Assessment of the Impact of Water Quality Variations on Crop Production in the Jordan Valley:

Restructuring Irrigation Water Tariffs in Jordan

March 1999

FORWARD

Executive Summary

The Water Quality Assessment addresses two concerns of the Government of Jordan: the impact of wastewater reuse on crop production, and the restructuring of water tariffs to reflect water quality differences. The assessment was carried out by a team of Jordanian and expatriate consultants under FORWARD in consultation with representatives from the Jordan Valley Authority, the Water Authority of Jordan, and the Ministry of Water and Irrigation, who together form the Joint Technical Working Group.

Water Quality Parameters

The team defined four water qualities in the Jordan Valley based on three water quality parameters: electrical conductivity (EC); chloride (Cl); and microbiological contamination. The Joint Technical Working Group agreed that definition of more water qualities would be difficult to assess and implement with regards to a differential tariff.

Given the underlying concern that irrigating crops with treated wastewater poses a potential risk to public health (pathogens), has implications for marketability, and raises policy issues, the Joint Technical Working Group examined a number of water quality parameters to assess their impact on crop production in the Jordan Valley. The parameters were chosen because of their potential impact on crop yield (EC), public health (fecal coliform), crop toxicity (Cl, B, Na and trace elements), or irrigation management and system maintenance (pH, sediments, nutrients, SAR, soil quality, and salts).

Salinity

Electrical conductivity of water (ECw), an indicator of salinity hazard, is the parameter of greatest concern affecting potential yields. Even a moderate level of salinity reduces yield of salt-sensitive and moderately sensitive crops, and over 90% of the crops in the Jordan Valley fall in these categories. Of all the water quality parameters, only ECw can be used to quantify the effect of degraded water quality on yield potential and production economics. The other water quality parameters may place the crop at risk to toxicity, limit the type of crops that can be planted, affect maintenance of the irrigation conveyance system and on-farm management, or affect the marketability of the crop, but their impact can only be evaluated in a descriptive manner.

This report provides an extensive assessment of the impacts of the four water qualities on yield potential of the major crops in each of the stage offices. It also uses an economic analysis to determine gross margins per cubic meter of water. The yield potential of major crops can be dramatically reduced in Water Quality

Zones 2, 3, and 4, particularly for crops that are sensitive to salinity. In some cases, increasing the leaching fraction will reduce soil salinity and improve yields, but in cases where additional water does not affect yields, the economic benefits are not achieved. The spread sheet program quantifies the impact of degraded water under different climatic conditions (different zones of crop water use) and different stage offices. It is an excellent decision making tool. In order to facilitate the inclusion of this important parameter into a modified tariff structure, a copy of the program will be provided to the Jordan Valley Authotrity on diskette.

Wastewater Reuse

The possible presence of pathogens in treated wastewater that is used for irrigation raises concerns for public health and safety and equals the salinity parameter (EC) in importance. The data indicate that total fecal coliform counts (an indicator of pathogens present) were acceptable during most of the months of monitoring, but exceeded WHO guidelines for unrestricted irrigation during times of peak winter vegetable production in the Jordan Valley. Consumer confidence can be eroded with even a single outbreak of disease attributed to produce irrigated with treated wastewater. Given its affect on the marketability of produce, the risk associated with pathogens is extremely high.

It is important to ensure that wastewater supplies intended for irrigation are acceptable for unrestricted use on a continuous basis. Modifications and expansions of the existing sewage treatment operation are required to increase the retention time for holding sewage before it is released to the King Talal Reservoir and assure that the pathogen counts are decreased. In addition, there are concerns of secondary contamination in the irrigation water supply. A thorough sanitary survey needs to be conducted within the JVA system to identify sources of contamination, and a plan needs to be developed to remove them. These changes may be costly. An estimate of the cost would help in the development of the tariff structure.

Crop Toxicity

Crop toxicity is a major concern for permanent crops such as trees and grapes. The element of greatest concern is chloride (Cl) which can accumulate in woody tissues over the years and become problematic to citrus, banana, grapes, and other fruits. Chloride, in conjunction with salinity, will affect the opportunity to grow such crops in Zones 3 and 4. Boron and sodium are of lesser concern. Both the concentration of sodium (Na) and the balance of Na to calcium (Ca) as indicated by the low SAR values suggest that Na toxicity should not be a major concern. Boron is potentially problematic in zone 4, but since salinity and chloride are far more limiting, boron should not be considered in the tariff structure. Trace elements are not a major concern at this time, but is recommended that a long-term monitoring program be developed to assess the concentrations of these constituents based on the potential risk. Unlike other water quality parameters, heavy metals that are applied in the irrigation water accumulate in the upper part of the crop's rootzone. It is virtually impossible to remove this contamination once it occurs.

Irrigation Management and Maintenance

Degraded water quality can have a profound influence on irrigation management and maintenance of the irrigation conveyance system. As water quality becomes degraded, the margin for error in irrigation management is reduced. Salinity can build up in soils over a relatively short time period if leaching and drainage are insufficient. Saline irrigation water and indigenous soil salinity both affect soil salinization. However, it is difficult to assess the impact of water quality alone because the soils are extremely variable and the management practices that affect leaching and drainage vary as well. It is known that indigenous soil salinity follows a general trend of increasing salinity from north to south and that irrigation supplies deteriorate in the same direction. This knowledge, although not as explicit as yield reductions resulting from EC, has been taken into account in the ranking and risk assessment of this parameter.

It is recommended that an extension education program be developed to improve the water management skills of growers, consultants, and JVA officials. Certain soils are poorly drained and salinity can only be reduced by reclamation whereby artificial drains are installed in problematic areas. Costs are associated with hiring an extension-education staff and for installation of drainage systems.

Examination of the SAR and ECw data from each water quality zone suggests that the chemistry of the water is sufficient to promote good water infiltration. Therefore SAR is not problematic and should not be considered in the tariff structure.

Clogging of drip irrigation systems is one of the most costly irrigation problems that affect growers. Suspended solids such as sediments and organic material (algae) as well as high pH are particularly problematic. Often the loads of suspended solids in water supplies that reach the growers' field are far beyond that which the system to designed to handle. Therefore it is recommended that some form of regional filtration system be installed so that growers are assured a water supply without excess levels of suspended solids. Growers who use KTR water are will likely have to chlorinate their water before it enters the drip laterals to avoid build up of bacterial slimes. The pH of all water supplies seems sufficiently high to warrant adoption of an on-farm acidification schedule to avoid chemical clogging. However it is not recommended that pH be a water quality parameter to be considered in the tariff structure since pH appears to be high regardless of water quality zone.

Although nutrients from the KTR can cause maintenance problems particularly in the form of algae in open canals and holding ponds on growers' fields, they can also be viewed as a resource. Nitrogen and phosphorus fertilizer applications to fields should be adjusted downward to account for contributions of these nutrients in the irrigation water supply. However nitrogen and phosphorus loads in the irrigation water are not dependable and late season nitrogen can adversely affect the quality of certain crops. Nevertheless, maintenance is required to reduce the build up of algae and other organic material in the open canals.

Restructuring Water Tariffs

The water quality parameters selected for consideration in the price structure of water are listed in Tables 1 and 2 along with their relative rankings. Two major factors were considered in the selection: the affect on crop production, crop marketability, or management and maintenance of the irrigation system; and the degree of risk. Pathogens and trace elements (heavy metals) pose a high potential risk to public health and crop toxicity and may put a grower out of business. Other water quality parameters may be problematic but if they can be readily managed or improved at the grower level, they have a lower risk. For parameters that affect production, marketability, or management, only those that vary substantially among water quality zones are considered for differential tariffs.

Table 1
Water Quality Parameters: Relative Risk and Potential Impact

Water Quality Parameter	Risk	Potential Impact			
		Water Quality Zone			
		1	2	3	4
EC	high	med	high	high	v.high
Pathogens	v. high	med	high	v.high	med
Chloride	high**	low	med	med	high
Nutrients	med	low	med	med	low
Trace Elements***	v.high	low	med	med	low
Sediments	med	med	med	med	med
PH	low	med	med	med	med
Boron	high	low	low	low	med
SAR or Na	med	low	low	low	low

* EC assumed to be 3.0 dS/m

** due to potential impact on trees and vines

*** insufficient data. Given data do not seem to be problematic, but more data are needed due to very high risk rating.

Table 2
Water Quality Parameters: Recommendations for the Tariff Structure

Water Quality Parameter	**Consider for Tariff Structure**
EC	Yes
Pathogens*	Yes
Chloride	Yes
Nutrients	No
Trace Elements**	No
Sediments	No
pH	No
Boron	No
SAR or Na	No

* Fecal coliform/nematodes

** The high ranking is based on risk factor. Because of low to medium levels in the water quality zones, it is not recommended that this water quality parameter be considered for tariffs at this stage.

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1. BACKGROUND

1.1. Water Supplies in the Jordan Valley

Water supplies are limited in the Jordan Valley. Water quality and quantity impose some restrictions on the cultivated areas and cropping patterns. Increasing diversions from the Jordan Valley for municipal and industrial use in the highlands draw on the supply of high quality water and offer in its place treated wastewater of lesser quality. This reuse of wastewater is expected to increase several fold considering population growth and the higher level of sanitary services expected in the future. Mixing fresh water with treated wastewater and other waters of marginal quality to irrigate crops is becoming more and more attractive as a means of stretching the existing water supply.

Rapidly expanding populations, particularly within the Amman-Zarqa River Basin, are expected to generate much higher demand for potable water to satisfy municipal and industrial development. This expansion will in turn cause increased discharge of treated wastewater into the King Talal Reservoir (KTR), thereby raising the percentage of effluent in the water used for irrigation in the middle and southern Jordan Valley.

Treated wastewater effluent that is discharged into KTR degrades water quality in the reservoir. The salinity of the effluent that leaves Amman is usually increased by 15-20% above that supplied to the city (Harza 1997). Other factors contribute to increased levels of salinity in the treated wastewater including evaporation during treatment and conveyance as well as industrial discharges in Amman-Zarqa Basin. This increased salt concentration poses a threat to crop production in the Jordan Valley where this water is used for irrigation either directly or blended with water from the King Abdullah Canal (KAC).

In addition to salts, other substances (organic, inorganic and biological parameters) are introduced into the KTR from wastewater that further degrade the water in this reservoir. These substances can adversely affect the maintenance of delivery systems, on-farm management, crop marketability, pose a threat to human health, and potentially restrict the types of crops where this water is intended for use.

Irrigation water in Jordan Valley originates from different sources. There are variations in water quality and its impact on crop productivity, product quality, and soil productivity. Lower quality water for irrigation presents a threat to existing agricultural production and marketing in the Jordan Valley, and to continued effective operation of the Jordan Valley Authority (JVA) irrigation system. Higher salt concentration poses a threat to crop quality and yields, particularly for crops that are sensitive or moderately sensitive to salinity – crops that currently dominate agricultural production in much of the Jordan Valley. Moreover, pathogens and contaminants in treated wastewater not only affect the yield, quality, and marketability of the crop, but also restrict the kinds of crops that can be grown successfully. Contaminants can also affect the maintenance and management of the irrigation system, at the system level and farm level, affect soil quality in certain locations, and pose a threat to human health.

Water Sources for Irrigated Agriculture in the Jordan Valley

Existing Sources

- King Abdullah Canal (KAC) water is a mix from the Yarmouk River, the Tiberias North Conveyor, Mukheibeh wells, and Wadi Al-Arab Dam. This is good quality water and is used as is in the northern Jordan Valley.
- King Talal Reservoir (KTR) water is mixed floodwater from the Zarqa River and treated wastewater from Amman. KTR water is conveyed to the KAC through the Zarqa River. Irrigation water coming solely from the KTR is poor quality and is applied only in the Zarqa Triangle.
- KTR water is mixed with KAC water to irrigate farms in the middle and south Jordan Valley downstream from the confluence point.

Potential Sources

- The Karamah Dam Project, where the water is anticipated to be of high salinity.
- A new storage system on the Jordan River, which is still in the feasibility planning stage.

Farmers in the Jordan Valley have complained that the quality of water delivered to them is not suitable for irrigation. Some farmers sued JVA, demanding compensation. JVA responded by acknowledging water quality variations but alleging that farmers have the legal responsibility to adjust their cropping patterns to the different levels of quality in irrigation water. So far, the farmer lawsuits have been dismissed.

1.2. The Jordan Valley Authority and the Water Authority of Jordan

The principal government institutions involved in managing the water sector are the Ministry of Water and Irrigation (MWI), the Jordan Valley Authority, and the Water Authority of Jordan (WAJ). The Government of Jordan (GOJ) has provided strong support for agricultural development in the Jordan Valley since the 1950s through various organizations. As a signal of increasing interest and concern, JVA was established in 1977 to operate an effective irrigation system and provide broad socio-economic support to farmers in the Jordan Valley.

WAJ was established in 1988 to manage municipal and industrial water supply and wastewater treatment for the Kingdom. It is responsible for bulk water supply, conveyance, treatment, storage, and distribution, as well as wastewater collection, treatment, and return flows. WAJ acquires water for its municipal and industrial uses from various sources, including some facilities that are shared with JVA. WAJ also supplies JVA with return flows of treated wastewater for irrigation purposes.

JVA and WAJ share the goal of effective water management for Jordan, but they have separate visions and functions. Developments in the late1980s have increased tension between the two authorities. Population growth in Amman required diversion of fresh water from the valley via the Deir Alla Zai project. JVA operates the Deir Alla intake station, where water for Amman is separated from the KAC and pumped to the city. Moreover, expanding urban populations generate increased wastewater, which required the construction of new treatment plants in Amman and other highland areas, and contributes to lower quality effluent water to the JVA irrigation system.

In 1992, GOJ established a ministry, MWI, to promote an effective, unified water system for the Kingdom and to encourage coordination between JVA and WAJ. While there has been growing recognition that the goals and functions of the two authorities are interdependent and complementary, good coordination has not yet been fully achieved.

Complex issues surround water in Jordan – scarcity, delivery, quality, cost allocation, price, and impacts on crop production – and are generating increasing pressures on the Jordan Valley Authority and the Water Authority of Jordan. Identifying and implementing effective policies for handling these issues depend in large part on the existence of a good working relationship between JVA and WAJ.

1.3. The Water Quality Issue in the Jordan Valley

JVA recognizes that there are different qualities of water in the valley and sees KTR as a polluted source. About half of KTR flows are from Es-Samra treatment plant, which is overloaded and unable to discharge wastewater of an acceptable standard for unrestricted irrigation. KTR water not only affects crop production and quality, but also imposes serious restrictions on cropping patterns and profitable markets. For JVA, the impact of KTR water on soils is a continuing concern. KTR salts and other contaminants, including heavy metals, accumulate in the soils and take land out of production. According to JVA, irrigation systems are affected and farmers incur additional costs because of KTR water.

WAJ admits there are potential impacts of different water qualities on crops but claims that water from KTR meets standards for unrestricted irrigation. For WAJ, the salinity of KTR should only cause slight to moderate restrictions if on-farm management practices of farmers are effective. WAJ believes that improved on-farm management could increase production and help avoid soil salinization.

WAJ sees potential benefits from wastewater reuse such as nutrients, including nitrates and phosphorus,found in treated wastewater. Moreover, WAJ argues that wastewater is a valuable resource to augment freshwater supplies in the Jordan Valley. Where there is evidence of yield reductions for certain crops, WAJ argues that indigenous soil salinity in some zones and not water salinity is the main cause.

Both authorities recognize the importance of treated wastewater in augmenting water supplies in the valley. They agree that every opportunity should be taken to optimize existing water resources including improvements in use efficiency and wastewater reuse.

1.4. Previous Attempts to Address the Water Quality Issue

Earlier attempts to assess the impacts of irrigation water quality in the Jordan Valley did not address the character of the problem and the course of its development. The focus was on agricultural production and crop quality in relation to water salinity. The impact of other water quality parameters including soil salinization, marketing of products, additional maintenance measures, and costs of farmer education programs was not examined.

Most recently, a study carried out under the Amman-Zarqa Wastewater Master Plan examined the water quality impacts of the Es-Samra treatment plant and KTR water on agricultural production in the valley. The study looked at development areas that are currently irrigated by KTR water and at their cropping patterns. A potential leaching fraction of 30% was used in the economic assessment of crop gross margins. However, not all the stakeholders agreed to this leaching fraction. JVA argued that farmer demands could not be met and that there was not enough water for such leaching. The study did assess the impacts of several water quality parameters on soils and crop marketability, but other parameters and their impacts were not assessed. As a result, JVA did not accept findings and conclusions of the study.

1.5. Water Strategy and Sectoral Policy

GOJ has expressed concern over continuing degradation of water quality in the Kingdom and the impact of variations of the quality of water used for irrigation in the Jordan Valley. MWI has recently changed its water policy to state that wastewater treatment should allow for “unrestricted agriculture” and that considerations shall be given to blending treated effluents with fresher water for appropriate reuse. MWI irrigation policy recognizes the impact of marginal water quality and calls for informing farmers of the potential quality of irrigation water so that their choice of crops and management is made with relevant background information and knowledge. Irrigation policy also states that “differential prices can be applied to irrigation water to account for its quality.” Wastewater management policy addresses crop selection based on irrigation water, soils type and chemistry, and the economics of reuse operations.

Water allocation and reallocation remain the responsibility of MWI, even though it results in shifting water between JVA and WAJ. In recent years, JVA water has been reallocated from agricultural use to urban uses under WAJ based on social, economic, and environmental considerations. Because tariffs are not based on actual costs, little attention is given to matching the costs of producing water for particular uses to the authority responsible for supplying that use.

The Jordan Water Strategy

First priority will be given to allocation of (water to) the basic human needs; as such first priority is given to...domestic water supplies (Article 16).

To accomplish this in Jordan, a water short country, a proposal is now being implemented to:

- transfer good quality water from the agricultural sector to urban uses and
- return treated wastewater to the agricultural sector to replace the water transferred to the urban sector.

The Jordan Water Strategy allows treated wastewater to be used as an irrigation resource (Article 12) but stipulates that the treated wastewater should allow sustainability of irrigated agriculture (Article 17). Article 12 stresses that the treated wastewater diverted to the agriculture sector allow unrestricted agriculture and that appropriate treatment technologies be used to implemented this. Because of an emphasis on ensuring that water quality does not limit agriculture, Article 12 also calls for blending of the treated wastewater with fresher water, if needed, to accomplish this goal.

1.6. Relation to the Cost/Tariff Model

JVA officials are considering restructuring tariffs to reflect differences in water quality and quantity, and perhaps seasonal variations as well. To this end, FORWARD developed a cost/tariff model of JVA irrigation water with two tariff options for winter and summer and four distinct tariff options for four potential water qualities. JVA Technical Working Group and FORWARD agreed that it would be rather difficult to implement more than four water quality tariffs in the Jordan Valley. To reduce the water quality tariff options, some water qualities could be given the same tariff rate. The number of water quality tariffs will be decided by JVA based on the results of this Water Quality Assessment Study and the institutional capacity to implement a number of different tariffs.

There are costs associated with operating the system at points where water moves between irrigation and municipal uses. One sheet in the JVA cost/tariff model estimates the costs of the supply sources and the transfer costs through KAC to Deir Alla. Allocation of these costs has not been addressed until now and remains a significant issue for JVA and WAJ. The cost/tariff model does address the issue of costs at the Deir Alla Transfer Point to Amman and offers a framework resolution to the issue of sharing costs between the two water authorities.

2. OVERVIEW

2.1. Objectives

In April 1997, H.E. Koussai Quteishat, then Secretary-General of both MWI and WAJ, proposed that USAID and MWI fund an assessment of the impacts of water quality variations in the Jordan Valley as part of the WAJ-JVA cost/tariff model development program. The activity was proposed as a joint effort of WAJ and JVA that integrated their objectives with a collaborative problem-solving process.

At the design and implementation start-up meeting in mid-August, USAID and MWI concurred with the following objectives of the activity:

- Reach consensus among concerned parties, including MWI, WAJ and JVA, about the nature of water quality differences and determine how water quality varies in different locations over the summer and winter seasons;
- Develop and execute an approach that relates water quality differences to their potential impact on crop yields, economic returns, marketability, and overall cropping patterns;
- Reflect water quality differences and their impacts in JVA tariff structure; and
- Contribute to consensus building concerning the reasonable sharing of costs between JVA and WAJ.

Later, the Joint Water Quality Technical Working Group (JTWG) agreed to add another objective:

- Identify relevant institutional, regulatory, or policy issues associated with irrigation with treated wastewater.

The overall objective was the successful adoption of recommendations on water quality and irrigation that reflect current data and responsible analysis. FORWARD's suggested approach to achieving this goal was to focus on reaching consensus on important technical and policy issues related to water quality variations among all parties who need to be on board for implementation.

2.2. Approach

This activity was designed to combine technical expertise and collaborative problem solving approaches to address the issues more effectively and reach agreements on the nature of the problem, the technical analysis, and ways to reflect results in an equitable irrigation tariff.

Other strict technical approaches have failed to address issues of this nature that are multi-dimensional. FORWARD's intervention process and approach has been based on involving the concerned parties and stakeholders in a serious dialogue from the beginning to build consensus on related issues. The approach is characterized by the following:

- Preparing and accepting the design and its scope of work;
- Establishing a Joint Technical Working Group with members from MWI, JVA, and WAJ to work together on the study;
- Conducting initial interviews with members of the JTWG and other MWI, JVA, and WAJ officials to solicit their views on related issues;
- Providing technical support to the JTWG;
- Offering training courses in collaborative problem-solving; and
- Conducting monthly Joint Technical Working Group meetings.

Activity Design

In August 1997, MWI, JVA, WAJ, and FORWARD met to initiate the FORWARD program in Jordan. The meeting was an opportunity to identify the technical issues and agree on the scope of work for the assessment of water quality variations in the Jordan Valley. The activity was proposed as a joint effort of WAJ and JVA that integrated their objectives with a collaborative problem-solving process. At the meeting the participants concurred with the objectives and decided on the mechanism of collaborative planning process and FORWARD's intervention process.

Joint Technical Working Group

MWI appointed a Joint Water Quality Technical Working Group consisting of four representatives from WAJ and two from JVA. At its initial organizing meeting in October, JVA members requested an additional representative, and in March 1998 a representative from the ministry was added at the request of the JTWG. The group has been following the study activities closely.

Joint Technical Working Group Members

- Elham Abu Aisheh, Department of Irrigation, JVA
- Khloud Aqrabawi, Department of Wastewater Treatment , WAJ
- Bilal Bashir, Directorate of Environment and Technology Transfer, JVA
- Ahmed Eliemat, Central Water Quality Laboratory, WAJ
- Mohammed Hisham, Wastewater Reuse Section, WAJ
- Rania Abd Al-Khaliq, Water Resources and Projects, MWI
- Abed Al Wahab Mattar, Wastewater Treatment Plant O&M, WAJ
- Mohammed Abu Taha, Zia Water Treatment Plant, WAJ

Initial Meetings

FORWARD facilitators interviewed members of the Joint Technical Working Group in early December. They developed a clear picture of JTWG perceptions of the Scope of Work, their assessment of water pricing and water quality, the role that facilitation can play in the process, and the proposed agenda items for the meeting. These interviews, along with feedback received during the group's meeting, served as a guide for the activity.

FORWARD Technical Team

Jordanian members of the FORWARD team held their first meeting in February 1998 to determine the needed expertise from expatriate members to provide the proper balance with Jordanian experts. Discussion also focused on the parameters of the study.

By early March 1998, FORWARD had assembled a technical support team consisting of consultants from Jordan and the United States. Team members were selected in full consultation with USAID, MWI, and the members of the Joint Technical Working Group to provide the additional expertise needed to achieve the objectives of the activity.

The FORWARD Team

- Raed Daoud, Program Manager
- Abdelnabi Fardous, Deputy Director General and Director of Water Research and Irrigation Management Program, NCARTT
- Steve Grattan, DAI, Salinity/Crop Production/Reuse Consultant
- Amer Jabarin, Assistant Professor of Agricultural Economics, University of Jordan
- Peter Reiss, DAI, FORWARD Project Director
- Awni Taimeh, Director General, NCARTT
- Dennis Westcot, DAI, Regulatory/Wastewater Reuse Expert

Training in Collaborative Problem-Solving

In June 1997, a FORWARD mediation team held an introductory session on collaborative problem solving for senior officials of MWI, WAJ, and JVA. Several members of the Joint Technical Working Group participated in the FORWARD mediator's workshop held in October 1997: Bilal Bashir and Avedis Serpekian of JVA; and Ayman Tuffaha of WAJ (Tuffaha moved to the Gulf after December and was replaced on the working group by a colleague). All three attended the December mediator workshop as well. A USAID official, the Jordanian facilitator, and the FORWARD program manager in Jordan also attended the October and December training sessions.

Joint Technical Working Group Meetings

The FORWARD team attended several meetings of the Joint Technical Working Group. In the initial meetings the participants refined the Scope of Work, agreed on assignments for data collection and sources of needed data. At a JTWG team building meeting they agreed on the overall role, specific functions, and organizational structure of the working group. In subsequent meetings, members of the group presented work progress on data collection and analysis and made agreements on the technical approach and activities. The JTWG decided to take on another expert to address issues related to regulatory, policy, and wastewater reuse.

2.3. Agreements

During the course of the activity, the Joint Technical Working Group and the FORWARD team reached several agreements concerning the issues, data sources, methods of analysis, and important water quality parameters. Due to the complexity of the issues and interrelations between water, plants and soils, they agreed to neutralize the externalities such as indigenous soil salinity, on-farm management, and bottleneck marketing issues.

The JTWG reached agreement on:

- Preliminary listing of water quality parameters evaluated;
- Importance of the parameter for identifying impacts;
- Criteria used for evaluating the impacts of such parameter;
- Sources of data acceptable for the assessment;
- Techniques used in the absence of an adequate database and the relative risk of proceeding without an adequate database; and
- Technical methods for analyzing the issues and identifying the impacts of certain parameters on crop production, marketability, public health, maintenance and management of the system.

2.4. Issues to be Resolved

- Does the parameter evaluation present policy issues that must be resolved prior to a decision?
- Is additional monitoring is needed to verify the preliminary conclusions?
- What criteria should be used in setting water tariffs?
- What parameters can or should be used in setting water tariffs in the future?
- What is the relative importance of the parameter for exchanges of water between the agricultural and urban sector?

- What cross-subsidy is needed between WAJ and JVA?

2.5. The Report

This technical report will be the basis for JTWG's discussion to reach consensus on the results of the assessment, criteria for tariff setting, and reflection of the results in water tariffs. The report presents the background, the approach, and the activity status and details the specific agreements pertaining to the following issues:

- Water quality parameters
- Data sources
- Water quality zones
- Yield potential
- Growers' economic returns
- Crop marketability
- Farm management
- Irrigation system maintenance
- Crop toxicity
- Public health

The report is presented in four separate volumes. Volume I contains the report and Annexes A-H with the summary data used in the report. Volumes II, III and IV contain the raw data and associated spread sheets, summarized and analyzed in Volume I, as well as other data that were collected but not analyzed.

Volume I: Annexes

Data Summaries, Results, Methodologies, and Guidelines

A – Water Quality Data

B – Soil and Plant Analyses

C – Cropping Data and Yield Potentials

D – Crop Budgets and Growers' Economic Returns

E – Crop Marketability

F – Soil Salinity and Drainage

G – Guidelines

H – Figures

Volume II: Water, Soil, and Plant Analyses

Volume III: Cropping Patterns and Yield Potentials

Volume IV: Economic Analyses

Crop Budget Spreadsheets by Stage Office and Water Quality.

Diskette

A copy of the spread sheet program will be provided to JVA on diskette.

3. WATER QUALITY PARAMETERS

3.1. The Issues

Differences in water quality affect the sustainability of irrigated agriculture in the Jordan Valley. In particular, the reuse of treated wastewater could impose serious economic constraints on the producers. Since wastewater will be used more extensively in the future, an evaluation of the expected changes in water quality is needed for agricultural users and wastewater treatment operators.

Wastewater treatment operators focus on public health parameters and meeting the disposal requirements. This is used to evaluate the effectiveness of the treatment methods. Agricultural users of treated wastewater have some of the same concerns, but their focus extends beyond public health and includes physical (sediment), biological (algae) and chemical (EC, B, Cl, Na, SAR, NO_3, PO_4, trace elements and pH) considerations. Although it is similar to all irrigation water evaluations, the evaluation of treated wastewater for irrigation use is critical considering that treated wastewater contains elevated concentrations of many of the physical, biological and chemical parameters.

Where concentrations are elevated, it is important to determine whether the contaminant is from the water source or is introduced to it during irrigation. This information will allow WAJ to evaluate the treatment system and sources of wastewater to determine whether they can be controlled or whether compensation will be needed to allow unrestricted use in agriculture. It will allow JVA to evaluate the impact of the quality of the treated wastewater on the crop production potential of the Jordan Valley.

Agreements: The water quality parameters which meet the needs of both organizations.

Agreement needed: Once the impacts of water quality variations based on these parameters have been assessed, a decision needs to be made as to which of the impacts are considered significant for tariff setting purposes.

3.2. Process

The Joint Technical Working Group and FORWARD identified a number of water quality parameters that need to be examined to thoroughly assess the impacts of water quality variations in the Jordan Valley.

To agree on the most important water quality parameters, the JTWG and FORWARD held several meetings to obtain a consensus on the measurable water quality parameters that have an impact on:

- Yield potential;
- Growers’ economic returns;

- Consumer confidence and marketability;
- Irrigation management ;
- System maintenance;
- Crop toxicity; and
- Public health.

The meetings and the technical discussions focused on identification of water quality parameters that are important for WAJ and for JVA. Once they are selected, the parameters will be assessed to determine the definitive thresholds (concentrations, loads, and temporal variations) that make these parameters important or unimportant to the two authorities.

The assessment will identify water quality parameters that result from irrigation water and not from the soil or other crop-affecting media. The parameters could be present in the irrigation water alone or in both soils and water. They should be measurable in both media in a way that enables the assessment of the parameters' impact as a result of its presence in the irrigation water alone.

3.3. Agreements

The JTWG identified and agreed upon the following measurable parameters:

Selected Water Quality Parameters

• Salinty or Electrical Conductivity (EC) • Sodium (Na) • Sodium Adsorption Ratio (SAR) • Nitrate (NO_3) • Bicarbonate (HCO_3) • Boron (B) • Chloride (Cl)	Microbiological Indicators: • Total/Fecal Coliforms • Heterotrophic Bacteria • Nematodes

The group selected these parameters because of their potential to impact crop production, marketing, and overall management and maintenance of the irrigation system, both before and after the farm gate. The JTWG also identified factors associated with degraded water quality that would indirectly affect costs, policy and planning, and the level of management.

3.4. Approaches

The assessment of the impact of water quality differences in the Jordan Valley on crop production will use both quantitative and qualitative approaches. Although numerous water quality parameters affect crop yield, marketability, and management of the overall system, only one parameter, electrical conductivity (EC), is a quantitative measure of the impact of water quality on crop yields which can be used to estimate the grower's economic return. EC is directly related to salt concentration and indicates the potential salinity hazard of the irrigation water.

All other water quality parameters can only be evaluated in a descriptive manner:

- Chloride and nitrogen affect crop quality;
- Excessive levels of fecal coliform will prohibit irrigation water use on vegetable crops that are eaten uncooked and limit the type of crops that can be planted; and
- Sediments, SAR, pH, organic and biological material affect maintenance of the irrigation conveyance system or on-farm management and affect the marketability of the crop.

4. Data Sources

4.1. Data Requirements

To conduct a comprehensive assessment of water quality impact variations on yield potential and grower's economic returns; consumer confidence and marketability; irrigation management and system maintenance; crop toxicity; and public health, the following data sets are required:

- Water quality analyses
- Soil and plant analyses
- Cropping data
- Drainage and irrigation systems

Each of these data sets is required at various levels of spatial, temporal and crop specific distribution. The distributions, extent and level of detail for these data sets are also often different and are limited by what is available and what is acceptable.

Existing water quality data were developed under a variety of programs and studies. Some of these independent data sources do not carry over to the next program. Data sources are often partial and insufficient for a full evaluation of the impact of water exchanges. Most water quality monitoring programs were designed for a specific purpose. The data need to be reviewed to see if they are adequate to evaluate, to an acceptable degree, the potential impact of the introduction of large quantities of wastewater in to the Jordan Valley.

Where existing data are inadequate, a monitoring program must be designed for water quality evaluation. There is need for agreement on the parameters and their importance, what constitutes an adequate database for decision making, the data review and quality control procedures to be used, and the data presentation techniques.

4.2. Acceptable Data Sources

Many of the required data sets are available through more than one source, including JVA, WAJ, MWI, Department of Statistics, Ministry of Agriculture, and various reports, studies and publications. The required data sets were gathered from these sources and reviewed by the JTWG and FORWARD for integrity and plausible validity. Bearing in mind the intended purpose of each data set, preliminary acceptance of data was based on whether or not the temporal or spatial distributions (by stage office and development area) are appropriate and sufficient for the anticipated analyses.

Before accepting any data set, the JTWG reviewed the data to assess their validity. The group also discussed the intended analysis to elicit any potential discrepancies or unrealistic findings that might result.

4.3. Data

Water Quality

JVA has collected data from various points along the KAC, wadis, and reservoirs. JVA tests various physical and chemical water quality parameters that concern agricultural water supplies. WAJ has collected water quality data at points where water is taken from the Jordan Valley for municipal purposes in Amman and other areas. WAJ focuses microbiological parameters that concern municipal water supplies. The sampling locations are shown in Annex H.

Sites Along the KAC

Key	Site No.	Site Name
1	101	Al Nafaq
2	102	Abu Sido
3	103	Kreimah
4	104	Dirar
6	105	Al Sawalha
7	106	Al Sawalha Pump
8	107	Muadi
9	108	Dhahrat Al Ramil
10	109	Karamah Pump
n/a	110	Tabria Line
5	111	Deir Alla

Reservoirs/Dams

Key	Site No.	Site Name
13	121	KTR (Exit)
11	201	Wadi Al-Arab Dam
12	202	Sharhabeel Dam
n/a	203	KTR (Al-Hwarat)
14	204	Wadi Shueib Dam
15	205/6	Kafrein Dam
17	207	Hisban (Old)
16	208	Hisban (New)

Springs, Wadis, Wells and Projects

Key	Site No.	Site Name
n/a	209	Hosban Irrigation Proj.
22	305	Wadi Kufrinja
28	3316	Seil Hisban (After the Dam)
27	3328	Seil Hisban

Laboratory analyses were carried out on a monthly and sometimes even on a daily basis for parameters such as EC, and twice a year, during October and November, for most other parameters. The data collected has mainly been sampled and analyzed from 1990 through to 1997. WAJ and JVA sampled and tested a number of water quality parameters:

Water Quality Analyses Data Set

• Calcium (Ca) • Calcium & Magnesium (Ca+Mg) • Electrical Conductivity (EC) • Sulphate (SO_4) • Nitrate (NO_3) • Sodium (Na) • Magnesium (Mg) • Potassium	• Boron (B) • Chloride (Cl) • Bicarbonate (HCO_3) • pH • Sodium Adsorption Ratio (SAR) • Total Heterotrophic Bacterial • Total Coliform • Fecal Coliform

The raw data from 23 sites along the KAC, reservoirs, dams, springs, wadis, wells, and projects were analyzed statistically on a monthly basis for Mean, Standard Deviation, Number of Samples (Cases), Minimum and Maximum Values, and Coefficient of Variation. The analysis can be found in Volume II. The summary data for nine selected sites are found in Annex A. Tables summarize the chemical water quality data on a monthly basis, show available microbiological sampling results, and present heavy metals concentrations in KTR and in As-Samra sludge.

Nine Selected Sampling Sites for Water Quality Data

Key	Site No.	Site Name
2	102	Abu Sido
3	103	Kreimah
22	305	Wadi Kufrinja
n/a	203	KTR (Al-Hwarat)

8	107	Muadi
10	109	Karamah Pump
n/a	n/a	Karamah Dam (Gibb 1997)
15	205/6	Kufrein Dam
14	204	Wadi Shueib Dam

Soil and Plant Analyses

Soil Analyses

Soil data was made available by JVA laboratory. Records of soil data included chemical analyses conducted since 1985 on different farm units. Therefore, data on soil depth were grouped as follows: 25 cm to represent samples taken from 0-30 cm depths, 50 cm to represent those of 30-60 cm depth, 75 cm represents those of 60-100 cm, 100 cm to represent those depths more than 100 cm. In a few cases, if more than 125-150 cm was present they were designed with the group of 150 cm.

Some soil samples were taken as a part of various projects from 1985 onwards. Thus, number of soil samples taken from different development areas varied every year. Furthermore, samples might or might not be taken from the same farm unit during subsequent years.

Statistical analyses were carried for different soil parameters represented by samples at the following depths: 25, 50, 75, 100, and 150 cm according to a time series (Volume II). It should be noted that although records provided by JVA always included surface samples, their absence in the tables was due to the fact that either the development area number or farm units was missing. Therefore, such records were not included in the analyses because of lack of proper references. A summary of the soil analysis data in terms of salinity (EC) and its distribution along the soil profile is available in Annex F. Summary of soil analysis data for other parameters, in many cases analyzed for plants as well, is available in Annex B.

Plant Analyses

The raw data is available in Volume II and a summary by stage office is available in Annex B. Plant analyses were conducted for various types of crops. Samples were not a part of systematic monitoring program, but rather sporadic or conducted for localized programs which continued for one year only.

The analyses covered a wide range of plants including fruit trees and vegetables. The analyses were also conducted on various plant parts such as leafs, stem, and/or fruit.

Plant analyses were distributed according to stage office (SO), development area (DA), and land class (LC) to indicate the soil from which the plant samples were taken (Annex F).

Cropping Data

The raw cropping data are presented in Volume III and the summary cropping data are found in Annex C.

Cropping Patterns

The data on cropping patterns were obtained from the JVA. The data are on a monthly basis for each crop in each stage office and cover the years 1995, 1996, and 1997. The data were also available on a crop family basis: vegetables; cereals; nurseries; fruit trees; and other trees, however, these data were disregarded for the more accurate crop distributed data. The JVA data were used to determine the major crops and the average areas (in donums) of the major crops in each stage office over the three years. A summary of the cropping patterns for trees and vines can be found in Annex C.

Yields

Yields data from the Department of Statistics was obtained for the major crops in each area based on production/area. This data is available in summary for the major crops in Annex C. Yield reductions (in percentage) were calculated for various crops, water qualities, and leaching fractions. The spreadsheets used for the yield reduction calculations are presented in Volume III.

Water Requirements

Crop specific water requirements were determined through a review of appropriate studies on crop water requirement and were slightly adjusted for the specific conditions of the Jordan Valley. Published data on crop water requirements grown in similar conditions to those in the Jordan valley were used. However, since soils and climate play an important role in determining crop water requirements, and these conditions, especially soils, vary considerable throughout the Valley, crop water requirements needed to be decided upon for different areas of the Jordan Valley. Therefore crop water requirements were also adjusted for each directorate: North, Middle, and South Directorates.

Levels of water requirements for selected crops were estimated in full collaboration between the researchers of MWI and the National Center for Agricultural Research and Technology Transfer (NCARTT). These crop water requirements are available in Table C-5.

Drainage and Irrigation Systems

Drainage systems were obtained from the JVA. The areas with drainage systems installed are summarized in Annex F. The irrigation system is represented schematically in Annex H. The FORWARD team prepared this schematic in coordination with the MWI, WAJ, and JVA staff. The schematic depicts reservoirs, stage offices, turn out assemblies, diversions, the KAC, and how irrigation water flows between them.

5. WATER QUALITY ZONES

5.1. The Issues

The quality of irrigation water varies throughout the Jordan Valley. Water quality has been monitored at a number of locations and reported in relation to stage office. In this way, water quality data are related to the spatial distribution of water qualities and climatic conditions.

Agreements: Four water quality zones based on three parameters: salinity, chloride, and microbiological characteristics.

5.2. Approach

Water quality records were collected for many of the sampling points denoted in Figure 1 and Figure 2, Annex H. The following nine representative points were chosen to determine the spatial distribution of water quality variations:

- Abu Sido
- Kreimah
- Wadi Kufrinja
- Al-Hwarat (representing King Talal Reservoir)
- Muadi
- Karamah Pump
- Karamah Dam (as given by the 1996-1997 Gibbs report)
- Kufrein Dam
- Wadi Shueib Dam (for the period of 1990-1997)

Statistical analysis (Annex A) was performed to provide summary data of long term averages for 1990-1997 and more accurate averages for 1995-1997 that depict a more current water quality situation. Additional tables show microbiological contamination and trace elements including heavy metals concentration in As-Samra sludge.

To evaluate the impact of various water qualities, surface water in the valley was divided into four general water qualities to reflect different sources and degrees of blending. The categorization of water quality is based on three WQ parameters: salinity (EC); Chloride (Cl); and microbiological characteristics.

5.3. Findings and Analysis

Several water sources discharge into the irrigation system within the Jordan Valley. Some of these sources discharge directly into the King Abdullah Cannel, the main water carrier. Others are used directly without mixing with KAC.

Categorization was was based on three parameters: salinity (EC); Chloride (Cl); and microbiological characteristics. The average numerical value of a single parameter not used in the categorization may be similar in two or more classes while other parameters may be different. However the overall water quality becomes progressively worse from WQ1 to WQ4.

For most of the sites the average 1995-1997 values were used. Because water originating from the KTR was recently separated from saline springs after the reservoir or along the KAC, 1997 water quality data was used for Al-Hwarat, Muadi and Karamah Pump. As for the Karamah Dam, the latest assessment of the water quality as given in the Gibbs report (1997) was used.

Salinity/Electrical Conductivity

The analyses of EC values for the selected water quality sampling locations (Table A-1) revealed the following trends:

- *Abu Sido, Kufrein, Wadi Shueib Dam, and Wadi Kufrinja:* Average monthly EC values vary from 0.6 – 1.0 dSm^{-1}. The average for each site ranging between 0.7 – 0.9 dSm^{-1}.
- *El-Hwarat, Muadi, and Karamah Pump:* Average monthly EC values varied between 1 and 2 dSm^{-1}. The average for each site ranging between 1.3 and 1.9 dSm^{-1}. Average EC value only exceeded 2 dSm^{-1} at Al-Hwarat during December and January.
- *Karamah Dam:* According to Gibb(1997) water quality of Karamah Dam was predicted to be 3-4 dSm^{-1}. EC is expected to become even higher during water abstractions. Repeated flushing and mixing with KAC could reduce the EC value. Therefore, an EC range of 2-4 dSm^{-1} is suggested to represent the salinity of Karamah Dam.

Table 5.1
Salinity and Water Quality

Site Name	EC Group	Range
Abu Sido, Kreimah, Wadi Kufrinja, Kufrein Dam, Wadi Shueib Dam	1	0.6-1.0 dSm^{-1}
Al-Hwarat, Muadi, Karamah Pump	2	1-2 dSm^{-1}
Karamah Dam	3	2-4 dSm^{-1}

Chloride

The analyses of Chloride for the selected water quality sampling locations revealed the following trends (Table A-2):

- *Wadi Shueib and Wadi Kufrinja:* Average Cl concentrations ranged from 1.4-3.4 meq/L at these sites. Maximum concentrations were recorded during October.
- *Abu Sido, Kreimah, and Kufrein Dam:* An average Cl concentration of 2.7 – 5.0 meq/L is observed at these locations. Maximum concentrations appear to occur during the winter months (October and November).
- *Muadi and Karamah Pump:* The average Cl concentration ranged from 4.2-7.3 meq/L at these sites.
- *Al-Hwarat:* An average Cl concentration range of 6.0-10.2 meq/L is observed. Maximum concentrations (above 9 meq/L) occur during December and January.
- *Karamah Dam: (meq/l???)* Data regarding chloride content is still pending. During the first flushing cycle (1996-1997) Cl concentration ranged from 2230 mg/l to 12333 mg/l at various depths. Water quality of the dam is expected to improve if flushing is repeated and after mixing with KAC. Nonetheless, such high values should not be expected to decrease dramatically.

Table 5.2
Chloride and Water Quality

Site Name	Cl Group	Range (meq/l)
Wadi Shueib Dam, Wadi Kufrinja	1	1.4 - 3.4
Abu Sido, Kreimah, Kufrein Dam	2	2.7 - 5.0
Muadi, Karamah Pump	3	4.2 -7.3
Al-Hwarat	4	6.0 - 10.2
Karamah Dam	5	V. High

Microbiological Parameters

Data on nematode eggs, heterotrophic bacteria and coliform counts are available at the KTR outlet. However, there is little microbiological sampling and analysis conducted along the KAC. North of Deir Alla, there is some evidence of microbiological contamination (Table A-23). According to RSS sampling during 1995 and 1996 (Table A-22) and the WHO Guidelines for irrigation of crops likely to be eaten raw (Table G-2), fecal coliform levels in the KTR outlet meet the criterion (less than 1000MPN/100L) except during November and December. Nematode eggs are not present.

For the purpose of identifying water quality classes (zones), water coming from KTR is used as the main criterion. According to the sampling sites selected for water quality zoning, the following represents assumed microbiological contamination:

- *Abu Sido, Kreimah, Wadi Kufrnija, Kufrein Dam, and Wadi Shueib Dam:* Little or no microbiological contamination (KAC only).
- *Muadi, Karamah Pump, and Karamah Dam*: Little to moderate microbiological contamination (KAC blended with KTR).
- *Al-Hwarat:* High microbiological contamination (KTR only).

Table 5.3
Microbiology and Water Quality

Site Name	Microbiological Group	Water Source
Abu Sido, Kreimah, Kufrein Dam, Wadi Shueib Dam, Wadi Kufrinja	1	KAC
Muadi, Karamah Pump, Karamah Dam	2	KAC + KTR
Al-Hwarat	3	KTR

5.4. Recommended Water Quality Zones

Table 5.4
Recommended Water Quality Classification

Site No.	Site Name	EC	Micro.	Cl	Recommended WQ Class
204, 305	Wadi Shueib Dam, Wadi Kufrinja	1	1	1	1
102, 103, 205, 206	Abu Sido, Kreimah, Kufrein Dam	1	1	2	
107, 109	Muadi, Karamah Pump	2	2	3	2
203	Al-Hwarat	2	3	4	3
n/a	Karamah Dam	3	2	5	4

Table 5.5
Water Quality by Stage Office and Development Area

Water Quality Reference		Water Quality Zone	Stage	Development Area
102	Abu Sido	1	7 1 2	33,34,35,36,37,38,39,3,4,7,8, 9,10 1,2,6,7,8,10 10,11,12,13,14,15,16,7
103, 305	Kreimah, Wadi Kufrinja	1	3	18,19,20,21
203	Al-Hwarat KTR	3	8	29
203	Al-Hwarat KTR	3	8	22,53
203	Al-Hwarat KTR	3	4	23
107	Muadi *	2	5	24,25
107	Muadi	2	5	30
109	Karamah pump	2	6.	18 km,26
Karamah Dam Karamah Dam **		4	6 9	18 km,27,28 14 km,49,50,51,52
Q 206 Kufrein Dam		1	10	31,32

* Could have some of KTR water.

** Currently stage 9 is irrigated by Shueib water (good water quality). Under the 14.5 km extension (DA 49, 50,51,52) will be irrigated by Karamah Dam water.

With respect to the relative water quality in the Jordan Valley, four zones are recognized represented by the following sampling points:

WQ 1	*Abu Sido, Kreimah, Wadi Shueib, Kufrinja, and Kufrein Dam*	Fresh water in the KAC north of Deir Alla and a small area around Kufrein Dam.
WQ 2	*Muadi and Karamah Pump*	KAC water mixed with KTR.
WQ 3	*Al-Hwarat*	KTR water used directly without blending with KAC water

WQ 4	*Karamah Dam*	A blend of KAC and KTR like WQ 2. Stored in Karamah Dam it becomes more saline through evapoconcentration.

5.5. Implications

The analysis identified major water quality zones, each including more than one stage, which are irrigated with different water quality. Establishing such zones is of vital significance to:

- assess water quality impacts;
- ensure equity;
- improve the management system to optimize water use efficiencies;
- facilitate transformation of farming system;
- introduce new crops adaptable to changes in soil and water; and
- address marketing problems.

6. YIELD POTENTIAL

6.1. The Issues

Salt can have a profound negative impact on crop production. Even a moderate level of salinity reduces the yield of salt-sensitive and moderately sensitive crops which include over 90% of the crops currently grown in the Jordan Valley. Electrical conductivity (ECw) is an indicator of the salinity hazard of the water. It is the water quality parameter of greatest concern affecting potential yields.

The quality of water that is diverted from KAC for the city of Amman is of much better quality than the treated wastewater discharged into the KTR. The water quality is degraded not only from the introduction of constituents and contaminants but also by evapoconcentration. Both processes are responsible for increasing the salt concentration in KTR water.

Salinity affects crop production in two ways; by osmotic effects and by specific-ion effects. The osmotic effects will be considered in this chapter. Specific-ion effects will be discussed in a later chapter on plant toxicity.

The most common whole-plant response to salt-stress is a general stunting of growth. This is generally referred to as an osmotic effect and is directly related to the salt content in the soil water. This in turn is related to the salinity in the irrigation water and the extent of leaching that takes place. As salt concentration in the crop rootzone increases above a threshold level, both the growth rate and ultimate size of the crop progressively decrease. However the threshold and the rate of growth reduction vary widely among different crop species. Some crops such as common bean, strawberry and most fruit trees are highly sensitive to salinity and begin to show reductions in growth at very low levels. More tolerant crops such as asparagus and date palm, on the other hand, can tolerant much higher salinity levels.

Agreements: Calculating yield potentials, the % leaching fractions, the assumed irrigation efficiencies; the crop water use data, and the economic approach for determining the economic impact.

6.2. Approach

Yield Potential

Yield potential was based on the Maas-Hoffman salinity-coefficients (Grattan and Maas 1998) and the relationship between ECw (electrical conductivity in the irrigation water) and ECe (average rootzone salinity expressed as the EC of the saturated soil extract) assuming steady-state conditions and leaching fractions of 10%, 15-20% and 30% (Ayers and Westcot 1985). These estimates denote the maximum yield potential a crop can achieve given the water quality and achievable leaching-fraction. Other factors such as extreme climatic conditions, poor soil conditions, inability to leach, inadequate drainage and long intervals between irrigation could aggravate the salinity problem such that the yield potential will be less than indicated here.

Maas and Hoffman (1977), as described by Ayers and Westcot (1985) proposed that salt-tolerance is best described by plotting its relative yield as a continuous function of average rootzone soil salinity (ECe). They proposed that this response curve could be represented by two line segments: a tolerance plateau with a zero slope and a concentration-dependent line whose slope indicates the yield reduction per unit increase in soil salinity. For soil salinities exceeding the threshold of any given crop, relative yield (Yr) or yield potential can be estimated using the following expression:

$$Yr(\%) = 100 - b(ECe - a)$$

where a = the threshold soil salinity value expressed in dS/m;

b = the slope expressed in % per dS/m; and

ECe = average rootzone salinity in the saturated soil extract.

Specific values for a and b are found in a publication by Maas and Hoffman (1977) or more recently by Maas and Grattan (1998). The greater the threshold value and lower the slope the greater the salt tolerance.

In order to assess the impact of irrigation water with a known ECw on crop yield, the relation between irrigation water salinity and soil salinity needs to be known. FAO 29 lists the relationship between ECw and ECe for various leaching fractions assuming steady-state conditions (Ayers and Westcot 1985). These are indicated below.

Leaching Fraction	Relation between ECw and ECe
10%	ECe = 2.1 (ECw)
15-20%	ECe = 1.5 (ECw)
30%	ECe = ECw

The leaching fraction is defined as the fraction (or percentage) of infiltrated water that drains below the rootzone. For example, if 5 ha-cm of water was applied to a one hectare field and 1 ha-cm of water drained below the rootzone, the leaching fraction would be 0.20 or 20%.

The team recognizes that steady-state conditions are never achieved under field conditions but these relationships serve as both a target and a guide. Leaching must eventually be satisfied to prevent salt accumulation. Below is an example how yield potentials are calculated based on salinity of the irrigation water (ECw).

Example:

ECw	2.0 dS/m
Crop	Tomato
Leaching fraction	15-20%

Yield Potential (%) = 100 - b(ECe - a)

For tomato, a = 2.5 and b = 9.9 (Maas and Grattan 1998)

If an irrigation water of 2.0 dS/m with a leaching fraction of 15 to 20% in steady-state with the crop rootzone will produce an average rootzone salinity (ECe) of 3.0 dS/m.

Therefore,

Yield Potential (%) = 100 - 9.9(3.0 - 2.5) = 95%

Since tomatoes are classified as moderately sensitive to salinity, crops more sensitive such as bean, banana, onion and most fruit trees or vines would be impacted more. For example the yield potential for bean under the same set of conditions would be 62%. More tolerant crops, on the other hand, would be less affected. For example date palm, a tree crop tolerant to salinity, would not be affected.

In the assessment, the major crops in each stage office are categorized according to both winter (October-March) and summer (April-September) seasons. A major crop is defined as a crop that accounts for more than 0.1% of the cropped area, averaged over 1995-97, in that particular stage office.

Yield potential was determined for the major crops as well as non-traditional crops that have export potential by the method described above. The spreadsheets used for the calculations are available in Volume III. This was done using ECw values averaged from 1995-97 for both winter and summer seasons (Tables C-3 and C-4). To reduce redundancy, yield potentials are reported based on water quality zones. The average ECw of each water quality zone was used to calculate ECe and thus yield potentials are presented in Annex C.

These yield-potential calculations for the major crops, along with estimates of irrigation water requirements for crops in different regions, were used as components for the economic analysis and crop budgets that follow.

Irrigation Water Requirements

Although the climate of the Jordan Valley falls in the Mediterranean category, there is a difference in both rainfall and evaporative demand in a north-south direction. Rainfall can vary quite dramatically from year to year but the average rainfall in the northern part, north of Deir Alla, exceeds 250 mm/yr whereas the average rainfall in the southern part is less than 50 mm/yr. Evaporative demand, on the other hand, far exceeds rainfall and is higher in the south than in the north.

Data on rainfall and crop water use at each stage office is needed to determine the irrigation water requirement of the crop. Accurate estimates of the irrigation water requirement are needed in order to determine the cost of water to produce a particular crop in a particular region. This is an important economic exercise for determining crop budgets.

The irrigation water requirement for the crop is the consumptive crop water use, cumulative evapotranspiration, plus additional water to account for leaching and irrigation efficiency minus the water from effective rainfall. To estimate the irrigation water requirement we assumed an irrigation efficiency of 80% for low-pressure systems, drip and micro-sprinkler, and 70% for surface irrigation systems such as furrow. By accounting for these efficiencies, the irrigation water requirement was adjusted upward to account for different leaching fractions. The average rainfall in each region was then subtracted from these adjusted values to derive the irrigation water requirement of the crop.

The Joint Technical Working Group recognizes that under field conditions, irrigation efficiencies vary quite dramatically from location to location. Therefore the efficiencies chosen here were based on typical efficiencies for drip and surface irrigation under good management practices. Other efficiencies can easily be substituted into this exercise which will either increase (lower efficiency) or decrease (higher efficiency) the irrigation water requirement. The group also recognizes that under field conditions the leaching fraction and efficiency would not be additive but more likely the larger of the two would be used to determine the irrigation water requirement.

The consumptive crop water use for each crop according to climatic zone is listed in Table C-5. Crop water use was determined based on evaporative demand assuming that the crop root zone has a continuous supply of readily available water. The crop water use was determined for each of the major crops in each of the stage offices. This calculation was done using meteorological data from the National Center for Agricultural Research and Technology Transfer and appropriate crop coefficients (Kc). The meteorological data is needed to determine reference evapotranspiration (ETo). Crop water use was then calculated using the FAO 24 procedure by multiplying ETo and Kc and summing these values for different time periods throughout the season (Doorenbos and Pruitt 1984). For some crops there were no crop coefficients available. In these cases we used crop coefficients of crops with similar morphology and growth characteristics in order to determine consumptive water use. Crop water use was determined based on three agro-climatical zones (Northern, Central and Southern regions of the Jordan Valley).

In the economic model, the yield potential and irrigation water requirements for each of the major crops were determined according to stage office and season.

6.3. Technical Discussion

The yield potential for the major crops varied considerably based upon the salinity (ECw) of the irrigation water, leaching fraction and overall tolerance to salinity (Tables C-6 through C-11). For a given ECw, the yield potential increases or remains at maximal yield as the leaching fraction increases. The higher the leaching fraction, the lower the average rootzone salinity, because more salts have leached below the rootzone. Therefore, if the leaching fraction can be increased under field conditions, a crop, within limits, will be able to tolerate water higher in salinity.

With exception of strawberry and bean, WQ1, average ECw 0.83 and 0.93 dS/m for winter and summer seasons respectively, can be used to achieve at least a 95% yield potential in all crops provided that the leaching fraction is 15-20% or higher. As water quality degrades to WQ2, average ECw 1.32 and 1.62 dS/m for winter and summer seasons, yield potential of all crops except strawberry and summer grown bean can be maintained at only 80% or more provided that the leaching fraction is 15-20%.

If KTR water is used unmixed as WQ3, average ECw 1.93 and 1.77 dS/m for winter and summer seasons, crops that are tolerant or moderately tolerant to salinity can be grown to their full yield potential provided that they are irrigated using a leaching fraction of 15-20% or higher. The majority of the crops currently grown in the valley, over 90% of which are fruits and vegetables, can not be grown with water of this class without a reduction in yield.

The projected salinity in the Karamah reservoir ranges from 2-4 dS/m (Gibb 1997). Therefore yield potentials were determined at three different salinities (2, 3 and 4 dS/m) with three leaching fractions for each salinity level. Because these are projected water qualities, there are no differences in yield potential between summer and winter seasons. Since water quality from this source is estimated to be worse than that from the other three zones, potential yields are less for a given crop using the same leaching fraction. If the ECw is 3 to 4 dS/m, yields of grape, most trees, and vegetables are severely affected and the cropping pattern will most likely shift in the direction of crops that are more salt tolerant.

Table 6.1 illustrates the types of crops that can be grown to 90% of their yield potential based on the water quality class and an assumed leaching fraction of 15-20%.

Table 6.1
Crops that Can Be Grown to 90% of their Yield Potential Assuming a 15-20% Leaching Fraction

Water Quality	Types of Crops	Examples
1	All crops	All crops
2	All crops except very salt-sensitive crops	All crops except strawberry, bean, onion and banana
3	Many moderately sensitive to moderately tolerant vegetables, trees, most field crops	Cantaloupe, cabbage, cauliflower cucumber, eggplant, garlic, tomatoes, squash, spinach, field crops
4 (EC 2-4 dS/m)	Salt-tolerant trees, moderately salt-tolerant vegetables, many field crops	Dates, olive, guava, wheat, barley, asparagus, sorghum, and sugarbeet

In summary, WQ 1 can be used to irrigate essentially all crops in the Jordan Valley provided that a leaching fraction of 15-20% can be achieved. The types of crops become more and more restricted as the water quality class changes from 1 to 4, particularly the salt-sensitive and moderately salt-sensitive crops. Ultimately, only salt-tolerant trees, date palm and guava, asparagus, and some field crops can be grown with WQ 4 water at its worse case scenario, ECw 4.0 dS/m.

6.4. Implications

The identified yield potentials of major crops will be used to determine the economic returns of major crops at the ten stage offices. The yield potentials under different leaching fractions implicitly delineate the optimal leaching fractions that could be used in different areas in the Jordan Valley.

7. GROWERS' ECONOMIC RETURNS

7.1. The Issues

Crop yields are very sensitive to salinity. However, they are the main measure for farmers economic returns. Irrigation water in the Jordan valley has different salinity levels that affect cropping patterns and impact crop production and profitability. Moreover, higher salinity levels require water for leaching that will affect farmer's profitability and have consequences on the national economy.

The quantitative assessment of farmer's economic returns is essential to design irrigation tariff structure that is sensitive to salinity variations as a major water quality parameter. This assessment identifies the impact of water qualities on selected crops at the ten stage offices in the Jordan Valley.

7.2. Approach

Growers' Economic Returns

The following approach was thoroughly discussed and approved by the JTWG. Comments and suggestion made by the JTWG during discussions were taken into consideration during this assessment.

Data sources data used in this part include:

- Ministry of Agriculture: "The Study of Future Adjustment of the Jordan Valley". The study includes crop enterprise budgets for major vegetables and fruits produced in the Jordan Valley, for the three agro-climatic zones: North, Central and South Ghors. Data of all technical coefficients was abstracted from this published study
- Levels of crop water requirements (Table 3 C) for selected crops were estimated in full collaboration between the researchers of the Ministry of Water and the National Center for Agricultural Research and Technology Transfer.
- The unit prices of the technical coefficients (quantities of inputs used per dunum) were obtained from the Farm Prices Bulletin of the Department of Statistics (DOS). The most recent volume contains the input prices that prevailed in the local markets during 1996.
- Figures on cultivated areas and cropping patterns (Volume III) were obtained from Jordan Valley Authority.

Crop enterprise budgets are considered the basic part of farm income analysis. Here they are used to identify the impact of different water qualities on the major crops grown at each of the ten stage offices. Enterprise crop budgets were developed for crops in each stage office using current technologies and under existing production systems. The budgets are then used to compare the gross margins and the returns per cubic meter of irrigation water of different qualities used in the production of the selected crop at each stage office. The stage offices are grouped by climatic zone in the Jordan Valley.

The analysis was conducted through the following steps:

- The crops were selected for each stage office based on the following criteria: most common crops; crops sensitive to water quality; and non-traditional crops which may have export potential;
- Crop budgets were updated in collaboration with team members and experts of the Ministry of Water and Irrigation and the Jordan Valley Authority. Four water quality zones were identified as shown in Table 7.1.
- The returns per cubic meter of irrigation water were calculated for each crop in each stage office under different technologies.

Table 7.1
Major Crops by Stage Office and Water Quality

Stage Office	Water Quality Class	Major Crops
1	1	Citrus, banana, wheat, eggplant, beans, squash, and tomatoes
2	1	Citrus, banana, wheat, eggplant, fava beans, string beans, potatoes, squash, and tomatoes
3	1	Citrus, wheat, squash, potato, cucumber, beans, peppers, banana, and tomatoes
7	1	Citrus, banana, wheat, fava beans, string beans, squash, melokhia, and tomatoes
10	1	Citrus, wheat, grapes and tomatoes
5	2	Citrus, wheat, squash, potato, banana, beans, grapes and tomatoes
6 (DA 26)	2	Citrus, banana, beans, and tomatoes
4	3	Citrus, wheat, squash, potato, onions, beans, melokhia, and tomatoes
8	3	Citrus, wheat, squash, potato, onions, beans, cucumber and tomatoes
6 (DA 27, 28)	4	Citrus, banana, beans, and tomatoes
9	4	Citrus, banana, and squash

Crop Enterprise Budgets

A crop budget is a plan of action to match the inflows and outflows of resources to achieve a set of given objectives. Budgets are mainly used to evaluate the efficiency of farms in terms of resource allocation. The different measures that can be estimated by such budgets are explained in detail in Annex D: Calculating Crop Budgets. The measures include:

- Selecting crops (activities)
- Specifying the technology level
- Defining the production season
- Determining the price and quantities of inputs
- Setting the level and price of outputs
- Calculating the variable costs
- Calculating gross margins
- Calculating returns (gross margins) of one dunum to cubic meters of water.

7.3. Analysis and Findings

Water Quality 1

Stage Offices 1,2,3,7, and 10 are irrigated using Water Quality 1. They are dispersed geographically. Stage Offices 1,2, and 7 are located in the North Directorate. Stage Office 3 is located in the Middle Directorate and Stage Office 10 is located in the South Directorate. The crop enterprise budgets for the selected crops in those five stage offices are found in Volume IV. Tables D-1 through D-4 include a summary of the main indicators estimated from budgets of the major crops in each of the stage offices. The indicators are estimated for three levels of leaching fractions (LF): 10%, 20%, and 30%.

Stage Offices 1,2 and 7

Since Stage Offices 1,2, and 7 in the North Directorate have the same climatic conditions and use the same water quality, the results of the analysis and the conclusions found in Tables D-1, D-2, D-4, and D-11 are combined:

- Yields of tomatoes, squash, and wheat did not vary at all with the increase in water supply for leaching purposes. However, yields of beans, eggplants, citrus, and banana improved slightly when additional water was added;
- Gross margins (GM) of five of the seven crops were positive at the three levels of LF. Beans showed a significant increase in GM when additional amounts of water are added. GM of banana and citrus increased when a 20% LF was used and decreased with 30% LF;
- Except for beans, giving additional amounts of water will increase the cost of production and decrease the returns per cubic meter of water without increasing the yields;

- Except for wheat, banana, and Jew's mallow, the cost of water was less than 10% of the total variable costs. The cost of water for vegetables is even less than 4% for the three levels of LF; and

The impact of changing the currently used water quality in these stage offices is expected to be drastic. Table D-11 shows three different scenarios that quantify the impacts of water quality change on gross margins per dunum of major crops and on the total gross margins. It is clear from the table that the worst impact would occur if WQ 4 is used. Switching to WQ 2, 3, or 4 will result in reducing the total gross margins of the three stage offices by JD 7,526,125, JD 9,501,129, and JD 15,612,644 respectively.

Stage Office 3

Table D-3 shows:

- Yields of peppers, cucumbers, potatoes, tomatoes, squash, wheat, and citrus did not vary at all due to the increase in water supply for leaching purposes. However, yields of beans and banana improved slightly when additional water was added.
- The gross margins of eight of the crops were positive at the three levels of LF. Beans showed a significant increase in GM when the leaching fraction increased from 10% to 20%. GM of banana increased when a 20% LF is used and dropped later.
- Except for beans and, to a certain extent, banana, giving additional amounts of water will increase the cost of production without increasing the yields and decrease the returns per cubic meter of water.
- Except for wheat, citrus and banana, the cost of water is less than 10% of the total variable costs. The cost of water of vegetables is even less than 4% for the three levels of LF.

Table D-11 shows three different scenarios that quantify the impacts of changing the water quality on gross margins per dunum of major crops at Stage Office 3. Switching to WQ 2, 3, or 4 will reduce the total gross margins of this stage office by JD 862,185, JD 1,144,249 and JD 1,998,687 respectively.

Stage Office 10

Crops in this stage office are currently irrigated with WQ 1, but a dramatic change in water quality is expected to take place in this zone after the completion of the Karamah Dam. The worst expected scenario is that water quality in this zone will drop to WQ 4 which irrigation experts consider to be the worst water quality for irrigation in the Jordan Valley. To predict the expected impact of this change in water quality on farmer's returns, a current scenario and a future scenario were calculated. The future was simulated using WQ 4 and the same parameters.

Tables D-5.a and D-5.b show:

- At WQ 1, yields of squash, citrus and banana did not vary at all due to the increase in water supply for leaching purposes. However, when WQ 4 is substituted, the yields of citrus and bananas dropped to zero at 10% leaching fraction and the yield of squash decreased from 2300 Kg/dn to about 1450 Kg/dn. Even when leaching fraction is increased to 20% and 30%, the yields of citrus and bananas did not improve.
- At WQ 1, the GM of citrus and bananas were positive at the three levels of LF while GM was negative for squash. However, when WQ 4 is substituted, the GM of all crops became negative at 10% and 20% levels of LF. At a 30% level of LF, the GM of citrus and bananas became positive but the GM of other crops remained negative.
- Additional leaching with WQ 1 will increase the cost of production without increasing the yields of the selected crops and in turn decrease the returns per cubic meter of water. With WQ 4, the returns per cubic meter of water decrease drastically.

The impact of switching to WQ 2, 3, or 4 will reduce the total gross margins of this stage office by JD 393,362, JD 1,148,540, and JD 2,341,013 respectively (Table D-11). It is clear that the worst impact on farmers and national returns is expected with WQ 4.

Water Quality 2

This water quality zone contains Stage Office 5 and one development area of Stage Office 6 (see Table 7.1). Tables D-7, D-8.a, and D-8.b include a summary of the main indicators estimated from budgets of major crops in each stage office. The following is a detailed description of each stage office as a distinct unit to show the major impacts of water quality on economic return per crop:

Stage Office 5

Table D-7 shows:

- Yields of all selected crops except for squash and wheat showed a significant increase when leaching fractions were increased from 10% to 20% and from 20% to 30%. However, yields of wheat and autumn squash did not improve when additional water was added.
- Crops that showed an increase in yields also showed an increase in GM. It is worth noticing here that the GM of grapes and bananas are the highest among the selected crops. Grapes grown in this stage office are mainly early-seedless varieties, which are produced for export markets in Europe.
- Giving additional amounts of water would increase the returns per cubic meter of water for crops such as beans, bananas, citrus, and tomatoes. However, for the rest of the crops, the additional amounts of water will increase the cost of production without increasing the yields and decrease the returns per cubic meter of water.

The impact of changing the water quality in this stage office is shown in Table D-12. The table clearly demonstrates that switching to a better water quality, WQ 1, will result in increasing the total GM of the stage office by JD 174,737. However, if the water quality is degraded and WQ 3 or 4 is used, the total GM of this stage office will be reduced by JD 198,517 and JD 939,947 respectively.

Stage Office 6

Tables D-8.a and D-8.b show:

- Yields of tomatoes, citrus and grapes increase as water supply increases for leaching purposes, while yields of wheat do not increase. However, when the water quality deteriorates to WQ 4, the yield of citrus dropped to zero and the yields of tomatoes and grapes decreased significantly at a10% leaching fraction. The wheat yield decreased slightly. Even when leaching fraction increases to 20% and 30%, there is little improvement in the yields of citrus, tomatoes and grapes.
- The GM of citrus and tomatoes are negative at the three levels of LF while it is positive for grapes and wheat. When water quality is substituted by WQ 4, the GM of all crops become negative at 10% and 20% levels of LF, except for grapes at 20% LF. When the LF is increased to 30%, the GM of citrus and grapes become positive but much lower than what can be obtained when WQ 2 is used.
- Giving additional amounts of water will improve the returns per m^3 for grape production.

WQ 2 is currently used in this stage office. Table D-12 shows that switching to WQ 1 will increase the total GM of this stage office by JD 176,610. However, if the water quality is substituted by WQ 3 or 4, the total GM of these stage offices will be reduced by JD 219,004 and JD 1,147,392, respectively.

Water Quality 3

Stage Office 4:

Table D-6 shows:

- Yields of faba and string beans, Jew's mallow, potatoes, tomatoes, onions and citrus show a significant increase when leaching fractions increase from 10% to 20% and from 20% to 30%. However, yields of wheat and autumn squash are not improved with additional water.
- Crops that showed an increase in yields also showed a significant increase in GM. For crops such as beans, onions and citrus, GM moved from negative values to positive values.
- Giving additional amounts of water would increase the returns per cubic meter of water for crops such as beans, Jew's mallow, tomatoes, onions and

citrus. However, for the rest of the crops, the additional amounts of water will increase the cost of production without increasing yields and in turn decrease the returns per cubic meter of water.

The economic impact of changing the current water quality in this stage office on farmer's GM is also tested here. Table D-13 shows that switching to WQ 1 or WQ 2 will result in increasing the total GM of this stage office by JD 254,467 and JD 147,176, respectively. However, if WQ 4 is substituted, the total GM of this stage office will decrease by JD 497,221.

Stage Office 8:

Table D-9 shows:

- Yields of all selected crops except for squash and wheat showed a significant increase when leaching fractions are increased from 10% to 20% and from 20% to 30%. However, yields of wheat and autumn squash did not improve with additional water.
- GM of cucumber, tomatoes and wheat are the only positive values at a leaching factor of 10%. When LF is increased from 10% to 20%, GM of onions and citrus become positive. The GM of potatoes and squash remained negative even when the LF is increased from 20% to 30%.
- Giving additional water would increase the returns per cubic meter of water for crops such as beans and onions at the three levels of leaching fractions. However, the GMCM for cucumbers and tomatoes increased only when the LF increased from 10% to 20%.

The currently used water quality is WQ 3. Table D-13 shows that switching to WQ 1 or WQ 2 will result in increasing the total GM of this stage office by JD 483,380 and JD 264,955, respectively. However, if WQ 4 is substituted, the total GM of this stage office will decrease by JD 942,311.

Water Quality 4

This water quality zone includes Stage Office 9 and Development Areas 27 and 28 of Stage Office 6. The analysis here is limited to the leaching fraction issue. The economic impact of changing water quality on GM was not performed due to lack of data on acreage for Stage Offices 9 and 6. WQ 4 is considered the worst water quality for irrigation in the valley.

Stage Office 9

No data on cultivated area is available at this stage office. Tomatoes, citrus, beans, and bananas are the most common crops produced in the neighboring stage offices. Table D-10 shows that at a leaching fraction of 10%, yields of beans, bananas and citrus are zero. Tomato yield amounts to about 2100 Kg/dn at a 10% LF. Even when the leaching fraction is increased to 20% and 30%, the yields of beans, citrus and bananas are still very low.

Stage Office 6:

As mentioned earlier, two of the three development areas of this stage office are irrigated with WQ 4. The available data on cultivated area at this stage does not specify how many dunums each type of water irrigates. Since the whole stage office will be irrigated by WQ 4 in the near future, a comparison is made to show the consequences of switching from WQ 2 to WQ 4 (see Water Quality 2, Stage Office 6).

7.4. Conclusions

- The high quality water (WQ 1) used in irrigating crops in many stage offices across the Jordan Valley makes it difficult to increase the potential yields by increasing the leaching fraction, excepts for faba beans and string beans. The analysis showed that an increase in leaching fraction from 10% to 20% is the most appropriate to improve the returns of crops currently produced in Stage Offices 1,2,3,7, and 10 where WQ 1 is used.
- The cost of irrigation water per dunum compared to the total variable costs (TVC) is low especially for vegetables, which may allow for an increase in water tariffs without affecting farmer's return. An increase in water price up to JD 0.03/M3 (doubling the current tariff) will not affect the farmer's income.
- Substituting WQ 2 for WQ 1 in Stage Offices 1,2,3,7, and 10 will result in huge losses in terms of GM which may amount to as much as JD 8,781,672. These losses increase as water quality deteriorates. They could amount to JD 19,952,345 if WQ 4 is used.
- As water quality deteriorates, more crops are phased out in many stage offices especially sensitive crops such as beans, citrus and bananas. This is mainly due to economic losses in terms of lost GM.

There are major impacts on farmers' economic returns from different water qualities in the Jordan Valley. The Joint Technical Working Group and FORWARD will use this quantitative assessment and its conclusions to determine a tariff structure for JVA that will be sensitive to quality variations.

8. CROP MARKETABILITY

8.1. The Issues

Data available on the wastewater from the As-Samra Wastewater Treatment Plant shows an unreliable effluent quality that frequently has fecal coliform and other pathogens at levels that exceed public health protection standards. This translates into a high-risk in the wastewater reuse area downstream in the Jordan Rift Valley (JRV). It is unlikely that conditions will improve greatly in the next decade. The planned wastewater reuse in the Jordan Valley is high risk since unreliable treatment levels could result in a loss of confidence in its agricultural products on the part of farmers, farm workers, and consumers. The risk, as seen from the Saudi Arabian experience discussed below, can extend beyond the actual reuse area and have serious economic consequences for all national production.

8.2. Approach

The methodology and data sources were presented and discussed with the JTWG. Comments and suggestions by the committee members were taken in consideration.

Different sources of data were used including:

- Ministry of Agriculture (MOA);
- Agricultural Marketing Organization (AMO) annual reports;
- Department of Statistics (DOS); and
- Food and Agricultural Organization of the United Nations (FAO);

This analysis is divided into three parts: traditional markets, high value crops, and consumer confidence. The first two parts are quantitative assessments of markets while the third part is a qualitative assessment of impacts associated with the use of treated wastewater.

To analyze the issue of lost traditional markets due to water quality, the team

- Reviewed the exports of horticultural products from Jordan according to different sources (Jordan Rift Valley and highlands);
- Determined the monthly export windows to different markets from the Jordan Rift Valley and the highlands; and
- Estimated the volume of horticultural exports produced by treated wastewater in specific parts of the JRV.

To determine the lost economic and social benefits in terms of lost opportunities for producing high value horticultural crops due to water quality, the team

- Specified the potential high value crops demanded in export markets which can be produced in the Jordan Valley during the off-season (mainly winter in importing countries);
- Determined the timing and the size of the marketing windows of the potential crops;
- Determined the expected profits that could be generated if the right products, volumes, and quality are met; and
- Estimated the needed investment, water, and labor to meet the demanded quantities of those high-value crops.

Failure to achieve such opportunities will incur expected losses in estimated economic profits, investment opportunities, and job vacancies.

8.3. Analysis and Findings

Traditional Markets

The data analysis followed the proposed methodology using the available data from the above-mentioned sources (Tables E-1 through E-6). The following were the conclusions:

- Fresh fruits and vegetables form about 90% of agricultural production in the Jordan Rift Valley;
- From 1990-1995 the total quantities of fruits and vegetables delivered to wholesale markets in Jordan averaged 787 thousand tons. Of this total, 287 thousand tons was produced in the Jordan Rift Valley. The JRV share of the production delivered to these wholesale markets averaged 33% of total fruits and 40% of total vegetables;
- The highlands and the Jordan Rift Valley are the major sources of horticultural exports. The JRV produced 54% of the fruit exports and 38% of vegetable exports during the period 1991-1995. The proportion of fruit exports from the JRV is higher than exports from the highlands because citrus is the major exported Jordanian fruit and it is grown only in the JRV;
- The Arab countries were the major importers of Jordanian fruits and vegetables during the period 1991-95. On average, the share of the Arab countries amounted to 98.9% of total exports. The remaining 1.1% was exported to Western and Eastern Europe.
- Vegetable exports to Arab countries during 1991-95 were concentrated during June to November (63% of total annual exports). The highlands are the major source of vegetables exported to these countries. Tomatoes, cucumbers, eggplants and squash are the main exported vegetables;

- Fruit exports to the Arab countries occur during two periods: from November to January, and from May to July. Exports from the first period, which comprise about 35% of total fruit exports, are mainly citrus from the Jordan Valley region. Exports from the second period, about 34% of the total, are mainly early grapes and melons from the Jordan Valley region; and
- Exports of tomatoes, cucumber, eggplants and squash represent about three fourths of total vegetable exports to Saudi Arabia.

Since 1995, the Saudi government has stopped all vegetable imports from Jordan claiming that these vegetables are irrigated with untreated wastewater. They also claimed that this decision was based on an analysis of water samples from KTR that confirmed the existence of several pollutants in the irrigation water. The Saudi restriction was not limited to vegetable imports from the Jordan Valley, but also applied to imports from the Highlands regions. Table E-6 shows the monthly distribution of exports of the four main vegetables to Saudi Arabia. The Highlands growers were badly hit by this decision because more than 80% of tomato exports were during the summer season.

The team estimated the economic consequences of this ban on Jordanian agriculture using data on monthly and annual exports and prices. The average exported quantity was calculated for the years 1990 and 1992. The export value was estimated by using a price vector for the years 1995, 1996, and 1997. A conservative estimate of the accrued losses due to this decision is outlined in Table E-7. The expected total losses were estimated at JD 13.7 million. The actual losses are expected to be even higher than this figure for two reasons: prices of the crop output used in the analysis are the most frequent prices at Amman wholesale markets, not the import prices at Saudi markets; and the losses were estimated only for major crops, not for all exports.

High Value Crops

A scenario was built to determine the expected economic and social losses due to the anticipated change in irrigation water quality in the South and Middle Directorates (Water Quality Zones 2 and 3). It was based on data abstracted from official records and market studies conducted by public institutions in Jordan. The research was funded by the Jordan Agricultural Marketing Development Project and conducted in 1991 by the SRD Group, Inc.

- The market studies indicated that the European Union (EU) countries offer a enormous potential winter season market for products which can be produced and shipped economically from Jordan.
- The sophisticated market research identified the market windows, the profitable demand levels for Jordan, and the expected private profit for a group of horticultural products.

The depth or the size of the market window for Jordanian products in these markets was estimated using the weekly wholesale price data and the weekly-marketed quantities in each market.

Profitable demand was determined using an estimate of the average Jordanian producer/exporter break-even price in each export market to be analyzed. The breakeven price was estimated by adding up the farm production costs, packaging costs, transport costs, tariffs, handling, and marketing fees for supplying one kilo of fresh produce to the different European markets. The break-even price differed slightly in the various markets because of differences in tariff and transportation costs.

The comparative advantage was estimated for major crops produced in the Jordan Valley. The whole analysis was carried out for early seedless table grapes, strawberries, green beans, eggplants, tomatoes, melons, and peppers, all of which are moderately sensitive-sensitive to salinity according to the FAO. Table E-8 demonstrates the market windows for the eight products as well as the estimated profitable total demand during those periods. It was found that:

- Jordan enjoys a comparative advantage in the production of tomatoes, peppers, melons, green beans, strawberry, eggplant, and grapes, all of which are moderately sensitive-sensitive to salinity according to the FAO. Production of these crops makes an efficient use of scarce water and land resources in the Jordan Valley.
- AMO statistics show that only a very small portion of that demand has been met by Jordanian producers till now.

In order to fulfill the unmet profitable demand in the selected EU market for a one-week period, a total of 108,928 dunums are needed to be cultivated (Table E-9). The needed area is slightly larger than the total area of southern and middle zones of the Jordan Valley. The land, investment, water, and labor required to meet the one-week profitable demand is shown in Table E-10. The table also includes the breakeven price per kilogram, the airfreight from Amman to Europe, and the total marketing costs. The total marketing cost is composed of the packaging materials, pre-cooling, and commissions.

Fulfilling this demand will yield a sum of USD 32,872,637 as net profit to producers only (Table E-11). Other beneficiaries include collateral support systems such as suppliers of cartons, post-harvest handlers, cold storage and pre-cooling providers and shippers. The shipping cost of this demand by air is expected to be about USD 65 million, which is a huge business to the national carriers. Production of these crops will also generate a sum of 631,416 working days.

8.4. Conclusions

The implications of using different water quality on the marketability of horticultural products in the Jordan Valley can be summarized as follows:

- Using KTR water, which is in part treated wastewater, has negatively affected Jordan's exports especially to Saudi Arabia. A conservative estimate of the accrued losses due to this decision was estimated at JD 13.7 million since the

Saudi government banned the imports of fresh vegetables from Jordan in 1995;

- Production of high value crops such as green beans, strawberries, and seedless grapes require the availability of high quality water in the Jordan Valley. The exceptional comparative advantage of Jordan in producing such off-season high-value crops could be lost if water quality deteriorates. Changing the quality of current irrigation water will result in a loss of JD 33 million in term of net profits to farmers alone and a sum of 1.4 million working days (equivalent to about 5,700 annual permanent job vacancies).
- The expansion in exports of fruits and vegetables could improve Jordan's balance of trade problems and increase incomes and employment in the agricultural sector and other supportive sectors such as transportation and manufacturing of boxes, fertilizers, plastics and other production materials.

9. FARM MANAGEMENT

9.1. The Issues

Soil Salinization

Degraded water quality affects a number of practices at the farm level. As the quality of irrigation water is degraded, the margin of error is reduced regarding irrigation management. Irrigation with water that is higher in salinity for example requires increased flexibility in water delivery schedules and extra care that soil salinization does not occur. This is particularly true for drip irrigation systems where roots are restricted to a smaller area within the soil profile compared to surface-irrigated crops. Certain soils are poorly drained and salinity can only be reduced by installation of artificial drains.

Permeability Hazard

Infiltration rate can be affected by the quality of the irrigation water applied. The two most common water quality factors that influence the infiltration rate are the salinity of the water (ECw) and its sodium content relative to the magnesium and calcium content (sodicity of the water). The Sodium Adsorption Ratio (SAR) is the primary indicator of a sodicity or permeability hazard. An irrigation water supply with a high SAR may indicate a potential hazard associated with water infiltration. Water infiltration is generally improved within a given soil as the ECw increases and SAR decreases (Ayers and Westcot 1985).

An infiltration problem related to water quality, in most cases, occurs in the surface few centimeters of the soil. It is linked to the structural stability of the surface layer and the affect of irrigation water quality on the calcium content of the soil relative to that of sodium. Management practices may need to include an application of gypsum to make sure that an adequate supply of calcium is maintained at and near the soil surface.

Agreement: SAR is a parameter worth examining, but SAR should not be considered in the tariff structure.

Agreement Needed: What types of management activities need to be considered: education, drainage installation, monitoring?

Nutrient Management

The nutrients in irrigation water and wastewater provide a similar benefit to the crop as fertilizer. The two most prevalent nutrients in water are nitrogen and phosphorus. Most natural flow irrigation waters contain low concentrations of these two nutrients. Wastewater on the other hand can contain significant quantities of nitrogen and phosphorus. Where wastewater is being used, nutrient management must be considered as part of the irrigation management. In the case of nitrogen, the plant needs significant quantities in the early stages of growth but nitrogen is much less beneficial towards maturity. Because the application of these nutrients occurs with the application of the water, there is little ability to regulate the application to meet crop needs.

Late season nitrogen may stimulate excessive vegetative growth, delay maturity, or reduce crop quality. For example, excessive vegetative growth in the late season may affect tomato or grape fruit maturation rates. Late season nitrogen may also affect crop quality such as reducing the sugar content of sugarbeets.

A similar reaction would not be expected with phosphorus because it is in lower concentrations and does not simulate vegetative growth like nitrogen.

Extension Education

Use of more saline water for irrigation requires several changes from standard irrigation practices such as selection of appropriate salt-tolerant crops, special care in managing and monitoring soils and water, changes in cropping patterns, and in some cases, the adoption of advanced irrigation technology. Extension education is necessary to improve on-farm management and irrigation methods.

9.2. Approach

Water Analysis

The water quality parameters that were assessed include Nitrate (NO_3); Salinity (ECw); and Sodium Adsorption Ratio (SAR). The average monthly values for these water quality parameters from 1990-1997 (NO_3: 1995-1997) at various sampling locations, are available in Annex A.

The EC values used for the purpose of water quality classifications were 1995-1997 averages. However, with regards to determining impacts of water quality on soil salinization, 1990-1997 average EC values are used. Therefore the ranges used in this part of the water quality impact assessment may differ from those determined earlier for the purpose of water quality classifications.

Soil Analysis

The soil analysis data in Annex B has been summarized from various samples taken in each stage office. A summary of the general soil morphology and soil analysis with regards to salinity is available in Annex F and has been grouped by soil area: northern (Stage Offices 1,2,3, and 7), middle (Stage Offices 4 and 8), and southern (Stage Offices 5,6,9, and 10) soil areas.

Soil Drainage

Table 9.1 shows what percentage of the soils is drained in each water quality zone. It was compiled from the information in Annex F. The total areas may not correspond exactly to other sections of the report, but the data represent areas with drainage in place.

Table 9.1
Soil Drainage by Water Quality Zone

WQ	Total Area Drained	% Drained
WQ 1	96743.28	11.71%
WQ 2	41971.12	16.07%
WQ 3	67639.78	16.21%
WQ 4	34734.49	4.58%

9.3. Technical Discussion

Soil Salinization

Irrigated areas south of Muadi (total area of 51180 dunums) included higher portion of exposed Lisan Marl distributed in a complex manner with other sediments. The soils in this area are covered with thin colluvium over Lisan Marl and a large area is covered with the Damya Formation on the top of a highly saline Lisan Marl. The Lisan Marl also contains discontinuous gypsum layers or segregated gypsum scattered and mixed with other sediments.

Generally, the soils of Stage Offices 1, 2, 3, and 7 are fine textured soils, originally of low indigenous soil salinity. Land Class 6, which reflects the influence of the Lisan Marl, occurs in isolated lenses and covers small areas which are usually not cultivated. The salinity of the top Lisan Marl in this area is far lower than those south of Deir Alla. Soils irrigated with relatively low salinity water from Kufrein Dam (Stage Office 10) are not influenced by the saline Lisan Marl, but rather by gravely sediment and the Damya formation, which is less saline than the Lisan Marl formation.

Stage Offices 8 and 4 (total area of 68379 dunums excluding DA 53) are characterized with soils low in indigenous salt content. However, due to undulating topography, the occurrence of the saline Lisan Marl closer to the surface and the existence of large exposed area become more obvious southwards.

The higher EC values associated with WQ 3 which prevail during the winter months of low evaporation demands should cause less salt accumulation than the WQ2 to the south, which has higher EC values during the summer months (maximum evaporation demands) thereby promoting more salt accumulation at the soil surface.

In the current situation in much of the Jordan Valley, irrigation water is available to growers only two to three times per week (Hagan and Taha 1997). This type of delivery schedule is more suited to surface irrigation than drip irrigation methods. The combination of poor quality water and extended intervals between irrigations can intensify the salinity effect on the crop. Farmers with drip irrigation try to improve their flexibility by building reservoirs on the farm. In the process, they lose the original pressure in the system and need to pump water from the storage pond to the crops.

Recommendation: The JVA and growers within each of the stage offices need to change existing practices to allow for irrigation water on immediate demand in order to optimize crop production.

Leaching Practices

The key to irrigation using more saline water is maintaining an adequate salt balance in the crop rootzone such that the accumulation of salts do not occur. All plants have an upper tolerance limit to the salt concentration in the root zone. To avoid damage, some downward displacement of salts below the rootzone, commonly referred to as leaching, is necessary to maintain plant productivity regardless of plant type or conditions. The amount of leaching is dependent on two factors: the salt tolerance of the plant and the salinity of the irrigation water. The greater the salt-tolerance, the lower the required leaching.

Leaching can only occur when there is adequate drainage. Some soils are naturally deep and well drained and leaching can be achieved easily, at least on a seasonal basis, provided that the farmer is supplied with sufficient quantities of water. Other soils have a restricting sub-surface layer that does not allow water to move vertically downward in the soil profile. An example of this is the marl layers that exist close to the surface in many areas within the southern Jordan Valley. The thickness of the colluvial sediments covering the marl layer increases from south to north and from east to west.

When drainage is not adequate, a buildup of salts can occur. It is often misunderstood that plant roots, for the most part, extract pure water from the soil water leaving the salts behind. The amount of nutrients that the plant-roots selectively remove from the soil solution is negligible compared to the bulk of the salts that remain. As the crop consumes this pure water from the soil, a smaller and smaller volume of water remains, thereby concentrating the salts. These salts must be leached from the soil. If drainage is not adequate, leaching can not take place, allowing salts to build up in the rootzone and affecting crop production.

Artificial drains have been installed in a number of areas within the middle and southern regions of the valley to facilitate leaching and avoid the build-up of salts in the soils. Maintaining similar well-drained conditions in the areas that will use the more saline KTR and Karamah Dam waters is a key factor in the success of the area.

Although effective in most areas, drains are expensive to install. Furthermore there are areas with shallow soils, where the marl layer approaches the soil surface, where drainage may be inadequate even with the installation of drains.

Recommendation: Problematic soils should be identified and restricted from cultivation.

Permeability Hazard

The Sodium Adsorption Ratio (SAR) is the primary indicator of a sodicity hazard or a permeability hazard, but this hazard potential can also be influenced by the salinity of the water supply. Water infiltration is generally improved within a given soil as the ECw increases and SAR decreases (Ayers and Westcot 1985). Both factors were used in this analysis to estimate the potential infiltration problem that may be encountered in the Jordan Valley. The evaluation procedure is described in the FAO guidelines for determining the suitability of an irrigation water supply (Ayers and Westcot 1985).

The database for the calculation of the SAR is limited to late spring and late fall, as this database was judged sufficient for analysis. **Not true.** The two periods used for analysis represented conditions at the end of the wet period (April) and conditions at the end of the dry period (October) just before the beginning of the winter rains. October is the period just after planting, a time of maximum surface soil disturbance. Table 9.2 shows the available SAR calculations from recent water quality data for three of the four water quality zones. No data were available for the Karamah Dam (Zone 4).

Table 9.2
Average ECs and SARs Calculated from Water Quality Data Measured from 1995 to 1997 in April and October

WQ	Measured Site	April		October		Permeability Hazard[a]
		(SAR)	EC (dSm^{-1})	(SAR)	EC (dSm^{-1})	
1	Abu Sido	2.57	0.89	2.26	0.94	Low
1	Kreimah	2.25	0.88	2.25	0.95	Low
1	Wadi Kufrinja	0.89	0.68	1.17	0.87	Low
1	Wadi Shaeb Dam	0.98	0.63	1.61	0.92	Low
1	Kufrein Dam	1.04	0.87	1.52	0.99	Low
1	New Hisban Dam	0.78	1.24			Low

2	Maudi	2.37	1.15	2.66	1.74	Low
2	Karamah Pump	1.78	1.09	2.59	1.51	Low
3	Al-Hwarat	3.16	1.66	2.57	1.91	Low

[a] Based on FAO Guidelines (Ayers and Westcot 1985)

Using the FAO guidelines (Ayers and Westcot 1995), the combination of low SAR and elevated water salinity levels (ECw) suggest that the permeability hazard is low. The low SAR is due to the elevated calcium level in the natural waters of Jordan relative to sodium. This same characteristic was found in water from the King Talal Reservoir. The soil conditions in the Jordan Valley, many of which have a strong calcium carbonate characteristic, would also work to reduce the permeability hazard. Another mitigating condition within the Jordan Valley is the use of the drip irrigation systems. The low volume application can often mitigate for a reduced infiltration rate resulting from a sodium to calcium imbalance.

The SAR is consistently below 3 for natural flow water supplies in Jordan. The flow from KTR shows a more elevated SAR. This is to be expected as municipal wastewater often shows an elevated sodium (Na) level compared to the urban supply water (Pettygrove and Asano 1985). This is commonly associated with the use of sodium-based detergents. The increase in SAR however is often offset by an increase in total salts (salinity) as measured by ECw. This can be shown in Table 6.2 with the Al- Hwarat site that contains water released from the King Talal Reservoir and shows an elevated SAR compared to other sites.

The above analysis is a summary of two significant time periods in water supply in the Jordan Valley. To assess variability, a full analysis was conducted using average monthly values for water quality at two sites. For 1995-97 the calculated SAR for the monthly water quality data ranged from 2.09 to 2.95 for King Abdullah Canal at Muadi and from 2.65 to 3.35 for flow below the King Talal Reservoir. These represent two distinct water qualities used in the JRV. As shown above, they demonstrate a low hazard to soil permeability problems based on the salinity levels measured in these water supplies (Ayers and Westcot 1985).

Nutrient Management

Nitrogen

Nitrogen is needed by all plants in significant quantities and is also a major component of many domestic wastewaters. Table 9.3 presents recent water quality monitoring data for nitrate for three of the four water quality classes in the Jordan Valley. The data are consistent with the finding that most natural flow irrigation water contains low levels of nitrogen and almost all of the nitrogen is present in the nitrate form. In almost all these sites, the nitrogen supplied by the irrigation supply water is an insignificant portion of the total nitrogen requirement of the crop (< 5%).

Table 9.3
Water Quality for Nitrate

WQ	NO_3*(mg/l)
1	1.6-9.1 (4.5)
2	5.6-8.8 (7.2)
3	4.9-12.8 (8.9)
4*	Up to 75

* Predicted value

Because WQ 2 and WQ 3 contain wastewater from the King Talal Reservoir, the measurement of nitrate alone may not be an adequate analysis to determine the total nitrogen in the water supply. Recent monitoring data from KTR (Harza 1996) shows that nitrate makes up less than 1% of the total nitrogen in KTR. Therefore while measurement of nitrate in the irrigation supply canals is a proper technique, when wastewater is present, an expanded analysis to include ammonium (NH_4) and organic forms of nitrogen is needed.

There is no long-term database on the total nitrogen that is being discharged from KTR. An assessment can be made however on the total nitrogen levels entering KTR to get an approximation of whether total nitrogen will be a concern in the irrigation water released from KTR.

The total nitrogen value in the discharge from the As-Samra Wastewater Treatment Plant during a 5-year period (January 1990 – November 1995) ranged from 61 to 114 mg/l with a median value of 97 mg/L (USBR 1998). This same United States Bureau of Reclamation study showed the total nitrogen levels entering KTR had diminished to a median value of 43 mg/L during the same time period. This reduction may be due to nitrogen losses, uptake along the wastewater route to KTR, or dilution due to other flows in the wadi entering KTR.

An evaluation of KTR was also done during a four-month period in 1996 which showed that total nitrogen (without organic nitrogen) averaged 32 mg/L. Because KTR is eutrophic, the major form of nitrogen in KTR is likely to be ammonia-N and organic-N forms (Harza 1996). The USBR evaluation estimated that the total nitrogen measured in KTR without organic nitrogen would need to be increased by approximately 20% to account for the organic-N.

In addition to the input and output analyses discussed above, the United States Bureau of Reclamation estimated that the average annual total nitrogen load to KTR is 480 Mg per year(USBR 1998). The discharge from KTR, from available data, was estimated to be 1200 Mg per year. Their analysis indicates that KTR is producing over 700 Mg per year of total nitrogen. The increase is likely due to the large population of N-fixing blue green algae present in KTR.

Phosphorus

Phosphorus is needed by plants in relatively large amounts and many wastewater effluents contain phosphorus at significant levels. The average phosphorus concentration entering KTR ranges from 5 to 7 mg/L as total phosphorus (Harza 1996 and USBR 1998). This is consistent with concentrations found in other wastewaters worldwide (Pettygrove and Asano 1985, Pescod and Arar 1988, and Pescod 1992).

Total phosphorus at the level found in KTR will act as a plant nutrient but is unlikely to cause excess phosphate availability to the plant. With the calcareous soils of the Jordan Valley, phosphorus in the KTR water delivered for irrigation should not cause a problem. Although there is a benefit from this plant nutrient, it is not at such a level that it would replace the need for supplemental fertilization.

Recommendation: Based on this finding, it is not recommended that total phosphorus be considered as a criteria in determining water pricing structures or water use patterns.

The United States Bureau of Reclamation (1998), after review of the KTR, has concluded that total phosphorus in the reservoir will continue to increase as it is estimated that about 50% of the total phosphorus entering the reservoir is being retained in the reservoir. The Bureau estimates that total phosphorus entering the reservoir is the primary reason that KTR is eutrophic. It is estimated that nutrient loads, in particular total phosphorus, would have to be reduced 100 - 200 times to improve the eutrophic condition of the reservoir. It is expected that phosphorus will continue to enter the reservoir at greater than 0.1 mg/L, thus causing the reservoir to remain hyper-eutrophic. This condition will result in the reservoir having an algae problem which may cause maintenance problems in the open canals downstream of KTR, clogging problems in downstream irrigation systems, and continue to result in aesthetic problems in and near the KTR. However it is difficult to estimate the economic impact related to increased maintenance costs.

Extension Education

When irrigating with marginal to poor quality water, special care needs to be taken to maintain a favorable environment in the crop root zone. A shift from low to higher salinity water requires a higher level of operational skill for JVA and the farmer. The skill level of the farmer needs to be upgraded in order to utilize water supplies of higher salinity successfully. The grower or irrigation manager needs to know crop water requirements, basic principles of irrigation management, and basic principles related to salinization and salinity control. In addition he needs to carefully monitor the soils for salinity build-up and identify poorly drained areas.

Because higher salinity water removes a portion of the margin of safety, adequate training is needed to ensure the farmer has the ability to survive. A mistake in salinity management may cause a yield loss, crop loss, or, in a worst case scenario, the loss of production capability until reclamation can be achieved. Because the Jordan Valley farmers do not have extensive capital backing, a loss at any level could put the farmer out of business. The success of the farmer is now closely tied to the success of wastewater reuse. If one or the other fails, both fail.

Extension education will enable JVA staff and growers to upgrade their irrigation management skills. Agriculture research centers and universities in Jordan in collaboration with JVA should review effective extension education programs throughout the world and consider modeling such a program within the Jordan Valley. To be most effective, it would require individuals with a graduate level education to be located not only in the field but also on the university campus. This group is not intended to replace existing irrigation consultants or the Irrigation Advisory Service (IAS) but rather to work with them and educate them so that their skills remain strong and current.

Irrigation Methods.

The method of irrigation influences the salt distribution in the soil, determines whether the leaves will be subjected to wetting, and determines the ease at which high soil-water potentials can be achieved (Maas and Grattan 1998). Thus the method of irrigation can affect the crop's response to salinity. Irrigation methods such as drip that maintain a higher soil-water potential reduce the time-averaged salt concentration in the soil-water. They allow for optimal plant performance if the systems are operated and maintained properly.

Although irrigating at a lower soil-water depletion may be desirable to maintain a favorable soil-water environment, use of sprinkler irrigation creates an additional problem. Salts in the irrigation water can be readily absorbed by wetted foliage and accumulate in the leaves to the point where injury can occur. In some species, leaves become severely injured and crop yields are reduced. Studies have shown that many crops are not nearly as tolerant to salinity when sprinkler irrigated.

The degree of injury is related to the salt concentration in the leaves, but weather conditions and water stress can influence the onset of injury. For example, leaves may contain toxic levels of Cl or Na for several weeks without exhibiting any injury symptoms, but the first hot, dry weather will cause severe leaf burn. Consequently there are no practical guidelines for correlating foliar injury to salt concentrations in the leaves. Since the weather in the southern part of the Jordan Valley is warmer, the evaporative demand is higher, and the water is generally more saline, sprinkler irrigation could be problematic.

At the present time sprinkler irrigation in not widespread in the Jordan Valley and consequently this type of problem may only be localized. Should sprinkler irrigation be expanded in the future, particularly in WQ Zones 3 and 4, it is important to note that the yield potential estimates in the quantitative section of this report will likely be underestimated.

9.4. Implications

Soil Salinization. It is difficult to assess the impact of water quality on soil salinization as a result of the extremely variable nature of soils and management that affect leaching and drainage. It is known that indigenous soil salinity follows a general trend of increasing salinity from north to south, and that irrigation supplies also generally deteriorate in that same direction. This knowledge, although not as explicit as yield reductions resulting from EC, should be taken into account in the ranking and risk assessment of this parameter (EC).

Permeability Hazard. Based on the analysis described above and the water quality data available to the project, it is recommended that SAR not be considered in developing water pricing policies or water use patterns.

Nutrient Management. Regardless of the type of analysis conducted, there is a significant load of total nitrogen that leaves KTR and is carried through the irrigation distribution system in Water Quality Zones 2 and 3. The data are not adequate however to evaluate the loads that will be received by any specific area as it will depend on the time of year and the dilution or mixing of irrigation supplies that occurs. In the future, when KTR water begins to make up a more significant portion of the total flow in these zones, the nitrogen levels will increase in importance. Because of this, a monitoring program that focuses on total nitrogen is needed. It is only with quality data that good management decisions can be made.

Because nitrogen is a fertilizer resource and water use can be measured, an approximation of the Kg/dn of nitrogen could be estimated or quantified. For example, if the total nitrogen concentration in the irrigation supply water was 50 mg/L, this would input 0.15 - 0.25 Kg (N)/dn/day, a significant quantity of nitrogen. Therefore pre-season applications of nitrogen need to be adjusted downward to account for the nitrogen contribution in the irrigation water supply. Reducing the application rate of fertilizer not only saves money but will reduce the risk of nitrate contamination of the ground water supplies.

Nitrogen has a value as a fertilizer, and a charge could be made for the fertilizer value of the irrigation water. This could be considered in the water pricing structure. Such a pricing approach is often recommended as a source of revenue for the wastewater treatment plant or to pay for the water distribution costs. There are few wastewater reuse projects where such charges have been successful. It is not recommended for the water pricing structure in the Jordan Valley for the following reasons:

- The nitrogen content in the water is not constant and would require continuous monitoring and adjustments to the water pricing;
- The farmer can not see or feel the nitrogen fertilizer and may doubt whether it is delivered as promised. In the event of a yield loss, the irrigation water will be the focus of the dispute;
- The nitrogen in the water supply will not always be delivered at the time and in the quantity needed for crop production. The farmer may need to apply

supplemental fertilizer, thus his costs for fertilizer applications may not be significantly reduced as the fertilizer material may not be a significant portion of the total application costs;

- The nitrogen is applied through the irrigation water. Often farmers apply fertilizers as a band or various other placement techniques. Applying over the larger area with the irrigation water may cause increased weed growth and additional cultivation costs;
- Late season application of nitrogen may cause yield losses or delayed maturity thus greatly influencing the marketability of the crop; and
- High nitrogen concentrations in the water supply may cause additional maintenance costs due to weed growth or system clogging.

10. IRRIGATION SYSTEM MAINTENANCE

10.1. The Issues

Clogging of drip irrigation systems is one of the most costly irrigation problems for growers. Certain parameters in the irrigation water associated with degraded quality (pH, algae, nutrients, and sediments) can clog emitters in drip irrigation systems. Should these parameters be problematic, irrigation water needs to be treated to reduce pH, algae, and sediments. The presence of nutrients promotes the growth of algae in open irrigation channels and holding ponds on grower's fields.

Drip irrigation systems must be well maintained to operate effectively. Substantial labor may be required to assure that the system is working at optimum efficiency and uniformity (Hanson et al. 1994). Labor includes a number of activities such as checking for leaks, back-flushing filters, flushing lines, chlorinating and/or acidifying the system, and cleaning or replacing emitters.

Suspended solids such as sediments and organic material as well as irrigation waters high in pH can play havoc on drip irrigation systems. Sediments in the irrigation water may vary considerably in different parts of the JRV and can vary dramatically over time. For example sediment loads, primarily silts and clays, may be particularly high just after a heavy rain. Both screen and media filters may frequently clog and even frequent back-flushing is insufficient to allow the system to operate efficiently. Often silts and organic material can accumulate in the drip irrigation laterals, drip lines, and inside emitters which can greatly reduce flow and affect the distribution uniformity (DU). High pH may be incompatible with certain fertilizers (phosphate types) injected into drip irrigation systems and facilitate precipitation of certain chemicals (calcium phosphate and carbonates) at the orifice of the emitter which can clog the system.

Agreement: Parameters that impact on irrigation system maintenance.

Agreement Needed: Parameters that should be considered in a tariff structure.

10.2. Water Analysis

The water quality parameters that were assessed include pH, bicarbonate (HCO_3); nitrate (NO_3); and calcium (Ca). The average monthly values for these water quality parameters, from 1995-1997 at various sampling locations, are in Annex A. A summary of these water quality parameters according to water quality classes and area irrigated is presented below.

Table 10.1
Summary Water Quality Data for pH, HCO_3, NO_3, and Ca

WQ	Water Quality Parameters 1995-1997 Range and (Average)				Stage Office
	PH	HCO_3 (meq/l)	NO_3 (mg/l)	Ca (meq/l)	
1	8.2-8.9 (8.5)	3.9-5.2 (4.5)	1.6-9.1 (4.5)	2.5-4.1 (3.2)	7, 1, 2, 3, 10
2	8.0-8.9 (8.4)	5.0-7.1 (5.9)	5.6-8.8 (7.2)	3.4-7.1 (5.1)	5, 6 (DA 26)
3	8.1-8.4 (8.2	6.3-8.6 (7.2)	4.9-12.8 (1.9)	4.3-9.6 (7.4)	8, 4
4*	n/a	high	up to 75	high	6 (DA 27, 28), 9

* Predicted values

Guidelines indicating potential problems with pH (Pestcod 1992): none < 7.0; slight-moderate 7.0 - 8.0; severe > 8.0.

10.3. Technical Discussion

Suspended Solids

Suspended solids such as sediment and organic material must be removed from the water before it enters the drip irrigation system. Sand and media filters are used by farmers in the Jordan Valley to remove such material provided that the irrigation water is not overloaded. The on-farm filtration units are not designed to remove the heavy levels of organic and inorganic contaminants often delivered in the water from the JVA (Hagan and Taha 1997). As a result, back-flushing of the filtration system becomes more and more frequent and burdensome to the point where some growers remove their screen filters (Hagan, personal communication). This action proves deadly to the drip irrigation system. Studies in the Jordan Valley have shown that about 75% of all farms experience significant clogging problems beginning the second year of lateral line use (Hagan and Taha 1997).

pH and Chemical Clogging of Emitters.

The pH of the water is an important parameter for drip irrigation systems but it is less important for surface irrigation. Chemical clogging of drip emitters is usually associated with lime ($CaCO_3$) and is often caused by water that is both high in pH (basic) and contains calcium. Clogging due to calcium-phosphate precipitation (Ca3 $(PO_4)_2$), however, can also be problematic in water sources containing substantial amounts of phosphorus such as KTR water supplies. The tendency of a water to cause calcium precipitation can be predicted although there is no proven practical method to evaluate how serious the problem will be since it depends upon other factors such as temperature and pH. A first approximation of calcium precipitation can be made using the saturation index of Langelier as described in the FAO guidelines (Ayers and Westcot 1985). This index indicates that upon reaching the calcium saturation point in the presence of bicarbonate, lime will precipitate from the solution.

An evaluation conducted by NCARTT showed that there is a strong positive value of the saturation index that indicates that there is a strong tendency for calcium carbonate to precipitate from the water. This positive index was found for both the King Talal Reservoir water and the King Abdullah Canal water. The latter was evaluated from a sample collection point where KTR water may have been mixed in with the KAC water during all or portions of the year that the samples were collected. The saturation remained positive throughout the entire year suggesting that the KAC water is similar in characteristics to the KTR water. However the index is not as strong.

Nutrients and Algae

Nutrients including phosphates and nitrates tend to encourage algae growth. Algae may cause maintenance problems in the open canals downstream of KTR, clogging problems in downstream irrigation systems, and aesthetic problems. WQ 3 and WQ 4 are expected to have higher quantities of nutrients and more associated system maintenance problems.

10.4. Recommendations

Suspended Solids. A central water conditioning facility should be installed at the start of the delivery pipeline in areas that are subjected to frequent and excessive loads of suspended material, (Hagan and Taha 1997).

pH and Chemical Clogging of Emitters. The Jordan Government should seek technical assistance to determine the extent of emitter clogging problems that are likely to occur with use of the KTR water. KAC water should also be evaluated to determine if it has a similar potential to cause clogging. If the KTR water shows that it is significantly different, then an evaluation needs to be made on the costs associated with maintaining the drip systems. Until the evaluation is completed, pH should not be used to determine water-pricing structures in the Jordan Valley.

The most effective method of preventing problems caused by precipitation of calcium carbonate is to control the pH or to treat the system periodically with an acid or/or an acidifying fertilizer in order to prevent deposits building up to levels where clogging might occur. The most common practice is to inject acid into the system periodically. Acidifying to a pH of 7.0 or lower is usually sufficient to minimize chemical precipitation problems (Hanson et al. 1994).

Nutrients and Algae. It is difficult to estimate the economic impact of increased maintenance costs. Chlorinating would be advised periodically to control algae and avoid the build-up of bacterial slimes within the system.

11. CROP TOXICITY

11.1. The Issues

Earlier chapters have shown how salinity can affect crop production. Crop production can also be impacted by direct toxicity from certain ions in the water that are usually associated with elevated salinity. Trees and vines are particularly sensitive to Cl, Na and B and can develop injury to leaves or stems if concentrations exceed certain levels. If concentrations are extremely high they can also produce injury on many annual crops. Specific-ion injury, if severe enough, will reduce yields beyond that predicted by salinity alone.

Some trace elements may be essential for plant growth at very low concentrations but quickly become toxic as the concentration increases. Most toxicities caused by trace elements are not related to specific management practices on the farm. In most cases, these elements accumulate in plants and soils. The concern is for their long-term buildup in the soil which could cause phytotoxicity in plants or result in human or animal health hazards. This accumulation takes place regardless of the management used.

Most irrigation waters do not need to be checked for trace elements unless there is wastewater from human activities present. As wastewater will be present in the irrigation supply water to a portion of the Jordan Valley that is supplied by the King Talal Reservoir, it is important to evaluate the potential for toxicities when using this water.

Agreements: The parameters to be considered in the evaluation, the criteria that will be used to evaluate the water quality, and the database needed to determine a potential problem.

Agreement Needed: The parameters that should be considered in the tariff structure.

11.2. Water Analysis

In order to assess this impact the water quality parameters that were assessed include boron (B); chloride (Cl); sodium (Na); and Sodium Adsorption Ratio (SAR). The average monthly values for these water quality parameters, from 1995-1997 at various sampling locations, are available in Annex A. Trace elements also need to be assessed. However, data for water quality with regards to trace elements is only available for the KTR and As-Samra wastewater treatment plant.

Table 11.1
Summary Water Quality Analysis

WQ	Water Quality Parameter 1995-1997 Range and (Average)				Stage Office
	Cl (meq/l)	B(mg/l)	Na (meq/l)	SAR	
1	1.4-4.9 (3.3)	0.12-0.26 (0.19)	1.4-4.0 (3.0)	0.9-2.6 (1.8)	7, 1, 2, 3, 10
2	4.2-7.3 (6.0)	0.22-0.72 (0.40)	3.2-6.5 (5.1)	1.8-2.7 (2.4)	5, 6 (DA 26)
3	6.8-10.3 (7.9)	0.42-0.65 (0.50)	5.9-8.6 (6.8)	2.6-3.2 (2.9)	8, 4
4*	high	high	33-290	10-23	6 (DA 27, 28), 9

*predicted values

Table 11.2
FAO 29 Guidelines for Irrigation Water Quality

Potential Irrigation Problem	Units	Degree of Restriction on Use		
		None	Slight to Moderate	Severe
Chloride (Cl)				
Surface Irrigation	Meq/l	< 4	4-10	> 10
Sprinkler Irrigation	Meq/l	< 3	> 3	
Boron (B)	Mg/l	< 0.7	0.7-3.0	> 3.0
Sodium (Na)				
Surface Irrigation	SAR	< 3	3-9	> 9
Sprinkler Irrigation	Meq/l	< 3	> 3	

11.3. Soil and Plant Analysis

The soil and plant analysis in Annex B has been summarized from the data in Volume II. The summary by stage office has been conducted for boron (B), chloride (Cl), copper (Cu), zinc (Zn), iron (Fe), and manganese (Mn). The summary is based on the indicative guidelines in Annex G for each parameter in terms of soil and plant contents.

11.4. Technical Discussion

Salinity can affect crop production by direct toxicity due to specific ions. the cropping patterns for trees and vines irrigated by WQ 2,3 and 4 are summarized in Table C-2. Extremely high concentrations of specific ions can produce injury on many annual crops. Specific-ion injury, if severe enough, will reduce yields beyond that predicted by salinity alone. Threshold levels in the irrigation water that produce such injury are reported in FAO 29 (Ayers and Westcot 1985).

Potential hazard to specific-ion toxicity increases if the crop foliage is wetted by sprinkler irrigation. Since sprinkler irrigation is rare in the valley (less than 5% according to Avadies Serpekian, personal communication), potential hazard assessment for these elements will be based on surface and drip irrigation systems that do not wet the foliage.

A summary table provided below indicates the relative risk among different plant toxicity parameters in relation to different water qualities in the Jordan Rift Valley. The basis for the listing in Table 11.3 is given in the following sections. Note that the relative ranking is based on the assumptions of good water management, soils with adequate leaching, and long-term water use.

Table 11.3
Relative Risk for Crop Injury

Plant Toxicity Parameter	Water Quality Zone			
	1	2	3	4
Chloride (Cl)	low	mild	moderate	severe
Boron (B)	low	low	low	mild
Sodium (Na)	low	low	low	moderate
Trace Elements*	low	mild*	mild*	mild*

* Continued monitoring both Zinc (Zn) and copper (Cu) are recommended.

Chloride Toxicity

Susceptibility to Cl toxicity varies among varieties and rootstocks within woody species. The degree of susceptibility is often reflected in the plant's ability to restrict or retard Cl translocation to the shoots (Maas and Grattan 1998). For example salt-tolerance in grapes, grapefruit, and orange is closely related to the Cl accumulation properties of the rootstock. By selecting rootstocks that exclude Cl from the scions, some degree of Cl toxicity problems can be avoided.

Chloride concentrations in various water supplies in the Jordan Valley are likely to be problematic in certain areas although there is no means of quantifying reductions in yield due to chloride (Cl) toxicity. Nevertheless a descriptive evaluation is provided based on Cl concentration in water supplies at the various stage offices and their potential damage to susceptible crops in the area. This is done using guidelines from Ayers and Westcot (1985) where threshold concentrations in the irrigation water are those which produce such an injury.

It is important to note that research is incomplete regarding the evaluation of modern or commonly used rootstocks for Cl and B tolerance. Therefore it is possible that rootstocks not mentioned in FAO 29 may be more or less tolerant than those indicated. In addition, no Cl toxicity ratings are provided for banana. Banana, being a crop of tropical nature and accustomed to highly leached soils, could be susceptible to Cl injury.

Water Quality Zone 1

The chloride concentration in Water Quality Zone 1 varies from 1.4 to 4.9 meq/l (Table 8.1), only exceeding 4.0 meq/l during October and November when Cl absorption rates by plants are minimal. It must also be noted that the analyses do not cover all months of the year. Water of this quality can be used to irrigate all crops (Ayers and Westcot 1985) provided good irrigation management is exercised and soils have good drainage.

Water Quality Zone 2

The Cl concentration in Water Quality Zone 2 varies from 4.2-7.3 meq/l (Table 8.1). This range indicates a slight to moderate degree of restriction. However it may pose a more serious threat to certain trees and vines depending upon the rootstock or variety. The guidelines provided in FAO indicate that the maximum Cl concentration of the irrigation water to avoid crop injury is 6.7 meq/L for sensitive rootstocks particularly on citrus and grapes. This value is approached and even exceeded in a number of cases.

Water Quality Zone 3

Average monthly data for Water Quality Zone 3 indicate that Cl concentrations exceed the 6.7 meq/L threshold each month (Tables A-2 and A-12). The concentrations vary from 6.8 to 10.3 meq/l (Table 13.1). Maximal values often exceed 10 meq/L but this occurs during the winter when Cl absorption rates by plants are minimal. Water of this quality can be problematic for most tree and vine crops and it is likely that plants of this type will exhibit some degree of injury should they use this water as their sole source of irrigation water.

Water Quality Zone 4

The Cl concentration in the Karamah Reservoir is likely to be higher than what is found in Water Quality Zone 3 but it is uncertain what that level will be. Regardless of the predicted level, it is likely that this water will be unsuitable for tree and vine crops with the exception of date palm. In terms of annual crops, the water will likely be unsuitable for most vegetables, particularly those sensitive or moderately sensitive to salinity.

Boron Toxicity

Boron (B) is an essential element for the crop but has a small concentration window between deficiency and toxicity. Certain crops, particularly trees and vines, are sensitive to B in the irrigation water and can develop injury to leaves or stems if concentrations exceed certain limits. Threshold levels in the irrigation water that produce such injury are reported in FAO 29 (Ayers and Westcot 1985). Much of the existing B tolerance data can only be used to indicate the maximum concentration above which such plant injury is likely to occur. Boron injury, if severe enough, will likely reduce yields beyond that predicted by EC alone but few data are available to predict such a yield loss.

There is limited water quality data from JVA available for analysis. The database used focused on two periods: the end of the wet season (April) and conditions at the end of the dry period and just before the start of the winter rains (October).

Water Quality Zone 1

The boron concentration in this zone consistently showed a low boron hazard. In most instances, boron concentrations were less than 0.25 mg/L (Tables A-3 and A-11) which is less than 1/3 the concentration where boron injury would first be expected to occur (Ayers and Westcot 1985).

Water Quality Zones 2 and 3

As shown in the water analysis section above, the boron concentration in the irrigation supply changes when that supply is derived partially (WQ 2) or totally (WQ 3) from the King Talal Reservoir. Because of this change and the storage of wastewater in KTR, an evaluation was made of the boron concentrations in KTR water to determine the potential for a boron toxicity problem.

Monitoring was conducted from January 1991 to December 1994 of the As-Samra WSP flows and flows in the downstream area prior to KTR (Harza 1996). Boron concentrations ranged from 0.2 to 1.2 mg/L. Boron concentrations entering KTR averaged 0.6 mg/L while the discharge from As-Samra WSP averaged 0.7 mg/L.

Harza (1996) has shown that boron concentrations have fallen since regulations were put in place in 1991 that prohibit the use of boron-based detergents. Additional monitoring by the Royal Scientific Society in 1995 has confirmed the Harza conclusion. Monthly inlet and outlet concentrations during 1995 were 0.58 and 0.37 mg/L, respectively. The change in concentration from inflow to outflow is likely due to different time periods of monitoring and does not reflect KTR as being a sink for boron. In almost all surface water sources, boron concentrations are conservative throughout the system and increases in concentration only reflect unaccounted for sources or evapoconcentration.

The Harza report (1996) concludes that the boron concentration in water sources being used from KTR are likely to remain below that observed prior to 1994 due to the prohibition on the use of boron-based detergents. Because of this action by the government, the boron concentrations are likely to remain low.

Guidelines in FAO 29 (Ayers and Westcot 1985) indicate the irrigation water with concentrations less than 0.7 mg/L can be used to irrigate all major crops in the Jordan Valley without restriction on use. Caution is advised, however, since these guidelines assume that leaching takes place and they do not account for situations where soils are natively high in boron. In addition, B has a higher affinity to the soil than ions like Cl. Therefore B will have a greater tendency to accumulate in the soil.

Recommendation: It is recommended that the soil be monitored periodically for B accumulation in areas where the irrigation water supply approaches or exceeds 0.7 mg/L. This is particularly important in areas planted with trees and vines.

Water Quality Zone 4

According to the Gibb report on the first flushing cycle of the Karamah reservoir (Gibb 1997), a boron concentration of around 1.4 mg/L or higher may occur in this water source. Such levels would be problematic for most trees and vines and even restrictive if the level exceeds 3mg/l.

SodiumToxicity

Sodium (Na) often produces specific ion injury in addition to causing a potential problem related to soil structure. Although clearly an ion of concern and potential toxicity, there are no clear-cut guidelines indicating concentrations in irrigation water that produce injury. This is due to the fact that numerous factors affect Na accumulation in leaves.

Most of the Na tends to concentrate in stems and woody tissue. Na uptake by roots and transport within the plant are affected by the level of calcium in the soil water and its ratio relative to Na (Lauchli and Epstein 1990). Initially, Na is retained in the roots and lower trunk. After three or four years, the conversion of sapwood to heartwood apparently releases the accumulated Na which is then transported to leaves causing leaf burn (Maas 1990). There are differences among rootstocks in their ability to absorb and retain Na.

The greatest concern with sodium appears to be the rapid absorption into the leaves during sprinkler irrigation when leaves are wet, particularly under conditions of high evaporative demand. The evaluation procedure used in this analysis is described in the FAO guidelines for determining the suitability of an irrigation water supply (Ayers and Westcot 1985).

Na toxicity is not only associated with irrigation water high in Na but with high sodium to calcium ratios as well. In light of the low Na concentrations and low SARs, it is unlikely that Na toxicity will occur under irrigation practices that do not wet the leaves and soil conditions that have adequate drainage. There is potential for Na toxicity due to foliar absorption should sprinkler irrigation occur. However because little or no sprinkler irrigation occurs in the Jordan Valley, a large-scale problem should not occur. In addition, the potential for toxicity would be low when sprinkler irrigation is used in the wintertime, as the evaporative demand would be low.

Water Quality Zones 1, 2, 3, and 4

The water quality data base for Na and SAR analysis is rather limited (Annex A) and is summarized in Table 8.1. The Na and SAR concentrations in Water Quality Zones 1, 2, and 3 range from 1.4 to 8.6 (Na) meq/l and 0.9 to 3.2 (SAR) and deteriorate progressively from WQ 1 to WQ 3.

Trace Elements

Treated wastewater is vital source for irrigation in the Jordan Valley. It is anticipated that increasing quantities of treated wastewater from As-Samra WWTP will be discharged to KTR, accounting for more than 75% of KTR inflows. Because KTR water is used for irrigation in the Jordan Valley an evaluation of the potential for toxicities when using this water was conducted.

There are limited data available on the level of most of the trace elements in the irrigation supply water from KTR (Table A-24). Because of the absence of data, a three-tiered evaluation process was used to detect any potential toxicities that may affect production and/or water pricing. The three-tiered evaluation was made based on:

- Existing discharge standards;
- Trace element levels in the sludge from As-Samra; and
- Monitoring data of the irrigation supply water from KTR.

Existing Discharge Standards

A review was made of Jordanian standard 202/1991 which describes the maximum allowable limits for discharge of industrial effluents into wadis and streams and when the effluent is used directly for irrigation (Table G-3). Both of these activities are reported to occur in the watershed above the KTR. Therefore a comparison was made between the Jordanian Standard and the FAO guidelines for maximum concentrations recommended for irrigation water (Ayers and Westcot 1985). Two trace elements, copper (Cu) and zinc (Zn), are permitted at concentrations above the FAO guidelines. The discharge of such effluent could have a potential to affect agriculture and should be evaluated further.

A review was made of the Jordanian Standard 893/1995 which describes the maximum allowable limits for discharge of treated domestic wastewater (Table G-4). Since industrial effluents are allowed to be discharged to the wastewater collection system at levels much higher than are allowed under Jordanian Standard 893/1995 (Table G-5), the domestic wastewater stored in KTR could be a potential source of elevated trace elements to the irrigated area of the Jordan Valley. Although the industrial discharge levels are higher, if Jordanian Standard 893/1995 is enforced, only zinc (Zn) would be discharged to the KTR at a concentration above that which is recommended by FAO for direct irrigation.

Trace Element Levels in the Sludge from As-Samra

As industrial wastes are discharged both to the domestic wastewater collection system and directly to Wadi Zarqa and Wadi Dhuleil, an evaluation of the sludge from the wastewater treatment plant and from the KTR would show whether the present discharge practices result in elevated levels of trace elements. Trace elements accumulate in sludge during normal biological treatment processes. If the sludge shows elevated levels, this is a first indicator that these levels were likely present in the wastewater discharge. This is a qualitative analysis and it can not be used to quantify the concentrations that were present in the wastewater. Quantification can only be done through direct water quality monitoring.

In 1993, an analysis was conducted of trace element content of As-Samra Wastewater Treatment Plant sludge (Table A-25). This plant also represents a significant source of water to KTR. No data could be located to conduct a similar evaluation of KTR but the As-Samra analysis should provide an early warning to trace element buildup in KTR or elevated levels in the water leaving KTR

The data indicate that the trace element levels in the sludge are below the limits established by the United States Environmental Protection Agency and the European Community Environmental regulations for continuous agricultural use of the sludge. Both of these regulations are based on studies of the impact of trace element buildup in soils that may affect soil productivity, crop uptake of the metals, and the effect these metals have on human health. It should be noted that direct application of these two regulations to Jordan may not be fully appropriate because guidelines are based on conditions that may differ from those found in Jordan. Until similar guidelines are developed for Jordan, use of these two existing regulations should provide adequate protection.

The exceptions in the above analysis are lead (Pb) and zinc (Zn). In addition, Harza (1996) identified copper (Cu) and nickel (Ni) as trace elements that show rates of accumulation in the sludge that are elevated and have the potential to buildup in the soil due to sludge application. Because of this concern, a similar concern should be raised for the concentration in the irrigation water leaving KTR.

Monitoring Data of the Irrigation Supply Water from KTR.

Monitoring for selected trace elements was conducted over a one-year period to determine concentrations in water leaving KTR intended for irrigation use in the

Jordan Valley (RSS 1995). The results shown in Table A-24 include monitoring data for the four trace elements, copper (Cu), lead (Pb), Nickel (Ni), and Zinc (Zn), that are potentially elevated in the water. When compared to the FAO guidelines and those used by the United States Environmental Protection Agency, the concentrations of the trace elements in the water leaving KTR indicate that no restrictions on the use of KTR water for irrigation should be considered. The guidelines are described in more detail in Table G-6.

An additional trace element of concern, not measured by the Royal Scientific Society (RSS), is molybdenum (Mo) which can accumulate rapidly in forage crops where it may pose a risk to animals that feed on this forage. As no monitoring has been conducted, priority to identify its concentration in the water should be pursued.

11.5. Implications

Chloride

Cl toxicity is not likely to be problematic for Water Quality Zone 1 unless soils are poorly drained and natively high in salts. In Water Quality Zone 2, Cl toxicity can be slightly problematic for citrus, grapes and other fruit trees, which account for approximately 33% of the cropping area. In Water Quality Zone 3, Cl toxicity risks to trees and vines, which account for approximately 34% of the cropping area, could approach moderately problematic. In Water Quality Zone 4, future areas that will use water from the Karamah Reservoir, water quality will be severely problematic for trees and vines, with the exception of date palm, which account for approximately 17% of the cropping area (based on estimates for Stage Office 6 – DA 27 and 28).

Chloride toxicity for most vegetable and field crops is not considered a major problem except for beans in Water Quality Zones 3 and 4, and in cases where the foliage is wetted by sprinkler irrigation. Usually by the time Cl injury is evident on annual crops, these plants are already experiencing severe salinity stress.

Boron

Although the level of B in Water Quality Zone 4 would be problematic for most fruit tree and vine crops (approximately 17% of the total area), it is not likely to be as restricting as salinity and chloride.

Boron concentrations in water sources have been reduced over the years to low levels, especially in Water Quality Zones 2 and 3, and they are low in Water Quality Zone 1. Therefore, specific-ion toxicity related to boron is not a major concern at this time. Based on this analysis and the low concentrations found in the natural water supplies used for irrigation in the Jordan Valley, it is recommended that boron not be considered in developing water pricing policies or water use patterns.

It was noticed in assessing B content in both water, soil, and plant that its content in both soil and water source used to irrigate Stage Offices 4, 5, 6, and 8 was within the normal level. However the B content in the plant was predominantly within the range of excessive or toxic level. This high correlation between the content of B in plant and only one source of water could point to the role of organic load of the water in fostering the availability of B to the plant, thus enhancing its accumulation in various parts of the plants. The fact that such correlation existed with annual or perennial plants suggests that B availability plays the primary role in its level in the plant, not its level as indicated by soil tests. This was also substantiated by the fact that B content was not always high in plants growing in soils with high indigenous B content, namely soils mixed with soils of Land Class 4 or 6.

Sodium

Based on the assessment and the water analysis provided, it is recommended that Na not be considered in developing water tariff policies. However, should sprinkler irrigation become a dominant practice in the future, this recommendation may have to be modified.

Trace Elements

The evaluation conducted above shows that the present levels of trace elements in the KTR water do not present a potential to limit crop production or limit short or long-term productivity because of trace element accumulation. As no evaluation has been conducted in the Jordan Valley, a long-term monitoring program is recommended. At this time trace elements should not be used as a factor in water pricing or water use because concentrations were well within acceptable guidance. However, the following steps are recommended for consideration by the Jordan government:

- Adopt a policy that declares that the soil in wastewater reuse areas is a resource to the country and trace element concentrations should be kept at a level that ensures that the soil resource does not suffer from irreversible damage. The long-term goal of Jordan should be to ensure that the soil resource can be used for all potential crops in the future. The policy should also stress that short-term gains made from disposal of extra quantities of trace elements should not be done at the expense of causing deterioration of soil and water resources.
- Strictly enforce the industrial and domestic discharge standards defined in the Jordan Standard 893/1995 and Jordan Standard 202/1991(Annex G).
- Continue to utilize the FAO guidelines or any modification to them as maximum trace-element concentrations for Jordan Standards to ensure that wastewater reuse projects in Jordan meet acceptable international standards.

- Monitor the KTR discharge on a periodic basis to ensure that the reuse water continues to meet acceptable international standards and the policy recommended here on protection of Jordanian soils and cropping resources.
- The evaluation indicates that consideration should be given to developing and conducting a long-term monitoring program for all trace elements in KTR outflow water. This monitoring program should give special consideration to lead (Pb), copper (Cu), molybdenum (Mo), nickel (Ni), and zinc (Zn) as each showed either elevated levels in the sludge from the present wastewater treatment plant, the industrial discharge standards allow an elevated level of these trace elements, or insufficient monitoring has been conducted.

12. POTENTIAL RISK TO PUBLIC HEALTH

12.1. The Issues

The primary constraint to any project proposing to use wastewater is public health. Wastewater, especially domestic wastewater, contains pathogens which can spread disease when not managed properly. The primary objective of any wastewater use project must be to minimize or eliminate potential health risks. This objective should also be the main goal of the Jordanian government in all projects within the Jordan Valley.

The health hazards associated with wastewater use are of two kinds:

- Threats to the health of those who work on the land or live near the land where the water is being used; and
- The risk that contaminated products from the area may infect humans or animals through consumption or handling.

Agreement Needed: The parameters to be used to evaluate this potential, the criteria to be used for the evaluation, and the database that is necessary to make a low risk decision.

12.2. Approach

The threat to human health can come from four pathogen groups: viruses, protozoa, bacteria, and helminths. The highest threat comes from helminths and the lowest comes from viruses (IRCWD 1985). There are no international guidelines or standards for the microbiological quality of irrigation water for use on a particular crop for the four pathogen groups. The reason is the lack of direct epidemiological data to show any relationship between the quality of the water actually applied at the field level and disease transmission or infection.

Guidelines for the quality of wastewater used for irrigation have focused on effluent standards at the wastewater treatment plant rather than the quality at the point of use. The most recent guidelines (Table G-2) were adopted by World Health Organization (WHO) in 1989 after an extensive epidemiological review. These new guidelines are stricter concerning the need to reduce helminth egg concentrations throughout the entire cropping systems. The purpose was to increase the level of protection for agricultural workers who are at high risk from intestinal nematode infections caused by various helminths. The scientific advisory group to WHO also concluded that no bacterial guideline was needed for the protection of agricultural workers since there was little evidence indicating a risk to such workers from bacteria (Westcot 1997).

The WHO guidelines were intended to be design goals for planning wastewater treatment plants and not quality control at the field level. Until these treatment goals can be reliably achieved, FAO is recommending that the present WHO guidelines be used to control the quality of water used to irrigate vegetable or high-risk crops (Westcot 1997). This control is best applied at the main irrigation water supply level. The FAO guidelines recommend that the major emphasis be placed on fecal coliform as the main indicator of the safety of the water supply while the original WHO guidelines emphasized both fecal coliform and helminths. It is recommended that both factors be utilized in monitoring and evaluation of the Jordan Valley wastewater reuse areas until safe levels of both helminths and fecal coliform are consistently achieved. At that time the monitoring should focus on fecal coliform as the indicator of water safety.

12.3. Findings and Analysis

Monitoring data for the main irrigation water supply for fecal coliform and helminths in Water Quality Zone 1 was not available although some data are available from the Zai Treatment Plant monitoring program. The only known sampling was cited in the Harza report (Harza 1996) for the King Abdullah Canal prior to mixing with water from the King Talal Reservoir. The average of six monthly samples during the period May to October 1994 was 3,500 MPN/100ml. The monitoring during this period shows that the KAC in Water Quality Zone 1, on average, exceeds the WHO guidelines for unrestricted irrigation. The source of this contamination is unknown but it should be located and steps should be taken to eliminate the discharges causing these exceedances.

The other potential source of contamination to the KAC would be releases from KTR. The releases from KTR should be considered a planned and managed source in contrast to unregulated discharges discussed earlier. Monitoring of the release from KTR has been conducted by the Royal Scientific Society for JVA. The microbiological data for the period February 1995 to January 1996 are shown in Table A-21. During this period, nematode eggs per liter (helminths) were zero, indicating that the wastewater treatment ponds and the retention time in KTR are sufficient to remove nematode eggs to a level that would allow unrestricted irrigation in the Jordan Valley. This removal rate is the result of an approximate 5-7 month theoretical retention time in KTR (USBR 1998). This retention time is expected to drop to 2 months with full development of the wastewater collection and treatment system in the years 2025 (Harza 1996). This theoretical retention time both now and in the future may vary depending upon the operation of the reservoir for irrigation demand, short circuiting that may occur in the reservoir, and the percentage of the total annual flow that is composed of wastewater. Harza (1996) estimates that the percentage of the total inflow to KTR that is wastewater will increase from less than 50% today to almost 80% in the year 2025.

Monthly monitoring of fecal coliform at the KTR outlet from February 1995 to January 1996 shows that total fecal coliform counts ranged from 2 to 30,000 MPN/100 ml. The WHO guidelines for unrestricted irrigation were exceeded in 2 of the 12 months of monitoring. The exceedances occurred during November and December. The reasons for exceedances were not clear and unfortunately occurred during the time of peak winter vegetable production in the Jordan Valley.

The variability of fecal coliform at the KTR outlet are consistent with the monitoring data from the five-year period (1990-1995) just prior to the RSS data presented in Table A-22. During this five-year period, fecal coliform averaged 43,000 MPN/100ml at the inlet and averaged 1,900 MPN/100 ml at the outlet (Harza 1996). Varying bacterial mortality rates, settling rates, dilution, short circuiting and a variety of other factors could be responsible for the bacterial reduction rates in KTR.

As discussed earlier, downstream of the KTR outlet, the data indicate that contamination from wastewater discharged directly into the irrigation supply in KAC is occurring prior to blending with KTR water (Table 21 A). During the six month monitoring period noted previously, KTR outflows averaged 43 MPN/100ml fecal coliform, while downstream after mixing with KAC water, fecal coliform levels increased to 4,000 to 8,000 MPN/100ml. The source of this contamination is either in the Yarmouk River supply or it occurs after the water is released into the distribution network and before it is blended with the KTR water and released into the field (secondary contamination).

In a recent review of the wastewater reuse scheme proposed by Harza (1996), the World Bank noted the presence of this secondary contamination and concluded that this water was not suitable for unrestricted irrigation. They recommended an additional treatment step, such as maturation ponds or disinfection at the field level, to allow unrestricted irrigation (Bahri 1997).

Maturation ponds would not be a cost effective alternative for individual farmers; they require a high level of management, large areas of land, and little assurance that quality would meet unrestricted irrigation standards. Disinfection is very costly as was demonstrated in Chile in 1992-93. The most cost effective alternative is to conduct a sanitary survey of the irrigation network and eliminate the direct discharges into the irrigation water supply canals. Based on present fecal coliform levels in KAC, the secondary contamination likely makes up less than 0.25% of the total flow in the supply network.

12.4. Implications

The microbiological quality of the irrigation water is variable and at times of marginal quality for unrestricted irrigation practices. At the present time, quality is such that safe production can be achieved through the use of drip irrigation, but restrictions on other types of irrigation systems may be needed to meet international standards. Monitoring and regulating the way water is applied is likely to be more difficult than attempting to correct the present contamination problems. The present level of secondary contamination in the irrigation supply system is not widespread and could be corrected. Such an effort would allow JVA to supply water that is fit for unrestricted use based on present guidelines recommended by FAO (Westcot 1997) which are based on the present WHO guidelines for design of wastewater treatment plants (WHO 1989).

Based on the data available it seems that KTR water can be used for unrestricted irrigation. However, present conditions produce water of marginal quality which raises concerns for public health and safety. The concern can quickly grow to a lack of public confidence, both nationally and internationally, if the Jordanian government is not proactive in monitoring and reducing present level of contamination. The recent (July 1998) public concern over the safety of the public water supply is an example where public confidence can quickly erode. It was only recovered in this case because the Jordanian government was proactive in assuring the safety of the water supply to Amman. The same level of assurance is not present for the irrigation water supply for the Jordan Valley. In addition, the vulnerability of the irrigation supply will increase in the future as larger portions of that supply are made up of wastewater.

In the past, organizations such as the Jordan Valley Authority have been given the responsibility of providing a timely supply of good quality irrigation water. Past and current concerns are largely directed towards salts because of the potential adverse affect on the crop, the soil, or the long-term viability of the farmer. Agriculture in the future will be asked to expand its consideration of water quality to include crop and worker safety. JVA is now preparing to assume this expanded role. To begin this process the following are recommended:

- Continue to pressure the wastewater treatment authorities to provide a consistently safe wastewater supply that is acceptable for unrestricted irrigation use. The needed standards for discharge are in place; they need to be enforced;
- Focus evaluation on fecal coliform (FC). It is easy to monitor and will provide a clear indicator of water safety. In particular, increase FC monitoring at the KTR outlet to ensure that adequate treatment levels are maintained as the wastewater flows increase and a larger percentage of the JVA supply in some areas is made up of wastewater;
- Conduct routine monitoring of the KAC throughout Water Quality Zone 1 to ensure that supply to that zone and for blending with KTR water remains a reliable and good quality supply; and
- Conduct a thorough sanitary survey of the JVA distribution system. The existing bacterial quality of the entire JVA main supply system is subject to fluctuations in quality and at times may be marginal for unrestricted irrigation. This could undermine public confidence in JVA management ability and products from the Jordan Valley. The JVA needs to identify sources of contamination and develop a plan to remove them. This will allow JVA to concentrate its efforts on two main functions: obtaining a high quality supply from WAJ and delivering water.

12.5. Remediation

There are a number of measures that address the issue of risk and concern for the safety of Jordanian agricultural produce. The simplest is to control the quality of the wastewater at its point of treatment and discharge. The alternative is to control where and how wastewater is used.

Wastewater Treatment

Controlling wastewater quality is the responsibility of the Water Authority of Jordan. Its effectiveness as a remediation measure depends on a well managed wastewater treatment system that produces a reliable quality of effluent. In the case of Jordan, the financial constraints to the development of the treatment works make this, at best, a long-term goal.

The long-term goal in developing the wastewater treatment works in Jordan must be to reduce the public health risk in wastewater reuse areas consistent with Articles 12 and 38 of the National Water Strategy. Jordan must have a treatment process that ensures that the wastewater is safe for unrestricted irrigation. The WHO guidelines (WHO 1989) describe the treatment levels needed for unrestricted irrigation that will protect public health. Once Jordan is capable of meeting these guidelines on a consistent basis, Jordanian specialists will be able to achieve the development goals defined in Article 28 of the Water Strategy.

Isolating Wastewater

Controlling where and how wastewater is used would bypass the need for an immediate, high-level of wastewater treatment and focus instead on restricting wastewater use within a specified area and controlling the cropping patterns in the reuse area. This approach requires a broader-based institutional structure to enforce a policy that isolates the wastewater to a defined area where cropping restrictions can be imposed. This approach is successfully used in Australia, United States, Canada, Cyprus, Tunisia, Mexico, Peru and Kuwait.

In Jordan, the policy of isolating the wastewater to a defined area is only partially practiced. Instead of wastewater being moved directly to a reuse area, the wastewater from the As-Samra and other wastewater treatment plants is discharged to the King Talal Reservoir where it is blended with uncontrolled natural flows from Wadi Zarqa and Wadi Dhuleil. Both wadis receive direct discharges of untreated industrial and domestic wastewater prior to entering KTR. Once all of these flows are blended, for all practical purposes and from the vision of an outside importing country, all the water in KTR is considered wastewater even though it is blended with better quality supplies. The total flow from KTR then requires a larger area of reuse as compared to utilizing the wastewater alone without blending of supplies, thus increasing the area where cropping restrictions must be imposed.

Water from KTR is released for unrestricted irrigation in the Middle and Southern portions of the Jordan Valley. At present there are only 1,100 ha in the Middle

Jordan Valley that are irrigated under a policy of isolation. This area receives only KTR water as the irrigation water supply.

Dispersion of Wastewater

Irrigating with diluted wastewater is far more common in Jordan. Some 8,900 ha in the Middle and Southern Jordan Valley use KTR releases after they enter the King Abdullah Canal, a policy of dispersion. The flows in the KAC are of good quality and provide additional dilution. As with the dilution flows that occurred before the wastewater entered KTR, a larger area is now required to utilize the diluted wastewater. With the mixed KAC and KTR water being dispersed over a larger area, this makes the control of cropping practices that much more difficult.

The major impact in using a policy of dispersion in Jordan is that any public health concern that results from the use of the wastewater from KTR will result in all cropping practices within the entire wastewater reuse area being suspect. As in the case of the Saudi Arabian experience, this concern could extend to all produce in the country.

The loss of public confidence could result simply from a perception that the crops are contaminated even though there is no actual evidence for concern. This perception can occur very quickly both nationally and internationally. A Jordanian example is the recent (July 1998) public concern that the drinking water supply for Amman was contaminated. Even though the government reassured the public that the water supply was safe, public confidence was eroded.

A similar loss of public confidence occurred in Chile in the early 1990s when irrigation water was identified as a major mechanism in the spread of cholera and other gastrointestinal diseases (FAO 1993 and Shuval 1993). Because the Chilean government had a policy of dispersion of wastewater within the irrigation network, all irrigation water and produce became suspect even though only certain areas were responsible. The Chilean government could not demonstrate strict crop controls in areas receiving wastewater, so all crops became suspect. The result was a severe financial loss in the international market and erosion of public confidence in the national market.

Managing Reuse Areas

Until a reliable treatment system can be built, operated and maintained in Jordan, the focus needs to be on managing the reuse areas. Once the wastewater is applied, the field and crop become the source of any infectious diseases transmitted through the wastewater. The field is the route of exposure to the agricultural worker and the crop becomes the route of exposure to the consumer.

In wastewater reuse areas, three groups are at risk: agricultural workers and their families; crop handlers; and individuals living in or near the reuse area. The greatest risk to these rural groups is from helminth infections (Mara and Cairncross 1989). Prevention must focus on the source of contamination, which is the irrigation water supply. If helminths are present in the wastewater, this is a strong indication that the level of wastewater treatment is poor and the risk from other infectious diseases in the water supply is very high.

Wastewater treatment in Jordan must give a priority to helminth control. Data available to the project for the wastewater from the As-Samra Wastewater Treatment Plant shows good control of helminths when the plant is operating well but when overloaded, the quality of the effluent is unreliable. Water quality data from KTR shows that under the present conditions, the reservoir gives an additional level of settling and provides excellent helminth control. This same level of control must be continued when the retention time in KTR is reduced due to increased flows in the future (Harza 1996). As discussed in the section on pathogens, continuation of this level of control is a necessity for worker safety and to maintain international creditability in the export market place. Once helminth control is achieved, the focus of concern shifts to preventing contact with other pathogens, primarily bacteria. The goal is to prevent an infection that could lead to disease. A broader discussion of these preventative measures is presented in WHO (1989).

Cropping Restrictions

Cropping restrictions in wastewater reuse areas can be an effective measure to protect the consumer. Many, however, feel that crop restrictions are administratively unattainable (Shuval et al. 1986) and that the institutional capacity to achieve compliance is not available (WHO 1989). Wastewater is not used within a defined and restricted area in Jordan. Instead there is a policy of dispersion and no capacity to monitor and control compliance with the regulations. Institutionally, the responsibility for cropping restrictions falls on the Ministry of Water and Irrigation, the Ministry of Health and the Ministry of Agriculture. No single ministry would have full control of the program. Enforcement of a crop restriction program at the field level will not be easy to accomplish in Jordan, but as the world population becomes increasingly aware of the need for clean water and clean food products, a crop quality control program is needed to achieve this goal.

Incentive Programs

International pressure is increasing as a result of recent food and food-processing-related outbreak of diseases. Countries importing food are requiring more restrictive health protection and product hygiene standards as consumer demands increase within their own countries. A program is needed to assure buyers they are purchasing a high quality product or a product that was produced in a safe environment.

A successful incentive program will encourage producers to use sanitary conditions when growing vegetables or other high risk crops. Farmers will cooperate with an economic incentive program but will oppose or obstruct any regulatory program. A program of market incentives would promote farm products that come from safe areas without having to implement the large surveillance and enforcement program that is usually associated with crop restrictions. This is consistent with the Jordanian Water Strategy which emphasizes economic incentives as a means of achieving two objectives: using wastewater in the agricultural sector and developing a sustainable agricultural economy.

Water Quality Certification

One approach is to create a certification program that shows which products are safe. This approach promotes prevention. There are two ways of operating such a program:

- End product control – certifying the quality of the produce; and
- Process control – certifying that the product was produced in a safe environment.

End Product Quality Control

Testing and certifying the quality of the produce focuses on end product quality control. Under this option, assessment and control is done after the crop is produced and harvested. This is a high risk program not only for the producer but also for the group making the product inspections. The growers face severe economic losses if the crop is declared unfit or unusable after they have made substantial investments to cover production and other fixed costs. The product inspection group is at considerable risk as well because of the need for timely and accurate analyses that could result in economic failure for some growers. These risks are more fully described in Westcot (1997).

Because of the high risk, high cost, and lack of well defined methods that ensure that all crops are free of contamination, FAO did not recommend end product control (Westcot 1997). This is consistent with the findings from a recent review of methods to develop a quality assurance system for fruit and vegetable production in Jordan. "During the past decade, the food industry in industrialized countries has moved away from a system in which end product control plays a key role, towards developing and implementing measures in their production that assures a defined level of quality of the end product" (Dietz 1996).

Process Control

Taking an approach that focuses on quality control of how the product was produced was also a key finding during a seminar organized by the Jordanian Agricultural Marketing Organization on Food Safety in Jordanian Fruit and Vegetable Production and Trade (15 July 1996). During the seminar, it was clearly felt that there was a need in Jordan to move away from monitoring and control of end product quality alone and move to a process that controlled the quality of how the product was produced and prepared (Dietz 1996).

The Food and Agricultural Organization of the United Nations is also using the concept of process control in developing programs to reduce or eliminate the potential for public health problems associated with food production or food processing. In reviewing the options to control food contamination from the contaminated irrigation water, FAO recommended the use of process control. An FAO review concluded that the most effective approach at the present time is a certification program that emphasizes prevention of contamination during crop production by developing safe production areas and assures the consumer that the product they are purchasing in the markets came from such a clean area. This is the same approach that is being used by the Jordanian AMO to assure consumers that products they receive are being produced with Integrated Pest Management (IPM) procedures rather than the testing the final product for evidence of different types of pesticides. An approach such as this in Jordan would be consistent with Article 38 of the Jordanian Water Strategy.

The primary cause for concern among local and international consumers of Jordanian vegetables and other high risk crops is that wastewater reuse areas carry the potential for disease transmission. The main source of contamination where wastewater is being used is the irrigation water itself. Because of this, any certification program developed in Jordan should focus on the quality of water being used in production and on how that water is being used. If a certification program is started, it should be a national program and include all water used in vegetable production, not just those areas where wastewater is being used.

Safe Production Areas

The intent of water quality certification would be to show that safe production areas (irrigation waters) exist in Jordan and that they are being used for production of vegetables. The goal of a national program should be to promote safe production areas, regardless of their location in the country and to promote the products that come from these areas. The intent of developing a national program would be to ensure that all vegetable or high-risk crop producers have the same economic or market advantage and the incentive to produce in a safe manner. In areas that fail to meet the criteria for a safe production area, growers would have added economic incentive to seek assistance in upgrading their production skills to show that their areas can meet acceptable safety standards. The long-term goal is to ensure there are sufficient quantities of safe vegetables to meet the demand on the national and international market.

A four-step process for an effective water quality certification program for promoting safe production areas is outlined by FAO (Westcot 1997). The program is relatively simple to implement and there are a number of ways to institutionalize it. The choice depends greatly on the staff and financial resources that are available. Two distinct approaches are:

- Certification of the water quality used in a large irrigated area; and
- Certification of the water quality used on a specific crop or field.

Because of the diversity of areas in production in Jordan, the first approach is recommended for Jordan. It would require the least resources and allow widespread use of the program within a relatively short period of time. The use of a program to certify large production areas requires that the presence of secondary contamination in the irrigation system be assessed and measures taken to eliminate them.

13. OTHER ISSUES

13.1. System Reliability - Water Supply vs. Water Needs

The irrigation supply system in the Jordan Valley has two distinct supply periods. The first is the winter season and the second is the year-round supply to the permanent crops such as orchards and vineyards. The majority of the permanent crops are in the Northern Ghor area (before the KTR inflow) where the water quality is better.

The wastewater management system described in the Harza Report (Harza 1996) will significantly change the water distribution patterns in the Jordan Valley. Wastewater flows will increase significantly in the future thus increasing the total flow available to the Middle and Southern Ghors of the Jordan Valley. The increased wastewater flows will also change the operation of the King Talal Dam releases so that water in KTR will having a residence time of two months instead of the present six months. These changes translate into a system with a larger total volume of flow where a slow release from KTR will be needed at a constant rate throughout the year in contrast to the store and seasonal release pattern now being used. The JVA needs to consider how to accomplish this type of system management and develop cropping patterns for areas where wastewater may need to be used year round.

13.2. System Reliability - Real Time Management of Flow and Salinity

The main irrigation supply system in the Jordan Valley is well equipped and maintained. The distribution of water is controlled from a central management unit in Deir Alla. The system can be operated remotely and computer updates can be made on water supply conditions. However, the operations are only functioning for 8 to 10 hours a day which is not adequate for real-time control of the system.

JVA staff are concerned with providing an adequate flow of water for the present irrigated area. The central operation is for flow only; JVA staff will need to manage flow and salinity simultaneously.

At the present time, salinity readings are submitted to the lab weekly. The results from these lab analyses are used to control the salinity level in the supply water. From the time of sampling to return of analyses there could be a ten-day to two-week lapse in time. Such a turnaround time will be unacceptable in the future if the farmers are to be continually provided a water supply of an acceptable quality.

The individual farmers receive water on the rotation days available to them. Since their time period for acceptance of water is 10 to 48 hours, knowing the salinity level within this timeframe is needed to ensure that they are receiving an acceptable quality of water. If the control of water quality is at a two-week interval, the individual farmer may receive very poor quality water with the expected consequences. The recent experience of a vineyard farmer in the Jordan Valley should be an early warning to JVA staff on the type of impacts such quality could have. It will only take one or two of these incidents to erode farmer confidence in the water supply managers.

Real-time management of flow and salinity are being done on the Murray River in Australia and the San Joaquin and Colorado River systems in the United States. As higher salinity wastewater becomes a larger portion of the Jordan Valley water supply, blending will be a key to farmer acceptance. Farmer acceptance is only as good as the confidence level the farmer places in the staff managing the distribution system. Consideration needs to be given to development of a real-time salinity monitoring system to increase farmer confidence in the water supplies being delivered and to provide the management flexibility to ensure that poor quality water is not delivered to any user in the Jordan Valley.

13.3. Blending Water vs. Cyclic Irrigation

The present proposal for wastewater use and for the operation of the Karamah Dam for irrigation is to blend supplies of differing qualities to extend the use of poor quality water. This policy needs to be examined to determine if it is the best approach to obtain the highest economic return or highest yield return per m^3 of water applied. The practice of blending or diluting certain higher salinity waters with good quality water supplies should only be undertaken after consideration is given to how this affects the total volume of usable water in both the combined and separate water supplies (Rhoades et al. 1992).

Crop production may be maximized from the total supply available by keeping the two supplies separate and using them to irrigate in a cyclic manner, especially if sensitive or moderately sensitive crops are being considered in the crop rotation.

Under the cyclic irrigation strategy, water supplies of different qualities are not blended but remain separate. The more saline water is used to irrigate salt-tolerant crops or crops at a more salt-tolerant growth stage. The better quality water is used at all other times. Using this irrigation technique, the soil salinity profile is not in steady state but transient allowing crops that vary in tolerance to be included in the rotation. The cyclic strategy keeps the average soil salinity lower especially in the most critical upper portion of the profile and during the early, salt-sensitive growth stage.

The cyclic strategy has many advantages over the blending method (Grattan and Rhoades 1990):

- Soil salinity can be lower at certain critical times allowing for more salt-sensitive crops to be included in the rotation;
- A water blending facility is not required;

- Water of higher salinity can be used for periodic irrigations than if used for all irrigations; and
- Greater use of the combined water supply (saline and non-saline sources) can be achieved.

This irrigation strategy can only be considered in stage offices that have two sources of water quality available for irrigation.

13.4. Need for Drainage

It is important to re-emphasize that the assessment of water quality variations on crop productivity in the Jordan Valley, as done is this report, assumes that soils are or can be adequately drained. As discussed in Chapter 8.3, some soils are not adequately drained and artificial drains have been installed to enhance productivity.

13.5. Groundwater Quality

A major concern with using KTR water for irrigation is the potential impact of water that is higher in salt and nitrogen concentration on leaching flows that return to groundwater. This impact is difficult to assess because no groundwater resource assessment study could be found for the area of the Jordan Valley that is being considered for wastewater reuse or where the Karamah Dam water is planned for use. This potential threat needs to be evaluated.

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Annexes

Annex A

Water Quality Data

Table A-1

Water Quality (EC) dSm^{-1} for 1995-97

Site	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
102 Abu Sido	0.86	0.77	0.76	0.89	0.93	0.94	0.96	0.94	0.98	0.94	0.94	0.89
103 Kreimah	0.86	0.78	0.75	0.88	0.92	0.93	0.96	0.94	0.96	0.95	0.93	0.89
203 Al-Hwarat *	2.28	1.84	1.72	1.66	1.64	1.63	1.78	1.84	1.80	1.91	1.98	2.08
107 Muadi *	1.39	1.37	1.11	1.15	1.60	1.53	1.73	1.97	1.85	1.74	1.62	1.46
109 Karamah Pump *	1.44	1.37	0.90	1.09	1.36	1.64	--	1.59	1.57	1.51	1.37	1.37
305 W. Kufrinja	0.69	0.69	0.63	0.68	0.70	0.76	0.90	1.03	0.94	0.87	0.84	0.79
204 W. Shueib Dam	0.60	0.61	0.62	0.63	0.61	0.62	0.79	0.85	0.99	0.92	0.85	0.82
206 Kafrein Dam	0.90	0.87	0.89	0.87	0.84	0.79	0.83	0.91	1.01	0.99	0.96	0.94

Table A-2

Water Quality (Cl) Meq/L for 1995-1997

Site	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
102 Abu Sido	--	--	--	3.47	--	--	--	--	--	4.03	4.89	--
103 Kreimah	--	--	--	3.43	--	--	--	--	--	4.12	4.66	--
203 Al-Hwarat *	10.25	8.35	7.75	7.54	7.12	7.15	7.11	6.95	6.94	6.76	8.94	10.19
107 Muadi *	5.78	6.35	4.23	4.73	7.27	6.79	5.76	6.16	6.66	6.69	6.17	6.86
109 Karamah Pump*	--	--	--	4.18	--	--	--	--	--	6.37	6.3	--
305 W. Kufrinja	--	--	--	1.38	--	--	--	--	--	2.23	--	--
204 W. Shueib Dam	--	--	--	1.37	--	--	--	--	--	3.39	--	--
206 Kafrein Dam	--	--	--	2.77	--	--	--	--	--	4.13	--	--

* 1997 only

Table A-3

Water Quality (B) mg/l for 1995-1997

Site	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
102 Abu Sido	--	--	--	0.20	--	--	--	--	--	0.16	0.22	--
103 Kreimah	--	--	--	0.16	--	--	--	--	--	0.12	0.17	--
203 Al-Hwarat *	0.65	--	0.46	0.55	0.56	0.42	0.52	0.42	0.45	0.43	0.50	0.59
107 Muadi *	0.32	0.41	0.22	0.32	0.59	0.36	0.40	0.31	0.39	0.39	0.31	0.34
109 Karamah Pump *	--	--	--	0.72	--	--	--	--	--	0.46	0.46	--
305 W. Kufrinja	--	--	--	0.15	--	--	--	--	--	0.13	--	--
204 W. Shueib Dam	--	--	--	0.23	--	--	--	--	--	0.22	--	--
206 Kafrein Dam	--	--	--	0.26	--	--	--	--	--	0.20	--	--

Table A-4

Water Quality (Na) Meq/L for 1995-1997

Site	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
102 Abu Sido	--	--	--	4.02	--	--	--	--	--	3.73	3.80	--
103 Kreimah	--	--	--	3.69	--	--	--	--	--	3.70	3.78	--
203 Al-Hwarat *	8.61	7.18	7.06	6.71	6.47	6.55	6.24	6.10	6.80	5.93	6.67	7.80
107 Muadi *	4.82	5.02	4.55	4.39	6.51	5.94	4.35	5.36	6.08	5.73	4.84	5.26
109 Karamah Pump *	--	--	--	3.17	--	--	--	--	--	5.21	5.21	--
305 W. Kufrinja	--	--	--	1.40	--	--	--	--	--	2.32	--	--
204 W. Shueib Dam	--	--	--	1.43	--	--	--	--	--	2.93	--	--
206 Kafrein Dam	--	--	--	2.39	--	--	--	--	--	3.39	--	--

* 1997 only

Table A-5

Water Quality (SAR) for 1995-1997

Site	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
102 Abu Sido	--	--	--	2.57	--	--	--	--	--	2.26	2.22	--
103 Kreimah	--	--	--	2.25	--	--	--	--	--	2.25	2.28	--
203 Al-Hwarat *	--	--	--	3.16	--	--	--	--	--	2.57	--	--
107 Muadi *	--	--	--	2.37	--	--	--	--	--	2.66	2.66	--
109 Karamah Pump *	--	--	--	1.78	--	--	--	--	--	2.59	2.59	--
305 W. Kufrinja	--	--	--	0.89	--	--	--	--	--	1.17	--	--
204 W. Shueib Dam	--	--	--	0.98	--	--	--	--	--	1.61	--	--
206 Kafrein Dam	--	--	--	1.04	--	--	--	--	--	1.52	--	--

Table A-6

Water Quality (HCO_3) Meq/L for 1995-1997

Site	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
102 Abu Sido	--	--	--	4.77	--	--	--	--	--	4.27	4.00	--
103 Kreimah	--	--	--	4.80	--	--	--	--	--	4.03	4.00	--
203 Al-Hwarat *	8.60	7.50	7.16	7.04	6.90	6.68	6.28	6.73	7.05	7.41	7.45	7.40
107 Muadi *	5.02	5.80	5.28	5.37	6.73	6.15	5.03	5.50	6.73	7.05	5.47	5.23
109 Karamah Pump *	--	--	--	5.64	--	--	--	--	--	7.00	7.00	--
305 W. Kufrinja	--	--	--	4.93	--	--	--	--	--	5.20	--	--
204 W. Shueib Dam	--	--	--	3.93	--	--	--	--	--	4.93	--	--
206 Kafrein Dam	--	--	--	4.23	--	--	--	--	--	4.93	--	

* 1997 only

Table A-7

Water Quality (NO_3) mg/l for 1995-1997

Site	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
102 Abu Sido	--	--	--	2.25	--	--	--	--	--	2.66	4.38	--
103 Kreimah	--	--	--	2.30	--	--	--	--	--	1.64	2.09	--
203 Al-Hwarat *	--	--	--	12.82	--	--	--	--	--	4.90	--	--
107 Muadi *	--	--	--	5.58	--	--	--	--	--	8.81	8.81	--
109 Karamah Pump *	--	--	--	5.70	--	--	--	--	--	7.12	7.12	--
305 W. Kufrinja	--	--	--	8.75	--	--	--	--	--	9.06	--	--
204 W. Shueib Dam	--	--	--	5.61	--	--	--	--	--	5.60	--	--
206 Kafrein Dam	--	--	--	5.42	--	--	--	--	--	3.99	--	--

Table A-8

Water Quality (pH) for 1995-1997

Site	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
102 Abu Sido	8.48	8.48	8.55	8.24	8.3	8.34	8.29	8.35	8.37	8.34	8.36	8.44
103 Kreimah	8.48	8.54	8.56	8.25	8.27	8.35	8.37	8.33	8.35	8.39	8.4	8.44
203 Al-Hwarat *	8.09	8.42	8.30	8.09	8.06	8.12	8.05	8.11	8.19	8.15	8.19	8.32
107 Muadi	8.59	8.57	8.69	8.53	8.33	8.22	8.07	8.01	8.06	8.21	8.27	8.5
109 Karamah Pump	8.44	8.66	8.63	8.93	8.69	8.22	--	8.7	8.21	8.07	8.11	8.35
305 W. Kufrinja	8.92	8.68	8.75	8.42	8.71	8.67	8.80	8.36	8.36	8.71	8.79	8.77
204 W. Shueib Dam	8.33	8.48	8.65	8.27	8.47	8.50	8.34	8.60	8.51	8.61	8.56	8.54
206 Kafrein Dam	8.44	8.43	8.42	8.27	8.27	8.49	8.38	8.48	8.25	8.3	8.41	8.5

* 1997 only

Table A-9

Water Quality (Ca) for 1995-1997

Site	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
102 Abu Sido	--	--	--	2.5	--	--	--	--	--	3.13	3.2	--
103 Kreimah	--	--	--	3.04	--	--	--	--	--	3.13	2.8	--
203 Al-Hwarat *	9.55	9.45	4.25	5.98	6.86	6.15	7.52	7.43	7.26	8.28	7.72	7.82
107 Muadi	5.52	7.1	3.95	3.91	6.03	5.98	5.53	4.93	5.5	5.52	4.65	4.88
109 Karamah Pump	--	--	--	3.36	--	--	--	--	--	4.7	4.7	--
305 W. Kufrinja	--	--	--	2.56	--	--	--	--	--	4.10	--	--
204 W. Shueib Dam	--	--	--	2.82	--	--	--	--	--	3.77	--	--
206 Kafrein Dam	--	--	--	3.61	--	--	--	--	--	3.2	--	--

Table A-10

Water Quality (EC) for 1990-1997

Site	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
102 Abu Sido	1.76	0.72	0.75	0.88	0.91	0.93	0.93	0.9	0.93	0.92	0.94	0.84
103 Kreimah	1.31	0.72	0.75	0.88	0.92	0.93	0.93	0.9	0.93	0.93	0.94	0.85
203 Al-Hwarat	2.35	2	1.8	1.7	1.71	1.74	1.84	1.89	1.78	2.12	2.08	2.11
107 Muadi	1.85	1.85	1.66	1.8	2.64	2.1	2.14	2.18	2.02	1.99	1.84	1.75
109 Karamah Pump	2.21	1.4	1.56	1.91	1.97	2.05	2.04	2.4	2.12	1.98	1.89	1.72
305 W. Kufrinja	0.7	0.64	0.63	0.69	0.74	0.81	0.89	0.99	0.95	0.9	0.82	0.82
204 W. Shueib Dam	1.72	0.64	0.63	0.66	0.66	0.72	0.81	0.85	0.93	0.9	0.86	0.77
206 Kafrein Dam	0.82	0.83	0.85	0.88	0.9	0.87	0.93	0.99	1.16	1.03	0.96	0.96

* 1997 only

Table 11

Water Quality (B) for 1990-1997

Site	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
102 Abu Sido	--	--	--	0.28	--	--	--	--	--	0.16	0.22	--
103 Kreimah	--	--	--	0.28	--	--	--	--	--	0.18	0.17	--
203 Al-Hwarat	0.4	0.52	0.46	0.45	0.56	0.57	0.53	0.55	0.51	0.63	0.44	0.49
107 Muadi	0.4	0.52	0.46	0.45	0.56	0.57	0.53	0.55	0.51	0.63	0.44	0.49
109 Karamah Pump	--	--	--	0.78	--	--	--	--	--	0.52	0.46	--
305 W. Kufrinja	-	--	--	0.13	--	--	--	--	--	0.13	--	--
204 W. Shueib Dam	-	--	--	0.24	--	--	--	--	--	0.22	--	--
206 Kafrein Dam	-	--	--	0.28	--	--	--	--	--	0.21	--	--

Table A-12

Water Quality (Cl) for 1990-1997

Site	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
102 Abu Sido	--	--	--	2.9	--	--	--	--	--	2.88	4.89	--
103 Kreimah	--	--	--	2.85	--	--	--	--	--	3.2	4.66	--
203 Al-Hwarat	10.25	8.12	8.64	7.13	8.56	8.36	8.3	8.34	8.44	9.18	9.59	10.34
107 Muadi	6.74	11.17	6.96	7.43	9.32	10.43	9.16	9.91	8.81	8.76	8.12	8.1
109 Karamah Pump	--	--	--	9.05	--	--	--	--	--	9.43	6.37	--
305 W. Kufrinja	--	--	--	1.51	--	--	--	--	--	2.54	--	--
204 W. Shueib Dam	--	--	--	1.55	--	--	--	--	--	3.26	--	--
206 Kafrein Dam	--	--	--	2.69	--	--	--	--	--	3.76	--	--

Table A-13

Water Quality (HCO3) for 1990-1997

Site	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
102 Abu Sido	--	--	--	4.59	--	--	--	--	--	4.49	4	--
103 Kreimah	--	--	--	4.72	--	--	--	--	--	4.55	4	--
203 Al-Hwarat	8.6	7.5	7.68	6.36	6.77	6.76	7.18	7.3	7.25	8.05	8.46	7.2
107 Muadi	6.17	7.33	5.93	6.28	7.58	7.25	7.17	7.38	7.33	7.96	6.6	6.71
109 Karamah Pump	--	--	--	6.74	--	--	--	--	--	6.92	7	--
305 W. Kufrinja	--	--	--	4.52	--	--	--	--	--	4.52	--	--
204 W. Shueib Dam	--	--	--	3.96	--	--	--	--	--	4.46	--	--
206 Kafrein Dam	--	--	--	3.77	--	--	--	--	--	4.54	--	--

Table A-14

Water Quality (Na) for 1990-1997

Site	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
102 Abu Sido	--	--	--	3.47	--	--	--	--	--	3.32	3.8	--
103 Kreimah	--	--	--	3.25	--	--	--	--	--	3.45	3.78	--
203 Al-Hwarat	8.61	6.84	7.53	6.22	7.39	6.9	7.09	6.89	7	7.86	7.9	8.73
107 Muadi	6.12	9.45	6.98	6.99	8.04	8.93	8.15	8.96	8.04	7.75	6.99	7.42
109 Karamah Pump	--	--	--	8.11	--	--	--	--	--	7.56	5.21	--
305 W. Kufrinja	--	--	--	1.42	--	--	--	--	--	2.23	--	--
204 W. Shueib Dam	--	--	--	1.39	--	--	--	--	--	2.45	--	--
206 Kafrein Dam	--	--	--	2.24	--	--	--	--	--	2.78	--	--

Table A-15

Water Quality (SAR) for 1990-1997

Site	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
102 Abu Sido	--	--	--	2.04	--	--	--	--	--	2.32	2.22	--
103 Kreimah	--	--	--	1.95	--	--	--	--	--	2.37	2.28	--
203 Al-Hwarat	--	2.29	3.3	2.7	3.53	3.08	3.18	3.1	--	3.38	--	--
107 Muadi	3.8	4.44	3.35	2.9	3.22	4.14	3.52	3.97	4.23	3.63	3.29	4.19
109 Karamah Pump	--	--	--	4.15	--	--	--	--	--	3.62	2.59	--
305 W. Kufrinja	--	--	--	0.91	--	--	--	--	--	1.23	--	--
204 W. Shueib Dam	--	--	--	0.9	--	--	--	--	--	1.36	--	--
206 Kafrein Dam	--	--	--	1.31	--	--	--	--	--	1.47	--	--

Table A-16

Water Quality (NO3) for 1990-1997

Site	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
102 Abu Sido	--	--	--	9.92	--	--	--	--	--	6	4.38	--
103 Kreimah	--	--	--	4.33	--	--	--	--	--	5.29	2.09	--
203 Al-Hwarat	--	--	--	15.49	--	--	--	--	--	10.31	--	--
107 Muadi	--	--	--	13.22	--	8.47	--	--	--	14.2	8.56	--
109 Karamah Pump	--	--	--	14.68	--	--	--	--	--	15.58	7.15	--
305 W. Kufrinja	--	--	--	14.21	--	--	--	--	--	10.53	--	--
204 W. Shueib Dam	--	--	--	11.2	--	--	--	--	--	7.62	--	--
206 Kafrein Dam	--	--	--	12.51	--	--	--	--	--	24.96	--	--

Table A-17

Water Quality (Ca+Mg) for 1990-1997

Site	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
102 Abu Sido	--	--	--	5.57	--	--	--	--	--	5.85	--	--
103 Kreimah	--	--	--	5.8	--	--	--	--	--	5.68	--	--
203 Al-Hwarat	--	--	--	9.01	--	--	--	--	--	10.4	--	--
107 Muadi	--	--	--	9.62	10.93	--	10.8	9.76	--	--	--	--
109 Karamah Pump	--	--	--	10.56	--	--	--	--	--	9.58	--	--
305 W. Kufrinja	--	--	--	4.1	--	--	--	--	--	6	--	--
204 W. Shueib Dam	--	--	--	5.2	--	--	--	--	--	6.07	--	--
206 Kafrein Dam	--	--	--	7.7	--	--	--	--	--	10.1	--	--

Table A-18

Water Quality (Ca) for 1990-1997

Site	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
102 Abu Sido	--	--	--	2.73	--	--	--	--	--	3.02	3.2	--
103 Kreimah	--	--	--	3.05	--	--	--	--	--	3.09	2.8	--
203 Al-Hwarat	9.55	9.88	4.25	5.96	6.86	6.15	7.52	7.43	7.26	8.1	7.72	7.82
107 Muadi	5.72	7.65	4.73	6.14	7.87	7.23	7.04	6.43	6.93	6.87	5.87	6.96
109 Karamah Pump	--	--	--	6.08	--	--	--	--	--	7.48	4.7	--
305 W. Kufrinja	--	--	--	2.85	--	--	--	--	--	4.05	--	--
204 W. Shueib Dam	--	--	--	3.1	--	--	--	--	--	3.89	--	--
206 Kafrein Dam	--	--	--	3.58	--	--	--	--	--	3.61	--	--

Table A-19

Water Quality (SO4) for 1990-1997

Site	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
102 Abu Sido	--	--	--	1.27	--	--	--	--	--	1.56	1.24	--
103 Kreimah	--	--	--	1.18	--	--	--	--	--	1.34	2.62	--
203 Al-Hwarat	2.15	3.04	2.14	2.92	1.74	2.29	2.49	2.65	2.49	2.46	1.79	--
107 Muadi	1.91	2.75	2.69	3.13	2.8	2.78	2.6	2.73	2.41	3.12	1.53	2.28
109 Karamah Pump	--	--	--	3.34	--	--	--	--	--	3.11	2.05	2.48
305 W. Kufrinja	--	--	--	0.8	--	--	--	--	--	1.86	--	--
204 W. Shueib Dam	--	--	--	1.06	--	--	--	--	--	1.44	--	--
206 Kafrein Dam	--	--	--	1.63	--	--	--	--	--	1.88	--	--

Table A-20

Water Quality (K) for 1990-1997

Site	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
102 Abu Sido	--	--	--	0.14	--	--	--	--	--	0.14	0.2	--
103 Kreimah	--	--	--	0.14	--	--	--	--	--	0.15	0.2	--
203 Al-Hwarat	0.41	0.35	0.66	0.5	0.63	0.65	1.29	0.7	0.64	0.96	0.6	0.5
107 Muadi	0.48	0.68	0.45	0.66	0.76	0.88	0.69	0.74	0.65	1.13	0.54	0.63
109 Karamah Pump	--	--	--	0.57	--	--	--	--	--	0.66	0.45	--
305 W. Kufrinja	--	--	--	0.29	--	--	--	--	--	0.14	--	--
204 W. Shueib Dam	--	--	--	0.16	--	--	--	--	--	0.18	--	--
206 Kafrein Dam	--	--	--	0.13	--	--	--	--	--	0.2	--	--

Table A-21

Monthly Averages of Microbiological Parameters of the Water Samples (May – October 1994)

Site	Total Heterotrophic Bacterial Counts (CFU/ml)[1]	Total Coliform Counts (MPN/100ml)	Fecal Coliform Counts (MPN/100ml)
Effluent of As-Samra WSP	3.99×10^6	4.77×10^3	3.41×10^3
23 km before KTD	3.92×10^6	2.94×10^4	4.72×10^4
KTD Reservoir	3.46×10^4	2.43×10^3	2.67×10^2
KTD Outfall	3.72×10^4	4.74×10^2	4.31×10^1
Tal Al-Thahab	5.03×10^4	4.0×10^3	3.53×10^2
Abu Zeighan	3.54×10^5	3.0×10^3	3.41×10^3
Yarmouk River (KAC before mixing)	3.93×10^4	5.26×10^3	3.44×10^3
KAC after mixing	4.17×10^5	2.64×10^4	7.88×10^4
KAC DA 22, 23	1.58×10^5	4.53×10^4	4.5×10^4
KAC DA 24, 25	4.22×10^5	2.97×10^4	4.10×10^4
KAC DA 26, 27	3.86×10^5	3.9×10^4	3.82×10^3

[1] Colony Forming Unit
Source: WQIC-USAID (1995) [6]

Table A-22

Microbiological Analysis of Water Samples from the KTR Outlet (February 1995 – January 1996)

Date	Nematode (Eggs/l)	BOD_5 (mg/l)	Total Heterotrophic Bacterial Counts (CFU/ml)[1]	Total Coliform Counts (MPN/100ml)	Total Fecal Coliform Counts (MPN/100ml)
12/2/95	0	5	5.2×10^2	1.7×10^3	9.0×10^1
14/3/95	0	11	1.1×10^4	9.0×10^3	5.0×10^2
10/4/95	0	10	5.0×10^3	3.0×10^3	8.0×10^1
15/5/95	0	4	1.0×10^4	5.0×10^2	1.1×10^2
11/6/95	0	10	3.0×10^3	2.4×10^3	2.0×10^1
9/7/95	0	7	8.6×10^2	1.7×10^3	$<2.0 \times 10^1$
13/8/95	0	8	1.0×10^3	2.4×10^2	4.0×10^0
10/9/95	0	8	4.6×10^3	7.0×10^2	4.0×10^0
16/10/95	0	10	9.8×10^2	1.1×10^2	2.0×10^0
12/11/95	0	<2	2.5×10^4	5.0×10^5	3.0×10^4
10/12/95	0	-	7.1×10^4	2.4×10^5	1.1×10^3
7/1/96	0	29	3.5×10^4	8.0×10^4	8.0×10^2

[1]Colony Forming Unit
Source: RSS (1996)

Table A-23

Monthly Summary of Fecal Coliform Testing at the KAC

1990	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
No. of Samples	11	-	-	-	-	-	-	-	-	-	-	-
Average Fecal Coliform (MPN/100ml)	3800	-	-	-	-	-	-	-	-	-	-	-
# SamplesDA	-	-	-	-	-	-	18	18	8	-	8	9
AFC-Deir Alla	-	-	-	-	-	-	246	136	420	-	540	954
1991												
No. of Samples	-	9	20	DA12	14	15	13	20	2	5	2	DA 6
Average Fecal Coliform (MPN/100ml)	-	1170	354	657	420	750	1300	1600	540	-	400	2340
1992												
No. of Samples	3	-	7	9	5	1	2	-	-	-	-	-
Average Fecal Coliform (MPN/100ml)	880	-	1290	3700	886	930	650	-	-	-	-	-
1993												
No. of Samples	16	4	9	4	2	6	11	7	5	-	10	12
Average Fecal Coliform (MPN/100ml)	3150	5775	6000	2800	780	2000	1830	1500	3400	-	1760	398
1994												
No. of Samples	9	11	10	8	7	5	13	10	6	-	9	8
Average Fecal Coliform (MPN/100ml)	920	1024	1326	1242	968	620	921	1020	12360	-	1920	3600
1995												
No. of Samples	8	-	9	6	-	11	15	5	4	10	10	11
Average Fecal Coliform (MPN/100ml)	4900	-	4560	4620	-	1328	1685	4600	730	1496	2100	1090
1996												
No. of Samples	7	7	12	4	9	6	5	5	5	2	3	5
Average Fecal Coliform (MPN/100ml)	3056	2400	3570	2200	2600	3450	3325	2800	850	5400	2680	494
1997												
No. of Samples	6	2	7	3	3	10	9	8	6	5	3	9
Average Fecal Coliform (MPN/100ml)	1100	2400	1290	1533	528	2360	1640	2031	707	2280	3033	2732

Table A-24

Monthly Average Concentrations of Trace Elements, Including Heavy Metals, in Water from the KTR Outlet (February 1994 – January 1995)

Element	Average of Monthly Concentrations at KTR Outlet (mg/l)	FAO Recommended Maximum Concentrations (mg/l)
Al	0.128	5.0
As	<0.002	0.10
Cd	<0.005	0.01
Co	<0.02	0.05
Cr	<0.01	0.10
Cu	<0.01	0.20
F	0.49	1.00
Fe	0.16	5.0
Li	0.019	2.5
Mn	0.13	0.20
Ni	<0.02	0.20
Pb	<0.02	5.0
Sn	<0.002	Specific tolerance not known
Zn	0.013	2.0

Source: RSS (1995) and Ayers and Westcot (1985)

Table A-25

Heavy Metal Concentrations in As-Samra Sludge in 1993

Element	Units (dry Solids Basis)	As-Samra Geometric Average	As-Samra Maximum Value	USEPA Pollutant Concentration Limit	European Community Agricultural Limit
Al	mg/kg	7,800	13,207	-	-
Ag	mg/kg	1.49	23.5	-	-
As	mg/kg	1.31	2.9	41	
Cd	mg/kg	3.65	8.1	39	20 to 40
Co	mg/kg	4.63	50.7	-	-
Cr	mg/kg	222	669	1200	-
Cu	mg/kg	231	362	1500	1000 to 1750
Fe	mg/kg	436	23676	-	-
Hg	mg/kg	2.49	5.3	17	16 to 25
Li	mg/kg	2.90	5.6	-	-
Mn	mg/kg	127	175	-	-
Ni	mg/kg	46.6	68.4	420	300 to 400
Pb	mg/kg	152	211	300	750 to 1200
Se	mg/kg	1.46	6.3	36	
Si	mg/kg	1.15	1028	-	-
Sn	mg/kg	0.19	0.6	-	-
Ti	mg/kg	78.8	316	-	-
V	mg/kg	22.1	141	-	-
Zn	mg/kg	2163	3850	2800	2300 to 4000
B	mg/kg	33.6	88.8	-	-
Mo	mg/kg	-	-	18	-

Annex B

Soil and Plant Analyses

Boron (B)

Samples for B tests for both soil and plant were collected after 1990. This caused some difficulty in establishing B base line in some soils, especially for Stage Offices 4, 5, 6, and 8. These stage offices are irrigated with KTR water or mixed with KTR water since 1985, which marked the use of treated wastewater and considered as the main contributor of B in the soils of the Jordan Valley.

Stage Offices 1 and 2

Very few samples were tested which cover a large area. The tests on crops in these stages showed that the B content in plants is in the range of excessive level.

Stage Office 3

Most of the samples were taken from DA 21. Few samples were collected in 1990 from DA 20. Generally speaking, the level of soil B content is low and is within the normal range. Nevertheless, a clear pattern of B accumulation toward the surface is obvious for most tested soils. An average value of 0.4-1.2 ppm represents B level in stage 3.

Plant sampling was not extensive. Some plant samples showed excessive B level in the plant leaves such as cucumber, tomato, and in fruits such as kalimantena. Although B content in soil was very low, all the plant tests showed real accumulation in tested plants. Few samples showed excessive B level.

Stage Office 4

Few samples were tested in DA 23, which occupies a very large area (42215 dunum). Samples were collected during the year 1991 only. No samples were collected since then. Clear accumulation of B in soils is indicated. The accumulation is not restricted to the surface but extend to the subsurface. B content level is still within the normal soil content. No plant tests were available.

Stage Office 5

Most of the soil samples were taken from DA 25. Very few samples were collected from DA 30. Only one plant sample was collected from DA 30. B levels of 1 ppm were recorded at a depth of 100 cm for some soils of LC 4 and 6 which reflect the indigenous B content of these soils. A clear pattern of B accumulation at the soil surface was observed. The B surface content was three times higher than that of the subsurface. A maximum of 6-8 ppm was recorded for surface or subsurface for some soils. Although the B content in the soils of this stage still falls within the normal range the difference between the surface and subsurface suggests strong B accumulation.

Samples were collected for vegetables and fruit trees. Most of the plant samples reflected excessive B level. Higher level seems to be recorded after 1995, especially in vegetable leaves, citrus, and banana roots.

Stage Office 6

Samples were collected primarily from DA 26. Few samples were collected from DA 27 and 28. Although the number of tests was not sufficient, almost all samples reflected high B content (>3.9 ppm) and a maximum of 19.4 ppm was recorded in the subsurface. A clear pattern of surface and subsurface accumulation had developed is evident. It was also noticed that when subsurface accumulation had occurred, the B content is usually high in both surface and subsurface (3-4 ppm). B content of 1-4 ppm seems to represent surface content. Generally, the B content of all soil samples was within the normal soil B content.

B content in either leafs of vegetables and fruit trees was within the excessive level. A lot of samples obtained showed toxic levels (Higher than 300 ppm) especially in citrus and grapes. Few samples were tested for pepper (1991) and showed excessive B content and about 8 samples for tomatos in 1991 showed normal B content.

Stage Office 7

Four samples were analyzed in both DA 33 and 7. However, number of samples are highly insufficient, level of B was similar to that of stage 1.

Four plant samples were tested for Guava, Pomely and Kalimantena. All four samples indicated excessive B content.

Stage Office 8

Soil samples included primarily DA 29. Few samples were collected from DA 22. Most of the samples were collected from soils of LC 1. About 26 samples were collected in 1985, which showed slight surface accumulation. Stronger accumulation is indicated after 1985. Generally, B content of surface layers is 1-2 ppm while in the subsurface it is generally lower, suggesting accumulation. Maximum B content did not exceed the 2.5 ppm, except in a few cases of soils mixed with LC 6.

Plant samples were collected after 1990. Most of the samples were collected within DA 29 and most of the tests were carried for citrus plant. Few samples were collected for tomato, grapes or banana. This is probably because those problems were encountered or speculated on citrus plant. B contents beyond the excessive level were recorded early in 1990 in various types of citrus plants. Moreover, excessive B content seemed to dominate 90% of the tested plant samples which clearly suggest a real problem.

Stage Office 9

Six samples were collected in 1991 from two profiles only. The analyses suggest accumulation of B at the surface. No plant samples were collected.

Stage Office 10

Samples were collected from DA 32 (9 samples from 3 profiles). Analyses showed low B content of subsurface layer and were close to its surface content.

Plant samples were exclusively collected from citrus fruit trees, except for two samples on banana tree. The data showed that, except for one sample, the B content was in the range of excessive level, and had exceeded the excessive level to what should be considered toxic to plants. Since all the analyses were carried out in 1990, it was not possible to establish the level of B development in plant since that time. Moreover, since samples were collected in one year, JVA staff might have sensed some signs of unfavorable plant growth, which they linked to B. Apparently, their speculation was right. B content of all tested samples showed a very high level.

Zinc (Zn)

Stage Offices 1 and 2

Few soil tests were conducted on DA 7 and 10 after 1992. The analyses indicated higher Zn content within the surface soil horizons.

A recent plant sample indicated a toxic level in lemon while another showed excessive Zn content. Zn deficiency was observed in two samples. The rest of the samples showed normal Zn content. Analyses were conducted on samples from DA 7 only.

Stage Office 3

Samples were mostly collected from DA 21. Few samples were collected from DA 19 and 20. Testing was conducted after 1993. Zn levels in the soil were below the normal range, except for two surface samples that exceeded the normal range. Zn Content was always higher for surface. Generally, this is related to the higher organic matter content within the surface layers.

Few plant samples were collected three of which in 1985 showed Zn deficiency. Since then other types of citrus showed Zn content within the deficiency range in 1993 and 1995. Similar number of tests showed excessive Zn content, especially in cucumber, tomato, and banana.

Stage Office 4

Very few soil tests were conducted in 1991. No tests are available after that date. The number of soil samples was insufficient; however, surface Zn content was higher than that of subsurface.

Insufficient plant samples were tested on Vegetables, Peach and Banana; however, Zn levels seem to be within the normal range. The number of samples and plant type is not sufficient.

Stage Office 5

Not very many soil tests were performed. All samples, except two were collected from DA 25. The soil analyses indicated that Zn content is below the normal average. However, few surface samples showed Zn value higher than the normal average. Generally, the level of available Zn in stage 5 was higher than stage offices 1-4. Moreover, high Zn content seems to occur in soils after 1995.

Intensive plant sampling have been conducted primarily in DA 25 with very few samples from DA 24 and 30. Most of the plant testing were done for cucumber and tomato. Few tests were conducted on citrus and banana. Deficient Zn level was recorded on citrus samples. The tests indicated either excessive or toxic Zn content, regardless of the plant type.

Stage Office 6

Soil samples were collected from DA 26, 27, and 28 since 1993. Three samples were collected in 1983. Most of the samples, although not sufficient, were collected from DA 26. The available Zn content in soil was below the normal levels. However, the surface content was higher than that of the subsurface in most samples.

More plant analyses were tested than soils and covered citrus, vegetables, banana and apple. Considering the great varieties of plants, the number of samples per plant species is not adequate. The analyses showed many samples of Zn contents exceeding the normal range; many samples indicated Zn toxic level as well as deficient level.

Toxic levels were restricted to vegetables while deficiency was restricted to fruit trees and citrus. This was especially evident in soil mixed with Lisan Marl (LC 6) which is highly calcareous.

Stage Office 7

Few soil samples were collected from DA 10 and 36. Five samples were collected from DA 7. The analyses indicated very low Zn content in the soils which varies between 1-3 ppm. Although the number of soil samples were inadequate, the Zn content in these soils are as predicted for highly calcareous soils. Nevertheless, Zn content in the surface samples was always double that of the subsurface.

Six plant samples were tested in DA 7 in 1993, and 1996 on citrus. One sample indicated toxic levels of Zn, while other samples indicated either deficient or close to deficient level. Generally, the number of samples was not enough to draw any solid conclusions. However, Zn content in soil and plant is expected to be similar to that of Stage Offices 1 and 2 due to similarity of soil types and climate conditions.

Stage Office 8

Soil samples were collected primarily from DA 22. Few samples were collected from DA 22 and only three samples were collected from DA 53. Soil samples seemed to have taken place systematically after 1990. The analyses indicated that, although generally the Zn content in soil was below the normal level, its content was high and even exceeded the normal level. Zn was reported within surface layers.

Intensive plant sampling was conducted in both DA 22 and 29. Most of tests were conducted on citrus, but covered some vegetables. Only eight plant tests indicated Zn content close to deficiency. The results of large number of samples were within the excessive levels of Zn, but none reached toxic levels. A high Zn content was primarily found in vegetables, while deficiency was restricted to citrus.

Stage Office 9

No soil or plant analyses are available for this stage office.

Stage Office 10

Very few soil samples were collected from DA 22 and 32. Zn content was very low in all tested samples.

Several plant samples were collected from citrus trees and a few samples from banana, primarily from DA 32. Zn content was at deficiency level for some citrus trees and slightly higher than the deficiency level for other plants. Very few samples indicated excessive or toxic Zn levels.

Copper (Cu)

Stage Offices 1 and 2

Soil samples were collected from DA 7 and 10. Although the number of samples was not enough to draw strong conclusions, the soil content indicated that Cu content was higher in the subsurface layers. Moreover, the Cu level was within its normal range in soils: 2-20 ppm.

Only six plant samples were analyzed: primarily on citrus. The 1993 plant tests showed Cu level close to deficiency, while those of 1996 showed extremely Cu toxic level (>25 ppm).

Stage Office 3

Soil samples were collected primarily from DA 21. Fewer samples were collected from DA 19 and 20. Soil sample collection started in 1993. Generally, Cu levels were within normal. However, two surface samples showed quite high Cu content in 1995. No strict pattern of availability was clear. The data showed higher surface content, while other profiles showed higher subsurface content.

Plant samples were collected from citrus, vegetables and banana. Few samples from tomato and banana indicated very toxic Cu level. Few samples were close to toxic levels, while some others were close to deficiency level. Generally, those samples, which showed higher Cu content were conducted recently.

Stage Office 4

Eight soil samples were collected only from DA 23 in 1991. They revealed that Cu levels were within normal.

Plant samples were collected from DA 23 in 1996 and 1987 for vegetables and banana. Cu level was between deficient and excessive level. However, the number of samples and the date of sampling do not help in drawing any acceptable conclusions.

Stage Office 5

Soil samples were collected from DA 25 during the period of 1983-1997. Generally, all surface samples showed higher Cu in comparison with the subsurface. Generally, those of recent date showed higher Cu content, especially for surface samples. Cu content in few samples exceeded the normal level for soils.

Extensive plant sampling was carried since 1985 in DA 25. Two samples were collected from DA 24 in 1991. Out of large number of samples collected for vegetables and few for banana and citrus trees, few citrus samples showed Cu deficiency. The majority of the tests showed extremely high (toxic) Cu contents or close to the lower limit of toxicity. Unfortunately, very few samples were taken after 1991. These samples showed deficiency level for Citrus and levels between deficient and excessive level for vegetables. Recent plant samples (1995), however, showed very high Cu toxic level in banana. Tomato also indicated an increase in Cu content.

Stage Office 6

Soil samples were taken primarily from DA 26. Very few samples were taken from DA 27 and 28 in 1993 and 1994. Cu content was generally low. Most of the samples showed Cu level below the normal soil content. However, Cu content was always higher for surface samples in comparison with subsurface.

Plant samples were taken from DA 26 and 27. The samples covered vegetables, citrus and banana since 1988 until 1991. Very few samples were taken during 1993-1995. Some samples of citrus showed deficient Cu level, while vegetables such as tomato and cucumber indicated either levels close to excessive or toxic levels. Most of the samples were either at deficiency or between deficient and excessive level.

Stage Office 7

Few soil samples were collected from DA 7, 10 and 36 in 1992 and 1993. The majority of the tests showed that the Cu content was higher for subsurface layers, however, Cu content was within the normal soil content.

Plant analyses results were similar to those of Stage Offices 1 and 2.

Stage Office 8

Soil samples were primarily taken from DA 29. Few samples were taken from DA 22. Samples were collected between 1990-1995. Most of the analyses showed that Cu content was below normal soil levels. However, some soils registered very high Cu content (>20 ppm). All these values were registered for recent samples and for surface layers.

Extensive plant tests were carried on DA 29, while inadequate samples were collected from DA 22 during the period between 1990-1995. The samples were collected primarily from fruit trees, mainly citrus, and 1-3 samples from vegetables. Generally, predominant Cu content was between the deficient and excessive level. Only one sample for banana showed toxicity level. However, few samples indicated deficiency in citrus trees. The few tested for vegetables showed toxic Cu level, but the number of vegetable samples was inadequate. Regarding Cu content in fruit tree, it can be indicated that generally, its level is above the deficiency level and far from toxicity level. Moreover, its level in citrus is not on the rise.

Stage Office 10

No soil samples were collected from this stage.

Plant samples were collected from DA 32 and very few samples from DA 31. The samples were collected for Citrus in 1990 and few samples in 1995 from banana, and one sample from tomato in 1988. A few of the citrus samples showed deficient Cu content, while the majority varies between 5-25 ppm. Tests on tomato indicated toxic Cu content, while for banana samples, tests were divided between deficient and adequate levels. The number of vegetable tested was inadequate.

Chloride (Cl)

Stage Office 1

Few soil samples were collected from DA 10 and only four samples collected from DA 1 during the period of 1991-1993. The Cl content of the soil varies between 0.9 and 7.9 meq/100 gm. No clear trend regarding surface or subsurface accumulation is noticed since the number of samples was inadequate.

No plant analyses were available.

Stage Office 2

Some soil samples were collected from DA 16, 10, 15 and 12. Majority of the soil samples were within the soil normal content except few samples were the Cl content was substantially high (>700 meq).

No plant samples were available.

Stage Office 3

A large number of soil samples were collected from DA 20, 19, 21 and very few samples from DA 18. The samples were collected since 1985. The Cl content was within the normal soil content. Surface samples with high Cl content were those of LC 1 or 3 and of recent date. Soils consisting of LC 6 were relatively uniform throughout, although recent samples showed very high surface content. Very few samples contained Cl higher than the normal soil content.

Plant samples were collected from DA 21, 20, and 19. The number of samples was inadequate. Samples were collected from citrus, banana, and very few vegetables. Samples were collected during 1991-1995.

Generally, Cl content was within the deficient level for citrus, but was within excessive level for banana and vegetables.

Stage Office 4

Few soil samples were taken from DA during the period of 1991-1993. Although the number of samples was not enough, accumulation of Cl in the surface and subsurface had exceeded the normal soil content. The high content was clear in soils classified as Land Class 4 or 6, but was lower in LC 1 and even if soil consists of LC 4 or LC 6.

Few plant samples were collected in 1986 and 1987 for vegetables, tomato, cucumber and banana. The level of Cl was either within the normal or excessive level. However, the number of samples was inadequate to draw any concrete conclusion.

Stage Office 5

Soil samples were primarily collected from DA 25 since 1985. Very few samples were collected from DA 30 and 24 after 1990. Cl content was clearly very high in soils of all land class. Strong difference in Cl content occurred between surface and subsurface layers, especially in the soil of LC 1. Surface Cl content beyond the soil normal level was very high even for soil samples of 1985 which suggests strong relation with indigenous Cl in soil. This is substantiated by the fact that the soils of this DA are highly influenced by the Lisan Marl which is very high in Cl, as indicated by the high subsurface content even for samples taken in 1985. However, this should not underestimate the strong surface Cl accumulation since 1985 which is very clear in soil of lower Lisan Marl influence.

Intensive plant sampling was conducted in DA 25 since 1985. Only two samples were collected from DA 24. Samples were primarily taken for tomato, cucumber, and banana. Very few samples were taken for citrus or peach. Toxic level was observed in tomato, since 1987, and in cucumber since 1992. Most of the vegetable showed Cl content within the excessive level. None showed Cl deficiency level. However, the pattern was different for citrus, which although was not covered with adequate number of samples, had indicated Cl content either of deficient or within normal Cl level. Furthermore, difference between recent test and those carried earlier, clearly suggest a higher Cl content in plant leaf or fruit. This was especially clear for tomato and cucumber and to a certain extent in banana.

Stage Office 6

A large number of soil samples was collected from DA 26, 27, and 28 since 1991, except for 12 samples taken in 1985. The analyses as indicated the complex nature of spatial Cl distribution in soils, as indicated by the extremely low Cl content at one location, and extremely high content at the another, in addition to the absence of clear difference between the surface and subsurface. A strong Cl accumulation within surface horizon occurred within different types of soils. However, such pattern could be masked by the strong subsurface content due to natural stratification. The Cl content exceeded the normal soil content by many folds for most of the samples. Only few samples showed Cl level below the normal soil content.

An adequate number of plant samples was collected from DA 26, 22, and 28. Samples were collected since 1987 until 1995. The sampling seemed to be primarily concerned with vegetables. Few samples were collected from fruit trees. Generally, many of the plant test for trees showed that mostly Cl content was within the deficient level. Few samples showed normal Cl content. Regarding vegetables excessive or toxic Cl content is recorded in varieties of plants since 1988. It is worth noting that most of the samples which showed toxic Cl content was primarily those tested until 1988. Although sample distribution regarding the crop types or regarding the time series of the sampling is not very well represented, only two samples for potato showed Cl close to toxic level. All other vegetable samples indicated either normal or excessive level, but far from being toxic.

Stage Office 7

Soils samples were collected from DA 3, 33, 36, 4, 10, and 38. Number of samples for individual development areas is inadequate. Samples were collected after 1991. Samples collected from DA 36 indicated Cl content higher than the normal level. Results for samples of other development areas was close to the lower limit of the normal soil content.

No plant tests were available.

Stage Office 8

A large number of samples was collected from DA 29 and fewer samples from DA 22 since 1991. Few samples were collected in 1985 and 1986. A clear pattern of Cl accumulation at the surface was noticed. This was noticed even for soil with relatively high indigenous Cl content. Cl content within surface layers had exceeded the normal soil content, even for soils whose subsurface has low Cl content. This was especially true for recent tests. Soils with high Cl content that exceeds the normal content throughout the soil profile occurred in DA 29.

Plant tests covered primarily citrus, and few tests for tomato and cucumber. Few tests were carried for banana. Samples were collected since 1990, except two samples collected in 1987. Many of the tests for the citrus indicated deficient Cl level. Many were within the normal level. No sample indicated an excessive Cl level in citrus. The banana samples indicated a Cl value within the excessive level. Similarly was the Cl level for vegetable. Although the vegetable samples were very inadequate, Cl content was close to the toxic level. Unfortunately, tests were not performed at different years to draw any conclusion regarding the temporal build up of Cl in vegetables. Nevertheless, one can conclude that currently for trees especially citrus, have to be treated for deficient symptoms and vegetables from toxicity.

Stage Office 9

The number of soil samples was quite inadequate and taken from DA 52 in 1991 and 1993. Some of the samples indicated very high Cl content throughout the soil profile which exceeded by many folds normal soil content.

No plant test are available.

Stage Office 10

Soils samples were collected from DA 32 after 1991. Cl content exceeded the normal Cl content in soils in almost all samples whether surface or subsurface.

A few plant samples were tested. Although type of plant was not indicated, Cl content was within the excessive Cl content.

Iron (Fe)

Stage Offices 1 and 2

Soil samples were collected from DA 10 and 8 during the period of 1992-1993. Number of samples was inadequate. Analyses indicated that Fe level was adequate. Low level was indicated in one sample taken from soil mixed with Lisan Marl. No substantial difference existed between surface and subsurface content since Fe availability depends on organic matter content, which is relatively high, for the subsurface layers, in the soils of this stage.

Plant samples were collected during the period of 1993-1997, mainly from citrus, DA 7 and 10. Number of samples was quite low. The analyses indicated a very high Fe level in all tested plants. It should be noted that Fe-fertilizers, especially leaf fertilizers is heavily used by farmers in the valley. Therefore, correlation between soil and plant analyses will not indicate a real pattern concerning the possible impact of water quality.

Stage Office 3

Soils samples were collected from DA 19, 20, and 21 during the period of 1993-1995 from surface and subsurface layers only. The number of samples was inadequate. Most of the samples showed low Fe level in soils, while very few soil tests showed adequate Fe content.

Plant analyses were conducted during period of 1993-1995 on vegetables and citrus. Number of tests were highly inadequate. However, Fe level in all plant was many times higher than adequate level. In some cases, excessive Fe level was observed on citrus. This could be attributed to intensive spraying with Fe-leaf fertilizers.

Stage Office 4

Soil samples were collected from DA 23 during 1991. The number of samples is not enough to draw any concrete conclusion. However, the analyses suggest an adequate Fe-level.

Plant samples were collected from DA 23 during the period of 1986-1987. Fe level in six tested samples indicated high Fe content in both vegetables and fruit trees.

Stage Office 5

Soil samples were collected primarily from DA 25 after 1993. Few samples were collected in 1993. The majority of soil tests suggested low Fe soil content. Few samples showed an adequate Fe level.

Plant samples were collected primarily from vegetables and few fruit trees other than citrus during the period of 1985-1995. Fe level in all tested plant parts and types of crops was excessively high. It seems that management played a significant role since fertilization with micronutrient is a major part of farm management.

Stage Office 6

Soils samples were collected from DA 22, 26, and 28. Number of samples was very low, some samples were collected in 1983 only, while sampling resumed during the period of 1991-1995. The level of Fe in the soils of these development areas was very low for surface or subsurface. This is expected due to the low organic matter content of these soils in addition to the calcareous nature of the soils. Very few samples indicated adequate Fe content.

A relatively good number of plant samples was collected from various types of plants since 1986 until 1997. Fe level in various types of plants and plant varieties was excessively high even for samples collected 10 years ago.

Stage Office 7

Soil samples were collected from DA 33, 36, 7, 10, and 8. The number of samples for each development area was highly inadequate. The samples were collected during 1992 and 1993. All the samples taken from DA 36 indicated a low Fe-soil content, while Fe level was adequate for DA 7, 10, and 33.

Plant samples were collected during the period of 1993-1997. Samples were primarily collected from citrus trees. Although the number of samples were highly insufficient. All samples indicated very high Fe content.

Stage Office 8

Soils samples were collected primarily from DA 29. Very few samples were collected from DA 22 and 53. Samples were collected during the period of 1990-1996. The analyses indicated that for samples taken from DA 22, although number of samples were inadequate, Fe-level was adequate. However, results for samples collected from DA 29 indicated the existence of soils with very low Fe availability. It is worth noting that deficiency of Fe, in most cases, requires continuous mitigation.

Plant samples were collected from citrus trees grown in DA 22 and 29 during the period of 1990-1995. Very few samples were collected from vegetables The results indicated very high Fe level in all tested plants. No specific trends is clear regarding the temporal changes in Fe level in plants or regarding differences between different plants.

Stage Office 9

No soil or plant analyses are available.

Stage Office 10

Few soil samples were collected from DA 31 and 32 in 1996. Samples collected from DA 31 indicated low Fe-availability, but suggested adequate level in DA 32.

Plant samples were collected from citrus during 1985 primarily from DA 32. The results indicated without any exception high level of Fe contents in various plant parts and in different plant species. In some cases, excessive Fe-content was obtained.

Manganese (Mn)

Soil samples were collected during 1983 in some development areas. The level of Mn in soils in most cases was far more than adequate. In some cases, the level was hundred times more than adequate level. A negligible number of samples indicated low or marginal Mn content. The Mn content of the surface layers was predominantly higher than substance layers. Moreover, the level of Mn was higher in Stage Offices

1, 2, 3, 4, 8. This could be explained on the bases of their higher organic matter content which is also higher for the surface horizon.

The influence of farm management is very clear on Mn level in plant tissues. No clear differences existed between plant species and types of soils of different stages with regards to Mn level in plant. A large number of plant tests showed excessive Mn level, while equal number of tests showed normal Mn level.

Annex C

Cropping Data and Yield Potentials

Table C-1

Cropping Patterns and Yields

Stage Office	Crop	Yield (Kg/dn) DOS	Area (dn) JVA
SO 1	Citrus		10912.7
	Banana		630.3
	Wheat		83.0
	Melokhia		52.3
SO 2	Citrus		13304.3
	Banana		256.0
	Wheat		3230.7
	Eggplants		654.7
	Beans		614.0
	Squash		497.8
	Tomatoes		1126.8
	Potatoes		772.5
	Melokhia		52.3
SO 3	Citrus		4115.0
	Banana		360.0
	Wheat		666.8
	Eggplants		128.2
	Beans		278.2
	Squash		835.0
	Tomatoes		562.8
	Potatoes		951.5
	Melokhia		238.0
SO 4	Citrus		1191.5
	Grapes		159.0
	Beans		877.0
	Wheat		3028.8
	Tomatoes		676.3
SO 5	Citrus		1911.5
	Banana		549.3
	Wheat		297.5
	Cucumber		162.6
	Squash		232.5
	Tomatoes		909.6
	Melokhia		511.3

SO 6	Citrus		1558.0
	Wheat		2107.6
	Cucumber		322.6
	Onions		315.2
	Beans		630.0
	Squash		437.5
	Tomatoes		2152.3
	Potatoes		557.2
	Melokhia		248.5
SO 7	Citrus		15937.0
	Banana		1083.0
	Wheat		1645.0
	Eggplants		283.0
	Beans		268.0
	Squash		631.5
	Tomatoes		731.0
	Melokhia		857.8
SO 8	Citrus		5238.2
	Beans		480.0
	Wheat		612.7
	Tomatoes		1041.7
SO 10	Citrus		790.0
	Banana		4337.5
	Eggplants		181.0

Table C-2

Trees and Vines Irrigated by WQ 2, 3, and 4

Stage Office	Year	1995	1996	1997	Average
SO 8	Trees & Vines (Dn)	7090.67	6466.67	6665.42	6740.92
	Total Area (Dn)	16102.50	12937.92	12399.33	13685.00
	% of Total Area	44.03%	49.98%	53.76%	49.26%
SO 4	Trees & Vines (Dn)		1963.58	1956.67	1960.13
	Total Area (Dn)		12148.17	11863.50	12004.40
	% of Total Area		16.16%	16.49%	16.33%
SO 6	Trees & Vines (Dn)	4837.25	4817.33	4822.58	4825.72
	Total Area (Dn)	18533.50	16403.17	18986.00	17901.98
	% of Total Area	26.10%	29.37%	25.40%	26.96%
SO 5	Trees & Vines (Dn)	4069.4	3990.963	3589.995	3883.45
	Total Area (Dn)	13217.83	10804.58	8691.917	10524.26
	% of Total Area	32.46609	36.93768	41.30269	36.90%

Yield Potentials

Table C-3

Average Monthly Electrical Conductivity (ECw) of the Irrigation Water at Different Stage Offices

		Winter								Summer							
Location	Water Quality Class	Nov	Dec	Jan	Feb	Mar	Apr	Avg	Std. Dev.	May	Jun	Jul	Aug	Sept	Oct	Avg.	Std. Dev.
SO 1	1	0.93	0.88	0.86	0.79	0.75	0.89	0.84	0.07	0.94	0.94	0.96	0.94	0.99	0.95	0.95	0.02
SO 2	1	0.93	0.88	0.86	0.79	0.75	0.89	0.84	0.07	0.94	0.94	0.96	0.94	0.99	0.95	0.95	0.02
SO 3	1	0.88	0.84	0.78	0.76	0.69	0.78	0.79	0.07	0.82	0.85	0.93	0.99	0.96	0.91	0.91	0.06
SO 4	3	1.98	2.08	2.28	1.84	1.72	1.66	1.98	0.23	1.64	1.63	1.78	1.84	1.80	1.91	1.74	0.11
SO 5	2	1.62	1.46	1.39	1.37	1.11	1.15	1.39	0.19	1.60	1.53	1.73	1.97	1.85	1.74	1.74	0.16
SO 6 (DA 26)	2	1.51	1.37	1.44	1.37	0.90	1.09	1.32	0.23	1.36	1.64	1.44	1.42	1.59	1.57	1.49	0.11
SO 6 (DA 27,28) (2 dS/m)	4	2.00	2.00	2.00	2.00	2.00	2.00	2.00	0.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	0.00
SO 6 (DA 27, 28) (3 dS/m)	4	3.00	3.00	3.00	3.00	3.00	3.00	3.00	0.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	0.00
SO 6 (DA 27,28) (4 dS/m)	4	4.00	4.00	4.00	4.00	4.00	4.00	4.00	0.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	0.00
SO 7	1	0.93	0.88	0.86	0.79	0.75	0.89	0.84	0.07	0.94	0.94	0.96	0.94	0.99	0.95	0.95	0.02
SO 8 (DA 29)	3	1.98	2.08	2.28	1.84	1.72	1.66	1.98	0.23	1.64	1.63	1.78	1.84	1.80	1.91	1.74	0.11
SO 8 (DA 22,53)	3	1.98	2.08	2.28	1.84	1.72	1.66	1.98	0.23	1.64	1.63	1.78	1.84	1.80	1.91	1.74	0.11
SO 9 (2 dS/m)	4	2.00	2.00	2.00	2.00	2.00	2.00	2.00	0.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	0.00
SO 9 (3 dS/m)	4	3.00	3.00	3.00	3.00	3.00	3.00	3.00	0.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	0.00
SO 9 (4 dS/m)	4	4.00	4.00	4.00	4.00	4.00	4.00	4.00	0.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	0.00
SO 10	1	0.97	0.87	0.75	0.73	0.77	0.72	0.82	0.10	0.72	0.74	0.79	0.89	1.06	1.08	0.84	0.16

Table C-4

Average Monthly Electrical Conductivity (ECw) of the Irrigation Water for Different Water Zones

		Winter									Summer								
Water Quality Class	**Stage Offices (DA)**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**Avg.**	**Std. Dev.**		**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**		**Avg.**	**Std. Dev.**
1	1, 2, 3, 7, 10	0.93	0.87	0.82	0.77	0.74	0.83	0.83	0.07		0.87	0.88	0.92	0.94	1.00	0.97		0.92	0.05
2	5, 6 (DA 26)	1.57	1.42	1.42	1.37	1.01	1.12	1.35	0.21		1.48	1.59	1.59	1.70	1.72	1.66		1.61	0.09
3	4, 8 (DA 22, 29, 53)	1.98	2.08	2.28	1.84	1.72	1.66	1.98	0.23		1.64	1.63	1.78	1.84	1.80	1.91		1.74	0.11
4 (2 dS/m)	6, 9	2.00	2.00	2.00	2.00	2.00	2.00	2.00	0.00		2.00	2.00	2.00	2.00	2.00	2.00		2.00	0.00
4 (3 dS/m)	6 (DA 27, 28), 9	3.00	3.00	3.00	3.00	3.00	3.00	3.00	0.00		3.00	3.00	3.00	3.00	3.00	3.00		3.00	0.00
4 (4 dS/m)	6 (DA 27, 28), 9	4.00	4.00	4.00	4.00	4.00	4.00	4.00	0.00		4.00	4.00	4.00	4.00	4.00	4.00		4.00	0.00

Table C-5

Gross Irrigation Requirements by Crop in the North, Middle, and South Jordan Valley

Crop	North	Middle	South
Citrus	952	1083	1187.3
Banana	1188	911	1458.2
Grapes	851	1306	981.2
Tomatoes (Summer)	303	717	365.4
Tomatoes (autumn)	222	392	315.7
Tomatoes (P)	331.8	402	436.9
Tomatoes (T)	221.1	267	296.6
Eggplant (Autumn)	198.5	238	274.5
Eggplant (Summer)	376.5	270	331.3
Pepper (Autumn)	169.5	220	245.6
Pepper (Summer)	390.5	131	456.8
Pepper (P)	241.5	265	458.1
Potatoes (Autumn)	179	215	284
Potatoes (Summer)	133	222	212
Squash (Autumn)	146.5	185	207.8
Squash (summer)	236.5	258	274.7
Squash (T)	167.1	179.5	262
Cucumber (Autumn)	92.5	220	213.2
Cucumber (P)	156.8	363.9	382.1
Water melon (T)	347.6	200.8	251.4
Melon (T)	328.5	200.8	251.4
Bean (Autumn)	134	138	158.4
Bean(Summer)	43	120	157.5
Bean (P)	145.6	161.4	169.4
Onion (Autumn)	141	110	230.7
Cabbage	234	152.6	193.8
Cauliflower	239	155	178.3
Lettuce	112.5	146.3	177.9
Melokhia (Summer)	595.7	635.9	669.2
Melokhia (P)	422.2	448.6	471.1
Wheat	176.5	265	336.8
Barley	118	182	249.6

Table C-6

Potential Yield for Crops Planted for Water Quality 1 under Three Levels of Leaching Fraction

Crop	Winter			Summer		
LF	10%	15-20%	30%	10%	15-20%	30%
Apple, Pear	99	100	100	96	100	100
Apricot	96	100	100	92	100	100
Asparagus	100	100	100	100	100	100
Banana	95	100	100	90	100	100
Barley	100	100	100	100	100	100
Beans	85	94	100	82	91	99
Cabbages	100	100	100	99	100	100
Cantaloupe	100	100	100	100	100	100
Carrots	90	97	100	87	95	100
Cauliflower	100	100	100	99	100	100
Chili	98	100	100	96	100	100
Citrus	99	100	100	96	100	100
Cucumber	100	100	100	100	100	100
Date Palm	100	100	100	100	100	100
Eggplant	96	99	100	94	98	100
Fig, Olive	100	100	100	100	100	100
Garlic	100	100	100	100	100	100
Glover	99	100	100	97	100	100
Grapes	97	100	100	96	100	100
Guava	100	100	100	100	100	100
Melokhia	94	98	100	92	97	100
Lettuce	95	100	100	92	99	100
Maize	99	100	100	97	100	100
Melon	94	99	100	92	97	100
Mushroom	100	100	100	100	100	100
Okra	94	98	100	92	97	100
Onion	91	98	100	87	96	100
Parsley	100	100	100	100	100	100
Peach	98	100	100	94	100	100
Pepper	96	100	100	94	100	100
Potato	99	100	100	97	100	100
Pumpkin	99	100	100	97	100	100
Radish	93	99	100	90	97	100
Safflower	100	100	100	100	100	100
Sesame	100	100	100	100	100	100
Sorghum	100	100	100	100	100	100
Spinach	100	100	100	100	100	100
Squash	100	100	100	100	100	100
Strawberry	77	95	100	70	88	100

Table C-7

Potential Yield for Crops Planted for Water Quality 2 under Three Levels of Leaching Fraction

Crop	Winter			Summer		
LF	10%	15-20%	30%	10%	15-20%	30%
Apple, Pear	83	96	100	73	88	100
Apricot	73	90	100	58	80	98
Asparagus	99	100	100	98	100	100
Banana	72	90	100	58	80	97
Barley	100	100	100	100	100	100
Beans	68	81	92	58	74	87
Cabbages	91	99	100	85	94	100
Cantaloupe	96	100	100	91	98	100
Carrots	75	87	96	66	80	92
Cauliflower	94	99	100	90	96	100
Chili	89	96	100	84	92	99
Citrus	83	96	100	73	88	100
Cucumber	97	100	100	88	99	100
Date Palm	100	100	100	100	100	100
Eggplant	89	94	99	84	91	96
Fig, Olive	99	100	100	94	100	100
Garlic	100	100	100	100	100	100
Glover	93	97	100	89	95	99
Grapes	88	95	100	82	91	99
Guava	100	100	100	100	100	100
Melokhia	85	92	97	80	88	95
Lettuce	81	91	100	73	85	96
Maize	87	97	100	80	91	100
Melon	85	92	97	80	88	95
Mushroom	100	100	100	100	100	100
Okra	85	92	97	80	88	95
Onion	76	87	97	66	80	92
Parsley	100	100	100	100	100	100
Peach	78	93	100	66	85	99
Pepper	82	93	100	74	87	98
Potato	87	97	100	80	91	100
Pumpkin	87	97	100	80	91	100
Radish	80	90	98	71	84	94
Safflower	100	100	100	100	100	100
Sesame	100	100	100	95	100	100
Sorghum	100	100	100	100	100	100
Spinach	94	100	100	89	97	100
Squash	100	100	100	100	100	100
Strawberry	41	68	90	20	53	80
Sugarbeet	100	100	100	100	100	100
Thyme	88	95	100	82	91	99
Tomatoes	97	100	100	91	99	100
Wheat	100	100	100	100	100	100

Table C-8

Potential Yield for Crops Planted for Water Quality 3 under Three Levels of Leaching Fraction

Crop	Winter			Summer		
LF	10%	15-20%	30%	10%	15-20%	30%
Apricot	50	74	94	45	71	92
Asparagus	97	99	100	97	99	100
Banana	50	74	94	45	70	91
Barley	100	100	100	100	100	100
Beans	52	69	84	48	67	83
Cabbages	81	91	100	79	90	99
Cantaloupe	89	97	100	87	95	100
Carrots	61	76	89	58	74	88
Cauliflower	88	94	100	86	94	99
Chili	81	90	98	79	89	97
Citrus	67	84	98	64	82	97
Cucumber	83	98	100	81	96	100
Date Palm	100	100	100	100	100	100
Eggplant	82	89	95	80	88	94
Fig, Olive	90	100	100	89	99	100
Garlic	100	100	100	99	100	100
Glover	87	93	98	86	92	98
Grapes	78	88	97	76	87	96
Guava	100	100	100	100	100	100
Melokhia	77	86	93	75	84	92
Lettuce	68	82	94	65	80	92
Maize	75	88	99	73	86	98
Melon	77	86	93	75	84	92
Mushroom	100	100	100	100	100	100
Okra	77	86	93	75	84	92
Onion	61	77	90	58	74	88
Parsley	100	100	100	100	100	100
Peach	59	80	97	55	77	95
Pepper	69	83	95	66	81	94
Potato	75	88	99	73	86	98
Pumpkin	75	88	99	73	86	98
Radish	67	81	92	64	79	91
Safflower	100	100	100	100	100	100
Sesame	91	100	100	88	100	100
Sorghum	100	100	100	100	100	100
Spinach	87	95	100	85	94	100
Squash	100	100	100	100	100	100
Strawberry	8	44	74	0	39	70
Sugarbeet	100	100	100	100	100	100
Thyme	78	89	97	76	87	96
Tomatoes	87	98	100	85	96	100
Wheat	100	100	100	100	100	100

Table C-9

Potential Yield for Crops Planted for Water Quality 4 (4) under Three Levels of Leaching Fraction

Crop	Winter			Summer		
LF	10%	15-20%	30%	10%	15-20%	30%
Apple, Pear	0	32	63	0	32	63
Apricot	0	0	45	0	0	45
Asparagus	88	93	97	88	93	97
Banana	0	1	45	0	1	45
Barley	98	100	100	98	100	100
Beans	0	15	48	0	15	48
Cabbages	36	59	79	36	59	79
Cantaloupe	55	73	87	55	73	87
Carrots	0	29	58	0	29	58
Cauliflower	59	74	86	59	74	86
Chili	42	62	79	42	62	79
Citrus	0	32	63	0	32	63
Cucumber	22	54	80	22	54	80
Date Palm	84	93	100	84	93	100
Eggplant	50	66	80	50	66	80
Fig, Olive	50	71	88	50	71	88
Garlic	36	70	99	36	70	99
Glover	61	74	86	61	74	86
Grapes	34	57	76	34	57	76
Guava	64	87	100	64	87	100
Melokhia	38	58	75	38	58	75
Lettuce	8	39	65	8	39	65
Maize	19	48	72	19	48	72
Melon	38	58	75	38	58	75
Mushroom	74	100	100	74	100	100
Okra	38	58	75	38	58	75
Onion	0	28	57	0	28	57
Parsley	80	100	100	80	100	100
Peach	0	17	55	0	17	55
Pepper	7	39	66	7	39	66
Potato	19	48	72	19	48	72
Pumpkin	20	48	72	20	48	72
Radish	7	38	64	7	38	64
Safflower	67	92	100	67	92	100
Sesame	35	64	88	35	64	88
Sorghum	74	100	100	74	100	100
Spinach	51	69	85	51	69	85
Squash	65	88	100	65	88	100
Strawberry	0	0	0	0	0	0
Sugarbeet	91	100	100	91	100	100
Thyme	34	57	76	34	57	76
Tomatoes	43	66	85	43	66	85
Wheat	83	100	100	83	100	100

Table C-10

Potential Yield for Crops Planted for Water Quality 4 (3) under Three Levels of Leaching Fraction

Crop	Winter			Summer		
LF	10%	15-20%	30%	10%	15-20%	30%
Apple, Pear	27	55	79	27	55	79
Apricot	0	33	67	0	33	67
Asparagus	92	96	99	92	96	99
Banana	0	34	67	0	34	67
Barley	100	100	100	100	100	100
Beans	10	39	64	10	39	64
Cabbages	56	74	88	56	74	88
Cantaloupe	70	83	94	70	83	94
Carrots	25	51	72	25	51	72
Cauliflower	72	83	93	72	83	93
Chili	60	75	87	60	75	87
Citrus	27	55	79	27	55	79
Cucumber	50	74	94	50	74	94
Date Palm	92	98	100	92	98	100
Eggplant	64	77	87	64	77	87
Fig, Olive	68	84	97	68	84	97
Garlic	66	91	100	66	91	100
Glover	73	83	91	73	83	91
Grapes	54	71	85	54	71	85
Guava	84	100	100	84	100	100
Melokhia	55	71	83	55	71	83
Lettuce	35	59	78	35	59	78
Maize	45	66	84	45	66	84
Melon	55	71	83	55	71	83
Mushroom	100	100	100	100	100	100
Okra	55	71	83	55	71	83
Onion	24	50	72	24	50	72
Parsley	100	100	100	100	100	100
Peach	12	46	74	12	46	74
Pepper	35	59	79	35	59	79
Potato	45	66	84	45	66	84
Pumpkin	45	66	84	45	66	84
Radish	34	57	77	34	57	77
Safflower	89	100	100	89	100	100
Sesame	60	82	100	60	82	100
Sorghum	100	100	100	100	100	100
Spinach	67	81	93	67	81	93
Squash	85	100	100	85	100	100
Strawberry	0	0	33	0	0	33
Sugarbeet	100	100	100	100	100	100
Thyme	54	71	86	54	71	86
Tomatoes	63	80	95	63	80	95
Wheat	98	100	100	98	100	100

Table C-11

Potential Yield for Crops Planted for the Water Quality 4 (2) under Three Levels of Leaching Fraction

Crop	Winter			Summer		
LF	10%	15-20%	30%	10%	15-20%	30%
Apple, Pear	60	79	95	60	79	95
Apricot	40	67	90	40	67	90
asparagus	96	99	100	96	99	100
Banana	41	67	89	41	67	89
Barley	100	100	100	100	100	100
Beans	44	64	81	44	64	81
Cabbages	77	88	98	77	88	98
Cantaloupe	86	94	100	86	94	100
Carrots	55	72	86	55	72	86
Cauliflower	85	93	99	85	93	99
Chili	77	87	96	77	87	96
Citrus	60	79	95	60	79	95
Cucumber	78	94	100	78	94	100
Date Palm	99	100	100	99	100	100
Eggplant	79	87	94	79	87	94
Fig, Olive	87	97	100	87	97	100
Garlic	96	100	100	96	100	100
Glover	85	91	97	85	91	97
Grapes	74	85	95	74	85	95
Guava	100	100	100	100	100	100
Melokhia	73	83	92	73	83	92
Lettuce	62	78	91	62	78	91
Maize	70	84	96	70	84	96
Melon	73	83	92	73	83	92
Mushroom	100	100	100	100	100	100
Okra	73	83	92	73	83	92
Onion	54	72	87	54	72	87
Parsley	100	100	100	100	100	100
Peach	51	74	93	51	74	93
Pepper	63	79	93	63	79	93
Potato	70	84	96	70	84	96
Pumpkin	70	84	96	70	84	96
Radish	61	77	89	61	77	89
Safflower	100	100	100	100	100	100
Sesame	86	100	100	86	100	100
Sorghum	100	100	100	100	100	100
Spinach	83	93	100	83	93	100
Squash	100	100	100	100	100	100
Strawberry	0	33	67	0	33	67
Sugarbeet	100	100	100	100	100	100
Thyme	74	86	95	74	86	95
Tomatoes	83	95	100	83	95	100
Wheat	100	100	100	100	100	100

Annex D

Crop Budgets and Growers’ Economic Returns

Calculating Crop Budgets

Crop Selection (Activities)

According to FAO Farm Data Handbook, an Activity is a process using a particular defined technology combining input factors to generate a particular type of output. For example a wheat enterprise on a particular farm may involve two activities (crops), a high yielding variety wheat and local variety of wheat; or barley harvested mechanically by combines vs barley harvested manually. Activities may be classified in various ways, e.g. by function such as productive, intermediate or marketing, or by type of product such as animal or crop.

Major crops in each of the ten stage offices were determined based on percentages of area planted. Any crop in a stage office that accounted for greater than 0.1% of the total cropped land has been included in the analysis.

Specifying Technology Levels

Recent studies have shown that several technology levels exist in the Jordan Rift Valley. Discussions with the steering committee at MOW concluded that two levels of technologies are used for vegetable production in the Jordan Rift Valley:

- Protected production; plastic house, non-conventional irrigation system (drip), intensive use of pesticides, chemical fertilizers and high yielding varieties; and

- Open field production: drip or gravity irrigation system, intensive use of pesticides, moderate application of chemical fertilizers.

Defining Production Seasons

Based on the cropping pattern provided by the JVA, the production season of the selected crops were specified. Records of the Department of Statistics (DoS) show that two production seasons predominate in the valley. The estimated dates for production of the selected crops in the different stage offices were specified with the help of experts of the Ministry of Irrigation, published bulletins and other studies.

Determining Price and Quantities of Inputs

The amount of inputs used per dunum of land are also known as technical coefficients. These coefficients include the requirements per dunum for: seeds and/or seedlings, chemical and organic fertilizers, pesticides, mulch, mechanical and manual labor, and water to meet the irrigation water requirement.

Data of all technical coefficients were provided in a recently published study prepared for the Ministry of Agriculture. This report includes all necessary coefficients except for irrigation water requirements. Methods for determining irrigation water requirements for the selected crops were described earlier.

The unit prices of the technical coefficients were obtained from the annually published report by the DoS called "Farm Prices Bulletin". The most recent volume of this report is available for the input prices that prevailed in the markets during 1996.

Determining the Level and Price of Outputs

Yields per dunum were abstracted from the different issues of the Agricultural Statistics bulletins published by DoS during 1992 to 1996. Yields of selected crops under plastic houses are not reported by DoS, therefore it was obtained from other published studies.

Calculating the Variable Costs

Costs of production include variable and fixed costs. The variable costs are those which vary with the level of production. Variable costs are components of total farm costs that are variable in that they change according to the scale of the activity or enterprise in which they are incurred. They may be in the form of direct or indirect costs. Variable costs include costs of seeds and/or seedlings, water, fertilizers, pesticides and labor. The cost per unit of land is obtained by multiplying the technical coefficients per dunum by its unit price.

Fixed costs, on the other hand, are incurred whether or not there is production. Fixed costs include rent, depreciation of the fixed capital goods, and interest on fixed capital (assets).

Calculating Gross Margins

The ultimate goal of this exercise is to calculate the gross margin (GM) per cubic meter of water (GMCM). This was done for each of the different water quality zones. The activity's GM per dunum is the gross income of one dunum minus the direct variable costs attributable to the activity.

Returns (Gross Margins) of One Dunum to Cubic Meters of Water

Gross margin per cubic meter (GMCM) of Water is the GM in Jordanian Dinars (JD) divided by irrigation water requirement in cubic meters per dunum. This parameter is calculated to show the efficiency of allocating the different qualities of the water at the different stage offices. It is calculated by dividing the GM of one dunum in JD by the amount of water used to irrigate that dunum.

Stage Office Budget Summaries

Table D-1

Major Indicators of Main Crops Produced in Stage Office 1 Using Different Leaching Fractions of Water Quality 1

Yields							
LF	Beans	Tomatoes	Eggplants	Squash	Wheat	Citrus	Banana
10%	613	4900	3059	1500	260	2596	1140
20%	678	4900	3168	1500	260	2622	1200
30%	719	4900	3200	1500	260	2622	1200
Gross Margins							
10%	70	86.33	-83.5	-40.38	57.97	181.2	286
20%	92.6	85.76	-79.1	-40.83	57.64	183	307
30%	197.4	83.54	-78.56	-41.41	57.2	180.11	304
Gross Margins per cbm Water							
10%	0.38	0.21	-0.16	-0.12	0.24	0.12	0.15
20%	0.44	0.18	-0.13	-0.11	0.21	0.11	0.14
30%	0.45	0.15	-0.12	-0.1	0.18	0.09	0.13
Percent of Water Cost in Total Variable Cost							
10%	0.01	0.02	0.03	0.02	0.18	0.09	0.11
20%	0.02	0.03	0.03	0.02	0.19	0.1	0.13
30%	0.02	0.03	0.03	0.02	0.22	0.11	0.14

Table D-2

Major Indicators of Main Crops Produced in Stage Office 2 Using Different Leaching Fractions of Water Quality 1

Yields										
LF	Fava Beans	String Beans	Autumn Potatoes	Tomatoes	Eggplants	Summer . Squash	Autumn Squash	Wheat	Citrus	Banana
10%	613	1032	2239	4900	3011	1500	1500	260	2598	1137
20%	678	1129.6	2250	4900	3135	1500	1500	260	2622	1200
30%	719	1200	2250	4900	3200	1500	1500	260	2622	1200
Gross Margin										
10%	70	168.4	-12.6	86.33	-83.7	-40.38	-144.6	57.97	181.2	283.7
20%	92.6	201.5	-11.3	85.76	-80.7	-40.83	-144.9	57.64	183	307
30%	197.4	222.6	-11.62	83.54	-78.56	-41.41	-145.3	57.2	180.11	304
Gross Margin/cum										
10%	0.38	1.05	-0.35	0.21	-0.16	-0.12	-0.71	0.24	0.12	0.15
20%	0.44	1.21	-0.31	0.18	-0.13	-0.11	-0.64	0.21	0.11	0.14
30%	0.45	0.93	-0.27	0.15	-0.12	-0.1	-0.55	0.18	0.09	0.13
Percent of Water Cost in TVC										
10%	0.01	0.01	0.01	0.02	0.03	0.02	0.01	0.18	0.09	0.11
20%	0.02	0.01	0.01	0.03	0.03	0.02	0.01	0.19	0.1	0.13
30%	0.02	0.02	0.01	0.03	0.03	0.02	0.01	0.22	0.11	0.14

Table D-3

Major Indicators of Main Crops Produced in Stage Office 3 Using Different Leaching Fractions of Water Quality 1

Yields										
LF	Fava Beans	String Beans	Autumn Potatoes	Tomatoes	Eggplants	Summer . Squash	Autumn Squash	Wheat	Citrus	Banana
10%	613	1032	2239	4900	3011	1500	1500	260	2598	1137
20%	678	1129.6	2250	4900	3135	1500	1500	260	2622	1200
30%	719	1200	2250	4900	3200	1500	1500	260	2622	1200
Gross Margin										
10%	70	168.4	-12.6	86.33	-83.7	-40.38	-144.6	57.97	181.2	283.7
20%	92.6	201.5	-11.3	85.76	-80.7	-40.83	-144.9	57.64	183	307
30%	197.4	222.6	-11.62	83.54	-78.56	-41.41	-145.3	57.2	180.11	304
Gross Margin/cum										
10%	0.38	1.05	-0.35	0.21	-0.16	-0.12	-0.71	0.24	0.12	0.15
20%	0.44	1.21	-0.31	0.18	-0.13	-0.11	-0.64	0.21	0.11	0.14
30%	0.45	0.93	-0.27	0.15	-0.12	-0.1	-0.55	0.18	0.09	0.13
Percent of Water Cost in TVC										
10%	0.01	0.01	0.01	0.02	0.03	0.02	0.01	0.18	0.09	0.11
20%	0.02	0.01	0.01	0.03	0.03	0.02	0.01	0.19	0.1	0.13
30%	0.02	0.02	0.01	0.03	0.03	0.02	0.01	0.22	0.11	0.14

Table D-4

Major Indicators for Main Crops Produced in Stage Office 7 Using Different Leaching Fractions of Water Quality 1

Yield							
LF	Fava Beans	Tomatoes	Summer. Squash	Melokhia	Wheat	Citrus	Banana
10%	613.10	4900	1500	626.6	260	2598.1	1137.1
20%	676.8	4900	1500	663.1	260	2622	1200
30%	719	4900	1500	668	260	2622	1200
Gross Margin							
10%	69.90	86.33	-40.38	1.16	57.97	181.5	283.7
20%	92.6	85.76	-40.83	2.8	57.64	183	307
30%	107.4	83.54	-41.41	1.69	57.2	180.11	304
Gross Margin/Cubic Meter of Water							
10%	0.38	0.21	-0.12	0	0.24	0.12	0.15
20%	0.44	0.18	-0.11	0	0.21	0.11	0.14
30%	0.45	0.15	-0.1	0	0.18	0.09	0.13
Percent of Water Cost in TVC							
10%	0.01	0.02	0.02	0.2	0.18	0.09	0.11
20%	0.02	0.03	0.02	0.22	0.19	0.1	0.13
30%	0.02	0.03	0.02	0.24	0.22	0.11	0.14

Table D-5.a

Major Indicators of Main Crops Produced in Stage Office 10 Using Different Leaching Fractions of Water Quality 1

Yield			
LF	Eggplants	Citrus	Banana
10%	3011	2598	1137
20%	3135	2622	1200
30%	3200	2622	1200
Gross Margin			
10%	-83.7	181.2	283.7
20%	-80.7	183	307
30%	-78.56	180.11	304
Gross Margin/Cubic Meter of Water			
10%	-0.16	0.12	0.15
20%	-0.13	0.11	0.14
30%	-0.12	0.09	0.13
Percent of Water Cost in TVC			
10%	0.03	0.09	0.11
20%	0.03	0.1	0.13
30%	0.03	0.11	0.14

Table D-5.b

Major Indicators of Main Crops Produced in Stage Office 10 Using Different Leaching Fractions of Water Quality 4

Yield			
LF	Autumn Squash	Citrus	Bananas
10%	1462.00	0.00	0
20%	1980	839	15.7
30%	2250	1651	707
Gross Margin			
10%	-146.80	-186.30	-187
20%	-130	-71.4	-184
30%	-121.6	39	95
Gross Margin/cum			
10%	-0.51	-0.10	-0.08
20%	-0.4	-0.03	-0.07
30%	-0.33	0.02	0.03
Percent of Water Cost in TVC			
10%	0.02	0.11	0.14
20%	0.02	0.12	0.15
30%	0.02	0.14	0.17

Table D-6

Major Indicators of Main Crops Produced in Stage Office 4 Using Different Leaching Fractions of Water Quality 2

LF	String beans	Melokhia	Autumn Potatoes	Tomatoes	Onions	Autumn Squash	Wheat	Citrus
Yield								
10%	328	1500	1686	3531	954	3076	143	1085
20%	435	1680	1979	3977.8	1204	3076	143	1360
30%	531	1840	2227	4059	1407	3076	143	1587
Gross Margin								
10%	-48	32.3	-82	7.2	-21.9	-101	22.46	-38
20%	-14.5	41.7	-41.6	32.47	3.1	-101	21.96	3.64
30%	15	50	-7.5	36.38	23.2	-102	21.31	32.35
Gross Margin/cum								
10%	-0.3	0.04	-0.46	0.02	-0.07	-0.39	0.06	-0.02
20%	-0.09	0.05	-0.29	0.06	0.01	-0.35	0.05	0
30%	0.09	0.06	-0.16	0.06	0.05	-0.31	0.05	0.01
Percent of Water Cost in TVC								
10%	0.01	0.2	0.01	0.02	0.03	0.01	0.24	0.1
20%	0.01	0.2	0.01	0.03	0.03	0.02	0.27	0.11
30%	0.01	0.2	0.01	0.03	0.04	0.02	0.29	0.13

Table D-7

Major Indicators of Main Crops Produced in Stage Office 5 Using Different Leaching Fractions of Water Quality 2

LF	Fava Beans	Autumn Potatoes	Tomatoes	Autumn Squash	Wheat	Citrus	Bananas	Grapes
Yield								
10%	584.10	1956.6	3693.7	3076	143	1344	1008	3291
20%	695.8	2181.5	4018.4	3076	143	1555	1260	3553
30%	790.3	2249	4059	3076	143	1620	1400	3740
Gross Margin								
10%	26.10	-44.3	16.6	-101	22.46	3.7	228.2	1648.2
20%	59.8	-13.3	34.8	-101	21.96	30.9	328.6	1791.6
30%	88.39	-4.3	36.4	-102	21.31	36.9	382	1893.1
Gross Margin/Cubic Meter of Water								
10%	0.14	-0.33	0.04	-0.39	0.06	0	0.11	1.3
20%	0.31	-0.2	0.07	-0.35	0.05	0.02	0.14	1.26
30%	0.46	-0.15	0.06	-0.31	0.05	0.02	0.14	1.16
Percent of Water Cost in TVC								
10%	0.01	0.01	0.02	0.01	0.24	0.1	0.13	0.08
20%	0.01	0.01	0.03	0.02	0.27	0.11	0.14	0.09
30%	0.01	0.01	0.03	0.02	0.29	0.13	0.16	0.1

Table D-8.a

Major Indicators of Main Crops Produced in Stage Office 6 Using Different Leaching Fractions of Water Quality 2- Current Situation

Yield								
LF	Fava Beans	Autumn Potatoes	Tomatoes	Autumn Squash	Wheat	Citrus	Bananas	Grapes
10%	584.10	1956.6	3693.7	3076	143	1344	1008	3291
20%	695.8	2181.5	4018.4	3076	143	1555	1260	3553
30%	790.3	2249	4059	3076	143	1620	1400	3740
Grossmargin								
10%	26.10	-44.3	16.6	-101	22.46	3.7	228.2	1648.2
20%	59.8	-13.3	34.8	-101	21.96	30.9	328.6	1791.6
30%	88.39	-4.3	36.4	-102	21.31	36.9	382	1893.1
Grossmargin/Cubic Meter of Water								
10%	0.14	-0.33	0.04	-0.39	0.06	0	0.11	1.3
20%	0.31	-0.2	0.07	-0.35	0.05	0.02	0.14	1.26
30%	0.46	-0.15	0.06	-0.31	0.05	0.02	0.14	1.16
Percent of Water Cost in TVC								
10%	0.01	0.01	0.02	0.01	0.24	0.1	0.13	0.08
20%	0.01	0.01	0.03	0.02	0.27	0.11	0.14	0.09
30%	0.01	0.01	0.03	0.02	0.29	0.13	0.16	0.1

Table D-8.b

Major Indicators of Main Crops Produced in Stage Office 6 Using Different Leaching Fractions of Water Quality 4

Yield				
LF	Wheat	Tomatoes	Citrus	Grapes
10%	88.80	1548.00	0.00	275
20%	107	2376	839	462
30%	107	3060	1651	616
Gross Margin				
10%	7.22	-110.00	-186.00	-25
20%	11.68	-62.5	-71	76.4
30%	10.85	-23.5	39	159
Gross Margin/cum				
10%	0.02	-0.22	-0.10	-0.02
20%	0.02	-0.11	-0.03	0.05
30%	0.02	-0.04	0.02	0.09
Percent of Water Cost in TVC				
10%	0.29	0.03	0.11	0.08
20%	0.32	0.03	0.12	0.09
30%	0.35	0.04	0.14	0.11

Table D-9

Major Indicators of Main Crops Produced in Stage Office 8 Using Different Leaching Fractions of Water Quality 3

LF	String Beans	Cucumber	Onions	Autumn Potatoes	Tomatoes	Autumn Squash	Wheat	Citrus
Yield								
10%	303.00	8715.00	954.00	1687	3531	3076	143	1085
20%	423	10290	1204	1979	3977	3076	143	1360
30%	524	10500	1407	2226	4059	3076	143	1587
Gross Margin								
10%	-55.80	278.00	-21.90	-82	7.2	-101	22.46	-38
20%	-18.4	547	3.1	-41.6	32.5	-101	21.96	3.64
30%	13.1	582	23.2	-7.5	36.4	-102	21.31	32.4
Gross Margin/Cubic Meter of Water								
10%	-0.35	0.55	-0.07	-0.46	0.02	-0.39	0.06	-0.02
20%	-0.12	0.96	0.01	-0.29	0.06	-0.35	0.05	0
30%	0.08	0.9	0.05	-0.16	0.06	-0.31	0.05	0.01
Percent of Water Cost in TVC								
10%	0.01	0.01	0.03	0.01	0.02	0.01	0.24	0.1
20%	0.01	0.005	0.03	0.01	0.03	0.02	0.27	0.11
30%	0.01	0.006	0.04	0.01	0.03	0.02	0.29	0.13

Table D-10

Major Indicators of Main Crops Produced in Stage Office 9 Using Different Leaching Fractions of Water Quality 4

LF	String beans	Tomatoes	Citrus	Bananas
Yield				
10%	0.00	2107.00	0.00	0
20%	180	3234	839	15.7
30%	576	4165	1652	706
Gross Margin				
10%	-151.00	-77.45	-186.00	-187
20%	-95	-12.44	-71	-184
30%	27.7	40.94	39	95
Gross Margin/cum				
10%	-0.69	-0.15	-0.10	-0.08
20%	-0.38	-0.02	-0.03	-0.07
30%	0.1	0.06	0.02	0.03
Percent of Water Cost in TVC				
10%	0.02	0.03	0.11	0.14
20%	0.02	0.03	0.12	0.15
30%	0.02	0.04	0.14	0.17

Growers’ Economic Returns

Table D-11

Current and Expected Total Gross Margins in JDs in Water Quality Zone 1

Main Crops	Area in Dunum	Current GM/Du Using WQ1	Expected GM/Du Using WQ2	Expected GM/Du Using WQ3	Expected GM/Du Using WQ4
Stage Office 1					
Citrus	10912.7	181	3.7	-33	-168
Banana	630.3	286	228	63	-187
Wheat	83.0	58	58	58	58
Melokhia	52.3	1.16	-3.5	-7.3	-27
Sub Total SO 1	11,678	2,160,343	188,724	-315,975	-1,947,799
Stage Office 2					
Citrus	13304.3	181	3.7	-33	-168
Banana	256.0	286	228	63	-187
Wheat	3230.7	58	58	58	58
Eggplants	654.7	-83.5	-93	-151	-159
Beans	614.0	168	26	-56	151
Squash	497.8	-40	-40	-40	-95
Tomatoes	1126.8	86	16.6	7.2	-77
Potatoes	772.5	-12.6	-45	-82	-258
Melokhia	52.3	1.16	-3.5	-7.3	-27
Sub Total SO 2	20,509	2,784,488	213,899	-444,302	-2,441,778
Stage Office 7					
Citrus	15937.0	181	3.7	-33	-168
Banana	1083.0	286	228	63	-187
Wheat	1645.0	58	58	58	58
Eggplants	283.0	-83.5	-93	-151	-159
Beans	268.0	168	26	-56	151
Squash	631.5	-40	-40	-40	-95
Tomatoes	731.0	86	16.6	7.2	-77
Melokhia	857.8	1.16	-3.5	-7.3	-27
Sub Total SO 7	21,436	3,349,740	365,822	-446,282	-2,928,497
Sub Total SO 1,2,7	53,624	8,294,570	768,445	-1,206,559	-7,318,074
Stage Office 3					
Citrus	4115.0	181	3.7	-33	-168
Banana	360.0	286	228	63	-187
Wheat	666.8	58	58	58	58
Eggplants	128.2	-83.5	-93	-151	-159
Beans	278.2	168	26	-56	151
Squash	835.0	-40	-40	-40	-95
Tomatoes	562.8	86	16.6	7.2	-77
Potatoes	951.5	-12.6	-45	-82	-258
Melokhia	238.0	1.16	-3.5	-7.3	-27
Sub Total SO 3	8,136	925,772	63,587	-218,477	-1,072,915
Stage Office 10					
Citrus	790.0	181	3.7	-33	-168
Banana	4337.5	286	228	63	-187
Eggplants	181.0	-83.5	-93	-151	-159
Sub Total SO 10	5,309	1,368,402	975,040	219,862	-972,612
Grand Total	67,068	10,588,744	1,807,072	-1,205,175	-9,363,601

Table D-12

Current and Expected Total Gross Margins in JDs in Water Quality Zone 2

Main Crops	Area in Dunum	Current GM/Du Using WQ2	Expected GM/Du Using WQ1	Expected GM/Du Using WQ3	Expected GM/Du Using WQ4
Stage Office 5					
Citrus	1911.5	3.7	40	-33	-184
Banana	549.3333	228	360	101	-185
Wheat	297.5	22.5	22.5	22.5	22.5
Cucumber	162.6667	530	583	278	-818
Squash	232.5	-101	-101	-101	-134
Tomatoes	909.6667	17	38	7.2	-96
Melokhia	511.3333	42	52	25	-6
Sub Total SO 5	4,575	238,685	413,423	40,169	-701,261
Stage Office 6					
Citrus	1558	3.7	40	-33	-184
Wheat	2107.667	22.5	22.5	22.5	22.5
Cucumber	322.6667	530	583	278	-818
Onions	315.1667	2	24	-22	-15
Beans	630	26	70	-16	-15
Squash	437.5	-101	-101	-101	-134
Tomatoes	2152.333	17	38	7.2	-96
Potatoes	557.1667	-44	-7	-82	-258
Melokhia	248.5	42	52	25	-6
Sub Total SO 6	*8,329*	*219,535*	*396,144*	*530*	*-927,857*
Grand Total	**12,904**	**458,220**	**809,567**	**40,699**	**-1,629,119**

Table D-13

Current and Expected Total Gross Margins in JDs in Water Quality Zone 3

Main Crops	Area in Dunum	Current GM/Du Using WQ3	Expected GM/Du Using WQ1	Expected GM/Du Using WQ2	Expected GM/Du Using WQ4
Stage Office 4					
Citrus	1191.5	-38	40	4	-185
Grapes	159.0	1370	1764	1648	528
Beans	877.0	-16	73	26	-151
Wheat	3028.8	23	23	23	23
Tomatoes	676.3	7.2	38	31	-96
Sub Total SO 4	5,933	233,054	487,521	380,230	-264,167
Stage Office 8					
Citrus	5238.2	-38	40	4	-185
Beans	480.0	-16	73	26	-151
Wheat	612.7	23	23	23	23
Tomatoes	1041.7	7.2	38	31	-96
Sub Total SO 8	7,373	-185,139	298,241	79,816	-1,127,450
Total Zone 3	13,305	47,915	785,762	460,045	-1,391,617

Annex E. Crop Marketability

Table E-1

Agricultural Production in Jordan and Jordan Rift Valley 1976-1994

JRV Share of Total (%)			**JRV (1000 tons)**			**Total Country (1000 tons)**			**Year**
Fruit Trees	Veg.	Field Crop	Fruit Trees	Veg.	Field Crop	Fruit Trees	Veg.	Field Crop	
39.4	76.4	10.6	14.9	171.8	16.9	37.8	224.9	160.2	1976
48.8	81.3	7.8	35.4	287.3	2.5	72.6	353.3	31.9	1979
41.3	70.7	13.5	51.0	312.5	13.4	123.6	442.3	99.1	1982
62.0	61.1	30.1	101.2	476.5	18.5	163.3	784.7	61.1	1986
56.5	64.8	9.4	138.3	431.0	13.9	244.7	644.6	148.6	1988
60.3	73.1	10.0	184.8	596.5	14.9	306.5	815.6	149.8	1990
66.8	68.7	10.5	190.0	477.7	12.6	284.5	695.3	119.6	1991
52.5	66.1	10.1	181.9	576.1	17.7	346.5	871.6	175.4	1992
59.0	63.8	13.5	145.7	433.3	15.5	246.9	679.1	114.5	1993
49.0	29.0	16.6	179.6	252.8	18.1	366.2	870.4	108.8	1994

Source: DOS, Annual Statistical Reports

Table E-2

JRV Share of Total Fruits and Vegetables Delivered to the Three Central Markets 1990-1995 (thousand tons)

Year	**Total Delivered**			**Total JRV**			**JRV Share of Total (%)**		
	Veg.	Fruits	Total	Veg.	Fruits	Total	Veg.	Fruits	Total
1990	432	254	686	211	84	295	49%	33%	43%
1991	429	263	692	181	93	274	42%	35%	40%
1992	509	287	796	186	82	268	37%	29%	34%
1993	517	278	795	201	81	282	39%	29%	35%
1994	533	300	833	199	116	315	37%	39%	38%
1995	630	290	920	211	79	290	33%	27%	32%
Avg.90-95	508	279	787	198	89	287	40%	33%	38%

Source: Agricultural Marketing Organization Annual report (1990-1995), Amman- Jordan.

Table E-3

Annual Exports of Fresh Fruit and Vegetables by Main Destination 1991-1995 (thousand tons)

	Vegetable Exports			Fruit Exports		
Destination	Total	JRV	% of JRV	Total	JRV	% of JRV
Arab Countries						
1991	153745	55691	36%	73022	32760	45%
1992	304208	90111	30%	76552	42116	55%
1993	242521	94207	39%	94160	54855	58%
1994	210247	81695	39%	102932	67516	66%
1995	254787	116756	46%	56816.2	27075.2	48%
Average 1991-95	233101.6	87692	38%	80696.44	44864.44	54%
Western Europe						
1991	3159	2624	83%	363	3	1%
1992	860	609	71%	473	0	0%
1993	1134	845	75%	676	4	1%
1994	1336	1038	78%	323	13	4%
1995	2010	1347	67%	427	1	0%
Average 1991-95	1699.8	1292.6	75%	452.4	4.2	1%
Eastern Europe						
1991	263	256	97%	152	48	32%
1992	469	206	44%	415	197	47%
1993	966	915	95%	376	205	55%
1994	743	567	76%	250	203	81%
1995	1223	832	68%	147.8	12.8	9%
Average 1991-95	732.8	555.2	76%	268.16	133.16	45%
All Countries						
1991	157167	58571	37%	73537	32811	45%
1992	305537	90926	30%	77440	42313	55%
1993	244621	95967	39%	95212	55064	58%
1994	212326	83300	39%	103505	67732	65%
1995	258020	118935	46%	57391	27089	47%
Average 1991-95	235534.2	89539.8	38%	81417	45001.8	54%

Source: AMO, Annual Reports 1991-1995

Table E-4

Monthly Vegetable Exports by Main Destination 1991-1995

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Arab Countries												
1991	9488	6828	6412	6142	10891	15617	21371	16990	13962	15441	14673	15930
1992	12888	10653	15107	8455	26241	48964	54258	42396	20610	26178	21691	16767
1993	13745	12629	12151	11741	26469	28968	37707	23288	24364	20271	13716	17472
1994	16175	15759	9830	9859	21232	22276	26148	26228	24365	18185	11350	8840
1995	13446	17372	19546	20891	23601	22408	22765	26299	24860	22638	19061	21900
Western Europe												
1991	804	276	580	230	69	33	67	28	10	29	368	665
1992	269	106	36	39	49	40	24	20	23	32	112	110
1993	145	122	167	124	67	41	32	24	39	41	112	220
1994	240	290	210	137	56	71	35	19	48	48	77	105
1995	181	289	237	144	217	140	68	99	81	107	168	279
Eastern Europe												
1991	0	13	96	127	20	0	0	3	4	0	0	0
1992	0	9	0	60	137	223	20	0	0	0	20	0
1993	220	254	275	71	49	51	0	0	0	0	0	46
1994	214	114	65	105	54	149	0	0	0	0	27	15
1995	59	0	93	231	260	333	18	0	0	0	40	189
All Countries												
1991	10292	7117	7088	6499	10980	15650	21438	17021	13976	15470	15041	16595
1992	13157	10768	15143	8554	26427	49227	54302	42416	20633	26210	21823	16877
1993	14110	13005	12593	11936	26585	29060	37739	23312	24403	20312	13828	17738
1994	16629	16163	10105	10101	21342	22496	26183	26247	24413	18233	11454	8960
1995	13686	17661	19876	21266	24078	22881	22851	26398	24941	22745	19269	22368
Average 1991-95	13575	12943	12961	11671	21882	27863	32503	27079	21673	20594	16283	16508

Table E-5

Monthly Fruit Exports by Main Destination 1991-1995

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Arab Countries												
1991	1277	2442	4891	7244	7980	14182	10940	2427	837	2022	9854	8926
1992	8999	5490	9508	3509	5454	12221	5624	4109	1054	1510	9918	9156
1993	8606	6699	8197	8075	10502	13429	5225	2884	2017	3837	11913	12776
1994	12982	9994	9998	11614	14623	8790	7461	2471	1470	4326	10898	8305
1995	2737.2	1680	700	561	9346	2658	6695	3008	1773	4364	11243	12051
Western Europe												
1991	1	0	0	0	0	209	132	17	0	2	0	2
1992	0	0	0	0	0	249	218	0	4	1	1	0
1993	0	0	0	0	3	539	120	5	3	3	2	1
1994	1	0	0	0	12	271	35	3	0	1	0	0
1995	0	0	0	0	1	370	52	2	0	1	1	0
Eastern Europe												
1991	0	0	0	0	48	87	17	0	0	0	0	0
1992	0	54	37	28	78	104	65	0	0	34	15	0
1993	19	25	18	9	5	139	0	0	0	0	32	129
1994	50	22	13	31	87	46	0	0	0	0	1	0
1995	0.8	0	1	1	1	78	48	0	0	0	9	9
All Countries												
1991	1278	2442	4891	7244	8028	14478	11089	2444	837	2024	9854	8928
1992	8999	5544	9545	3537	5532	12574	5907	4109	1058	1545	9934	9156
1993	8625	6724	8215	8084	10510	14107	5345	2889	2020	3840	11947	12906
1994	13033	10016	10011	11645	14722	9107	7496	2474	1470	4327	10899	8305
1995	2738	1680	701	562	9348	3106	6795	3010	1773	4365	11253	12060
Average 1991-95	6934.6	5281.2	6672.6	6214.4	9628	10674.4	7326.4	2985.2	1431.6	3220.2	10777.4	10271

Table E-6

Monthly Exports of Main Fresh Vegetables to Saudi Arabia 1990-1997 (tons)

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept.	Oct	Nov	Dec
Tomato												
1990	7381	4502	3239	0	12373	21401	24468	27806	26870	13	0	0
1991	0	0	0	0	0	0	0	0	0	2400	3837	1283
1992	4094	3457	4098	571.9	3413	21098	26402.6	21132	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	6.15	37.5	0	0	0	0
1996	0	0	0	0	15.2	0.75	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0
Cucumber												
1990	829	1184	1408	1001	2742	3984	2721	2434	3163	3	0	0
1991	0	0	0	0	0	0	0	0	0	158.4	176	116
1992	296	857.7	616.5	267.5	1557	4611	3127.3	950.4	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0.3	0
1994	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	1.9	1.85	0	0	0	0
1996	0	0	0	0	1.8	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0
Eggplant												
1990	277	168	185	122	426	528	441	457	584	0	0	0
1991	0	0	0	0	0	0	0	0	0	62.6	342	321
1992	435	185.4	91.3	62.2	708	797.2	616.1	341.1	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0.3	0
1994	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0.8	0.6	0	0	0	0
1996	0	0	0	0	0.98	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0
Squash												
1990	311	237	247	373	556	479	268	249	237	0	0	0
1991	0	0	0	0	0	0	0	0	0	28.7	70	165
1992	207	73.3	69.5	201.5	564	487.2	209.9	128.7	0	0	0	0

1993	0	0	0	0	0	0	0	0	0	0	0.3	0
1994	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0.665	0.65	0	0	0	0
1996	0	0	0	0	0.55	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0

Table E-7

Estimated Losses of Vegetable Exports to Saudi Arabian Market 1995-1997

Crop	Average Exports (tons)	1995 Lost Value (JD)	1996 Lost Value (JD)	1997 Lost Value (JD)	Total 95-97 (JD)
Tomatoes	21564.45	2824942.95	3148409.7	3148409.7	9121762.35
Cucumber	5379.35	1027455.85	1086628.7	1086628.7	3200713.25
Eggplant	1329.95	176883.35	184863.05	184863.05	546609.45
Squash	1419.65	261215.6	295287.2	295287.2	851790
Total		4290497.75	4715188.65	4715188.65	13720875.05

Table E-8

Market Windows and Potential Exports to Four Major European Markets

Product	Market Window	Profitable Weekly Demand (tons)	Total Profitable Seasonal Demand (tons)
Grapes	May-Jul	25,000	250,000
Strawberry	Nov-Feb	10,000	160,000
Green Beans	Dec-Mar	18,000	288,000
Tomatoes	Dec-Apr	41,000	820,000
Eggplant	Dec-Mar	2,240	35,840
Melons	Dec-Apr	15,000	300,000
Peppers	Feb-Apr	7,340	88,080

Source: Harrison & Jabarin, Evaluation of the Economic Benefits of Horticultural Exports to Europe, Sigma One Co.

Table E-9

Estimate of Land Required to Fulfill One Week's Demand in the Specified EU Markets

Crop	Weekly Demand (ton)	Annual Demand (ton)	Yield per Dunum (ton/dunum)	Exported Yield (ton/dunum)	Required Land (Dunum)
Grapes	25,000	250,000	2	1	25000
Strawberry	10,000	160,000	1.5	0.75	13333
Green Beans	18,000	288,000	0.8	0.4	45000
Tomatoes	41,000	820,000	10	5	8200
Eggplant	2,240	35,840	8	4	560
Melons	15,000	300,000	2	1	15000
Peppers	7,340	88,080	8	4	1835
TOTAL					108928

Table E-10

Land, Capital, Labor, and Water Requirements to Meet the Estimated Demand

Crop	Land (Dunum)	Capital USD/du	Labor Man/day	Water Cm3/du	Breakeven Price USD/kg	Air Freight USD/kg	Marketing Cost USD/kg
Grapes	25000	2500	23	1700	1.218	1	0.4263
Strawberry	13333.33	2311	12	800	1.799	1	0.62965
Green Beans	45000	1500	10	400	1.4	1	0.49
Tomatoes	8200	1800	13	600	1.085	1	0.37975
Eggplant	560	2500	10	557	1.162	1	0.4067
Melons	15000	1550	5	370	1.155	1	0.40425
Peppers	1835	1000	35	1000	1.099	1	0.38465

Table E-11

Expected Total Profits in USD from Exporting the Selected Crops

Crop	Demand Ton	Profit USD/ ton	Total Profit USD
Grapes	25,000	232.5	5812500
Strawberry	10,000	1156.8	11567500
Green Beans	18,000	629.3	11327143
Tomatoes	41,000	-71.4	0
Eggplant	2,240	183.3	410560
Melons	15,000	-282.6	0
Peppers	7,340	511.6	3754934

Total			32872637

Annex F. Soil Salinity and Drainage

Soil Salinity Summary

There are six land classes in the Jordan Valley (LC 1 through LC 6). The sampling data have been grouped according to year of sampling and depth of sampling. LC 13 means that the plant samples were collected from a farm unit which was primarily Land Class 1 with some soil of Land Class 3. LC 136 means the farm unit is composed of LC 1, 3, and 6.

The following is a summary of the general soil morphology and soil analysis available. The data have been grouped by soil area: Northern (SO 1,2,3, and 7), Middle (SO 4 and 8), and Southern (SO 5,6,9, and 10) Soil Areas.

Table F-1

Northern Soil Area (North of Wadi Rajib)

Stage Office	DAs Sampled	Land Classes and ECe(dSm^{-1})	Comments
1	7, 8, 10, 11, 14, 15, 16	LC 1 (0.9-2.9) LC 3 (1.5-3.0) LC 6 (4-6)	Slight surface salt accumulation. Values higher than 6 dSm^{-1} were recorded.
2	7, 11, 15, 16, 10, 14	LC 1 (EC 0.9-2.0) LC 3 (higher EC) LC 6 (higher EC)	Clear pattern of surface salt accumulation.
3	18, 19, 20 & 21	LC 1,3,13 (EC 1-2.5) LC 6 (EC 1-3) LC 136 (EC 1-2)	Strong salt accumulation in LC1 & 3. LC16 showed tendency for surface salt accumulation
7	3, 7, 9, 33, 4, 10, 8, 38, 36	Generally, EC values of 0.7-2 dSm^{-1}	Slight salt accumulation at the surface. Some soils showed subsurface accumulation. Soils with higher salinity are those affected by the Lisan Marl in isolated spots. Maximum EC values vary from 1-5 dSm^{-1} but 1-3 dSm^{-1} dominate the maximums

Morphology: Generally, the soils of DAs 1 to 21 are fine textured soils, originally of low indigenous soil salinity. Soil of Land Class 6, which reflects the influence of the Lisan Marl, occurs in isolated lenses and covers small area are usually not cultivated. The salinity of the upper Lisan Marl in this area is far lower than soils occurring South of Deir Alla.

Table F-2

Middle Soil Area (between Wadi Rajib and Muadi)

Stage Office	DAs Sampled	Land Classes EC (dSm^{-1})	Comments
4	23	Hetero-geneous soils many LCs	Very strong surface salt accumulation. The EC values for surface is double subsurface. Subsurface salinity is high for LC 4&6. General redistribution of salt from subsurface towards the surface is suggested.
8	22, 29, 53	2-3 dSm^{-1} DA 22 (Lower EC) LC 1, 13, 6 (Higher EC).	Large areas of LC 1 & 3. Clear surface salt accumulation in LC3, 13 & 6. Surface salt accumulation at 50. More saline-subsurface soils in DA 29.

Morphology: Not of high indigenous salt content. However, due to undulating topography, the occurrence of Lisan Marl closer to the surface and the existence of large exposed area become more obvious southwards.

Table F-3
Southern Soil Area (South of Muadi)

Stage Office	DAs Sampled	Land Classes EC (dSm^{-1})	Comments
5	25, 30	EC of 3-10 & up to 100	LC 4 and 6: salt accumulation at the surface distinct transition to subsurface. LC 1 and others: surface salt accumulation gradual transition to subsurface. Indigenous soil salinity, strong soil variation, and management practices are important factors contributing to salinity
6	26	High surface EC 5 dSm^{-1}	Indigenous soil salinity contribution to salinity seems more significant than that of water salinity. Surface and subsurface accumulation present
9	52 (few)	20-30 dSm^{-1}.	Maximum EC values varied from 37 to 102 dSm^{-1}. Strong surface salt accumulation. High subsurface salinity as well.
10	31 (few), 32	2-9 dSm^{-1}	Clear surface and subsurface salt accumulations. Maximum EC values vary from 2-36 dSm^{-1}.

Morphology: Higher portion of exposed Lisan Marl distributed in a complex manner with other sediment. The soil in this area is covered with thin colluvium over Lisan Marl and large area covered with Damya Formation on the top of highly saline Lisan Marl. The Lisan Marl also contains discontinuous gypsum layers or segregated gypsum scattered and mixed with other sediments.

Table F-4

Development Areas with Drainage Systems in Place 1981-1994 (Dunums)

DA	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
3	-	-	-	-	-	-	-	-	-	-	-	60	30	-
4	900	30	-	270	-	-	-	30	240	-	-	90	90	-
5	-	-	-	30	-	120	-	-	-	30	-	-	-	-
6	-	-	-	-	-	-	360	150	-	30	90	-	-	-
7	-	150	-	-	-	630	-	-	30	-	-	180	-	-
8	-	-	-	-	-	-	120	60	-	60	30	-	330	-
9	-	-	-	90	60	-	-	-	-	-	-	-	-	-
10	90	-	-	60	220	-	-	480	60	90	90	90	180	-
11	150	-	250	-	-	350	-	150	30	30	-	30	90	60
12	-	-	250	-	120	210	-	-	180	60	60	-	180	-
13	60	-	100	150	300	120	-	-	210	30	60	-	-	30
14	30	210	100	-	-	-	-	30	210	180	60	-	60	-
15	60	30	60	-	-	210	510	-	-	180	60	30	30	-
16	90	120	-	70	-	-	-	-	-	-	-	30	30	60
17	-	-	-	-	-	-	-	-	-	-	-	-	30	-
18	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	60	-	-	-	-	-	-	-
20	-	-	-	-	-	-	-	-	-	-	-	-	-	60
21	-	-	-	-	-	-	30	-	-	-	-	-	-	-
22	60	150	320	900	-	150	-	-	180	150	-	-	180	60
23	210	1200	930	1500	1800	600	1200	600	30	-	-	30	180	120
24	-	-	35	-	-	-	-	90	-	-	-	30	-	-
25	1200	-	650	350	450	630	600	210	-	-	150	180	150	-
26	30	100	1200	100	-	50	120	180	-	-	-	-	-	30
27	-	-	-	-	-	-	120	330	-	-	-	-	60	60
28	-	-	-	-	-	-	-	-	60	180	270	-	30	150
29	-	70	-	-	-	-	-	60	-	150	-	-	90	30
30	-	-	-	-	-	-	-	-	-	-	-	210	-	-
33	-	-	150	-	-	-	-	90	-	90	-	-	-	-

Annex G: Guidelines

Table G-1

FAO Guidelines for Interpretation of Water Quality for Irrigation

Potential Irrigation Problem	Units	Degree of Restriction on Use		
		None	**Slight to Moderate**	**Severe**
Salinity				
ECw	dS/m	< 0.7	0.7-3.0	> 3.0
TDS	mg/l	< 450	450-2000	> 2000
Infiltration				
SAR = 0-3 and ECw =	dS/m	> 0.7	0.7-0.2	< 0.2
3-6		> 1.2	1.2-0.3	< 0.3
6-12		> 1.9	1.9-0.5	< 0.5
12-20		> 2.9	2.9-1.3	< 1.3
20-40		> 5.0	5.0-2.9	< 2.9
Specific Ion Toxicity				
Sodium (Na)	SAR	< 3	3-9	> 9
Surface Irrigation	meq/l	< 3	> 3	
Sprinkler Irrigation				
Chloride (Cl)	meq/l	< 4	4-10	> 10
Surface Irrigation	meq/l	< 3	> 3	
Sprinkler Irrigation				
	mg/l	< 0.7	0.7-3.0	> 3.0
Boron (B)				
Miscellaneous Effects				
(affects susceptible crops)				
	mg/l	< 5	5-30	> 30
Nitrogen *(NO_3-N)				
Bicarbonate (HCO_3)	meq/l	< 1.5	1.5-8.5	> 8.5
overhead sprinkling only				
PH	SU	Normal Range 6.5 -8.4		

* NO_3-N is nitrate nitrogen reported in terms of elemental nitrogen (NH_4-N and Organic-N should be added when wastewater is being evaluated for irrigation).

Source:Ayers and Westcot (1985) [2].

Table G-2

WHO Microbiological Quality Guidelines for Wastewater Use in Agriculture

Category	Reuse Condition	Exposed Group	Intestinal Nematodes[b] (arithmetic mean no. of eggs per liter[c])	Fecal Coliforms (geometric mean no. per 100 ml[c])	Wastewater Treatment Expected to Achieve the Required Microbiological Quality
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks[d]	Workers consumers public	<=1	<=1000[d]	A series of stabilization ponds designed to achieve the microbiological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees[e]	Workers	<=1	No standard recommended	Retention in stabilization ponds for 8-10 days or equivalent helminth and fecal coliform removal
C	Localized irrigation of crops in category B if exposure of workers and the public does not occur	None	Not applicable	Not applicable	Pretreatment as required by the irrigation technology, but not less than primary sedimentation

a: In specific cases, local epidemiological, socio-cultural and environmental factors should be taken into account, and the guidelines modified accordingly.
b: *Ascaris* and *Trichuris* species and hookworms.
c: During the irrigation period.
d: A more stringent guideline (<= 200 fecal coliforms/100ml) is appropriate for public lawns, such as hotel lawns, with which the public may come into direct contact.
e: In the case of fruit trees, irrigation should cease two weeks before fruit is picked, and no fruit should be picked off the ground. Sprinkler irrigation should not be used.

Source: WHO (1989).

Table G-3

Jordanian Standard 202/1991 Requirements for Discharge of Industrial Effluents

Parameter	Maximum Allowable Limit (mg/l)	
	Disposal To Wadis and Rivers	Reuse for Irrigation**
Al	5	5
As	0.05	0.1
Cr	0.1	0.1
Cu	2	0.2
Fe	1	5
Mn	0.2	0.2
Ni	0.2	0.2
Pb	0.1	1
Se	0.02	0.02
Cd	0.01	0.01
Zn	15	15
Sn	0.1	0.1
Hg	0.001	0.001

+ All units are in mg/l except where noted.

** Depends upon, type and quantity of crops, irrigation methods, soil type, climate, and groundwater in the area concerned (Ayers and Westcot 1985).

Table G-4

Jordanian Standard 893/1995 for Reuse of Treated Domestic Wastewater (mg/L)

Parameter	Cooked Vegetables[1]	Fruit and Forestry Trees, Crops, and Industrial Products	Discharge to Streams, Wadis, and Reservoirs	Irrigation of Fodder Crops
Al	5	5	5	5
As	0.1	0.1	0.05	0.1
Be	0.1	0.1	0.1	0.1
Cu	0.2	0.2	0.2	0.2
F	1	1	1	1
Fe	5	5	2	5
Li	2.5	5	1	5
Mn	0.2	0.2	0.2	0.2
Ni	0.2	0.2	0.2	0.2
Pb	5	5	0.1	5
Se	0.02	0.02	0.02	0.02
Cd	0.01	0.01	0.01	0.01
Zn	2	2	15	2
Cr	0.1	0.1	0.05	0.1
Hg	0.001	0.001	0.001	0.001
V	0.1	0.1	0.1	0.1
Co	0.05	0.05	0.05	0.05
Mo	0.01	0.01	0.01	0.01

[1] Values for trace elements and heavy metals are calculated based on the quantity of water of $1000m^3/1000m^2$/yr. These concentrations should be reduced in case more irrigation water is used.

Table G-5

Water Authority of Jordan Requirements for Discharge of Industrial and Commercial Wastewater into the Sanitary Sewer System (mg/L)

Parameter	Maximum Allowable Limit
Cr*	5
Cu*	4.5
Zn*	15
Sn	10
Be	5
Ni*	4
Cd*	1
As	5
Ba	10
Pb*	0.6
Mn	10
Ag*	1
Hg*	0.5
Fe	50

*The total concentration of all the asterisked materials should not exceed 10 mg/L.

Table G- 6

Recommended Maximum Concentration of Trace Elements in Irrigation Water as Defined by the FAO and the EPA with Notes on their Potential Application to the Jordan Rift Valley

Element		Recommended Maximum Concentration[2] (mg/l)	Remarks
Al	Aluminum	5.0	Can cause non-productivity in acid soils (pH < 5.5), but more alkaline soils at pH >7 like those in the Jordan Rift Valley will precipitate the ion and eliminate any toxicity.
As	Arsenic	0.10	Toxicity to plants varies widely, ranging from 12 mg/l for Sudan grass to < 0.05 mg/l for rice.
Be	Beryllium	0.10	Toxicity to plants varies widely, ranging from 5 mg/l for kale to 0.5 mg/l for bush beans.
Cd	Cadmium	0.01	Toxic to beans, beets and turnips at concentrations as low as 0.1 mg/l in nutrient solutions. Conservative limits recommended due to its potential for accumulation in plants and soils to concentrations that may be harmful to humans.
Co	Cobalt	0.05	Toxic to tomato plants at 0.1 mg/l in nutrient solution. Tends to be inactivated by neutral and alkaline soils like those in the Jordan Rift Valley.
Cr	Chromium	0.10	Not generally recognized as an essential growth element. Conservative limits recommended due to lack of knowledge on its toxicity to plants.
Cu	Copper	0.20	Toxic to a number of plants at 0.1 to 1.0 mg/l in nutrient solutions.
F	Fluoride	1.0	Inactivated by neutral and alkaline soils like those in the Jordan Rift Valley.
Fe	Iron	5.0	Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of availability of essential phosphorus and molybdenum. Overhead sprinkling may result in unsightly deposits on plants, equipment and buildings.
Li	Lithium	2.5	Tolerated by most crops up to 5 mg/l: mobile in soil. Toxic to citrus at low concentrations (<0.075 mg/l). Acts similar to boron.
Mn	Manganese	0.20	Toxic to a number of crops at a few tenths to a few mg/l, but usually only in acid soils few of which are found in the Jordan Rift Valley.
Mo	Molybdenum	0.01	Not toxic to plants at normal concentrations in soil and water. Can be toxic to livestock if forage is grown in soils with high concentrations of available molybdenum.
Ni	Nickel	0.20	Toxic to a number of plants at 0.5 mg/l to 1.0 mg/l; reduced toxicity at neutral or alkaline pH like those in the Jordan Rift Valley.

Pd	Lead	5.0	Can inhibit cell growth at very high concentrations.
Se	Selenium	0.02	Toxic to plants at concentrations as low as 0.025 mg/l and toxic to livestock if forage is grown in soils with relatively high levels of added selenium. An essential element to animals but in very low concentrations.
Sn	Tin		
Ti	Titanium	----	Effectively excluded by plants; specific tolerance unknown.
W	Tungsten		
V	Vanadium	0.10	Toxic to many plants at relatively low concentrations
Zn	Zinc	2.0	Toxic to many plants at widely varying concentrations; reduced toxicity at pH >6.0 and in fine textured or organic soils like those in the Jordan Rift Valley.

[1] Adapted from National Academy of Sciences (1972) and Pratt (1972).
[2] The maximum concentration is based on a water application rate which is consistent with good irrigation practices (10 000 m^3/hectare/year). If the water application rate greatly exceeds this, the maximum concentrations should be adjusted downward accordingly. No adjustment should be made for application rates less than 10 000 m^3 / hectare/year. The values given are for water used on a continuous basis at one site.

Table G-7

Indicative Guidelines for Trace Elements (ppm)

Boron (B)

Soil	Normal content:	2-100 ppm.
Plant	Deficiency:	2-15 ppm,
	Normal:	5-50 ppm,
	Excess:	75-300 ppm.

Zinc (Zn)

Soil	Normal content:	10-30 ppm.
Plant	Deficiency:	5 ppm,
	Normal:	10-50 ppm,
	Toxicity:	200 ppm.

Note: The soil of the JV is known to be highly calcareous soils. Under such conditions, Zn availability to plant is low.

Copper (Cu)

Soil	Normal content:	2-100 ppm.
Plant	Deficiency:	5 ppm,
	Excessive:	> 20 ppm,
	Toxicity:	25 ppm.

Chloride (Cl) Meq/100 gm

Soil	Normal content:	50-500 ppm (1.4-14.3 meq).
Plant	Deficient:	< 0.2, (%)
	Normal:	0.2-1.0,
	Excessive:	0.5-2.5,
	Toxic:	> 2.5.

Iron (Fe) DTPA extraction methods

Soil	Low:	< 4.5 ppm,
	Adequate:	> 4.5 ppm.
Plant	Deficient:	30 ppm.

Manganese (Mn)

Soil	Low:	<1 ppm,

	Marginal:	1-2 ppm,
	Adequate:	> 2 ppm.
Plant	Deficiency	5-20 ppm,
	Normal	15-100 ppm,
	Excessive	> 100 ppm (phytotoxicity).

Annex H: Figures

Figure 1. Jordan River Basin and Sampling Locations

Figure 2. Schematic Irrigation Diagram and Sampling Locations