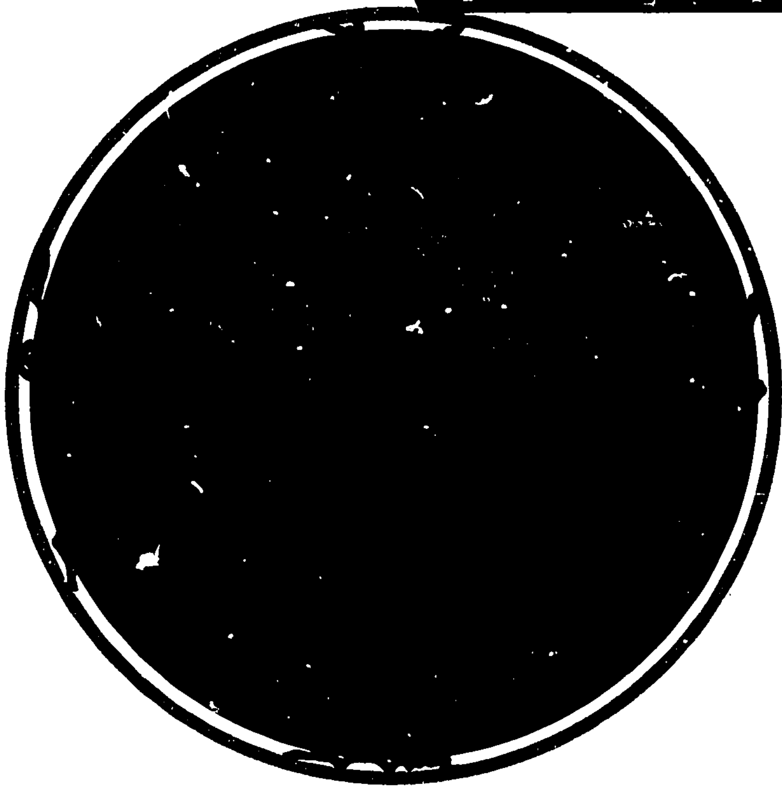

REVIEW OF IRRIGATION FACILITIES OPERATION AND MAINTENANCE

JORDAN

USAID

WATER MANAGEMENT SYNTHESIS II PROJECT
WMS REPORT 30

REVIEW
OF
IRRIGATION FACILITIES
OPERATION AND MAINTENANCE

for

JORDAN VALLEY AUTHORITY

USAID/Jordan
March 22 - April 20, 1984

All reported opinions, conclusions or recommendations are the sole responsibility of the authors and do not represent the official or unofficial positions of any agency of the governments of Jordan or the United States or of the Consortium for International Development or Utah State University.

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WMS Report 30

PREFACE

This study was conducted as part of the Water Management Synthesis II Project, a program funded and assisted by the United States Agency for International Development through the Consortium for International Development. Utah State University, Colorado State University and Cornell University serve as co-lead universities for the Project.

The key objective is to provide services in irrigated regions of the world for improving water management practices in the design and operation of existing and future irrigation projects and give guidance for USAID for selecting and implementing development options and investment strategies.

For more information about the Project and any of its services, contact the Water Management Synthesis II Project.

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The support of USAID/Amman staff members in various details of the study is appreciated. Special thanks go to DeAnn Draper and Karen Hammer for the production of the manuscript and to Linda Fields and JoAnn Biery for their valuable editorial suggestions. We express our gratitude to the many others who assisted in any way toward the successful completion of this report.

JORDAN/USAID

REVIEW OF IRRIGATION FACILITIES OPERATION
AND MAINTENANCE FOR JORDAN VALLEY AUTHORITY

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At the invitation of the Jordan Valley Authority (JVA) and with sponsorship of USAID, a study Team inspected the JVA irrigation facilities; visited with many operation and maintenance personnel in the Jordan Valley and with administrative officers in Amman; discussed system performance and expectations with a number of farmers in the Jordan Valley; and reviewed numerous design documents and consultant reports. The Team was composed of three expatriate engineers and one engineer from the JVA.

The Team realizes that much of what is presented in this report has already been mentioned elsewhere. Although we do not make a point of giving credit to all written or verbal inputs, it is not our intent to receive undue credit but rather to summarize our own and others' thinking on Operations and Maintenance (O&M) of JVA's irrigation facilities.

Conclusions

Water Charges and Costs

The current water charge is 3 fils per cubic meter (1000 fils equals 1 Jordanian Dinar, [JD]; 1 JD = $2.75 US). This is not a trivial charge; it is a moderate charge relative to typical agricultural water charge. For example, it is equivalent to 30 JD per hectare/meter, $82 US per hectare/meter, $10 US per acre/foot, or $0.03 US per 1000 US gallons.

Unfortunately, this current water charge falls short of covering the O&M cost of the Jordan Valley irrigation systems; the 3 fils do not even cover the cost of billing the farmers. The actual O&M cost is 7 to 10 times higher, i.e., 21 to 30 fils per cubic meter. The JVA intends to increase water charges over a period of time until they covered the O&M costs, but this is politically difficult and, while a charge of perhaps 25 fils per cubic meter may be a problem for producers of high value fresh market vegetable and fruit crops, it may be an almost overwhelming burden to producers of lower value processed vegetables and ordinary field crops.

An important reason why O&M charges are high per unit of water delivered is because the system only accounts for the delivery of about 500 mm of water over the approximately 240,000 dunums (du) (24,000 ha) served. Competition for water is high at critical times during the year and the system has to be operated continuously throughout the year. Furthermore, in order to assure a reasonable degree of equity throughout the system, the JVA provides delivery services to the headgates of each farm unit. In addition, the project serves a long, narrow and complicated irrigated area.

Water is very valuable in the Jordan Valley. In comparison with wells, the capital plus operating cost of pumped water from private tubewells in the region is estimated to be more than 30 fils per cubic meter. For the most part, private tubewells are only used to irrigate high value crops. Furthermore, farmers with their own wells have complete control of their water supply so tend to pay a premium for this security. At any rate, this gives evidence that farmers are willing (and can) pay more for their water.

Operation and Maintenance

The Operation and Maintenance Department in the Jordan Valley has kept the water distribution systems sufficiently maintained to deliver water for more than 20 years without major problems or interruptions of service. Furthermore, the system boasts of having an 87 percent conveyance efficiency at normal flow, disregarding spillage losses and unbilled deliveries. During low flows the conveyance efficiency averages from 70 to 80 percent. From the available records the Team estimated that in normal years only about two-thirds of the salable water is billed.

The equity of distribution is quite good because the JVA has placed a high priority on assuring that each farm unit receives its fair share of water. Upon a system of farmer-initiated requests, during critical (low) flow periods in the main crop season, each farm unit probably receives approximately 70 percent or more of its fair share of the delivered water (part of the variation is due to variations along the length of main canal).

Achieving this has been costly since the JVA services and maintains the distribution system up to the turnout of each farm and provides water distributors (ditchriders) to control and monitor the quantity of water delivered to each farm unit. The Team felt that there was room for savings in distribution and maintenance cost of the small laterals by turning some of this responsibility over to the farmers. Further savings could be achieved by more efficient deployment of and better transport for the JVA ditchriders.

Although the cost of O&M is high and the system has provided basic reliability, it is not particularly well maintained. This is especially true for the more sophisticated mechanical equipment associated with the pressurized pipe networks. In addition, weed, debris and sediment control along and in the East Ghor Main Canal and main laterals is not handled in a systematic and efficient manner. For the most part O&M personnel do not appear very effectively occupied. The study Team believes that a better and more cost effective job of maintenance could be achieved by a well organized and properly equipped but smaller staff.

Operation and Maintenance Manuals

The Team searched for but was unable to find comprehensive manuals covering the details for the system. Not only were manuals not available for the field personnel, adequate manuals were not available anywhere in the JVA. The Team assembled all the useful manuals discovered and, in fact, did find suitable manuals giving O&M instructions for the Hisban-Kafrein Sprinkle Irrigation Scheme and the associated pumping plant. The Team speculated that similar manuals for other schemes and stages of the project were never adequately provided. However, some useful documents were discovered for the mechanical portion of Stage 6 (18 Km Extension).

Central Workshop and Spare Parts

In view of the newly constructed central workshop and the effort which was being placed on staffing and outfitting it, the Team spent little time investigating needs in this area. In general, we did concur with manufacturers on the desirabilility of maintaining an inventory of approximately 10 percent spare parts, or a year's supply of spare parts. These general guidelines should be modified in accordance with actual field experience. To do this requires careful inventory control and continuous analysis of the rate of parts outflow and time lag for replenishing the inventory. We did not see this being done.

Water Scheduling and Computerized Assistance

The current method of managing the daily water balance of the East Ghor Main Canal is based on a simple analysis of inflows and anticipated outflows. No systematic flow or stage measurements are made along the canal. The accuracy and workability of this operational strategy depended on the expert judgment of the Canal Inspector (water master or operations engineer) and his assistants. In the Team's opinion, the canal is being operated quite well considering the complexity of the system and method of operation employed. However, there is opportunity for more precise water management to improve the equity of distribution along the length of the Main Canal, reduce spillage, optimize reservoir releases, and give farmers more accurate advice on irrigation scheduling and water availability.

The Team has studied the various reports on the automation of the Main Canal and the proposed computerized management information system. We felt this was an ambitious program and concurred with GERSAR that it should be carried forward with caution and by stages or steps. Flexibility should be maintained and the early steps should be modest. Each step should be tested in a geographic area where appropriate, and modified to fit local conditions, capabilities and confidence levels.

In addition to the computer monitoring and telecommunications hardware needed, much must be done in the area of canal inlet and outlet flow measuring and control hardware and software. Furthermore, a very large amount of information must be obtained and kept up-to-date in terms of areas planted by crop, irrigation application efficiencies, and estimates of consumptive water use from the north to south end of the Main Canal as well as by crops, soils and planting dates.

The Team agrees with GERSAR's comments that the proposed Computerized Management Information System is larger and more complex than anything as yet installed (worldwide) for managing an irrigation system; and that it would have been good if the JVA had begun some time ago to develop the capacity and control systems which were essential for such an operation. Thus, we felt that as a starting point full and immediate advantage should be taken of the DEC PDP-11 Computer which is now located at the new Section II office in the Valley to begin a modest program of computer assisted system management.

Assumptions

The Team's comments and recommendations are presented in view of the following assumptions:

1. That the desire at the upper administrative levels of the JVA to improve the efficiency and effectiveness of the operation and maintenance of the JVA's irrigation facilities will also be shared at the operational and supervisory management levels. This is the single most important issue facing the JVA in the effort to improve the operation and maintenance of their irrigation facilities;

2. That the JVA can find a way to provide the necessary incentives, fringe benefits, high morale, and/or working conditions to attract and retain competent employees at all levels;

3. That there is some effective mechanism by which the JVA can and does reward employees for superior performance by increased salaries, added benefits and/or formal recognition; and that there is also a realistic mechanism for reprimanding or discharging employees whose performance is unsatisfactory;

4. That the JVA is in a position to reorganize the staffing of the O&M Department, within the existing budgetary limits, to improve performance and efficiency. This may require redeployment of personnel to increase the staffing in critical areas at the expense of reducing staffing in less critical areas;

5. That the JVA can find the means to purchase, maintain and operate the few pieces of new and different equipment necessary for more efficient O&M of their irrigation systems;

6. That the JVA can find the necessary resources to rehabilitate and modernize the Jordan Valley Irrigation Project on a critical but very limited level;

7. That the newly constructed and soon to be staffed Central Workshop and Maintenance Stations for the JVA, which are being established with German assistance, are adequate for the mechanical maintenance needs of the JVA projects;

8. That the JVA can, in a practical political sense, control the equitable distribution of water to the individual farmer so that the area of farmland receiving unusually favorable water supplies during critical periods is very limited. The Team considers very favorable supply to be between 125 and 150 percent of the average supply received by each farm unit, and by very limited area we mean less than 10 percent of the area served;

9. That the JVA has an effective and politically practical means for disciplining farmers who steal water and the JVA employees who assist them;

10. That although the 3 fils/m^3 charged to the farmers for water only covers about 10 percent of O&M costs, the JVA's objective is to optimize the water use economics; and

11. That the JVA has practical control over the flexible deployment of resources between operation, maintenance, rehabilitation and modernization.

The Team realizes the difficulty in developing the will to improve system performance at all levels, providing adequate incentives, and disciplining personnel. This may be particularly difficult under the circumstances in the Jordan Valley, but we did observe many examples of dedicated peformance by adequately trained personnel and believe that the human potential does exist. Recommendations which might assist in validating certain of the above assumptions are:

-- Assumptions 1, 2 and 3 might be better realized by: a more participatory management system (including farmer and the JVA field worker inputs); a reduction in the number of employees so that each job or position requires full-time effort; a better definition of the timing and ranking of preventive and routine maintenance; a streamlining of operational procedures using a computer assisted water management program; and a system of inspection, reporting, and monitoring to improve accountability;

-- Assumption 8 could be better realized by allowing the farmer to collectively manage more of the delivery system. For example, farmers could be responsible for opening and closing their own turnouts along each lateral (or lateral network) serving from 10 to 20 farm units. The ditchriders would be responsible for regulating the flow into the laterals and for training the farmers in adjusting their turnouts and monitoring their performance. Community run systems have been successful in the past and the surface systems in old Stage 5 are still being operated in the above manner by the farmers; and

-- Assumption 9 might be better achieved by modifying the system of fines for water related offenses. The Team feels that the current fine of 150 JD is excessive for a first-time offender. Thus, there is a strong reluctance to levy it and consequently it is seldom used. A sliding scale of, say, 15 JD for the first offense increasing to 150 JD for the third offense might be more realistic for water stealing. Fines might also be levied for vandalism and throwing or placing debris or garbage in the channels.

Recommendations

These summary recommendations are divided into the general areas of: irrigation systems maintenance; water scheduling and distribution; organization and staffing; and training.

Canal Cleaning

Upon inspecting the distribution system and evaluating the approaches to maintaining it, the Team feels there are better and more cost effective ways and strategies to keep the main and lateral canals clean of sediment, gravel and weeds.

Recommendations. The Team recommends the following:

-- Immediately clean the sediment from the Main Canal. This can be accomplished with one or a combination of three methods:

  - Utilization of a piece of equipment similar to the dragline presently being used, with the exception that it should have a telescoping arm and be operated entirely from the operator's seat.

- A hydraulic dredge that works within the canal.

- A piece of steel that is the shape of the canal cross section and is towed down the canal, accumulating sediment in front to be removed with a dragline (crane). We suggest that the dredge and steel sheet be used on a trial basis to determine their suitability under actual site conditions. Any piece of equipment for main canal cleaning should be dedicated to that purpose and used for the full daylight period.

-- Weeds and grasses should be removed from within the canal and along its banks to halt their establishment in the concrete expansion joints. Weeds can be controlled by herbicides, cutting or burning with a torch. Sediments cleaned from the laterals should be moved away from the edge and hauled away or spread along in the right-of-way. All rock and debris should be hauled away so they cannot be thrown back into the canal.

-- Sterner efforts must be made to control the large quantities of garbage from getting into the canal. Methods to control this include providing better garbage service, education, levying fines, or fencing or piping along the more populated areas.

-- The banks of both the Main Canal and laterals should be reshaped wherever they are encroaching on the channel and providing a source of debris which can be easily dislodged by rain, animals or humans.

Preventive Maintenance

The Team noted that the existing program of service and maintenance of structures, channels and mechanical equipment is on an as needed basis. With this approach, periodic rehabilitation and modernization will be needed. The Team believes that it would be more cost effective to improve the preventive maintenance program.

Recommendations. The Team recommends that a routine program of preventive maintenance be established for the conveyance system and mechanical works. We also recommend that an annual inspection of the system be implemented. This should take place during a concentrated one- to two-week period and involve the Vice President of the JVA, the Director of O&M and his subordinates. A prioritized list of achievable maintenance items would be developed for the coming year. This should be followed by an annual field day in which the President of the JVA would spend two days reviewing the project and the goals achieved from the previous year.

Pressure System Modification

Few farmers used sprinkler irrigation as planned for in the development of the pressurized pipe distribution networks. These were designed to deliver a continuous flow of 4 lps to each farm unit of 40 du. Instead, farmers preferred to receive water only during daylight hours with larger flows of 8-10 lps so they could more conveniently utilize a combination of trickle, sprinkler and surface irrigation application systems. In order to obtain the larger flows, the farm units have been vandalized so that the flow control mechanisms are inoperative. The Team feels that in view of this reality, the pressurized systems should be modified to better serve the farmers' needs.

Recommendations. Instead of leaving the flow and pressure control valves inoperative as they are on the American farm turnouts, (FTOs), and with 4 lps flexible flow control orifices on the French FTOs, all FTOs should be outfitted with 8 lps flexible flow control orifices. In addition, the hydraulics of the pipe distribution networks should be studied and, where practical and feasible, parallel lines should be installed to increase flow capacities. A rotational irrigation water delivery strategy should then be employed so that almost all farm units (except those adjacent to the canal) will be provided with sufficient pressure to operate trickle systems without booster pumps.

The variations in discharge and inadequate pressure within the pressurized pipe distribution networks with American FTOs result from the vandalism which has been done to the pressure/flow regulator valves. Rather than repair the valves, the Team recommends that they be replaced with flexible flow control orifices as suggested above. An alternate would be to repair the existing valves, replace the 1.4 inch fixed orifices with 8 lps orifices, and provide a protective vault for each of the American style FTOs.

Computer Assisted Operations

The Team has studied the distribution procedures and policies at the Main Canal and lateral distribution system levels. We feel that given the practical realities in the Valley, the equity of water distribution within the individual sections (stages) is reasonable except in the pressurized pipe networks with American FTOs. However, we believe there is opportunity to improve the equity of distribution along the Main Canal. Furthermore, by computer assisted management (using better stage and flow measurement of inputs and outputs, plus information on crop water use) overall system delivery efficiency could be improved by 10 to 20 percent.

Recommendations. In view of the potential cost-effective benefits which can be derived from a computer assisted approach to managing the

Main Canal inputs and outputs, the Team recommends that a program be initiated immediately utilizing the mini computer now on hand. A two- or three-person computer management group should be set up and an advisor with expertise in on-farm and canal system water management should be contracted to aid them in assisting the Main Canal Inspector and Study Section with a computer assisted water management system. The Team recommends this as a first and essential step in developing the more comprehensive computer assisted and automated management system now being considered.

O&M Manuals

The study Team was unable to locate an appropriate set of documents and instructions for operating and maintaining the JVA irrigation systems. In fact, we believe the Hisban-Kafrein Sprinkle Irrigation Scheme is the only subproject for which an appropriate set of manuals was developed and even these were not available to the personnel in charge of operations.

Recommendations. The study Team commended the O&M instruction manuals developed for the Hisban-Kafrein Schemes and recommends that these be used as a model for all the JVA irrigation systems and subsystems. In addition, as-built drawings of the distribution network and structures along with pertinent details on the maintenance of the various mechanical devices should be available to the appropriate personnel. The Team cautions that these manuals and drawings should be updated to reflect changes and that master copies of all current documents, manuals and plans needed for O&M be kept in a vault in the JVA library and at least two field copies made available in the Valley (one at the Central Workshop, and one on-site). The Team gathered all of the manufacturer's catalog cuts and service instructions which were found in the JVA library (and left them with Dr. Beni Hani). To develop the needed set of manuals, the Team recommends that a consultant familiar with the O&M of similar irrigation systems be retained to assist in expanding this available material into a comprehensive set of O&M manuals. In all future project expansions, ten sets of manuals similar to those provided for the Hisban-Kafrein Scheme diversion works, distribution system, and pump station should be included as part of the contract.

The consultant retained for developing the O&M manuals should also assist in developing an organizational chart and job descriptions for the O&M personnel. The Team believes that between 18 and 24 person months of consultancy time will be required for the above and to assist in training the O&M staff.

Management

The Team observed an expensive and relatively ineffective management system for the operation and maintenance of the Jordan Valley Irrigation

Scheme. The levels of responsibility were too diffuse and too many decisions depended on the Director of O&M and the Section Managers. Official work hours seemed to be loosely controlled. Professional staff moral appeared low. Too many workers had specialized functions which only occupied a small part of their time, but they were not asked (required) to help with other needed, useful activities. There seemed to be a lack of instructions (and availability of appropriate as-built drawings and manuals) for use in the field. Finally, in many cases work loads appeared minimal.

Recommendations. The Team does not feel confident with dealing in depth with the above issues in the Jordanian social structure. We feel that the Director of O&M and Section Managers are very important positions and must be staffed with exceptionally capable professionals. We approve of the recent reduction in personnel and reorganization of the O&M Department and suggest that further reductions would be appropriate. We recommend that work loads and accountability be analyzed carefully and further reductions in personnel be made where appropriate. Job descriptions should be assigned for each position and, where feasible, workers should be assigned dual or secondary functions to fill in slack times. We do not understand the appropriate mechanisms for Jordan, but recommend that more attention be directed to improving morale and that spot investigations (checks) be employed to focus on improved performance. To assist with the above, the consultant retained to help develop the O&M manuals should be utilized.

Design Quality Control

The Team visited the Southern Ghor Project presently under construction and believed that the contractor on-site was doing a good job; however, because of improperly prepared design plans and specifications, too many change orders were required and this caused the JVA to spend a considerable amount of time and effort in processing and approving them. Moreover, the consultant was not fulfilling his duties as the JVA's representative.

Recommendations. The Team recommends that the consultant be reminded of his responsibility or removed. Replacement could be by an outside consultant or JVA personnel. For future design work, the Team recommends that when the final design is about 75 to 90 percent completed, a "Value Engineering" team be brought in to perform a very thorough review of plans and specifications. The purpose is to review the overall project concept and evaluate ways of meeting the project objectives and construction procedures in a more efficient and cost-effective manner. In all cases we are familiar with, "Value Engineering" has saved the owner money by the time the project is operable.

Portable Sprinkle Equipment

Very little of the portable sprinkle equipment that was acquired by the JVA for sale to the farmers has been purchased by them. The JVA should not be overly embarrassed by this because this resulted from technology changes which took place after the new project extensions had already been designed and were being implemented.

Recommendations: The Team recommends that up to three-quarters of the remaining portable sprinkle equipment should be used elsewhere in Jordan or sold to the highest international bidder. The remaining equipment should be rented or sold for leaching and/or growing appropriate crops.

Farmer Participation

The Team noted that in Stage 5 the farmers were responsible for managing the allocation of water deliveries between themselves. We also have noted evidence of older community developed, managed and maintained irrigation systems in the local areas. We have discussed the possiblities for more farmer involvement in system management and maintenance with a number of JVA officials and their general reaction has been that this is unworkable because of the individualistic nature of the farmers. However, the officials do generally agree that more farmer participation would have the potential of reducing O&M costs.

Recommendations: The Team recommends that a socio-engineering study be conducted to gain an understanding of the potential for greater farmer participation in the operation and maintenance of the Jordan Valley Irrigation Project. The output of this study should be a recommendation to continue current operating policies or a detailed plan for testing and implementing a program involving greater farmer participation in project management.

Training

To improve O&M and establish a computer assisted accounting and water management program, specific training will be required.

Recommendations. The Team recommends that the following training programs be set up:

-- Special training will be required for the computer group recommended above. At least two professional [illegible] should have sufficient training to be capable of manipulating and revising the water management programs. (Recent graduates from accredited computerized engineering bachelors and masters programs would ordinarily have sufficient computer training.) Such training will require approximately three months of essentially full-time effort on the part of graduate engineers. This type of training is available in Jordan.

-- Short course training programs should be set up for technicians who will be inputing and utilizing the computer. These short courses will take approximately one week and can be developed by the adviser recommended above for setting up the computer assisted management program. The graduate engineers mentioned above could be instructors for the short courses.

-- When the O&M manuals are completed, they can be used for hands-on instruction of the field personnel. Such instruction should be formalized and presented in appropriate short courses. The field personnel should not only be instructed in the specific functions they are to perform, but they should also become acquainted with the whole system to better understand the importance of their position. The O&M consultant could help develop the required training programs. The actual training materials should be presented (and written) in Arabic by the supervisory staff with assistance from local training specialists.

-- Periodic (at least quarterly) half or full day training sessions should be developed for all supervisory and technical staff. Such sessions could be lectures, field day visits to various features of the project, visits to specific farms, or general information sessions in staffing and operating procedures, etc.

-- Two civil engineers from (or who will be assigned to) the O&M Department should be selected for three to six months of on-the-job training in the U.S.A. or Europe. They should be assigned to work in the O&M departments at irrigation projects which have similar situations to the JVA systems.

INTRODUCTION

This study was initiated at the request of the President of the Jordan Valley Authority (JVA). The original scope of work for the study Team was initially specified as follows:

-- Study the existing pressurized irrigation system in the Jordan Valley, both the design and operational aspects, and recommend ways of improvement. Included will be an evaluation of maintenance personnel activities, equipment, spare parts inventory and control, recommendations for new or different staffing patterns, training requirements, equipment modifications, etc;

-- Study the open irrigation network with a view towards improvement in the O&M system as outlined above;

-- Advise the JVA on procedures for cleaning and maintenance of the canal system while filled;

-- Advise on water scheduling and water demand and release, and review proposals being made for computerizing the irrigation system in the Jordan Valley and Southern Ghors; and

-- Visit the Southern Ghors and Wadi Araba and review irrigation programs underway, especially the O&M procedures.

In addition, the JVA requested that the Team provide guidelines on the development of O&M Manuals for projects in the Jordan Rift Valley.

It was requested that the study Team be composed of four engineers, three expatriates and one from the JVA. The Team was instructed to conduct the entire study and develop a draft report during a three-week period beginning in mid-March 1984.

Study Approach and Itinerary

The study Team began with a rather random approach to addressing the scope of work. The Team visited the Jordan Valley and had unannounced discussions with various farmers and JVA employees, and inspected the physical works for five days. In between visits to the Jordan Valley, the Team searched the JVA's library for pertinent documents, studied documents, and visited the JVA personnel in Amman. Two additional announced and scheduled visits were made to the Valley and a single day visit was made to Southern Ghors. The full Team spent the remainder of the three-week period in Amman reviewing documents, writing the report and in debriefing sessions with the JVA and USAID. Keller and Serpekian continued for an additional week to finalize a rough draft of this report and hold further debriefing sessions. Details of the Team's itinerary are presented in Appendix A.

JVA Irrigation Projects

Detailed descriptions of the various JVA projects are contained in the numerous related design documents and reports. This section outlines the scope and locations of the JVA irrigation projects. Figure 1 shows the general location of the Jordan Valley and Southern Ghors (between Mazra'ah and a few kilometers south of Safi in the vicinity of the south end of the Dead Sea) irrigated areas.

Jordan Valley

Figures 2 and 3 show the present development and planned new development, respectively, in the Jordan Valley. The East Ghor Main Canal (EGMC), which is the main carrier in the Jordan Valley, has a capacity of 20 m^3/sec at the inlet end and, when completed, will be approximately 110 km long as indicated on Figures 2 and 3. Besides the direct diversion from the Yarmouk River, water is also supplied from various side wadis, springs and, more recently, wells (which are not shown on the maps). In addition to uncontrolled (river and spring) and controlled (well) flows, there are four important reservoirs: Wadi Arab (19 MCM), Wadi Ziglab (5 MCM), King Talal (52 MCM) and Wadi Kafrein (5 MCM), which provide some controlled flow (see Figure 4).

In the Jordan Valley, the standard size of farm units is 40 du (4 ha) and the existing systems directly and indirectly serve approximately 6000 farm units. Table 1 shows an approximate breakdown of the existing irrigation system. Water resources in the area are very limited and in order to conserve water, beginning in 1972 all new areas have been provided with pressurized pipe distribution systems having an average delivery capacity of approximately 0.5 liters per second per hectare (lps/ha). This flow rate will provide approximately 4 mm gross application per day to each 40 du farm unit. The main cropping season is between October and May and during drought years (like in 1983-84) water could only be delivered about 50 percent of the time which only provided about 2 mm/day.

Fortunately, much of the citrus area is being converted to sprinkle irrigation and the banana and vegetable areas to trickle irrigation. During the winter months, the vegetable areas only require about 2 mm/day under trickle irrigation. Approximately 15 percent of the irrigated area is already under trickle irrigation. It is estimated that the farmers may install trickle irrigation on up to 75 percent of the area in the near future providing the fresh fruit and vegetable markets are sufficient.

The surface irrigated areas under the EGMC (see Figure 2 and Table 1) serve approximately 135,000 du (13,500 ha). Farm units vary from 3 to 5 ha and are served from trapezoidal concrete lined channels (see Table 1) with each farm unit turnout equipped with a constant head

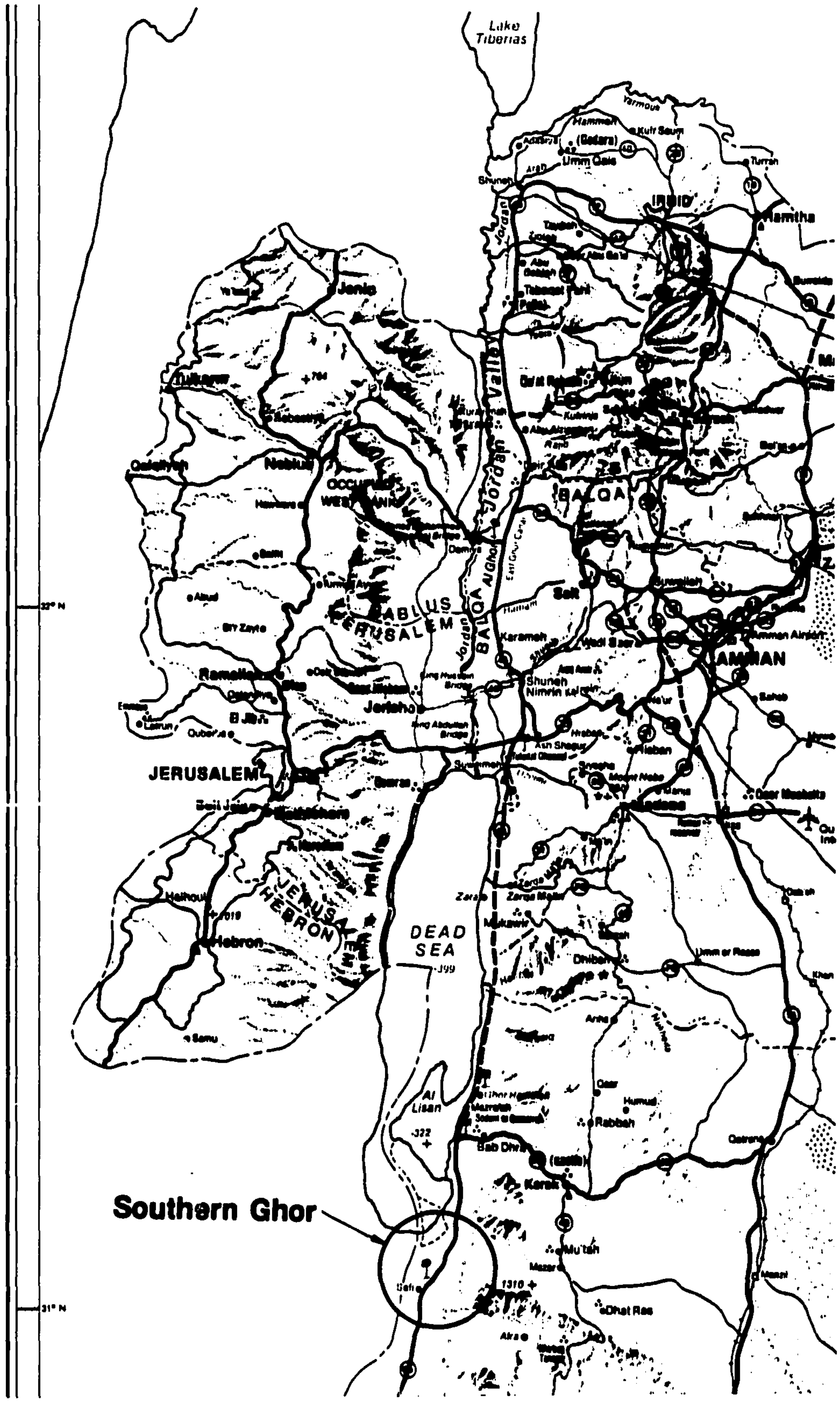


Figure 1. General Location of Jordan Valley and Southern Ghors.

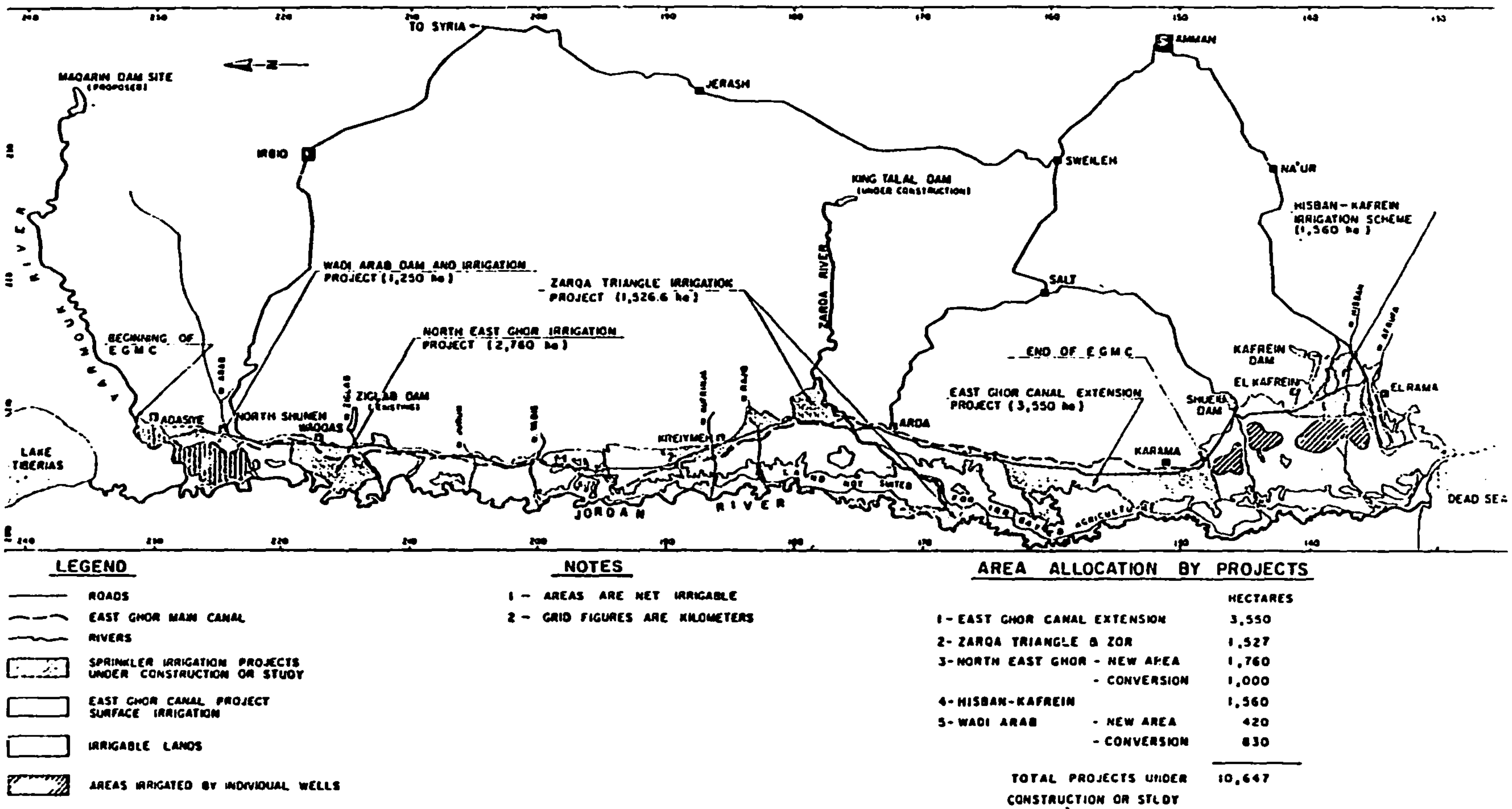
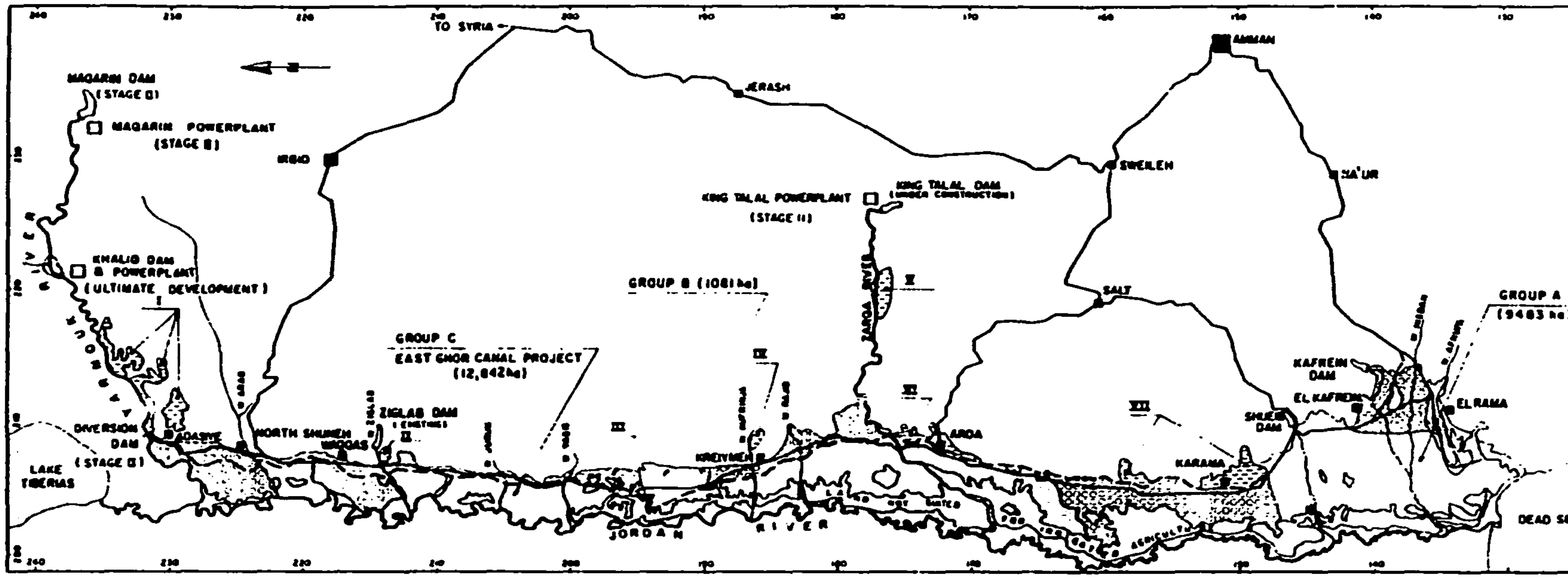


Figure 2. Present Development of Irrigation in the Jordan Valley (Dar Al-Handasah Consultants [Shair and Partners]), April 1977.



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II - ZIGLAB GORGE	50
III - BETWEEN KUFRINJA & YABIS	432
IV - KUFRINJA GORGE	100
V - ZARQA GORGE	216
VI - SOUTH OF ZARQA	293
VII - ABOVE 18Km EXTENSION	525
TOTAL	1947

STAGE II PROJECT AREA

	HECTARES
CONVERSION LANDS (INCLUDES UPGRADED AREAS)	12,842
NEW LANDS	10,564
POTENTIALLY IRRIGABLE LANDS	1,947
TOTAL	25,353

TOTAL AREA

ON GOING PROJECTS	9,397
JAPANESE PROJECT ON WADI ARAB	1,250
STAGE II LANDS	25,353
TOTAL	36,000

Figure 3. General Plan of Irrigation Development for the Jordan Valley (Dah Al-Handasah Consultants [Shair and Partners]), January 1978.

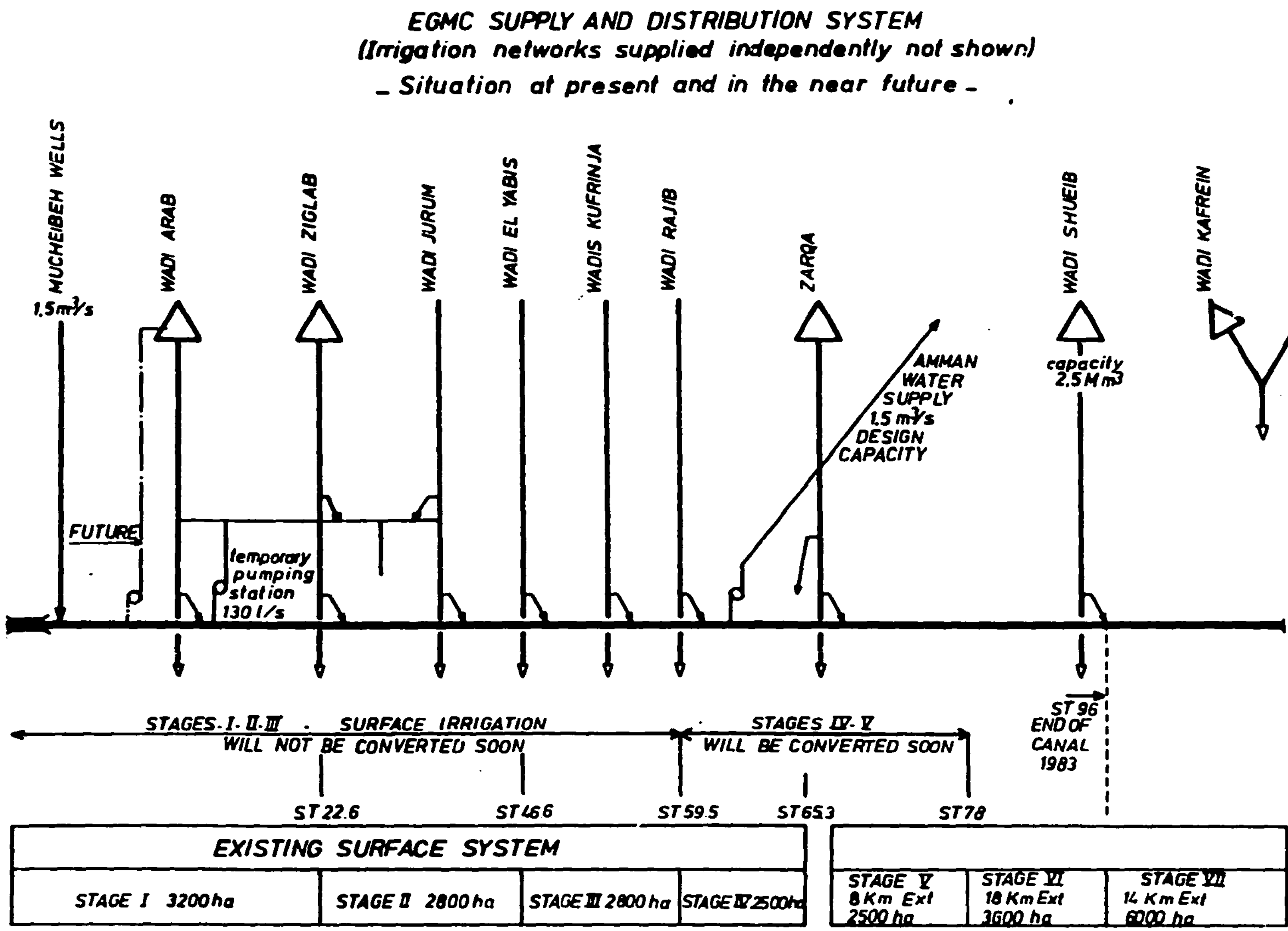


Figure 4. Schematic of East Ghor Main Canal Supply and Distribution System. (Taken from GERSAR Report "Management Information System - Water Management System," September 1983.)

Table 1. Approximate Breakdown of the Irrigated Areas Served by Existing Surface Channel and Piped Distribution Systems in the Jordan Valley.

Section	Type System	Project	Farm Units	Main-Lateral Canals	Tertiary-Lateral Canals km	Planted Area			
						Citrus	Bananas	Vegetable	Cereals
I	Surface	Stage 1	998	23	98	14064	1449	18186	1685
I	Surface	Stage 2	990	34	86	8617	50	27188	2858
II	Surface	Stage 3	507	24	70	3726	332	19606	1041
II	Surface	Stage 4	1183	17	125	1800	-	21700	7185
III	Surface	Stage 5	430	15	61	661	-	15043	3314
III	Piped	Stage 6	993	47	133	100	data not available		
I	Piped	North/ East	701						
II	Piped	Zarqa Training	291						
III	Piped	Zarqa Zr.	116						
III	Piped	Hisb.- Kafrein	475			250	350	15553	100

orifice flow control gate. Most of these open channel canal distribution networks were completed by 1962.

More recent project expansions (since 1972) utilizing pressurized pipe networks cover approximately 10,000 du with about 12,500 du more soon to be completed. Plans are to use pressurized pipe networks for any future extensions of the system and to convert the existing 135,000 du of surface channel distribution systems to pressurized pipes. In the pressurized portions each farm unit is equipped with a turnout structure and buried pipeline with hydrant outlets along its edge. Each farm turnout is provided with flow and pressure regulators, an isolation valve and a flow meter. Unfortunately, most of the turnouts have been vandalized and the flow control, pressure regulator and flow meters are badly damaged.

Gravity pressure sufficient to operate sprinkle or trickle application systems is available for large areas; however, where the natural pressure is insufficient adjacent to and above the water supply, electric powered pumping stations are called for. At present there are only five pumping plants in operation. Plans call for another 27 pumping stations to complete the expansion to new lands and the conversion of the existing open channel distribution systems to pressurized pipe networks.

Southern Ghors

The Southern Ghor Irrigation Project is being planned to serve a total of approximately 90,000 du of trickle irrigated lands. The various subsystems will provide filtered water under a minimum pressure head of approximately 20 m to each farm unit. The average farm unit size is 30 du (3 ha) and each unit will be provided with an average flow rate of approximately 3.3 lps for 6 hrs/day. This is equivalent to 0.027 lps/du on a continuous flow basis which is sufficient to meet a crop water requirement of 2 mm/day, assuming an 85 percent application efficiency.

The Southern Ghor Projects receive their water from spring flows which have diurnal flow variation of up to ± 15 percent. This is compensated for by holding ponds at the pipeline headworks. In addition, the pipelines are designed to carry an extra 15 percent flow to accommodate seasonal flow variations. The pipe delivery systems are assumed to be 92 percent efficient (6 percent operating loss and 2 percent leakage). Pressure is provided by gravity to the lower reaches and by pumping for the higher reaches. Phase I of the project which is now being constructed, will serve approximately 2,600 ha near Safi and another 2,300 ha in ghors, north and south of Safi. These subprojects will be commissioned during 1984 and 1985.

MAIN AND SUBSYSTEM OPERATION AND MAINTENANCE

The main canal and subsystems are the lifeline of the Jordan Valley. Interruption in the delivery of irrigation water any time of the year could be costly to many project farmers. Therefore, it is of utmost importance that the system be properly operated and maintained. The operation and maintenance items needing attention will be pointed out in this chapter. Once these items are taken care of, preventive maintenance is highly recommended.

Operation

At present, the East Ghor Main Canal (EGMC) extends some 96 km in a southerly direction from the outlet tunnel below the Yarmouk River Diversion headworks. The main canal runs along the east side of the Jordan River Valley and crosses several significant side drainages such as Wadi Arab, Wadi Ziglab and the Zarqa River. It also passes near many villages or towns such as North Shuneh, Deir Alla and Arda along the path to the present termination near Karama. The EGMC is a trapezoidal concrete lined channel with a bottom width of 3 meters and side slopes of 1 to 1.5 (vert:horiz). The depth varies from 1.8 to 2.9 meters. The design flow is 20 cubic meters/second (cms) at the head end, reducing to 8 cms at the lower end of the 18 km extension (96 km). The design capacities and other descriptive information are summarized in Table 2. The bottom slope is 0.00018 from 0-70 km and 0.00028 from 70-96 km. Plans call for a 0.00010 slope from 96-110 km for the 14 km extension.

There are 35 check structures consisting of a 3-meter wide, manually operated radial gate with symmetrical side overflow weirs, two on each side of the gate, for a joint crest length of 3.7 m. Flash boards are used for adjusting weir overflow heights. Other structures include 11 siphons and three flumes across various wadis, several waste ways for flushing and numerous side drainage overshoots and bridges. There is one 3-bay trapezoidal weir measuring structure towards the northern end of the canal. Many submain and lateral turnouts are installed directly on the main canal. These turnouts have steel gates which vary in width from 110 cm to 120 cm. The gates are manually operated by the ditchriders who use a wrench (called a "key") to adjust them.

Water Allocation

The water supply and allocation is controlled by the Canal Inspector who determines the water inflow to the EGMC from the tunnel and uncontrolled side wadis (W. Jurum, Yabis, Kufrinja and Rajis) each day. The computed inflows are reduced by 15 percent in winter and 30 percent in summer to estimate the available water supply after accounting for canal and lateral seepage and evaporation losses. The available supply

Table 2. Current and Projected Capacities of the East Ghor Main Canal.

Chainage (km)	Capacity (m^3/s)	Notes
0		(Intake Channel 0 to 0.130)
	20	(Tunnel 0.130 to 1.080)
19.020		
	19	End of Irrigation Stage 1
22.771		
	18	
37.345		
	17	
43.447		
	16	End of Irrigation Stage 2
46.991		
	17	(36 m long Flume)
47.027		
	16	
53.985		
	15	
58.088		Ends of Irrigation Stage 3 (approx 59.5)
	13	and Irrigation Stage 4 (65.290)
65.290		
	12	(Zarqa Siphon 65.290 to 66.011)
69.850		
	10.87	End of Irrigation Stage 5 (8 km Extension) at approx. 78.0
82.820		
	9.76	
86.865		
	9.48	
92.551		End of Irrigation Stage 6 (18 km Extension)
	8.68	
95.970		
	5.71	
99.038		
	5.14	
102.616		
	4.27	
105.858		
	2.27	End of 14.5 km Extension (not yet built)
110.408		

is then compared to the accumulated water orders in each Section by laterals for the following day as received from the farmers. If the orders exceed the available uncontrolled water supply, then reservoir releases from Ziglab and King Talal Dams are made to compensate for the difference. Releases from King Talal are adjusted by 40 percent to allow for channel and other losses or side diversions. The water allocated to each farm unit is proportionately reduced below demand in times of shortage.

The confirmed orders or allocations for each Section are determined by OBM headquarters staff, based on the Canal Inspector's calculations. These allocation sheets are hand carried back to the Section offices for distribution to the various ditchrider supervisors at their offices by 1 or 2 p.m. The ditchrider supervisors then assign the various ditchriders to a lateral and issue the order sheets for the next day.

The ditchrider arrives directly at the lateral at 7 a.m. the next morning to open and set the lateral turnout (LTO) to provide the ordered flow rate (adjusted for any shortage) plus an additional 10 percent to compensate for losses from the smaller laterals or 15 percent for the main laterals. The water distribution along the laterals is discussed in the section on distribution system operation.

Main Canal Management

The main canal serves as a storage reservoir every night since the majority of irrigation takes place during the daylight hours, typically between 7 a.m. - 5 p.m. There are, however, some nighttime releases from the main canal into laterals supplying banana and citrus fields. Nighttime irrigation is also practiced during times of shortages.

The monthly water sales, total water inflow, losses and calculated spills for the EGMC and side wadis for a recent time period (1980) are shown in Figure 5. These values were obtained from JVA reports and show that water sales vary from 0.4 to 14.8 MCM per month and losses range from 0.5 to 4.1 MCM per month. The losses vary from 6 to 26 percent of inflow. Spills, calculated as the residual of inflow (losses-sold water), range from 0 to 6.7 MCM per month. In a similar fashion the annual and four-year average water balance for 1978-1981 are shown in Figure 6. During the four years total inflow averaged 156.5 MCM, water sales plus rights averaged 100.2 MCM, spills 24.9 MCM and losses 31.7 MCM. Combined losses and spills averaged 36 percent of total inflow. Thus, an estimate of average delivery efficiency is 64 percent (64 = 100 x 100.2/156.5) for that four-year period.

The operation of the EGMC as a nighttime storage reservoir requires some manipulation of the 35 checkgates to release the water down the canal in the morning after the laterals have been opened. This must be

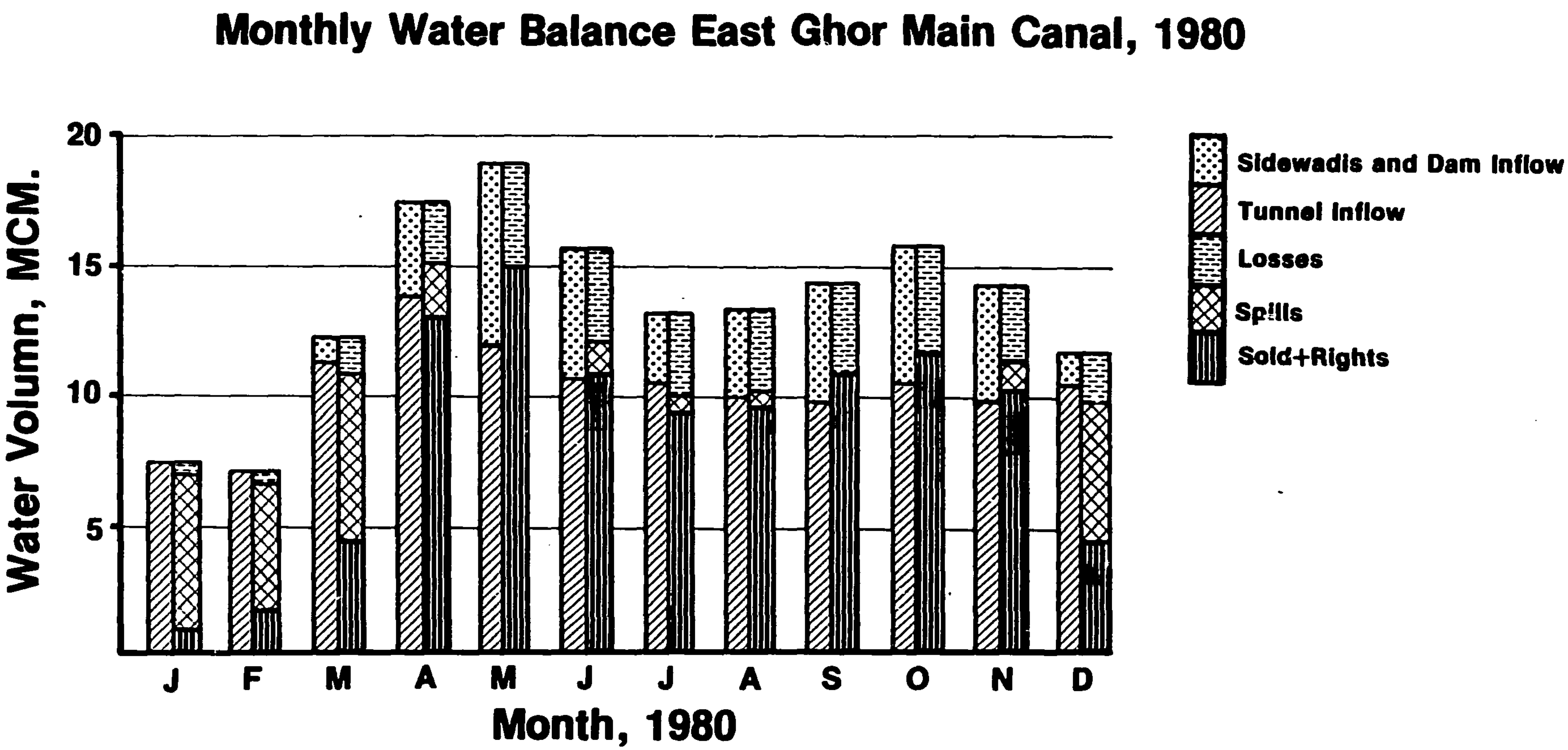


Figure 5. Monthly Water Balance for the East Ghor Main Canal During 1980. (Data Obtained from JVA Reports.)

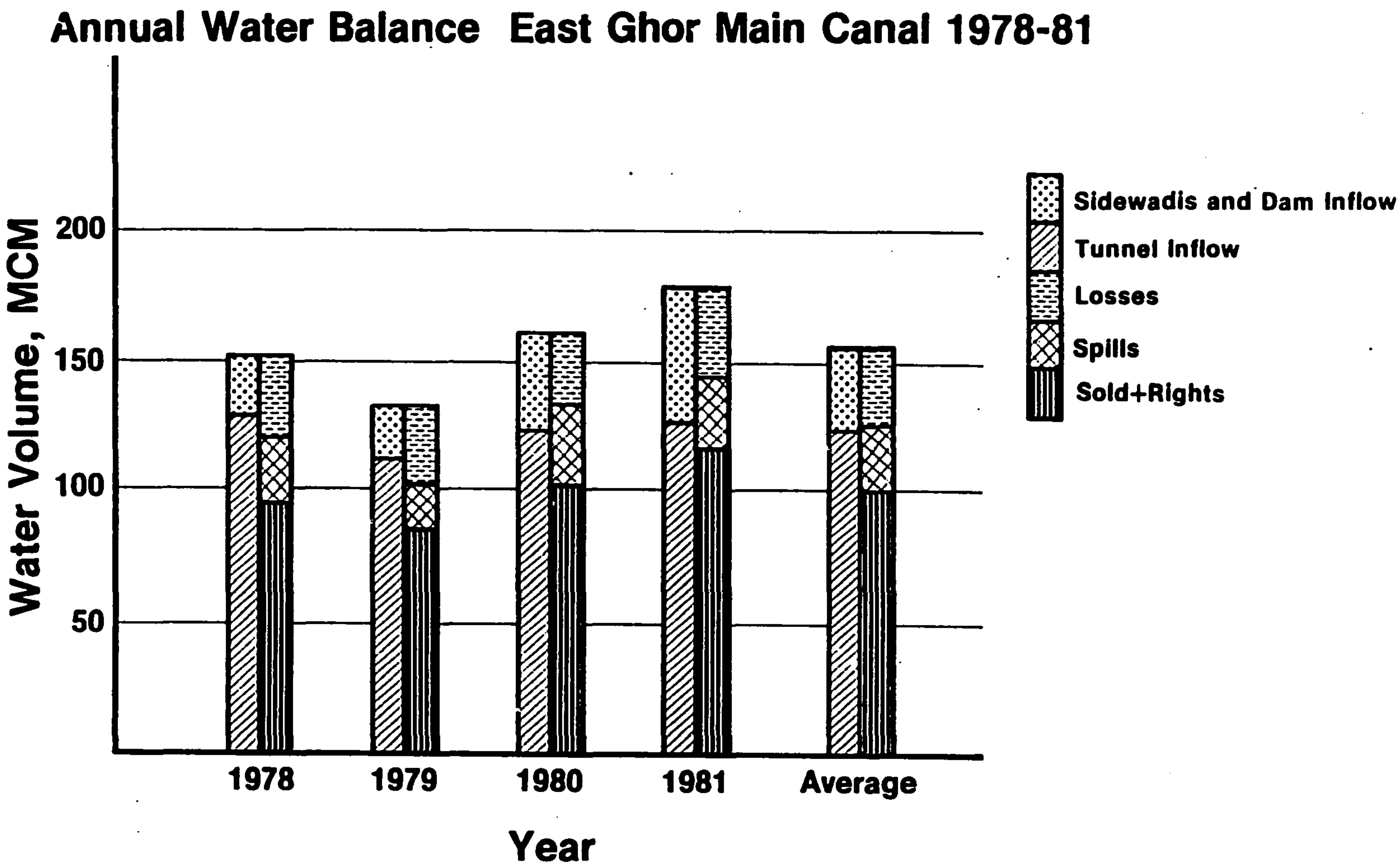


Figure 6. Annual and Average Water Balance for the East Ghor Main Canal During 1978-1981. (Data Obtained from JVA Reports.)

done in such a way as to maintain as nearly a constant level as possible to avoid fluctuating flows to the laterals. A reverse procedure is necessary in the evening to prevent excess spills from the lower end of the EGMC while utilizing the canal channel storage capacity in the off peak hours. The Canal Inspector orchestrates these gate adjustments based on his experience and judgment. During rainy periods when water is abundant there is not much demand on the delivery system and the gates are only operated as required. For example, it was rainy and we observed little evidence of gate adjustment during our field visits.

Water measurement is accomplished by making periodic readings of staff gages located at the trapezoidal weir (drop) downstream from the tunnel on the EGMC, and at rectangular or trapezoidal weirs at Wadi Arab, Wadi Jurum, and for the seepage water below Ziglab Dam. The water entering the pipe system at Ziglab is measured by flow meters at the dam outlet. No measurement appeared possible at Wadi Yabis. We did not make visits to measurement sites on the Zarqa River or other wadis. The frequency of measurements was reportedly three times daily: 8:00 a.m., 12 noon and 6:00 p.m.; however, this was not observed. It may be that less frequent observations are made when water is abundant and the delivery system is not under stress. It was not evident how or where nighttime spills were measured.

The process by which the staff gauge readings at the various inflow points are translated into flow values and delivered to the Canal Inspector is unclear. It appears that these reports may be transferred daily, or as often as taken via messengers. These reports go to the Canal Inspector for operation as well as to the report and record keeping officer of Section I. No staff gauges were observed in the main canal, although it is possible the Team overlooked them. What appeared to be a staff gauge was observed at only one checkgate. We made an attempt to obtain a stage discharge rating curve during the field visit but were unsuccessful as the officers who reportedly had the curves could not be located at the time of the visit. Periodic calibration of the measurement structures should be made with use of a current meter. This was not observed in the field and the frequency of such calibration is also unknown.

A stage recorder was located just upstream of the tunnel outlet measuring weir. Its condition and operation was not verified because the key was not available. Several other sites were observed which had a place for but no recorder installed. However, there was some evidence that stage recorders have been or are being used at flood measurement sites on the larger wadis downstream from the diversion works to the main canal.

Accurate and timely measurement of inflow water and of lateral turnout discharge as well as spills is required before significant benefit can be realized from improved operational procedures. Thus, the Team recommends that attention be given to calibration of existing measurement structures where suitable. Where suitable structures do not exist, then appropriate flow measurement devices should be installed and maintained. The use of a device such as the broad crested weir (Replogle, et al.) should be considered. These are relatively easy to install, produce a minimum of head loss and are accurate. Calibration is readily accomplished by available computer programs which would run in BASIC on the JVA PDP-11 computers with some minor programming changes.

Staff gauges should be installed, or reinstalled, upstream and downstream at a selected set of check structures as recommended by the Canal Inspector. The gate flow rate properties should be field calibrated for comparison with the theoretical equations. It may also be desirable to install one or two broad crested weirs at strategic points in the main canal. The upgrading of the measurement facilities and processes should be considered as a prerequisite before implementing a complex computerized operation program.

The use of a complete, but relatively simple, computer water balance and irrigation demand program could help the Canal Inspector make his daily determination of required reservoir releases. Such a program, which would include the effects of Yarmouk River and side wadi inflow as well as channel storage, could make the water balance calculation as soon as the accumulated lateral orders are received at headquarters from the Sections. This would permit rapid calculation for each canal reach of potential inflow, losses, outflow demand and required reservoir releases. In times of shortage the proportionate reductions could also be determined. The use of the simpler computer program management scheme envisioned here could reduce spills. The study Team estimates that about 75 percent of the spill reduction envisioned in the GERSAR report (2) for the more complex computerization could be achieved by this simple program at an early time, using the existing JVA PDP-11 computer at Deir Alla. This will be discussed further in a later section of this report.

The routing of water along the Main Canal could be improved by training selected personnel in the manual operation of gates at critical locations on the canal. Radio communication could then be used to convey instructions for opening and closing gates as recommended by the Canal Inspector or according to some critera based on stage changes in the upstream and downstream reaches. The gate tenders could also relay stage readings back to the office for use in determining canal flow rates at the check structures. Either process would be helped by using the computer for the calculations. The time interval at which a manual/computer assisted assessment of canal conditions and gate operation was carried out could not be less than every two hours or more, depending on the reliability of communications.

It is possible that modified gate operation rules could be obtained as the result of hydraulic modeling of the EGMC under a variety of historical or assumed conditions, such as The Wallingford study (4).

This would be a reasonable, relatively low cost preliminary step towards more complete automation and remote monitoring of Stages and control of canal checkgate movement as proposed in other studies, such as GERSAR.

Automation is defined, in this context, as the addition of motors to the gate opening gear heads but still requiring a person to push the open/close switches at the check. Remote control is defined as the ability to open or close a checkgate from a remote location, such as the Canal Inspector's office. Remote control would also require remote monitoring of upstream and downstream stage and gate position at each check. Reliable absolute-position sensors are essential in such an installation. Three would be required at each check, along with suitable protection against vandalism. As previously discussed, accurate flow rate calibration is also essential at each check. The unpredictable influence on flow characteristics at the checks caused by the presence of debris (often unseen) in the canal would require careful and frequent inspection and adequate maintenance for the successful functioning of a complex automated remote control (computer monitored) system on any canal.

Maintenance

The main purpose of ongoing and preventive maintenance is to ensure that the farmers will be supplied an adequate amount of irrigation water with minimal interruption. Since the growing season is year round, maintenance must be accomplished with water in the canal. Unfortunately, this makes it extremely difficult to observe conditions below the water surface. Based on our visual observation of the system above the water surface, the Team offers the following.

Silt and Debris Deposition and Cleaning Along the Main Canal

Along most of the length of the canal, the Team observed evidence of an accumulation of sediment in the bottom and along the sides. The silt and debris are coming from four main sources. The first is water borne silt which settles out when flow velocities are slow because of the flat grade of the canal and ponding during the night. The second is that created by humans, accidentally or purposely knocking loose material into the canal or depositing their refuse into it. The third source is that of rocks and silt from stormwater runoff. The fourth source is cast-aside greenhouse plastic which is blown into the canal.

In many places the deposition of silt is sufficient to sustain growth of aquatic plants and grass. Not only does the sediment restrict the canal capacity, thus causing operational problems, but it advances the deterioration of the canal itself by allowing plant roots to enter and widen expansion joints and cracks in the concrete.

The Team recommends immediate attention be given to repairing the canal where the concrete lining has been extended. Due to vegetative growth in and along the canal, the lining extension is being displaced in many places.

The study Team observed that, due to the physical layout of the diversion, it is difficult to obtain Jordan's proportionate share of water from the Yarmouk River. This is compounded by the fact that the inlet channel into the tunnel is overgrown with grass, aquatic weeds and overhanging trees.

Because it was not possible to drain the Zarqa River siphon, the Team could not observe the amount of silt that has accumulated. However, it stands to reason that there could be a considerable amount of sediment acc umulated since the actual velocities are somewhat slower than design. Furt ermore, presently the outlet drain is plugged and we were informed that it has been plugged since startup.

The Team recommends that the entire length of the canal be cleaned immediately and emphasis be given to the reach from the mouth to the Zarqa River. Thereafter, inspections of sediment accumulations should be made quarterly. Whenever and wherever 20-30 cm of silt has built-up, the canal should be cleaned.

Three methods of cleaning the canal while filled with water have been reviewed and discussed at length by the Team. The first method would utilize a dredge pump mounted on wheels. The machine would be towed down the canal invert or sides by a crawler tractor. A discharge hose coming from the pump would carry the silt and water (containing 65 percent solids) to areas above or below the canal. Such devices have worked very well on the 150 cm/s California aqueduct with a cleaning rate of 380 m/d. At this rate it would take 263 days to clean the 100 km EGMC. However, the unit does have some limitations in that the maximum sized solid that can pass through the pump is 6 cm. The sheets of plastic and large rocks in the canal could lead to serious plugging of the pump. Also, the point of discharge could be restrictive because in many places there is farmable ground on either side of the canal. The discharged material could cause damage to the adjacent farms.

Another method considered is a scraper consisting of a steel plate shaped to the cross section of the canal. This is pulled down the canal by a tractor or pushed by water pressure. As it travels sediment is put in suspension and mounded in front of it. When a sufficiently large mound of settlement is accumulated, the material should be removed with a crane-mounted bucket or an excavator. Where large amounts of sediment are in the canal, the travel distance would be very short between stops to excavate the pushed up material.

The third method the Team considered was a method similar to that which JVA is presently using. The exception would be that the excavating machine should be self-propelled from the operator's seat and consist of a telescoping arm with an articulating bucket rather than a cable mounted bucket. This would allow more control when positioning the bucket. Dropping the bucket would be eliminated, thus reducing the potential for damage to the concrete lining.

It is the Team's understanding that the German Technical Cooperation Team has also suggested methods similar to the first two discussed above. We would agree that these should be used on a trial basis to determine their adaptability and workability under JVA conditions. We also recommend that a machine with a telescoping arm be purchased rather than another cable and bucket machine. This machine should be dedicated entirely to canal cleaning and a flagman should be employed to delay traffic for short periods of time while the machine is working so that the operation is not interrupted each time a vehicle passes by.

From a review of the available studies, the Team observed that desilting basins have been recommended at strategic locations in the system. We would strongly recommend that sediment ejection structures be added at the outlet of the Yarmouk Tunnel as well as sediment desilting basins located as near to other diversions as physically possible.

The Team observed that during periods of high rainfall the Yarmouk River carries a large amount of suspended and bedload sediment. Utmost care must be taken to limit diversions during these events to only that required for irrigation purposes in order to minimize the sediment being transported into the canal. Attention should be given to cleaning of the grass, weeds, and overhanging trees that are encroaching on the tunnel inlet channel. Furthermore, flow should be stopped at the Yarmouk diversion tunnel for a period of time sufficient to allow an inspection of the tunnel and any required repairs should be made immediately.

The physical characteristics of the Yarmouk River diversion make it difficult for the JVA to divert their allocation of water and the Team recommends that a diversion structure be built in conjunction with a sediment exclusion structure.

The weeds and grass that grow along and in the canal should receive immediate and ongoing attention. Those growing in the canal due to sediment deposition will be removed during the sediment removal procedures. Grass and weeds which have started to grow in the canal lining expansion joints and along the banks should be eliminated by one or a combination of processes. The easiest method of control would be through the use of selective herbicides, if such are available. Herbicides selected must be those which, if introduced into the canal, would not harm the irrigated crops or people who obtain their drinking water from the canal.

One method of weed control worthy of consideration would be that of cutting the grass and weeds along the bank with a mechanical device at one- to three-month intervals, depending on the time of the year.

Another safe method and which we recommend in the absence of selective herbicides, is that of burning with a controlled flame. This method utilizes a truck or trailer mounted liquid gas (propane or butane) burner. A wand is attached to the liquid gas tank by means of a hose. A controlled amount of fuel is supplied to the tip of the wand which, when lit, produces a hot flame. The flame is used to burn the weeds and grass when they are at an early stage of development and there is little chance of uncontrolled burning.

To help reduce or eliminate the amount of debris entering the canal from people living adjacent to it, the Team suggests a combination of approaches. The first is that of providing a better garbage pickup service and educating the people to use the service. More garbage cans or dumpsters could be provided and in villages where the problem is most severe, fencing or covering the canals may be the only alternative.

Fencing itself becomes a maintenance problem, because they accumulate trash, and also restrict the movement of maintenance equipment and personnel along the canal banks. Covering the canal would appear logical but has some inherent problems. First of all, it would be expensive to do with precast concrete sections. Second, there are safety problems if a child or adult should happen to get into the canal in an open area and be carried beneath the covering. A plastic cover would not be suitable as it would soon be torn and of no use. A more appropriate system may be to levy a fine on people who dump debris into the canal or allow their waste plastic to blow into it.

The Zarqa River siphon should be inspected for sediment buildup. It will be necessary to open the plugged siphon drain to do this or if the drain cannot be opened, it may be necessary to cut a hole in the siphon. If an accumulation of sediment is found, the Team would recommend that a "pig" be used to dislodge the sediment. The "pig" could consist of a cylinder with cone shaped ends and spiral cutting edges and used with water flowing in the siphon. A cable could be attached to both ends and the "pig" pulled back and forth with winches to dislodge the sediment, thus allowing the water to wash away the dislodged sediment. Another method would be that of mining the sediment; that is, the sediment could be loaded in a suitable device and hauled out. This method would put the system out of service for a considerable period of time. However, this could be done in an off season by feeding the upper end of the EGMC from the Yarmouk and the lower end from the Zarka River.

A preventive maintenance step which would reduce the amount of sediment entering the siphon would be to close the radial gate at the siphon inlet and let the cleaner water run over the flashboards, thus accumulating the sediment above the siphon rather than sluicing it under the gate and into the siphon.

Plugged Pump Screens

During the hot summer months, the production of aquatic plants becomes more severe and causes plugging of the pump screens. This is especially true below the Zarqa River diversion. The increase below this point could be due to a high organic loading in the water resulting from Amman's wastewater. The existing screens are stationary devices placed vertical. During the height of algae production the screens must be cleaned several times during the daily pump operation. In many instances, in order to clean the screens the pumps must be shut down to reduce the flow velocity across them.

The Team recommends that the screening structure be modified to one of two schemes. One would be to place a trash rack, with vertical bars 4 cm apart, in front of finer mesh screens. Both the trash rack and the screens should be placed on a 4 to 1 or flatter slope. The effective screen area should be sufficient so the velocity is 0.3 mps or less through the screen. Placing the screens on a slope will allow the material to work itself up the screens, thus reducing the frequency of plugging and increasing the time between cleanings as well as eliminating the need for pump shut down to clean the screens.

The second scheme would be to use mechanically cleaned screens. These are screens placed on approximately a 2 to 1 slope with a series of electrically driven brushes which automatically remove the debris and moss as it accumulates. The units can be operated continually or on an intermittent basis. From the amount of material that has been reported to accumulate, and based on personal experience, the Team recommends that such screens be installed at the pump stations below the Zarqa River diversion.

Pump Stations

The mechanical portions of the pump stations appear to be in good operating condition. However, some items which should be implemented are:

1. The ventilation should be improved to prevent overheating during the hot season. This could be accomplished by providing cross ventilation through the building. The existing ceiling fans do little, if any, good in providing cooling;

2. A set of pump start-up and shut-down procedures should be posted on each pump house wall, available for ready access. Additional training for the operators concerning the mechanical and electrical components would give them a feeling of being a part of the system;

3. A study should be conducted to determine why all the pumps cannot be operated at the same time without causing overloading and subsequent tripping of the safety relays;

4. The automatic pump shutoffs should either be repaired or replaced with another type to prevent damage to the pumps and motors in the event of water stoppage; and

5. Spare part catalogs, operating manuals and service instructions should be obtained and made available to the appropriate O&M personnel.

Uncontrolled Construction

Along the Zarqa feeder canal, the Team observed a construction road that had been built to provide access to a JVA Amman water supply pump station. The road had been built too close to the canal and the side slopes of the road fill were steeper than those of the canal. This allowed gravel to fall into the canal, thus aggravating maintenance problems. Also, a small wadi drainage channel crossing over the canal was plugged off during this construction, and during a subsequent rainstorm, the flood waters created a new route to the canal. The floodwaters caused a 10 m section of the canal lining to fail and filled a 50 m section of the canal with gravel and silt.

In another case a dam built with debris had been placed across the Zarqa feeder canal to allow a farmer to divert water. In the first case, one segment of JVA was causing maintenance problems for another. The Team would recommend that all proposed construction activities be closely coordinated and approved before commencing.

Drains

In addition to the wadi drain crossings mentioned above, we saw several others that were choked with weeds and debris. The Team recommends that the 1963 Drain Maintenance Memorandum prepared by Harza Engineering Company International be followed and updated to include those wadi crossings not covered therein.

Special Structures

The Team noted that the two diversions on the Zarka River have received a considerable amount of damage from rolling rocks and sand which has exposed the reinforcing steel in the energy dissipators. These damaged structures should be repaired as soon as possible to prevent total failure. All concrete structures should be inspected on an annual basis and appropriate repairs made.

Maintenance Equipment

The equipment available to clean and maintain the EGMC is minimal, inappropriate and is not being fully utilized. During the Team's visit, of the three draglines (cranes), one is no longer operable, another had electrical problems and was out of service and the remaining one was being used mainly to unload pipe. A review of the operating records showed that on the average the cranes were only being operated four to five hours per day for 300 days per year. This includes mobilization and demobilization. Concerning the Team's recommendations, more suitable cleaning equipment was discussed under "Silt and Debris Deposition and Cleaning..." The Team would recommend that the heavy equipment be more fully utilized by operating more hours per day. This could be accomplished by either providing overtime pay or adding another shift. Also, we would recommend that all lubrication and fueling be done before the workday begins or after it is over. The Main Canal cleaning equipment should be dedicated to that purpose only.

The pins in the radial gate arms need to be greased on a regular basis. Some maintenance equipment should be located within each of the three sections. Each section should be provided with at least one backhoe and loader, one small dozer with Briscoe and two dump trucks. Maintenance of this equipment should be provided from the Central Workshop where the more specialized maintanence equipment is stored and available as needed.

DISTRIBUTION SYSTEM OPERATION AND MAINTENANCE

The laterals are an integral part of the JVA water conveyance system and as such should continue to receive a high level of operation and maintenance attention. The Team would encourage the JVA to continue their procedures of operation and maintenance and would like to offer some suggestions in this chapter which would facilitate their efforts.

The distribution system operation process is initiated by the farmers as they place their orders by 11 or 11:30 a.m. at the section headquarters for desired water delivery the next day (although many farmers live as far as 17 km away). A clerk records their farm unit numbers, the lateral that serves it and the desired flow rate (5, 10 or 20 lps) and duration. A check is made at that time to see if the farmer's bill is paid. He is considered not eligible for water if his bill is more than two months past due. The farmer's order is recorded on the lateral order sheet if he is paid up and if it is his day to get water. However, he may receive water out of turn in times of abundant water, if necessary.

The water orders are accumulated by laterals and totaled for each Section by 12 noon and then hand carried to headquarters where the Canal Inspector determines the available water from the Yarmouk and side wadis for the day. The confirmed orders are assigned as described in the section Main and Subsystem Operation and Maintenance. These confirmed orders are assigned and returned to the Sections for distribution to the supervisors of the ditchriders. The supervisors in turn give the orders for the following day's deliveries to the ditchriders by 1:30 or 2:00 p.m. We found it interesting that the ditchriders do not necessarily always regulate the same lateral, as the supervisors may rotate them from lateral to lateral.

The number of farm units, laterals and area served by the various stages of EGMC for pipeline and open ditch distribution are given in Table 1.1. The number of farm units per stage varies from 430 to 1,183. The number of lateral canals ranges from 15 to 47 and the total length varies from 61 to 133 km. Thus, the derived average lateral length is 2.5 to 7.4 km.

Open Channel Operation

The ditchrider arrives at the lateral turnout (LTO) at or near 7:00 a.m. to turn the water on. He remains there for a few minutes to adjust the gate opening to give approximately 110 percent of the sum of the farm unit orders for the day. A tape measure is used to measure upstream and downstream heads on the second gate at the LTO and the equation used for flow rate, with no backwater, is: $Q = (L/40)\ d \sqrt{h}$, where Q is in lps, L is gate width in cm, d is gate opening in cm and h is upstream head on the gate in cm. It was not clear if the ditchriders knew this equation, since the supervisors were using it at the time of our field visit. It may be that the ditchrider just estimates the flow. There also appeared to be some uncertainty about the exact gate opening.

When the ditchrider is satisfied with the regulation of the LTO, he moves on down the lateral and opens the controlled head orifice farm turnouts (CHO) at the farm units which have water orders while closing those left open from before. The travel time of water is considered as he goes along in order to reduce the amount of readjustment needed. Flow rates at the CHO turnouts are estimated from the rule of thumb that for submerged conditions on the first gate each 6 cm of head difference gives about 2 lps through the gate for each 1 cm of opening. The equation used for flow rate in lps for nonsubmerged conditions is: $Q = d \times 0.85 \sqrt{h}$ where h is the upstream head on the 40 cm wide CHO, and d the gate opening. Nonsubmerged conditions were observed at those gates where the second gate could not be moved because of damage to the stem, and at the end of the lateral. During our visit the measurements for flow rate determinations were all made with a tape measure to the nearest centimeters. We do not know the accuracy of the LTO and CHO measurements since no independent measuring device was available for checking. There was no evidence of the use of discharge charts, graphs or small calculators.

After the flow has stabilized, the ditchrider moves up the lateral. He checks each gate setting against the ordered amount and makes the first entry in a report form indicating the time and quantity delivered. He then returns to the office. Three hours after the initial gate opening (10 a.m., nominally), he returns to the field for another check of the setting of the LTO and farm turnouts and makes a second entry in the report, verifying the time and flow rates. At about 1 p.m. a second shift of ditchriders (only about one-fifth as large as the first shift) comes on duty and makes a third check and entry in the report. At the end of the water turn, 3 p.m. for eight hours of water or 5 p.m. for ten hours, the second shift of ditchriders shuts the LTO gates.

Calibration checks of flow rate through the LTO and CHO turnouts should be conducted to determine the general accuracy of water measurement at the lateral and farm turnout level. It is possible that the use of tables or charts by the ditchriders would help considerably in improving the accuracy of flow rate determination.

Apparently, the ditchriders are expected to assist in cleaning the laterals but the amount of assistance expected is somewhat arbitrary and uncertain: the ditchriders make reports concerning needed repairs; however, apparently the response from maintenance may take more than three months. Moreover, there was a general consensus among the distribution staff that improved maintenance at the lateral level is needed.

Scheduling water among laterals is accomplished by rotation, for example, a particular lateral may have water five out of the seven days. Thus, it is not necessary for every lateral to be turned on every day. It was not clear whether a ditchrider was assigned to more than one lateral in a given day. The water is scheduled along the laterals so that each farm unit can have water during one of the days that water is in the lateral. Some laterals may have water six out of seven days with provision for the farms to take water two out of the six days. We do not know whether the various scheduling rotations are used to accommodate lateral capacity constraints or to limit water use to the available supplies during spring and summer months.

The ditchriders provide their own transportation. Some walk, some have bicycles, and some use small motorcycles. The JVA pays a 10 JD monthly transportation allowance to those who own motorcycles. The use of a motorcycle significantly increases the efficiency of a ditchrider; however, the 10 JD allowance is not sufficient to encourage them all to purchase motorcycles. Adjustments to the allowance are suggested if that would increase the number of motorcycles used. We estimate that perhaps the number of ditchriders and supervisors could be reduced by as much as 25 percent if they all had motorcycles. It is possible that further reduction in staff could be achieved by making some adjustments in rotations among laterals so that fewer laterals required turning on at the same time.

Open Channel Maintenance

From the Team's observations, a great deal of effort is being spent on maintenance of the laterals. The laborers are hard working and doing a commendable job. We would like to commend the JVA for this effort.

Silt Debris Deposition and Cleaning

The Team observed a considerable amount of silt, rocks, weeds, wood, plastic and human derived garbage in the laterals and noted that the laterals are cleaned three or four times a year. Presently, the materials removed from the laterals are placed on the adjacent banks which in many cases are now 1/2 to 1 m higher than the top of the concrete lining. We noted that within a day or two after a section had been cleaned, that much of the material had already fallen back into the lateral.

Immediately after cleaning the lateral, the material should be spread within the right-of-way or hauled to a spoil pile. With proper disposal of this material away from the lateral banks, along with weed and grass control, we believe the lateral cleaning efforts could be reduced by 40 to 50 percent.

A Briscoe sloper would be useful for removing material to a place where it could easily be spread in the right-of-way or picked up with a loader. The Briscoe sloper is a blade which can be attached to the rear of a crawler tractor. A spoil wing can also be attached to the rear of the tractor to spread the material away from the edge of the lateral. If the material is spread within the right-of-way, care must be taken not to damage crops. We would suggest that garbage and all rock larger than 20 cm be hauled away. As discussed for the main canal operation and maintenance, the weeds and grass should be controlled either by herbicides, burning, cutting or a combination of all three.

Turnouts

The Team observed the following: the concrete in many of the turnouts is deteriorating or has been badly damaged; the wood sill within the turnouts may require replacing two or three times a year; lubrication of the gate stems is adequate; many of the gates themselves have been damaged; and many of the opening nuts on the gate stems and the keys with which they are turned have become badly worn which makes the gates hard to open.

An annual program should be initiated to repair or replace the concrete in the turnout structure. An inventory should be taken of their condition and a commitment made to replace a certain number each year until they are all brought up to standard. From then on, they should be repaired or replaced as necessary.

The frequency with which the wood sills are replaced could be reduced if better quality control is used during repair or a change of procedures is implemented. After the old wood sill is removed, greater care should be taken to clean the sill channel; then, before the new wood sill is set in concrete, the concrete base should be wetted. A procedural change would be to use an epoxy grout to hold the wood sills in place. There are epoxy grouts available which would adhere to the old concrete and be stronger than concrete itself. The Team also suggests that the JVA experiment with the use of rubber strips in place of the wood sills.

To increase the ditchriders' efficiency, gate opening keys and nuts which are badly worn should be replaced.

Pressurized System Operation

The pressurized distribution systems were originally designed to deliver a continuous flow of 4 lps to each farm unit with sufficient pressure to operate a low pressure (approximately two atmospheres) sprinkle system. Except for citrus, some wheat and a few vegetable crops such as peppers, carrots and potatoes, farmers have elected not to employ sprinkle irrigation. Instead, they have opted for trickle irrigation or traditional surface irrigation methods. Furthermore, the farmers only want to irrigate during daylight hours.

Most, if not all, of the farm turnouts (FTO) have been vandalized so that now, instead of delivering only 4 lps, they deliver 8 to 12 lps. (Vandalism is particularly severe on the American FTOs where the external plumbing on the pressure regulators has been ripped off.) This affects the pressures throughout the system and makes it impossible to accurately control flows. Along the higher reaches the pressures are too low to operate sprinkle or trickle systems and in many areas it is difficult to even get sufficient discharge rates to supply the farm units.

In addition to problems with the FTOs and the loss of flow and pressure controls, the techite pipe in the mainlines is breaking and causing much down time.

The pipeline inlet gates are opened each morning and the booster pumps for the upper reaches are turned on. Then the piperiders (counterparts of ditchriders for open channels) open (and close) the FTOs to provide water to the farmers in accordance with the list of orders from the previous day. Since the flow regulators are not functioning, the flows to each farm unit are estimated. Flow estimates are based on the location and elevation of each farm unit in relation to the pipeline inlet. The piperiders make an effort to adjust the on times of the various FTOs in order to give each farm unit its proportional share of water. But under existing circumstances, it is practically impossible to equitably distribute the water. Often 8 to 10 or 12 hours, depending on the farm, the pipe inlet gates are closed and the pumps shut down.

Some farm units receive water under sufficient pressure to operate their trickle or sprinkle systems without booster pumps. However, many required storage tanks to accumulate a sufficient supply and booster pumps for operating trickle (or sprinkle) systems.

The reason pressures are low is because the mainline flow rates are much higher than anticipated in the design which in turn increases pressure losses due to pipe friction. The high flow rates are necessary because instead of operating the pressurized systems continuously, they are operated less than half time. To better accommodate the higher FTO discharges, the farm units are given water on a rotational basis with rotation schedules dependent on the supply and demand.

In an effort to improve system performance the JVA has been installing some parallel mainlines to increase the system capacity to specific critical areas. The Team commends the practice and recommends analyzing all the pressurized systems in terms of the economic practicality for increasing capacities.

Portable Aluminum Pipe and Sprinklers

The large supply of portable aluminum pipe and sprinklers which the JVA obtained some years ago has not attracted the Valley farmers. This is because following the planning for the pressurized pipe system, the net advantages of trickle irrigation overcame those of sprinkle irrigation for most of the high value crops grown in the Valley. For the most part the farmers have opted to trickle irrigate their high value crops and surface irrigate the low value crops. While the large, essentially unutilized supply of portable sprinkle equipment is an embarrassment to the JVA, it should not be. During those early planning stages, sprinkle irrigation did appear to be the most efficient application method!

Given the current evidence, the Team recommends that most (up to three-quarters) of the portable sprinkle equipment be utilized elsewhere in Jordan or sold to the highest bidder. The remaining portable equipment should be kept in hand and possibly rented for use in reclaiming saline lands, leaching certain previously trickle irrigated lands, or growing small grain and vegetable crops (such as potatoes, peppers, onions, cabbage, broccoli and carrots). Of course, the equipment could also be sold for the above uses.

Pipeline and Hydrant Maintenance

The items requiring maintenance are the pipeline inlet screens and gates and pumping plants which we have already discussed plus the pipelines along with their safety control valves and the FTOs.

Techite Pipelines

Numerous breaks have occurred in the large diameter Techite (RPM) pipe, which breaks are most probably caused by rough handling and by improper bedding, pipe placement or backfilling procedures. The current repair practice is to replace broken RPM sections with steel pipe joined to adjacent RPM with mechanical couplings. For satisfactory performance, we recommend the following installation procedures:

1. The steel pipe must be manufactured within certain tolerances as specified by the coupling manufacturers. The supplier of the steel pipe (STECTA) is proposing to manufacture the pipe to these tolerances. This is very good, but it should not be assumed that this has taken place and the tolerance between the pipe and coupler should be verified during installation;

2. The sand on the end of the RPM pipe must be cleaned from the surface for a distance that will allow the coupler to be installed and seated in position. During this cleaning process,

care must be taken to grind evenly all the way around so that the pipe will remain sound and the coupler's gasket will seat properly;

3. External anodes must be installed to the steel pipe to prevent external and internal corrosion. An expert in this specialized engineering field should be consulted;

4. During excavation of the broken RPM pipe, care must be taken not to over-excavate the pipe bedding material. If over-excavation occurs and the new bedding for the steel pipe is not properly accomplished, settlement of the steel pipe could occur, thus causing shear or bending stresses behind the coupler in the RPM pipe and possible breakage. If over-excavation occurs, the pipe bedding must be compacted with a mechanical vibrator to a depth higher than the pipe invert. The excess material should then be removed by hand to the desired elevation; and

5. With respect to the two suppliers quoting prices on the mechanical couplings, i.e., Dresser and Viking Johnson, we have experience only with Dresser since Viking Johnson is an English firm. Dresser is the top grade coupler sold in the U.S. If Viking Johnson specifications meet or exceed those of Dresser, then satisfactory performance should be realized.

Safety Valves and Fittings

Various pressure and air relief as well as pressure control valves have been installed along the mainlines to dampen or relieve excessive pressures. For the safety of the systems it is important that these valves be maintained. To achieve this will require an understanding of the location, purpose, and function and operating characteristics of each valve. Then each valve should be periodically checked (calibrated), adjusted and serviced in accordance with the manufacturer's recommendations.

The Team noted that considerable effort has been spent by the JVA in an effort to better understand the complicated valving found in many parts of the system. However, there are some valves which are so complicated that even the manufacturer's representative has not been able to properly adjust them.

In view of what now appears to be overly complicated valving, the Team recommends that each pipe network be studied for possibilities of eliminating certain valves and/or replacing them with less complicated ones. In addition, a special valve maintenance crew should be established and trained to service and maintain the special safety valves throughout all the pressurized pipe systems.

Farm Turnouts

Plans are to repair the vandalized FTOs. We recommend that this be done along with replacing the 4 lps orifices with orifices designed to discharge 8 lps. We see little reason to place a heavy emphasis on repairing the pressure control valves and flow meters. This is because the farmers can adjust or control their own system inlet pressures and the use can be efficiently estimated from the operating time and flow rate.

Once the FTOs have been repaired, all delicate parts must be sufficiently protected against vandalism. In the case of the American FTOs (especially if it is decided to repair the flow meters and pressure regulations) this will require steel or concrete vaults.

Once the FTOs have been repaired, they should be inspected periodically and maintained accordingly. Piperiders should report any malfunctioning FTO during the irrigation season. In addition, a month prior to the beginning of the irrigation season, all FTOs should be inspected, calibrated, and serviced or repaired as needed.

The study Team particularly liked the French flexible orifice flow regulators and recommends that the American flow regulators and fixed orifices eventually be replaced with them. We realize that repair parts are already on hand for bringing the American valves up to design standards and suggest that these parts be utilized accordingly. However, in the future, rather than continue purchasing new repair parts, we recommend that the old valves be replaced with the flexible orifice fittings. Rather than repairing all of the American FTOs, we suggest the possibility of replacing up to one-half of them with flexible orifices now. The extra repair parts could then be kept on hand for the remaining American FTOs; moreover, this would reduce the number of vaults required.

Farm Supply Lines

Maintenance of the underground pipelines taking off from the FTO and running along the upper edge of each farm unit should be the responsibility of the farmers. The JVA should have a supply of pipe and repair parts for the hydrant valves for the farmers to purchase. In addition, the JVA should provide a farmer training program to point out the value and proper use of the farm mains and hydrants and how to maintain and/or repair them.

PROJECT MANAGEMENT

The study Team visited the project during a time of flux while the Irrigation Division of the JVA was being reorganized into a more consolidated organization. This section discusses the old organization and its inherent problems and comments on the new organization. Recommendations are given for the new organization which will assist it in working in a more efficient manner.

Old Project Organization

For many years, the project was organized to deliver water and provide maintenance to six separate stages of the main canal. In addition, there were several subprojects being irrigated from side rivers or wadis. As can be seen from the organization outline (Figure 7), every separate entity of the JVA could report directly to the chief of the East Ghor Canal Division or his assistant. With no upper or mid-level supervision to consolidate these separate entities, there was, without doubt, much confusion and inefficient use of time. It appears that it would have been extremely difficult for top management to do an effective job or accomplish work through delegation. The Team would like to compliment the JVA for taking the following approach.

New Project Organization

The new organization shown in Figure 8 has implemented five mid-level management positions which will report to the Director of Operation and Maintenance. This is an appropriate move, establishing an efficient chain of command. At this level, the Team would suggest two minor changes. The first would be a title change to more fully explain positions of responsibility. The title of Assistant Director of Maintenance should be changed to Manager of Operation and Maintenance/Main Canal, then to this position add the responsibility for the operational branch which measures and delivers water to the laterals. This would provide an organization for the Main Canal similar to that for the three sections. To accomplish this, the title of the Assistant Manager for Operation should be changed to Manager for Operation and Maintenance/Laterals. This would move 49 of the 698 people from the O&M/Lateral to the O&M/Main Canal branch which only has 144 people. This would help offset the uneven distribution of people in these two branches.

Another change that should be considered is to consolidate, within the management branch, the three sub-branches of the money collecting division, checking division and accountant into one division called "Accounting." Consideration should also be given to consolidating the other four branches into one or two branches. The organization as shown

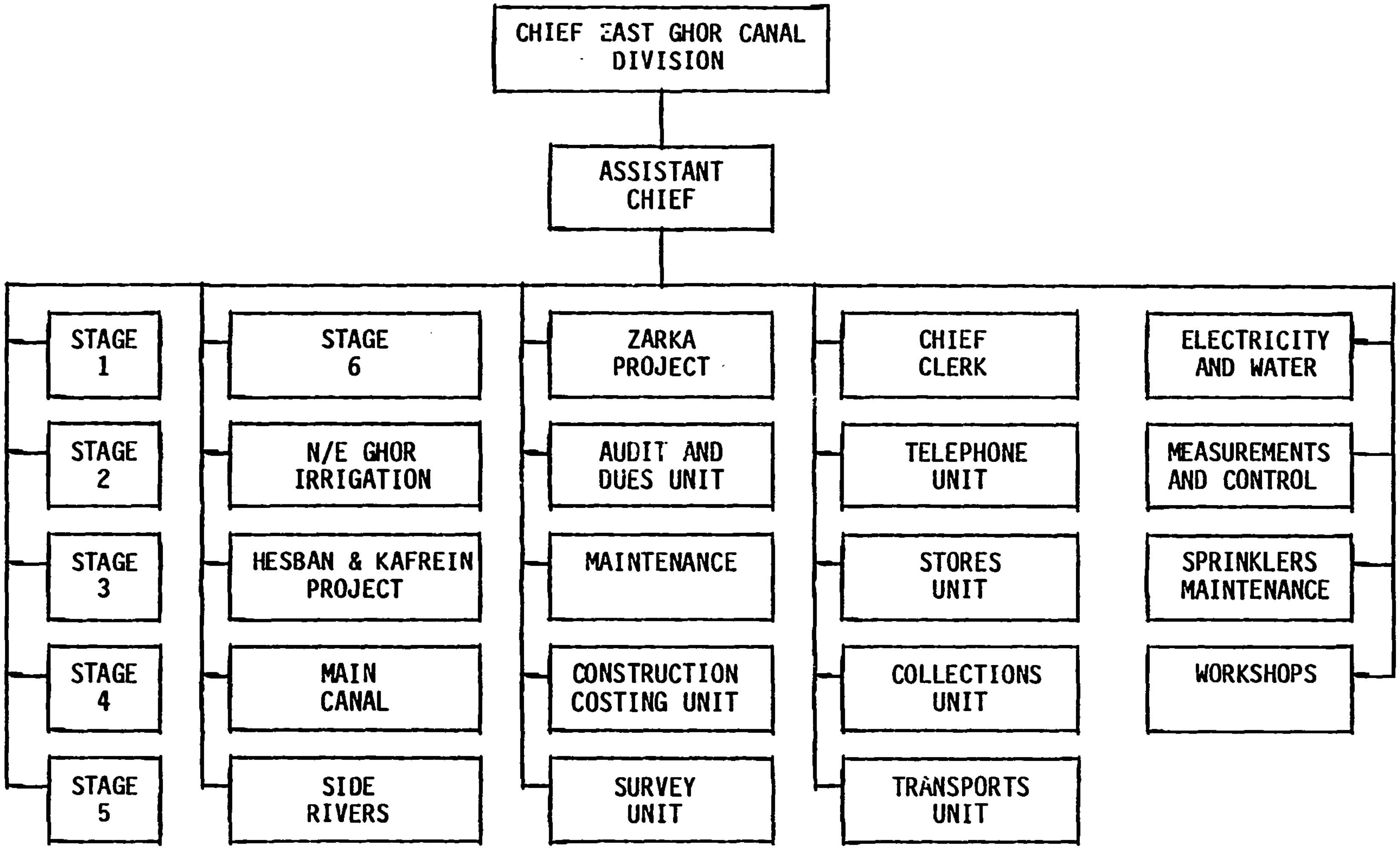
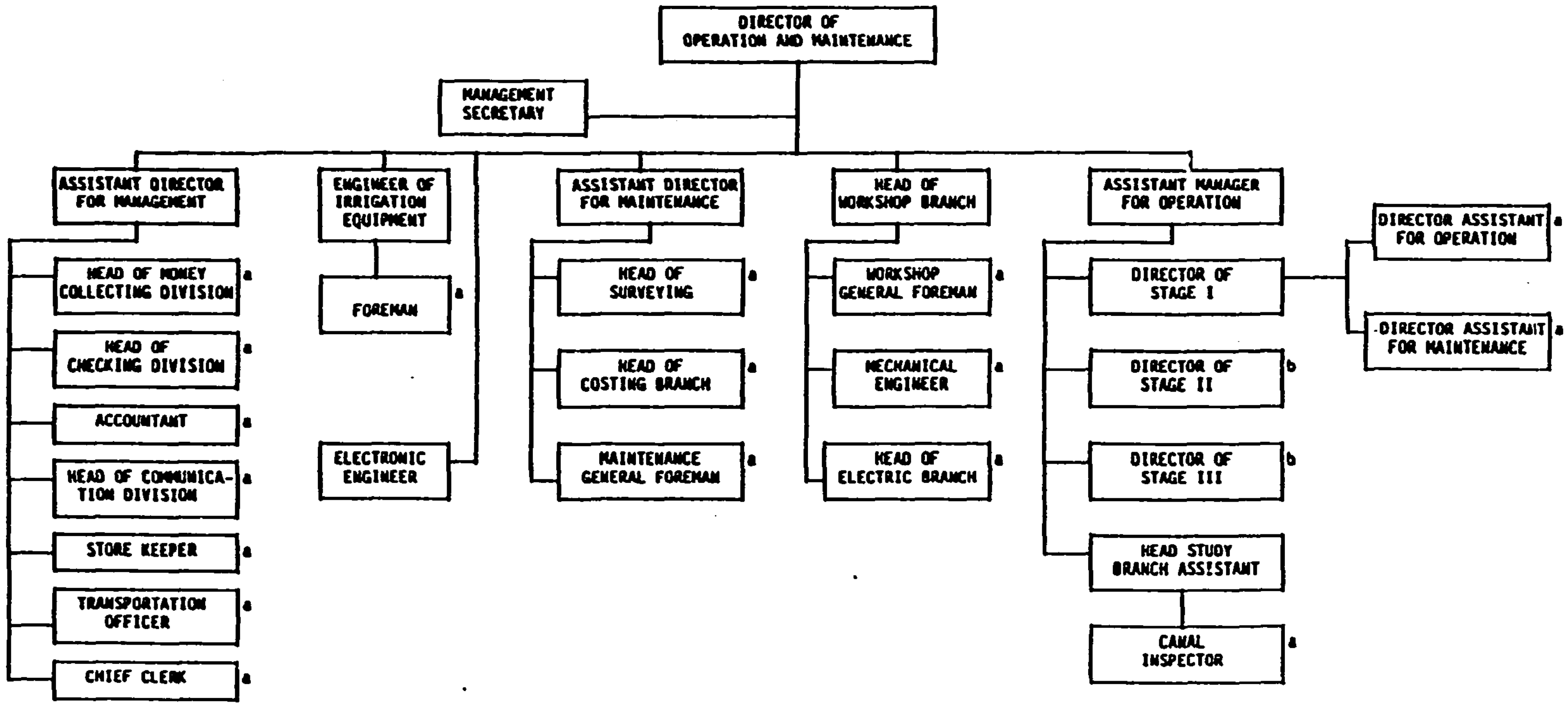


Figure 7. Project Organization (prior to 1984).



[a] Other Staff Positions Not Shown.
[b] Same Organization as Stage I.

Figure 8. Project Organization (revised 1984).

on the chart has too many branches reporting to the Assistant Director of Management. Too many decisions that should be made at a lower level management position will end up at the mid-level. This type of operation structure reduces effectiveness of the top decision makers on more important issues. This recommended consolidation would also reduce the number of office boys needed.

Again, the Team would like to commend the JVA on this new organization. We would suggest and highly recommend that, as follow-up to this reorganization, each job, from top to bottom, and its education requirements and responsibilities be thoroughly outlined. Employee manuals should be provided that discuss the JVA organization, the benefits provided to the employers, work hours, vacation procedures, and conditions of termination.

A good example of the job description, responsibilities and education goal requirements is given on pages 33 through 38 of the final Design Report for the Hisban-Kafrein Sprinklers Irrigation Scheme, prepared by Sir M. MacDonald and Partners, January 1976 (see Appendix B).

Work Ethics

The Team realizes that because of the many farm units equitable distribution of water is a difficult task and requires a large staff. However, the Team observed during its seven or eight trips to the Valley that the JVA appears to be overstaffed in most areas. Providing jobs solely for the purpose of providing employment creates an indifferent attitude by the employees as there is not sufficient work to keep them fully occupied.

The best production and efficiency from a person can be obtained when workloads slightly stress capacity; however, some overtime pay may be necessary. The Team does not feel it should be necessary to employ people in the JVA solely for the sake of providing jobs. The thousands of expatriate laborers working in the Valley provide evidence that there are jobs available; thus, the JVA should not be required to subsidize the work force.

In many cases, when we visited the various areas of the project unannounced, many JVA employees were absent or unoccupied. The exceptions to this were the lateral cleaning crews that we observed. They were always actively engaged in their tasks. We also observed that office (work) hours are not rigidly observed, with people coming in late but more often going home early. Leaving the field an hour or so before official quitting time and returning to the office where the laborers sit around until it is time to go home seems to be commonplace. Good work ethics cannot be implemented if those in charge do not observe the work hours. They should set the example by arriving on time or early and not departing early.

From the lower management level down there are 25 to 50 percent more employees than actually required to operate the project at its present level. Some areas where a reduction in staff may be possible are:

1. Pump stations - Reduce the number of operators from two or three per pump station to one plus a roving operator for several stations to fill in on the regular day off and alternate the days off for the various operators. Also, continue to provide the operator housing at the pump station site. Under the present mode of operation, each pump station is ordinarily operated eight hours per day. On days when longer operation is necessary it would be more cost effective to pay the operator some overtime rather than to bring in another one;

2. Reduce the number of office boys in most areas and increase the duties of those remaining to include office and grounds maintenance, plus other odd jobs;

3. Reduce the number of drivers and when a crew goes to the field, have one of the work crew do the driving; and

4. Reduce the number of ditchriders and require them to own and ride motorcycles. If all ditchriders had a motorcycle the total could be reduced by up to 25 percent. This will require more financial assistance through loans and/or increased vehicle allowances.

The above recommendations and observations are based on a cursory review of the system. Therefore, we encourage a more thorough review and evaluation of the workload by someone very familiar with the Jordan social structure before making any large reductions in staff. An appropriate time to assess the actual work needed would be at the time job capability descriptions are evaluated and written as recommended earlier.

QUALITY CONTROL AND TRAINING

The operation and maintenance of the canal and delivery system becomes increasingly important as the irrigated area in the valley continues to expand, water is diverted to Amman for municipal purposes and the original system deteriorates. In order to provide state-of-the-art operation and maintenance, it is necessary for the JVA to provide quality control and training. Quality control and training can be provided through different schemes as outlined below.

System Operation and Maintenance

For the maintenance of the system a critical list of required items should be made each year. This list would be developed during an intensive review of the system by the Vice President of Irrigation, the Director of Operation and Maintenance, the Manager of Operation and Maintenance/Main Canal, and his counterpart for the laterals during a period of one to two weeks. Once the list is drawn up, the items should be categorized by A, B, or C with A being of the highest importance. Then, the list of A items should be maintenance prioritized. The work should then be done in an orderly manner by completing the highest priority items before advancing to the next task. The list should be large enough to be achievable but not so large that it is unreasonable.

The Team suggests that an annual inspection tour be conducted. This team should include the President of JVA and his subordinates. The year's goals and objectives as established through the procedure discussed above should be presented at the beginning of the tour and an accounting of the previous year's goals should be made against that which was actually accomplished.

Prior to the annual tour it should be widely publicized to the local inhabitants, encouraging them to clean and maintain their personal farms and residences. At the conclusion of the tour those who have exemplified extraordinary performance should be publically recognized and possibly rewarded.

Throughout the year, on a weekly or at the minimum on a biweekly basis, the Director of Operation and Maintenance should spend a day or two in the field reviewing progress of work and general system conditions.

Unannounced visits by JVA top management should continue and is encouraged. During these visits with the personnel recognition of good work performance should be given when appropriate.

Professionalism

To promote high morale within the organization, the right person should be selected for the job as determined by the job description. The people in the upper and middle management positions should be of highest caliber, i.e., well educated, hard working, aggressive and able to delegate work. Engineers should not be supervised by non-engineers or receive less pay for comparable work experience.

Training

Training can be provided through one of two methods, or a combination of both: on-the-job training elsewhere; or by an advisor located on the JVA Projects. In order to strengthen the capability of the maintenance program, the Team suggests that the manager of O&M/Main Canal and his counterpart from the lateral system be given on-the-job training at an irrigation district in the U.S. for one irrigation season. The candidates should live within the project and work with the maintenance people.

Another alternative for the JVA is to retain a senior technical advisor to provide training to the maintenance managers and their staff. To be most effective the advisor should have full control of the resources available.

Computerized Management Assistance for the EGMC

The study Team reviewed several studies (or proposals) by Harza, ERNO, GERSAR and Dar Al-Handasah (Wallingford Hydraulics Lab) related to computerization of various aspects of the East Ghor Main Canal operation and information management. These studies could be grouped into three main categories: Water Management Systems; Management Information Systems; and Hydrodynamic Models. Team members also visited the JVA computer facilities and discussed the present and future possibilities with JVA personnel and with representatives of various donor agencies. The Team agrees in principle with the review study by GERSAR (September 1983), as summarized in the following quotes from their report:

> "1-There is no doubt as to the necessity of installing computers at JVA whether it be by using a real time or an off-line system.
>
> The size of the organization, its importance for the economy of the country, the complexity of its technical, administrative and financial relationship with the farmer - all call for rationalizing methods and providing a better public service, which can only be achieved by computerization. Moreover, we regret that an experiment on a reduced scale has not been tried

out over the past few years, as this would have helped taking final options now.

The question now is to know what are the priority tasks to be done by the computer and what are the different phases for partial and definitive installation of equipment.

2-We repeat that to our knowledge, no other computer system exists in the world which associates, on such a large scale and in similar conditions, the administration in charge of irrigation, the farmers and the economic activities of the area concerned. Of course, systems which are more complicated do exist in other fields for giving advice to farmers or for organizing distribution of water to farms covering vast areas.

This, of course, does not mean that the project should not be implemented but it confirms our opinion for the need to accumulate safeguards for setting up the system and operating it. These could be provided by carrying out the project in stages over limited geographical areas and over a certain period of time.

3-As far as cost evaluation for buying the computer system and for its operation and maintenance are concerned, the cost is generally underestimated, particularly for the operation and maintenance. We have tried to bring to light the main corrections to be considered.

4-To install a temporary system to regulate the EGMC, while waiting for the on-line computer to be installed, we propose that solutions be setup in successive stages. Naturally, some of the suggestions made will need to be checked by additional studies. On the other hand, the interim regulation system proposed will never achieve the same operational standard as the on-line computer proposed by Harza.

If the report had to be summed up in one recommendation, we would suggest the following:

In practice, the technical solutions proposed by the consultants to JVA appear to be adapted to the situation. On the other hand, there is a combination of many factors, due to the size and complexity of the proposed system which make it compulsory during studies, implementation and putting into service, to make sure there is a project follow-up, and that this is applied under conditions which are more stringent than those used for classic computer systems (accounting, finance, regulation of a canal independent from water distribution)."

The study Team believes that the question of computerizing the management of the East Ghor Main Canal is not so much a question of "if" but rather of "how" and "when." What is proposed here is a preliminary stage of computer adaptation which would precede Stage I, Stage II, etc., as proposed by Dr. Hans Wolter (personal communication) relative to the GERSAR report. This preliminary stage emphasizes the water management with a low level of detailed data collection at the farm unit level. This can be implemented in successive steps over a relatively short time period. Data acquisition could be accomplished parallel with programming.

The simplified programs envisioned could operate on the existing JVA PDP-11 64K computer system now in the Valley. These programs could determine a daily water demand and water balance of the EGMC using existing weather stations. The benefit derived from implementing the preliminary stage of computerization is estimated at 75 percent of those suggested by GERSAR (2). Thus, the annual water savings would be 11 mcm (11 = .75 x 15) with an estimated economic value, using the current water price of 3 fils/cubic meter, of 33,000 JD.

This preliminary stage implementation could be accomplished most rapidly through a combined effort of outside expertise in irrigation engineering computer applications combined with JVA personnel for on-site data assembly and entry. Depending on the resources available, the water balance system could be operational in a few months.

Preliminary Stage Computer Utilization and Training

The overall objective of the preliminary stage as we envision it is to develop and implement computer programs (on JVA PDP-11 computers) which will perform complete water balances for the EGMC. These will include lateral level accounting of water orders or calculated demand (eventually). A printout of required outflow between each check section will be provided as well as allocation of available inflow and adjustment for shortages in each section with corresponding adjustments to lateral flowrates. Demand models will be implemented in steps of increasing detail and geographic scope.

The following specific tasks or components are proposed:

1. Conceptual development, including data required, frequency and computer modeling schedule. This will require close communication between expatriate experts, JVA engineers and operation personnel (i.e., the Canal Inspector);

2. Development and implementation of the EGMC daily water balance model to determine the flow rate of laterals and in various canal reaches from water orders as received by the Section headquarters. The computer coding could be in either BASIC or

FORTRAN IV with program development done out of country. The working program could then be transferred to the JVA during a two-week on-site training and application seminar for appropriate personnel;

3. The data acquisition process should begin concurrently with Task 2. This will involve locating information of farm unit cropping areas, planting dates, etc. It is suggested that this be done by Sections and laterals in numerical order. A small computer program should be written to facilitate data entry and storage on diskettes. While the program may be written out of country, the collection of data, keyboard entry, and checking for accuracy must be performed by JVA. This task should be completed prior to Task 4b;

4. Development and implementation of the crop water requirements program to calculate daily crop water requirements (ET) using weather data from existing stations. The Ministry of Agriculture weather station at Deir Alla has sufficient daily weather data to permit ET calculations with the modified Penman equation. The station meteorologist has indicated that arrangements could be made to supply the appropriate data on a daily basis. The program should be implemented by steps as follows:

   a. Calculation of crop water requirements and estimated average daily water demand using total areas, by crops, for each of the six EGMC Stages. Crop coefficient curve equations should be developed for the various crops. These should be flexible in time so as to be used with any given planting date. This should be transferred to JVA (along with Task 2) with appropriate training; and

   b. Adaption of the program from Task 4a to perform the daily water demand by farm unit, laterals, checks and sections. This process should allow for specified rotation along and between laterals. This cannot be made fully operational until Task 3 has been completed.

   After the program in Task 4b is operational, the orders received by the farmers by laterals and accumulated by Sections should be compared with corresponding hand calculated values for a period of six months to one year. This will provide time to work out the problems in data transfer and permit some calibration adjustments of the computer models. Two or three visits by the expatriate expert should be scheduled during this time period for consultation and training;

5. Integration of the programs developed and implemented in Task 2 and 4b to allow calculation of the EGMC daily water balance

independently of farmer orders. Although the practical field implementation of this task may not be possible due to farmer perceptions of government agency control, etc., it can be altered to fit the existing situation and used as a guide in estimating the farm water use efficiency;

6. Development of a hydraulic model of the EGMC which, while similar to previous models (Wallingford), it should be adapted to run on the JVA PDP-11. This model should be tested with actual operational data from the canal system. This data should be collected for two or three typical operation conditions from low to high flow conditions. The implementation of the hydraulic model on the JVA computer should allow close interaction between model calibration and field data collection; and

7. Incorporation of the results of the hydraulic model of the EGMC to provide a printout of canal check structure gate opening and closing operations at intervals during the day along with the water balance. The successful implementation of this task should provide a realization of the anticipated benefits of reduced spills and more consistent flow rates at the lateral turnouts.

The above tasks are a necessary prerequisite to the full-scale computerization anticipated by JVA sometime in the future. As outlined above, the preliminary stage computer utilization and training could be initiated as soon as possible. This would provide the JVA with essential experience in data management and computer assisted canal operations without requiring extensive hardware modifications beyond present conditions.

The existing 64K PDP-11 computers may need to be upgraded to 256K before Tasks 6 and 7 can be computationally efficient. This can be readily achieved by installation of additional memory boards. The addition of one Arabic character terminal to each of the two machines should also be investigated. This would help in training of non-technical staff for data aquisition and correction.

Other Studies

Three areas of other studies have been suggested (Dr. Hans Wolter, Memo April 1984) to complement the water management system: hydraulic (hydrodynamic) modeling of the EGMC; hydrologic, long-term water availability studies; and a data transmission cable study. The data transmission study is beyond the scope of this review; however, the following comments are offered on the other two studies.

The hydraulic modeling of the EGMC would be valuable in identifying check gate operation strategies for several typical conditions. This can be achieved only if the model is calibrated to a set of observed flow conditions in the canal and allowance is made for the level of sediments in the canal bottom. A new approach here would be to develop the hydraulic models for use on the JVA's PDP-11 computers (see Task 6 and 7 in previous section). This would facilitate verification with field data and testing of alternatives. Utah State University, along with several other U.S. institutions, is qualified to perform these types of model studies.

The hydrologic models for long-term water supply forecasting could be developed and calibrated using historical data for a certain date in the spring to forecast summer flow volumes. This could be accomplished in a relatively straightforward manner by using modifications of existing deterministic watershed hydrology models. This, in fact, may be more realistic than the statistical approach suggested by Wolter.

Computer Programs for Engineering Analysis and Design

The JVA PDP-11 computers are well suited for the development, on-site or elsewhere, of a number of relatively small straightforward programs to aid the engineering staff in design and analysis. Repetitive calculations of flow conditions in open channels, printing of discharge tables for weirs and LTO or CHO gates, and structural design calculations are a few of the tasks that lend themselves to computer solutions. Some JVA engineers have written such programs, mostly on their own time, during the past seven months. This interest and activity should be recognized and encouraged by JVA as a worthwhile contribution. Interest was expressed by several young engineers for on-site training and program development workshops. This could prove to be a very effective vehicle for increasing computer usage and improving the efficiency of the JVA staff engineers.

There are many small or moderate size design and analysis programs which could be implemented on the JVA PDP-11 computers. These are generally in the area of civil engineering structures, hydraulics and surveying. There are some programs available specifically for irrigation, such as the design of branching pipe networks for sprinkle or trickle irrigation systems. A consultant could be retained to locate useful programs in the U.S., adapt them to a PDP-11 compatible system, and then transfer them to the JVA with appropriate on-site verification and training.

OPERATION AND MAINTENANCE MANUALS

As a result of conversations with field personnel and an extensive search through the JVA library, the only operation and maintenance manuals that we were able to find were related to the Hisban-Kafrein Sprinkler Irrigation Scheme. Without proper documentation of operation and maintenance procedures, confusion permeates the operation of the project and maintenance is deferred and completed only on an as-needed basis.

In reviewing several of the contract documents from past stages of development, the Team found that most asked for were instruction manuals for specific pieces of mechanical equipment. Such requests, which normally would include a parts list and catalog cuts of the piece of equipment, should not be confused with an operation and maintenance manual of the entire project. For example, an operation and maintenance manual for a specific piece of equipment is usually requested as part of the equipment specification. For a typical example of what has been requested in past tender and contract documents, we refer to Section 9.13.13 of the East Ghor Extension Project - Tender and Contract Documents, Main Canal Pumping Plants Sprinkler System and Farmgrading, May 1974, which is quoted below.

> "The Contractor shall furnish and submit to the Engineer, in triplicate, bound Instruction Manuals containing the following material:
>
> 1. Manufacturer's mechanical equipment parts list of all functional components of the systems listed on the Equipment Schedule Drawings, control diagrams and wiring diagrams of controllers. List shall give system no., unit no., manufacturer's model no., and manufacturer's drawings no. Parts shall include manufacturer's recommended spare parts for one year operation;
>
> 2. Chart of the tag numbers, location and function of each valve;
>
> 3. Maintenance instructions for each type of equipment;
>
> 4. Possible breakdowns and repairs for each type of equipment;
>
> 5. List of nearest local suppliers for all equipment; and
>
> 6. Manufacturer's literature describing each piece of equipment listed on the Equipment Schedule, control diagrams and wiring diagrams of controllers.

The Contractor shall furnish all of the foregoing to the Engineer for his review as to the fulfillment of the specified requirements."

In contrast to this request for a specific piece of equipment, we refer to the project operation and maintenance instructions prepared by Sir M. MacDonald and Partners for the Hisban-Kafrein Sprinkler Irrigation Scheme, included as Appendix B. This document, along with project maps, form the basis of a properly prepared O&M project manual. Also, the description and O&M instructions prepared by Weir Pumps Ltd. for the Hisban-Kafrein Sprinkler Irrigation Scheme is a well prepared manual and provides a good example to follow.

The Team highly recommends that appropriate operation and maintenance manuals be prepared for the JVA personnel. In reviewing the contract documents for the Mujib and Southern Ghors Irrigation Project, we find that an instruction manual has been requested for the electrically and hydraulically operated equipment, but a request for overall project O&M is not included. We would suggest that steps be taken now to have the contractor provide an O&M manual for the entire project.

SOUTHERN GHORS

The Team visited the new construction of the Phase I Southern Ghors project and carefully studied the various Phase I and Phase II feasibility reports and design documents. We like the basic design concepts and concur that trickle irrigation is appropriate.

Maintenance

The same comments which we have presented elsewhere for the Jordan Valley system will be even more important for the Southern Ghors. In review of the very limited supply of water per unit of land area served, the normal delivery capacity of the system is only 2.0 mm/day over the total irrigable area; and this is barely enough water for winter vegetable crops under trickle irrigation and only about one-fourth of the water needed for summer crops.

The farm turnout hardware (water meter, flow and pressure control valves) are secured in an underground vault. They should be safe from vandalism; however, the steel covers appear to be vulnerable. Because of this, a careful and systematic checking program should be set up to maintain the security of the turnouts.

We noted that the vaults did not have drains and expect that this will complicate maintenance. Therefore, either drains should be provided (except where the vaults are installed in very high water table areas) because valves tend to leak a bit, or portable sump pumps should be on hand.

Maintenance of the system will require that the water meter and flow control valves be periodically calibrated. Calibration will be relatively easy since the two can be checked against each other and only occasional checks on the overall accuracy (discharge) will be needed.

Operation

The Team feels that it would be simpler to control the system operation (have the water distributors turn the farm unit values on and off) if farm units are provided with a 12-hour water delivery every other day rather than the specified six hours per day. (This would not alter the design as it is only a management decision.) Pairs of farmers would switch the water between each other's fields and the JVA water distributors would only need to set (open and close) valves once per day. The water distributors could also be trained to service and monitor the meters and flow and pressure control valves.

Manuals, Training and Staffing

Careful attention should be given to developing the necessary O&M manuals for each subproject. The organization of the O&M Division should be carefully developed and the water distributors should have adequate transportation to efficiently carry out these duties. Since this is a new and very technical project, it is an excellent place to begin with an efficient, well trained O&M Department. All supervisors, technicians and field workers should be fully trained for the functions which they will be expected to perform. The O&M manuals should form the basis for the needed hands-on training. In addition, farmer training programs for the efficient use of the project water O&M of their own trickle systems should be developed.

Outline of Operational Management

The Team feels the following outline (taken from pages 56-59 from the Drip Operation Study Report - Mujib and Southern Ghors Irrigation Project Phase II, February 1981 - Binnie and Partners) for the O&M of the project, developed by the consultant, forms a good point of departure.

General

This section has been prepared to outline the operational management which would be required for the project.

Water Control

The basic objectives of the control system are:

-- To ensure that as much of the baseflow as possible is delivered to the farmer and used effectively;

-- To ensure that each farmer receives his fair share of the water and that he has his share of supply at the most favorable time of day; and

-- To ensure that the water is distributed in such a way that the farmers' and operators' time is most efficiently used.

It was agreed with JVA that each farmer would receive "low", "normal" and "high" supplies of water for six hours each day. He would receive "excess" supplies for twelve hours per day. The same farmer should not always receive his water at night but the times each farmer receives his water should be periodically changed.

For the proposed method of water distribution there are two control variables: first, the settings of the automatic flow limiting valves at the farm turnouts; and second, the length of time for which each farmer is supplied water. The aim would be to estimate in advance the baseflow and set the valves in the turnouts to ensure that the maximum percentage of the baseflow enters the system and is fairly distributed without the need for irregular ditchrider switching.

The Water Control Office (WCO) would estimate the average baseflow for the month, ten days in advance. For each farm turnout the flow rate required to deliver its share of the water source would be calculated. The automatic flow limiting valve at each farm turnout would be set to the appropriate value at the start of the period, the farmer being notified of the increase or decrease over the previous period's value.

Each day the total baseflow of the source and the flow abstracted through the intake would be measured. The information built up with time from these measurements would indicate trends in the baseflow so that the seasonal changes in settings of the automatic flow limiting valves at the farm turnouts could be predetermined with more certainty. It is these valves which control the maximum flow entering the pipeline at the intake (unless there is insufficient baseflow and storage to satisfy the requirements of the valves). The frequency of changing the settings of the valves would determine how much of the baseflow is wasted. The valves could be adjusted infrequently at a conservatively low value or frequently at higher values. The former would result in more work for the JVA but less wastage of water.

The flows passing through the pipeline upstream and downstream of the sand filters would be measured. By summing all the flows through the farm turnout flow meters (which would be less than summing all the settings of the farm turnout flow limiting valves if some farmers were not using their full allocation of water) the losses in the distribution system downstream of the sand filters and the losses from flushing the sand filters would be calculated.

As the storage pond would be in-line and would have an overflow there would be no control exercised on the flow at the headworks during routine operation.

With the originally proposed method of water distribution of four farmers sharing a continuously supplied turnout and each farmer switching, no ditchriders would be required for routine turnout switching. They would be required only to adjust the automatic flow limiting valves at intervals of the order of three months and might be required to arbitrate in case of disputes between farmers. With the proposed method of water distribution the ditchrider switching of each farm turnout would be required at 12-hour intervals.

Tariff System

The tariff system should be such as to encourage the farmer to use the full amount of his share of the water source, whether for crops or leaching. A charge based on land area would thus be appropriate. However, a farmer who managed somehow to take more than his share of the water should be heavily penalized. The water meters at the farm turnout would be used to check for such misuse.

Operational Details of the Project System

We have listed below the principal duties in addition to general maintenance which will have to be carried out during operation of the scheme. Note that not all duties will be applicable to all parts of the scheme.

1. Headworks
   Measurement of baseflow.
   Measurement of flow diverted into intakes.
   Rebuilding of diversion bunds.
   Inspection of foundations and flood protection for scour damage.
   Operation of scour gates to clear intakes.
   Operation of intake gates (especially during floods).
   Operation of gates into settling basins.
   Scouring of settling basins (and possibly occasional dosing).
   Scouring of storage ponds.
   Operation of flushing and other gates on open channels.
   Hand excavation of any sediment entering open channels.
   Inspection of condition of gates including automatic flood gates.
   Reporting gate settings and measurements to WCO.

2. Pipelines
   Inspection of all valves and fittings.
   Periodic operation of flushing valves (very important).
   Inspection of pipeline for buildup of sediment, scale, growths, etc.
   Operation of pump stations including fuel supply, routine maintenance of pumps and motors, setting of pump supply controls, etc.
   Inspection for leaks.
   Inspection of foundations and flood protection in wadis.
   Reporting to WCO.

3. Sand-filters
   Measurement of the primary pipeline flows upstream and downstream of the sand filters.
   Measurement of pressure drops across filters.

Inspection and maintenance of automatic backflushing systems if installed or operation of manual backflush (very important).
Inspection and replacement if necessary of filter media.
Switching of flow to even out flow between individual filters and minimize pressure drop.
Reporting to WCO.

4. Farm turnouts
Adjustments to automatic flow limiting valves in accordance with baseflow data from headworks.
Recording of flow meter readings and reporting to WCO.
Operation of isolating valves in lockable JVA box.
Routine inspection of turnout equipment.
Arbitration in disputes between farmers.
Reporting to WCO.

In addition to his normal duties the farmer would have the following duties related specifically to the drip system:

-- Switching on and off the appropriate isolating/control valve in the farm turnouts (or at the control head);

-- Switching of water to each plot in turn during the period when he receives water;

-- Measurement of head loss across the strainer, regular thorough-washing and occasional removal of the screen for cleaning when required;

-- Dosing with fertilizer (and to control scale and micro-organisms if required); and

-- Periodic flushing of mains, submains and driplines.

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APPENDICES

APPENDIX A

STUDY TEAM ITINERARY

March 24 - April 20, 1984

STUDY TEAM ITINERARY

Following is the itinerary of the study Team giving the places and persons visited and a brief description of what was reviewed or discussed:

March 24/Amman	Team members arrived in Amman.
March 25/Amman	Fuad Qushair, Tom Rishoi, and Doug Sheldon - Checked in with USAID; discussed logistics of visit.
March 25/Amman	Dr. M. Hadadine and Dr. M. Beni Hani - Had brief meeting with President of Jordan Valley Authority (JVA) and Irrigation Vice President.
	Dr. F. Natour, Mr. Avides Serpekian, and Mr. Wael Jouhari - Met with JVA Vice President, Irrigation Vice President, and a design engineer and maintenance engineer. Had further discussion of what the JVA expected of the Team. Mr. A. Serpekian from the JVA assigned as member of the study Team as well as a guide and interpreter.
March 26/Field	Mr. Hasan Abedel Rahman Saleh - Met canal inspector at the Yarmouk River diversion works; observed island development which is restricting Jordanian diversions and obstruction in tunnel inlet channel. Continued by driving along the canal bank service road. Visited ditchriders at station near Wadi Arab; continued along canal. Stopped at Stage I Headquarters at Wadi Arab. Discussed water ordering and allocation process. Continued along canal bank.
March 27/Madi	Engineer Wael Jouhari - Met at Headquarters and discussed repair of French water meters in pipeline systems and other aspects of maintenance. Observed Zarga diversion canal.
March 27/Along Canal	Engineer Rashed Hassan, Engineer Hareth Remani, Engineer Dawlat - Visited maintenance (old) workshop. (Deir Alla) Discussed canal cleaning equipment and performance. Continued traveling along canal; stopped at Stage IV ditchrider station at Zarqa Siphon. Traveled down main lateral at 65.3 km with ditchrider. Observed gate setting and measuring process at ditch 291.

March 28/Drar	Engineer Farouk Albashabsheh - Met with chief of Stage II; discussed operation and maintenance procedures.
March 28	Engineer Yousef Hasan, Engineer Dawlat - Observed computer room (PDP-11) at this location. Discussed communications system.
March 28/Along canal	Traveled to end of canal; stopped at a pump station; observed turnon procedure and cavitation.
March 29/Amman	Engineer Hana Hanbali, Dr. M. Beni Hani - Had preliminary discussion of field observations and response as to purpose of review. Looked through the JVA Library for pertinent documents and O&M manuals.
March 30/Jerash	Visited Roman site; observed water conveyance and other construction.
March 31/Deir Alla	Mr. Saleh Hubeisheh - Met with director of O&M and discussed organization, maintenance procedures, etc. Visited maintenance crew at main lateral 65.3; 18 workers manual cleaning. Continued south to Hisban-Kafrein project; observed dam, diversion and pump station.
April 1/Madi	Engineer Wael Jouhari - Met Wael at his office. Watched crane function as dragline to clean section of main canal at 65.3 km. Checked on maintenance crew progress on main lateral 65.3 Looked at Zarqa triangle pipe inlet structures and Laval sediment separators. Also visited another pump station. The operator knew that cavitation was not a good sound.
April 2/Amman	JVA Office, Kenneth Laurent - Studied available reports. Met with USAID for a brief updating of the Team's situation.
April 3/Valley	Ditchrider, Engineer Shafik - Traveled early to Valley to spend day with ditchrider on open ditch lateral (Hill) and on pipeline system (Keller, Serpekian and Mickelson).
April 4/Amman	Dr. Hans Wolter - Met with representative of German assistance program. Discussed new maintenance workshop and computer proposals of ERNO and GERSAR. Continued study of reports.

April 5/Safi	Engineer Suheil Wahsheh, Engineer Ibrahim Mazhar - Traveled to Southern Ghor met with the JVA construction engineers; reviewed some items with Italian Engineers; observed diversion works, etc. for pipe system.
April 6/Petra	Observed Nabataen and Roman water works and construction.
April 7/Amman	Dr. M. Hadadine, Dr. F. Natour, Dr. M. Beni Hani - Met with President, Vice President, and Irrigation Vice President of the JVA. Discussed findings and observations to date. Continued review of reports, etc.
April 8/Amman	JVA Office - Worked on report; met with Representative of Sir Alexander Gibbs about Mahalla dam study efficiencies and evapotranspiration (ET).
April 9/N.E. Ghor	Mr. Abdullah Safadi - Observed Yarmouk diversion situation at a low flow. Team split up. Hill traveled with measurement staff to observe inflow measurements at tunnel outlet weir and side wadis.
	Keller, Mickelson, and Serpekian -Looked at surface irrigation and pump station in the area.
April 9/Deir Alla	Ministry of Agricultural Experiment Station - Keller met with Bob Harwood and Gordon Roddwal of Washington State team. Hill visited weather station and discussed data with observer.
	JVA maintenance and new workshop - Mickelson and Serpekian visited new central workshop and talked with mechanical engineer.
April 10/Amman	JVA Office - Worked on report.
April 11/Amman	JVA Office - Worked on report.
April 12/Amman	JVA Headquarters - Debriefing with President, Vice President, Vice President Irrigation and the JBA O&M administration. Debriefed with AID. Final day of study.
April 13/Amman	Hill and Mickelson departed.
April 13-18/Amman	The JVA office - Keller and Serpekian completed rough draft of report.

April 19/Amman	The JVA headquarters - Keller and Serpekian had exit visits with Drs. Hadadine, Natour and Beni Hani and delivered draft report. AID - Keller had exit visits with Laurent and Rishoi.
April 20/Amman	Keller departed.

APPENDIX B

HISBAN - KAFREIN SPRINKLER IRRIGATION SCHEME

OPERATING AND MAINTENANCE INSTRUCTIONS

HASHEMITE KINGDOM OF JORDAN

JORDAN VALLEY AUTHORITY

HISBAN - KAFREIN SPRINKLER
IRRIGATION SCHEME

OPERATING AND MAINTENANCE INSTRUCTIONS

D R A F T

JUNE 1980

SIR M. MACDONALD & PARTNERS
CONSULTING ENGINEERS
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UNITED KINGDOM

HISBAN-KAFREIN SPRINKLER IRRIGATION SCHEME
INSTRUCTIONS FOR OPERATION AND MAINTENANCE

CONTENTS

HISBAN-KAFREIN SPRINKLER IRRIGATION SCHEME
INSTRUCTIONS FOR OPERATION AND MAINTENANCE

1. DESCRIPTION OF SCHEME

The scheme makes use of available water supplies in Wadis Hisban and Kafrein as well as the stored water at Kafrein reservoir to irrigate an area of 15 500 donums (1550 ha) be means of overhead irrigation by sprinklers fed by underground mains.

The scheme as a whole has the following components:

- i) Hisban Offtake
- ii) Kafrein Reservoir
- iii) Seepage Collection Pond
- iv) Pump Station
- v) Pipe Conveyor Network
- vi) On-farm Irrigation Equipment

The general layout of the scheme is shown on Drg. No. HK-39 in the album of "as constructed" drawings (Drg. 1). Details of the different components of the scheme are shown on drawings 2 to 17 in this album. Details of the conveyor network, method of identification of pipelines and positions of valves etc are shown on drawings 2, 3 and 4.

2. PRINCIPLES FOR IRRIGATION SUPPLY

HISBAN OFFTAKE is the only source of supply to the area fed by conveyor H and pipeline HK1. The priority of supply by conveyor H (over the conveyor HK) is built into the system by the construction of a chamber 112 metres away from the offtake. When the flow in Wadi Hisban exceeds the demand of area H, the surplus is carried in conveyor HK either to Kafrein Reservoir or to feed the area supplied through pipeline HK1 or both.

KAFREIN RESERVOIR supplies directly (from conveyor K) the area fed by pipeline K2. It can also supply indirectly (by discharging through conveyors K1 and K into the seepage pond) the area fed by conveyor S.

SEEPAGE COLLECTION POND collects seepage water emerging in the Wadi Kafrein channel downstream of the dam and supplies conveyor S. The pond can be supplemented with water from the Kafrein Reservoir through conveyors K1 and K.

PUMP STATION draws on water from the seepage pond and, at times when seepage into the pond exceeds the irrigation demand, may be used to pump water back to Kafrein Reservoir or pipeline K2 or both.

3. HISBAN OFFTAKE (Drg. 6)

3.1 Operation for Irrigation Supply

The water entering pipelines H and HK for irrigation purposes is supplied from upstream of the scour sluice gate of the Hisban Offtake, through the orifice in the sluice side wall and under the baffle wall into the silt settling pond, from where it passes over the skimming weir into the valve intake well. Normally, the scour sluice gate and desilting valve should be kept closed, and the irrigation valves open, so that any water coming down the Wadi may be used for irrigation, up to the maximum discharge of 460 l/sec for which the pipelines from the Offtake are designed.

If the scour sluice gate remains closed during a spate in the Wadi Hisban, any flow in the Wadi in excess of that entering the settling pond will pass over the flood weir of the Offtake, and any water entering the settling pond but not drawn off for irrigation will spill into the scour sluiceway over the side spillweir. The settling pond is designed to act satisfactorily under this overflow condition. It is important, however, to operate the scour sluice gate during spates in the Wadi, in order to keep the upstream part of the sluiceway and the orifice to the settling pond clear of debris.

Hence, when the water level in the settling pond reaches the level of the side spillweir, the scour sluice gate should be opened sufficiently to prevent the water level in the settling pond rising further. The level in the pond may fall to 0.33 m below the side spillweir (that is to a level of -111.93) while still allowing the full irrigation demand of 460 l/sec to be abstracted. The recommended method of sluice gate control is as follows:

i) When the water level in the settling pond reaches the level of the side spillweir open the scour sluice gate fully. (This action will help to remove any detritus or floating debris which may have collected against the scour sluiceway crest or against the gate itself).

ii) When the water level in the settling pond has fallen to 0.30 m below the side spillweir (-110.90), close the scour sluice gate gradually to a partially open position necessary to retain the water level in the settling pond between 0.10 m and 0.33 m below the top of the side spillweir. (If the water level in the settling pond continues to rise after the scour sluice gate has been fully opened, no further action can be taken until the flow in the Wadi has fallen).

iii) When the spate in the Wadi has finished, close the scour sluice gate fully again.

3.2 Desilting of the Silt Settling Pond

The silt settling pond is designed to allow small particles, generally of size greater than 0.1 mm, to settle out before the water enters the irrigation supply pipeline. It will therefore require cleaning from time to time to remove the silt which it has collected. This desilting operation should be carried out when the irrigation supply can be cut for a few hours, since it will be necessary to drain the settling pond. The best time for the operation would be as a spate in the Wadi is subsiding. The flow available should be at least 500 l/sec for flushing the bottom of the pond, although scouring of any silt in the base of the pond will take place with a flow as low as 200 l/sec. The operation cannot be carried out when the flow in the Wadi is greater than 3 m^3/sec, since for those flows water will enter the orifice even if the scour sluice gate is fully open. The method of desilting is as follows:

i) Close the irrigation valves to prevent reverse flow in the first 112 m of pipeline

ii) Open the scour sluice gate fully. (The flow in the scour sluice will be drawn down below the entry orifice for the settling pond)

iii) Open the desilting valve on the dividing wall between the settling pond and the scour sluiceway to drain the pond

iv) Remove the baffle screen and clean it if necessary.

v) When the top of the desilting valve opening is exposed inside the settling pond, close the scour sluice gate, either partially or fully, sufficiently to maintain the water level at or near the top of this valve opening until the silt is cleared. The operation may be speeded by shovelling silt towards the centre and downstream end of the pond base

vi) If required, cleaning of the valve intake well and the first 112 m of the pipelines (as far as the chamber) should be carried out at this stage. For this purpose open the irrigation valves at the Offtake. The water flowing back into the valve intake well will flush out the first 112 m of the pipelines and the irrigation valves themselves. It will then be necessary to pump out the valve intake well and to remove any remaining sediment or debris with hand implements

vii) After satisfactory desilting replace the baffle screen, close the desilting valve, open the irrigation valves and close the scour sluice gate to resume irrigation supply.

3.3 Removal of debris

The Offtake will perform satisfactorily even with the bed load deposited up to the top of the flood weir. The action of the scour sluice will ensure at least a localised reduction in the amount of bed load deposited upstream. However it must be accepted that a routine clearance of rocks, stones and other bed load deposited against the structure has to be carried out. This clearance could be made a preliminary operation before desilting.

4. CHAMBER ON HK-H LINES AT CHAINAGE 0 + 112 (Drg. 10)

The purpose of this chamber is to ensure that priority of supply is automatically given to the H line. The chamber also acts as a large and efficient air valve. There are no operational requirements. If it should be necessary to stop the flow through one of the lines for repair or flushing purposes on the line, the stop logs can be placed in position and the appropriate irrigation valve closed at the Hisban Offtake.

5. KAFREIN RESERVOIR (Drg. 12)

No operation other than opening or closing the irrigation valves at Kafrein control tower is necessary. The maintenance of sluice valves is given in the Kafrein Dam - Instruction of Operation, Inspection and Maintenance of July 1970.

6. SEEPAGE COLLECTION POND (Drg. 7)

The maintenance requirements for the seepage pond are simple. The water surface in the pond should be cleared of wind blown debris to prevent clogging of the grating at the irrigation offtake. When cleaning of the bottom of the pond is necessary (which should not be required often, because any deposits will be of a wind blown nature) open the washout sluice to drain the pond. This should be carried out at times when no irrigation supply from the pond is required.

7. PUMP STATION (Drg. 13)

Description and operating and maintenance instructions are fully covered by Instructions supplied by Weir Pumps Limited.

8. PIPE CONVEYOR NETWORK

8.1 Operation

The operation of the network is contained in para 2: "Principles for Irrigation Supply" and in the information provided in the album of as-constructed drawings, particularly drawings 2, 3 and 4.

8.2 Maintenance

The maintenance of the network is limited (a) to periodic inspection of the line of pipelines for signs of leakage and (b) to washing out the pipelines as and when necessary. One of the symptoms of (a) and (b) above would be reduction in pressure for same operating conditions.

i) Flushing of HK Line

When the line is to be flushed close the 500 mm dia irrigation valve at the Hisban Offtake and place stop logs in the chamber at chainage 0 + 112. Keep the outlet valve at Kafrein Reservoir open. When the flow ceases open all washout valves on the line in sequence, starting from the Kafrein end.

After the line has been drained open the 500 mm dia valve at Hisban Offtake. Proceed to close the washout valves, starting from the Hisban end, when water flowing out of washout is clean. When all washout valves have been closed remove stop logs from chamber.

ii) Flushing of K and K1 Pipelines

Any flushing of lines K and K1 should be carried out in conjunction with the maintenance work on the seepage pond. This should be done at a period when no irrigation is taking place.

1. Close valves on the K and K1 lines at the Y junction at pump station.

2. Open the washout sluice in the seepage pond and allow the pond to drain. When the pond has been drained and the float valves have dropped, open one line at a time. Leave running until water runs clean.

3. Repeat with the other line and again leave running until water runs clean.

4. Close washout sluice to allow silt pond to regain original level and leave both lines K and K1 open.

iii) Flushing of Sections of any Line

When flushing of one section is necessary isolate that section by closing slowly the downstream valve and then the upstream valve. Open the washout valve and allow the section to drain. When draining is completed crack open the upstream valve to flush. When water flowing out of washout is clean open the downstream valve and close the washout valve. Finally fully open the upstream valve.

If the whole line requires flushing then this should be carried out in sections (the exception is K, K1 and HK) starting from the upstream end of line.

9. CONNECTION OF FARM TAKE-OFFS

It is recommended that no meters should be installed on the system until a farmer has taken over the responsibility for the meter and the meter reading. Thus the farmer should be made responsible for the protection of his meter against vandalism and for ensuring that it is always available for inspection by the Authority's meter reader.

The sequence of administration should be such that a farmer makes application for a water supply, and the supply is first of all made available by the Authority's technician or meter reader flushing out the supply from the distributor main to the meter box. When this supply is running clear and clean then the meter should be installed with the necessary distribution elbow to suit the farmer's overground equipment. The farmer should then be instructed in the use of the elbow depending on the pressure required for his own specific type of equipment.

From this point on the responsibility for distribution of the water becomes the farmer's and advice will have to be given on the proper use of the distribution equipment, which has been chosen for use for irrigation of the particular crops intended to be grown.

10. MAINTENANCE AND USE OF METERS AND PRESSURE REDUCERS

1. The whole operation of this scheme depends upon no farmer being able to take an excess amount of water which would lead to others being deprived of their entitlement. The amounts of water taken will vary according to pressure and therefore, pressure reducing valves must be adjusted to ensure that the pressure downstream

of the valve does not exceed the maximum required for the approved system of irrigation to be practiced by the farmer.

2. Where farmers are for any reason entitled to more water than that obtainable from one outlet point then it will be necessary to install a second outlet point on the line.

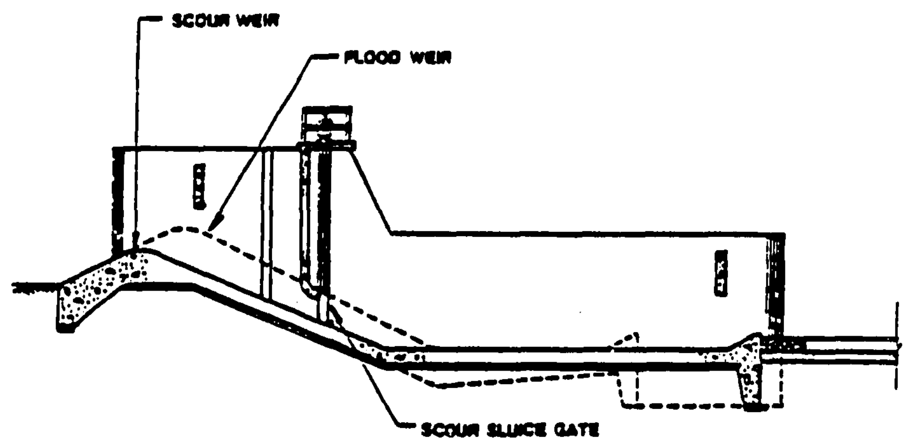
3. If this process is adopted then meters will be installed as farms become occupied and the irrigation water utilised. It will then be necessary to apply a maintenance programme for the meters to be exchanged, checked, repaired and tested. This should be done on a replacement basis so that no farmer is without water supply except for the period when the meter is being exchanged. At this time readings of the meter should be agreed and signed for by the farmer.

4. Spare parts for the water meters should be ordered in accordance with manufacturers' recommendations and kept in the maintenance workshop.

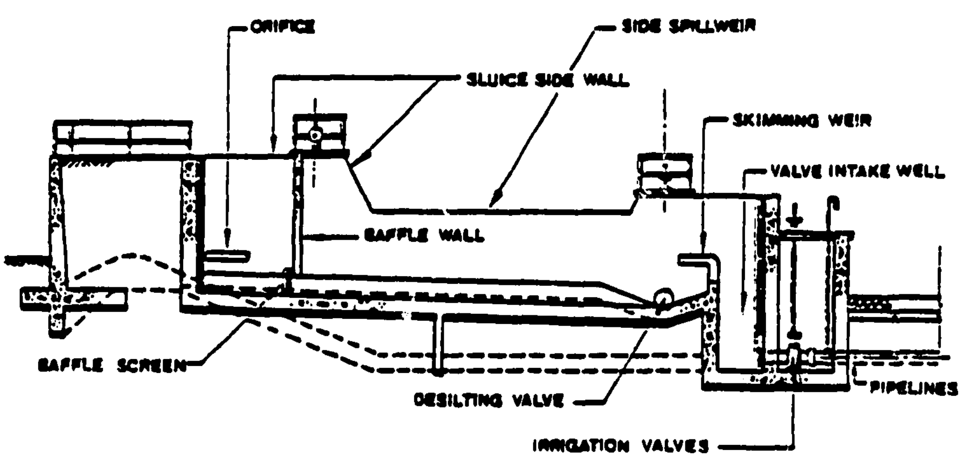
If maintenance instructions were not provided with the meters the manufacturers should be requested to do so now.

FIGURE 1

HISBAN OFFTAKE
NOMENCLATURE



SECTION THROUGH SCOUR SLUICEWAY



SECTION THROUGH SILT SETTLING POND

WATER MANAGEMENT SYNTHESIS PROJECT REPORTS

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WMS 3 Bangladesh/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 4 Pakistan/USAID: Irrigation Development Options and Investment Strategies for the 1980's

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WMS 7 General Asian Overview

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WMS 9 Senegal/USAID: Project Review for Bakel Small Irrigated Perimeters Project No. 685-0208

WMS 10 Sri Lanka/USAID: Evaluation Review of the Water Management Project No. 383-0057

WMS 11 Sri Lanka/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 12 Ecuador/USAID: Irrigation Sector Review

WMS 13 Maintenance Plan for the Lam Nam Oon Irrigation System in Northeast Thailand

WMS 14 Peru/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 15 Diagnostic Analysis of Five Deep Tubewell Irrigation Systems in Joydebpur, Bangladesh

WMS 16 System H of the Mahaweli Development Project, Sri Lanka: 1980 Diagnostic Analysis

WMS 17 Diagnostic Analysis of Farm Irrigation Sysems on the Gambhiri Irrigation Project, Rajasthan, India: Volumes I-V

WMS 18 Diagnostic Analysis of Farm Irrigation in the Mahi-Kadana Irrigation Project, Gujarat, India

WMS 19 The Rajangana Irrigation Scheme, Sri Lanka: 1982 Diagnostic Analysis

WMS 20 System H of the Mahaweli Development Project, Sri Lanka: 1983 Diagnostic Analysis

WMS 21 Haiti/USAID: Evaluation of the Irrigation Component of the Integrated Agricultural Development Project No. 521-0078

WMS 22 Synthesis of Lessons Learned for Rapid Appraisal of Irrigation Strategies

WMS 23 Tanzania/USAID: Rapid Mini Appraisal of Irrigation Development Options and Investment Strategies

WMS 24 Tanzania/USAID: Assessment of Rift Valley Pilot Rice Project and Recommendations for Follow-On Activities

WMS 25 Interdisciplinary Diagnostic Analysis of a Work Plan for the Dahod Tank Irrigation Project, Madhya Pradesh, India

WMS 26 Prospects for Small-Scale Irrigation Development in the Sahel

WMS 27 Improving Policies and Programs for the Development of Small-Scale Irrigation Systems

WMS 28 Selected Alternatives for Irrigated Agricultural Development in Azua Valley, Dominican Republic

WMS 29 Evaluation of Project No. 519-0184 USAID/El Salvador, Office of Small-Scale Irrigation - Small Farm Irrigation Systems Project

WMS 30 Review of Irrigation Facilities, Operation and Maintenance for Jordan Valley Authority

WMS 31 Training Consultancy Report: Irrigation Management and Training Program

WMS 32 Small-Scale Development: Indonesia/USAID