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Water Quality Improvement and Conservation Project

Achieving Sustainable Irrigation Water Conservation in the Jordan Valley

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USAID

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Preface/Acknowledgment

This report is a synthesis of the information and data on irrigation water management the writer has been exposed to since arrival in Jordan. Deficiencies in irrigation water management are discussed and solutions presented. An attempt was made to look at the issues as a whole and not be confined to the Zarqa Triangle, the Water Quality Improvement and Conservation Project mandate area. It is up to the reader to judge how successful this attempt has been. It is hoped that this report will be read, the ideas presented thought about, and the reader's thoughts/comments passed back to the writer.

The writer wishes to thank all those persons in the Ministry of Water and Irrigation (MWI), the Jordan Valley Authority (JVA), Development Alternatives, and the Water and Environment Research & Study Center (WERSC) who read and commented on drafts of this report. Special thanks are extended to Avedis Serpekian, JVA, Dr. Hani Rashid, MWI, and Dr. Mohammad Shatanawi, WERSC, for many thought provoking discussions on irrigation water management in Jordan.

Opinions and conclusions expressed in this report are those of the writer and do not reflect those of any other person or organization.

Executive Summary

It is the operation and maintenance that define and limit the modern irrigation system, and through which most water conservation is achieved. ***Conservation of irrigation water does not necessarily mean that more water will be available for other users. What it does mean is that wastage of water is minimized and beneficial use of water is maximized.*** State-of-the-art equipment and technology do not assure that modern water delivery and irrigation systems are in-place and functioning. It is unfortunate that many cannot see beyond the physical system to the operation and maintenance of the system. The baseline survey of irrigation management in the Central Jordan Valley illustrates this point well.[1]

The baseline survey found annual average management efficiencies for high technology trickle irrigation systems lower than those for low technology surface irrigation systems, 64% and 76%, respectively. The most sophisticated production systems, plastic houses using trickle irrigation under plastic mulch, had the lowest efficiency numbers, 44%. The data shows that irrigated agriculture in the Jordan Valley is far from reaping the water conservation benefits possible with the modern systems; both the pressurized pipeline delivery system and the high technology irrigation systems are modern systems.

A sustainable irrigation water conservation effort in the Jordan Valley is comprised of interlinked components, which form a unified program for modernizing irrigation management in the Valley. Inattention to any component will weaken the successful accomplishment of the program. The components of the program are:

- an irrigation water delivery schedule compatible with micro irrigation (requires a high level decision to change the current rigid delivery schedule to a limited rate demand schedule);
- upgrading the skills base of Jordan Valley Authority operations and maintenance personnel through a combination of US based advanced degree education and short-term training and local on-the-job and in-service training;
- rehabilitation of the irrigation water delivery infrastructure and modernization of the operations and maintenance vehicle and equipment pool;
- water delivered to the farm turnout that can be economically "polished" prior to introduction into the micro irrigation delivery system;
- farmers trained in the correct operation and maintenance techniques required by the micro irrigation systems used;
- organization of a water user organization(s) to give farmers a conduit for input into irrigation water delivery operations and maintenance activities;
- information and technical assistance available to assist farmers in obtaining high water use efficiencies;

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[1] DAI. 1995. Irrigation management & water quality in the Central Jordan Valley (Baseline Survey). Water Quality Improvement and Conservation Project Report 3114-95-3b-05.

- forging linkages between the Jordan Valley Authority, Ministry of Agriculture Extension Service, Universities in Jordan, National Center for Agricultural Research and Technology Transfer, and the Department of Meteorology;
- a marketing system that gives farmers a fair return on their investments; and
- a water delivery fee structure that encourages farmers to use water conservatively.

To gain irrigation water conservation benefits in the shortest amount of time, work should proceed on all components simultaneously. Given the seriousness of the deficiencies and the time required to get trained personnel on-the-job, the advanced degree training programs for Jordan Valley Authority staff should be initiated early in the program.

The last two components of the program, marketing and fees, are outside the scope of work of the author and will not be addressed in this document. They are however, of vital importance to achieving the irrigation water conservation needed. Without an incentive to conserve irrigation water and a fair return on production investments, the on-farm portion of the program will not yield significant results.

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ACRONYMS

DAI	Development Alternatives Inc.
ET	Evapotranspiration
JVA	Jordan Valley Authority
MOA	Ministry of Agriculture
MWI	Ministry of Water and Irrigation
NCARTT	National Center for Agricultural Research and Technology Transfer
PRIDE	Project in Development and the Environment
UJ	University of Jordan
US	United States
USAID	United States Agency for International Development
WQIC	Water Quality Improvement and Conservation
WUO	Water User Organization

Introduction

PRIDE[2] conducted a study of available water resources and their use in Jordan. The study highlighted the "looming crisis in water supply" facing Jordan.

> ***"Jordan has insufficient water for the kind of future it envisions. There is not enough water for its desired standard of living; nor for the additional jobs and income that should accompany the development of industry, services, and tourism; nor for more irrigation to expand food output for domestic consumption and export earnings."***

Ghezawi and Khasawneh[3] report that in 1991, irrigation used about 90.6% of the surface water resources available to the Jordan Valley. The remaining 9.4% of the water was pumped to Amman. The Yarmouk and Zarqa (King Talal Reservoir) Rivers provided 46.7% and 22.7%, respectively, of the total irrigation water in the Valley. Table 1 shows the percentages of all water resources in Jordan that are used by irrigation. Agriculture is the largest user of water resources in Jordan and therefore, offers the greatest opportunity for water conservation.

Table 1. Use of water resources in Jordan, 1993.[4]

Source	Total MCM	Municipal MCM	Industrial MCM	Livestock MCM	Irrigation Use MCM	Irrigation Use (%)
Surface	400.608	57.010	2.568	4.000	337.030	84.13
Ground water	532.664	156.532	28.679	6.349	341.104	64.04
Waste water	50.310	0.000	2.000	0.000	48.310	96.02
Total	983.582	213.542	33.247	10.349	726.444	73.86

The PRIDE study was used by USAID to develop the framework for a project to assist the Ministry of Water and Irrigation (MWI) in meeting the challenges outlined in the study report. The Water Quality Improvement and Conservation (WQIC) Project contract was signed in January of 1994 and the expatriate team arrived one month later.

The WQIC Project has as one of its goals the development of a sustainable irrigation water conservation program. In the contract Scope of Work, the irrigation water conservation component of this program is comprised of four interrelated components or tasks: develop

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2 PRIDE. 1992. "A water management study for Jordan." Cemonics International and Associates.

3 Ghezawi, A. Z. and M. M. Khasawneh. 1993. Irrigation water and agriculture in the Jordan Valley and Southern Ghore: The possibility of cultivating substitute crops. Centre for Scientific Studies, Royal Scientific Society, Amman.

4 Bani Hani, M. 1995. "Jordan's strategies for freshwater resources development," presented at the CEDARE and Ford Foundation sponsored seminar on *Options and strategies for freshwater development and utilization*, Amman, Jordan, 26-28 June.

water delivery conservation program; develop on-farm water conservation program; feasibility of water users organization; and research, training, and demonstrations. This document integrates these components into one encompassing program for achieving the project goal.

The program focuses on micro irrigation methods[5] for on-farm water application. This is a deliberate decision based on the belief that micro irrigation is the only future for irrigated agriculture in the Jordan Valley. Regardless of the state of micro irrigation as currently practiced in the Valley, it is the only method that offers a potential for very high water use efficiencies.

It is simplistic to say that in the absence of an incentive irrigation water conservation can be achieved by obtaining high distribution uniformities (on-farm measure of the water delivery system design and construction) and conveyance efficiencies (delivery system). The baseline survey found that distribution uniformities in Jordan were comparable with values found in the central valley of California. Satisfactory distribution uniformities for Jordanian systems, indicating well designed and constructed systems, did not translate into high irrigation management efficiencies because farm managers lack an incentive, the price of water is too low, to conserve water and the knowledge to properly schedule irrigations and to determine the quantity of water required at each irrigation.[6] This point is very important to the discussion that follows. Conveyance efficiencies do not reflect the impact delivery system management can have on the quantity of water that reaches the farm gate. Management controls the pressure and availablility of water in the pipe, both significantly impact on farm gate water deliveries and affect farmers' decision making and water use patterns.

Projected Irrigation Water Savings

The purpose of the program developed in this document is to conserve or save irrigation water. Data from the Zarqa Triangle area of the Central Jordan Valley will be used to indicate the magnitude of the water savings that are possible. Savings in areas serviced by newer delivery systems should be lower than those from the older Zarqa Carrier I. Data used for the calculations are conservative, i.e., savings could easily be higher than those projected.

Battikhi and Abu-Hammad[7] found the average delivery efficiency of the pressurized pipe system serving the Zarqa Triangle to be 72% over the period 1989 - 1991. For the same period the Hisban-Kafrein pipe system was operating at an average delivery efficiency of

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[5] Micro irrigation methods used in Jordan include micro sprays or micro sprinklers and insert emitters, used on bananas, trees, and grapes; and inline emitters, used on vegetable crops.

[6] This topic is discussed in more detail in Annex A.

[7] Battikhi, A. M. and A. H. Abu-Hammad. 1994. "Comparison between the efficiencies of surface and pressurized irrigation systems in Jordan." Irrigation and Drainage Systems , Kluwer Academic Publishers.

89%. A pipeline in good condition and correctly operated should have delivery efficiencies of 90% or above, as achieved by the Hisban-Kafrein system in some years.

The baseline survey found that 45.1% of the land irrigated in the central Jordan Valley was irrigated using "high tech" or trickle and microjet irrigation methods. The arithmetic annual average efficiency of these micro irrigation systems was 64% in the open field and 44% in plastic houses. The attainable efficiencies for line-source emitters, the type used for vegetable production, is 70% to 85%, for the point source emitters used on trees and grapes attainable efficiencies are 75% to 90%.[8] Attainable efficiencies are those that can be achieved with reasonable design and management, i.e., efficiencies within reach of most farmers. Micro irrigation systems in the central Jordan Valley are performing at levels significantly below the attainable efficiencies.

In 1994, 48.7 million cubic meters (MCM) of water was diverted at the Tal Al-Thahab Weir, and supplied via the Zarqa Carrier I pipe line, to irrigate the 1,186 hectares of land in the Zarqa Triangle area of the central Jordan Valley.

Assume the efficiency of the Zarqa Carrier I irrigation water delivery pipeline can be increased from 72% to 90% by rehabilitation of the infrastructure and implementing proper operation and maintenance procedures.

- Volume of the diverted water that can be saved by an increase in delivery efficiency:

$$\left[\frac{90-72}{100}\right]_{\text{efficiency increase}} \times 48.7_{\text{water diverted}} = 8.77 \text{ MCM}$$

Assume the following: that all irrigated lands, regardless of irrigation method, in the Zarqa Triangle use the same quantity of irrigation water;[9] and irrigation management efficiencies for micro irrigation irrigation can be increased from 64% to 80% by improvements in management and maintenance of the systems. Based on the 45.1% of the area irrigated using micro irrigation, projected on-farm irrigation water savings are calculated as:

- Volume of the diverted water that is delivered to farm gates:

$$\left[\frac{72}{100}\right]_{\text{delivery efficiency}} \times 48.7_{\text{water diverted}} = 35.06 \text{ MCM}$$

- Volume of the farm gate water available to the portion of the area irrigated by micro irrigation methods:

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8 Solomon, K.H. 1988. "Irrigation systems and water application efficiencies," Center for Irrigation Technology Publication No. 880104, Fresno, California.

9 JVA water allocations are crop based and not irrigation method based and micro irrigation is used on high value crops that often have a higher water allocations. There is also evidence that some trickle irrigated lands use more water for the same crop. Both factors tend to increase the percentage of the total water delivered to micro irrigated farms, i.e., increase the quantity of water that could be saved.

$$\left[\frac{45.1}{100}\right]_{\text{area portion}} \times 35.06_{\text{farm gate water}} = 15.8 \quad \text{MCM}$$

- Volume of the farm gate water that can be saved by an increase in on-farm efficiencies:

$$\left[\frac{80-64}{100}\right]_{\text{efficiency increase}} \times 15.81_{\text{farm gate water}} = 2.53 \text{ MCM}$$

The total projected savings brought by improvements in both sectors are 8.77 (18%) + 2.53 (5%) = 11.3 MCM or 23% of the annual quantity of water diverted at the weir. A large part of these projected savings may be "paper savings" only.

The efficiency of the delivery system is calculated from the quantity of water diverted and the amount of water billed. A part of the unbilled water is being beneficially used. Its being billed in the future will increase the calculated efficiency of the delivery system but will not result in any saved water that can be used by other consumers. Increasing efficiencies on farm is also unlikely to result in a large volume of water that can be used by other consumers. Currently many farms are not fully planted because of insufficient water deliveries. Water saved by increasing efficiencies on the part of the farm planted will be used to plant more of the same farm.

Irrigation Water Delivery Scheduling

Irrigation water delivery schedules can be developed from two perspectives; that of the irrigation water recipient or the water delivery organization. Minimization of operation and management costs and efficient delivery of water will result in different schedules from the two perspectives. The farmer prefers a system with a high level of flexibility because it gives him maximum freedom in his farming operation. If deliveries are reliable, farmers are willing to pay a higher water delivery fee to get this flexibility. The water delivery organization prefers a rigid rotation because it is the easiest to operate; labor and water demands on the system are predictable, skills required by the field staff are minimal, and system operation cost is low. The limits and benefits of both schedules will be discussed in this section.

Farmer Requirements

Given that the farmer is the ultimate user of about 90% of all surface water resources in the Jordan Valley, it is important that his requirements for achieving irrigation water conservation are fully understood.

To understand the farmers' needs one must first realize that micro irrigation is significantly different than surface irrigation. Surface irrigation is characterised by the infrequent application of large quantities of water, which wets the entire field, over a short period of time. The trickle irrigation method, if correctly managed, is characterized by: (1) water is applied at a low rate; (2) water is applied over a long period of time; (3) water is applied at

frequent intervals; (4) water is applied near or into the plant's root zone; and (5) water is applied by a low-pressure delivery system.[10] It is obvious that the method of delivering water to the plant differs from surface irrigation. The demands on the water delivery system are not so obvious. This demand is well described by Kruse et al.[11]

> ***". . . delivery of water to the farm will need to be on a nearly continuous basis. A water storage facility on the farm may be necessary."***

Under micro irrigation the root zone volume wetted each irrigation is significantly smaller than that wetted by surface irrigation. In the past, a 30 to 50% root zone wetting has been recommended for trickle irrigation of annual crops.[12] Studies in the US show that the seasonal water demand for trickle irrigated vegetable crops can be as low as 50% of the seasonal demand for surface irrigated crops.[13] To maximize the potential benefits, (measured as return on investment) from micro irrigation, while using these smaller volumes of water, the farmer must have the flexibility to alter his irrigation schedule as the crop season progresses. Irrigation applications must vary from once every two weeks during germination and early growth to every day during the peak growing season. In the absence of flexible delivery schedules and reliable deliveries of ordered water, farmers construct pools.

Farmers also require water that is relatively clean. To apply water at low rates requires small openings, openings that are easily plugged by debris and sediment in the lines. Sand media and screen filter units are used by farmers to "polish" the water delivered to the farm. The on-farm units are not designed nor expected to remove the levels of sediment and debris currently delivered in the water from the Jordan Valley Authority (JVA) operated pressurized pipeline. Pools can be used to remove much of the contaminants from the delivered water.[14]

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[10] Bucks, D. A. and S. Davis. 1986. "Introduction," In F. S. Nakayama and D. A. Bucks (eds.) Trickle irrigation for crop production. Elseveir Sci. Pub., Amsterdam, p. 1.

[11] Kruse, E. G., D. A. Bucks, and R. D. Von Bernuth. 1990. "Comparison of irrigation systems," Irrigation of Agricultural Crops edited by B. A. Stewart and D. R. Nielsen, Agronomy; no. 30, American Society of Agronomy, Madison, Wisconsin, pp. 493-494.

[12] Nakayama, F. S. and D.A. Bucks. 1986. Trickle irrigation for crop production, Design, operation, and management. Elsevier, Amsterdam, p. 231.

[13] Grove, R. and J. C. Wells, Jr. 1985. "Drip irrigation: The grower's learning curve." Drip/Trickle in Action: Proceedings of the Third International Drip/Trickle Irrigation Congress, ASAE, Michigan, pp. 111 - 114.

[14] Most of the farm pools are incorrectly designed and operated for sediment removal. Pools are round, which means there will be little stratification of water and sediment unless water enters the pool at the center (none have this feature). The pump intake should be at the opposite end of the pool from the water inlet, many are next to each other. Farmers report that the primary reason they construct pools is for irrigation scheduling flexibility.

Jordan Valley Authority Water Delivery Schedule

Replogle et al.[15] describes the types of water delivery schedules in use. Schedules consist of the delivery frequency to the farm, the delivery flow rate, and the delivery duration. The relations between these three factors bear heavily on the effective and economical use of water, labor, energy, and capital investment on the farm.

During the summer season, the JVA uses a rotation schedule of the fixed amount-fixed frequency type. In winter the delivery frequencies are variable (they may change from twice weekly to three times per week but the farmer still cannot request delivery on specific days out of the rotation) but the amount remains fixed. These are rigid-schedule irrigation water delivery systems, which are primarily for the convenience of control by the responsible organization. The rigid frequency and amount schedule often supplies excess water in the spring and late summer, contributing to water waste and drainage problems. The frequency seldom matches the soil or the crop needs. These schedules may function quite well for perennial crops needing the same depth of water applied at each irrigation.

On a project or district basis rigid schedules often result in low project irrigation efficiencies, create drainage problems, leach soil nutrients, and waste labor on the farm. They frequently become expensive methods when supply, distribution, application, and limitations on crops are considered in the whole production system. These systems are frequently modified by using reservoirs or pools on farm, as occurs in the Jordan Valley.

Some in JVA contend the system is not capable of delivering water by an on-demand schedule. This belief follows from an analysis of the quantity of water allocated each season for the crops planted in the service area; water that must be delivered via the pipelines. However, the crop water allocation JVA uses is based on surface irrigation needs. For crops grown under mulch and watered by trickle irrigation this allocation is excessive, resulting in an unnecessary high demand on the delivery system.[16]

Others in JVA contend that the pipeline delivery system was designed for limited rate demand scheduling of sprinkler irrigation; the problems have occurred because sprinkler was not adopted and surface methods were retained. Given that micro irrigation methods use less water than both surface and sprinkler, pipeline capacity should be adequate for a limited rate demand schedule.

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[15] Replogle, J. A., J. L. merriam, L. R. Swarner, and J. T. Phelan. 1980. "Farm water delivery systems," In M. E. Jensen (ed.) Design and operation of farm irrigation systems. American Society of Agricultural Engineers, St. Joseph, Michigan.

[16] Trickle irrigation methods that wet a small percentage of the soil surface under a plastic mulch have a negligible evaporation loss. Therefore, evapotranspiration (ET) requirements for these crops are less than ET requirements for the same crop under surface irrigation. In addition to the reduction in ET requirements, the root zone wetted by micro irrigation is significantly smaller than that wetted by surface irrigation. The demand reductions deriving from lower ET requirements, a smaller wetted root ball, and less water wasted to deep percolation or run off indicate a need to rethink and recalculate water allocations for crops grown under plastic mulch and trickle irrigation.

Another factor in the equation is the absence of staff trained in the operation of pressurized pipe delivery systems. Current operations personnel do not know how to maximize the benefits offered by the in-place delivery system. Management only knows how to operate the system as it has always been operated. Other modes of operation are not understood and are dismissed as not possible before they are fully evaluated.

To infuse flexibility and change ability into JVA, a Board of Directors should be established at each Irrigation Directorate. The Board would have members from JVA, the Water User Organization (WUO), and other interested parties. The board should have the authority to make the policy and management decisions necessary to effect efficient irrigation water use within their mandate area. Much of the decision making power and responsibility within JVA should be decentralized and delegated to positions lower down the chain of command.

Schedule Recommended

With a pressurized pipeline delivery system, irrigation water should be present in the pipe at all times. Theoretically at least, it is possible for water to be delivered in a timely fashion and in the quantities allocated. If the delivery system is operated in a reliable manner, such that farmers have confidence that they can obtain water when needed, demands should decrease and the available pipe capacity would be sufficient. The need for nearly continuous delivery of water to a farm using micro irrigation indicates that limited rate demand scheduling of water deliveries is more appropriate than the rigid schedules currently in place.

Limited rate demand scheduling allows flexible rate and duration deliveries as well as frequency but with a limit on the maximum flow rate. With this schedule the rate may be varied by the irrigator during the irrigation, and the duration is controlled by him within the requested period.[17] The limited rate demand schedule is highly practical for the water user. It enables the user to irrigate each crop when needed. Thus, differences in soils and crop requirements can normally be accommodated. The limited rate demand schedule is practical when the system has adequate capacity and closed pipelines. The turnout is kept locked except for the scheduled days and the volume of water is measured by a totalizing meter at each farm turnout. A reliable limited rate demand schedule for deliveries of clean irrigation water can decrease or remove the necessity for farm pools.

Implementation of a new water delivery schedule requires policy changes within JVA management, training of management and supervisory field personnel, and rehabilitation of the delivery system physical infrastructure. In effect JVA must change it's image from that

[17] In a limited rate demand schedule type of operation the water delivery organization opens their valve at the time requested. The farmer can adjust his valve whenever he wishes, he has complete control of the water delivery during the hours requested. He can decrease the flow, turn it off if desired, or increase the flow up to the maximum allowed by the flow restrictor. At the end of the requested time period, the delivery organization representative shuts their valve and water delivery terminates. Delivery organization involvement in irrigation water delivery is limited to opening and closing the control valve belonging to the organization.

of an inefficient paternalistic government organization to that of a dedicated service organization that constantly strives to satisfy its farmer customers by giving them the service they need.

- Farmers require flexibility in water delivery, daily access during peak crop water use periods, and relatively clean water.
- JVA should evaluate a limited rate demand delivery schedule for irrigation water deliveries. Such a delivery schedule would be compatible with the on-farm irrigation water distribution system and crop water needs.
- JVA needs to rethink and recalculate water allocations for those crops grown under plastic mulch and trickle irrigation.
- To infuse flexibility and change ability into JVA, a Board of Directors having customer representation should be established at each Irrigation Directorate.
- Much of the decision making power and responsibility within JVA should be decentralized and delegated to positions lower down the chain of command.

Operation and Maintenance Deficiencies

The most significant deficiencies within JVA are the lack of adequate training of field and management staff and the absence of standard operation and maintenance protocols. Untrained management staff operate the pipelines as if they were open channels, the operational benefits of a pipeline are not realized. Maintenance is carried out on a "repair as needed" basis, the system is allowed to deteriorate until it reaches the point where complete rehabilitation (reconstruction) is required. Staff need to be trained and standard protocols developed and implemented for each delivery system. Implementation implies that the operation staff understand and follow the protocols at all times. Reliable water deliveries requires a disciplined and dedicated staff in addition to an efficient delivery system. JVA must begin to enforce discipline in the field staff and develop incentives for rewarding superior performance by its staff.

Due to the age of the delivery system serving the Zarqa Triangle, and a lack of regular maintenance, some rehabilitation and upgrading works are required. Many of the pipeline accessories, such as pressure control and air relief valves, are in need of overhaul or replacement. Many of the flow meters at the farm turnouts are broken; mostly by debris in the water carried by the pipeline. A not insignificant deficiency is the poor condition of many of the vehicles and heavy equipment used for day-to-day operation and maintenance activities, GITEC (1994).[18] There are existing shortages of some types of vehicles used

[18] GITEC. 1994. "Study for the Recovery of Operation and Maintenance Costs of Irrigation Water in Jordan," A study of JVA O&M functions funded by GTZ.

for daily operations and maintenance. To offer reliable and timely service to its customers, JVA field personnel must be able to do their work in a prompt manner. This requires a fully functional equipment pool; Annex B shows current vehicle and equipment requirements.

- Staff need to be trained and standard protocols developed and implemented for each delivery system.
- Some rehabilitation and upgrading works are required for the delivery system serving the Zarqa Triangle.
- JVA requires a fully functional vehicle and equipment pool for day-to-day operation and maintenance activities.

Manpower Development Within The Jordan Valley Authority

JVA has 125 employees with education beyond secondary school. The numbers of JVA employees with civil or agricultural engineering degrees are shown in Table 2. The Table illustrates that the JVA has a critical shortage of these engineering degree holders in the Ghor. Within the five directorates responsible for irrigation water delivery in the Ghor, excluding the Mechanical and Laboratory Directorates, there are eleven B.Sc. degrees and one M.Sc. degree.

The Water Management Education component of the WQIC Project conducted a training needs assessment that included JVA.[19] Respondents to the survey (heads of directorates, divisions, branches, and units) identified 154 potential nominations for training: 52% fell under the "high need," 32% under the "medium need," and 16% under the "low need" category. The specific topics selected for training, in descending order, were: operation and maintenance of irrigation projects, irrigation water management, water conservation, water resource allocation to minimize water contamination, developing an on-farm water conservation plan, and irrigation scheduling. All of these training programs are designated for professional staff, less well educated field staff training needs were not addressed by the needs assessment.

A new JVA requires a skilled manpower base that can only come from an intensive training program. Training is required at all management and supervision levels of the Directorates that would be responsible for implementing the new operation and maintenance policies. A combination of US based M.Sc., formal short-course, and internship training in addition to local in-service and on-the-job-training is needed. For the field staff implementation personnel, intensive on-the-job and in-service training programs would suffice.

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[19] DAI. 1995. Water management education, training needs assessment. Water Quality Improvement and Conservation Project Report 3114-94-4a-06.

Table 2. Civil, irrigation, and agricultural engineering higher degree holders employed by JVA.[20]

Location & Directorate	Ph.D.	M.Sc.	Diploma	B.Sc.
Amman				
Administration & Finance		1		2
Studies & Information		1	1	2
Land				3
Rural Development				4
Dams		2	1	14
Public Management & Planning		2		3
Irrigation		2		16
Subtotal		**8**	**2**	**44**
Ghor				
Central Operations & Maintenance		1	1	3
Mechanical				
Soil and Land Laboratory	1			5
North				3
Middle				1
South				3
Southern Ghors				1
Subtotal	**1**	**1**	**1**	**16**
Totals	**1**	**9**	**3**	**60**

At a minimum there should be three M.Sc. degree holders, specializing in irrigation, in middle level management positions in the Ghor.[21] The person assigned to the Central O&M Directorate, responsible for the King Abdullah Canal system, would be concerned with open channel delivery systems. One of the other candidates should be directed toward pressurized pipeline delivery system operations and maintenance. The remaining candidate should concentrate on micro irrigation systems and be the head of the Irrigation Advisory Service.

Two candidates should receive MBA degrees with the focus area being management of public utility type organizations. These persons should be assigned to assist the engineer manager of each Directorate. These persons can advise on the budgeting, personnel management, organizational, and other activities of the Directorate that are not directly related to engineering. It is expected that one person can assist more than one Directorate.

[20] Data obtained from the JVA.

[21] If and when JVA operations in the Valley are reorganized, these numbers should be reevaluated.

In the modernization program the JVA also needs to recruit local B.Sc. degree holders to assist the advanced degree holders. Specialized in-service short courses and on-the-job-training would be required to develop the specialized skills required by JVA.

A program focused on retention of trained manpower is essential. Salary and benefit levels competitive with the private sector are minimum requirements. An incentive program should be instituted for rewarding excellence in job performance. If these programs are not in-place the newly trained personnel will leave JVA as soon as they can find better opportunities, as is currently happening, and the new JVA will revert to the old JVA. The JVA must become an organization of professionals dedicated to serving its clientele.

Serious consideration should be given to building a linkage with an Irrigation District in the US that has a similar delivery system, crop mix, and on-farm irrigation systems. The central valley of California has several districts that would qualify. An employee exchange program, on an irrigation season basis, can be used to upgrade hands-on technical and management skills. Timing of irrigation for the two locations is ideal for such a program; the peak irrigation season in Jordan coincides with the off-season in the US and vice versa. Small groups of farmers who use micro irrigation could also benefit from a visit to the US. Criteria for membership in such a group would need to be based on benefit to the program, not political considerations.

- JVA has a critical shortage of engineering degree holders in the Ghor.
- A combination of US based MSc., formal short-course, and internship training in addition to local in-service and on-the-job-training is needed.
- A program focused on retention of trained manpower is essential.
- Consider building a linkage with an Irrigation District in the US that has a similar delivery system, crop mix, and on-farm irrigation systems.

Quality of Delivered Water

The micro in micro irrigation derives from small volumes of water delivered per emitter, typically about 4 liters per hour for vegetable crops, and the small water passages in the emitter, 0.25 and 2.5 millimeter. Given the small passages, any sediment and debris in the water easily clogs the opening. Farmers use sand media and screen filters to clean the delivered irrigation water before it is introduced into the lateral lines.

Screen filters are designed to remove inorganic particles larger than the openings in the screen. When organic material, primarily algae, are present in the water, screens plug frequently and require manual cleaning. Screens are primarily used on the pump intake line, if present, and following the media filter. The latter screen placement is used to catch any media that escapes the media filter when it is backwashed.

Media filters are ideal for removing organic contaminants, such as algae. Algae is trapped in the upper layers of the filter media bed and removed from the system when the filter is backwashed. Fine inorganic particles are also captured on the upper layers of the bed and in the algae that accumulates on the surface of the filter bed.

Neither filter is suitable for efficient removal of the high concentrations of organic or inorganic contaminants currently in the delivered water. Manual cleaning of screens and frequent backwashing of media filters require much system down time and wastage of backflushing water unless it is returned to a pool. In cases where the water carries a high contamination load, such as the Zarqa river, a large scale central water conditioning facility should be used.

Rehabilitation of the water delivery system should include the addition and improvement of water conditioning equipment at the head works of the pipelines. Inspection of non-functioning water meters returned to the JVA workshop shows that trash removal efforts are inadequate. Consideration must be given to automating the removal of large debris at the Tal Al-Thahab intake from the Zarqa River; a bar screen with an automatic power operated rake would be appropriate. At the exit of the settling basin, screening equipment should be installed to catch any wind blown debris entering the settling basin and to remove smaller debris that passes the bar screen. In the winter season the pipeline carries a heavy silt load, which rapidly plugs the on-farm media filters that are directly connected to the delivery pipeline. The design of the existing settling basins must be checked against the maximum flow rate required and the size of sediment particles carried by the water. For the winter season flow rate the basins appear to be under designed. The need for centrifugal sand separators should be assessed. The assessment should determine why the separators installed at the Tal Al-Thahab weir are currently non-functional.

The argument is made by some in JVA that as long as the sediment and debris does not hinder operation of the pipeline it is not JVA's responsibility to clean-up the water. Even from the narrow JVA perspective this argument is questionable, and it reinforces the belief that the JVA is not focused on serving its customers. From a national perspective the argument is invalid. Because of debris in the delivered water, JVA must expend significant funds to replace all volumetric water meters used at farm turnouts. The condition of water currently delivered is another reason farmers are encouraged to use pools. Pools require funds to construct, remove land from production, and offer breeding areas for mosquitoes. Pumps must be purchased, operated, and maintained to pressurize water for the micro irrigation system. The additional costs contribute to the high price of Jordanian produce, making it more expensive on the European market than that of many competitors.

- Rehabilitation of the water delivery system should include the addition and improvement of water conditioning equipment at the head works of the delivery pipelines.

Farmer Training Program

Benefits from micro irrigation and the education level required by the user is succinctly stated by Kruse et al.[22]

> ***". . . micro irrigation offers opportunities for applying irrigation water efficiently where other methods can have difficulties. As a management tool, a micro irrigation system can improve the level of water management or conservation. However, most micro irrigation systems are not well adapted to the poor or uneducated user."***

A lack of training and the unavailability of information on management and maintenance of micro irrigation systems are two reasons the performance of such systems in the Jordan Valley is so poor (another larger reason is the lack of an incentive to conserve water). Under the WQIC Project, materials for training farmers and assisting personnel in micro irrigation system operation and maintenance, irrigation scheduling, and irrigation practices evaluation are being prepared; Table 3. lists topics for which training material is being prepared. Annex A presents a more in-depth discussion of this subject. In addition, pilot demonstration farms are planned to show farmers what can be achieved with proper system design, operation, and maintenance.

Table 3. Micro irrigation training material titles.

System Operation	System Management	System Evaluation
1-0 System Overview	2-1 Media Filter Backwashing	3-1 Evaluation Overview
1-1 Pumping Units	2-2 Crop Water Requirements	3-2 Data Collection
1-2 Motors and Engines	2-3 Irrigation Scheduling	3-3 Data Analysis
1-3 Media Filters	2-4 Water Quality	3-4 Recommendations
1-4 Mesh Screens	2-5 Irrigated Soils	
1-5 Fertilizer Injection System	2-6 Salinity Control	
1-6 Piping System	2-7 Drainage Needs	
1-7 Layout Considerations		
1-8 Laterals		
1-9 Emitters		
1-10 Pipeline Protection		
1-11 Stilling Basins		

[22] Kruse, E. G., D. A. Bucks, and R. D. Von Bernuth. 1990. "Comparison of irrigation systems," Irrigation of Agricultural Crops edited by B. A. Stewart and D. R. Nielsen, Agronomy; no. 30, American Society of Agronomy, Madison, Wisconsin, pp. 496.

The training material is being prepared in a modular format. Most modules are independent and do not depend upon another for material. This format requires some duplication of material but allows the trainer to select modules to suit the training requirement and time restrictions for a given program.

Although the training material will be prepared and field tested, there is no organization with qualified personnel responsible for training farmers in the subject area. Currently no organization in Jordan offers training and assistance to farmers in the operation and maintenance of micro irrigation systems; though many groups in Jordan talk about the necessity for farmers to conserve irrigation water. This deficiency must be changed through establishment of an organization for farmer training and assistance that has a clear definition of jurisdictional boundaries and responsibilities. High level decisions, perhaps even legislation, are required to resolve this issue.

The current organization of JVA does not allow it to become involved in the operation and maintenance of on-farm irrigation systems; it does not have designated positions, trained staff, or budget. The Ministry of Agriculture (MOA) Extension Service also does not have the trained manpower or budget to assist farmers in irrigation issues. If on-farm water use efficiency is to improve some organization must be given responsibility and budget for assisting farmers.

An Irrigation Advisory Service (IAS) should be established. Personnel for the IAS should come from both the JVA and the MOA extension service. As a first step, one person from each organization should be trained. Duties would include training farmers, using the modules listed in Table 3, and assisting farmers in changing their irrigation practices. IAS staff should be intimately involved with pilot farms and all other pilot programs that effect farmers' irrigation practices.

- Most micro irrigation systems are not well adapted to the poor or uneducated user.
- Materials for training farmers and assisting personnel in micro irrigation system operation and maintenance, irrigation scheduling, and irrigation practices evaluation are being prepared.
- Pilot demonstration farms are planned to show farmers what can be achieved with proper system design, operation, and maintenance.
- Currently no organization in Jordan offers training and assistance to farmers in the operation and maintenance of micro irrigation systems.
- Establishment of an organization, IAS, for farmer training and assistance that has a clear definition of jurisdictional boundaries and responsibilities and budget is required.

Water User Organizations

Reiss et al.[23] interviewed 50 farmers in the Central Jordan Valley to assess the feasibility of establishing a pilot WUO. They concluded that a small pilot WUO was feasible; elements might include:

- making bulk sales to the head unit on the line;
- having farmers manage distribution along the line, ending the need for farmers to confirm deliveries individually;
- assisting users in resolving potential or actual water conflicts on the line;
- introducing irrigation extension information and/or water conservation measures;
- working with farmers to produce seasonal cropping plans;
- assigning JVA staff to work closely with the lateral group, mirroring what was done in the 1960s before the rapid expansion of the system;
- providing sensitization and training to both farmers and JVA staff; and
- assisting with or linking to marketing imperatives.

The organizational unit for the pilot WUO would be a line/lateral off the main carrier pipe. A line off the carrier pipe in the Zarqa Triangle has up to 49 farm turnouts, which would be the maximum number of farmers on a line. Reiss et al. recommended the selection of a line having from ten to 19 turnouts for the pilot WUO. This would be a small organization likely to have little influence with JVA. The report also mentioned that a larger trial organization could be established but did not provide many details. An outline of next steps is provided in the report. It must be said that experience in other countries has shown that a donor must make a long-term commitment to the effort if a new WUO is to brought up to a sustainable level.

The JVA monopolizes the control of irrigation water in the Jordan Valley. Given the absence of competition, even if a new customer oriented JVA emerges, there must be some organization of customers to keep the pressure on the new organization. A WUO having a significant member base can fill this role. The land holdings of members of the WUO should roughly coincide with the JVA Irrigation Directorate. This would allow the WUO to concentrate its efforts on that part of JVA controlling water deliveries to members.

As proposed above, the WUO could be the primary vehicle through which farmers receive training. As farmers become trained they will be better able to articulate their needs in the language understood by JVA; in effect they will educate JVA personnel to WUO member needs.

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[23] Reiss, P., J. A. Rashdan, and M. Hanbali. 1995. "Opportunities & options for participatory irrigation management in Central Jordan Valley." Water Quality Improvement and Conservation Project Report 3114-95-3b-02.

If JVA is decentralized or becomes a semi-governmental or quasi-private organization, the WUO could provide representatives to sit on a board that oversees the management and operations of JVA. In effect the JVA would become more like an Irrigation District in the US; managed and operated for the benefit of the irrigation water users. The current Board of Directors for JVA, ten members, does not have a designated position for a farmer or customer representative.

- To ensure good service, there must be some organization of customers to keep the pressure on the JVA.
- A study in the Central Jordan Valley found that the establishment of a pilot Water User Organization was feasible.
- A pilot Water User Organization should be established in the Central Jordan Valley.
- Establishment of a pilot Water User Organization requires a long-term commitment by a donor agency.
- Farmer training programs could be channeled through the Water User Organization.
- In the future, the Water User Organization can provide representatives to sit on the board that oversees JVA management and operations.

Management Information

Aside from the national importance of on-farm water use efficiency, JVA has a significant interest in the issue. Increasing the efficiency of on-farm water use will decrease the demand on pipeline delivery systems servicing developed areas. Decreased demand will in turn allow JVA more flexibility in the operation of the system allowing it to better meet its customers needs.

The JVA is encouraging the adoption of micro irrigation systems, systems that require the highest level of management expertise. It should be incumbent upon the organization to offer the follow-up engineering support required by the adopting farmers. In a new JVA, positions should be created at each water delivery directorate for personnel to assist farmers in the design, operation, and maintenance of micro irrigation systems.[24] Given that there are no qualified staff currently employed by the JVA, advanced degree training will

[24] The Jordan Valley Development Law No. 19 of 1988 states in Article 3 that the JVA shall undertake . . . The development of the water resources of the Valley . . .; also their protection and conservation . . . Article 4 gives the JVA authority to carry out all works required for implementation of projects specified in Article 3. . . regardless of whether these projects, in accordance with the provisions of any law, . . . are within the jurisdiction of a ministry . . . This language can be interpreted as giving JVA the mandate to work with on-farm irrigation, regardless of what the MOA extension service is doing.

be required for employees selected to fill these positions. Skills of assisting personnel can be upgraded through short-term, in-service, and on-the-job training programs.

Once farmers and assisting personnel are trained and begin working in the field, a serious information gap will be faced. There are no supplemental resources and information available to allow the farmer to fully benefit from his training. Weather information required for irrigation scheduling, re-calibrated evapotranspiration (ET) crop coefficients for trickle irrigation under mulch and plastic house conditions, and extension literature covering all aspects of on-farm irrigation water management, operation, and evaluation are unavailable.

A package of simplified irrigation management recommendations (i.e., timing and duration of irrigation applications throughout the growing season) is needed for each of:

- the major irrigated crops produced in a given area,
- the methods of irrigation used (drip, drip in plastic houses, surface irrigation),
- summer and winter growing seasons, and
- the major irrigated areas of Jordan.

This information must come from organizations other than the JVA. See Annex C for a draft proposal designed to meet this need.

- Since JVA is encouraging the adoption of micro irrigation systems, they should offer the follow-up engineering support required by the adopting farmers. This support could come from an Irrigation Advisory Service.
- Positions should be created at each water delivery directorate of JVA for personnel to assist farmers in the design, operation, and maintenance of micro irrigation systems.
- There are no supplemental resources and information available to allow the farmer to fully benefit from his training.
- Packages of simplified irrigation management recommendations (e.g., timing and duration of irrigation applications throughout the growing season) are needed for each crop.

Organizational Linkages

Sustainable irrigation water conservation can only occur where there is a concerted and coordinated effort by all players in the arena. To effectively conserve irrigation water the farmer needs information on daily crop water use, irrigation scheduling, quantities of water to apply at each irrigation, and efficient operation of the irrigation system. At a bare minimum, programs concerning irrigated agriculture conducted by the JVA, MOA, National Center for Agricultural Research and Technology Transfer (NCARTT), and the

Universities in Jordan should be coordinated. Each organizations' contribution can complement input from others to support irrigation water conservation.

The NCARTT and universities do applied research on crop water use, irrigation scheduling, and irrigation systems. All have significant bodies of research results that have never been used for extension materials. A major constraint in the preparation of extension literature is an apparent shortage of skilled personnel who can translate research results into something usable by farmers. To overcome this constraint a cadre of persons skilled in agricultural communication should be developed to transform research results into media from which farmers can benefit. The MOA Extension Service is responsible for getting the developed extension information to farmers.

Linkages with the Department of Meteorology and the Water Authority of Jordan are important because they collect the weather information used to calculate evapotranspiration (ET) requirements. Between collection of the weather data and use of the ET data, processing and dissemination must occur; this is best handled by the MOA Extension Service. Actual crop water use estimates and forecasts, based on ET calculations, should be translated into simple irrigation system operating parameters (when to irrigate and duration of irrigation at a given flow rate) for dissemination to farmers. Granted the universities and JVA could do the job but it is somewhat out of the normal scope of work for them. Dissemination of ET data is within the scope of work for the Extension Service; plus, the MOA has access to the communication channels; radio, press, and television.

- Programs concerning irrigated agriculture conducted by the Jordan Valley Authority, Ministry of Agriculture, National Center for Agricultural Research and Technology Transfer, and Universities in Jordan should be coordinated.
- A major constraint in the preparation of extension literature is an apparent shortage of skilled personnel who can translate research results into something usable by farmers.
- A cadre of persons skilled in agricultural communication should be developed to transform research results into media beneficial to farmers.
- Processing and dissemination of evapotranspiration data is best handled by the Ministry of Agriculture Extension Service.

Technical Assistance

The program outlined is a multifaceted and complex undertaking. The MWI and JVA do not currently have the trained personnel to implement such a program. Expatriate technical assistance is a must for the provision of guidance and training during program implementation. A multi-disciplinary expatriate team is recommended to assist in implementing the program.

One long-term specialist is recommended to assist in the transition of the irrigation sector in Jordan. This specialist should be an irrigation engineer with expertise in all facets of irrigated agriculture, i.e., an irrigation generalist rather than a subject matter specialist. This person would coordinate tasks of the program with the JVA, MWI and other involved organizations once a decision has been made to implement the program.

Recommended short-term expatriate specialist are:

- Irrigation Engineer — delivery systems operation and maintenance: Assist in the transition of the rigid rotation schedule to a limited rate demand schedule. Continue the skills building in delivery systems operations and maintenance began under the WQIC Project. The duration of this assignment will depend upon the results from the on-the-job-training program conducted under the WQIC Project. Additional time is allocated for this specialist under the WQIC Project.
- Agricultural Communications: There is a large body of research results available that could be turned into farmer focused extension literature. The Agricultural Communications specialist would use on-the-job-training procedures to develop a capacity in-country for preparing extension material from research results and other works. See Annex D for a draft scope of work for this specialist.
- Training Video Preparation Specialist: Certain training topics are best presented in a video tape format. The University of Jordan has state of the art video training equipment but lacks trained personnel to operate the equipment. This specialist would use on-the-job-training procedures to develop a capacity in-country for preparing training video tapes. See Annex E for a draft scope of work for this specialist.
- Water User Organizations: To date there are no service based farmers associations in Jordan and the commodity based organizations have had limited success. Intensive expatriate assistance is required to assist in the development of a structure for the organization, clarifying objectives, and developing an implementation plan. Periodic assistance will be needed until the organization is fully viable. Time is allocated for this specialist under the WQIC Project. Scheduling of the use of this specialist is dependent upon action by the JVA and MWI.
- Public Awareness: This specialist would work with the Water User Organization to develop a capability for informing the public and building a consensus on irrigation water related issues. Time is allocated for this specialist under the WQIC Project. Scheduling of the use of this specialist is dependent upon action by the JVA and MWI.

- One long-term irrigation engineer generalist is recommended to assist in the transition of the irrigation sector in Jordan.
- Recommended short-term expatriate specialist are:
  - Irrigation Engineer — delivery systems operation and maintenance: Assist the transition from a rigid rotation schedule to a limited-rate demand schedule.

- Agricultural Communications: use on-the-job-training procedures to develop a capacity in-country for preparing extension material from research results and other works.
- Training Video Preparation Specialist: use on-the-job-training procedures to develop a capacity in-country for preparing training video tapes.
- Water User Organizations: assist in the development of a structure for the organization, clarifying objectives, and developing an implementation plan.
- Public Awareness: develop a capability for informing the public and building a consensus on irrigation water use related issues.

ANNEXES

ANNEXES

ANNEX A

IRRIGATION WATER CONSERVATION, TRAINING AND COMMUNICATION PROGRAM

Background

On-farm irrigation in the Jordan Valley is transitioning from surface methods, primarily furrow for vegetables and small basins for orchards, to trickle and micro spray irrigation. The more modern methods offer savings in labor costs, higher yield potentials (giving higher returns per cubic meter of water used), and less fertilizer and chemical used, but are in fact about equal in achievable water application efficiency to well managed surface irrigation. It is a fallacious belief that trickle irrigation offers opportunities for higher efficiencies in water application. One must be careful however to separate water application efficiencies from total volume of water used. Compared to surface irrigation methods, trickle and micro-spray irrigation offers opportunities for reductions in the volume of water used for a crop because a smaller surface area and soil volume should be wetted at each irrigation.

The baseline survey of irrigation practices in the Central Jordan Valley shows that irrigation water use efficiencies for the "high technology" or trickle irrigation systems are significantly lower than efficiencies for surface irrigation. These low efficiencies are due to several factors.

- The price of water is too low to create an economic incentive for best use. Strict enforcement of reduced allocations is not practiced. These two approaches to conservation or "best use" of irrigation water are linked and have common demands if they are to work. For both cases, water deliveries must be controlled and accurately measured.

  The price of water is a political question and is not something the WQIC Project can change. It must be recognized however, that until the price of water delivery increases to a level where it has a significant impact on returns from a crop, irrigation water conservation will be minimal. For the conservation incentive expected from a higher water delivery fee to be realized, strict enforcement of water allocations must occur. The farmer does not feel the price increase otherwise, the cost of water is spread over legally and illegally obtained water.

  If the price of water cannot be raised, for political or other reasons, enforcing reduced deliveries can also be effective in encouraging water conservation. As with higher prices, enforcement of the reduced allocation is a must.

- Farmers use excess water as insurance against loss of yield due to water stress.

  The trickle systems with the lowest efficiencies are those in plastic houses. Farmers have a large investment in the production infrastructure and cannot afford a yield decrease caused by water deficit. Another contributing factor is that many farmers are not aware that over-irrigation, like under-irrigation, can cause yield decreases.

- During the winter season, farmers generally can get water more frequently.

There are few restrictions on water allocations in the winter crop season because there are insufficient storage facilities to capture the winter flood flows. The Jordan Valley Authority (JVA) delivers water to those farmers making requests. The feeling is that flood water used for leaching serves a higher beneficial use than that served by the water flowing unused into the Dead Sea. Once the Karameh Dam is completed, the quantity of water available for unrestricted use will diminish significantly.

- The irrigation water delivery system is not operated to service on-farm trickle irrigation systems.

  Trickle irrigation is designed to give the plant a small quantity of water each day to meet it's daily transpiration demand. The small quantity of water only wets from 50% to 60% of the volume of soil containing the roots of the crop. Therefore, to efficiently use trickle irrigation, farmers must irrigate daily during peak seasonal demand periods. Currently JVA delivers water two or three times weekly. As a result the farmer is forced to over irrigate, or store water in a pool, to ensure that enough water is retained in the root zone to carry the plant to the next irrigation period. Water flowing from a point source or emitter onto a loamy or sandy soil moves vertically at a more rapid rate than it moves horizontally. In order to fill the entire root zone large quantities of water are lost to deep percolation.

- Technical assistance on trickle irrigation system design and installation is not available to the farmer; most trickle irrigation systems are farmer designed.

  Most equipment sales agents and manufacturers do not offer no cost or low cost services to farmers. Consequently, most systems are farmer designed. There are private consulting engineers who sell services to wealthier farmers, but most farmers cannot purchase such services. Farmers seeking free or low cost information or assistance in the design and installation of their irrigation system have difficulty in obtaining either one. Trickle irrigation is equipment oriented and to achieve high efficiencies of water use requires sophisticated management. Without training and on-going assistance the benefits from trickle irrigation will not be fully achieved.

- No extension literature covering trickle irrigation system design, installation, operation, and maintenance is available to the farmer.

  Law No. 19 of 1988, Jordan Valley Development, in Article 3 states that the Jordan Valley Authority shall undertake the planning, design, construction, operation, and maintenance of irrigation water delivery and distribution networks. In no place does the law say the authority is responsible for assisting the farmer make best use of the delivered irrigation water. The current organization structure of the JVA does not have a division or office responsible for assisting farmers, and consequently no budget for such work. Also, there are no JVA personnel trained in on-farm irrigation methods and their proper operation and maintenance.

  The Extension Division of the Ministry of Agriculture (MOA) also does not have a program to assist farmers in on-farm irrigation. Similar to the JVA, the MOA has no personnel trained in on-farm irrigation methods and their proper operation and maintenance. Even more fundamental, the MOA Extension Division has no personnel

with an Agricultural or Civil Engineering background that could be trained in more than the most basic of irrigation principles. Given the void in required skills, it is not unexpected that extension literature on trickle and surface irrigation operation and maintenance has not been prepared.

The void in literature coupled with the absence of technical assistance means the farmer is left to struggle-by on his own and the country is not reaping the full benefit of the new irrigation technology; technology the government is encouraging the farmer to adopt.

Filling the Training and Information Void

Of the constraints to irrigation water conservation discussed above, it is in the provision of training, information, and assistance that the WQIC Project can have an impact. Under the Project, funds are designated for subcontracting with a Jordanian organization for Irrigation Management Training/Communication.[1] A subcontract has been written with the Water and Environment Research & Study Center at the University of Jordan to accomplish several tasks.

- Preparation of training modules on aspects of trickle irrigation design, operation, and maintenance;
- Field testing of the prepared modules;
- Evaluation of the field test and revision of the modules;
- Field testing of the revised modules; and
- A final evaluation and revision of the training modules.

WQIC Project team members from the MWI are involved in all phases of subcontract execution. During the field testing phases, some trainees will be drawn from the JVA and MWI and in effect trained as trainers. It is hoped that these persons, once trained, can continue to conduct training programs for other farmers.

Realistically, the training portion of the program is unlikely to be sustainable under current conditions. Though a body of material will be prepared, persons committed to using this material in training farmers, and those who work with farmers, do not exist. Commitment can only come through establishment of an office, with qualified personnel and an operating budget, responsible for assisting farmers to improve on-farm irrigation practices.

Jordan is facing increasing scarcities in fresh water supplies. Already increasing quantities of water is being diverted from Valley agriculture to municipal and industrial uses. In the not too distant future, steps will have to be taken to increase irrigation water use efficiencies if agriculture is to remain a vibrant part of Jordan's economy. At that time money will have to be allocated for training and extension activities and the training material developed under the WQIC Project put to effective use.

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[1] WQIC Project Contract, page 70 of 92, Table III, Comp. 3.b.

ANNEX B

VEHICLE AND EQUIPMENT REQUIREMENTS OF THE JORDAN VALLEY AUTHORITY

The Jordan Valley Authority (JVA) is moving from a new projects construction orientation to one of operation and maintenance (O&M) of existing infrastructure. GITEC (1994)[2] conducted a detailed review and assessment of JVA O&M methods, procedures, and services (including infrastructure, personnel, and institutional aspects). The review found:

- A shortage of transportation equipment for operation and maintenance staffs.
- An aging equipment pool that suffers greatly from break downs.

Table 4.5 in Volume II of the GITEC report lists the vehicles and equipment available and those needed for JVA to efficiently operate and maintain the existing irrigation water delivery infrastructure.

The attached lists of equipment and tools are the highest priority items of the Mechanical Directorate of the JVA and are essential for JVA to begin to improve water delivery service to their farmer clientele. A comparison with Table 4.5 (mentioned above) shows that the equipment requested in this document is less than that recommended by the GITEC report and reflects JVA's commitment to a more focused role in Jordan Valley water management.

The attached lists of vehicles and equipment are costed as follows:

• Vehicle and machinery needs for year 1995	$ 3,884,000
• Spare parts needed for each vehicle or machine	388,000
• Maintenance shop tools	89,000
• Maintenance shop equipment	663,000
• Shipping and other costs	978,000
• **Total estimated cost**	**$ 6,002,000**

Shipping and other costs are estimated at 25% of the purchase cost, with the exception of the machines from caterpillar which are inclusive of these costs. Cost estimates were obtained from US suppliers of such equipment and vehicles and are believed to be accurate as of June 1995. Upon approval of the purchase plan detailed specifications will be prepared.

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[2] GITEC. 1994. "Study for the Recovery of Operation and Maintenance Costs of Irrigation Water in Jordan," A study of JVA O&M functions funded by GTZ.

Vehicles and Machinery[3]:

DESCRIPTION	NUMBER REQUIRED 1995	1996	1997	ITEM COST	1995 COST
Utility Sedans — 4 x 4, 6 cylinder (Toyota Land cruiser or equivalent)	10	5	5	36000	360,000
Pickup — diesel, double cab, 4 x 4, 6 cylinder, 1/2 ton rating	35	20	10	26000	910,000
Van — 9 passenger, 6 cylinder, A/C, tourist type seats	2	—	—	27000	54,000
Bus — 20 passenger, 6 cylinder, A/C, tourist type seats	1	1	—	43000	43,000
Bus — 30 passenger, 6 cylinder, school bus type	2	2	1	42000	84,000
Side boom truck — extended length 4m (up to 6m preferred), retracted load limit of 10 tons, 10 ton flat bed truck	2	—	1	39000	78,000
Back hoe loader — on wheels (Cat 426B or equivalent)	2	2	1	112000	224,000
Wheeled loader — 1.8 m^3 bucket, 2.5 m^3 preferred (Cat 914G or equivalent)	2	2	1	76000	152,000
Excavator — on wheels (Caterpillar M318 or equivalent)	2	1	1	180000	360,000
Dozer — (Caterpillar D7H DS or equivalent)	2	1	1	295000	590,000
Multishank ripper attachment for Dozer, includes 3 teeth	1	—	—	25000	25,000
Grader — (Caterpillar 120G or equivalent)	2	1	1	149000	298,000
Truck with water tank — gear pump driven by truck engine - rear mount, 10 m^3 tank	3	2	1	60000	180,000
Fork lift — 3 ton capacity, inside use, solid rubber tires (Caterpillar DP30 or equivalent)	1	1	—	26000	26,000
Excavator — on tracks (Caterpillar 322L or equivalent)	2	1	1	250000	500,000
TOTAL					**$ 3,884,000**

Highest priority are the pickups and back hoe loaders.

[3] Vehicles are estimated by costing Ford Motor Co. equivalents, machinery costs are based on Caterpillar equivalents.

Spare Parts Needed for each Vehicle or Machine:
(cost estimated at 10% of purchase price)

Filters — oil, air, and fuel
Gaskets — head, exhaust manifold
Manuals — spare parts lists on microfiche, mechanical repair, electrical system repair
V-belts — water pump, cooling fan, a/c if installed, etc.
Wind shield wiper blades
Shock absorbers — front, rear
Rubber hoses — radiator top & bottom, fuel line, vacuum
Brakes — pads, shoes
Clutch — pressure plate, disk, throw out bearing
Steering — tie rod ends, tie rods, shock absorber
Tires
Drive shaft universal joints
Water pumps
Exhaust — pipes, mufflers, hanging brackets
Repair kits — Diesel injector pumps, carburetor, wheel brake cylinder, master brake cylinder
Diesel engine glow plugs, starting sensors

MAINTENANCE SHOP TOOLS[4]

Description	Item Cost	Number Needed	Total Cost
Floor jacks			
2 ton rating	100	4	400
5 ton rating	200	4	800
10 ton rating	400	4	1600
12 ton rating	500	4	2000
Hydraulic bottle jacks			
3 ton rating	25	4	100
5 ton rating	50	4	200
10 ton rating	60	4	240
Chain hoist — 4 ton, continuous chain, hand operated	550	2	1100
Come-along — 2 ton rating, wire cable	80	2	160
Mechanics creepers, steel wheels	27	10	270
Battery charger — 220v 50hz, for 12v & 24v batteries, 25A	270	2	340
Spray gun — auto refinishing with siphon cup	200	2	400
Air hose — 1/2 inch diameter, 200 psi rating		600 ft	360
Blow nozzles — air line type, straight	12	15	180
Body repair tool box	1,500	4	6000
Mechanics tool box	2,500	20	50000
Electrical repair tool box	1,000	4	4000
AC/DC volt/ohm meter, 500 amp, clamp type, digital	400	2	800
Hydraulic hose connection replacement tools, up to 2" lines		1 set	2500
Tire repair tools	700		700
Special tools required for each vehicle or machine, 2 sets	500	12 items	12000
Total			**$ 84,150**

[4] Prices based on McMaster Carr catalog No. 94 and prior experience in purchasing tools.

TOOL ROOM

Tool Item	Specifications	Cost
Air ratchet	3/4" drive	500
Drive sockets 6 point	3/4" to 1 5/8" Universal 3/4"	300
Adapter	3/4"F to 1/2"M	13
Torque wrench, digital readout, micro setting	3/4" 1/2" 3/8"	370 113 90
Torque multiplier, 1/2" input 3/4" output	4 to 1	300
Slate bar	1" stock, 60"	15
Timing light, digital		140
Torx screwdrivers, 6 pc. set	T10, T15, T20, T25, T27, T30	25
RPM meter		350
Vibration detector		1100
Sound level meter, 45 to 130 dB		310
Compression gauge & fittings	Gasoline engines	35
Compression gauge & fittings	Diesel engines	150
Metal cutter, center cut, heavy duty (bolt cutter)	42"	170
Pipe wrenches, heavy duty, straight	8" 12" 18"	11 16 26
Standard puller set		300
Chain wrench	13", 1/2" to 4 3/4" capacity	14
30° flare nut wrench (hydraulic lines)	11 pc. set	220

Total for Tool Room **$ 4,568**

MAINTENANCE SHOP EQUIPMENT[5]

Description	Cost
Exhaust pipe bending machine, including bending dies	6000
Air compressor — 34 cfm @ 175 psi, 120 gal tank, electric motor 220v 50hz	2000
Wheel alignment — four wheel, computerized	16000
High pressure steam cleaner — 150 gph @ 100 psi	2000
Vacuum cleaner — heavy duty shop type, stainless tank, 20 gal, wet and dry	400
Copy machine — Selex GR 1650 or equivalent	2000
Water distillation unit — 2.0 liters/hr	3000
Sheet metal shear — 380v 50hz, metal thickness to 10mm, 3m width	32000
Sheet metal bending — 380v 50hz, metal thickness to 10mm, 3m width, 1000 KN pressure	280000
Sheet metal roll — 380v 50hz, metal thickness to 20mm, 2m width, electrical adjustment	56000
Hydraulic stamping press — 900 KN rating, 380v 50hz, 80 cm x 90 cm bed	250000
TIG Welder — AC, 380v 50hz 30 amps, Argon-Helium Type	1000
Portable welder — diesel engine, 500 amps AD/DC, on wheels	9500
MIG-MAG welder — AC, 380v 50hz 30 amps, Argon-CO_2 Type	1000
Cutting machine — 380v 50hz, 16 inch diameter abrasive plate	2000
Total Estimate	**$662,900**

[5] Prices based on quotes from US manufacturers and McMaster Carr Catalog No. 94, all machines to include full safety shields and other safty features.

TOOL BOXES, MECHANICS[6]

Tool	Size	Cost
5 drawer cabinet, on wheels		150
5 drawer chest		100
Open end wrench	6 — 26 mm, 12 pc.	100
Combination	6 — 22 mm, 17 pc.	100
Box end	6 — 32 mm	100
Half moon box	6 — 19 mm	100
Flat screwdriver	set	25
Phillips	set	25
Spark plug sockets, universal joint	5/8" and 13/16"	12
Socket set, 1/2" with ratchet & extensions	6 — 22 mm, about 40 pc.	100
Socket set, 3/8" with ratchet & extensions	6 — 22 mm, about 40 pc.	100
Deep well sockets	1/2" drive, 6 — 32 mm	60
Deep well sockets	3/8" drive, 6 — 32 mm	60
Universal joints	1/2" and 3/8"	25
Adapter	1/2"F to 3/8"M	5
Measuring Tape	3 m	10
Air ratchet	1/2" drive	350
Drive sockets, 6 pt	10 — 27 mm	70
Hex key sets, mm and inch	short arm	10
Flat files	coarse and fine	16
Round files	coarse and fine	16
File brush		5
Feeler gauge	mm and inch	10
Head gasket file		15
Chisels and punches	set	45
Oil filter wrench		12
Hacksaw, hand		13
Pliers, Straight nose	5" & 6"	12
Bent nose	6 5/8"	13
High leverage	Side cutter 8"	13
	Adjustable 9 1/2"	8
curved jaw	Vise grip 7"	10
Retaining ring pliers, inside & outside	set, 6 1/2" long	23
Electric wire stripper	8 3/4" long	15
Hammers, ball peen	4 oz	10
	8 oz	11
	16 oz	12
Cross peen	32 oz	14
Sledge	8 LB	20
Hammer	16 oz	13
Rubber Hammer	small, 8 oz	11

[6] Ibid

	medium, 16 oz large, 2 1/2 LB	15 24
Ball joint remover	13/16" 1" 1 1/4"	20 25 30
Ball joint press		50
Pry bar, rolling head	12" 16" 20"	12 20 25
Pinch bar	7/8" stock, 30"	15
Brake pliers	19" long	23
Brake adjusting tools		50
Carburetor tools		50
Flexible magnet	21" long, 14" flex	8
Points screw driver	5"	10

Total per tool box **$ 2,216**

ANNEX C

DEVELOPMENT OF IRRIGATION MANAGEMENT EXTENSION LITERATURE AND AN IRRIGATION MANAGEMENT INFORMATION SYSTEM FOR MAJOR IRRIGATED AREAS OF JORDAN

Summary

The proposed project is a natural extension of two USAID sponsored projects in Jordan: the University Linkage Project (No. B/PCE-92-100), "Improving Management of Natural Resources in Jordan and Washington State through Cooperation in Applied Research and Technology Transfer and Graduate Education," between the University of Jordan (UJ) and Washington State University (WSU) and the Water Quality Improvement and Conservation (WQIC) Project (No. 278-0288-00-C-4026-00), being implemented by Development Alternatives, Inc. (DAI). The proposed project also builds upon existing linkages and cooperation between the Ministry of Water and Irrigation (MWI), University of Jordan, Ministry of Agriculture (MOA) Extension Service, and National Center for Agricultural Research and Technology Transfer (NCARTT).

Cooperative activities in applied research, technology transfer, and graduate education will contribute to a better understanding of technical, management, and institutional approaches to improving natural resources management through research. At the UJ, linkage programs and research are focused on:

- Increasing incremental water supply through water harvesting and artificial recharge,
- Monitoring water quality of major dams in Jordan,
- Determination of water consumption of major crops in Jordan and best leaching fraction,
- Studying the environmental impact of using treated wastewater for agriculture, and
- Testing new irrigation technology before transferring the technology to farmers.

Under the WQIC Project, materials for training farmers in irrigation system operation and maintenance, irrigation scheduling, and irrigation practices evaluation are being prepared by the Water and Environment Research & Study Center (WERSC) of the UJ. These materials will be field tested and trainers trained.

There is concern however that once the farmer is trained there are no supplemental resources and information available to allow him to fully benefit from his training. The proposed project is designed to meet these needs through:

- Applied field research to calibrate University of Jordan research findings to the different climatic zones of Jordan;
- Preparation of extension literature, including video tapes where appropriate, covering all aspects of on-farm irrigation water management, operation, and evaluation;

- Establishment of a farm weather information network encompassing weather data collection and dissemination of the information in a format that can be readily used by farmers for irrigation scheduling;
- Re-calibration of evapotranspiration (ET) crop coefficients developed for surface irrigation to trickle irrigation under mulch and plastic house conditions;
- On-farm demonstrations of scientific irrigation scheduling;
- Development of mechanisms for delivery of developed information to Jordan's irrigated crop producers; and
- Training of Jordanian personnel in pertinent government agencies.

Background

It is estimated that irrigated agriculture consumes 70% of Jordan's developed water resources. Scarce surface water supplies preclude further irrigation development and require judicious use of existing irrigation supplies. Recent studies in the Central Jordan Valley show that in general farms use excessive amounts of irrigation water and irrigation management efficiencies are below potentially achievable levels.

The Jordan Valley is the main irrigated agricultural and horticultural crop production region in Jordan. A wide variety of high value fruit, vegetable, field, and grain crops are produced in the Valley during summer and winter cropping seasons. Average annual rainfall in the Jordan Valley ranges between 100-150 mm in the South to near 350 mm in the North making irrigation for crop production essential.

The primary irrigation water carrier in the Jordan Valley is the King Abdullah Canal. In the North Valley irrigation water originates from the Yarmouk River. The Central and South Valley uses water from the Zarqa River (releases from King Talal Reservoir). In the winter months there is some mixing of the two sources of water. All deliveries to the farm gate are from gravity or pump pressurized pipelines fed from the KAC. A recent report on irrigated agriculture in the Central Jordan Valley indicated a total of 29,000 ha of land are equipped to receive water from the irrigation distribution network, but only 23,000 ha currently receive water due to scarce water supplies (ISPAN, 1994).

Primary on-farm irrigation methods in the Jordan Valley are drip irrigation of row crops, micro sprayer irrigation of widely spaced crops (citrus, grapes), drip irrigation in plastic houses (primarily vegetable crops), and surface irrigation. ISPAN (1994) reported that approximately one half of the farms in the Central Jordan Valley use drip irrigation and the remainder use some form of surface irrigation.

In an analysis of irrigation application efficiency (irrigation management efficiency) for crops produced during the winter season, ISPAN (1994) reported that inadequate management of high technology drip irrigation systems in the Central Jordan Valley resulted in lower irrigation management efficiencies, 56% or less on average for these systems, as compared to the conventional surface irrigation systems. Conventional surface irrigation systems were found to have an average irrigation management efficiency of 70%.

Even though water supplies for irrigation are tightly controlled in the summer, DAI (1995) reported irrigation water use trends similar to those found for winter.

The primary factor contributing to low irrigation management efficiencies for drip systems was identified as a lack of knowledge by farmers about crop irrigation water requirements, the timing and durations of irrigation throughout the growing season. This was especially evident in plastic house culture where drip irrigation management in the house was the same as drip irrigation management in the open field. Crop ET inside plastic houses is up to 40% less when compared to the open field.

Engineering evaluation of the distribution uniformity of the drip systems determined the systems were physically capable of distributing water with acceptable uniformity. Most problems due to emitter clogging result from inadequate water filtration and/or treatment.

Irrigation water use could be significantly reduced by improving the irrigation water management decision making capabilities of Jordan's farmers. This would save water and, in some areas, allow expansion of irrigated crop production areas. Irrigation scheduling information (crop water use rates, crop coefficients, etc.) has been developed through considerable research (detailed later) conducted by UJ scientists at the University Research Farm in the Central Jordan Valley. This information needs to be verified and calibrated at other Jordan Valley locations and other irrigated crop production locations in Jordan. After calibration the information needs to be appropriately packaged as easy to understand and easy to implement irrigation system operational parameters, i.e., how long to irrigate to replace soil water used since the last irrigation.

A relatively recently developed, higher elevation, irrigated production area for tree fruits is located near Shoubak, about 180 km south of Amman. This area receives an average annual rainfall of about 200 mm. The Shoubak production area consists of approximately 2,500 ha of irrigated fruit. Although drip irrigation is used for irrigation of the fruit crops in this area, ground water resources are being overdrafted. Improved operation of on-farm irrigation systems could reduce stress on the aquifer.

Overview of Relevant Irrigation Research in Jordan

Faculty in the Department of Soil and Water and the UJ/WERSC, have been conducting research in the Jordan Valley for over 10 years. This long-term research effort has developed a large body of information relative to crop water use patterns and water use-yield relationships for many of the major irrigated crops produced in the Jordan Valley.

Research on water consumption and crop coefficients for different irrigation methods and crops were conducted in the Central Jordan Valley. Crops studied included okra (Ghawi et al., 1986), broad beans and beans (Ghawi and Shatanawi, 1987), wheat and barley (Shatanawi et al.,1987), corn (Ghawi, 1988), cauliflower and water melon (Ghawi et al., 1989). Irrigation production functions have been developed for wheat (Shatanawi et al., 1987), potatoes (Oweis et al., 1988), tomatoes (Oweis et al., 1988) and snap beans (Oweis et al., 1990) grown in plastic houses in the Central Jordan Valley.

Objective

The objective of the proposed project is to develop a package of irrigation management information (irrigation extension literature) for Jordan's irrigated crop producers, which would provide simplified irrigation management recommendations (i.e., timing and duration of irrigation applications throughout the growing season). This information will be developed for each of:

- The major irrigated crops produced in a given area,
- The methods of irrigation used (drip, drip in plastic houses, surface irrigation),
- Summer and winter growing seasons, and
- The major irrigated areas of Jordan.

Daily crop water use estimates and forecasts will be derived by applying daily crop coefficient values to daily reference ET estimates computed using weather parameters from automatic weather stations to estimate actual crop water use. Actual crop water use estimates and forecasts will translated into simple irrigation system operating parameters (when to irrigate and duration of irrigation at a given flow rate).

Important ancillary objectives of the project are:

- Training selected personnel of agencies and institutions in Jordan (Jordan Valley Authority (JVA), MWI, NCARTT, MOA Extension Service, etc.) through formal training sessions and on-farm laboratory exercises. The training would use materials prepared under the WQIC Project.

- Providing Ph.D. level education and training in the US to a Jordanian scientist in the area of irrigation water management. Upon successful completion of the program the scientist would have responsibility for the operation, management and continuing development of the Irrigation Management Information System.

- Providing MS level education and training in the US to two Jordanians in the areas of agricultural communications, extension literature preparation, and educational video production. Upon completion of the program the two persons would become actively involved in the extension literature and video tape preparation phases of the project.

SCOPE OF WORK

The work described in detail in the following sections will be conducted in four locations: 1) the North Jordan Valley, 2) the Central Jordan Valley, 3) the South Jordan Valley, and 4) the Shoubak fruit growing area. On-farm applied research and demonstration trials will be conducted during each of three summer and winter growing seasons. The focus will be the major irrigated crops produced in each area during each season (i.e., citrus in the North Jordan Valley, vegetables in open field and vegetables in plastic houses in the Central and South Jordan Valley, and tree fruits (primarily apple) in the Shoubak area). Training of Jordanian personnel will be conducted each year of the project, concurrent with establishment of the automatic weather station network and on-farm demonstrations. Ph.D.-level graduate education of a Jordanian student at WSU will be initiated in the first

year of the project. A detailed timeline for the project is included in a later section of this proposal.

Goals

To achieve the research and training objectives, the following project goals are identified:

- Within the first four months of the project identify and establish in each of the four locations cooperator farms (three or four per location) on which on-farm demonstrations of scientific irrigation scheduling will be conducted. Install at each location an automatic weather station equipped to collect daily total solar radiation, temperature, relative humidity, wind speed and direction, and rainfall. Install at each location a screened Class-A evaporation pan.
- Evaluate the layout, design and operating parameters of typical irrigation systems used in each of the four areas (primarily drip, drip in plastic houses, and furrow irrigation) during the first annual cycle (summer and winter growing seasons) of the project. This information will add to the baseline data developed by WQIC Project.
- Using available long-term weather records (daily temperature and rainfall) develop long-term daily average reference ET estimates for as many locations as possible in the major irrigated crop production areas of Jordan. This work will be accomplished during the first year of the project.
- Develop, test, and refine packages of irrigation management recommendations through on-farm testing and demonstrations with cooperating farmers in each of the four locations. This work will begin the first full growing season after initiation of the project and extend through three annual cycles. Calibrate and verify crop coefficients and crop water use for the major irrigated crops produced in each of the four locations. Document crop phenology (planting, germination, vegetative development, and other growth characteristics). Annual results will be used to refine irrigation management recommendations for successive years.
- Develop training materials (fact sheets, slide sets, videos, etc.) in both Arabic and English languages in subject areas such as on-farm water management, scientific irrigation scheduling, crop water use (seasonal patterns, environmental effects, etc.), and soil water monitoring and measurement. These new materials will build upon the body of material prepared under the WQIC Project.
- Train selected personnel from agencies and institutions in Jordan (JVA, MWI, NCARTT, MOA Extension Service, etc.) on field implementation of the results from the applied research. This training would continue for each year of the project.
- Provide Ph.D. level education, at WSU, of one Jordanian student in irrigation water management. The program would begin the first year of the project.
- Provide MS level education, at a US university, to two Jordanian students in agricultural communications and extension literature preparation. The programs would begin the first year of the project.

Methodology

Four work areas will be identified and established: in the North, Central and South parts of the Jordan Valley and in the fruit growing area near Shoubak. It is anticipated that cooperating commercial farms will be identified in each area on which field demonstrations will be conducted. Incentives for these cooperating farms to participate in the project include upgrades and design improvements to their irrigation systems (including new filter stations, fertilizer injection units, partial system automation, etc.) and possibly insurance against crop loss. These incentives have been included in budget estimates.

An automatic weather station and Class-A pan evaporation station will be installed in each area. These will allow the computation of reference ET on a real-time basis using daily measurements of solar radiation, temperature, relative humidity and average wind speed. Daily reference ET will be computed using the Penman-Monteith combination equation. Class-A pan evaporation will also be used to compute reference ET. In the Central and South Jordan Valley, where plastic houses are widely used for crop production, pan evaporation measurements will also be made inside the plastic houses.

A representative sample of irrigation systems in each location will be surveyed and evaluated using standard irrigation system evaluation procedures. The survey and evaluation will determine design and layout characteristics and typical operation and management parameters. These data will be added to the database of irrigation system design information already developed in the WQIC Project baseline study. Where these are found to be relatively standard, irrigation management recommendations can be easily simplified, i.e., irrigate so many hours per week to meet crop ET requirements.

Long term weather records (i.e., daily temperature and rainfall) will be collected and validated for as many locations as possible in and near the major irrigated crop production areas of Jordan. These weather records will then be used to compute long term daily average reference ET estimates using a temperature based ET equation such as that by Hargreaves. These long term daily average reference ET estimates can be used with appropriate crop coefficients to forecast crop ET for the coming period (i.e., week, etc.).

Irrigation management recommendations for each crop and system type will be developed as follows:

- Crop coefficient and automatic weather station reference ET data will be used to compute actual crop ET. When accumulated over the period of time between irrigations this represents the depth of water that needs to be applied.
- The results of the irrigation system surveys will be used to translate the required depth of water application into required hours of irrigation considering irrigation application rates and efficiencies. Ideally such recommendations would be developed for each given crop at discrete intervals of the growing season.
- Crop ET forecasts for the coming period (next week, etc.) will be translated into forecasts of the expected hours of irrigation needed for the next irrigation in order to meet the expected crop ET.

The packages of irrigation management recommendations will be tested and refined in on-farm scientific irrigation scheduling demonstrations at each location. Crop coefficients will be calibrated and crop water use verified in each location during the demonstrations. Initial crop coefficient values used in computing the actual ET for each crop will be those developed through research at the UJ Research Farm near Deir Alla, or where local values are not available, published values from FAO Report No. 24: "Crop Water Requirements."

Appropriate measurements will be made on the cooperating farms to refine irrigation management recommendations and to assure that adequate levels of irrigation water are indeed being applied. Irrigation applications will be carefully measured in all demonstrations. A weekly soil water balance will be computed for each field using weekly neutron probe or time domain reflectometry (TDR) soil water content measurements in the root zone of the crop. The residual soil water balance will be an estimate of weekly crop ET. The estimated crop ET values will be compared with crop ET values computed from crop coefficients and reference ET. With this information for each week of the growing season, crop coefficients may be appropriately calibrated. Leaching requirements will be calculated based on measured salinity of the irrigation and soil waters and published salt tolerance values for each crop.

Crop growth stage data and yields will be measured for each water treatment level. These data will be used to locally calibrate crop coefficient data and to establish "typical" crop production schedules. Soil water content measurements will be used to monitor under irrigation, to assure the grower that his crops are not being water stressed, and excessive water application, loss of applied water to deep drainage below the root zone of the crop. In addition, the range of measurements to be made will help determine water savings and improvements in irrigation application efficiency on the cooperating farms.

Extension-type fact-sheets, brochures, slide sets, videos where appropriate, and other training materials will be prepared in both Arabic and English languages on the results of this project, e.g., irrigation management information for each of the major crops by area and method of irrigation. The development of these training materials is a complementary and natural extension of the training materials on farm irrigation systems prepared under the MWI/WQIC Project by the UJ/WERSC. A short-term US consultant specializing in Agricultural Communications and Extension Literature Preparation will be brought in for three weeks to conduct a workshop on the preparation of extension literature prior to the preparation of any material to be released to farmers. A draft scope of work for this specialist is found at the end of this proposal. The same specialist will return for three weeks, later in the project, to evaluate the literature prepared and to give "brush up" training as required.

After topics have been identified that are suitable for production of video tapes, an expert in the preparation of training video tapes will be brought in to conduct a workshop on the design and production of videos. A draft scope of work for this specialist is found at the end of this proposal. The same specialist will return after the script and story board are completed in draft and raw footage has been shot. At this time the specialist will critique the work completed, assist in finalizing the script and story board, supervise the narration recording, assist in editing the raw footage, and assist in final preparation of the video. At all stages of his assignment on-the-job-training will be conducted.

Training of selected personnel of relevant agencies and institutions in Jordan (JVA, MWI, NCARTT, MOA Extension Service, etc.) on the results of this project is essential. This training will be conducted concurrent with the establishment of the work locations and the development of the irrigation management information system. These activities will be conducted in close cooperation with MOA, WQIC Project, and NCARTT personnel.

Training will consist of formal workshops and hands-on experience with the on-farm demonstration work. Mechanisms for implementation and dissemination of the irrigation management information to farmers will be explored and developed with the assistance of these agency personnel. It is expected that this training will be given several times at each work location, as information packages are refined. Feedback from these agencies and personnel is expected to stimulate the development of additional information packages.

A Jordanian student/scientist with at least an MSc in soils and irrigation will be identified during the first few months of the project for Ph.D. level training in irrigation water management at WSU. It is expected the successful candidate will work closely with the listed US Principle Investigator at WSU. The expected duration of the Ph.D. program will be four years. Potential candidates for this program must possess superior academic and English language skills. The early identification of the candidate is essential so that a Ph.D. topic having relevance to the stated purposes of this project and to Jordan and Washington State irrigated agriculture may be identified (in support of the stated objectives of the UJ and WSU University Linkage Project) This will also allow the preparation of potential Jordanian supporting data sets for analyses at WSU.

Two Jordanian students will be identified during the first few months of the project for MS level training in agricultural communications and extension literature preparation at a selected US university. By completing the program early in the project, the students can return and assist in the preparation of extension literature resulting from the applied research efforts. During their graduate programs, both students should be exposed to the training video design and production process.

Linkage Development, Cooperation and Institution Building

The work proposed by this project is meant to enhance and sustain the efforts of two current USAID sponsored projects in Jordan: the WQIC Project and the UJ/WSU Linkage Project. The development of an irrigation management information system for Jordan is a natural extension of the WQIC Project irrigation component. A stated objective of the UJ/WSU Linkage Project is to strengthen the applied research and technology transfer capabilities of the UJ/WERSC. The proposed work involves UJ experts in the soil and water area in the development, evaluation and refinement of the irrigation management information system. Additionally, Ph.D. level training of a Jordanian scientist at WSU in collaboration with WSU experts in the development of such irrigation management information systems will enhance the sustainability of the final products, strengthen linkages between the MWI and the UJ, between the UJ and WSU, etc. The expected training efforts and the continued operation and development of a Jordan irrigation management information system will enhance cooperation and linkages between the MWI, MOA, NCARTT and MOA Extension Service.

It is expected that an advisory committee of representatives from the MWI, WQIC Project, UJ, NCARTT, MOA, and USAID will be established and meet regularly to review progress of the proposed work and make recommendations to enhance the work plan and help assure successful results.

Reporting

The following reports and literature will be prepared during the course of this project:

- Extension-type fact sheets on irrigation water management recommendations for each of the irrigated crops studied. The sheets, prepared in both Arabic and English, will give details for each irrigation method and location. These will be used in formal training sessions with Jordanian agency personnel and in training of farmers.
- Summary reports will be prepared after each growing season detailing the results of the on-farm demonstrations. A total of six such reports will be prepared. The first two reports (for the first summer and winter cropping seasons) will include results of the irrigation system surveys and evaluations.
- A summary research report will be prepared detailing the available long-term climate data, verification of the data, methodologies used, and computed long term reference ET values for each location where long-term climate data are available.
- A mid-term progress report detailing the progress and results obtained during the first half of the project.
- A final project report detailing the results of the project and providing a recommended framework for the continuing operation, maintenance and development of a Jordan Irrigation Management Information System.

Should the dissertation research of the Ph.D. student involve (partially or in whole) data from irrigation research in Jordan, the student would be expected to prepare summary papers and or reports of the work accomplished apart from the dissertation.

Principle Investigators

Dr. Muhib Awwad, Assistant Professor, Soil and Water Department, Faculty of Agriculture, University of Jordan

Dr. Ibrahim Ghawi, Professor, Soil and Water Department, Faculty of Agriculture, University of Jordan

Dr. Thomas W. Ley, Extension Irrigation Engineer, Biological Systems Engineering Department, Irrigated Agriculture Research and Extension Center (IAREC), Washington State University, Prosser WA, USA

Dr. Muhammed Shatanawi, Director, Water and Environment Research and Study Center, University of Jordan

Cooperators

Dr. Abdel Nabi Fardous, Director of Water Research and Irrigation Management Program, NCARTT, MOA

Director, Agricultural Extension and Information Division, MOA

Irrigation Component, WQIC Project, MWI

A Jordanian scientist with a minimum of an MSc in soil and water will be identified and employed by the project as a research associate and will have responsibility for day-to-day management of project activities. Field research staff will consist of B.Sc. level research technicians (one for each of the Jordan Valley locations) housed at the University Research Farm, and a cooperating researcher from the Regional Agriculture Service Center of NCARTT, Ministry of Agriculture, in the Shoubak location. It is proposed that the three B.Sc. level field research assistants in the Jordan Valley would be matriculating graduate students in the Dept. of Soil and Water, Faculty of Agriculture, University of Jordan working towards their MSc degrees. Field labor will be employed from time to time to assist field research activities.

Overall project coordination and management is the responsibility of the principle investigators.

Project Duration

4 years (1 January 1996 - 31 December 1999)

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Timeline

	1996				1997				1998				1999			
Activity	Ja	Ap	Jl	Oc	Ja	Ap	Jl	Oc	Ja	Ap	Jl	Oc	Ja	Ap	Jl	Oc
Identify and establish cooperative farm sites	—	—	—													
Ph.D. student at WSU	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Install automatic weather stations and evaporation pans		—														
Summer crops:																
On-farm applied research and demonstrations		—	—	—		—	—	—		—	—	—		—	—	—
Reporting				—				—				—				—
Winter crops:																
On-farm applied research and demonstrations				—	—	—	—	—	—	—	—	—	—	—	—	
Reporting							—				—				—	
Irrigation systems surveys and evaluations		—	—	—	—	—										
Preparation of extension training materials		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Training of Jordanian personnel		—		—		—		—		—		—		—		—
Mid-term Progress Report								—	—							
Final Report															—	—

ATTACHMENT A

QUALIFICATIONS OF PRINCIPLE INVESTIGATORS

Dr. Muhib Awwad is an Assistant Professor in the Department of Soil and Water, Faculty of Agriculture, UJ.

Dr. Ibrahim O. Ghawi is a soil physicist and Associate Professor in the Department of Soils and Irrigation at the UJ. The main emphasis of Dr. Ghawi's research is soil water management in irrigated regions, mainly in Jordan's rift valley. Dr. Ghawi has studied the effect of plastic mulches on water conservation. Dr. Ghawi is studying the actual and potential ET of major crops in the Central Jordan Valley using drainage type lysimeters. Crop coefficients for different empirical equations and class-A pan evaporation were determined for these crops. Dr. Ghawi is studying the scientific irrigation scheduling of major crops under plastic houses by using class-A pans inside plastic houses. Studies were conducted by Dr. Ghawi to determine production functions of the main crops as they are affected by irrigation amounts. Dr. Ghawi was the team leader for the baseline survey of irrigation water management and water quality in the Central Jordan Valley. Dr. Ghawi has supervised M.Sc. students working in the above listed areas.

Dr. Thomas W. Ley is Extension Irrigation Engineer and Associate Professor in the Department of Biological Systems Engineering of Washington State University. Dr. Ley is stationed at the WSU Irrigated Agriculture Research and Extension Center in Prosser, WA. Dr. Ley was the Principle Investigator in the design and development of the Washington Public Agriculture Weather System (PAWS) , a network of 61 remote automatic weather stations located in irrigated Central Washington State. Dr. Ley is currently the manager of PAWS. Dr. Ley is responsible for the design, development and delivery of extension education programs in the areas of irrigation system design, operation, evaluation, and improvement; crop water use and irrigation management; irrigation water quality; and irrigation energy use. There are approximately 800,000 irrigated hectares producing some 65-70 different irrigated crops in the area Dr. Ley serves. The main activities relative to the PAWS network are development of extension education materials and design and implementation of on-farm demonstrations in scientific irrigation scheduling using the crop water use estimates generated by the PAWS network.

Dr. Muhammed Shatanawi is Director of the Water and Environment Research and Study Center (WERSC) and Professor in the Department of Soil and Water, Faculty of Agriculture, UJ. Dr. Shatanawi has wide expertise in water resources management, irrigation systems design and management, design of water distribution networks, water harvesting and the environmental impacts of water and irrigation projects. He is heavily involved, in cooperation with the WQIC Project, in the preparation and field delivery of on-farm irrigation system operation and maintenance training material for farmers. Dr. Shatanawi has over fifteen years of experience in water resources and irrigation. He worked for FAO as an expert in water and irrigation in Egypt. Dr. Shatanawi is involved with many applied research topics related to irrigation water use

and the environment. He has more than 30 publications in irrigation modeling and management; water resources planning and policy. Dr. Shatanawi is the former head of the Department of Soils and Irrigation at the UJ.

ANNEX D

AGRICULTURAL COMMUNICATIONS
EXTENSION LITERATURE PREPARATION SPECIALIST

I. SCOPE OF WORK

Within two weeks of arrival the consultant will conduct a workshop covering at a minimum: communication methods, how farmers learn and are motivated; selection of appropriate communication method based on information to be conveyed, leaflet, brochure, pamphlet, radio message, video, poster, etc.; and preparation of effective training material, each communication method will be covered. At the end of the workshop the participants will emerge with an action plan to complete development of extension materials. Workshop attendees will comprise members of research teams and staff from the MOA, MWI, NCARTT, Universities in Jordan, and implementing Project. In the two weeks before arrival of the expert, a team from the implementing Project and universities will collect background data and information and begin preliminary planning for preparation of the extension material.

Following the workshop the expert will assist attendees, and cooperators from other organizations, in developing the first sets of extension materials to be released to farmers under the project.

II. QUALIFICATIONS

A minimum of 5 years experience working with the preparation of extension materials for use by working farmers on topics related to on-farm irrigation water management and conservation. The consultant must be knowledgeable about adult education principles and the field testing of agricultural self-instruction materials. Graduate education in the principles of extension work and extension materials preparation, or closely related subject area, is required. Experience in developing countries is desirable.

III. TIMING

The workshop should be held after personnel receiving M.Sc. degrees in the US have returned. This will allow these persons to receive on-the-job-training to supplement their theoretical or class room instruction.

IV. DURATION

First assignment, including the workshop, should about eight weeks. This would allow adequate time to prepare and conduct the workshop and allow time afterwards to assist in the finalization of the first extension materials.

A second assignment of about six weeks should occur within eight months of the first. During this second assignment, another workshop should be held to reinforce and refine skills developed at the first workshop and by material preparation during the intervening period.

ANNEX E

TRAINING VIDEO PREPARATION SPECIALIST

I. SCOPE OF WORK

Within two weeks of arrival the consultant will conduct a workshop covering at a minimum: equipment requirements, camera for shooting raw footage, video and audio recording and editing equipment, character generator; topic selection, what subjects are suitable for video; planning the production process, the logic behind the planning sequence; script writing, what makes a good script; story board preparation; selection and shooting of raw footage, how to select scenes, camera movement, blank tape preparation (logging); narration recording, what qualities are required in a good narration, selection of narrator; editing the raw footage, blank tape preparation (logging), selection of scenes to use with narration; and final editing/preparation of the video. In the two weeks before arrival of the expert, a team from the implementing Project and selected workshop attendees will collect background data and information and begin preliminary planning for preparation of a training video tape.

After the workshop the specialist will assist workshop attendees in the preparation of a training video tape.

II. QUALIFICATIONS

A minimum of 5 years experience working with the design and production of training videos for use by working adults. The consultant must be knowledgeable about adult education principles and the preparation of self-instruction materials. Graduate education in the principles of training video design and production is required. Experience in developing countries is desirable.

III. TIMING

The workshop should be held after personnel receiving M.Sc. degrees in the US have returned. This will allow these persons to receive on-the-job-training to supplement their theoretical or class room instruction.

IV. DURATION

First assignment, including the workshop, should about twelve weeks. This would allow adequate time to prepare and conduct the workshop and allow time afterwards to assist in the finalization of the first training video.

A second assignment of about eight weeks should occur within one year of the first. During this second assignment, another workshop should be held to reinforce and refine skills developed at the first workshop and by video tape preparation during the intervening period.