater treatment plants in the basin (MWI/ARD, 2000a).

These investigations are part of planning water reuse in the Amman-Zarqa basin (Taha, et. al, 2001), which is also investigating agricultural (MWI/ARD, 2000b), industrial and municipal use in the highlands of the basin, groundwater recharge, and agricultural use in the wadi itself (MWI/ARD, 2001c). These options are the building-blocks for possible scenarios for managing recycled water in the Amman-Zarqa basin, which will be examined using, among other things, a basin level model that considers both the water quantity balance and the water quality (MWI/ARD, 2001a). The planning effort has also examined the existing water reuse standards and developed a framework for revising them (MWI/ARD, 2001b). A summary of documents produced to date as part of the planning process is provided at the beginning of this document.

OBJECTIVES

The objectives of these particular investigations were:

- Identify potential options for further use of recycled water in the Jordan Valley, and
- Investigate each option to pre-feasibility level.

Specific outputs required from these investigations are the expected water demands for the identified water reuse options for use in assessing the scenarios for managing the basin, and the basic costs for developing these options for the overall economic analysis of the scenarios.

SCOPE & LIMITATIONS

It has already been established that irrigated agriculture in the Jordan Valley using recycled water from the Amman-Zarqa basin is technically feasible, although less productive (Grattan, 2000). The findings from this earlier study will be re-iterated in this document, where appropriate.

The overall conclusion is that irrigated agriculture can sustainably produce a wide variety of crops in the Jordan Valley using the quality of recycled water that is available from KTR. The restrictions on crops, primarily due to the salt and chloride levels, will require good management to be productive and prevent salinization of the soils. However, given poor management, any damage done can, in most cases, be reversed.

The investigation was focused on identifying and characterizing options that would provide good returns from the resource, recycled water. In addition to improving the productivity of irrigated agriculture, the investigations closely considered potential options for exchange with fresh water, which could be used for domestic purposes.

According to the National Irrigation Policy (MWI, 1998) "…No water shall be diverted without a replacement water source that is treated to a such a quality that it can be used unrestricted for agricultural…". It is assumed that the restrictions of concern are with respect to human health and, therefore, the constituents of interest are the pathogens. This is discussed in detail in MWI/ARD (2001b).

Although the diversion of fresh water from the Northern Directorate for domestic water use in Amman is not a stated objective, if it was to occur it would have a very significant impact on the overall water balance in the Amman-Zarqa basin and Jordan Valley. It is important to realize that the allocation of projected recycled water resources to other uses will remove the opportunity of replacing any short-fall in fresh water resources in the Northern Directorate. With this in mind, the option to replace fresh water resources in the North Directorate is included.

It is assumed that the effluent from the wastewater treatment plants will be treated to meet the Jordanian Standards (MWI/ARD, 2000a) for discharge to wadis.

The process of investigating the potential options for using recycled water for irrigation in the Jordan Valley has been iterative. The latest versions of each of these options are presented herein.

This document does not include the economic and financial analysis, which will be completed separately. This document does include cost estimates of enhanced infrastructure.

All of the options considered will place demands on the existing infrastructure, particularly storage. Without sufficient storage, such developments may not reach optimum agricultural production. Finalization of the storage requirements will be beyond the scope of this document, as this will be determined from the output of these investigations in conjunction with the basin model (MWI/ARD, 2001a).

II. OVERVIEW OF THE JORDAN VALLEY

This chapter includes an overview of the land resources, water resources and their management, and the cropping patterns in the Jordan Valley.

The Jordan Rift Valley is divided into the Jordan Valley area and the Southern Ghor. This study is concerned with the Jordan Valley area, which lies to the North of the Dead Sea. This area is divided into the North, Middle and Karameh (or southern) Directorates, which are in turn, sub-divided into stage offices, with each stage office supplying water to a number of development areas.

This study investigated the present and potential water supply needs of the Jordan Valley at the stage office level. The final conclusions and recommendations are presented for each of the directorates.

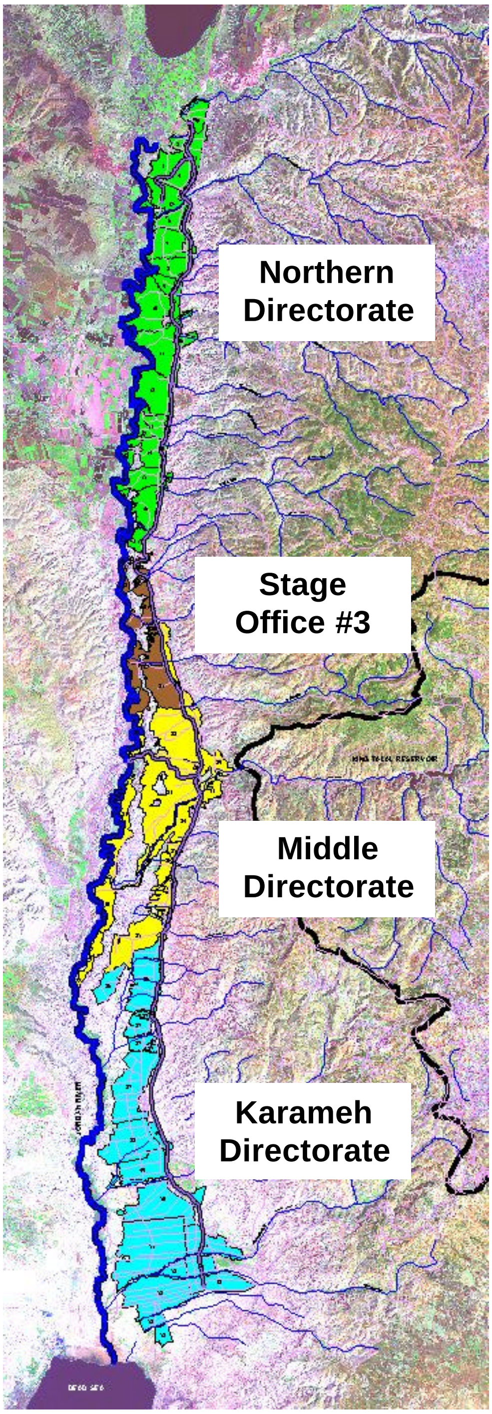

Figure II.1. Layout of the Jordan Valley

II.1. LAND RESOURCES

As summarized in Grattan (2000), soils vary considerably within the Jordan valley. The depth to the hard, impermeable layer varies throughout the valley. In the Northeastern part of the valley, soils are generally well drained and the depth to the restrictive layer is 2 to 3 meters. As one moves towards the Southwest, the depth to the layer declines. In the Karameh directorate the depth to the restrictive marl layer is from zero to 1-m. These soils are more difficult to manage and are subsequently more saline. The shallowest soils and those formed from the Marl parent material are not suitable for irrigation.

It is estimated that about 20-25,000 dunums of land have been artificially drained in the Jordan Valley in the northern (DA 3-16), the middle (DA21, 22, 23, 25 and 29) and in the Karameh (DA 26 and 27), and other areas are reported to have relatively good natural drainage (Grattan, 2000). Clearly, the natural conditions towards the southern part of the valley are least conducive to natural drainage. In accordance with the Irrigation Water Policy (MWI, 1998), additional drains should be installed in irrigated areas where natural drainage is insufficient. However, the shallower soils in the Karameh directorate would not be suitable for artificial drainage.

The Jordan Valley lands have been classified with regards to their irrigability. The irrigable areas in each of the three Directorates are presented in Table II.1, along with the areas irrigated in the 1998 season.

Table II.1. Cropped, irrigable and irrigated areas in the Jordan Valley.

JV	Irrigated Areas	Irrigable Areas	Cropped Areas	Total Area
North*	68,713	100,259	100,808	127,119
Middle*	42,846	71,305	75,001	97,427
South*	34,101	103,708	21,635**	115,071
	TOTAL	**275,272**	**197,444**	**339,617**

* North = stage offices (1,2,3,7,). Middle = stage offices (4,5,8). South = stage offices (6,9,10).

** Without stage office 9, but the other areas include SO9.

Many of the irrigable lands of the Jordan Valley have been developed to allow intensive irrigation. In fact, Stage Office #9 has been developed, but, with the drought of the past few years, has not been officially allocated water, although it does receive unofficial supplies. The allocation of official "water rights" to these areas will only occur when sufficient supplies have been secured (Abu Zuneineh, 2001)

The Jordan Valley has not been receiving the required supplies to meet regular demands and, even when water is available, some farmers are not fully utilizing their available lands because of the generally poor market for crops. Given this, the irrigated areas presented in Table II.1 could be on the low side, especially in the Middle and Karameh Directorates, where seasonal crops dominate. Most of the irrigated area in the Northern Directorate is in permanent tree crops.

II.2. WATER RESOURCES & THEIR MANAGEMENT

This section presents an overview of water resources and their management, in terms of supply and demand, in the Jordan Valley. It is sub-divided into water quantity and water quality. A schematic of the water resources system is presented in Figure II.1.

The water resources and supplies, in terms of quantity and quality, of the Jordan Valley have been described in many reports, most recently by Forward (2000) and JICA (2000), and extensively under the WIQC project (WIQC, 1997) and the World Bank (World Bank, 1997).

A detailed summary of the recent water balance in the Jordan Valley and the projected volumes of effluent are presented in Appendices D and E respectively. These tables have been generated using data from various sources, including the Ministry database (MWI, 2001) and the JVA (JVA, 2001).

II.2.1. Water Quantity

II.2.1.1. Supply

As shown in Figure II.1., water available to the Jordan Valley comes from the Yarmouk River, the Tiberias North Conveyor, Mukheiibeh wells, Wadi Al-Arab, and other side wadis in the north; wadi Zarqa in the middle; and wadis Shueib, Kafrein and Hisban in the south. Unlike the other water sources mentioned, the three side-wadis in the south are not connected to the King Abdulah Canal, the main carrier from north to south in the Jordan Valley. Wadis Arab, Ziglab, Zarqa, Shueib and Kafrein have in-stream dams.

Table II.2 shows the monthly diversions to each of the Directorates for the 1998 season. These data were obtained from the Ministry database (MWI, 2000). Also, the total quantities of water diverted for irrigation use in the three directorates for 1996, 97 and 98 are summarized in Table II.2. Further details are provided in Appendix D. Note that stage office 9 represent the kilometer 14 extension of 60,000-dunnums, and is yet to be officially assigned to farmers. However, irrigated agriculture is already practiced there using groundwater and, as indicated by the data in Table II.3, the tailwater from KAC.

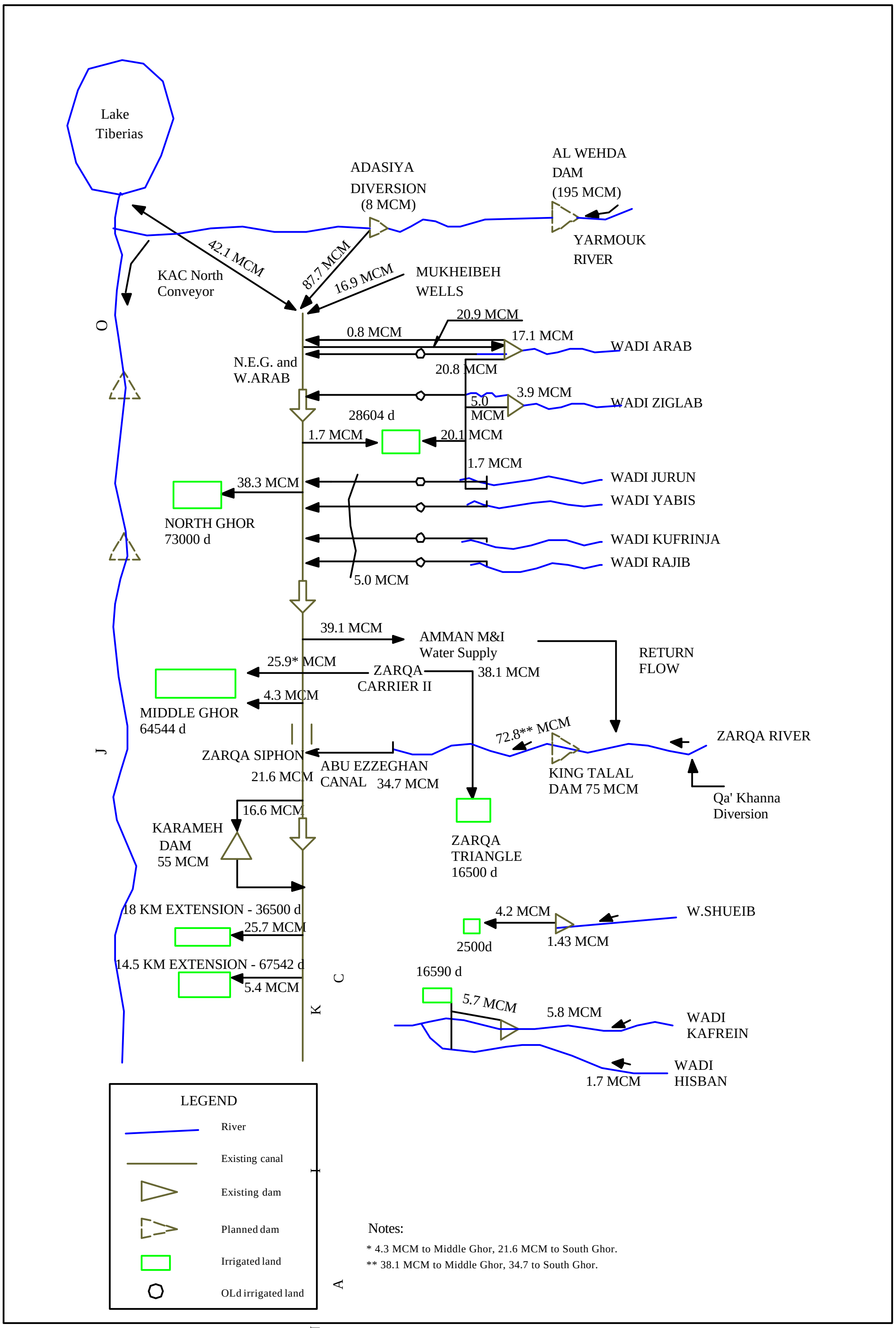

Figure II.1. Schematic of the Jordan Valley water system (volumes are averages for 1995-2000).

Table II.2. Gross water diverted to directorates in 1998

	DIRECTORATE NORTH Stage 1, 2, 3 & 7	MIDDLE Stage 4, 5 & 8	KARAMEH Stage 6 & 10
JAN	587,200	1,382,840	1,290,176
FEB	1,001,500	1,929,713	1,980,288
MAR	2,707,500	3,191,253	3,325,293
APR	5,466,500	5,388,877	3,733,234
MAY	9,965,100	6,283,655	3,327,979
JUN	10,044,100	4,912,839	2,409,866
JUL	10,390,800	3,402,170	1,716,451
AUG	10,468,500	3,877,772	2,195,173
SEP	10,080,500	4,564,032	2,676,267
OCT	9,388,500	5,143,368	2,736,298
NOV	7,626,500	4,013,440	2,351,303
DEC	5,383,900	3,309,535	2,573,393
	83,110,600	**47,399,494**	**30,315,722**

Source: Ministry database (MWI, 2000)

Table II.3. Annual volume of water diverted to each stage office and directorate (1996-1998)

DIRECTORATE	STAGE OFFICE	1996	1997	1998
Northern	1	9,260,560	11,060,583	11,691,385
	2	18,569,367	21,756,801	23,395,889
	3	12,613,887	13,882,617	15,502,726
	7	20,091,312	28,029,100	32,520,600
	Sub-Total	**60,535,125**	**74,729,100**	**83,110,600**
Middle	4	15,233,213	13,768,660	15,314,409
	5	14,529,069	14,102,106	15,957,625
	8	16,022,160	14,465,321	16,127,460
	Sub-Total	**45,784,441**	**42,336,087**	**47,399,494**
Karameh	6	19,310,249	19,164,859	22,401,922
	9	7,558,649	6,385,753	7,097,685
	10	10,435,974	10,825,900	7,913,800
	Sub-Total	**37,304,871**	**36,376,513**	**37,413,406**
	Sub-Total*	**29,746,222**	**29,990,759**	**30,315,722**
TOTAL		**143,624,438**	**153,441,700**	**167,923,500**
TOTAL *		**136,065,789**	**147,055,947**	**160,825,815**

* Sub-total & total without stage office #9

Note that some data-sets include stage office #3 in the Northern Directorate and others include it in the Middle Directorate. In this document it was considered to be in the Northern Directorate, because, as with the other stage offices in the North, it does not receive water from KTR at this time.

II.2.1.2. Demand

The quantity and pattern of water use in an actual irrigation system rarely matches with the theoretical crop water use, and, according to a number of observers (WQIC, 1997; and Hanbali, 2000), this is the case in the Jordan Valley.

Using data from 1998, the theoretical water demands for each of the stage offices were generated (see Appendix A) and compared with the actual supplies delivered. The actual response of the system, in terms of actual water diverted to each stage office, is different from the theoretical water requirements of the crops being grown. However, the results from each Directorate do show that actual water delivered in the middle of the season (hot and dry) is less than will meet the needs of the crops and allow for the expected efficiency of the system, whereas, the quantity of water delivered in the cool winter season is considerably greater than the needs of the crops and the expected losses in the system. This additional usage of water is most likely because the supply is available and, at least to some extent, the need to leach the soils. It also distorts gross efficiency numbers as much of the water supply is only available when the crops cannot use it effectively.

The quantities of water used are generally not much greater than the theoretical needs of the crops and the expected losses in what is a relatively efficient conveyance, distribution and application system. However, the timing of the supplies do not always meet the needs of the crops resulting in lower than expected yields (Hanbali, 2000).

The improvement of water management in the Jordan Valley has been the focus of considerable effort (WQIC, 1997; and Hanbali, 2000). Specific limitations are well documented (WQIC, 1997), and some in-roads have been made to partly addressing the constraints, notably the automation of KAC, the Irrigation Advisory Service (IAS), revising the land tenure system and water pricing. However, there remains considerable room for further improvements.

The relatively poor performance of water in the Jordan Valley is of concern, particularly with relatively high salt levels in the water supply. However, it does not preclude the further use of recycled water in the valley, rather it limits the returns from any proposed developments. The constrained productivity remains whether the water supply is fresh or recycled. In addition, the constraints of water supply, especially in the hotter and drier months, limits the extent to which irrigated crops can reach their full productivity.

II.2.1.4. Future Water Sources

In this particular study, the water source of interest is the effluent generated in the Amman-Zarqa basin. However, there are potentially other sources of water available to the Jordan Valley, including new fresh water sources, and further effluent from the side wadis and, in terms of overall volume, Irbid. The projections of gross effluent expected from all of these plants are presented in Appendix E. The potential contributions from these plants will be discussed in Chapter III for the relevant options.

The availability of new fresh water resources in the Jordan Valley is dependent on a number of major interventions, particularly the development of the Al Wheda dam on the Yarmook River. This dam, according to JICA (2000), will provide a further 50 M-m^3/annum for use in Amman and Zarqa, and water to irrigate 35,500-dunnums (approximately 35 M-m^3/annum) in the Jordan Valley. Considering the Government's policy to not develop new areas of irrigation, and the limitations on available land discussed elsewhere in this report, it seems unlikely that this water would go to new lands, although it could be used to meet the needs of Stage Office #9.

Using the information described above and the overall plans summarized for the National Water Management Plan (JICA, 2000), a basic water balance was developed for the Jordan Valley. This is presented in Appendix F. Whatever the scenario for developing increased fresh water supplies in the Jordan Valley, the likelihood of another 45 M-m^3 being diverted for domestic use and the timeline for a major dam, as is being developed on the Yarmook, could create a short fall in the short to medium term.

In the context of these investigations, the development of new fresh water sources for irrigation is not considered as part of the overall water balance. It is assumed that the maximum use of fresh water resources for irrigation will be similar to the present. That is, the Northern Directorate gets fresh water to meet most of its needs, and the Middle and Karameh Directorates get fresh water in winter when it is available.

II.2.2. Water Quality

Water supplied from wadi Zarqa is a blend of surface runoff (floods), base flow from springs and effluent from Amman's wastewater treatment plants that is stored in King Talal Reservoir for use in the Middle and Karameh Directorates. In theory, the KTR water is blended before with fresh KAC water for use in these directorates. However, most recently, the KTR water has been delivered at full strength. For 1998 and 1999, the portion of the water supplied to the Middle Directorate from KTR was 91 and 100 percent respectively, based on records from the Middle Directorate. Ironically, those farmers in the Karameh Directorate who presently use saline groundwater, view KTR water as being better quality, at least with respect to salt, than their present supply.

Figure II.2 compares the portion of KTR water delivered to Middle and Karameh (excluding stage office 10) Directorates from 1995 through 1999. The very low number in early 1998 is associated with water being diverted through KAC to fill the Karameh Reservoir. The average proportion of KTR water delivered to the Middle and Karameh Directorate over these five years was 87 and 67 percent, respectively. The average for the Karameh Directorate excluding the data for the period when the Karameh Reservoir was filling was 73 percent.

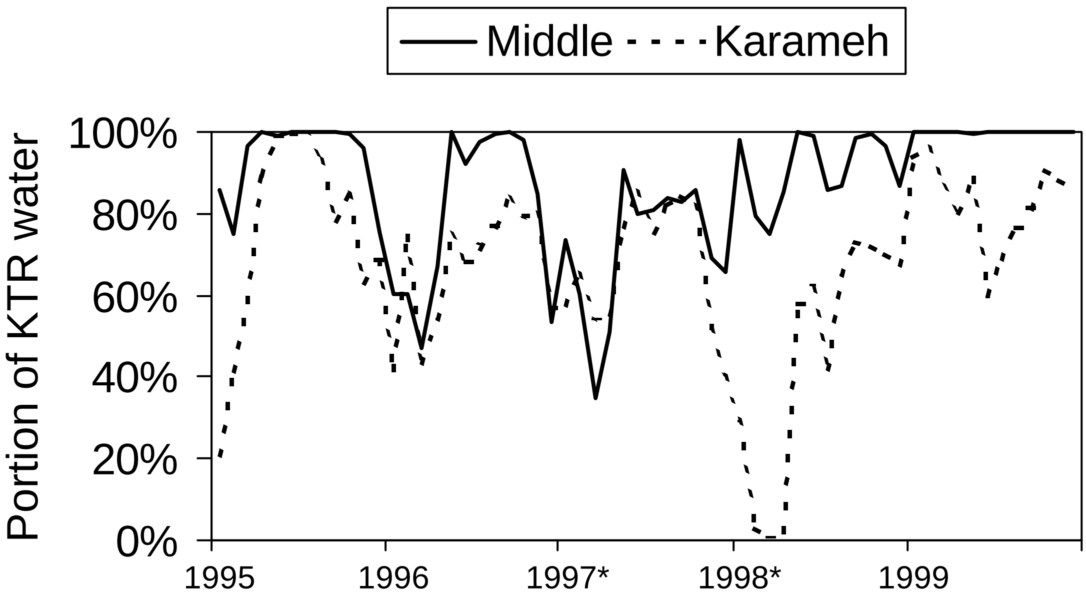

Figure II.2. Blending of KTR with KAC water to the Middle and Karameh Directorates.

II.2.2.1. Impact on Irrigated Agriculture

The expected impact of increased supplies of recycled water on irrigated agriculture in the Jordan Valley has been discussed in detail in Grattan (2000). Water quality can impact irrigated agriculture in terms of crop production, management, maintenance and human safety.

With respect to the sustainability of irrigated agriculture, the conclusion is that irrigated agriculture can sustainably produce a wide variety of crops in the Jordan Valley using the quality of recycled water that is available from KTR (Grattan, 2000). The restrictions on crops, primarily due to the salt and chloride levels, will require good management to be productive and prevent salinization of the soils. However, given poor management, any damage done can, in most cases, be reversed.

The average salinity level in KTR water from 1994 to 1999 (ECw = 1.9 dS/m) impacts sensitive crops, such as strawberries and beans, but should allow 72 percent of the mainc rops grown in the Jordan Valley to be grown at more than 80 percent of their yield potential. However, if the quality of KTR water were to stabilize at the 1999 level (2.4-dS/m), then only half of the major crops grown in the Jordan Valley would reach more than 80 percent of their yield potential, according to Grattan (2000). A relatively slight increase in salinity levels would have a devastating effect on the current crops grown in the areas presently using KTR water. Crops such as banana, stone fruits, apples, onions and carrots become difficult to sustain in these areas. Crops which could sustain 90 percent of their yield potential with salinity levels in the water supply of 2.4-dS/m include asparagus, cauliflower, dates, fig, garlic, guava, peas, olive, squash and many forage and grain crops.

It is important to emphasise that further increases in the salt levels in KTR will have serious consequences on the cropping patterns. The elevated levels of salt in the KTR over the past two years have been due to the drought conditions. The present and projected salinity levels in the effluent from As Samra are expected to remain at or slightly below 1250-mg/l (1.95-dS/m) (MWI/ARD, 2000a). Further sources of salt in KTR include emmissions from industry in the Zaraq area and the saline springs along the wadi. It is important that such sources do not contribute to a further raising of the salinitiy.

Because of increased supply, the situation in the Middle and Kharameh Directorates may in fact improve due to increased leaching and further intensification of cropping patterns. However, in the Northern Directorate, where the better quality water from KAC is presently used, the introduction of KTR water, would have a significant negative effect on the relatively salt and chloride sensitive citrus-dominated cropping patterns. Other toxic ions such as Sodium (Na) and Boron (B) are not likely to be problematic. Soil infiltration is, generally, not considered to be of concern, although there may be some localised problems.

Presently nitrogen levels in KTR water are between 26-30 mg/L most of which is in the ammonium (NH_4) form, which presents a significant load. With the projected increases in effluent volumes, these levels could rise significantly, until the new As Samra facility is completed, when nitrogen levels will be significantly reduced. Nitrogen is not always beneficial to crops. For example high concentrations late in the season can adversely affect fruit quality, cause unnecessary vegetative growth and/or delay maturity. Despite the high levels of nitrogen in the water, many farmers receiving KTR water are still apllying nitrogen, which is generally not required. Phosphorus levels in the KTR water does not present a hazard to the irrigated crops. However, it does create algae blooms in the reservoir, which results in organic suspended solids. It has been argued that irrigating with KTR water has a positive effect on the environment. The reduction of the N and P in the water, which is then discharged to the Jordan Valley and the Dead Sea, thereby improving the quality of discharge to the receiving waters.

Trace elements are not likely to be a limitation to the sustainability of irrigated agriculture with recycled water from KTR. However, it will be prudent to be vigilant, with particular attention given to Mn, Mo, Li and V due to their concentrations in the irrigation water being close to the Jordanian guidelines (Grattan, 2000).

Irrigation with freshwater does allow more flexibility with respect to crop selection. Furthermore, irrigating with effluent of the quality expected from KTR will require careful management. The margin of safety with respect to crop health and soil salinization is reduced.

II.2.2.2. Impact on Human Health

Pathogens in the water supplied pose a threat to human health. From 1994 through 1999 the Fecal Coliform Count in water reaching Abu Zeighan on wadi Zarqa is above the limit (1000 MPN/ml) for reuse in the Jordanian Standards three months out of the year. Furthermore, water from the King Abdullah Canal (KAC) prior to mixing with KTR water also, on occasions, exceeds this standard (WQIC, 1995). More recent data (1994 through 1999) indicate a downward trend in the KAC water, but exceedance events do occur.

The microbiological quality of irrigation water is variable and at times of marginal quality for unrestricted irrigation practices. The prevalence of drip irrigation combined with plastic mulches does limit the risk of workers and edible portions of the crop coming in contact with the contaminated water.

In addition to the pathogens from As Samra and the other wastewater treatment plants in the basin, the waters in the wadi are subjected to contamination from the urban areas, intensive livestock production, illegal dumping of septage, and smaller communities along the wadi. FCC levels well above the Jordanian Standards for discharge to wadis are common, particularly during the wet season. This contaminated runoff reaches a relatively empty reservoir giving very little opportunity for die-off in the reservoir before it is delivered to the Jordan Valley.

In the dry season, the reservoir is effective in reducing the FCC well below the Jordanian Standards. However, recontamination of the releases from the dam in the wadi downstream results in levels of FCC that can exceed the respective standard before it reaches the valley.

A comprehensive investigation of the sources of this microbiological contamination is required. Existing data do not allow rigorous investigation from which a control plan could be developed. However, if the wet season contamination proves to be the over-topping of sewers in Amman, it will be difficult to correct.

II.2.2.3. Future Water Quality

The quality of water available in the Jordan Valley in the future depends on many factors, particularly how the water resources, including the surface water and the recycled water, are managed in the Amman-Zarqa basin. The basin level model (MWI/ARD, 2001a) accounts for the major water quality constituents for given basin management scenarios, at least with respect to the use of recycled water and the present level of pollution from point and non-point sources within the basin. In the following discussion, it is assumed, unless otherwise stated, that pollution levels either remain the same or are reduced, and that quality of the effluent from the wastewater treatment plants are as projected in MWI/ARD (2000a), which is essentially that major constituents either stay as they are now, or, where they presently exceed the Jordanian Standards for discharge to wadis, are brought in to compliance with these standards.

From the above, it is assumed that the target blending ratio will be 80 percent KTR water to 20 percent fresh water. It is assumed that in wetter periods, further excess flows available in KAC will be supplied to these Directorates, as is the practice now.

Failure to prevent increased pollution levels or implemented the planned improvements at the wastewater treatment plants will have serious consequences. Of particular concern is the level of salts in the KTR water. Further elevation of this constituent in the water will jeopardize irrigated agriculture in the Middle and Karameh Directorates.

Microbiological contamination in the KTR water is presently of concern. The implementation of the As Samra improvements will address part of this problem, but not remove it. The contribution from the urban development in the upper reaches of wadi Zarqa and the intensive livestock operations along the wadis will continue to contribute, particularly in the wet season. Furthermore, the recontamination of the KTR water after it is released from the dam will continue. This contamination from the side wadis needs to be addressed.

III. OPTIONS FOR REUSE

This chapter present the basic options for further use of recycled water in the Jordan Valley, and, for each option, the expected water needs, impact on cropping patterns, the benefits, and the required facilities and their costs.

The main option for increased water reuse in the Jordan Valley is agriculture. Because of differences in present water use characteristics, and expected requirements and impacts of increasing the use of recycled water in each of the three directorates (Karameh, Middle and Northern), they are consider as three separate options. The option of groundwater recharge in the Jordan Valley will be considered under the investigations for groundwater recharge in the basin.

A further "option" discussed is to spill to the Dead Sea. To date, excess flows from the Amman-Zarqa basin, which cannot be captured in either King Talal or Karameh reservoirs, discharges into the Jordan River and, eventually, into the Dead Sea. At present, this is considered a loss. However, in the future, when further development in the Rift Valley results in the diversion of further flows from the Dead Sea and the accelerated decline of the sea level, recycled water could be used to offset this loss of water to the Dead Sea.

The general availability of water supply from KTR is dependant on the quantity of effluent produced (MWI/ARD, 2000a), the other options that may be developed and the available storage facilities. It is assumed for this discussion that sufficient quantities of water will be made available for each option and that storage will be available. The storage issues will be address in a following report. The costs herein do not include additional storage or modifications to existing storage, such as Karameh dam.

According to the data present in Chapter II, 69, 60, and 33 percent of the irrigable area in the Northern, Middle and Karameh Directorates was used to produce a t least one irrigated crop in 1998. In an intensively cropped area where water was not a constraint, it would be expected to see around 90 percent of the irrigable land irrigated, suggesting that all three Directorates have considerable room for intensification of irrigation within their existing boundaries. In the case of the Middle and Karameh Directorates this is due in part to shortage of water supply. It is conservatively assumed that given more KTR water, the expected maximum irrigated area for all Directorates would be similar to that of the Northern Directorate, at 69 percent. The expected irrigated areas are summarized in Table III.1.

Table III.1. Present, maximum and difference in irrigated areas (dunums)

Directorate	1998	Maximum	Difference
Northern	69,000	69,000	0
Middle	43,000	49,000	6,000
Karameh	34,000	72,000	38,000
TOTAL	**146,000**	**190,000**	**40,000**

As described in Chapter II, actual water management in irrigation systems is usually complex, and not necessarily following the expected water needs of the crops being grown. However, a comparison of the expected needs of the crops being grown with the actual water diverted does provide insight into what would happen with further water supplies (see Appendix A).

Using the increases in areas from Table III.1. and the existing cropping patterns, expected Gross Irrigation Requirements for the intensified Middle and Karameh Directorates were developed. The results are presented in the relevant section below. For the Northern Directorate, where the quality of water would result in a dramatic change in cropping patterns, it was assumed that the cropping pattern would be similar to that in stage office 5 in the Middle Directorate, which, at 1.8, has the highest cropping intensity of the stage offices irrigated with KTR water.

III.1. Karameh Directorate Option

The water reuse option in the Karameh Directorate is to use more recycled water for irrigated agriculture in stage offices 6, 9 and 10. In the case of stage office 9, this would be irrigating lands that are presently partly irrigated with groundwater and partly irrigated with tailwater from KAC. In the case of stage office 10, this would be supplementing existing water sources (Kufrein dam, Wadi Hisban and shallow groundwater), and in stage office 6 it would be to supply water as it is now, a blend of KTR and KAC water. Note, the water from Kufrein dam is not considered as a source for domestic/municipal water (Abu Zuneineh, 2001) because there is a wastewater treatment plant upstream, therefore, there is no value in exchanging with KTR water.

From chapter II, the water resources presently supplied to the Kufrein area (stage office 10) is approximately 8 M-m^3/annum. As discussed above, present irrigated area in the Karameh directorate extends to a total of around 34,000 dunums, including the unofficial areas irrigated in stage office 9. The total irrigated area in the directorate could be expanded to a total of 72,000 dunums, the bulk of which would be within stage office 9.

The present cropping pattern in the Karameh directorate is dictated, in part, by the lack of water supply. Improved supply would result in further intensification. It is assumed that the resulting cropping pattern would be similar to that in Stage Office 5, presently the most intensively irrigated area using KTR water. With this, and with 70 percent of the irrigable area in the directorate irrigated, the annual Gross Irrigation Requirement would be around

63 M-m^3. Including 20 percent for leaching, the potential total demand for water with the intensification of irrigated agriculture is estimated to be 76 M-m^3. The total expected monthly demand for water (GIR) for each month are shown in Figure III.1.

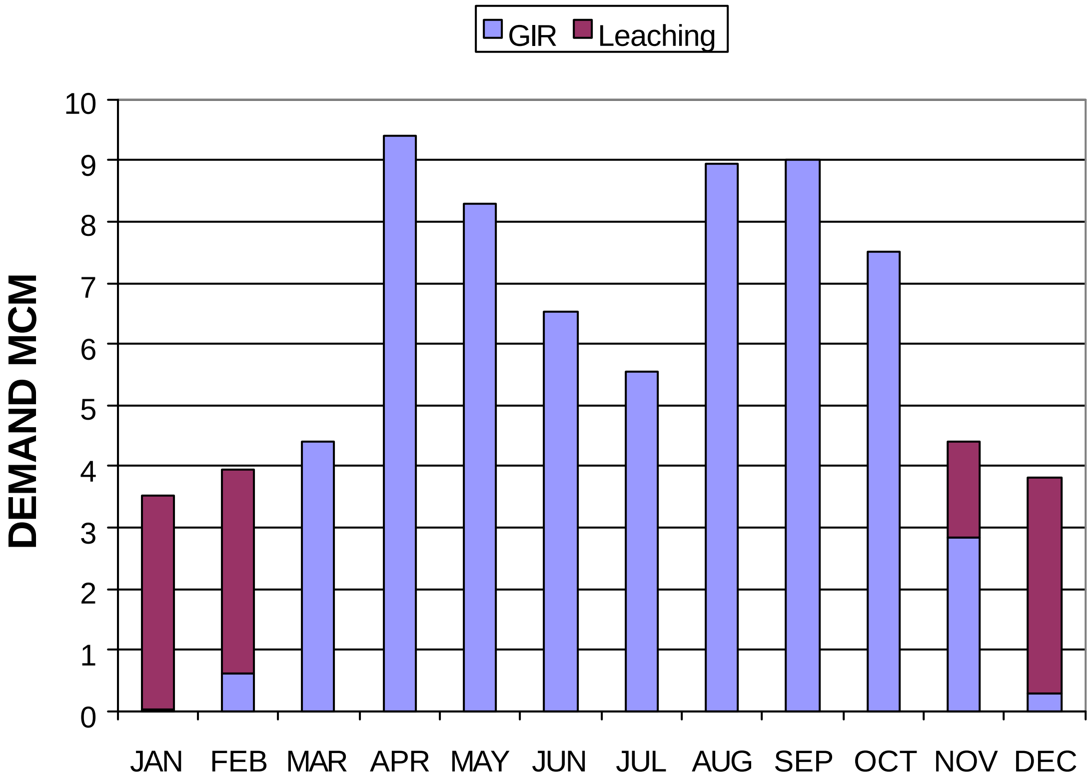

Figure III.1. Estimated water requirements for Karameh Directorate after intensification.

It is assumed that areas that are not yet receiving reliable water supply, would not receive fresh water for blending, except in wet years. Using 1998 figures and assuming that existing areas in stage office 6 would receive 20 percent fresh water for blending, the fresh water supplied from KAC would be approximately 4.4 M-m^3. The water to be supplied from KTR would therefore be 63.6 M-m^3, which compares with approximately 24 M-m^3, presently supplied to the directorate from KTR. This is an increase of 39.6 M-m^3.

III.1.1. Facilities & Costs

The conveyance and delivery facilities for all three stage offices are in place, with the exception of the connection between KAC and stage office 10. The pre-feasibility level design for the transfer pipeline and pumping facilities is presented in Appendix G. The total design discharge was determined to be 180-lps, the total length of the pipeline would be 5,500-m, its diameter needs to be 600-mm, and the lift is 68-m, excluding friction losses. The total cost of this facility is estimated to be around JD 2.2 M. Further investment would be required on-farm, primarily in stage office 9. These would include filter and application systems. These costs are not included here.

III.1.2. Benefits & Impacts

The primary benefit from increased KTR supplies to the Karameh directorate is increased agricultural production extending to approximately 38,000 dunums, for a total area of 72,000 dunums. The total water requirement would be 76 M-m^3, 63.6 M-m^3 of which would come from KTR or Karameh reservoir, and the remainder would be fresh water from KAC and/or Kufrein.

The main negative impact would be potential contamination of the groundwater underlying these irrigated areas.

III.2. Middle Directorate Option

The water reuse option in the Middle Directorate is to use more recycled water for irrigated agriculture in stage offices 4, 5 and 8 by intensification. Although there is some use of KAC water in these directorates, the opportunity for exchange with recycled water is very limited.

As discussed above, present irrigated area in the Middle directorate extends to a total of around 43,000-dunums. With further increases in supply of KTR water, the irrigated area in the directorate could be expanded to a total of 49,000-dunums, a 6,000-dunum increase.

The total annual Gross Irrigation Requirement, assuming a cropping intensity similar to that in Stage Office #5, which is presently the highest, is estimated to be 43M-m^3. Including 20 percent for leaching, the total demand for water with the intensified cropping pattern is estimated to be 52 M-m^3, of which 43 M-m^3 would come from KTR. This is 6 M-m^3 higher than 1998, and all would come from KTR. The expected monthly distribution of water requirements, including leaching, is shown in Figure III.2.

III.2.1. Facilities & Costs

The conveyance and delivery facilities for all three stage offices are in place. It is not anticipated that further major developments would be required for this intensification. Further on-farm facilities would be needed for the 6,000-dunums, including filter and application systems.

III.2.2. Benefits & Impacts

The primary benefit from increased KTR supplies to the Middle directorate is increased agricultural production extending to approximately 6,000-dunums, which, along with general intensification, would consume a further 6 M-m^3 of KTR water. The further negative impacts would be minimal.

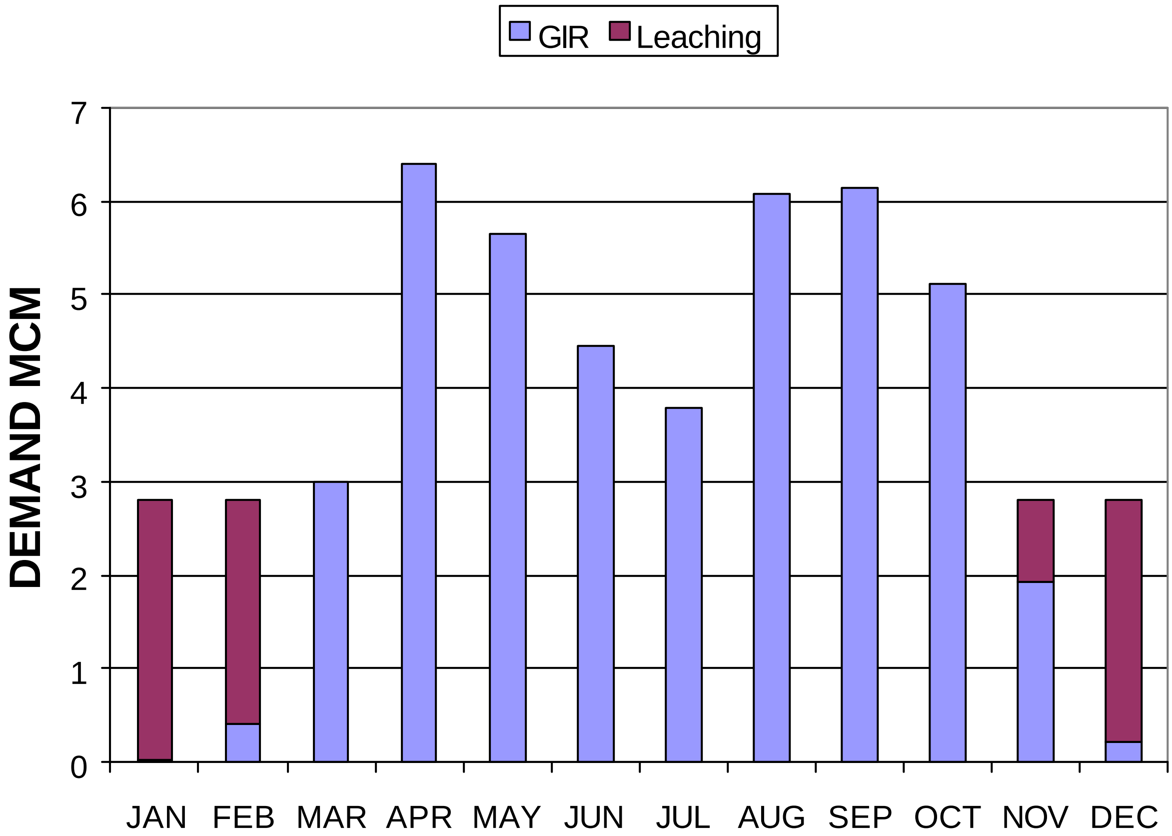

Figure III.2. Estimated water requirements for Middle Directorate after intensification.

III.3. Northern Directorate Option

The water reuse option in the Northern Directorate is to replace some or all of the existing fresh water, if were to be used for domestic purposes. This could apply to some or all of stage offices 1, 2, 3 and 7. As discussed above, present irrigated area in the Northern Directorate extends to a total of around 69,000-dunums, which, based on 1996-98 data (see Table II.2), presently consumes between 60 and 83 M-m^3 including loses.

In addition to KTR water, there is a source of recycled water from Irbid wastewater treatment plants (Irbid and Wadi Arab), which presently generate around 4 M-m^3 of effluent each year, and are projected to increase by a further 13 M-m^3, by 2025. A conveyance pipe already exists from the Wadi Arab plant to the Jordan Valley, so losses will be minimal. The effluent is presently discharged into wadi Arab downstream of KAC, where some unplanned reuse is practiced. The feasibility of reuse from Irbid is presently being investigated by KFW. For these investigations it was assumed that 10 M-m^3, would be available to the Northern Directorate from these sources.

The total annual Gross Irrigation Requirement is estimated to be approximately 59 M-m^3 excluding reclaimed water from Irbid wastewater treatment plant. Including 20 percent for leaching, the total demand for water with the revised cropping pattern is estimated to be 72 M-m^3. The expected monthly distribution of gross irrigation requirement and leaching, based on the revised cropping pattern, is shown in Figure III.3.

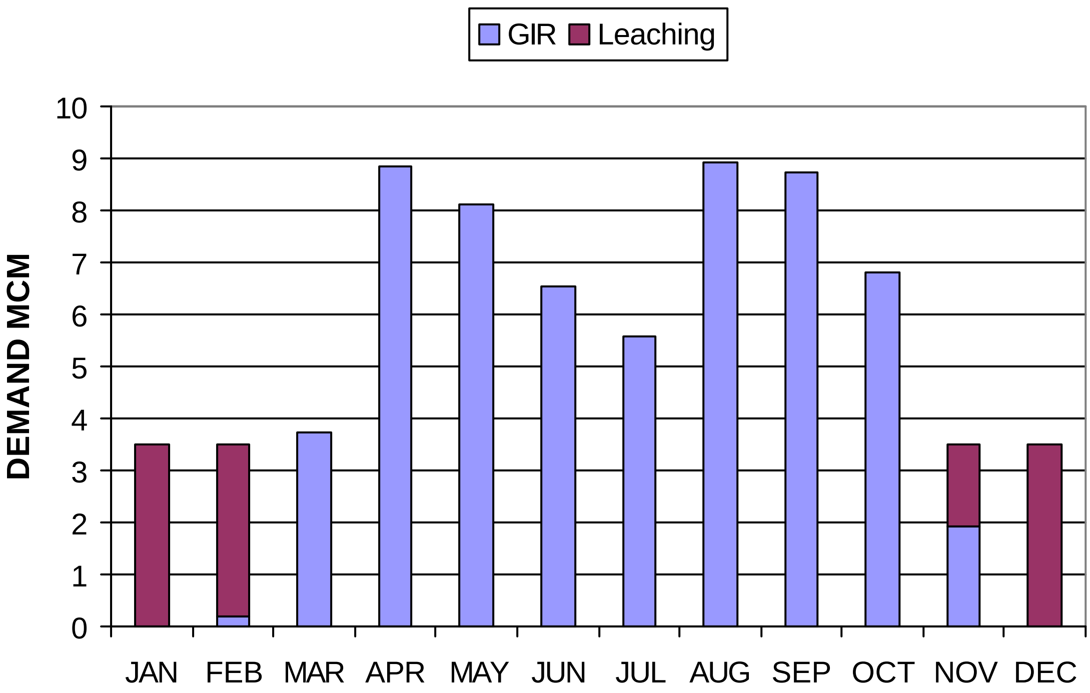

Figure III.3. Estimated water requirements for Northern Directorate after replacement of fresh water.

III.3.1. Facilities & Costs

The conveyance facility to the intake of the stage offices would have to be developed from Wadi Zarqa if this option were to be implemented. A pre-feasibility level design is presented in Appendix C. According to this design, pumping is not required to deliver to each of the stage offices in the Northern Directorate. If the pipeline were to reach all turnouts it would have to be nearly 67-km long, and have a maximum diameter of 1600-mm. The total cost for such a pipeline is estimated to be in excess of JD 87 M.

In addition, the use of KTR water would necessitate the use of filter equipment, and the replacement of much of the existing application systems, which are presently developed to irrigate trees.

III.3.2. Benefits & Impacts

The primary benefit from increased KTR supplies to the Northern Directorate would be to replace fresh water supplies diverted for domestic use. Assuming a blending ratio of 20 percent of freshwater, the quantity of KTR water required would be around 58 M-m^3, replacing a similar amount of fresh water.

The negative impacts would be considerable, requiring a major adjustment to cropping patterns and potential contamination of the underlying groundwater. The expected reduction in yields and loss of certain crops has been detailed in Grattan (2000). Estimation of the cost will be undertaken as part of the economic analysis.

IV. SUMMARY OF OPTIONS & CONCLUSIONS

IV.1. Summary of Options

Table IV.1. Summary of options

OPTION	(A) AREA ** dunum	VOLUME OF WATER Total	(B) KTR*	FRESH REPLACED	C CAPITAL COST Total	(C/A) JD/Dn	(C/B) JD/CUM	OPERATING COST JD/CUM
Karameh	38,000	39,600,000	39,600,000	0	2,200,000	58	0.056	0.074
Middle	6,000	6,000,000	6,000,000	0	0	0	0.000	0.000
Northern	69,000	72,000,000	58,000,000	58,000,000	87,000,000	1,261	1.500	0.015

* Where blending, assumes20 percent freshwater
** Either increased area through intensification or replacement of area presently using freshwater

Table IV.1. presents a summary of the areas, water volumes, and costs for the three basic options examined. In the case of the Karameh directorate, where the option is intensification of irrigation on already developed lands, the total demand for water would be 76 M-m^3. Of that 63.6 M-m^3 would come from KTR, and the remainder, as fresh water, from KAC and/or Kufrein. The total additional water requirements, compared to present, from KTR is 39.6 M-m^3. The cost for implementing this, exclusive of on-farm costs, is JD 2,200,000, which is the conveyor from KAC to Kufrein (stage office 10).

With the middle directorate, the costs of intensification are nominal as the infrastructure is already in place. However, the volume of water involved (6 M-m^3) is small. In practice, this intensification in the middle directorate is likely to happen with no intervention. The reason it is not presently functioning at this intensity is the constraint on water supply.

The cost of developing a conveyor to the Northern Directorate is high, even without considering the loss of yields caused by the lower quality water, and the need for further on-farm developments, such as filters. This option is only a consideration if the fresh water in the north was needed elsewhere, however, the volume of water required to meet the needs of a water-short northern directorate is high (58 M-m^3), which, if other options are developed elsewhere in the Jordan Valley or the Amman-Zarqa basin, will not be available to replace lost fresh water sources.

IV.2. Other Conclusions

Irrigation water management in the Jordan Valley, despite considerable efforts in recent years, has much room for improvement. Using recycled water does increase the management challenges, but, in the absence of fresh water sources, the recycled water can be effectively used for sustainable irrigation in the valley. Improved irrigation water management with recycled water, as with fresh water, will result in better agricultural returns.

Irrigated agriculture with recycled water from the Amman-Zarqa is sustainable, although the quality of water will have a major impact on cropping patterns presently using fresh water.

The major constituents that constrain irrigated agriculture, other than the microbiological contaminants, are salts in general and specifically chlorides. Any further elevation of these constituents will have a major negative impact in the Jordan Valley. Planned industrial developments in the Zarqa area pose a significant threat to the sustainability of irrigated agriculture in the Middle and Karameh Directorates. This needs to be carefully managed. Furthermore, further development of industries in this same area that could produce higher levels of heavy metals and trace elements will greatly increase the risk of such constituents becoming a threat to irrigated agriculture when, presently, they are not.

Microbiological contamination of the KTR water reaching the Jordan Valley poses a significant health risk, primarily in the winter months. The prevalence of drip irrigation and the use of plastic mulches reduces the risk of the water coming in contact with the part of the crop that is likely to be eaten raw. However, the present levels of contamination are unacceptable.

The microbiological contamination of the KTR water is only, in part, due to the wastewater treatment plants. Other sources of contamination have resulted in fecal coliform counts in excess of the Jordanian Standards reaching the Jordan Valley one month out of four over the past few years. Restricting cropping patterns in the Jordan Valley to comply with the Jordanian Standards is not realistic. Further disinfection of the water supply once it reaches the valley should be considered. In the short term, minimizing the water supplied from KTR during the wet winter months when microbiological contamination from the highlands is high, would alleviate the problem.

The clogging agents in both the KTR and KAC water create a large maintenance problem for the farmers in the Jordan Valley. On-farm filter systems are used, but the frequency of failure is high. It is reported by the Irrigation Advisory Service that the appropriate media for filters is not available in Jordan. Centralized filter systems were installed at the Zagleb weir diversion, but these are no longer functioning, reportedly because back-flushing had to be done too frequently.

Further efforts in developing and introducing on-farm filter methodologies suitable for the Jordan Valley are needed, and the overall concept of a more centralized filter system needs to be re-evaluated. The use of drip systems with larger emitters (bubblers) may be appropriate for some crops.

There is considerable confusion with regards to the quality of the KTR water, especially amongst the smaller farmers who do not have access to this type of information. For instance, many farmers still perceive Boron as a threat, and yet others are unaware of the potential harm that chlorides will cause to their key crops or microbiological contamination will cause to them or the general public. Dissemination of the quality information, which is already available will alleviate this situation.

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GLOSSARY OF TERMS

Cropped area: The cumulative area of crops planted over a year.

Cropping intensity: Cropped area / irrigated area

Direct Water Reuse: The beneficial use of reclaimed water that has been transported from the treatment plant to the point of use directly through pipes or in lined channels, without an intervening discharge to a natural water body, such as a stream of pond.

Domestic Wastewater: Wastewater generated in residential and commercial activities, possibly also including minor amounts of industrial wastewater subjected to pre-treatment meeting the requirements of connection to the sewer network issued by the Department of Meteorology and Standards.

Effluent: Flow discharged at the end of a treatment process or a treatment train, which may be suitable for some uses, depending on the level of remaining pollutants.

Food Crops: Any crops intended for human consumption.

Guidelines: Semi-official rules and limits for long-term sustainability of water activities in agricultural, industrial or urban sectors.

Indirect Water Reuse: The use of effluent from a wastewater treatment plant after it has been discharged to a natural water body, such as a stream, pond, or reservoir.

Irrigable area: The area of land that can sustainably be used for irrigation.

Irrigated area: The area of land that is under irrigation.

Recycled Water: Water created as a result of treatment and disinfection of wastewater, and deemed safe for specific, intended uses (defined above). Recycled water is a water resource, with tremendous beneficial usefulness, the only limitations being dependent upon level of treatment, salt content and other characteristics that might restrict it to certain uses.

Reclaimed Water: Synonymous with "recycled water," and usually used interchangeably. Strictly speaking, "reclaimed" water originates at a central water reclamation facility, whereas "recycled" water originates onsite. This is especially true at an industrial site recycling its own water over and over again, for example in a cooling tower.

Regulations: Legally adopted, enforceable rules and limits for water reclamation activities, with measured penalties provided for violations.

Standards: Limits on specific parameters, set for the purpose of protecting the public health, or the environment. Standards are usually incorporated in regulations. Sometimes "standards" are used synonymously with "regulations".

Unplanned Reuse: Withdrawal by gravity or pumping from wadis where a major portion of the flow is effluent from an upstream wastewater treatment plant. This is an unauthorized use of wastewater, even if at the point of discharge, effluent quality meets the standards in effect.

Unrestricted Use: Use of pathogen-free water for all non-potable uses, including irrigation of food crops consumed without further processing. The restriction on potable use still applies, unless treatment includes membrane filtration and fail-safe provisions against survival of microorganisms and trace organic compounds.

Use Area: Any area where reclaimed water is used, with defined boundaries.

Wastewater: Polluted and contaminated sewage, resulting from residential, and industrial uses of water and carrying waste products, including organic materials, inorganic compounds, and various microorganisms. Wastewater, *per se*, is not a water resource for any beneficial uses, unless treated appropriately and converted to "recycled water".

Wastewater Reuse: Unregulated (illicit) use of wastewater or inadequately treated wastewater effluent for irrigation of crops or for any other uses.

Water: All usable water, including surface runoff, groundwater, brackish, and recycled water, but excluding contaminated, saline, and raw wastewaters, which are unsuitable for beneficial use.

Water Reclamation: The process of salvaging usable water from wastewater by mechanical treatment (physical, chemical and biological) and disinfection, salt removal, or natural processes.

Water Recycling: Synonymous with “water reuse.” This term is used in some regions exclusively in reference to all water reclamation and reuse activities, because of the positive public image of “recycling” as an environmentally good deed.

Water Reuse: The intentional, planned reclamation of water from wastewater and its conveyance and distribution to agricultural, industrial, and other sites, where it can be put to beneficial use. The terminology “wastewater reuse” is avoided in this document to prevent confusion with the unplanned, unauthorized uses of inadequately treated waste and its unwholesome consequences.

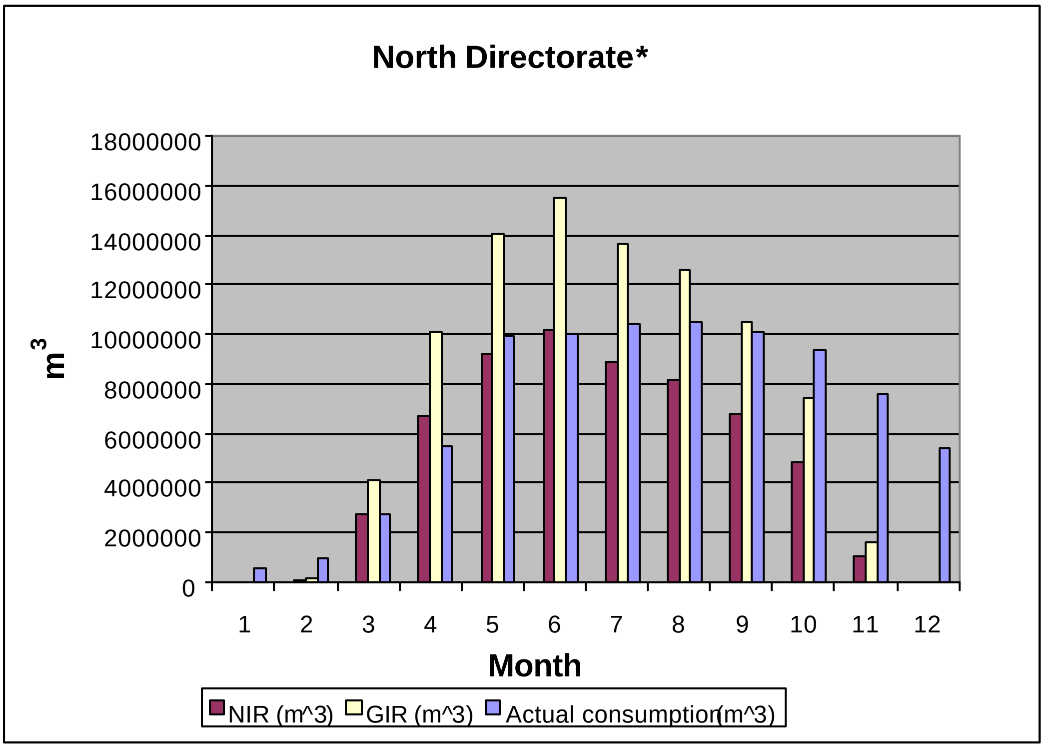
APPENDIX A

Actual & Theoretical Irrigation Water Use in the Jordan Valley (1998)

Using year 1998 data, net irrigation requirements for each Stage Office were generated using CropWat 4 Windows Version 4.2. (FAO, 1998). CropWat uses the FAO Penman-Monteith method to calculate reference crop evapotranspiration. These were generated from monthly climate data (temperature, humidity, wind speed and sunshine) from the Wadi Yabis climate station for the Northern Directorate, and from Deir Alla climate station for the Middle and Karameh Directorate. Monthly rainfall data were also obtained from these stations. Cropping patterns and planting dates were taken from the Ministry (MWI, 2000) database. Crop-water use coefficients (kc) used were those in CropWat, or from FAO paper 56.

Gross irrigation requirements (NIR/efficiency) for each stage office were generated. The average application efficiency for each stage office was developed from the efficiency of each application method (drip, sprinkler or surface, which are respectively 84, 75 and 60 percent), as defined in the MWI (2000) database, and the proportion of the method in that stage office (MWI, 2000). The aggregated results for each directorate are presented below.

As should be expected, the response of the system, in terms of actual water diverted to each stage office, is different from the theoretical water requirements of the crops being grown. Furthermore, there are inaccuracies inherent with predicting theoretical crop-water use, including the available information on cropping patterns (Abu Zuneineh, 2001). However, the results from each Directorate do show that actual water delivered in the middle of the season (hot and dry) is less than will meet the needs of the crops and allow for the expected efficiency of the system, whereas, the quantity of water delivered in the cool winter season is considerably greater than the needs of the crops and the expected losses in the system. This additional usage of water is most likely because the supply is available and, at least to some extent, the need to leach the soils. It also distorts gross efficiency numbers as much of the water supply is only available when the crops cannot use it effectively.

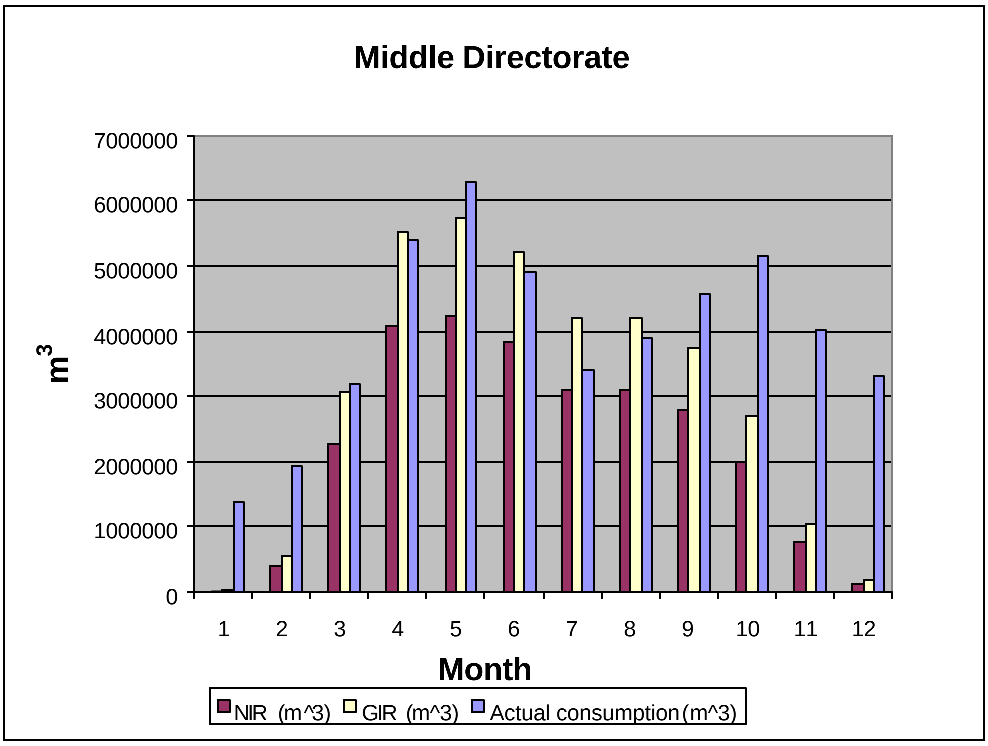


* including stage office 3.

North Directorate (Stages 1, 2, 3 & 7)

Month	NIR (m^3)	GIR (m^3)	Actual (m^3)	Actual/NIR
1	974	1,458	351,659	360.90
2	88,665	130,438	702,566	7.92
3	2,724,168	4,106,248	1,798,122	0.66
4	6,696,664	10,115,096	4,132,812	0.62
5	9,206,980	14,022,641	8,770,116	0.95
6	10,140,071	15,501,133	8,761,949	0.86
7	8,909,193	13,677,108	8,654,511	0.97
8	8,194,853	12,586,053	8,498,804	1.04
9	6,826,487	10,466,847	8,375,177	1.23
10	4,845,839	7,411,459	8,070,157	1.67
11	1,052,465	1,598,822	6,581,559	6.25
12	188	281	4,147,605	22,061.73
	58,686,547	**89,617,584**	**68,845,037**	**1.17**

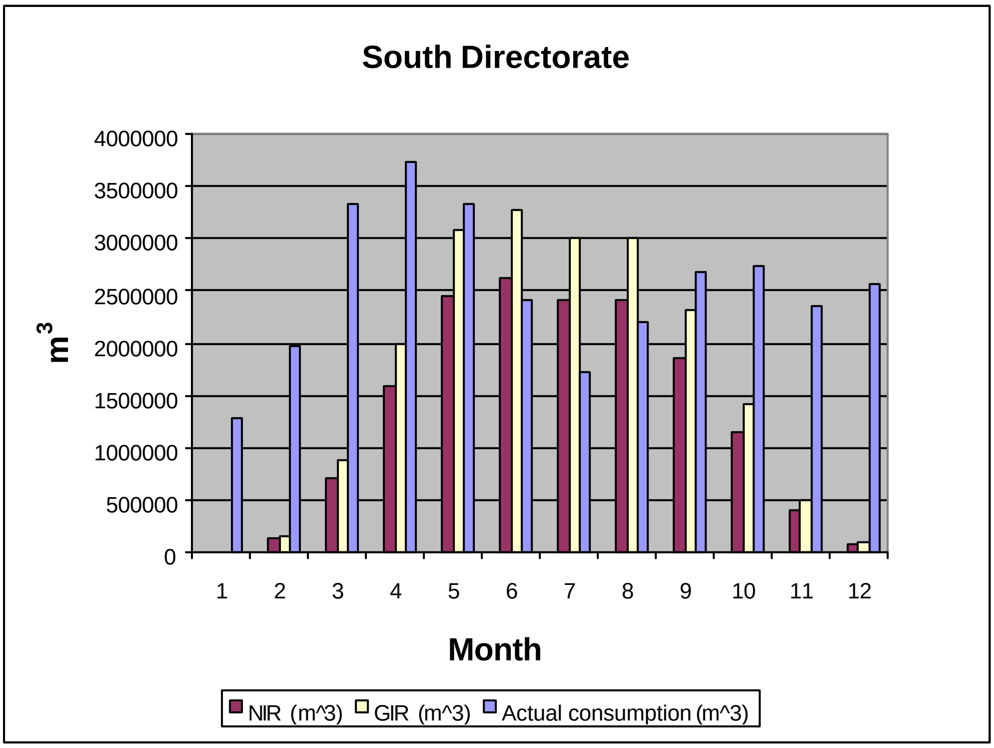
In the case of the Northern Directorate, the theoretical needs of the crops and system losses (GIR) are greater than the annual quantity of water diverted to the stage office, clearly indicating that the actual water delivered to the crops is insufficient to meet the needs of the crops. From the graph, it can be seen that there is a significant deficit during the heat of the summer months, when water supplies are limited. Also, in the wetter and cooler winter months it appears that there is more water used than is necessary to meet the needs of the crops. Some of this is for pre-irrigation, and, whether by design or not, leaching is taking place.



Middle Directorate (Stages 4, 5 & 8)

Month	NIR (m^3)	GIR (m^3)	Actual (m^3)	Actual/NIR
1	10,552	14,207	1,023,817	97.03
2	403,758	547,066	1,529,421	3.79
3	2,254,624	3,055,160	2,594,323	1.15
4	4,071,225	5,514,614	4,169,962	1.02
5	4,232,518	5,739,370	4,728,459	1.12
6	3,830,737	5,195,583	3,621,993	0.95
7	3,097,538	4,197,311	2,758,203	0.89
8	3,098,600	4,185,467	3,287,483	1.06
9	2,776,227	3,746,860	3,341,540	1.20
10	2,007,434	2,707,145	3,923,526	1.95
11	780,301	1,052,779	3,004,417	3.85
12	132,787	179,732	2,671,506	20.12
	26,696,301	**36,135,293**	**36,654,650**	**1.37**

In the case of the Middle Directorate, at least for 1998, there is good agreement between the theoretical needs and actual water supplied over the season. However, more water was supplied in the winter than needed by the crops, some for pre-irrigation and some, deliberately or not, leaching, which is consistent with the findings relating to salt levels in the soils (Grattan, 2000).



South Directorate (Stages 6 & 10)

Month	NIR (m^3)	GIR (m^3)	Actual (m^3)	Actual/NIR
1	1,175	1,483	1,251,918	1,065.38
2	128,986	158,468	1,653,302	12.82
3	713,259	889,110	2,337,721	3.28
4	1,591,280	1,993,648	3,303,853	2.08
5	2,458,884	3,083,775	3,456,128	1.41
6	2,622,116	3,276,694	2,527,755	0.96
7	2,412,517	3,003,943	1,852,664	0.77
8	2,415,709	3,016,095	1,872,549	0.78
9	1,859,166	2,316,385	2,570,801	1.38
10	1,144,636	1,418,080	3,376,212	2.95
11	407,079	500,239	2,943,384	7.23
12	76,316	91,871	2,315,212	30.34
	15,831,123	**19,749,791**	**29,461,499**	**1.86**

In the case of the Karameh (Southern) Directorate, the actual water supplies are greater than theoretically expected. However, the bulk of the excess water is supplied in the winter months and, in fact, the demands of the crops are not met in the early summer months. Again, this demonstrates that water supply is a limiting factor in the warmer and drier months, yet water is available for pre-irrigation and leaching in the winter.

APPENDIX B
CROPPED, IRRIGATED & IRRIGABLE AREAS IN THE JORDAN VALLEY

Table B.1. Irrigated areas by stage office.

Stage No	Year	Irrigated Areas_Wnt*	Irrigated Areas_Smr*	Irrigated Areas_Aut*	Irrigated Areas**
1	1998	12,433	12,215	12,176	12,433
2	1998	14,499	14,499	14,499	14,499
3	1998	15,133	6,082	12,468	15,133
4	1998	4,833	6,279	10,930	10,930
5	1998	13,664	12,285	9,369	13,664
6	1998	10,606	9,290	5,434	10,606
7	1998	26,648	25,202	8,265	26,648
8	1998	18,252	8,265	14,715	18,252
9	1998				17,545
10	1998	5,950	5,950	5,950	5,950

* March is representative for the winter season, July for the summer season, November for the autumn season.

** Maximum of the three areas.

Table B.2. Cropped & Irrigable areas by stage office.

Stage No	Irrigable Areas	Cropped Areas	Total Area
1	33,448	13,325	37,274
2	31,560	28,426	41,312
3	18,572	24,068	29,207
4	24,891	18,199	41,633
5	33,560	25,101	39,261
6	33,336	15,380	43,988
7	16,679	34,989	19,326
8	12,854	31,701	16,533
9	54,504		54,504
10	15,868	6,255	16,579

Table B.3. Areas by Directorates.

JV	Irrigated Areas	Irrigable Areas	Cropped Areas	Total Area
North*	68,713	100,259	100,808	127,119
Middle*	42,846	71,305	75,001	97,427
South*	34,101	103,708	21,635**	115,071
	TOTAL	**275,272**	**197,444**	**339,617**

* North = stage offices (1,2,3,7,). Middle = stage offices (4,5,8). South = stage offices (6,9,10).

** Without stage office 9, but the other areas with SO9.

APPENDIX C

PRE-FEASIBILITY DESIGN FOR TRANSFER PIPELINE TO THE NORTHERN DIRECTORATE

Objective

One of the reuse options for the Jordan Valley is to exchange fresh water from King Abdullah Canal (KAC) with recycled water from King Talal Reservoir (KTR).

In order to achieve this, a pipeline must be designed to transfer recycled water from the existing settling basin at Tal Al Dahab to the upper most turnout at KAC namely T.O. 2 (see Figure 1).

Design Assumptions

The design of the pipeline was based on the following assumptions at this pre-feasibility stage:

1. The alignment will follow the route determined by the Zarqa River Conveyance Study – July 1995 (carried out by Harza and Consolidated Consultants), for the section between Tal Al Dahab and KAC, and will follow the KAC alignment from the middle ghor all the way to Turnout T.O.2
2. The pipeline will deliver the design flows at each turnout. These design flows were obtained from the JVA control room at Dirar in the Jordan Valley. These are presented in Table 1.
3. No pumping is needed, but the pipe will be under pressure.
4. Recycled water will be transferred to the farm units via the turnouts and the existing irrigation networks connected to the turnouts.
5. No major structures for wadi crossings.

Design

An "EXCEL" based sheet was prepared to carry out the hydraulic design for transferring the required flows up north. The total design flow was calculated to be 4967 l/s. Design details are presented in Table 2 and Figure 2 below.

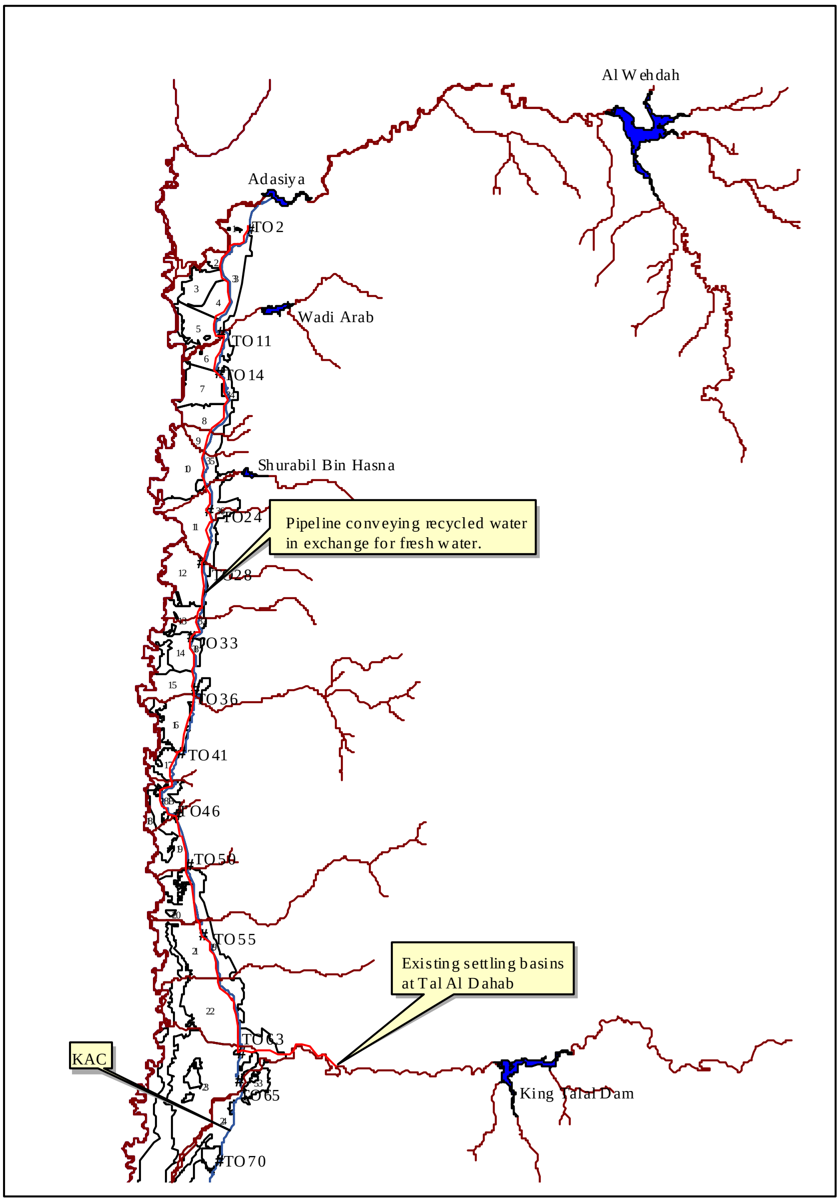


Figure 1. Pipeline to the Northern Directorate

TURNOUT NO.	AREA SERVED (Ha)		DESIGN FLOW (l/s)	
	BY PUMPING	BY GRAVITY	BY PUMPING	BY GRAVITY
T.O. 2	432	-	294	-
T.O.10	NA	-	125	-
T.O.11	NA	-	120	-
T.O.14	456	512	306	342
T.O.24	252	422	216	294
T.O.28	525	206	336	150
T.O.33	507	328	312	222
T.O.36	536	243	318	150
T.O.41	1000	-	336	-
T.O.46	181	86	126	78
T.O.50	584	151	402	120
T.O.55	672	547	396	324
T.O.63	-	-	-	-

Table 1. Design Flows and Areas Served North of Wadi Zarqa

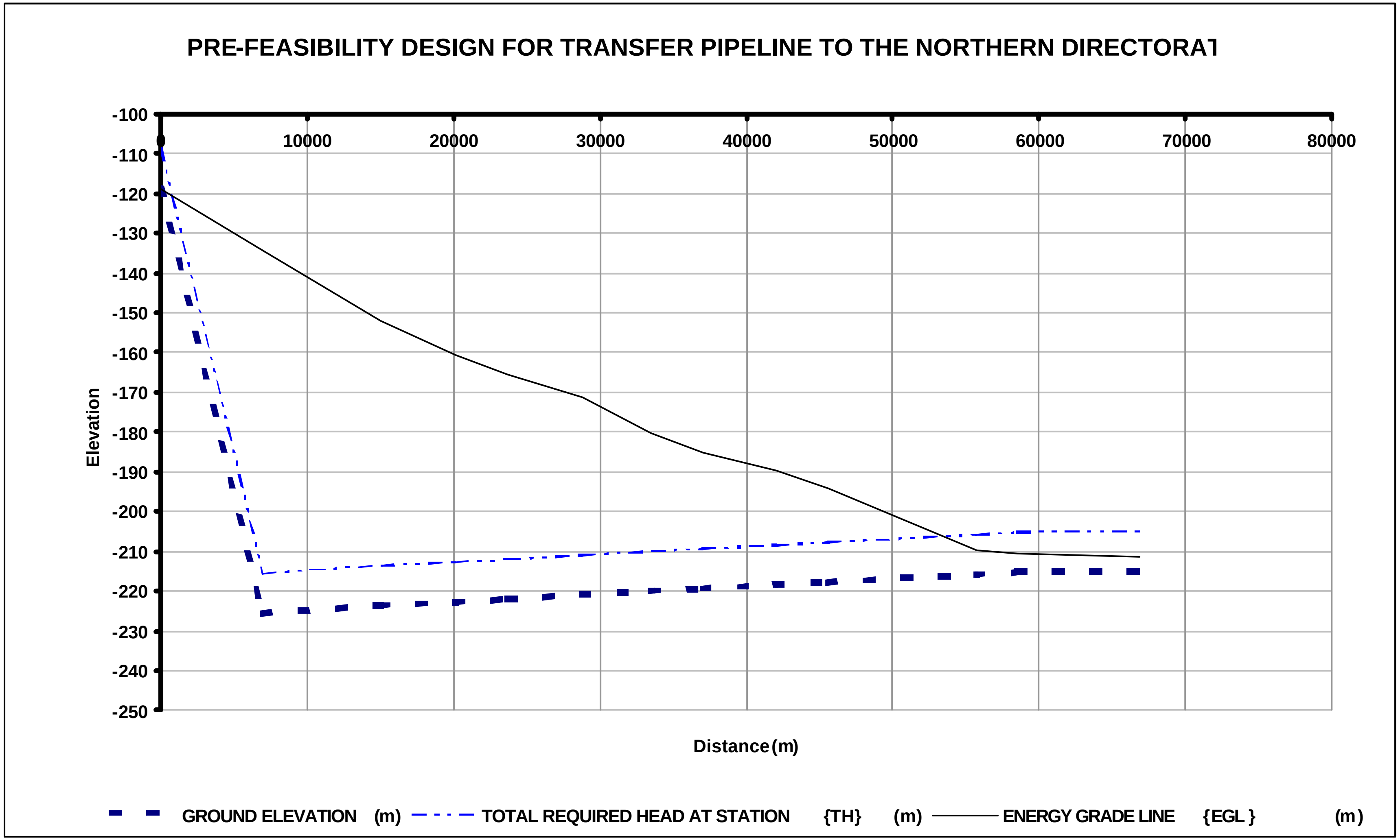


Figure 2 Hydraulics of conveyance pipeline to the Northern Directorate

TURNOUT NO.	STATION (m)	GROUND ELEVATION(m)	PRESSURE HEAD REQUIRED FOR LATERALS (m)	TOTAL REQUIRED HEAD AT STATION {TH} (m)	FLOW AT STATION (l/s)	DIAMETER (mm)	"C" VALUE	VELOCITY (m/s)	HEADLOSS AT STATION (m)	ENERGY GRADE LINE {EGL} (m)	EGL-GL (m)
SB*	0	-118.7	10	-108.70	4967	1600.00	140	2.47	0.00	-118.70	0.00
63	7000	-225.57	10	-215.57	4967	1600.00	140	2.47	15.60	-134.30	91.27
55	15051	-223.61	10	-213.61	4967	1600.00	140	2.47	17.94	-152.24	71.37
50	20127	-222.74	10	-212.74	4247	1600.00	140	2.11	8.46	-160.70	62.04
46	23710	-222.1	10	-212.10	3725	1600.00	140	1.85	4.69	-165.39	56.71
41	28779	-220.96	10	-210.96	3521	1600.00	140	1.75	5.97	-171.36	49.60
36	33530	-219.98	10	-209.98	3185	1400.00	140	2.07	8.91	-180.27	39.71
33	37001	-219.38	10	-209.38	2717	1400.00	140	1.76	4.85	-185.12	34.26
28	41995	-218.5	10	-208.50	2183	1400.00	140	1.42	4.65	-189.78	28.72
24	45592	-217.8	10	-207.80	1697	1200.00	140	1.50	4.45	-194.23	23.57
14	55685	-215.88	10	-205.88	1187	1000.00	140	1.51	15.67	-209.90	5.98
11	58511	-215.23	10	-205.23	414	1000.00	140	0.53	0.62	-210.52	4.71
2	66815	-215.02	10	-205.02	294	1000.00	140	0.37	0.97	-211.49	3.53

* SB is the settling basin at Tal Al Dahab.

Table 2. Hydraulics of conveyance pipeline to the Northern Directorate

Cost Estimate

The estimated capital cost for the project is 87.21 M-JD as outlined below in Table 3.

Description	Unit	Quantity	Unit Cost	Amount
			(JD)	
A. Mobilization & Demobilization. 3% of (B)				**1,772,488**
Site Preparation	LS	1	150,000	150,000
Land Acquisition (Project Area)	Ha	66.0	16,000	1,056,000
Water System: - Pumping:				
Pump station for conveyance	LS	0	0	0
Pump station for distribution system	LS	0	0	0
- Conveyance System:				
Pipes (1600 mm) DI + Fittings	m	28779	1120	32,232,480
Pipes (1400 mm) DI + Fittings	m	13216	870	11,497,920
Pipes (1200 mm) DI + Fittings	m	3597	655	2,356,035
Pipes (1000 mm) DI + Fittings	m	21223	421	8,934,883
- Storage:				
Earth Embankment	m^3	0	0	0
Substrate Clay Seal	m^2	0	0	0
Inlet Works	LS	0	0	0
Outlet Works	LS	0	0	0
- Connections to structures of Turnouts				
Pipes, miscellaneous valves and civil works	No	12	30,000	360,000
- Site Development:				
Roads, Drainage	Km^2	7	215,000	1,505,000
Wadi Crossings	No	13	76,200	990,600
B Sub-total (B)				**59,082,918**
Engineering (Planning, Design & Construction):				
Feasibility (Geotechnical, Site Investigation, Survey & Mapping) 5% of (B)				2,954,146
Design, Tender Documents 10% of (B)				5,908,292
Construction, Management 5% of (B)				2,954,146
C Sub-total (C)				**11,816,584**
D. Sub-total (D)= (A)+(B)+(C)				**72,671,989**
Contingencies:				
Design Contingency. 10% of (D)				7,267,199
Cost Contingency. 10% of(D)				7,267,199

Table 3. Cost estimate for the conveyance pipeline to the Northern Directorate

APPENDIX D
SUMMARY WATER BALANCE IN THE JORDAN VALLEY

Summary Water Balance - Jordan Valley

North	1995	1996	1997	1998	1999	2000	Total of 6 yrs m3	6 yr avg MCM	loss
Yarmouk	108,014,774	100,818,000	99,711,384	100,417,464	62,854,015	54,615,689	526,431,326	87.7	
KAC Conveyor	21,790,118	30,830,702	47,912,600	55,927,371	41,878,168	54,484,879	252,823,838	42.1	
Mukhaibeh	16,551,216	20,568,470	15,127,595	15,023,147	16,342,820	17,694,978	101,308,226	16.9	
Arab Dam	3,122,852	289,450	190,000	288,317	731,981	299,981	4,922,581	0.8	
Zeglab Dam	-	-	-	-	-	-	-	0.0	
Side Wadis	6,782,802	6,455,983	6,466,000	7,596,548	1,133,482	1,575,850	30,010,665	5.0	
Total	**156,261,762**	**158,962,605**	**169,407,579**	**179,252,847**	**122,940,466**	**128,671,377**	**915,496,636**	**152.6**	
Irrigation	37,357,690	41,115,406	39,350,456	43,679,842	35,818,366	32,356,689	229,678,449	38.3	
Amman	37,558,512	38,099,843	38,616,386	37,743,488	41,393,723	41,147,570	234,559,522	39.1	
KAC South	12,594,614	17,141,849	25,264,525	54,351,908	7,182,948	12,781,845	129,317,689	21.6	
Pump to Wadi Arab Da	17,175,230	23,553,074	26,477,662	21,886,131	19,260,310	16,841,865	125,194,272	20.9	
To NEG	162,259	1,650,672	368,410	1,993,765	2,333,231	3,961,872	10,470,209	1.7	
To MG	2,151,360	6,683,904	10,353,379	3,631,824	21,341	2,762,121	25,603,929	4.3	
Wasted	405,368	150,250	1,027,850	-	-	108,173	1,691,641	0.4	
Total	**107,405,033**	**128,394,998**	**141,458,668**	**163,286,958**	**106,009,919**	**109,960,135**	**756,515,712**	**126.2**	**26.4**
Efficiency	0.69	0.81	0.84	0.91	0.86	0.85	0.83	0.83	

NEG	1995	1996	1997	1998	1999	2000	Total of 6 yrs m3	6 yr avg MCM	loss
Wadi Arab Dam	15,122,138	20,368,944	27,330,528	26,443,859	20,384,783	15,115,161	124,765,413	20.8	
Zeglab Dam	5,992,501	4,718,297	3,900,314	5,812,947	5,131,815	4,365,360	29,921,234	5.0	
Wadi Jurum	2,669,350	1,665,872	1,315,979	1,254,861	783,648	2,563,143	10,252,853	1.7	
From KAC North	162,259	1,650,672	368,410	1,993,765	2,333,231	3,961,872	10,470,209	1.7	
Total	**23,946,248**	**28,403,785**	**32,915,231**	**35,505,432**	**28,633,477**	**26,005,536**	**175,409,709**	**29.2**	
Irrigation	14,639,076	18,025,372	19,895,607	25,165,195	22,222,584	20,489,919	120,437,753	20.1	
Gardens	208,224	145,498	116,115	182,081	236,037	209,951	1,097,906	0.2	
Wasted	-	-	142,500	-	-	-	142,500	0.1	
Total	**14,847,300**	**18,170,870**	**20,011,722**	**25,347,276**	**22,458,621**	**20,699,870**	**121,535,659**	**20.3**	**9.0**
Efficiency	0.62	0.64	0.61	0.71	0.78	0.80	0.69	0.69	

Middle Ghor	1995	1996	1997	1998	1999	2000	Total of 6 yrs m3	6 yr avg MCM	loss
King Talal Dam	46,149,092	37,915,085	31,381,500	37,794,995	38,062,484	37,454,317	228,757,473	38.1	
From KAC North	2,151,360	6,683,904	10,353,379	3,631,824	21,341	2,762,121	25,603,929	4.3	
Total	**48,300,452**	**44,598,989**	**41,734,879**	**41,426,819**	**38,083,825**	**40,216,438**	**254,361,402**	**42.4**	
Irrigation	38,109,742	36,864,013	32,483,383	36,654,650	29,278,109	27,919,904	201,309,801	33.6	**8.8**
Efficiency	0.79	0.83	0.78	0.88	0.77	0.69	0.79	0.79	

KAC South	1995	1996	1997	1998	1999	2000	Total of 6 yrs m3	6 yr avg MCM	loss
King Talal Dam	38,312,283	36,748,873	40,150,083	25,088,087	33,886,109	33,881,329	208,066,764	34.7	
From KAC North	12,594,614	17,141,849	25,264,525	54,351,908	7,182,948	12,781,845	129,317,689	21.6	
Total	**50,906,897**	**53,890,722**	**65,414,608**	**79,439,995**	**41,069,057**	**46,663,174**	**337,384,453**	**56.2**	
Irrigation	25,939,969	26,439,820	23,088,460	29,461,499	24,089,305	25,097,313	154,116,366	25.7	
Mators	6,369,408	-	-	-	-	-	6,369,408	6.4	
14.5 extension	5,091,005	7,558,649	1,912,730	5,357,180	4,347,863	7,923,900	32,191,327	5.4	
Special pumps	-	6,384,960	2,152,165	-	-	-	8,537,125	4.3	
Karamah Dam	-	-	15,529,940	30,886,432	-	3,334,003	49,750,375	16.6	
Wasted	-	175,738	540,000	-	-	-	715,738	0.4	
Total	**37,400,382**	**40,559,167**	**43,223,295**	**65,705,111**	**28,437,168**	**36,355,216**	**251,680,339**	**58.6**	?
Efficiency	0.73	0.75	0.66	0.83	0.69	0.78	0.75	1.04	

Hisban-Kafrein Dam	1995	1996	1997	1998	1999	2000	Total of 6 yrs m3	6 yr avg MCM	loss
Wadi Hisban	2,291,155	1,613,952	1,681,096	1,681,949	1,627,548	1,375,056	10,270,756	1.7	
Kafrein Dam	6,306,385	6,879,058	12,978,200	5,665,496	421,113	2,625,092	34,875,344	5.8	
Wadi course after Dam	5,676,029	1,942,963	1,457,096	-	-	-	9,076,088	3.0	
Total	**14,273,569**	**10,435,973**	**16,116,392**	**7,347,445**	**2,048,661**	**4,000,148**	**54,222,188**	**10.5**	
Irrigation	9,309,235	6,344,280	7,695,748	5,692,210	2,805,833	2,292,101	34,139,407	5.7	**4.9**
Efficiency	0.65	0.61	0.48	0.77	1.37	0.57	0.63	0.54	

Sheuib Project	1995	1996	1997	1998	1999	2000	Total of 6 yrs m3	6 yr avg MCM	loss
Inflow	-	-	5,762,800	3,239,695	3,124,507	4,779,351	16,906,353	4.2	
Outflow	-	-	5,762,800	3,239,695	3,124,507	4,779,351	16,906,353	4.2	**0.0**
Efficiency	-	-	1.00	1.00	1.00	1.00	1.00	1.00	

Total losses **49.0**

APPENDIX E

PRESENT & PROJECTED EFFLUENT DISCHARGES TO THE JORDAN VALLEY

Potential Future Effluent from Wastewater Treatment Plants Contributing to the Jordan Valley

No.	WWTP	Annual effluent (MCM/yr)						Location
		Effluent 2000 (MCM)	**Effluent 2005 (MCM)**	**Effluent 2010 (MCM)**	**Effluent 2015 (MCM)**	**Effluent 2020 (MCM)**	**Effluent 2025 (MCM)**	**Location**
1	Cental Irbid	1.70	2.65	3.99	3.99	3.99	3.99	Zone 1 North Jordan Valley
2	Wadi Arab	2.29	4.64	7.31	9.06	11.24	13.94	
3	Wadi Shallala		3.34	4.05	4.91	5.95	7.24	
4	Kofur Asad			3.09	3.58	4.14	4.79	
5	Dair Abi Said		1.08	1.26	1.47	1.72	2.00	
6	North Shuna		2.10	2.79	3.38	4.07	4.65	
7	Kufranja	0.79	1.24	2.00	2.71	3.44	4.05	
8	Khirbet As-Samra*	45.90	65.40	104.70	120.70	137.90	157.60	Zone 2 Middle Jordan Valley
9	Jerash**	0.60	1.30	3.90	4.50	5.00	5.80	
10	Abu - Nuseir	0.50	0.50	0.60	0.70	0.70	0.80	
11	Baqa	3.60	5.30	8.40	9.70	10.90	12.40	
13	Deir Alla		2.28	2.65	3.08	3.58	4.17	Zone 3 South Jordan Valley
14	South Shuna		1.44	1.67	1.94	2.25	2.62	
15	Salt	1.07	2.11	2.65	3.31	3.84	4.46	
16	Wadi Seer	0.31	0.38	0.53	0.69	0.80	0.94	
17	Fuhes	0.31	0.57	0.74	0.91	1.10	1.29	
18	Naur			0.95	1.31	1.71	2.07	
	Totals	**57.06**	**94.33**	**151.28**	**175.94**	**202.33**	**232.81**	

* Including the proposed wadi zarqa treatment plant
**Including the proposed Jordan West treatment plant

APPENDIX F

FUTURE SCENARIOS FOR FRESH WATER IN THE JORDAN VALLEY

Year	FRESH WATER SUPPLIES						DEMANDS	
	Groundwater	Yarmouk River with Dam	Peace Treaty	Lower Jordan River Dam	Side Wadis	TOTAL Optimistic	Municipal	Irrigation
2000	55	95	40		60	250	40	210
2005	45	95	60		80	280	90	190
2010	40	180.5	60	20	80	380.5	140	240.5
2015	37	180.5	60	20	80	377.5	140	237.5
2020	37	180.5	60	20	80	377.5	140	237.5
2025	37	180.5	60	20	80	377.5	140	237.5

Increase from Yarmouk is 50 M for municipal and 35 M for irrigation
Assumes Wehda dam is completed by 2010.
Peace treaty water includes 50 MCM from Jordan River, 20 MCM from pump storage in Tiberius, and 10-MCM from desalination. Expected total = 80-MCM
Presently only 30-MCM is diverted from Tiberius. In the event that Wehda dam is constructed , the 20-MCM will be part of the water in this reservoir.
Highly unlikely the Lower Jordan River Water will be "fresh"
Demand from Amman could be much more aggressive .

APPENDIX G

PRE-FEASIBILITY DESIGN FOR THE KUFREIN TRANSFER PIPELINE

An “EXCEL” based sheet was prepared to carry out the design for transferring the required flows from KAC to Al-Batous pond near Kufrein Dam.. The total design flow was calculated to be 180.5 l/s. Design details are presented in Table 1 and Figure 1.

STATION (m)	GROUND ELEVATION (m)	PRESSURE HEAD REQUIRED FOR LATERALS (m)	TOTAL REQUIRED HEAD AT STATION {TH} (m)	FLOW AT STATION (l/s)	DIAMETER (mm)	"C" VALUE	VELOCITY (m/s)	HEADLOSS AT STATION (m)	ENERGY GRADE LINE {EGL} (m)	TH-EGL (m)
0	-253	5	-248.00	180.5	600.00	140	0.64	0.00	-180.00	-68.00
5500	-185	5	-180.00	180.5	600.00	140	0.64	3.14	-183.14	3.14

Table 1. Hydraulics of conveyance pipeline pipeline from KAC to Al-Batous pond at Kufrein Dam

Station “0+00” being near PS 105 and station “5+500” being near Al-Batous pond.

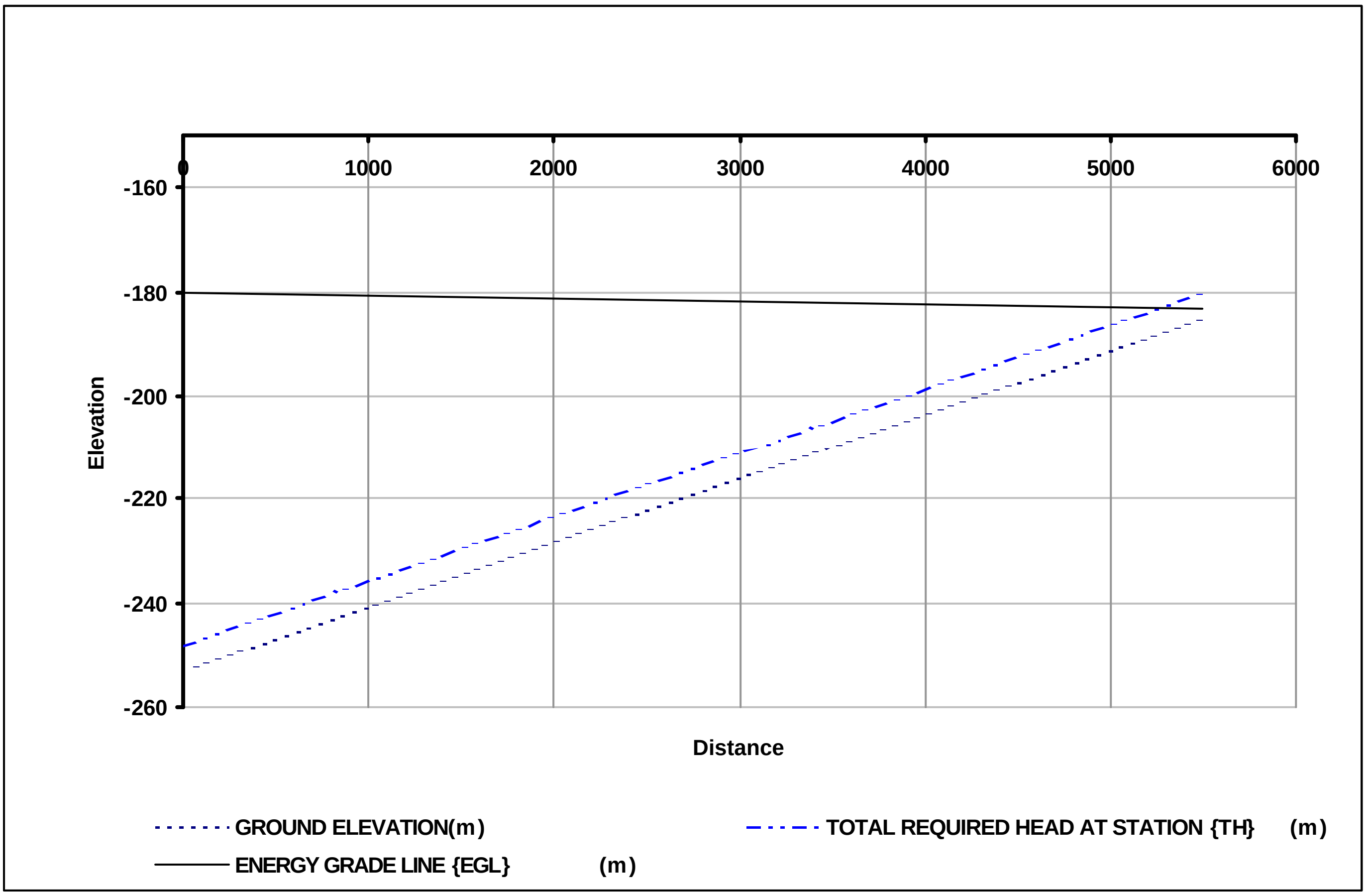


Figure 1. Hydraulics of conveyance pipeline from KAC to Al-Batous pond at Kufrein Dam

The total cost for this connection is summarized in Table 2 below:

Description	Unit	Quantity	Unit Cost	Amount
			(JD)	
A. Mobilization & Demobilization. 3% of (B)				**43,913**
Site Preparation	LS	1	20,000	20,000
Land Acquisition(Project Area)	Ha	0.1	16,000	1,600
Water System:				
Pumping				
Pump station for conveyance	LS	1	261,650	261,650
Pump station for distribution system	LS	0	0	0
Conveyance System:				
Pipes (600 mm) DI + Fittings	m	5500	211	1,160,500
Connections to structures				
Pipes, miscellaneous valves and civil works	No	2	10,000	20,000
Site Development				
Roads, Drainage	Km^2	0	0	0
Wadi Crossings	No	0	0	0
B Sub-total (B)				**1,463,750**
Engineering (Planning, Design & Construction):				
Feasibility (Geotechnical, Site Investigation Survey & Mapping) 5% of (B)				73,188
Design, Tender Documents, 10% of (B)				146,375
Construction, Management 5% of (B)				73,188
C Sub-total (C)				**292,750**
D. Sub-total (D)= (A)+(B)+(C)				**1,800,413**
Contingencies:				
Design Contingency, 10% of (D)				180,041
Cost Contingency, 10% of(D)				180,041
		TOTAL CAPITAL COST =		**2,160,495**

Table 2. Cost Estimate of conveyance pipeline from KAC to Al-Batous pond at Kufrein Dam