IMPLEMENTING THE IRRIGATION MAINTENANCE AND OPERATIONS (M & O) LEARNING PROCESS REGIONALLY OR NATIONALLY

USAID

WATER MANAGEMENT SYNTHESIS II PROJECT

WMS REPORT 81

IMPLEMENTING THE IRRIGATION MAINTENANCE AND OPERATIONS (M & O) LEARNING PROCESS REGIONALLY OR NATIONALLY

This study is an output of
Water Management Synthesis II Project
under support of
United States Agency for International Development
Contract AID/DAN-4127-C-00-2086-00

By

Gaylord V. Skogerboe - Agricultural Engineer

Utah State University
Department of Agricultural and Irrigation Engineering
Logan, Utah 84322-4105

March 1988

WMS Report 81

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. 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.

Jack Keller, Project Co-Director
Agricultural and Irri. Engr.
Utah State University
Logan, Utah 84322-4105
(801) 750-2785

Wayne Clyma, Project Co-Director
University Services Center
Colorado State University
Fort Collins, Colorado 80523
(303) 491-6991

E. Walter Coward, Project Co-Director
Department of Rural Sociology
Warren Hall
Cornell University
Ithaca, New York 14853-7801
(607) 255-5495

TABLE OF CONTENTS

LIST OF FLOW CHARTS

LIST OF TRAINING MODULES

FOREWORD

This "Maintenance and Operations Learning Process" was developed as the result of a series of assignments under the USAID-funded Water Management Synthesis II (WMS II) Project. The first assignment was for a 3-month period from September to December, 1982 in developing a "Maintenance Plan for the Lam Nam Oon Irrigation System in Northeast Thailand" (WMS Report 13). This process was first reported as Annex I in WMS Report 33, "Irrigation Systems Management Project Design Report: Sri Lanka", as part of a 2-month team assignment during September to November, 1984. This process was also incorporated in the Project Paper, "Irrigation Management Project" prepared as a WMS II team assignment in Nepal during February and March of 1985.

I am particularly indebted to two individuals for their comments during the development of this process. Dr. Alan C. Early, Department of Agricultural and Chemical Engineering, Colorado State University was a member of the WMS teams in Sri Lanka and Nepal, where he made many valuable suggestions. Khun Nukool Thongtawee, Director, Operation and Maintenance Division, Royal Irrigation Department (RID) has made suggestions, but more importantly, is actively engaged in implementing this process in Thailand under the WMS II activity, "Operation and Maintenance Training and Applied Study Program".

Under the program in Thailand, the "visible success story" is the Lam Nam Oon Irrigation Project. After completing the Maintenance Plan in December 1982, at least 80 percent of the Priority Maintenance Needs (PMN) were completed three years later. Today, this is the best maintained project in Northeast Thailand. The leadership for this achievement has been provided by the Project Field Director, Khun Vichai Sanguanpaiboon, and the Project Engineer, Khun Banjong Tanangsuangnun.

The first training course was on "Maintenance of Irrigation Systems" given at the Lam Pao Irrigation Project in October 1985 for one-week with 30 participants. The following week, the same course was given for another 30 participants at the Lam Nam Oon Irrigation Project.

The participants were field staff at these projects plus field staff from the seven medium-scale irrigation projects being improved under the USAID-funded Northeast Small-Scale Irrigation (NESSI) Project. The RID Project Field Director for NESSI, Khun Vira Wongsangnak, deserves much credit for the organization of the various training courses. The logistical support for all of the training courses (7) was outstanding. Both NESSI grant funds and WMS II funds were used to provide U.S. dollar support costs, while RID funds were used for local costs.

In 1986, two two-week training courses were given on "Operation of Irrigation Systems". The first course was given in June for 37 participants at the Huai Aeng Irrigation Project, which is one of the NESSI sites. The following two weeks, which ended July 3, the same course was given for 40 participants at the Lam Nam Oon Irrigation Project.

Also, in June 1986, a two-week training course was conducted at the Kampangsaeng Campus of Kasetsart University for 15 participants on the "Design and Production of Irrigation Television Programs." This was followed by three weeks of travel to some irrigation projects to obtain video tapes for the following modules:

1. Developing Irrigated Agriculture in Thailand.
2. Introduction to the Operations and Maintenance Learning Process.
3. Main System Maintenance.
4. Main System Operation.
5. Computerized Irrigation System Management.
6. Irrigation Water Management in Tertiary Systems.
7. Water Users Groups.
8. On-Farm Irrigated Agricultural Production.

The scripts for these eight video modules were begun in late June of 1986. The scripts for the first six video programs were completed in English in late 1987. During February 1988, video programs 2, 3 and 4 were completed in Thai and shown at a special program on March 3, 1988 at the RID Irrigation Engineering Center in Bangkok. Modules 1, 5 and 6 are being translated into Thai and will then be produced by trained RID employees.

In 1986, two groups of Thai trainers came to Utah State University (USU) for short-term assignments with the International Irrigation Center (IIC). The first group consisted of three RID and one Department of Agricultural Extension (DOAE) employees (Kittichai Krataithong, Yot Sanguanbun, Wutthikrai Smitthimadhindra and Supranee Chandratat). They attended the six-week IIC international training course, "On-Farm Water Management", then stayed afterwards for four weeks to review the 12 IIC manuals used in this course. In collaboration with IIC staff, a training course, "On-Farm Water Management for Tertiary Systems" was designed for use in Thailand using appropriate IIC materials and supplemented with some materials already available in Thai. These materials were partially translated while the group was at USU, but most of the training materials were translated after their return to Thailand.

The second group consisted of two RID engineers (Suchin Iampracha and Pong Madsatan) who attended the six-week IIC international training course, "Management, Operation and Maintenance of Irrigation Delivery Systems" beginning in October 1986. They stayed afterwards for four weeks and worked with IIC in selecting appropriate training materials suitable for use in Thailand. Also, additional materials were identified that have now been prepared by both RID and IIC staff. The available materials were taken with them to Thailand and then translated. These training manuals are presently available in Thai and were published by the Training Division in RID.

This training of trainers at IIC during 1986 had a tremendous impact upon the training courses given in 1987. Prior to 1987, all of the training courses were mostly presented in English with Thai interpreters. Beginning with the course, "On-Farm Water Management for Tertiary Systems" given at the Lam Nam Oon Irrigation Project for 35 participants (25 from RID and 10 from DOAE) from March 9-27, all of the training has been conducted in Thai by Thai trainers.

A major achievement in training occurred during July 1987. A 15-day training course on "Maintenance of Irrigation Systems" was conducted at the Lam Phra Plerng Irrigation Project near Korat in Northeast Thailand. There were 37 participants, 13 trainers and two typists. The course was presented in Thai by the Thai trainers. The reason for having so many trainers was because this was the last scheduled WMS II training activity. The maintenance field work was completed for the entire project. At the closing ceremony, a bound 450-page "Maintenance Plan for the Lam Phra Plerng Irrigation Project" was given to each participant and each trainer, as well as the Project Engineer. This document in Thai surprised everyone. Since most of the training is conducted in the field everyday, this documentation had to be produced in the evening. This was the first time that a Maintenance Plan had been produced by a training course.

The next training course will be "Operation of Irrigation Systems" to be given during 1988 for three weeks at the Lam Phra Plerng Irrigation Project. The goal of this training course will be to calibrate all of the flow control structures; evaluate channel losses in every reach of the main canals, laterals and sub-laterals; and produce an Operations Plan for this project. If successful, this will be the first time that an Operations Plan has been produced by a training course. Then, both the Operations Plan and the Maintenance Plan will be implemented during the next fiscal year (October 1, 1988 to September 30, 1989).

This "Operation and Maintenance Training and Applied Study Program" in Thailand has been very successful in developing a cadre of about 18 trainers, and most of them do a superb job. However, these are very qualified personnel who are not likely to be available for more than a few years for training assignments. Thus, provisions need to be made for continually developing new trainers.

Certainly, the project field staff at Lam Nam Oon and the NESSI sites are well trained in the M & O Learning Process, as well as having some feeling for tertiary system management. In addition, some Provincial Irrigation Office personnel and Irrigation Regional Office personnel in the Northeast have received training. The project field staff at Lam Phra Plerng have some knowledge of the Maintenance Phase; soon, they should receive training in the Operations Phase. Over the following three years it is very feasible for this project to become the next "visible success story".

In the mean time, the accomplishments at some of the medium-scale irrigation projects under NESSI are impressive. Besides the WMS II support at the Huai Aeng Irrigation Project for computer operation, a field data collection program is underway at three other project sites so that the weekly microcomputer steady state model can be employed. A "Maintenance Plan for the Huai Kaeng Irrigation Project" was published in Thai in early March 2531 (1988). Field trainers are available under the NESSI project and plans have already been developed for preparing a Maintenance Plan for each project site.

Probably, in 1989, this Irrigation M & O Learning Process will be launched on at least one other large-scale irrigation project in Thailand, but most likely two large-scale irrigation projects.

I have always appreciated the support provided by USAID/Thailand. In particular, since September 1982, I have always relied upon Khun Kamol Chantanumate to give me advice and guidance in implementing this program.

In getting this program underway, I give much credit to Dr. Jack Keller, USU WMS II Project Director, for his support in obtaining the WMS II funding. Also, I am very grateful to Dr. Worth Fitzgerald, the USAID WMS II Project Officer, who I feel has believed in me and in Khun Nukool Thongtawee, that together we could be successful, so he has strongly supported our efforts.

Finally, to those of you who read this report, I would like to recommend that you visit Thailand to observe this process in action. Although this process has only begun, there are some important accomplishments, with many more expected in the next few years. "Seeing is believing". You will quickly realize that this same process can be readily adapted to the "site specific" conditions in your country.

Gaylord V. Skogerboe

IRRIGATION M & O LEARNING PROCESS

The flow chart at the end of this section of the report illustrates the essence of the Irrigation Maintenance and Operations (M & O) Learning Process. As shown, this process has two major phases -- the Maintenance Phase and the Operations Phase.

Conceptual Approach

Most countries in the world have already constructed the most economical irrigation projects. Consequently, the major focus for these countries in the future will be on improving management practices to increase crop production on existing lands. However, deteriorating irrigation channels and inadequate operating procedures often preclude any significant improvement. This Maintenance and Operations (M & O) Learning Process has been developed to provide guidelines that will: (a) identify problems which commonly prevent irrigation systems from operating effectively; (b) develop solutions that treat the causes of these problems, rather than just the symptoms, in order to more effectively sustain improved maintenance and operations; and (c) provide field experience and insights for further improvements in the irrigation system.

An irrigation system can be divided into four major subsystems:

1. Water Source(s);
2. Water Delivery;
3. Farm; and
4. Water Removal.

The Farm subsystem is considered to be the "heart" of an irrigation system; it performs the system's primary function, that of food growth for humans and animals. The Water Delivery and Water Removal subsystems support the Farm subsystem.

Even if all four irrigation subsystems have been properly designed, the lack of an adequate technological and institutional framework for operating the system in accordance with the design criteria will likely lead to failure of the system, or low agricultural production levels. Generally, operating conveyance facilities have not been related to sustaining long-term productive agriculture.

There is a growing awareness world-wide that improved farm water management practices can be cost-effective in achieving increases in crop production. But, in so many cases, improved maintenance practices and improved operating procedures in the water delivery subsystem are required before any significant improvements in farm water management practices can be attained.

A common problem in irrigation systems is the continual cycle of irrigation system construction, followed by deterioration of the system because of inadequate maintenance, and then rehabilitation (which ends up being major re-construction), followed again by deterioration. This significantly inhibits the development of irrigated agriculture. As the irrigation channel network deteriorates, there is a decreasing capability for equitably delivering water throughout the system. The adequacy and dependability of the irrigation water supply decreases for some farmers, depending upon their location; thus, they are less likely to risk other expensive agricultural inputs such as fertilizer, etc. In some cases, a portion of the lands have to be abandoned for lack of water. The consequence is very slow progress in agricultural production.

As mentioned, the emphasis in the future will be improving water management practices and increasing crop production on existing irrigated lands. Technology alone will not bring about the necessary improvements. Instead, both technological changes and institutional modifications are usually required to help existing irrigated lands become more productive.

For example, it is not sufficient to rehabilitate a network of irrigation channels; the channels must be maintained season-after-season so that a dependable water supply can be delivered to every farmer. Likewise, it is not sufficient to just fill the channels with water; flow measurement devices are needed so that irrigation supplies are equitably delivered to each farmer. First of all, in order to operate and maintain an irrigation system on a sustained basis, highranking government officials need to provide the necessary manpower, equipment and budget. Secondly, the personnel responsible for operations and maintenance must provide farmers with timely and equitable water deliveries.

The recurring cycle of construction-deterioration-rehabilitation (construction) - deterioration usually precludes the timely and equitable distribution of irrigation water supplies. Besides resulting in stagnant growth in agricultural production, the construction phase adds to the national debt burden, which has now become a painful problem for many countries. In general, the economic benefits resulting from irrigation investments in recent decades have been dismal. Not only donors are questioning irrigation investments, but senior officials in a number of countries are raising the question, "Isn't there a better way?".

Recognizing the "site specific" nature of irrigated agriculture, where each project area is uniquely different, an effective approach must be process oriented, rather than an emphasis on technology alone, or a "prescriptive" approach that lists step-by-step procedures that are to be used on every irrigation project. Although a "prescription" is usually preferred by most irrigation officials, the disadvantages are: (a) the procedures will lead to less than optimal results for most projects; and (b) project field personnel do not "learn" how to accommodate the unique characteristics within their project area in order to improve the performance of the system. Instead, a process (or a series of processes) is required that is capable of being adapted to each "site specific" situation in order to be transferable.

The maintenance and operations "learning process" provides one technological approach for effectively sustaining an irrigation network over a long time period. This process emphasizes: (a) maintaining rather than rehabilitating; (b) documenting maintenance needs to improve financial management and accountability; (c) using existing flow control structures in irrigation channels for water measurement; (d) developing more detailed physical knowledge about what is occurring within the system; (e) increasing sensitivity about operating the system to meet the needs of farmers; and (f) documenting the needs and costs for irrigation system improvements.

In discussing operations and maintenance (O & M) issues, it is useful to subdivide the water delivery subsystem into the "main subsystem", usually called the main system, and the tertiary subsystem (or system) or Unit Command Area (UCA). The tertiary system or UCA is the land served by the last flow control structure along the main system. An irrigation project consists of a main system channel network that serves many UCAs. Many irrigation projects around the world have a division of O & M responsibilities between the main system and the UCA. Usually, a government agency is responsible for O & M activities in the main system, while the farmers within a UCA are responsible for O & M activities in the tertiary channel network.

This process is focused upon the water delivery subsystem, but the same principles would apply to the water removal subsystem (surface and subsurface drainage channel network). Most likely, the farmers would be responsible for maintaining the drainage channels in the tertiary subsystems, while the appropriate government agency would maintain the main drains and the branch drains flowing into each main drain.

For new irrigation projects, and recently rehabilitated systems, the initial emphasis would be the operations phase followed shortly afterwards with initiating activities under the maintenance phase, which would then be termed an O & M Learning Process. In contrast, for irrigation systems that are deteriorating, the term M & O Learning Process would be more appropriate, because the initial emphasis should be the maintenance phase, followed by an increasing emphasis on the operations phase as more and more of the maintenance needs are corrected. This is particularly true for lined irrigation channel networks that have deteriorated. However, for earthen channel networks, much of the data generated by implementing the Operations Phase is needed in order to make decisions about maintenance requirements (particularly the reconstruction of earthen embankments).

Maintenance Phase

The first step in both the operations and maintenance phases of the learning process is to do a field survey of required Essential Structural Improvements (ESI) for flow control (e.g., replacing gates) and water measurement (e.g., repairing damaged structures or installing new flow measuring devices). If there is structural damage, then it becomes important to assess the cause(s) of the damage, so that appropriate remedies can be applied; otherwise, the damage may recur in a very short time period. This Operations Control Maintenance Survey can be done separately or simultaneously with the maintenance survey. In either case, the results of the operations survey are incorporated into the maintenance survey to develop a Maintenance Plan.

The Operations Control Maintenance Survey is conducted after identifying the flow control structures in the irrigation system and deciding if all, or only some, of these structures will be used for discharge measurement. Of particular importance is each division point in the channel network because these are locations where water is diverted from a larger channel into a smaller channel, and the smaller channels' discharge rate should be measured. These division structures should be inspected for necessary cleaning, repairs and replacement (e.g., gates, bricks, etc.). The field inspection results for each structure should be recorded in a field book with sufficient detail so that a good cost estimate can be prepared later; then, the necessary maintenance should be done in order to have the structure function for both flow control and water measurement.

In many irrigation systems, numerous open channel constrictions can be used for measuring water such as drop structures, check structures, or flow regulating structures. Many of these structures should be improved (ESI) so that they can function as water measurement devices. Then, the channel losses between two structures can be measured. Sometimes, such measurements will require special operating procedures for 1/2-2 days so that water is not diverted between the two structures (unless the water diversions can also be accurately measured).

A detailed "Essential Structural Improvements Plan" should be prepared that includes:

1. Physical Description of Irrigation System
2. Proposed Flow Measurement Program for Equitably Distributing Water Supplies
3. Proposed Flow Measurement Program for Evaluating Channel Losses
4. Essential Structural Improvements (ESI)

5. Costs of Essential Structural Improvements
6. ESI Implementation Plan
7. Field Notes and Sketches.

Once the ESI Plan has been approved, then detailed cost records should be kept of actual expenditures during ESI implementation. This is important for planning similar investments in other irrigation networks because these costs reflect the minimum investment that should be made in upgrading the irrigation channels' operation. Accumulating this information for many irrigation systems will allow planners to allocate more realistic funding for upgrading other irrigation projects in their region or country.

The most important step in the maintenance phase is to conduct a detailed Diagnostic "Walk-Thru" Maintenance Survey that lists all maintenance needs along each main canal, branch or lateral canal, and distributary or sub-lateral including the inlet structure to each tertiary system (UCA). The survey requires 2-3 individuals (e.g. irrigation engineer and technical assistant) walking along the irrigation channels, taking notes on each maintenance need (e.g. removal of sediment, repair of canal bank, repair of damaged structure, etc.). These notes must provide sufficient details for preparing a cost estimate for correcting each maintenance need.

The concept of a "walk-thru", rather than driving, is for field personnel to gain more sensitivity about maintenance problems, not just major problems, but also minor problems that often develop into major maintenance problems in another year or two. Many of these minor problems are overlooked when driving, even slowly, along a canal bank.

The term "diagnostic" is very important in all aspects of irrigated agriculture, including maintenance. The majority of maintenance problems are easily observed in the field. Unfortunately, on many irrigation projects around the world, only the major maintenance problems are corrected, so that minor problems that could be corrected inexpensively are ignored until they grow into major expensive problems. Even more importantly, often only the symptoms of the problem are treated rather than the cause of the problem. This is done sometimes purposefully because of less expense and sometimes because the causes are not recognized. By developing an understanding of the causes, an individual attains "maintenance eyes" wherein minor defects are readily perceived and mentally pictured as growing into a major problem unless remedial maintenance measures are implemented.

A report should be prepared for each irrigation project that describes a maintenance plan to be implemented and completed within a reasonable time period, preferably 3-5 years. This report should include:

1. Physical Description of Irrigation Project
2. Essential Structural Improvements (ESI)
3. Status and Costs of ESI Plan
4. Inventory of Required Maintenance
5. Maintenance Costs
6. Priority Maintenance Needs (PMN) and Costs
7. Maintenance Equipment Requirements
8. Maintenance Manpower Requirements
9. Maintenance Plan
   a. Maintenance Issues
   b. Method of Implementation
   c. Implementation Schedule
10. Field Notes and Sketches

For each fiscal year, a Priority Maintenance Needs Work Plan would be forwarded to appropriate authorities for approval and funding. At the end of each year, the Irrigation Engineer for each project area would prepare a Annual Maintenance Completion Report that lists each maintenance need that had been corrected and its actual cost. This report would also be forwarded to appropriate authorities for their review.

Accountability is a key factor in this annual cycle of preparing a work plan and filing a completion report. Irrigation project personnel must develop credibility with central headquarters that the provision of manpower, equipment and funds will be used appropriately to correct Priority Maintenance Needs (PMN). In turn, this documentation allows central or regional headquarters to monitor and audit the effectiveness of the field maintenance program, as well as provide essential data for central planning of future maintenance funding requirements.

Some funds will already have been expended for essential structural improvements (ESI), while additional funds will need to be allocated to correct PMN. The allocated funds to the project may not be sufficient to correct all maintenance needs, so the highest priority maintenance needs should be corrected first, then the next highest priority, etc., until all allocated maintenance funds have been expended, or all PMN have been corrected.

When the operations phase has proceeded to the point where channel losses (including the tertiary systems) are being measured, along with field evaluations of irrigation application efficiencies on cropped fields, then the maintenance plan should be refined. A revised maintenance plan should be prepared that includes a section on maintenance requirements for tertiary systems, which would be undertaken by the farmers organization (e.g., Water Users Association, WUA) for each UCA with technical assistance provided by appropriate government agency personnel. As a minimum, the irrigation engineer, farmer representative for the particular UCA being inspected, and the technical assistant responsible for delivering water to the UCA should walk along the tertiary (watercourse) channel network and collectively prepare detailed notes on maintenance needs. At the same time, revisions in the previous maintenance plan can be made based on new information and experience gained during implementation. One of the more valuable insights that should have been gained by this time is an understanding of the causes of the maintenance problems, rather than just the symptoms.

After completing PMN, and gaining experience and credibility with WUAs, a Preventive Maintenance Plan should be prepared that would be the basis for continued long-term maintenance activities. This plan should discuss:

1. Physical Causes of Maintenance Problems
2. Anticipated Extent of Maintenance Problems
3. Maintenance Equipment Requirements
4. Maintenance Manpower Requirements
5. Maintenance Requirements for Farmers Organizations (WUAs)

6. Estimated Annual Maintenance Costs
7. Preventive Maintenance Plan
    a. Maintenance Issues
    b. Preventive Maintenance Activities
    c. Preventive Maintenance Requirements

This document should be forwarded for appropriate review and approval.

Operations Phase

The first step in the Operations Phase began when the structures in the irrigation system that are important for controlling the flow discharges in the system were identified. These structures were inspected under the Maintenance Phase in order to prepare an ESI Plan.

After making necessary essential structural improvements (ESI), a concerted effort will be needed to develop discharge ratings for all of the flow control structures. For the large main canals and branch canals, a current meter could be used to calibrate each structure, whereas portable flow measuring flumes can probably be used to calibrate the inlet structures for smaller irrigation channels (e.g., watercourses or sublaterals). Distributary or lateral channel structures would be rated using portable flow measuring devices wherever feasible; otherwise, a current meter would be used. Periodically, the discharge ratings should be checked and adjusted, if necessary, which should become a routine operations procedure. Also, detailed field books should be kept to describe the physical condition of the structure and nearby channel each time a discharge rating is made. With periodic maintenance, the discharge rating for each structure will change very little with time. Although this technology is simple, periodic maintenance and attention to details are important in order to have discharge measurements that are accurate within five percent.

After discharge ratings have been developed for each flow measurement structure, channel losses can be evaluated for most of the reaches in the irrigation network using the inflow-outflow method. In fact, stage readings collected at each structure prior to developing a discharge rating can be converted to calculated discharge rates that will be fairly accurate provided there has been no significant changes in channel sedimentation or vegetative growth, both of which are problems in many irrigation systems. Channel losses should be measured periodically throughout each irrigation season to determine the effects of channel water depths and water table depths on seepage rates. There will usually be some reaches where ponding tests will need to be conducted prior to or after the irrigation season, or perhaps before and after a scheduled rotation period, in order to accurately measure the conveyance losses.

Each irrigation project needs detailed maps showing all irrigation and drainage channels, along with all cropped lands served by these channels. These maps, along with adequate flow control structures that have been rated for discharge measurement, provide the tools for developing an Operations Plan. Presently, water delivery schedules are calculated for most irrigation projects in the world, but the lack of flow control and water measurement structures precludes measuring water deliveries. Consequently, conveyance efficiencies are crudely estimated by "pulling numbers out of the air" because there is usually only a meager amount of data, or none, on actual conveyance losses.

A simple Operations Plan can be prepared on paper beginning with some methodology for establishing water requirements or water demands for each tertiary system that is served by an outlet from the main system. Then, by knowing the conveyance losses in the main system between the canal headworks and the inlet to the tertiary system, the discharge requirements at the canal headworks can be calculated. The remaining data that is needed will be the time lag from the time that the appropriate discharge rate is diverted into the canal headworks until it reaches the main system outlet serving the tertiary system. The time lag can be determined by field experience, but preferably by field measurements.

Implementing the Operations Plan will provide more equitable distribution of irrigation water supplies throughout the irrigation project because channel losses will be taken into account, and the water delivered to each outlet from the main system can be measured. Monitoring can improve water delivery schedules as more field data are collected, and those individuals doing the monitoring will become more sensitive about what is happening within the system.

The monitoring, evaluation and feedback (ME & F) program should be designed to develop communication between the water users and those personnel responsible for controlling the main system outlet gates, which are the inlet gates to the tertiary systems. In addition, cropping patterns and discharge measurements are monitored and reported to project management staff, who in turn provide feedback to project field personnel for improving water delivery schedules.

During the irrigation season, a systematic procedure should be followed to periodically check the discharge rating for each, or most, of the flow control structures. These ratings will change with time as a result of deterioration of the structural components, or because of sedimentation and vegetative growth nearby.

Before each irrigation season, a "Walk-Thru" operations survey should be conducted. As a minimum, this should be done by the individual responsible for controlling the outlets from the main system into the tertiary system, plus that individual's supervisor. At each outlet, an informal discussion should be held with the farmer leader for that particular tertiary system. Discussions should be held with all farmers met along the way. This is an important activity for strengthening communication with farmers and gaining more sensitivity on how to improve the operation of the system. Using this information to further improve the Operations Plan each season will lead to improved credibility with farmers.

To achieve truly equitable water deliveries to farmers, more information is required to determine water losses in the tertiary channels and calculate water budgets on croplands. This can be done by undertaking a field data collection program to determine channel losses and irrigation application efficiencies. Tertiary channel (watercourses) losses for each UCA can be determined using the rated inlet structure and portable flow measuring device(s). Irrigation application efficiencies would be field measured on a relatively small sample of cropland areas taking into account the various soil types. This will provide much more realistic estimates of the water requirements at each tertiary system (UCA) inlet (main system outlet) throughout the irrigation season.

If sufficient field data are collected, then the Operations Plan could be placed on a microcomputer model that would adequately simulate the real irrigated system. A simple steady-state, volume balance operations computer program could be utilized consisting of three models: (a) weekly (or any other appropriate time period) irrigation requirements; (b) weekly water delivery schedules; and (c) weekly records and seasonal analysis. Experience has demonstrated that computer modeling leads to more field data collection, greater sensitivity about the system, and more equitable distribution of irrigation water supplies.

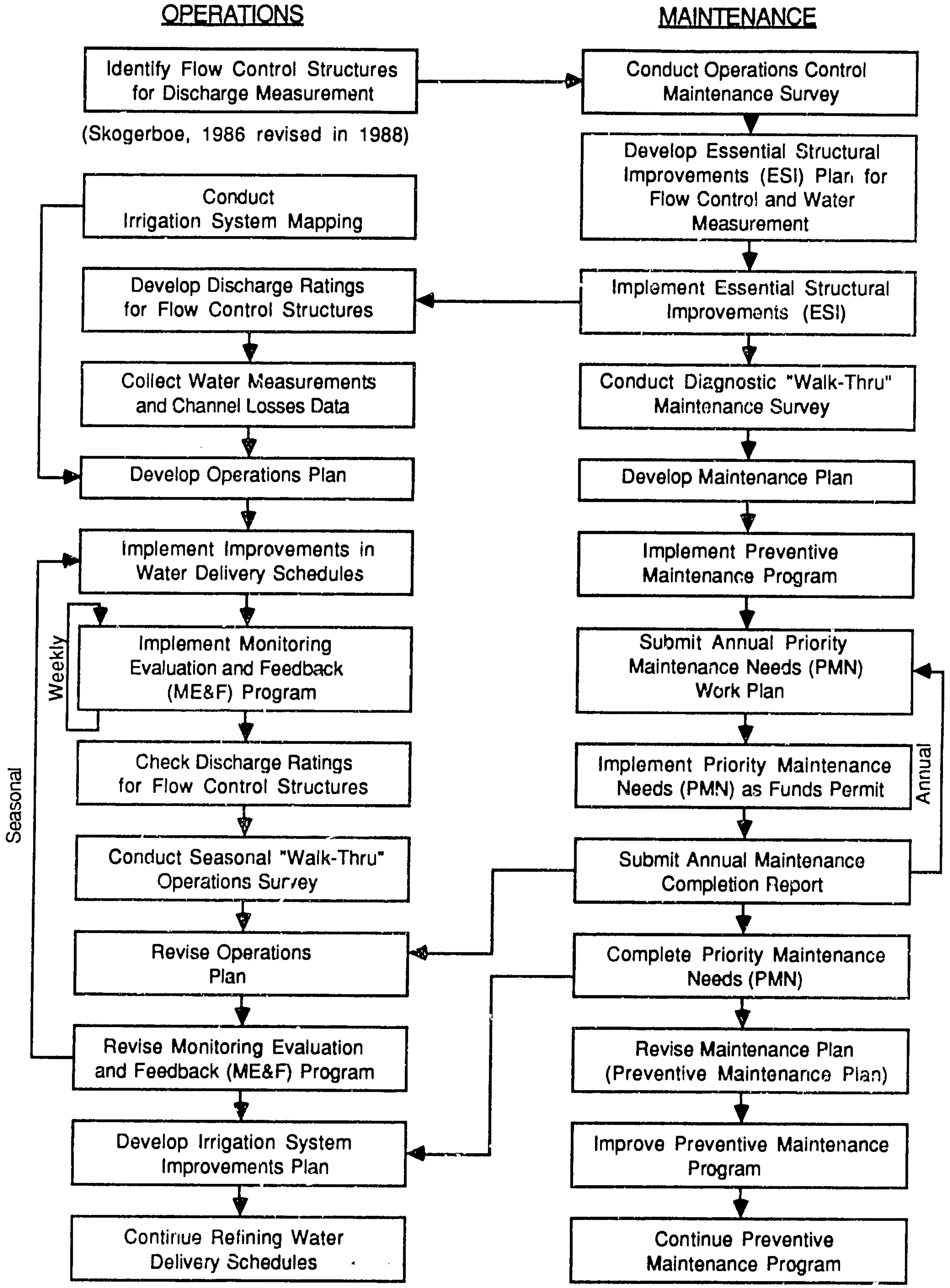
The more field data collected, the better the internal workings of the irrigation project will be understood. The field data will lead to some preliminary conclusions as to necessary improvements that would reduce water losses, thereby allowing more water to be available for crop production. A computer model, if developed, can be effectively used to simulate potential irrigation water management improvements in meeting crop water requirements anywhere in the irrigation system. For example, channel losses might be reduced in some high water loss reaches by placing compacted clay lining, soil-cement lining, plastic membrane lining, brick-and-mortar lining, or concrete lining. In other cases, some modifying of the rotation schedules might reduce losses. Providing farmers with technical assistance to improve their water management practices might also be beneficial. In some cases, additional storage on the irrigated lands could lead to more beneficial use of the available water supplies. Then, a cost estimate should be prepared for each potential improvement. The two data sets (water savings and costs) can be combined to formulate options for improving the irrigation scheme that would achieve higher levels of water use. These options can be prioritized by ranking according to cost per unit of water, or analyzing cost-effectiveness, to develop a "package" of technologies that would cost the least to achieve whatever objectives were used in the analysis.

The prioritized options should be documented and presented in an Irrigation System Improvements Plan. A suggested outline for this report would be:

1. Physical Description of Irrigation Project
2. Available Water Supplies
3. Irrigation Project Water Budgets
    a. Main Subsystems
        (i) Monsoon or Summer Season
        (ii) Dry or Winter Season
    b. Tertiary Subsystems
        (i) Monsoon or Summer Season
        (ii) Dry or Winter Season
4. Irrigation Project Performance
    a. Present Performance
    b. Historical Trends in Performance
    c. Potential Performance
5. Alternative Irrigation System Improvements
    a. Proposed Alternatives
    b. Impact of Alternatives Upon Project Performance
    c. Costs of Alternative Improvements
        (i) Capital Costs
        (ii) Operation and Maintenance Costs

The advantage of this document is that justification for the options can be readily understood by government and donor officials. Therefore, these officials can easily decide the level of investment that they consider appropriate at that point in time. Thus, this document makes it easier to seek support and more likely to obtain funding for implementing some, or all, of the recommended improvements. This, in turn, will allow continued improvement in the performance of the irrigation system that will facilitate, rather than hinder, increased agricultural production.

IRRIGATION M & O LEARNING PROCESS



IMPLEMENTING THE M & O LEARNING PROCESS

The last page of this section of the report contains the flow chart for Implementing the Irrigation Maintenance and Operations (M & O) Learning Process. As shown on the flow chart, implementation involves three major objectives:

1. Selecting Trainers and Developing Field Training Materials;
2. Developing Field Experienced Trainers and Project Staff; and
3. Creating "Visible Success Stories".

The purpose of this implementation process is to Create a National Awareness and Capability for Implementing the Irrigation Maintenance and Operations (M & O) Learning Process. The purpose in Implementing a National Program for the M & O Learning Process is to more effectively sustain an irrigation network over a long time period (say 50 years or more) so that water supplies can be more equitably distributed to farmers. The goal of the M & O Learning Process is to increase the agricultural productivity on croplands served by irrigation systems.

Selecting Trainers and Developing Field Training Materials

When implementing a new program, it is always very important to carefully select the initial group of Trainers, which should number 4-15, with at least 6 or 8 recommended. These individuals should be available for a minimum of 3 years and preferably 5 years. Most likely, if good qualified individuals have been selected to be trainers, they will also be important for other job assignments, so after 3-5 years in this job as a Trainer they will become even more valuable as leaders for the National Program for Implementing the M & O Learning Process. Thus, after completing the training for the first irrigation project to be improved, Assistant Trainers need to be selected for assisting the initial group of Trainers when conducting training at other selected irrigation projects. At that time, part of the responsibility of the Trainers will be to adequately train these Assistant Trainers.

The most rapid and effective approach developed to date for generating training materials suitable to a particular country, or region within a country, has been to have selected trainers sit with staff of the International Irrigation Center (IIC) at Utah State University (USU) following their attendance at the six-week international course on "Operation, Maintenance and Management of Irrigation Delivery System". This course provides training on the M & O Learning Process. Meeting with IIC staff after this training is also done to develop detailed course schedules for both the "Maintenance of Irrigation Delivery Systems" training course and the "Hydraulic Operation of Irrigation Delivery Systems" training course. The hour-by-hour schedule for each day of the training courses is developed. Then, the training materials required for these courses are identified. Usually, the majority of the required training materials are available at IIC; however, some of these materials require modifications to be more suitable for the "site specific" conditions at the irrigation projects, where the training courses will be conducted. Much of the modifications can be done while the selected trainers are at USU, depending upon the available time. (Usually, four weeks is recommended, but sometimes only two weeks have been allowed after completion of the training course at IIC.) The selected trainers take a copy of the materials home with them. In many cases, the training materials will have to be translated from English into another language, and it is preferable that this be done in their country. However, if this is difficult to accomplish, the IIC can have the materials translated and the required number of copies produced, and then shipped to the training course site.

The present availability of training materials for the M & O Learning Process is adequate for undertaking a program, such as has been done in Thailand and partially in Pakistan, but there is considerable variability in the amount and quality of necessary training materials. The lack of quality training materials previously had to be compensated for by using very experienced trainers.

The best training materials are available for the course. "Hydraulic Operation of Irrigation Delivery Systems". The listing of Training Modules on the following page cites seven modules. With USAID/Pakistan funding, IIC completed the development of Modules 1-5 in December 1987. Module 1 contains three video programs (1a, 1b and 1c),

TRAINING MODULES FOR
HYDRAULIC OPERATION OF IRRIGATION DELIVERY SYSTEMS

Module 1. Maintenance and Operations (M & O) Learning Process for Irrigation Delivery Systems
- 1(a) - Introduction to the M & O Learning Process
- 1(b) - Maintenance Learning Phase
- 1(c) - Operations Learning Phase

Module 2. Field Calibration of Irrigation Structures for Discharge Measurement
- 2(a) - Calibrating Irrigation Structures for Discharge Measurements
- 2(b) - Developing Discharge Ratings for Open Channel Constrictions with Free Flow
- 2(c) - Developing Discharge Ratings for Open Channel Constrictions with Submerged Flow
- 2(d) - Developing Discharge Ratings for Orifice Structures
- 2(e) - Developing Discharge Ratings for Culverts
- 2(f) - Developing Discharge Ratings for Overflow Structures
- 2(g) - Developing Discharge Ratings for Canal Outlets

Module 3. Measuring Discharge in Irrigation Channels with a Current Meter
- 3(a) - General Theory and Application
- 3(b) - Current Meter Discharge Measurements

Module 4. Measuring Discharge in Irrigation Channels with a Cutthroat Flume
- 4(a) - Development of Cutthroat Flume
- 4(b) - Cutthroat Flume Size Selection
- 4(c) - Checking Cutthroat Flume Fabrication and Maintenance
- 4(d) - Field Installation of Cutthroat Flume and Reading Discharge

Module 5. Measuring Irrigation Channel Seepage
- 5(a) - Inflow-Outflow Method
- 5(b) - Ponding Method

Module 6. Developing a Main System Operations Plan
- 6(a) - Methods of Operation
- 6(b) - Water Delivery Schedules

Module 7. Monitoring, Evaluation and Feedback Program
- 7(a) - Monitoring Procedures
- 7(b) - Data Analysis and Evaluation Reporting
- 7(c) - Communication and Feedback

plus the scripts, instructor's guide, and a manual. This particular module is suitable for presenting to everyone, from participants in the training course to high-ranking government officials. Module 2 contains seven video programs, plus numerous overhead projector overlays (28), homework problems, a technical manual (88 pages) that also contains problems with solutions, and an instructor's guide. For example, the Royal Irrigation Department in Thailand has already completed Module 1 in Thai and is undertaking the translation of Modules 2, 3, 4 and 5, with the exception that video program 2g will likely not be translated because it is suited more to Pakistan and India (thus, it can be expected that these training materials will require only a small amount of modification to be suitable for use in each country).

Module 6 will be developed in the near future. As listed, this module would demonstrate the preparation of an Operations Plan by hand calculations. The training materials are available in Thai and the English version will be contained in the WMS II Report, "Handbook of Improved Irrigation Project Operations Practices for the Kingdom of Thailand".

In addition to Module 6, there are a number of publications that are available for computer operation of an irrigation system. For example, the field data collected during the field training on "Hydraulic Operation of Irrigation Delivery Systems" is the same field data needed for the "Micro-Computer Steady-State Modeling of Irrigation Delivery Systems", which is an IIC manual and computer software that utilizes the work of Glenn Dearth at the Gal Oya Irrigation Project in Sri Lanka, and is now being expanded by IIC staff. This same software is being used for computer operation of the NESSI medium-scale irrigation projects in Thailand (see the Preface of this report). If use of this software were to be undertaken, individuals should be selected for participant training for eight weeks at IIC, six weeks attending the international course on "Applied Micro-Computer Use in Irrigation and Drainage" followed by the two-week option on "Computer Operation of Irrigation Delivery Systems". Individuals completing this eight weeks of training will be fully capable of implementing micro-computer steady-state operation of any irrigation project in their country.

Under the WMS II Project, with funding from USAID, the Department of Agricultural and Irrigation Engineering at USU has been developing computer software to assist in the planning, design, and operations of irrigation projects. Four submodels have been under development: (a) a watershed catchment model for predicting precipitation-runoff processes; (b) a river and reservoir model for addressing water management issues associated with the collection and storage of water resources; (c) a main system model to evaluate water management in conveyance networks; and (d) a command area (tertiary system) model for analyzing aggregate crop water requirements, irrigation application efficiencies, on-farm practices, and crop yields. Two of the models, the Unit Command Area Model and the USU Irrigation Main System Hydraulic Model were completed in 1987 and are being implemented on an experimental basis at the Lam Nam Oon Irrigation Project and Huai Aeng Irrigation Project in the Northeast of Thailand. The other models will be completed in 1988. There are six video programs available that describe the development and application of these models.

The USU Irrigation Main System Hydraulic Model performs hydrodynamic simulations of water flow in irrigation channels. The major applications of this model are: (a) hydraulic operation of irrigation channel networks; (b) as a training tool for canal operators where many different operational schemes can be quickly and safely evaluated; and (c) as a design tool to evaluate proposed canal system improvements under real-time operating conditions. The hydrodynamic simulation capability means that unsteady flow conditions can be simulated, such as the filling and emptying of irrigation channels, or the changes in water levels with time after changing a gate setting. Thus, the real system is more closely simulated than using the steady-state simulation described above. If this modeling capability is to be utilized, then individuals should be selected for participant training in the 49-week IIC international course on "Computer-Assisted Irrigation System Management". Individuals completing this course will be extremely proficient on the computer and can undertake many other irrigation project assignments, such as computerized maintenance planning and reporting, and financial management. The reader should consult the WMS II report, "USU Irrigation Main System Hydraulic Model: Replication of Modeling Capability in Other Countries" for a description of the model, personnel, equipment, data requirements, model installation, field applications, implementation in other countries, and a complete listing of references.

In Thailand, the "Computer-Assisted Irrigation System Management" program, using both the steady-state model and the hydrodynamic unsteady flow model, has been undertaken in conjunction with the "Irrigation M & O Learning Process". This is certainly not required, but doing the two programs conjunctively has been mutually beneficial to both programs.

In concluding the remarks about the training materials for the course, "Hydraulic Operation of Irrigation Delivery Systems", Module 7 on the "Monitoring, Evaluation, and Feedback Program" is not presently available. However, it is described in detail in the WMS report, "Handbook of Improved Irrigation Project Operations Practices for the Kingdom of Thailand". Thus, the material in this Handbook could be adapted to the "site specific" conditions in another country for use in the training program.

The required training modules for the course, "Maintenance of Irrigation Systems" is listed on the following page. Only Module 1 is presently available. For this training course in Thailand, which has been given at three different irrigation projects, the WMS report "Maintenance Plan for the Lam Nam Oon Irrigation Project in Northeast Thailand" has been used, with various sections of this report translated into Thai. There is descriptive material available for all six modules in the WMS report, "Handbook of Improved Irrigation Project Maintenance Practices for the Kingdom of Thailand". The materials contained in this Handbook would have to be adapted to the "site specific" conditions wherever this process is being implemented. However, having this Handbook greatly reduces the effort required in developing appropriate maintenance training materials for use in another country, or a region within another country.

There is a great need to develop these maintenance training modules in the same format as presently available for the five operations

TRAINING MODULES FOR MAINTENANCE OF IRRIGATION DELIVERY SYSTEMS

Module 1. Maintenance and Operations (M & O) Learning Process for Irrigation Delivery Systems

- 1(a) - Introduction to the M & O Learning Process
- 1(b) - Operations Learning Phase
- 1(c) - Maintenace Learning Phase

Module 2. Maintenance of Facilities

- 2(a) - Physical and Social Phenomena Causing Maintenance Problems
- 2(b) - Maintenance of Channels
- 2(c) - Maintenance of Structures

Module 3. Essential Structural Improvements

- 3(a) - Maintenance Survey of Flow Control Structures
- 3(b) - Developing an Essential Structural Improvements (ESI) Plan for Flow Control and Water Measurement

Module 4. Development of a Maintenance Plan

- 4(a) - Conducting a Diagnostic "Walk-Thru" Maintenace Survey
- 4(b) - Preparing Cost Estimates for Priority Maintenance Needs (PMN)
- 4(c) - Preparation of a Maintenance Plan

Module 5. Administrative Accountability

- 5(a) - Review and Approval of Maintenance Plan
- 5(b) - Submitting Annual Maintenance Work Plan
- 5(c) - Budget Control and Accountability
- 5(d) - Submittal of Annual Maintenance Completion Report
- 5(e) - Computerized Maintenance Planning and Reporting (COMPARE)

Module 6. Preventive Maintenance

- 6(a) - Revising the Maintenance Plan
- 6(b) - Implementing a Preventive Maintenance Program

training modules. The author hopes very much that funding can be acquired soon to undertake this assignment. Possibly, these training modules can be completed in 1989 so they are available for use in other countries.

Experience gained while conducting the training courses at the first irrigation project to be improved will provide valuable insights on necessary improvements in the training materials. In fact, the Trainers should be allowed a significant amount of time, say 2-4 months after each training course, to improve the training materials. The amount of time required is difficult to predict in advance and an appropriate decision can only be made at the completion of each training course. The trainers can discuss this matter in the evenings throughout the training course, so that at the time of the Closing Ceremony, they have already agreed among themselves what work is required to improve the field training materials.

After completing the revisions, the new training materials can be used at the additional irrigation projects selected for improvement. After every training course, the training materials should be improved until everyone is satisfied that a finalized set of training materials are available for the "Maintenance of Irrigation Delivery Systems" training course and the "Hydraulic Operation of Irrigation Delivery Systems" training course. Also, by this time, the Assistant Trainers should be fully qualified to function as Trainers.

Developing Field Experienced Trainers and Project Staff

Ideally, the entire group of initially selected Trainers should be sent abroad to attend the IIC international training course on "Operation, Maintenance and Management of Irrigation Delivery Systems". If funding is available, this should be done. If not, then perhaps some of the trainers can be sent each year. This would also be an ideal situation for the Assistant Trainers that are selected later. Of course, the most important is the first group of Trainers who are sent abroad, which should be at least 4, because they will also be involved in the selection of appropriate training materials and the development of hour-by-hour daily course schedules. A very important aspect of this training abroad is to provide mental pictures and technical knowledge about the Irrigation M & O Learning Process. For this reason, it may also be advisable to have the Irrigation Engineer in-charge of the irrigation project that has been selected for improvement to attend this training course, as well as the individual who will be responsible for supervising the Trainers.

There are some very important lessons that have been learned while implementing this M & O Learning Process. First of all, the training is conducted at the irrigation project, not in some centralized training center. Secondly, the participants in the training course include all of the irrigation project field staff who will be involved in the implementation process; however, other participants can also attend. Thirdly, each training course is expected to do much more than just provide training, it is also expected to produce a piece of work required in the M & O Learning Process. For example, for the first irrigation project selected for improvement, the first training course will produce an Essential Structural Improvements Plan, the second training course will produce a Maintenance Plan, and the third training course will produce on Operations Plan. Thus, the training is used to produce work required for improving the maintenance practices and operations activities at each selected irrigation project.

Experience is needed in improving the first selected irrigation project, then everyone will have more insight as to the time required for each training course. There are many variables such as the number of Trainers, number of Participants, the size of the project, and most of all, how hard is everyone willing to work. Too often, training courses are only offered for two weeks. This should be sufficient time for completing an Essential Structural Improvements Plan, but 3-4 weeks may be required to complete a Maintenance Plan or to complete an Operations Plan. The Preface to this report provides some insights, but this is a matter that needs to be seriously considered before undertaking each training course.

After completing the training, the Irrigation Project Staff implements the Plan resulting from the course. Although the training can be completed in a relatively short time period of only a few months, implementing the three Plans may require 3-5 years for completion. Thus, the training should probably be spread over at least a one-year time period. If the irrigation project is badly deteriorated, and considerable maintenance is required, then the Operations training may have to be delayed for a few years. Thus, it can be expected that the training at other selected irrigation projects will begin long before the first irrigation project has completed all of the necessary improvements. Again, exactly how this would be done in terms of timing is another "site specific" decision.

After completing the training courses at the first irrigation project to be improved, the flow chart indicates that three more irrigation projects would be improved. Actually, the number of irrigation projects to be improved during this phase of developing a national capability for Implementing the M & O Learning Process is again a "site specific" question. Instead, one, two, three, four or five irrigation projects could be selected for improvement. Certainly, before implementing a large regional or national program, at least two irrigation projects should have been improved, and preferably three or four. This will provide sufficient field experience for the Trainers and a fairly large group of Irrigation Project Staff. More importantly, it should have created at least two "visible success stories", or more.

Creating "Visible Success Stories"

One of the most powerful mechanisms for generating support in implementing change is to create at least one "visible success story", and preferably more than one. By doing so, not only do irrigation project staff develop an understanding of how to improve the performance of an irrigation project, but farmers will definitely recognize the tremendous improvements in water deliveries, and high-ranking government officials and politicians will also know that significant improvements have been made.

The major questions in creating a visible success story is the cost in terms of financial and human resources. Fortunately, the Irrigation M & O Learning Process has been designed to minimize the cost of improving the irrigation project, as well as train the project field staff how to sustain the improved system and to more equitably distribute water. The costs for improving the first irrigation project may be relatively high because everyone is "learning", but certainly the costs for improving the second irrigation project, and thereafter, will prove to be very reasonable.

As indicated in the flow chart, the first activity is to select at least the first irrigation project to be improved. The first project should be in definite need of improvement, so that the impact of implementing this process is obvious to everyone afterwards; the project should be somewhat representative of other projects that will also need to be improved in the near future; and appropriate resources must be made available to improve this project as quickly as possible, preferably in 3 years but not more than 5 years.

The selection of the second, third, fourth, etc., irrigation projects might be based upon different physical environments, or it may be desirable to improve irrigation projects in different regions of the country to demonstrate this process more broadly. Also, the size of the irrigation projects to be improved should probably be modest in the beginning and larger projects undertaken later (perhaps the third irrigation project) after more experience has been gained.

Also, it is important that at least two irrigation projects be improved to demonstrate the transferability of this process. In fact, there is a significant benefit to improving irrigation projects that are quite different, both to demonstrate transferability and to "learn" more from the implementation process, thereby providing more insight for Designing a National Program for Implementing the Irrigation M & O Learning Process.

After two, three or four irrigation projects are undergoing improvement, a program should be carefully designed to "create awareness" among the agricultural community, government agencies (especially, among all levels of Irrigation Department and Agriculture Department personnel) and politicians. The flow chart lists quite a few possibilities for creating awareness. There are already Video Modules and Handbooks that are available, which can be modified to reflect the particular situation in another country. At the same time, a Technical

Report and Executive Summary could be prepared for each irrigation project being improved. Certainly, a Slide Show can be prepared depicting project activities. Field Days and Field Tours are also valuable mechanisms for demonstrating project improvements. The combination of executive summaries, slide sets, and video modules are useful for communicating to high-ranking government officials at briefings, or before technical groups at seminars, and to inform farmers in the project area.

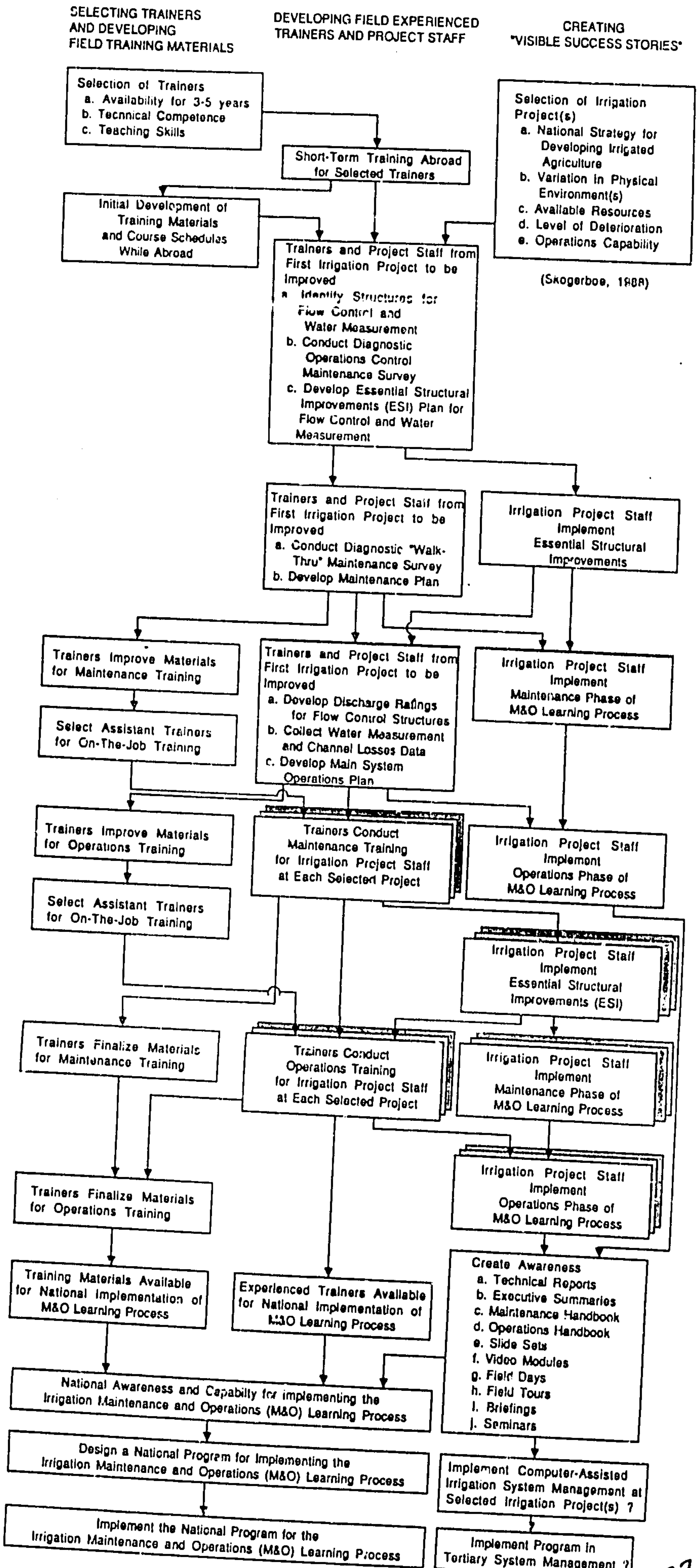
The combination of good training materials, field experienced trainers and irrigation project staff, along with creating awareness through "visible success stories" are the ingredients needed for establishing a National Program for the Irrigation Maintenance and Operations (M & O) Learning Process.

As indicated earlier in this text, there is also the question as to whether or not to Implement Computer-Assisted Irrigation System Management at Some Selected Irrigation Project(s) as part of this learning process for increasing the agricultural productivity from irrigation projects. Certainly, this will occur to some extent in almost every country in the near future.

The question that cannot be avoided is -- not whether to, but when -- to Implement a Program in Tertiary System Management. Generally, this is the most neglected portion of irrigation projects around the world. Unfortunately, implementation of the M & O Learning Process does not complete the need for irrigation system improvements. Instead, this Learning Process only tackles the easiest problems -- improving the main system. Improving the tertiary systems is much more difficult, but very necessary. Miracles can be created in the main system within 5 years, but major achievements in improving the performance of tertiary systems in an irrigation project are more likely to require 20 years.

Thus, the need for improving the performance of irrigation projects is never-ending. Hopefully, future generations will continue to improve the performance of irrigation projects and the quality of life for their inhabitants.

IMPLEMENTING THE IRRIGATION MAINTENANCE AND OPERATIONS (M&O) LEARNING PROCESS



WATER MANAGEMENT SYNTHESIS PROJECT REPORTS

18

WATER MANAGEMENT SYNTHESIS PROJECT REPORTS

WMS 1 Irrigation Projects Document Review

Executive Summary
Appendix A: The Indian Subcontinent
Appendix B: East Asia
Appendix C: Near East and Africa
Appendix D: Central and South America

WMS 2 Nepal/USAID: Irrigation Development Options and Investment Strategies for the 1980's

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

WMS 5 Thailand/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 6 India/USAID: Irrigation Development Options and Investment Strategies for the 1980's

WMS 7 General Asian Overview

WMS 8 Command Area Development Authorities for Improved Water Management

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 Systems 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-C078

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

WMS 33 Irrigation Systems Management Project Design Report: Sri Lanka

WMS 34 Community Participation and Local Organization for Small-Scale Irrigation

WMS 35 Irrigation Sector Strategy Review: USAID/India; with Appendices, Volumes I and II (3 volumes)

WMS 36	Irrigation Sector Assessment: USAID/Haiti
WMS 37	African Irrigation Overview: Summary; Main Report; An Annotated Bibliography (3 volumes)
WMS 38	Diagnostic Analysis of Sirsia Irrigation System, Nepal
WMS 39	Small-Scale Irrigation: Design Issues and Government Assisted Systems
WMS 40	Watering the Shamba: Current Public and Private Sector Activities for Small-Scale Irrigation Development
WMS 41	Strategies for Irrigation Development: Chad/USAID
WMS 42	Strategies for Irrigation Development: Egypt/USAID
WMS 43	Rapid Appraisal of Nepal Irrigation Systems
WMS 44	Direction, Inducement, and Schemes: Investment Strategies for Small-Scale Irrigation Systems
WMS 45	Post 1987 Strategy for Irrigation: Pakistan/USAID
WMS 46	Irrigation Rehab: User's Manual
WMS 47	Relay Adapter Card: User's Manual
WMS 48	Small-Scale and Smallholder Irrigation in Zimbabwe: Analysis of Opportunities for Improvement
WMS 49	Design Guidance for Shebelli Water Management Project (USAID Project No. 649-0129) Somalia/USAID
WMS 50	Farmer Irrigation Participation Project in Lam Chamuak, Thailand: Initiation Report
WMS 51	Pre-Feasibility Study of Irrigation Development in Mauritania: Mauritania/USAID
WMS 52	Command Water Management - Punjab Pre-Rehabilitation Diagnostic Analysis of the Niazbeg Subproject
WMS 53	Pre-Rehabilitation Diagnostic Study of Sehra Irrigation System, Sind, Pakistan
WMS 54	Framework for the Management Plan: Niazbeg Subproject Area
WMS 55	Framework for the Management Plan: Sehra Subproject Area
WMS 56	Review of Jordan Valley Authority Irrigation Facilities
WMS 57	Diagnostic Analysis of Parakrama Samudra Scheme, Sri Lanka: 1985 Yala Discipline Report

WMS 58 Diagnostic Analysis of Giritale Scheme, Sri Lanka: 1985 Yala Discipline Report

WMS 59 Diagnostic Analysis of Minneriya Scheme, Sri Lanka: 1986 Yala Discipline Report

WMS 60 Diagnostic Analysis of Kaudulla Scheme, Sri Lanka: 1986 Yala Discipline Report

WMS 61 Diagnostic Analysis of Four Irrigation Schemes in Polonnaruwa District, Sri Lanka: Interdisciplinary Analysis

WMS 62 Workshops for Developing Policy and Strategy for Nationwide Irrigation and Management Training. USAID/India

WMS 63 Research on Irrigation in Africa

WMS 64 Irrigation Rehab: Africa Version

WMS 65 Revised Management Plan for the Warsak Lift Canal, Command Water Management Project, Northwest Frontier Province, Pakistan

WMS 66 Small-Scale Irrigation--A Foundation for Rural Growth in Zimbabwe

WMS 67 Variations in Irrigation Management Intensity: Farmer-Managed Hill Irrigation Systems in Nepal

WMS 68 Experience with Small-Scale Sprinkler System Development in Guatemala: An Evaluation of Program Benefits

WMS 69 Linking Main and Farm Irrigation Systems in Order to Control Water (5 volumes)

WMS 70 Integrating Strategies for Improving Irrigation System Design and Management

WMS 71 The USU Unit Command Area Model

WMS 72 Development of a Branching Canal Network Hydraulic Model

WMS 73 User's Manual for the FORTRAN Version of the USU Main System Hydraulic Model

WMS 74 Hydraulic Modeling Applications in Main System Management

WMS 75 User's Manual for the Pascal Version of the USU Main System Hydraulic Model

WMS 76 Formulation and Evaluation of the USU Main System Allocation Model

WMS 77 Irrigated Land Use and Irrigation Distribution Systems for Four Schemes in the Polonnaruwa District of Sri Lanka

WMS 78 Classification of Gravity Irrigation Systems and their Operation

WMS 79 Development and Management of Small Marais

WMS 80 Baskets of Stones: Government Assistance and Development of Local Irrigation in a District of Northern Sumatra

WMS 81 Implementing the Irrigation Maintenance and Operations (M & O) Learning Process Regionally or Nationally

WMS 82 Handbook of Improved Irrigation Project Operations Practices for the Kingdom of Thailand

WMS 83 Handbook of Improved Irrigation Project Maintenance Practices for the Kingdom of Thailand

WMS 84 USU Irrigation Main System Hydraulic Model: Replication of Modeling Capability in Other Countries

WMS 85 Development of the Centre International de l'Irrigation

WMS 86 Forum on the Performance of Irrigated Agriculture in Africa: Papers and Proceedings

WMS 87 Niger Irrigation Scheme Case Studies (English & French)

WMS 88 Irrigation Management for Development

WMS 89 Bureaucratic and Farmer Participation in Irrigation Development

WMS 90 Irrigation System Management: An Interdisciplinary Synthesis of Water Management Studies

WMS 91 Assessment Report: Maharashtra Irrigation Program. USAID/India

WMS 92 Irrigation System Operation Intensity and Relative Water Supply: The Asian Case

WMS 93 Methodologies for Interdisciplinary Diagnosis of Irrigation Systems

WMS 94 Management-Focused Improvement of Irrigated Agriculture