8th N.D. Gulhati Memorial Lecture for International Cooperation in Irrigation and Drainage

The Irrigation Sector Shift from Construction to Modernization: What is Required for Success?

Dr. Charles M. Burt
Chairman
Irrigation Training and Research Center (ITRC)
California Polytechnic State University (Cal Poly)
San Luis Obispo, CA 93407-0730
USA

Presented at
ICID's 21st International Congress on Irrigation and Drainage
19 October 2011, Tehran, Iran

ICID•CIID

INTERNATIONAL COMMISSION ON IRRIGATION AND DRAINAGE

The N.D. Gulhati Memorial Lecture for International Cooperation in Irrigation and Drainage

President Honoraire Late N.D. Gulhati (India) has been rightly called 'the father' of the International Commission on Irrigation and Drainage (ICID) owing to his initiative in its establishment in 1950 at New Delhi, as its Secretariat.

Perpetuating the memory of the visionary Water Resource Engineer, ICID has been organizing the 'N.D. Gulhati Memorial Lecture for International Cooperation in Irrigation and Drainage' at the time of triennial Congress, commencing from the year 1981. The memorial lecture aims at reporting on significant global developments in irrigation and drainage engineering including all allied aspects like environment, sociology, economics etc. and fostering and enhancing international cooperation to meet ICID objectives. The lecture is delivered by an invited eminent person chosen amongst the nominations received from the ICID national committees.

An honorarium of US$ 1000 is presented to the invited distinguished Lecturer out of the interest earned on the 'Endowment Fund' set apart by Er. Gulhati's family.

N.D. Gulhati Memorial Lectures held so far:

2008 : Prof. Dr. Chandra A. Madramootoo (Canada), Vice President Hon., ICID on "Irrigation in Context of Today's Global Food Crisis" at Lahore, Pakistan

2005 : Er. Albert J. Clemmens (USA) on "A Process-Based Approach to Improving the Performance of Irrigated Agriculture" at Beijing, China

1999 : Er. R. Rajkumar, Prof. N.V. Pundarikanthan, Er. K.R. Chezian (India) on "Controlled Water Saving Method for Paddy Cultivation - A Case Study" – prize winning paper for young professionals at Granada, Spain

1996 : Ms. Margreet Z. Zwarteveen (Sri Lanka) on "A Plot of One's Own: Gender Relations and Irrigated Land Allocation Policies in Burkina Faso" – prize winning paper for young professionals at Cairo, Egypt

1993 : Er. Marvin E. Jensen (USA), President Hon., ICID on "The Impacts of Irrigation and Drainage on the Environment" at The Hague, Netherlands

1990 : Late W.R. Rangeley (UK), President Hon., ICID on "Irrigation at a Crossroads" at Rio de Janeiro, Brazil

1987 : Late Adriaan Volker (The Netherlands), Vice President Hon., ICID on "Role of Failures and Negative Secondary effects in the Development of Irrigation, Drainage and Flood Control" at Casablanca, Morocco

1984 : Late K.K. Framji (India), President Hon., ICID on "Past and Likely Future Developments in Irrigation and Drainage and Flood Control Measures in Developing Countries" at Fort Collins, USA

1981 : Er. M. Holy (Czech Rep.), President Hon., ICID on "Irrigation Systems and their Role in the Food Crisis" at Grenoble, France

Er. N.D. Gulhati – A Visionary Water Resources Engineer

(1904-1978)

President Honoraire Late N.D. Gulhati was born in Lahore, Pakistan on 15 November 1904. He took his technical education at the Thomson Civil Engineering College, Roorkee (now University of Roorkee) and passed out with honours in1926. He was appointed to the Indian Service of Engineers in October 1927 and posted to the Irrigation Branch of the Public Works Department, Punjab. From August 1945 to March 1949, he was Secretary of the Central Board of Irrigation and Power.

In 1950 he was responsible as the Chief of the Natural Resources Division in the Planning Commission, Government of India, for initiating proposals relating to the development of irrigation and power, soil conservation and mineral development in the First Five-Year Plan. He was made Chief Engineer and Joint Secretary in 1953 and Additional Secretary to Government of India in1958. From 1952 until the Indus Waters Treaty was concluded 1960 (and ratified in 1961), Er. Gulhati was India's Chief Representative on the Indus Waters negotiations conducted under the aegis of IBRD. He represented India in many International Engineering Conferences.

He was awarded the high distinction of "PADMA BHUSHAN" by the President of India in 1961 "for distinguished services of a high order".

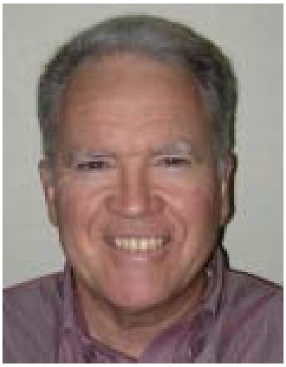
Late N.D. Gulhati dedicated his entire professional life to the development of irrigation engineering and conceived and implemented the concept of an 'International Commission' for ensuring international cooperation on advancing the world knowledge in the fields of irrigation, drainage, flood management and river training. The proposal of setting up of the Commission was mooted to the Government of India by him in 1946. The Commission was set up in the year 1950 and Er. Gulhati was elected as its first Secretary General. He served ICID as founder Secretary General from 1950 to 1957, as Vice President from 1957 to 1960, and as President from 1960 to 1963.

After retirement, President Honoraire Gulhati worked as Water Resources Consultant to many State Governments in India and as Consultant to IBRD (1963), International Development Association (1963-1973), and United Nations (ESCAP) in 1969.

Besides engineering and scientific papers contributed to the national institutes (e.g. Punjab Engineering Congress; Institution of Engineers, India) and the American Society of Civil Engineers, Er. Gulhati had some 20 books and publications to his name.

Er. Gulhati was always amongst the foremost supporters of ICID and did everything Possible to promote the objects of ICID. He was the founder Editor of the then ICID Bulletin. He was responsible for getting the land for the office building of the Central Office of the Commission in the prestigious Diplomatic Enclave. His mature leadership, dynamic personality and diplomatic and adroit handling of all matters won him universal respect and endearment with all the members of the ICID fraternity.

Dr. Charles M. Burt



Dr. Charles M. Burt is a Professor of Irrigation, and Chairman of the Irrigation Training and Research Center (ITRC), California Polytechnic State University (Cal Poly), San Luis Obispo, California. Dr. Burt received a BS (Honors) in Soil Science from Cal Poly, an MS in Irrigation and Drainage Engineering from Utah State University, and a Ph.D. in Engineering from USU. He is a registered professional engineer in California in both Civil and Agricultural Engineering. Experiences include professional irrigation and drainage work in 26 countries, 3 tours in Vietnam (1968-1970) as a decorated combat demolition specialist, work as a farm laborer in the San Joaquin Valley as a youth, designer/sales/ installation in a major irrigation dealership in Fresno, partner in a consulting agricultural engineering firm. He has since spent 33 years at Cal Poly with a mix of teaching as a professor, with research and applied technical assistance through ITRC, which he founded in 1989.

Prof. Burt has written and worked extensively regarding on-farm irrigation system design, water balances, irrigation efficiency, automation, and irrigation project modernization. He has trained most of the irrigation dealers in California on drip/micro irrigation, was the original chairman of The Irrigation Association's Designer Certification program, and is well known for his leading work with the World Bank and FAO on the topic of 'Rapid Appraisal and Benchmarking' of irrigation projects.

One of Dr. Burt's specialties is conceptualizing and implementing both simple and sophisticated canal modernization projects that perform as anticipated. He has been a key contributor to major concepts regarding on-field irrigation evaluations, three-dimensional water balances to predict true water conservation volumes, and implementing the service provision concept in irrigation projects. At any one time, he directs approximately 10-15 irrigation district modernization efforts. Examples of current interesting projects are (i) the modernization of the 200,000 ha Imperial Irrigation District in California, (ii) the modernization of the heavily damaged (via earthquakes) canal infrastructure in the 200,000 ha Mexicali Valley District 014, in northern Mexico, (iii) development of innovative electric utility rebate programs for improving agricultural pumping plant efficiency, and (iv) prediction of project-level evapo-transpiration rates using remote sensing.

Prof. Burt has received a variety of awards including the Person of the Year from the Irrigation Association; Person of the Year from the California Irrigation Institute; the Royce J. Tipton Award from ASCE; first recipient of the Cal Poly Distinguished Research, Creative Activity, and Professional Development Award; and the Merriam Irrigation Improvement Award from USCID. He is a Diplomate, Water Resources Engineer with the American Academy of Water Resources Engineers. He has served a variety of committees in ASCE, the Irrigation Association, and USCID. He was the co-founder of a non-profit organization to help hill tribesmen in the Central Highlands of Vietnam. He is happily married with 3 children and 6 grandchildren, and is active in his local church.

Prof. Burt's professional goal is to help remove the art from irrigation through pragmatic and economic improvements that are based on sound theory, science, and engineering.

Dr. Charles M. Burt, Ph.D., P.E.
Chairman, ITRC, Cal Poly, CA, USA

N.D. Gulhati Memorial Lecture[1]

The Irrigation Sector Shift from Construction to Modernization: What is Required for Success?

by

Dr. Charles M. Burt[2]

Abstract

External pressures related to environmental protection, commodity prices, energy availability, larger populations, and climate change have combined to require an immediate and substantial improvement in agricultural irrigation performance. Worldwide progression towards modernized irrigation projects has been uneven and slower than desired, but decades of irrigation modernization development have clarified certain requirements for success, as well as illuminated indicators of project failure. Of particular importance are required shifts within the state and national irrigation bureaucracies, as well as universities.

1. Background

In the past, irrigation projects have traditionally operated as autonomous entities that are answerable only to their own bureaucracies and regulations. However, continually increasing external pressures on irrigation projects (the nature of which vary by location) to improve performance no longer allow this to hold true. Discussed below is a list of factors that impact not only irrigation agencies, but the environment, governmental policies, and the public in general.

1 Presented at ICID's 21st International Congress on Irrigation and Drainage, 16-22 October 2011, Tehran, Iran

2 Chairman, Irrigation Training and Research Center (ITRC), Cal Poly, CA, USA, E-mail: cburt@calpoly.edu, www.itrc.org

1.1 Groundwater

In China, Mexico, the USA, and numerous other countries, there has been a rapid decline in groundwater levels in many projects. Furthermore, many groundwater basins essentially serve as non-sustainable salt sinks (where irrigation deep percolation recharges the aquifers, but only with water containing fertilizers and pesticides). Additionally, energy is needed to pump groundwater. Yet the aquifers serve an extremely important function as water distribution systems, functioning as buffers for annual and seasonal changes in surface water supply to projects. Still, many surface water conservation projects ignore the position of the groundwater basins within the overall regional water balance. Conjunctive use management (managing both surface and groundwater supplies) especially tends to be rather ad-hoc and without effective, implemented strategies for management.

1.2 Population Increases

This is simple yet complicated: Larger populations require more food, and more affluent populations have more complex diets that require more grain production to feed animals, but cities tend to expand on productive agricultural land. For decades, irrigation experts predicted food shortages and increased commodity prices would increase that never occurred, largely because the green revolution (new grain varieties) and expanded irrigated acres, increased the food supply at pace with the population expansion. However, the agricultural improvements could only go so far. At present, there are very few new water supplies to support expanded irrigated acreages, and no new grain varieties (with the tremendous yield increases we previously saw) are on the horizon. In other words, the previous solutions were relatively easy to implement (more acreage, new varieties). The future solutions will be much more complex.

1.3 Environmental Awareness

In the USA, irrigation district modernization is often driven by environmental regulations. The specific requirements of each new piece of legislation may include more water diversions to wild bird refuges (meaning less water delivered to farms), the need for increased in-stream flow requirements (which requires reductions in irrigation diversions), or heavy restrictions on the qualities of return flows from irrigation projects to rivers – especially in regards to boron, salt, and selenium. While most people understand the importance of a healthy environment, there are substantial unanswered questions regarding who should pay for the required irrigation system improvements, or what the particular numerical standards for water quality and quantity should be.

In many countries, environmental restrictions have also halted new dam construction on rivers. Many of the new dam projects throughout the world will provide hydroelectric power, and will also increase irrigated acreages, but because of the limit in the total amount of water available within a basin (e.g., the Nile), expansion of acreage in one area will require a reduction of irrigated acreage in another area.

1.4 Climate Change

Predictions of the exact impact of climate change in specific regions of the world are highly variable. However, even moderate increases in global temperatures will reduce the huge reservoirs of mountain snowfall that gradually melt and release water to irrigated areas. The lack of snowfall storage at higher elevations will cause serious usable water supply reductions in some areas of the world.

2. The Challenges

In short, we know that among the numerous challenges that face the irrigation sector, we have two that dominate:

1. The irrigation sector must do more with less. That is, crop production must increase per unit of water and energy consumed.
2. The environment must be protected.

Strong irrigation departments in most countries were built with a focus on the construction of dams and large canals, and flood prevention. But the days of construction of new dams and canals have diminished; we need to improve what already exists. The questions are: (i) Do the irrigation departments recognize that times have changed, and (ii) Do they have a vision of how to re-organize to meet today's complex irrigation demands? The main question for ICID is: Is this organization structured and operated in a way that effectively recognizes and promotes a necessary, new approach?

2.1 Moving Beyond Conferences

All of the topics above have been the subjects of numerous conferences, papers, and studies. However, those conferences, papers, and studies have generally had very little impact on the ground. Irrigation projects continue to experience the vicious cycle of rehabilitation and deterioration. Water is still being delivered with a lack of flexibility, equity, and reliability.

Within the large state and national irrigation bureaucracies, and within the large donor agencies, there is much hand wringing, economic analysis, and modeling - all without a good understanding of the complex ground-level internal processes (both physical and organizational) of irrigation projects that must be re-organized or implemented to achieve successful change. Those processes are typically relegated to the level of "details" that will somehow be solved by others at the lower levels in the organization. But in irrigation modernization, we have learned that "the devil is in the details", and they must be approached and solved properly to achieve success.

2.2 Can Successful Change Occur?

Throughout the world, local irrigation agencies can be found that insist the existing methods of irrigation distribution cannot be changed – they have been adapted for local conditions. One is told that significant change cannot be accomplished because farmers don't listen to the irrigation department. People steal water and vandalize the systems. There is little or no budget. There is too much area and too little water. Different things have been tried but only worked for awhile before failing. Therefore, the best approach is the "structured" approach or some other physical/social system that at least puts water out onto a project. Farmers have learned to adapt, one is told, and they do their own form of linear programming optimization of cropping patterns to minimize their risk.

All of the statements above can be true. However, they do not change the fact that continuing in the current mode is unacceptable from a food supply and environmental point of view. Things need to change, and the changes cannot be minor. This leads to a conclusion that we must change our processes of improvement.

Fortunately, there are examples of success. The challenge is to effectively transfer the lessons learned to other projects. As an example, in the early 1970's there was a large interest in studying the organization of traditional water user associations in the Valencia area of Spain. The idea was that those successes could be transferred to other areas of the world. In the end, it became apparent that many of the water user organization aspects in the Valencia area were successful because of the unique history of the area, the sense of community, and a heritage of voluntary religious brotherhoods. There was a general “service” mentality among the groups involved in the project. Massive irrigation projects with a complex history and social structure needed a different approach – yet could also benefit from some of the characteristics seen in Valencia.

2.3 Potential for Improvement

When discussing improvement, we first need to determine whether there truly is a potential for “more crop per drop” of consumption. Second, we must determine how much of the improvement can be accomplished through on-farm investment, and how much will require irrigation water delivery improvement.

The Potential is There. Certainly in the USA we have seen huge improvements in cotton, tomato, nut, fruit, lettuce, and grain yields – much higher than what we thought were possible 20 years ago. In many cases, yields that were historically considered to be high have doubled within the last 15 years. The improvements are due to improved on-farm practices related to fertilization, irrigation, cultivation practices, etc. They have been enhanced by better awareness of spatial variability of yields within fields. We have learned that “average” yield numbers are deceiving because there are fields that have higher-than-average yields, and within those fields there are areas of high and low yield. A focus is on improved uniformity of the high crop yields within fields and between fields.

Energy Consumption. The issue of reducing energy consumption is more complex. Many water conservation measures require pumps at key points within the water delivery/recirculation network. Drip and sprinkler systems generally require pumps at the field level. However, if one considers the total energy requirement (tractor fuel, fertilizer, concrete construction, etc.), and if the yields increase (per hectare), there is almost always an increase in yield per unit of energy consumed with modern irrigation.

On-Field versus Water Delivery Investments. If the ultimate benefit comes from the fields, does this mean that irrigation investments should be targeted to the field, rather than to the water delivery system? In some cases, the answer is yes. But in most cases in the world, the irrigation water is delivered to fields in such a way that farmers have little choice in how they irrigate. The water comes in a rotation schedule (if that), which means that attempts at modern irrigation scheduling (on-farm) is completely worthless. And often, the rotation schedules are inequitable and unreliable.

While some basic on-field practices such as land leveling almost always improve yields, excellent field water management requires that the water supply, delivered to the field, be manageable. That means the water must be delivered with **reliability, equity**, ***and*** **flexibility**.

Flexibility, which is required for excellent field irrigation management, assumes that the supply is equitable and reliable. Providing water "on demand" to individual fields (which means farmers can receive water without giving any advance notice) is highly discussed in intellectual circles, but it is impractical for almost all irrigation projects. Instead, providing water "on request" at some level in the distribution system is quite practical.

Until water is delivered to farmers (or groups of farmers) in a reliable, manageable (for them) manner, the farmers simply cannot afford to make large investments in field irrigation improvements. Giving these farmers lessons in irrigation water management is futile if they have no control over the frequency, rate, and duration of the water deliveries made to them. So improvement in water delivery systems is extremely important.

3. Two Big Concepts: Modernization and "Art"

One goal of investment is to break away, or stay away, from the rehabilitation-deterioration cycle where large construction projects create new infrastructure that simply breaks down over time. It is therefore illogical to invest only in rehabilitation. Rather, a modern approach to investment is needed.

Up to this point, the term **"modernization"** of irrigation projects has been used without providing a definition. Modernization specifically refers to "*technical, managerial and organizational upgrading, as opposed to mere physical rehabilitation, of irrigation schemes with the objective to improve resource utilization (labor, water, economics, environmental) and water delivery service to farms*" (Wolter and Burt, 1997). Such modernization investment focuses on the details of the inner workings of an irrigation project as opposed to traditional simple and broad-brush investments in canal lining or rehabilitation.

Modernization is a ***process*** that sets specific objectives and selects specific actions and tools to achieve them. Planners and engineers for irrigation projects frequently equate modernization with practices such as canal lining and computerization. Such investments are often the lowest priority if one examines the process needed to improve performance.

An irrigation system is typically a series of layers through which water passes. Each layer has an obligation, and needs incentives, to provide a good level of service to the next lower layer (Burt and Styles, 1999). It has already been mentioned that the final product of irrigation systems – crop yield – is created at the field level. Therefore, the modernization concept ultimately points to improved water delivery service to the fields (or groups of fields). Irrigation systems must serve the farmers well enough so that they attain high on-farm production and irrigation efficiencies and can afford to pay the water service fee.

A second big concept is that the "art" of irrigation must not be introduced during the modernization process. Or if art has already been introduced, it must be removed. Art can be defined as "non-transferrable knowledge" and usually exists in the form of specific, local practices that were honed through decades of trial and error and are known only by the specific local workers who developed them. When those workers leave, the process must be completely re-learned by their replacements.

When looking at the old rotation and *warabandi* delivery processes, it seems that these have almost no art. In theory (but rarely in practice) all the deliveries are made in a systematic manner according to well-defined and verifiable schedules. However, although these old schedules and services can in theory provide equity, they are incapable of providing the flexibility of water delivery service that is needed for more crop per drop and environmental protection. Flexibility implies that there are frequent adjustments made to flow rates and durations throughout an irrigation project on a schedule that constantly changes. Weekly and monthly delivery schedules must be treated as approximations.

When irrigation systems change to allow flexibility, if a project has incorrect hardware, communications, and organization of operators, projects can easily become chaotic. Because flows and water levels continually change, operators who are not provided with well-designed internal procedures are often left to manage the water delivery with whatever innovation they can summon. Modernization, therefore, must have well-defined rules and concepts of operation, accompanied by the proper hydraulic structures and communications and upper-level management support, to avoid the entry of "art".

3.1 Modernization Considerations

As mentioned before, modernizing an irrigation project is not as simple as constructing a dam or lining a canal. Interestingly, the design and construction of large dams and canals have been traditionally considered to be the most prestigious irrigation engineering positions. But modernization engineering should become the new prestigious field. The complexity of successful modernization is tremendous.

Because of the complex interactions within and throughout an irrigation network, modernization requires a huge human operation component not only during construction and design, but also after construction. This is quite different from dam or barrage projects.

Irrigation modernization should create and properly manage unsteady flow conditions within and throughout the irrigation distribution system, as opposed to rotation schemes that attempt to maintain fairly steady state systems. This means that the traditional irrigation control structures that have been used for decades are typically unsuitable for the new operation techniques. Modernization engineers must be to change the design procedures with frequent innovation. Until this is permitted, the consulting engineers and the government designers will ultimately revert to the decades-old design manuals, and end up producing more of the same.

The young engineers who will design and run the systems also require extensive training. The engineers must be taught to think out the minute-to-minute operation of every structure they design, and how that operation impacts the performance of structures and operations upstream and downstream. It takes years to develop the skill set that is necessary to accomplish this. Yet irrigation modernization projects tend to have a training component that is nothing more than a token effort.

The study tour training approach can be very helpful as one small piece of the training program. However, driving through a project and hearing about issues that the project has dealt with is completely different from being confronted by a specific design problem and coming up with a workable, pragmatic, economic solution. A good training program would take top graduates from universities and give them at least five years of additional, concentrated training and field experience with meaningful modernization efforts. Engineers need considerable formal, appropriate training as well as extensive, practical work under qualified mentors. That work should include total involvement in: the diagnosis of problems, the design of the solutions, work with the construction, and making the solution function properly after construction. The need for qualified mentors cannot be over-emphasized. We do not have enough.

This approach is completely contrary to the traditional approach by governments and international funding agencies. Grants and loans are often compressed into a 5-year time period. The first three years involve negotiations and initial construction. Then there is a hurried design, with no written meaningful operation rules, and an even more compressed construction schedule. Training, which should have been finished ***before*** the project was envisioned or designed, becomes an after-thought.

It would be better to begin serious, well-funded training programs and incremental modernization implementation efforts that last 5-10 years than to launch new large modernization efforts in most countries. It takes time to properly identify and design proper hardware solutions. People need time to gain confidence in their work, and to learn how to design and manage new hardware and procedures. Additionally, the new hardware and procedures must fit into social and organizational structures in a way that everything works together. It takes time to learn how to deal with the social and organizational aspects such as billing, communication, maintenance, minute-to-minute operation, water allocations, and so on that must be resolved.

In summary, the typical large, rapidly implemented irrigation modernization projects are almost guaranteed to produce less-than-anticipated benefits because of the complex details, inter-relationships, and learning curves associated with change.

3.2 Common Modernization Pitfalls to Avoid

Probably the first rule in successful modernization is that it isn't easy. It takes a lot of effort and coordination, time, and money. Modernization is hard work.

Certainly, an important consideration is whether water will truly be conserved if conservation is promised. A good understanding of water balances would save hundreds of millions of dollars. And one must realize that achieving "more crop per drop" may not save any "drops" of water. It may just increase the "crop".

Keeping in mind that many higher educated irrigation specialists have a background in computer modeling and very little field experience, it is only logical that they will often recommend computer modeling of an irrigation system, complex centralized automation with computers, and other such rather exotic solutions. These approaches are generally the last things that are needed in early modernization efforts. Many simulation models are already available from other institutions or companies. However, such projects often consume huge budgets but result in little or no successful field implementation. They are “safe” projects that can be done in an office.

Large irrigation modernization project contracts are typically given to a large, single engineering firm that rarely has experience with modernization. The contracts are awarded to companies that have customary experience in construction, contract negotiations, and construction management. The modernization design and implementation are sub-contracts that are often awarded to unqualified companies. A point of interest may be that the majority of successful modernization projects in the US have been accomplished by small companies in which the senior engineers have personal involvement in the projects.

Budgets are often unrealistically low, even though the dollar number is high. Budgets must account for required long-term support and maintenance. As an example, with modern SCADA systems we estimate a 15% per year maintenance cost that must be identified up-front.

In the end, modernization requires serious funding, excellent training, a design that has envisioned how the project will operate on a minute-by-minute basis, deliberate and slow implementation, and great attention to detail. There are no quick, magical solutions.

4. Experience in the Western USA

In the western USA we have experienced a gradual increase in successful irrigation district modernization programs over the past 20 years. The rate of increase has now achieved critical mass, and improvements are commonplace.

Thirty years ago, federal (US Bureau of Reclamation, USBR) and California state (California Dept. of Water Resources, DWR) engineers were angered by a report (Burt et al 1981) that stated that the lack of flexibility from large federal and state canals was hindering flexible operation by irrigation districts. Based on their historical experiences with construction and operation, they felt they were doing as good a job as possible. Since then, of course, the flexibility of water delivery service from those canals has improved. That report was the first of its kind that documented the flexibility of water delivery service provided by California irrigation districts to farmers.

Thirty years ago the western USA irrigation district managers were typically trained as construction engineers. Often, they had worked for the government or a private company on a construction project in an irrigation district, and were later hired as a manager. At that time, there was no service mentality; the irrigation districts did not recognize the close linkage between the irrigation district operation and on-farm irrigation management. Again, recommendations for change were met with strong resistance and a defensive attitude.

In the 1980's, the American Society of Civil Engineers had a first of many specialty conferences related to canal modernization. Selected speakers from throughout the world were invited to discuss specific aspects of canal automation. At the time, we thought that we were on the verge of rapid expansion of canal automation. It didn't happen.

In the 1980's there was also an emphasis on unsteady flow simulation models for canal automation. But the simulation models required large computers and cumbersome procedures. That work fell within the realm of university or USBR researchers.

By the mid 1990's there had been numerous attempts at computerized automation. These were often stimulated by extensive computer-generated simulations of various forms of downstream control. However, there was almost no successful computerized automation, although there were a number of successful projects using simple local Programmable Logic Controllers (PLCs) for upstream control. Some of the large canal systems, such as the California Aqueduct, used computers and remote monitoring but in reality were operated in manual remote mode. One of the few examples of centralized automation was the Canal de Provence in France.

Since the mid 1990's there has been a rather rapid expansion of modernization efforts throughout the western US. How this happened will be described below.

4.1 Irrigation Training and Research Center (ITRC)

The Irrigation Training and Research Center (ITRC) was a major factor in the evolution of successful modernization efforts. ITRC was formalized as a university center of excellence in 1989 and is completely self-supporting. ITRC specifically targeted two audiences: irrigation dealers (private companies that design and install in-field irrigation systems such as drip and sprinkler), and irrigation districts. ITRC approached the irrigation district modernization on many fronts:

- ***Training.*** ITRC developed an outdoor laboratory to demonstrate most of the available technologies related to flow control, water level control, and flow measurement. This has been invaluable for teaching.

  ITRC developed two sets of short courses (1-5 days in duration): one for irrigation district operators, and another for irrigation district and consulting engineers. These classes have been provided annually since 1999 and are continually updated. Standard topics include pipeline flow measurement, open channel flow rate measurement, modernization, pumps, and Supervisory Control and Data Acquisition (SCADA). Most irrigation districts in California, and many others from throughout the western USA, have sent their personnel to these training classes. They have provided a common set of vocabulary and objectives for irrigation district personnel throughout the west.

  Many irrigation districts have contracted with ITRC to provide special classes for their operators. Some of the classes are held at ITRC, and others are held at the districts. These classes are customized to address the specific problems of the districts. In total, ITRC provides about 60 short courses per year, which represents about 7% of ITRC's total effort.

- ***Documentation of Performance.*** ITRC developed performance indicators for irrigation districts in the western USA, and has performed evaluations on over 100 districts. ITRC also developed the Rapid Appraisal Process (RAP) that was adopted by some in the World Bank and FAO. These evaluations have been important in identifying common needs and gaps in service. They are also useful when discussing modernization with specific districts; success stories in other districts have been documented and can be shared.

- ***Graduates from Cal Poly.*** ITRC supports the academic irrigation program of Cal Poly by maintenance of the training facilities and constant updating of teaching materials. Graduates from California Polytechnic State University's BioResource and Agricultural Engineering department are found throughout the irrigation districts within California. This qualified pool of engineers now has enough seniority that it is impacting the advance of modernization.

- ***Development of Automation Techniques.*** By 1995, the theory of canal automation and our simulation abilities had outpaced our abilities to successfully implement even the most basic (upstream control) PLC automation. So ITRC took on the task of analyzing and improving every aspect of PLC-based upstream control. In addition to developing new control algorithms and modeling processes, ITRC systematically addressed the complex details of sensors, calibration, programming of PLCs, communication, mechanical movement of various gates, etc.

- ***Direct Technical Assistance to Irrigation Districts.*** Perhaps fifty percent of ITRC's work is the development of modernization plans, and implementation of those plans, for irrigation districts. Payment may come directly from the irrigation districts, or from agencies such as DWR or USBR.
- ***Promotion of New Technologies.*** Modernization has utilized a huge suite of new products and technologies. These range from software for irrigation billing, to hand-held data recorders for canal operators, to new communications techniques, to new usages of variable frequency drives on pumps, to technologies for cleaning the trash out of water. ITRC provides independent review of such technologies and often sponsors workshops in which various manufacturers of a technology can introduce their products and approaches.
- ***Specifications.*** As the rate of modernization has expanded, private companies have entered the market, especially providing "integration" services. In the USA, an "integration" company is one that typically installs the equipment needed for Supervisory Control and Data Acquisition (SCADA) systems – sensors, radios, office software, PLCs, etc. Unfortunately, it is very difficult to find good integration companies. An important role of ITRC is to provide detailed specifications for equipment and performance of SCADA systems, assist the irrigation districts with their selection of the SCADA integrator, and then verify performance before the integrator is paid.
- ***PLC Programming***. When ITRC began work with PLC-based automation, we thought that we could provide about 20 lines of control code to an integrator for automation. The results of this were assumptions, errors, and finger-pointing. Now we only do PLC-based automation if we provide the complete PLC control code, which consists of hundreds of lines of code.
- ***Strategy.*** ITRC has worked with over two hundred irrigation districts on modernization programs. Perhaps only forty of these have used any type of PLC-based automation. And none of those forty districts use PLC-based automation on more than a fraction of their total delivery network. A modernization strategy should recommend the most robust, economical, and effective solution possible rather than starting with an assumption that PLC-based automation is needed. With modernization there is extensive use of improved flow measurement, regulating

reservoirs, remote monitoring, simple long crested weirs or ITRC flap gates for upstream water level control, and recirculation systems. Often a major change involves who controls the water distribution throughout the main canal system – something that has nothing to do with automation.

- ***Patience.*** Another essential element of success is the slow, incremental progression of modernization plans. It is difficult to plan and implement even a simple change within a single year. Successful districts have made incremental progress over the past 10-15 years, and by now they have the experience and expertise to move forward even more rapidly.

4.2 A New Environment

While ITRC was developing the technical foundation for modernization in irrigation districts, the external pressures for change gained momentum. Districts in the USA are often faced with less water supply, restrictions of drainage outflows to rivers, and the need to verify their reasonable and beneficial use. They can only meet these demands by changing the way they manage water. And working harder, without having the physical tools to help, was insufficient to meet the demands.

Simultaneously, many of the old engineer managers retired. Younger persons, who often were not engineers, replaced the old managers. They were more receptive to a re-examination of priorities and the development of new long-term plans.

4.3 State and Federal Agencies

State and Federal agencies have played a crucial role in stimulating modernization efforts. However, there is no doubt that many of these actions have been taken by small, inadequately funded sub-departments within the federal and state agencies. Many success stories are due to the initiative of individual program managers who have doggedly worked within their large bureaucracies to obtain funding. In other words, irrigation district modernization efforts in the US have not been a primary, or even secondary, emphasis of these agencies. Modernization falls into a third or fourth, lower level.

Nevertheless, even small stimulation grants have been extremely important. Incidentally, their small size avoided the rapid large projects that generally fail. As mentioned previously, irrigation districts must proceed slowly – gaining knowledge of techniques, construction, costs, operation, etc. The way the system has worked, the initiative has had to come from the irrigation districts – a bottom-up approach. The funding by USBR and state agencies of ITRC to provide conceptual plans, and to assist with implementation, worked out very well. Technical expertise for modernization design is not generally found within the agencies themselves.

It must be recognized that the USA's irrigation sector is organized quite differently from those in many other countries. In the USA, the irrigation districts are largely local governments with the power to tax, condemn land for rights-of-ways, and with many other important legal powers. If people steal water, the irrigation district first tries to deal with them, but if there is no success the local sheriff has the authority, and will exercise it, to arrest offenders.

In other words, there is an additional legal and administrative and engineering layer between the farmers and the governments in the US that is often not seen in other countries. Many of the irrigation districts are strong, and they are willing to and capable of making sound investment decisions. The management also answers to a board of directors, which means that investments are required to produce positive results. Successful modernization efforts and planning begin at the irrigation district level, rather than at the state or federal levels. Even modest grant/incentive programs by the state and federal governments can be important in stimulating improvements.

4.4 United States Committee on Irrigation and Drainage (USCID)

Until about twenty years ago, USCID was dominated by conventional civil engineers who happened to work on conventional water projects. More recently, it has evolved to provide a significant resource to irrigation districts. USCID is the only professional organization in the USA that has focused on the technical needs of irrigation districts. It sponsors two conferences per year in different locations within the western US, each with a different technical emphasis.

4.5 Universities in the US

The universities, except for Cal Poly, have been largely absent from irrigation district technical work. Large irrigation engineering programs have almost disappeared or have been absorbed into other academic departments. This provides a serious challenge for future US modernization efforts.

Unfortunately, the unsteady flow research and teaching at universities rarely address the actual design problems found in the field. University classes on unsteady flow in open channels focus on numerical methods and modeling – none of which is needed for initial modernization efforts. This means that recent graduates, professors, and researchers often find it difficult to provide pragmatic solutions for modernization. They simply do not have the technical background and field experience to properly identify problems and solutions, and to provide proper designs. Worldwide, we need to encourage universities to produce more pragmatic graduates, and to sponsor pragmatic research.

Irrigation design manuals must be changed, because traditional structures that have been used in irrigation systems are not suitable for modern control. For example, typical sluice gates have very limited application yet they are the cross regulator design of choice in numerous projects. But because of the lack of practical knowledge in university teaching and research groups, it is difficult to find people to write the new design manuals. The new manuals must include information of flow measurement, flow control, water level control, and numerous other topics.

5. Summary

This brief presentation of the shift to modernization only begins to scratch the surface of the details that must be addressed in a successful program that will provide excellent service to farmers while strengthening the environment. Such programs require a dedicated cadre of technical specialists with extensive experience in successful modernization. Developing that cadre takes many years, serious funding, and pragmatic training - an effort that is as large as, and more important than, building several large dams. Modernization is expensive, and must be approached slowly with excellent attention to detail. The good news is that there is tremendous potential, through modernization, to improve the environment and increase the “crop per drop” of water and energy consumed.

References

Burt, C.M., J. Bryner, and J.M. Lord. 1981. Distribution System Improvement to Facilitate Water Delivery. A report by JM Lord, Inc. and the Ag. Division, OWC, Calif. Dept. of Water Resources.

Burt, C.M., and S.W. Styles. 1999. Modern Water Control and Management Practices in Irrigation: Impact on Performance. Water Reports #19. 224 p. Food and Agriculture Organization of the United Nations.

Wolter, H.W. and C.M. Burt. 1997. Concepts of Modernization. In Modernization of irrigation schemes: past experiences and future options. RAP Publication 1997/22. Water Report 12. FAO. pp 65-88.

Notes