1996. Proceedings of the Expert Consultation on Modernization of Irrigation Schemes: Past Experiences and Future Options.
Bangkok, Thailand. 26-29 Nov. Food and Agricultural Organization of the United Nations
http://www.itrc.org/papers/modwatercontrol/modernwatercontrol.pdf ITRC Paper 96-001

Modern Water Control and Management Practices in Irrigation: Methodology and Criteria for Evaluating the Impact on Performance[1]

by

Charles M. Burt, P.E., Ph.D.
Professor and Director
Irrigation Training and Research Center (ITRC)
California Polytechnic State University (Cal Poly)
San Luis Obispo, California 93407
USA
(805) 756-2379
e-mail: cburt@oboe.calpoly.edu

Presented at the

Food and Agriculture Organization of the United Nations (FAO)
Conference

on

Modernization of Irrigation Schemes:
Past Experiences and Future Options

November 26-29, 1996

Bangkok, Thailand

[1]The author would like thank Mssrs. Herve Plusquellec, Randall Purcell, and Chris Perry for valuable input to many of the ideas presented in this discussion.

Table of Contents

Overview

Modernization of irrigation projects results in an improved level of service to the ultimate users, the farmers. All modernization programs should contain these steps:

- An evaluation of the present status of the project, including a description of the quality of water delivery service which is provided.
- Realization by all project parties (from top management down to the lowest level operators) that the purpose of an irrigation project is to provide good water delivery service. Such service can be defined and quantified.
- An understanding by engineers of the important principles of water control structures and strategies, as they can be applied to providing better water delivery service.
- Deliberate implementation of modernization in steps which can be evaluated and corrected.

Motivation and Context

The Challenge

The need for proper modernization of irrigation project deliveries is set against the following background:

1. Worldwide, there are few remaining untapped irrigation water sources, and donor and country funding for the construction of new dams is declining rapidly.
2. Many countries have overdrafted their water supply (surface and groundwater); irrigation has been a primary consumer of that water supply.
3. Population gains will accelerate the need for increased grain yields.
4. The least expensive and most simple options for increasing crop yields through irrigation (expanding irrigated acreage) have already been exercised; attaining incremental improvements in yield will be increasingly difficult and expensive.
5. Historically, modifications to irrigation projects did not give thorough consideration to environmental consequences. Scarce water and

concern for environmental impacts increase the need for improved on-farm irrigation management.

Possible Options for Increased Agricultural Water Supplies

Low irrigation efficiencies have been documented in various projects, and improved irrigation efficiencies are often listed as a major source of "new" water. However, it is now evident that return flows from an "inefficient" project are often the supply for downstream projects, in the form of surface flows or groundwater recharge. Therefore, typical project irrigation efficiencies in the 20-30% range by themselves give no indication of the amount of conservable water within a hydrological basin unless that project is at the tail end of the basin (Clemmens et. al., 1995). Conservation (i.e., less spill, deep percolation, and seepage) within one project may deprive a downstream project of part of its accustomed water supply. Effective modernization programs will have to adopt a more sophisticated approach to examining water consumption and conservation.

Most "new" water for existing basins and projects will only appear if there is improved irrigation water manageability by farmers. The potential sophistication of on-farm water management[2] is highly dependent upon the level of water delivery service[3] provided to individual fields, which in turn depends upon the conveyance manageability[4] within the complete water distribution system (Plusquellec, 1988). For example, it is impossible to

[2]On-farm water management. The management of water by the farmer within a field. This includes factors such as the design of the field irrigation system (furrow length, type of land grading, sprinkler spacing, etc.) and selection of flow rates and durations in various portions of the field (e.g., the number of furrows irrigated simultaneously with a given flow rate). In situations where farmers can request water "on demand", on-farm water management also includes the concept of irrigation scheduling to meet crop evapotranspiration (ET) requirements. Also referred to as field water management.

[3]Level of service. The definition of irrigation service must include specification of the water right of the beneficiary ; the point of delivery; flexibility in rate of delivery; flexibility in duration; flexibility in frequency. See the later section on "The Concept of Service".

[4]Conveyance manageability. The ease with which the water supply can be manipulated to respond to changing upstream and downstream conditions. It includes the relative difficulty of moving water through canals, and the ability to change flow rates, maintain safe water levels, and store water within the distribution system of main, secondary, tertiary, etc. canals and pipelines.

implement drip irrigation throughout an irrigation project which only delivers water to fields once every two weeks (a typical delivery schedule in most non-rice irrigation projects). Drip irrigation requires daily irrigations with dependable small flow rates.

The methods that yield "new" water will include:

1. Improved Water Use Efficiency (WUE), where WUE is defined as:

$$\text{WUE} = \frac{\text{Crop Yield}}{\text{Irrigation Water Consumed}}$$

where consumption is evaporation plus transpiration

Improved WUE can come from:

- Improved use of rainfall,
- Improved timing of irrigations to match critical stages of crop growth,
- Improved investment in fertilizers, pesticides, and cultural practices,
- Reduced water logging.

Although improved WUE does not generate new water, it does generate more harvested crop for the amount of irrigation water consumed. This is analogous to increasing water supply. WUE increases of 25% - 100% are possible on various grain crops if on-farm water management and associated agronomic practices are improved (Hanks, 1983; Howell, et. al, 1990; Doorenbos and Kassam, 1986). Water management at the field level is generally a primary constraint on improvement in other agronomic practices.

2. Improvements in the quality of surface return flows. Water which runs off the surface of agricultural fields contains pesticides and some fertilizers, thereby decreasing its value to downstream users. Downstream users must dilute this water in order to achieve the yields obtainable with uncontaminated water. Reducing surface return flows is therefore equivalent to a small savings in water consumption.

3. Reduction of deep percolation from farmer fields, and the associated reduction of nitrate leaching. Deep percolation is expensive to the farmer and damages water quality in the aquifers. In the United States, high levels of nitrates in aquifers under agricultural lands have led to potential human health problems and crop quantity and quality reductions. Such problems can be expected in other countries as the extensive use of fertilizers expands.

4. Reduction of on-field deep percolation destined for a salt sink. This typically occurs in one of two ways. Either deep percolation passes through subsurface shale (or similar marine layer) and picks up a high load of salts, or deep percolation ends up in a salt sink, such as the ocean. This deep percolation is then unfit for future agricultural use.

Competition for Agricultural Water Supplies

Of course, agriculture is not the only user of water supplies. Urban, industrial, and environmental concerns must be considered and in the future will drive many agricultural irrigation modernization decisions.

Environmental Concerns

We are beginning to understand the critical importance of maintaining minimum flow rates and water qualities in natural drains and rivers. In the U.S., for example, many of the recent irrigation system modernization efforts have stemmed from the need to reduce in-stream damage to endangered species of fish. The quantities and timing of river diversions, and qualities and quantities of irrigation return flows, have a tremendous impact on the environment.

As an example, for rice production in California, new legislation requires that farmers hold water inside rice paddies (called "lockup") for a minimum of 28 days after herbicides are applied. That is, surface drainage is not allowed during this period. This has put new pressures on the irrigation projects to provide only the amount of water which is needed, even though the weather can change rapidly.

Other Farmer Needs

Rice farmers may not remain rice farmers in future years, or they may grow upland crops after the rice is harvested in a single year. The demands for farm irrigation water from the project are completely different for rice, as compared to upland crops. The upland crops need a high flow rate for a short duration. Also, flow-through distribution systems (in which water flows through several fields of rice before reaching downstream fields) is unacceptable for upland crops.

With rice, it is obvious that the irrigation delivery systems must be flexible in order to respond to fluctuations in weather conditions (varying evapotranspiration rates and rainfall). There is also a need to do a better job of providing large flow rates rapidly during the initial flood irrigations.

Defining Modernization

Improvement

Modernization implies change for the sake of improvement, not just change for the sake of change. Therefore, the very first aspect of a modernization program is that the present status of a project must be assessed. After an initial status and needs survey of a project, modernization can proceed in a deliberate, focused manner to address key deficiencies.

Essential Elements of Modernization

Modernization of irrigation projects virtually always involves modification of three things:

1. Everyone in the project, from the lowest operator to the highest administrator, must adopt the concept of providing good service. This requires that they understand the service concept, and truly have a desire to provide as high a level of service to their customers as is possible.
2. Hardware must be modified in order to provide better service. The hardware changes are the result of a deliberate analysis of service requirements. Hardware modifications may be as simple as replacing undershot gates (orifices) with manual long crested overshot gates

(weirs) for water level control, or the proper installation of flow control points. In some cases, it may require more advanced supervisory control and data acquisition (SCADA) systems and automation. The desired level of water delivery service and existing budget and other constraints will define the required hardware, and not vice-a-versa.

3. Operation rules must be changed. The way that water is ordered and delivered, the form and frequency of communications (between operators and their bosses, and between farmers and project personnel), and the way various control structures are manipulated on an hourly or daily basis must be changed to match the defined service objectives.

There have been many studies which address the need for water rights legislation, improved hiring/firing procedures, and other social aspects of irrigation projects. While those are critical points, the three items mentioned above, especially as related to improved service, have often been overlooked and are considered by the author to be indispensable elements of any modernization program.

The Concept of Service

Chris Perry of IIMI has noted that irrigation is an input into agriculture, just as electrical power is an input into industrial manufacturing. Providing power without a clear definition of the service in terms of voltage, frequency, and a number of other characteristics, would greatly reduce the value of the input, because users would be unable to plan their activities or select appropriate equipment to use the resource. These considerations apply to other service or utility sectors -- for example, a transportation service is defined by schedule, pick-up points, fare structure, and nature of the goods which can be carried. Distinctions among these factors are apparent for bus, taxi, train services, or a road haulage agency, and the differences allow users to compare and select the most appropriate service.

In most cases, the service definition implies responsibilities for both the provider and the user of the service; the power company is responsible for delivering 110 volts, 60 Hz. electricity to the buyer. If the user wishes to run a 12 volt DC radio, then the user must insure that the required transformer is provided. Similarly, a bus company indicates time and place of pickup and a traveler must arrive at the appropriate place, on or before the scheduled time.

Applied to irrigation, these considerations suggest a number of aspects to the definition of irrigation service.

Definition of Service

The definition of water delivery service at any layer[5] in the distribution system includes:

1) specification of the water right of the beneficiary (for example, cubic meters per hectare per season for volumetric deliveries, or proportional allocation of available supplies in the case of uncertain supplies);
2) specification of the point of delivery (farm level; user association; 'chak' outlet);
3) flexibility in rate of delivery (fixed; variable; variable between limits);
4) flexibility in duration (fixed; variable but predetermined; variable by agreement); and
5) flexibility in frequency (every day; once per week, undefined).

The service definition will also specify the responsibilities of all parties (farmers, Water User Associations (WUAs), operators of the tertiary canal, operators of the secondary canals, operators of the main canals, and project authorities) in operating and maintaining all elements of the system. A main canal provides water, with a certain level of service, to secondary canals. Each upstream layer in a hydraulic distribution system provides service to the layer immediately downstream of it. The actual levels of service at each layer must be examined to understand the constraints behind the level of service which is provided to the field.

[5] Distribution system layers. Most water distribution systems in irrigation projects consist of networks of canal and/or pipelines. Water is supplied to downstream layers from the upstream layers. A main canal would be one layer, supplying water to secondary canals, the next downstream layer. For this research, a "layer" may also be considered that portion of the distribution system which operates with the same equipment and set of rules. Therefore, the top "layer" may consist of both main and secondary canals.

Point of Differentiation

The point of differentiation within an irrigation system is the location for which upstream water deliveries can be deliberately and effectively manipulated separately with time. Downstream of the point of differentiation, all turnouts are treated identically, without the ability to provide special treatment to any of them. The point of differentiation is not the point of ownership transfer. A water user organization may become responsible for the distribution system above, below, or at the point of differentiation.

For all systems in which there is a concept of water management by the individual farmer, the point of differentiation must be at the individual field scale.

Different Levels of Service

It is clear from consideration of the service definition that there is a wide range of levels of irrigation service, and that the nature of the service may vary significantly from a highly flexible service differentiated at the farm level (analogous to a taxi service) to an inflexible service provided on an undifferentiated basis to a large number of farmers (analogous to a train service). For many irrigation projects, levels of service at various points through an irrigation distribution network are not clearly defined in the proposal or design stages.

Evaluating Existing Performance

History

Although the primary function of irrigation dams, canals, and pipelines is to provide water delivery service for agricultural use, there have been few significant efforts made to measure the characteristics and success of this function.

World Bank Staff Appraisal Reports (SAR) and Impact Evaluations do not yet touch upon quality of water delivery service or conveyance manageability. Rather, appraisals concentrate on large-scale inputs (gross water supply, total acreage, etc.) and gross output indicators of success or failure (IRR, cropping intensity, etc.). The internal indicators which measure and evaluate the processes between initial input and final output are not audited, analyzed, or discussed in appraisal reports.

The concept of providing service in irrigation projects is relatively new, although it has been promoted before. Merriam (1973) was instrumental in providing early definitions of service in terms of frequency, rate, and duration. The idea of assessing performance, including some measures of service, is even more recent.

The realization that institutional constraints can be as important as hardware constraints in the success of irrigation projects became clear in the early 80's. Various international organizations put considerable effort into promoting water user organizations. For almost a decade, discussions on irrigation project improvements emphasized management improvements almost entirely over better hardware selection and design. Meanwhile, H. Frederiksen and others in the Bank began to promote the concept that irrigation projects must provide service to customers. In the early 1990's, IIMI began to develop "Performance Indices" for international projects.

Murray-Rust and Snellen (1993) examined 15 projects and documented significant differences between promised versus delivered flow rates at various offtakes. They also provided a narrative discussion of factors which they felt influenced the level of service. Their recommendations emphasized management improvements over hardware improvements. Plusquellec et al (1994) re-emphasized the importance of proper hardware selection and articulated the need for a approach to modernization based on the service concept. They pointed out that many management goals are impossible to achieve without the proper hardware in place.

IIMI has defined an action research program for the years 1994-1998 (IIMI, 1994; ILRI, 1995) which includes some types of performance assessment. ICID has a Working Group on irrigation and drainage performance which coordinates with IIMI. The ICID Working Group (ICID, 1995) recently published a list and description of currently used performance indicators.

The performance indicators emphasize ratios of volumes of water delivered, lost, and consumed at various times and locations. In addition, some indices have been developed for concepts such as dependability of supply and regularity of water deliveries.

A task committee of the Water Resources Division of the American Society of Civil Engineers has recently completed a significant, multi-year effort to provide a definitive document regarding Irrigation Efficiency (Burt et.al., 1996). Having a proper understanding of project and basin efficiency is an important prerequisite to making modifications in an irrigation project; there have been numerous examples of modernization efforts in the U.S. which have over-estimated potential water savings because the planners did not understand irrigation efficiency concepts.

Where to Start

It is apparent that even though work on performance indices is relatively new, there are already several different ways to define and quantify performance. However, not all aspects of performance must be defined in order to determine how best to modernize an irrigation project.

As noted at the beginning of the paper, high efficiencies are the result of having a manageable irrigation project which provides the required degree of service. Therefore, most modernization programs should concentrate upon improving service at all layers within the project delivery system.

Precedents

Some examples can be given of what has been successfully done to assist with modernization of irrigation projects.

Two large-scale surveys of service levels within irrigation districts have been conducted in the U.S., both in California (Burt et. al., 1981 and Burt et.al., 1996). Key needs were identified in both surveys that allowed funding organizations to develop meaningful technical assistance and education programs to rapidly enhance modernization efforts.

Working for IPTRID (International Program for Technology Research in Irrigation and Drainage), Burt and Wolter (1992) developed Guidelines for Irrigation System Modernization in Mexico. These guidelines were based upon a rapid assessment of irrigation projects in Mexico. Most of the recommendations have been implemented. Mexico has had a remarkably successful and rapid privatization program of irrigation projects.

Burton et al (1996) have recently recommended an "asset management" approach to planning long term investment in infrastructure. They conducted studies on this approach in Indonesia and found similarities between modernization in the UK water industry and irrigation projects in Indonesia. They list six stages of an asset management plan (AMP):

1. Devise procedures for preparing the AMP and keeping it up to date. These must be traceable and repeatable.
2. Prepare a statement of the project's relevant standards and policies.
3. Identify various functions of the project and prepare a list of systems under each heading. Each system will comprise of a number of assets.
4. Collect information on *performance* and *condition* of the principal components of each system. This may be done by sampling. (Note that *performance* information relates to a *system*, whereas condition information relates to individual assets).
5. Estimate long term investment (20 years).
6. Prepare short term program of expenditure for 5 years.

Burton et al (1996) note that "stage 2 is particularly important because it introduces the notion of service provision to customers as a key driving force in determining investment needs. This was a major step forward in terms of changing the ethos of the water utility from the provider of services as determined by the priorities of management and government to the provider of service to the customer."

In short, they have also endorsed the absolutely necessity of adopting a service ethic and philosophy if there is a desire for modernization.

Components of a Status Survey

General

A survey of an irrigation project status does not necessarily require many years of study. In general, the water delivery and service aspects of a project can be evaluated in a few weeks or less by experienced personnel.

Defining the Levels of Service in a Project

The first thing to identify in any pre-modernization study is the existing level of service. It is important to re-emphasize that an irrigation project is a network which consists of many hydraulic delivery layers, and each layer provides service to the next lower layer, finally ending at a "point of differentiation". The levels of service may be different at each layer.

A study should not only identify what the existing level of service is, but what the expectations are at each layer of operation. Factors to define in a study include:

1. The flexibility of water delivery. The three aspects of flexibility, <u>at any layer</u> in the system, are:
   a. Frequency. How often can water be delivered, or can a flow be changed when desired?
   b. Flow rate. What flow rate can be delivered at a point? How often can the flow rate be changed, and how much advance notice must be given? Is the flow rate controllable? Is the flow rate even known?
   c. Duration. Can the duration of an irrigation or water delivery be adjusted?
2. The equity of water delivery to all levels in the system.
3. The reliability of water deliveries. If something is promised, is the promise fulfilled?
4. The timeliness of water deliveries. If a flow rate change or delivery is scheduled for 9 am, can it actually occur at that time?

Controllability of Water

What really sets **modernization** apart from **rehabilitation** is the <u>improvement of the controllability of water for the purposes of providing</u>

better service. The controllability of water in a project depends upon many things, most of which should be evaluated in a status study. These include:

1. Ease of access to key structures and delivery points.
2. The communication system. Aspects to consider are:
   - What information is communicated?
   - How often is the information communicated?
   - Who communicates to whom?
   - Is the communication system reliable?
   - How is information archived and accessed?
3. Operation instructions. Often, the instructions given to operators are impossible to follow and the operators may actually move or manipulate the structures in an entirely different manner than what is perceived in the office.
4. The types and locations of water level control structures. For example, manually operated underflow gates are extremely difficult to operate correctly if the flows change frequently.
5. The types and locations of flow control and flow measurement structures. These are often two different types of structures.
6. The number of parcels receiving water downstream of the most downstream flow control point.
7. Lag time (wave travel time) throughout the system.
8. The existence of buffer storage and freeboard.
9. The relative elevation of canal water surfaces above the turnouts.
10. Robustness of structures, and the general condition of them.

General Project Conditions

The specific solutions, and the economic viability of them, will also be affected by other conditions which should be examined in a status study. These include:

1. The relative magnitude of seepage losses.
2. The existence of conjunctive use.
3. Whether the water supply is from a controlled supply (i.e., a dam) or from a rapidly fluctuating river.

4. Typical crop yields and intensity of farming.
5. Rainfall patterns.
6. The existence and enforcement of water rights and laws.

7. The quality of the maintenance.

In order to establish modernization program priorities, the values of these factors do not need to be known precisely; rather, an approximate estimate of their magnitudes is sufficient. For example, a detailed study of seepage losses would take a long time and be very expensive, and the detailed knowledge gained from such a study would not change the decisions made regarding the first appropriate modernization steps.

Social Issues

Certain social issues have been observed to be important for the viability of water projects. These include:

1. The existence of a reasonable method for assessing costs for water and the ability to collect those water charges and to withhold water from those not paying.
2. The characteristics of project employee/employer relationships. Some aspects to consider include:
   - The existence of incentive programs for employees.
   - The existence of meaningful training programs.
   - Salaries of employees.
   - The ability to assess performance of employees, and the ability for managers to fire those with documented poor performance.
   - The tenure of employees (how long they have worked on the project).

Assessments should briefly examine these factors, to help determine if new policies and enforcement capabilities will be needed in the future.

Defining the Needs

Sharing a Common Vision

Once the status of a project has been documented, the real challenge remains - defining what should be done in the modernization program.

The decision of what should be done is generally arrived at with the consensus of many parties. It is therefore important that all parties share a common vision of the points which were detailed at the beginning of this paper. These include:

- The importance of good on-farm irrigation, which is possible if the farmers have the proper tools (flexibility, reliability, etc.) to work with their water supply.
- The absolutely necessity of understanding how to physically provide good water delivery service at all layers in the system (i.e., the details of proper engineering for good service).

What we have learned at Cal Poly is that when we work with irrigation projects in the U.S., we need to start by bringing all the key players together for a short (few days) training program. Such an orientation program emphasizes the service concept, and various water control strategies which are available to help provide good service. We try to bring together policy makers and engineers in the same room, so that they share the new vocabulary and the same point of reference for future discussions of modernization options.

In short, a first step for meaningful modernization is an education/awareness component on the general concepts of modernization.

Engineering Education

A second step is to make sure that the engineers and technicians who will be involved in the project have the proper tools with which to recommend improvements. One only needs to look at the poor levels of performance of existing projects to conclude that we have some serious problems in this regard. In general, water control concepts are not taught to engineers in college. Unfortunately, many universities believe that they are being taught. The biggest question is: where can people get the proper education?

This is a sensitive subject. There is almost a natural inclination for engineers to have a defensive attitude about their present designs, because they have worked very hard on various projects, and discussions of change may imply that in the past they did not do a good job. What needs to be conveyed, however, is that there are new techniques available to help us work smarter. The changes need to be presented as opportunities rather than as criticisms - a difficult task. We have found that if we can get past defensive attitudes about the existing projects, engineers can quickly grasp the concepts of design for modernization. Resources are available, such as the slide series on modernization by the World Bank (Plusquellec, 1988) and training programs by a few organizations such as the Cal Poly Irrigation Training and Research Center (ITRC).

The concepts of service absolutely must filter past the upper levels of management. The design engineers who actually do the structure drawings (individuals who are not paid to risk anything) must also be provided with specific design tools. For example, if there is a standard design handbook, it will almost certainly need to be upgraded so that the lower-level engineers will actually design the correct structures.

Typical Design Changes

The points covered earlier in this paper regarding questions for a status survey will give good guidance for modernization. A typical sequence for modernization, after initial education efforts, will be something as follows:

1. Demonstrate the effectiveness of modernization on a small but significant part of the project. Actions often include:
   a. Improvement of access to key control sites.

b. Improvement of communications (people-to-people) through the use of radios.
c. Implementation of flow control and flow measurement at the headings of key laterals.
d. Installation of a few remote monitoring sites.
e. Improvement of water level control structures, such as with automatic hydraulic gates or simple long crested weirs.
f. Improvement of turnout structures and locations.
g. Formation of effective water user organizations, often which operate like a business, at the lower ends of a system.
h. Improvement of maintenance programs.

The participation of farmers and water user organizations is generally not useful when changes are made to the main canal system. However, their participation is extremely valuable and necessary when changes are made to the system at the distributary or small lateral level.

The author is a bit hesitant about the wording of this recommendation, because it may appear to be nothing more than a typical "pilot project" recommendation. A difference here is that selective improvements can be made simultaneously throughout the system, rather just having them concentrated in one area. These improvements would not be considered demonstrations as much as initial shake-down trials.

2. Make certain that the initial efforts work and work well. Frequently consult with the people who are affected by those improvements, whether they be canal operators, engineers, or end users (farmers). Be certain that those individuals are happy with the improvements, solicit their suggestions, and incorporate necessary changes.

3. Bring in people from other areas of the project and let them talk with the people involved in step (2). These people from other areas will develop a desire for changes in their own regions if the local people are enthusiastic. If the beneficiaries mentioned in step (2) are not convinced and enthusiastic, the project modernization efforts are probably inappropriate.

4. Develop a master plan for the complete project modernization, using lessons learned in steps (1) and (2), and relying on input from operators and users throughout the project.

5. Begin to implement the larger plan for modernization.

Cost Effectiveness

One of the biggest hurdles facing modernization efforts is the desire to compute the cost effectiveness of all proposed improvements. Although the author understands the absolute necessity of economic viability, the author has also learned that traditional engineering economics are insufficient for modernization programs. For example, a large diameter pipeline (which can provide much more flexibility than a small pipeline) will always cost more per meter than a small diameter pipeline. The true economics must consider whether or not yields will increase (a difficult thing to estimate and guarantee), and how improved service will affect recovery of water charges and maintenance. These factors will not necessarily show improvement in the first or second year.

Summary

What is presented here is a conceptual framework for the process of modernization. What is important for irrigation projects is not the number of hectares served, or the kilometers of canal, or the number of structures. Rather, the key factor is how well all those kilometers of canal and hundreds of structures function to provide the defined and required level of service to the ultimate users. To provide good service to the farmers, a project must be considered as a network of layers, each of which provides service to the next lower layer.

A status and needs survey should be conducted in any project prior to modernization. The survey can be rather brief, only needing a few weeks or months. However, it must be targeted to identify the levels of service provided (i.e., performance) and the factors which affect that performance.

In most of the many projects that the author has visited worldwide, there are serious deficiencies in the hardware designs and physical water control. Often, very simple and robust solutions are available to solve these problems. A first step to solving them, however, requires a common understanding of control principles.

The question of cost will always arise in modernization programs. The author has observed that many, if not most, modernization programs are underfunded. There is no shortcut to some things - it simply takes money and time to make certain changes. Of course, there are always some effective changes which can be made at a small cost.

When considering costs of modernization, one might remember a popular slogan: "If you think education is too expensive, just see how much it costs without it". Similarly, with irrigation projects we know that the performance must improve. The competition for water is growing, and the need for food is also increasing. Can we afford to not modernize? The author believes we cannot.

Successful modernization programs will require strong individual leaders who have vision, and who are willing to gamble for the future. These leaders must be nurtured at all levels of projects, from the project managers to university professors to canal operators to farmers. Only then will we meet the challenges which face us.

References

Burt, C. M., A.J. Clemmens, T.S. Strelkoff, K.H. Solomon, R.D. Bliesner, L.A. Hardy, T. A. Howell, and D.E. Eisenhauer. 1996. Irrigation Performance Measures - Efficiency and Uniformity. Task Committee on Efficiency and Uniformity. Water Resources Division of the American Society of Civil Engineers. submitted to Journal of Irrigation and Drainage, ASCE.

Burt, C., K. O'Connor, S. Styles, M. Lehmkuhl, C. Tienken, and R. Walker. 1996. Status and Needs Assessment: Survey of Irrigation Districts, USBR Mid-Pacific Region. Irrigation Training and Research Center. California Polytechnic State University. San Luis Obispo, CA 93407. 39 p.

Burt, C. J. Gartung, J. Lord, J. Parrish, and J. Bryner. 1981. Distribution System Improvement to Facilitate Water Delivery. A report by JM Lord, Inc. to the Agric. Division, Office of Water Conservation, Calif. Dept. of Water Resources.

Burt, C. and H. Wolter. 1992. Guidelines for Irrigation System Modernization in Mexico. A Report to IPTRID. Prepared for the Comision Nacional del Agua, Mexico.

Burton, M.A., W.D. Kingdom, and J.W. Welch. 1996. Strategic Investment Planning for Irrigation. Irrigation and Drainage Systems 10:207-226. Kluwer Academic Publishers. The Netherlands.

Clemmens, A.J., T.S. Strelkoff, and C. M. Burt. 1995. Defining Efficiency and Uniformity: Problems and Perspectives. Proceedings of the ASCE Water Conference in San Antonio, Texas (Water Resources Engineering). American Society of Civil Engineers, N.Y., N.Y. pg. 1521-1525.

Doorenbos, J. and A.H. Kassam. 1986. Yield Response to Water. FAO Irrigation and Drainage Paper 33. Food and Agriculture Organization of the United Nations. Rome.

Hanks, R.J. 1983. Yield and Water-Use Relationships: An Overview. Chapter 9A in Limitations to Efficient Water Use in Crop Production. Amer. Soc. of Agronomy. Madison, WI.

Howell, T.A., R.H. Cuenca, and K.H. Solomon. 1990. Crop Yield Response. Chapter 5 of Management of Farm Irrigation Systems. ASAE Monograph 9. Amer. Soc. of Agric. Engr. St. Joseph, MI.

ICID. 1995. Currently Used Performance Indicators. Research Program on Irrigation Performance. Contact: M.G. Box, Wageningen, The Netherlands.

IIMI. 1994. Assessing and Improving the Performance of Irrigated Agriculture: Indicators of Productivity, Economic Profitability and Environmental Sustainability. An Action Research Program: 1994-1998.

ILRI. 1995. Research Programme on Irrigation Performance, RPIP. Annual Progress Report no. 2. A report by the Intern. Inst. for Infrastructural Hydraulic and Environ. Engr. (Delft, the Netherlands), IIMI, and ORMVAM (Berkane, Morocco)

Merriam, J.L. 1973. Float Valve Provides Variable Flow Rates at Low Pressures. Agricultural and Urban Considerations in Irrigation. ASCE Specialty Conference. Ft. Collins, Colo. April 22-24. pp. 385-402.

Murray-Rust, D.H., and W. B. Snellen. 1993. Irrigation Performance Assessment and Diagnosis. Colombo, Sri Lanka. International Irrigation Management Institute. 148 pp.

Acrobat Document

Perry, C. 1995. Determinants of Function and Dysfunction in Irrigation Performance, and Implications for Performance Improvement. Water Resources Development 11(1): 25-38.

Plusquellec, H. 1988. Improving the Operation of Canal Irrigation Systems. A seven-part slide series. Washington, D.C. The Economic Development Institute of the World Bank.

Plusquellec, H., C. Burt, and H. Wolter. Modern Water Control in Irrigation - Concepts, Issues, and Applications. 1994. World Bank Technical Paper No. 246. Irrigation and Drainage Series.